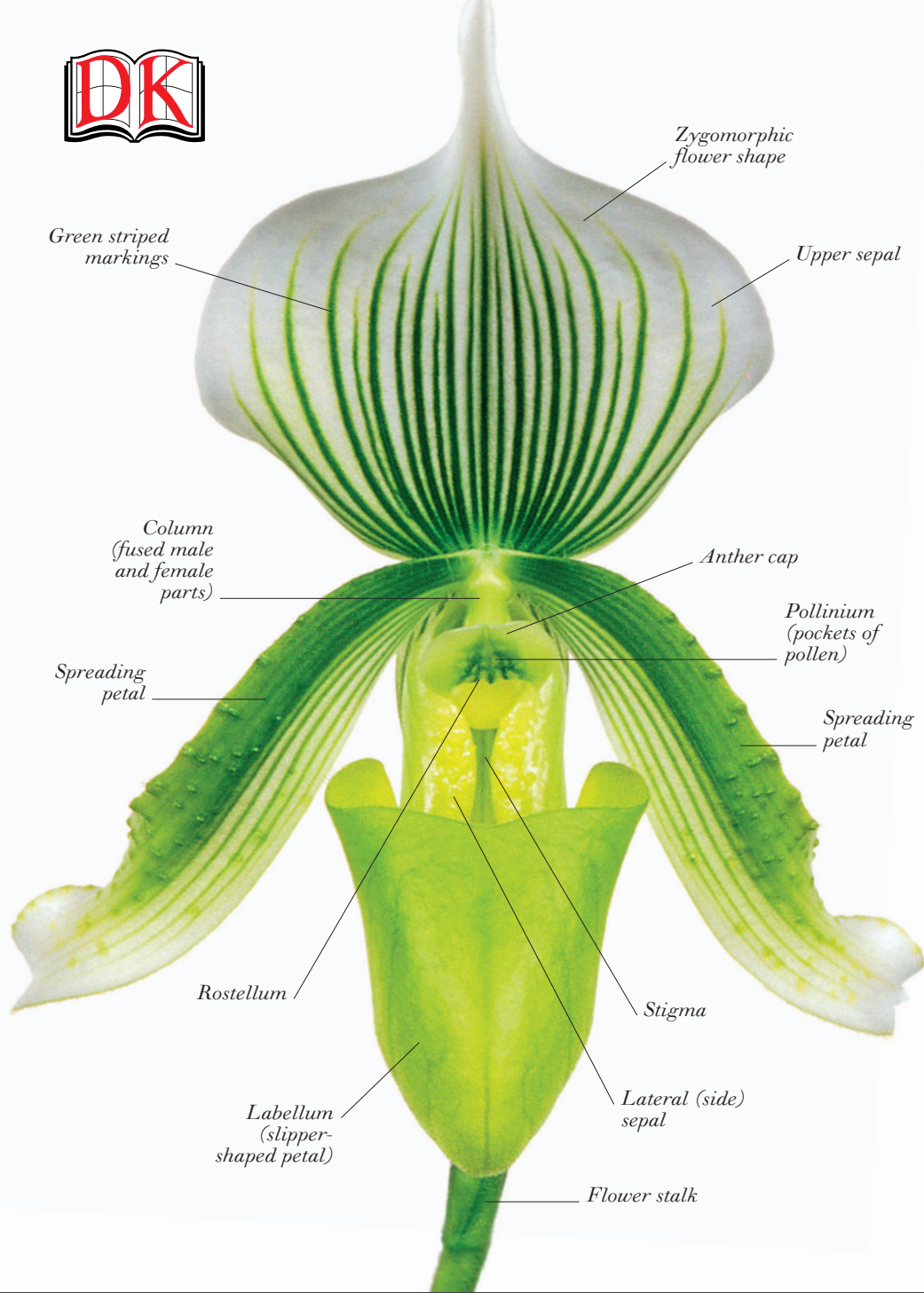




ULTIMATE

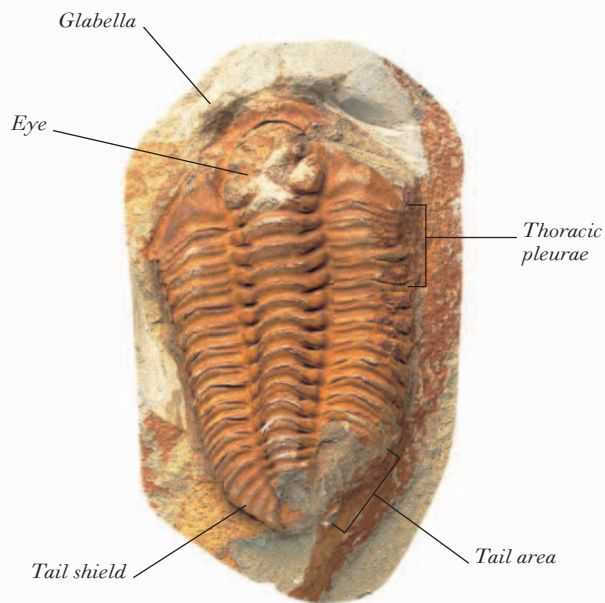
VISUAL
SCIENCE
FACTS



REVISED AND UPDATED

dictionary

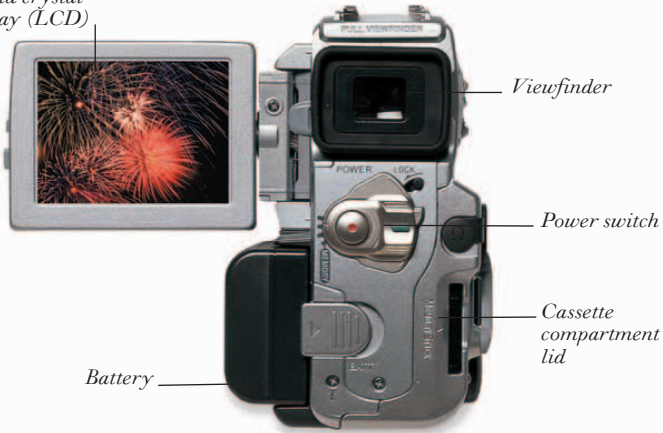
VISUAL dictionary



PREHISTORIC TRILOBITE

DIGITAL VIDEO CAMERA

Liquid crystal display (LCD)



Battery

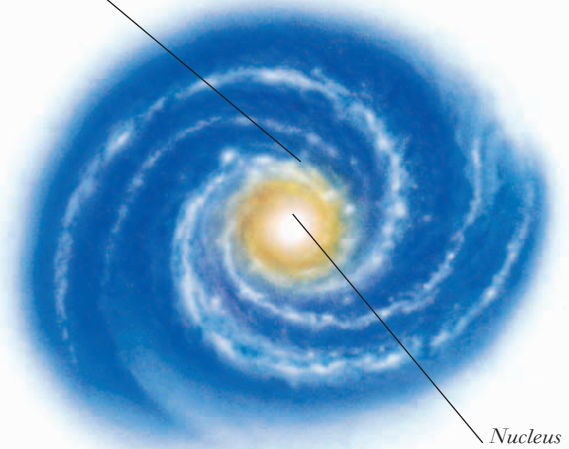
Viewfinder

Power switch

Cassette compartment lid

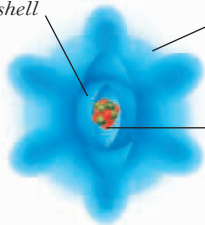
OVERHEAD VIEW OF OUR GALAXY

Location of solar system



Nucleus

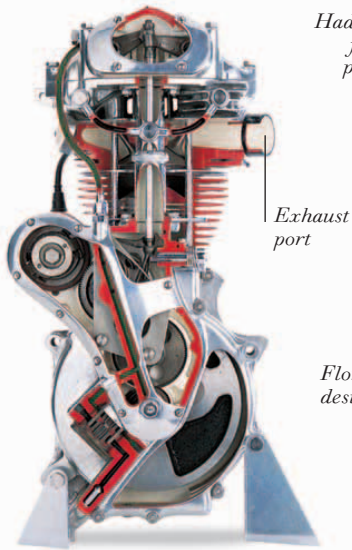
First electron shell



Second electron shell

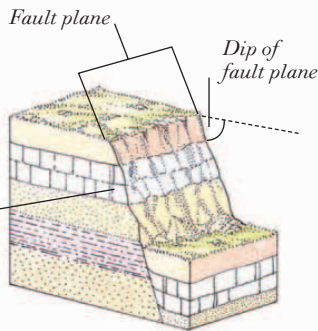
Nucleus

ANATOMY OF A FLUORINE-19 ATOM



Exhaust port

VELOCETTE OHV ENGINE



STRUCTURE OF A FAULT



Floral design

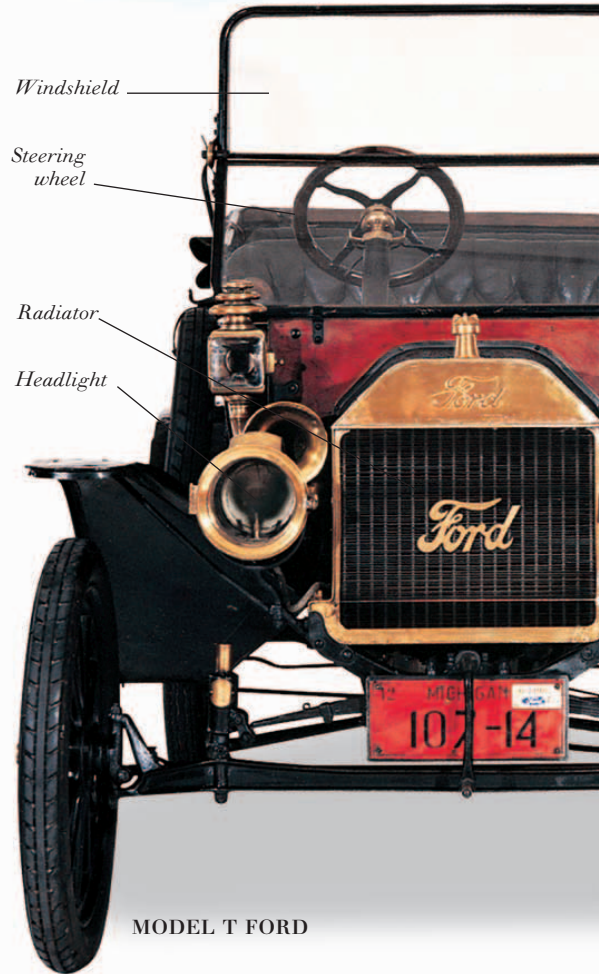
MOSAIC DESIGN

Windshield

Steering wheel

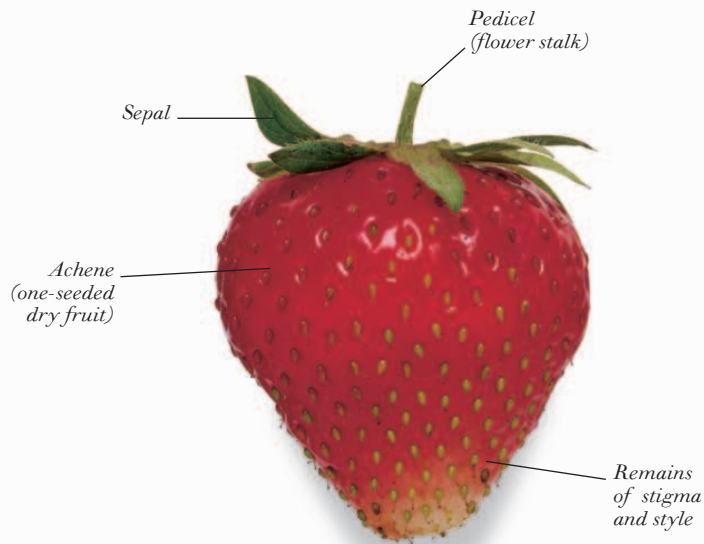
Radiator

Headlight



MODEL T FORD

VISUAL dictionary



STRAWBERRY



DK PUBLISHING



LONDON, NEW YORK, MUNICH, MELBOURNE, AND DELHI

THIS EDITION

DK LONDON

Editorial Consultants Ian Graham, Darren Naish, Carole Stott
Picture Researcher Karen VanRoss
Jacket Designer Silke Spingies
Digital Conversion Coordinator Linda Zacharia
Production Editor Joanna Byrne
Production Controller Linda Dare
Managing Editor Julie Ferris
Managing Art Editor Owen Peyton Jones
Art Director Philip Ormerod
Associate Publishing Director Liz Wheeler
Publishing Director Jonathan Metcalf

DK DELHI

Managing Art Editor Arunesh Talapatra
Managing Editor Saloni Talwar
Deputy Managing Art Editor Priyabrata Roy Chowdhury
Senior Art Editor Rajnish Kashyap
Senior Editor Neha Gupta
Art Editors Arijit Ganguly, Pooja Pipil
Assistant Art Editor Pooja Pawwar
DTP Manager Balwant Singh
DTP Designer Jaypal Singh Chauhan
Managing Director Aparna Sharma

Anatomical And Botanical Models Supplied By Somso Modelle, Coburg, Germany



ORIGINAL EDITION (*Ultimate Visual Dictionary*)

Project Art Editors Heather McCarry, Johnny Pau, Chris Walker, Kevin Williams
Designer Simon Murrell
Project Editors Luisa Caruso, Peter Jones, Jane Mason, Geoffrey Stalker
Editor Jo Evans
DTP Designer Zirrinia Austin
Picture Researcher Charlotte Bush
Managing Art Editor Toni Kay
Senior Editor Roger Tritton
Managing Editor Sean Moore
Production Manager Hilary Stephens

FIRST AMERICAN EDITION PUBLISHED UNDER THE TITLE
ULTIMATE VISUAL DICTIONARY, 1994

THIS REVISED EDITION PUBLISHED IN 2011 BY
DK PUBLISHING
375 HUDSON STREET
NEW YORK, NEW YORK 10014

11 12 13 14 15 10 9 8 7 6 5 4 3 2 1
001-178144-NOV/2011

REVISED EDITIONS IN 1996, 1997, 1998, 1999, 2000, 2002, 2006, 2011

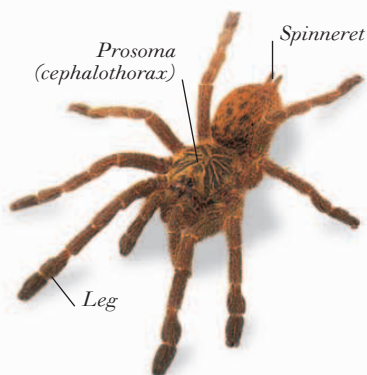
COPYRIGHT © 1994, 1996, 1997, 1998, 1999, 2000, 2002, 2006, 2011 DORLING KINDERSLEY LIMITED

ALL RIGHTS RESERVED UNDER INTERNATIONAL AND PAN-AMERICAN COPYRIGHT CONVENTIONS.
NO PART OF THIS PUBLICATION MAY BE REPRODUCED, STORED IN A RETRIEVAL SYSTEM, OR
TRANSMITTED IN ANY FORM OR BY ANY MEANS, ELECTRONIC, MECHANICAL, PHOTOCOPYING,
RECORDING OR OTHERWISE, WITHOUT THE PRIOR WRITTEN PERMISSION OF THE COPYRIGHT OWNER.
PUBLISHED IN GREAT BRITAIN BY DORLING KINDERSLEY LIMITED.

A CATALOG RECORD FOR THIS BOOK IS AVAILABLE FROM THE LIBRARY OF CONGRESS.
ISBN 978-0-7566-8685-5

COLOR REPRODUCTION BY Colorscan, Singapore
PRINTED AND BOUND BY Star Standard, Singapore

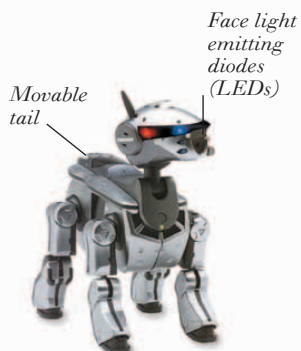
Discover more at www.dk.com



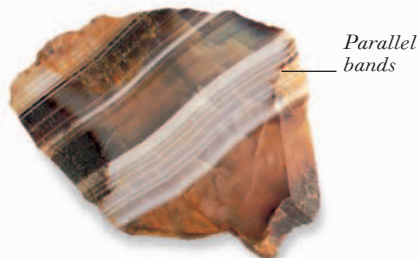
EXTERNAL FEATURES
OF A SPIDER



FOUNTAIN PEN AND INK



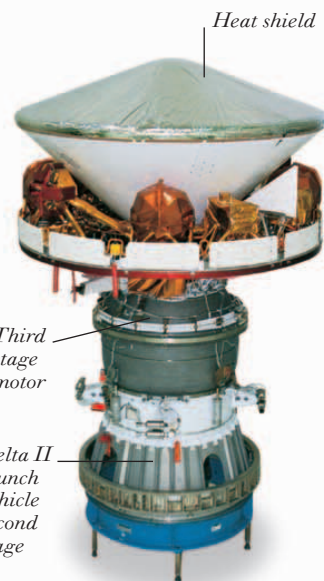
SONY AIBO
ROBOT DOG



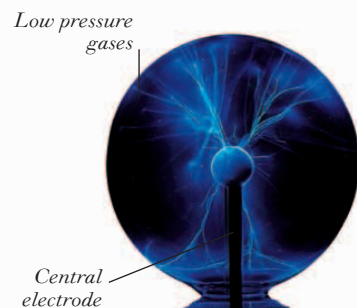
ONYX



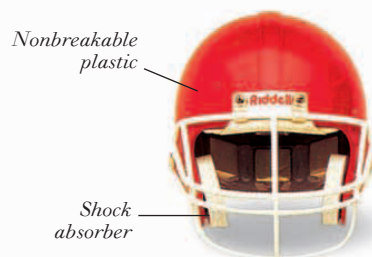
SIDE VIEW OF ARV SUPER 2 AIRPLANE



MARS PATHFINDER



BALL CONTAINING HIGH
TEMPERATURE GAS (PLASMA)



FOOTBALL HELMET

CONTENTS

INTRODUCTION 6

THE UNIVERSE 8

PREHISTORIC EARTH 54

PLANTS 110

ANIMALS 164

THE HUMAN BODY 208

GEOLOGY, GEOGRAPHY,
AND METEOROLOGY 262

PHYSICS AND CHEMISTRY 304

RAIL AND ROAD 322

SEA AND AIR 370

THE VISUAL ARTS 428

ARCHITECTURE 456

MUSIC 500

SPORTS 522

THE MODERN WORLD 564

APPENDIX 616

INDEX 624

Introduction

THE VISUAL DICTIONARY is a completely new kind of reference book. It provides a link between pictures and words in a way that no ordinary dictionary ever has. Most dictionaries simply tell you what a word means, but the *VISUAL DICTIONARY* shows you—through a combination of detailed annotations, explicit photographs, and illustrations. In the *VISUAL DICTIONARY*, pictures define the annotations around them. You do not read definitions of the annotated words, you see them. The highly accessible format of the *VISUAL DICTIONARY*, the thoroughness of its annotations, and the range of its subject matter make it a unique and helpful reference tool.

How to use the VISUAL DICTIONARY

You will find the *VISUAL DICTIONARY* simple to use. Instead of being organized alphabetically, it is divided by subject into 14 sections—THE UNIVERSE, PREHISTORIC EARTH, PLANTS, ANIMALS, THE HUMAN BODY, etc. Each section begins with a table of contents listing the major entries within that section. For example, The Visual Arts section has entries on *Drawing, Tempera, Fresco, Oils, Watercolor, Pastels, Acrylics, Calligraphy, Printmaking, Mosaic, and Sculpture*. Every entry has a short introduction explaining the purpose of the photographs and illustrations, and the significance of the annotations.

If you know what something looks like, but don't know its name, find the term you need by turning to the annotations surrounding the pictures; if you know a word, but don't know what it refers to, use the comprehensive index to direct you to the appropriate page.

Suppose that you want to know what the bone at the end of your little finger is called. With a standard dictionary, you wouldn't know where to begin. But with the *VISUAL DICTIONARY* you simply turn to the entry called *Hands*—within THE HUMAN BODY section—where you will find four fully

annotated, color photographs showing the skin, muscles, and bones of the human hand. In this entry you will quickly find that the bone you are searching for is called the distal phalanx, and for good measure you will discover that it is attached to the middle phalanx by the distal interphalangeal joint.

Perhaps you want to know what a catalytic converter looks like. If you look up “catalytic converter” in an ordinary dictionary, you will be told what it is and possibly what it does—but you will not be able to tell what shape it is or what it is made of. However, if you look up “catalytic converter” in the index of the *VISUAL DICTIONARY*, you will be directed to the *Modern engines* entry on page 344—where the introduction gives you basic information about what a catalytic converter is—and to page 350—where there is a spectacular exploded-view photograph of the mechanics of a Renault Clio. From these pages you will find out not only what a catalytic converter looks like, but also that it is attached at one end to an exhaust pipe and at the other to a muffler.

Whatever it is that you want to find a name for, or whatever name you want to find a picture for, you will find it quickly and easily in the *VISUAL DICTIONARY*. Perhaps you need to know where the vamp on a shoe is; or how to tell obovate and lanceolate leaves apart; or what a spiral galaxy looks like; or whether birds have nostrils. With the *VISUAL DICTIONARY* at hand, the answers to each of these questions, and thousands more, are readily available.

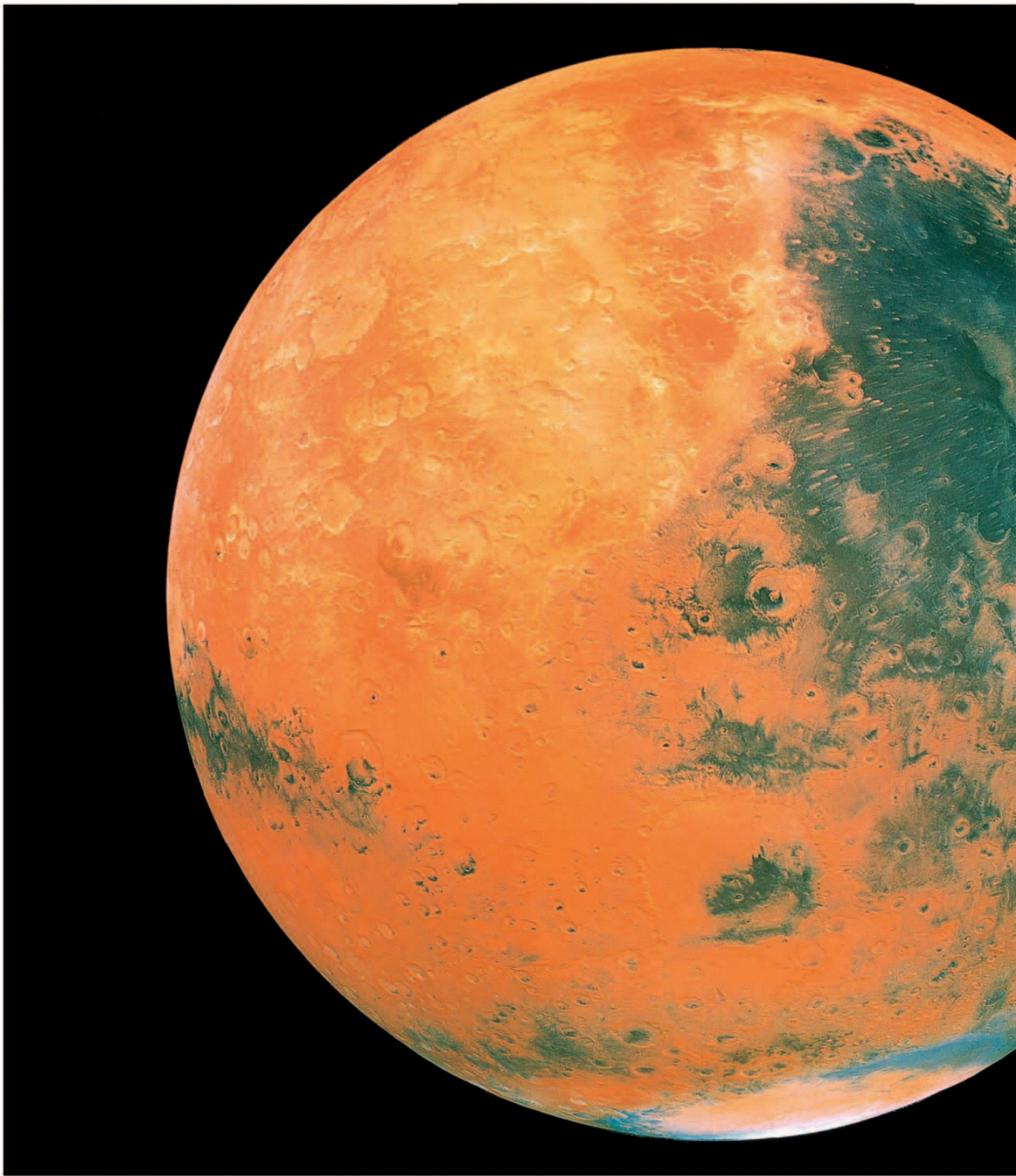
The *VISUAL DICTIONARY* does not just tell you what the names of the different parts of an object are. The photographs, illustrations, and annotations are all specially arranged to help you understand which parts relate to one another and how objects function.

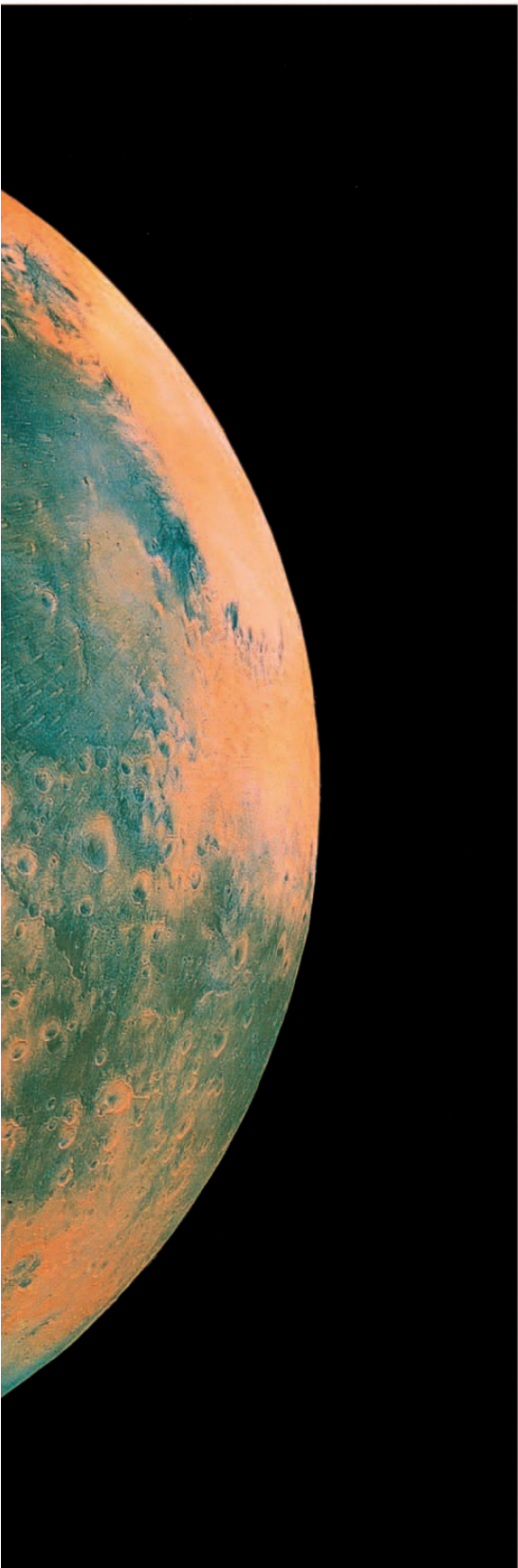
With the *VISUAL DICTIONARY* you can find in seconds the words or pictures that you are looking for; or you can simply browse through the pages of the book for your own pleasure. The *VISUAL DICTIONARY* is not intended to replace a standard dictionary or conventional encyclopedia, but is instead a stimulating and valuable companion to ordinary reference volumes. Giving you instant access to the language that is used by astronomers and architects, musicians and mechanics, scientists and sportspeople, it is the ideal reference book for specialists and generalists of all ages.

Sections of the **VISUAL DICTIONARY**

The 14 sections of the *VISUAL DICTIONARY* contain a total of more than 30,000 terms, encompassing a wide range of topics:

- In the first section, **THE UNIVERSE**, spectacular photographs and illustrations are used to show the names of the stars and planets and to explain the structure of solar systems, galaxies, nebulae, comets, and black holes.
- **PREHISTORIC EARTH** tells the story in annotations of how our own planet has evolved since its formation. It includes examples of prehistoric flora and fauna, and fascinating dinosaur models—some with parts of the body stripped away to show anatomical sections.
- **PLANTS** covers a huge range of species—from the familiar to the exotic. In addition to the color photographs of plants included in this section, there is a series of micrographic photographs illustrating plant details—such as pollen grains, spores, and cross-sections of stems and roots—in close-up.
- In the **ANIMALS** section, skeletons, anatomical diagrams, and different parts of animals' bodies have been meticulously annotated. This section provides a comprehensive guide to the vocabulary of zoological classification and animal physiology.
- The structure of the human body, its parts, and its systems are presented in **THE HUMAN BODY**. The section includes lifelike, three-dimensional models and the latest false-color images. Clear and authoritative annotations indicate the correct anatomical terms.
- **GEOLOGY, GEOGRAPHY, AND METEOROLOGY** describes the structure of the Earth—from the inner core to the exosphere—and the physical phenomena—such as volcanoes, rivers, glaciers, and climate—that shape its surface.
- **PHYSICS AND CHEMISTRY** is a visual journey through the fundamental principles underlying the physical universe, and provides the essential vocabulary of these sciences.
- In **RAIL AND ROAD**, a wide range of trains, trams and buses, cars, bicycles, and motorcycles are described. Exploded-view photographs show mechanical details with striking clarity.
- **SEA AND AIR** gives the names for hundreds of parts of ships and airplanes. The section includes civil and fighting craft, both historical and modern.
- **THE VISUAL ARTS** shows the equipment and materials used by painters, sculptors, printers, and other artists. Well-known compositions have been chosen to illustrate specific artistic techniques and effects.
- **ARCHITECTURE** includes photographs of exemplary architectural models and illustrates dozens of additional features such as columns, domes, and arches.
- **MUSIC** provides a visual introduction to the special language of music and musical instruments. It includes clearly annotated photographs of each of the major groups of traditional instruments—brass, woodwind, strings, and percussion—together with modern electronic instruments.
- The **SPORTS** section is a guide to the playing areas, formations, equipment, and techniques needed for many of today's most popular sports.
- In **THE MODERN WORLD**, items that are a familiar part of our daily lives are taken apart to reveal their inner workings and give access to the language used by their manufacturers. It also includes systems and concepts, such as the internet, that increasingly influence our 21st century world.





THE UNIVERSE

ANATOMY OF THE UNIVERSE.....	10
GALAXIES.....	12
THE MILKY WAY.....	14
NEBULAE AND STAR CLUSTERS.....	16
STARS OF NORTHERN SKIES.....	18
STARS OF SOUTHERN SKIES.....	20
STARS.....	22
SMALL STARS.....	24
MASSIVE STARS.....	26
NEUTRON STARS AND BLACK HOLES.....	28
THE SOLAR SYSTEM.....	30
THE SUN.....	32
MERCURY.....	34
VENUS.....	36
THE EARTH.....	38
THE MOON.....	40
MARS.....	42
JUPITER.....	44
SATURN.....	46
URANUS.....	48
NEPTUNE AND PLUTO.....	50
ASTERIODS, COMETS, AND METEORIODS.....	52



Anatomy of the universe

THE UNIVERSE CONTAINS EVERYTHING that exists, from the tiniest subatomic particles to galactic superclusters (the largest structures known). No one knows how big the universe is, but astronomers estimate that it contains at least 125 billion galaxies, each comprising an average of 100 billion stars. The most widely accepted theory about the origin of the universe is the Big Bang theory, which states that the universe came into being in a huge explosion—the Big Bang—that took place between 10 and 20 billion years ago. The universe initially consisted of a very hot, dense fireball of expanding, cooling gas. After about one million years, the gas began to condense into localized clumps called protogalaxies. During the next five billion years, the protogalaxies continued condensing, forming galaxies in which stars were being born. Today, billions of years later, the universe as a whole is still expanding, although there are localized areas in which objects are held together by gravity; for example, many galaxies are found in clusters. The Big Bang theory is supported by the discovery of faint, cool background radiation coming evenly from all directions. This radiation is believed to be the remnant of the radiation produced by the Big Bang. Small “ripples” in the temperature of the cosmic background radiation are thought to be evidence of slight fluctuations in the density of the early universe, which resulted in the formation of galaxies. Astronomers do not yet know if the universe is “closed,” which means it will eventually stop expanding and begin to contract, or if it is “open,” which means it will continue expanding forever.

FALSE-COLOR MICROWAVE MAP OF COSMIC BACKGROUND RADIATION

Pink indicates “warm ripples” in background radiation

Pale blue indicates “cool ripples” in background radiation

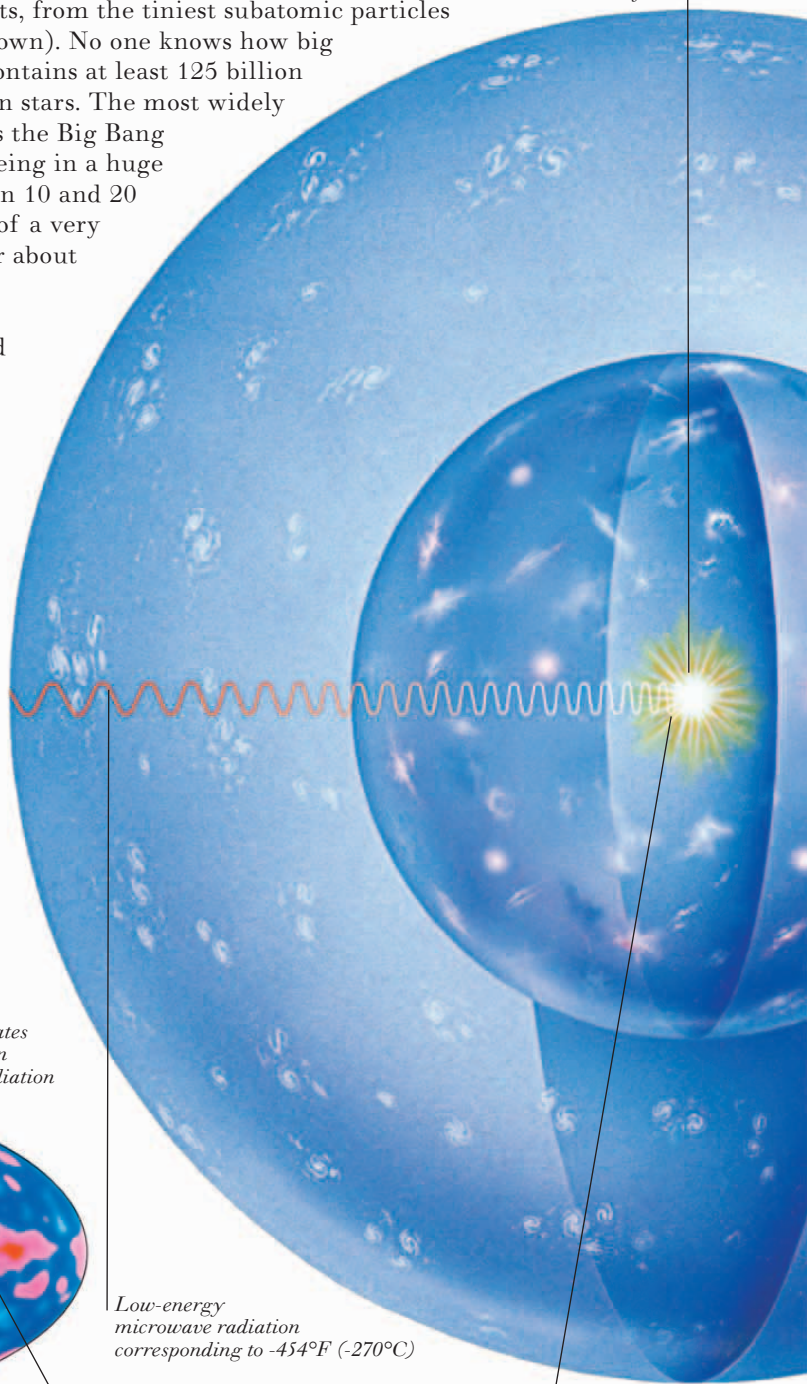
Deep blue indicates background radiation corresponding to -454°F (-270°C); (remnant of the Big Bang)

Red and pink band indicates radiation from our galaxy

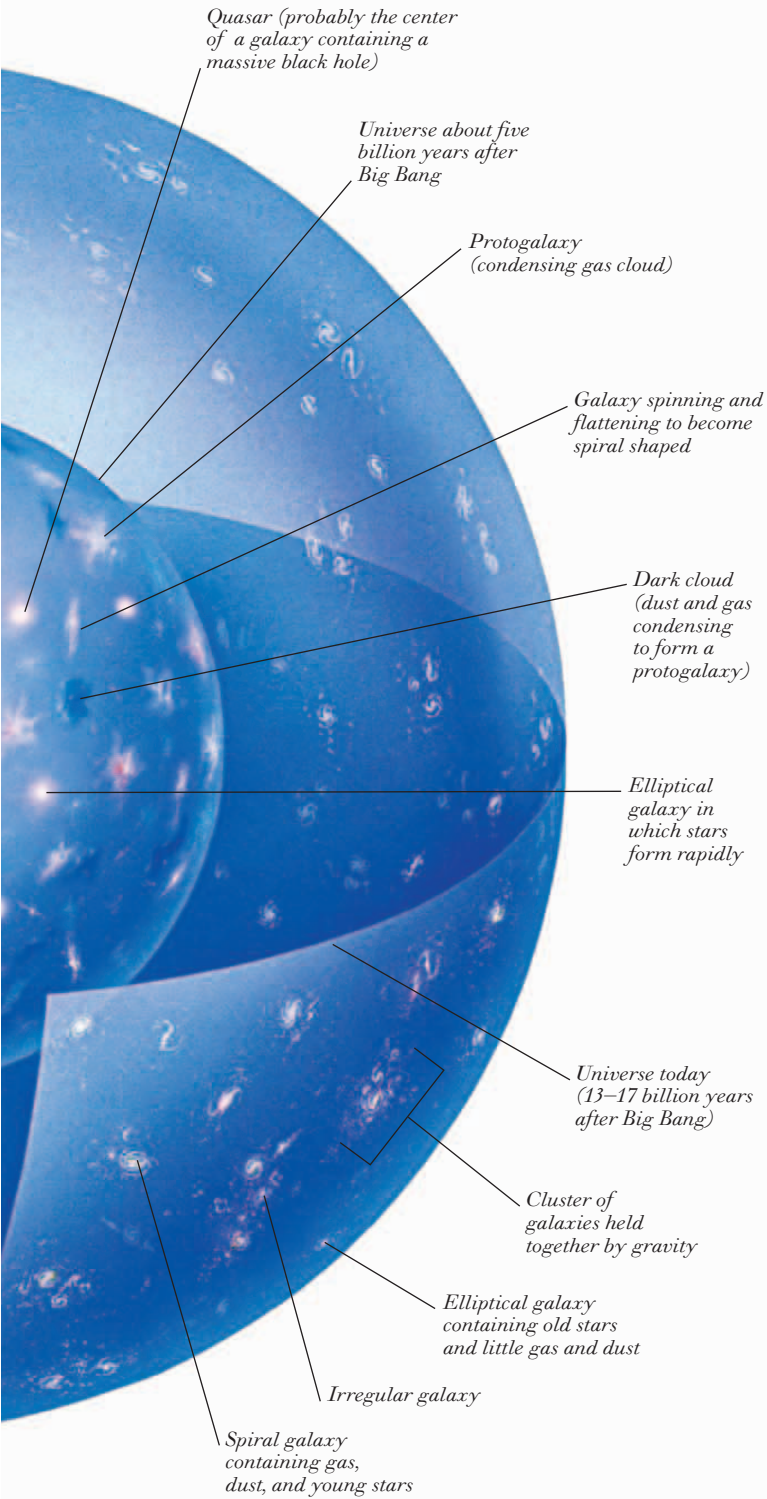
Low-energy microwave radiation corresponding to -454°F (-270°C)

High-energy gamma radiation corresponding to $5,400^{\circ}\text{F}$ ($3,000^{\circ}\text{C}$)

Fireball of rapidly expanding, extremely hot gas lasting about one million years



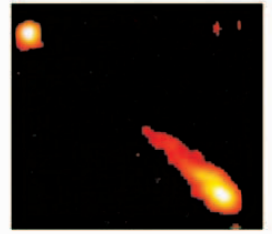
ORIGIN AND EXPANSION OF THE UNIVERSE



OBJECTS IN THE UNIVERSE



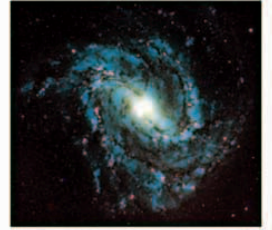
CLUSTER OF GALAXIES IN VIRGO



FALSE-COLOR IMAGE OF 3C273 (QUASAR)



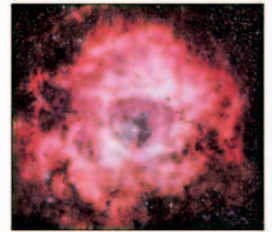
NGC 4406 (ELLIPTICAL GALAXY)



NGC 5236 (BARRED SPIRAL GALAXY)



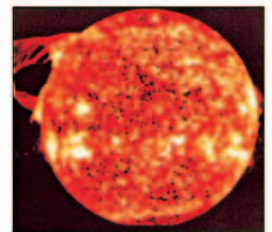
NGC 6822 (IRREGULAR GALAXY)



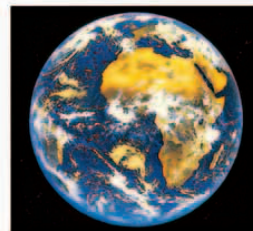
THE ROSETTE NEBULA (EMISSION NEBULA)



THE JEWEL BOX (STAR CLUSTER)



THE SUN (MAIN SEQUENCE STAR)



EARTH



THE MOON

Galaxies



SOMBRERO,
A SPIRAL GALAXY

A GALAXY IS A HUGE MASS OF STARS, nebulae, and interstellar material. The smallest galaxies contain about 100,000 stars, while the largest contain up to 3 trillion stars. There are three main types of galaxy, classified according to their shape: elliptical, which are oval shaped; spiral, which have arms spiraling outward from a central bulge (those whose arms spiral from a bar-shaped bulge are called spirals); and irregular, which have no obvious shape. Sometimes, the shape of a galaxy is distorted by a collision with another galaxy. Quasars (quasi-stellar objects) are thought to be galactic nuclei but are so far away that their exact nature is still uncertain. They are compact, highly luminous objects in the outer reaches of the known universe: while the farthest known “ordinary” galaxies are about 12 billion light-years away, the farthest known quasar is about 13 billion light-years away. Active galaxies, such as Seyfert galaxies and radio galaxies, emit intense radiation. In a Seyfert galaxy, this radiation comes from the galactic nucleus; in a radio galaxy, it also comes from huge lobes on either side of the galaxy. The radiation from active galaxies and quasars is thought to be caused by material falling into central black holes (see pp. 28-29).

OPTICAL IMAGE OF NGC 4486
(ELLIPTICAL GALAXY)



- Globular cluster containing very old red giants*
- Central region containing old red giants*
- Less densely populated region*
- Neighbouring galaxy*

OPTICAL IMAGE OF LARGE MAGELLANIC CLOUD (IRREGULAR GALAXY)



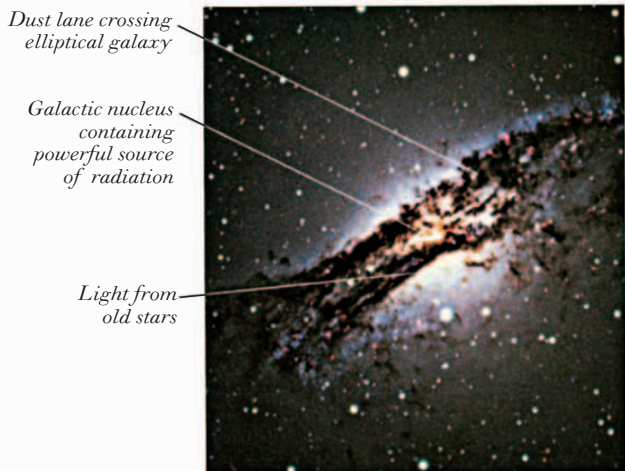
- Tarantula Nebula*
- Dust cloud obscuring light from stars*
- Emission nebula*
- Light from stars*

OPTICAL IMAGE OF NGC 2997 (SPIRAL GALAXY)

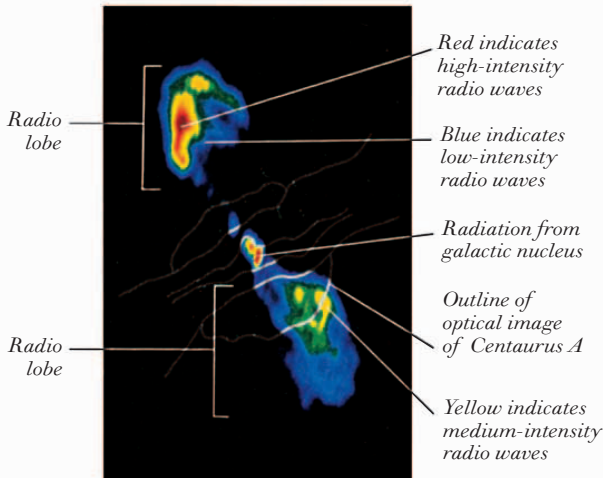


- Glowing nebula in spiral arm*
- Spiral arm containing young stars*
- Galactic nucleus containing old stars*
- Dust in spiral arm reflecting blue light from hot young stars*
- Hot, ionized hydrogen gas emitting red light*
- Dust lane*

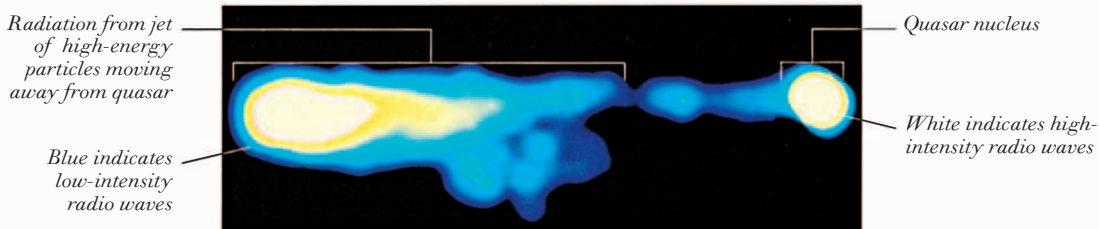
OPTICAL IMAGE OF CENTAURUS A (RADIO GALAXY)



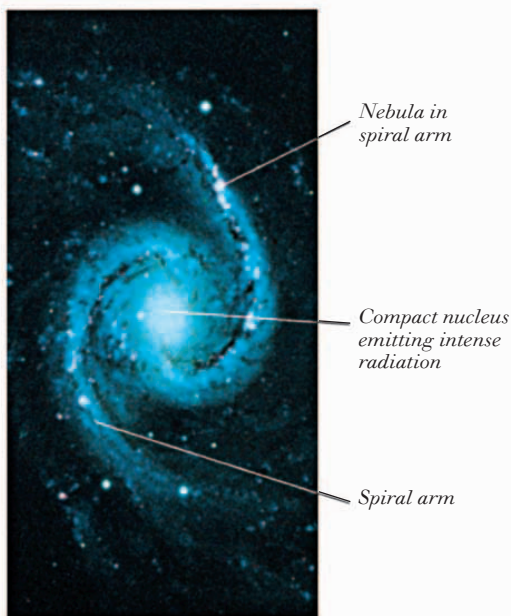
FALSE-COLOR RADIO IMAGE OF CENTAURUS A



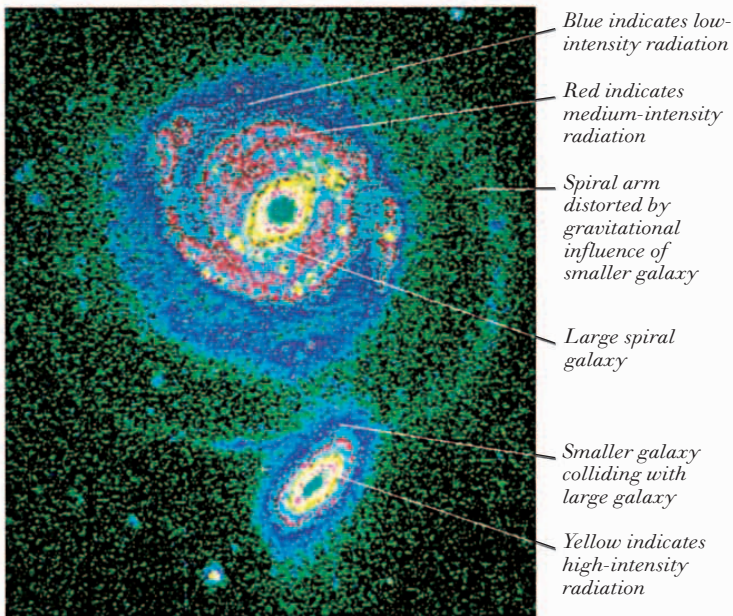
FALSE-COLOR RADIO IMAGE OF 3C 273 (QUASAR)



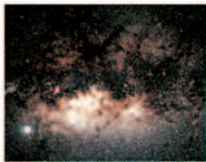
OPTICAL IMAGE OF NGC 1566 (SEYFERT GALAXY)



FALSE-COLOR OPTICAL IMAGE OF NGC 5754 (TWO COLLIDING GALAXIES)



The Milky Way

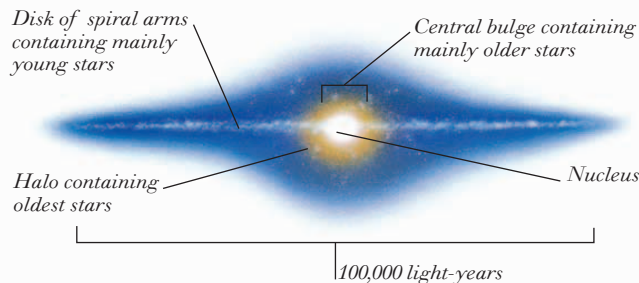


VIEW TOWARD GALACTIC CENTER

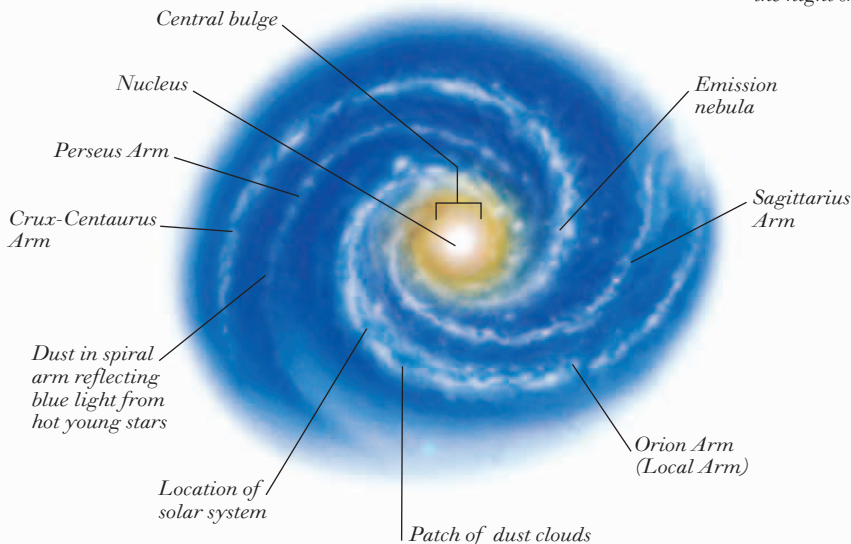
THE MILKY WAY IS THE NAME GIVEN TO THE FAINT BAND OF LIGHT that stretches across the night sky. This light comes from stars and nebulae in our galaxy, known as the Milky Way Galaxy or simply as “the Galaxy.” The Galaxy is believed to be a barred spiral, with a dense central bar of stars encircled by four arms spiraling outward and surrounded by a less dense halo. We cannot see the spiral shape because the solar system is in one of the spiral arms, the Orion Arm (also called the Local Arm). From our position, the center of the Galaxy is completely obscured by dust clouds; as a result, optical maps give only a limited view of the Galaxy. However, a more complete picture can be obtained by studying radio, infrared, and other radiation. The central part of the Galaxy is relatively small and dense and contains mainly older red and yellow stars. The halo is a less dense region in which the oldest stars are situated; some of these stars are as old as the Galaxy itself (possibly 13 billion years). The spiral arms contain main sequence stars and hot, young, blue stars, as well as nebulae (clouds of dust and gas inside which stars are born). The Galaxy is vast, about 100,000 light-years across (a light-year is about 5,870 billion miles/9,460 billion km); in comparison, the solar system seems small, at about 12 light-hours across (about 8 billion miles/13 billion km). The entire Galaxy is rotating in space, although the inner stars travel faster than those farther out. The Sun, which is about two-thirds out from the center, completes one lap of the Galaxy about every 220 million years.

PANORAMIC OPTICAL MAP OF OUR GALAXY AND NEARBY GALAXIES

SIDE VIEW OF OUR GALAXY



OVERHEAD VIEW OF OUR GALAXY



Polaris (the North Star), a blue-green variable binary star

Light from stars and nebulae in the Perseus Arm

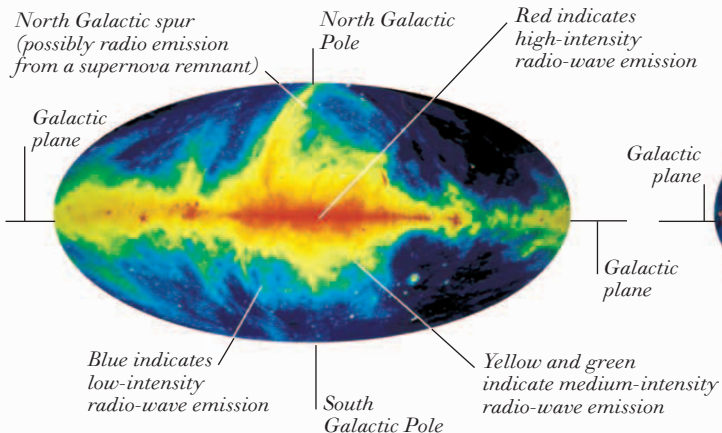
Galactic plane

Milky Way (the band of light that stretches across the night sky)

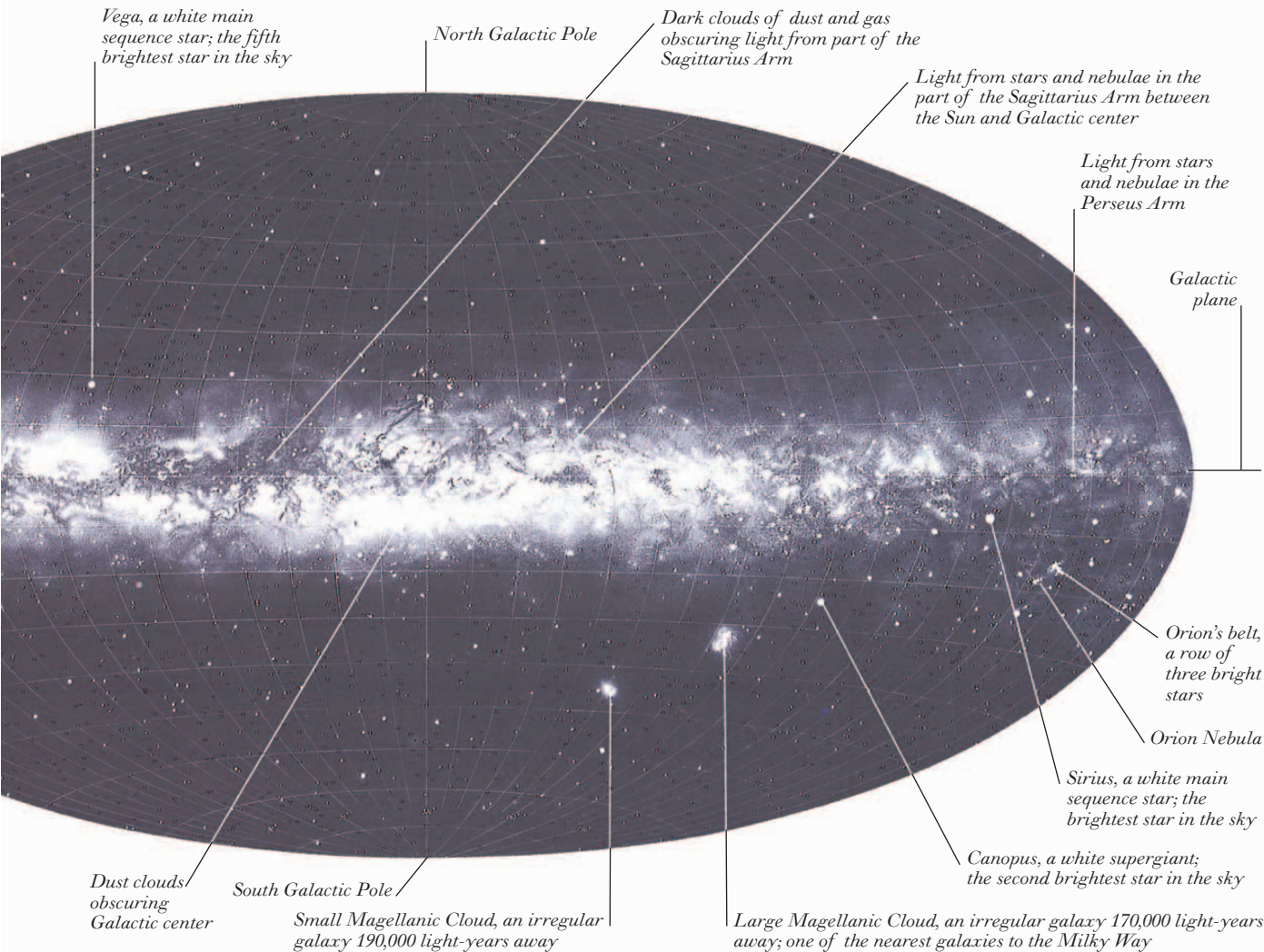
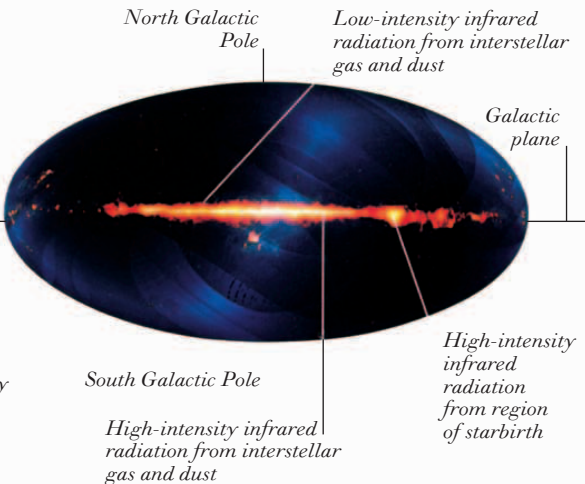
Pleiades (the Seven Sisters), an open star cluster

Andromeda Galaxy, a spiral galaxy 2.2 million light-years away; the most distant object visible to the naked eye

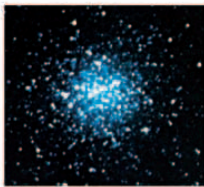
PANORAMIC RADIO MAP OF OUR GALAXY



PANORAMIC INFRARED MAP OF OUR GALAXY



Nebulae and star clusters



HODGE 11, A GLOBULAR CLUSTER

A NEBULA IS A CLOUD OF DUST AND GAS inside a galaxy. Nebulae become visible if the gas glows, or if the cloud reflects starlight or obscures light from more distant objects. Emission nebulae shine because their gas emits light when it is stimulated by radiation from hot young stars. Reflection nebulae shine because their dust reflects light from stars in or around the nebula. Dark nebulae appear as silhouettes because they block out light from shining nebulae or stars behind them. Two types of nebula are associated with dying stars: planetary nebulae and supernova remnants. Both consist of expanding shells of gas that were once the outer layers of a star. A planetary nebula is a gas shell drifting away from a dying stellar core. A supernova

remnant is a gas shell moving away from a stellar core at great speed following a violent explosion called a supernova (see pp. 26-27). Stars are often found in groups known as clusters. Open clusters are loose groups of a few thousand young stars that were born from the same cloud and are drifting apart. Globular clusters are densely packed, roughly spherical groups of hundreds of thousands of older stars.

PLEIADES (OPEN STAR CLUSTER) WITH A REFLECTION NEBULA

Wisps of dust and hydrogen gas. The cluster is passing through a region of interstellar material

Young star in an open cluster of more than 1,000 stars

Reflection nebula



TRIFID NEBULA (EMISSION NEBULA)

Reflection nebula

Emission nebula

Dust lane

Starbirth region (area in which dust and gas clump together to form stars)



HORSEHEAD NEBULA (DARK NEBULA)

Glowing filament of hot, ionized hydrogen gas

Alnitak (star in Orion's belt)

Dust lane

Emission nebula

Star near southern end of Orion's belt

Emission nebula

Horsehead Nebula

Reflection nebula

Dark nebula obscuring light from distant stars



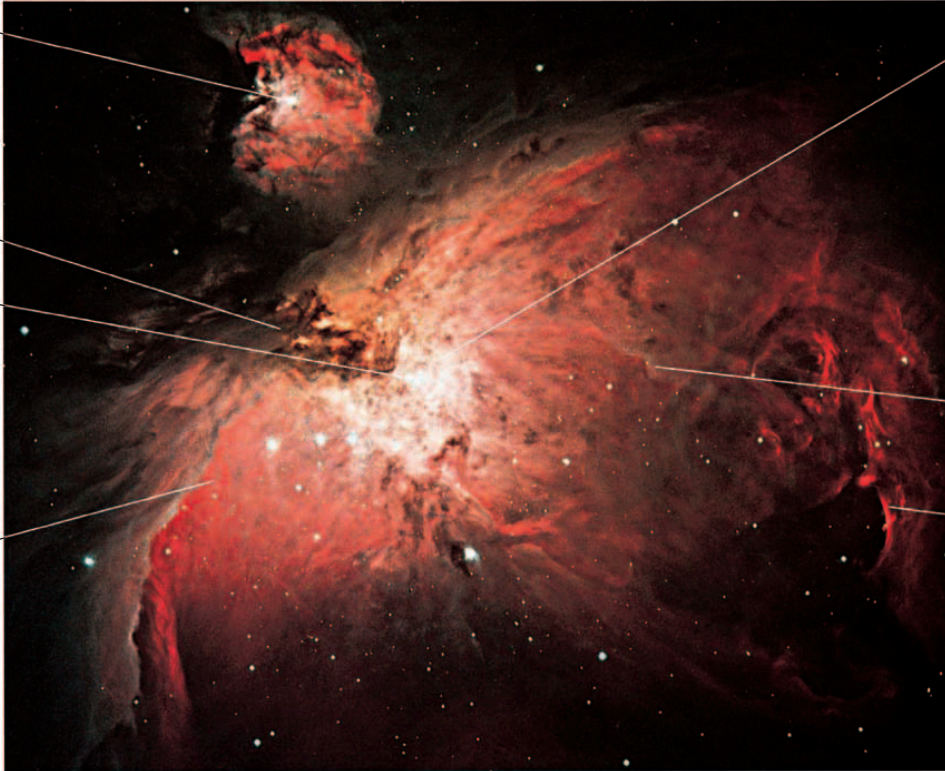
ORION NEBULA (DIFFUSE EMISSION NEBULA)

Glowing cloud of dust and hydrogen gas forming part of Orion Nebula

Dust cloud

Trapezium (group of four young stars)

Red light from hot, ionized hydrogen gas



Gas cloud emitting light due to ultraviolet radiation from the four young Trapezium stars

Green light from hot, ionized oxygen gas

Glowing filament of hot, ionized hydrogen gas

HELIX NEBULA (PLANETARY NEBULA)



Planetary nebula (gas shell expanding outward from dying stellar core)

Core remnant with surface temperature of about 180,000°F (100,000°C)

Red light from hot, ionized hydrogen gas

Blue-green light from hot, ionized oxygen and nitrogen gases

VELA SUPERNOVA REMNANT



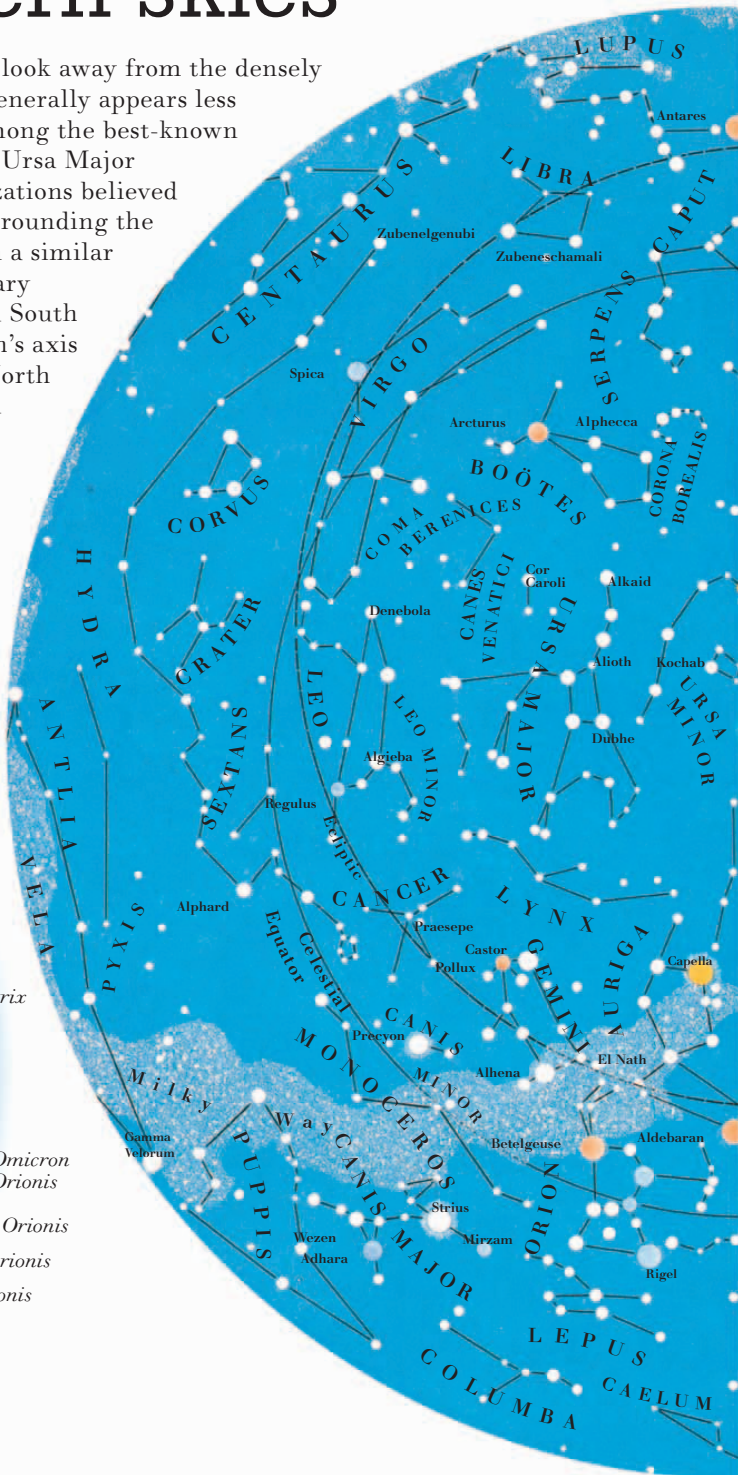
Supernova remnant (gas shell consisting of outer layers of star thrown off in supernova explosion)

Hydrogen gas emitting red light due to being heated by supernova explosion

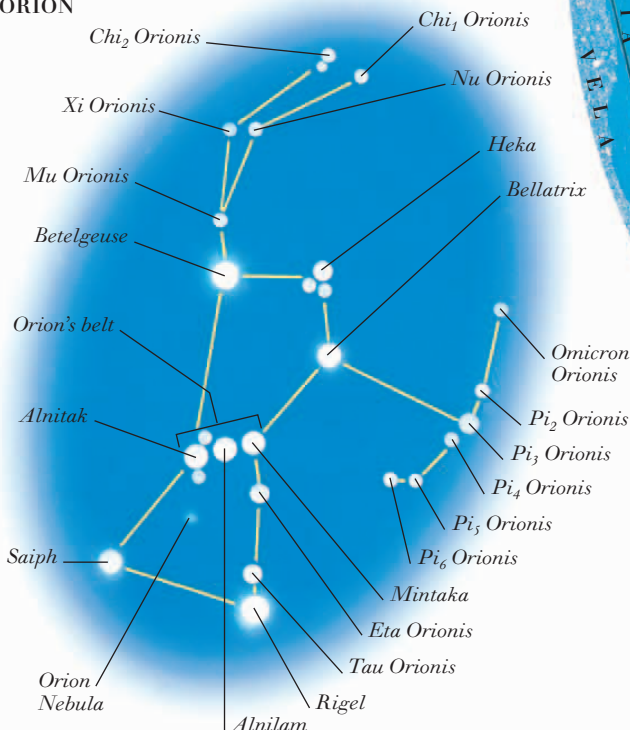
Glowing filament of hot, ionized hydrogen gas

Stars of northern skies

WHEN YOU LOOK AT THE NORTHERN SKY, you look away from the densely populated Galactic center, so the northern sky generally appears less bright than the southern sky (see pp. 20-21). Among the best-known sights in the northern sky are the constellations Ursa Major (the Great Bear) and Orion. Some ancient civilizations believed that the stars were fixed to a celestial sphere surrounding the Earth, and modern maps of the sky are based on a similar idea. The North and South Poles of this imaginary celestial sphere are directly above the North and South Poles of the Earth, at the points where the Earth's axis of rotation intersects the sphere. The celestial North Pole is at the center of the map shown here, and Polaris (the North Star) lies very close to it. The celestial equator marks a projection of the Earth's equator on the sphere. The ecliptic marks the path of the Sun across the sky as the Earth orbits the Sun. The Moon and planets move against the background of the stars because the stars are much more distant; the nearest star outside the solar system (Proxima Centauri) is more than 50,000 times farther away than the planet Jupiter.

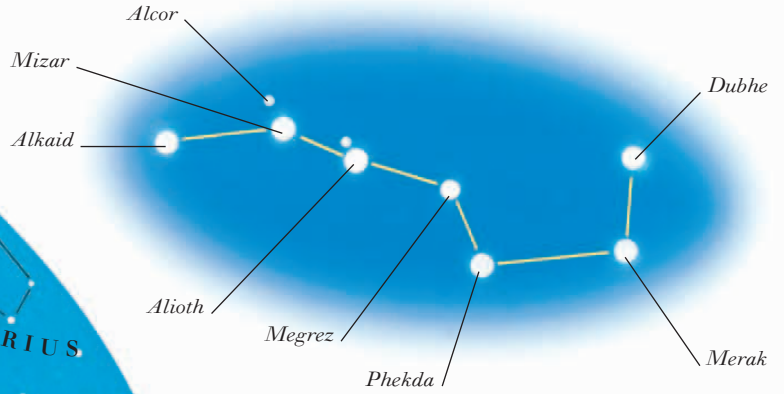


ORION



VISIBLE STARS IN THE NORTHERN SKY

THE BIG DIPPER, PART OF URSA MAJOR (THE GREAT BEAR)



PEGASUS AND ANDROMEDA

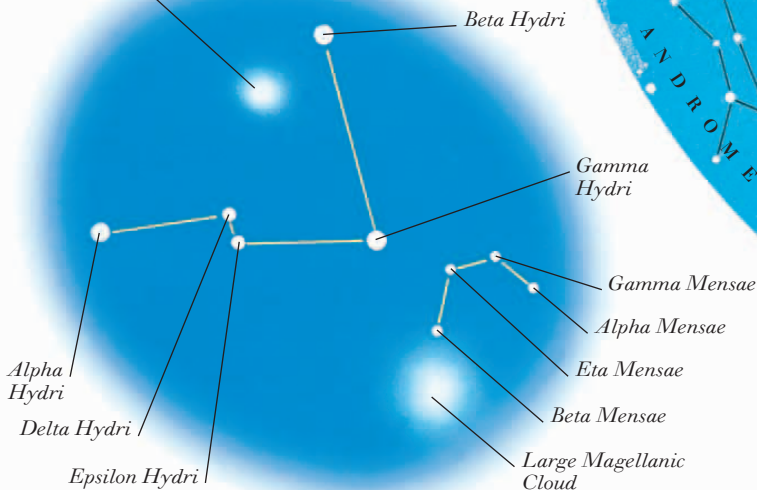


Stars of southern skies

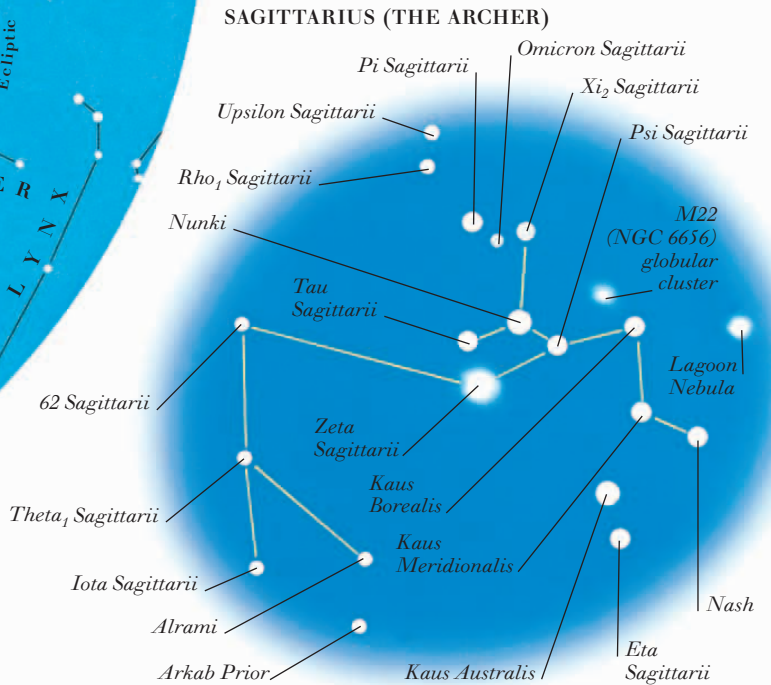
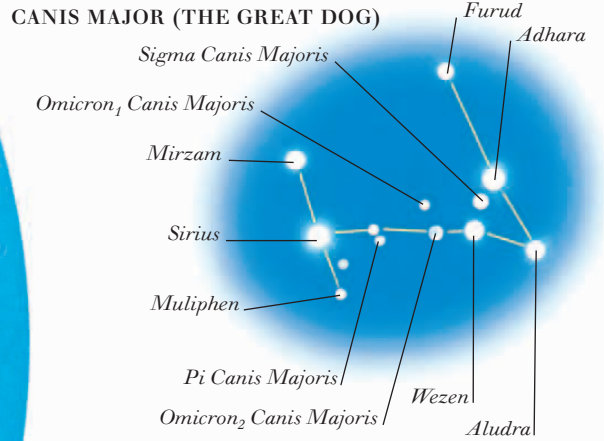
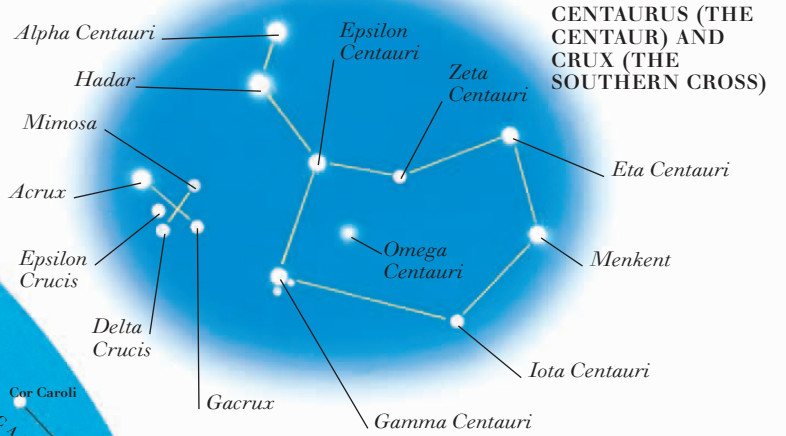
WHEN YOU LOOK AT THE SOUTHERN SKY, you look toward the Galactic center, which has a huge population of stars. As a result, the Milky Way appears brighter in the southern sky than in the northern sky (see pp. 18-19). The southern sky is rich in nebulae and star clusters. It contains the Large and Small Magellanic Clouds, which are two of the nearest galaxies to our own. Stars make fixed patterns in the sky called constellations. However, the constellations are only apparent groupings of stars, since the distances to the stars in a constellation may vary enormously. The shapes of constellations may change over many thousands of years due to the relative motions of stars. The movement of the constellations across the sky is due to the Earth's motion in space. The daily rotation of the Earth causes the constellations to move across the sky from east to west, and the orbit of the Earth around the Sun causes different areas of sky to be visible in different seasons. The visibility of areas of sky also depends on the location of the observer. For instance, stars near the celestial equator may be seen from either hemisphere at some time during the year, whereas stars close to the celestial poles (the celestial South Pole is at the center of the map shown here) can never be seen from the opposite hemisphere.

HYDRUS (THE WATER SNAKE) AND MENSA (THE TABLE)

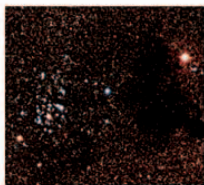
Small Magellanic Cloud



VISIBLE STARS IN THE SOUTHERN SKY



Stars



OPEN STAR CLUSTER AND DUST CLOUD

STARS ARE BODIES of hot, glowing gas that are born in nebulae (see pp. 24-27). They vary enormously in size, mass, and temperature: diameters range from about 450 times smaller to over 1,000 times bigger than that of the Sun; masses range from about a twentieth to over 50 solar masses; and surface temperatures range from about 5,500°F

(3,000°C) to over 90,000°F (50,000°C). The color of a star is determined by its temperature: the hottest stars are blue and the coolest are red.

The Sun, with a surface temperature of 10,000°F (5,500°C), is between these extremes and appears yellow. The energy emitted by a shining star is usually produced by nuclear fusion in the star's core. The brightness of a star is measured in magnitudes—the brighter the star, the lower its magnitude. There are two types of magnitude: apparent magnitude, which is the brightness seen from Earth, and absolute magnitude, which is the brightness that would be seen from a standard distance of 10 parsecs (32.6 light-years). The light emitted by a star may be split to form a spectrum containing a series of dark lines (absorption lines). The patterns of lines indicate the presence of particular chemical elements, enabling astronomers to deduce the composition of the star's atmosphere. The magnitude and spectral type (color) of stars may be plotted on a graph called a Hertzsprung-Russell diagram, which shows that stars tend to fall into several well-defined groups. The principal groups are main sequence stars (those which are fusing hydrogen to form helium), giants, supergiants, and white dwarfs.

STAR SIZES

Red giant from 10 to 100 million miles (15 to 150 million km) wide

The Sun (main sequence star; diameter 870,000 miles/1.4 million km)

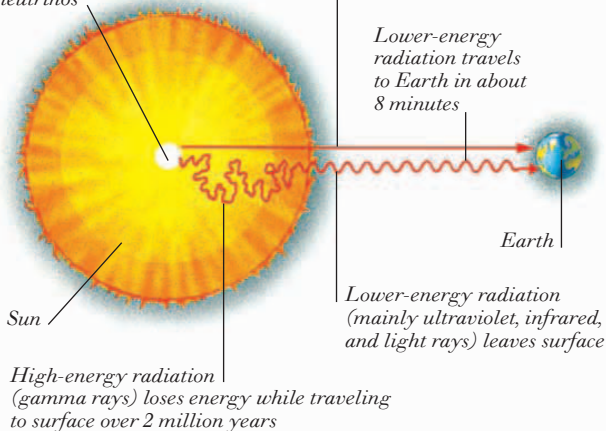
White dwarf (diameter of 2,000 to 30,000 miles/3,000 to 50,000 km)

ENERGY EMISSION FROM THE SUN

Nuclear fusion in core produces gamma rays and neutrinos

Neutrinos travel to Earth directly from Sun's core in about 8 minutes

Lower-energy radiation travels to Earth in about 8 minutes



Lower-energy radiation (mainly ultraviolet, infrared, and light rays) leaves surface

High-energy radiation (gamma rays) loses energy while traveling to surface over 2 million years

STAR MAGNITUDES

APPARENT MAGNITUDE

ABSOLUTE MAGNITUDE

Brighter stars

Fainter stars

Sirius: apparent magnitude of -1.46

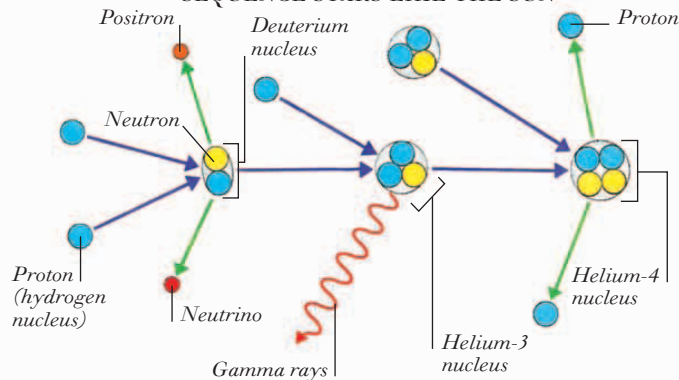
Rigel: apparent magnitude of +0.12

Objects of magnitude higher than about +6.0 cannot be seen by the naked eye

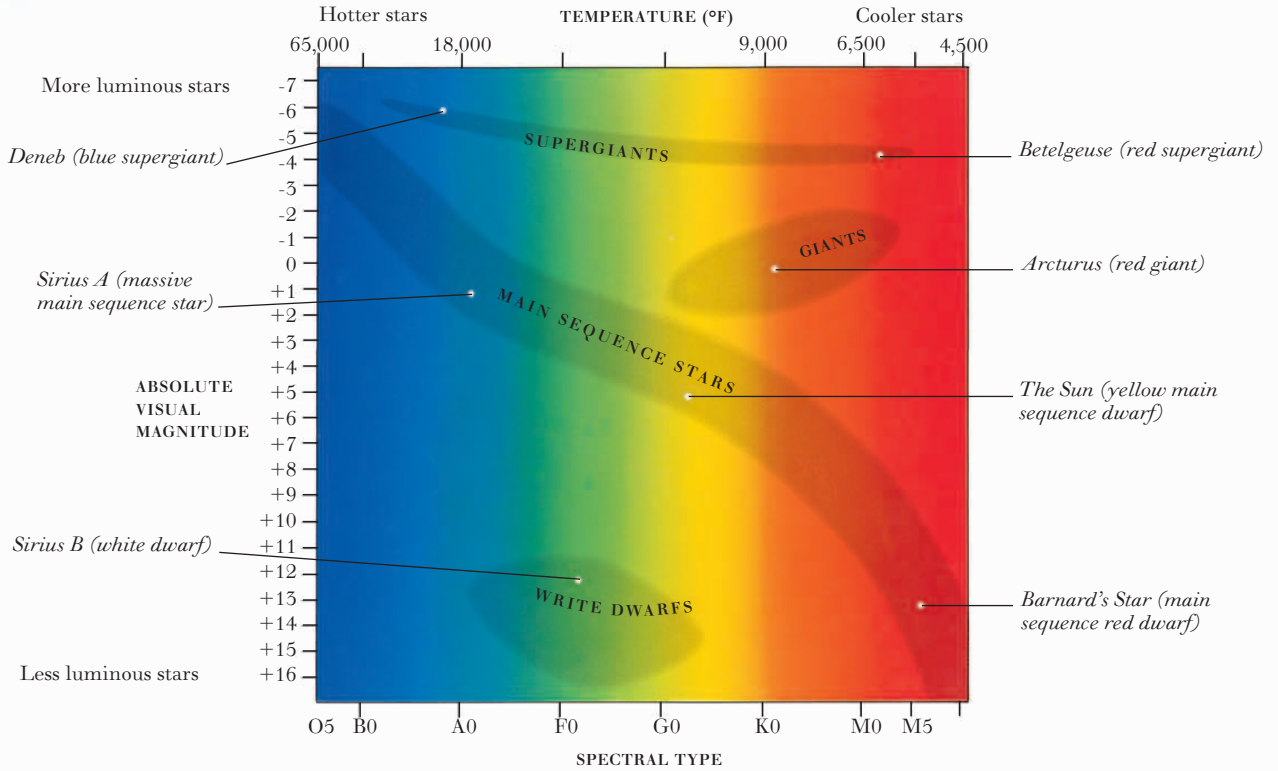
Rigel: absolute magnitude of -7.1

Sirius: absolute magnitude of +1.4

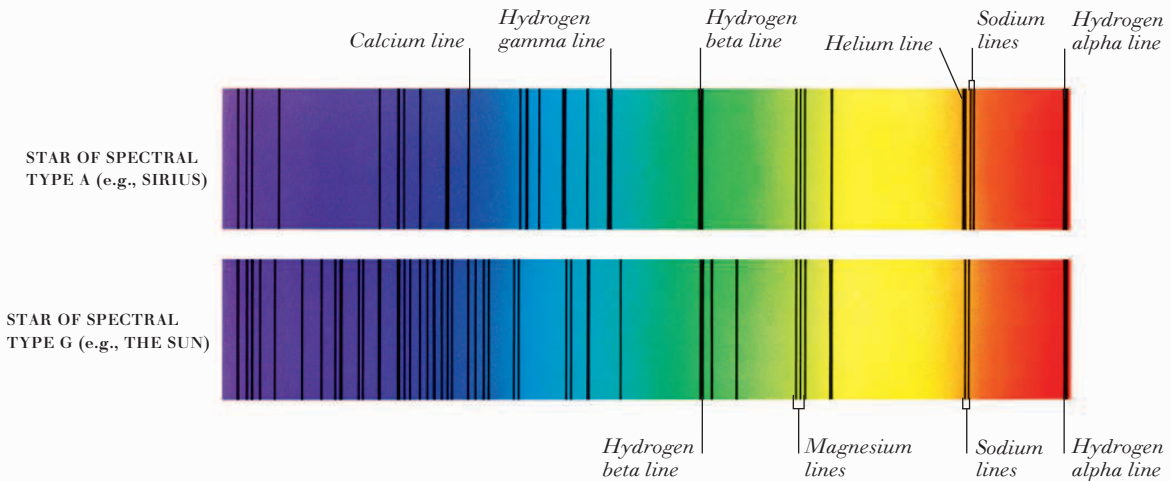
NUCLEAR FUSION IN MAIN SEQUENCE STARS LIKE THE SUN



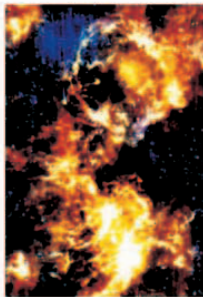
HERTZSPRUNG-RUSSELL DIAGRAM



STELLAR SPECTRAL ABSORPTION LINES



Small stars

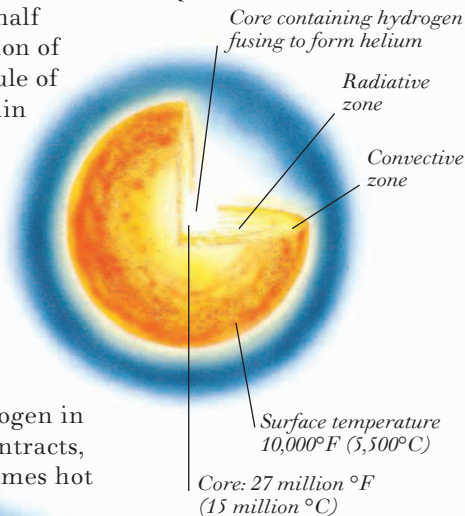


REGION OF STAR FORMATION IN ORION

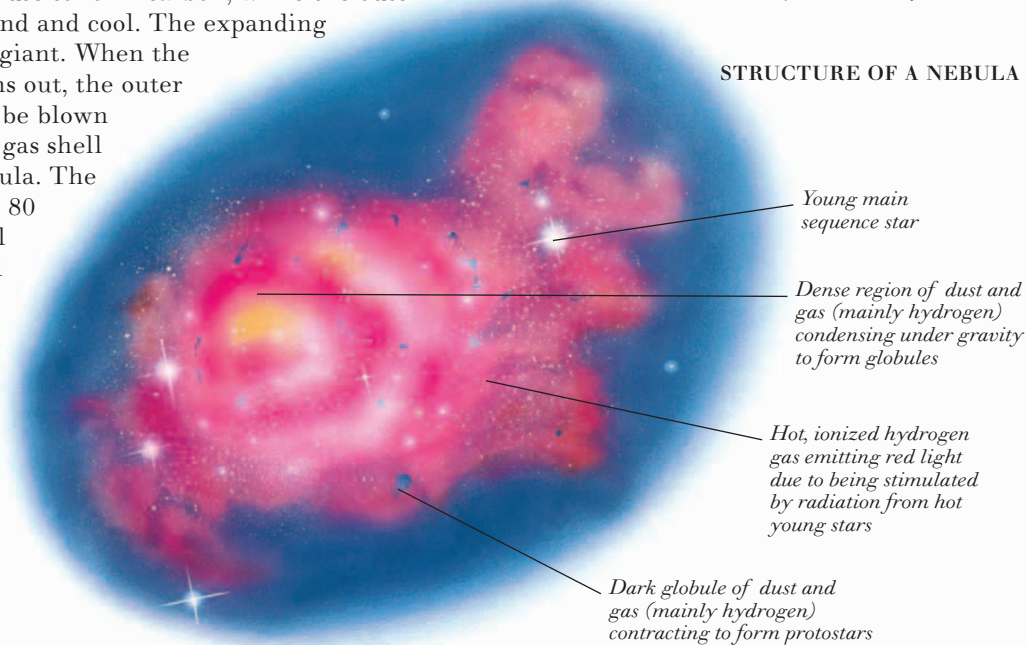
SMALL STARS HAVE A MASS of up to about one and a half times that of the Sun. They begin to form when a region of higher density in a nebula condenses into a huge globule of gas and dust that contracts under its own gravity. Within a globule, regions of condensing matter heat up and begin to glow, forming protostars. If a protostar contains enough matter, the central temperature reaches about 27 million °F (8 million °C). At this temperature, nuclear reactions in which hydrogen fuses to form helium can start. This process releases energy, which prevents the star from contracting more and also causes it to shine; it is now a main sequence star. A star of about one solar mass remains

on the main sequence for about 10 billion years, until much of the hydrogen in the star's core has been converted into helium. The helium core then contracts, and nuclear reactions continue in a shell around the core. The core becomes hot enough for helium to fuse to form carbon, while the outer layers of the star expand and cool. The expanding star is known as a red giant. When the helium in the core runs out, the outer layers of the star may be blown away as an expanding gas shell called a planetary nebula. The remaining core (about 80 percent of the original star) is now in its final stages. It becomes a white dwarf star that gradually cools and dims. When it finally stops shining altogether, the dead star will become a black dwarf.

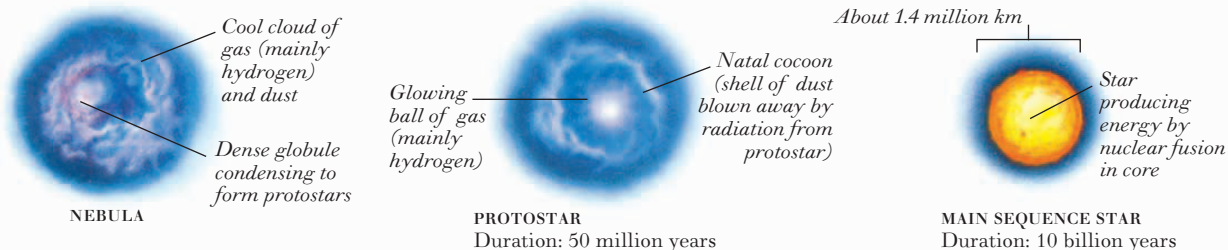
STRUCTURE OF A MAIN SEQUENCE STAR



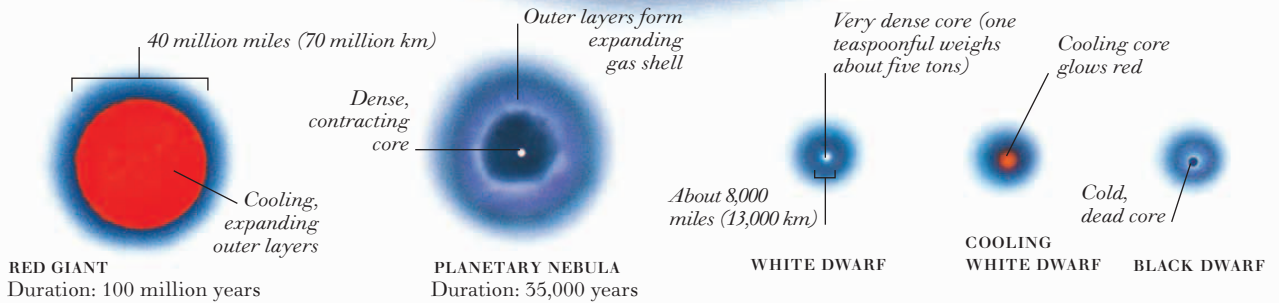
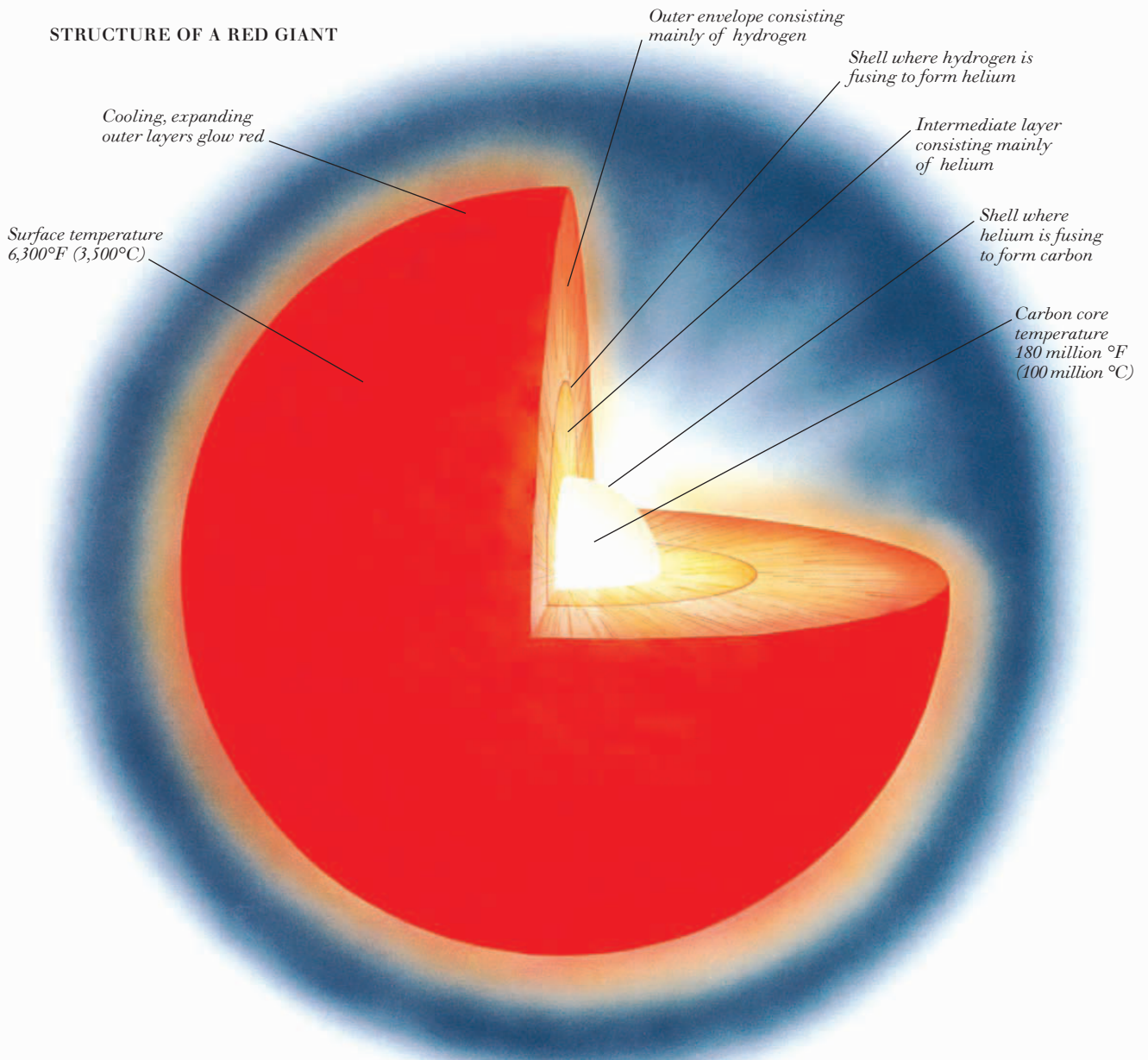
STRUCTURE OF A NEBULA



LIFE OF A SMALL STAR OF ABOUT ONE SOLAR MASS



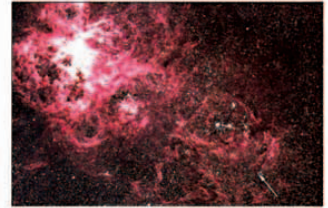
STRUCTURE OF A RED GIANT



Massive stars

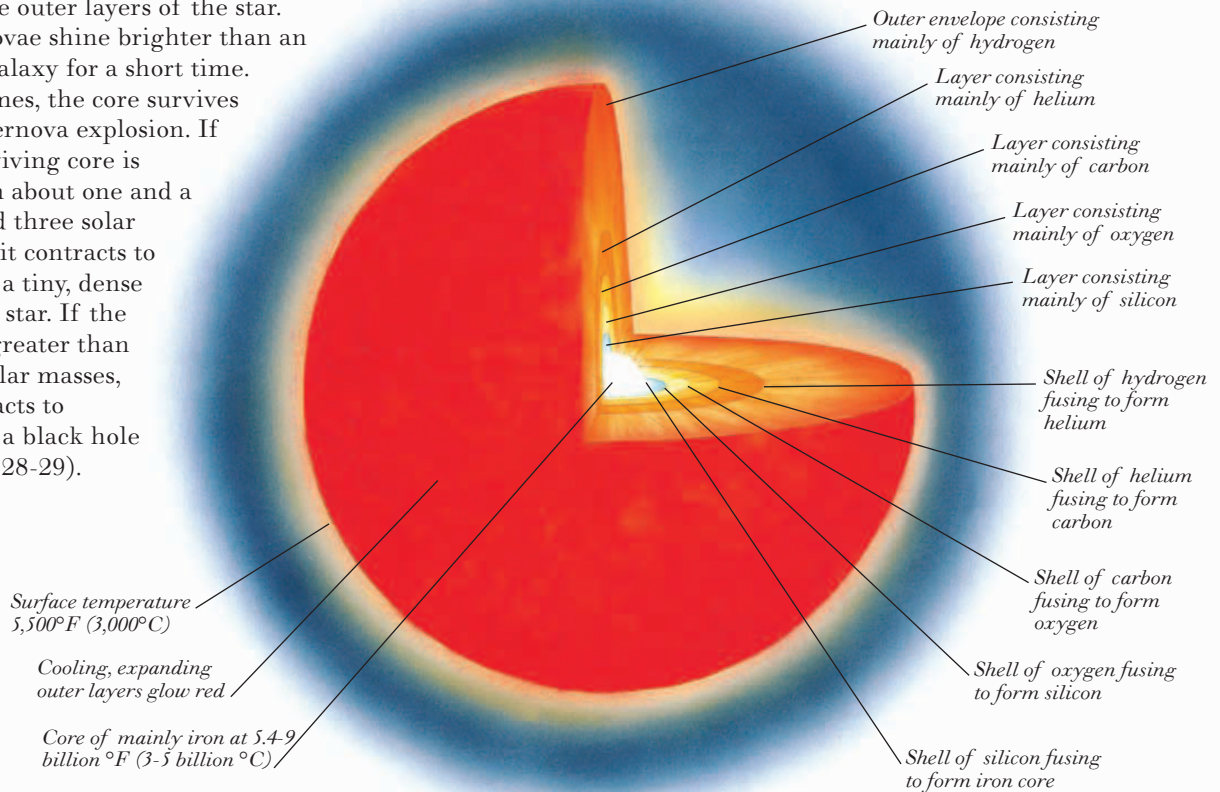
MASSIVE STARS HAVE A MASS AT LEAST THREE TIMES that of the Sun, and some stars are as massive as about 50 Suns. A massive star evolves in a similar way to a small star until it reaches the main sequence stage (see pp. 24-25). During its life as a main sequence star, it shines steadily until the hydrogen in its core has fused to form helium. This process takes billions of years in a small star, but only millions of years in a massive star. A massive star then becomes a red supergiant, which initially consists of a helium core surrounded by outer layers of cooling, expanding gas. Over the next few million years, a series of nuclear reactions form different elements in shells around an iron core. The core eventually collapses in less than a second, causing a massive explosion called a supernova, in which a shock wave blows away the outer layers of the star. Supernovae shine brighter than an entire galaxy for a short time. Sometimes, the core survives the supernova explosion. If the surviving core is between about one and a half and three solar masses, it contracts to become a tiny, dense neutron star. If the core is greater than three solar masses, it contracts to become a black hole (see pp. 28-29).

SUPERNOVA

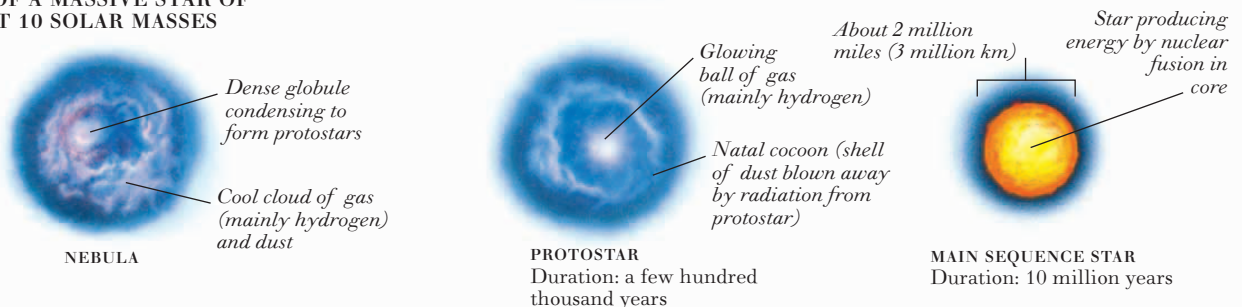


TARANTULA NEBULA BEFORE SUPERNOVA

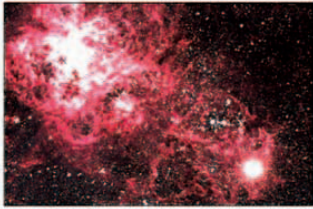
STRUCTURE OF A RED SUPERGIANT



LIFE OF A MASSIVE STAR OF ABOUT 10 SOLAR MASSES



FEATURES OF A SUPERNOVA



TARANTULA NEBULA SHOWING SUPERNOVA IN 1987

Chemical elements heavier than iron are produced in the explosion and scattered into space

Ejecta (outer layers of star thrown off during explosion) travels at 6,000 miles/sec (10,000 km/sec)

Shock wave travels outward from core at 20,000 miles/sec (30,000 km/sec)

Reverse shock wave moves inward and heats ejecta, causing it to shine

Central temperature: 18 billion °F (10 billion °C)

Contracting core consisting mainly of neutrons remains after explosion

Light energy of a billion Suns emitted during explosion

Extremely dense core (one teaspoonful weighs about a billion tons)
6 miles (4 km)
Core mass of less than three solar masses

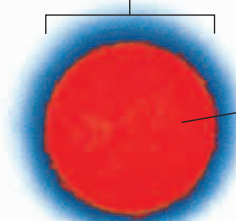
NEUTRON STAR

Core of mass greater than three solar masses continues contracting to become black hole

Accretion disk

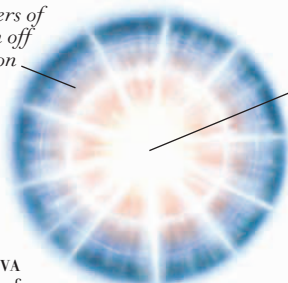
BLACK HOLE

60 million miles (100 million km)



RED SUPERGIANT
Duration: 4 million years

Outer layers of star blown off in explosion

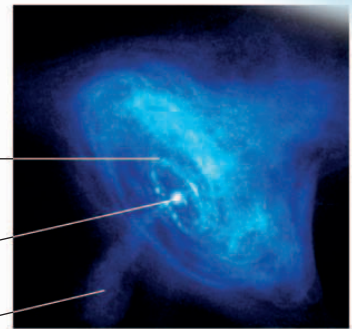


SUPERNOVA
Duration of visibility: 1-2 years

Contracting stellar core may remain after supernova

Neutron stars and black holes

NEUTRON STARS AND BLACK HOLES form from the stellar cores that remain after stars have exploded as supernovae (see pp. 26-27). If the remaining core is between about one and a half and three solar masses, it contracts to form a neutron star. If the remaining core is greater than about three solar masses, it contracts to form a black hole. Neutron stars are typically only about 6 miles (10 km) in diameter and consist almost entirely of subatomic particles called neutrons. Such stars are so dense that a teaspoonful would weigh about a billion tons. Neutron stars are observed as pulsars, so-called because they rotate rapidly and emit two beams of radio waves, which sweep across the sky and are detected as short pulses. Black holes are characterized by their extremely strong gravity, which is so powerful that not even light can escape; as a result, black holes are invisible. However, they can be detected if they have a close companion star. The gravity of the black hole pulls gas from the other star, forming an accretion disk that spirals around the black hole at high speed, heating up and emitting radiation. Eventually, the matter spirals in to cross the event horizon (the boundary of the black hole), thereby disappearing from the visible universe.



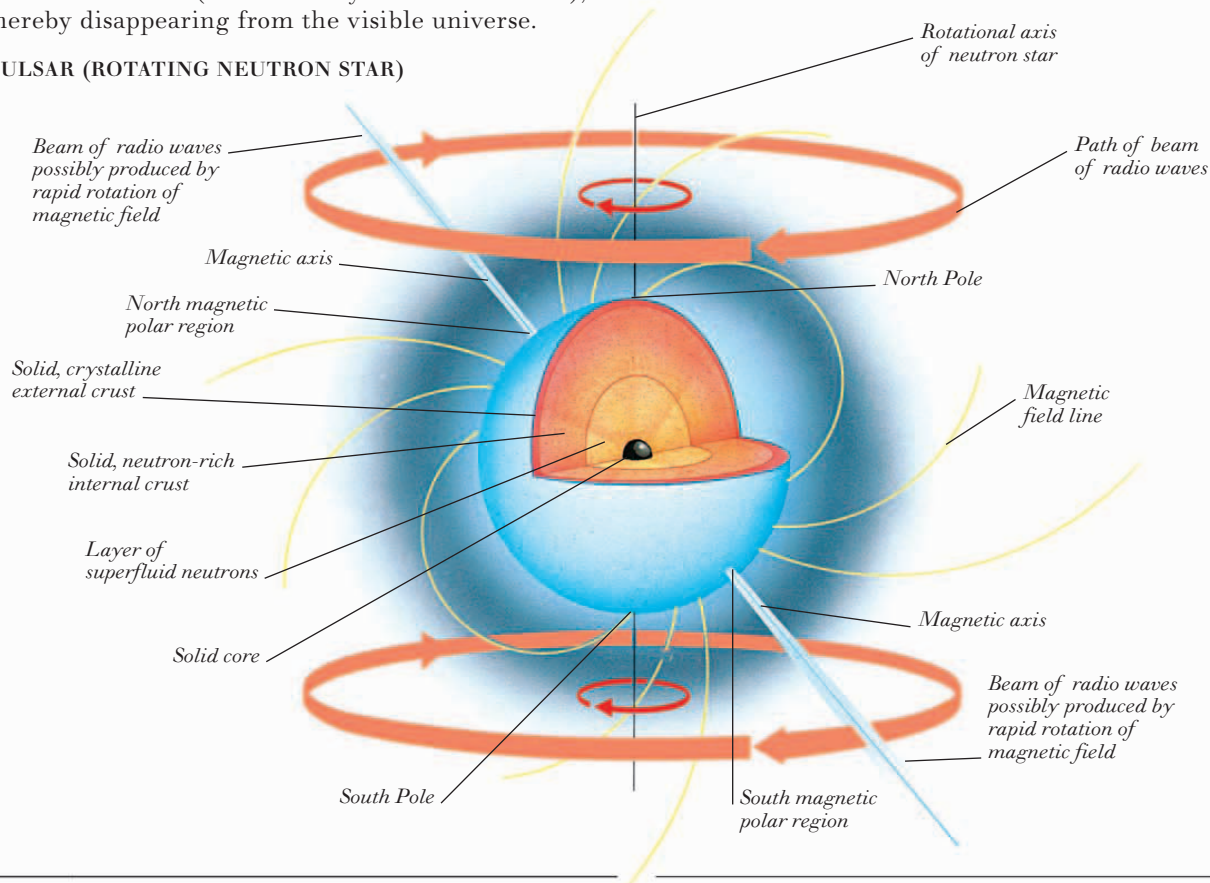
Nebula of gas and dust surrounds pulsar

Rapidly rotating pulsar

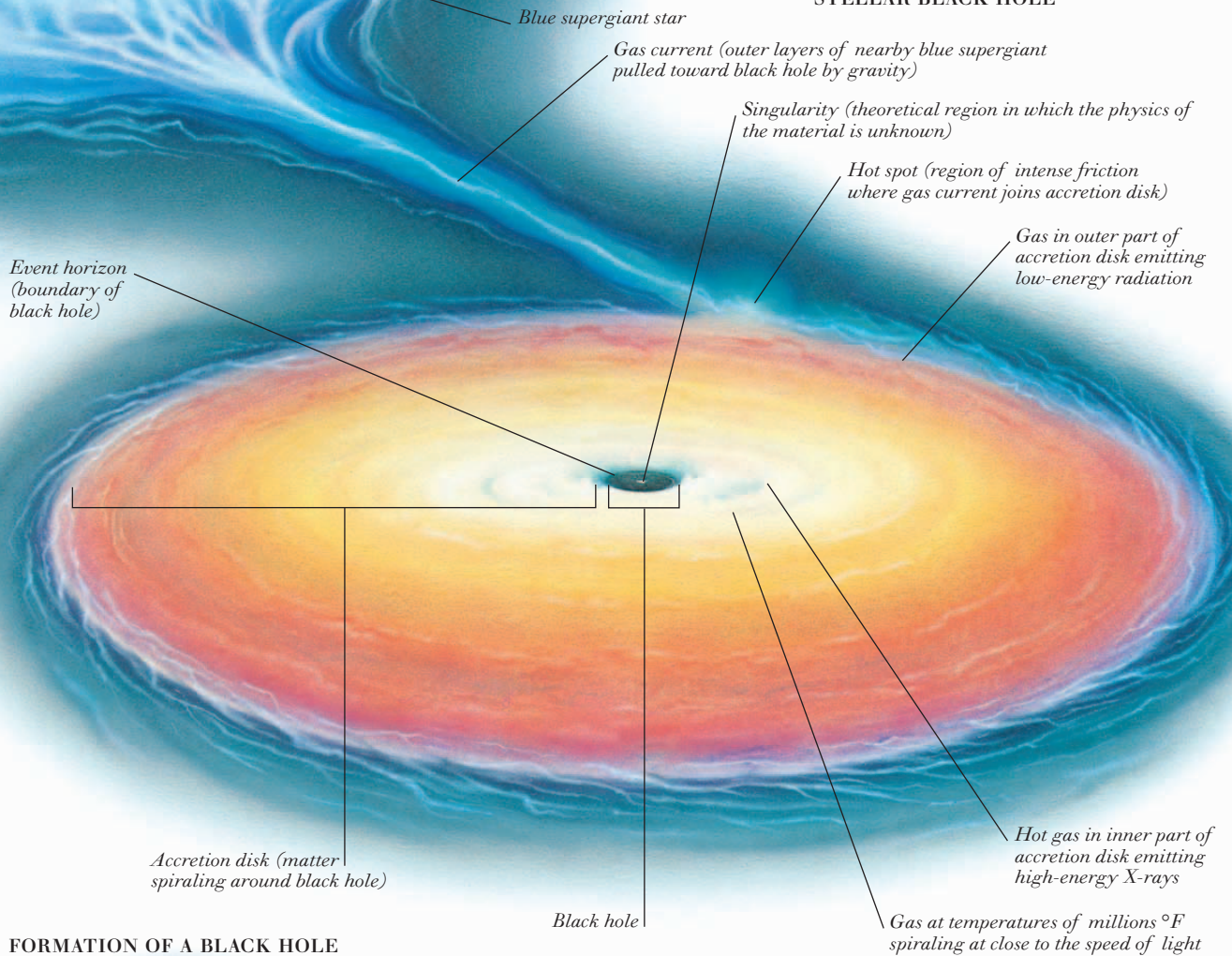
Beam of radiation from pulsar

X-RAY IMAGE OF PULSAR AND CENTRAL REGION OF CRAB NEBULA (SUPERNOVA REMNANT)

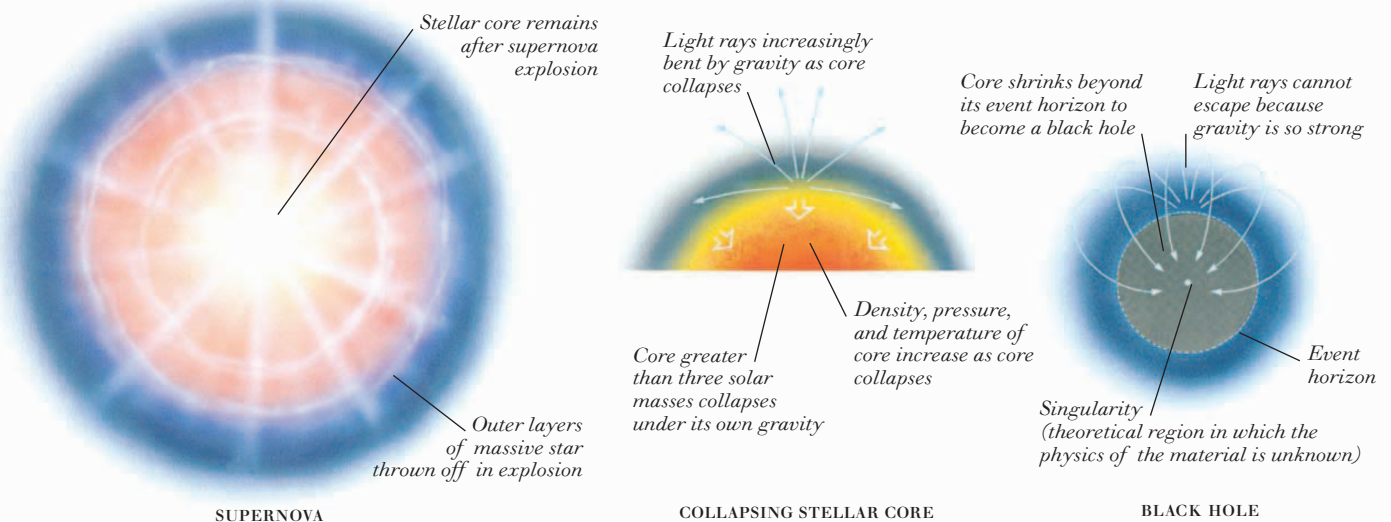
PULSAR (ROTATING NEUTRON STAR)



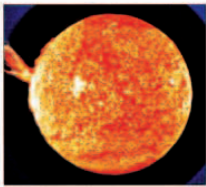
STELLAR BLACK HOLE



FORMATION OF A BLACK HOLE



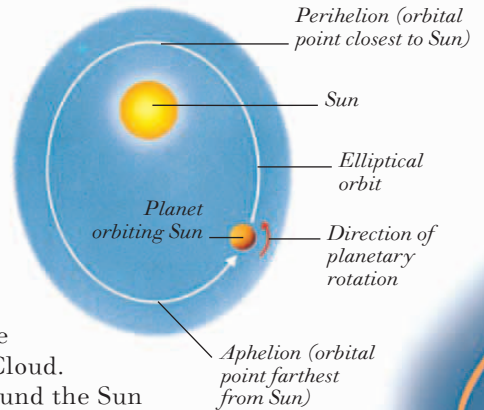
The solar system



THE SOLAR SYSTEM consists of a central star (the Sun) and the bodies that orbit it. These bodies include eight planets and their more than 160 known moons; dwarf planets; Kuiper Belt objects; asteroids; comets; and meteoroids. The solar system also contains interplanetary gas and dust. The planets fall into two groups: four small rocky planets near the Sun (Mercury, Venus, Earth, and

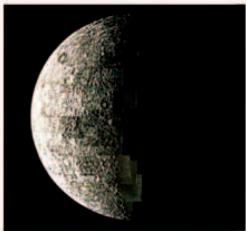
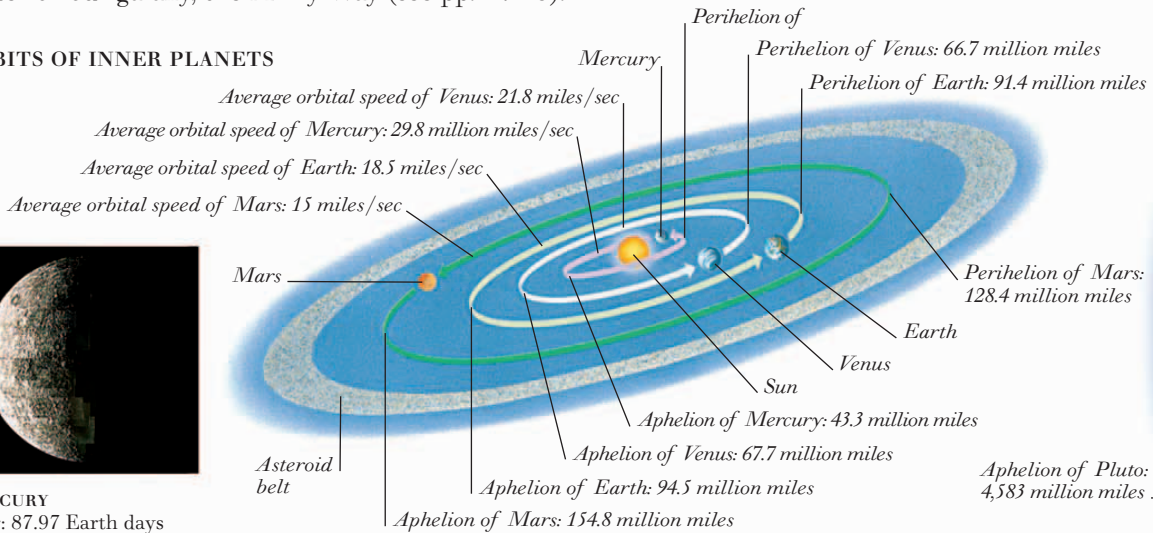
Mars); and four planets farther out, the giants (Jupiter, Saturn, Uranus, and Neptune). Between the rocky planets and giants is the asteroid belt, which contains thousands of chunks of rock orbiting the Sun. Beyond Neptune is the Kuiper Belt and, more distant, the Oort Cloud. Most of the bodies in the planetary part of the solar system move around the Sun in elliptical orbits located in a thin disk around the Sun's equator. All the planets orbit the Sun in the same direction (counterclockwise when viewed from above) and all but Venus and Uranus also spin about their axes in this direction. Moons also spin as they, in turn, orbit their planets. The entire solar system orbits the center of our galaxy, the Milky Way (see pp. 14-15).

PLANETARY ORBIT (EXAGGERATED)

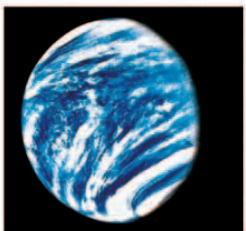


Aphelion of Neptune: 2.8 billion miles

ORBITS OF INNER PLANETS



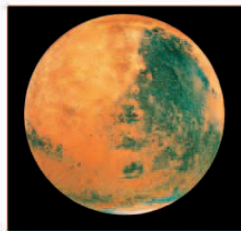
MERCURY
Year: 87.97 Earth days
Mass: 0.06 Earth masses
Diameter: 3,051 miles



VENUS
Year: 224.7 Earth days
Mass: 0.81 Earth masses
Diameter: 7,521 miles



EARTH
Year: 365.26 days
Mass: 1 Earth mass
Diameter: 7,926 miles

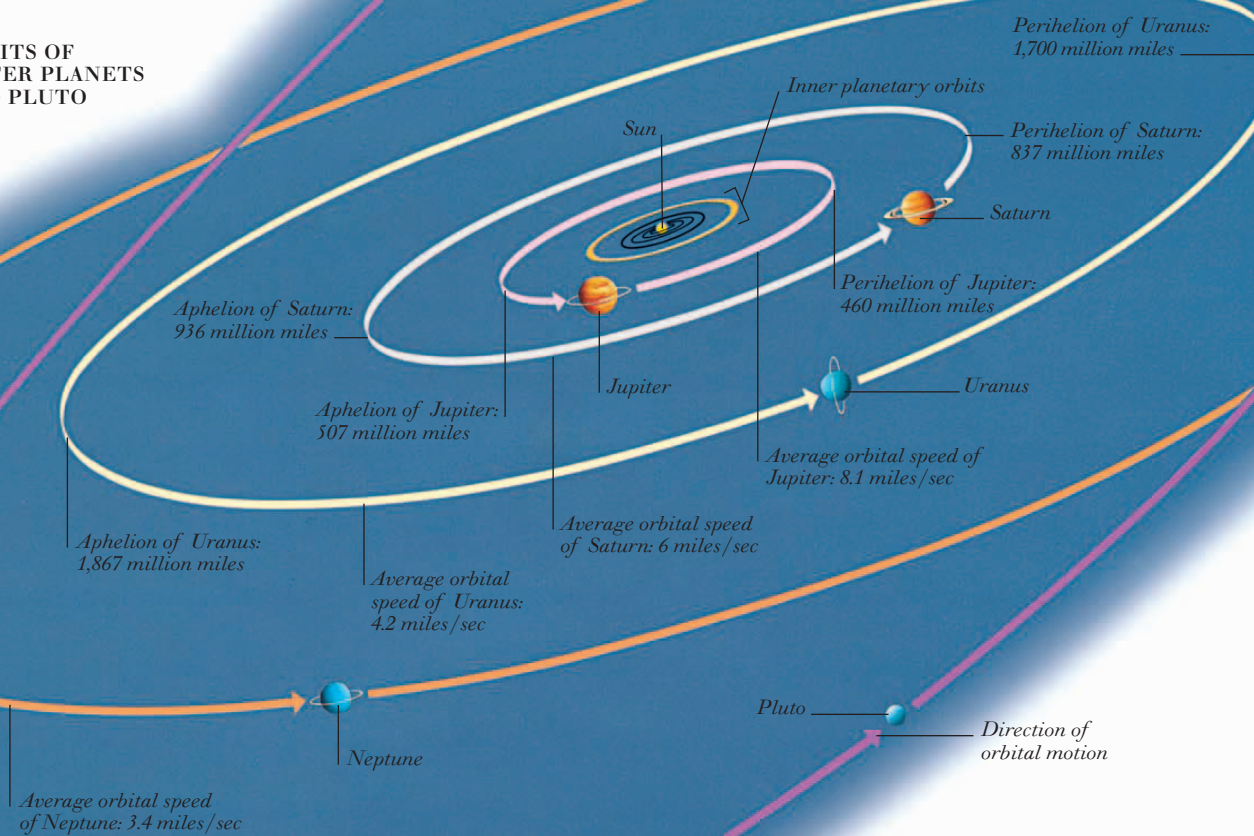


MARS
Year: 1.88 Earth years
Mass: 0.11 Earth masses
Diameter: 4,217 miles

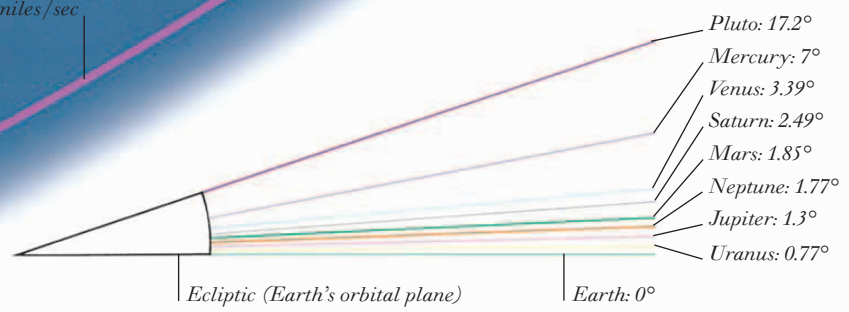


JUPITER
Year: 11.87 Earth years
Mass: 317.85 Earth masses
Diameter: 88,850 miles

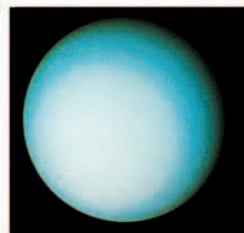
ORBITS OF OUTER PLANETS AND PLUTO



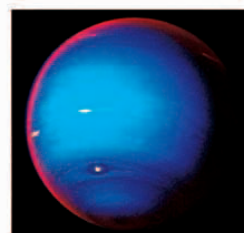
INCLINATION OF ORBITS TO THE ECLIPTIC



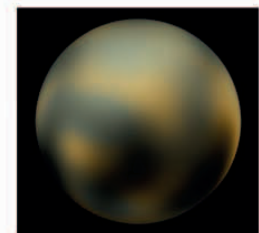
SATURN
 Year: 29.66 Earth years
 Mass: 95.16 Earth masses
 Diameter: 74,901 miles



URANUS
 Year: 84.13 Earth years
 Mass: 14.54 Earth masses
 Diameter: 31,765 miles

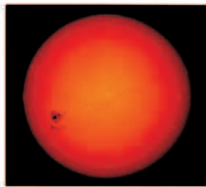


NEPTUNE
 Year: 164.70 Earth years
 Mass: 17.14 Earth masses
 Diameter: 30,777 miles



PLUTO
 Year: 248.09 Earth years
 Mass: 0.0022 Earth masses
 Diameter: 1,429 miles

The Sun

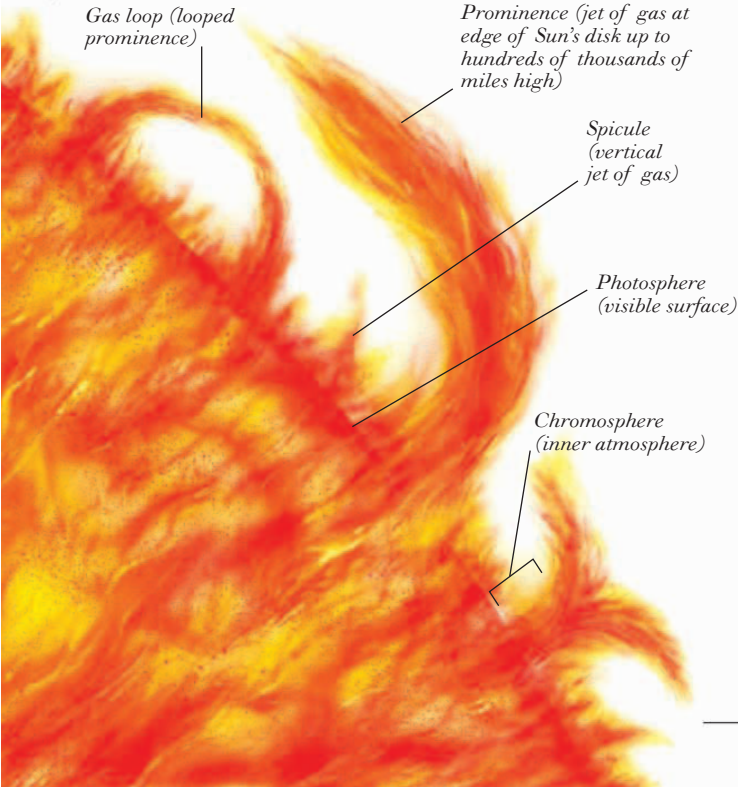


SOLAR PHOTOSPHERE

THE SUN IS THE STAR AT THE CENTER of the solar system. It is about five billion years old and will continue to shine as it does now for about another five billion years. The Sun is a yellow main sequence star (see pp. 22-23) about 870,000 miles (1.4 million km) in diameter. It consists almost entirely of hydrogen and helium. In the Sun's core, hydrogen is converted to helium by nuclear fusion, releasing energy in the process. The energy

travels from the core, through the radiative and convective zones, to the photosphere (visible surface), where it leaves the Sun in the form of heat and light. On the photosphere there are often dark, relatively cool areas called sunspots, which usually appear in pairs or groups and are caused by the cooling effect of the magnetic field. Other types of solar activity are flares, which are usually associated with sunspots, and prominences. Flares are sudden discharges of high-energy radiation and atomic particles. Prominences are huge loops or filaments of gas extending into the solar atmosphere; some last for hours, others for months. Beyond the photosphere is the chromosphere (inner atmosphere) and the extremely rarified corona (outer atmosphere), which extends millions of miles into space. Tiny particles that escape from the corona give rise to the solar wind, which streams through space at hundreds of miles per second. The chromosphere and corona can be seen from Earth when the Sun is totally eclipsed by the Moon.

SURFACE FEATURES



Gas loop (looped prominence)

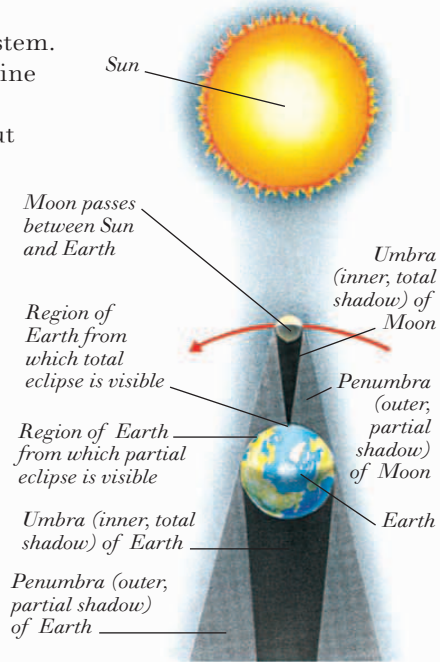
Prominence (jet of gas at edge of Sun's disk up to hundreds of thousands of miles high)

Spicule (vertical jet of gas)

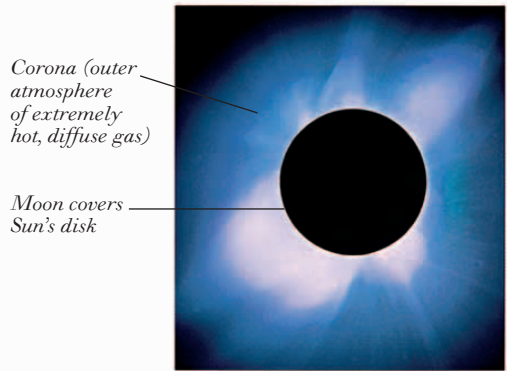
Photosphere (visible surface)

Chromosphere (inner atmosphere)

HOW A SOLAR ECLIPSE OCCURS



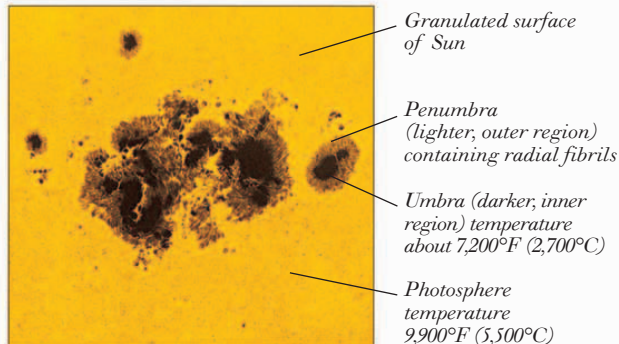
TOTAL SOLAR ECLIPSE



Corona (outer atmosphere of extremely hot, diffuse gas)

Moon covers Sun's disk

SUNSPOTS



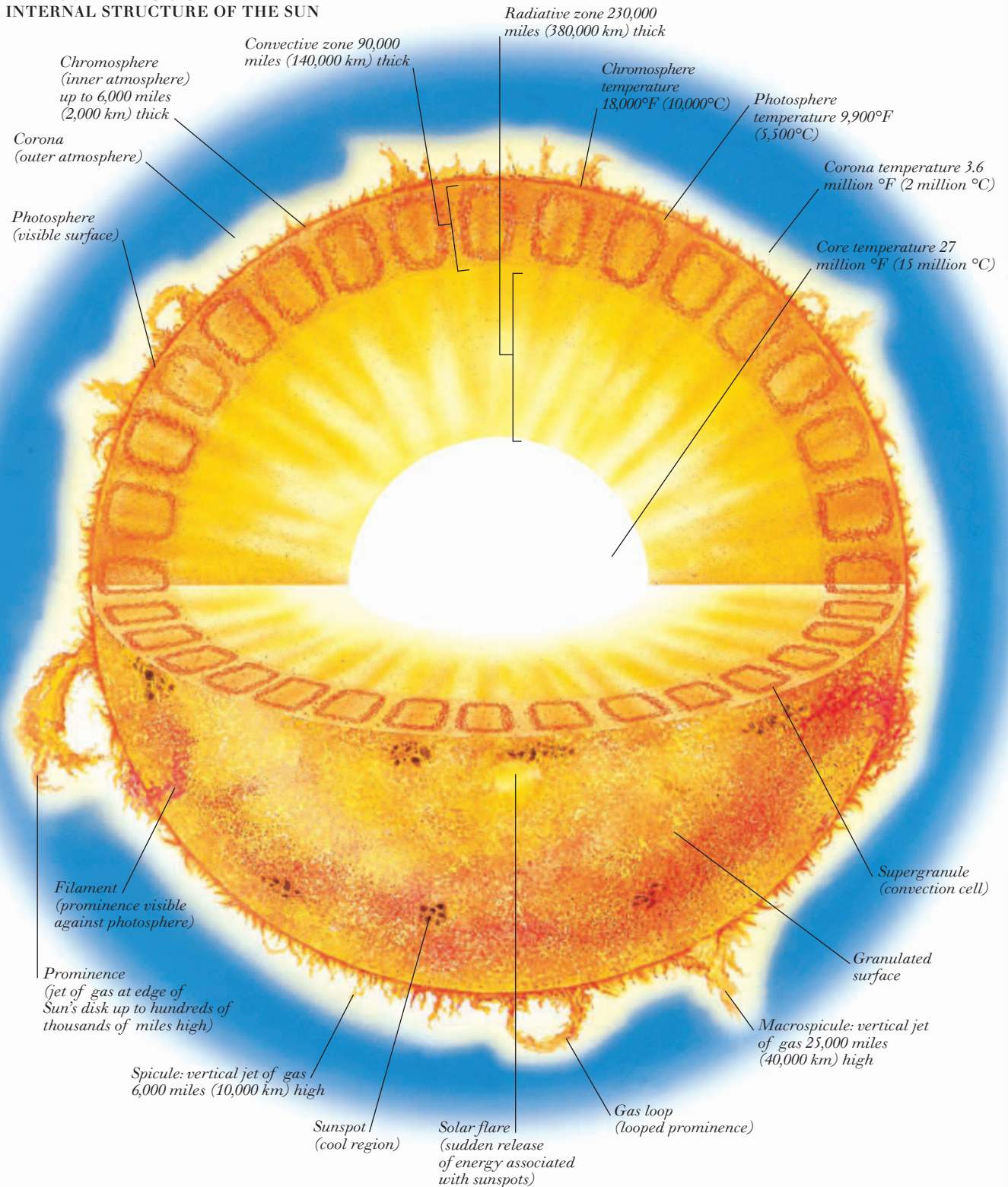
Granulated surface of Sun

Penumbra (lighter, outer region) containing radial fibrils

Umbra (darker, inner region) temperature about 7,200°F (2,700°C)

Photosphere temperature 9,900°F (5,500°C)

**EXTERNAL FEATURES AND
INTERNAL STRUCTURE OF THE SUN**



Mercury

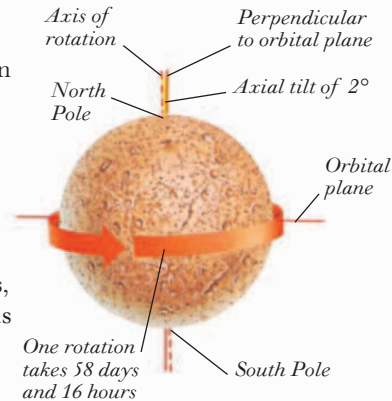


MERCURY

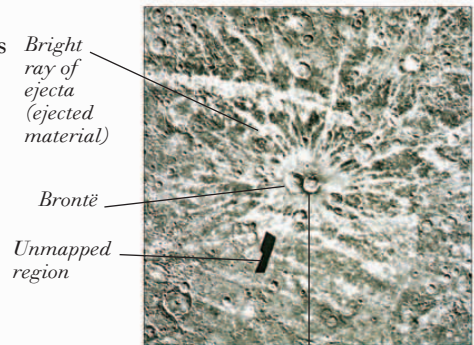
MERCURY IS THE NEAREST PLANET to the Sun, orbiting at an average distance of about 36 million miles (58 million km). Because Mercury is the closest planet to the Sun, it moves faster than any other planet, travelling at an average speed of nearly 30 miles (48 km) per second and completing an orbit in just under 88 days. Mercury is very small (only 40 percent bigger than the Moon) and rocky. Most of the surface has been heavily cratered by the impact of meteorites,

although there are also smooth, sparsely cratered lava-covered plains. The Caloris Basin is the largest crater, measuring about 800 miles (1,300 km) across. It is thought to have been formed when a 38-mile- (60-km-) diameter asteroid hit the planet, and is surrounded by concentric rings of mountains thrown up by the impact. The surface also has many clifflike ridges (called rupes) that are thought to have been formed when the hot core of the young planet cooled and shrank about four billion years ago, buckling the planet's surface in the process. The planet rotates about its axis very slowly, taking nearly 59 Earth days to complete one rotation. As a result, a solar day (sunrise to sunrise) on Mercury is about 176 Earth days—twice as long as the 88-day Mercurian year. Mercury has extreme surface temperatures, ranging from a maximum of 800°F (430°C) on the sunlit side to -270°F (-170°C) on the dark side. At nightfall, the temperature drops very quickly because the planet's atmosphere is almost nonexistent. It consists only of minute amounts of helium and hydrogen captured from the solar wind, plus traces of other gases.

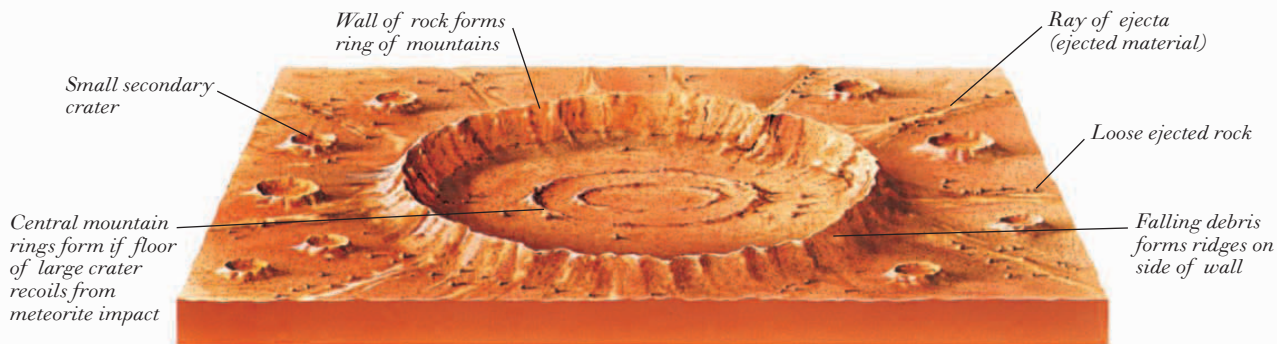
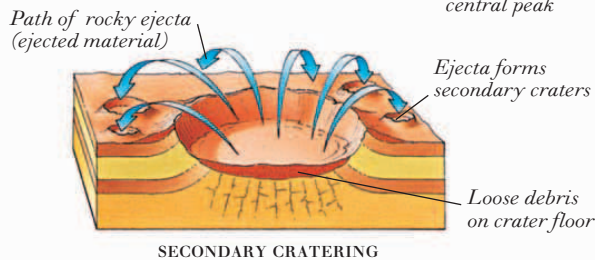
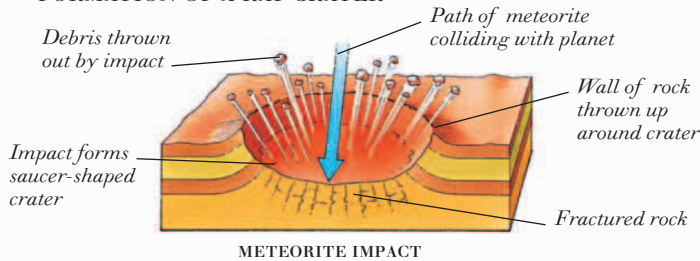
TILT AND ROTATION OF MERCURY



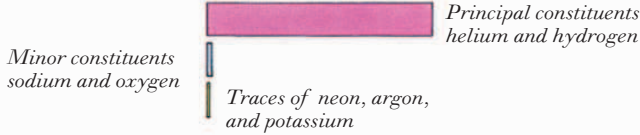
DEGAS AND BRONTË (RAY CRATERS)



FORMATION OF A RAY CRATER

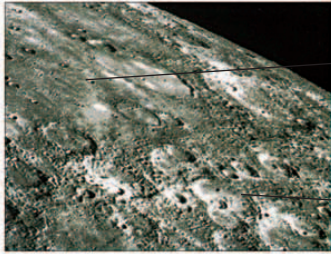


COMPOSITION OF ATMOSPHERE



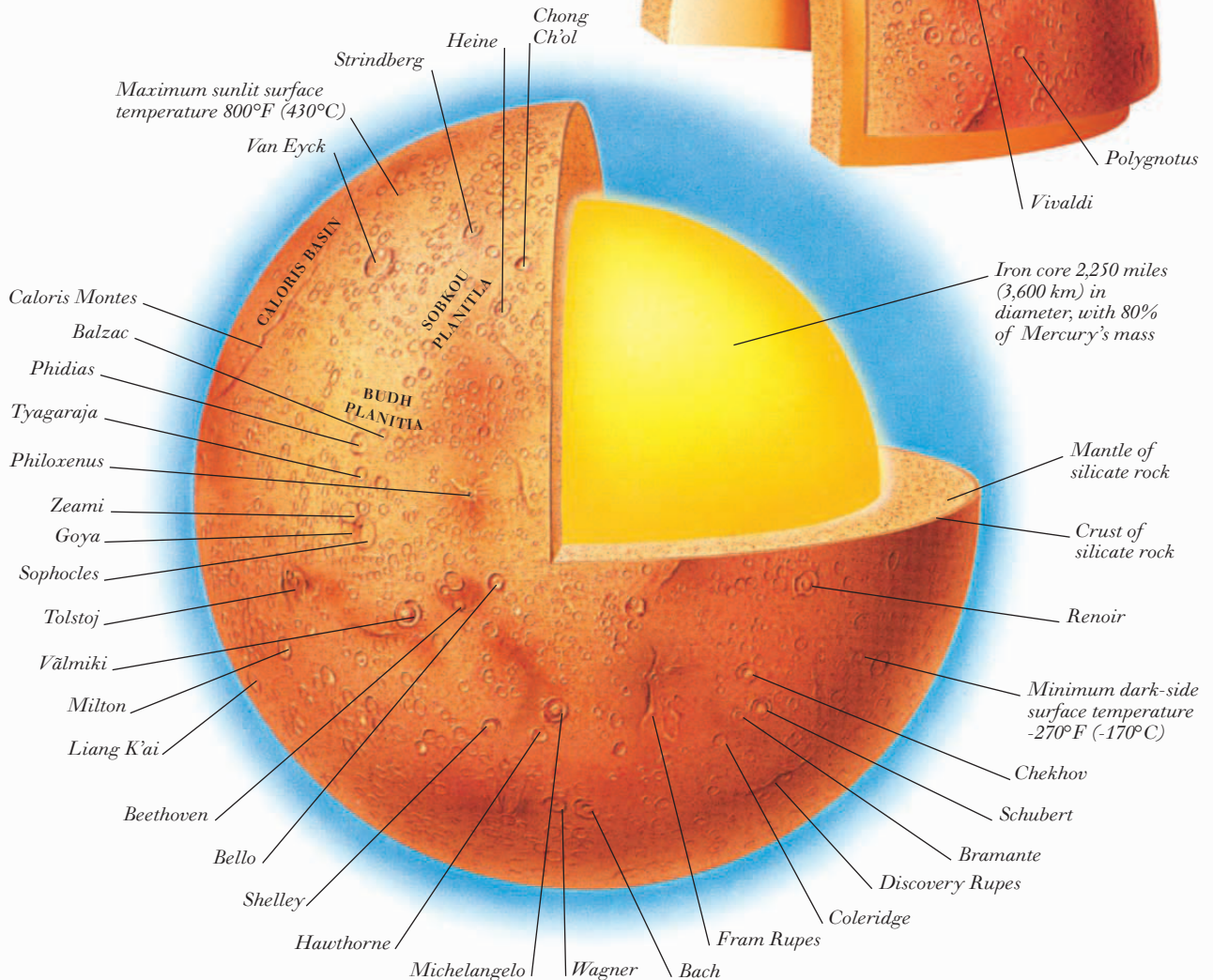
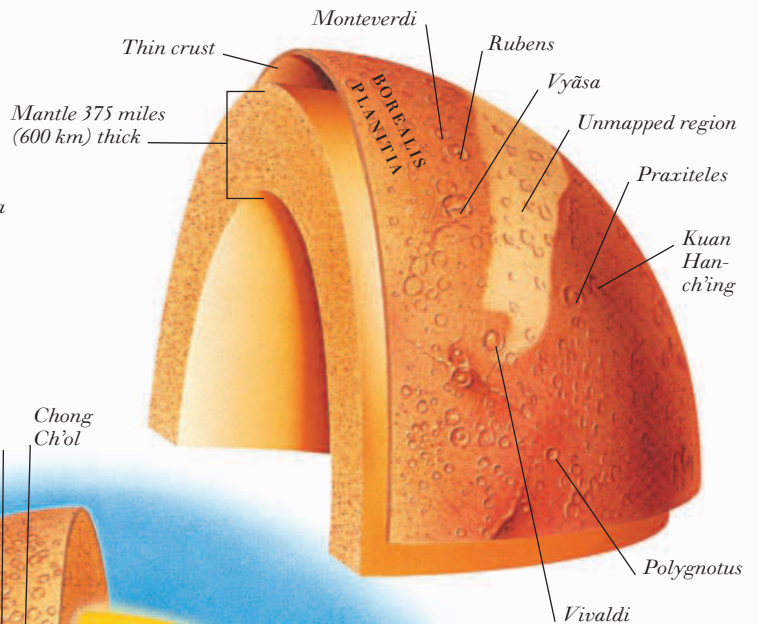
EXTERNAL FEATURES AND INTERNAL STRUCTURE OF MERCURY

CRATERS AND PLAINS NEAR MERCURY'S NORTH POLE

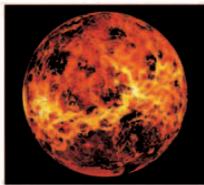


Borealis Planitia (smooth plain with a few young craters)

Terrain with many old craters



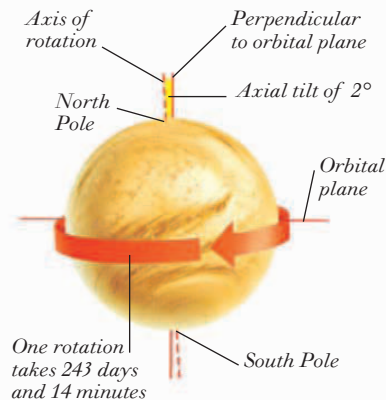
Venus



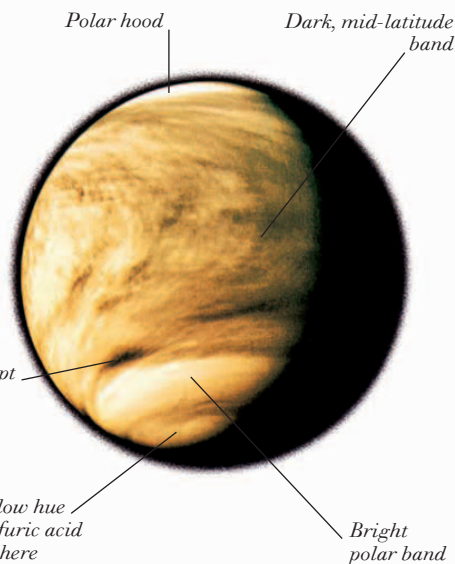
RADAR IMAGE OF VENUS

VENUS IS A ROCKY PLANET and the second planet from the Sun. Venus spins slowly backwards as it orbits the Sun, causing its rotational period to be the longest in the solar system, at about 243 Earth days. It is slightly smaller than Earth and probably has a similar internal structure, consisting of a semisolid metal core, surrounded by a rocky mantle and crust. Venus is the brightest object in the sky after the Sun and Moon because its clouds reflect sunlight strongly. The main component of the atmosphere is carbon dioxide, which traps heat in a greenhouse effect far stronger than that on Earth. As a result, Venus is the hottest planet, with a maximum surface temperature of about 900°F (480°C). The thick cloud layers contain droplets of sulfuric acid and are driven around the planet by winds at speeds of up to 220 miles (360 km) per hour. Although the planet takes 243 Earth days to rotate once, the high-speed winds cause the clouds to circle the planet in only four Earth days. The high temperature, acidic clouds, and enormous atmospheric pressure (about 90 times greater at the surface than that on Earth) make the environment extremely hostile. However, space probes have managed to land on Venus and photograph its dry, dusty surface. The Venusian surface has also been mapped by probes with radar equipment that can “see” through the cloud layers. Such radar maps reveal a terrain with craters, mountains, volcanoes, and areas where craters have been covered by plains of solidified volcanic lava. There are two large highland regions called Aphrodite Terra and Ishtar Terra.

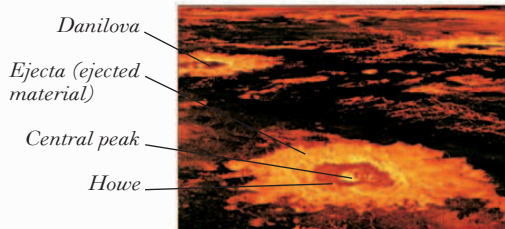
TILT AND ROTATION OF VENUS



CLOUD FEATURES



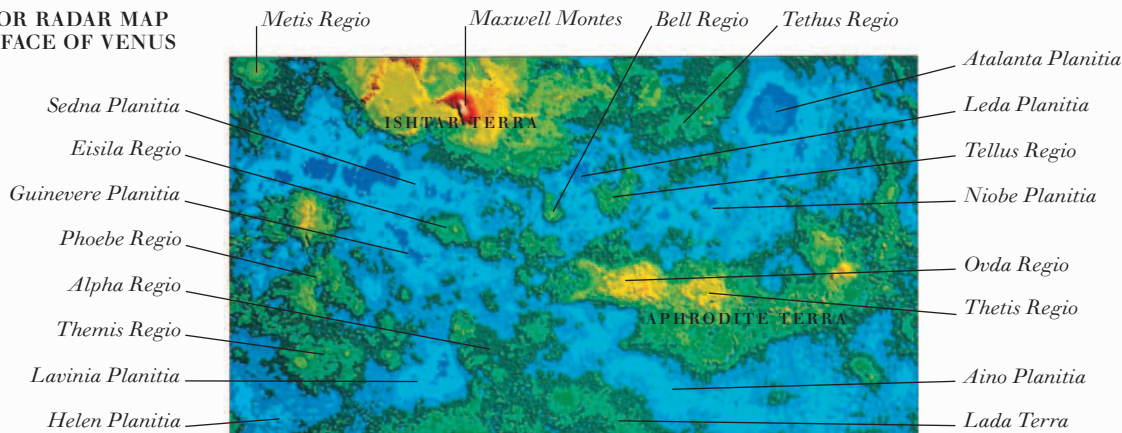
VENUSIAN CRATERS



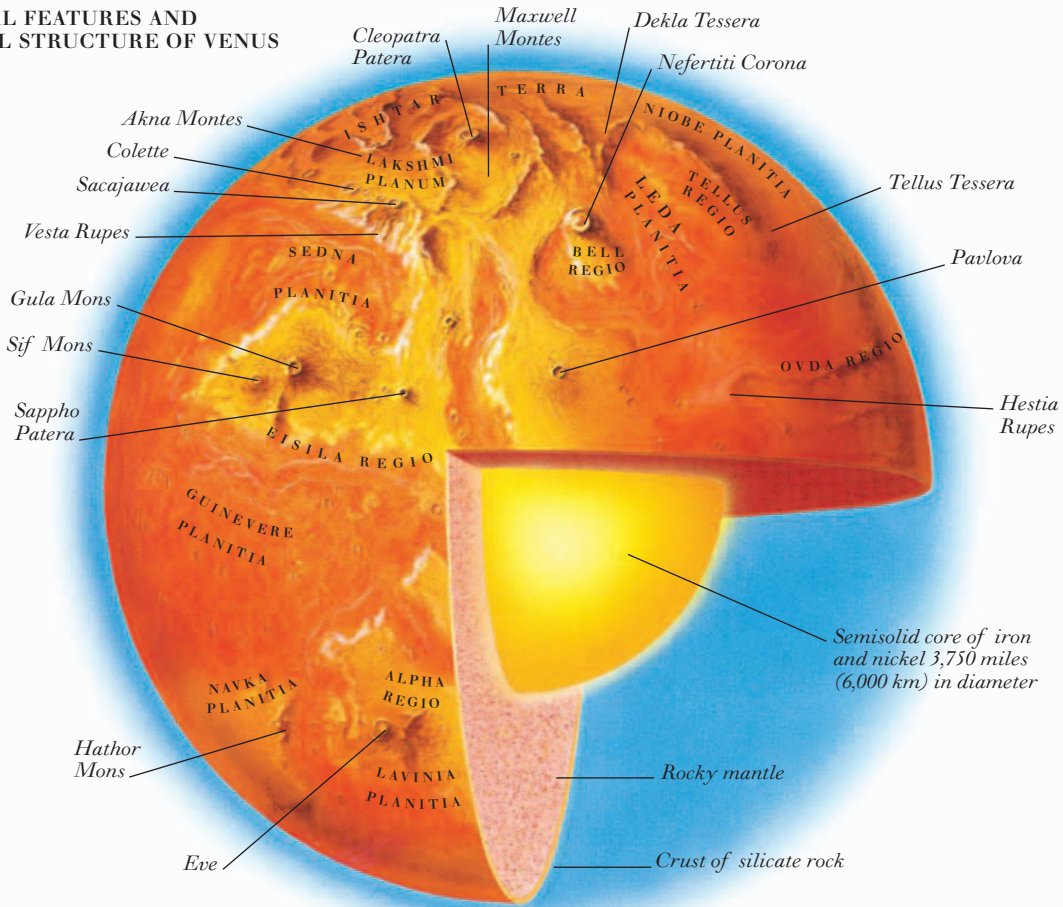
Cloud features swept around planet by winds of up to 220 miles (360 km/h)

Dirty yellow hue due to sulfuric acid in atmosphere

FALSE-COLOR RADAR MAP OF THE SURFACE OF VENUS

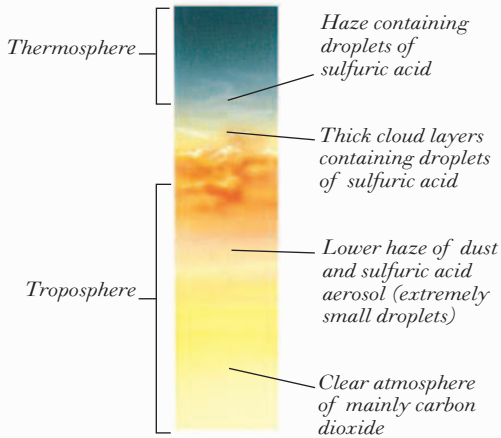


EXTERNAL FEATURES AND INTERNAL STRUCTURE OF VENUS

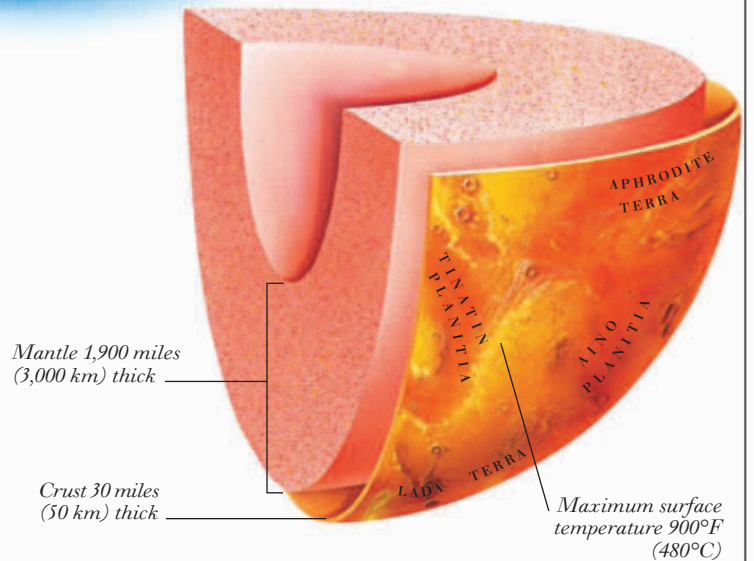
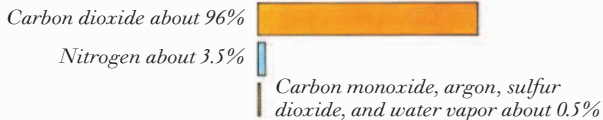


ATMOSPHERE

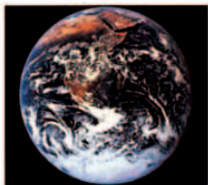
STRUCTURE



COMPOSITION



The Earth

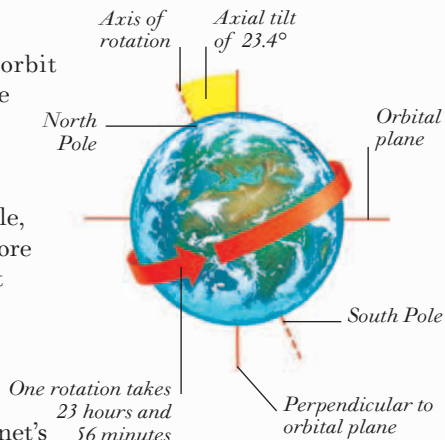


THE EARTH

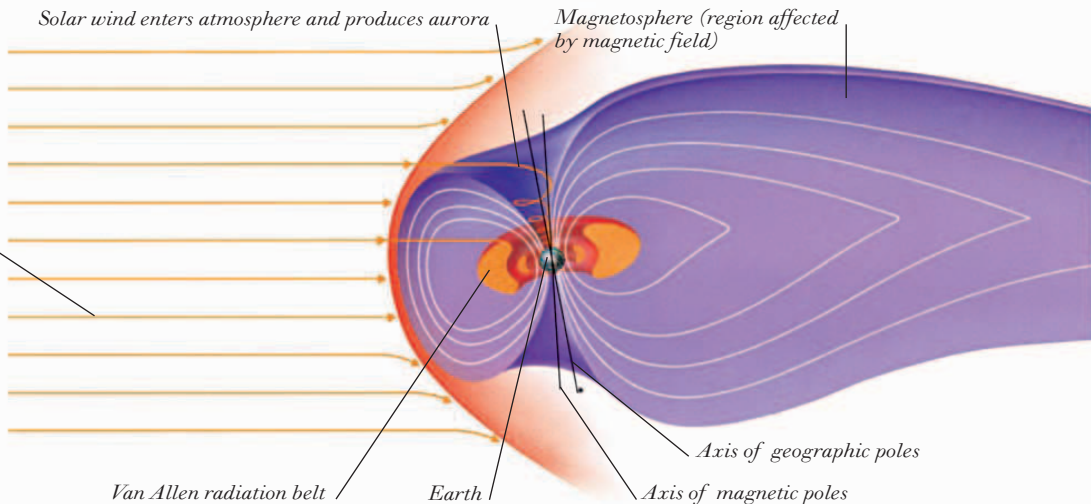
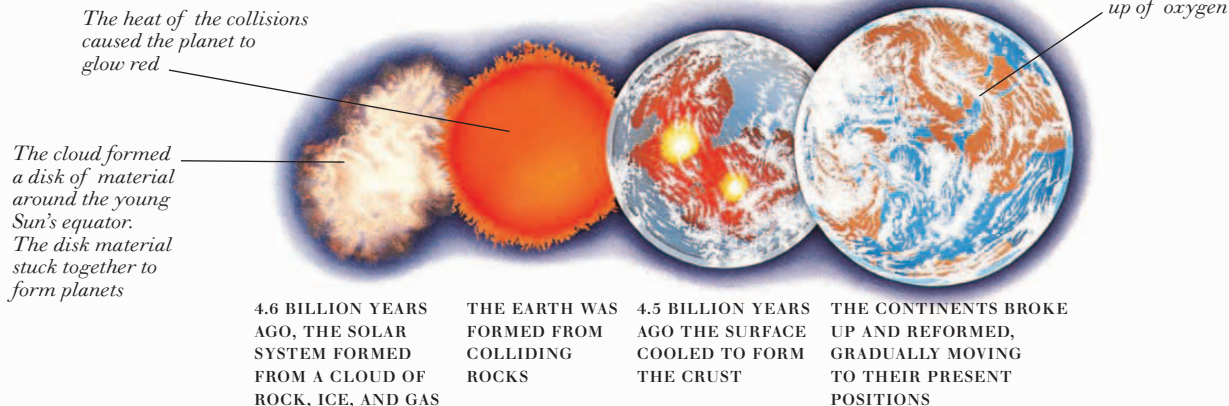
THE EARTH IS THE THIRD of the eight planets that orbit the Sun. It is the largest and densest rocky planet, and the only one known to support life. About 70 percent of the Earth's surface is covered by water, which is not found in liquid form on the surface of any other planet. There are four main layers: the inner core, the outer core, the mantle, and the crust. At the heart of the planet the solid inner core has a temperature of about 11,900°F (6,600°C). The heat

from this inner core causes material in the molten outer core and mantle to circulate in convection currents. It is thought that these convection currents generate the Earth's magnetic field, which extends into space as the magnetosphere. The Earth's atmosphere helps screen out some of the harmful radiation from the Sun, stops most meteoroids from reaching the planet's surface, and traps enough heat to prevent extremes of cold. The Earth has one natural satellite, the Moon, which is thought to have formed when a huge asteroid impacted Earth in the distant past.

TILT AND ROTATION OF THE EARTH



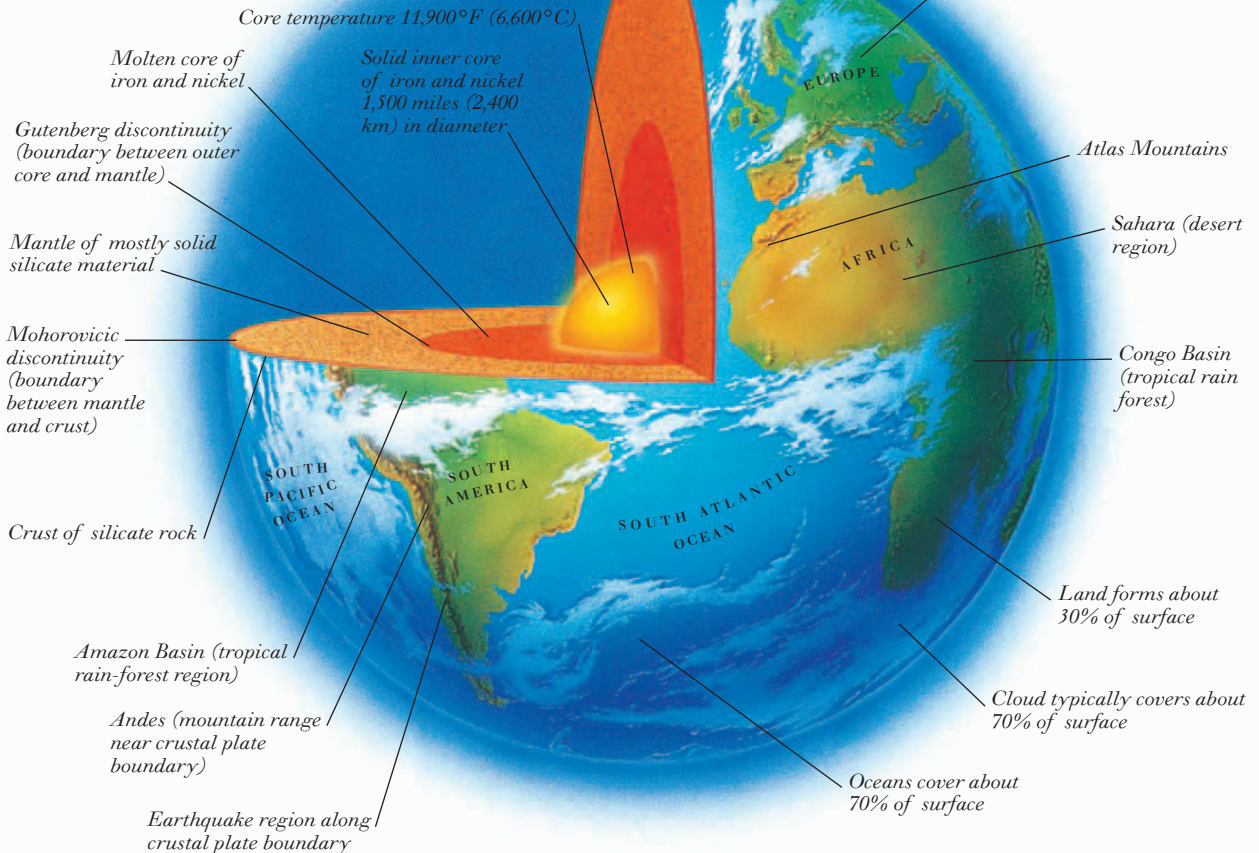
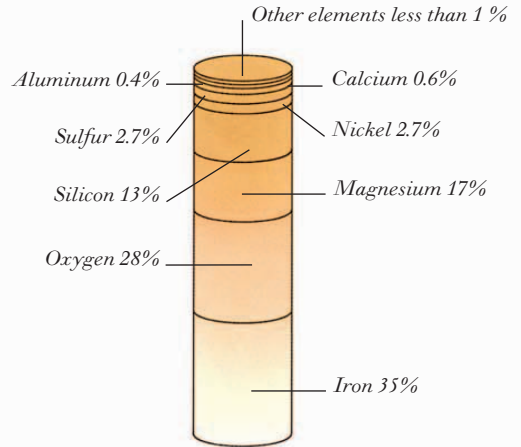
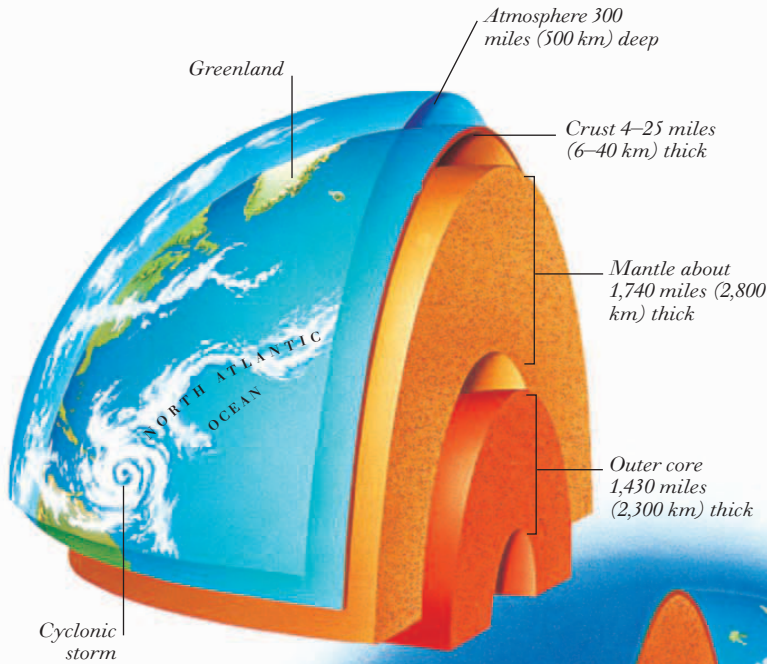
THE FORMATION OF THE EARTH



THE EARTH'S MAGNETOSPHERE

EXTERNAL FEATURES AND INTERNAL STRUCTURE OF THE EARTH

COMPOSITION OF THE EARTH



The Moon

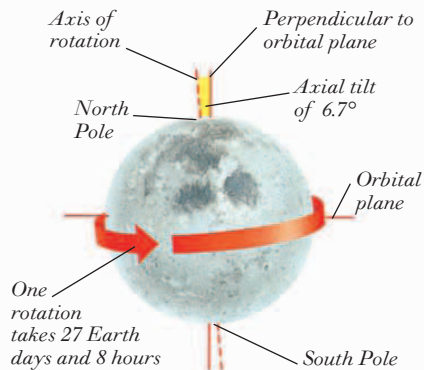


THE MOON FROM EARTH

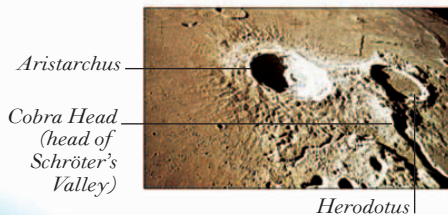
THE MOON IS THE EARTH'S only natural satellite. It is relatively large for a moon, with a diameter of about 2,155 miles (3,470 km)—just over a quarter that of the Earth. The Moon takes the same time to rotate on its axis as it takes to orbit the Earth (27.3 days), and so the same side (the near side) always faces us. However, the amount of the surface we can see—the phase of the Moon—

depends on how much of the near side is in sunlight. The Moon is dry and barren, with negligible atmosphere and water. It consists mainly of solid rock, although its core may contain molten rock or iron. The surface is dusty, with highlands covered in craters caused by meteorite impacts, and lowlands in which large craters have been filled by solidified lava to form dark areas called maria or “seas.” Maria occur mainly on the near side, which has a thinner crust than the far side. Many of the craters are rimmed by mountain ranges that form the crater walls and can be thousands of feet high.

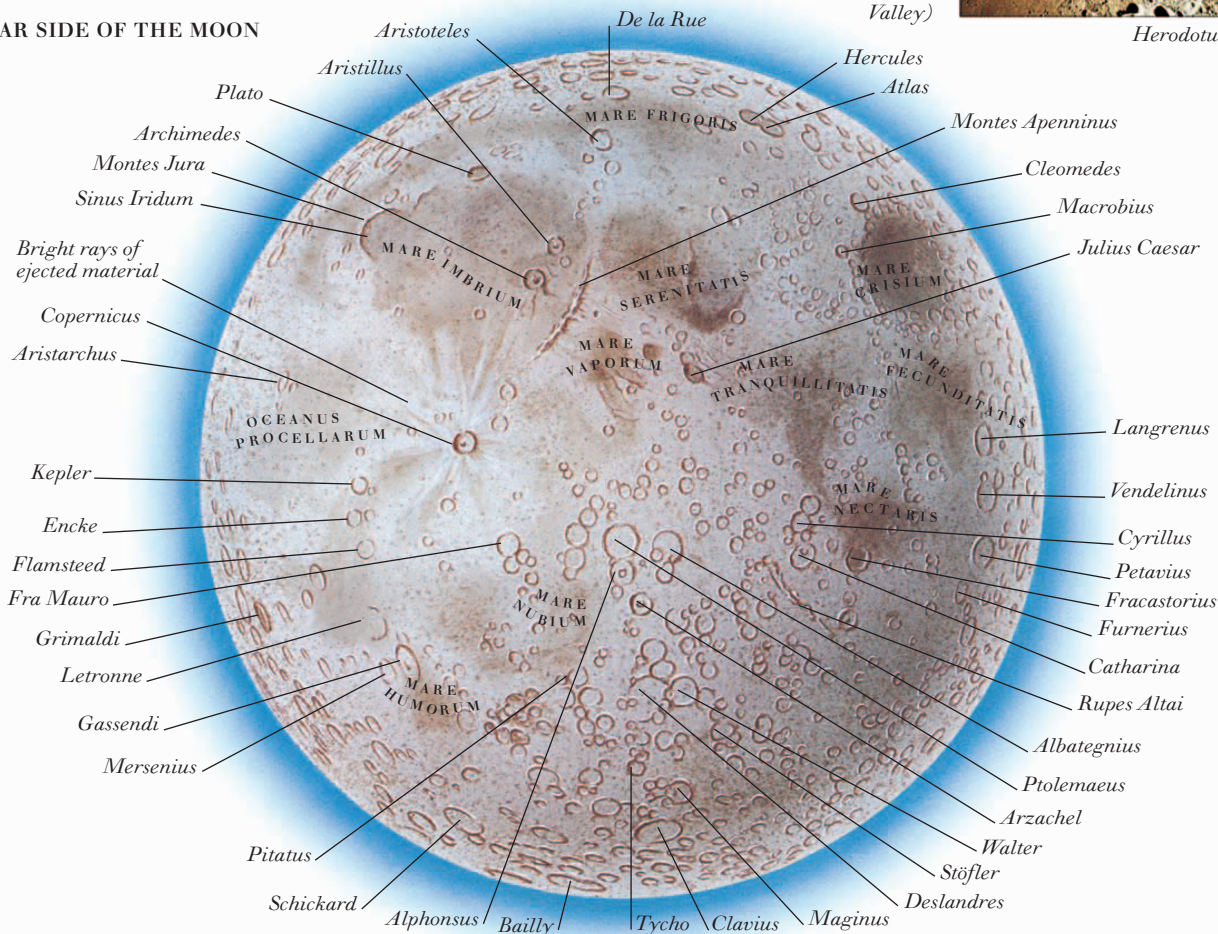
TILT AND ROTATION OF THE MOON



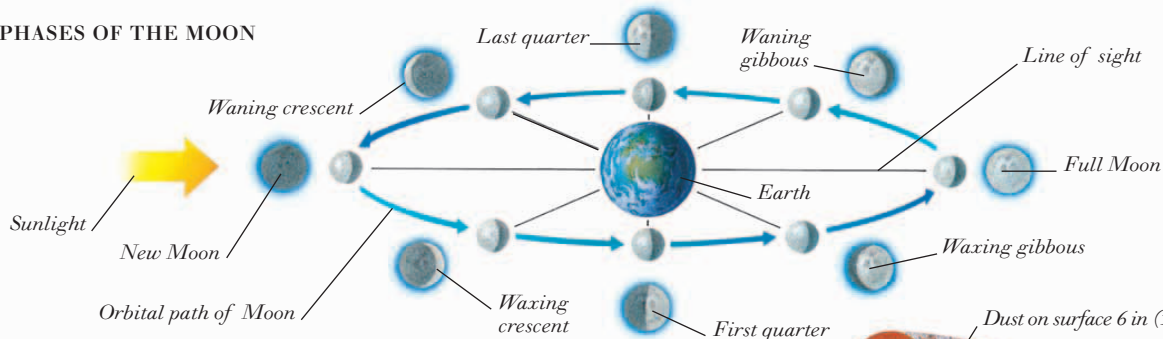
CRATERS ON OCEANUS PROCELLARUM



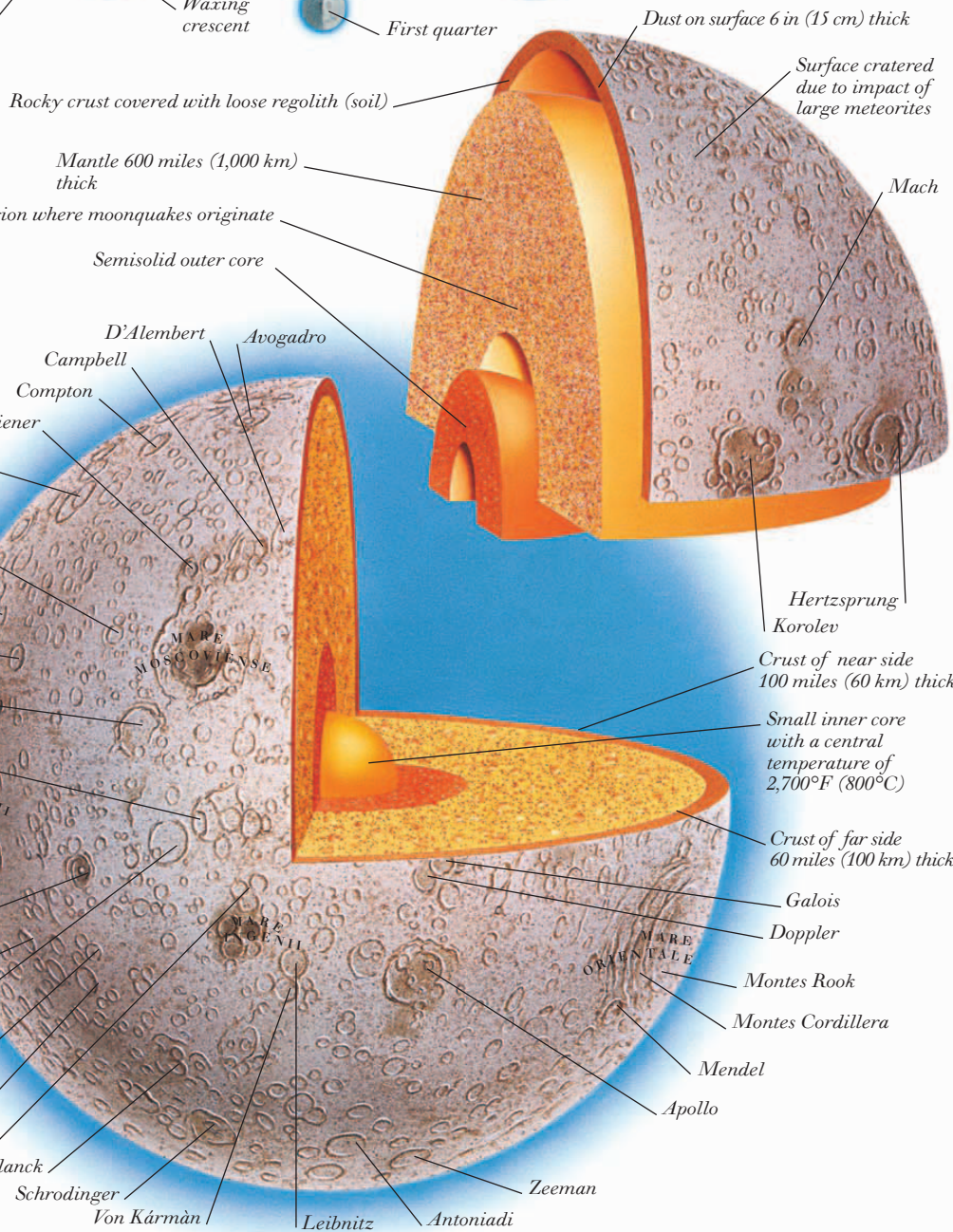
NEAR SIDE OF THE MOON



PHASES OF THE MOON



FAR SIDE OF THE MOON



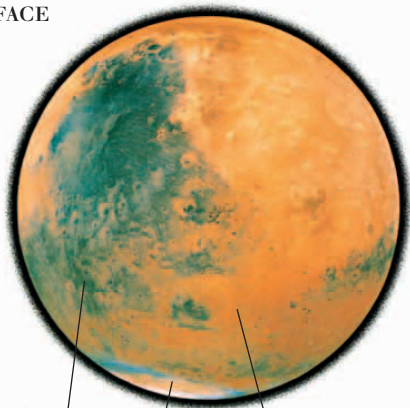
Mars



MARS

MARS, KNOWN AS THE RED PLANET, is the fourth planet from the Sun and the outermost rocky planet. In the 19th century, astronomers first observed what were thought to be signs of life on Mars. These signs included apparent canal-like lines on the surface, and dark patches that were thought to be vegetation. It is now known that the “canals” are an optical illusion, and the dark patches are areas where the red dust that covers most of the planet has been blown away. The fine dust particles are often whipped up by winds into dust storms that occasionally obscure almost all the surface. Residual fine dust in the atmosphere gives the Martian sky a pinkish hue. The northern hemisphere of Mars has many large plains formed of solidified volcanic lava, whereas the southern hemisphere has many craters and large impact basins. There are also several huge, extinct volcanoes, including Olympus Mons, which, at 370 miles (600 km) across and 15 miles (25 km) high, is the largest known volcano in the solar system. The surface also has many canyons and branching channels. The canyons were formed by movements of the surface crust, but the channels are thought to have been formed by flowing water that has now dried up. The Martian atmosphere is much thinner than Earth’s, with only a few clouds and morning mists. Mars has two tiny, irregularly shaped moons called Phobos and Deimos. Their small size indicates that they may be asteroids that have been captured by the gravity of Mars.

THE SURFACE OF MARS

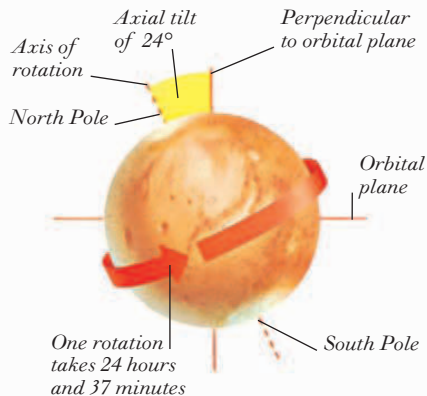


Dark area where dust has been blown away by wind

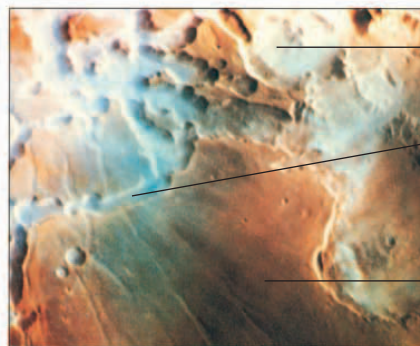
South polar ice cap

Surface covered with red-colored iron oxide dust

TILT AND ROTATION OF MARS



SURFACE FEATURES OF MARS



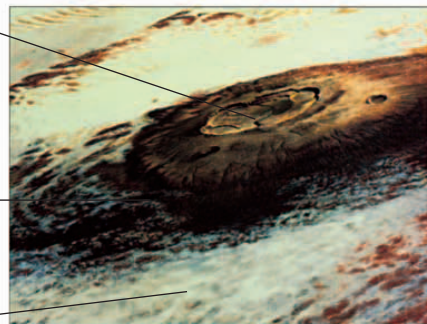
Bright water-ice fog

Fog in canyon 12 miles (20 km) wide at end of Valles Marineris

Syria Planum

NOCTIS LABYRINTHUS (CANYON SYSTEM)

Summit caldera consisting of overlapping collapsed volcanic craters



Gentle slope produced by lava flow

Cloud formation

OLYMPUS MONS (EXTINCT SHIELD VOLCANO)

MOONS OF MARS



PHOBOS

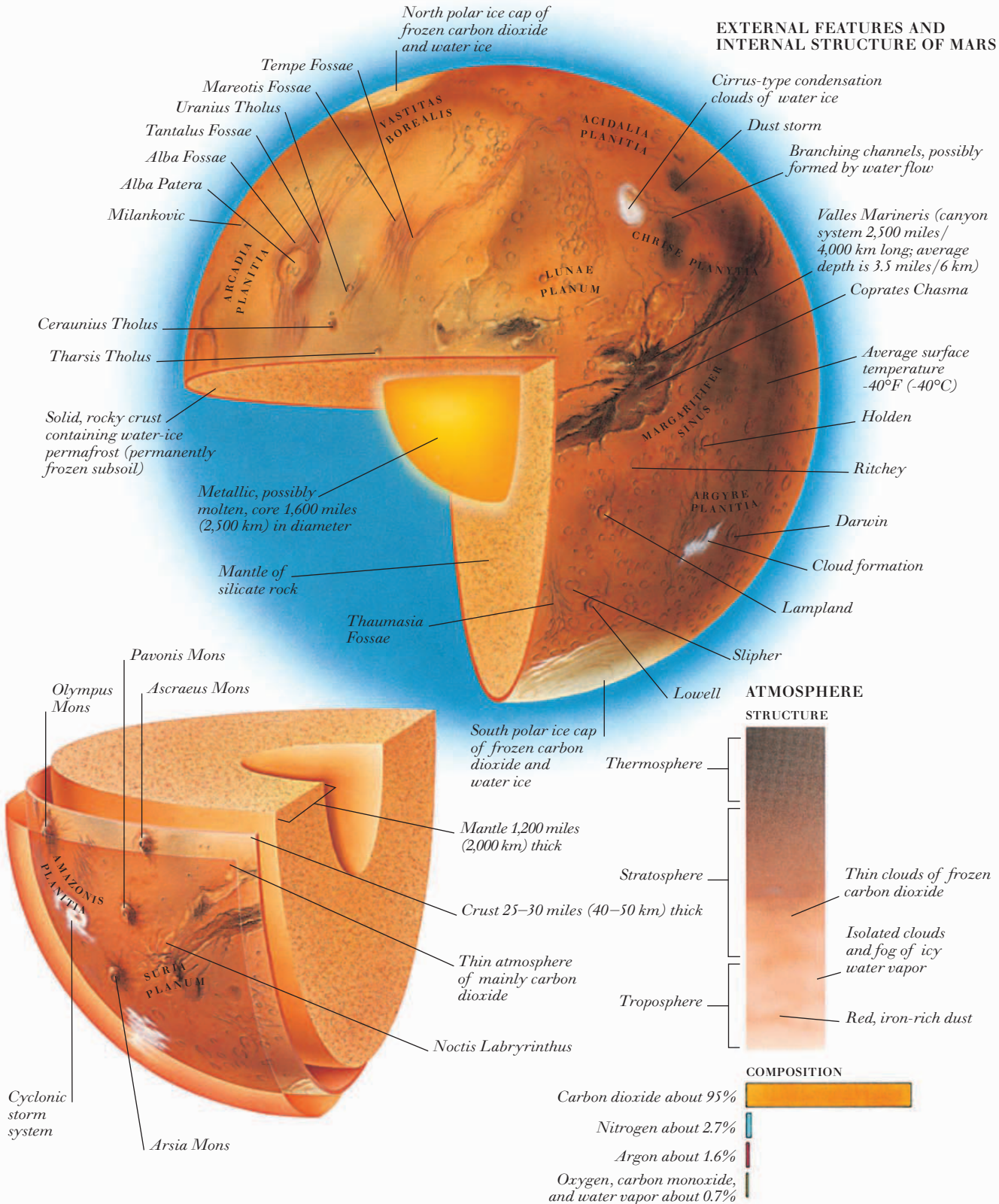
Average diameter: 14 miles
Average distance from planet: 5,800 miles



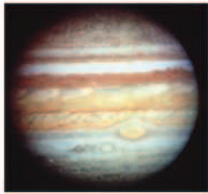
DEIMOS

Average diameter: 8 miles
Average distance from planet: 14,600 miles

EXTERNAL FEATURES AND INTERNAL STRUCTURE OF MARS



Jupiter



JUPITER

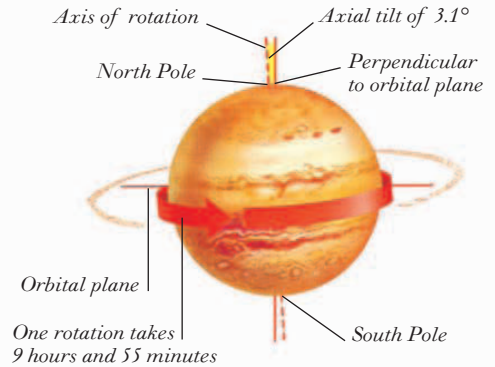
JUPITER IS THE FIFTH PLANET from the Sun and the innermost of the four giant planets. It is the largest and the most massive planet, with a diameter about 11 times that of the Earth and a mass about 2.5 times the combined mass of the seven other planets. Jupiter is thought to have a small rocky core surrounded by an inner mantle of metallic hydrogen (liquid hydrogen that acts

like a metal). Outside the inner mantle is an outer mantle of liquid hydrogen and helium that merges into the gaseous atmosphere.

Jupiter's rapid rate of rotation causes the clouds in its atmosphere to form belts and zones that encircle the planet parallel to the equator. Belts are dark, low-lying, relatively warm cloud layers, and zones are bright, high-altitude, cooler cloud layers.

Within the belts and zones, turbulence causes the formation of cloud features such as white ovals and red spots, both of which are huge storm systems. The most prominent cloud feature is a storm called the Great Red Spot, which consists of a spiraling column of clouds three times wider than the Earth that rises about five miles (8 km) above the upper cloud layer. Jupiter has a thin, faint, main ring, inside which is a tenuous halo ring of tiny particles. Beyond the main ring's outer edge is a broad and faint two-part gossamer ring. There are 63 known Jovian moons. The four largest moons (called the Galileans) are Ganymede, Callisto, Io, and Europa. Ganymede and Callisto are cratered and icy. Europa is smooth and icy and is thought to have a subsurface water ocean. Io is covered in bright red, orange, and yellow splotches. This coloring is caused by sulfurous material from active volcanoes that shoot plumes of lava hundreds of miles above the surface.

TILT AND ROTATION OF JUPITER

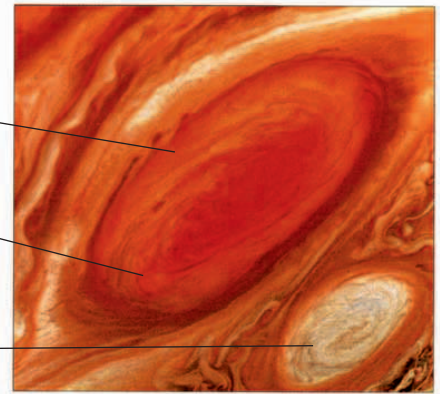


GREAT RED SPOT AND WHITE OVAL

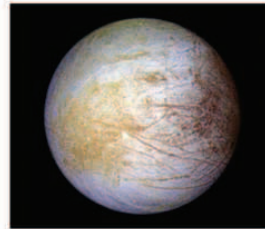
Great Red Spot
(anticyclonic storm system)

Red color probably due to phosphorus

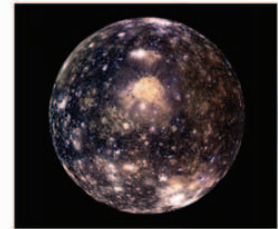
White oval
(temporary anticyclonic storm system)



GALILEAN MOONS OF JUPITER



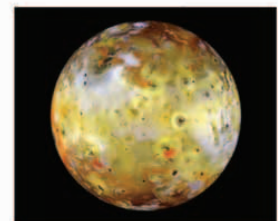
EUROPA
Diameter: 1,950 miles
Average distance from planet: 416,900 miles



CALLISTO
Diameter: 2,983 miles
Average distance from planet: 1,168,200 miles

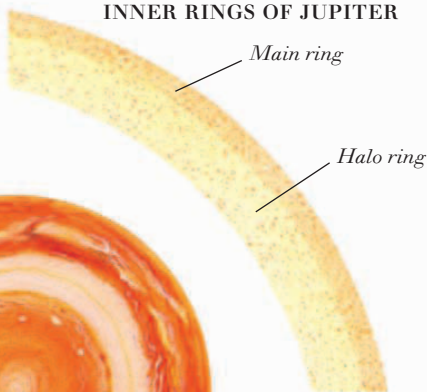


GANYMEDE
Diameter: 3,270 miles
Average distance from planet: 664,900 miles



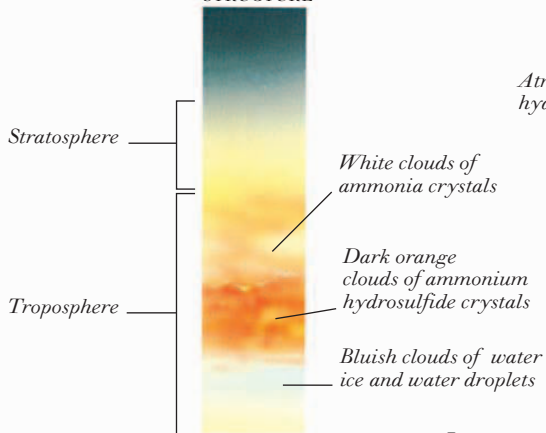
IO
Diameter: 2,263 miles
Average distance from planet: 262,100 miles

INNER RINGS OF JUPITER

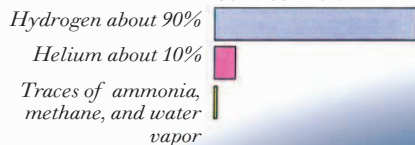


ATMOSPHERE

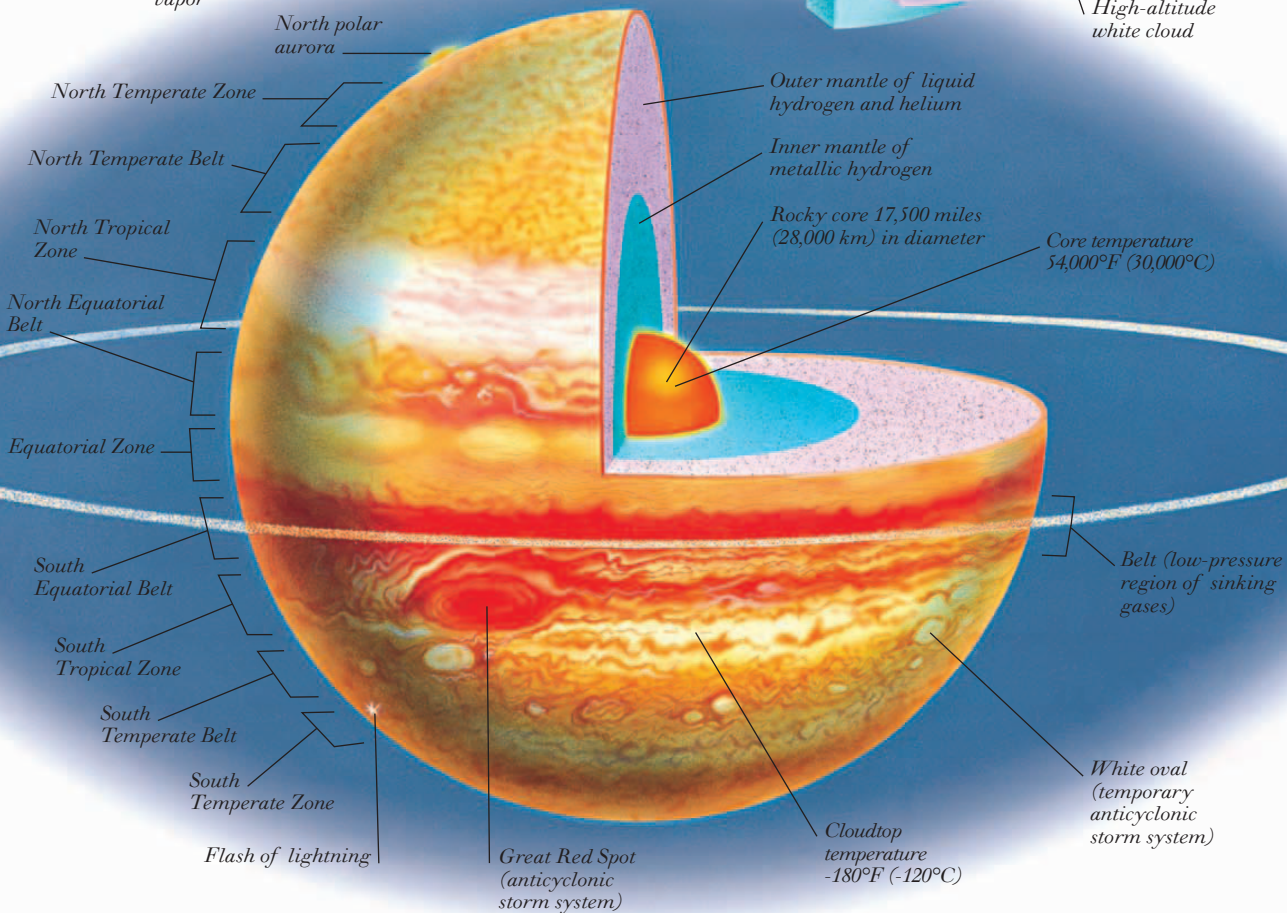
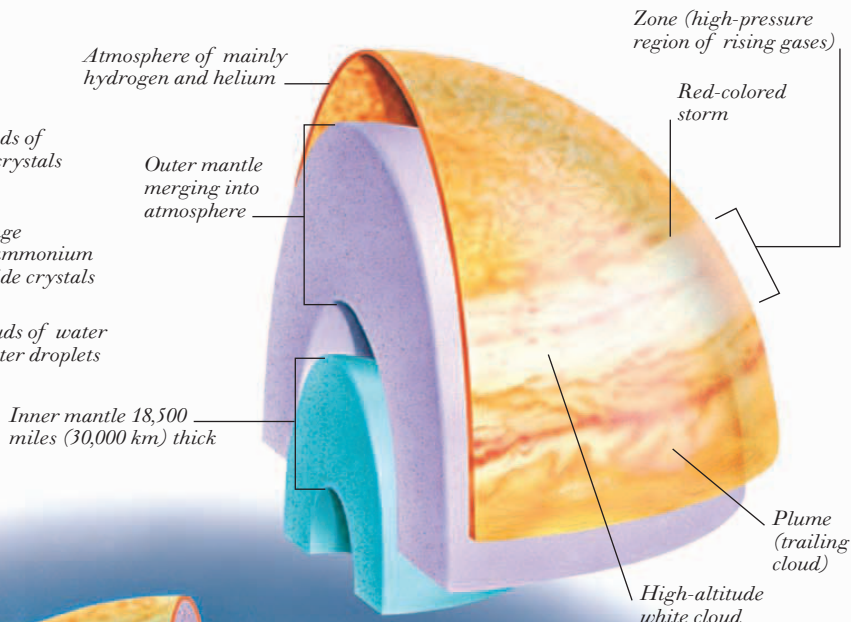
STRUCTURE



COMPOSITION



EXTERNAL FEATURES AND INTERNAL STRUCTURE OF JUPITER



Saturn

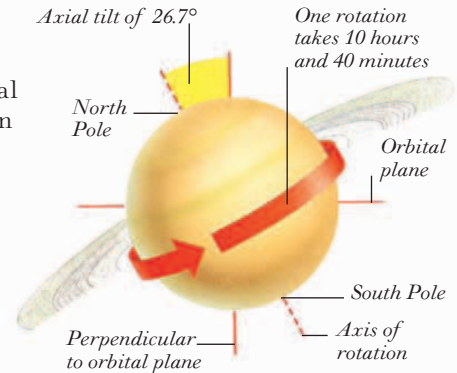


FALSE-COLOR
IMAGE OF SATURN

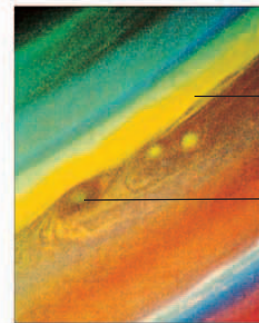
SATURN IS THE SIXTH PLANET from the Sun. It is a gas giant almost as big as Jupiter, with an equatorial diameter of about 75,000 miles (120,500 km). Saturn is thought to consist of a small core of rock and ice surrounded by an inner mantle of metallic hydrogen (liquid hydrogen that acts like a metal). Outside the inner mantle is an outer mantle of liquid hydrogen that merges into a gaseous atmosphere. Saturn's clouds form belts and zones similar to those on

Jupiter, but obscured by overlying haze. Storms and eddies, seen as red or white ovals, occur in the clouds. Saturn has an extremely thin but wide system of rings that is about half a mile (1 km) thick but extends outward to about 260,000 miles (420,000 km) from the planet's surface. The main rings comprise thousands of narrow ringlets, each made of icy rock lumps that range in size from tiny particles to chunks several yards across. The D, E, and G rings are very faint, the F ring is brighter, and the A, B, and C rings are bright enough to be seen from Earth with binoculars. In 2009, a huge dust ring was discovered 4 million miles (6 million km) beyond the main system. Saturn has more than 60 known moons, some of which orbit inside the rings and are thought to exert a gravitational influence on the shapes of the rings. Unusually, seven of the moons are co-orbital—they share an orbit with another moon. Astronomers believe that such co-orbital moons may have originated from a single satellite that broke up.

TILT AND ROTATION OF SATURN



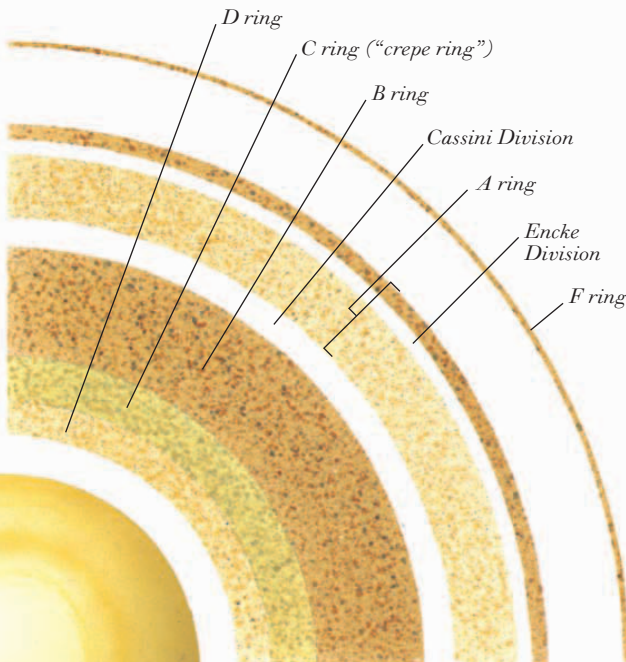
FALSE-COLOR IMAGE OF SATURN'S CLOUD FEATURES



Ribbon-shaped striation caused by winds of 335 mph (540 km/h)

Oval (rotating storm system)

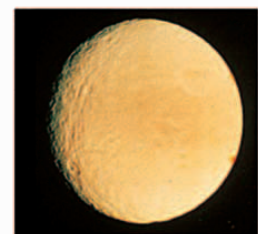
INNER RINGS OF SATURN



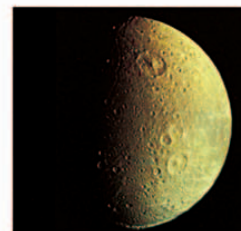
MOONS OF SATURN



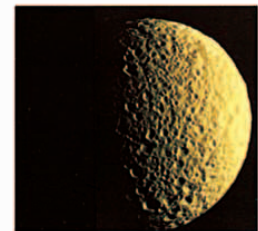
ENCELADUS
Diameter: 509 miles
Average distance from planet: 148,000 miles



TETHYS
Diameter: 652 miles
Average distance from planet: 185,000 miles

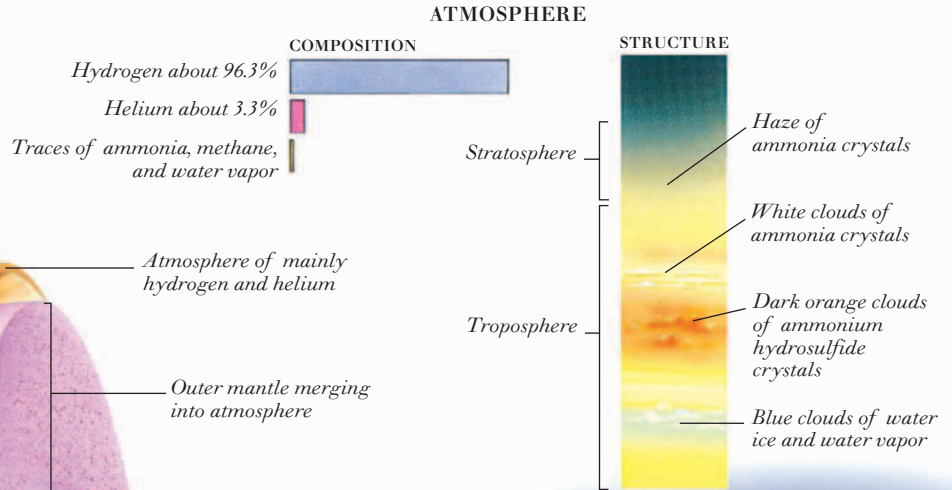


DIONE
Diameter: 695 miles
Average distance from planet: 254,000 miles



MIMAS
Diameter: 247 miles
Average distance from planet: 115,600 miles

EXTERNAL FEATURES AND INTERNAL STRUCTURE OF SATURN



Clouds form belts (dark, low-altitude layers) and zones (bright, high-altitude layers)

Atmosphere of mainly hydrogen and helium

Outer mantle merging into atmosphere

Inner mantle 9,000 miles (15,000 km) thick

Outer mantle of liquid hydrogen

Inner mantle of liquid metallic hydrogen

Rock and ice core 18,500 miles (30,000 km) in diameter

Core temperature 27,000°F (15,000°C)

Equator swept by winds of 1,100 mph (1,800 km/h)

Radial spoke (probably dust particles above plane of rings)

Anne's Spot (anticyclonic storm system)

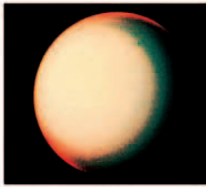
Cloud-top temperature about -290°F (-180°C)

F ring
 A ring (broad ring comprising many ringlets)
 B ring (broad ring comprising many ringlets)
 C ring ("crepe ring"; broad ring comprising many ringlets)
 D ring

Cassini Division (apparent gap containing at least 100 ringlets)

Encke Division (gap in which the moon Pan orbits)

Uranus

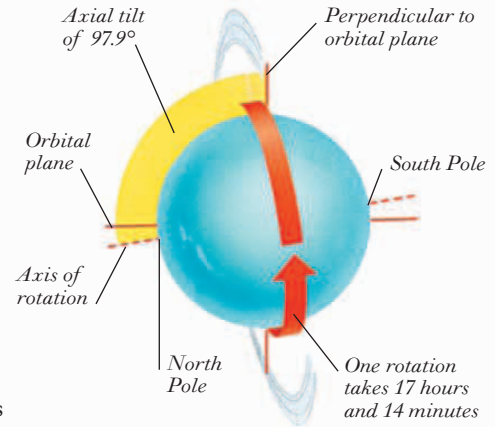


FALSE-COLOR
IMAGE OF URANUS

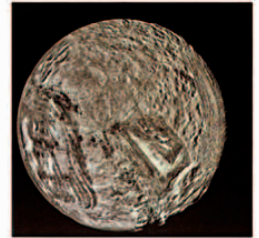
URANUS IS THE SEVENTH PLANET from the Sun and the third largest, with a diameter of about 32,000 miles (51,000 km). It is thought to consist of a dense mixture of different types of ice and gas around a solid core. Its atmosphere contains traces of methane, giving the planet a blue-green hue, and the temperature at the cloud tops is about -350°F (-210°C). Uranus is the most featureless planet to have been closely observed:

only a few icy clouds of methane have been seen so far. Uranus is unique among the planets in that its axis of rotation lies close to its orbital plane. As a result of its strongly tilted rotational axis, Uranus rolls on its side along its orbital path around the Sun, whereas other planets spin more or less upright. Uranus is encircled by main rings that consist of rocks interspersed with dust lanes and two distant outer rings made of dust. The rings contain some of the darkest matter in the solar system and are extremely narrow, making them difficult to detect: most of them are less than 6 miles (10 km) wide, whereas most of Saturn's rings are thousands of miles in width. There are 27 known Uranian moons, all of which are icy and most of which are farther out than the rings. The 13 inner moons are small and dark, with diameters of less than 100 miles (160 km), and the five major moons are between about 290 and 1,000 miles (470 and 1,600 km) in diameter. The major moons have a wide variety of surface features. Miranda has the most varied surface, with cratered areas broken up by huge ridges and cliffs 12 miles (20 km) high. Beyond these are nine much more distant moons with diameters less than 90 miles (150 km).

TILT AND ROTATION OF URANUS

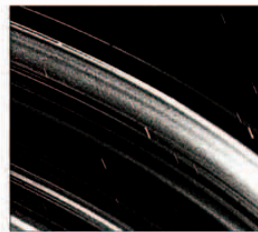
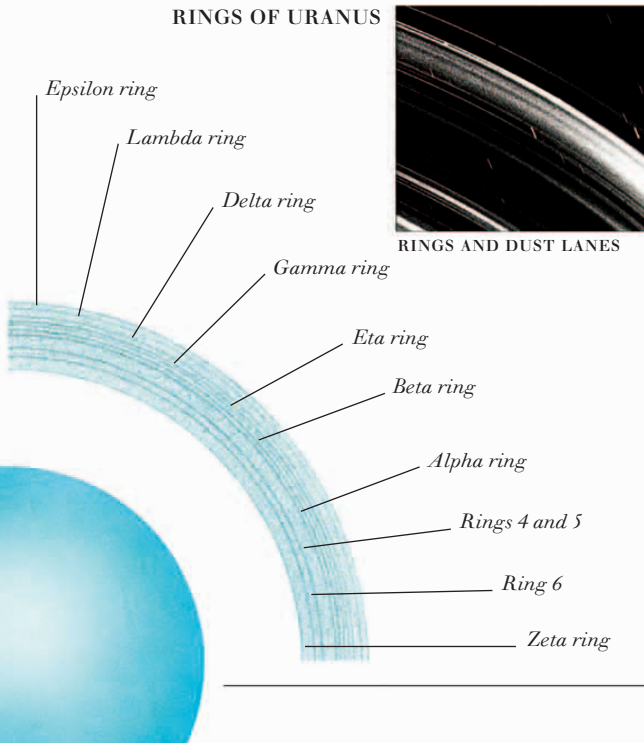


MAJOR MOONS

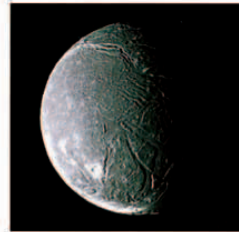


MIRANDA
Diameter: 295 miles
Average distance from planet: 80,700 miles

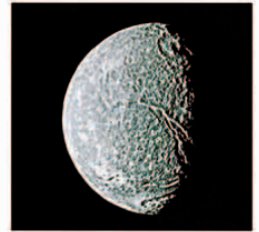
RINGS OF URANUS



RINGS AND DUST LANES



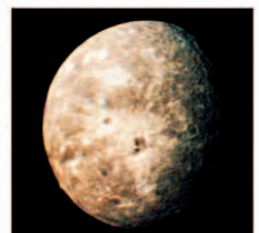
ARIEL
Diameter: 720 miles
Average distance from planet: 118,800 miles



TITANIA
Diameter: 981 miles
Average distance from planet: 270,900 miles

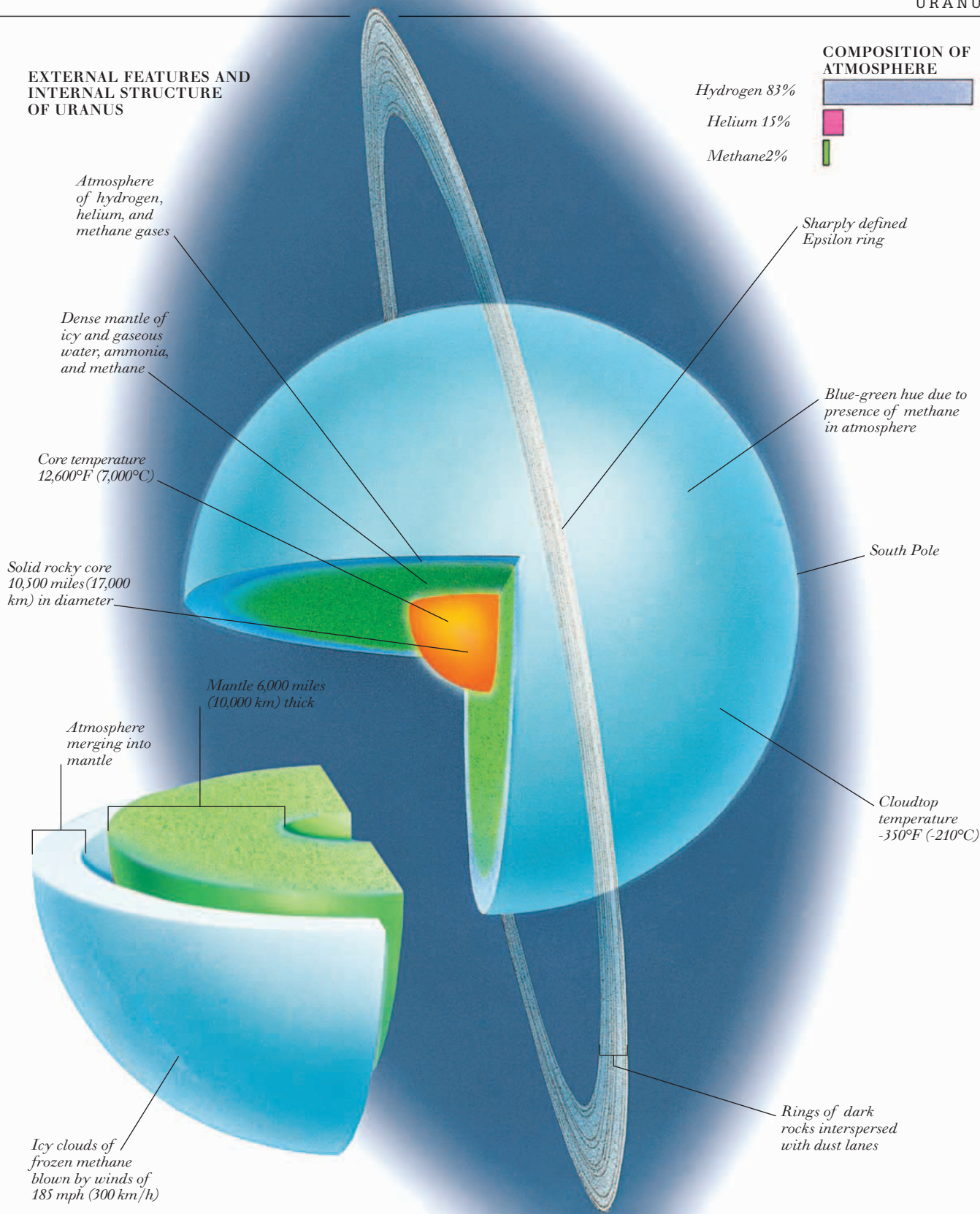


UMBRIEL
Diameter: 726 miles
Average distance from planet: 165,500 miles

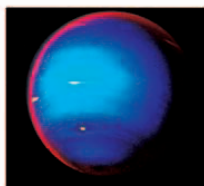


OBBERON
Diameter: 946 miles
Average distance from planet: 362,000 miles

EXTERNAL FEATURES AND INTERNAL STRUCTURE OF URANUS



Neptune and Pluto

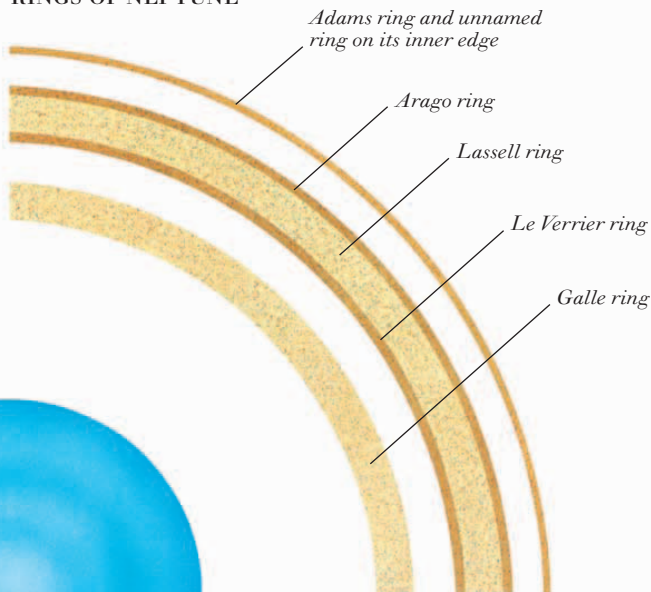


FALSE-COLOR
IMAGE OF NEPTUNE

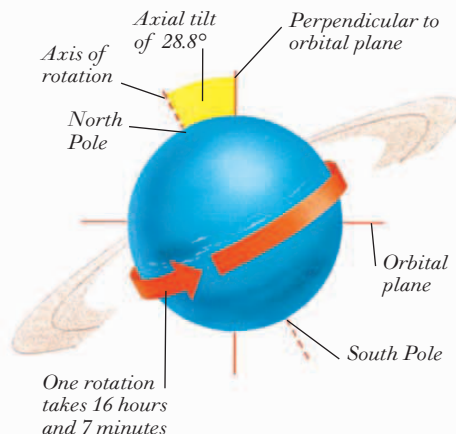
NEPTUNE IS the farthest planet from the Sun, at an average distance of about 2.8 billion miles (4.5 billion km). Neptune is the smallest of the giant planets and is thought to consist of a small rocky core surrounded by a mixture of liquids and gases. Several transient cloud features have been observed in its atmosphere. The largest of these were the Great Dark Spot, which was as wide as the Earth, the Small Dark Spot, and the Scooter.

The Great and Small Dark Spots were huge storms that were swept around the planet by winds of about 1,200 miles (2,000 km) per hour. The Scooter was a large area of cirrus cloud. Neptune has six tenuous rings and 13 known moons. Triton is the largest Neptunian moon and the coldest object in the solar system, with a temperature of -390°F (-240°C). Unlike most moons in the solar system, Triton orbits its mother planet in the opposite direction of the planet's rotation. The region extending out from Neptune's orbit is populated by Kuiper Belt objects and dwarf planets. They make a doughnut-shaped belt called the Kuiper Belt. The Kuiper Belt objects are a mix of rock and ice, irregular in shape, and less than 600 miles (1,000 km) across. The larger dwarf planets, which include Pluto, are almost round bodies. Pluto was the first object discovered beyond Neptune and was considered a planet until the dwarf planet category was introduced in 2006. It is made of rock and ice and is 1,365 miles (2,274 km) across. It has three known moons. The largest, Charon, is about half Pluto's size and the two probably had a common origin.

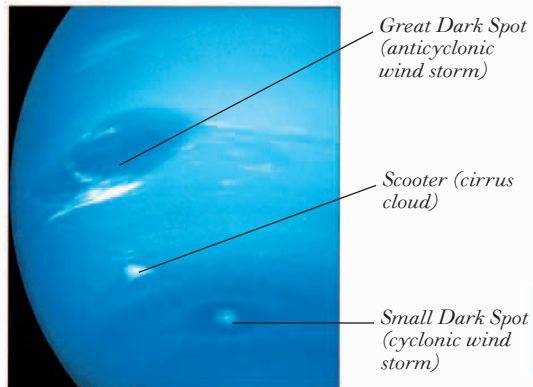
RINGS OF NEPTUNE



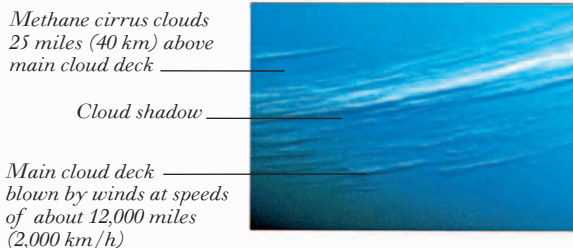
TILT AND ROTATION OF NEPTUNE



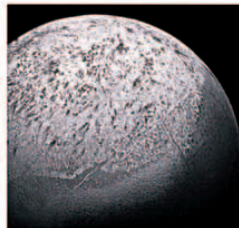
CLOUD FEATURES OF NEPTUNE



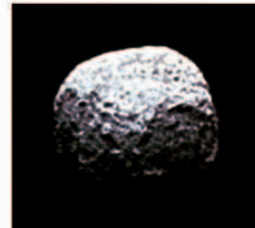
HIGH-ALTITUDE CLOUDS



MOONS OF NEPTUNE

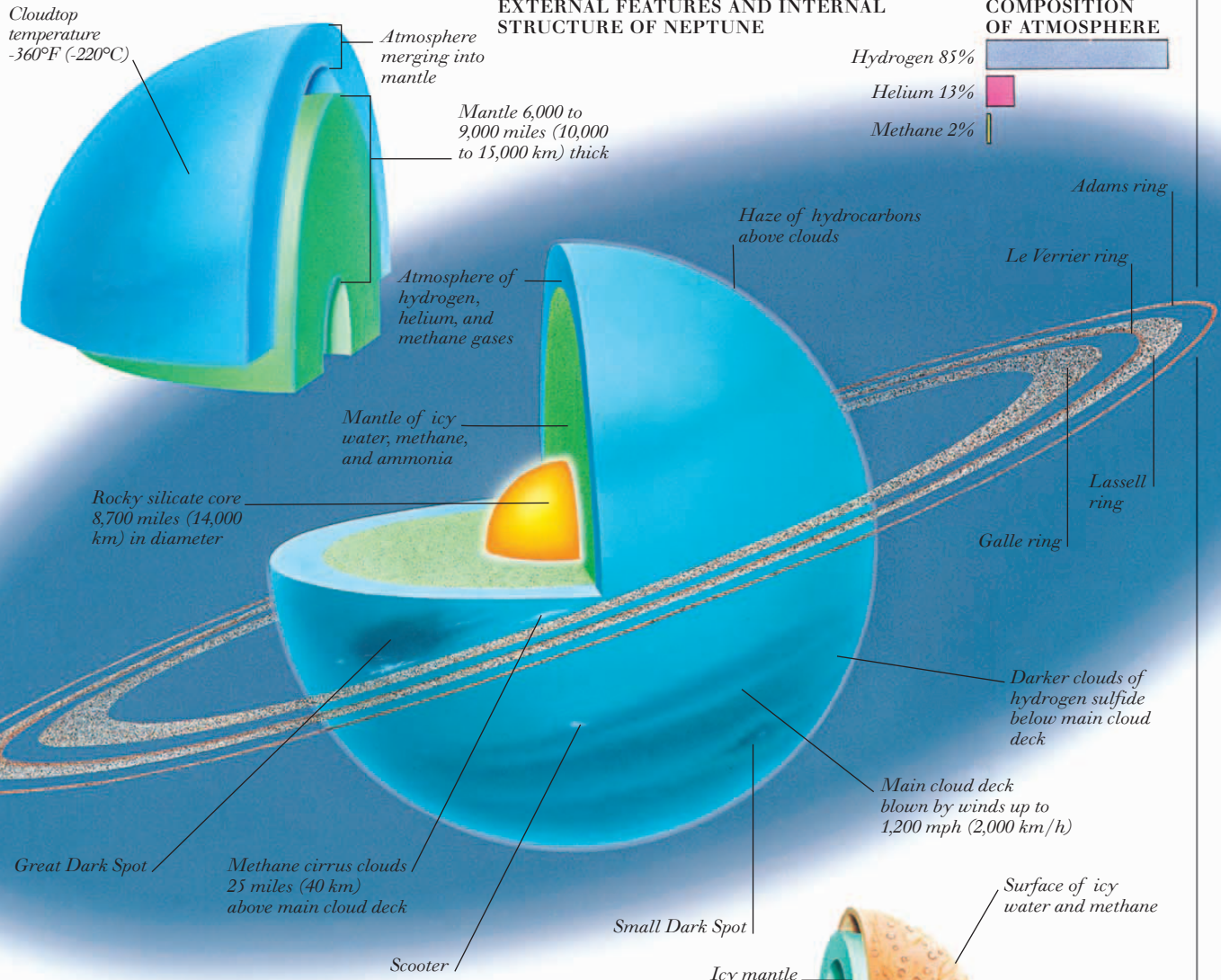


TRITON
Diameter: 1,681 miles
Average distance from planet: 220,500 miles

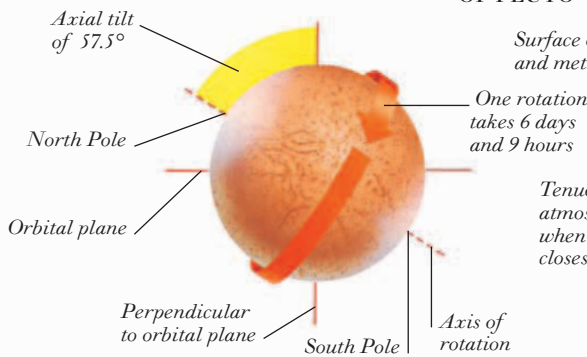


PROTEUS
Diameter: 259 miles
Average distance from planet: 73,100 miles

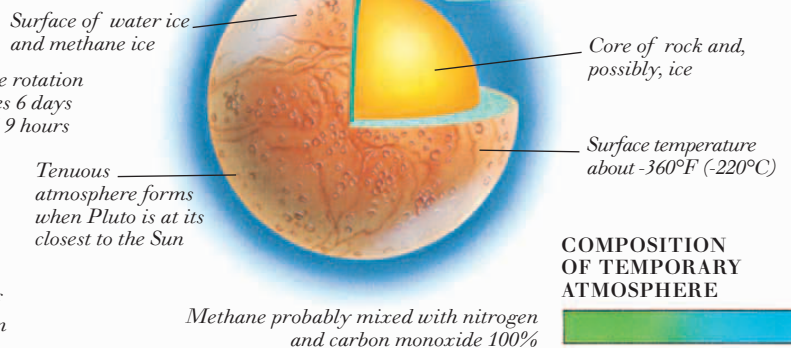
EXTERNAL FEATURES AND INTERNAL STRUCTURE OF NEPTUNE



TILT AND ROTATION OF PLUTO



EXTERNAL FEATURES AND INTERNAL STRUCTURE OF PLUTO



Asteroids, comets, and meteoroids



ASTEROID 951 GASPRA

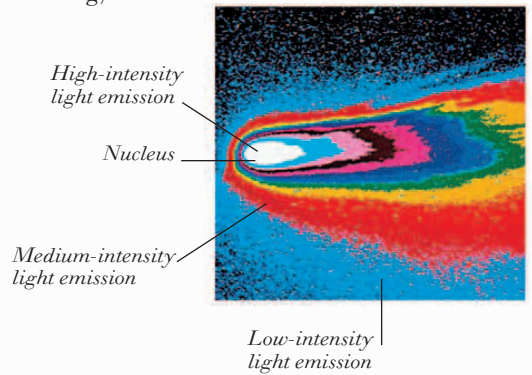
ASTEROIDS, COMETS, AND METEOROIDS are all debris remaining from the nebula from which the solar system formed 4.6 billion years ago. Asteroids are rocky bodies up to about 600 miles (1,000 km) in diameter, although most are much smaller. Most of them orbit the Sun in the asteroid belt, which lies between the orbits of Mars and Jupiter. Cometary nuclei exist in a huge cloud (called the Oort Cloud) that surrounds the planetary part of the solar system. They are made of frozen water and dust and are a few miles in

diameter. Occasionally, a comet is deflected from the Oort Cloud on to a long, elliptical path that brings it much closer to the Sun. As the comet approaches the Sun, the cometary nucleus starts to vaporize in the heat, producing both a brightly shining coma (a huge sphere of gas and dust around the nucleus), and a gas tail, and a dust tail. Meteoroids are small chunks of stone or stone and iron, which are fragments of asteroids or comets. Meteoroids range in size from tiny dust particles to objects tens of meters across. If a meteoroid enters the Earth's atmosphere, it is heated by friction and appears as a glowing streak of light called a meteor (also known as a shooting star). Meteor showers occur when the Earth passes through the trail of dust particles left by a comet. Most meteoroids burn up in the atmosphere. The remnants of the few that are large enough to reach the Earth's surface are termed meteorites.

OPTICAL IMAGE OF HALLEY'S COMET



FALSE-COLOR IMAGE OF HALLEY'S COMET



FALSE-COLOR IMAGE OF A LEONID METEOR SHOWER

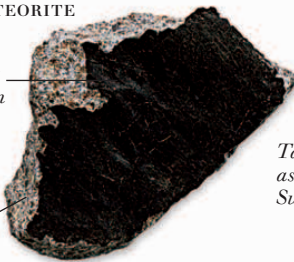


METEORITES

STONY METEORITE

Fusion crust formed when passing through atmosphere

Olivine and pyroxene mineral interior

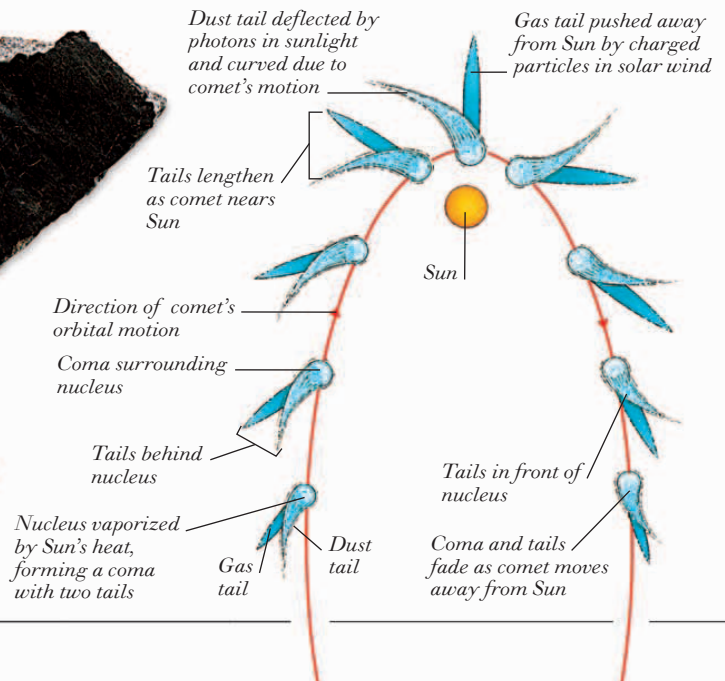


STONY-IRON METEORITE

Iron
Stone (olivine)



DEVELOPMENT OF COMET TAILS



FEATURES OF A COMET

Comet tails up to 60 million miles (100 million km) long

Head (coma and nucleus)

Gas molecules excited by Sun and emitting light

Thin, straight gas tail

Thin, straight gas tail blown by solar wind

Broad, curved dust tail

Coma surrounding nucleus

Nucleus a few miles across

STRUCTURE OF A COMET

Glowing coma 600,000 miles (1 million km) across around nucleus

Dust layer with active areas emitting jets of gas and dust

Jet of gas and dust produced by vaporization on sunlit side of nucleus

Ices, mainly water ice, but also frozen carbon dioxide, methane, and ammonia

Broad curved dust tail

Dust particles reflecting sunlight



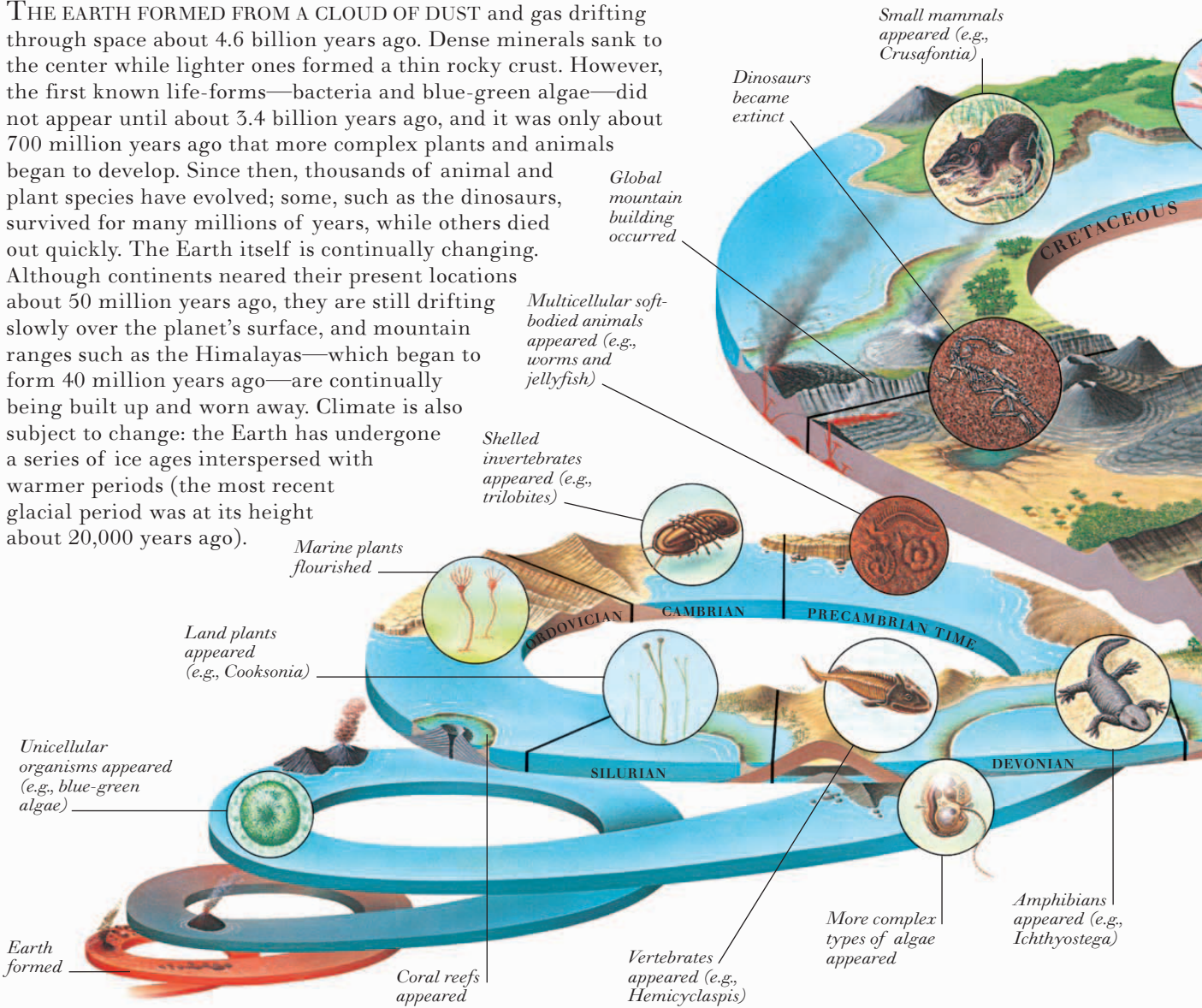


PREHISTORIC EARTH

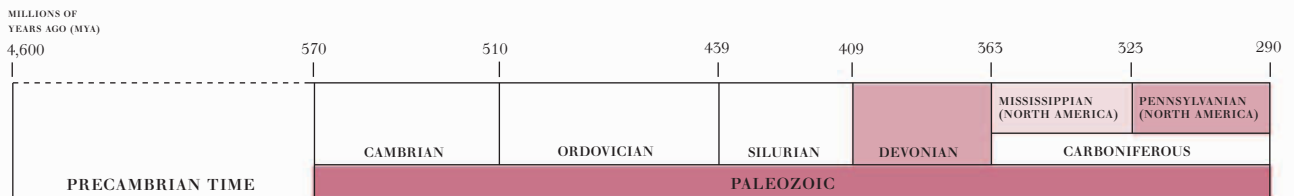
THE CHANGING EARTH	56
THE EARTH'S CRUST	58
FAULTS AND FOLDS	60
MOUNTAIN BUILDING	62
PRECAMBRIAN TO DEVONIAN PERIOD	64
CARBONIFEROUS TO PERMIAN PERIOD	66
TRIASSIC PERIOD	68
JURASSIC PERIOD	70
CRETACEOUS PERIOD	72
TERTIARY PERIOD	74
QUATERNARY PERIOD	76
EARLY SIGNS OF LIFE	78
AMPHIBIANS AND REPTILES	80
THE DINOSAURS	82
THEROPODS 1	84
THEROPODS 2	86
SAUROPODOMORPHS 1	88
SAUROPODOMORPHS 2	90
THYREOPHORANS 1	92
THYREOPHORANS 2	94
ORNITHOPODS 1	96
ORNITHOPODS 2	98
MARGINOCEPHALIANS 1	100
MARGINOCEPHALIANS 2	102
MAMMALS 1	104
MAMMALS 2	106
THE FIRST HUMANS	108

The changing Earth

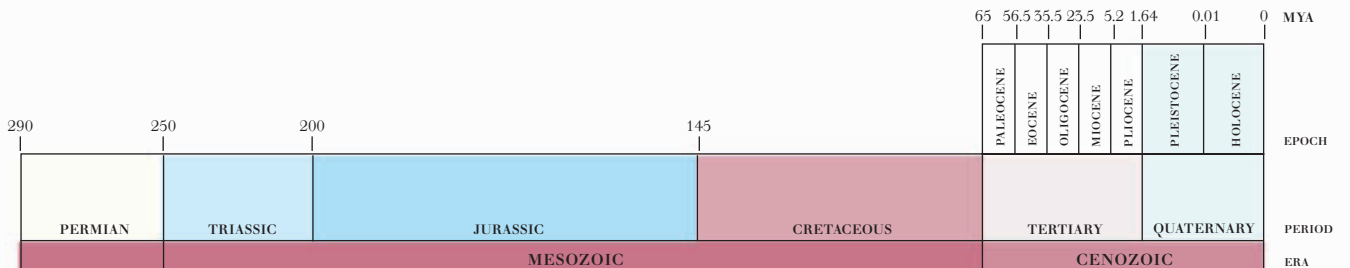
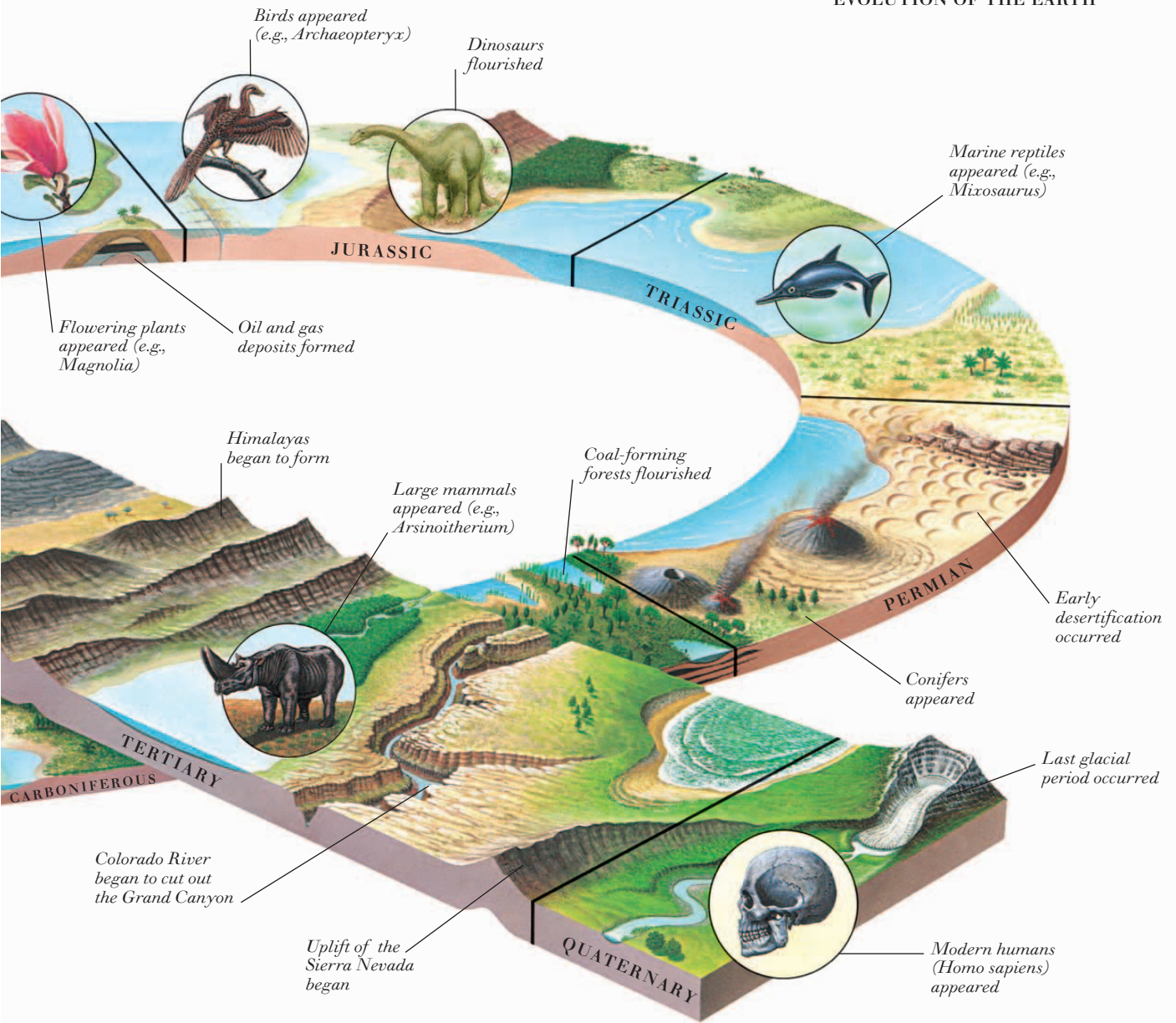
THE EARTH FORMED FROM A CLOUD OF DUST and gas drifting through space about 4.6 billion years ago. Dense minerals sank to the center while lighter ones formed a thin rocky crust. However, the first known life-forms—bacteria and blue-green algae—did not appear until about 3.4 billion years ago, and it was only about 700 million years ago that more complex plants and animals began to develop. Since then, thousands of animal and plant species have evolved; some, such as the dinosaurs, survived for many millions of years, while others died out quickly. The Earth itself is continually changing. Although continents neared their present locations about 50 million years ago, they are still drifting slowly over the planet's surface, and mountain ranges such as the Himalayas—which began to form 40 million years ago—are continually being built up and worn away. Climate is also subject to change: the Earth has undergone a series of ice ages interspersed with warmer periods (the most recent glacial period was at its height about 20,000 years ago).



GEOLOGICAL TIMESCALE



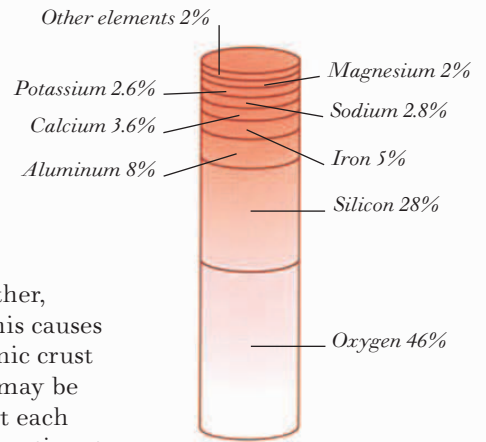
EVOLUTION OF THE EARTH



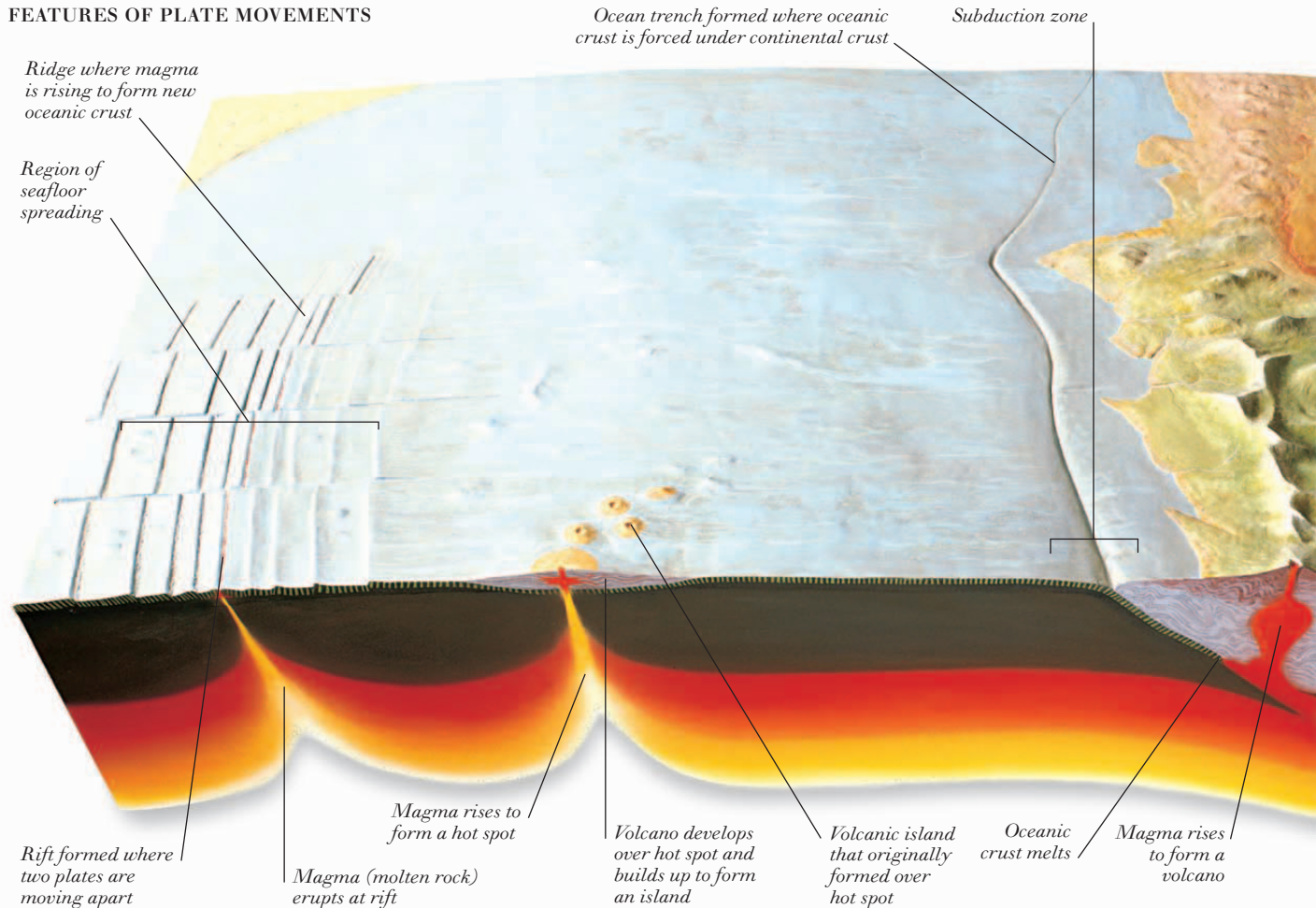
The Earth's crust

THE EARTH'S CRUST IS THE SOLID outer shell of the Earth. It includes continental crust (about 25 miles/40 km thick) and oceanic crust (about four miles/6 km thick). The crust and the topmost layer of the mantle form the lithosphere. The lithosphere consists of semirigid plates that move relative to each other on the underlying asthenosphere (a partly molten layer of the mantle). This process is known as plate tectonics and helps explain continental drift. Where two plates move apart, there are rifts in the crust. In mid-ocean, this movement results in seafloor spreading and the formation of ocean ridges; on continents, crustal spreading can form rift valleys. When plates move toward each other, one may be subducted beneath (forced under) the other. In mid-ocean, this causes ocean trenches, seismic activity, and arcs of volcanic islands. Where oceanic crust is subducted beneath continental crust or where continents collide, land may be uplifted and mountains formed (see pp. 62–65). Plates may also slide past each other—along the San Andreas fault, for example. Crustal movement on continents may result in earthquakes, while movement under the seabed can lead to tidal waves.

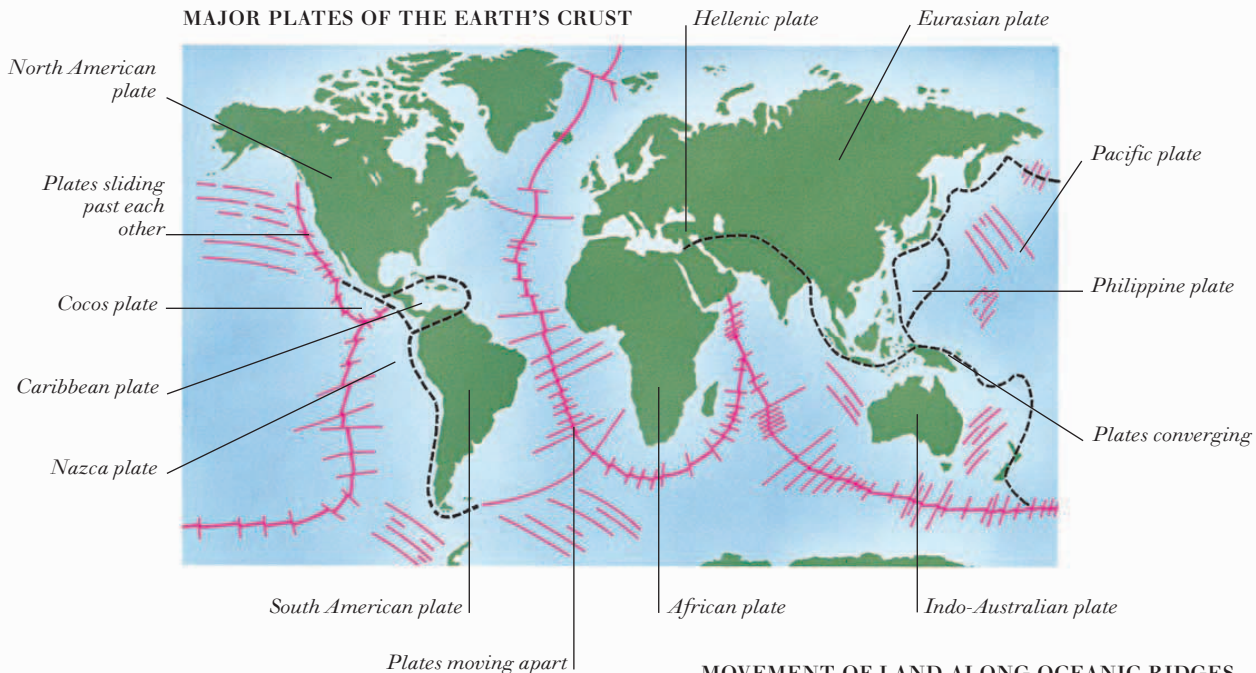
ELEMENTS IN THE EARTH'S CRUST



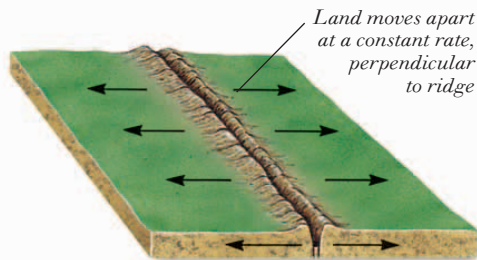
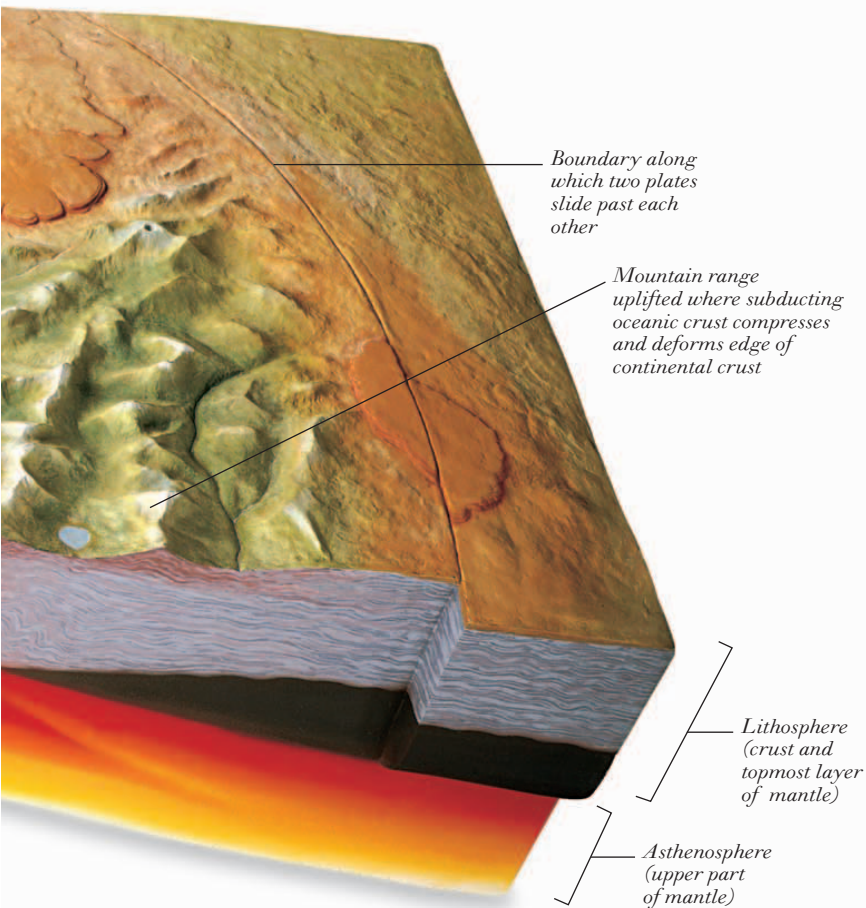
FEATURES OF PLATE MOVEMENTS



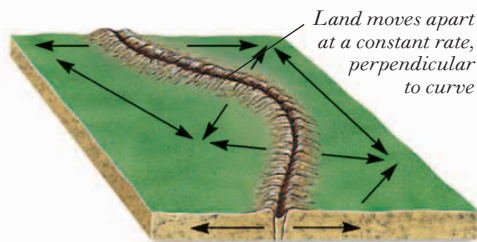
MAJOR PLATES OF THE EARTH'S CRUST



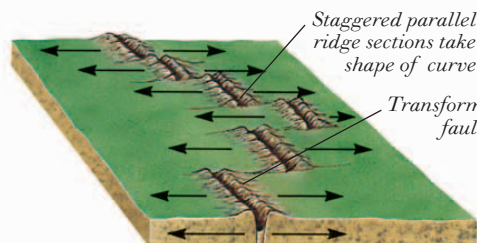
MOVEMENT OF LAND ALONG OCEANIC RIDGES



STRAIGHT OCEANIC RIDGE



CURVED OCEANIC RIDGE

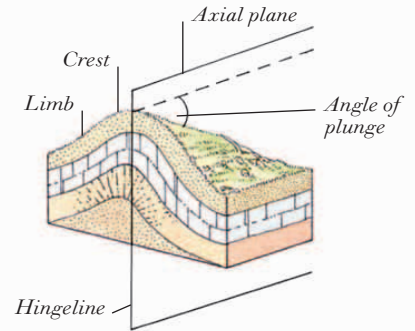


STRESSES RESOLVE INTO SECTIONS

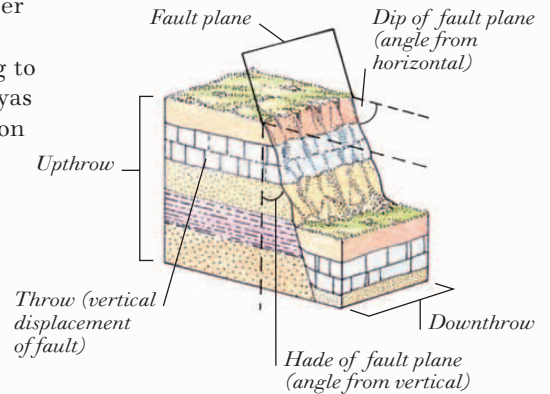
Faults and folds

THE CONTINUOUS MOVEMENT of the Earth's crustal plates (see pp. 58–59) can squeeze, stretch, or break rock strata, deforming them and producing faults and folds. A fault is a fracture in a rock along which there is movement of one side relative to the other. The movement can be vertical, horizontal, or oblique (vertical and horizontal). Faults develop when rocks are subjected to compression or tension. They tend to occur in hard, rigid rocks, which are more likely to break than bend. The smallest faults occur in single mineral crystals and are microscopically small, whereas the largest—the Great Rift Valley in Africa, which formed between 5 million and 100,000 years ago—is more than 6,000 miles (9,000 km) long. A fold is a bend in a rock layer caused by compression. Folds occur in elastic rocks, which tend to bend rather than break. The two main types of fold are anticlines (upfolds) and synclines (downfolds). Folds vary in size from a few millimeters long to folded mountain ranges hundreds of miles long, such as the Himalayas (see pp. 62–63) and the Alps, which are repeatedly folding. In addition to faults and folds, other features associated with rock deformations include boudins, mullions, and *en échelon* fractures.

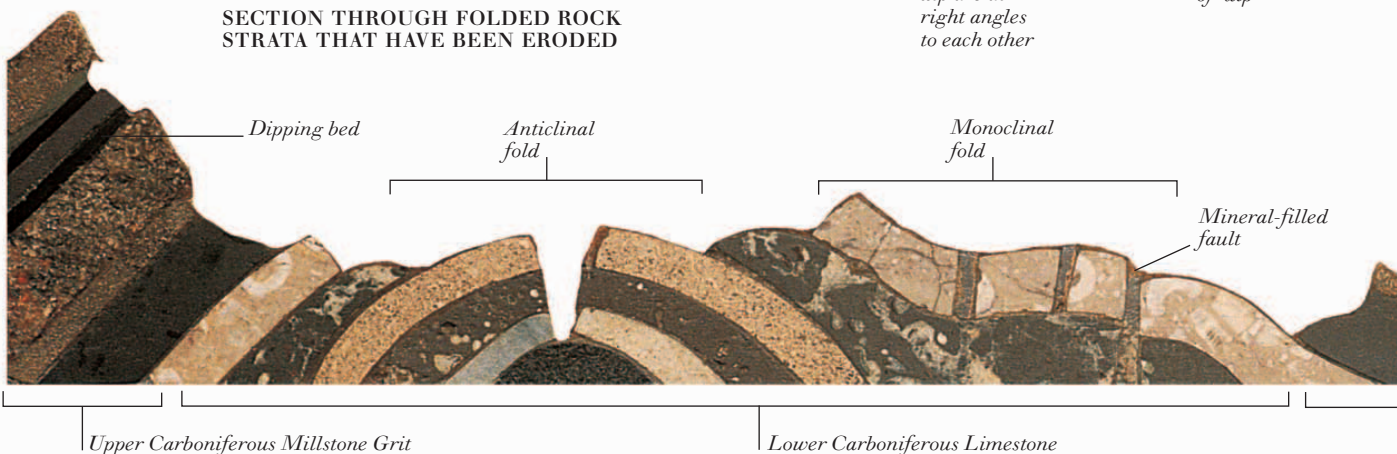
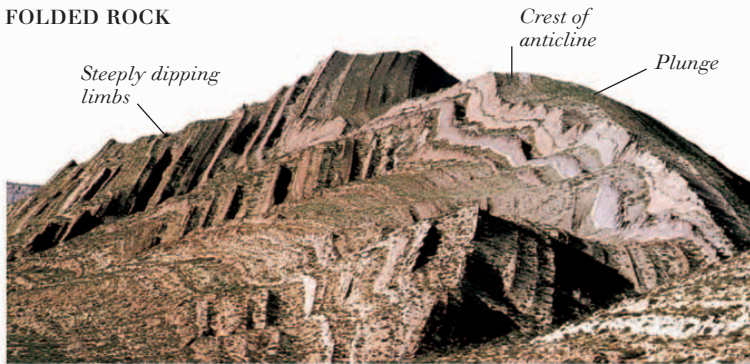
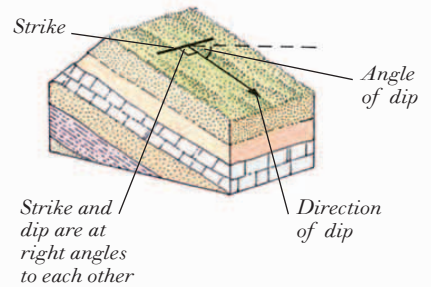
STRUCTURE OF A FOLD



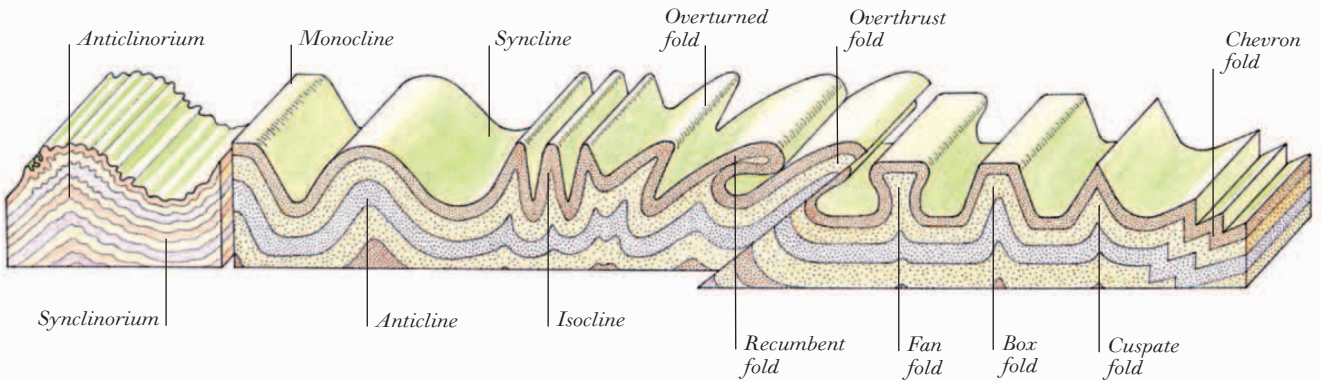
STRUCTURE OF A FAULT



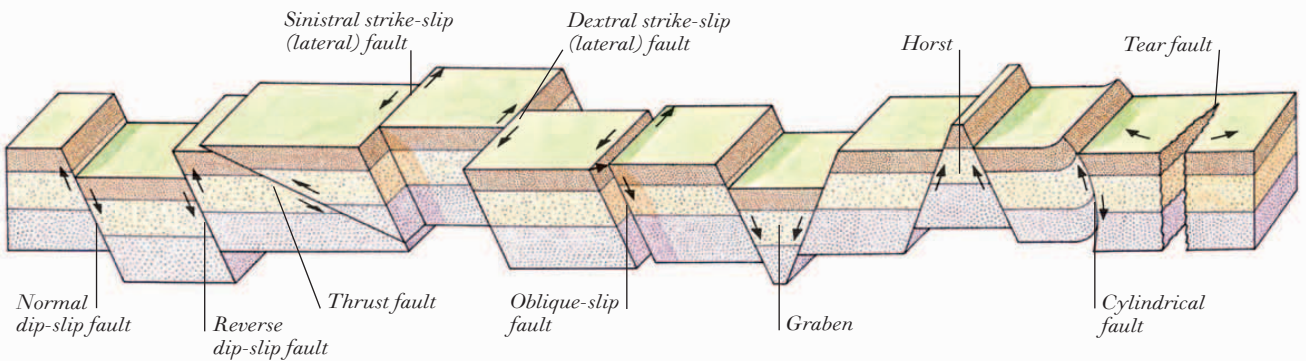
STRUCTURE OF A SLOPE



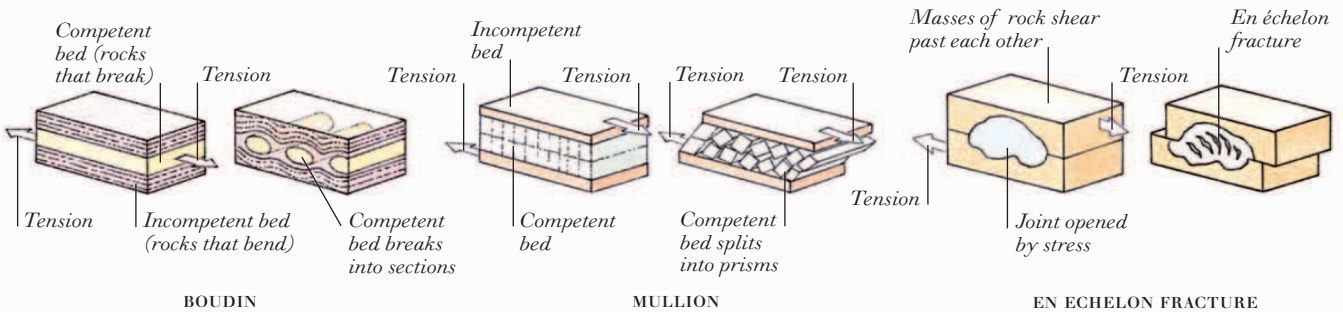
EXAMPLES OF FOLDS



EXAMPLES OF FAULTS



SMALL-SCALE ROCK DEFORMATIONS



Upper Carboniferous Millstone Grit

Upper Carboniferous Coal Measures

Mountain building

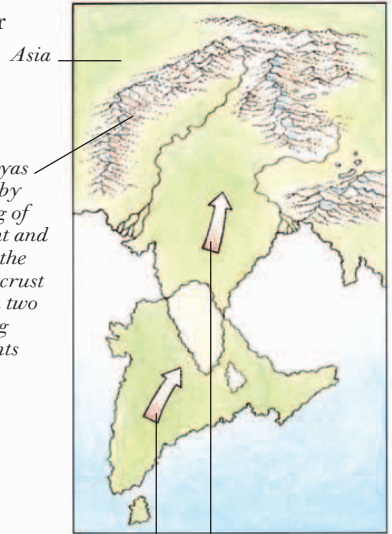
THE PROCESSES INVOLVED in mountain building—termed orogenesis—occur as a result of the movement of the Earth’s crustal plates (see pp. 58–59).

There are three main types of mountains: volcanic mountains, fold mountains, and block mountains. Most volcanic mountains have been formed along plate boundaries where plates have come together or moved apart and lava and other debris have been ejected onto the Earth’s surface. The lava and debris may have built up to form a dome around the vent of a volcano. Fold mountains are formed

where plates push together and cause the rock to buckle upward. Where oceanic crust meets less dense continental crust, the oceanic crust is forced under the continental crust. The continental crust is buckled by the impact. This is how folded mountain ranges, such as the Appalachian Mountains in North America, were formed. Fold mountains are also formed where two areas of continental crust meet. The Himalayas, for example, began to form when India collided with Asia, buckling the sediments

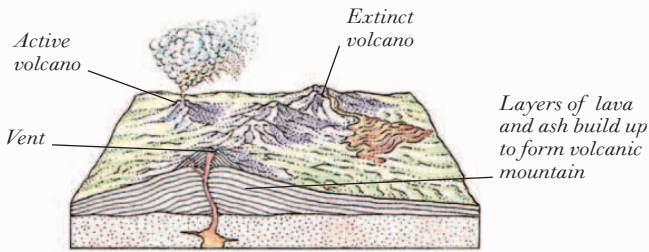
and parts of the oceanic crust between them. Block mountains are formed when a block of land is uplifted between two faults as a result of compression or tension in the Earth’s crust (see pp. 60–61). Often, the movement along faults has taken place gradually over millions of years. However, two plates may cause an earthquake by suddenly sliding past each other along a faultline.

FORMATION OF THE HIMALAYAS

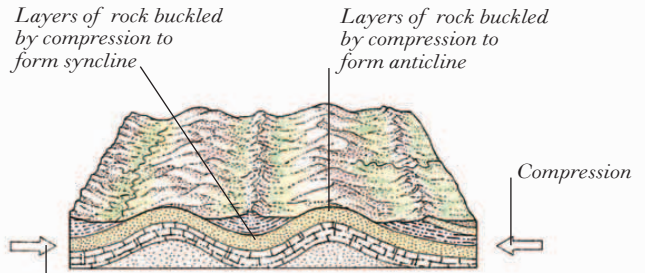


BHAGIRATHI PARBAT,
HIMALAYAS

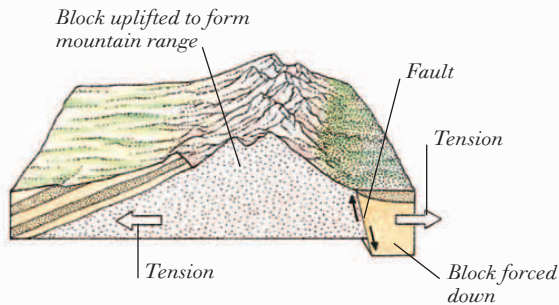
EXAMPLES OF MOUNTAINS



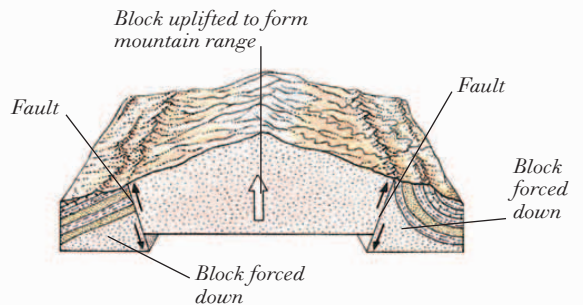
VOLCANIC MOUNTAIN



FOLD MOUNTAIN

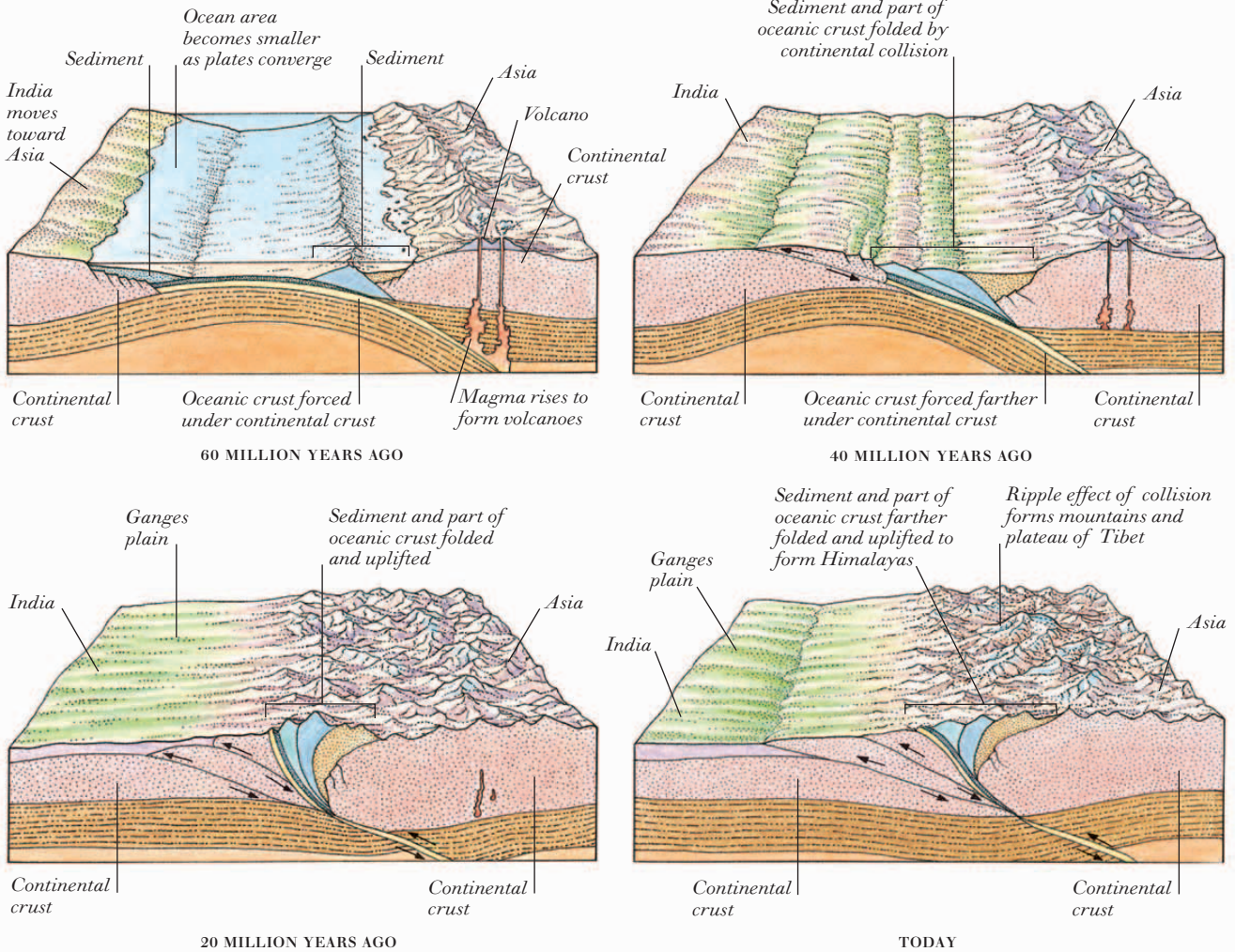


BLOCK-FAULT MOUNTAIN



UPLIFTED BLOCK-FAULT MOUNTAIN

STAGES IN THE FORMATION OF THE HIMALAYAS

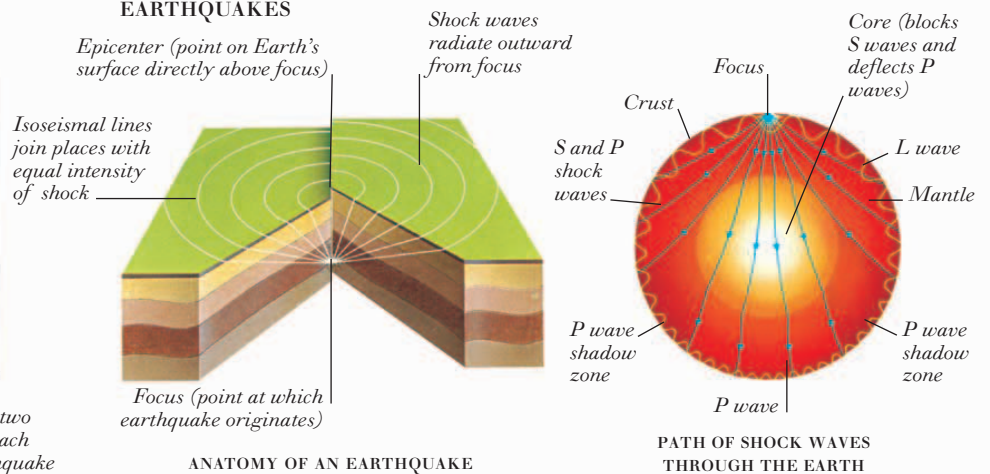


SAN ANDREAS FAULT



Faultline along which two plates may slide past each other, causing an earthquake

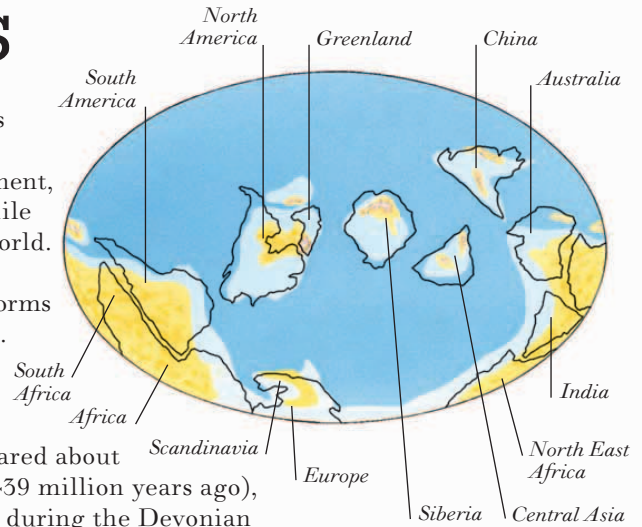
EARTHQUAKES



Precambrian to Devonian periods

WHEN THE EARTH FORMED about 4.6 billion years ago, its atmosphere consisted of volcanic gases with little oxygen, making it hostile to most forms of life. One large supercontinent, Gondwana, was situated over the southern polar region, while other smaller continents were spread over the rest of the world. Constant movement of the Earth's crustal plates carried continents across the earth's surface. The first primitive life-forms emerged around 3.4 billion years ago in shallow, warm seas. The build up of oxygen began to form a shield of ozone around the Earth, protecting living organisms from the Sun's harmful rays and helping to establish an atmosphere in which life could sustain itself. The first vertebrates appeared about 470 million years ago, during the Ordovician period (510–439 million years ago), the first land plants appeared around 400 million years ago during the Devonian period (409–363 million years ago), and the first land animals about 30 million years later.

MIDDLE ORDOVICIAN POSITIONS OF PRESENT-DAY LANDMASSES



EXAMPLES OF PRECAMBRIAN TO DEVONIAN PLANT GROUPS



A PRESENT-DAY CLUBMOSS
(*Lycopodium sp.*)



A PRESENT-DAY LAND PLANT
(*Asparagus setaceus*)



FOSSIL OF AN EXTINCT LAND PLANT
(*Cooksonia hemisphaerica*)



FOSSIL OF AN EXTINCT SWAMP PLANT
(*Zosterophyllum llanoveranum*)

EXAMPLES OF PRECAMBRIAN TO DEVONIAN TRILOBITES



ACADAGNOSTUS
Group: Agnostidae
Length: ½ in (8 mm)



PHACOPS
Group: Phacopidae
Length: 1¼ in (4.5 cm)

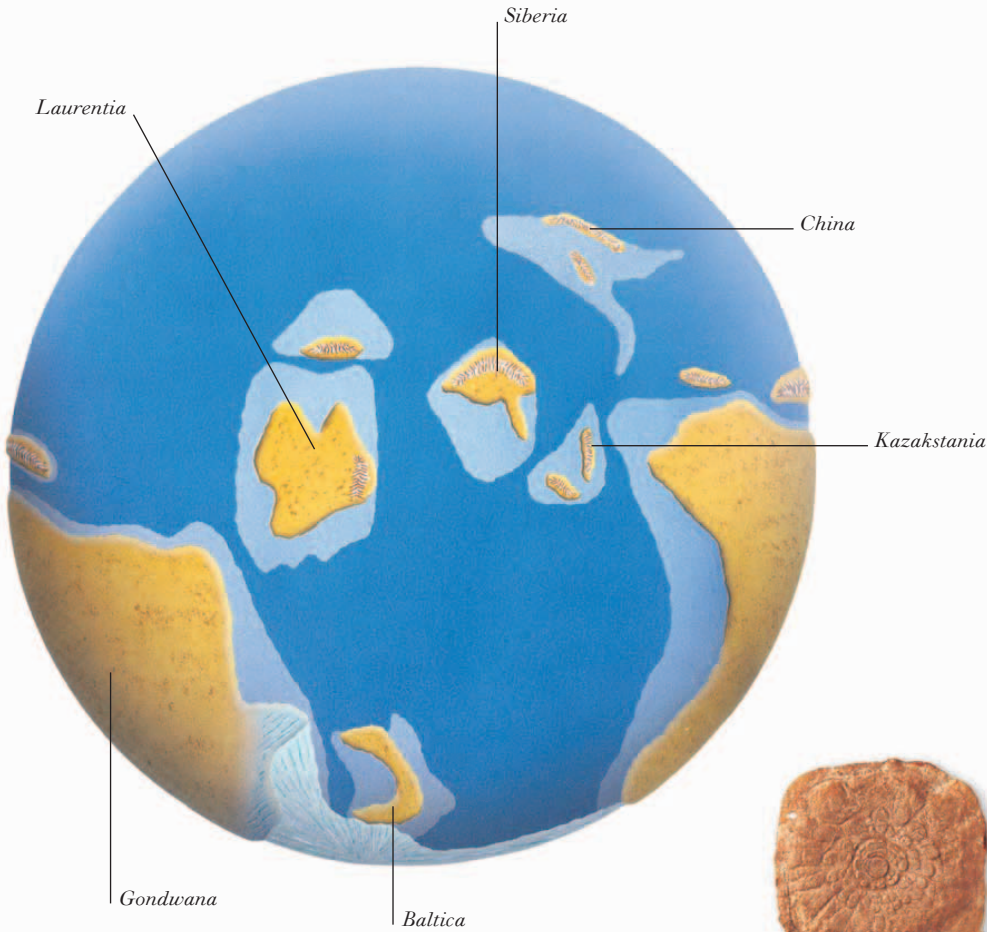


OLENELLUS
Group: Olenellidae
Length: 2½ in (6 cm)



ELRATHIA
Group: Ptychopariidae
Length: ¾ in (2 cm)

THE EARTH DURING THE MIDDLE ORDOVICIAN PERIOD



EXAMPLES OF EARLY MARINE INVERTEBRATES



FOSSIL NAUTILOID
(*Estonioceras perforatum*)



FOSSIL BRACHIOPOD
(*Dicoelosia bilobata*)



TRACE FOSSIL
(*Mawsonites spriggi*)



FOSSIL GRAPTOLITE
(*Monograptus convolutus*)

EXAMPLES OF DEVONIAN FISH



RHAMPHODOPSIS
Group: Ptyctodontidae
Length: 6 in (15 cm)



PTERASPIS
Group: Pteraspidae
Length: 10 in (25 cm)



COCCOSTEUS
Group: Coccosteidae
Length: 14 in (35 cm)



BOTHRIOLEPIS
Group: Bothriolepididae
Length: 16 in (40 cm)



CHEIRACANTHUS
Group: Acanthodidae
Length: 12 in (30 cm)



PTERICHTHYODES
Group: Asterolepididae
Length: 6 in (15 cm)



CHEIROLEPIS
Group: Cheirolepididae
Length: 6¾ in (17 cm)

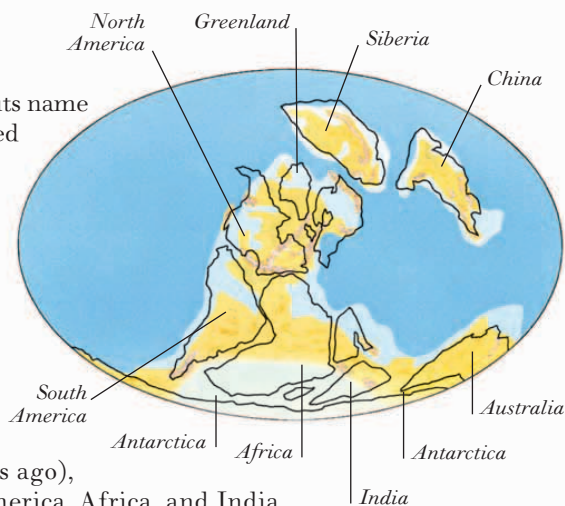


CEPHALASPIS
Group: Cephalaspidae
Length: 8¾ in (22 cm)

Carboniferous to Permian periods

THE CARBONIFEROUS PERIOD (363–290 million years ago) takes its name from the thick, carbon-rich layers—now coal—that were produced during this period as swampy tropical forests were repeatedly drowned by shallow seas. The humid climate across northern and equatorial continents throughout Carboniferous times produced the first dense plant cover on Earth. During the early part of this period, the first reptiles appeared. Their development of a waterproof egg with a protective internal structure ended animal life's dependence on an aquatic environment. Toward the end of Carboniferous times, the earth's continents Laurasia and Gondwana collided, resulting in the huge landmass of Pangaea. Glaciers smothered much of the southern hemisphere during the Permian period (290–245 million years ago), covering Antarctica, parts of Australia, and much of South America, Africa, and India. Ice locked up much of the world's water and large areas of the northern hemisphere experienced a drop in sea level. Away from the poles, deserts and a hot dry climate predominated. As a result of these conditions, the Permian period ended with the greatest mass extinction of life on Earth ever.

LATE CARBONIFEROUS POSITIONS OF PRESENT-DAY LANDMASSES



EXAMPLES OF CARBONIFEROUS AND PERMIAN PLANT GROUPS



A PRESENT-DAY FIR
(*Abies concolor*)



FOSSIL OF AN EXTINCT FERN
(*Zeilleria frenzlii*)



FOSSIL OF AN
EXTINCT HORSETAIL
(*Equisetites sp.*)



FOSSIL OF AN
EXTINCT CLUBMOSS
(*Lepidodendron sp.*)

EXAMPLES OF CARBONIFEROUS AND PERMIAN TREES



PECOPTERIS
Group: Marattiaceae
Height: 13 ft (4 m)



PARIPTERIS
Group: Medullosaceae
Height: 16 ft 6 in (5 m)

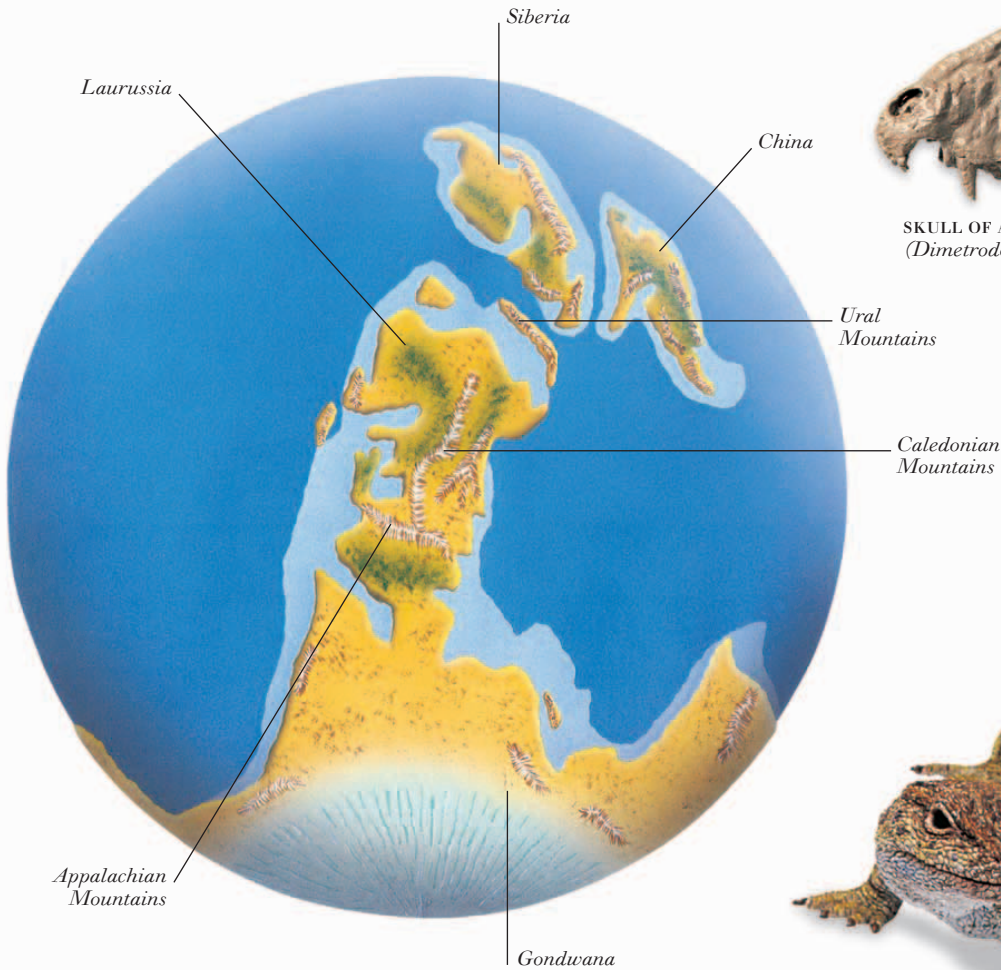


MARIOPTERIS
Group: Lyginopteridales
Height: 16 ft 6 in (5 m)



MEDULLOSA
Group: Medullosaceae
Height: 16 ft 6 in (5 m)

THE EARTH DURING THE LATE CARBONIFEROUS PERIOD



EXAMPLES OF CARBONIFEROUS AND PERMIAN ANIMALS



SKULL OF AN EXTINCT SYNAPSID
(*Dimetrodon loomisi*)



FOSSIL TEETH OF AN EXTINCT SHARK
(*Helicoprion bessonowi*)



MODEL OF AN EXTINCT EARLY REPTILELIKE ANIMAL
(*Westlothiana lizziae*)



LEPIDODENDRON
Group: Lepidodendraceae
Height: 100 ft (30 m)



CORDAITES
Group: Cordaitaceae
Height: 33 ft (10 m)



GLOSSOPTERIS
Group: Glossopteridaceae
Height: 26 ft (8 m)

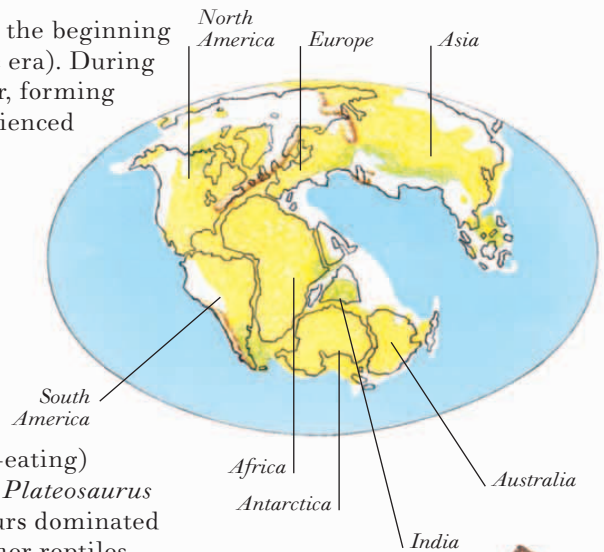


ALETHOPTERIS
Group: Medullosaceae
Height: 16 ft 6 in (5 m)

Triassic period

THE TRIASSIC PERIOD (250–200 million years ago) marked the beginning of what is known as the Age of the Dinosaurs (the Mesozoic era). During this period, the present-day continents were massed together, forming one huge continent known as Pangaea. This landmass experienced extremes of climate, with lush green areas around the coast or by lakes and rivers, and arid deserts in the interior. The only forms of plant life were nonflowering plants, such as conifers, ferns, cycads, and ginkgos; flowering plants had not yet evolved. The principal forms of animal life included diverse, often gigantic, amphibians, rhynchosaurs (“beaked lizards”), and primitive crocodylians. Dinosaurs first appeared about 230 million years ago, at the beginning of the Late Triassic period. Among the earliest dinosaurs were the carnivorous (flesh-eating) herrerasaurids, such as *Herrerasaurus* and *Staurikosaurus*. Early herbivorous (plant-eating) dinosaurs first appeared in Late Triassic times and included *Plateosaurus* and *Technosaurus*. By the end of the Triassic period, dinosaurs dominated Pangaea, possibly contributing to the extinction of many other reptiles.

TRIASSIC POSITIONS OF PRESENT-DAY LANDMASSES



EXAMPLES OF TRIASSIC PLANT GROUPS



A PRESENT-DAY CYCAD
(*Cycas revoluta*)



A PRESENT-DAY GINKGO
(*Ginkgo biloba*)



A PRESENT-DAY CONIFER
(*Araucaria araucana*)



FOSSIL OF AN EXTINGUISHED FERN
(*Pachypteris sp.*)



FOSSIL LEAF OF AN EXTINGUISHED CYCAD
(*Cycas sp.*)

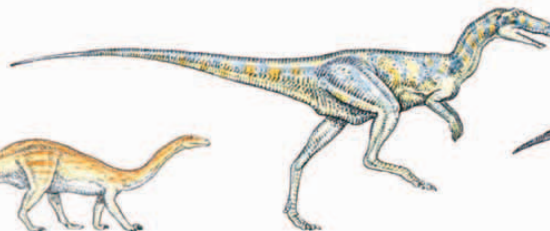
EXAMPLES OF TRIASSIC DINOSAURS



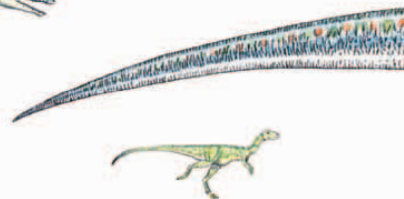
MELANOROSAURUS
Group: Melanorosauridae
Length: 40 ft (12.2 m)



MUSSAURUS
Group: Sauropodomorpha
Length: 6 ft 6 in–10 ft (2–3 m)

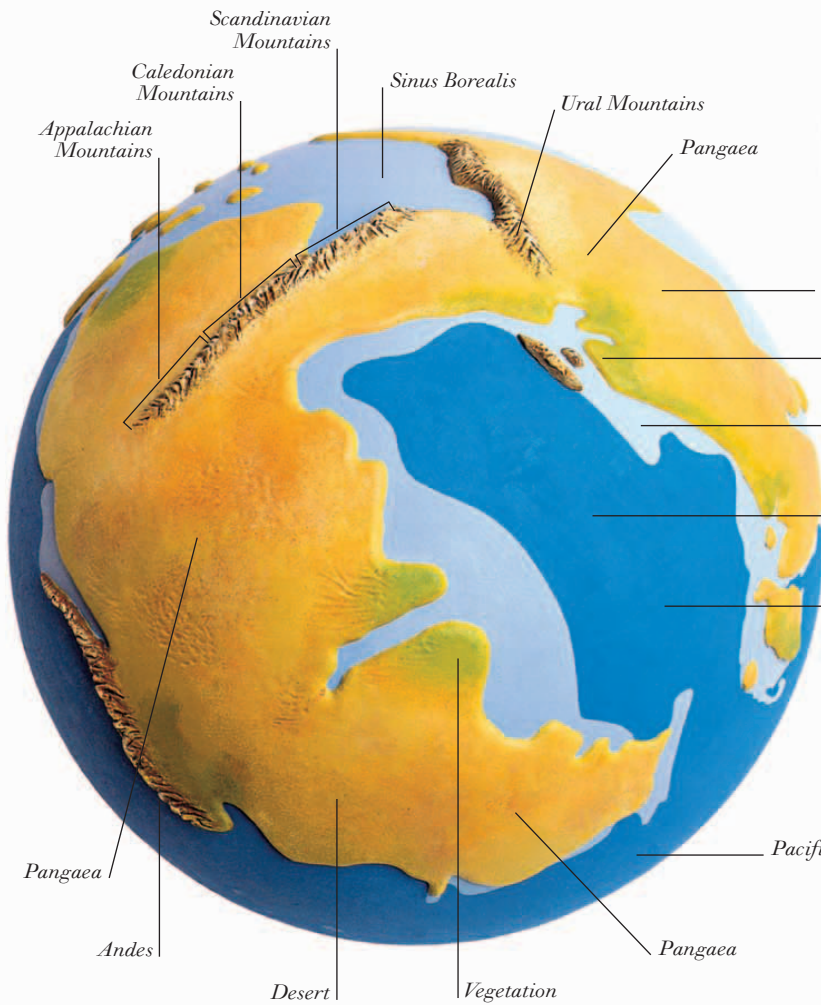


HERRERASAURUS
Group: Herrerasauridae
Length: 10 ft (3 m)



PISANOSAURUS
Group: Ornithischia
Length: 3 ft (90 cm)

THE EARTH DURING THE TRIASSIC PERIOD



EXAMPLES OF TRIASSIC ANIMALS



AN EXTINCT AMPHIBIAN



A NAUTILOID MOLLUSK (*Nautilus sp.*)

Desert

Vegetation

Continental shelf



AN EXTINCT CHONDROSTEAN FISH (*Cleithrolepis granulatus*)

Tethys Sea

Deep ocean



AN EXTINCT SEA-GOING REPTILE (*Pachypleurosaurus sp.*)



AN EXTINCT RHYNCHOSAURIAN REPTILE (*Scaphonyx fischeri*)



PLATEOSAURUS
Group: Plateosauridae
Length: 26 ft (7.9 m)



TECHNOSAURUS
Group: Ornithischia
Length: 3 ft 3 in (1 m)



COELOPHYSIS
Group: Coelophysidae
Length: 10 ft (3 m)



STAURIKOSAURUS
Group: Herrerasauridae
Length: 6 ft 6 in (2 m)

Jurassic period

THE JURASSIC PERIOD, the middle part of the Mesozoic era, lasted from 199 to 145 million years ago. During Jurassic times, the landmass of Pangaea broke up into the continents of Gondwana and Laurasia, and sea levels rose, flooding areas of lower land. The Jurassic climate was warm and moist. Plants such as ginkgos, horsetails, and conifers thrived, and giant redwood trees appeared, as did the first flowering plants. The abundance of plant food coincided with the proliferation of herbivorous (plant-eating) dinosaurs, such as the large sauropods (e.g., *Diplodocus*) and stegosaurs (e.g., *Stegosaurus*). Carnivorous (flesheating) dinosaurs, such as *Compsognathus* and *Allosaurus*, also flourished by hunting the many animals that existed—among them other dinosaurs. Further Jurassic animals included shrewlike mammals, and pterosaurs (flying reptiles), as well as plesiosaurs and ichthyosaurs (both marine reptiles).

JURASSIC POSITIONS OF PRESENT-DAY LANDMASSES



EXAMPLES OF JURASSIC PLANT GROUPS



A PRESENT-DAY FERN
(*Dicksonia antarctica*)



A PRESENT-DAY HORSETAIL
(*Equisetum arvense*)



A PRESENT-DAY CONIFER
(*Taxus baccata*)

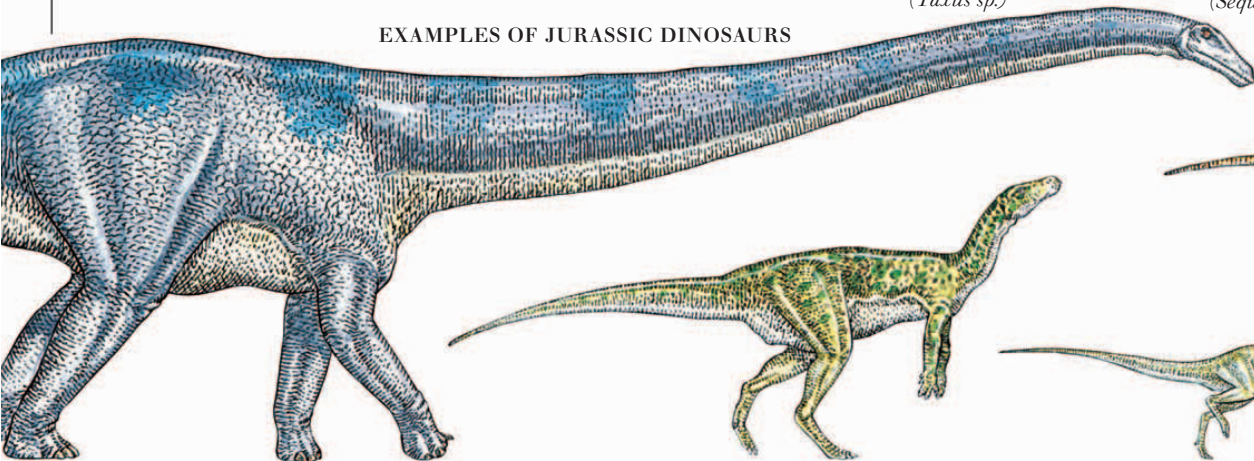


FOSSIL LEAF OF AN
EXTINCT CONIFER
(*Taxus* sp.)



FOSSIL LEAF OF AN
EXTINCT REDWOOD
(*Sequoiadendron
affinis*)

EXAMPLES OF JURASSIC DINOSAURS



DIPLODOCUS
Group: Diplodocidae
Length: 88 ft (26.8 m)



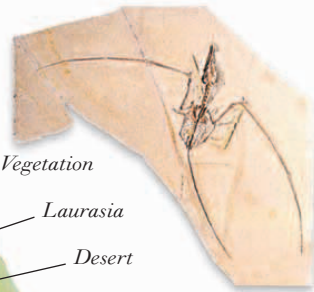
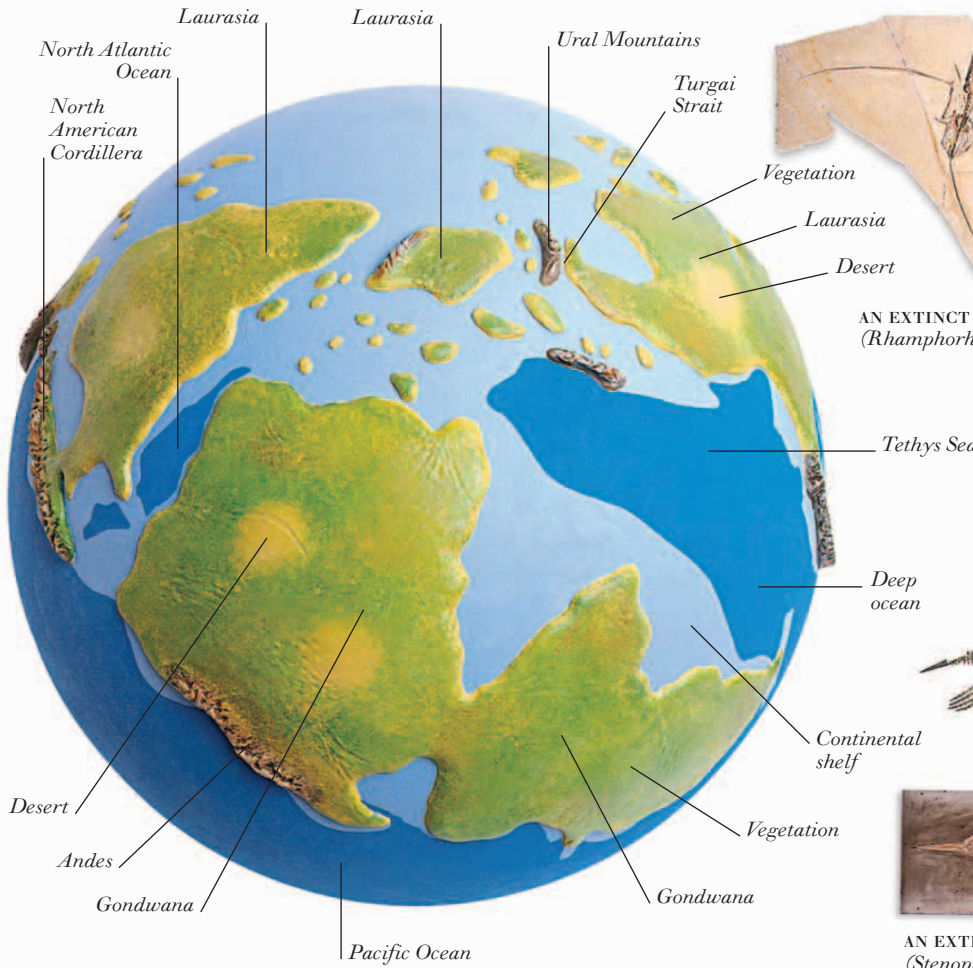
CAMPTOSAURUS
Group: Iguanodontia
Length: 16–25 ft (4.9–7 m)



DRYOSAURUS
Group: Dryosauridae
Length: 10–13 ft (3–4 m)

THE EARTH DURING THE JURASSIC PERIOD

EXAMPLES OF JURASSIC ANIMALS



AN EXTINCT PTEROSAUR
(*Rhamphorhynchus* sp.)



AN EXTINCT BELEMNITE MOLLUSK
(*Belemnoteuthis* sp.)



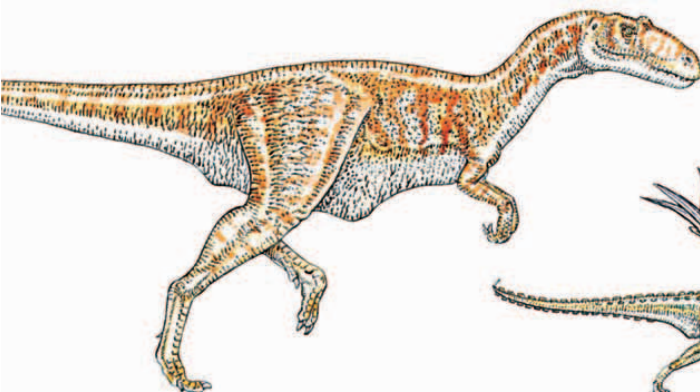
AN EXTINCT RHYNCHOSAURIAN REPTILE
(*Homeosaurus pulchellus*)



AN EXTINCT PLESIOSAUR
(*Peloneustes philarcus*)



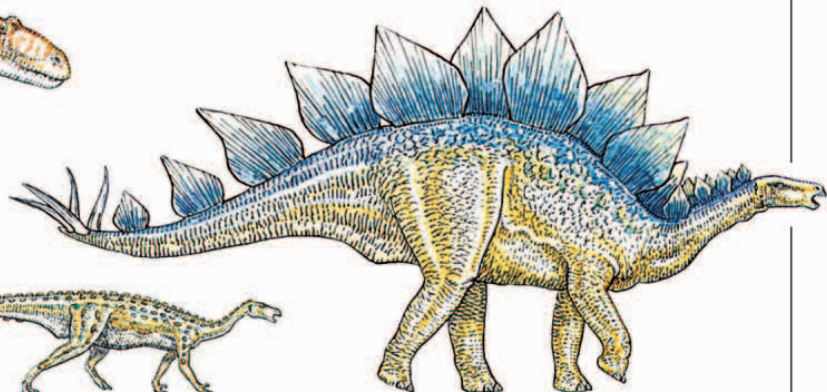
AN EXTINCT ICHTHYOSAUR
(*Stenopterygius megacephalus*)



ALLOSAURUS
Group: Allosauroidea
Length: 36 ft (11 m)



SCOLIDOSAURUS
Group: Thyreophora
Length: 13 ft (4m)

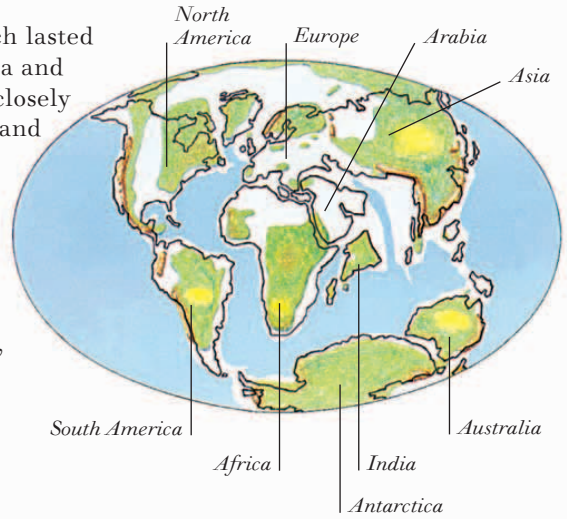


STEGOSAURUS
Group: Stegosauridae
Length: 30 ft (9.1 m)

Cretaceous period

THE MESOZOIC ERA ENDED WITH the Cretaceous period, which lasted from 146 to 65 million years ago. During this period, Gondwana and Laurasia were breaking up into smaller landmasses that more closely resembled the modern continents. The climate remained mild and moist but the seasons became more marked. Flowering plants, including deciduous trees, replaced many cycads, seed ferns, and conifers. Animal species became more varied, with the evolution of new mammals, insects, fish, crustaceans, and turtles. Dinosaurs evolved into a wide variety of species during Cretaceous times; more than half of all known dinosaurs—including *Iguanodon*, *Deinonychus*, *Tyrannosaurus*, and *Hypsilophodon*—lived during this period. At the end of the Cretaceous period, however, most dinosaurs became extinct. The reason for this mass extinction is unknown but it is thought to have been caused by climatic changes due to either a catastrophic meteor impact with the Earth or extensive volcanic eruptions.

CRETACEOUS POSITIONS OF PRESENT-DAY LANDMASSES



EXAMPLES OF CRETACEOUS PLANT GROUPS



A PRESENT-DAY CONIFER
(*Pinus muricata*)



A PRESENT-DAY DECIDUOUS TREE
(*Magnolia sp.*)



FOSSIL OF AN EXTINCT FERN
(*Sphenopteris latiloba*)

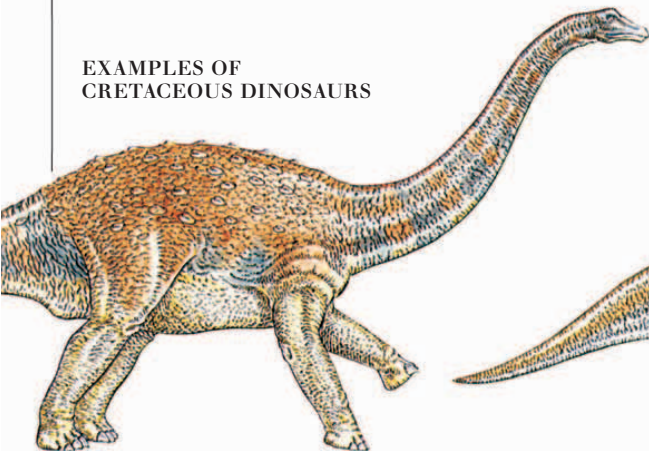


FOSSIL OF AN EXTINCT GINKGO
(*Ginkgo pluripartita*)

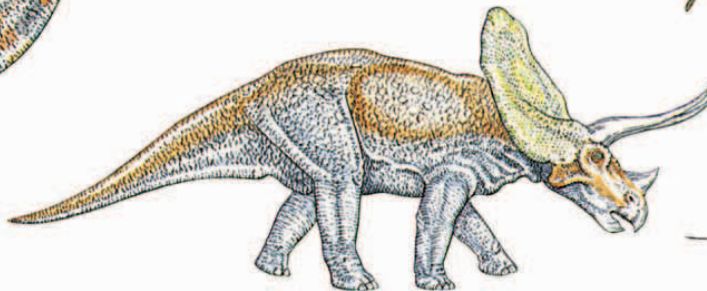


FOSSIL LEAVES OF AN EXTINCT DECIDUOUS TREE
(*Cercidiphyllum sp.*)

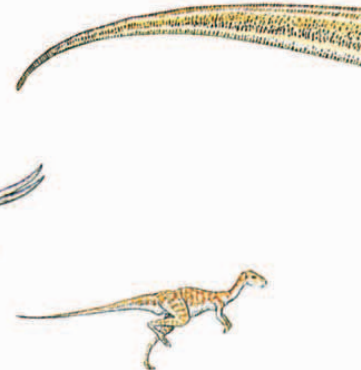
EXAMPLES OF CRETACEOUS DINOSAURS



SALTASAURUS
Group: Saltasauridae
Length: 40 ft (12.2 m)

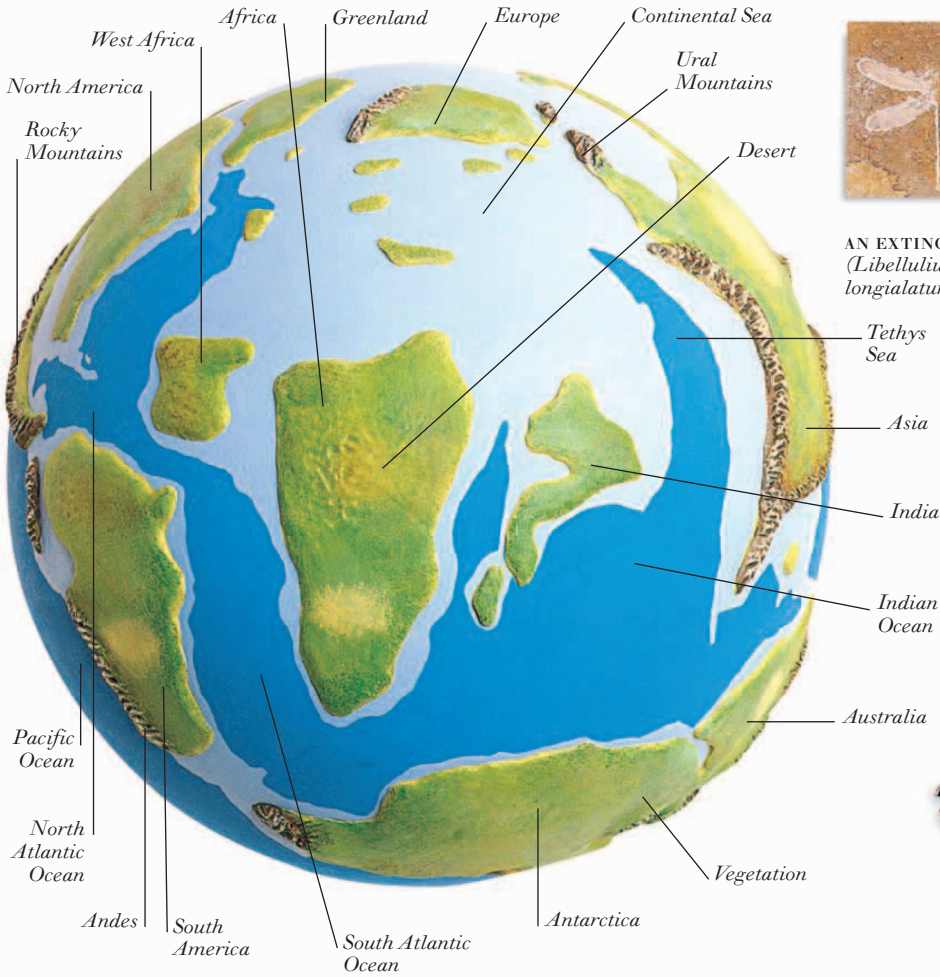


TOROSAURUS
Group: Ceratopsidae
Length: 25 ft (7.6 m)



HYPSILOPHODON
Group: Ornithopoda
Length: 4 ft 6 in–7 ft 6 in (1.4–2.3 m)

THE EARTH DURING THE CRETACEOUS PERIOD



EXAMPLES OF CRETACEOUS ANIMALS



AN EXTINCT INSECT
(*Libellulum longialatum*)



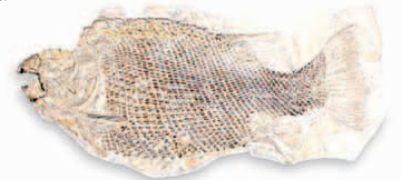
AN EXTINCT MARINE TURTLE
(*Plesiochelys latiscutata*)



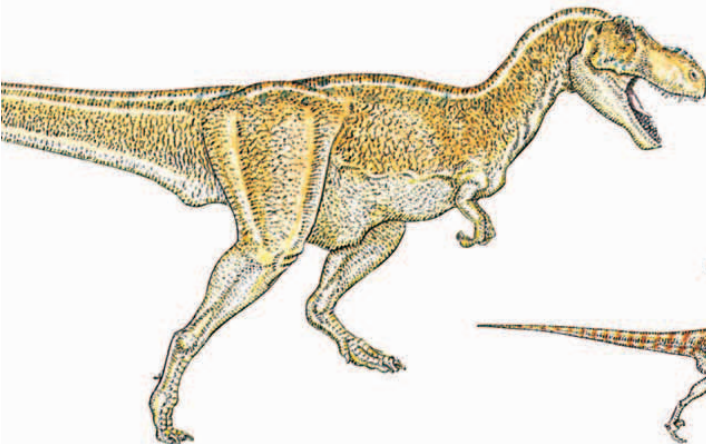
AN EXTINCT CRUSTACEAN
(*Homarus sp.*)



AN EXTINCT CROCODYLIAN



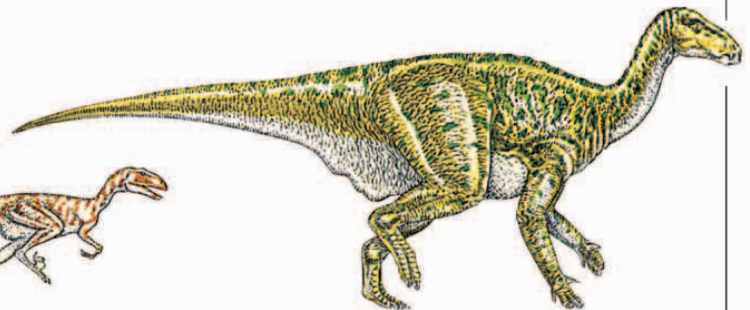
AN EXTINCT HOLOSTEAN FISH
(*Lepidotes maximus*)



TYRANNOSAURUS
Group: Tyrannosauridae
Length: 40 ft (12.2 m)



DEINONYCHUS
Group: Dromaeosauridae
Length: 8–11 ft (2.4–3.4 m)

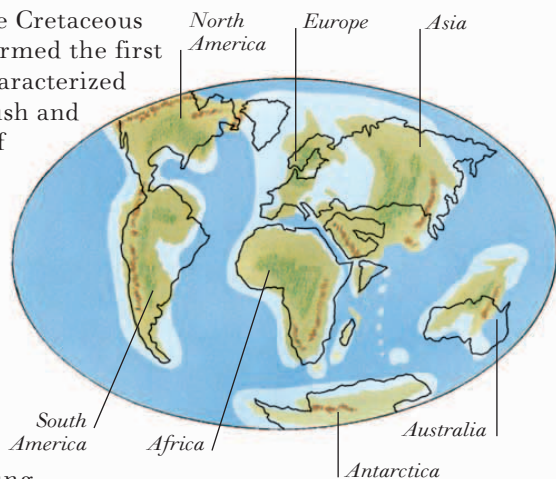


IGUANODON
Group: Iguanodontia
Length: 30 ft (9.1 m)

Tertiary period

FOLLOWING THE DEMISE OF THE DINOSAURS at the end of the Cretaceous period, the Tertiary period (65–1.6 million years ago), which formed the first part of the Cenozoic era (65 million years ago–present), was characterized by a huge expansion of mammal life. Placental mammals nourish and maintain the young in the mother's uterus; only a few groups of placental mammals existed during Cretaceous times, compared with a few dozen during the Tertiary period. One of these included the first hominid (see pp.108–109), *Ardipithecus*, which appeared in Africa. By the beginning of the Tertiary period, the continents had almost reached their present position. The Tethys Sea, which had separated the northern continents from Africa and India, began to close up, forming the Mediterranean Sea and allowing the migration of terrestrial animals between Africa and western Europe. India's collision with Asia led to the formation of the Himalayas. During the middle part of the Tertiary period, the forest-dwelling and browsing mammals were replaced by mammals such as the horses, better suited to grazing the open savannas that began to dominate. Repeated cool periods throughout the Tertiary period established the Antarctic as an icy island continent.

TERTIARY POSITIONS OF PRESENT-DAY LANDMASSES



EXAMPLES OF TERTIARY PLANT GROUPS



A PRESENT-DAY OAK
(*Quercus palustris*)



A PRESENT-DAY BIRCH
(*Betula grossa*)



FOSSIL LEAF OF AN
EXTINCT BIRCH
(*Betulites sp.*)



FOSSILIZED STEM OF
AN EXTINCT PALM
(*Palmoxylon sp.*)

EXAMPLES OF TERTIARY ANIMAL GROUPS



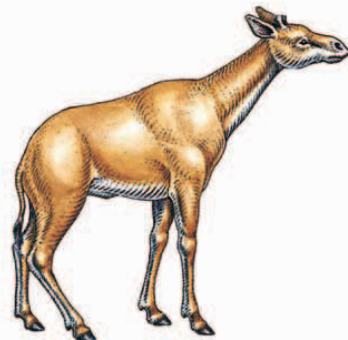
HYAENODON
Group: Hyaenodontidae
Length: 6 ft 6 in (2 m)



TITANOHYRAX
Group: Pliohyracidae
Length: 6 ft 6 in (2 m)



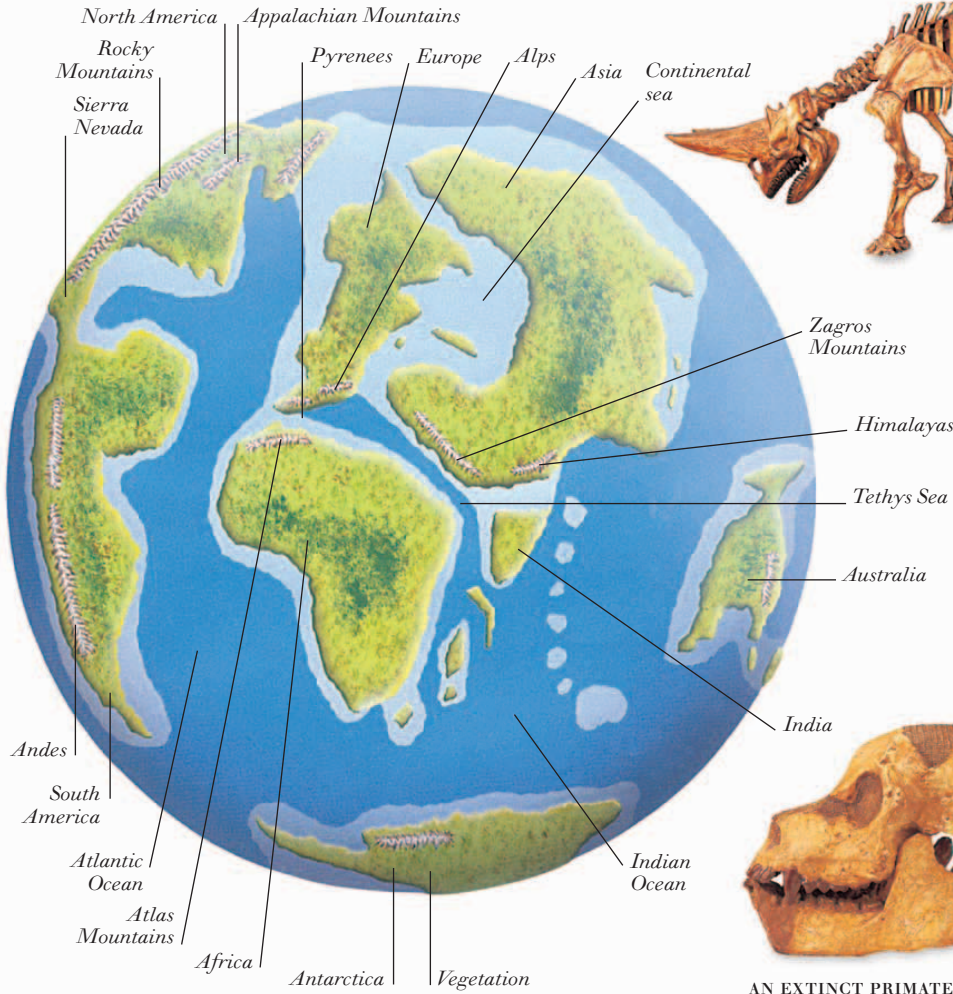
PHORUSRHACOS
Group: Phorusrhacidae
Length: 5 ft (1.5 m)



SAMOTHERIUM
Group: Giraffidae
Length: 10 ft (3 m)

THE EARTH DURING THE TERTIARY PERIOD

EXAMPLES OF TERTIARY ANIMALS



AN EXTINCT MAMMAL
(*Arsinoitherium*)



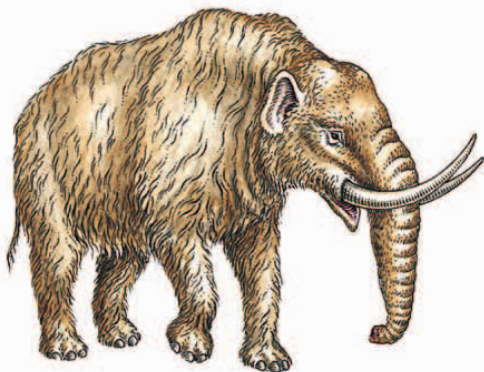
AN EXTINCT MAMMAL
(*Merycoidodon culbertsonii*)



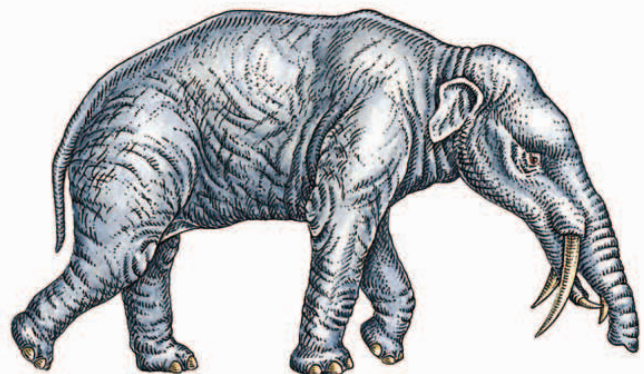
AN EXTINCT PRIMATE
(*Aegyptopithecus sp.*)



AN EXTINCT GASTROPOD MOLLUSK
(*Ecphora quadricostata*)



MAMMUT
Group: Mammutidae
Length: 8 ft (2.5 m)

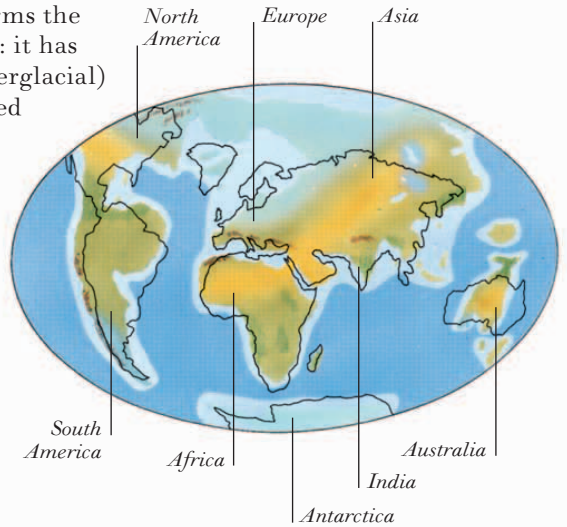


TETRALOPHODON
Group: Gomphotheriidae
Length: 8 ft (2.5 m)

Quaternary period

THE QUATERNARY PERIOD (1.6 million years ago–present) forms the second part of the Cenozoic era (65 million years ago–present): it has been characterized by alternating cold (glacial) and warm (interglacial) periods. During cold periods, ice sheets and glaciers have formed repeatedly on northern and southern continents. The cold environments in North America and Eurasia, and to a lesser extent in southern South America and parts of Australia, have caused the migration of many life-forms toward the Equator. Only the specialized ice age mammals such as *Mammuthus* and *Coelodonta*, with their thick wool and fat insulation, were suited to life in very cold climates. Humans developed throughout the Pleistocene period (1.6 million–10,000 years ago) in Africa and migrated northward into Europe and Asia. Modern humans, *Homo sapiens*, lived on the cold European continent 30,000 years ago and hunted other mammals. The end of the last ice age and the climatic changes that occurred about 10,000 years ago brought extinction to many Pleistocene mammals, but enabled humans to flourish.

QUATERNARY POSITIONS OF PRESENT-DAY LANDMASSES



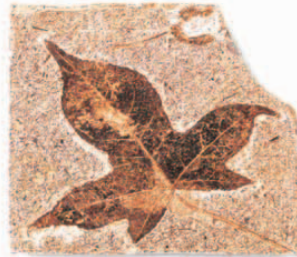
EXAMPLES OF QUATERNARY PLANT GROUPS



A PRESENT-DAY BIRCH
(*Betula lenta*)



A PRESENT-DAY SWEETGUM
(*Liquidambar styraciflua*)



FOSSIL LEAF OF A SWEETGUM
(*Liquidambar europaeum*)



FOSSIL LEAF OF A BIRCH
(*Betula sp.*)

EXAMPLES OF QUATERNARY ANIMAL GROUPS



PROCOPTODON
Group: Macropodidae
Length: 10 ft (3 m)



DIPROTODON
Group: Diprotodontidae
Length: 10 ft (3 m)



TOXODON
Group: Toxodontidae
Length: 10 ft (3 m)



MAMMUTHUS
Group: Elephantidae
Length: 10 ft (3 m)

THE EARTH DURING THE QUATERNARY PERIOD



EXAMPLES OF QUATERNARY ANIMALS



A MAMMAL SKELETON
(*Hippopotamus amphibius*)



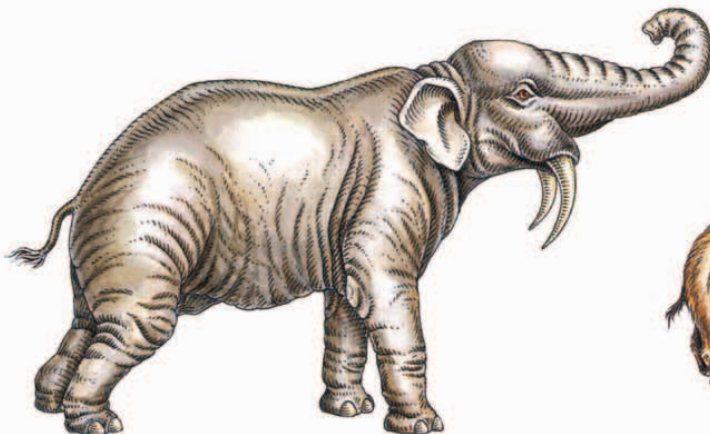
SKULL OF AN EXTINCT
CAVE BEAR
(*Ursus spelaeus*)



SKULL OF AN
EXTINCT TORTOISE
(*Meiolania platyceps*)



A MAMMOTH TOOTH
(*Mammuthus primigenius*)



DEINOTHERIUM
Group: Deinotheriidae
Length: 15 ft (4 m)



COELODONTA
Group: Rhinocerotidae
Length: 15 ft (4 m)

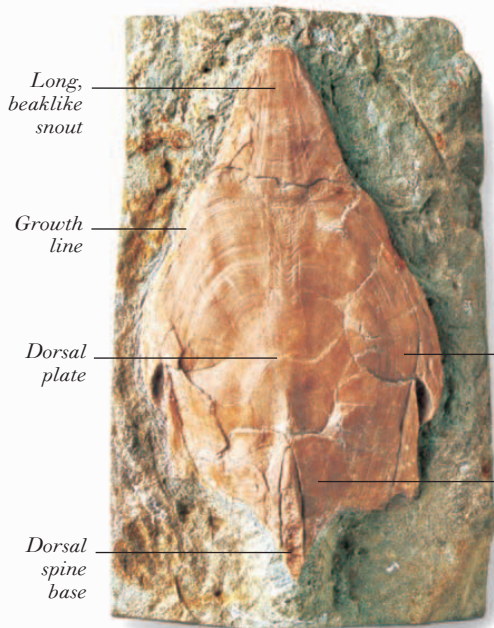
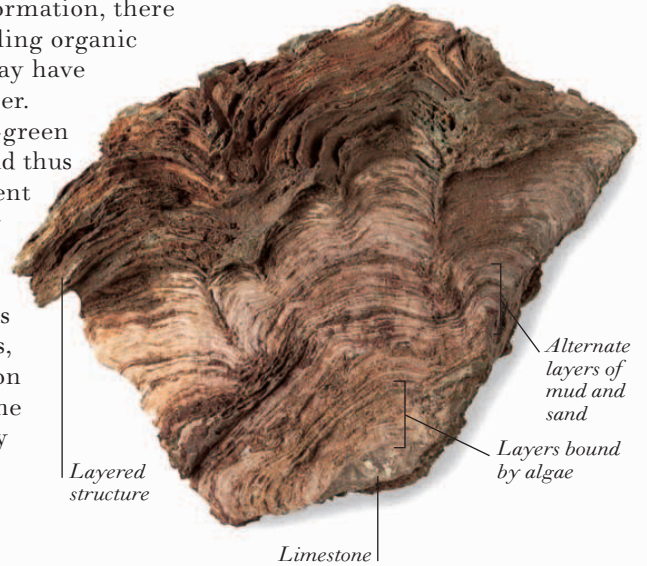


AUSTRALOPITHECUS
Group: Hominidae
Length: 4 ft (1.2 m)

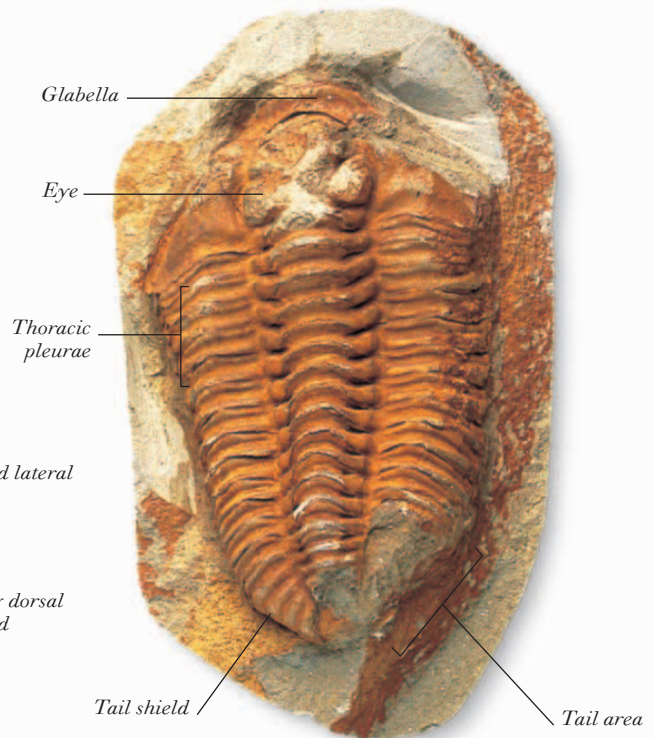
Early signs of life

FOR ALMOST A THOUSAND MILLION YEARS after its formation, there was no known life on Earth. The first simple, sea-dwelling organic structures appeared about 3.5 billion years ago; they may have formed when certain chemical molecules joined together. Prokaryotes, single-celled microorganisms such as blue-green algae, were able to photosynthesize (see pp. 138–139), and thus produce oxygen. A thousand million years later, sufficient oxygen had built up in the Earth's atmosphere to allow multicellular organisms to proliferate in the Precambrian seas (before 570 million years ago). Soft-bodied jellyfish, corals, and seaworms flourished about 700 million years ago. Trilobites, the first animals with hard body frames, developed during the Cambrian period (570–510 million years ago). However, it was not until the beginning of the Devonian period (409–363 million years ago) that early land plants, such as *Asteroxylon*, formed a water-retaining cuticle, which ended their dependence on an aquatic environment. About 360 million years ago, the first amphibians (see pp. 80–81) crawled onto the land, although they probably still returned to the water to lay their soft eggs. By the time the first reptiles and synapsids appeared late in the Carboniferous, animals with backbones had become fully independent of water.

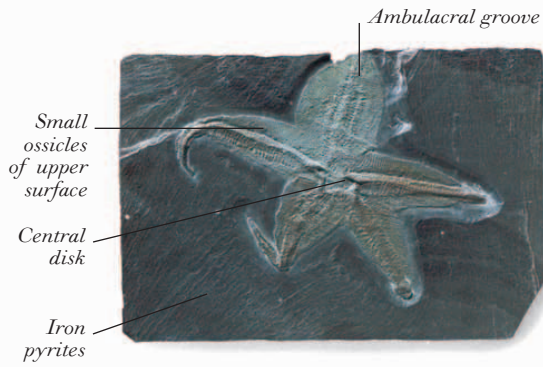
STROMATOLITIC LIMESTONE



FOSSILIZED JAWLESS FISH



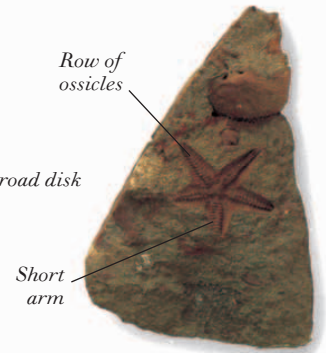
FOSSILIZED TRILOBITE



FOSSILIZED STARFISH



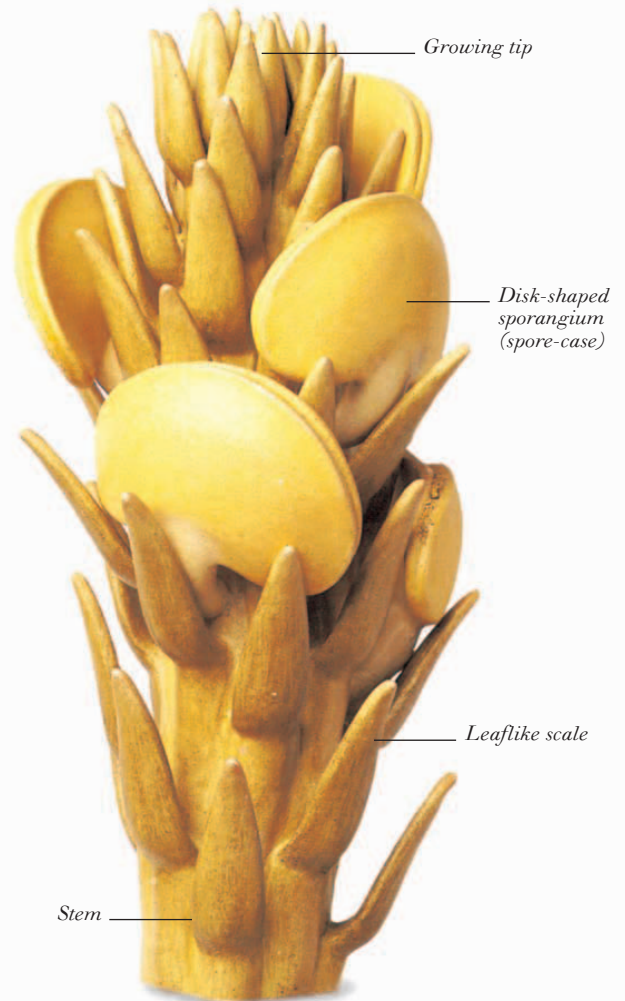
UPPER SURFACE OF FOSSILIZED STARFISH



LOWER SURFACE OF FOSSILIZED STARFISH



UNDERSIDE OF FOSSILIZED EURYPTERID



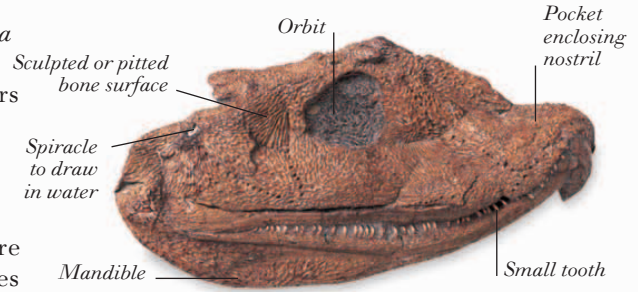
RECONSTRUCTION OF ASTEROXYLON



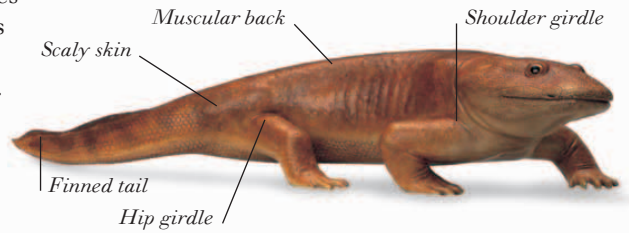
FOSSIL OF AN EXTINCT SHRIMP

Amphibians and reptiles

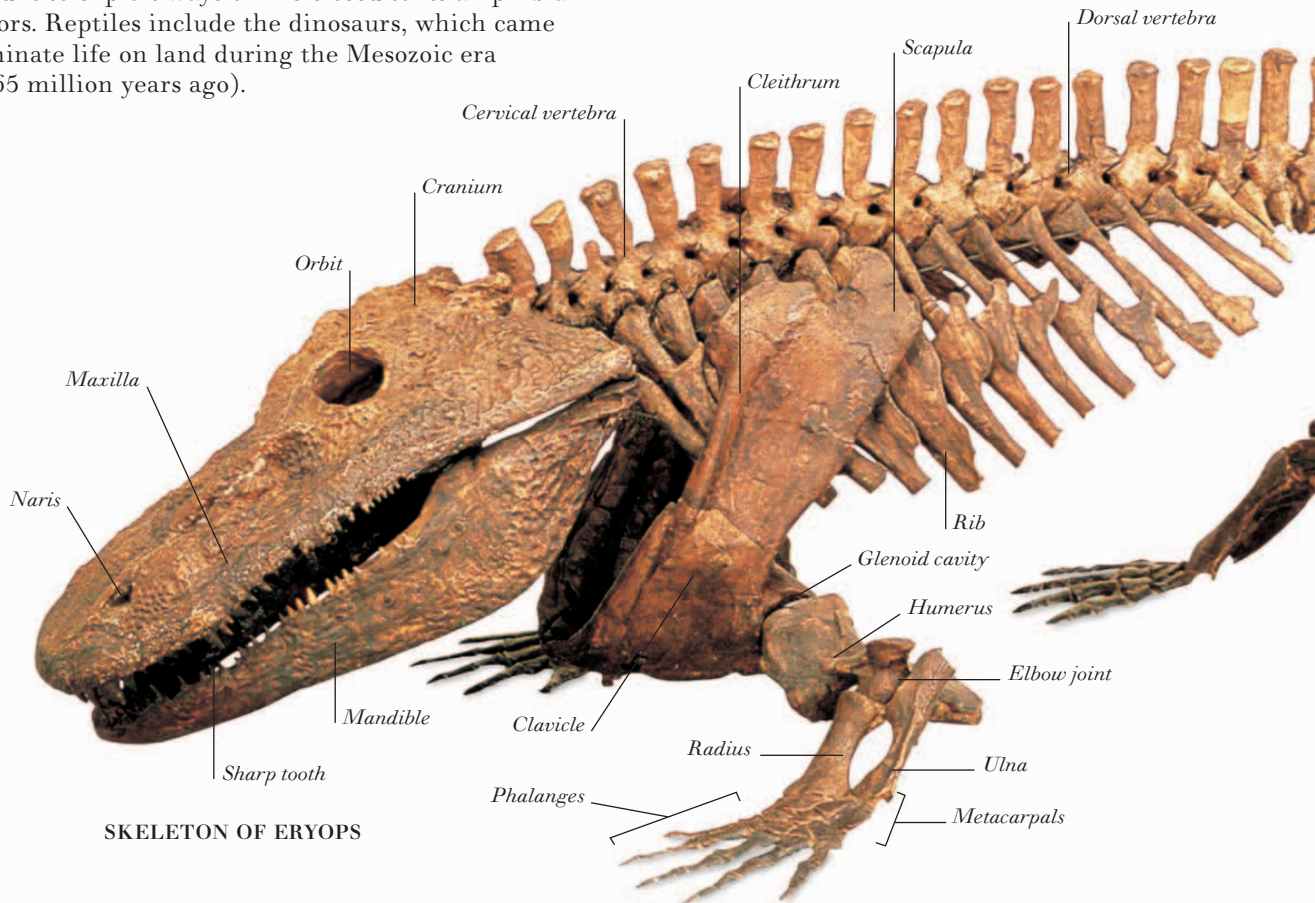
THE EARLIEST KNOWN AMPHIBIANS, such as *Acanthostega* and *Ichthyostega*, lived about 363 million years ago at the end of the Devonian period (409–363 million years ago). Their limbs may have evolved from the muscular fins of lungfishlike creatures. These fish can use their fins to push themselves along the bottom of lakes and some can breathe at the water's surface. While amphibians (see pp. 182–183) can exist on land, they are dependent on a wet environment because their skin does not retain moisture and most species must return to the water to lay their eggs. Evolving from amphibians, reptiles (see pp. 184–187) first appeared during the Carboniferous period (363–290 million years ago): *Westlothiana*, a possible early reptile, lived on land 338 million years ago. The development of the amniotic egg, with an embryo enclosed in its own wet environment (the amnion) and protected by a waterproof shell, freed reptiles from the amphibian's dependence on a wet habitat. A scaly skin protected the reptile from desiccation on land and enabled it to exploit ways of life closed to its amphibian ancestors. Reptiles include the dinosaurs, which came to dominate life on land during the Mesozoic era (245–65 million years ago).



FOSSIL SKULL OF ACANTHOSTEGA

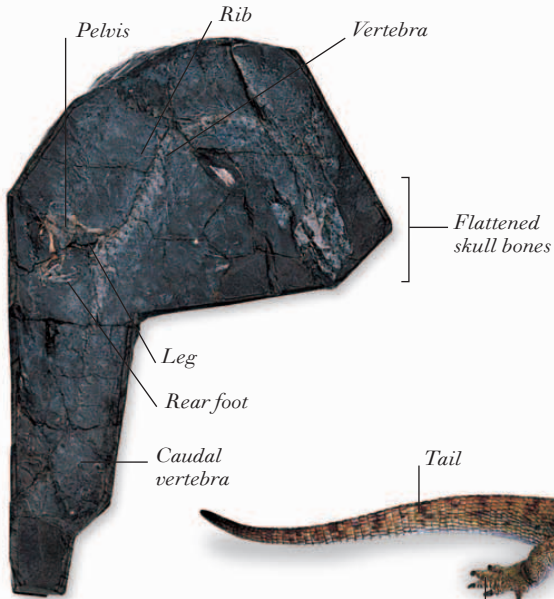


MODEL OF ICHTHYOSTEGA

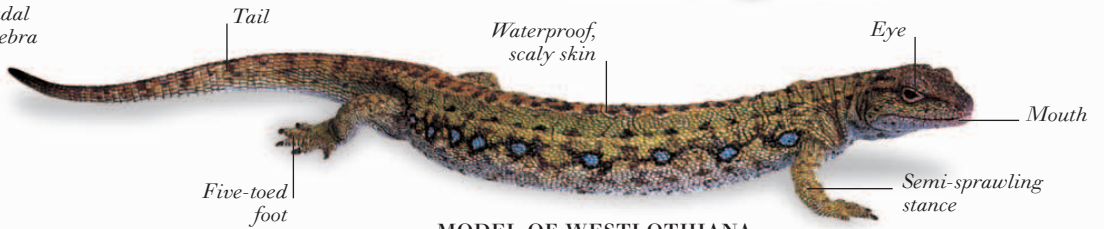
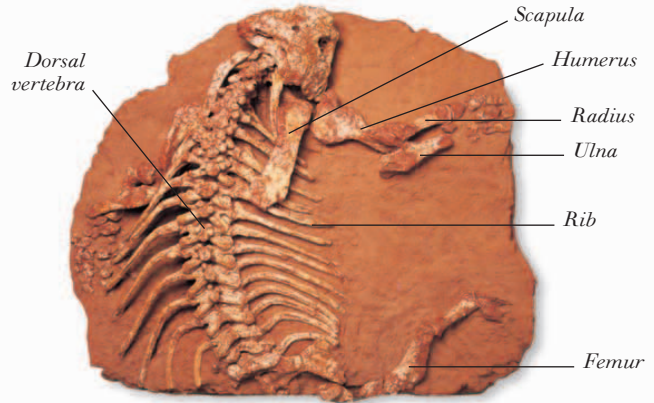


SKELETON OF ERYOPS

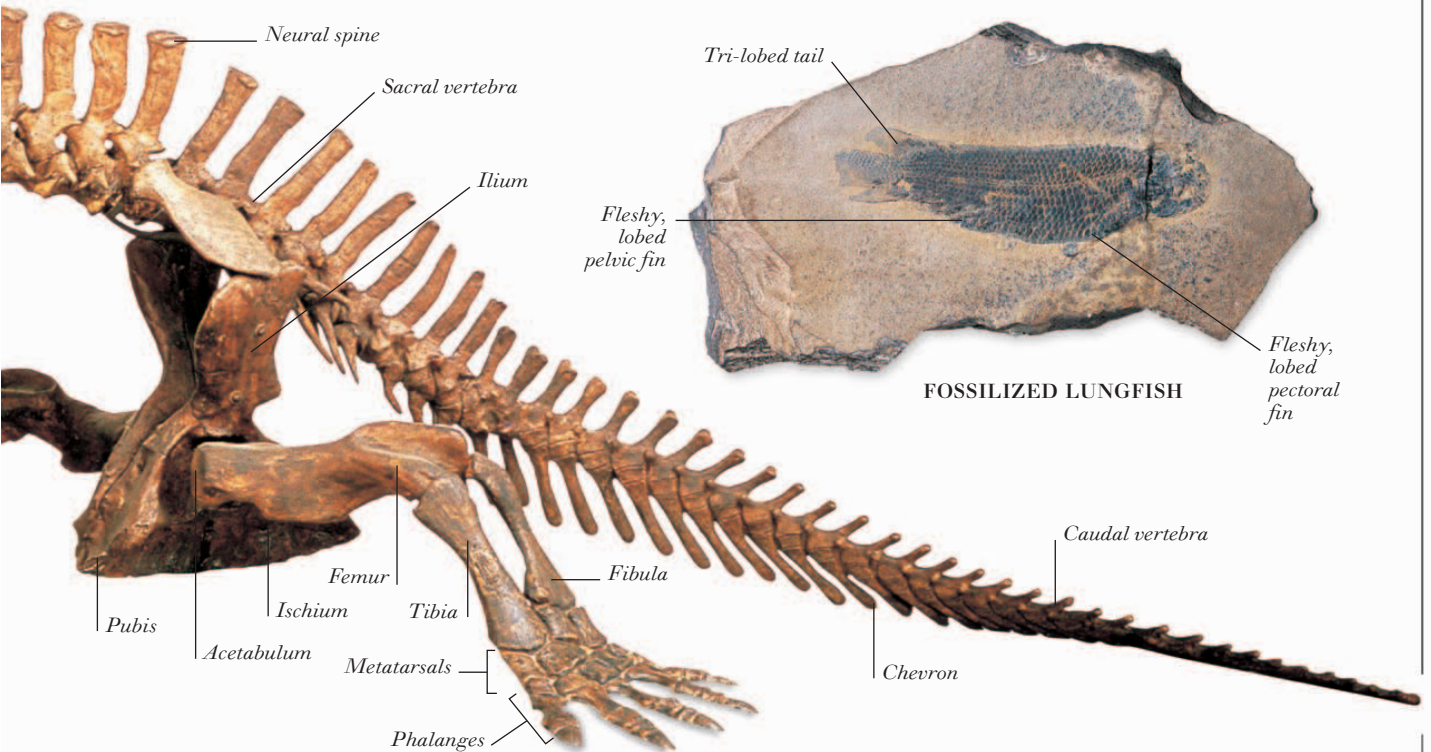
FOSSIL SKELETON OF WESTLOTHIANA



FOSSIL SKELETON OF A PAREIASAUR



MODEL OF WESTLOTHIANA



FOSSILIZED LUNGFISH

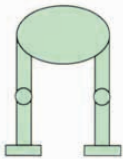
The dinosaurs

THE DINOSAURS WERE A LARGE GROUP of reptiles that were the dominant land vertebrates (animals with backbones) for most of the Mesozoic era (245–65 million years ago). They appeared some 230 million years ago and were distinguished from other scaly, egg-laying reptiles by an important feature: dinosaurs had an erect limb stance. This enabled them to keep their bodies well above the ground, unlike the sprawling and semisprawling stance of other reptiles. The head of the dinosaur's femur (thighbone) fit into a socket in its pelvis (hip-bone), producing efficient and mobile locomotion. Dinosaurs are categorized into two groups according to the structure of their pelvis: saurischian (lizard-hipped) and ornithischian (bird-hipped) dinosaurs. In the case of most saurischians, the pubis (part of the pelvis) jutted forward, while in ornithischians it slanted back, parallel to the ischium (another part of the pelvis). Dinosaurs ranged in size

from smaller than a domestic cat to the biggest land animals ever known. The Dinosauria were the most successful land vertebrates ever, and survived for 165 million years, until most became extinct 65 million years ago.

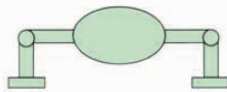


BAROSAURUS
A saurischian dinosaur

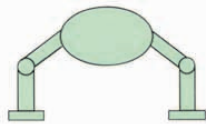


ERECT STANCE
The thighs and upper arms project straight down from the body so that the knees and elbows are straight.

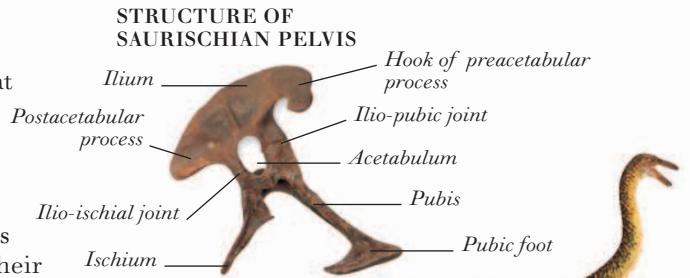
COMPARISON OF ANIMAL STANCES



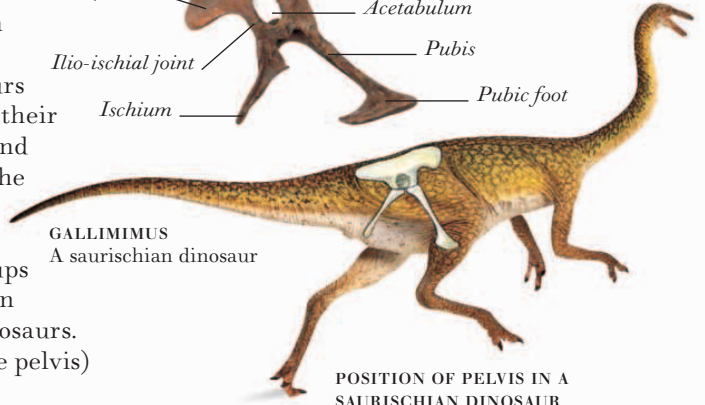
SPRAWLING STANCE
The thighs and upper arms project straight out from the body so that the knees and elbows are bent at right angles.



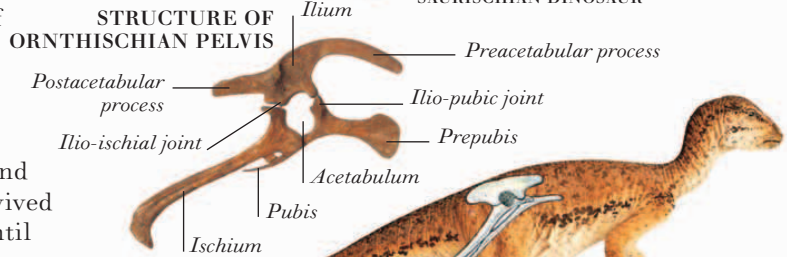
SEMISPRAWLING STANCE
The thighs and upper arms project downwards and outwards so that the knees and elbows are slightly bent.



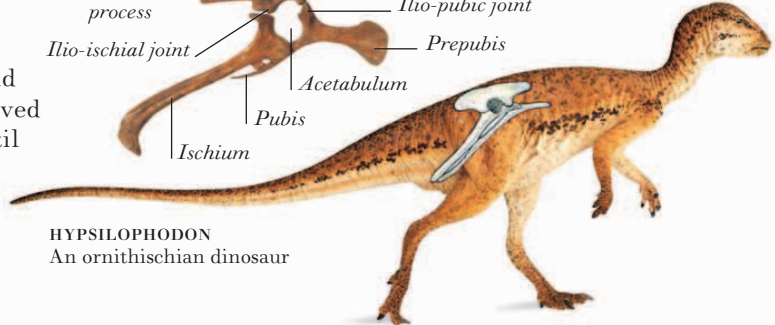
GALLIMIMUS
A saurischian dinosaur



POSITION OF PELVIS IN A SAURISCHIAN DINOSAUR



HYSILOPHODON
An ornithischian dinosaur



POSITION OF PELVIS IN AN ORNITHISCHIAN DINOSAUR

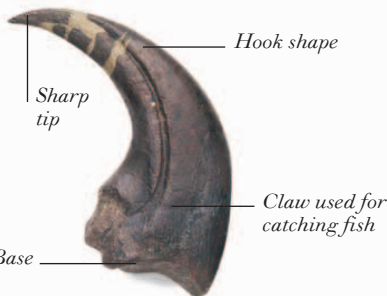


COMMON IGUANA
(*Iguana iguana*)
A present-day reptile

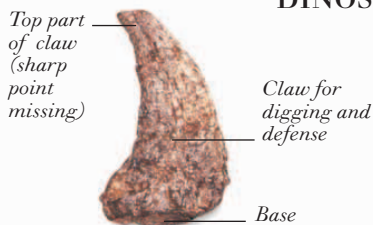


DWARF CROCODILE
(*Osteolaemus tetraspis*)
A present-day reptile

EXAMPLES OF DINOSAUR CLAWS



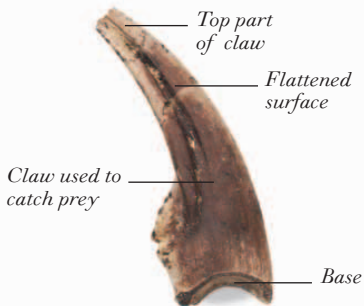
**BARYONYX
THUMB-CLAW**



**MASSOSPONDYLUS
THUMB-CLAW**



**APATOSAURUS
THUMB-CLAW**



**ORNITHOMIMUS
FINGER-CLAW**

DINOSAUR CLADOGRAM

DINOSAURIA

SAURISCHIA

THEROPODA

HERRERASAURIDAE



CERATOSAURIA



TETANURAE

SAUROPODOMORPHA

SAUROPODA



PROSAUROPODA



SCOLIDOSAURUS



THYREOPHORA

STEGOSAURIA



ANKYLOSAURIA



ORNITHISCHIA

PACHYCEPHALOSAURIA



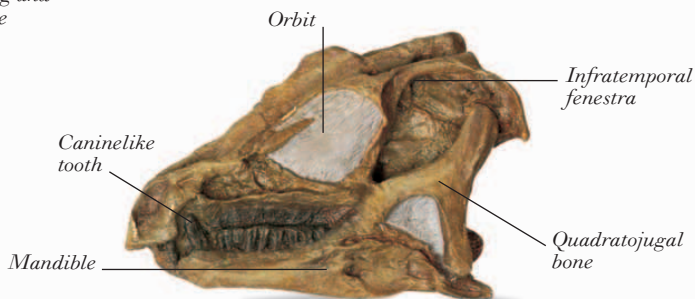
MARGINOCEPHALIA

CERATOPSIA

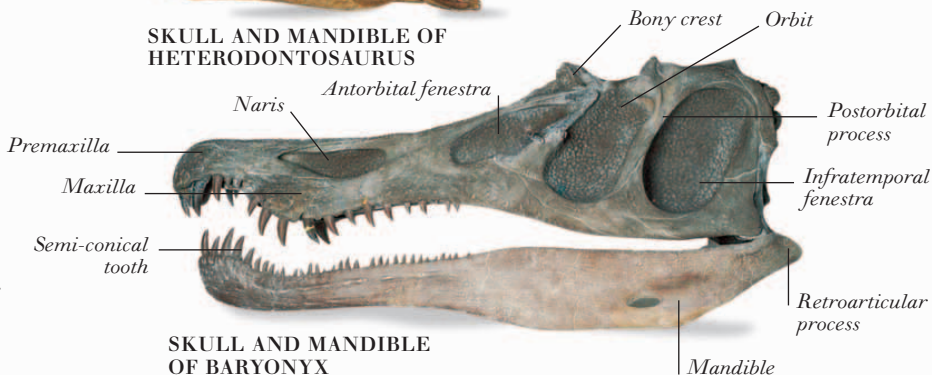


CERAPODA

ORNITHOPODA



**SKULL AND MANDIBLE OF
HETERODONTOSAURUS**

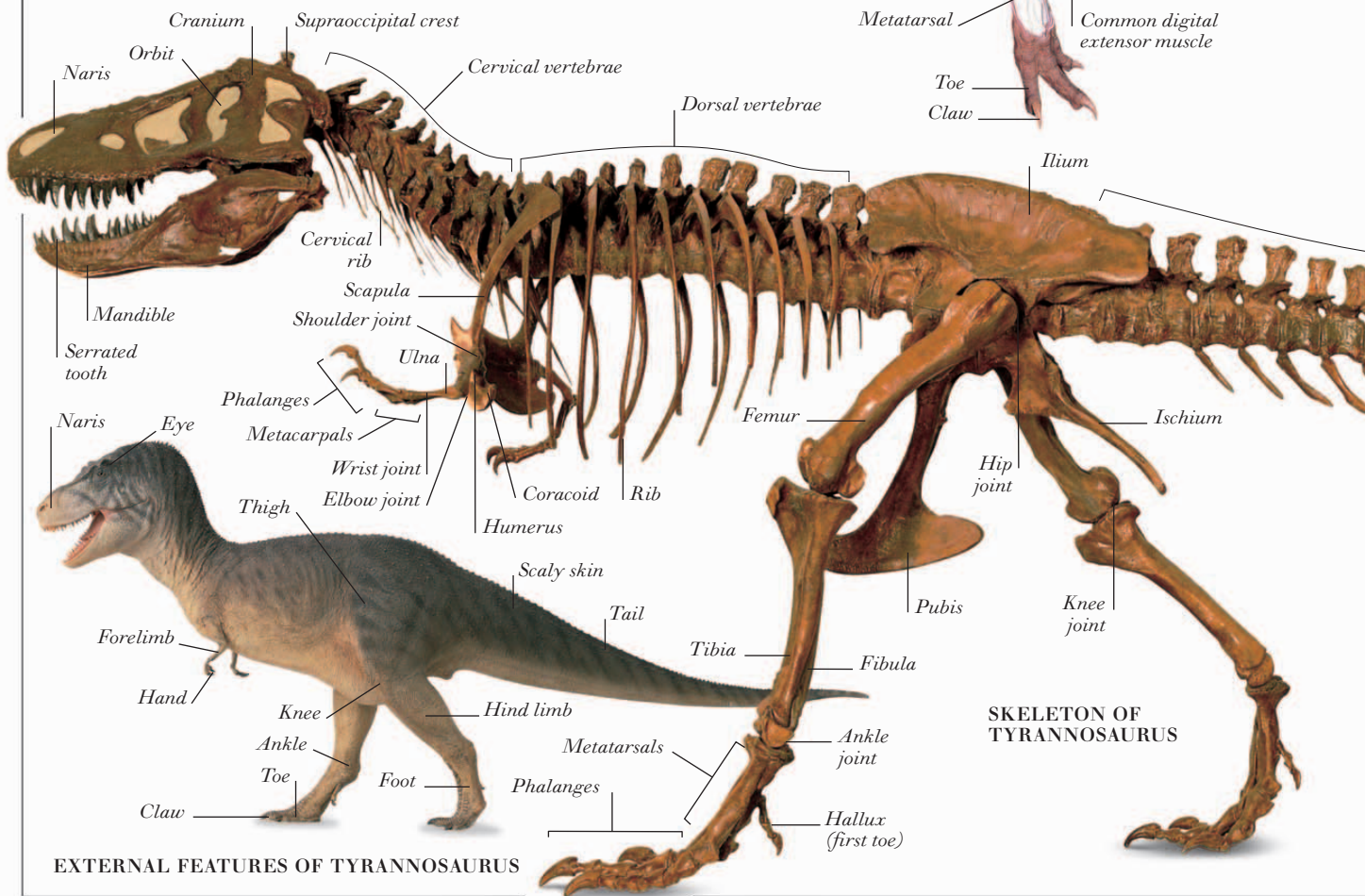
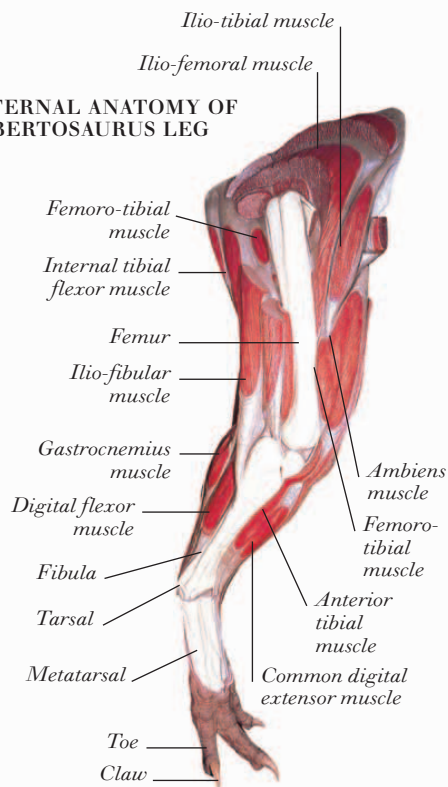


**SKULL AND MANDIBLE
OF BARYONYX**

Theropods 1

AN ENORMOUSLY SUCCESSFUL SUBGROUP of the Saurischia, the bipedal (two-footed) theropods (“beast feet”) emerged 230 million years ago in Late Triassic times; the oldest known example comes from South America. Theropods spanned the age of most dinosaurs (230–65 million years ago) and beyond, and included most of the known predatory dinosaurs. The typical theropod had smallish arms with sharp, clawed fingers; powerful jaws lined with sharp teeth; an S-shaped neck; long, muscular hind limbs; and clawed, usually four-toed feet. Many theropods may have been warm-blooded; most were exclusively carnivorous. Theropods ranged from animals no larger than a chicken to huge creatures, such as *Tyrannosaurus* and *Baryonyx*. The group also included ostrichlike omnivores and herbivores with toothless beaks, such as *Struthiomimus* and *Gallimimus*. Birds are dinosaurs and evolved from within a group of tetanuran theropods called maniraptorans. *Archaeopteryx*, small and feathered, was the first known bird and lived alongside other dinosaurs.

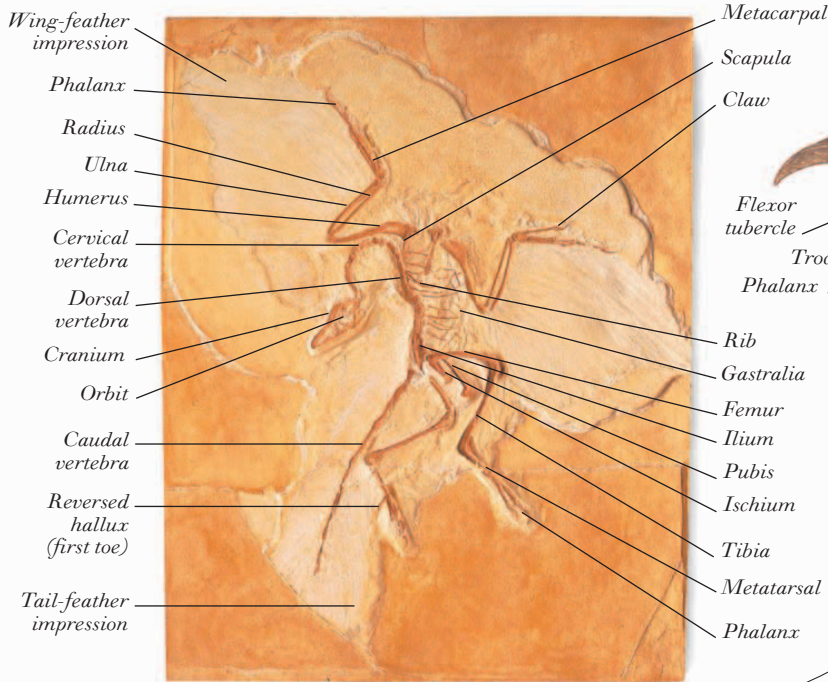
INTERNAL ANATOMY OF ALBERTOSAURUS LEG



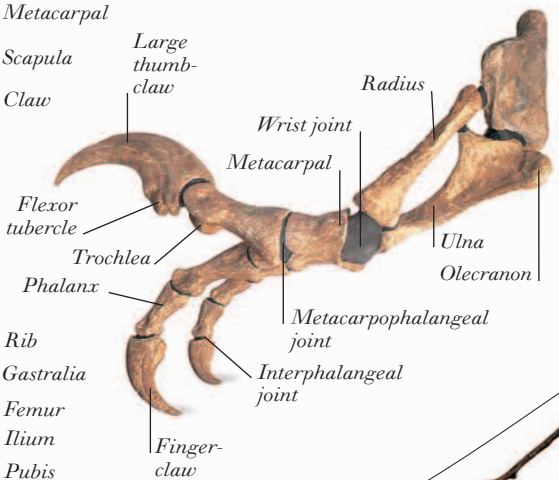
EXTERNAL FEATURES OF TYRANNOSAURUS

SKELETON OF TYRANNOSAURUS

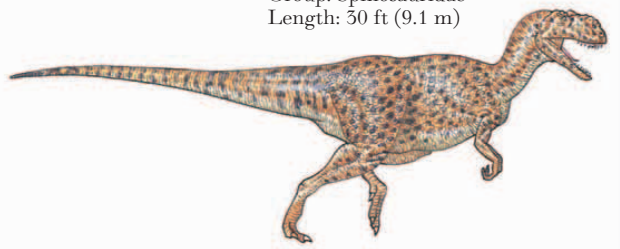
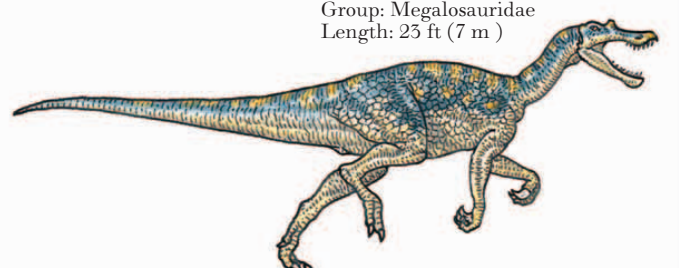
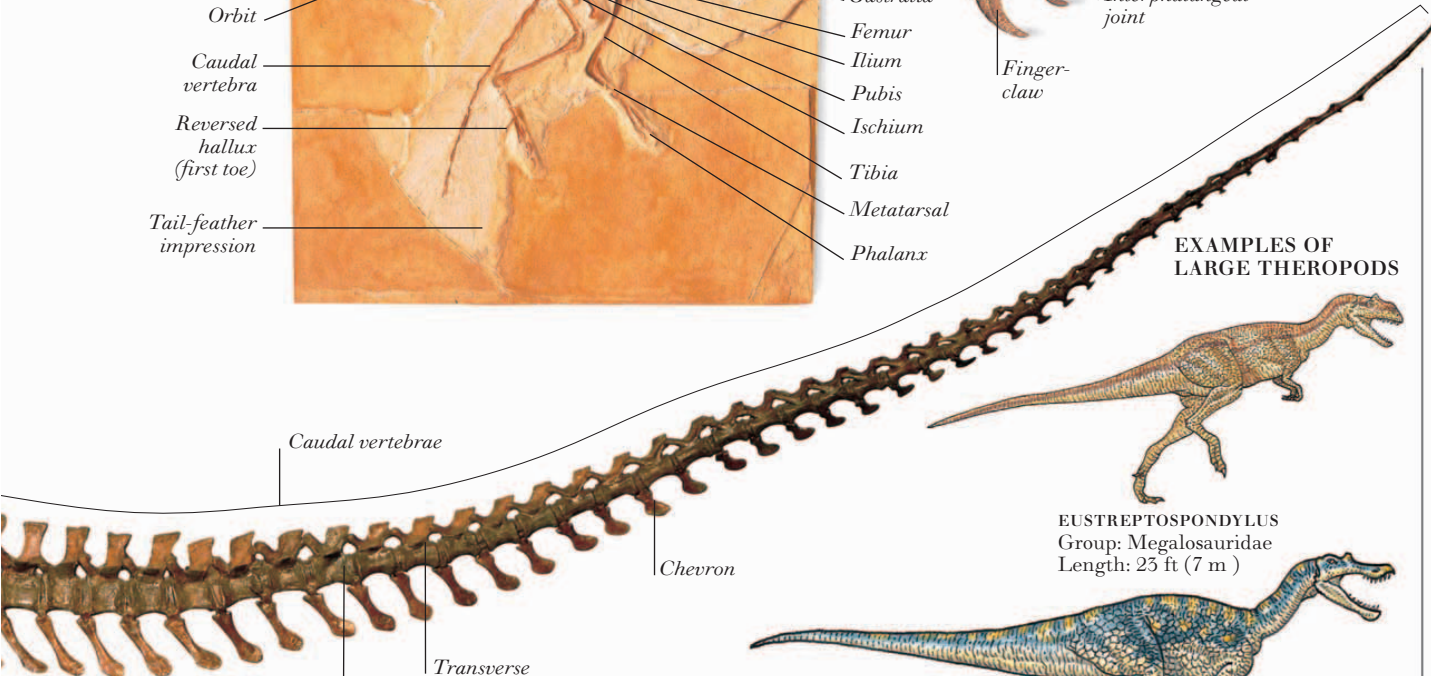
FOSSIL SKELETON OF ARCHAEOPTERYX



SKELETON OF BARYONYX HAND



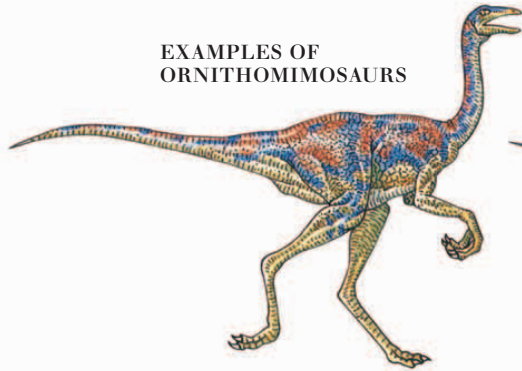
EXAMPLES OF LARGE THEROPODS



HEAD OF ALLOSAURUS

Theropods 2

EXAMPLES OF ORNITHOMIMOSAURS

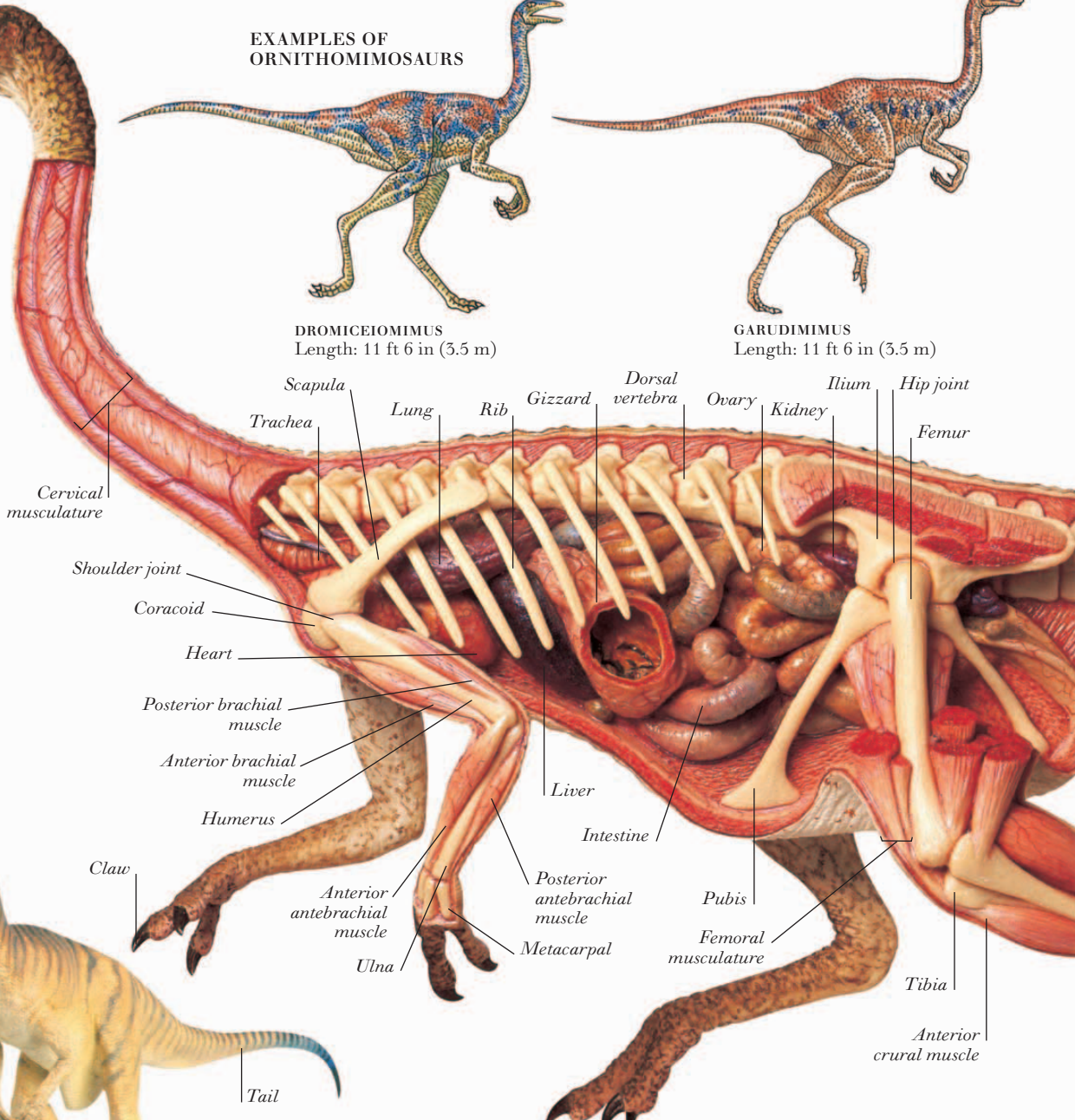


DROMICEIOMIMUS
Length: 11 ft 6 in (3.5 m)

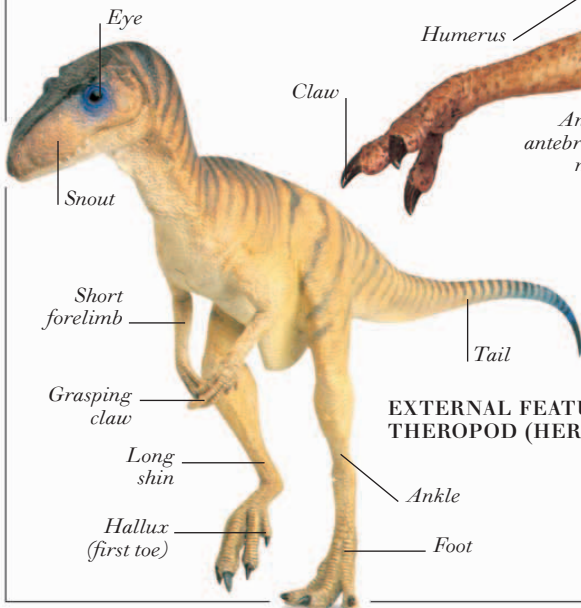


GARUDIMIMUS
Length: 11 ft 6 in (3.5 m)

Eye
Toothless beak



INTERNAL ANATOMY OF FEMALE GALLIMIMUS

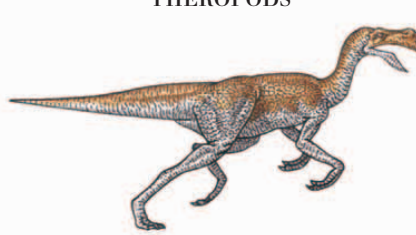


EXTERNAL FEATURES OF AN EARLY THEROPOD (HERRERASAURUS)

EXAMPLES OF SMALL THEROPODS



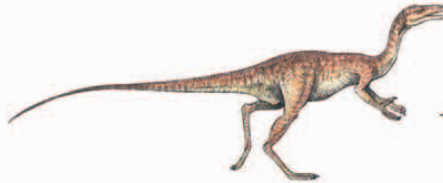
STRUTHIOMIMUS
Length: 11 ft 6 in (3.5 m)



CHIROSTENOTES
Length: 6 ft 6 in (2 m)



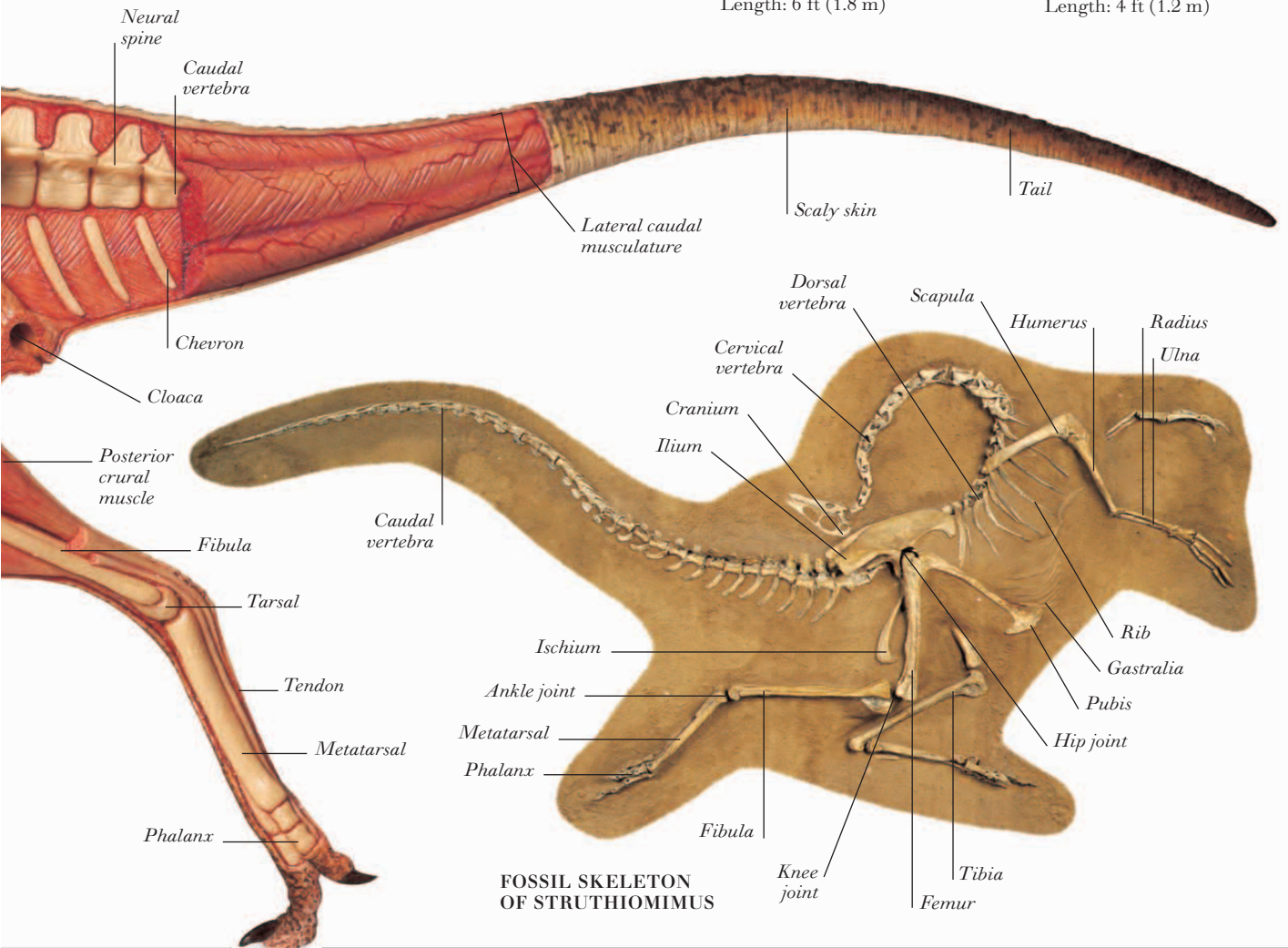
AVIMIMUS
Length: 5 ft (1.5 m)



COELURUS
Length: 6 ft (1.8 m)



PROCOMPSOGNATHUS
Length: 4 ft (1.2 m)



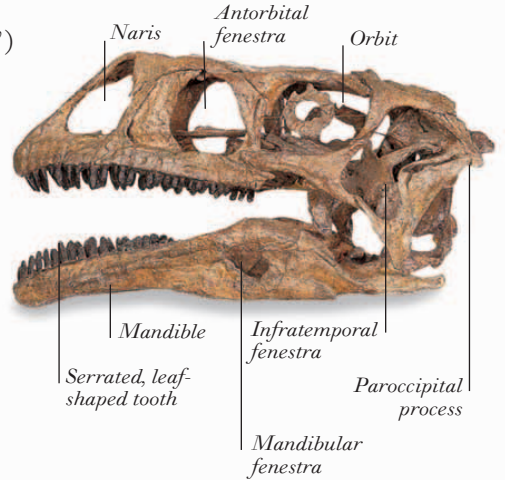
Sauropodomorphs 1



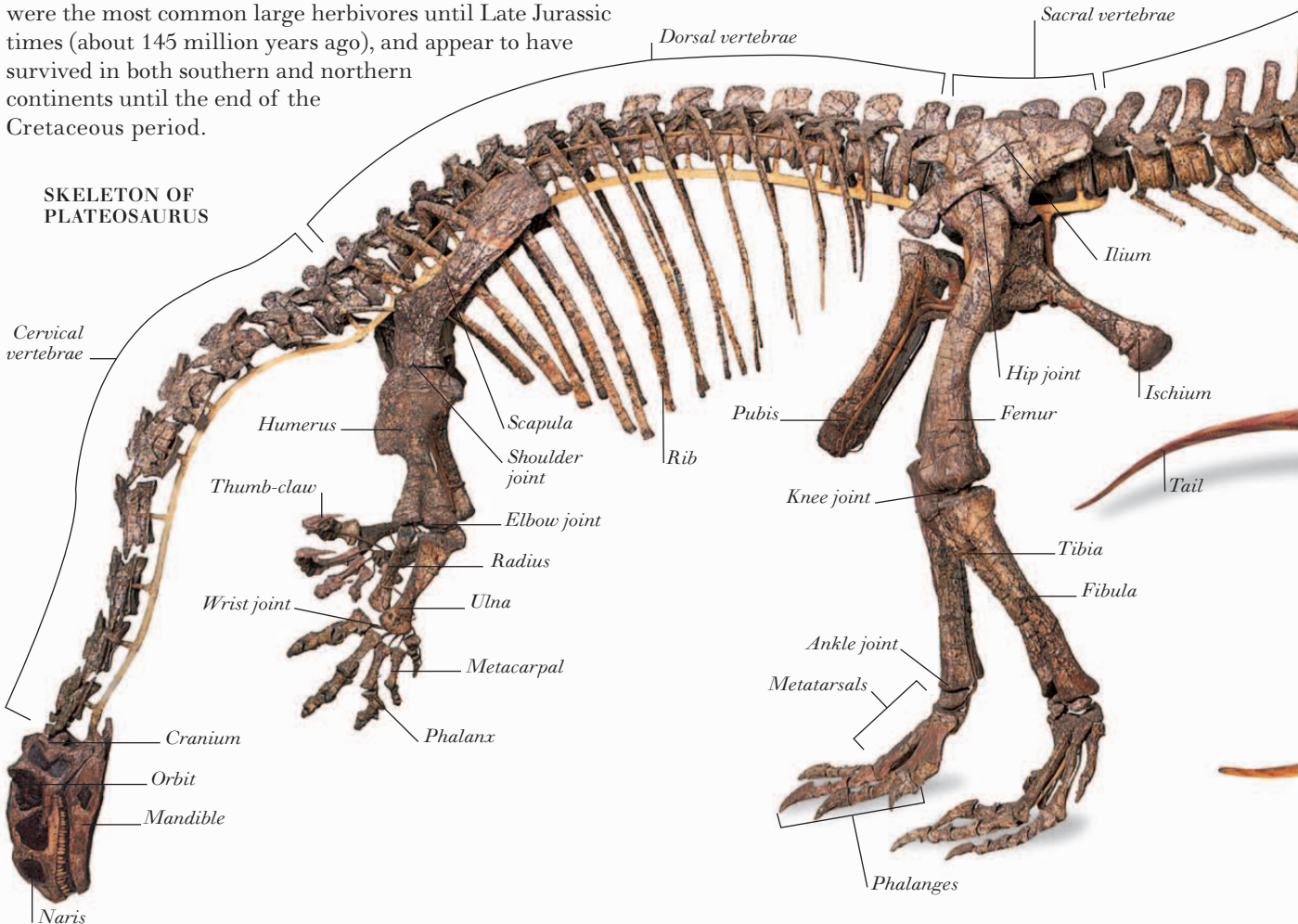
THECODONTOSAURUS

THE SAUROPODOMORPHA (“lizard-feet forms”) were herbivorous, usually quadrupedal (four-footed) dinosaurs. A suborder of the Saurischia, they were characterized by small heads, bulky bodies, and long necks and tails. Sauropodomorphs have often been split into two groups: prosauropods and sauropods. Prosauropods lived from Late Triassic to Early Jurassic times (225–180 million years ago) and included beasts such as the small *Anchisaurus* and one of the first very large dinosaurs, *Plateosaurus*. By Middle Jurassic times (about 165 million years ago), sauropods had replaced prosauropods and spread worldwide. They included the heaviest and longest land animals ever, such as *Diplodocus* and *Brachiosaurus*. Sauropods persisted to the end of the Cretaceous period (65 million years ago). Many of these dinosaurs moved in herds, protected from predatory theropods by their huge bulk and powerful tails, which they could use to lash out at attackers. Sauropodomorphs were the most common large herbivores until Late Jurassic times (about 145 million years ago), and appear to have survived in both southern and northern continents until the end of the Cretaceous period.

SKULL AND MANDIBLE OF PLATEOSAURUS



SKELETON OF PLATEOSAURUS



Cervical vertebrae

Cranium
Orbit
Mandible
Naris

Humerus
Scapula
Shoulder joint
Thumb-claw
Elbow joint
Radius
Ulna
Wrist joint
Metacarpal
Phalanx

Dorsal vertebrae

Rib

Pubis

Knee joint

Metatarsals

Phalanges

Ilium
Hip joint
Femur
Ischium
Tibia
Fibula
Ankle joint

Sacral vertebrae

Tail

Mandible
Serrated, leaf-shaped tooth

Infratemporal fenestra
Mandibular fenestra

Paroccipital process

Naris

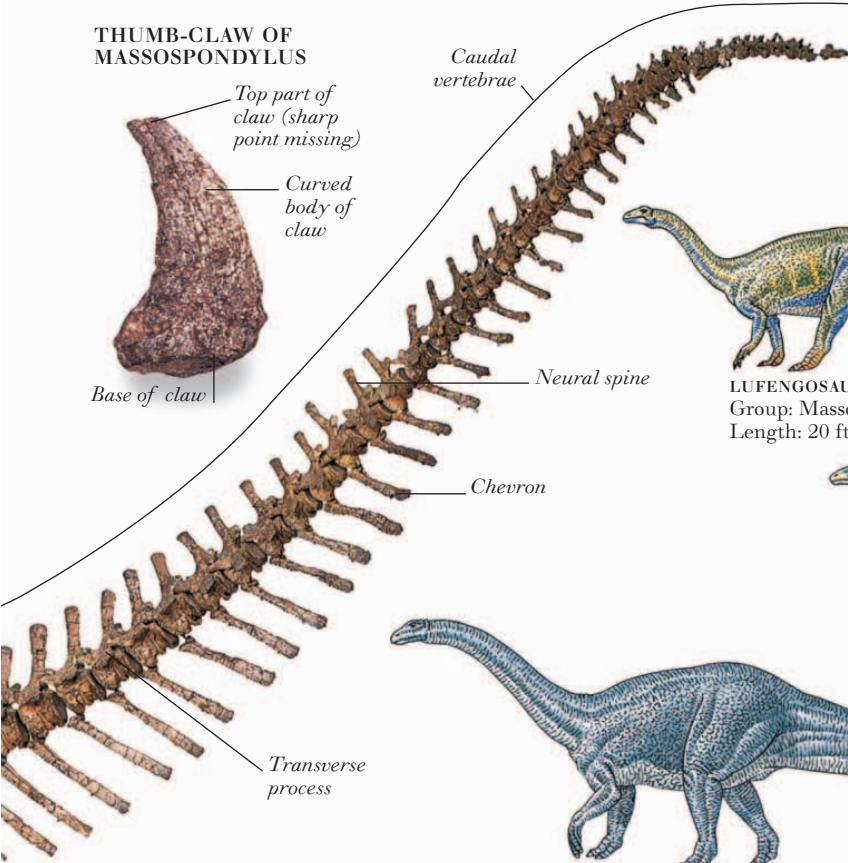
Antorbital fenestra

Orbit

THUMB-CLAW OF MASSOSPONDYLUS



Caudal vertebrae



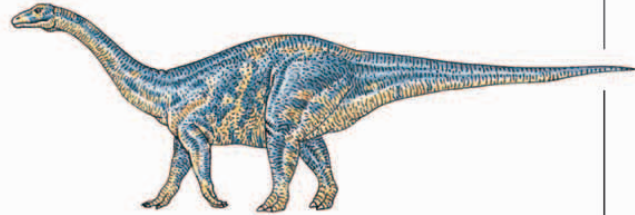
EXAMPLES OF PROSAUROPODS



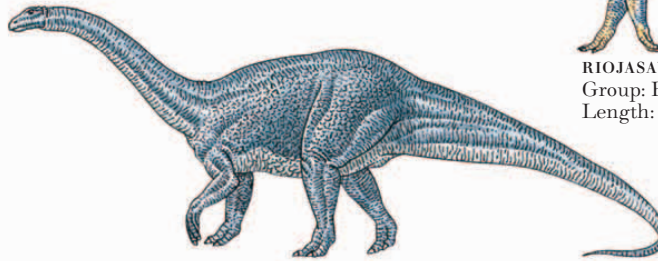
MASSOSPONDYLUS
Group: Massospondylidae
Length: 16 ft (5 m)



LUFENGOSAURUS
Group: Massospondylidae
Length: 20 ft (6.1 m)

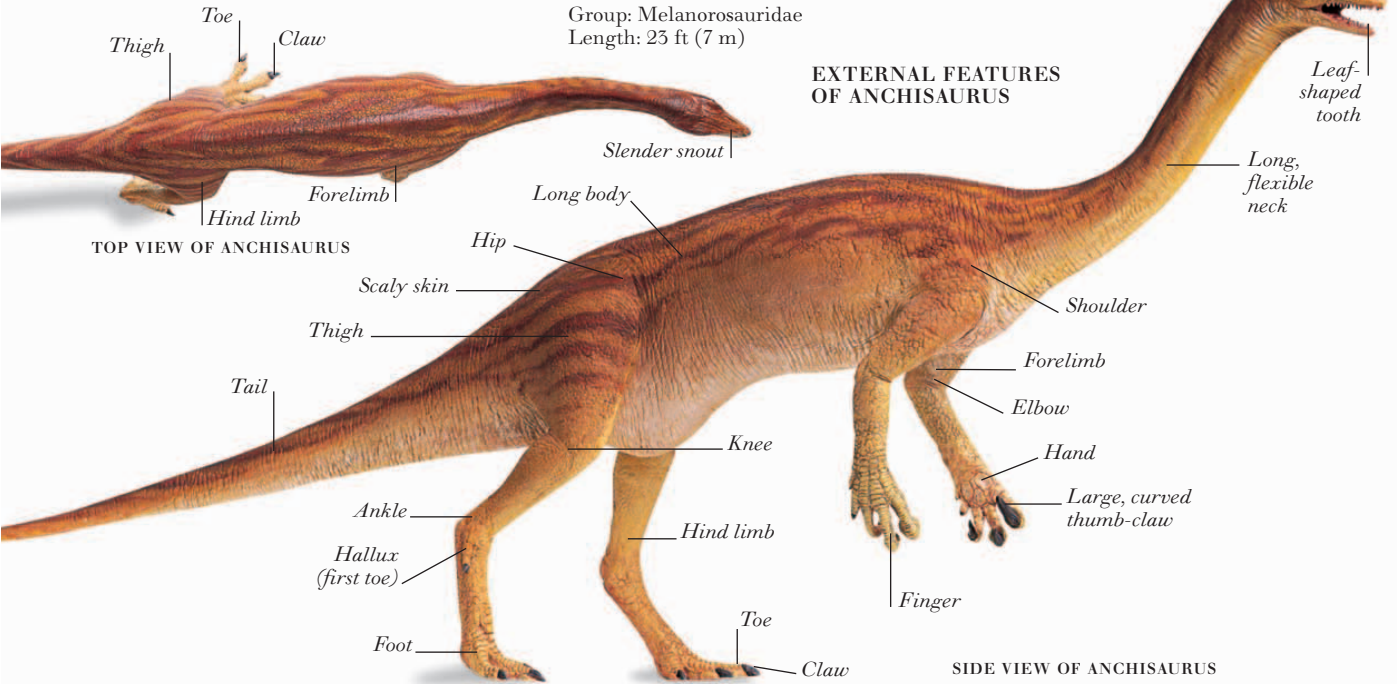


RIOJASAURUS
Group: Riojasauridae
Length: 36 ft (11 m)



MELANOROSAURUS
Group: Melanorosauridae
Length: 23 ft (7 m)

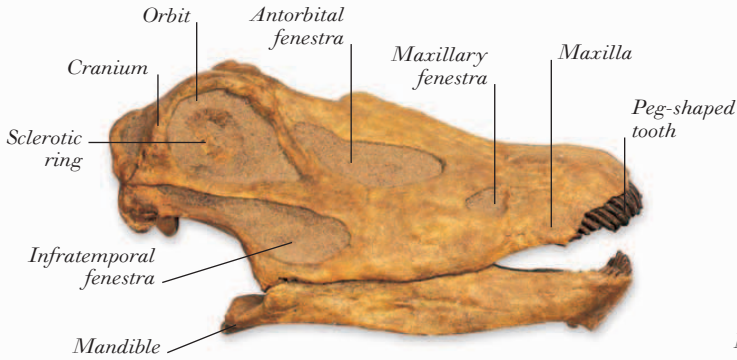
EXTERNAL FEATURES OF ANCHISAURUS



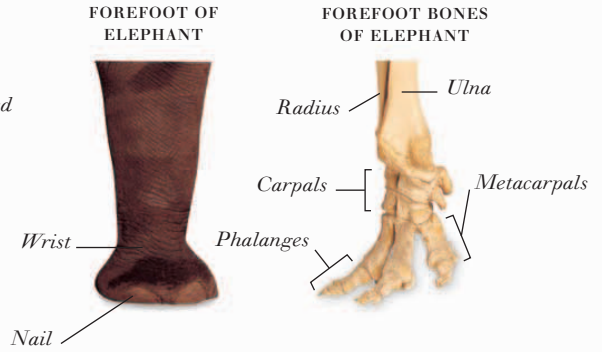
TOP VIEW OF ANCHISAURUS

SIDE VIEW OF ANCHISAURUS

Sauropodomorphs 2

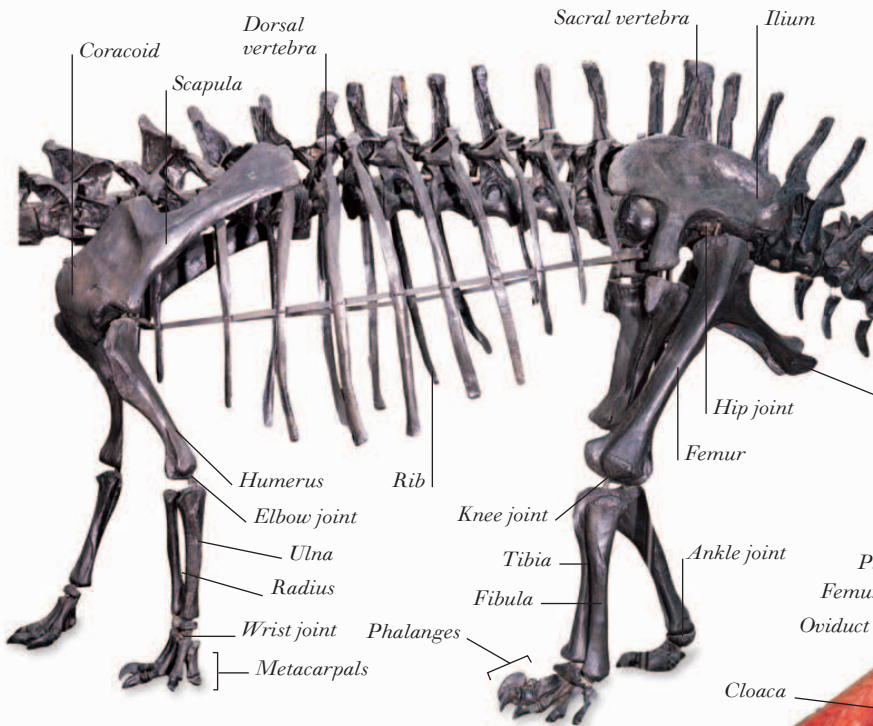


SKULL AND MANDIBLE OF DIPLODOCUS

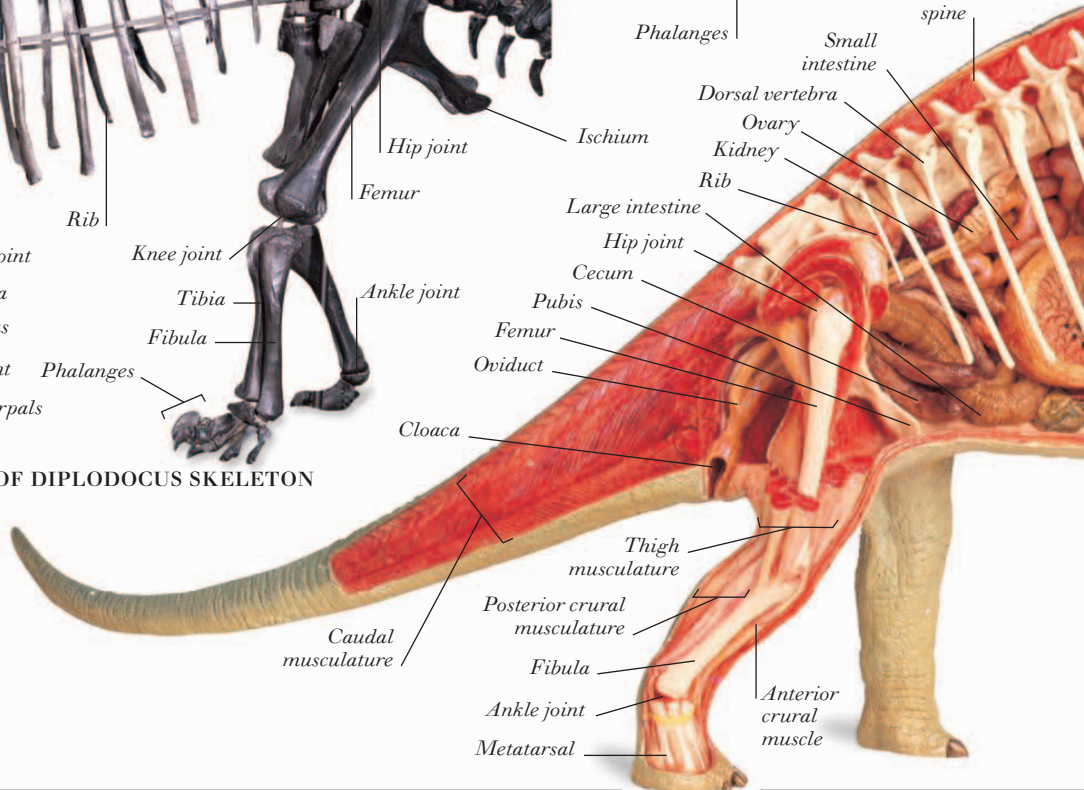
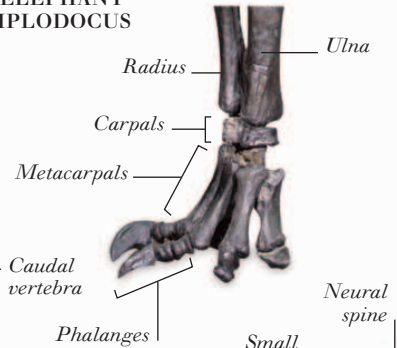


COMPARISON OF THE FOREFEET OF AN ELEPHANT AND DIPLODOCUS

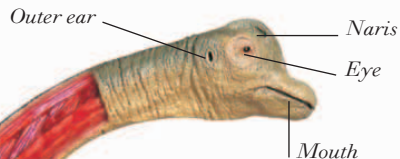
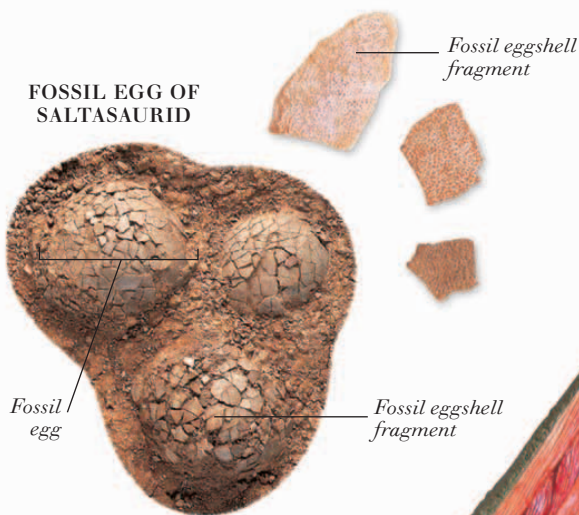
FOREFOOT BONES OF DIPLODOCUS



MIDDLE SECTION OF DIPLODOCUS SKELETON

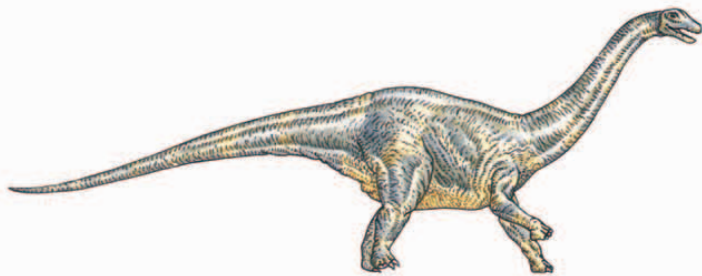
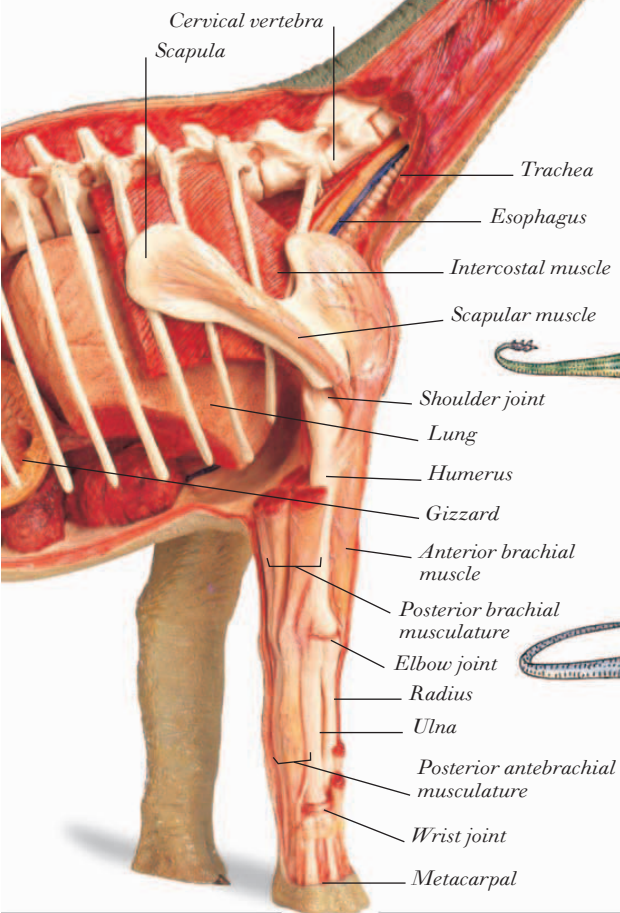


FOSSIL EGG OF SALTASAURID



SKULL AND MANDIBLE OF CAMARASAURUS

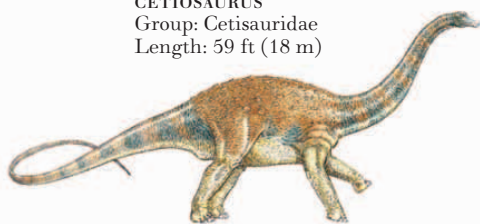
INTERNAL ANATOMY OF FEMALE BRACHIOSAURUS



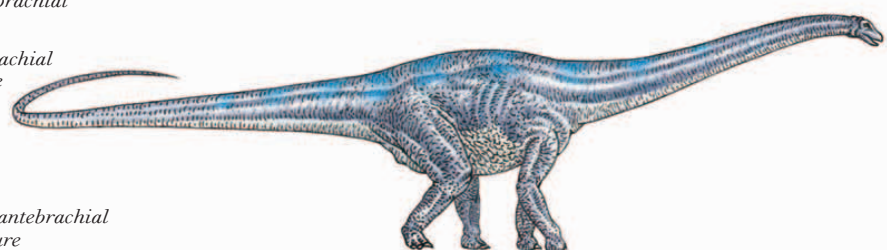
CETIOSAURUS
Group: Cetosauridae
Length: 59 ft (18 m)



SHUNOSAURUS
Group: Eusauropoda
Length: 33 ft (10 m)



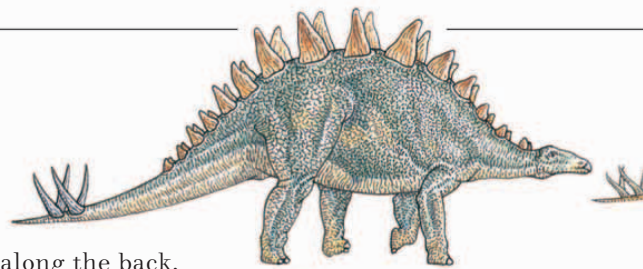
SALTASAURUS
Group: Saltosauridae
Length: 40 ft (12.2 m)



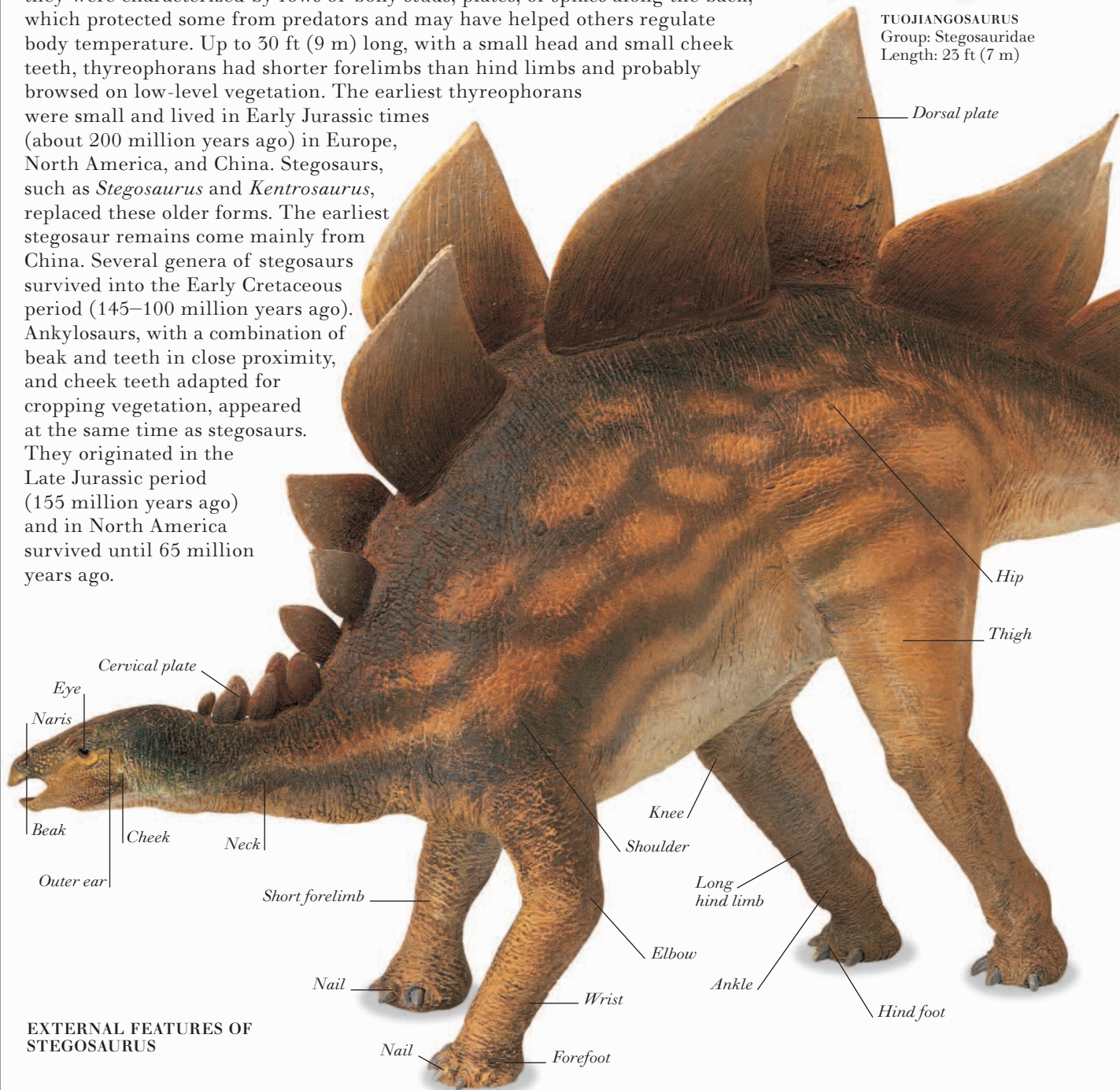
DIPLODOCUS
Group: Diplodocidae
Length: 90 ft (27.4 m)

Thyreophorans 1

THYREOPHORANS (“SHIELD BEARERS”) were a group of quadrupedal armored dinosaurs. They were one clade among several within the Ornithischia (bird-hipped dinosaurs), they were characterized by rows of bony studs, plates, or spikes along the back, which protected some from predators and may have helped others regulate body temperature. Up to 30 ft (9 m) long, with a small head and small cheek teeth, thyreophorans had shorter forelimbs than hind limbs and probably browsed on low-level vegetation. The earliest thyreophorans were small and lived in Early Jurassic times (about 200 million years ago) in Europe, North America, and China. Stegososaurs, such as *Stegosaurus* and *Kentrosaurus*, replaced these older forms. The earliest stegosaur remains come mainly from China. Several genera of stegosaurs survived into the Early Cretaceous period (145–100 million years ago). Ankylosaurs, with a combination of beak and teeth in close proximity, and cheek teeth adapted for cropping vegetation, appeared at the same time as stegosaurs. They originated in the Late Jurassic period (155 million years ago) and in North America survived until 65 million years ago.



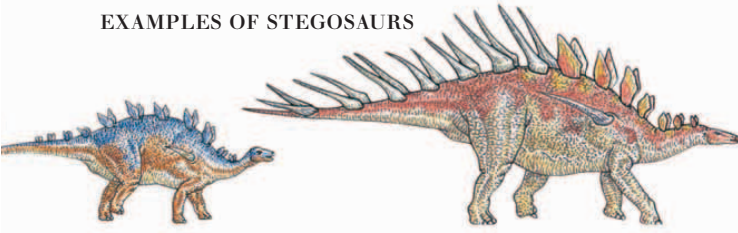
TUOJIANGOSAURUS
Group: Stegosauridae
Length: 25 ft (7 m)



EXTERNAL FEATURES OF STEGOSAURUS

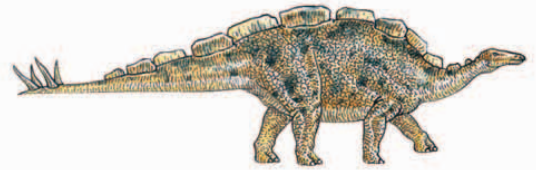
- Cervical plate
- Eye
- Naris
- Beak
- Outer ear
- Cheek
- Neck
- Short forelimb
- Nail
- Wrist
- Nail
- Forefoot
- Shoulder
- Elbow
- Knee
- Long hind limb
- Ankle
- Hind foot
- Hip
- Thigh

EXAMPLES OF STEGOSAURS



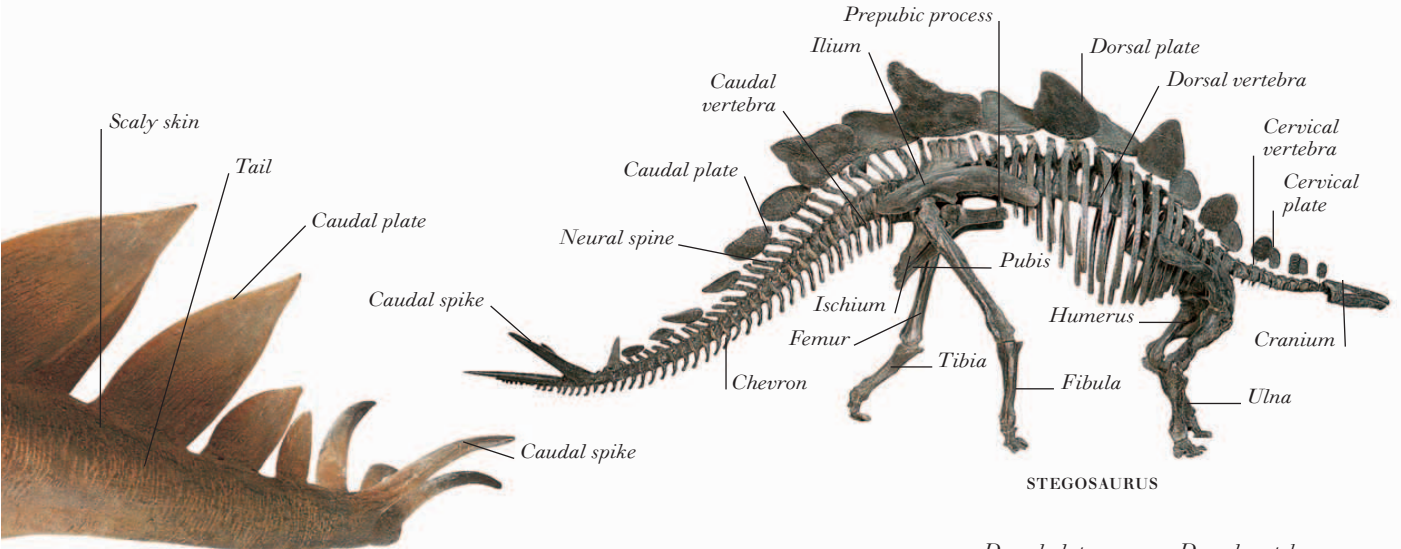
HUAYANGOSAURUS
Group: Huayangosauridae
Length: 13 ft (4 m)

KENTROSAURUS
Group: Stegosauridae
Length: 16 ft (4.9 m)



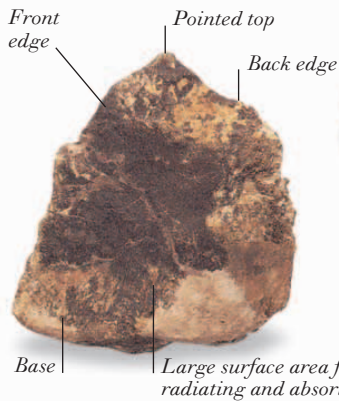
WUERHOSAURUS
Group: Stegosauridae
Length: 20 ft (6.1 m)

EXAMPLES OF STEGOSAUR SKELETONS

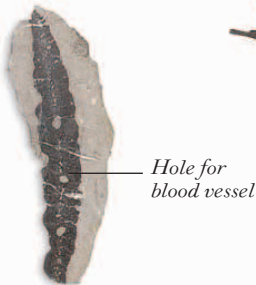


STEGOSAURUS

DORSAL PLATE OF STEGOSAURUS

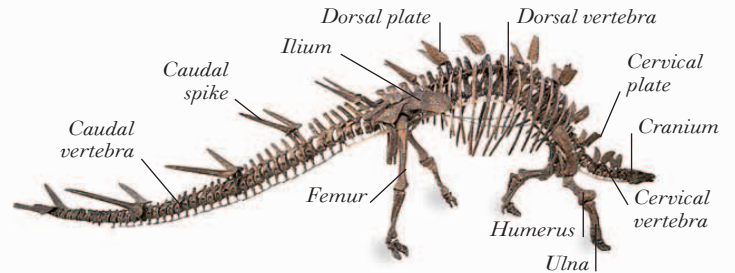


SIDE VIEW OF DORSAL PLATE

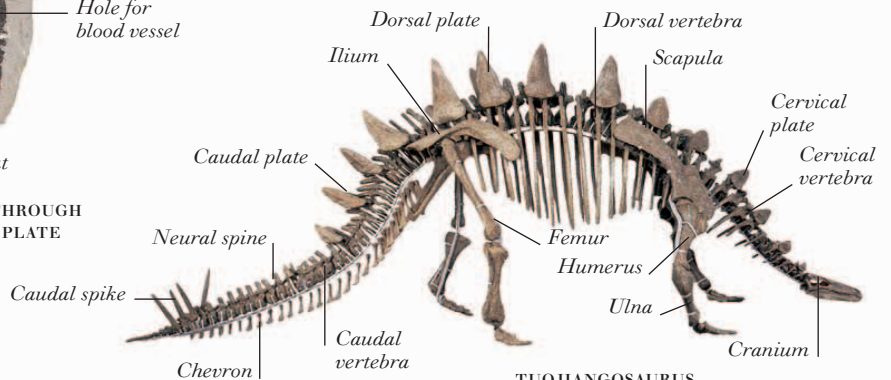


SECTION THROUGH DORSAL PLATE

Large surface area for radiating and absorbing heat



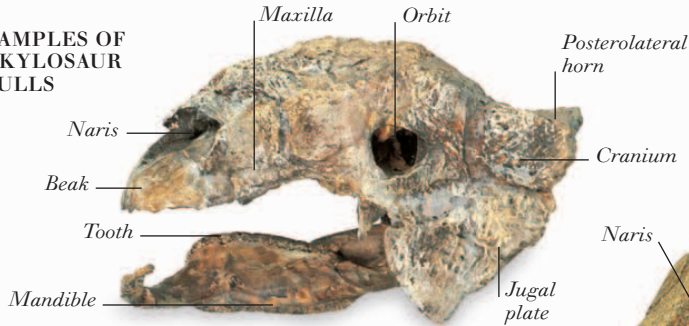
KENTROSAURUS



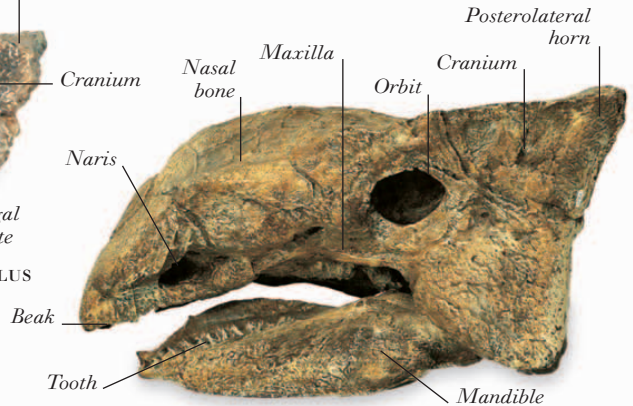
TUOJIANGOSAURUS

Thyreophorans 2

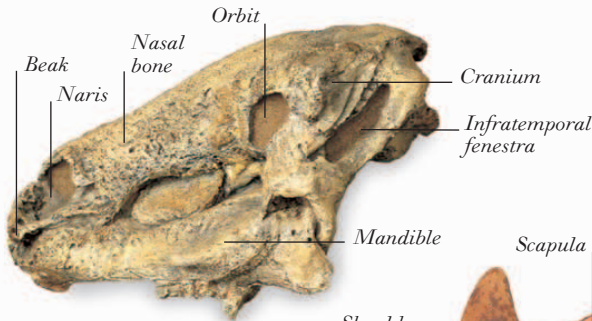
EXAMPLES OF ANKYLOSAUR SKULLS



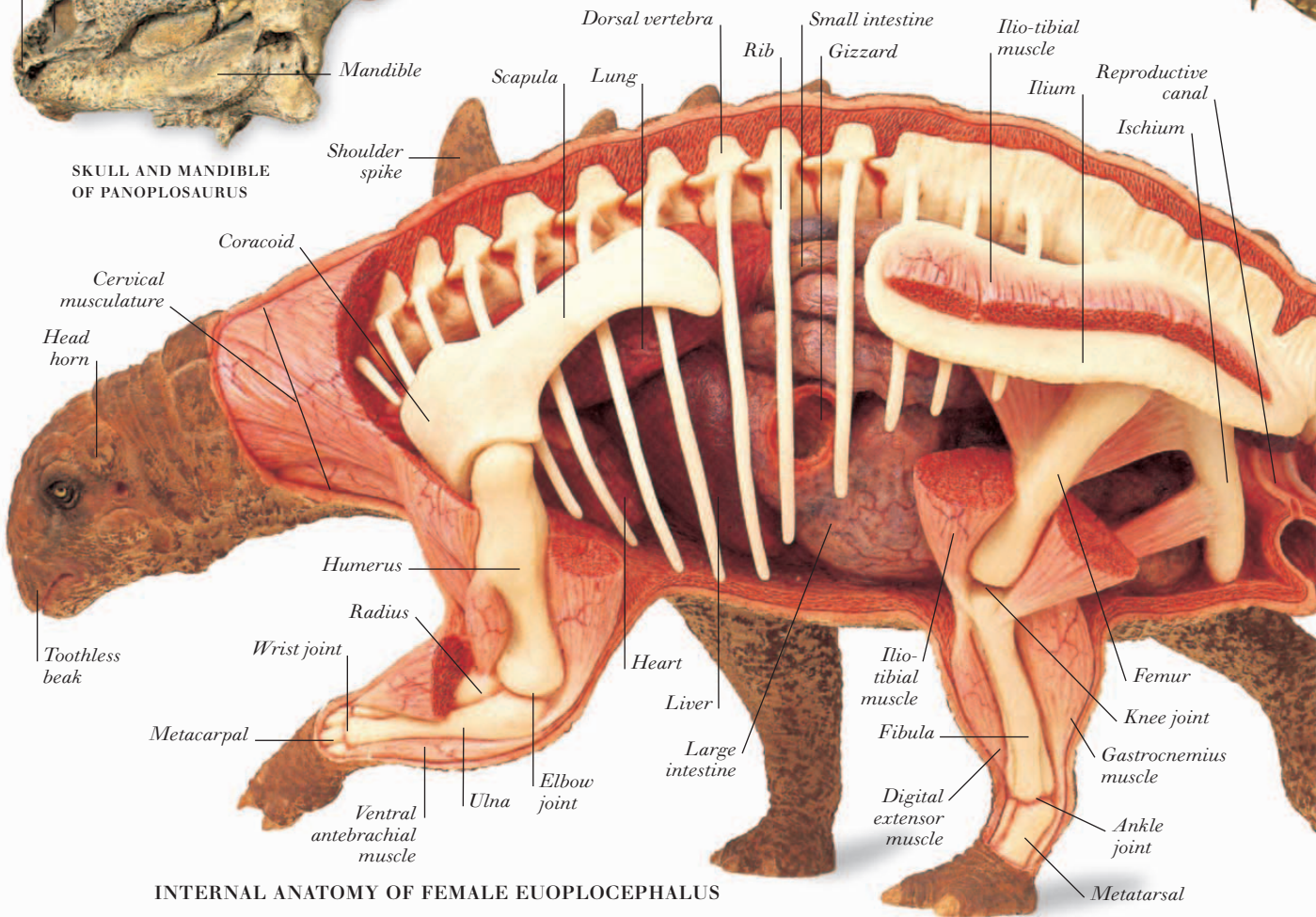
SKULL AND MANDIBLE OF EUOPLOCEPHALUS



SKULL AND MANDIBLE OF ANKYLOSAURUS

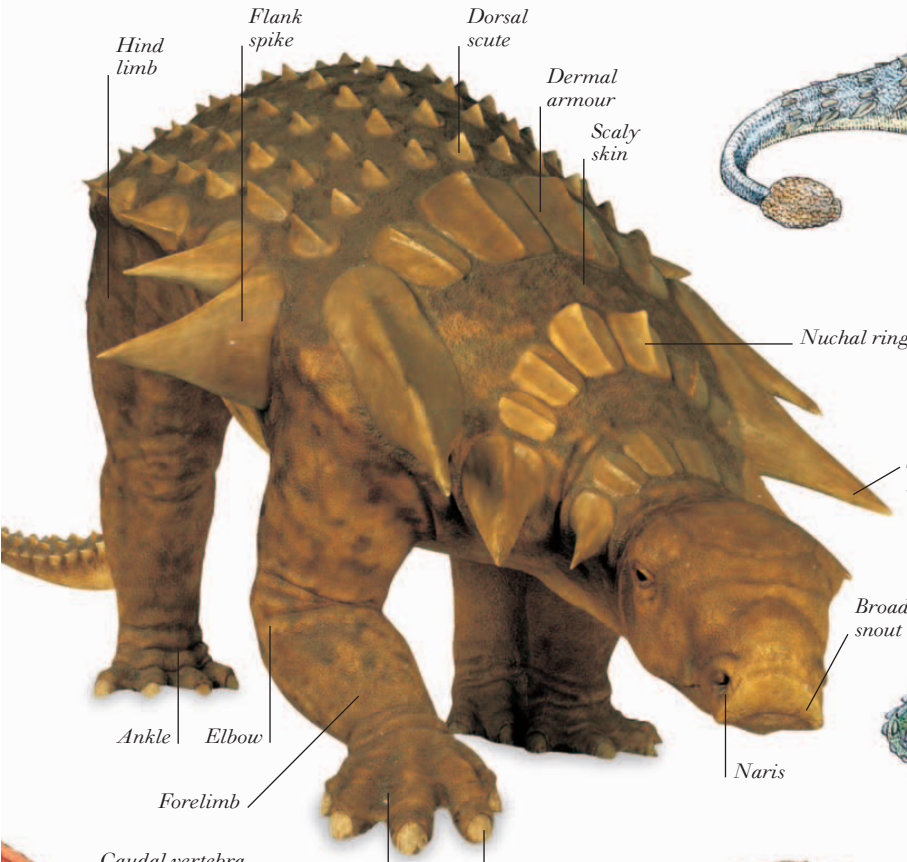


SKULL AND MANDIBLE OF PANOPLSAURUS

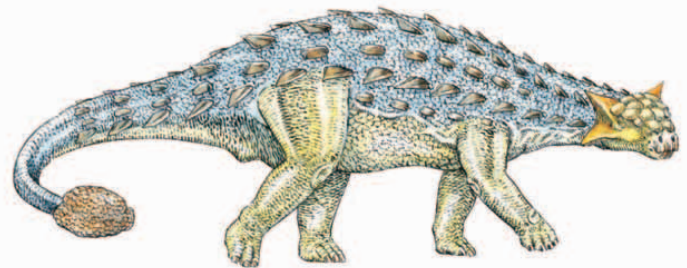


INTERNAL ANATOMY OF FEMALE EUOPLOCEPHALUS

EXTERNAL FEATURES OF EDMONTONIA



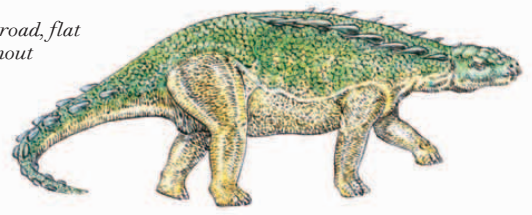
EXAMPLES OF ANKYLOSAURS



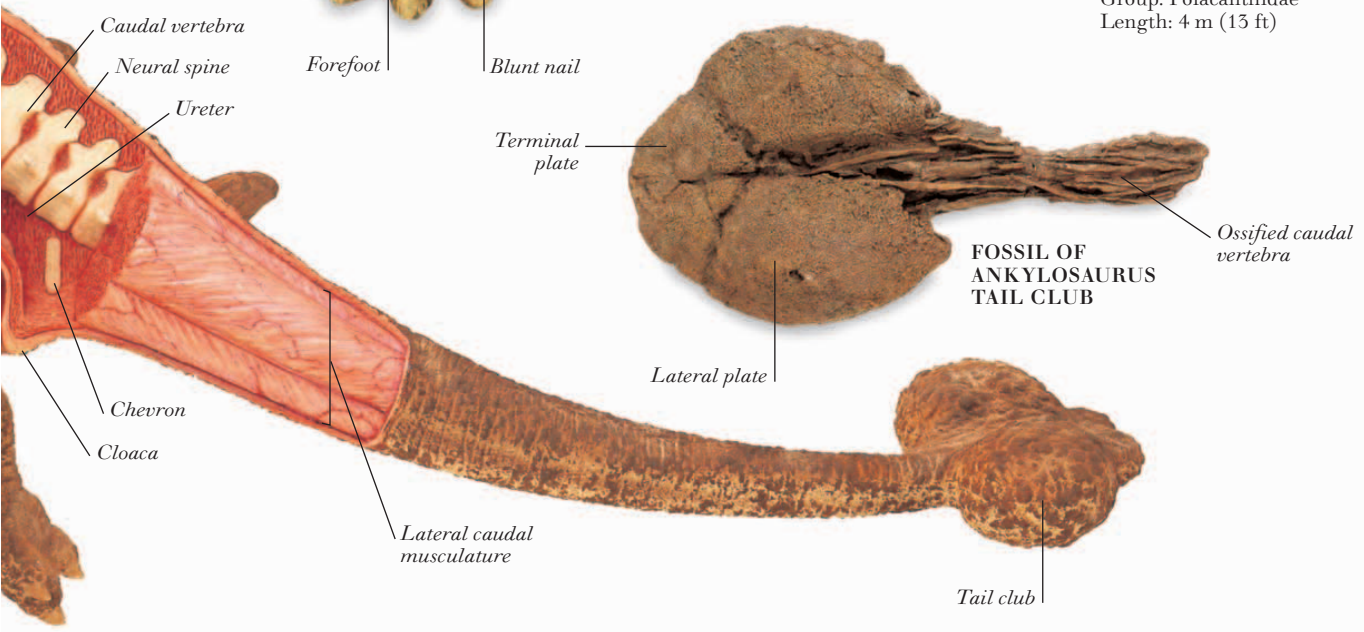
PINACOSAURUS
Group: Ankylosauridae
Length: 5 m (16 ft 6 in)



MINMI
Group: Ankylosauria
Length: 2.4 m (8 ft)



POLACANTHUS
Group: Polacanthidae
Length: 4 m (13 ft)



FOSSIL OF ANKYLOSAURUS TAIL CLUB

Ornithopods 1

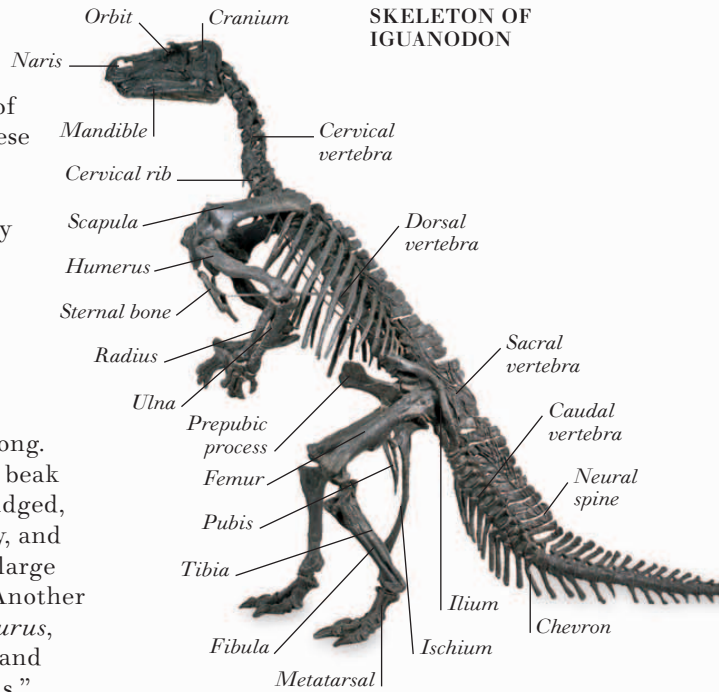


IGUANODON TOOTH

ORNITHOPODS (“BIRD FEET”) were a group of ornithischian (“bird-hipped”) dinosaurs. These bipedal and quadrupedal herbivores had a horny beak, plant-cutting or grinding cheek teeth, and a pelvic and tail region stiffened by bony tendons. They evolved teeth and jaws adapted to pulping vegetation and flourished from the Middle Jurassic to the Late

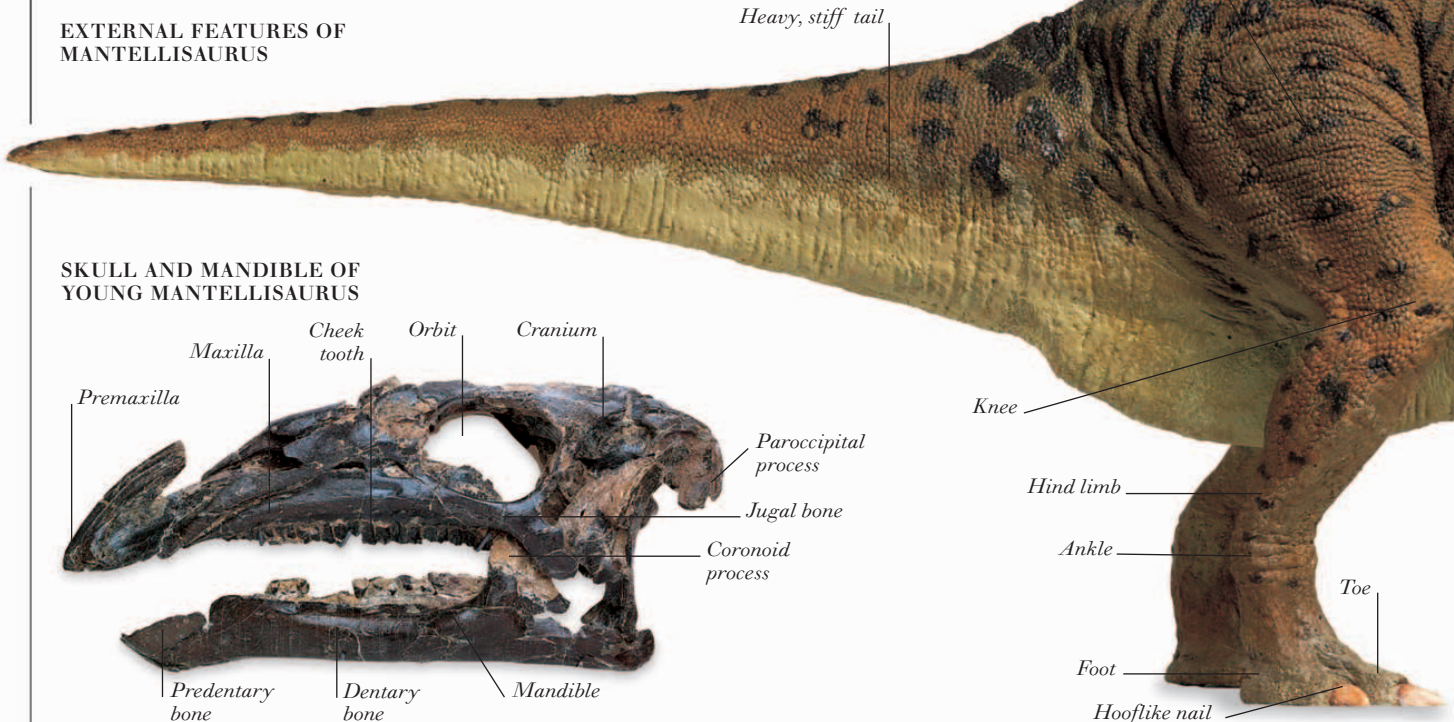
Cretaceous period (165–65 million years ago)

in North America, Europe, Africa, China, Australia, and Antarctica. Some ornithopods were no larger than a dog, while others were immense creatures up to 49 ft (15 m) long. Iguanodonts, an ornithopod group, had a broad, toothless beak at the end of a long snout, large jaws with long rows of ridged, closely packed teeth for grinding vegetation, a bulky body, and a heavy tail. *Iguanodon* and some other iguanodonts had large thumb-spikes that were strong enough to stab attackers. Another group, the hadrosaurs, such as *Gryposaurus* and *Hadrosaurus*, lived in Late Cretaceous times (97–65 million years ago) and with their broad beaks are sometimes known as “duckbills.” They were characterized by their deep skulls and closely packed rows of teeth, while some, such as *Corythosaurus* and *Lambeosaurus*, had tall, hollow, bony head crests.

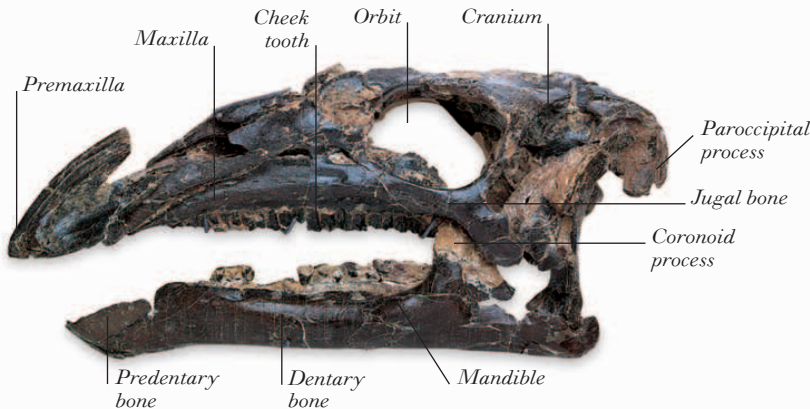


SKELETON OF IGUANODON

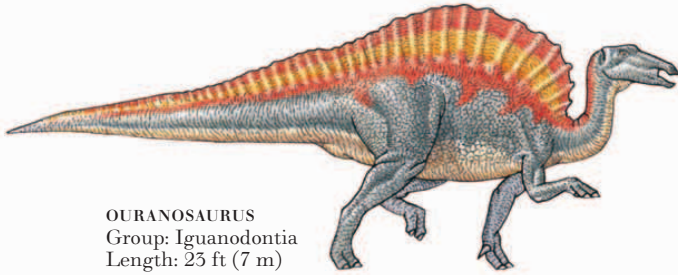
EXTERNAL FEATURES OF MANTELLISAURUS



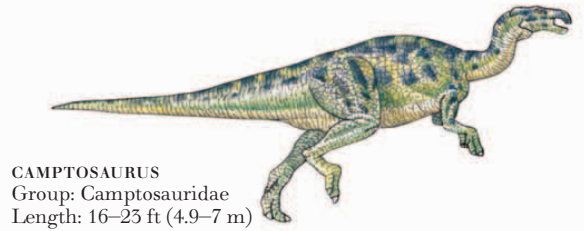
SKULL AND MANDIBLE OF YOUNG MANTELLISAURUS



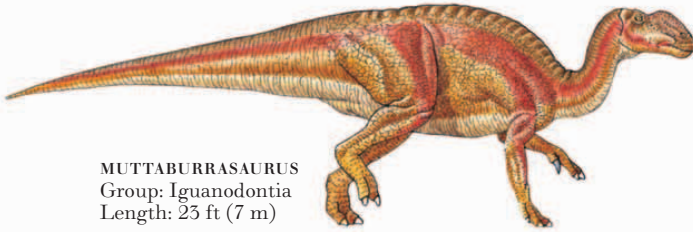
EXAMPLES OF IGUANODONTS



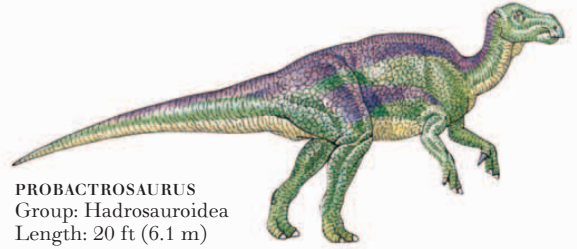
OURANOSAURUS
Group: Iguanodontia
Length: 25 ft (7 m)



CAMPTOSAURUS
Group: Camptosauridae
Length: 16–25 ft (4.9–7 m)

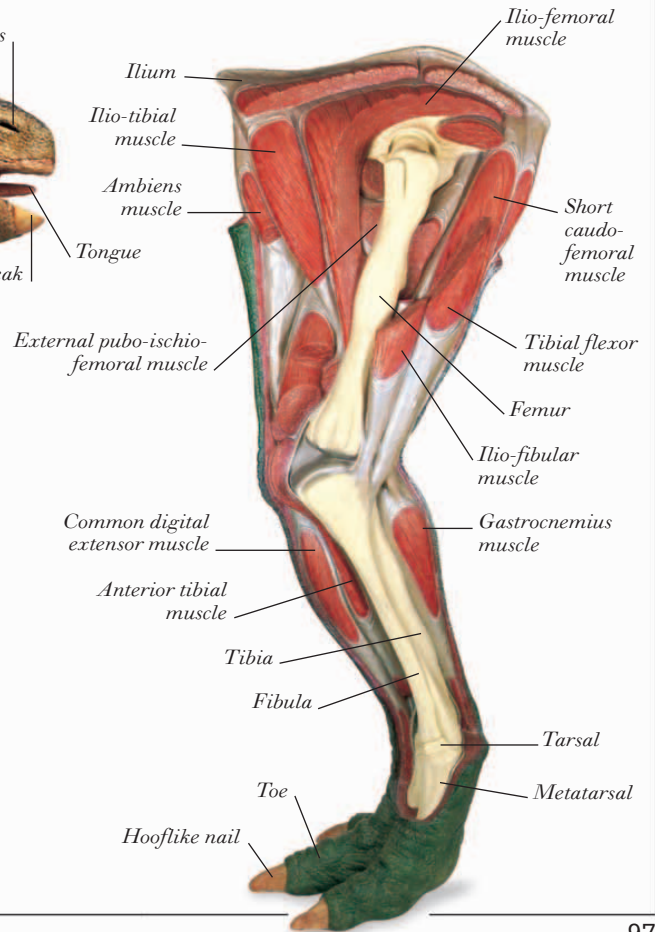
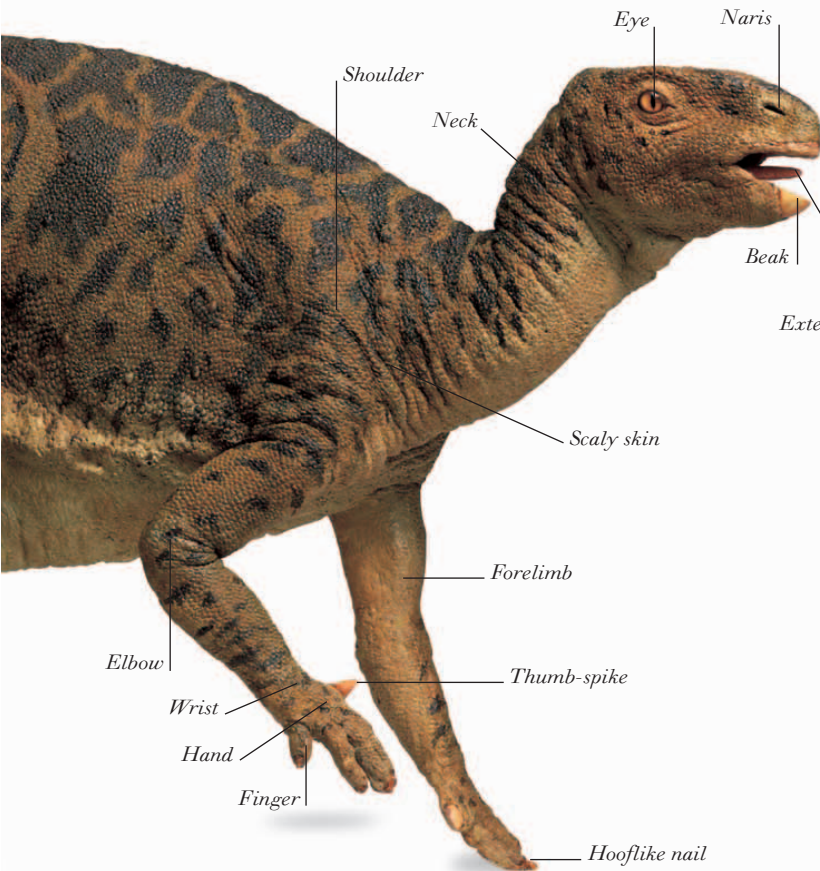


MUTTABURRASAUURUS
Group: Iguanodontia
Length: 25 ft (7 m)



PROBACTROSAURUS
Group: Hadrosauroida
Length: 20 ft (6.1 m)

INTERNAL ANATOMY OF HIND LEG OF IGUANODON



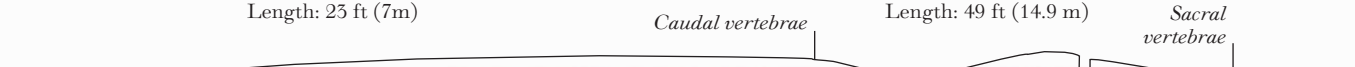
Ornithopods 2



BRACHYLOPHOSAURUS
Length: 25 ft (7m)

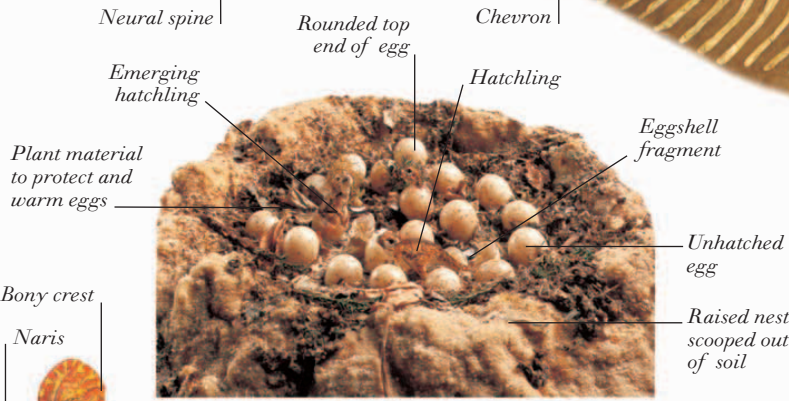


LAMBEOSAURUS
Length: 49 ft (14.9 m)



Caudal vertebrae

Sacral vertebrae



MODEL OF MAIASAURA NEST

Neural spine

Rounded top end of egg

Chevron

Emerging hatchling

Hatchling

Eggshell fragment

Plant material to protect and warm eggs

Unhatched egg

Raised nest scooped out of soil

Bony crest

Naris

Eye

Cheek pouch

Neck

Tongue

Toothless beak

Shoulder

Forelimb

Wrist

Nail

Elbow

Tubercle

Knee

Toe

Nail

Thigh

Scaly skin

Hind limb

Ankle

Foot

Ilium

Ischium

Hip joint

Prepubic process

Femur

Knee joint

FOSSIL SKELETON OF PARASAUROLOPHUS

Long, thick tail

Ankle joint

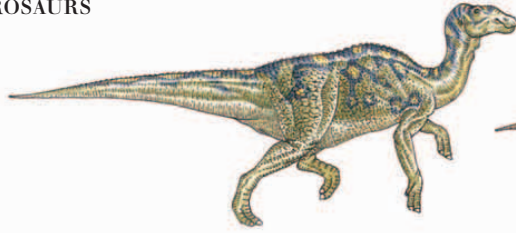
Metatarsal

EXTERNAL FEATURES OF CORYTHOSAURUS

EXAMPLES OF HADROSAURS



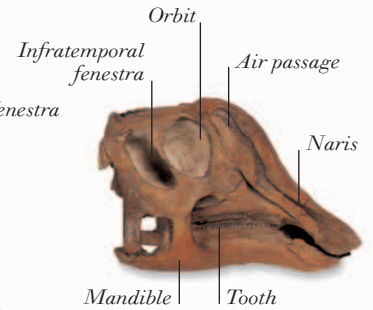
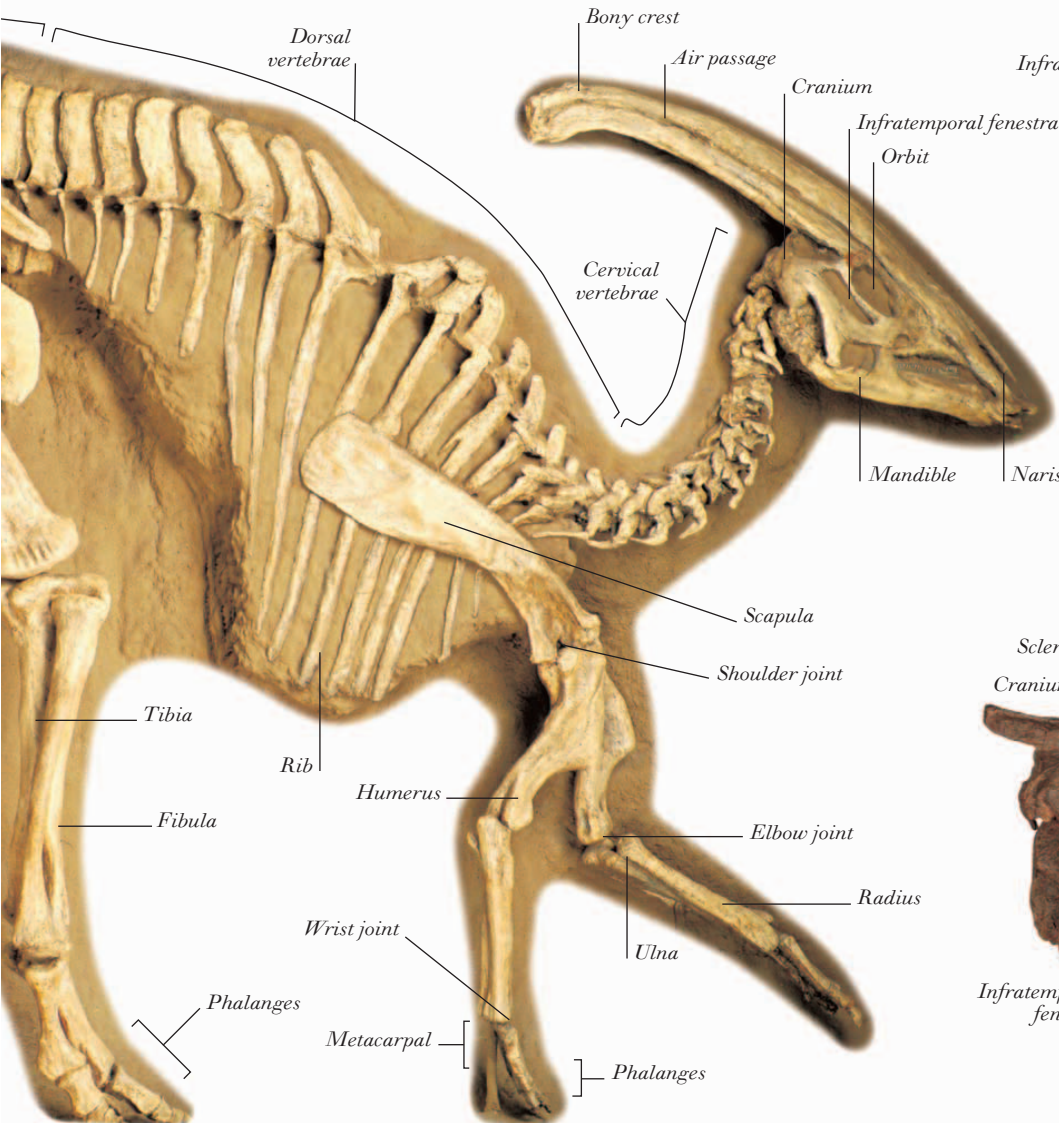
HYPACROSAURUS
Length: 30 ft (9.1 m)



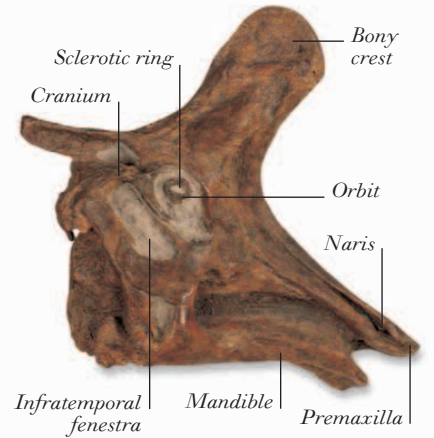
HADROSAURUS
Length: 26–33 ft (7.9–10 m)



GRYPOSAURUS
Length: 26–33 ft (7.9–10 m)



SKULL AND MANDIBLE OF JUVENILE LAMBEOSAURUS



SKULL AND MANDIBLE OF ADULT LAMBEOSAURUS

Marginocephalians 1

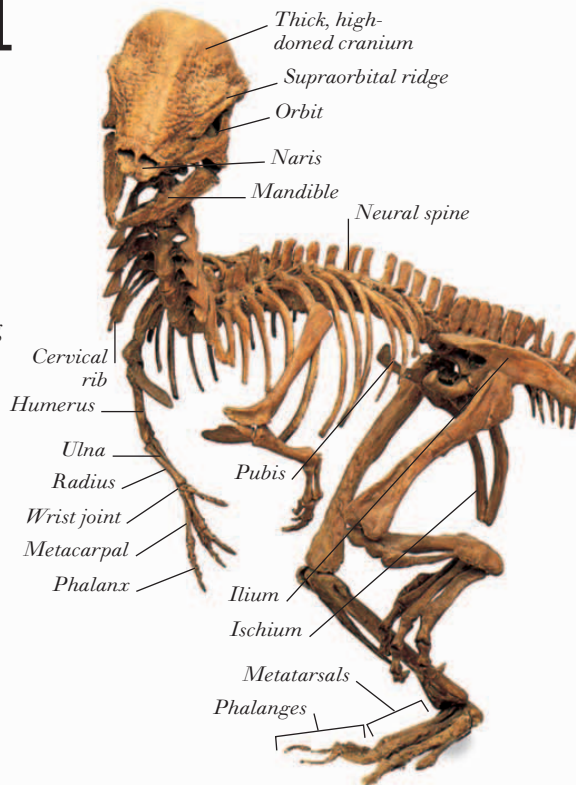


HEAD-BUTTING PRENOCEPHALES

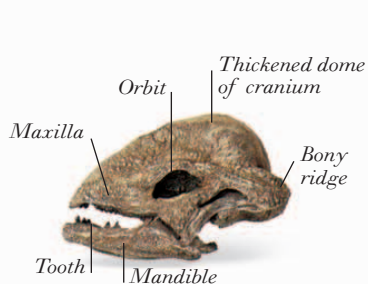
MARGINOCEPHALIA ("margined heads")

were a group of bipedal and quadrupedal ornithischian dinosaurs with a narrow shelf or deep, bony frill at the back of the skull. Marginocephalians were

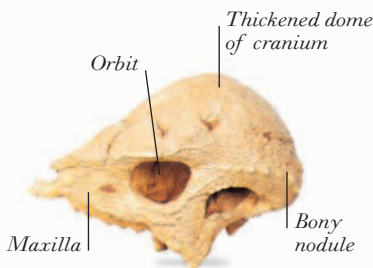
probably descended from the same ancestor as the ornithopods and lived in what are now North America, Africa, Asia, and Europe during the Cretaceous period (145–65 million years ago). They were divided into two groups: Pachycephalosauria ("thick-headed lizards"), such as *Pachycephalosaurius* and *Stegoceras*, and Ceratopsia ("horned faces"), such as *Triceratops* and *Psittacosaurus*. The thick skulls of Pachycephalosauria may have protected their brains during possible head-butting contests fought to win territory and mates; their hips and spines may also have been strengthened to withstand the shock. The bony frill of Ceratopsia would have added to their frightening appearance when charging; the neck was strengthened for impact and to support the huge head, with its snipping beak and powerful slicing toothed jaws. A charging ceratopsian would have been a formidable opponent for even the largest predators. Ceratopsians were among the most abundant herbivorous dinosaurs of the Late Cretaceous period (97–65 million years ago).



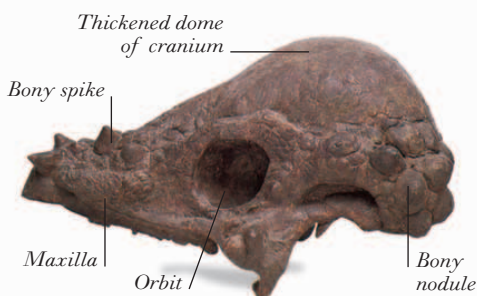
EXAMPLES OF SKULLS OF PACHYCEPHALOSAURS



SKULL AND MANDIBLE OF STEGOCERAS

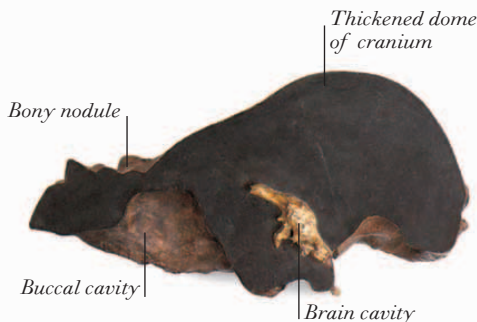
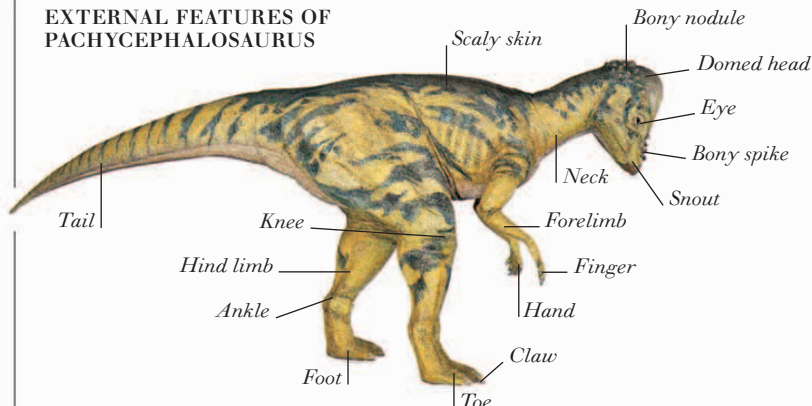


SKULL OF PRENOCEPHALE



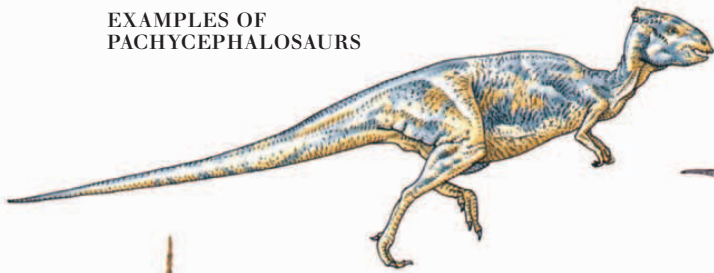
SKULL OF PACHYCEPHALOSAURIUS

EXTERNAL FEATURES OF PACHYCEPHALOSAURUS



SECTION THROUGH SKULL OF PACHYCEPHALOSAURIUS

EXAMPLES OF PACHYCEPHALOSAURS



HOMALOCEPHALE
Group: Pachycephalosauria
Length: 10 ft (3 m)

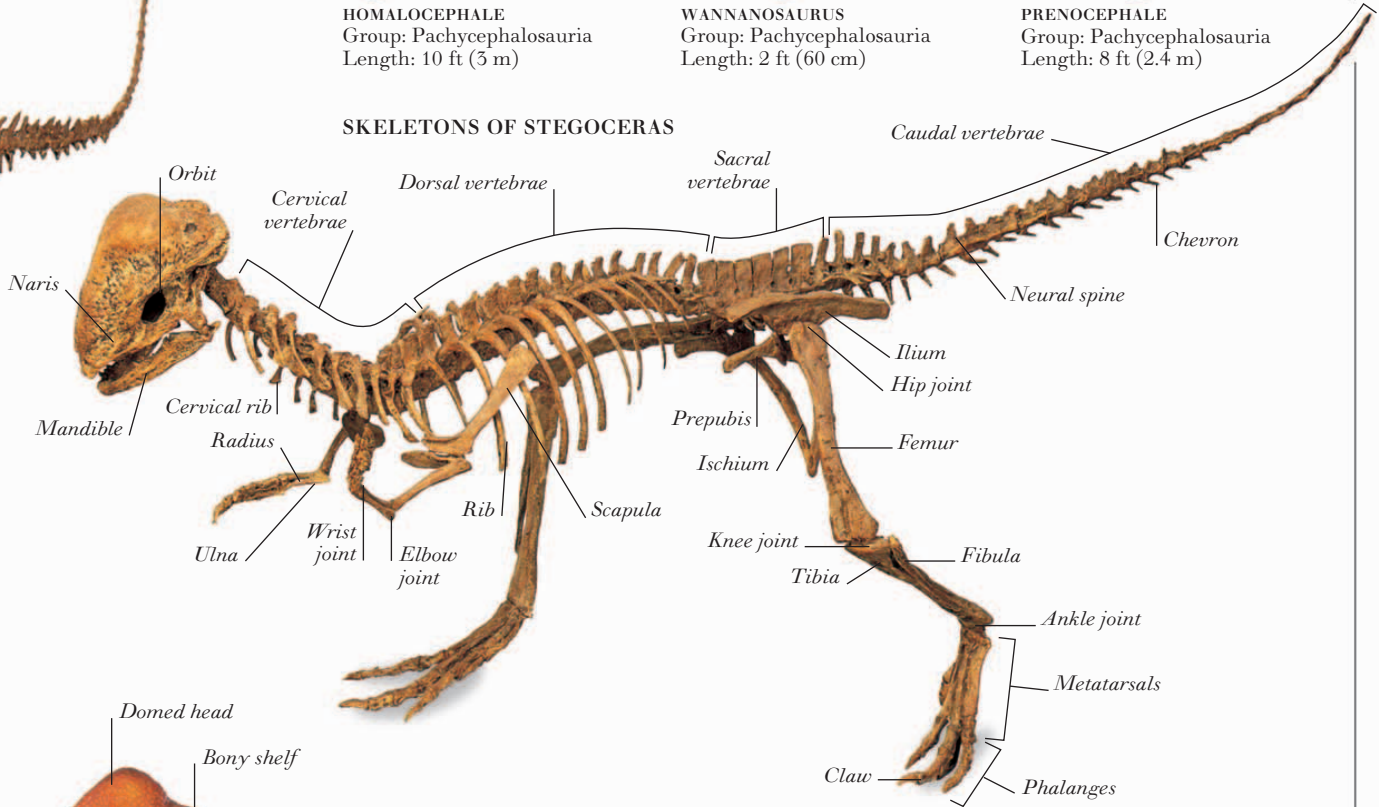


WANNANOSAURUS
Group: Pachycephalosauria
Length: 2 ft (60 cm)

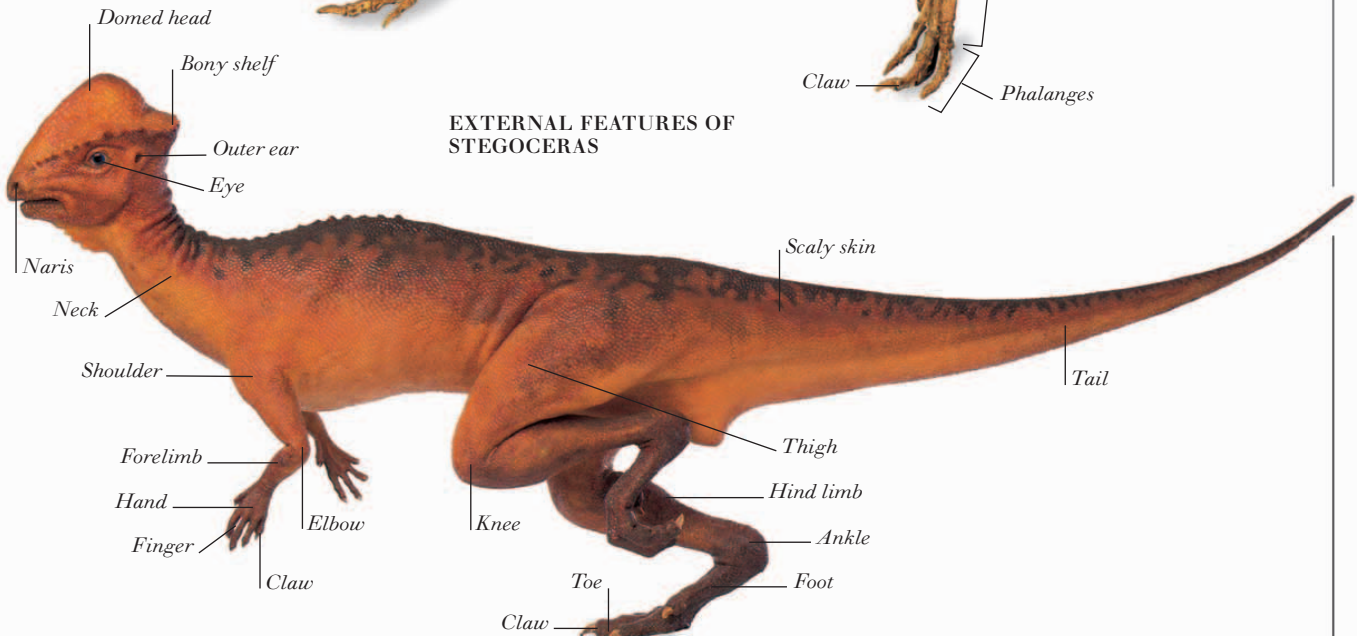


PRENOCEPHALE
Group: Pachycephalosauria
Length: 8 ft (2.4 m)

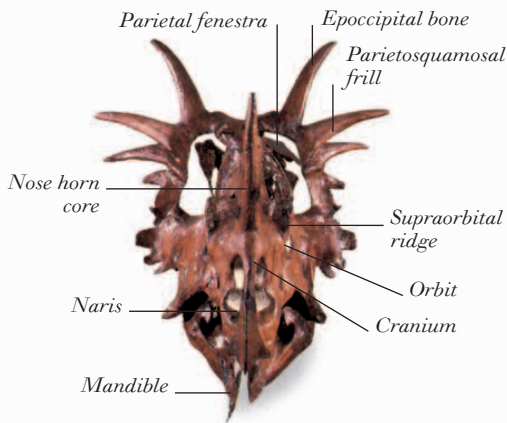
SKELETONS OF STEGOCERAS



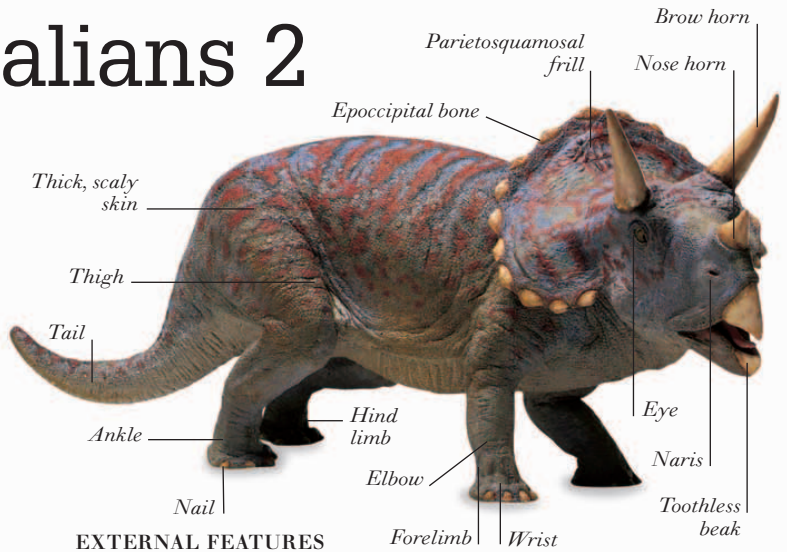
EXTERNAL FEATURES OF STEGOCERAS



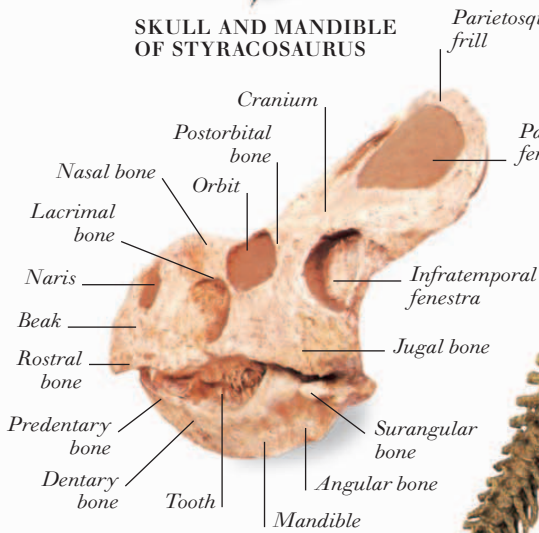
Marginocephalians 2



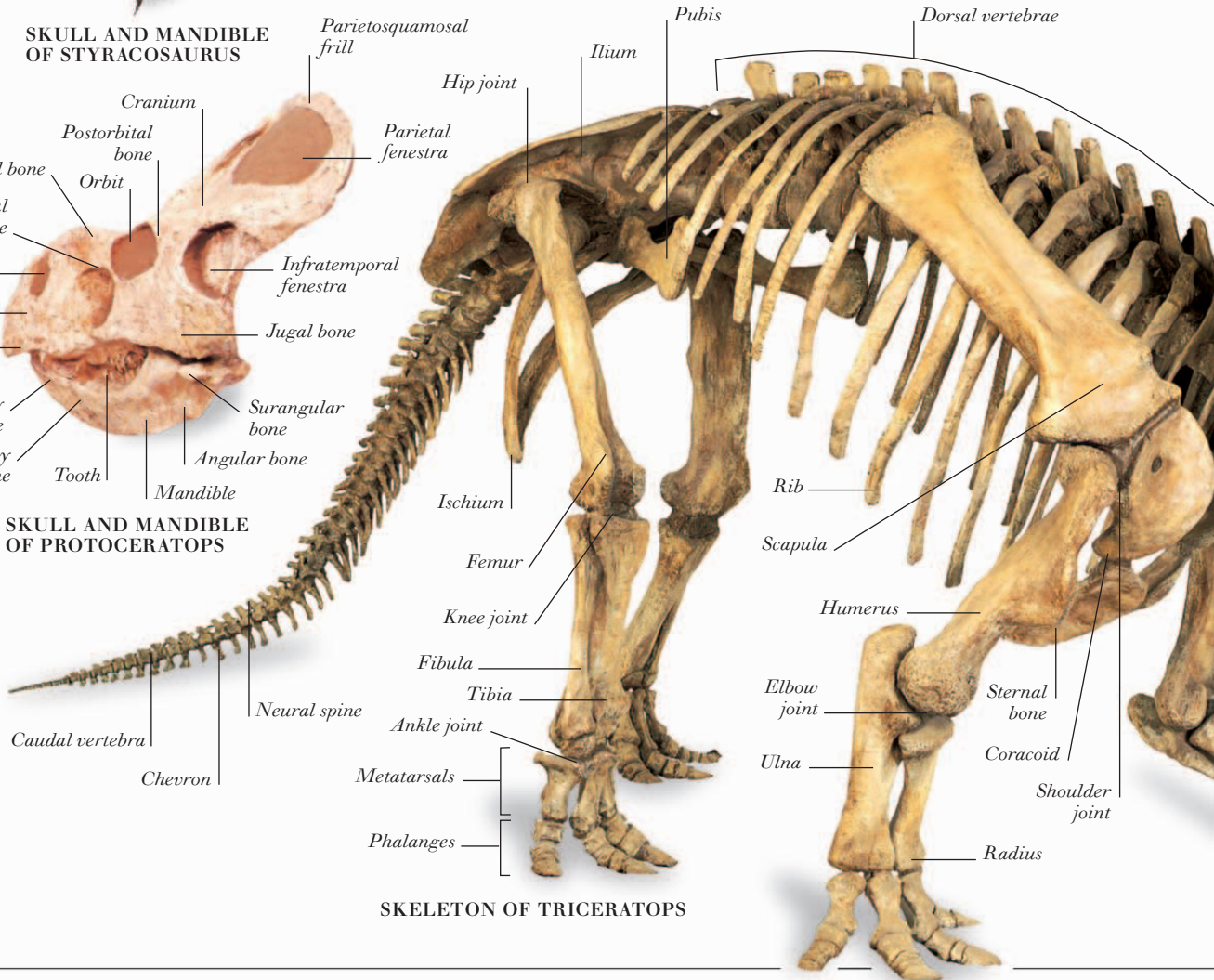
SKULL AND MANDIBLE OF STYRACOSAURUS



EXTERNAL FEATURES OF TRICERATOPS

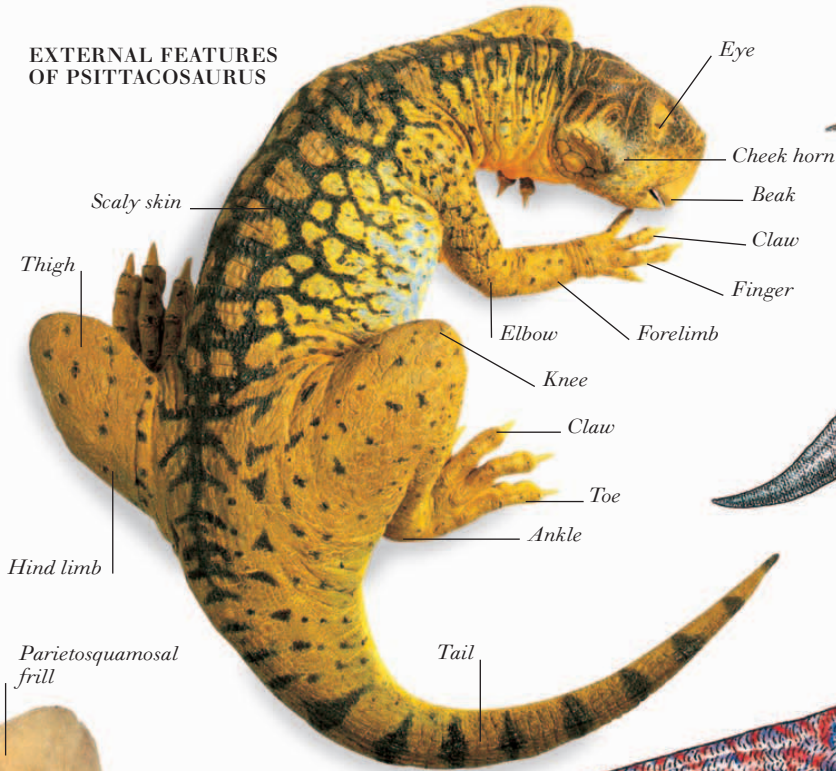


SKULL AND MANDIBLE OF PROTOCERATOPS



SKELETON OF TRICERATOPS

EXTERNAL FEATURES OF PSITTACOSAURUS



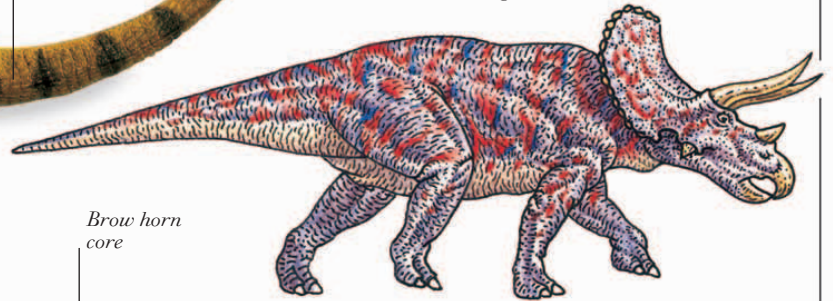
EXAMPLES OF CERATOPSIA



PROTOCERATOPS
Group: Protoceratopsidae
Length: 9 ft (2.7 m)



STYRACOSAURUS
Group: Centrosaurinae
Length: 18 ft (5.5 m)



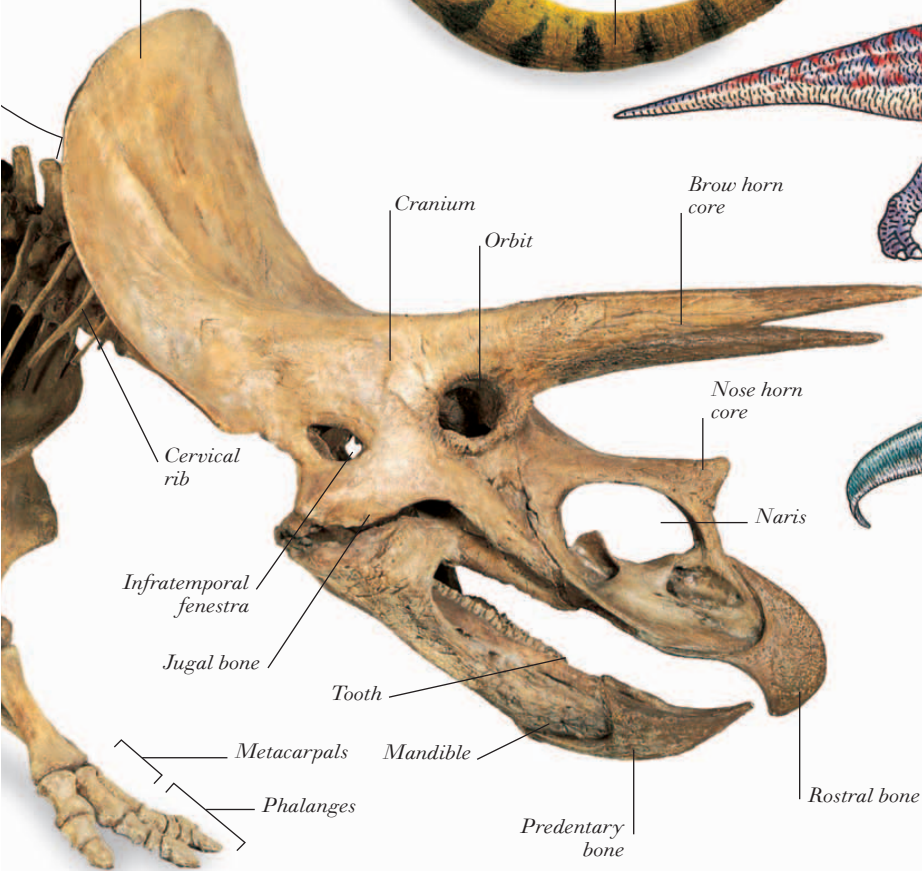
TRICERATOPS
Group: Chasmosaurinae
Length: 30 ft (9.1 m)



PACHYRHINOSAURUS
Group: Centrosaurinae
Length: 18 ft (5.5 m)



LEPTOCERATOPS
Group: Leptoceratopsidae
Length: 7 ft (2.1 m)



Mammals 1

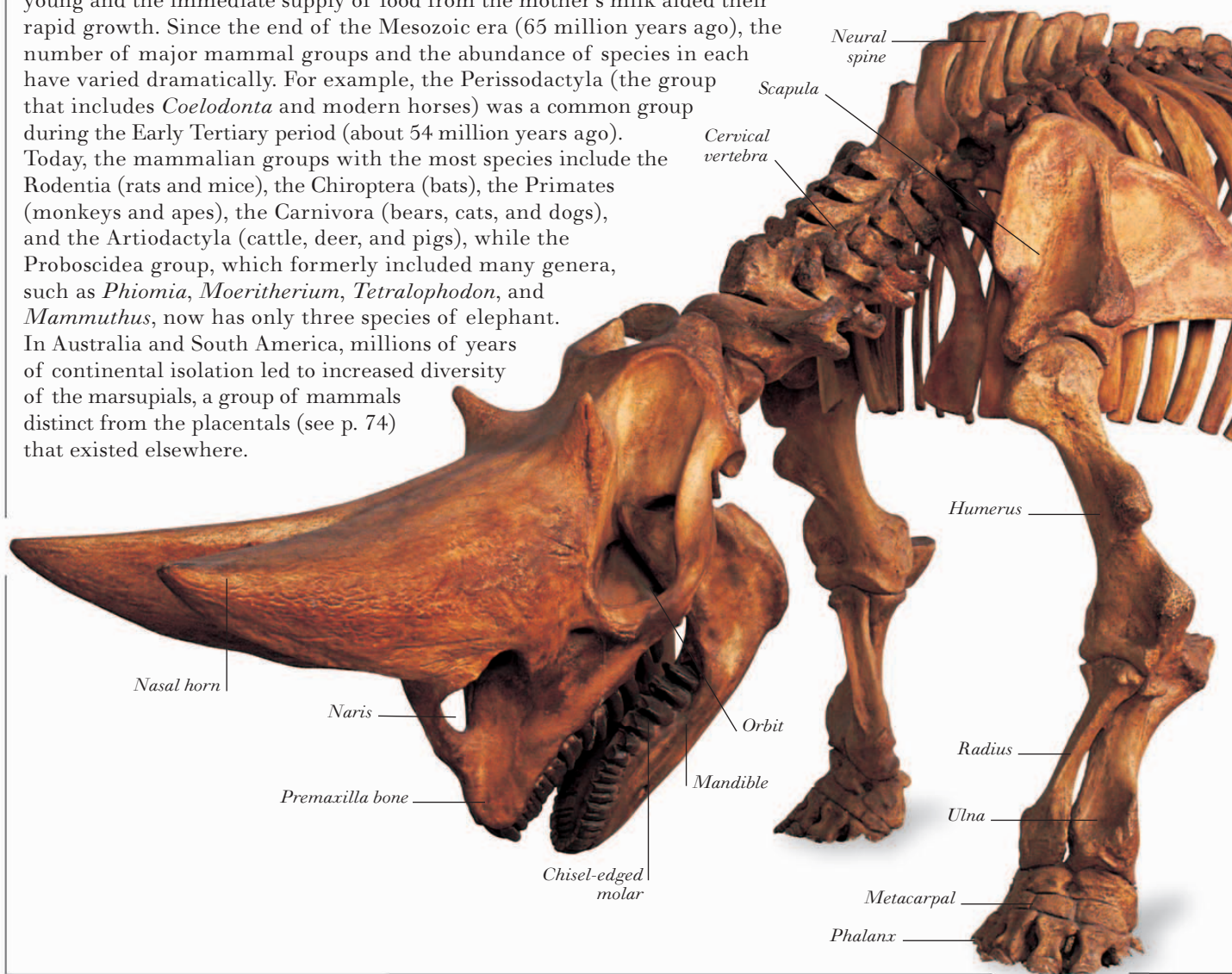
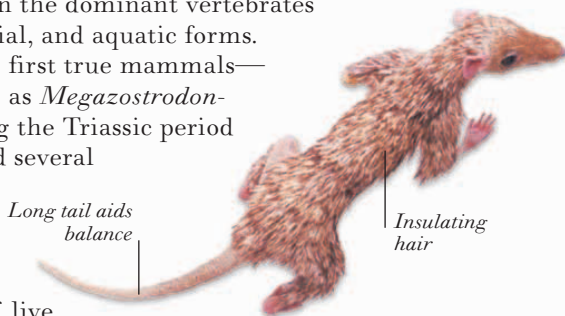


TETRALOPHODON
CHEEK TEETH

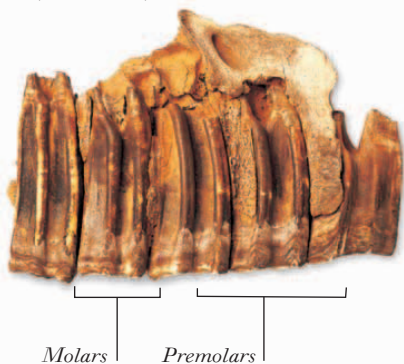
SINCE THE EXTINCTION of most of the dinosaurs 65 million years ago, mammals (along with birds) have been the dominant vertebrates on land. This class includes terrestrial, aerial, and aquatic forms. Having developed from the therapsids, the first true mammals—small, nocturnal, shrewlike creatures, such as *Megazostrodon*—appeared over 200 million years ago during the Triassic period (250–200 million years ago). Mammals had several

features that differed from those of their ancestors: an efficient four-chambered heart allowed these warm-blooded animals to sustain high levels of activity; a covering of hair helped them maintain a constant body temperature; an improved limb structure gave them more efficient locomotion; and the birth of live young and the immediate supply of food from the mother's milk aided their rapid growth. Since the end of the Mesozoic era (65 million years ago), the number of major mammal groups and the abundance of species in each have varied dramatically. For example, the Perissodactyla (the group that includes *Coelodonta* and modern horses) was a common group during the Early Tertiary period (about 54 million years ago). Today, the mammalian groups with the most species include the Rodentia (rats and mice), the Chiroptera (bats), the Primates (monkeys and apes), the Carnivora (bears, cats, and dogs), and the Artiodactyla (cattle, deer, and pigs), while the Proboscidea group, which formerly included many genera, such as *Phiomia*, *Moeritherium*, *Tetralophodon*, and *Mammuthus*, now has only three species of elephant. In Australia and South America, millions of years of continental isolation led to increased diversity of the marsupials, a group of mammals distinct from the placentals (see p. 74) that existed elsewhere.

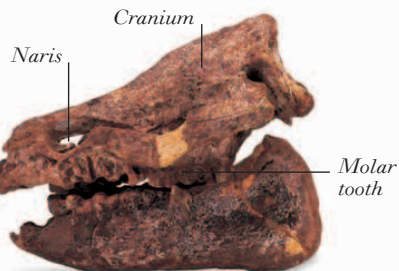
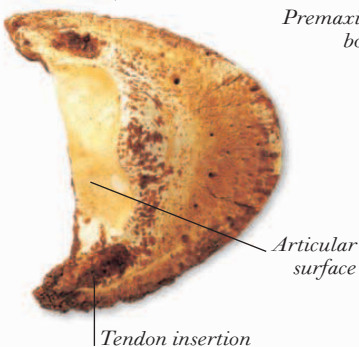
MODEL OF A
MEGAZOSTRODON



UPPER JAWBONE (MAXILLA) OF A HORSE



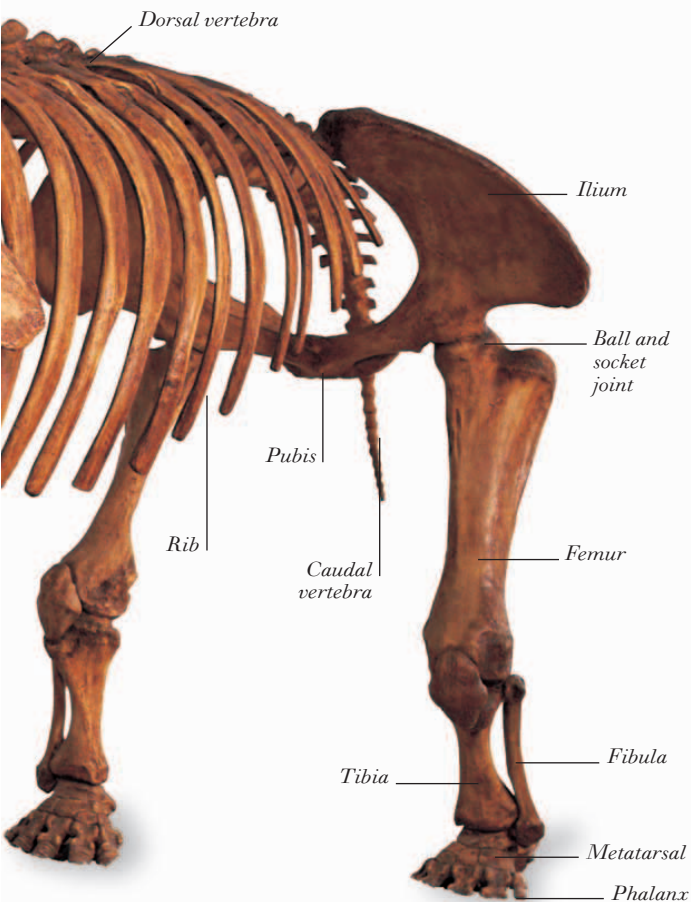
HOOFBONE (THIRD PHALANX) OF A HORSE



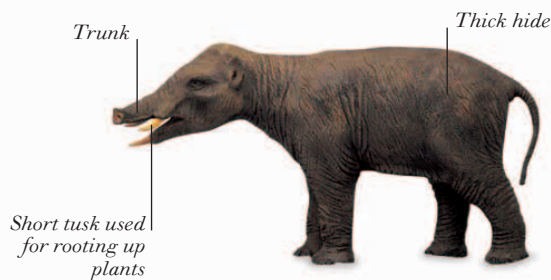
SKULL AND MANDIBLE OF A MOERTHERIUM



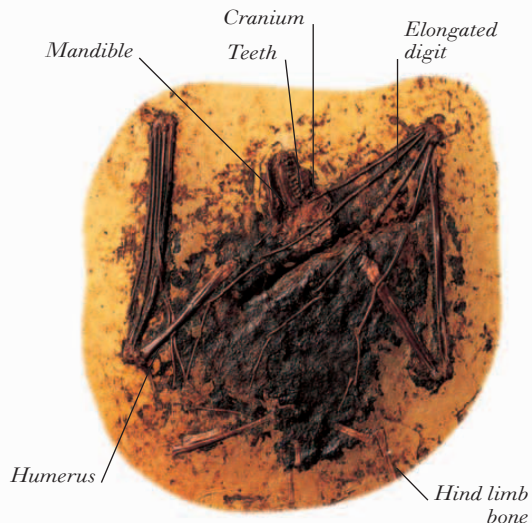
SKULL AND MANDIBLE OF A PHIOMIA



SKELETON OF AN ARSINOITHERIUM



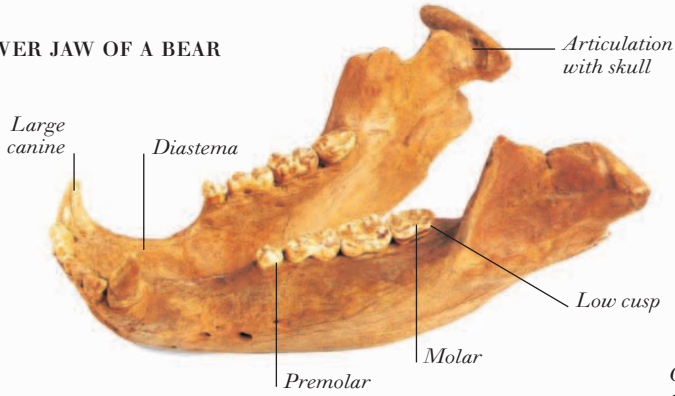
MODEL OF A PHIOMIA



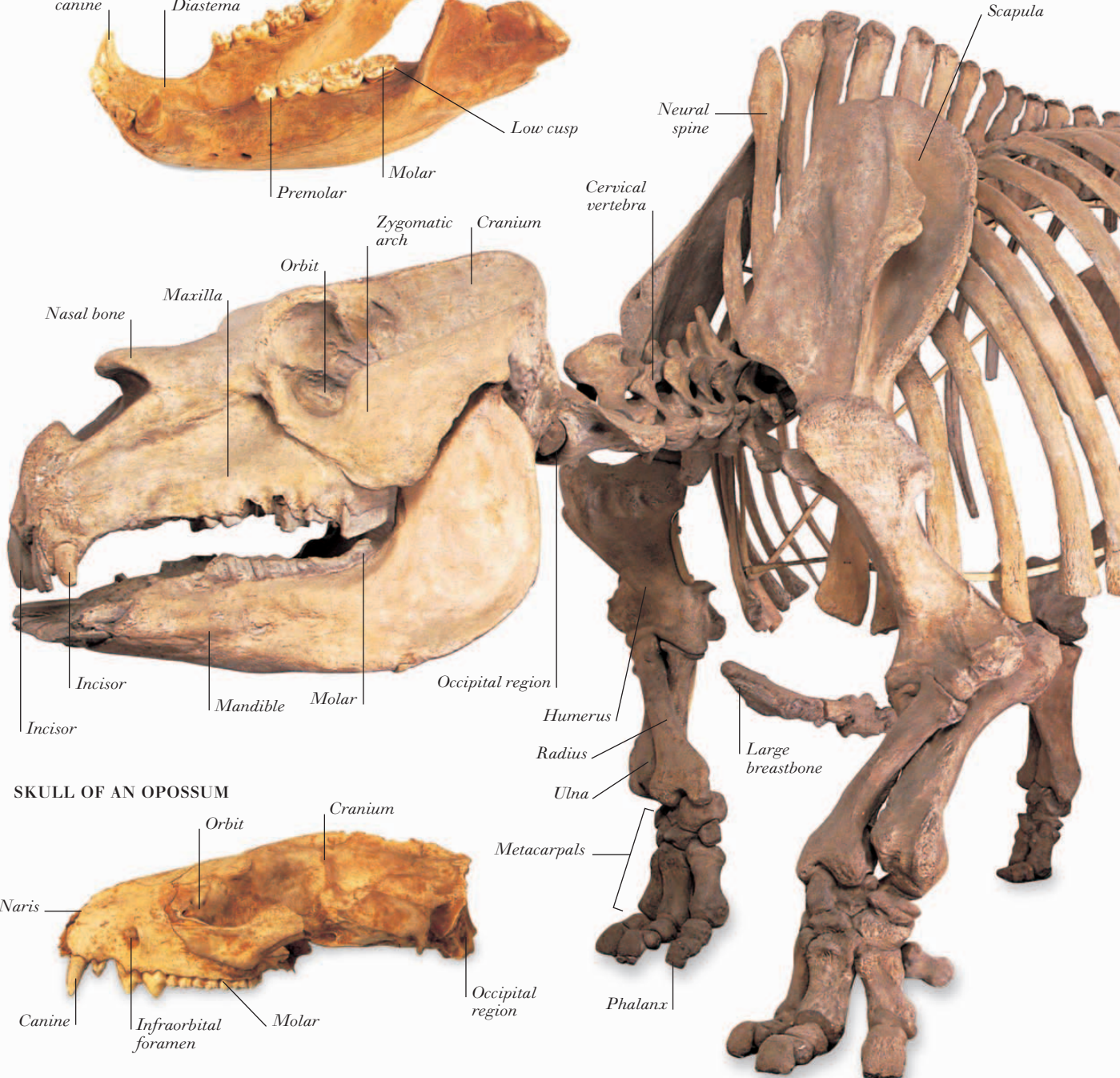
FOSSIL SKELETON OF A BAT

Mammals 2

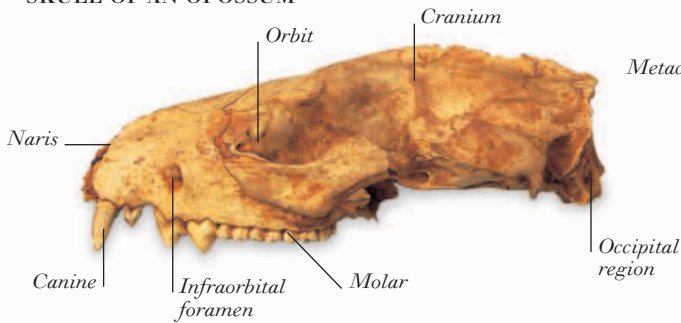
LOWER JAW OF A BEAR



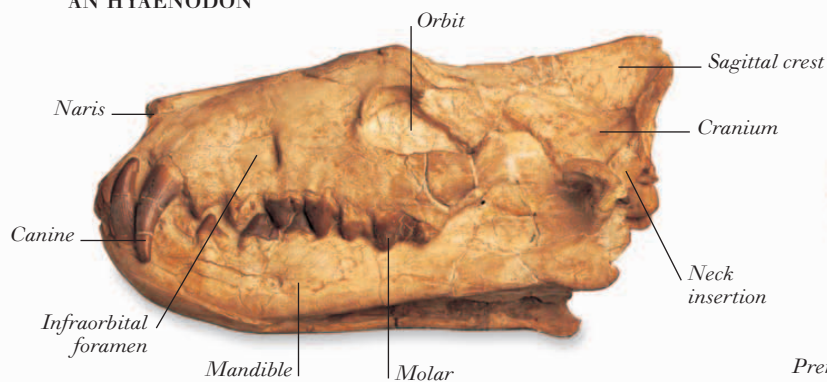
SKELETON OF A TOXODON



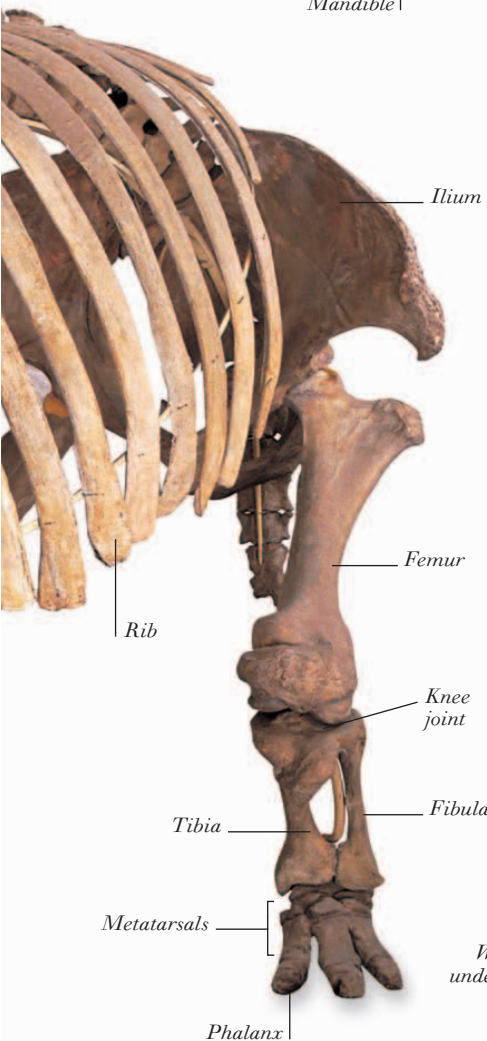
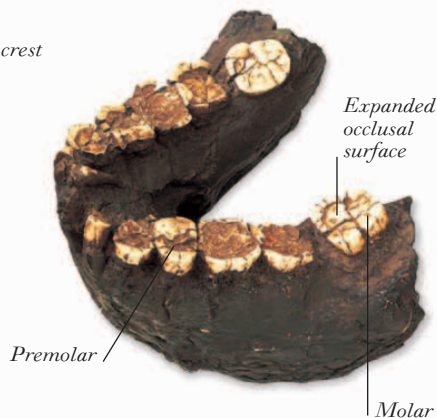
SKULL OF AN OPOSSUM



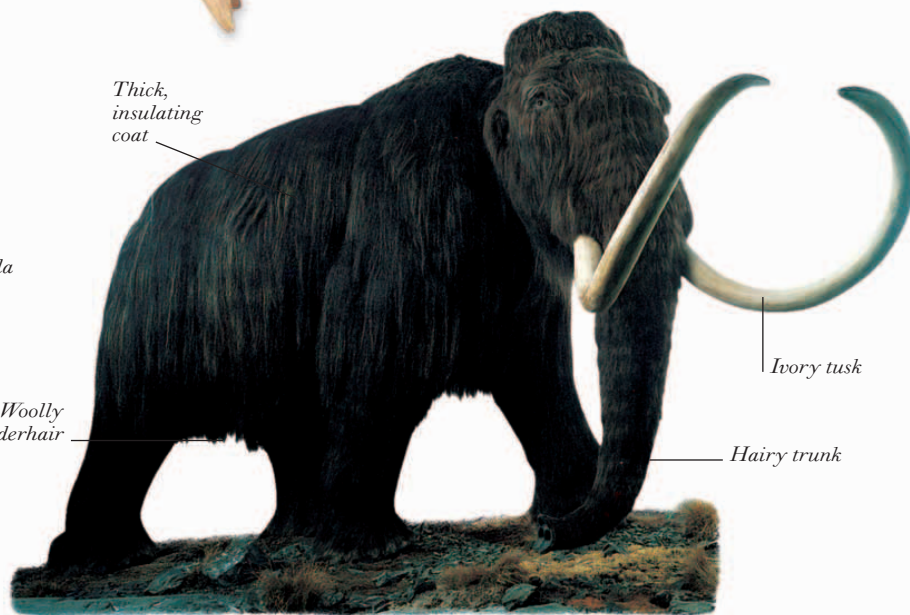
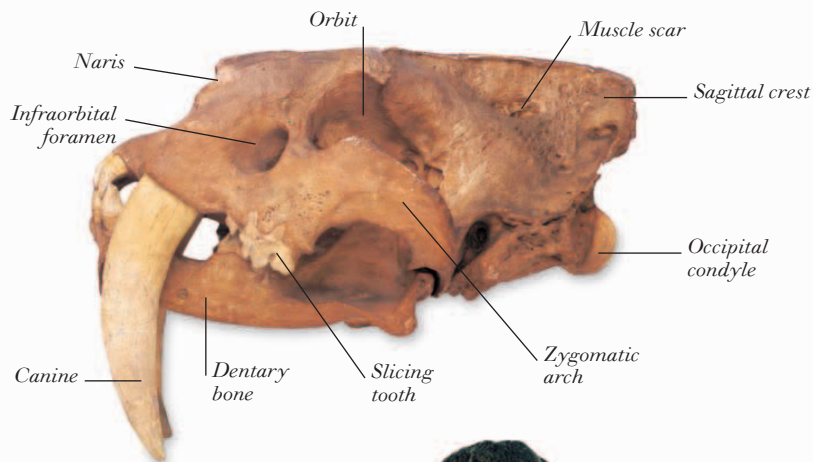
FOSSIL SKULL OF AN HYAENODON



LOWER JAW OF AN AUSTRALOPITHECUS



SKULL OF A SMILODON

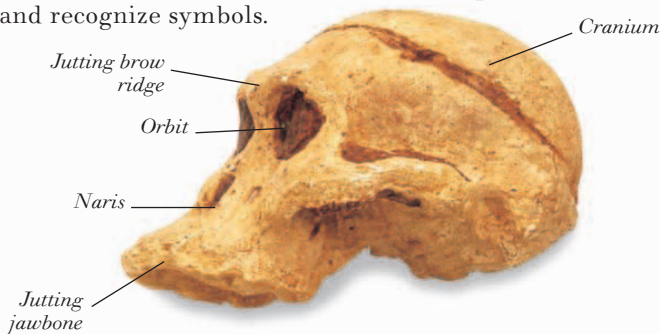
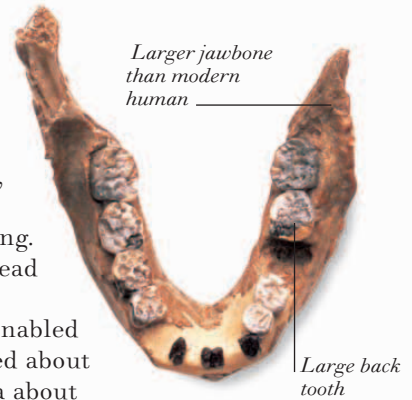


RECONSTRUCTION OF A MAMMOTH

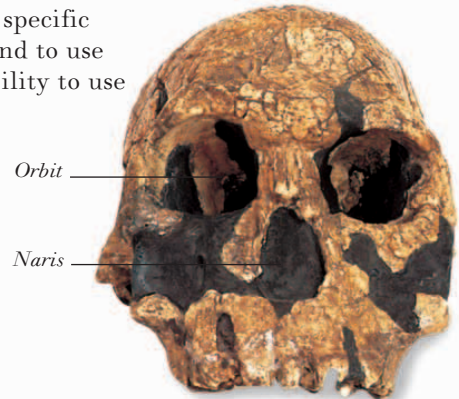
The first humans

MODERN HUMANS BELONG TO THE MAMMALIAN order of primates (see pp. 202–203), which originated about 55 million years ago; primates included the only extant hominid species. The earliest hominid was *Ardipithecus* (“ground ape”) and *Australopithecus* (“southern ape”), both small-brained intermediates between apes and humans that were capable of standing and walking upright. *Homo habilis*, the earliest member of the genus *Homo*, appeared at least 2 million years ago. This larger-brained “handy man” began making tools for hunting. *Homo ergaster* first appeared in Africa about 1.8 million years ago and spread into Asia about 800,000 years later. Smaller-toothed than *Homo habilis*, *H. ergaster*—followed by *Homo erectus*—developed fire as a tool, which enabled it to cook food. Neanderthals, a near relative of modern humans, originated about 200,000 years ago, and *Homo sapiens* (modern humans) appeared in Africa about 100,000 years later. The two coexisted for thousands of years, but by 30,000 years ago, *Homo sapiens* had become dominant and the Neanderthals had died out. Classification of *Homo sapiens* in relation to its ancestors is enormously problematic: modern humans must be classified not only by bone structure, but also by specific behavior—the ability to plan future action; to follow traditions; and to use symbolic communication, including complex language and the ability to use and recognize symbols.

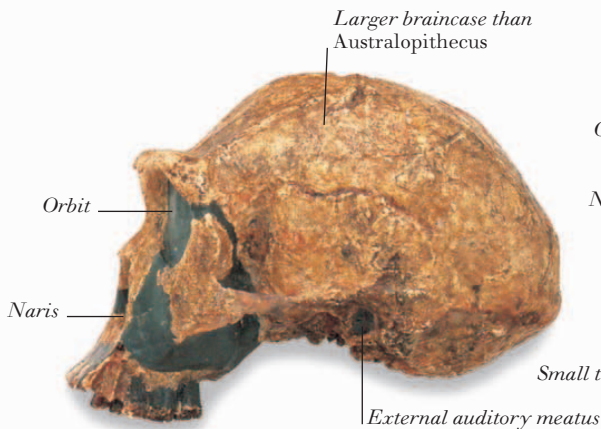
JAWBONE OF AUSTRALOPITHECUS (SOUTHERN APE)



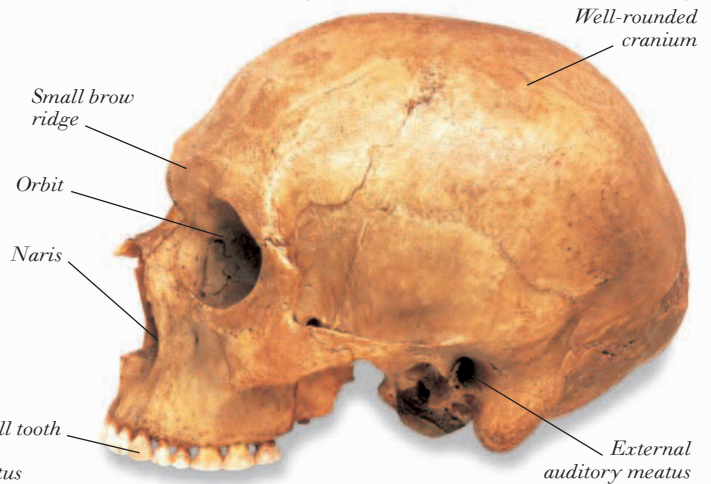
SKULL OF AUSTRALOPITHECUS (SOUTHERN APE)



SKULL OF HOMO HABILIS (FIRST MEMBER OF HOMO GENUS)

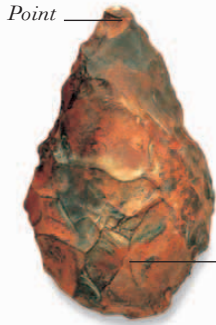


SKULL OF HOMO ERECTUS (UPRIGHT MAN)



SKULL OF HOMO SAPIENS (MODERN HUMAN)

FLINT TOOL MADE ABOUT 250,000 YEARS AGO



FLINT HANDAXE

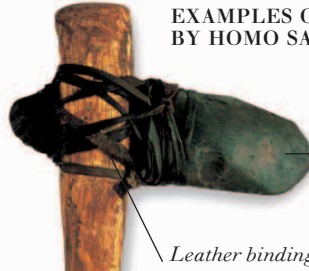
Sharp edge used to cut meat



FLINT FLAKE

Flint may have been carved by Homo erectus

EXAMPLES OF TOOLS USED BY HOMO SAPIENS



Leather binding

Axe used to clear land

Wooden mouthpiece held drill securely

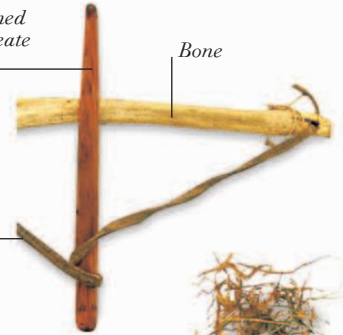
FIRE-MAKING TOOLS



WOODEN MOUTHPIECE

Wooden drill turned in drill hole to create spark

Bone



Leather bow kept drill upright

BOW DRILL



DRY STRAW

Drill hole



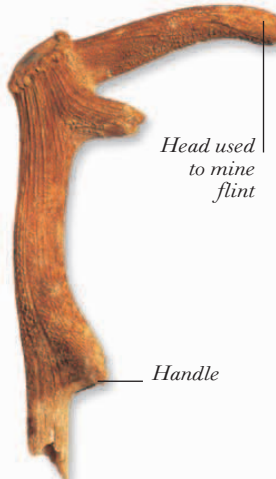
WOODEN HEARTH

Hammer head used to detach chips of flint



ANTLER HAMMER

Handle



RED DEER ANTLER HAMMER

Head used to mine flint

Handle

Handle

FARMING AX

EXAMPLES OF PREHISTORIC FOODS



MINT



WHEAT GRAINS



SALMON

SPEAR AND ARROW HEADS



Antler

HARPOON POINT

Twine binding



FISHING TACKLE

Wooden point hardened by fire



WOODEN ARROW

Flint glued into groove cut in shaft



FLINT ARROW





PLANTS

PLANT VARIETIES	112
FUNGI AND LICHENS	114
ALGAE AND SEAWEEDS	116
LIVERWORTS AND MOSSES	118
HORSETAILS, CLUBMOSSES, AND FERNS	120
GYMNOSPERMS 1	122
GYMNOSPERMS 2	124
MONOCOTYLEDONS AND DICOTYLEDONS	126
HERBACEOUS FLOWERING PLANTS	128
WOODY FLOWERING PLANTS	130
ROOTS	132
STEMS	134
LEAVES	136
PHOTOSYNTHESIS	138
FLOWERS 1	140
FLOWERS 2	142
POLLINATION	144
FERTILIZATION	146
SUCCULENT FRUITS	148
DRY FRUITS	150
GERMINATION	152
VEGETATIVE REPRODUCTION	154
DRYLAND PLANTS	156
WETLAND PLANTS	158
CARNIVOROUS PLANTS	160
EPIPHYTIC AND PARASITIC PLANTS	162

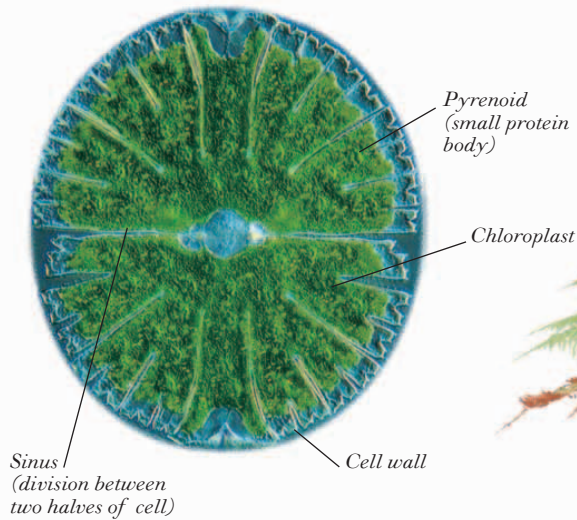
Plant varieties

THERE ARE MORE THAN 300,000 SPECIES of plant.

They show a wide diversity of forms and life-styles, ranging, for example, from delicate liverworts, adapted for life in a damp habitat, to cacti, capable of surviving in the desert, and from herbaceous plants, such as corn, which completes its life-cycle in one year, to the giant redwood tree, which can live for thousands of years. This diversity reflects the adaptations of plants to survive in a wide range of habitats. This is seen most clearly in the flowering plants (phylum Angiospermophyta), which are the most numerous, with over 250,000 species, and the most widespread, being found from the tropics to the poles. Despite their diversity, plants share certain characteristics: typically, plants are green, and make their food by photosynthesis; and most plants live in or on a substrate, such as soil, and do not actively move. Algae (kingdom Protista) and fungi (kingdom Fungi) have some plantlike characteristics and are often studied alongside plants, although they are not true plants.

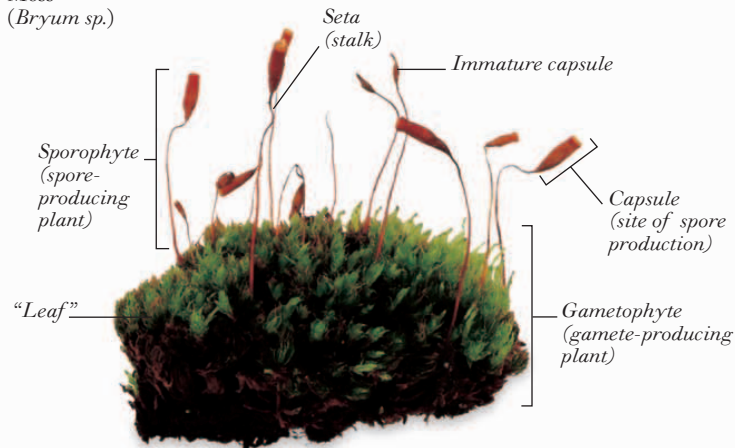
GREEN ALGA

Micrograph of desmid
(*Micrasterias* sp.)



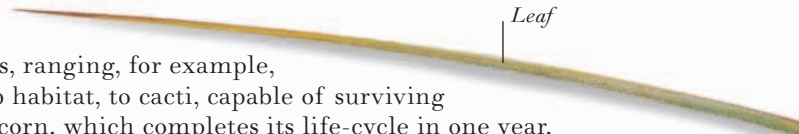
BRYOPHYTE

Moss
(*Bryum* sp.)



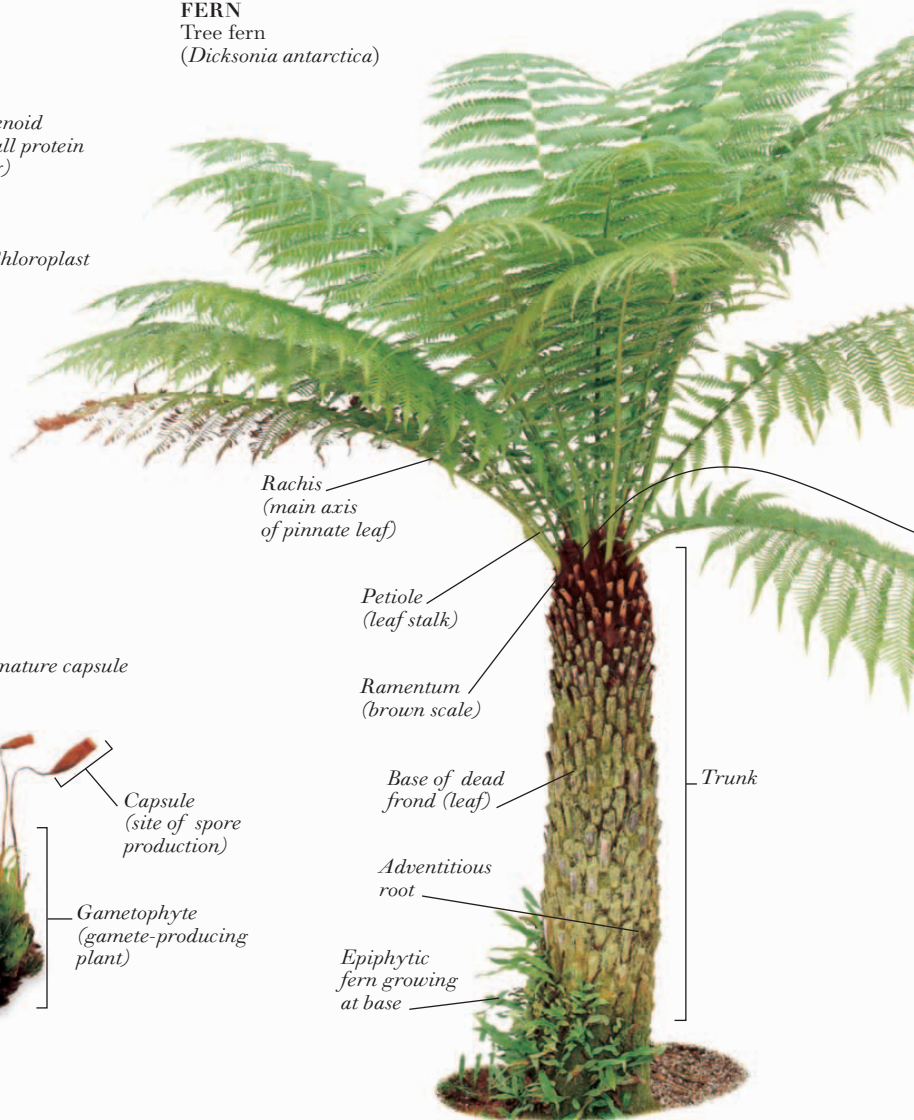
FLOWERING PLANT

Bromeliad
(*Acanthostachys strobilacea*)

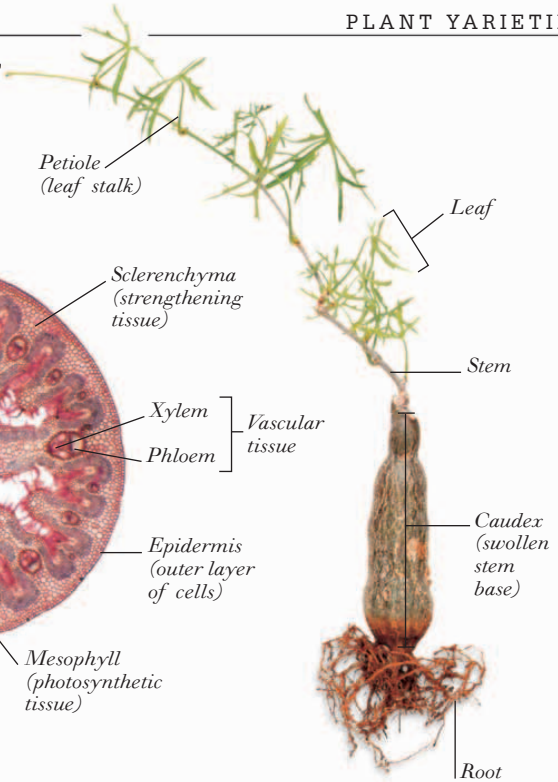


FERN

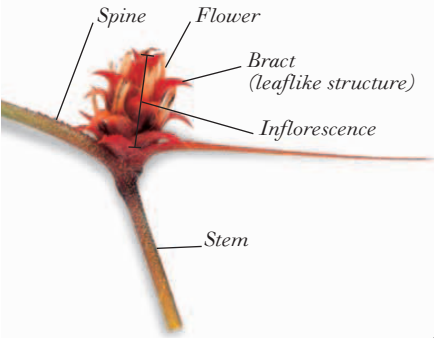
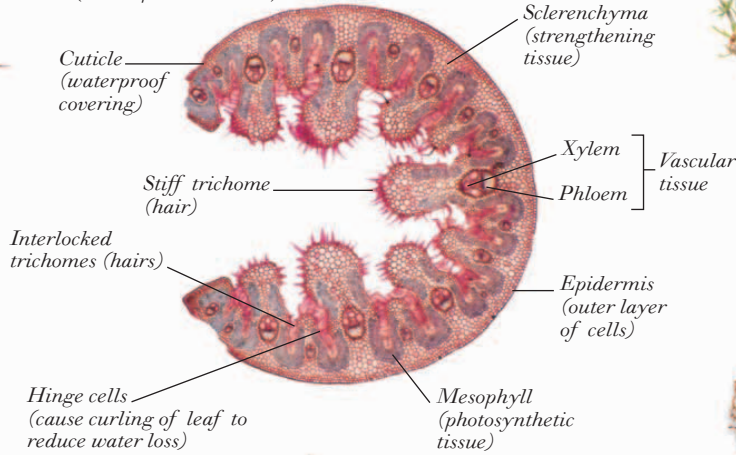
Tree fern
(*Dicksonia antarctica*)



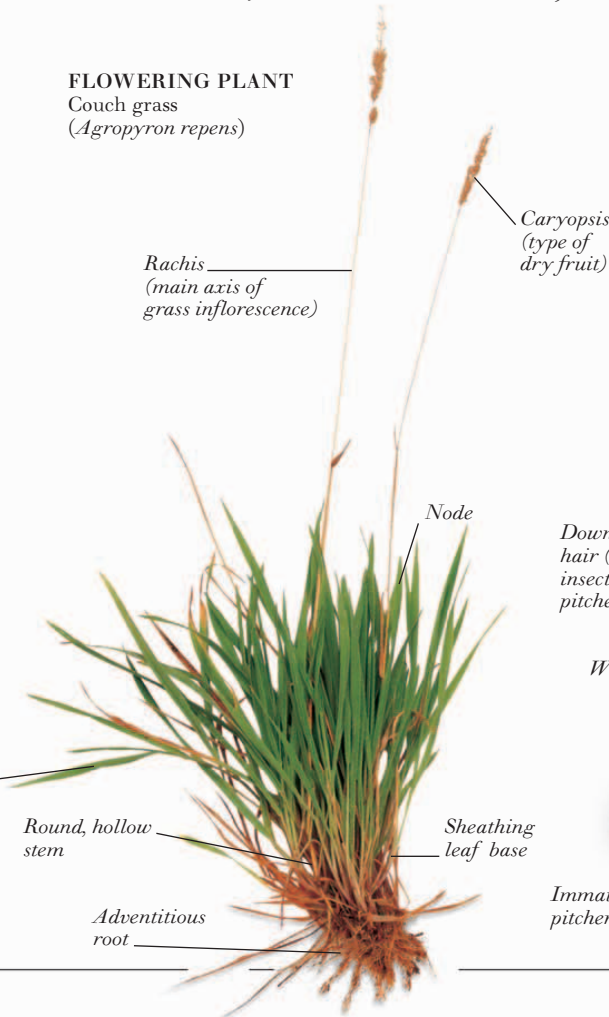
FLOWERING PLANT
Succulent
(*Kedrostis africana*)



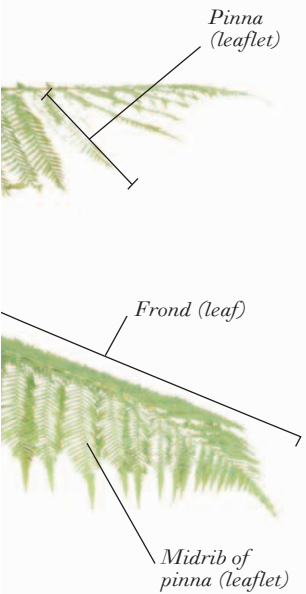
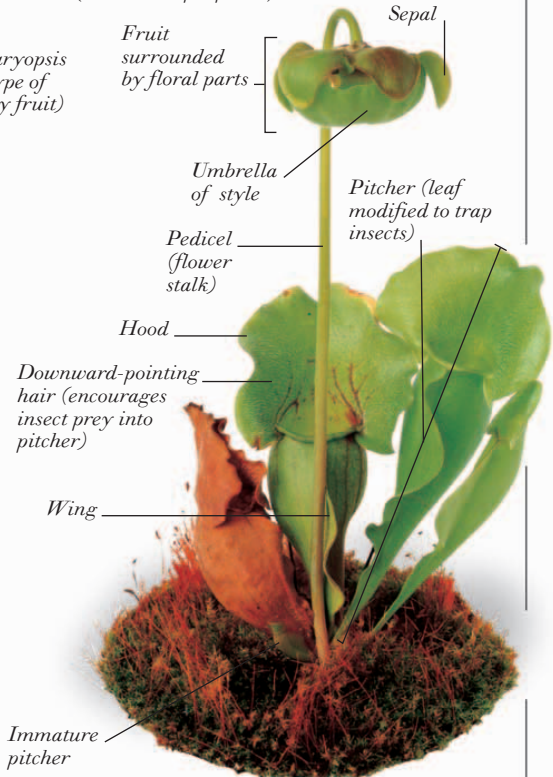
FLOWERING PLANT
Micrograph of cross-section
through leaf of marram grass
(*Ammophila arenaria*)



FLOWERING PLANT
Couch grass
(*Agropyron repens*)



FLOWERING PLANT
Pitcher plant
(*Sarracenia purpurea*)



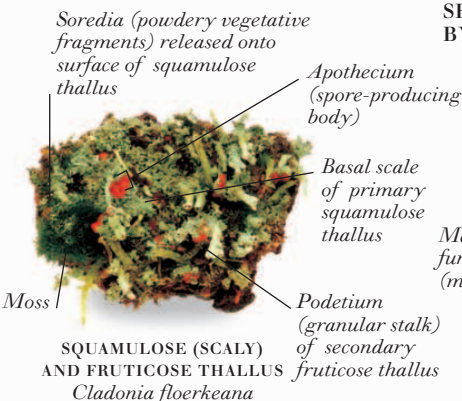
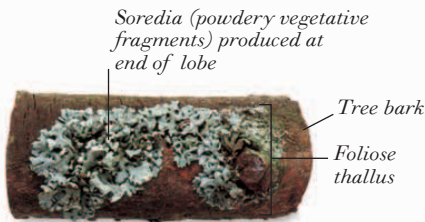
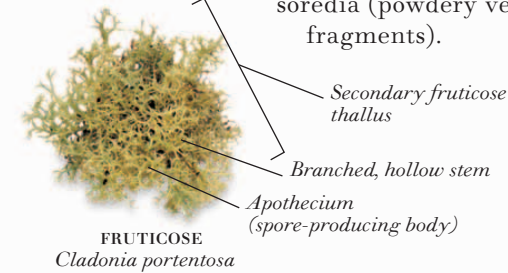
Lamina (blade)

Fungi and lichens

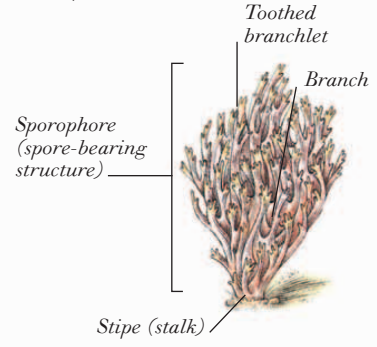
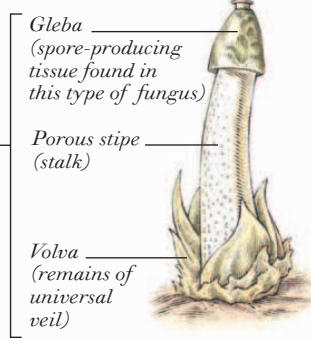
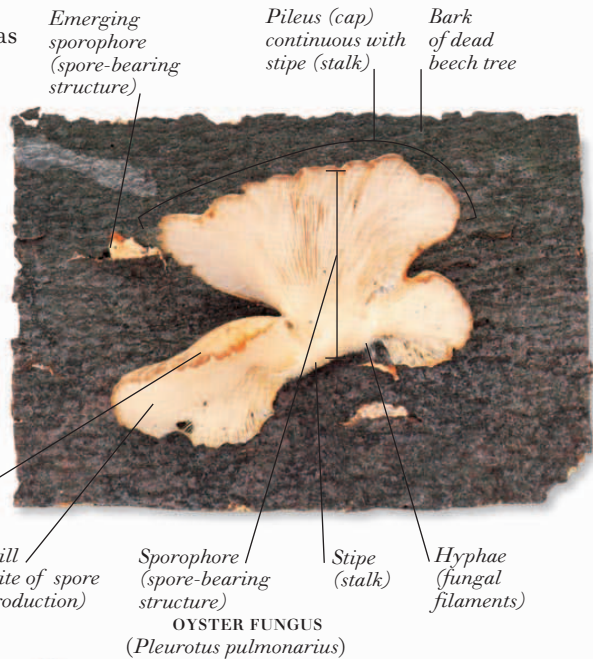
FUNGI WERE ONCE THOUGHT OF AS PLANTS but are now classified as a separate kingdom. This kingdom includes not only the familiar mushrooms, puffballs, stinkhorns, and molds, but also yeasts, smuts, rusts, and lichens. Most fungi are multicellular, consisting of a mass of threadlike hyphae that together form a mycelium. However, the simpler fungi (e.g., yeasts) are microscopic, single-celled organisms. Typically, fungi reproduce by means of spores. Most fungi feed on dead or decaying matter, or on living organisms. A few fungi obtain their food from plants or algae, with which they have a symbiotic (mutually advantageous) relationship. Lichens are a symbiotic partnership between algae and fungi. Of the six types of lichens, the three most common are crustose (flat and crusty), foliose (leafy), and fruticose (shrublike). Some lichens (e.g., *Cladonia floerkeana*)

are a combination of types. Lichens reproduce by means of spores or soredia (powdery vegetative fragments).

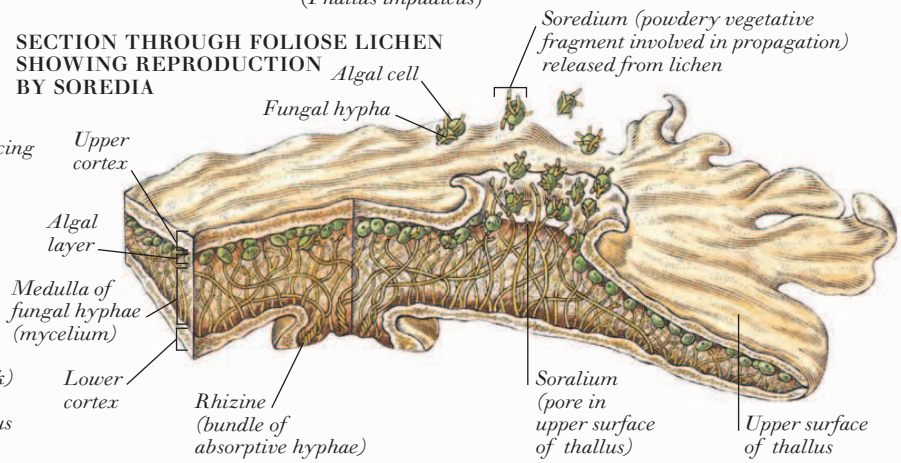
EXAMPLES OF LICHENS



EXAMPLES OF FUNGI

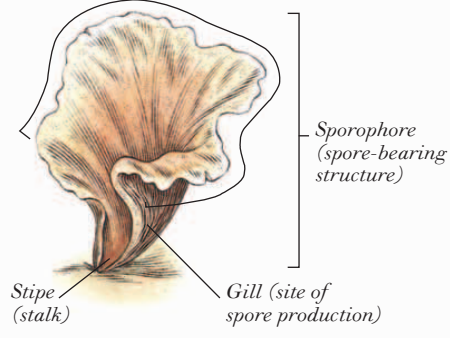


SECTION THROUGH FOLIOSE LICHEN SHOWING REPRODUCTION BY SOREDIA





COMMON PUFFBALL
(*Scleroderma citrinum*)

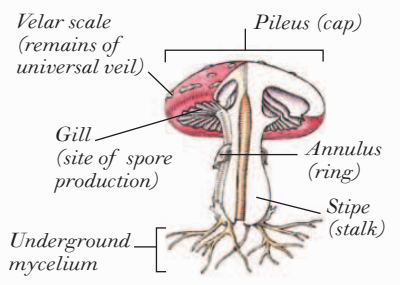


HOHENBUEHELIA PETALOIDES



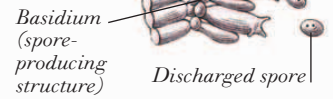
FRINGED CRUMBLE CAP
(*Psathyrella candolleana*)

LIFE-CYCLE OF A MUSHROOM

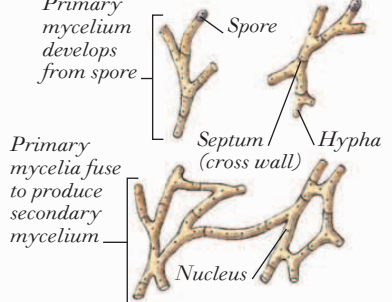


MATURE SPOROPHORE

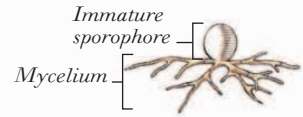
Sporophore (spore-bearing structure)



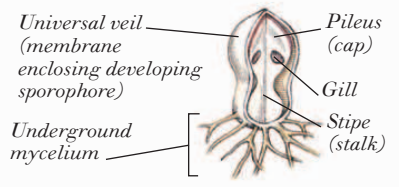
SECTION OF GILL



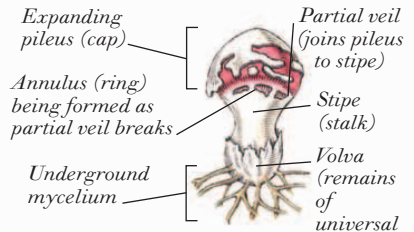
SPORES GERMINATE AND PRODUCE MYCELIUM



MYCELIUM FORMS SPOROPHORE



SPOROPHORE GROWS ABOVE GROUND



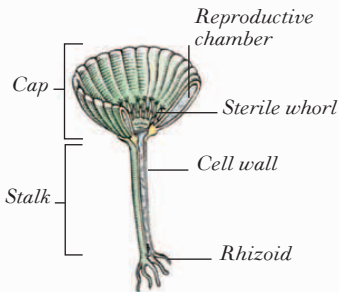
UNIVERSAL VEIL BREAKS

Algae and seaweeds

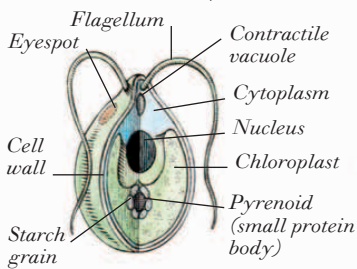
ALGAE ARE NOT TRUE PLANTS. They form a diverse group of plantlike organisms that belong to the kingdom Protista. Like plants, algae possess the green pigment chlorophyll and make their own food by photosynthesis (see pp. 138-139). Many algae also possess other pigments by which they can be classified; for example, the brown pigment fucoxanthin is found in the brown algae. Some of the 10 phyla of algae are exclusively unicellular (single-celled); others also contain aggregates of cells in filaments or colonies. Three phyla—the Chlorophyta (green algae), Rhodophyta (red algae), and Phaeophyta (brown algae)—contain larger, multicellular, thalloid (flat), marine organisms commonly known as seaweeds.

EXAMPLES OF ALGAE

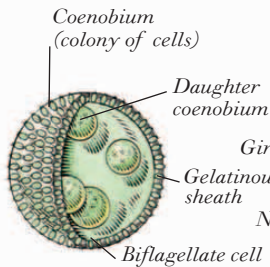
Most algae can reproduce sexually. For example, in the brown seaweed *Fucus vesiculosus*, gametes (sex cells) are produced in conceptacles (chambers) in the receptacles (fertile tips of fronds); after their release into the sea, antherozoids (male gametes) and oospheres (female gametes) fuse; the resulting zygote settles on a rock and develops into a new seaweed.



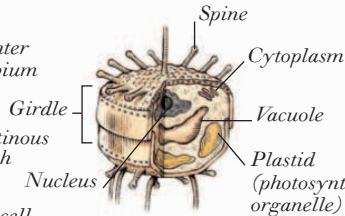
GREEN ALGA
Acetabularia sp.



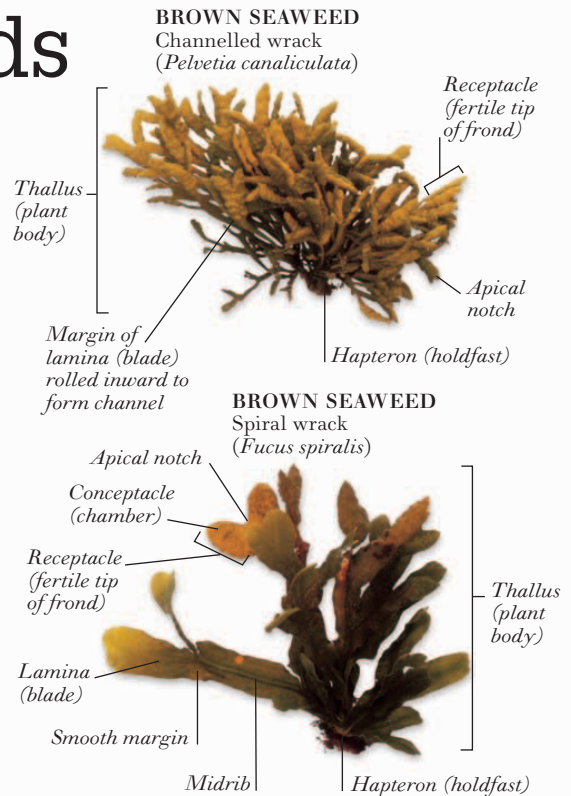
GREEN ALGA
Chlamydomonas sp.



GREEN ALGA
Volvox sp.



DIATOM
Thalassiosira sp.

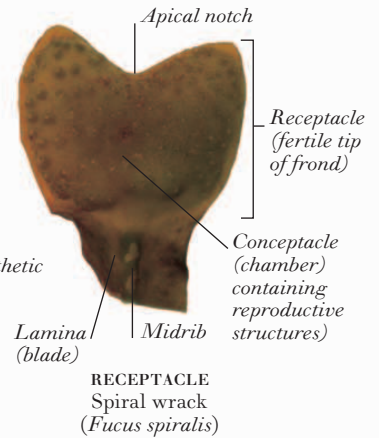


BROWN SEAWEED
Channelled wrack
(*Pelvetia canaliculata*)

BROWN SEAWEED
Spiral wrack
(*Fucus spiralis*)

BROWN SEAWEED
Oarweed
(*Laminaria digitata*)

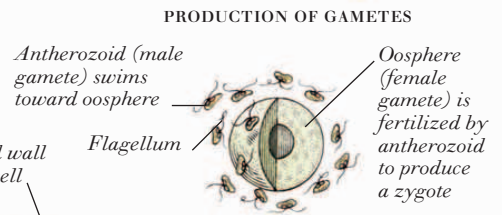
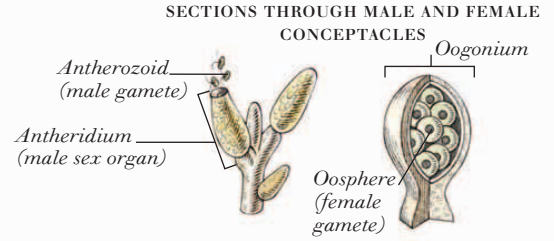
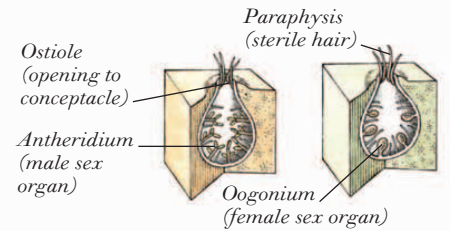
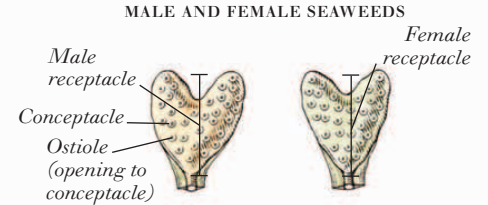
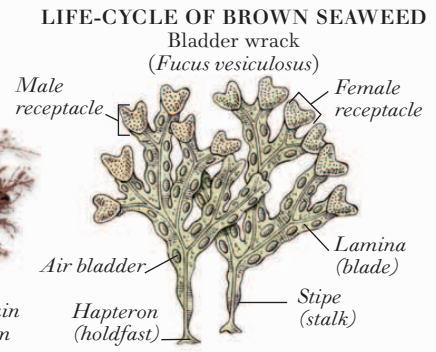
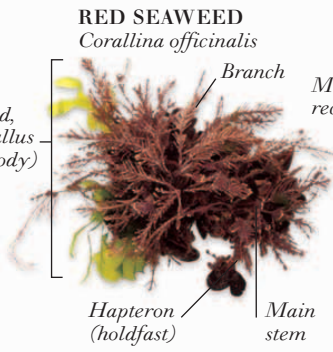
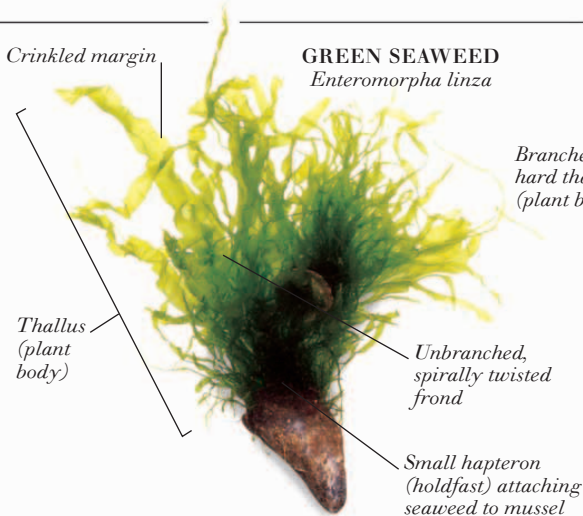
Thallus (plant body)



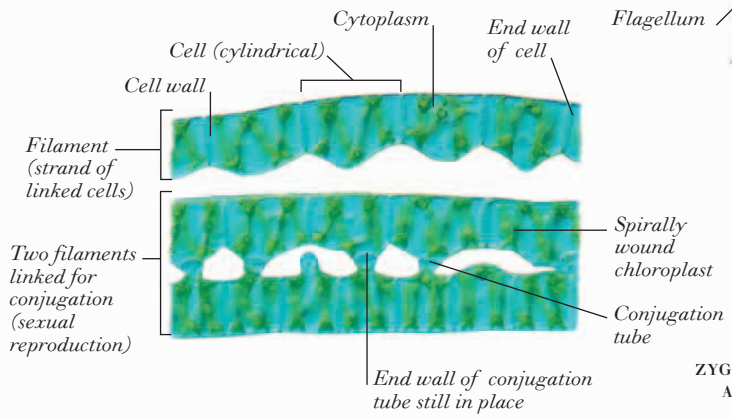
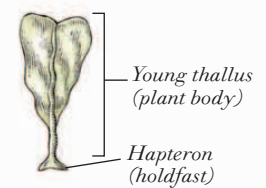
RECEPTACLE
Spiral wrack
(*Fucus spiralis*)



Lamina (blade)
palmately
divided



FERTILIZATION

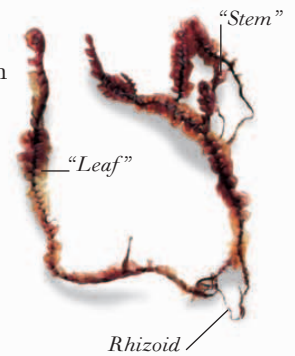


Liverworts and mosses

LIVERWORTS AND MOSSES ARE SMALL, LOW-GROWING PLANTS that belong to the phylum Bryophyta. Bryophytes do not have true stems, leaves, or roots (they are anchored to the ground by rhizoids), nor do they have the vascular tissues (xylem and phloem) that transport water and nutrients in higher plants. With no outer, waterproof cuticle, bryophytes are susceptible to drying out, and most grow in moist habitats. The bryophyte life-cycle has two stages. In stage one, the green plant (gametophyte) produces male and female gametes (sex cells), which fuse to form a zygote. In stage two, the zygote develops into a sporophyte that remains attached to the gametophyte. The sporophyte produces spores, which are released and germinate into new green plants. Liverworts (class Hepaticae) grow horizontally and may be thalloid (flat and ribbonlike) or “leafy.” Mosses (class Musci) typically have an upright “stem” with spirally arranged “leaves.”

A LEAFY LIVERWORT

Scapania undulata



A THALLOID LIVERWORT

Marchantia polymorpha

Archegoniophore (stalked structure carrying archegonia)

Disk
Lobe
Stalk

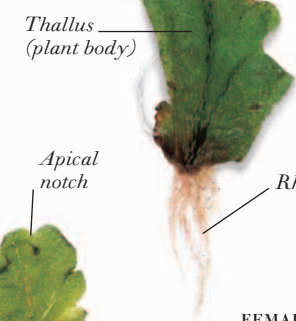
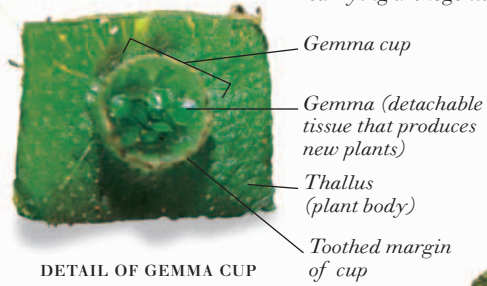
Disk

Lobe

Stalk

Ray (radial groove)
Stalk
Disk

ARCHEGONIOPHORE FROM BELOW



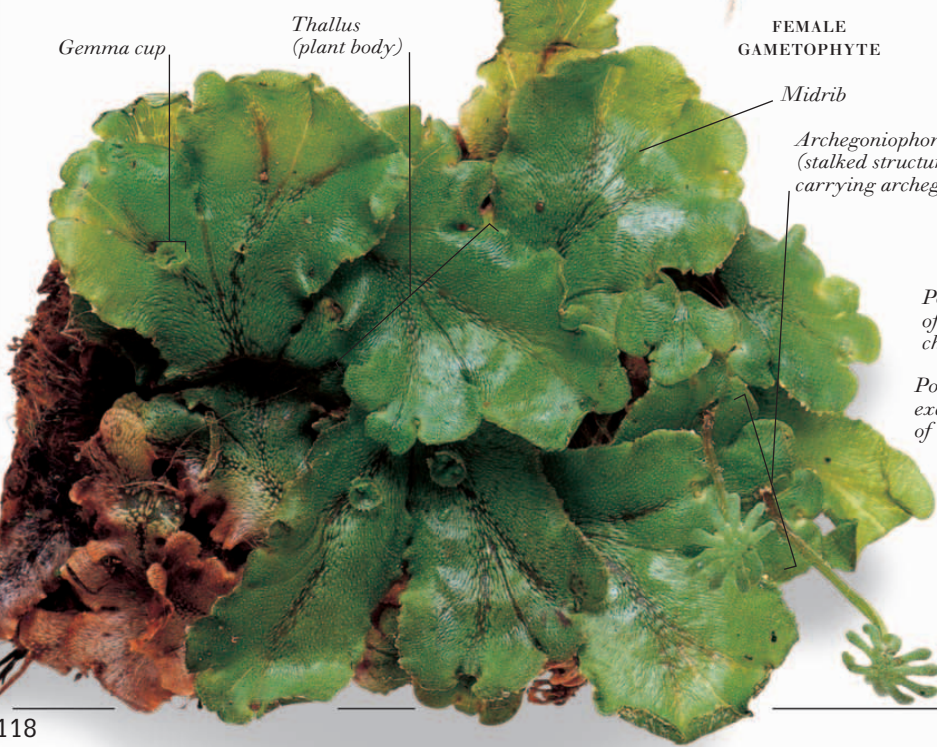
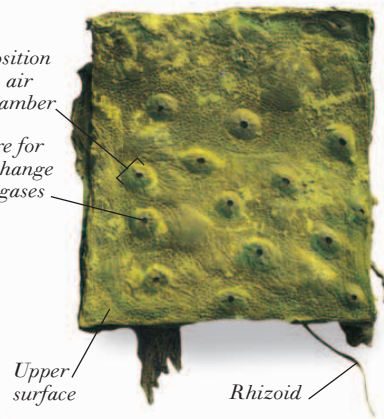
SIDE VIEW OF ARCHEGONIOPHORE



MICROGRAPH OF LOBE

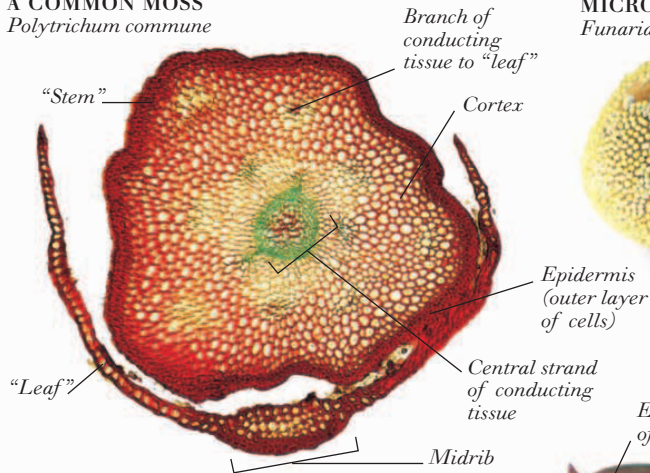
MICROGRAPH OF THALLUS
Conocephalum conicum

Position of air chamber
Pore for exchange of gases



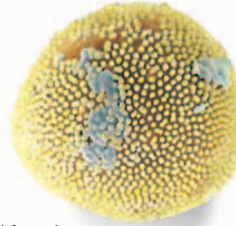
FEMALE GAMETOPHYTE

A COMMON MOSS
Polytrichum commune

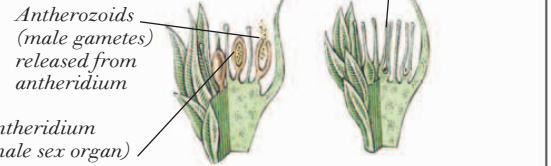
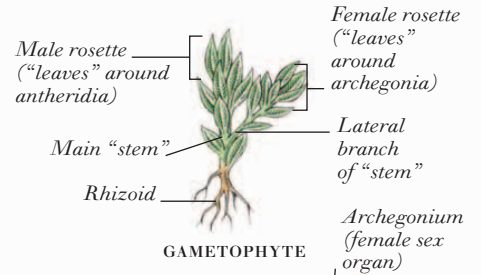


MICROGRAPH OF CROSS-SECTION THROUGH STEM AND LEAF

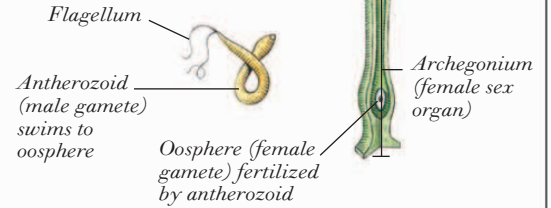
MICROGRAPH OF MOSS SPORE
Funaria hygrometrica



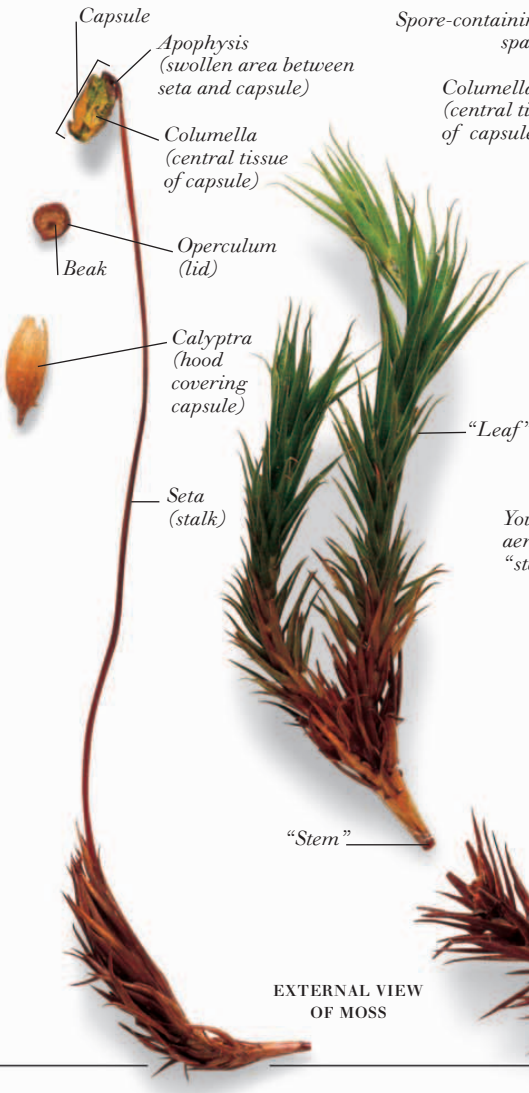
LIFE-CYCLE OF MOSS
Funaria sp.



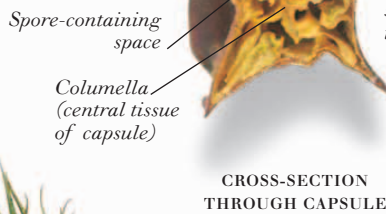
SECTION THROUGH MATURE MALE APEX SECTION THROUGH MATURE FEMALE APEX



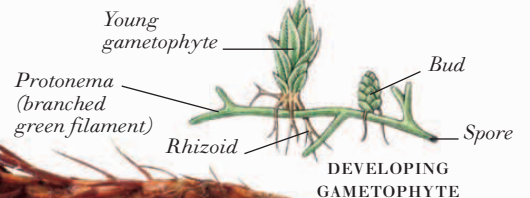
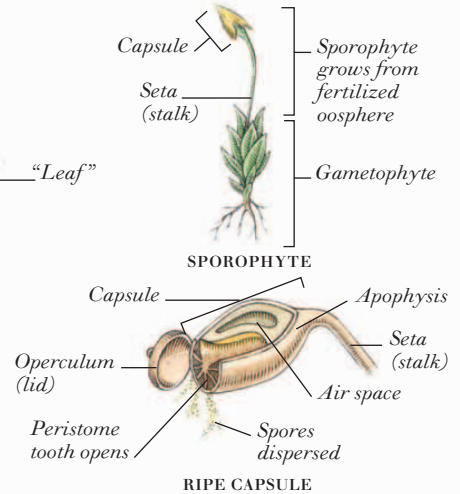
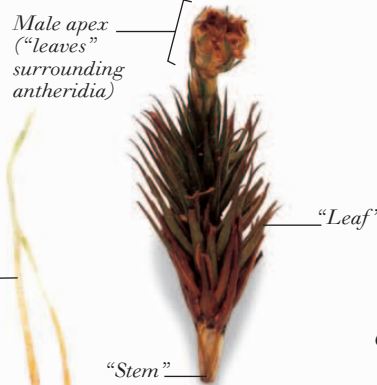
FERTILIZATION



EXTERNAL VIEW OF MOSS



CROSS-SECTION THROUGH CAPSULE



Horsetails, clubmosses, and ferns

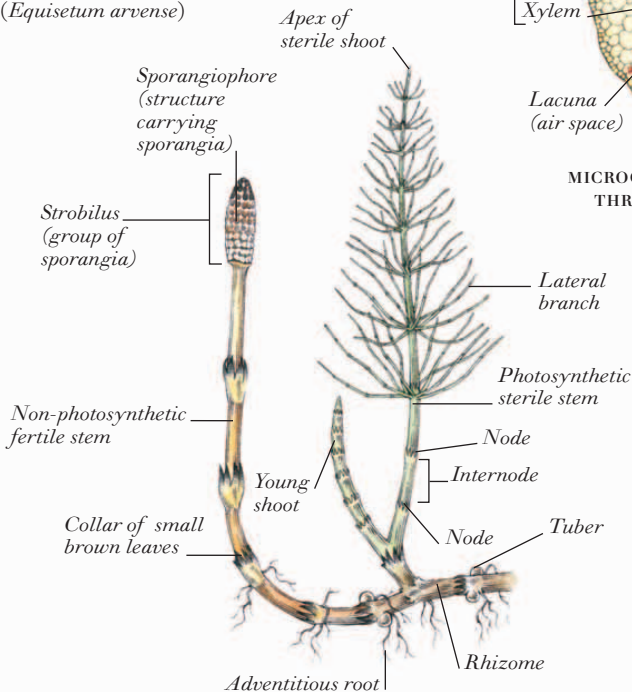


FROND
Male fern
(*Dryopteris filix-mas*)

HORSETAILS, CLUBMOSES, AND FERNS are primitive land plants, which, like higher plants, have stems, roots, and leaves, and vascular systems that transport water, minerals, and food. However, unlike higher plants, they do not produce seeds when reproducing. Their life-cycles involve two stages. In stage one, the sporophyte (green plant) produces spores in sporangia. In stage two, the spores germinate, developing into small, short-lived gametophyte plants that produce male and female gametes (sex cells); the gametes fuse to form a zygote from which a new sporophyte plant develops. Horsetails (phylum Sphenophyta) have erect, green stems with branches arranged in whorls; some stems are fertile and have a single spore-producing strobilus (group of sporangia) at the tip.

Clubmosses (phylum Lycopodophyta) typically have small leaves arranged spirally around the stem, with spore-producing strobili at the tip of some stems. Ferns (phylum Filicinophyta) typically have large, pinnate fronds (leaves); sporangia, grouped together in sori, develop on the underside of fertile fronds.

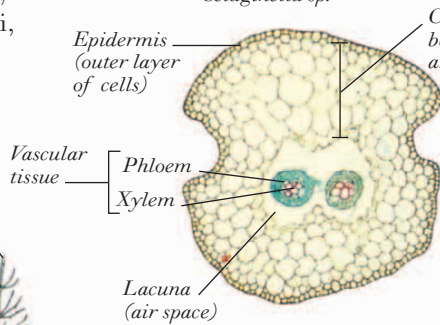
HORSETAIL
Common horsetail
(*Equisetum arvense*)



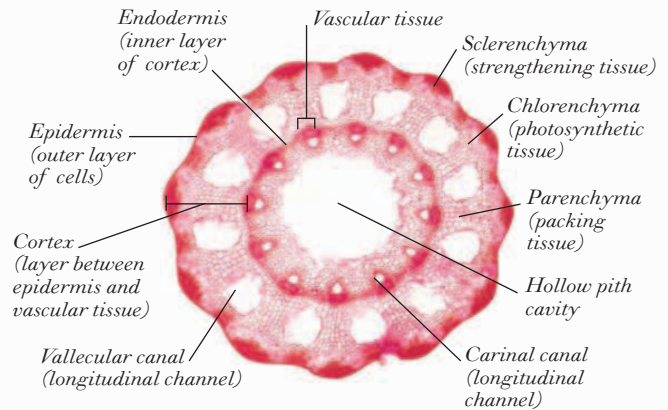
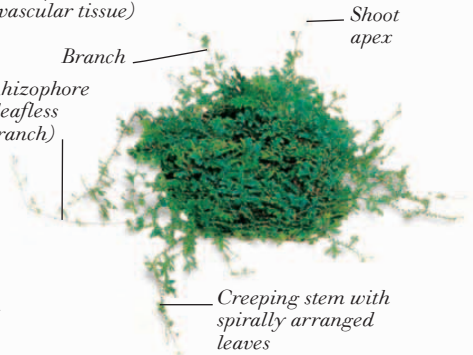
CLUBMOSS
Lycopodium sp.



CLUBMOSS
Selaginella sp.



MICROGRAPH OF CROSS-SECTION THROUGH CLUBMOSS STEM

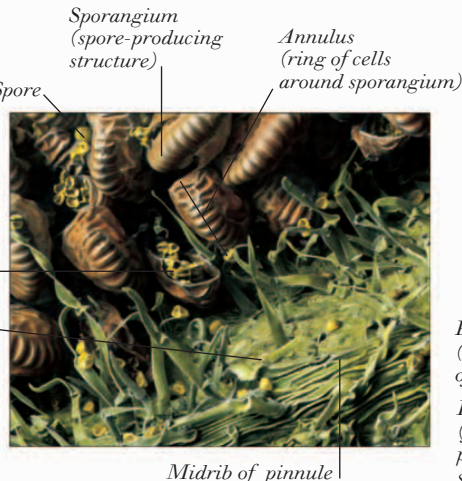


MICROGRAPH OF CROSS-SECTION THROUGH HORSETAIL STEM

SPORE PRODUCTION IN FERN

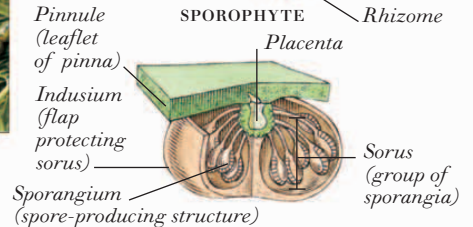
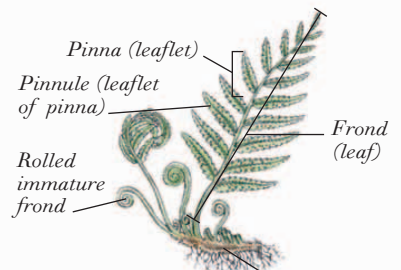


MICROGRAPH OF LOWER SURFACE OF FERTILE PINNULE



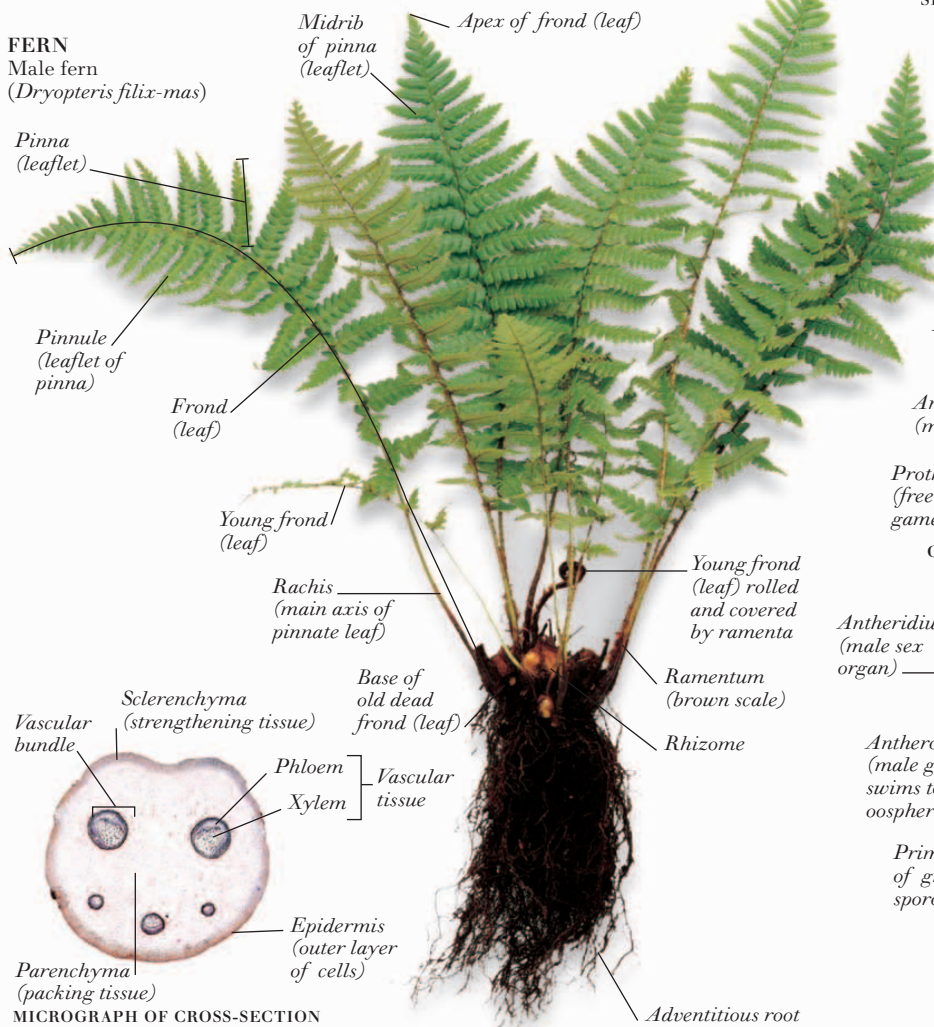
MICROGRAPH OF SPORANGIA ON LOWER SURFACE OF FERTILE PINNULE

LIFE-CYCLE OF FERN



SECTION THROUGH MATURE PINNULE

FERN
Male fern
(*Dryopteris filix-mas*)



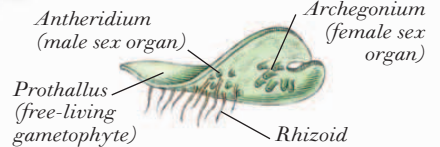
MICROGRAPH OF CROSS-SECTION THROUGH FERN RACHIS



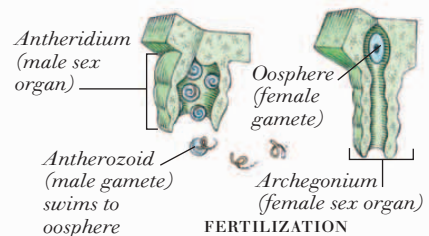
RELEASE OF SPORES FROM SPORANGIUM



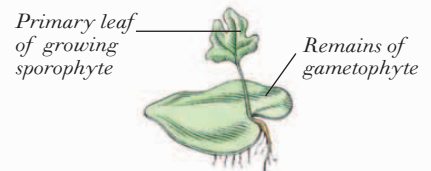
GERMINATION OF SPORE



GAMETOPHYTE PRODUCES GAMETES



FERTILIZATION

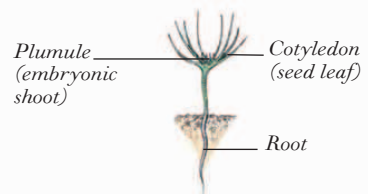
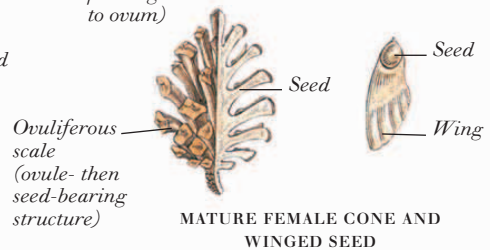
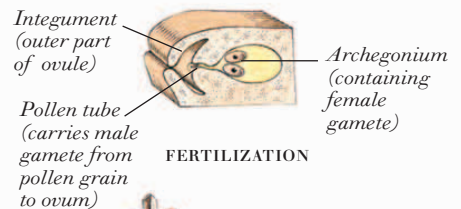
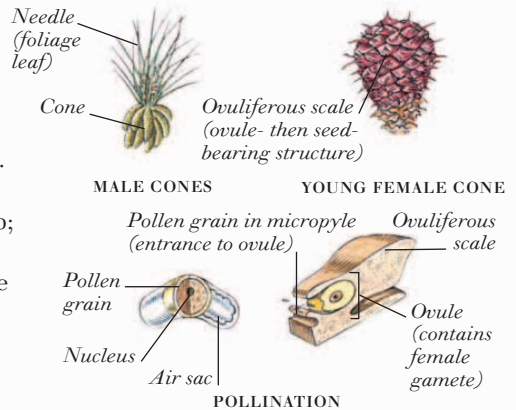


FERTILIZED OOSPHERE GROWS INTO NEW SPOROPHYTE PLANT

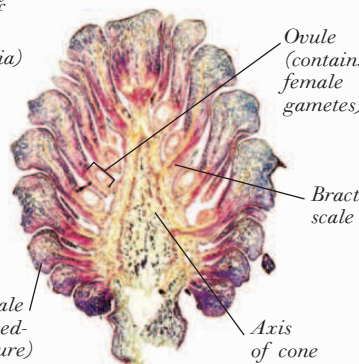
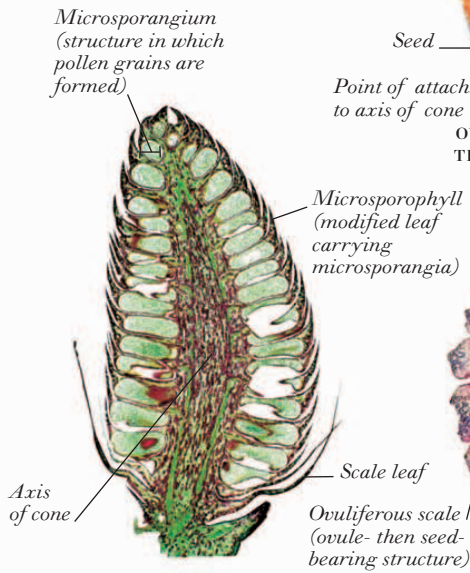
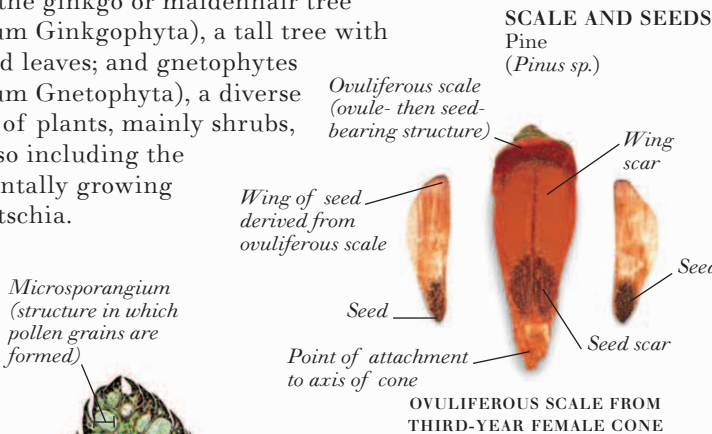
Gymnosperms 1

THE GYMNOSPERMS ARE FOUR RELATED PHYLA of seed-producing plants; their seeds, however, lack the protective, outer covering that surrounds the seeds of flowering plants. Typically, gymnosperms are woody, perennial shrubs or trees, with stems, leaves, and roots, and a well-developed vascular (transportat) system. The reproductive structures in most gymnosperms are cones: male cones produce microspores in which male gametes (sex cells) develop; female cones produce megaspores in which female gametes develop. Microspores are blown by the wind to female cones, male and female gametes fuse during fertilization, and a seed develops. The four gymnosperm phyla are the conifers (phylum Coniferophyta), mostly tall trees; cycads (phylum Cycadophyta), small palmlike trees; the ginkgo or maidenhair tree (phylum Ginkgophyta), a tall tree with bilobed leaves; and gnetophytes (phylum Gnetophyta), a diverse group of plants, mainly shrubs, but also including the horizontally growing welwitschia.

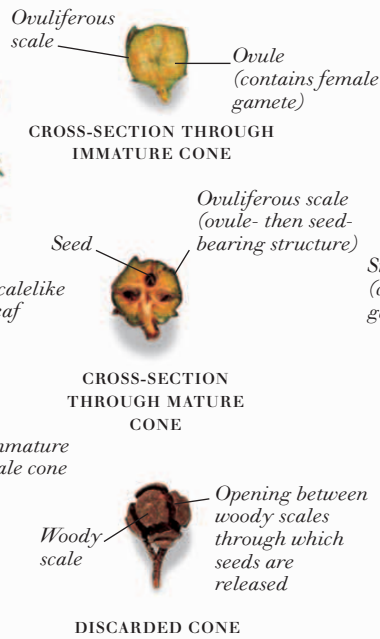
LIFE-CYCLE OF SCOTS PINE (*Pinus sylvestris*)



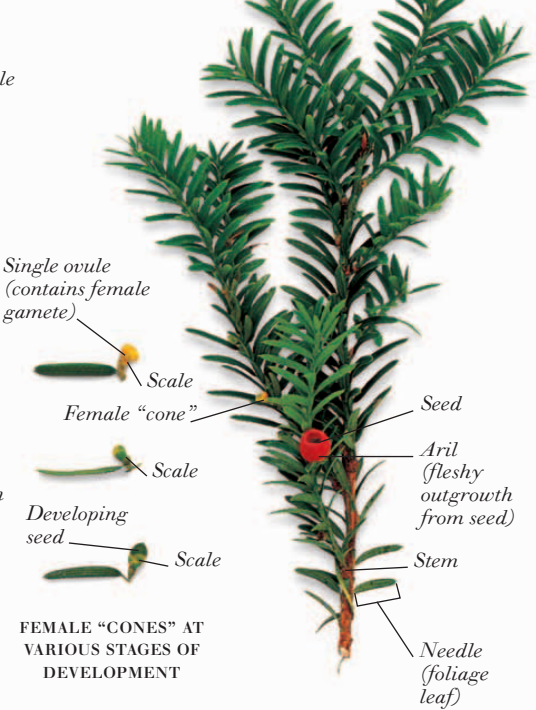
WELWITSCHIA (*Welwitschia mirabilis*)



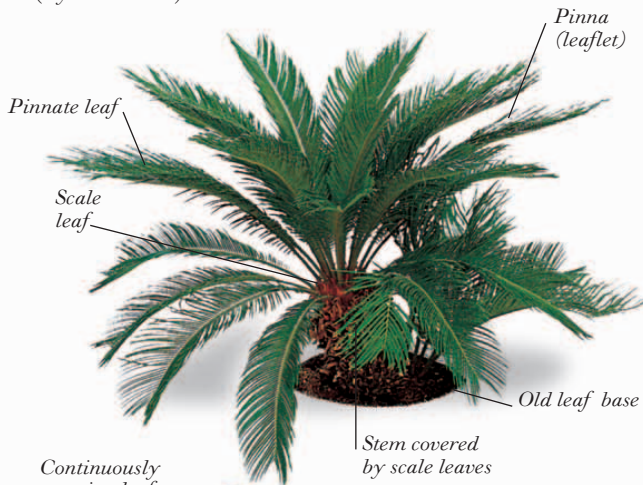
SMOOTH CYPRESS
(*Cupressus glabra*)



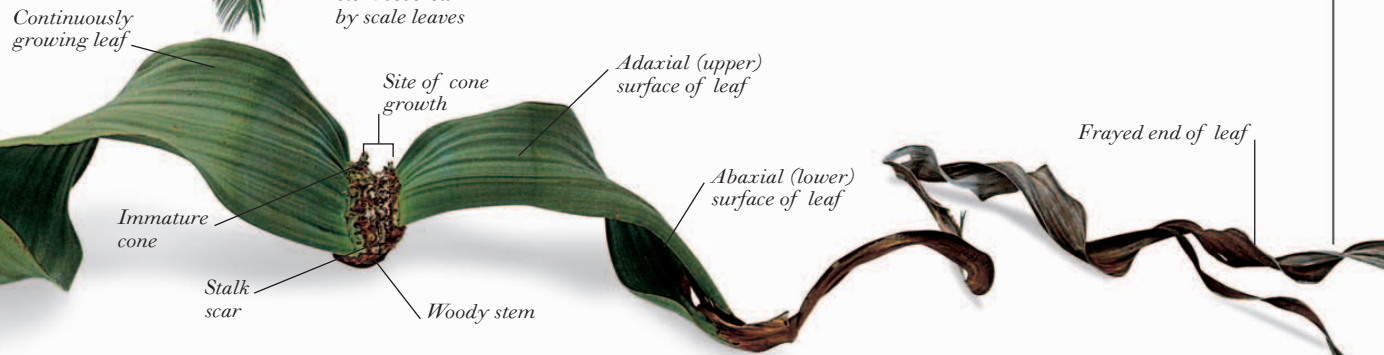
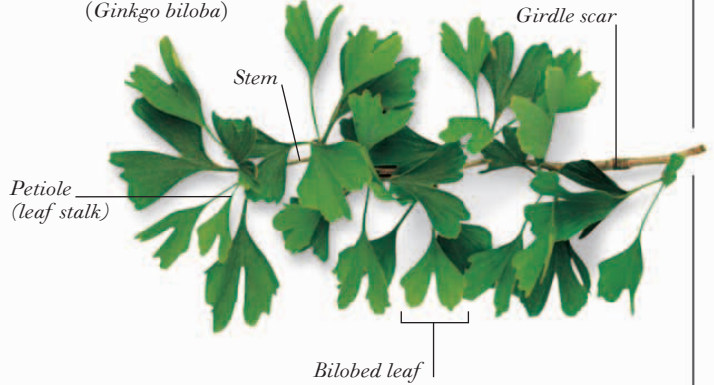
YEW
(*Taxus baccata*)



CYCAD
Sago palm
(*Cycas revoluta*)

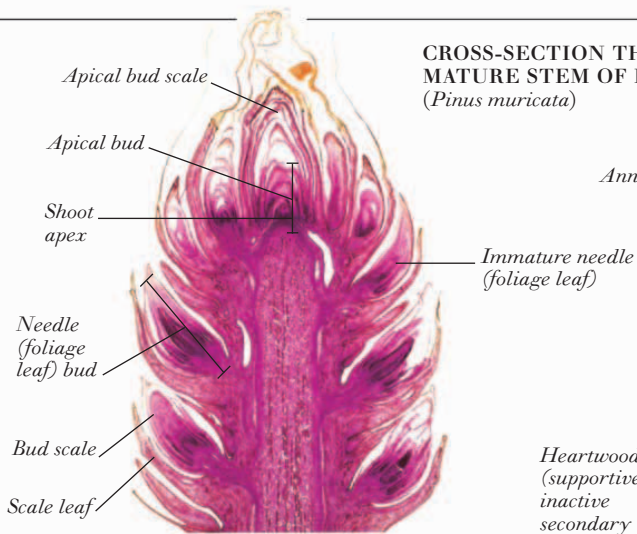


MAIDENHAIR TREE
(*Ginkgo biloba*)

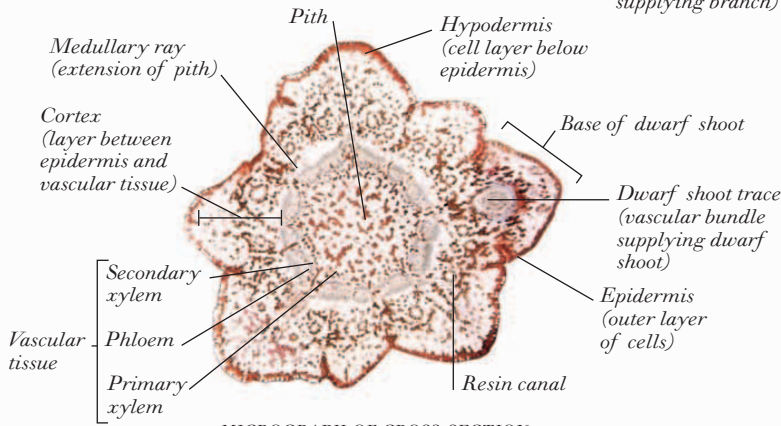


Gymnosperms 2

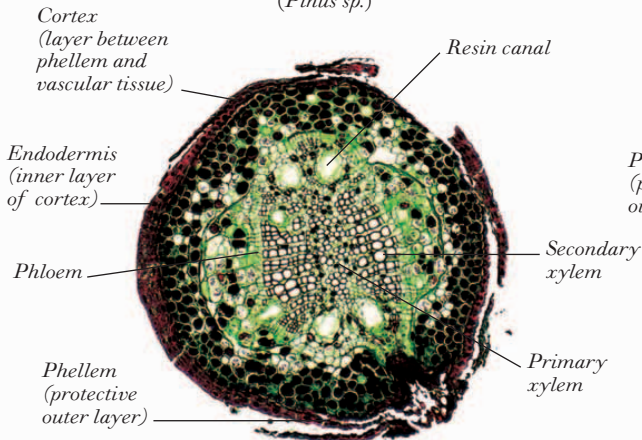




MICROGRAPH OF LONGITUDINAL SECTION THROUGH SHOOT APEX OF PINE (*Pinus sp.*)

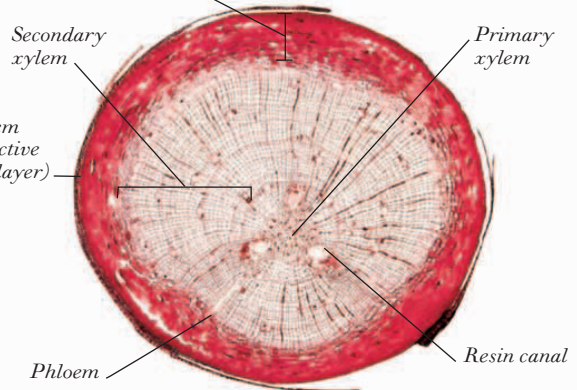
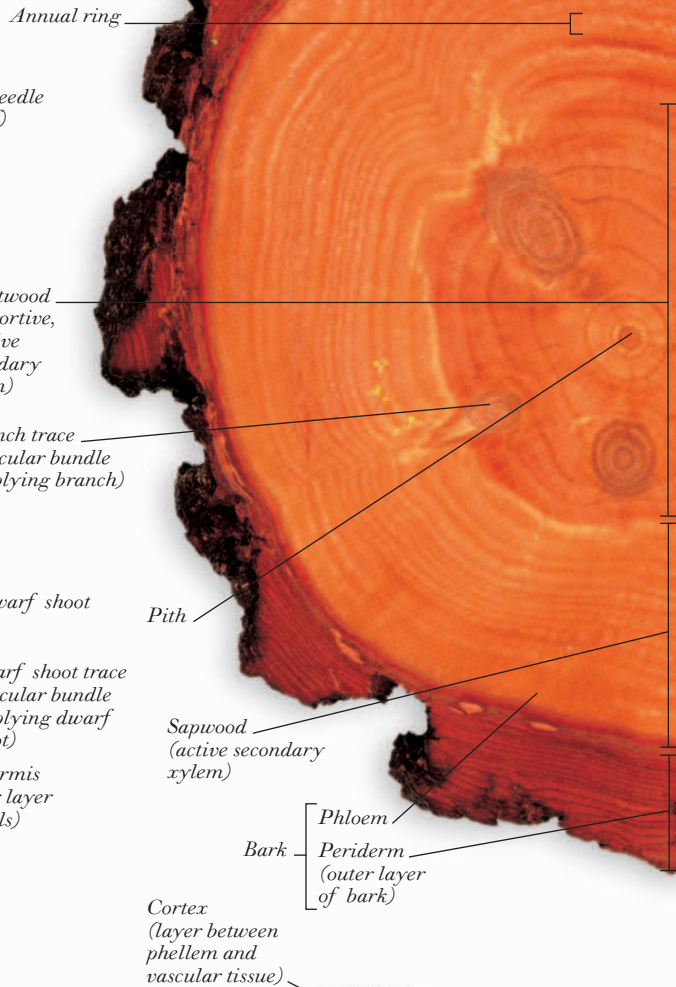


MICROGRAPH OF CROSS-SECTION THROUGH YOUNG STEM OF PINE (*Pinus sp.*)



MICROGRAPH OF CROSS-SECTION THROUGH YOUNG ROOT OF PINE (*Pinus sp.*)

CROSS-SECTION THROUGH MATURE STEM OF BISHOP PINE (*Pinus muricata*)



MICROGRAPH OF CROSS-SECTION THROUGH MATURE ROOT OF PINE (*Pinus sp.*)

Monocotyledons and dicotyledons

COMPARISONS BETWEEN MONOCOTYLEDONS AND DICOTYLEDONS

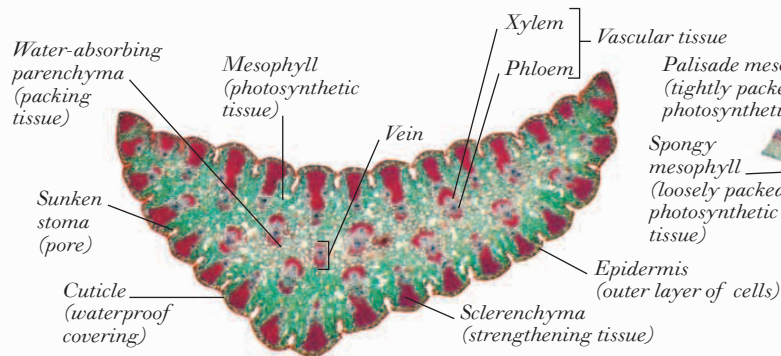
FLOWERING PLANTS (PHYLUM ANGIOSPERMOPHYTA) are divided into two classes:

monocotyledons (class Monocotyledoneae) and dicotyledons (class Dicotyledoneae). Typically, monocotyledons have seeds with one cotyledon (seed leaf); their foliage leaves are narrow with parallel veins; the flower components occur in multiples of three; sepals and petals are indistinguishable and are known as tepals; vascular (transport) tissues are scattered in random bundles throughout the stem; and, since they lack stem cambium (actively dividing cells that produce wood), most monocotyledons are herbaceous (see pp. 128-129).

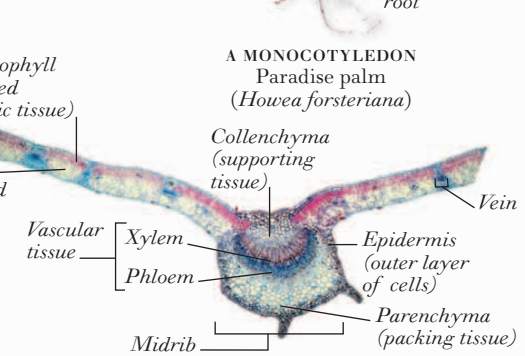
Dicotyledons have seeds with two cotyledons; leaves are broad with a central midrib and branched veins; flower parts occur in multiples of four or five; sepals are generally small and green; petals are large and colorful; vascular bundles are arranged in a ring around the edge of the stem; and, because many dicotyledons possess wood-producing stem cambium, there are woody forms (see pp. 130-131) as well as herbaceous ones.



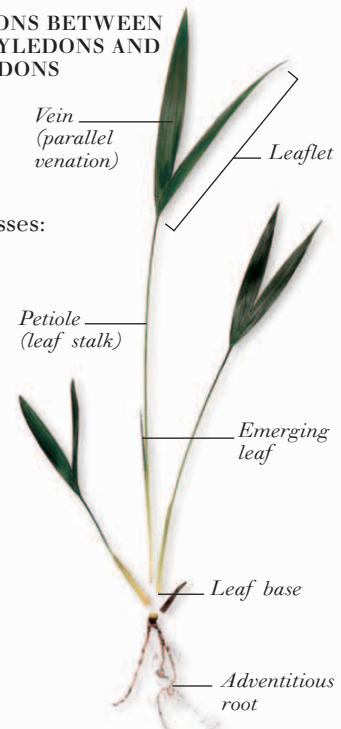
CROSS-SECTION THROUGH MONOCOTYLEDONOUS LEAF BASES



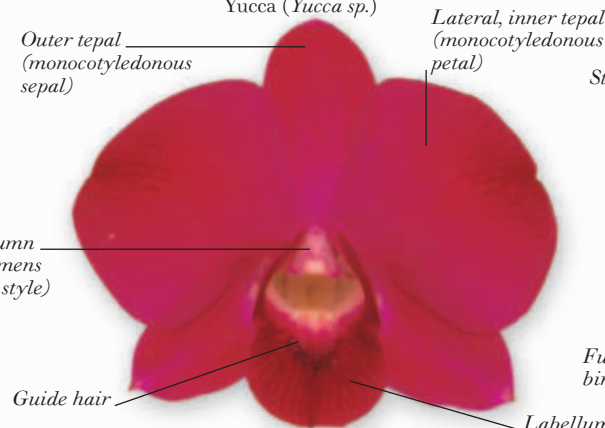
MICROGRAPH OF CROSS-SECTION THROUGH A MONOCOTYLEDONOUS LEAF
Yucca (*Yucca* sp.)



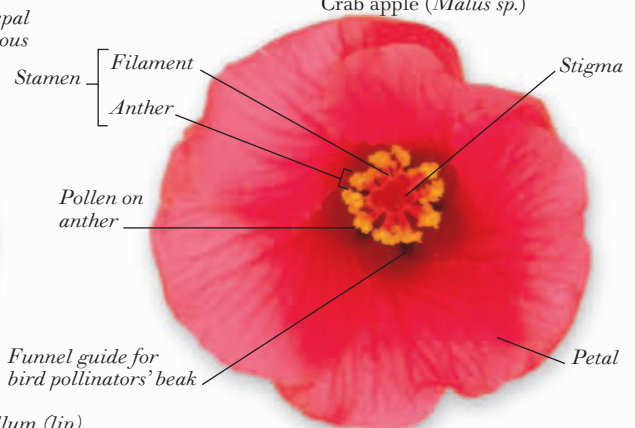
MICROGRAPH OF CROSS-SECTION THROUGH A DICOTYLEDONOUS LEAF
Crab apple (*Malus* sp.)



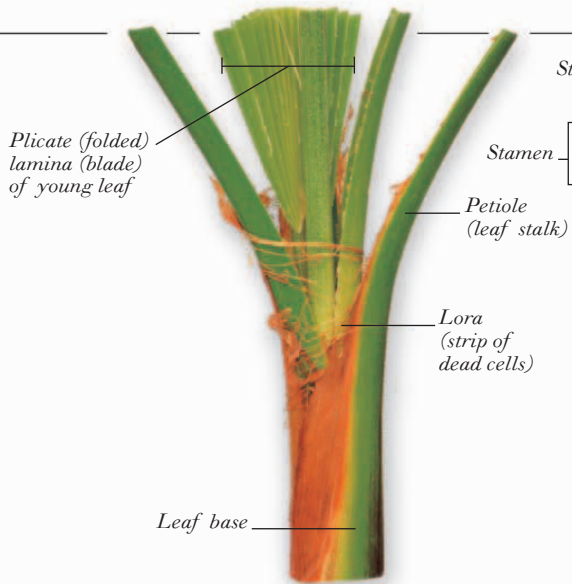
A MONOCOTYLEDON
Paradise palm
(*Howea forsteriana*)



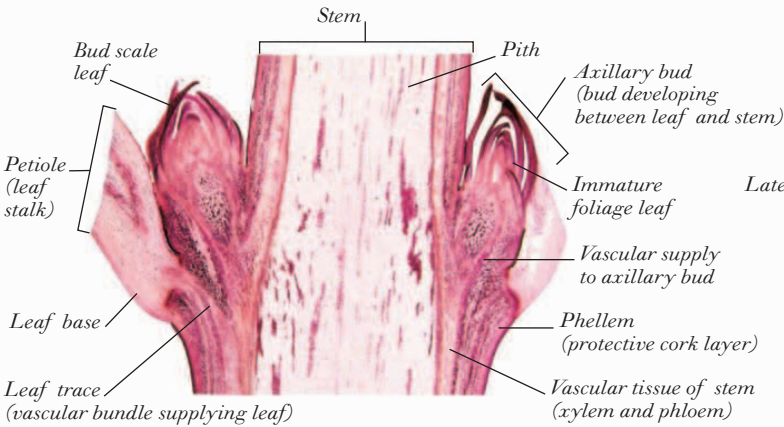
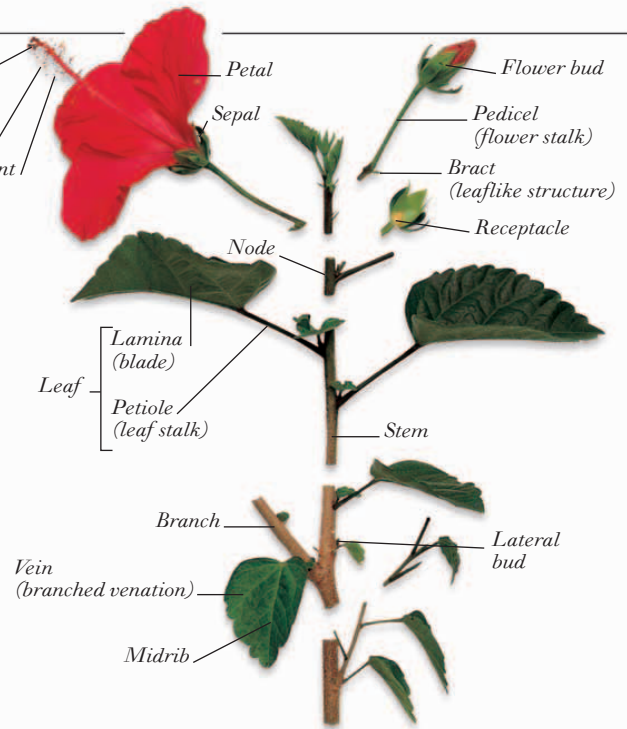
A MONOCOTYLEDONOUS FLOWER
Orchid
(*Phalaenopsis* sp.)



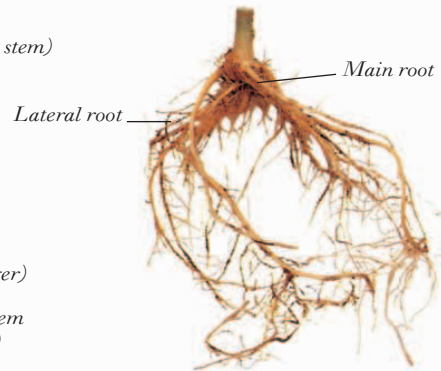
A DICOTYLEDONOUS FLOWER
Hibiscus
(*Hibiscus rosa-sinensis*)



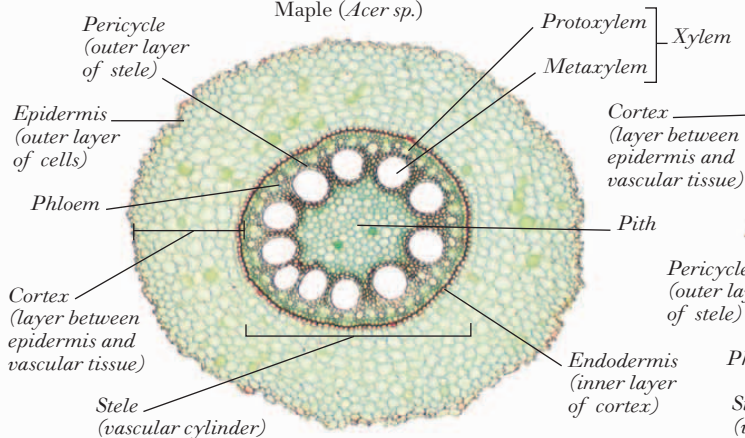
MONOCOTYLEDONOUS LEAF BASES FORMING STEM
Chusan palm
(*Trachycarpus fortunei*)



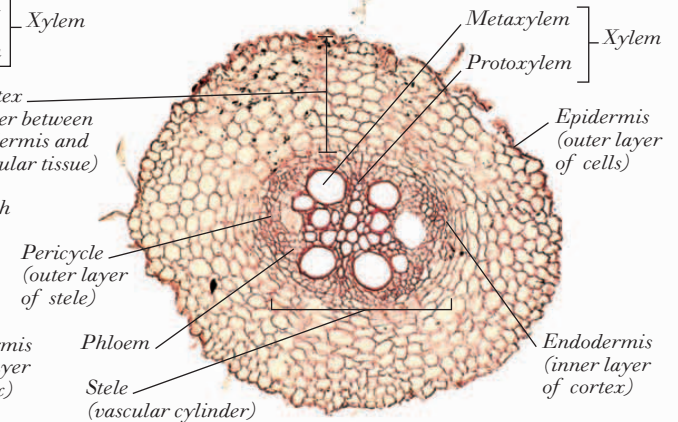
MICROGRAPH OF LONGITUDINAL SECTION THROUGH
A WOODY DICOTYLEDONOUS STEM
Maple (*Acer sp.*)



A DICOTYLEDON
Hibiscus (*Hibiscus rosa-sinensis*)



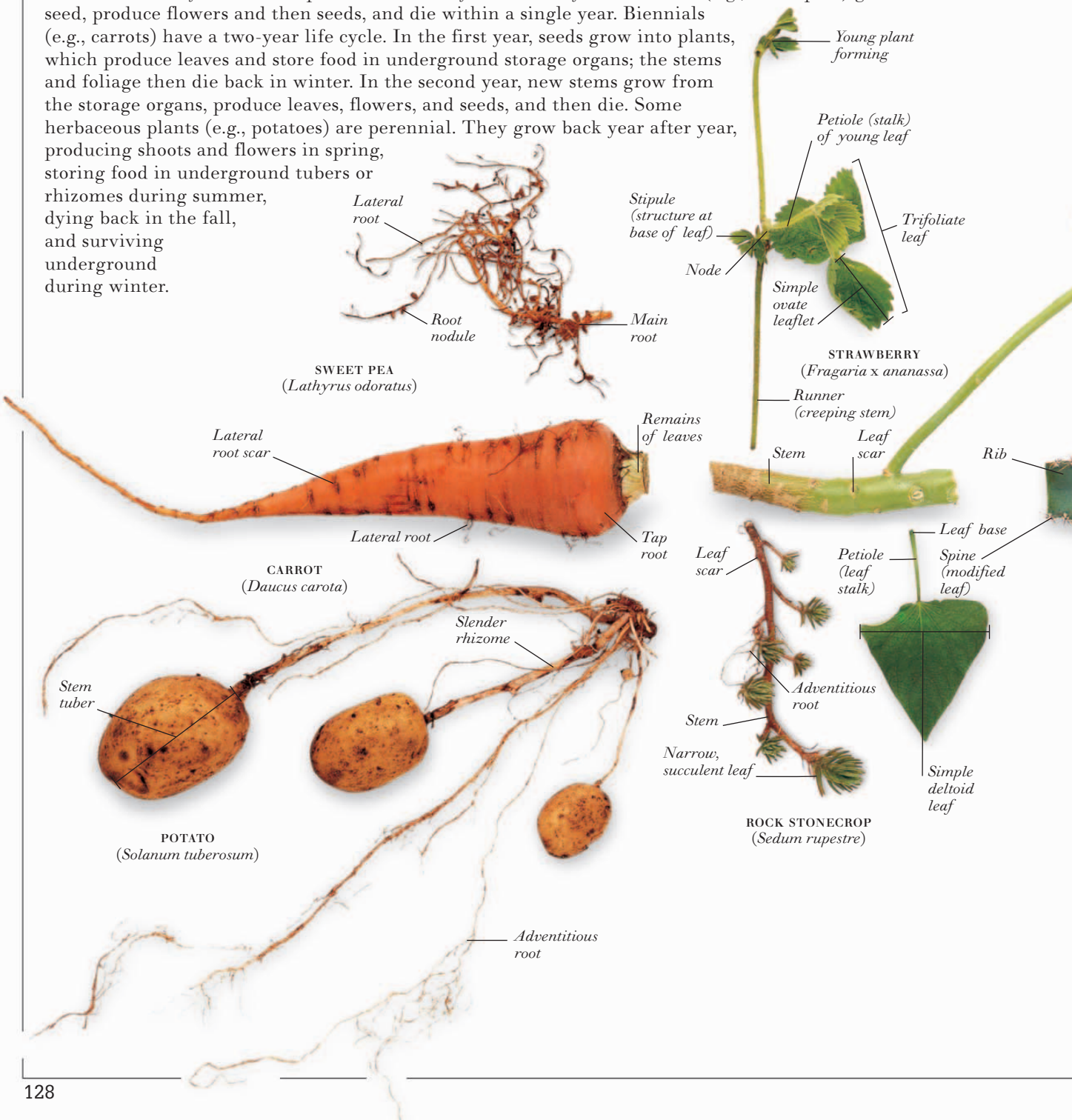
MICROGRAPH OF CROSS-SECTION THROUGH
A MONOCOTYLEDONOUS ROOT
Corn (*Zea mays*)



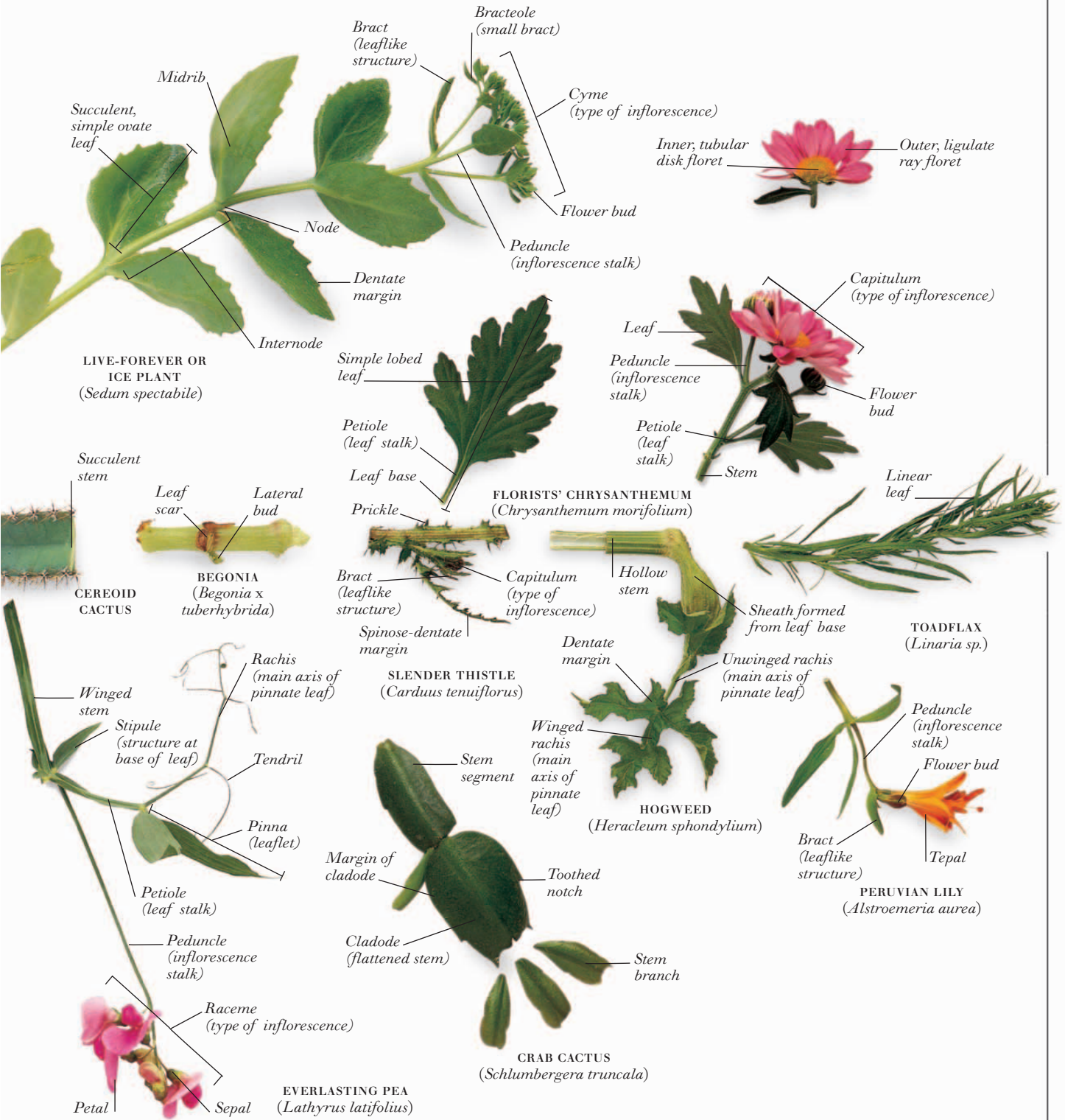
MICROGRAPH OF CROSS-SECTION THROUGH
A DICOTYLEDONOUS ROOT
Buttercup (*Ranunculus sp.*)

Herbaceous flowering plants

HERBACEOUS FLOWERING PLANTS TYPICALLY HAVE GREEN, NON-WOODY STEMS, and tend to be relatively short-lived. Many herbaceous plants live for only one or two years. Annuals (e.g., sweet peas) grow from seed, produce flowers and then seeds, and die within a single year. Biennials (e.g., carrots) have a two-year life cycle. In the first year, seeds grow into plants, which produce leaves and store food in underground storage organs; the stems and foliage then die back in winter. In the second year, new stems grow from the storage organs, produce leaves, flowers, and seeds, and then die. Some herbaceous plants (e.g., potatoes) are perennial. They grow back year after year, producing shoots and flowers in spring, storing food in underground tubers or rhizomes during summer, dying back in the fall, and surviving underground during winter.



PARTS OF HERBACEOUS FLOWERING PLANTS



LIVE-FOREVER OR ICE PLANT (*Sedum spectabile*)

CEREOID CACTUS

BEGONIA (*Begonia x tuberhybrida*)

FLORISTS' CHRYSANTHEMUM (*Chrysanthemum morifolium*)

SLENDER THISTLE (*Carduus tenuiflorus*)

HOGWEED (*Heracleum sphondylium*)

CRAB CACTUS (*Schlumbergera truncala*)

EVERLASTING PEA (*Lathyrus latifolius*)

TOADFLAX (*Linaria sp.*)

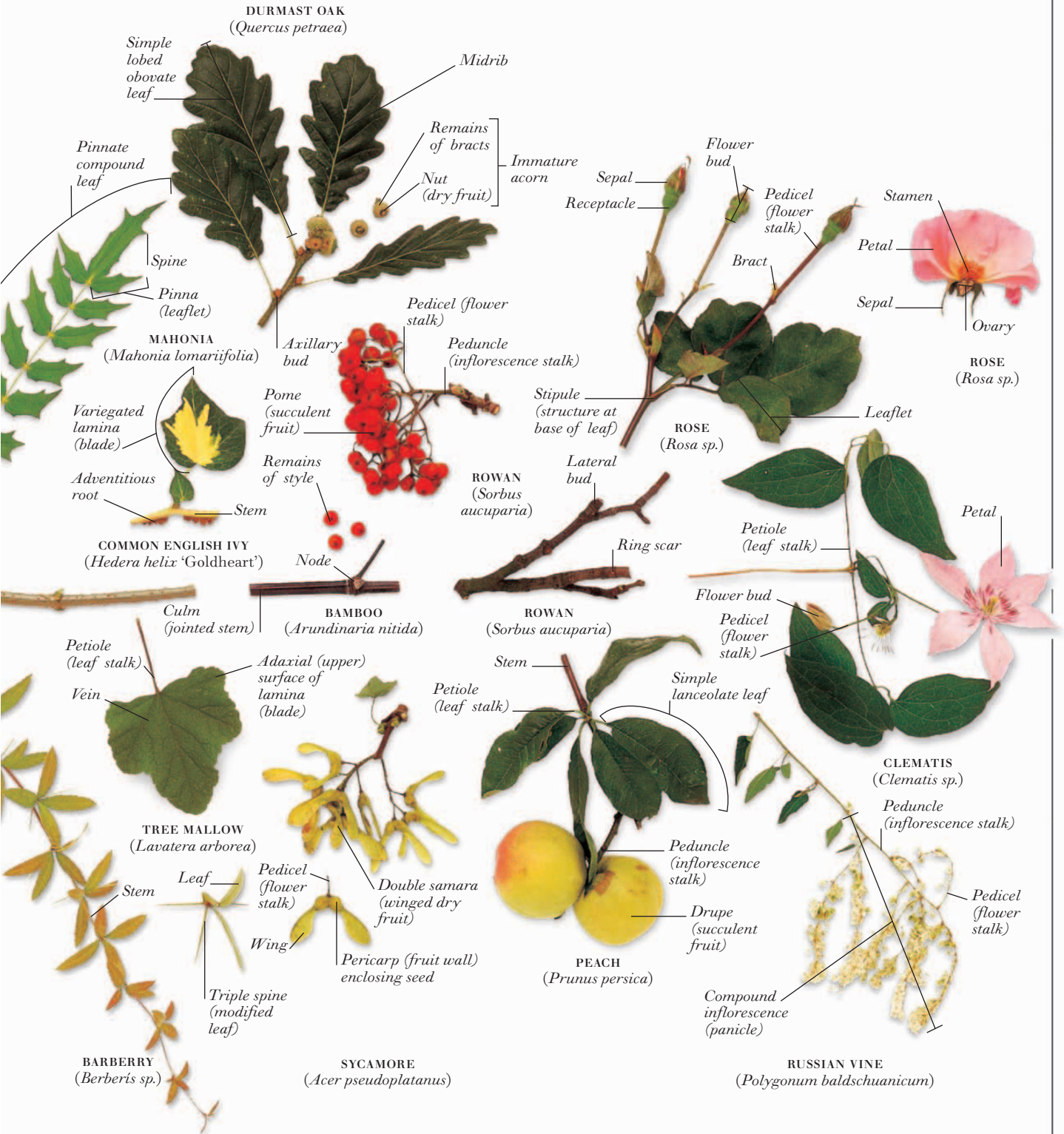
PERUVIAN LILY (*Alstroemeria aurea*)

Woody flowering plants

WOODY FLOWERING PLANTS ARE PERENNIAL, that is, they continue to grow and reproduce for many years. They have one or more permanent stems above ground, and numerous smaller branches. The stems and branches have a strong woody core that supports the plant and contains vascular tissue for transporting water and nutrients. Outside the woody core is a layer of tough, protective bark, which has lenticels (tiny pores) in it to enable gases to pass through. Woody flowering plants may be shrubs, which have several stems arising from the soil; bushes, which are shrubs with dense branching and foliage; or trees, which typically have a single upright stem (the trunk) that bears branches. Deciduous woody plants (e.g., roses) shed all their leaves once a year and remain leafless during winter. Evergreen woody plants (e.g., ivy) shed their leaves gradually, so retaining full leaf cover throughout the year.



PARTS OF WOODY FLOWERING PLANTS



DURMAST OAK
(*Quercus petraea*)

Simple lobed obovate leaf
Midrib
Pinnate compound leaf
Spine
Pinna (leaflet)

MAHONIA
(*Mahonia lomariifolia*)

Axillary bud
Pedicel (flower stalk)
Peduncle (inflorescence stalk)
Pome (succulent fruit)
Remains of style
Stem
Adventitious root
Variiegated lamina (blade)

COMMON ENGLISH IVY
(*Hedera helix* 'Goldheart')

Node
Culm (jointed stem)

BAMBOO
(*Arundinaria nitida*)

Petiole (leaf stalk)
Vein
Adaxial (upper) surface of lamina (blade)

TREE MALLOW
(*Lavatera arborea*)

Stem
Leaf
Pedicel (flower stalk)
Wing
Triple spine (modified leaf)

BARBERRY
(*Berberis sp.*)

SYCAMORE
(*Acer pseudoplatanus*)

Rowan (Sorbus aucuparia)
Lateral bud
Ring scar
Stem

ROWAN
(*Sorbus aucuparia*)

Petiole (leaf stalk)
Simple lanceolate leaf
Pedicel (inflorescence stalk)
Drupe (succulent fruit)

PEACH
(*Prunus persica*)

Immature acorn
Sepal
Receptacle
Flower bud
Pedicel (flower stalk)
Bract
Stamen
Petal
Ovary

ROSE
(*Rosa sp.*)

Leaflet
Stipule (structure at base of leaf)
Lateral bud
Ring scar
Flower bud
Petal
Petiole (leaf stalk)

CLEMATIS
(*Clematis sp.*)

Peduncle (inflorescence stalk)
Petal
Pedicel (flower stalk)
Compound inflorescence (panicle)

RUSSIAN VINE
(*Polygonum baldschuanicum*)

Roots

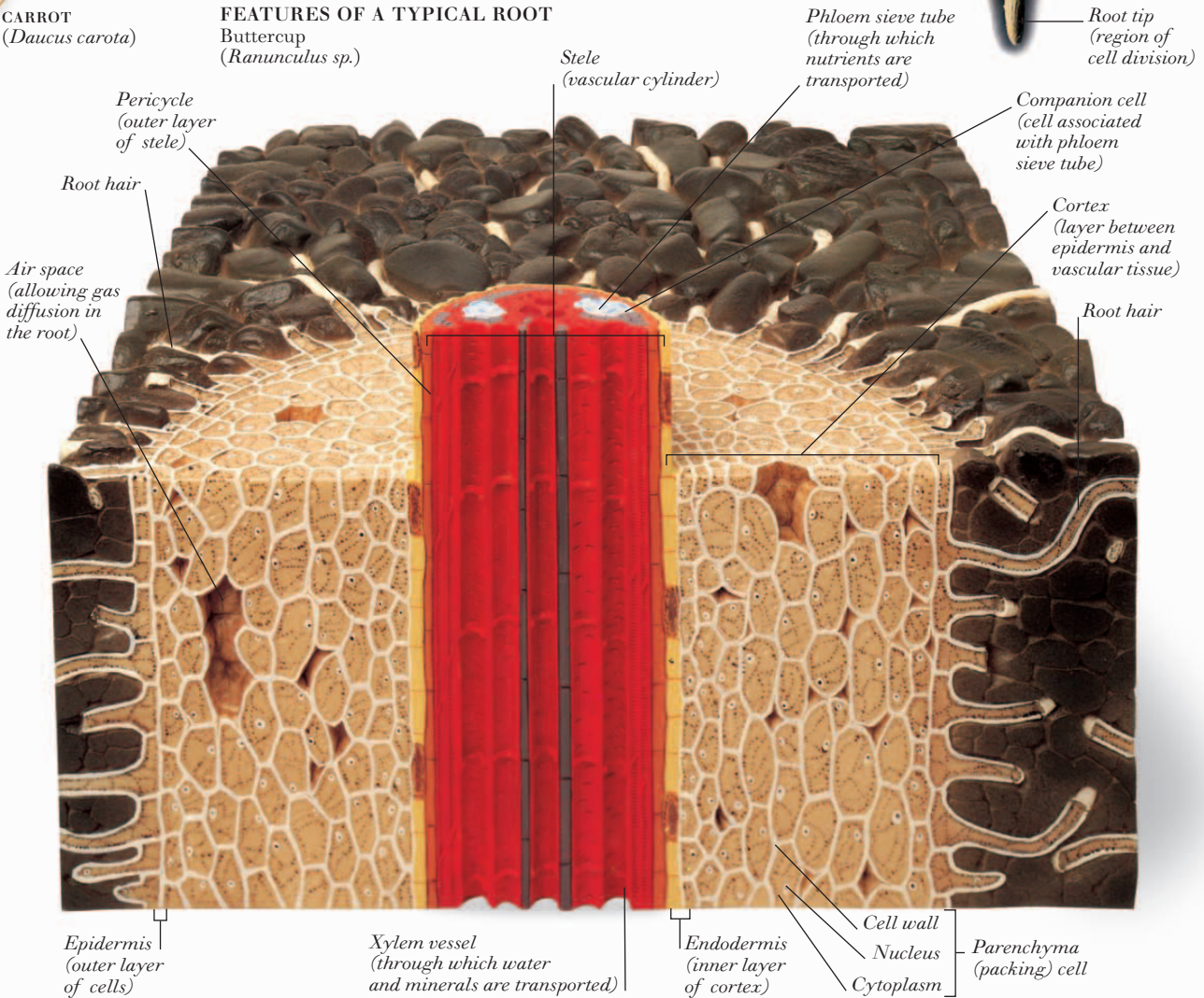
ROOTS ARE THE UNDERGROUND PARTS OF PLANTS. They have three main functions. First, they anchor the plant in the soil.

Second, they absorb water and minerals from the spaces between soil particles; the roots' absorptive properties are increased by root hairs, which grow behind the root tip, allowing maximum uptake of vital substances. Third, the root is part of the plant's transport system: xylem carries water and minerals from the roots to the stem and leaves, and phloem carries nutrients from the leaves to all parts of the root system. In addition, some roots (e.g., carrots) are food stores. Roots have an outer epidermis covering a cortex of parenchyma (packing tissue), and a central cylinder of vascular tissue. This arrangement helps the roots resist the forces of compression as they grow through the soil.

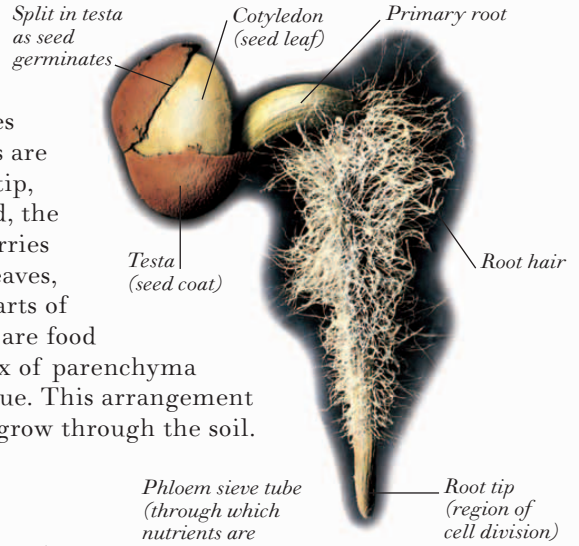


CARROT
(*Daucus carota*)

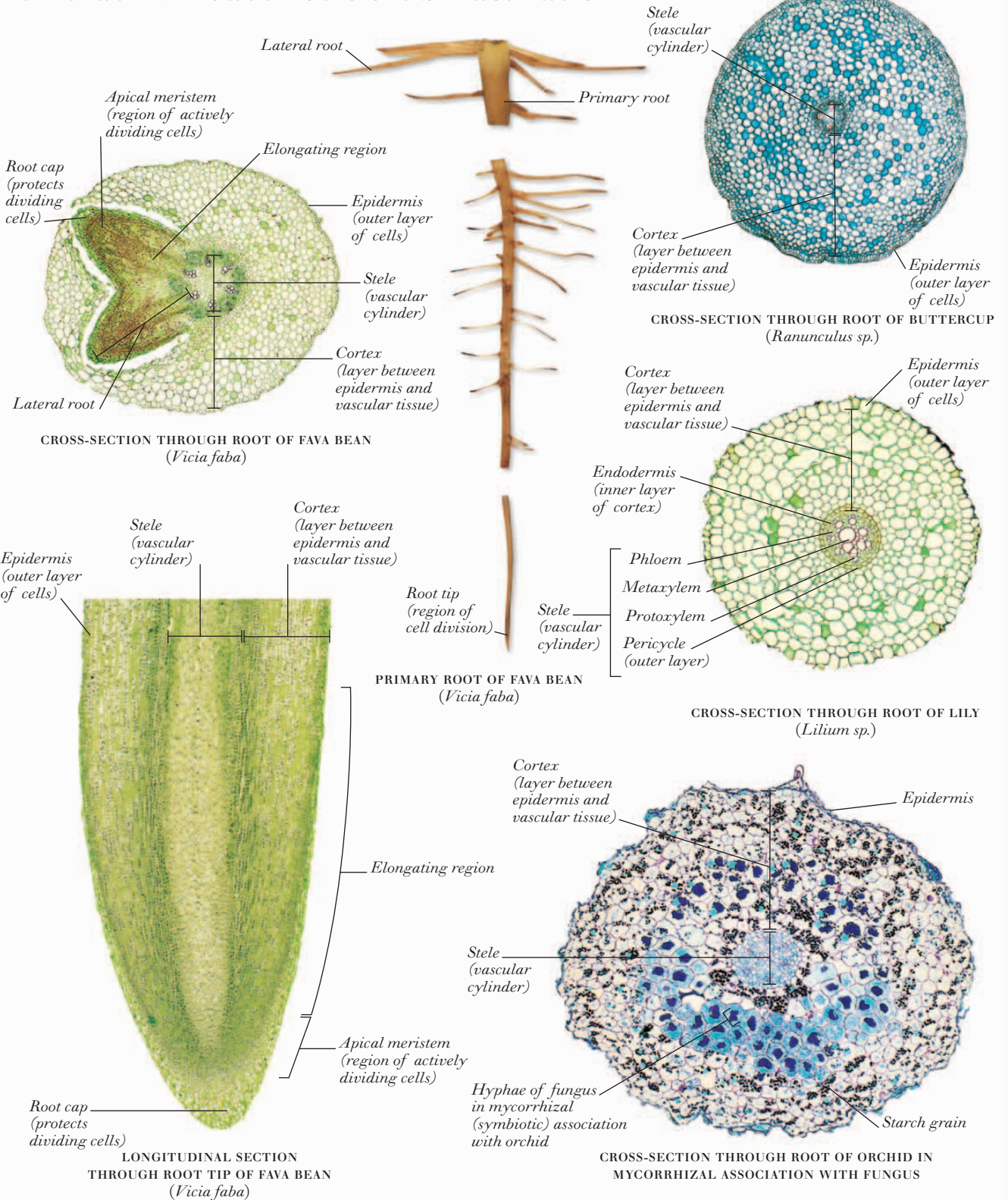
FEATURES OF A TYPICAL ROOT
Buttercup
(*Ranunculus sp.*)



MICROGRAPH OF PRIMARY ROOT DEVELOPMENT
Cabbage (*Brassica sp.*)



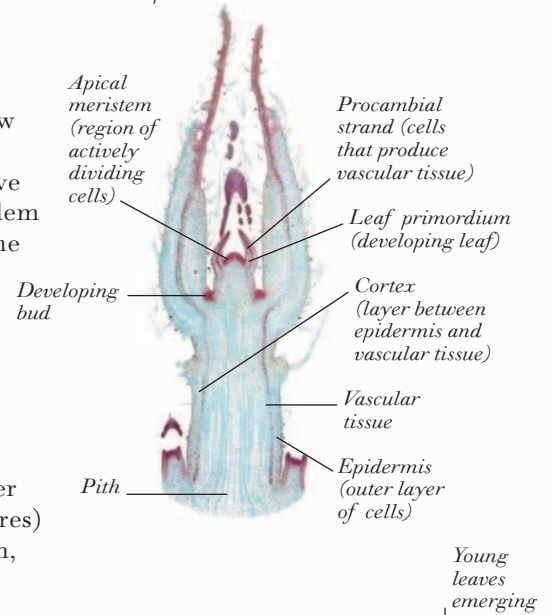
PRIMARY ROOT AND MICROGRAPHS OF SECTIONS THROUGH ROOTS



Stems

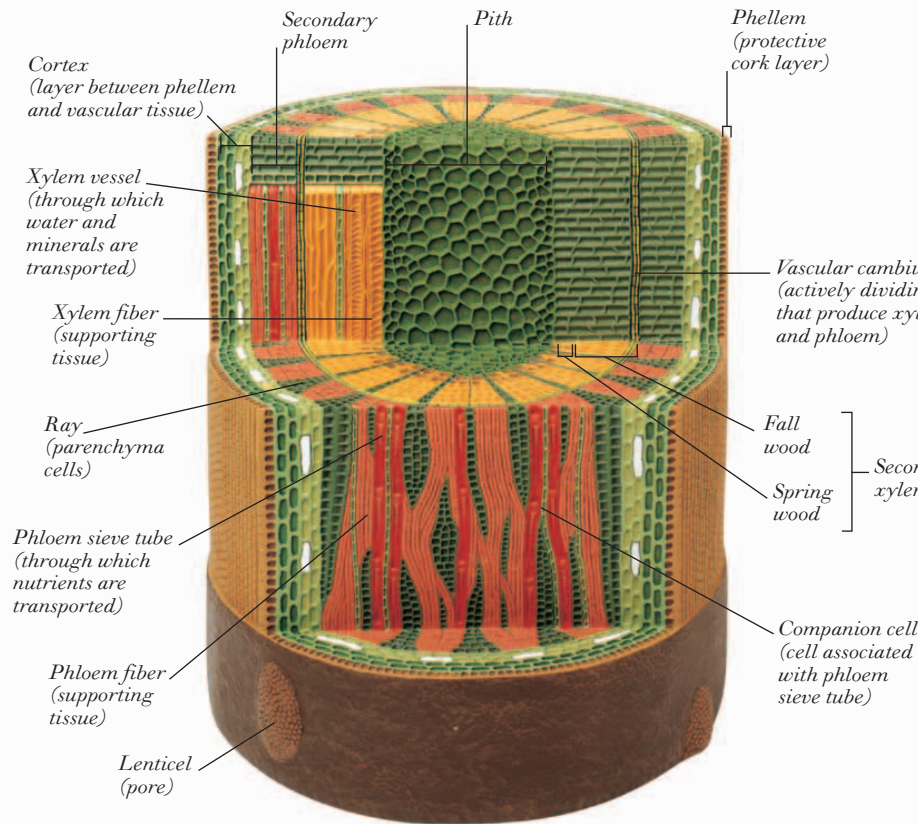
THE STEM IS THE MAIN SUPPORTIVE PART OF A PLANT that grows above ground. Stems bear leaves (organs of photosynthesis), which grow at nodes; buds (shoots covered by protective scales), which grow at the stem tip (apical or terminal buds) and in the angle between a leaf and the stem (axillary or lateral buds); and flowers (reproductive structures). The stem forms part of the plant's transport system: xylem tissue in the stem transports water and minerals from the roots to the aerial parts of the plant, and phloem tissue transports nutrients manufactured in the leaves to other parts of the plant. Stem tissues are also used for storing water and food. Herbaceous (non-woody) stems have an outer protective epidermis covering a cortex that consists mainly of parenchyma (packing tissue) but also has some collenchyma (supporting tissue). The vascular tissue of such stems is arranged in bundles, each of which consists of xylem, phloem, and sclerenchyma (strengthening tissue). Woody stems have an outer protective layer of tough bark, which is perforated with lenticels (pores) to allow gas exchange. Inside the bark is a ring of secondary phloem, which surrounds an inner core of secondary xylem.

MICROGRAPH OF LONGITUDINAL SECTION THROUGH APEX OF STEM
Coleus sp.



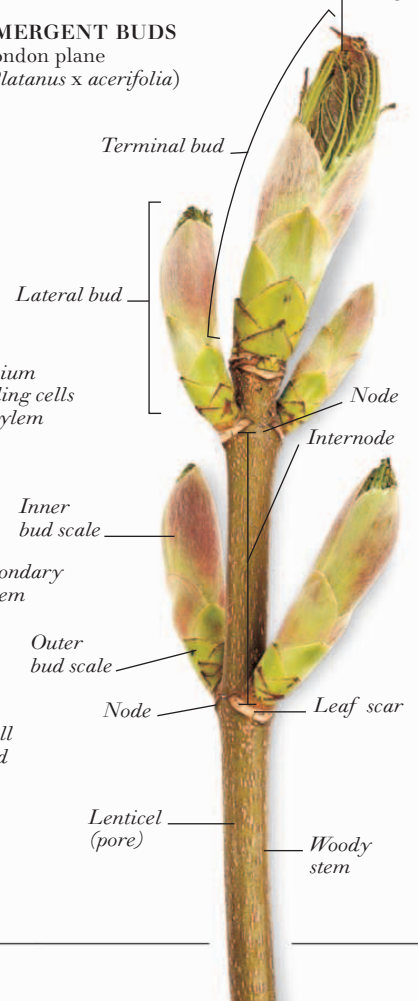
YOUNG WOODY STEM

Lime
(Tilia sp.)

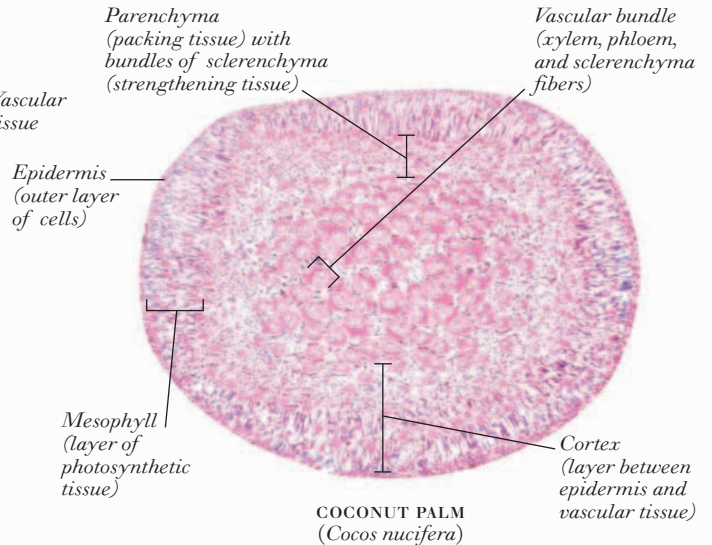
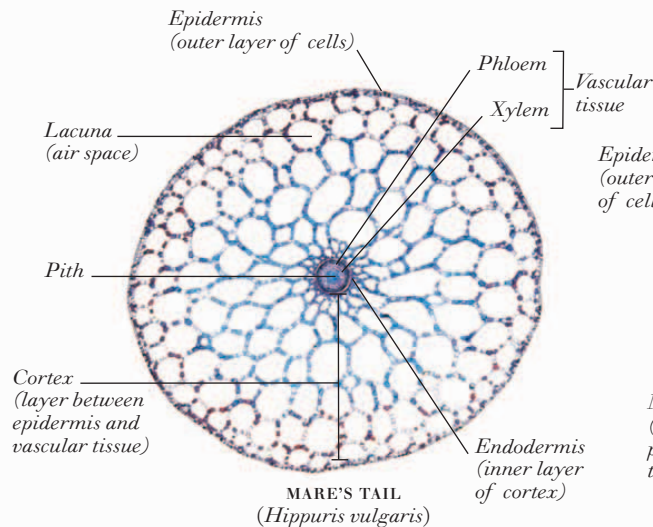
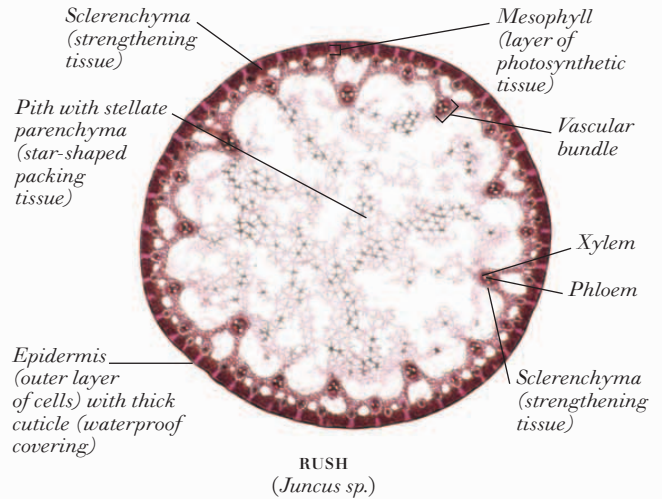
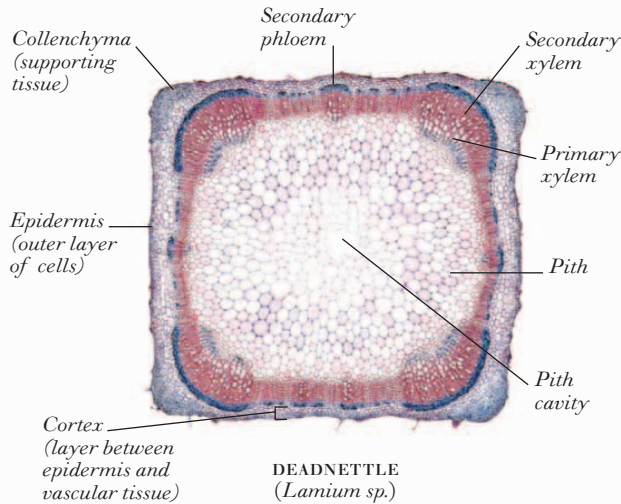
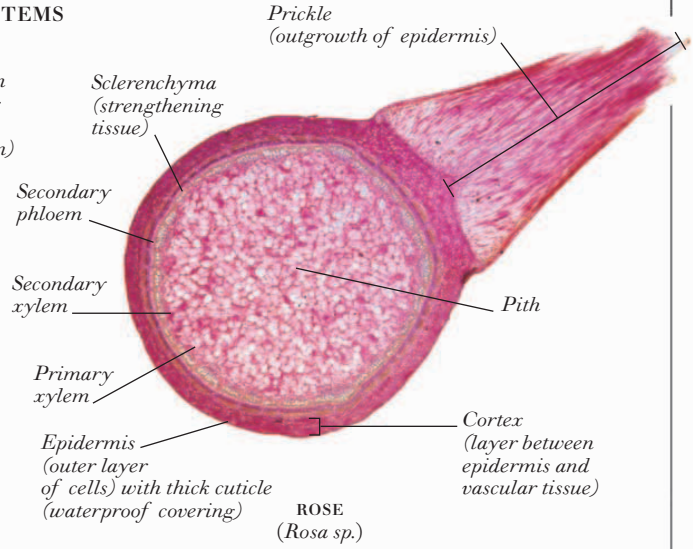
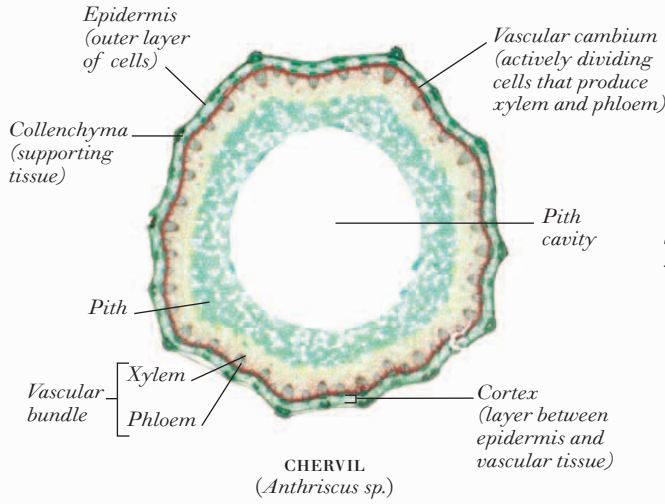


EMERGENT BUDS

London plane
(Platanus x acerifolia)



MICROGRAPHS OF CROSS-SECTIONS THROUGH VARIOUS STEMS



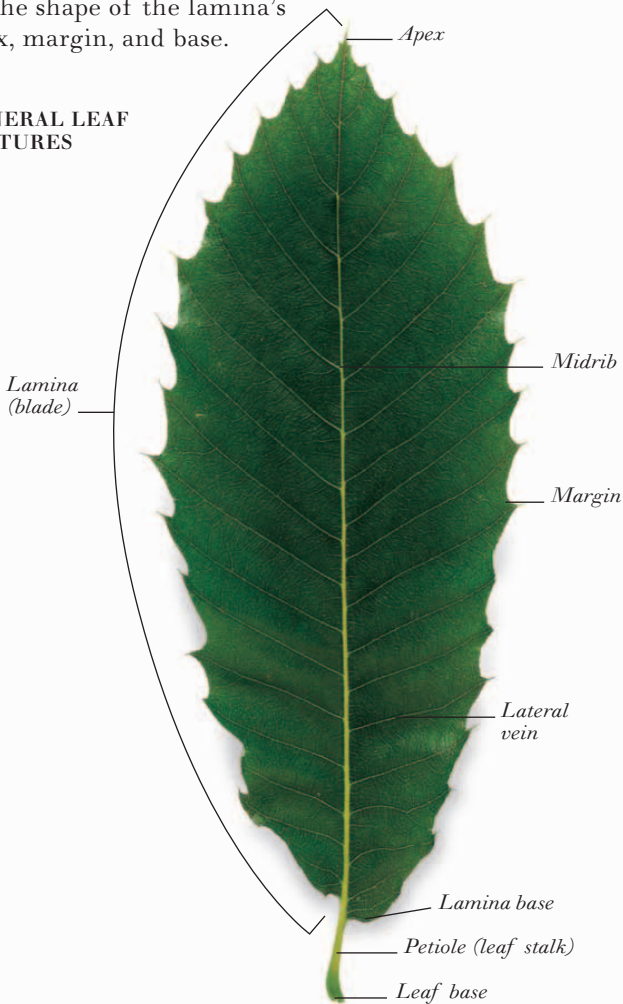
Leaves



LEAVES ARE THE MAIN SITES OF PHOTOSYNTHESIS (see pp. 138-139) and transpiration (water loss by evaporation) in plants. A typical leaf consists of a thin, flat lamina (blade) supported by a network of veins; a petiole (leaf stalk); and a leaf base, where the petiole joins the stem. Leaves can be classified as simple, in which

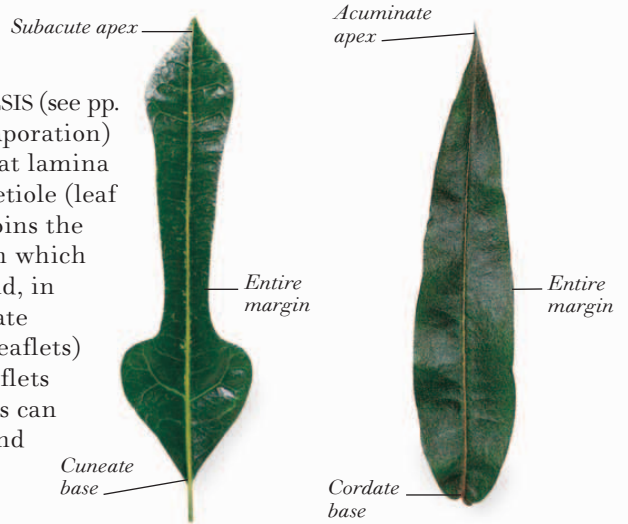
the lamina is a single unit, or compound, in which the lamina is divided into separate leaflets. Compound leaves may be pinnate, with pinnae (leaflets) on both sides of a rachis (main axis), or palmate, with leaflets arising from a single point at the tip of the petiole. Leaves can be classified further by the overall shape of the lamina, and by the shape of the lamina's apex, margin, and base.

GENERAL LEAF FEATURES



Sweet chestnut
(*Castanea sativa*)

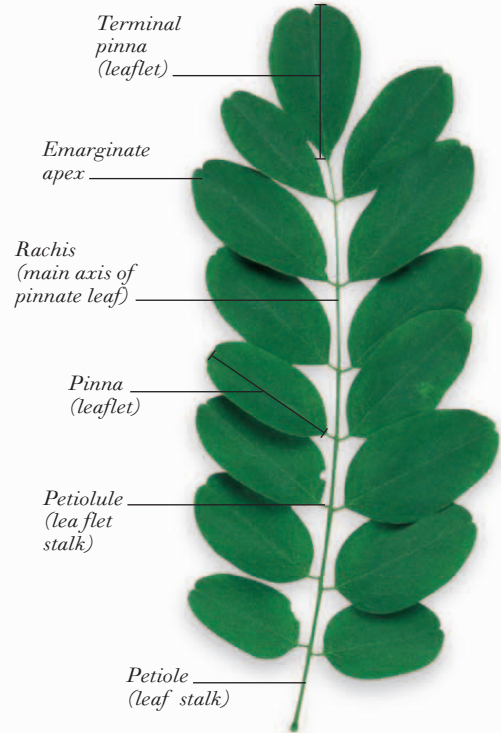
SIMPLE LEAF SHAPES



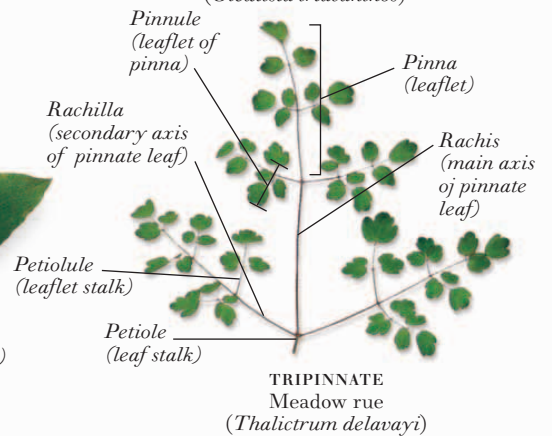
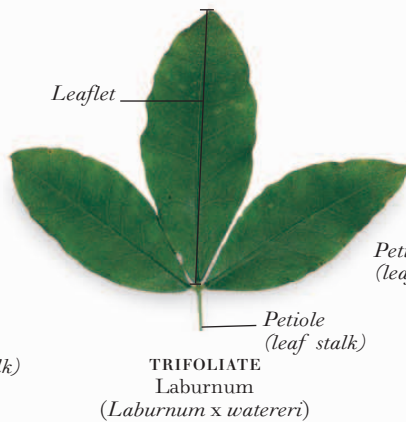
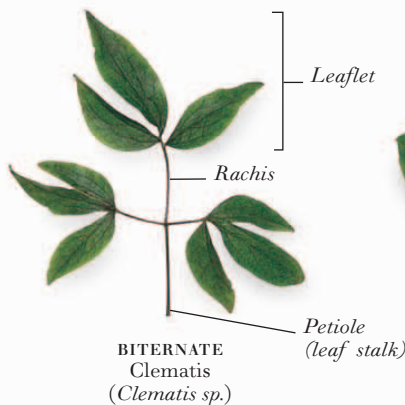
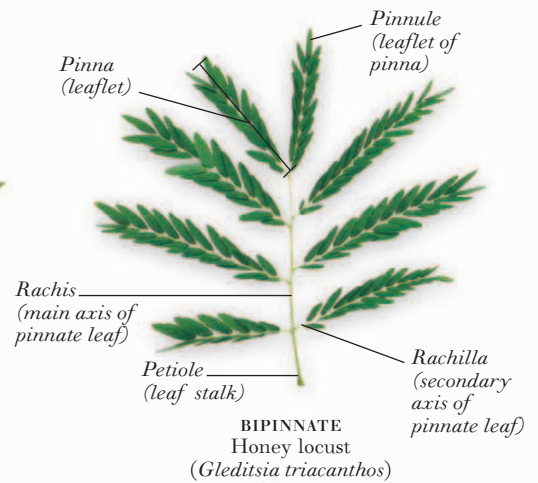
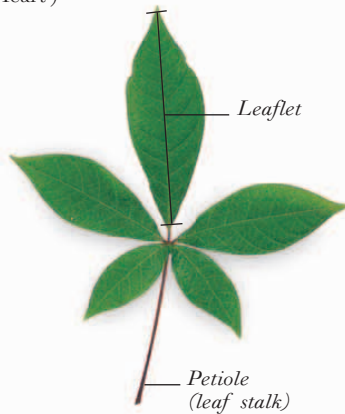
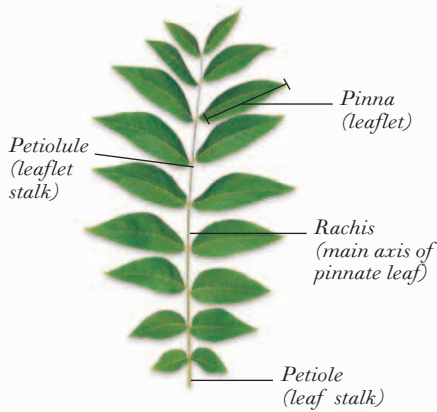
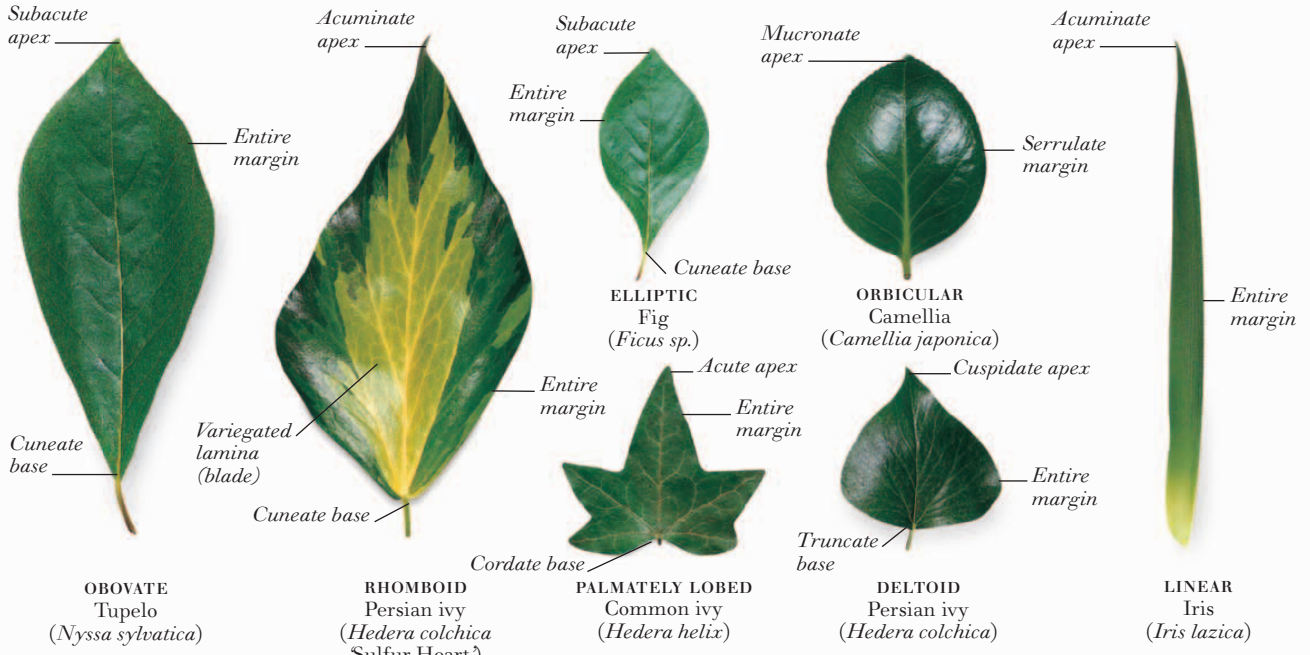
PANDURIFORM
Croton
(*Codiaeum variegatum*)

LANCEOLATE
Sea buckthorn
(*Hippophae rhamnoides*)

COMPOUND LEAF SHAPES



ODD PINNATE
False acacia
(*Robinia pseudoacacia*)

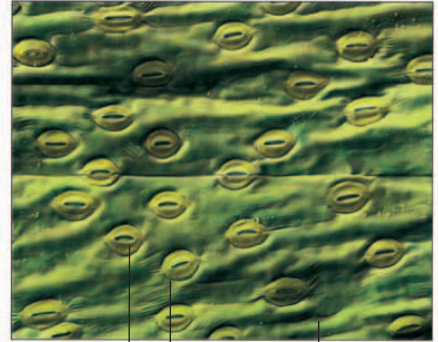


Photosynthesis

PHOTOSYNTHESIS IS THE PROCESS by which plants make their food using sunlight, water, and carbon dioxide. It takes place inside special structures in leaf cells called chloroplasts. The chloroplasts contain chlorophyll, a green pigment that absorbs energy from sunlight. During photosynthesis, the absorbed energy is used to join together carbon dioxide and water to form the sugar glucose, which is the energy source for the whole plant; oxygen, a waste product, is released into the air. Leaves are the main sites of photosynthesis, and have various adaptations for that purpose: flat laminae (blades) provide a large surface for absorbing sunlight; stomata (pores) in the lower surface of the laminae allow gases (carbon dioxide and oxygen) to pass into and out of the leaves; and an extensive network of veins brings water into the leaves and transports the glucose produced by photosynthesis to the rest of the plant.

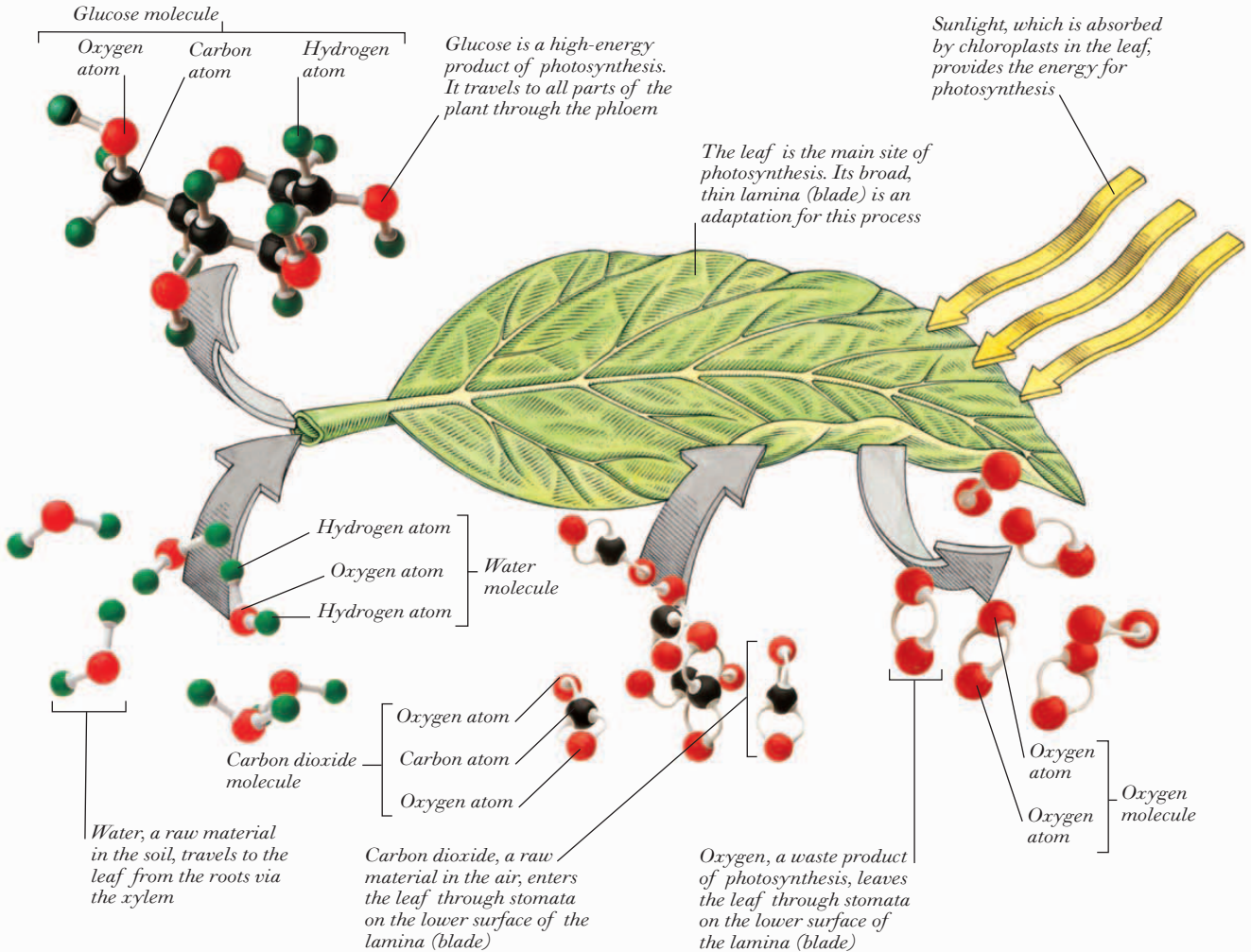
MICROGRAPH OF LEAF

Lily (*Lilium sp.*)



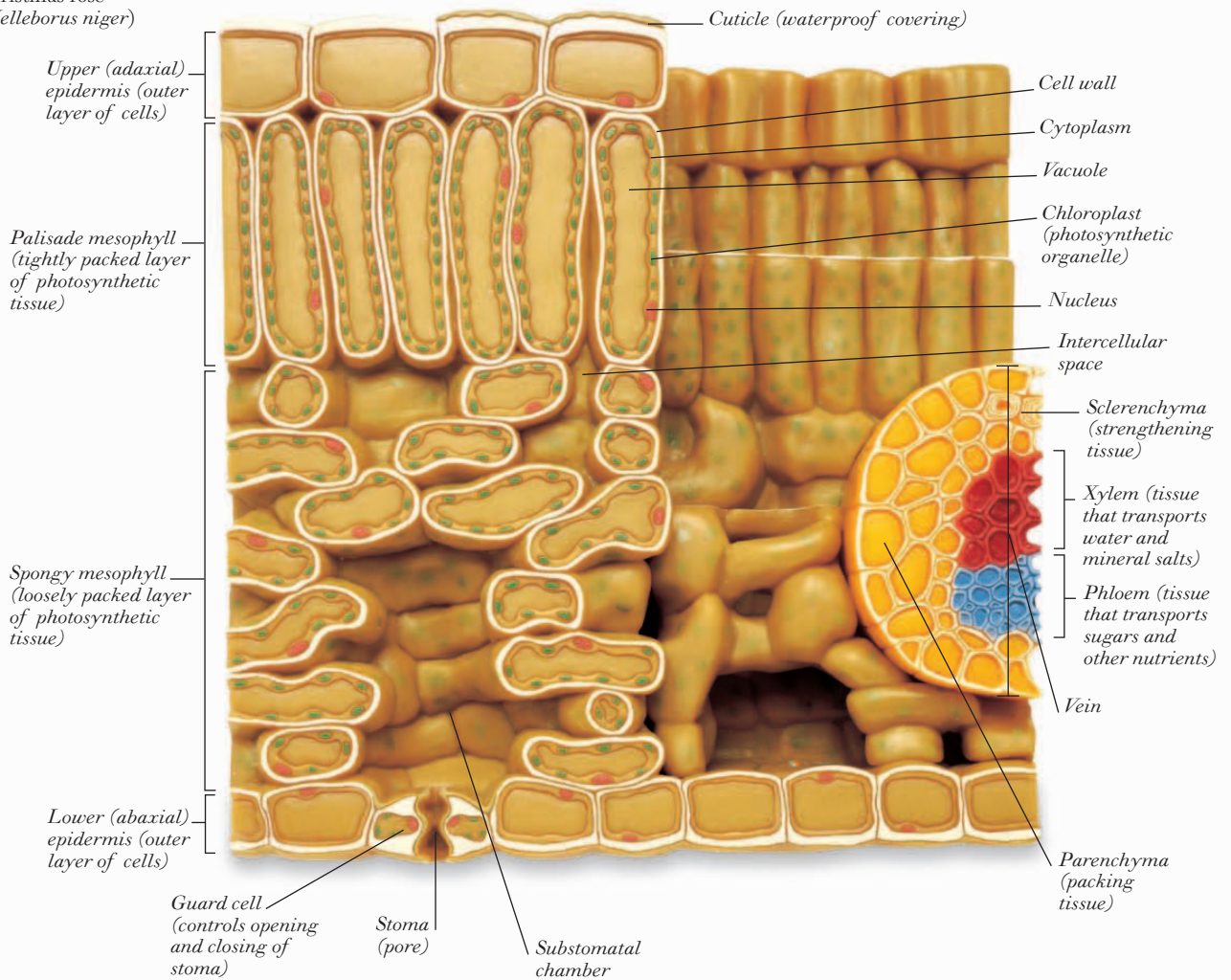
Stoma (pore)
Guard cell (controls opening and closing of stoma)
Lower surface of lamina (blade)

THE PROCESS OF PHOTOSYNTHESIS

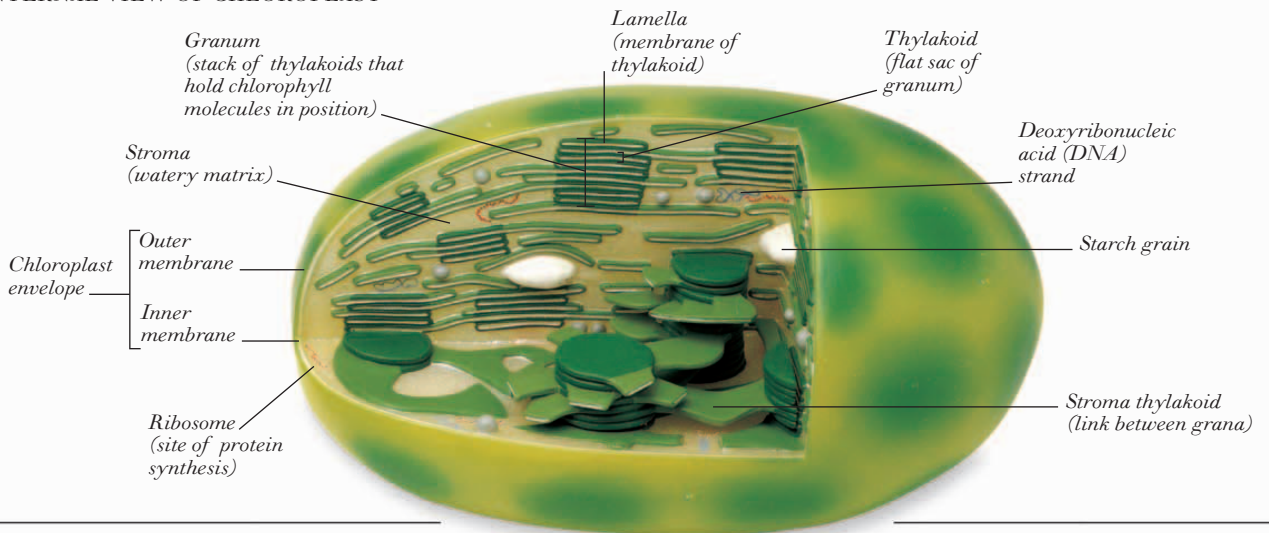


CROSS-SECTION THROUGH LEAF

Christmas rose
(*Helleborus niger*)



INTERNAL VIEW OF CHLOROPLAST



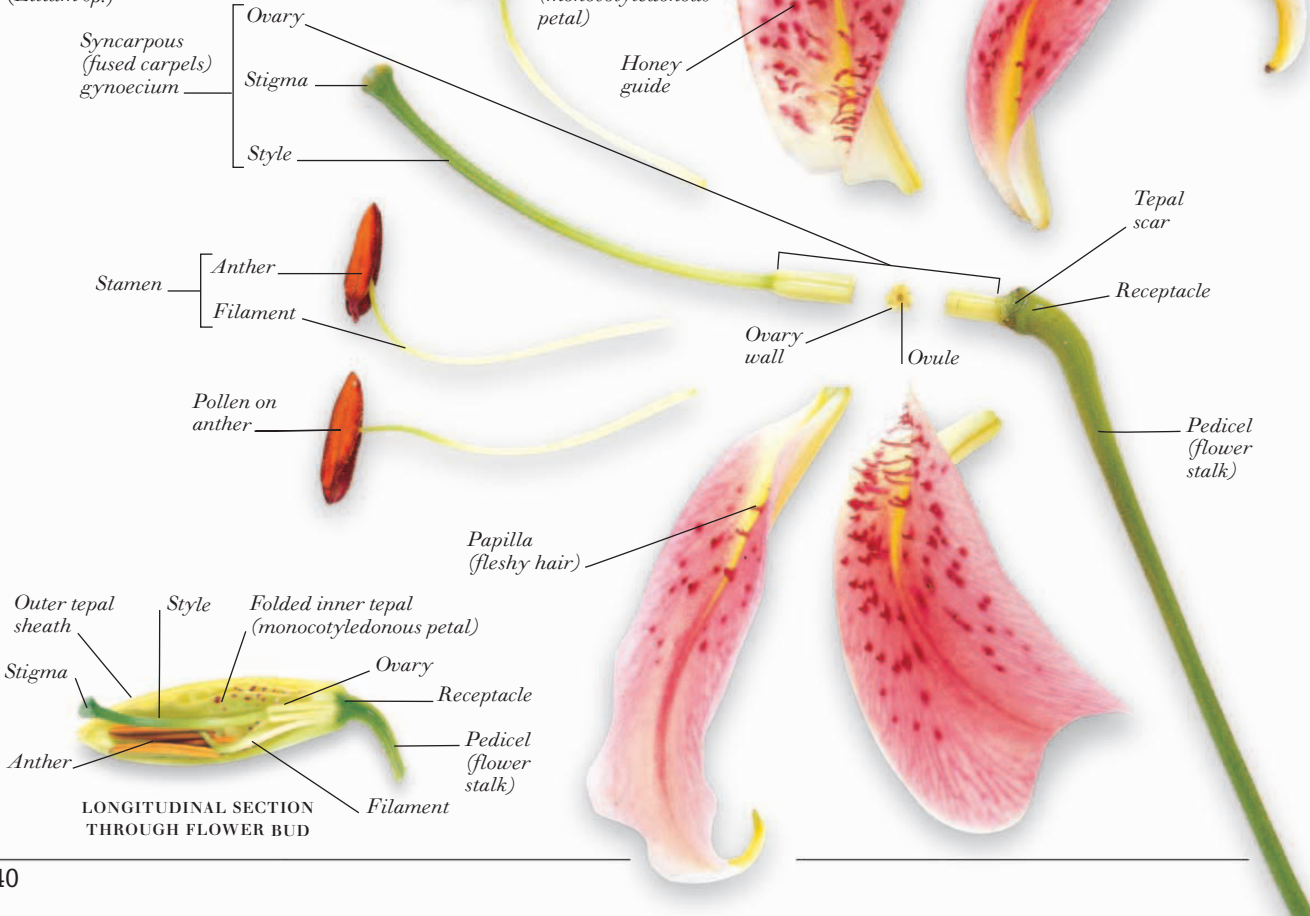
Flowers 1

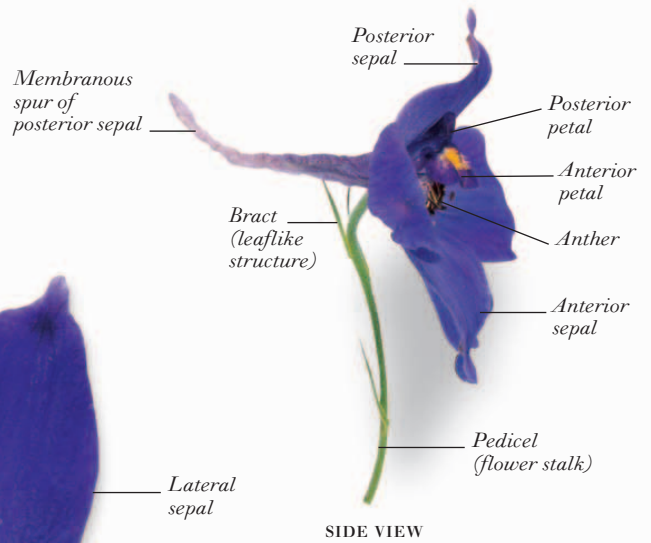
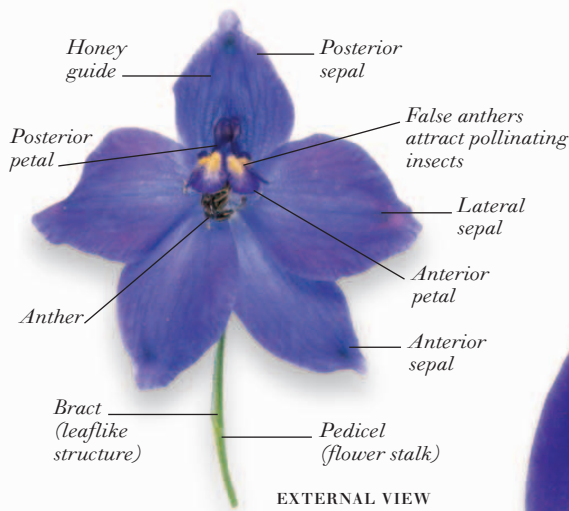


FLOWERS ARE THE SITES OF SEXUAL REPRODUCTION in flowering plants. Their component parts are arranged in whorls around the receptacle (tip of the flower stalk). The sepals (collectively called the calyx) are outermost; typically small and green, they protect the developing flower. The petals (collectively called the corolla) are typically large and brightly colored; they are found inside the sepals. In monocotyledonous flowers (see pp. 126-127), sepals and petals are indistinguishable; individually they are called tepals (collectively called the perianth). The petals surround the male and female reproductive structures (androecium and gynoecium). The androecium consists of stamens (male organs); each stamen is made up of a filament (stalk) and anther. The gynoecium has one or more carpels (female organs); each carpel consists of an ovary, style, and stigma. Some flowers (e.g., lily) occur singly on a pedicel (flower stalk); others (e.g., elder, sunflower) are arranged in a group (inflorescence) on a peduncle (inflorescence stalk).

A MONOCOTYLEDONOUS FLOWER

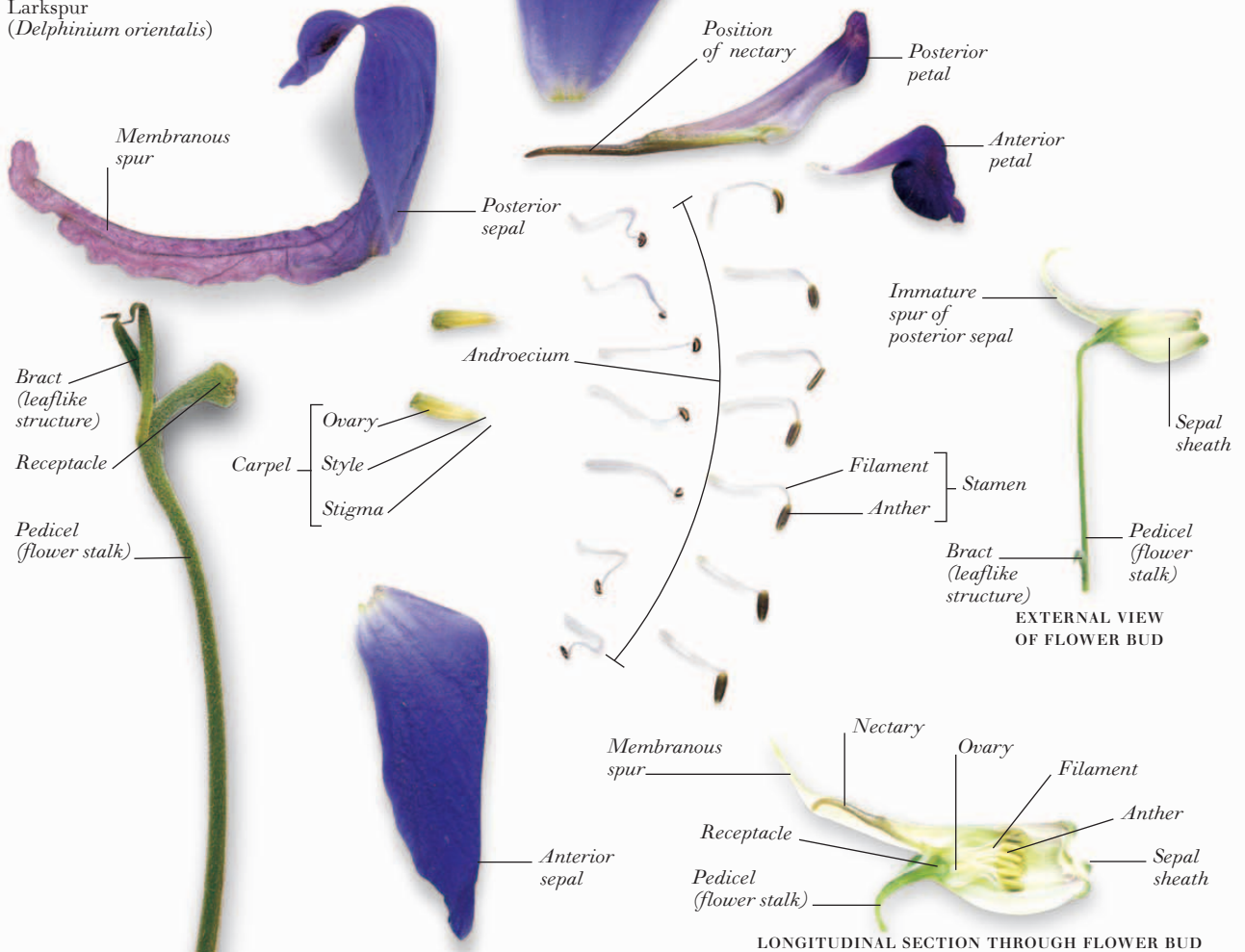
Lily
(*Lilium sp.*)





A DICOTYLEDONOUS FLOWER

Larkspur
(*Delphinium orientalis*)



Flowers 2

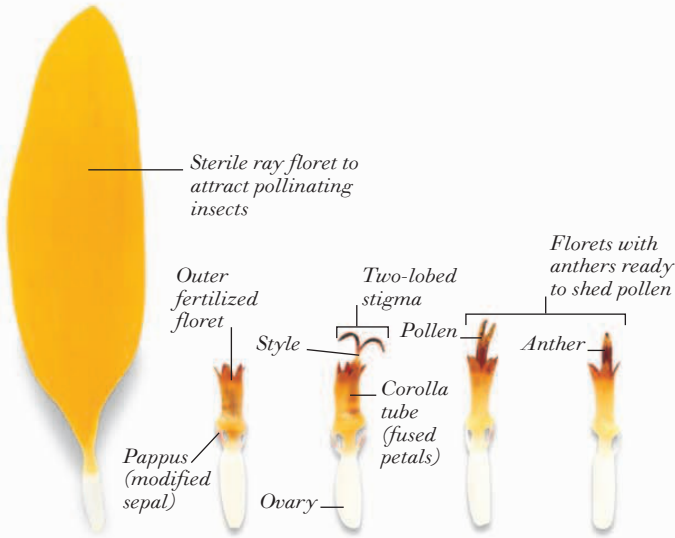
COMPOUND INFLORESCENCE (CAPITULUM)
Sunflower
(*Helianthus annulus*)



Disk florets

Ray floret

Florets (small flowers) are grouped together to resemble a single large flower



Sterile ray floret to attract pollinating insects

Outer fertilized floret

Pappus (modified sepal)

Ovary

Style

Two-lobed stigma

Pollen

Corolla tube (fused petals)

Florets with anthers ready to shed pollen

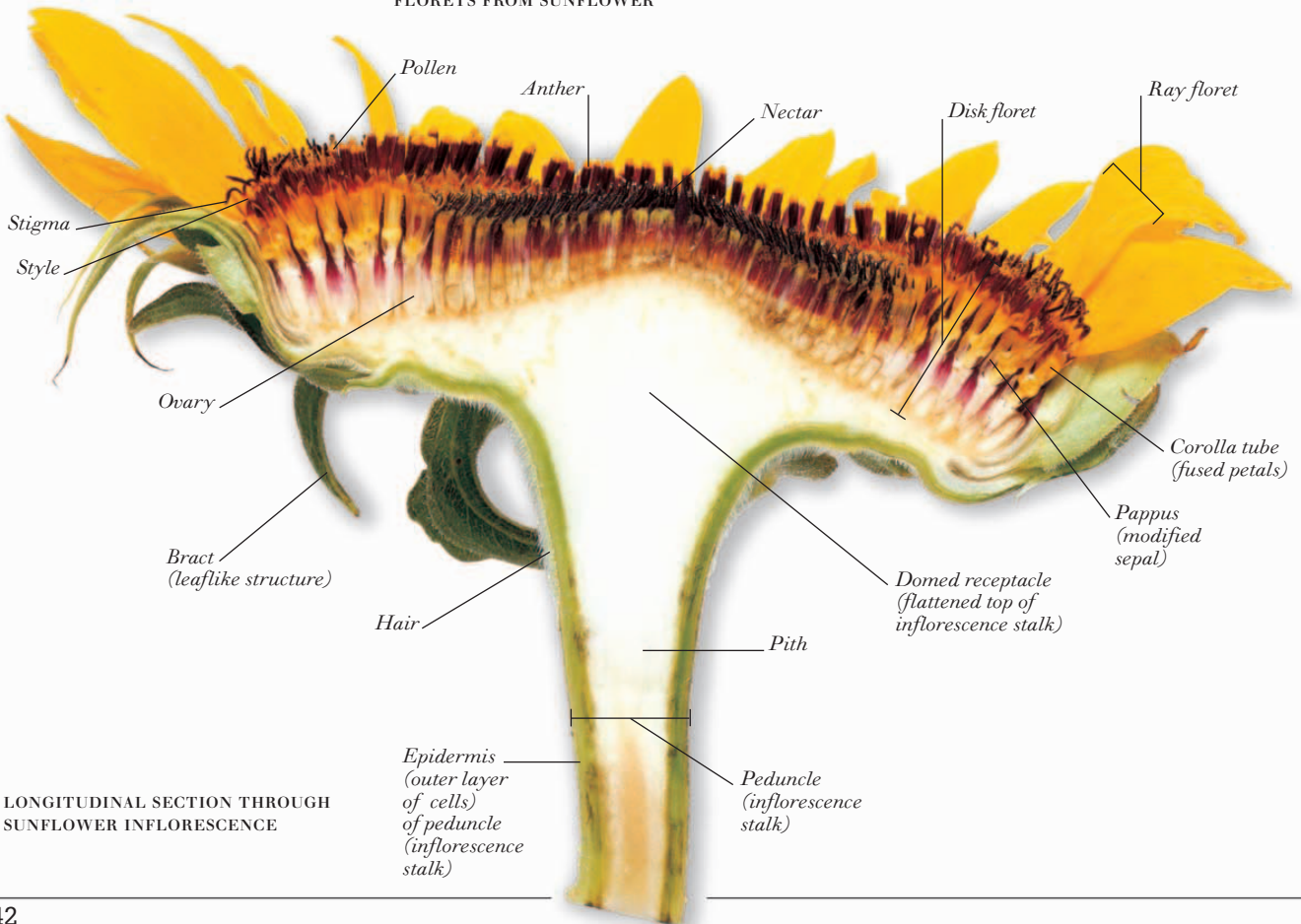
Anther

Inner, immature florets

Corolla tube (fused petals)

Ovary

FLORETS FROM SUNFLOWER



Pollen

Anther

Nectar

Disk floret

Ray floret

Stigma

Style

Ovary

Bract (leaflike structure)

Hair

Pith

Corolla tube (fused petals)

Pappus (modified sepal)

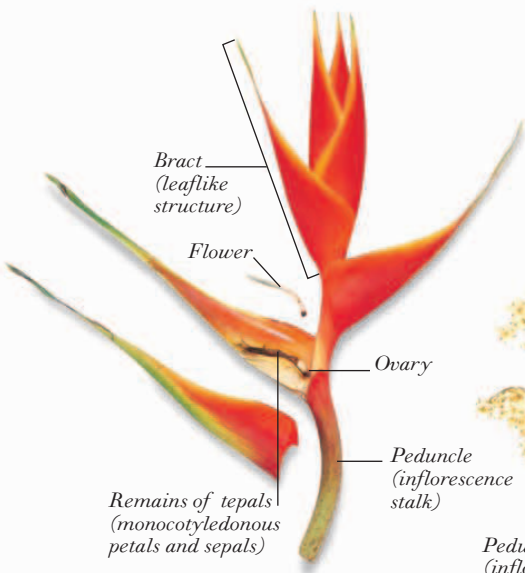
Domed receptacle (flattened top of inflorescence stalk)

Peduncle (inflorescence stalk)

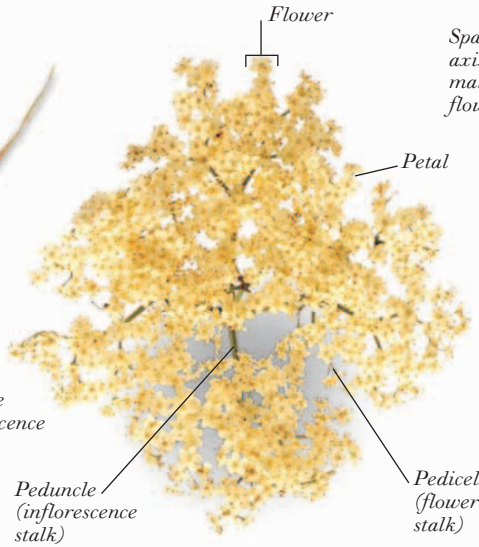
Epidermis (outer layer of cells) of peduncle (inflorescence stalk)

LONGITUDINAL SECTION THROUGH SUNFLOWER INFLORESCENCE

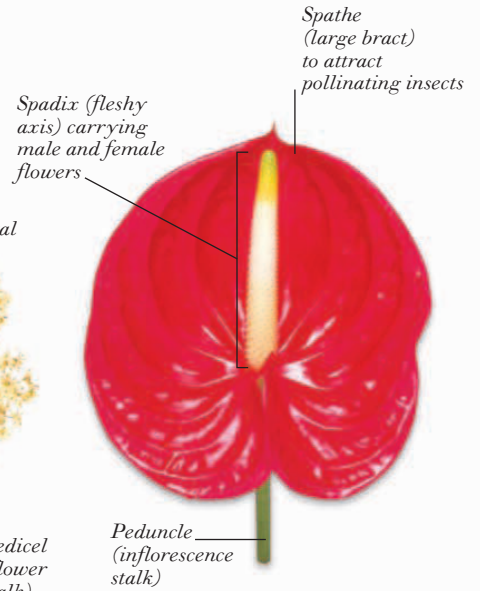
ARRANGEMENT OF FLOWERS ON STEM



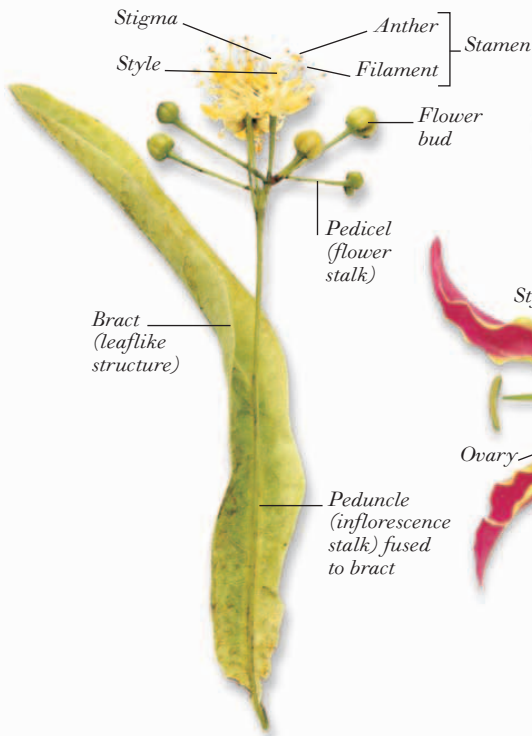
INFLORESCENCE (SPIKE)
Heliconia peruviana



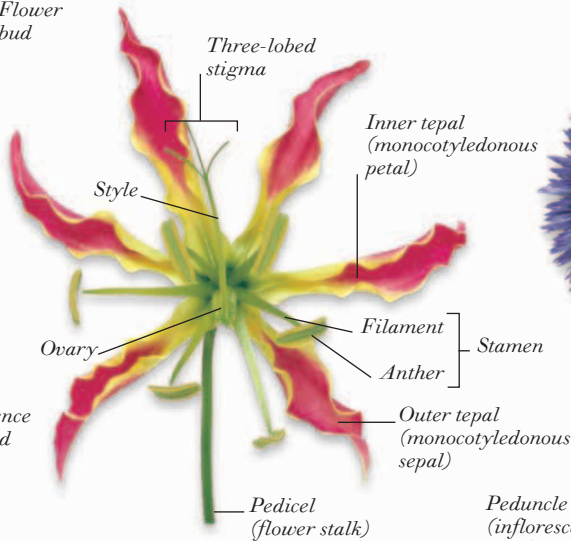
INFLORESCENCE (COMPOUND UMBEL)
Common elder (*Sambucus nigra*)



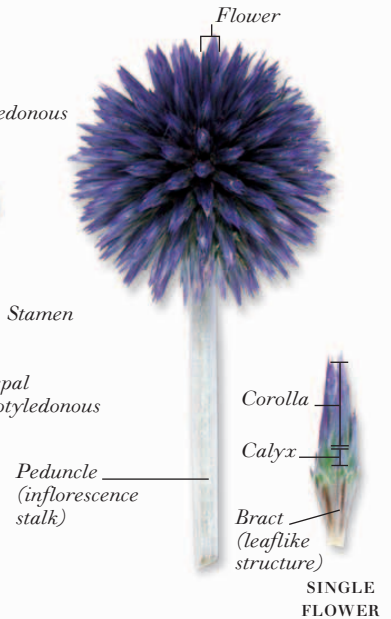
INFLORESCENCE (SPADIX)
Painter's palette (*Anthurium andreaenum*)



INFLORESCENCE (DICHASIAL CYME)
Common lime (*Tilia x europaea*)



SINGLE FLOWER
Glory lily (*Gloriosa superba*)



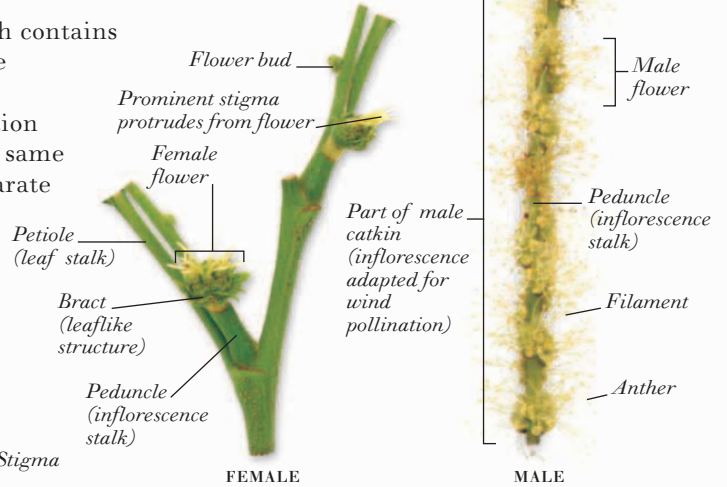
INFLORESCENCE (SPHERICAL UMBEL)
Allium sp.

Pollination

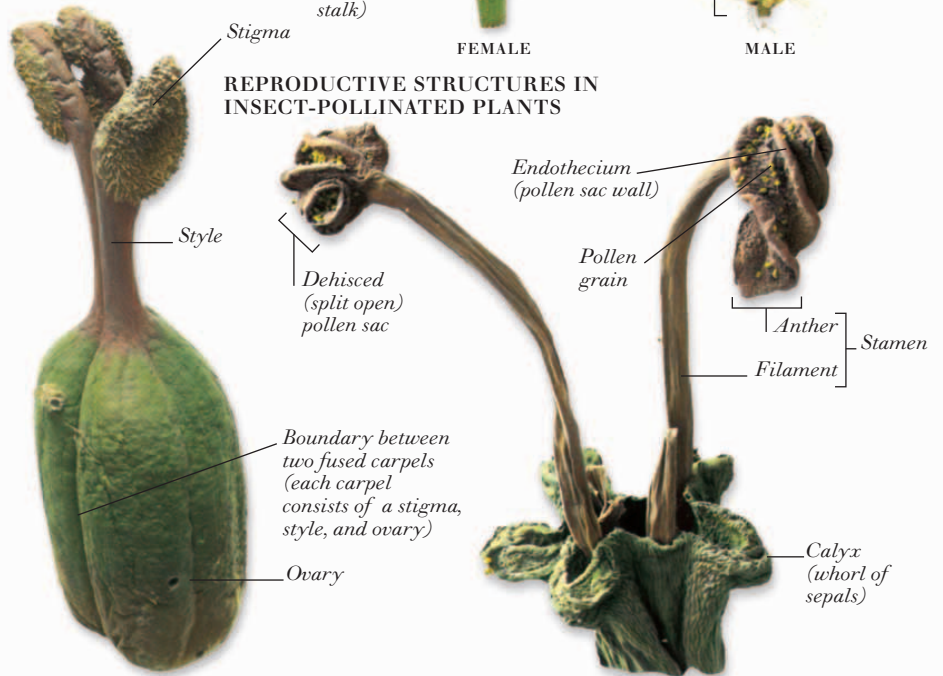
POLLINATION IS THE TRANSFER OF POLLEN (which contains the male sex cells) from an anther (part of the male reproductive organ) to a stigma (part of the female reproductive organ). This process precedes fertilization (see pp. 146-147). Pollination may occur within the same flower (self-pollination), or between flowers on separate plants of the same species (cross-pollination). In most plants, pollination is carried out either by insects (entomophilous pollination) or by the wind (anemophilous pollination). Less commonly, birds, bats, or water are the agents of pollination. Insect-pollinated flowers are typically brightly colored, scented, and produce nectar, on which insects feed. Such flowers also tend to have patterns that are visible only in ultraviolet light, which many insects can see but which humans cannot. These features attract insects, which become covered with the sticky or hooked pollen grains when they visit one flower, and then transfer the pollen to the next flower they visit. Wind-pollinated flowers are generally small, relatively inconspicuous, and unscented. They produce large quantities of light pollen grains that are easily blown by the wind to other flowers.

REPRODUCTIVE STRUCTURES IN WIND-POLLINATED PLANT

Sweet chestnut
(*Castanea saliva*)



REPRODUCTIVE STRUCTURES IN INSECT-POLLINATED PLANTS



MICROGRAPHS OF POLLEN GRAINS

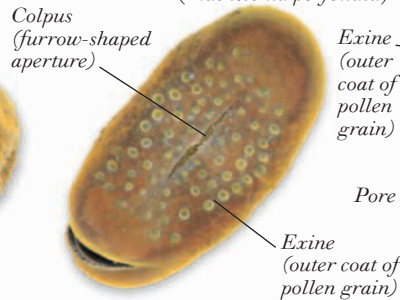
Exine (outer coat of pollen grain)



EUROPEAN FIELD ELM
(*Ulmus minor*)

MICROGRAPH OF CARPELS (FEMALE ORGANS)

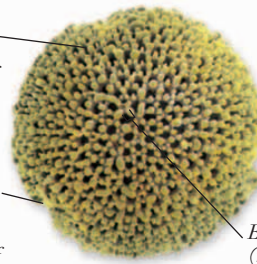
Yellow-wort
(*Blackstonia perfoliata*)



JUSTICIA AUREA

Exine (outer coat of pollen grain)

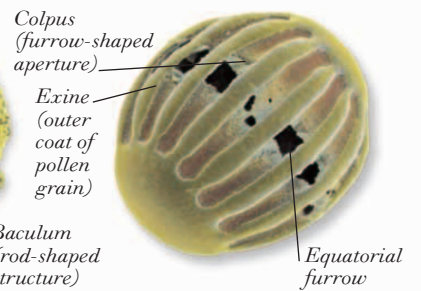
Pore



MEADOW CRANESBILL
(*Geranium pratense*)

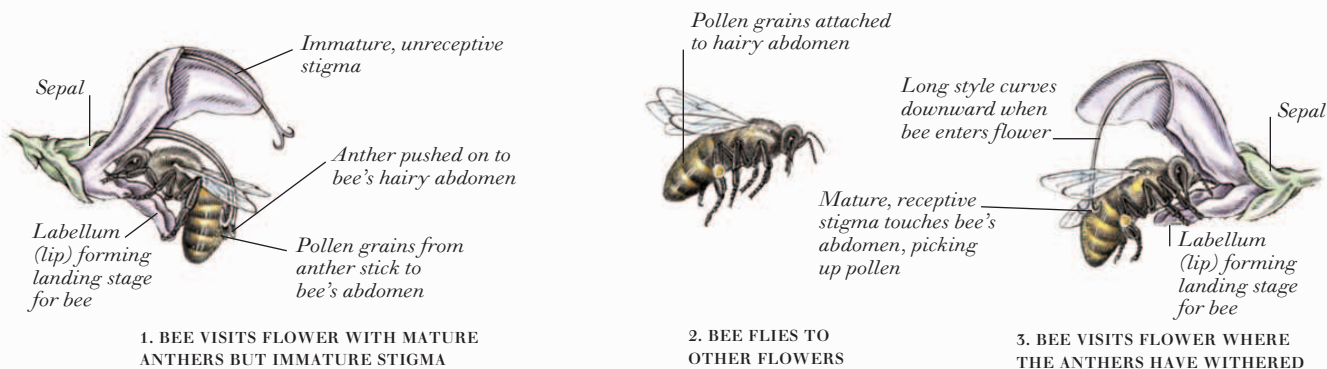
MICROGRAPH OF STAMENS (MALE ORGANS)

Common centaury
(*Centaurium erythraea*)

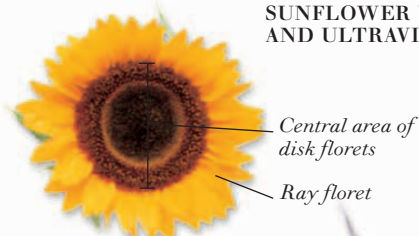


BOX-LEAVED MILKWORT
(*Polygala chamaebuxus*)

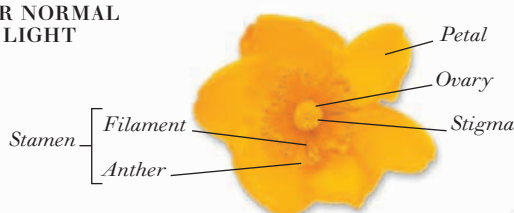
INSECT POLLINATION OF MEADOW SAGE



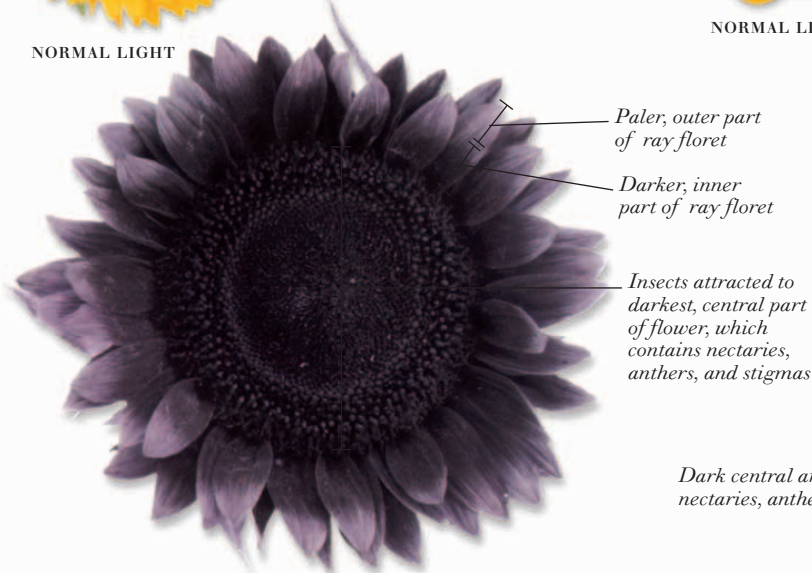
SUNFLOWER UNDER NORMAL AND ULTRAVIOLET LIGHT



NORMAL LIGHT



NORMAL LIGHT

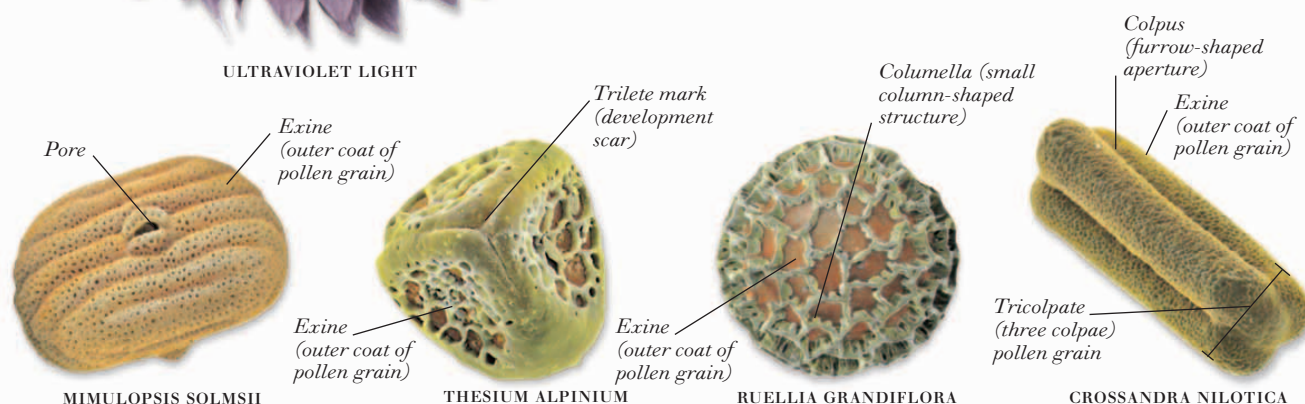


ULTRAVIOLET LIGHT

ST. JOHN'S WORT UNDER NORMAL AND ULTRAVIOLET LIGHT



ULTRAVIOLET LIGHT



MIMULOPSIS SOLMSII

THESIUM ALPINUM

RUELLIA GRANDIFLORA

CROSSANDRA NILOTICA

Fertilization

FERTILIZATION IS THE FUSION of male and female gametes (sex cells) to produce a zygote (embryo).

Following pollination (see pp. 144-145), the pollen grains that contain the male gametes are on the stigma, some distance from the female gamete (ovum) inside the ovule. To enable the gametes to meet, the pollen grain germinates and produces a pollen tube, which grows down and enters the embryo sac (the inner part of the ovule that contains the ovum).

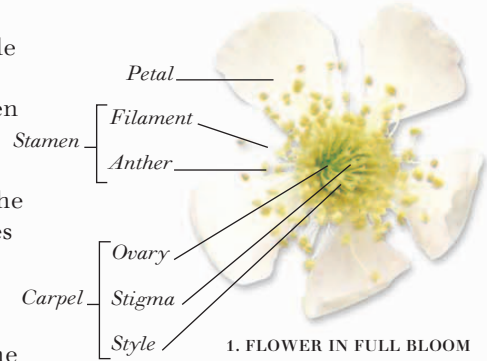
Two male gametes, traveling at the tip of the pollen tube, enter the embryo sac. One gamete fuses with the ovum to produce a zygote that will develop into an embryo plant. The other male gamete fuses with two polar nuclei to produce the endosperm, which acts as a food supply for the developing embryo. Fertilization also initiates other changes: the integument (outer part of ovule) forms a testa (seed coat) around the embryo and endosperm; the petals fall off; the stigma and style wither; and the ovary wall forms a layer (called the pericarp) around the seed. Together, the pericarp and seed form the fruit, which may be succulent (see pp. 148-149) or dry (see pp. 150-151).

In some species (e.g., blackberry), apomixis can occur: the seed develops without fertilization of the ovum by a male gamete but endosperm formation and fruit development take place as in other species.

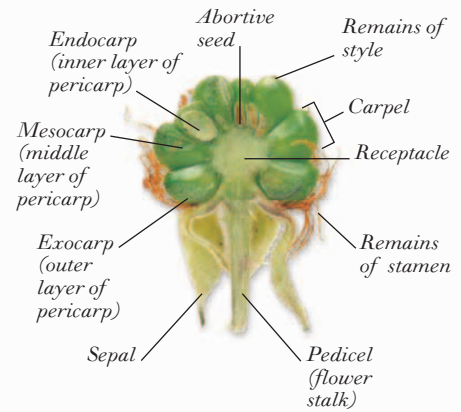


BANANA
(*Musa 'lacatan'*)

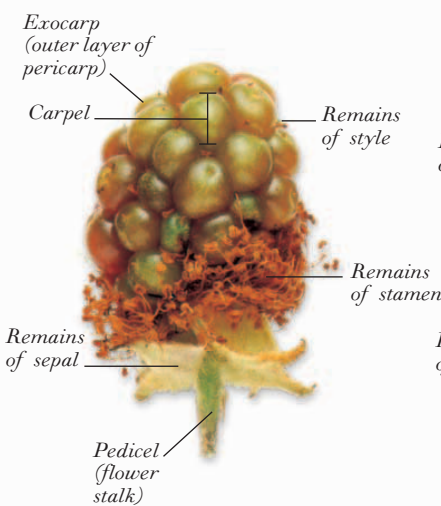
DEVELOPMENT OF A SUCCULENT FRUIT Blackberry (*Rubus fruticosus*)



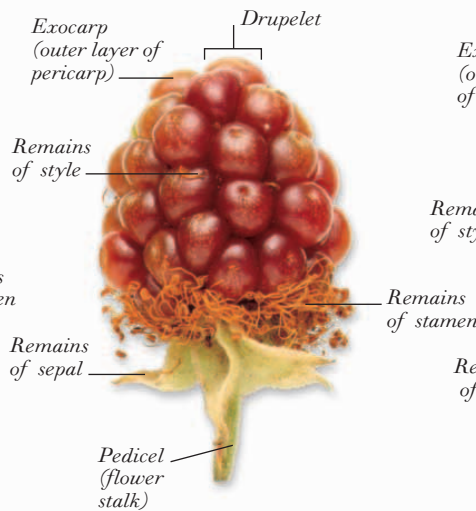
1. FLOWER IN FULL BLOOM ATTRACTS POLLINATORS



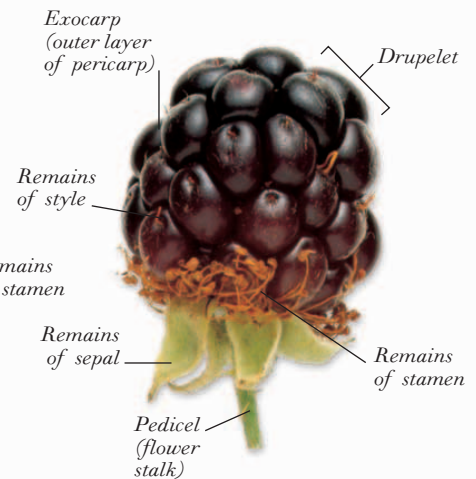
4. PERICARP FORMS FLESH, SKIN, AND A HARD INNER LAYER (SHOWN IN CROSS-SECTION)



7. MESOCARP (FLESHY PART OF PERICARP) OF EACH CARPEL STARTS TO CHANGE COLOR

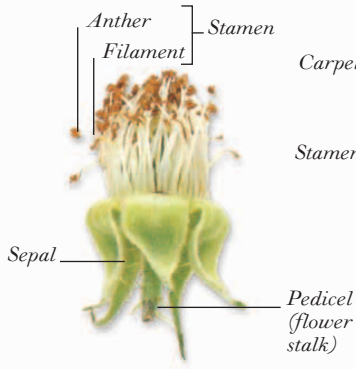


8. CARPELS MATURE INTO DRUPELETS (SMALL FLESHY FRUITS WITH SINGLE SEEDS SURROUNDED BY HARD ENDOCARP)

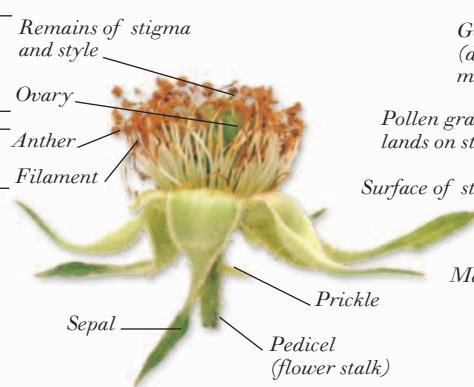


9. MESOCARP OF DRUPELET BECOMES DARKER AND SWEETER

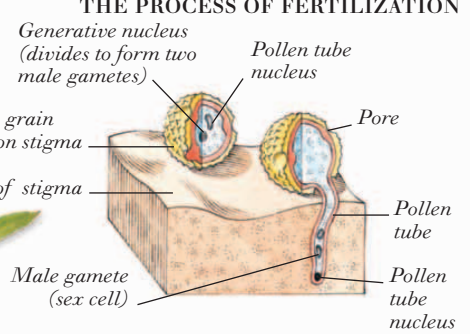
THE PROCESS OF FERTILIZATION



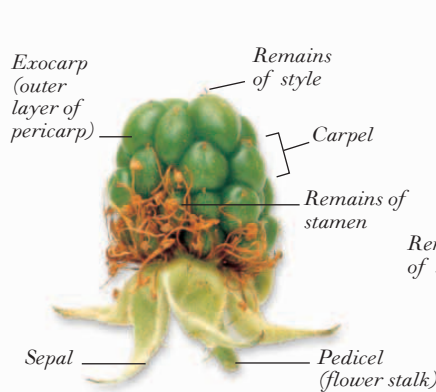
2. FERTILIZATION HAS TAKEN PLACE; PETALS FALL OFF



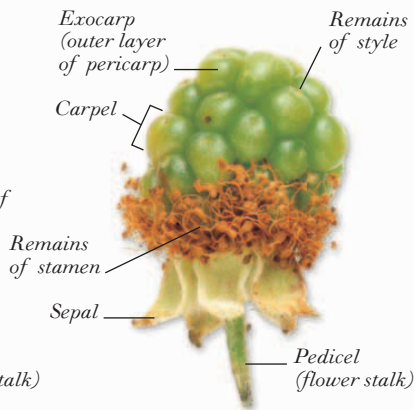
3. OVARIES BEGIN TO SWELL; STAMENS WITHER AND DIE



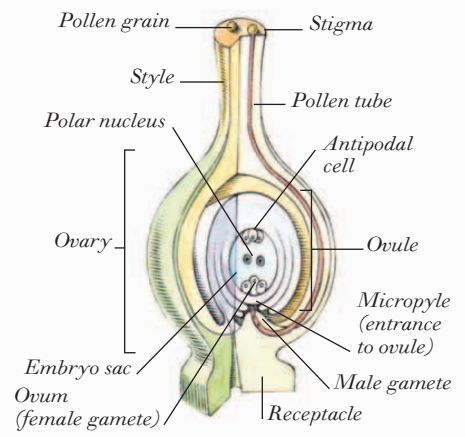
POLLEN GRAIN GERMINATES



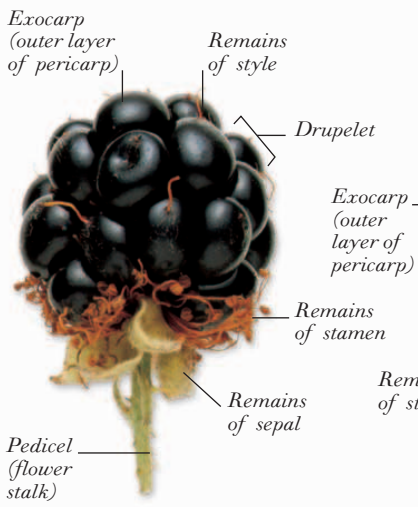
5. CARPELS EXPAND AND BECOME MORE FLESHY



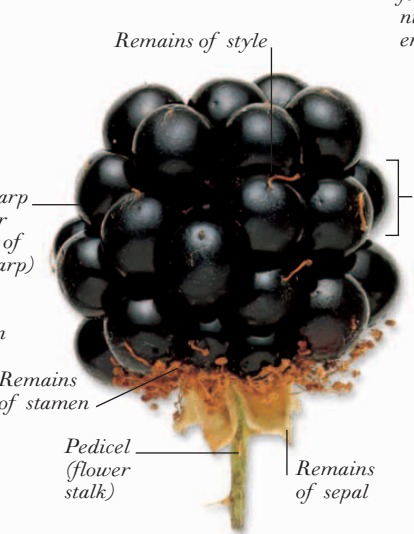
6. CARPELS EXPAND FURTHER



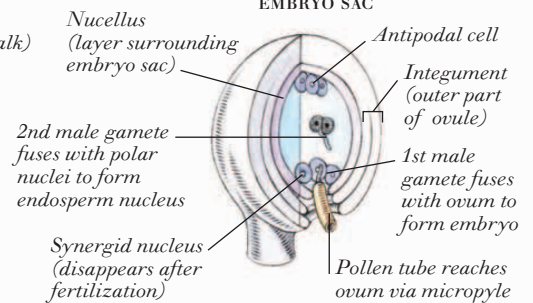
MALE GAMETES TRAVEL TO EMBRYO SAC



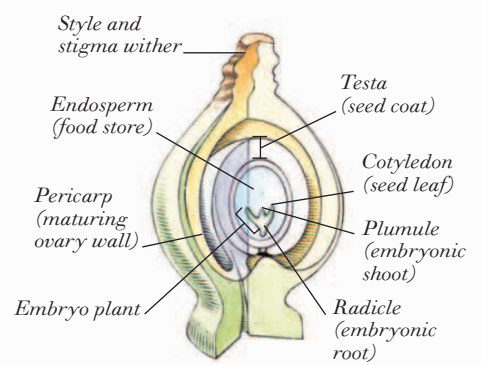
10. DRUPELETS (COLLECTIVELY AN AGGREGATE FRUIT) EXPAND



11. DRUPELETS RIPEN FULLY



FERTILIZATION



DEVELOPMENT OF EMBRYO

Succulent fruits

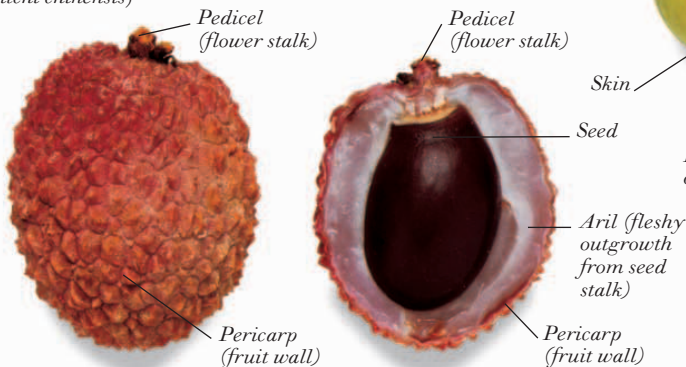
A FRUIT IS A FULLY DEVELOPED and ripened ovary (seed-producing part of a plant's female reproductive organs). Fruits may be succulent or dry

(see pp. 150-151). Succulent fruits are fleshy and brightly colored, making them attractive to animals, which eat them and so disperse the seeds away from the parent plant. The wall (pericarp) of a succulent fruit has three layers: an outer exocarp, a middle mesocarp, and an inner endocarp. These three layers vary in thickness and texture in different types of fruits and may blend into each other. Succulent fruits can be classed as simple (derived from one ovary) or compound (derived from several ovaries). Simple succulent fruits include berries,

which typically have many seeds, and drupes, which typically have a single stone or pit (e.g., cherry and peach). Compound succulent fruits include aggregate fruits, which are formed from many ovaries in one flower, and multiple fruits, which develop from the ovaries of many flowers. Some fruits, known as false fruits or pseudocarps, develop from parts of the flower in addition to the ovaries. For example, the flesh of the apple is formed from the receptacle (the upper end of the flower stalk).

FRUIT WITH FLESHY ARIL

Lychee
(*Litchi chinensis*)

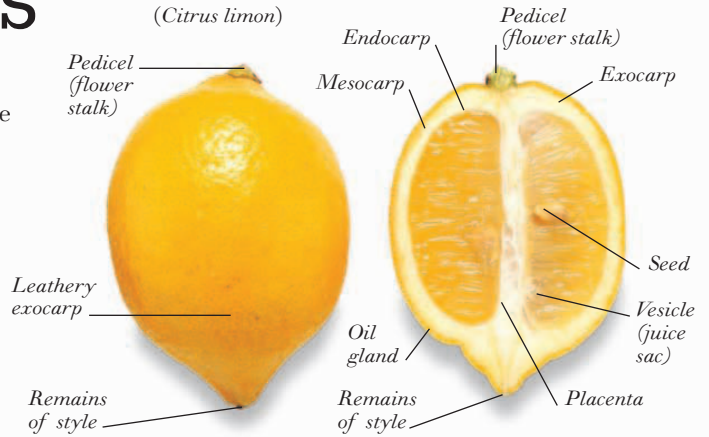


EXTERNAL VIEW OF FRUIT

LONGITUDINAL SECTION THROUGH FRUIT

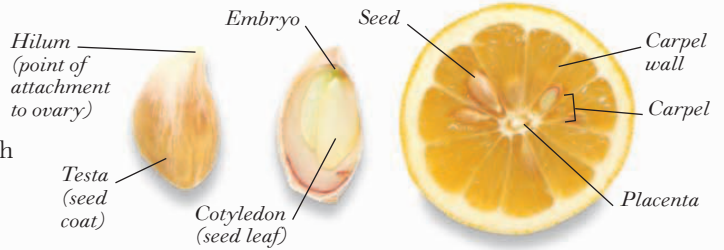
HESPERIDIUM (A TYPE OF BERRY)

Lemon
(*Citrus limon*)



EXTERNAL VIEW OF FRUIT

LONGITUDINAL SECTION THROUGH FRUIT

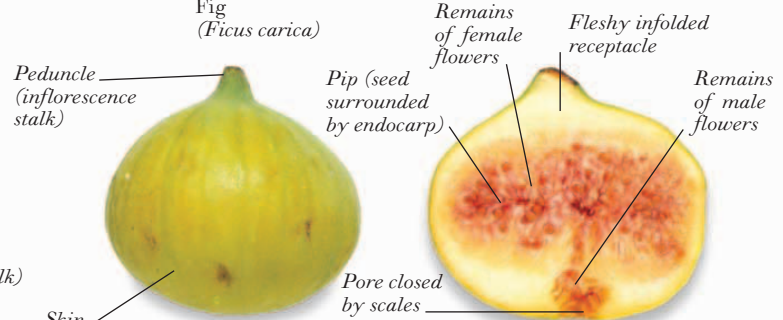


EXTERNAL VIEW AND SECTION THROUGH SEED

CROSS-SECTION THROUGH FRUIT

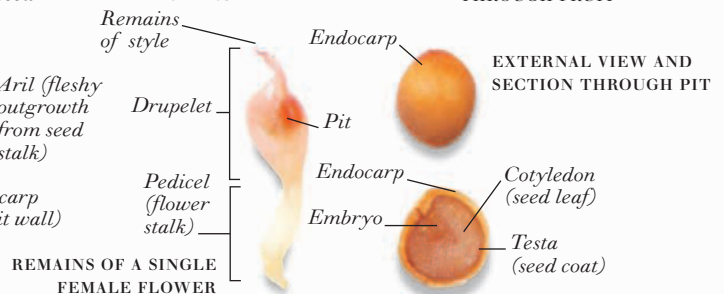
SYCONIUM (A TYPE OF FALSE FRUIT)

Fig
(*Ficus carica*)



EXTERNAL VIEW OF FRUIT

LONGITUDINAL SECTION THROUGH FRUIT

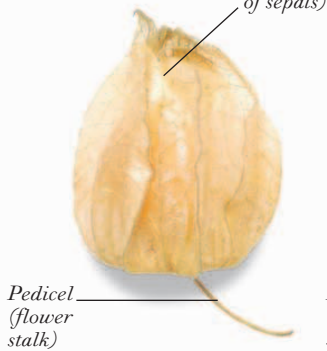


EXTERNAL VIEW AND SECTION THROUGH PIT

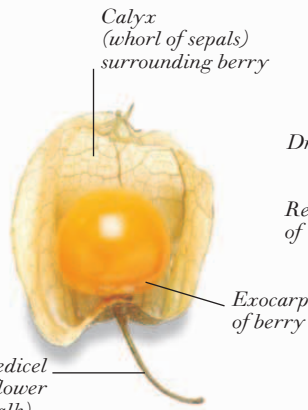
REMAINS OF A SINGLE FEMALE FLOWER

BERRY

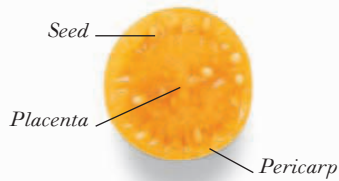
Cape gooseberry
(*Physalis peruviana*)



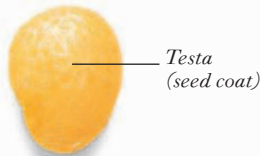
EXTERNAL VIEW OF FRUIT



INTERNAL VIEW OF FRUIT



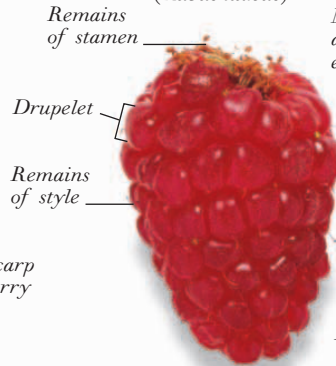
CROSS-SECTION THROUGH FRUIT



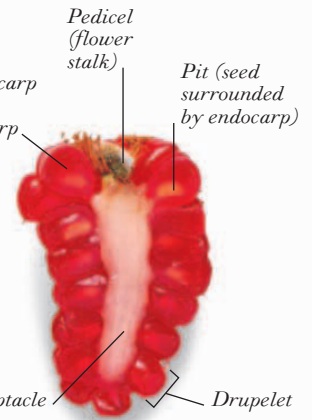
EXTERNAL VIEW OF SEED

AGGREGATE FRUIT

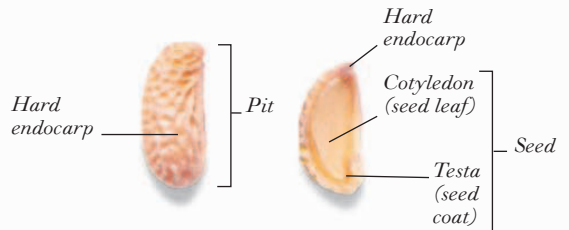
Raspberry
(*Rubus idaeus*)



EXTERNAL VIEW OF FRUIT



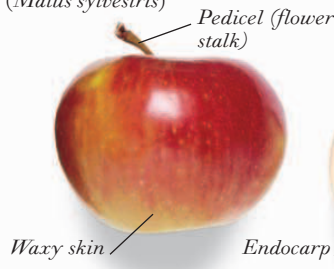
LONGITUDINAL SECTION THROUGH FRUIT



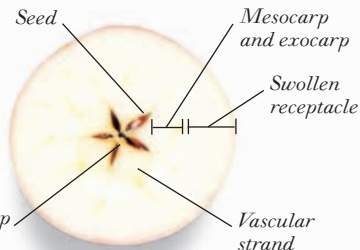
EXTERNAL VIEW AND SECTION THROUGH PIT

POME (A TYPE OF FALSE FRUIT)

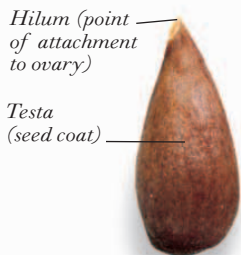
Apple
(*Malus sylvestris*)



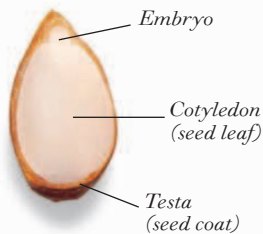
EXTERNAL VIEW OF FRUIT



CROSS-SECTION THROUGH FRUIT



EXTERNAL VIEW AND SECTION THROUGH SEED

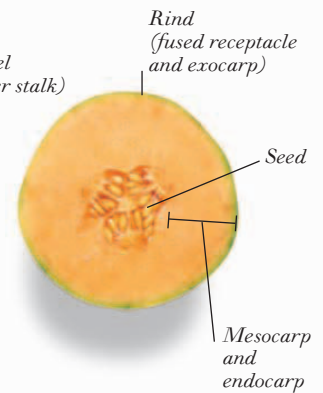


PEPO (A TYPE OF BERRY)

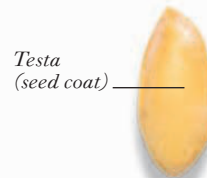
Charentais melon
(*Cucumis melo*)



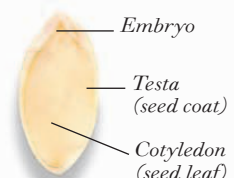
EXTERNAL VIEW OF FRUIT



CROSS-SECTION THROUGH FRUIT

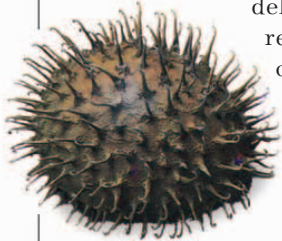


EXTERNAL VIEW AND SECTION THROUGH SEED



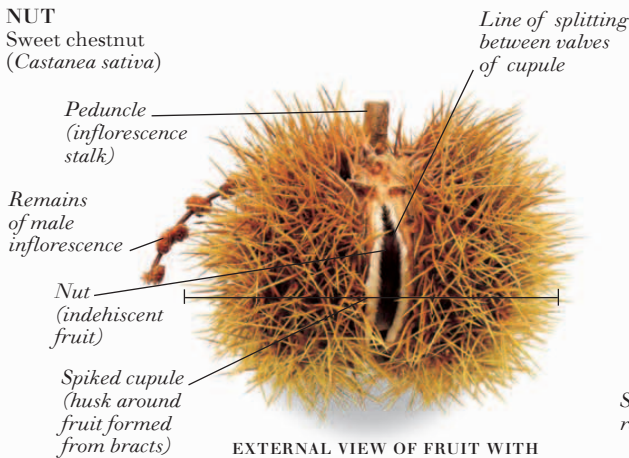
Dry fruits

DRY FRUITS HAVE A HARD, DRY PERICARP (fruit wall) around their seeds unlike succulent fruits, which have fleshy pericarps (see pp. 148-149). Dry fruits are divided into three types: dehiscent, in which the pericarp splits open to release the seeds; indehiscent, which do not split open; and schizocarpic, in which the fruit splits but the seeds are not exposed. Dehiscent dry fruits include capsules (e.g., love-in-a-mist), follicles (e.g., delphinium), legumes (e.g., pea), and siliquas (e.g., honesty). Typically, the seeds of dehiscent fruits are dispersed by the wind. Indehiscent dry fruits include nuts (e.g., sweet chestnut), nutlets (e.g., goosegrass), achenes (e.g., strawberry), caryopses (e.g., wheat), samaras (e.g., elm), and cypselas (e.g., dandelion). Some indehiscent dry fruits are dispersed by the wind, assisted by “wings” (e.g., elm) or “parachutes” (e.g., dandelion); others (e.g., goosegrass) have hooked pericarps to aid dispersal on animals’ fur. Schizocarpic dry fruits include cremocarps (e.g., hogweed), and double samaras (e.g., sycamore maple); these are dispersed by the wind.

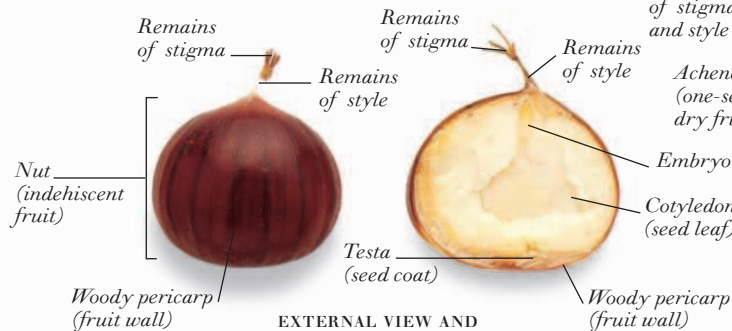


NUTLET
Goosegrass
(*Galium aparine*)

NUT
Sweet chestnut
(*Castanea sativa*)

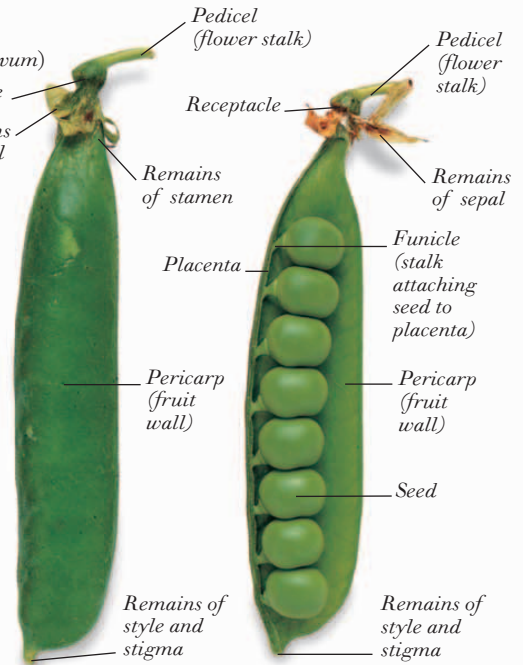


EXTERNAL VIEW OF FRUIT WITH SURROUNDING CUPULE



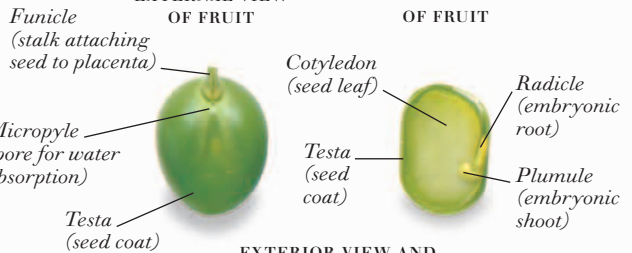
EXTERNAL VIEW AND SECTION THROUGH FRUIT

LEGUME
Pea
(*Pisum sativum*)



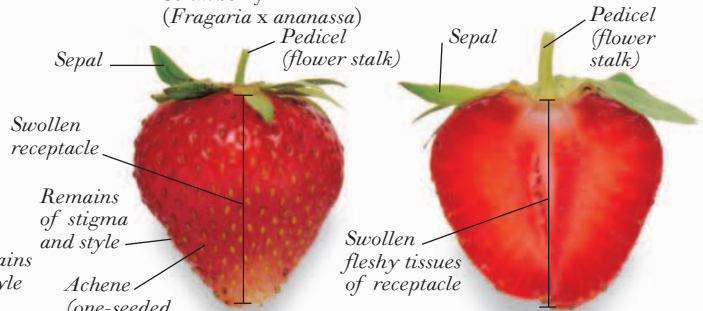
EXTERNAL VIEW OF FRUIT

INTERNAL VIEW OF FRUIT



EXTERIOR VIEW AND SECTION THROUGH SEED

ACHENE
Strawberry
(*Fragaria x ananassa*)



EXTERNAL VIEW OF FRUIT

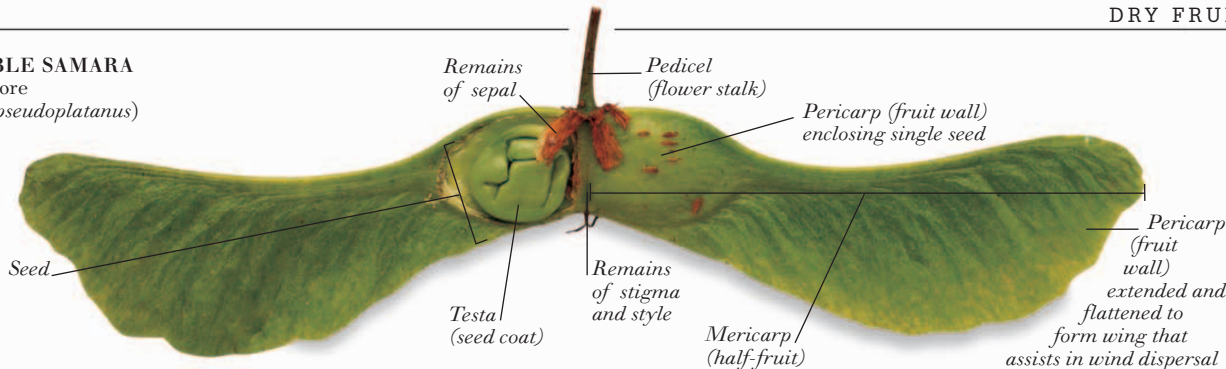
LONGITUDINAL SECTION THROUGH FRUIT



EXTERNAL VIEW AND SECTION THROUGH SEED

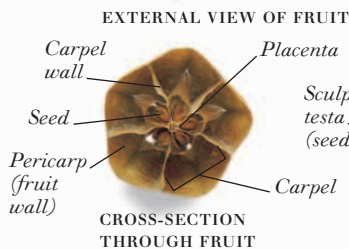
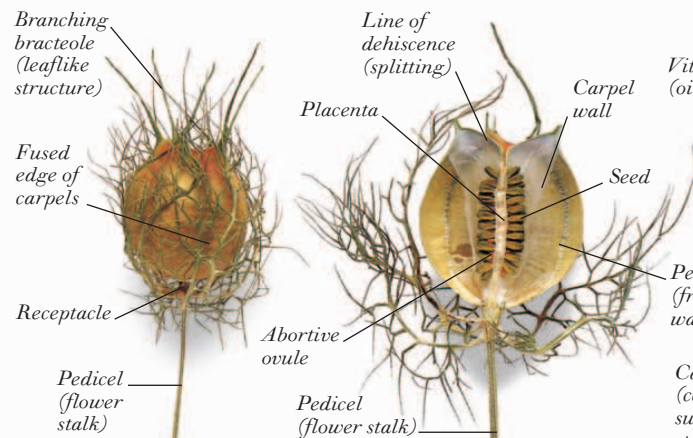
DOUBLE SAMARA

Sycamore
(*Acer pseudoplatanus*)



CAPSULE

Love-in-a-mist
(*Nigella damascena*)



EXTERNAL VIEW OF FRUIT



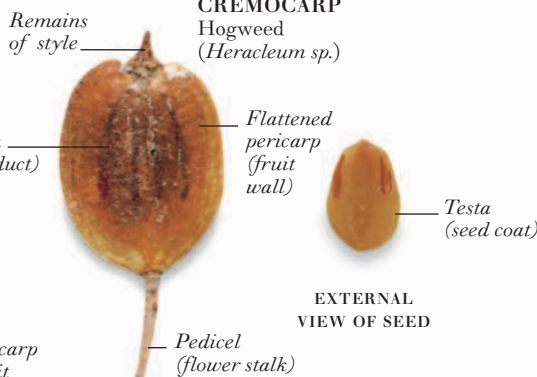
LONGITUDINAL SECTION THROUGH FRUIT



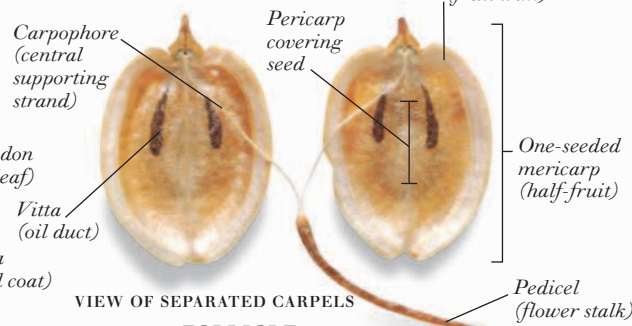
EXTERIOR VIEW AND SECTION THROUGH SEED

CREMOCARP

Hogweed
(*Heracleum* sp.)



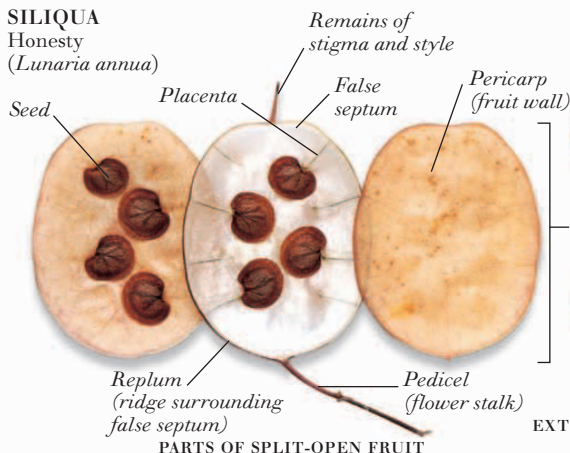
EXTERNAL VIEW OF FRUIT



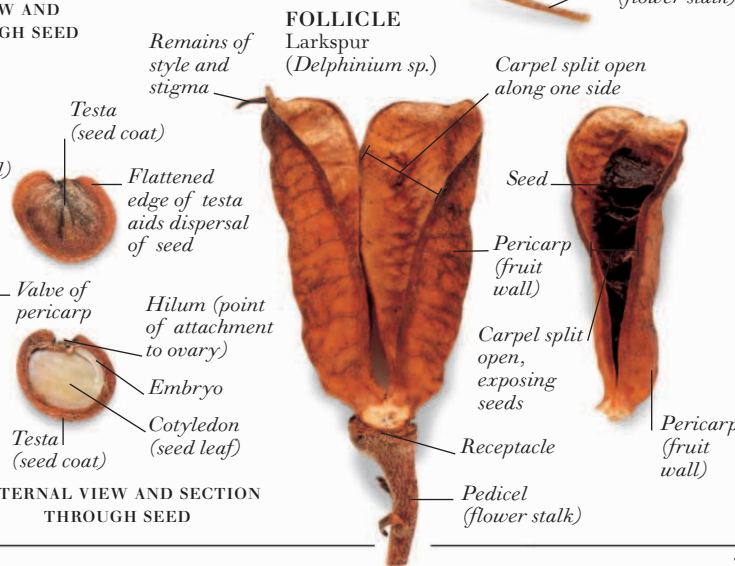
VIEW OF SEPARATED CARPELS

SILIQUA

Honesty
(*Lunaria annua*)



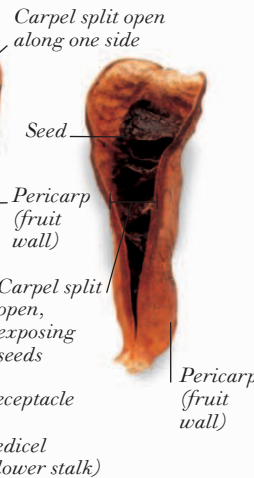
PARTS OF SPLIT-OPEN FRUIT



EXTERNAL VIEW AND SECTION THROUGH SEED

FOLLICLE

Larkspur
(*Delphinium* sp.)

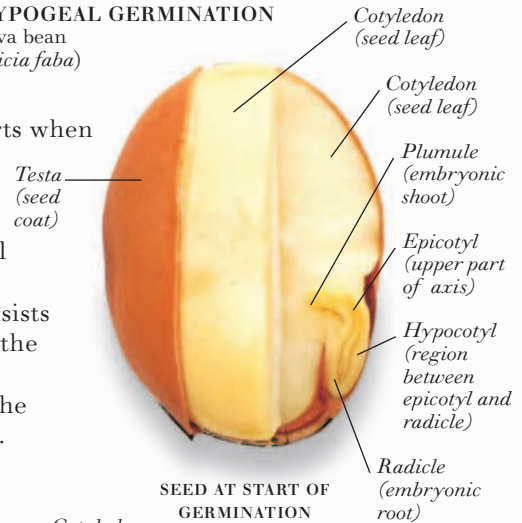


Germination

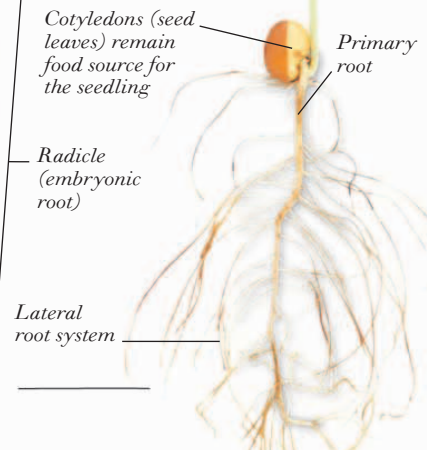
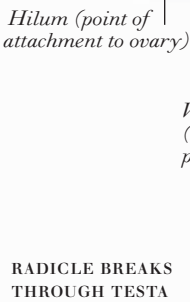
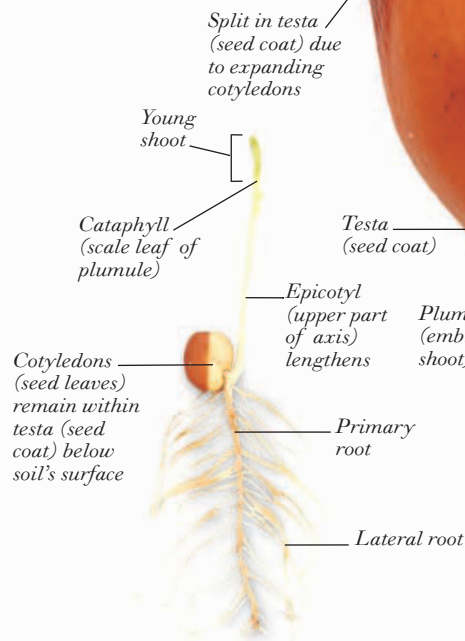
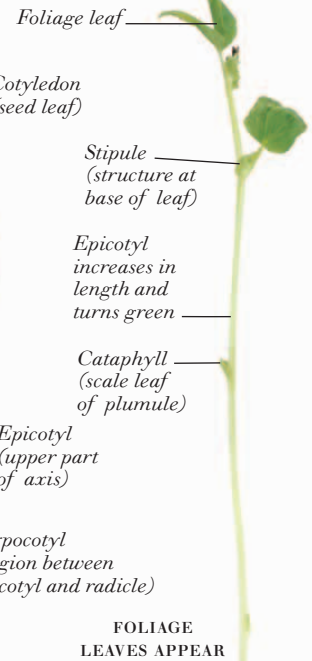
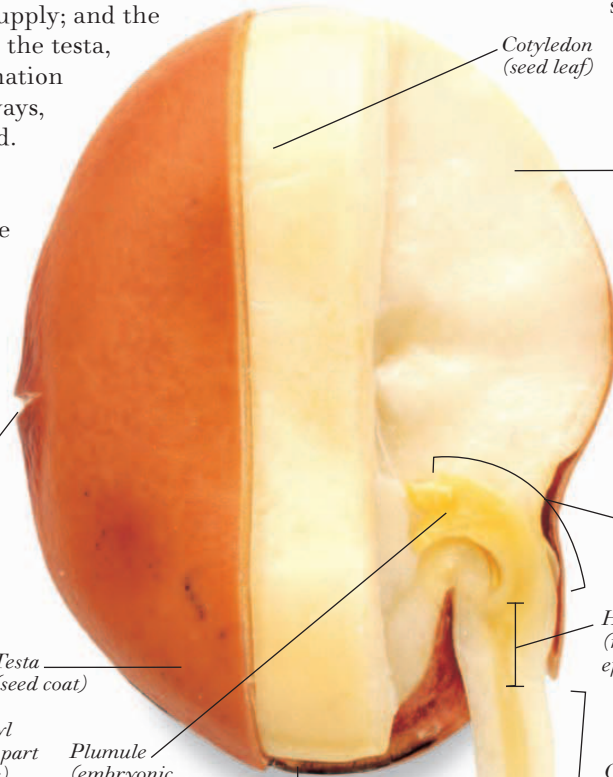
GERMINATION IS THE GROWTH OF SEEDS INTO SEEDLINGS. It starts when seeds become active below ground, and ends when the first foliage leaves appear above ground. A seed consists of an embryo and its food supply, surrounded by a testa (seed coat). The embryo is made up of one or two cotyledons (seed leaves) attached to a central axis. The upper part of the axis consists of an epicotyl, which has a plumule (embryonic shoot) at its tip. The lower part of the axis consists of a hypocotyl and a radicle (embryonic root). After dispersal from the parent plant, the seeds dehydrate and enter a period of dormancy. Following this dormant period, germination begins, provided that the seeds have enough water, oxygen, warmth, and, in some cases, light. In the first stages of germination, the seed takes in water; the embryo starts to use its food supply; and the radicle swells, breaks through the testa, and grows downward. Germination then proceeds in one of two ways, depending on the type of seed. In epigeal germination, the hypocotyl lengthens, pulling the plumule and its protective cotyledons out of the soil. In hypogeal germination, the cotyledons remain below ground and the epicotyl lengthens, pushing the plumule upward.

HYPOGEAL GERMINATION

Fava bean
(*Vicia faba*)

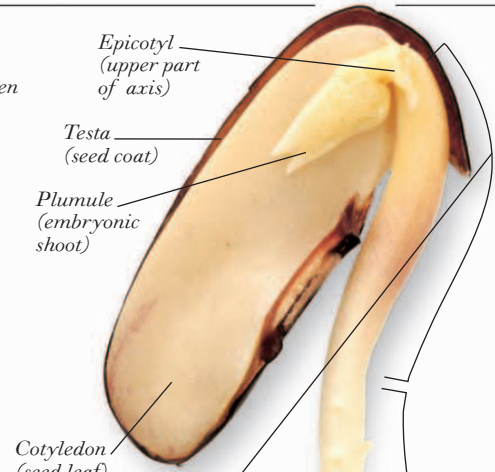
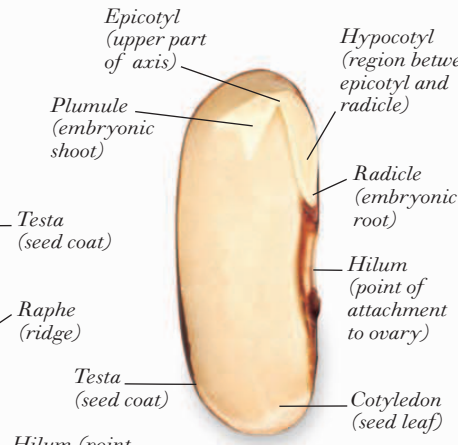


SEED AT START OF GERMINATION

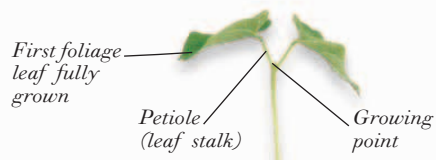


EPIGEAL GERMINATION

Black bean
(*Phaseolus sp.*)

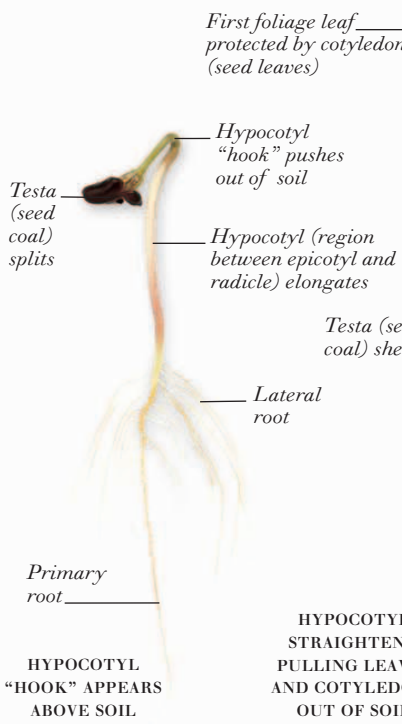


LONGITUDINAL SECTION THROUGH SEED AT START OF GERMINATION

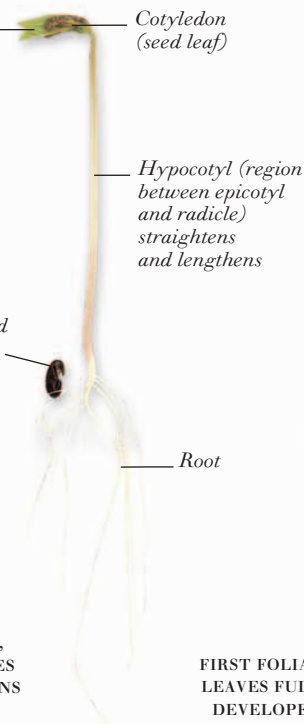


Lateral root

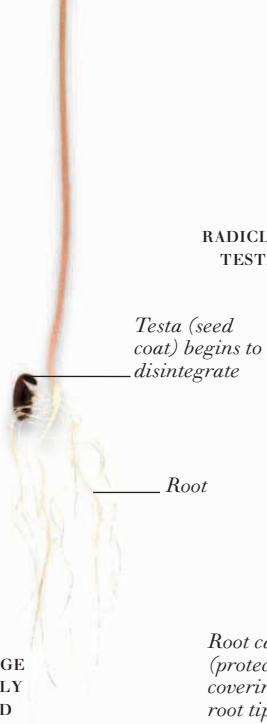
EXTERNAL VIEW OF SEED AT START OF GERMINATION



HYPOCOTYL "HOOK" APPEARS ABOVE SOIL



HYPOCOTYL STRAIGHTENS, PULLING LEAVES AND COTYLEDONS OUT OF SOIL



FIRST FOLIAGE LEAVES FULLY DEVELOPED

RADICLE BREAKS THROUGH TESTA AND LENGTHENS

Testa (seed coat) begins to disintegrate

Root

Root

Root cap (protective covering for root tip)

Primary root (elongated radicle)

Vegetative reproduction

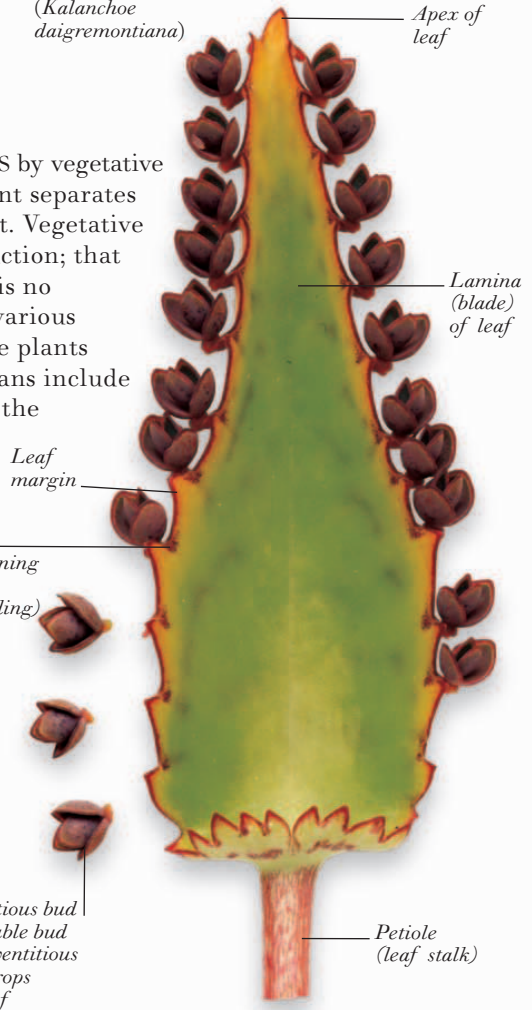


CORM
Gladiolus
(*Gladiolus sp.*)

MANY PLANTS CAN PROPAGATE THEMSELVES by vegetative reproduction. In this process, part of a plant separates off, takes root, and grows into a new plant. Vegetative reproduction is a type of asexual reproduction; that is, it involves only one parent, and there is no fusion of gametes (sex cells). Plants use various structures to reproduce vegetatively. Some plants use underground storage organs. Such organs include rhizomes (horizontal, underground stems), the branches of which produce new plants; bulbs (swollen leaf bases) and corms (swollen stems), which produce daughter bulbs or corms that separate off from the parent; and stem tubers (thickened underground stems) and root tubers (swollen adventitious roots), which also separate off from the parent. Other propagative structures include runners and stolons, creeping horizontal stems that take root and produce new plants; bulbils, small bulbs that develop on the stem or in the place of flowers, and then drop off and grow into new plants; and adventitious buds, miniature plants that form on leaf margins before dropping to the ground and growing into mature plants.

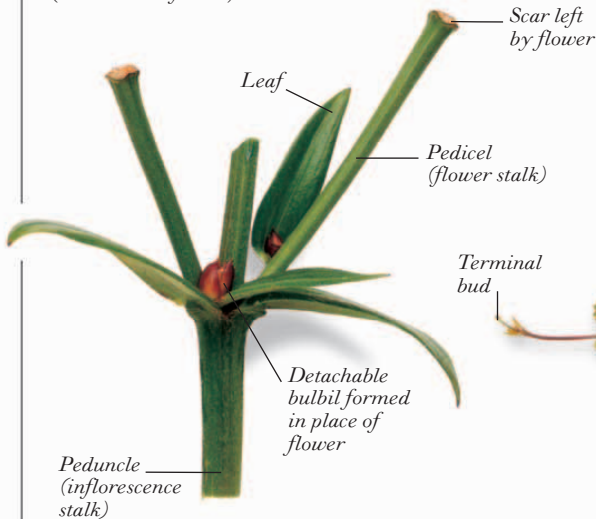
ADVENTITIOUS BUD

Mexican hat plant
(*Kalanchoe daigremontiana*)



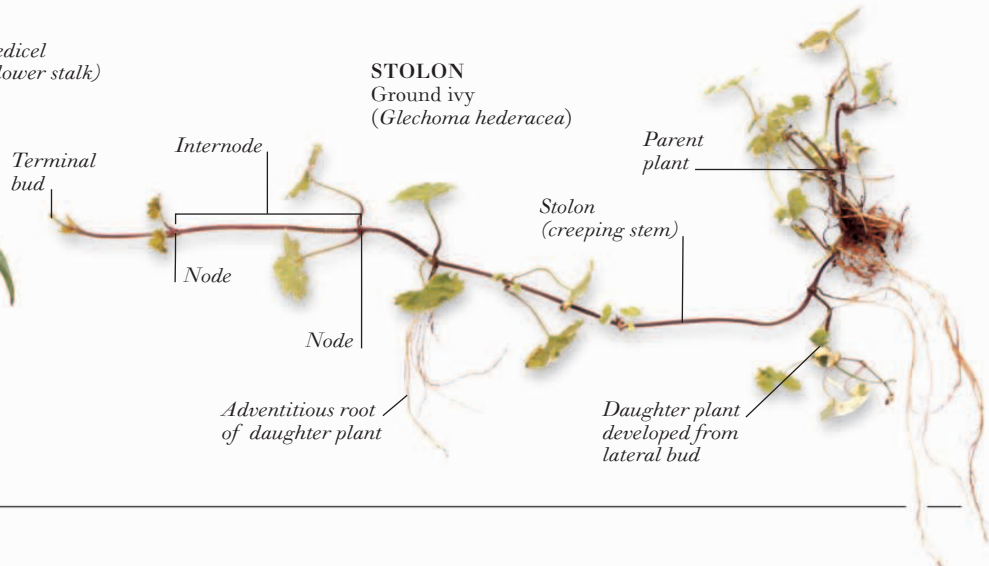
BULBIL IN PLACE OF FLOWER

Orange lily
(*Lilium bulbiferum*)

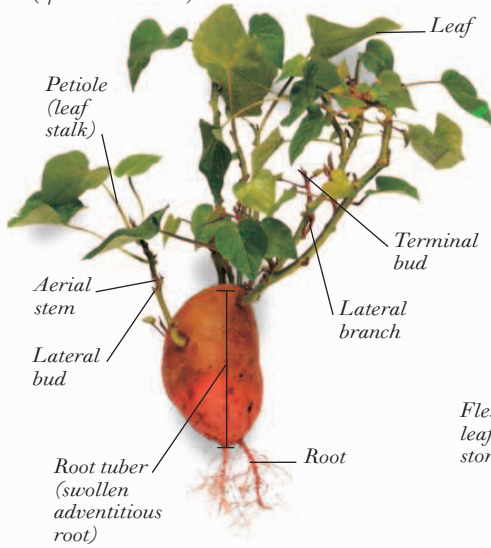


STOLON

Ground ivy
(*Glechoma hederacea*)



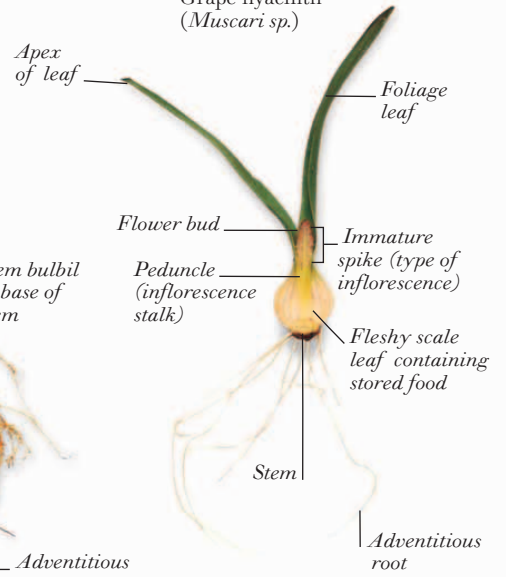
ROOT TUBER
Sweet potato
(*Ipomoea batatas*)



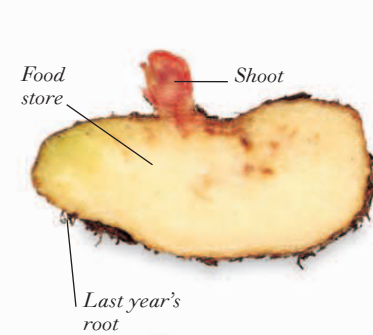
STEM BULBIL
Lily
(*Lilium sp.*)



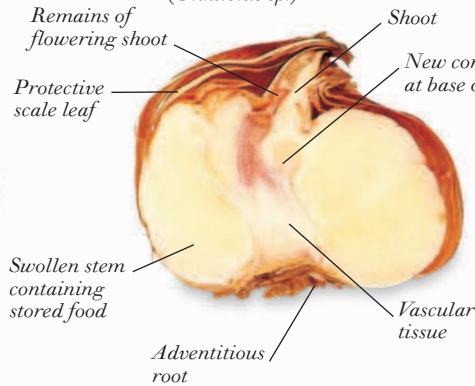
GROWING BULB
Grape hyacinth
(*Muscari sp.*)



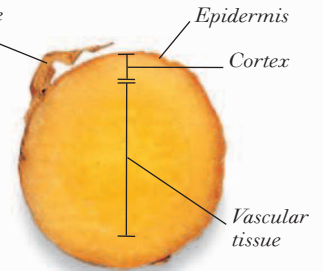
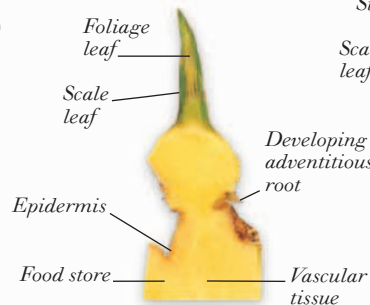
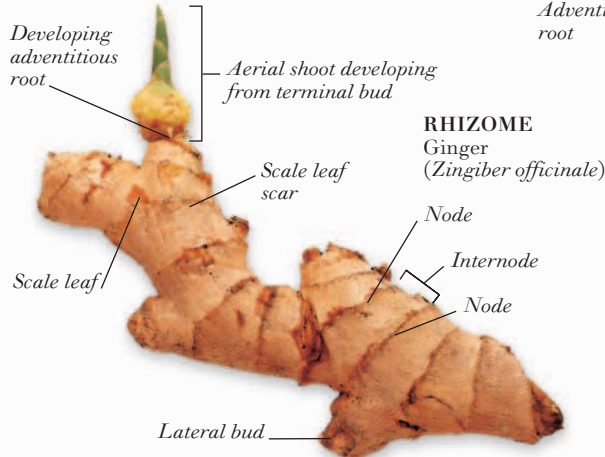
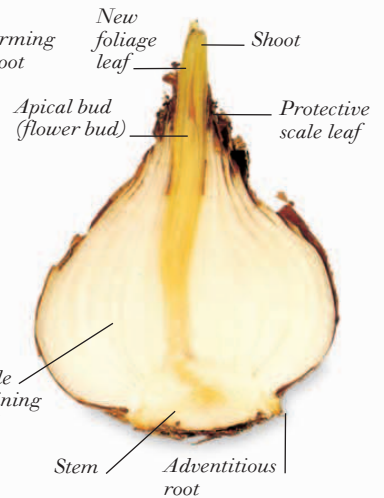
ROOT TUBER
Begonia
(*Begonia x tuberhybrida*)



CORM
Gladiolus
(*Gladiolus sp.*)



BULB WITH SHOOT
Amaryllis
(*Hippeastrum sp.*)



EXTERNAL VIEW

LONGITUDINAL SECTION THROUGH AERIAL SHOOT

CROSS-SECTION THROUGH RHIZOME

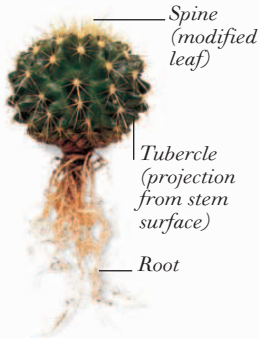
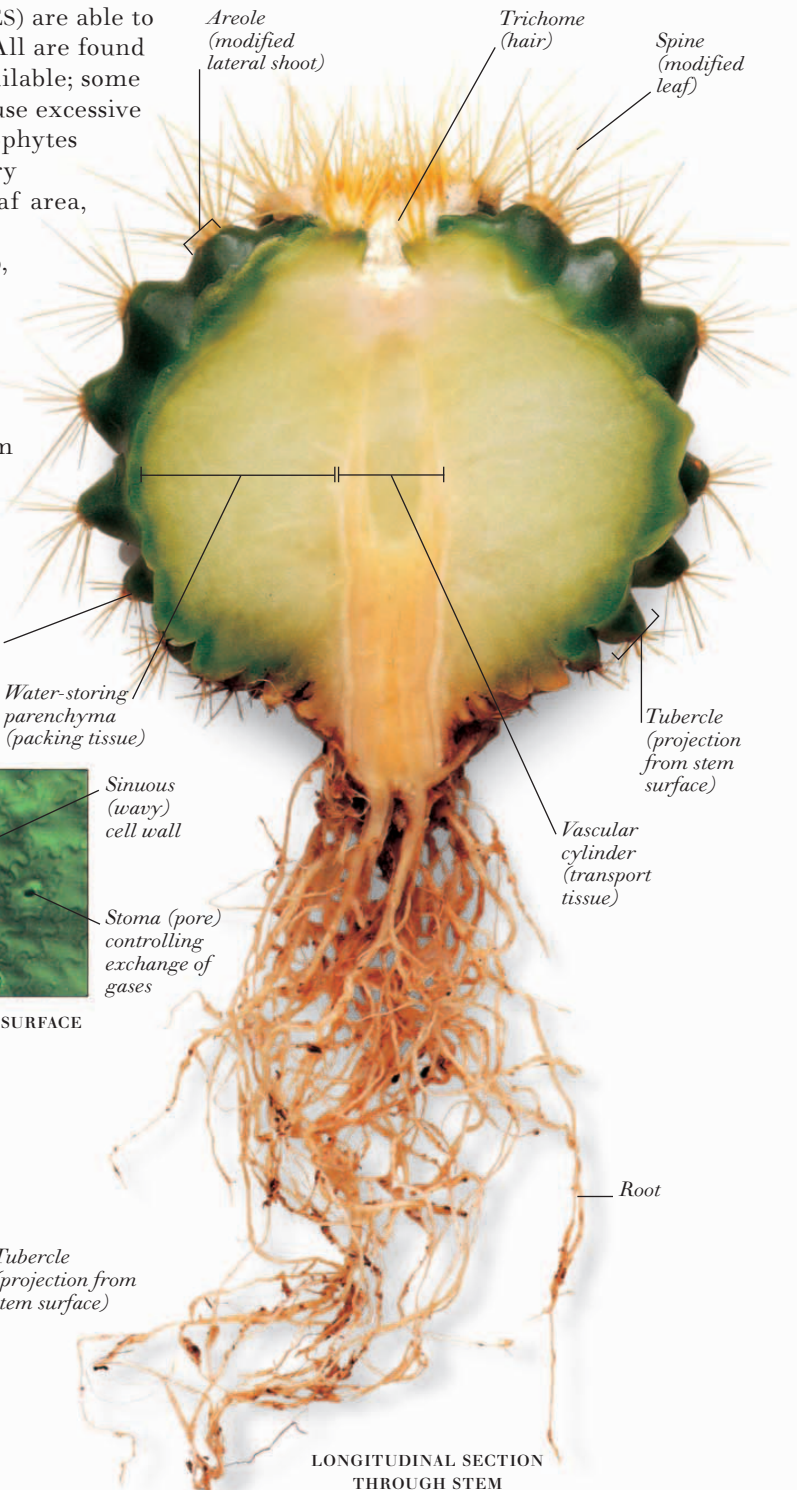
Dryland plants



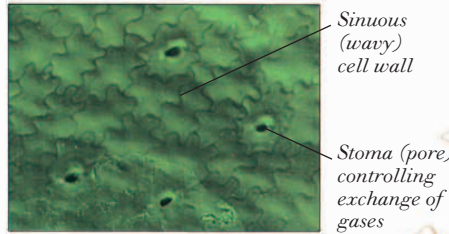
LEAF
SUCCULENT
Lithops sp.

DRYLAND PLANTS (XEROPHYTES) are able to survive in unfavorable habitats. All are found in places where little water is available; some live in high temperatures that cause excessive loss of water from the leaves. Xerophytes show a number of adaptations to dry conditions; these include reduced leaf area, rolled leaves, sunken stomata, hairs, spines, and thick cuticles. One group, succulent plants, stores water in specially enlarged spongy tissues found in leaves, roots, or stems. Leaf succulents have enlarged, fleshy, water-storing leaves. Root succulents have a large, underground water-storage organ with short-lived stems and leaves above ground. Stem succulents are represented by the cacti (family Cactaceae). Cacti stems are fleshy, green, and photosynthetic; they are typically ribbed or covered by tubercles in rows, with leaves being reduced to spines or entirely absent.

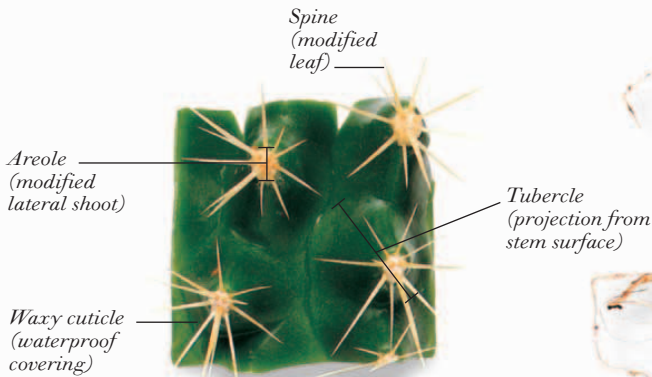
STEM SUCCULENT
Golden barrel cactus
(*Echinocactus grusonii*)



EXTERNAL VIEW



MICROGRAPH OF STEM SURFACE



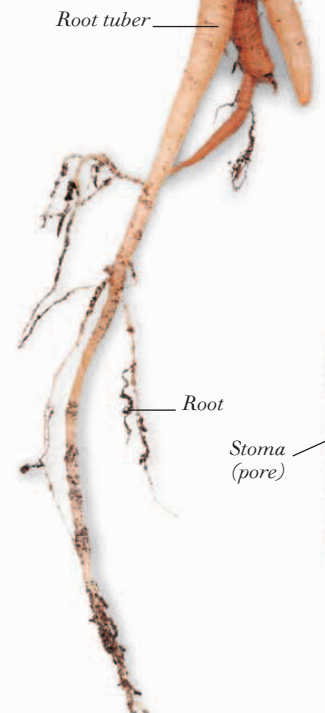
DETAIL OF STEM SURFACE

LONGITUDINAL SECTION
THROUGH STEM

LEAF SUCCULENT

Haworthia truncata

Translucent "window" allows light to reach base of leaf



Succulent leaf

Root tuber

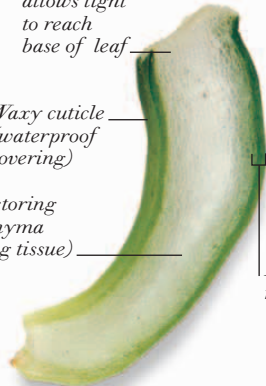
Root

Stoma (pore)

Translucent "window" allows light to reach base of leaf

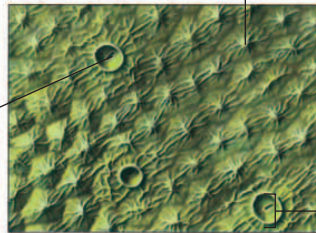
Waxy cuticle (waterproof covering)

Water-storing parenchyma (packing tissue)



LONGITUDINAL SECTION THROUGH LEAF

Raised cell surface



Cup surrounding sunken stoma (pore)

MICROGRAPH OF LEAF SURFACE

LEAF SUCCULENT

Lithops bromfieldii

Leaf

Dead, withered leaf

Fissure

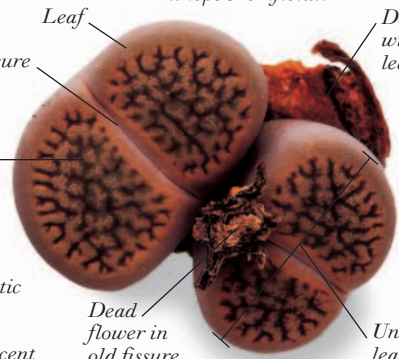
Mottled surface of leaf

Photosynthetic region

Translucent "window" allows light to reach center of leaf

Dead flower in old fissure

Unified leaf pair

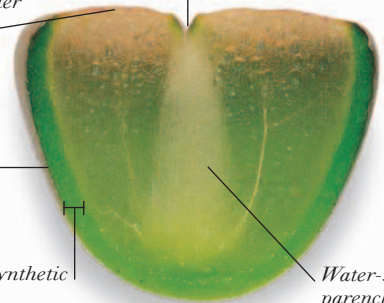


Fissure

Waxy cuticle (waterproof covering)

Photosynthetic region

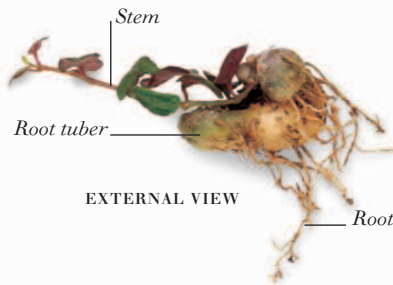
Water-storing parenchyma (packing tissue)



LONGITUDINAL SECTION THROUGH LEAF PAIR

STEM AND ROOT SUCCULENT

String of hearts (*Ceropegia woodii*)



EXTERNAL VIEW

Stem

Root tuber

Root

Petiole (leaf stalk)

Succulent trailing stem

Succulent leaf

Root tuber

Water-storing parenchyma

Root

LONGITUDINAL SECTION THROUGH ROOT TUBER

ROOT SUCCULENT

Oxalis sp.

Petiole (leaf stalk)

Flower bud

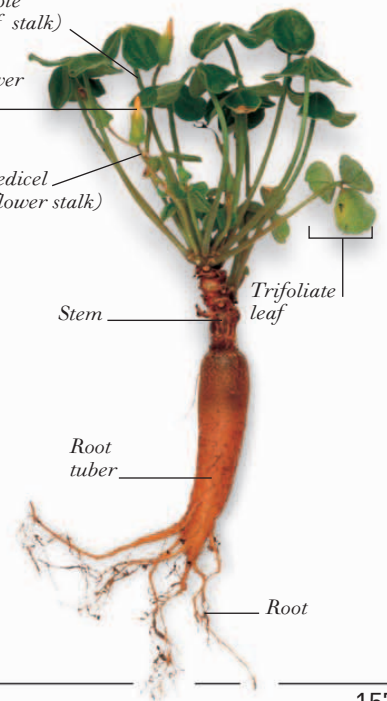
Pedicle (flower stalk)

Stem

Trifoliate leaf

Root tuber

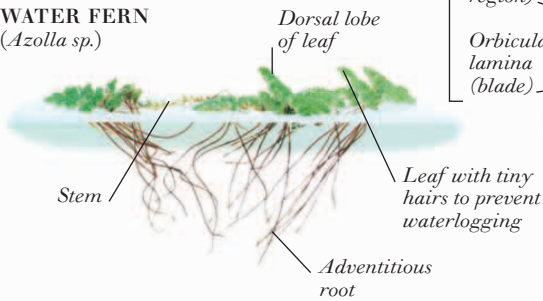
Root



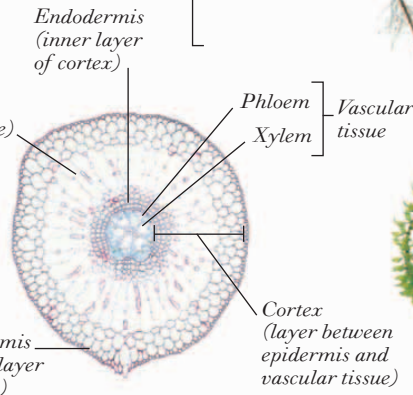
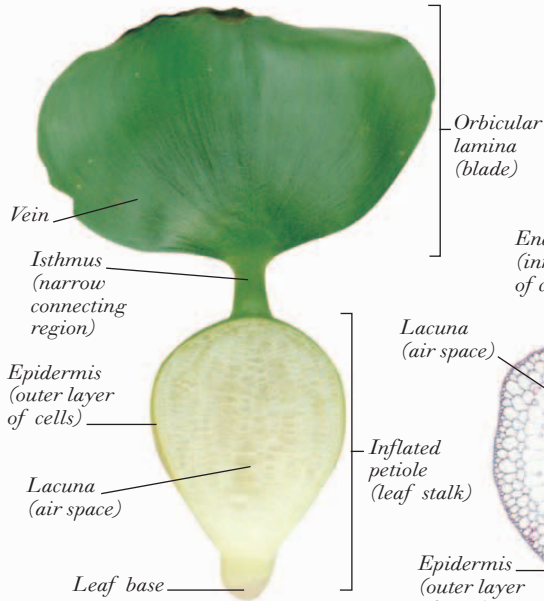
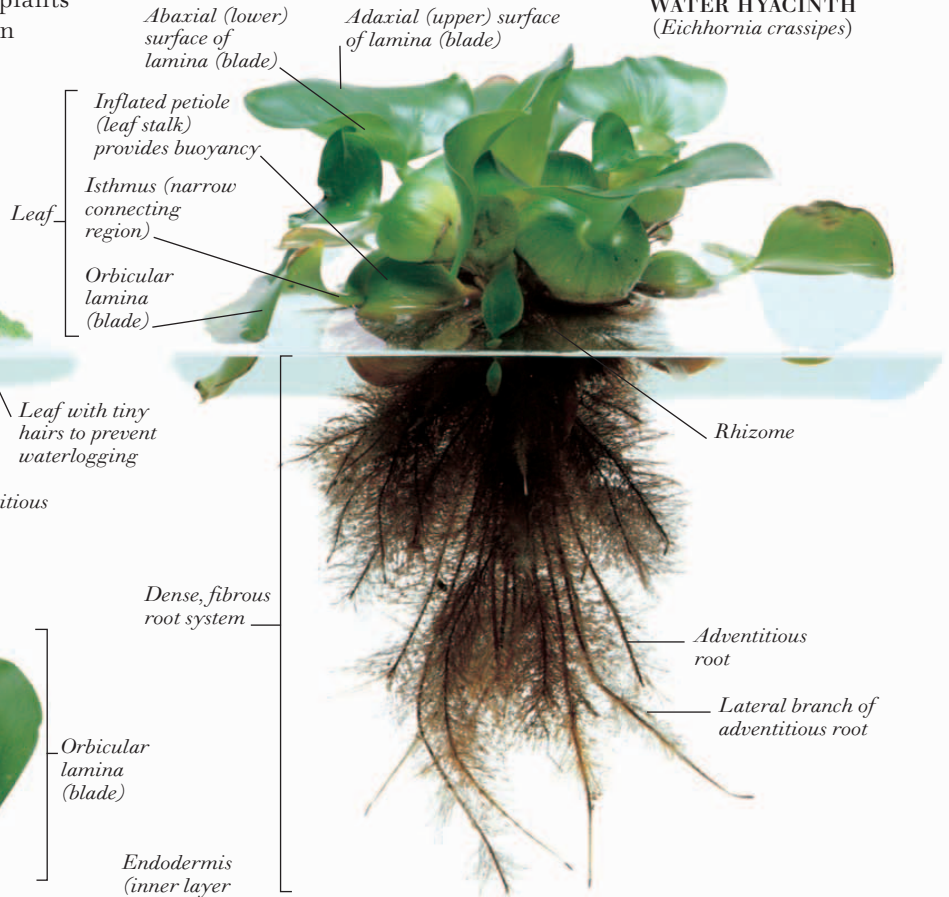
Wetland plants

WETLAND PLANTS GROW SUBMERGED IN WATER, either partially (e.g., water hyacinth) or completely (e.g., pond weeds), and show various adaptations to this habitat. Typically, there are numerous air spaces inside the stems, leaves, and roots; these aid gas exchange and buoyancy. Submerged parts generally have no cuticle (waterproof covering), enabling the plants to absorb minerals and gases directly from the water; in addition, being supported by the water, they need little of the supportive tissue found in land plants. Stomata, the gas exchange pores, are absent from plants that are completely submerged; in partially submerged plants with floating leaves (e.g., water lilies), stomata are found on the upper leaf surfaces, where they cannot be flooded.

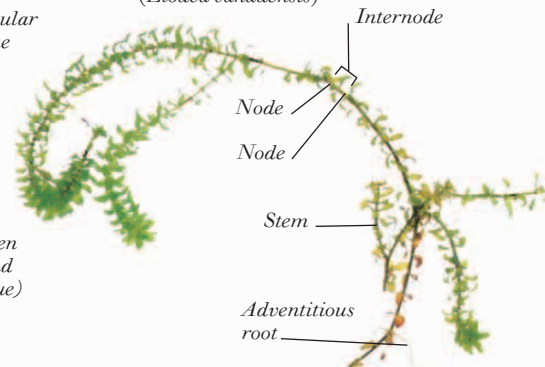
WATER FERN
(*Azolla* sp.)



WATER HYACINTH
(*Eichhornia crassipes*)



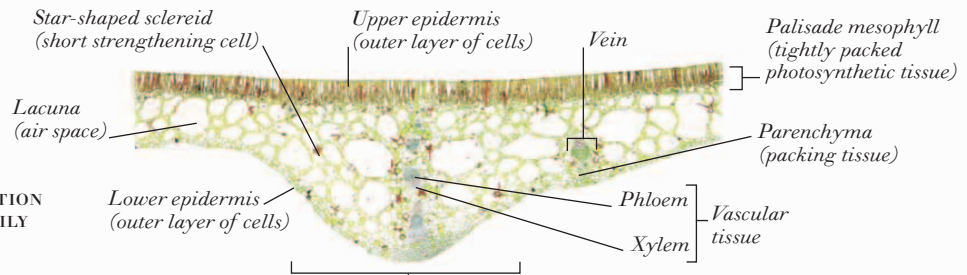
CANADIAN POND WEED
(*Elodea canadensis*)



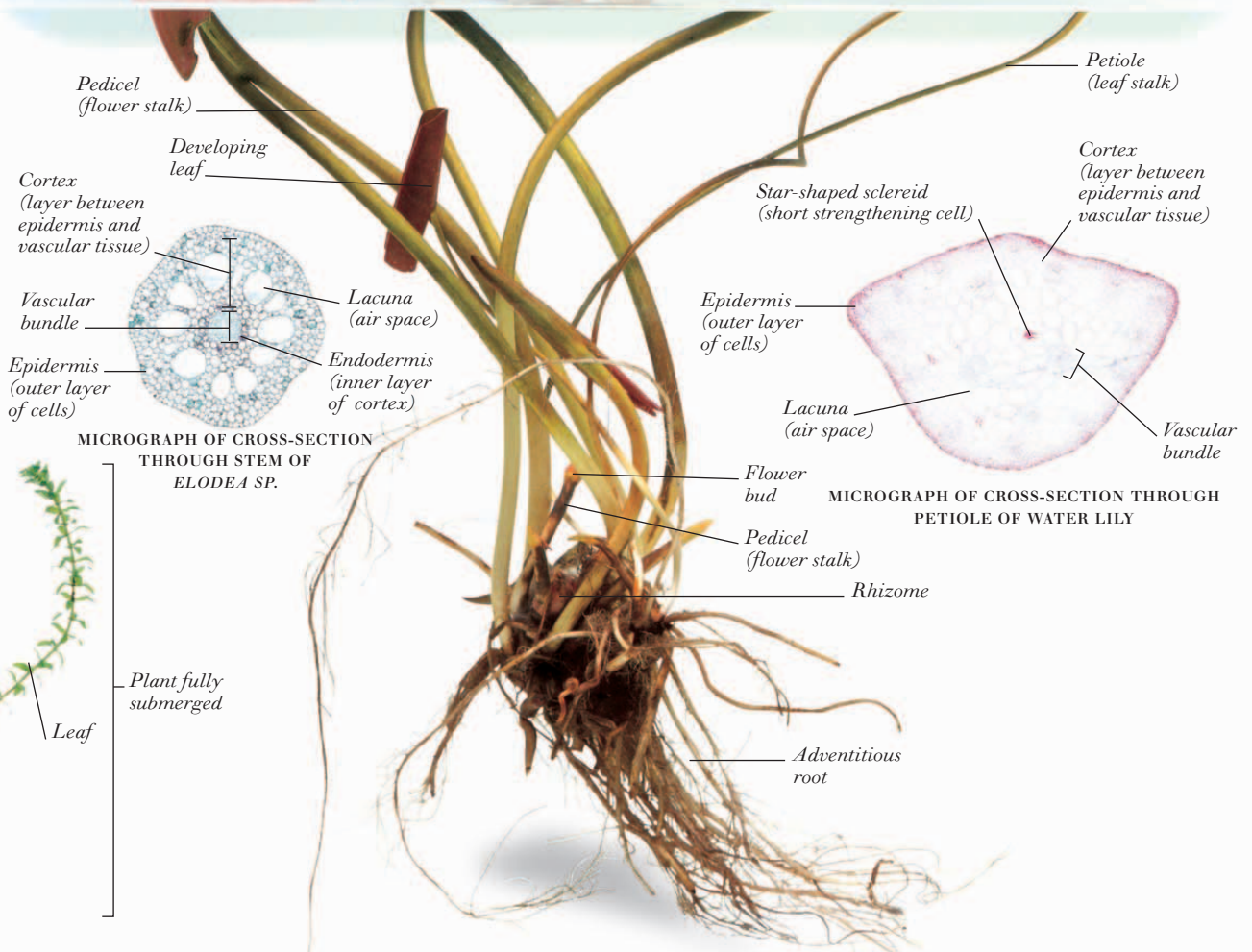
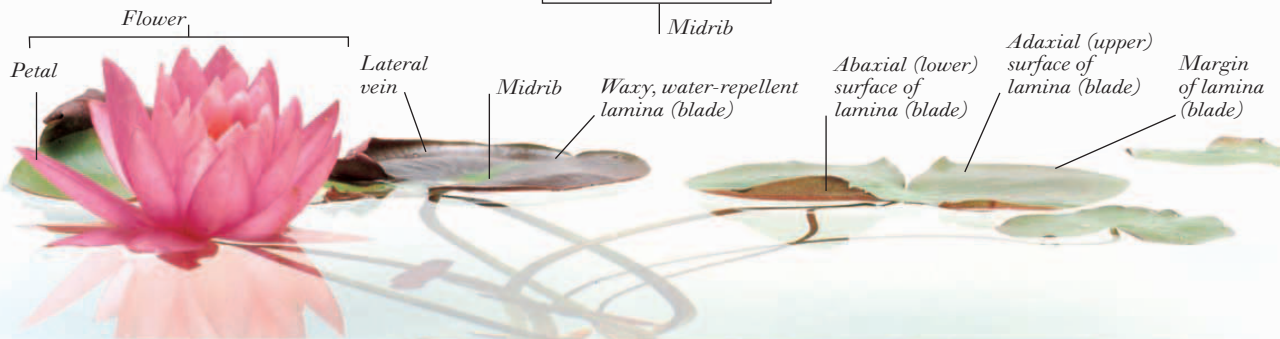
LAMINA AND SECTION THROUGH INFLATED PETIOLE OF WATER HYACINTH

MICROGRAPH OF CROSS-SECTION THROUGH ROOT OF WATER HYACINTH

WATER LILY
(*Nymphaea sp.*)



MICROGRAPH OF CROSS-SECTION THROUGH LEAF OF WATER LILY



MICROGRAPH OF CROSS-SECTION THROUGH STEM OF *ELODEA SP.*

MICROGRAPH OF CROSS-SECTION THROUGH PETIOLE OF WATER LILY

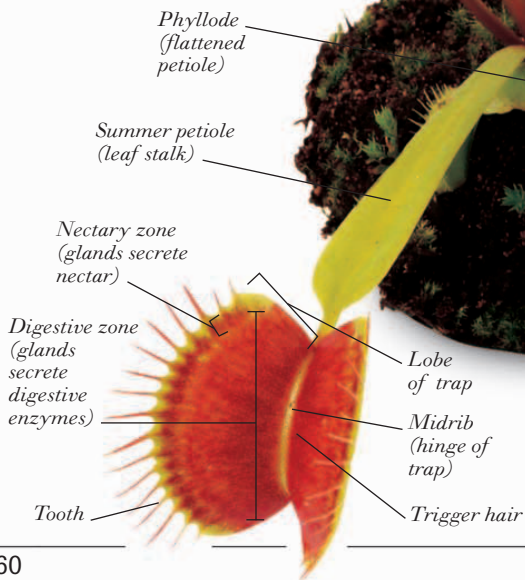
Plant fully submerged

Carnivorous plants

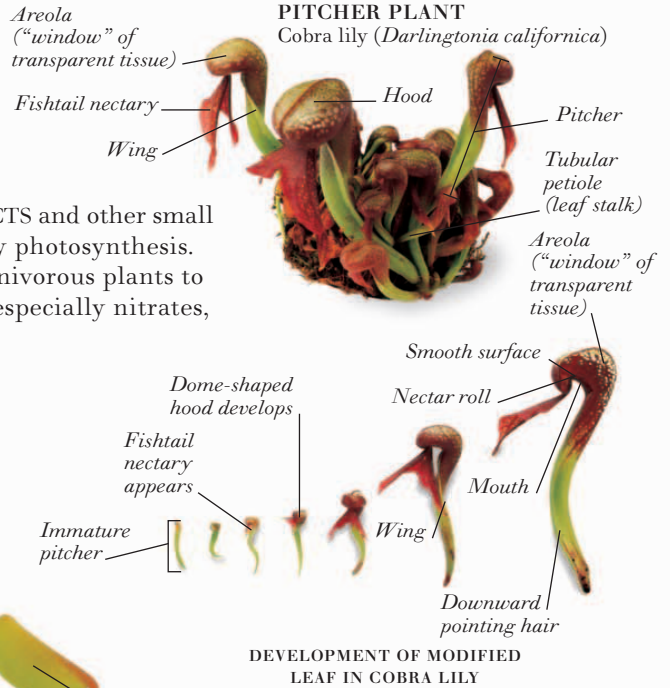
CARNIVOROUS (INSECTIVOROUS) PLANTS FEED ON INSECTS and other small animals, in addition to producing food in their leaves by photosynthesis. The nutrients absorbed from trapped insects enable carnivorous plants to thrive in acid, boggy soils that lack essential minerals, especially nitrates, where most other plants could not survive.

All carnivorous plants have some leaves modified as traps; many use bright colors and scented nectar to attract prey; and most use enzymes to digest the prey. There are three types of traps. Pitcher plants, such as the monkey cup and cobra lily, have leaves modified as pitcher-shaped pitfall traps, half-filled with water; once lured inside the mouth of the trap, insects lose their footing on the slippery surface, fall into the liquid, and either decompose or are digested. Venus fly traps use a spring-trap mechanism; when an insect touches trigger hairs on the inner surfaces of the leaves, the two lobes of the trap snap shut. Butterworts and sundews entangle prey by sticky droplets on the leaf surface, while the edges of the leaves slowly curl over to envelop and digest the prey.

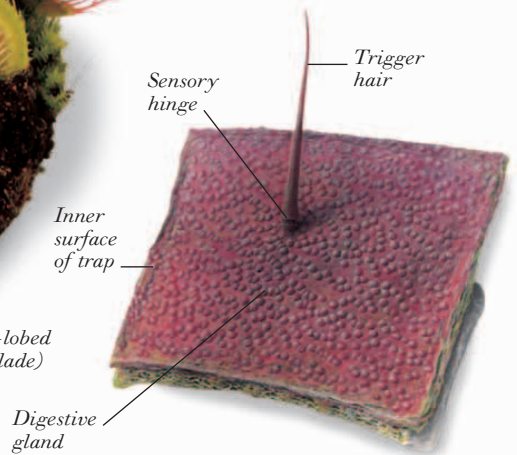
VENUS FLY TRAP (*Dionaea muscipula*)



PITCHER PLANT Cobra lily (*Darlingtonia californica*)

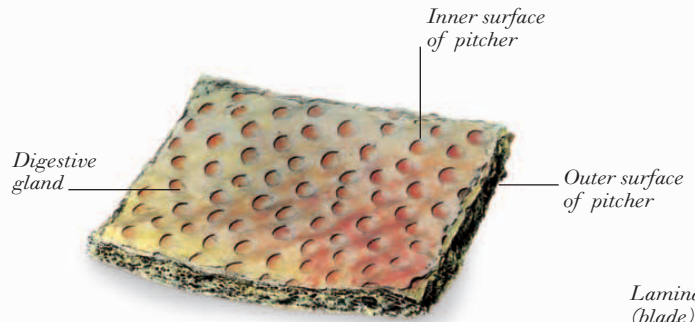
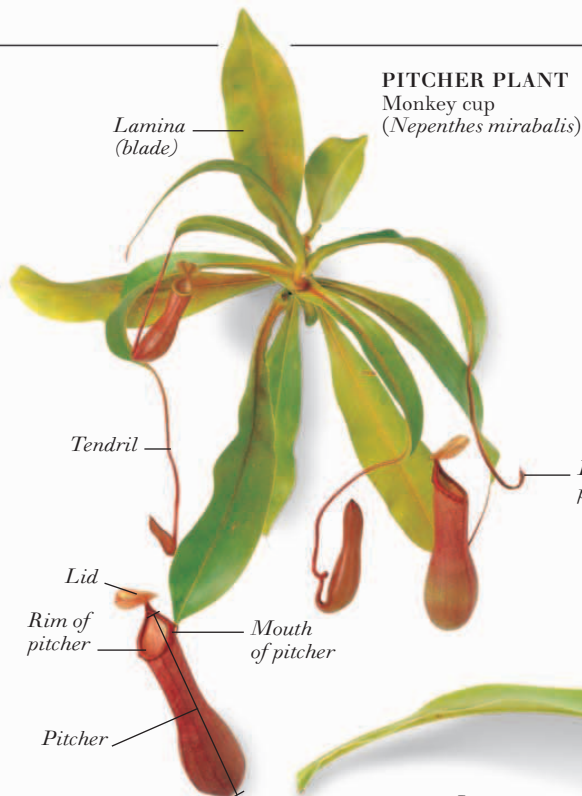


Red color of trap attracts insects

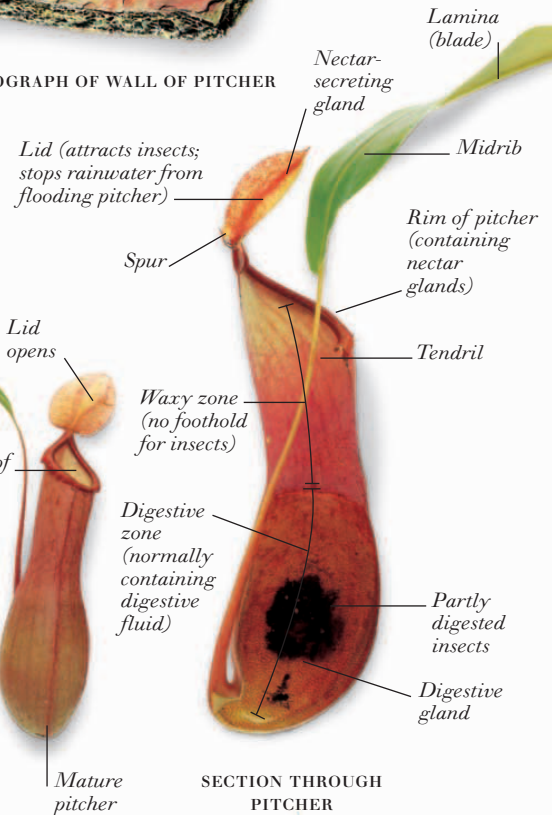


MICROGRAPH OF LOBE OF VENUS FLY TRAP

PITCHER PLANT
Monkey cup
(*Nepenthes mirabilis*)

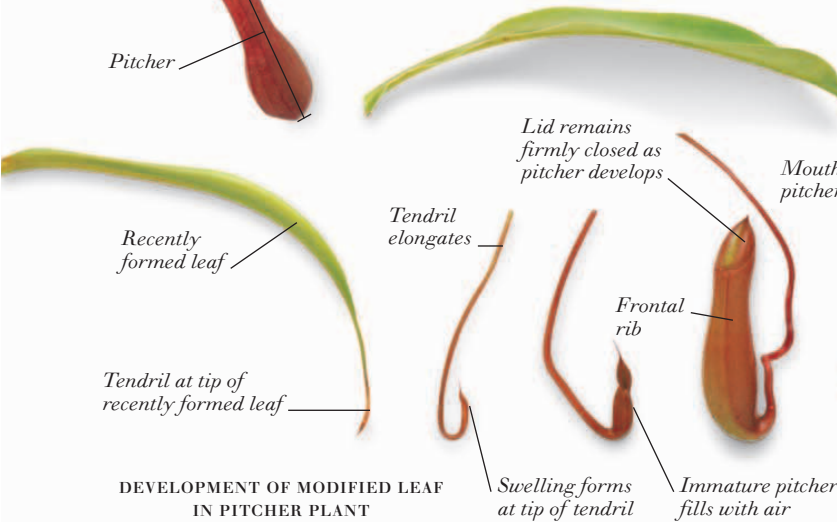


MICROGRAPH OF WALL OF PITCHER

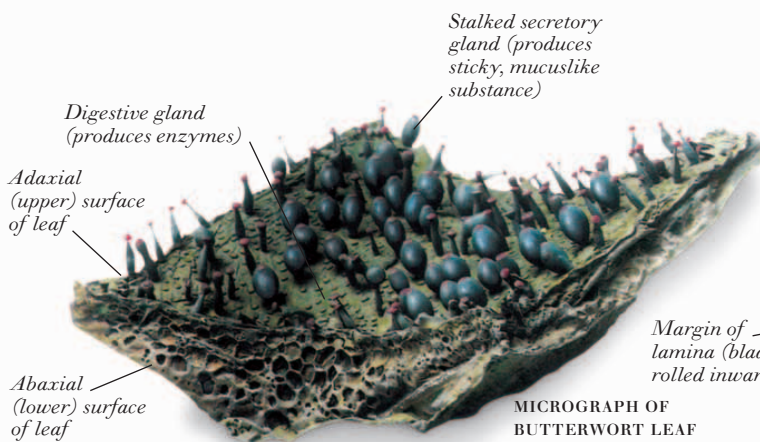


SECTION THROUGH PITCHER

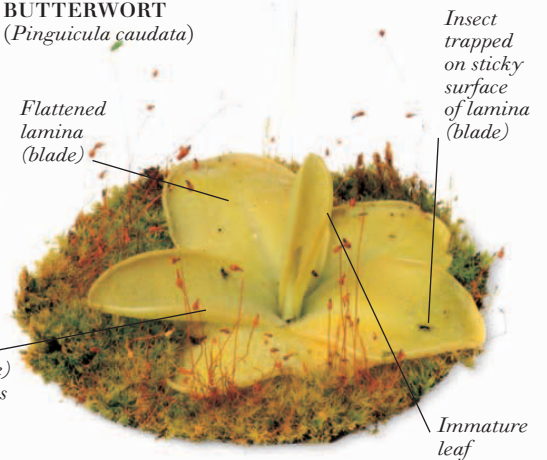
DEVELOPMENT OF MODIFIED LEAF IN PITCHER PLANT



BUTTERWORT
(*Pinguicula caudata*)



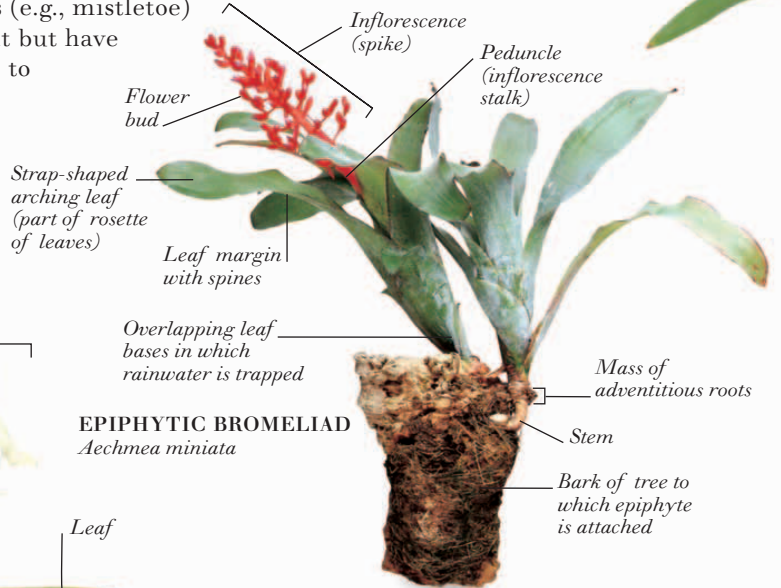
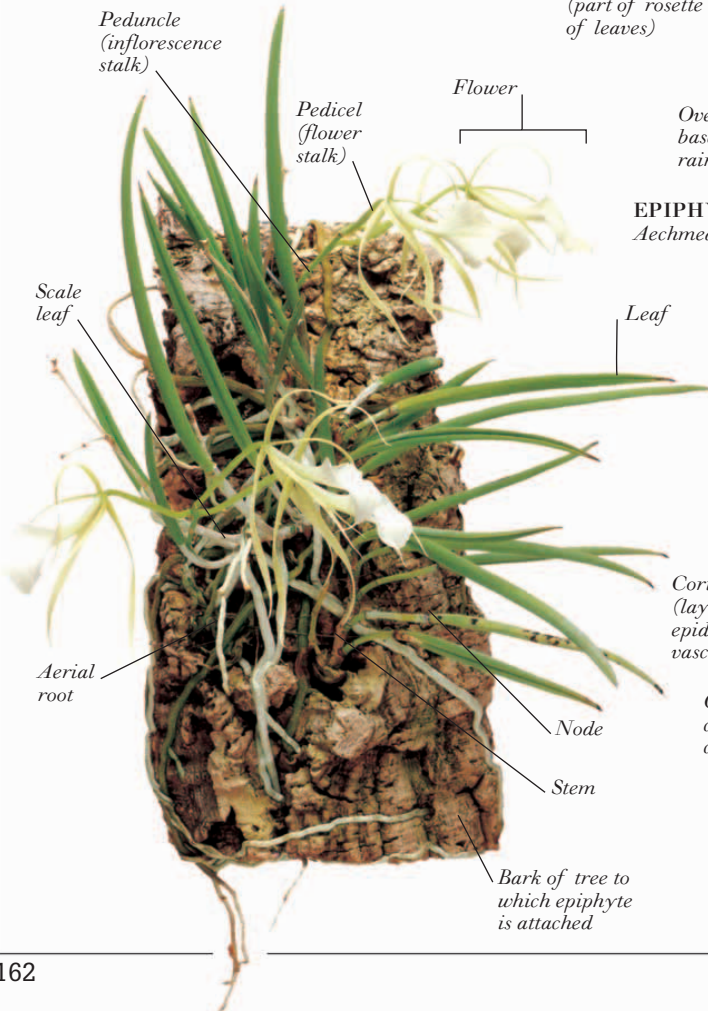
MICROGRAPH OF BUTTERWORT LEAF



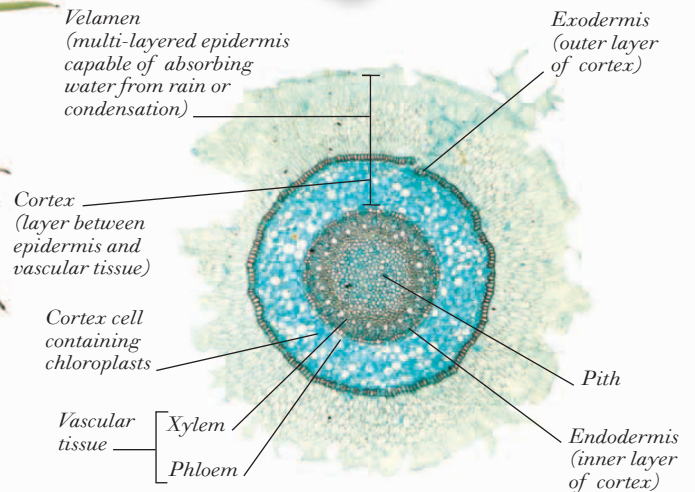
Epiphytic and parasitic plants

EPIPHYTIC AND PARASITIC PLANTS GROW ON OTHER LIVING PLANTS. Typically, epiphytic plants are not rooted in the soil; instead, they live above ground level on the stems and branches of other plants. Epiphytes obtain water from trapped rainwater and from moisture in the air, and minerals from organic matter that has accumulated on the surface of the plant on which they are growing. Like other green plants, epiphytes produce their food by photosynthesis. Epiphytes include tropical orchids and bromeliads (air plants), and some mosses that live in temperate regions. Parasitic plants obtain all their nutrient requirements from the host plants on which they grow. The parasites produce haustoria, rootlike organs that penetrate the stem or roots of the host and grow inward to merge with the host's vascular tissue, from which the parasite extracts water, minerals, and manufactured nutrients. As they have no need to produce their own food, parasitic plants lack chlorophyll, the green photosynthetic pigment, and they have no foliage leaves. Partial parasitic plants (e.g., mistletoe) obtain water and minerals from the host plant but have green leaves and stems and are therefore able to produce their own food by photosynthesis.

EPIPHYTIC ORCHID *Brassavola nodosa*



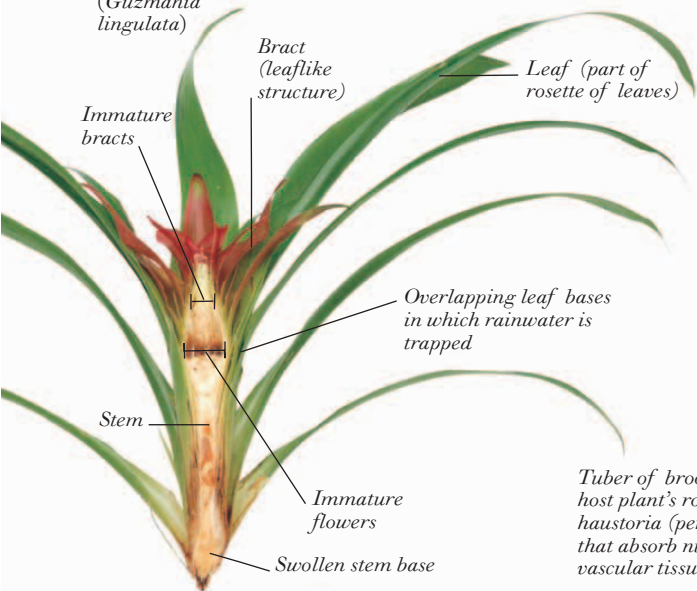
EPIPHYTIC BROMELIAD *Aechmea miniata*



MICROGRAPH OF CROSS-SECTION THROUGH AERIAL ROOT OF EPIPHYTIC ORCHID

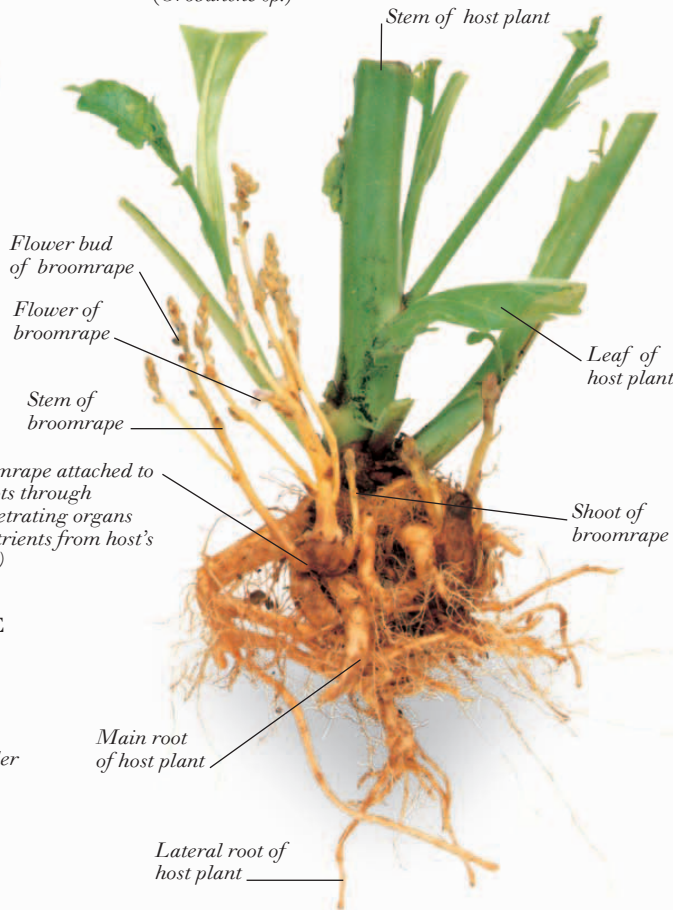
LONGITUDINAL SECTION THROUGH EPIPHYTIC BROMELIAD

Scarlet star
(*Guzmania lingulata*)



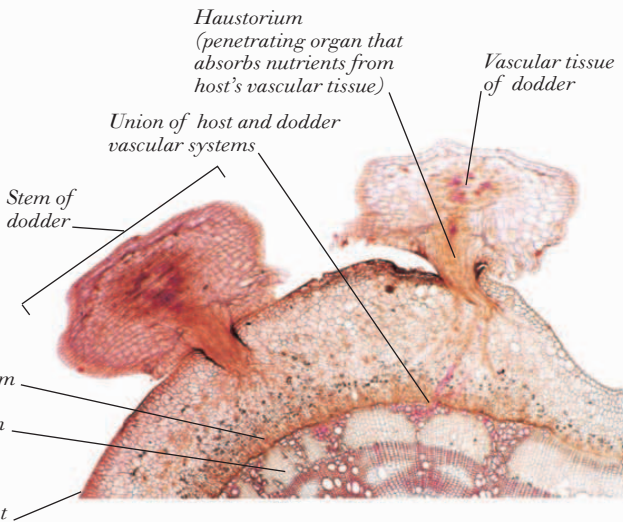
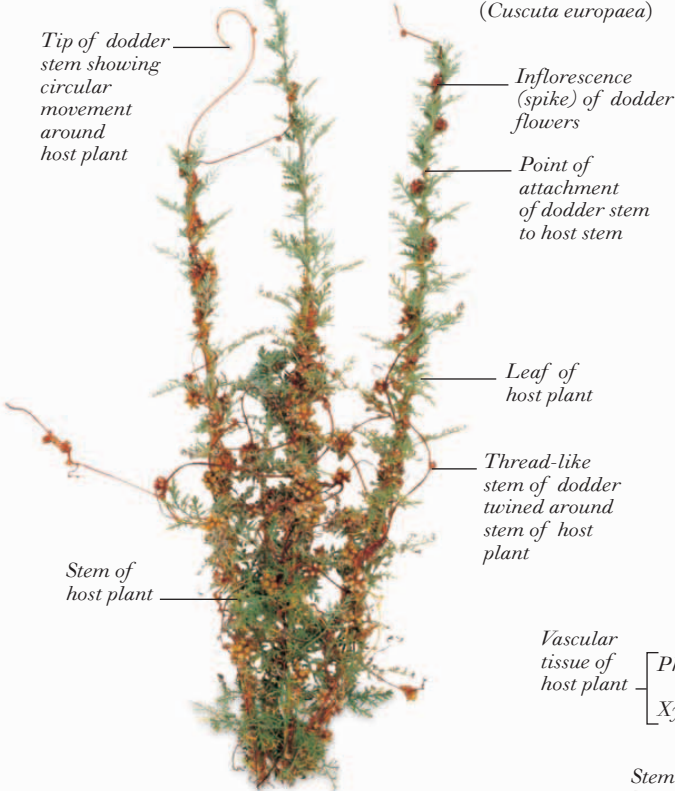
ROOT PARASITE

Broomrape
(*Orobanche sp.*)



STEM PARASITE

Dodder
(*Cuscuta europaea*)



EXTERNAL VIEW OF PLANT PARASITIZED BY DODDER

MICROGRAPH OF CROSS-SECTION THROUGH STEM OF PLANT PARASITIZED BY DODDER





ANIMALS

SPONGES, JELLYFISH, AND SEA ANEMONES	166
INSECTS	168
ARACHNIDS	170
CRUSTACEANS	172
STARFISH AND SEA URCHINS	174
MOLLUSKS	176
SHARKS AND JAWLESS FISH	178
BONY FISH	180
AMPHIBIANS	182
LIZARDS AND SNAKES	184
CROCODILIANS AND TURTLES	186
BIRDS 1	188
BIRDS 2	190
EGGS	192
CARNIVORES	194
RABBITS AND RODENTS	196
UNGULATES	198
ELEPHANTS	200
PRIMATES	202
DOPHINS, WHALES, AND SEALS	204
MARSUPIALS AND MONOTREMES	206

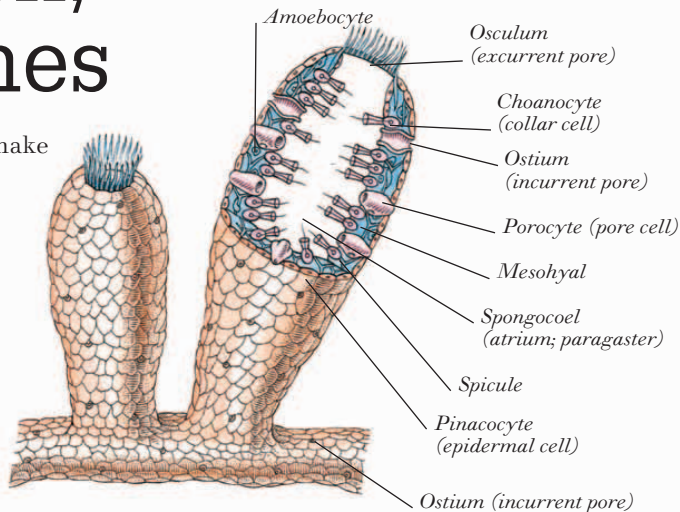


Sponges, jellyfish, and sea anemones

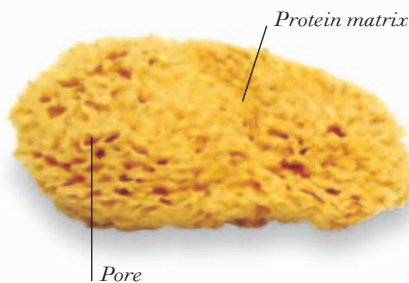
SPONGES ARE MAINLY MARINE animals that make up the phylum Porifera. They are among the simplest of all animals, having no tissues or organs. Their bodies consist of two layers of cells separated by a

jellylike layer (mesohyal) that is strengthened by mineral spicules or protein fibers. The body is perforated by a system of pores and water channels called the aquiferous system. Special cells (choanocytes) with whiplike structures (flagella) draw water through the aquiferous system, thereby bringing tiny food particles to the sponge's cells. Jellyfish (class Scyphozoa), sea anemones (class Anthozoa), and corals (also class Anthozoa) belong to the phylum Cnidaria, also known as Coelenterata. More complex than sponges, coelenterates have simple tissues, such as nervous tissue; a radially symmetrical body; and a mouth surrounded by tentacles with unique stinging cells (cnidocytes).

INTERNAL ANATOMY OF A SPONGE



SKELETON OF A SPONGE



EXTERNAL FEATURES OF A SEA ANEMONE



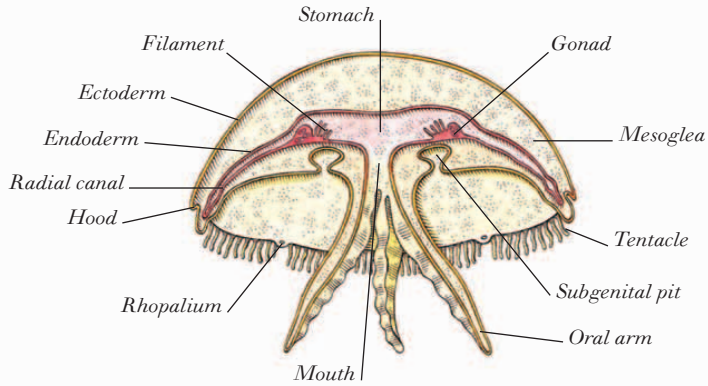
EXAMPLES OF SEA ANEMONES





EXTERNAL APPEARANCE OF A JELLYFISH

INTERNAL ANATOMY OF A JELLYFISH



EXAMPLES OF CORALS



HONEYCOMB CORAL (*Goniastrea aspera*)

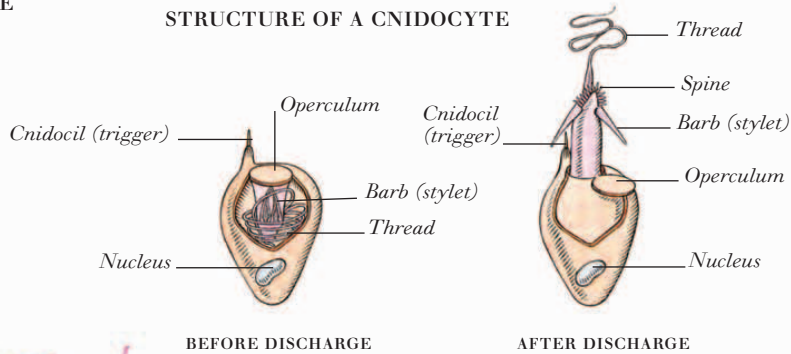


MUSHROOM CORAL (*Fungia fungites*)

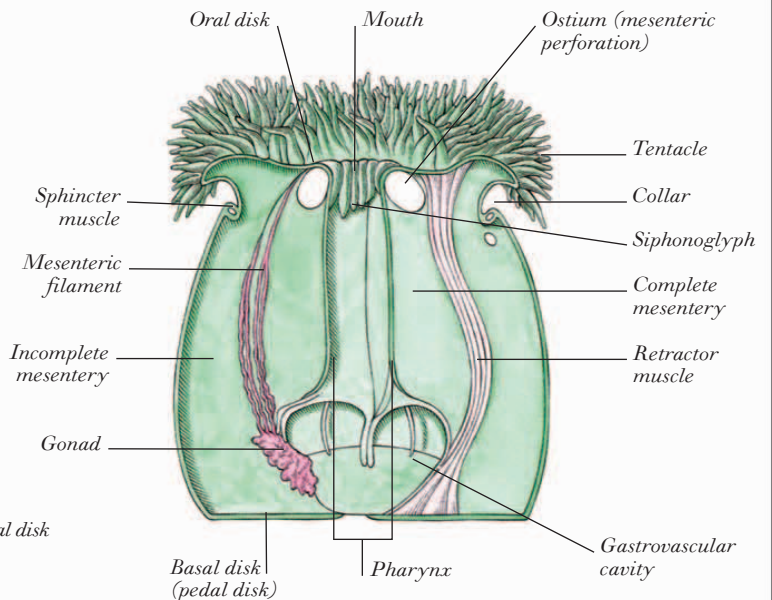


STAR CORAL (*Balanophyllia regia*)

STRUCTURE OF A CNIDOCYTE



INTERNAL ANATOMY OF A SEA ANEMONE



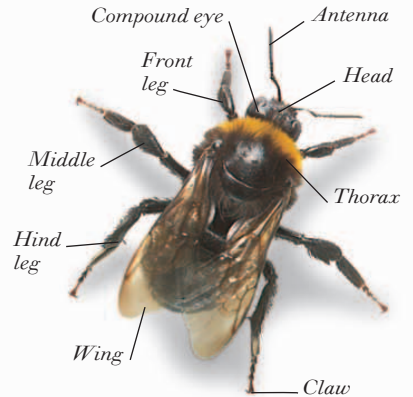
Insects



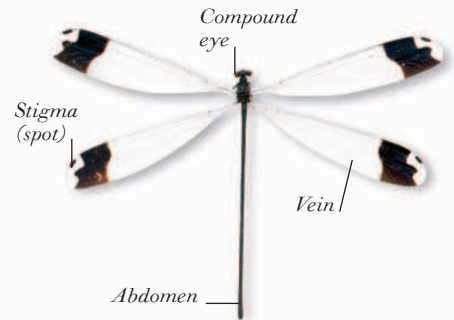
PUPA (CHRYSALIS)

THE WORD INSECT REFERS to small invertebrate creatures, especially those with bodies divided into sections. Insects, including beetles, ants, bees, butterflies, and moths, belong to various orders in the class Insecta, which is a division of the phylum Arthropoda. Features common to all insects are an exoskeleton (external skeleton); three pairs of jointed legs; three body sections (head, thorax, and abdomen); and one pair of sensory antennae. Beetles (order Coleoptera) are the biggest group of insect, with about 300,000 species (about 30 percent of all known insects). They have a pair of hard elytra (wing cases), which are modified front wings. The principal function of the elytra is to protect the hind wings, which are used for flying. Ants, together with bees and wasps, form the order Hymenoptera, which contains about 200,000 species. This group is characterized by a marked narrowing between the thorax and abdomen. Butterflies and moths form the order Lepidoptera, which has about 150,000 species. They have wings covered with tiny scales, hence the name of their order (Lepidoptera means “scale wings”). The separation of lepidopterans into butterflies and moths is largely artificial, since there are no features that categorically distinguish one group from the other. In general, however, most butterflies fly by day, whereas most moths are night-flyers. Some insects, including butterflies and moths, undergo complete metamorphosis (transformation) during their life-cycle. A butterfly metamorphoses from an egg to a larva (caterpillar), then to a pupa (chrysalis), and finally to an imago (adult).

EXAMPLES OF INSECTS

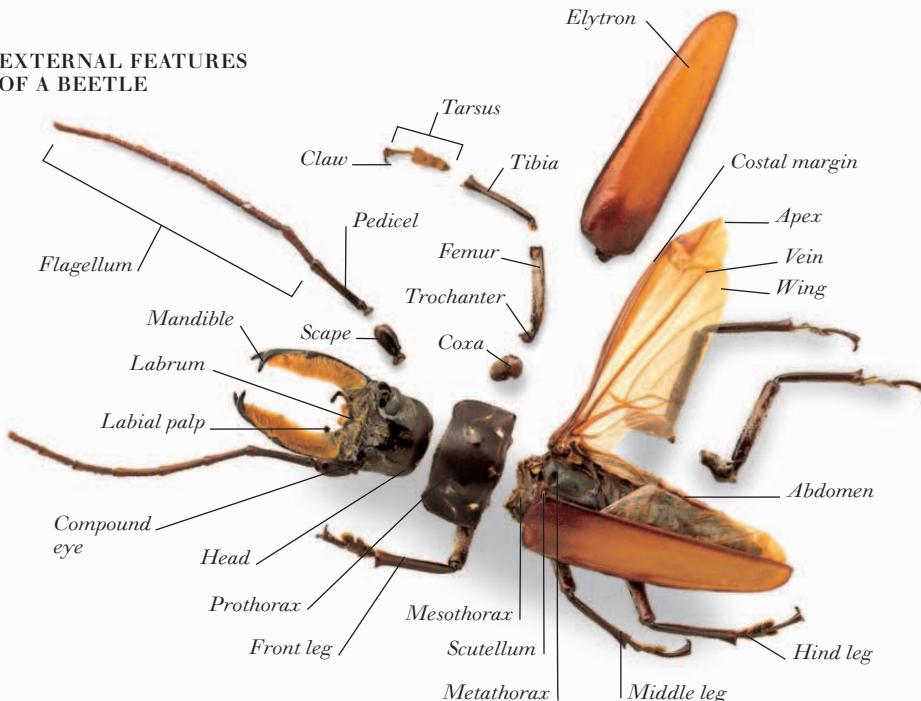


BUMBLEBEE



DAMSELFLY

EXTERNAL FEATURES OF A BEETLE



CRICKET



ANT

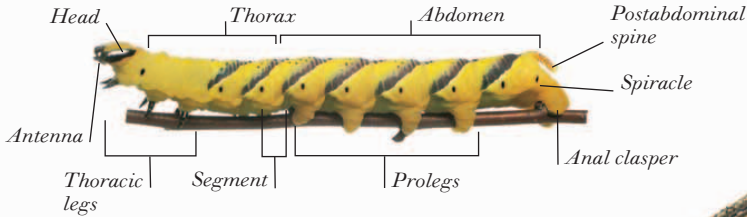


FLY

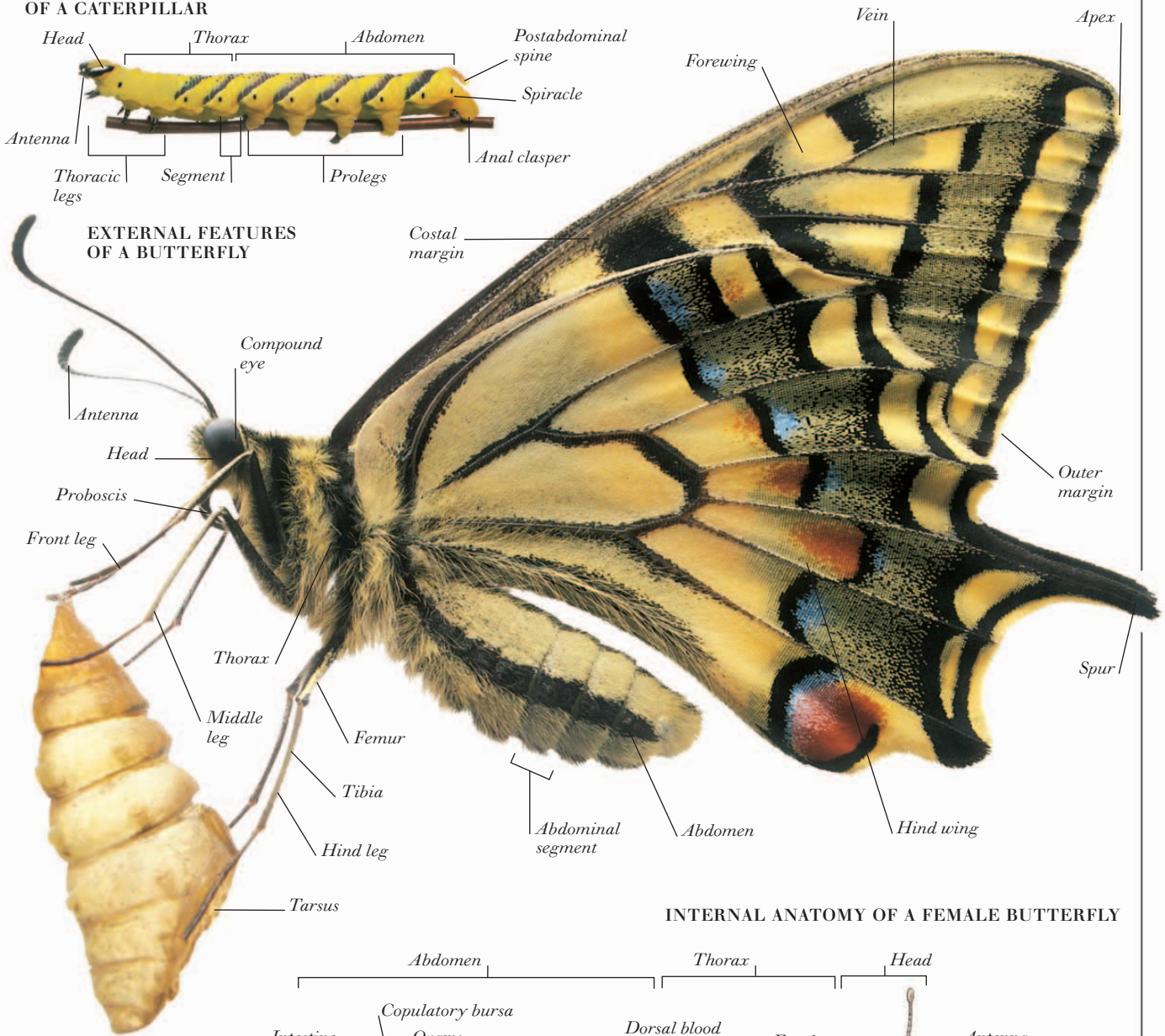


EARWIG

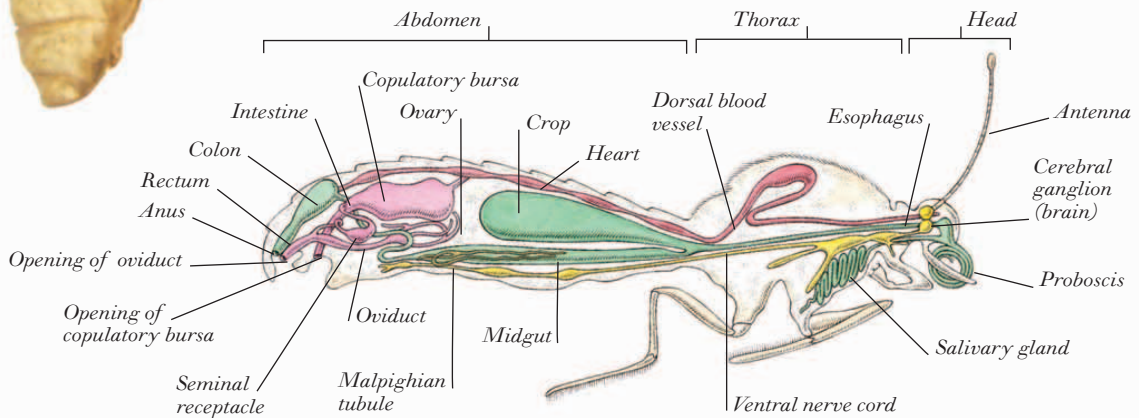
EXTERNAL FEATURES OF A CATERPILLAR



EXTERNAL FEATURES OF A BUTTERFLY



INTERNAL ANATOMY OF A FEMALE BUTTERFLY



Arachnids



THE CLASS ARACHNIDA INCLUDES SPIDERS (order Araneae) and scorpions (order Scorpiones). The class is part of the phylum Arthropoda, which also includes insects and crustaceans.

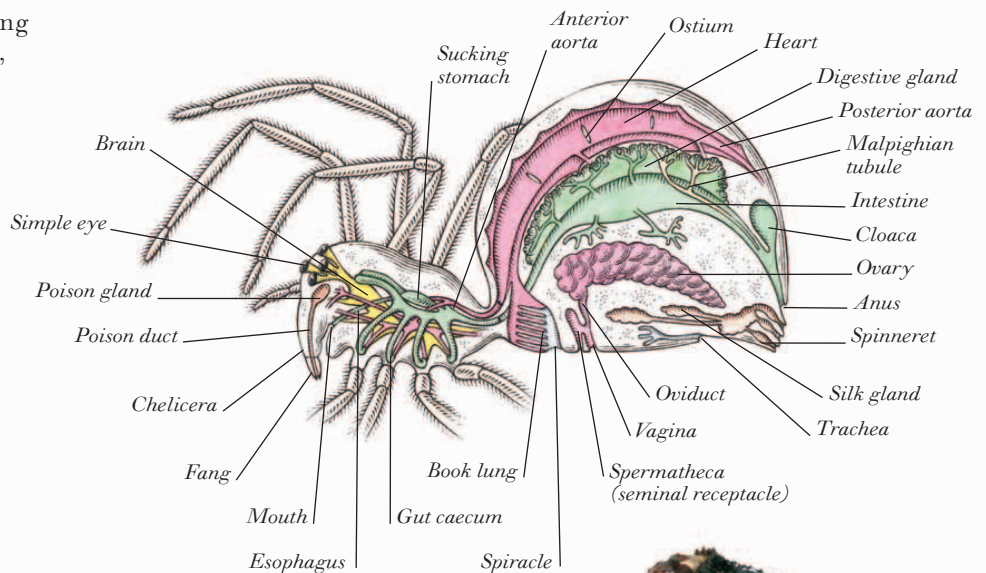
Spiders and scorpions are characterized by having four pairs of walking legs; a pair of pincerlike mouthparts called chelicerae; another pair of frontal appendages called pedipalps, which are sensory in spiders but used for grasping in scorpions; and a body divided into two sections (a combined head and thorax called a cephalothorax or prosoma, and an abdomen or opisthosoma).

Unlike other arthropods, spiders and scorpions lack antennae. Spiders and scorpions are carnivorous. Spiders poison prey by biting with the fanged chelicerae, scorpions by stinging with the end of the metasoma (tail).

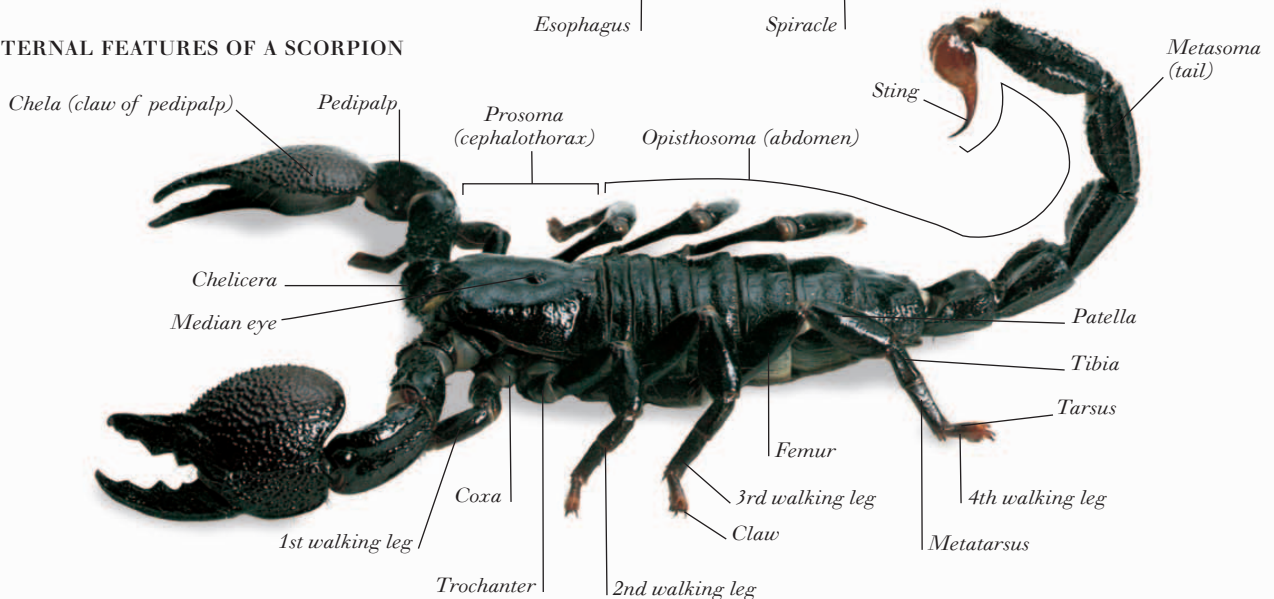


MEXICAN TRUE RED-LEGGED TARANTULA (*Euathlus emilia*)

INTERNAL ANATOMY OF A FEMALE SPIDER



EXTERNAL FEATURES OF A SCORPION



EXAMPLES OF SPIDERS



RAFT SPIDER
(Dolomedes fimbriatus)



ORB SPIDER
(Nuctenea umbratica)



HUNTSMAN SPIDER
(Heteropoda venatoria)

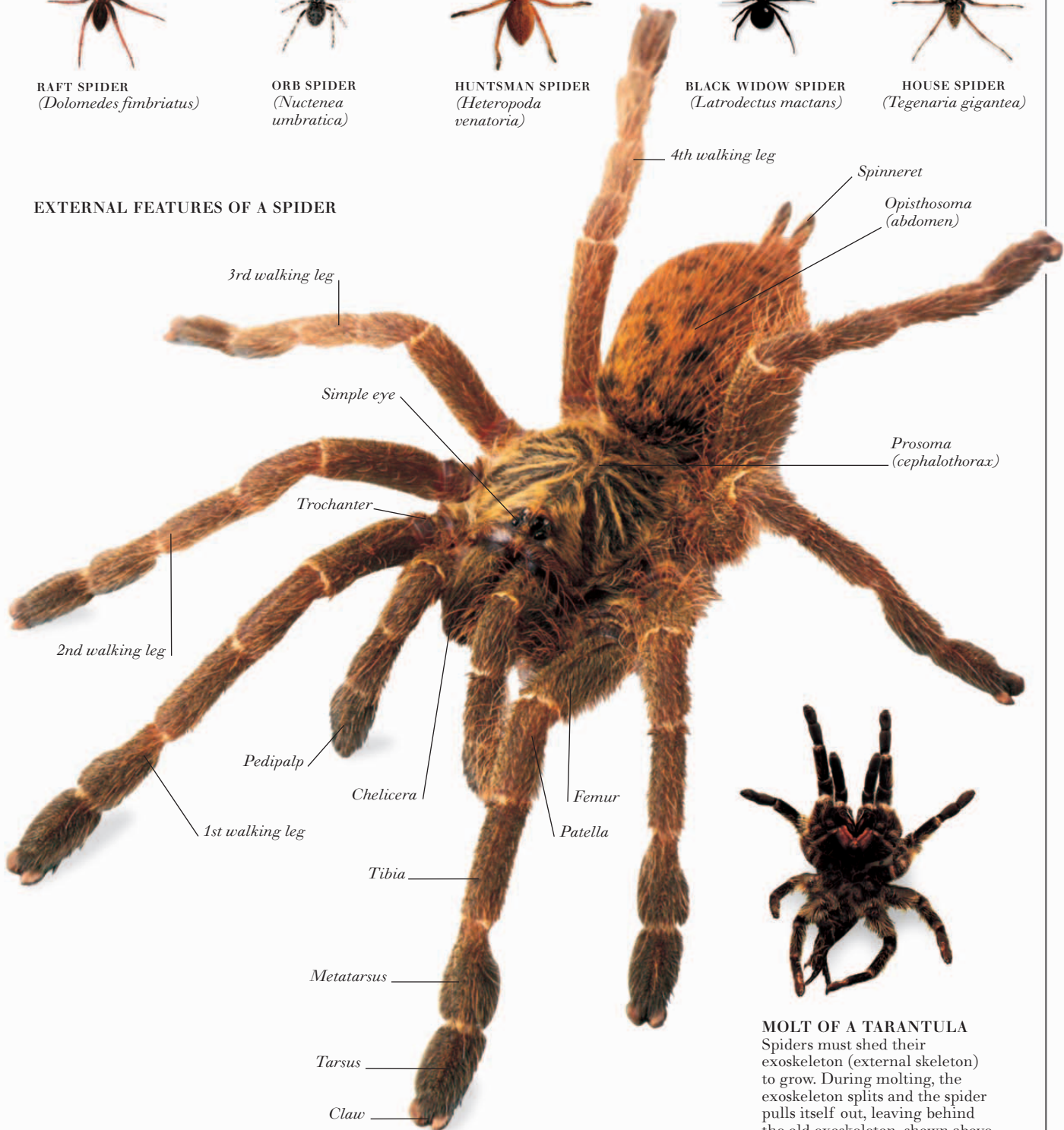


BLACK WIDOW SPIDER
(Latrodectus mactans)



HOUSE SPIDER
(Tegenaria gigantea)

EXTERNAL FEATURES OF A SPIDER

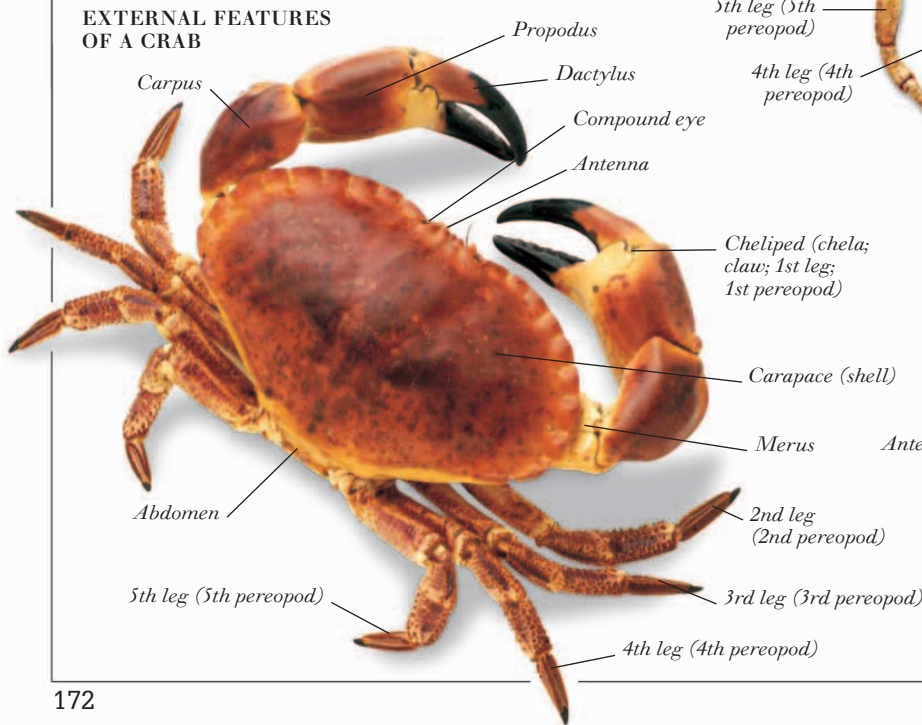


MOLT OF A TARANTULA
Spiders must shed their exoskeleton (external skeleton) to grow. During molting, the exoskeleton splits and the spider pulls itself out, leaving behind the old exoskeleton, shown above.

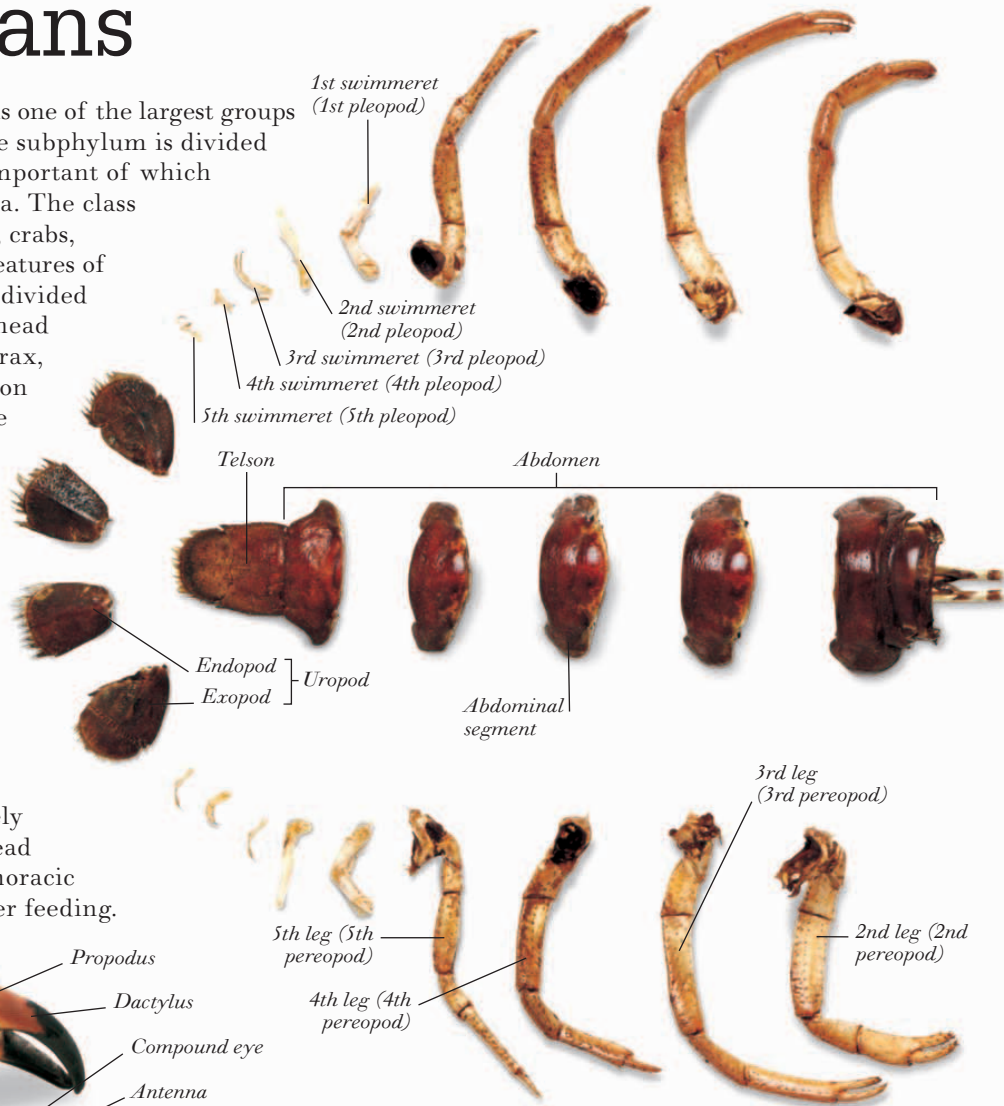
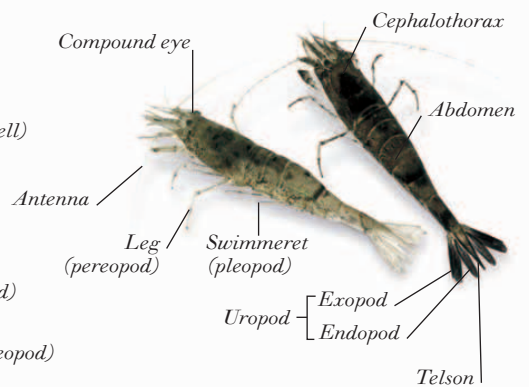
Crustaceans

THE SUBPHYLUM CRUSTACEA is one of the largest groups in the phylum Arthropoda. The subphylum is divided into several classes, the most important of which are Malacostraca and Cirripedia. The class Malacostraca includes crayfish, crabs, lobsters, and shrimps. Typical features of malacostracans include a body divided into two sections (a combined head and thorax called a cephalothorax, and an abdomen); an exoskeleton (external skeleton) with a large plate (carapace) covering the cephalothorax; stalked, compound eyes; and two pairs of antennae. The class Cirripedia includes barnacles, which, unlike other crustaceans, spend their adult lives attached to a surface, such as a rock. Other characteristics of cirripedes include an exoskeleton of overlapping calcareous plates; a body consisting almost entirely of thorax (the abdomen and head are minute); and six pairs of thoracic appendages (cirri) used for filter feeding.

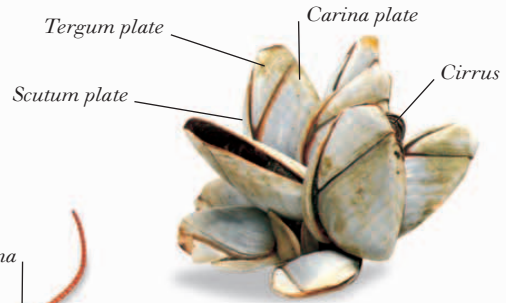
EXTERNAL FEATURES OF A CRAB



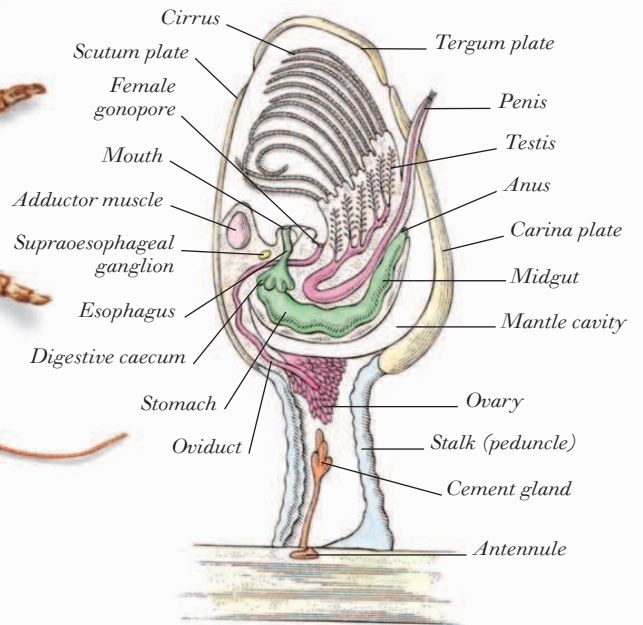
EXTERNAL FEATURES OF A SHRIMP



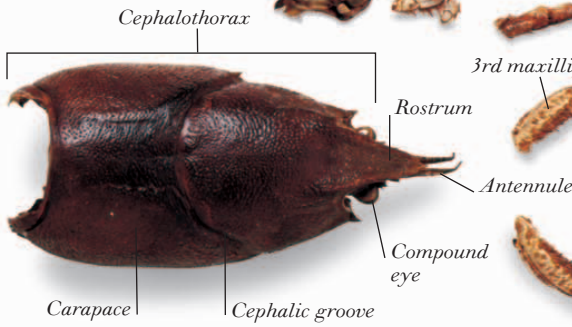
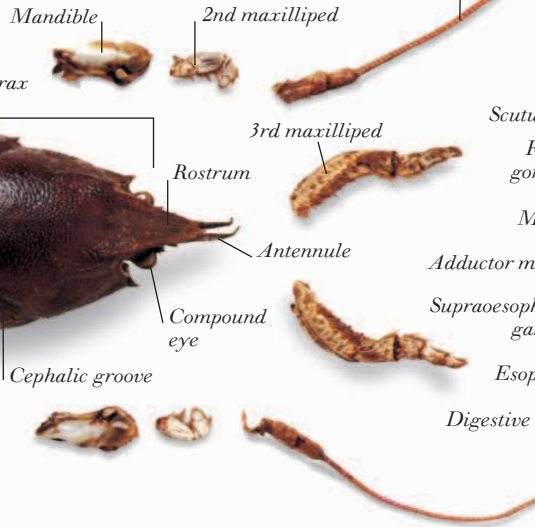
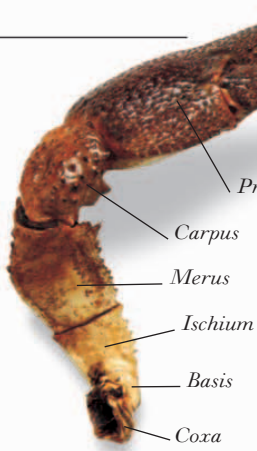
EXTERNAL FEATURES OF A STALKED BARNACLE



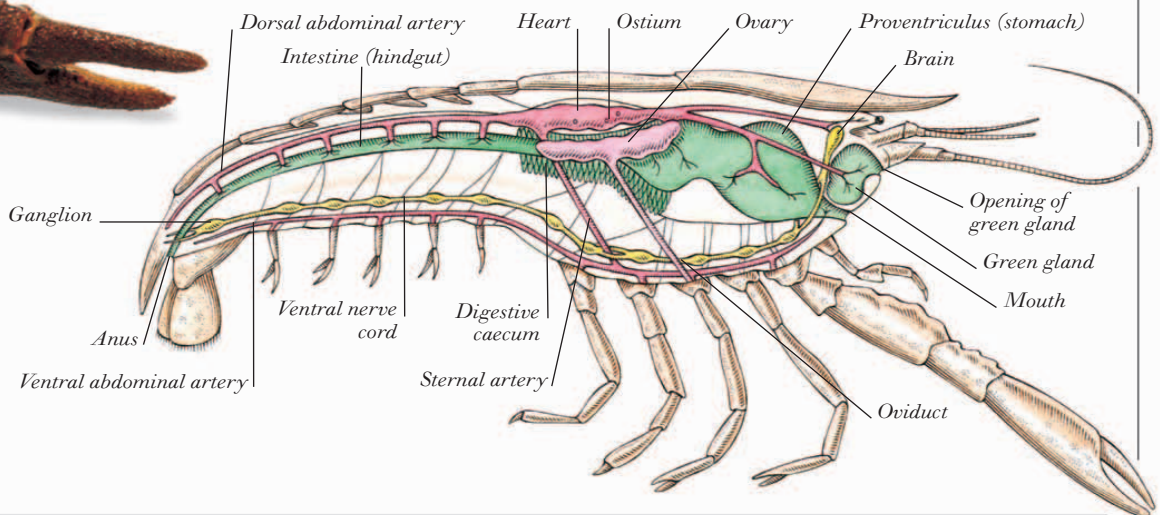
INTERNAL ANATOMY OF A STALKED BARNACLE



EXTERNAL FEATURES OF A CRAYFISH



INTERNAL ANATOMY OF A FEMALE CRAYFISH



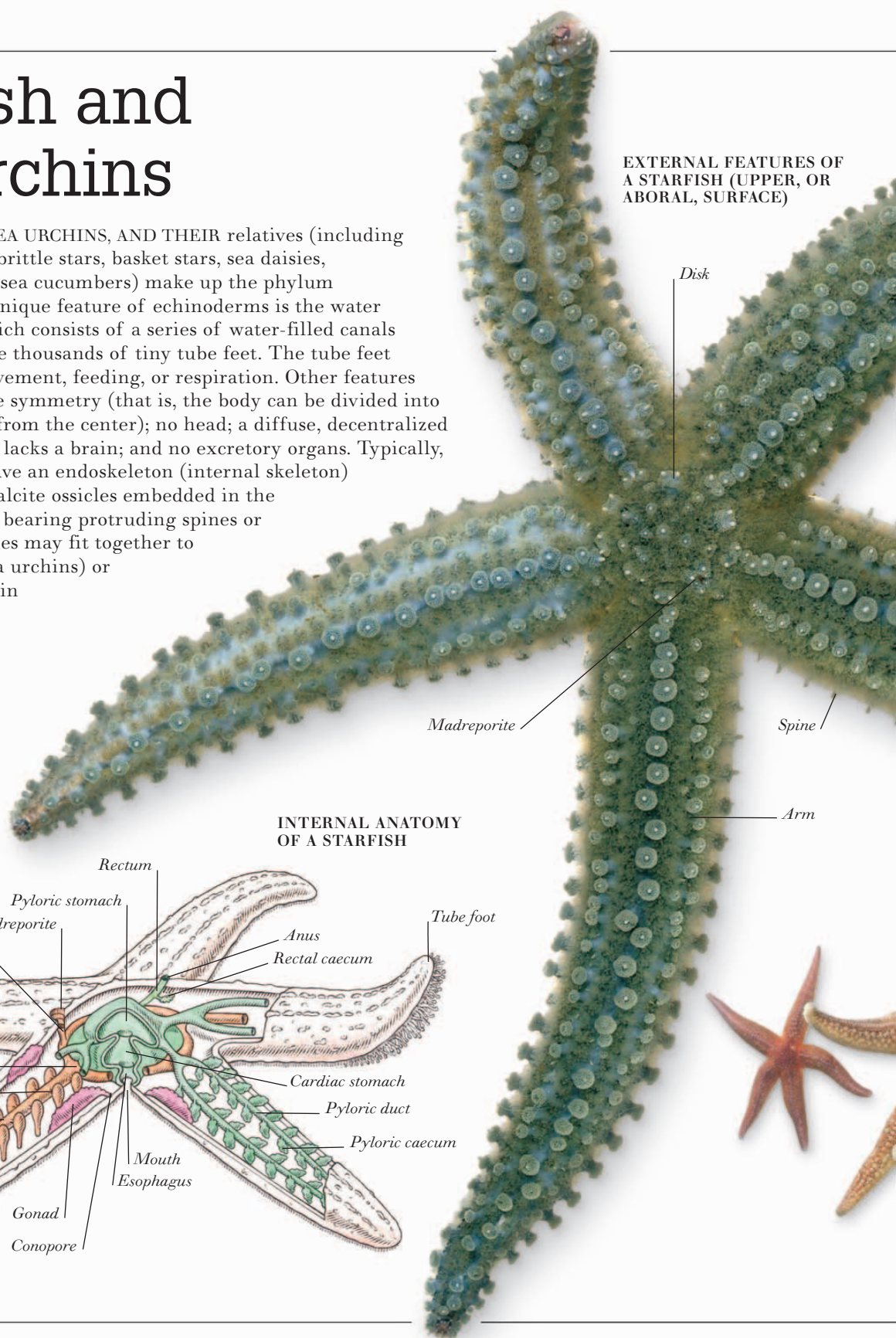
Starfish and sea urchins



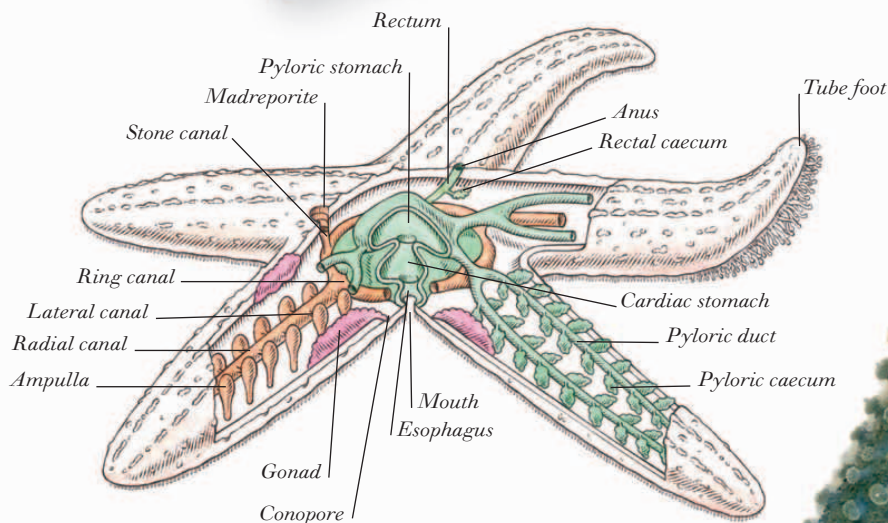
STARFISH, SEA URCHINS, AND THEIR relatives (including feather stars, brittle stars, basket stars, sea daisies, sea lilies, and sea cucumbers) make up the phylum

Echinodermata. A unique feature of echinoderms is the water vascular system, which consists of a series of water-filled canals from which protrude thousands of tiny tube feet. The tube feet may be used for movement, feeding, or respiration. Other features include pentaradial symmetry (that is, the body can be divided into five parts radiating from the center); no head; a diffuse, decentralized nervous system that lacks a brain; and no excretory organs. Typically, echinoderms also have an endoskeleton (internal skeleton) consisting of hard calcite ossicles embedded in the body wall and often bearing protruding spines or tubercles. The ossicles may fit together to form a test (as in sea urchins) or remain separate (as in sea cucumbers).

EXTERNAL FEATURES OF A STARFISH (UPPER, OR ABORAL, SURFACE)



INTERNAL ANATOMY OF A STARFISH



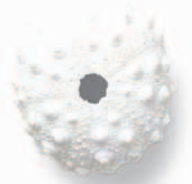
EXAMPLES OF SEA URCHINS



EDIBLE SEA URCHIN
(*Echinus esculentus*)

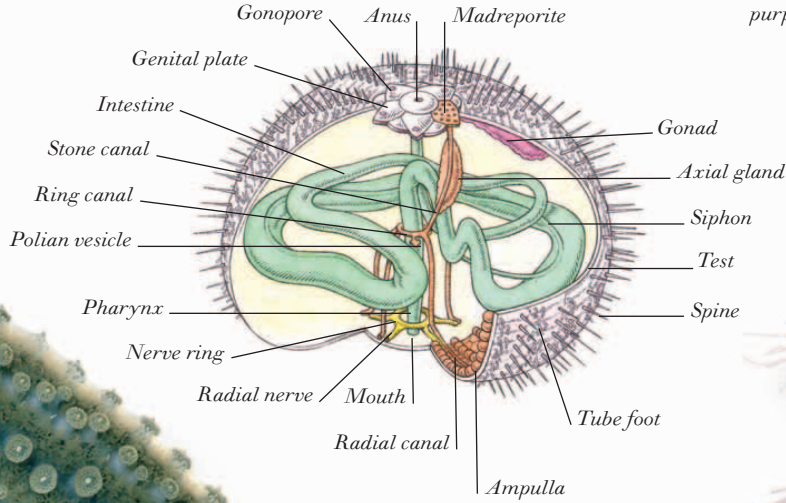


CALIFORNIAN PURPLE
SEA URCHIN
(*Strongylocentrotus
purpuratus*)

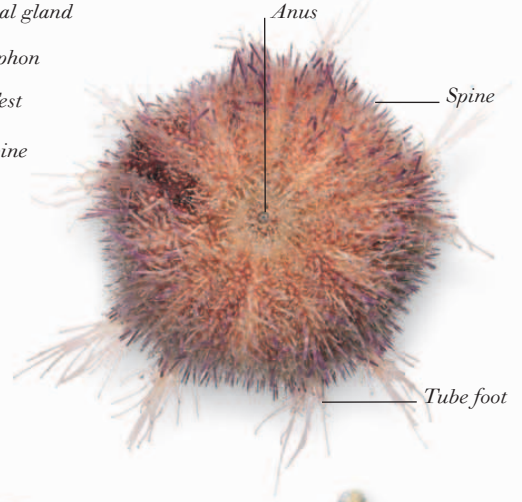


PENCIL SLATE SEA
URCHIN
(*Heterocentrotus
mammillatus*)

INTERNAL ANATOMY
OF A SEA URCHIN



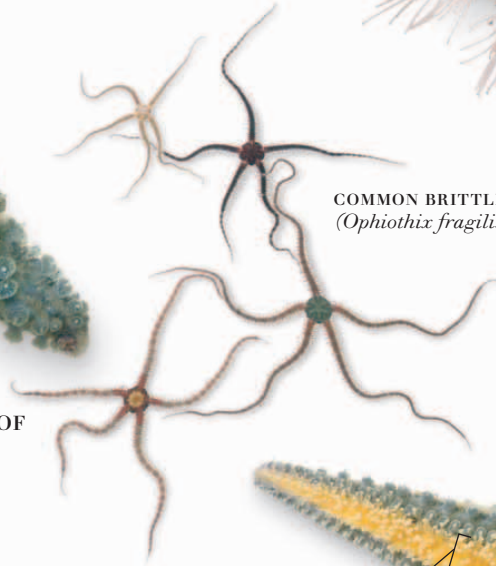
EXTERNAL FEATURES OF A
SEA URCHIN (UPPER, OR
ABORAL, SURFACE)



CUSHION STAR
(*Asterina gibbosa*)

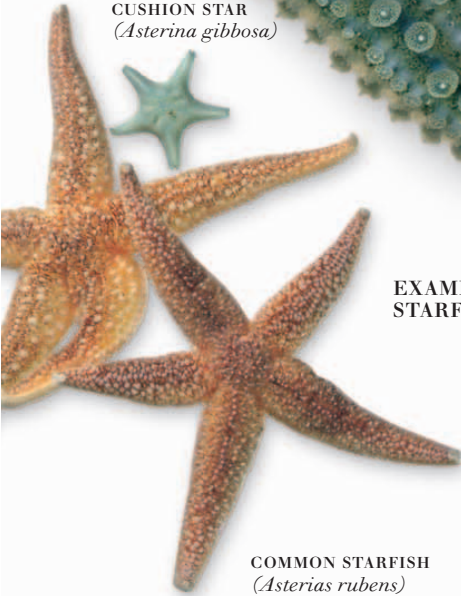


COMMON BRITTLE STAR
(*Ophiothrix fragilis*)

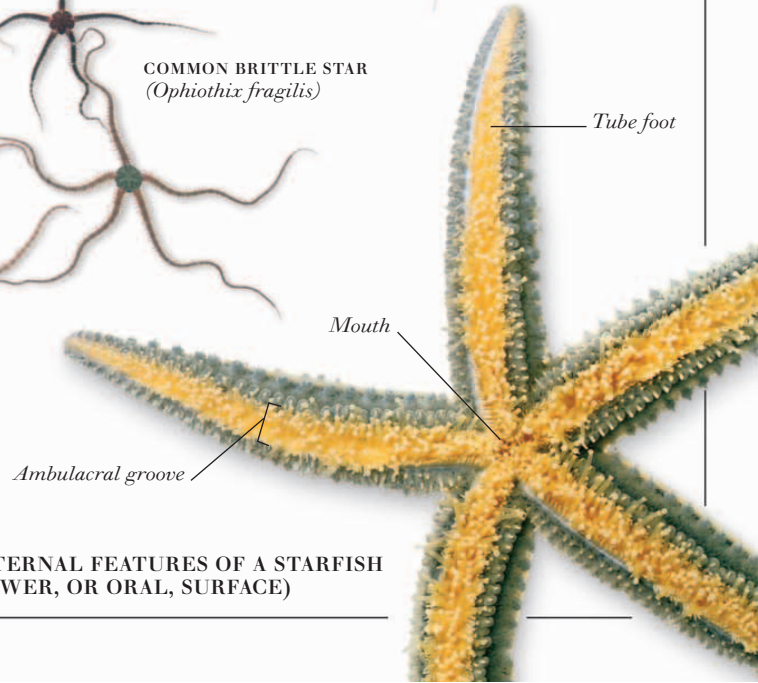


EXAMPLES OF
STARFISH

COMMON STARFISH
(*Asterias rubens*)



EXTERNAL FEATURES OF A STARFISH
(LOWER, OR ORAL, SURFACE)

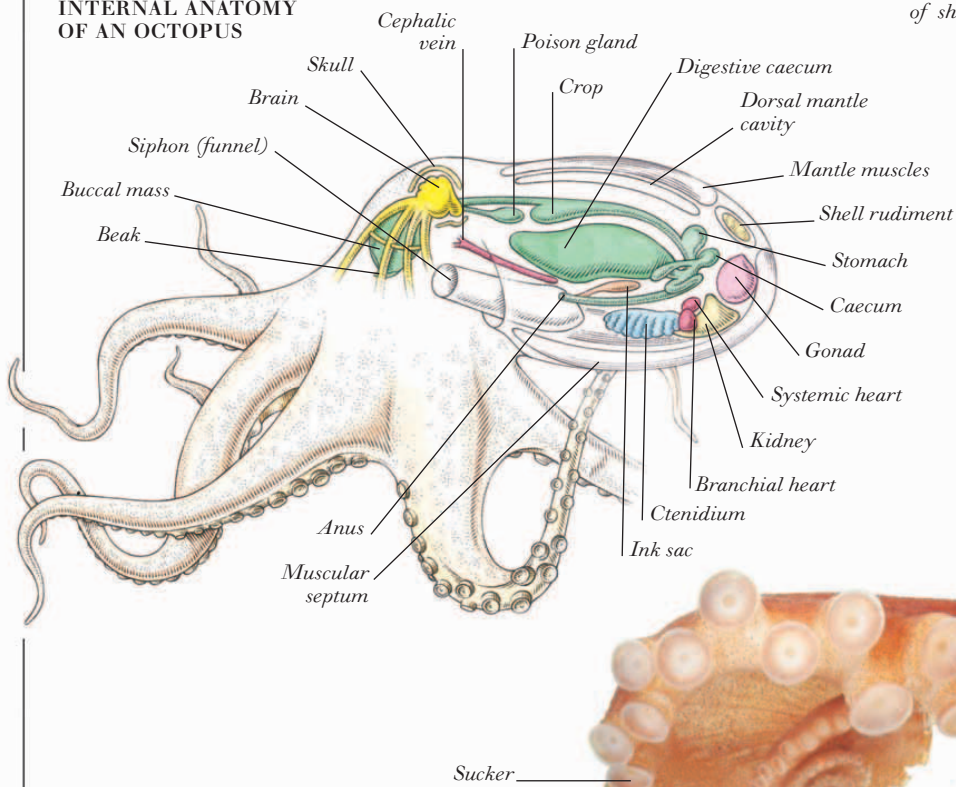


Mollusks

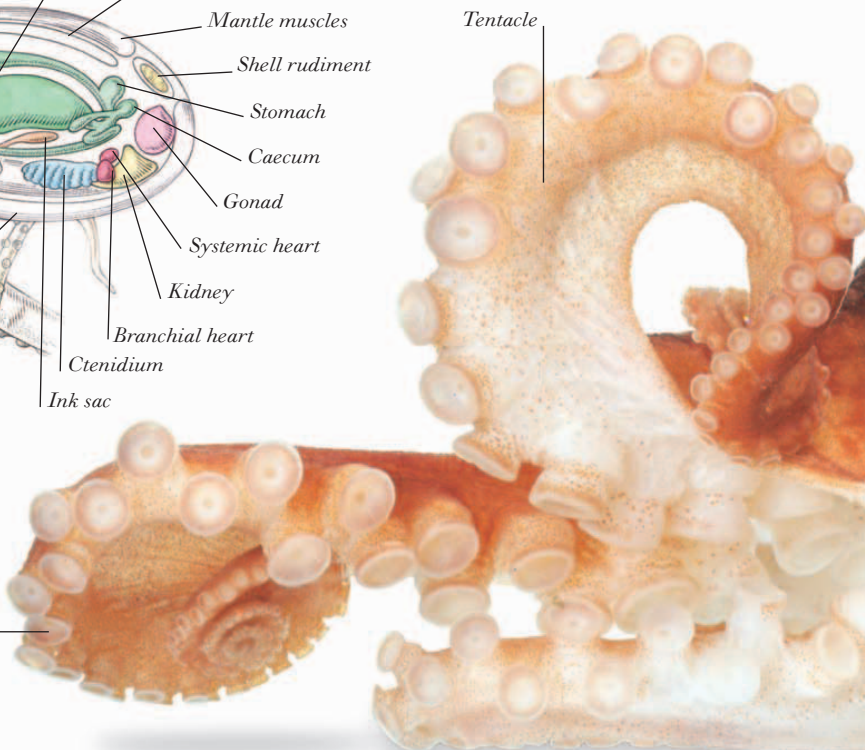
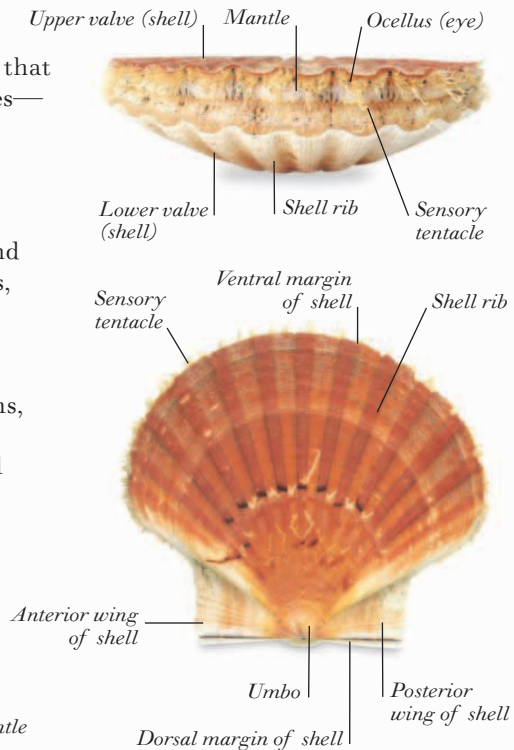
THE PHYLUM MOLLUSCA (MOLLUSKS) is a large group of animals that includes octopuses, snails, and scallops. Octopuses and their relatives—including squid and cuttlefish—form the class Cephalopoda. Cephalopods typically have a head with a radula (a filelike feeding organ) and beak; a well-developed nervous system; sucker-bearing tentacles; a muscular mantle (part of the body wall) that can expel water through the siphon, enabling movement by jet propulsion; and a small shell or no shell. Snails and their relatives—including slugs, limpets, and abalones—make up the class Gastropoda. Gastropods typically have a coiled external shell, although some, such as slugs, have a small internal shell or no shell; a flat foot; and a head with tentacles and a radula. Scallops and their relatives—including clams, mussels, and oysters—make up the class Bivalvia (also called Pelecypoda). Features of bivalves include a shell with two halves (valves); large gills that are used for breathing and filter feeding; and no radula.



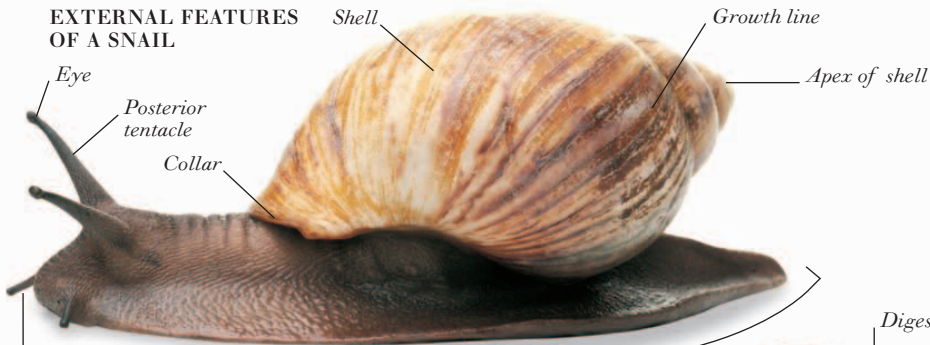
INTERNAL ANATOMY OF AN OCTOPUS



EXTERNAL FEATURES OF A SCALLOP



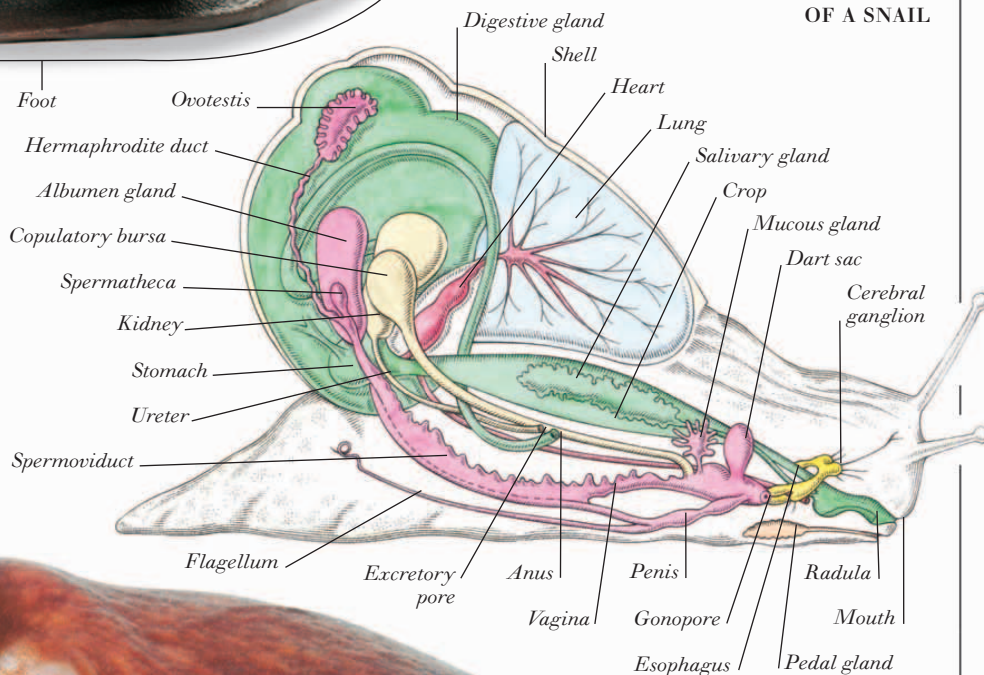
EXTERNAL FEATURES OF A SNAIL



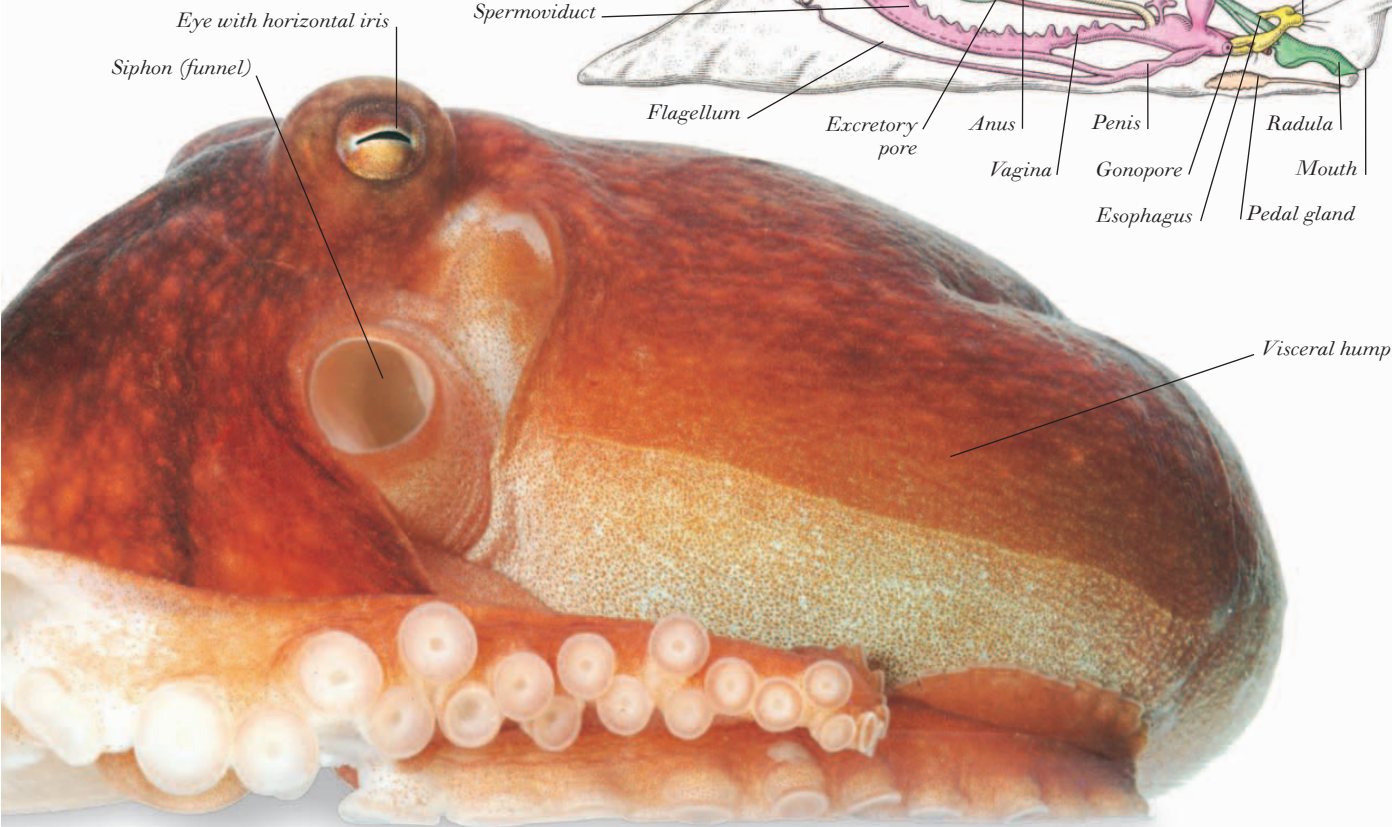
Head
Anterior tentacle

Foot

INTERNAL ANATOMY OF A SNAIL



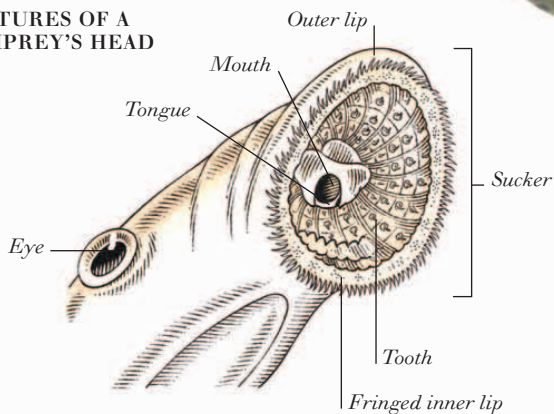
EXTERNAL FEATURES OF AN OCTOPUS



Sharks and jawless fish

SHARKS, DOGFISH (WHICH ARE actually small sharks), skates, and rays belong to a class of fishes called Chondrichthyes, which is a division of the superclass Gnathostomata (meaning “jawed mouths”). Also sometimes known as elasmobranchs, sharks and their relatives have a skeleton made of cartilage (hence their common name, cartilaginous fish), a characteristic that distinguishes them from bony fish (see pp. 180-181). Other important features of cartilaginous fish are extremely tough, toothlike scales, and lack of a swim bladder. Jawless fish—lampreys and hagfish—are primitive, eellike fish that make up the order Cyclostomata (meaning “round mouths”), a division of the superclass Agnatha (meaning “without jaws”). In addition to their characteristic round, suckerlike mouths and lack of jaws, cyclostomes also have smooth, slimy skin without scales, and unpaired fins.

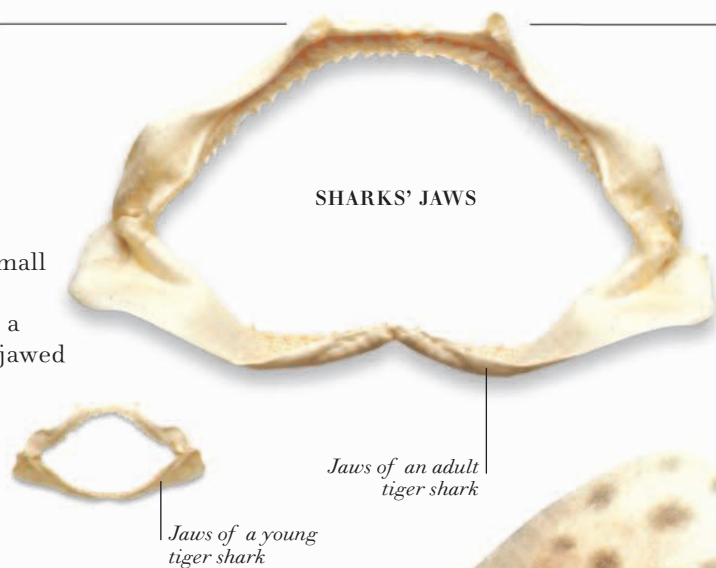
FEATURES OF A LAMPREY'S HEAD



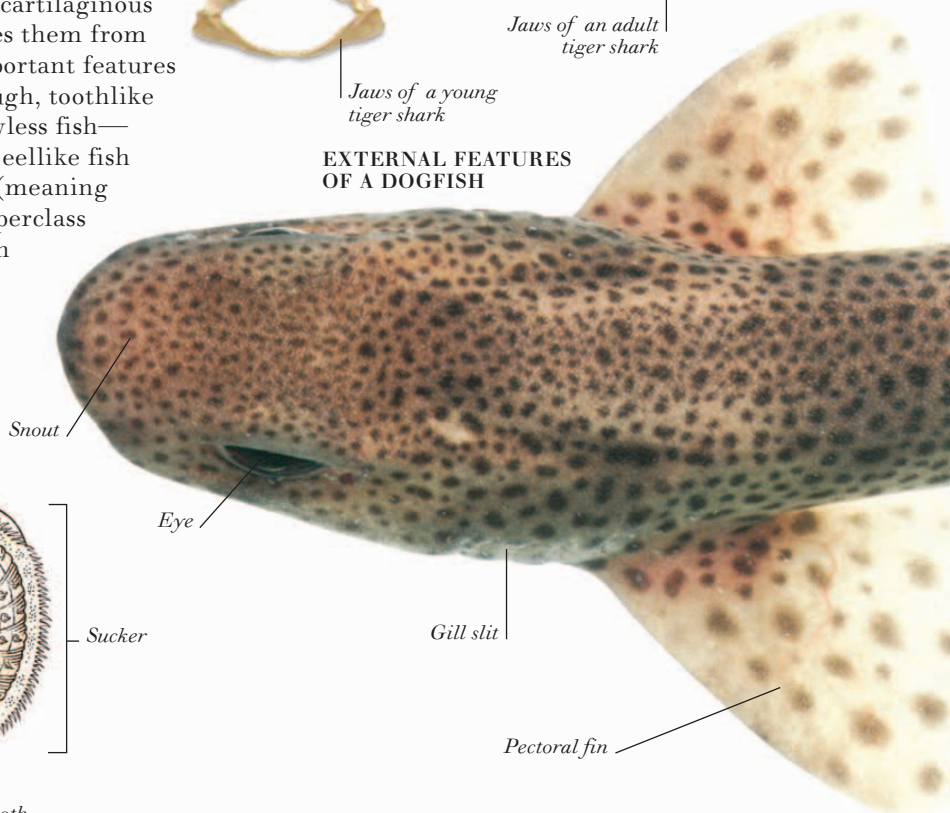
EXTERNAL FEATURES OF A LAMPREY



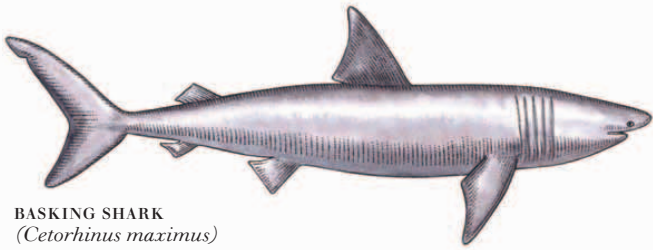
SHARKS' JAWS



EXTERNAL FEATURES OF A DOGFISH



EXAMPLES OF CARTILAGINOUS FISH



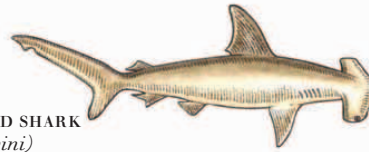
BASKING SHARK
(*Cetorhinus maximus*)



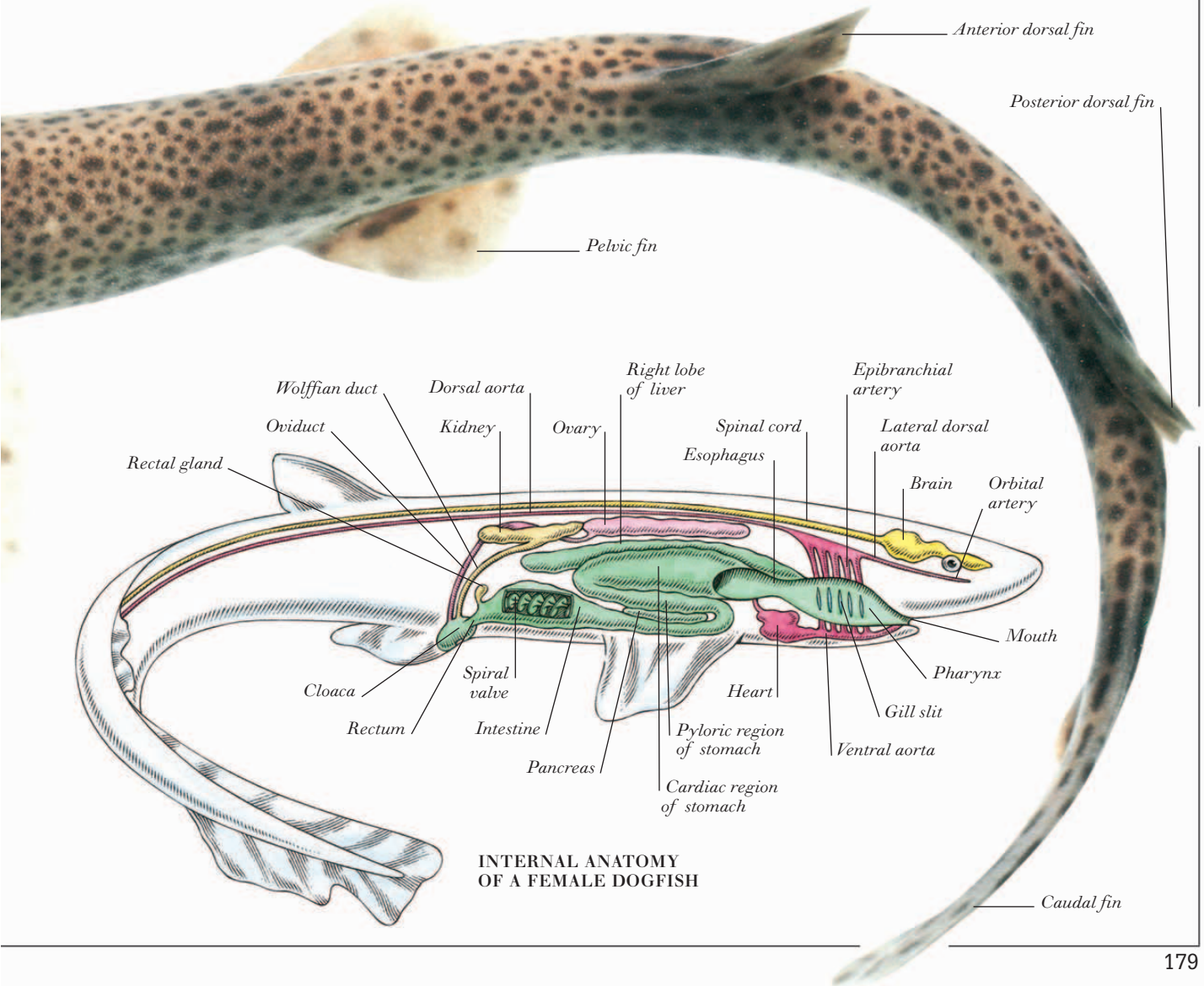
TIGER SHARK
(*Galeocerdo cuvier*)



THORNBAC RAY
(*Raja clavata*)



SCALLOPED
HAMMERHEAD SHARK
(*Sphyrna lewini*)



Anterior dorsal fin

Posterior dorsal fin

Pelvic fin

Caudal fin

- Wolffian duct
- Oviduct
- Rectal gland
- Dorsal aorta
- Kidney
- Ovary
- Right lobe of liver
- Spinal cord
- Esophagus
- Epibranchial artery
- Lateral dorsal aorta
- Brain
- Orbital artery
- Mouth
- Pharynx
- Gill slit
- Ventral aorta
- Heart
- Pyloric region of stomach
- Cardiac region of stomach
- Pancreas
- Intestine
- Spiral valve
- Cloaca
- Rectum

INTERNAL ANATOMY
OF A FEMALE DOGFISH

Bony fish

BONY FISH, SUCH AS CARP, TROUT, SALMON, perch, and cod, are by far the best known and largest group of fish, with more than 20,000 species (over 95 percent of all known fish). As their name suggests, bony fish have skeletons made of bone, in contrast to the cartilaginous skeletons of sharks, jawless fish, and their relatives (see pp. 178-179). Other typical features of bony fish include a swim bladder, which functions as a variable-buoyancy organ, enabling a fish to remain effortlessly at whatever depth it is swimming; relatively thin, bonelike scales; a flap (called an operculum) covering the gills; and paired pelvic and pectoral fins. Scientifically, bony fish belong to the class Osteichthyes, which is a division of the superclass Gnathostomata (meaning “jawed mouths”).

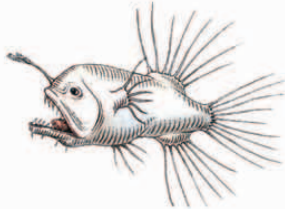
EXAMPLES OF BONY FISH



MANDARINFISH
(*Synchiropus splendidus*)



OCEANIC SEAHORSE
(*Hippocampus kuda*)



ANGLERFISH
(*Caulophryne jordani*)



LIONFISH
(*Pterois volitans*)



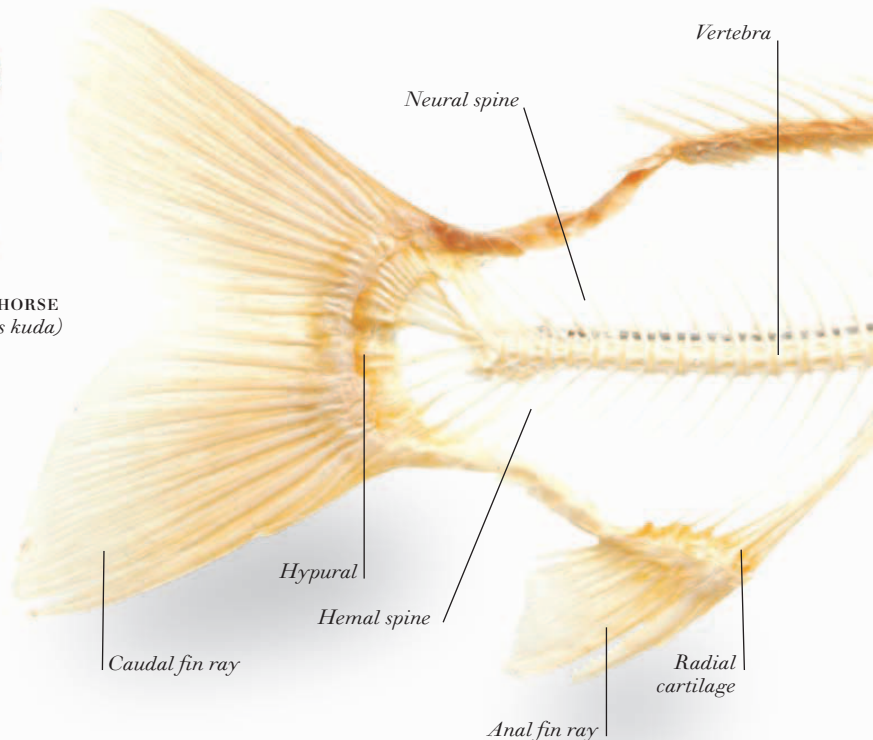
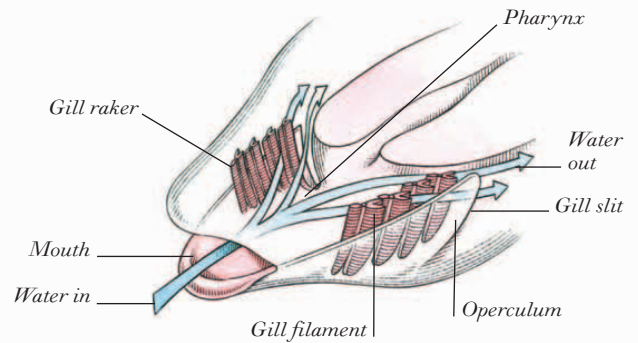
STURGEON
(*Acipenser sturio*)



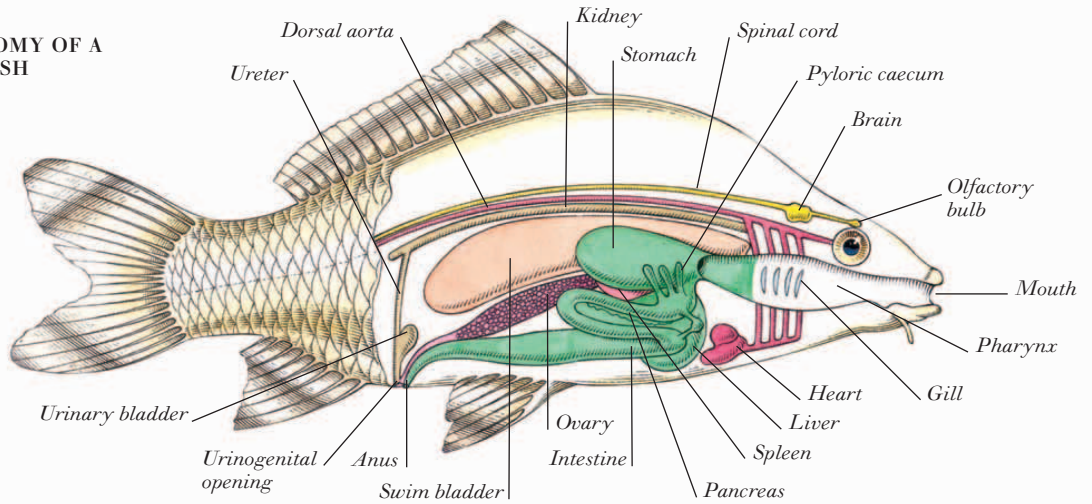
SNOWFLAKE MORAY EEL
(*Echidna nebulosa*)

HOW FISH BREATHE

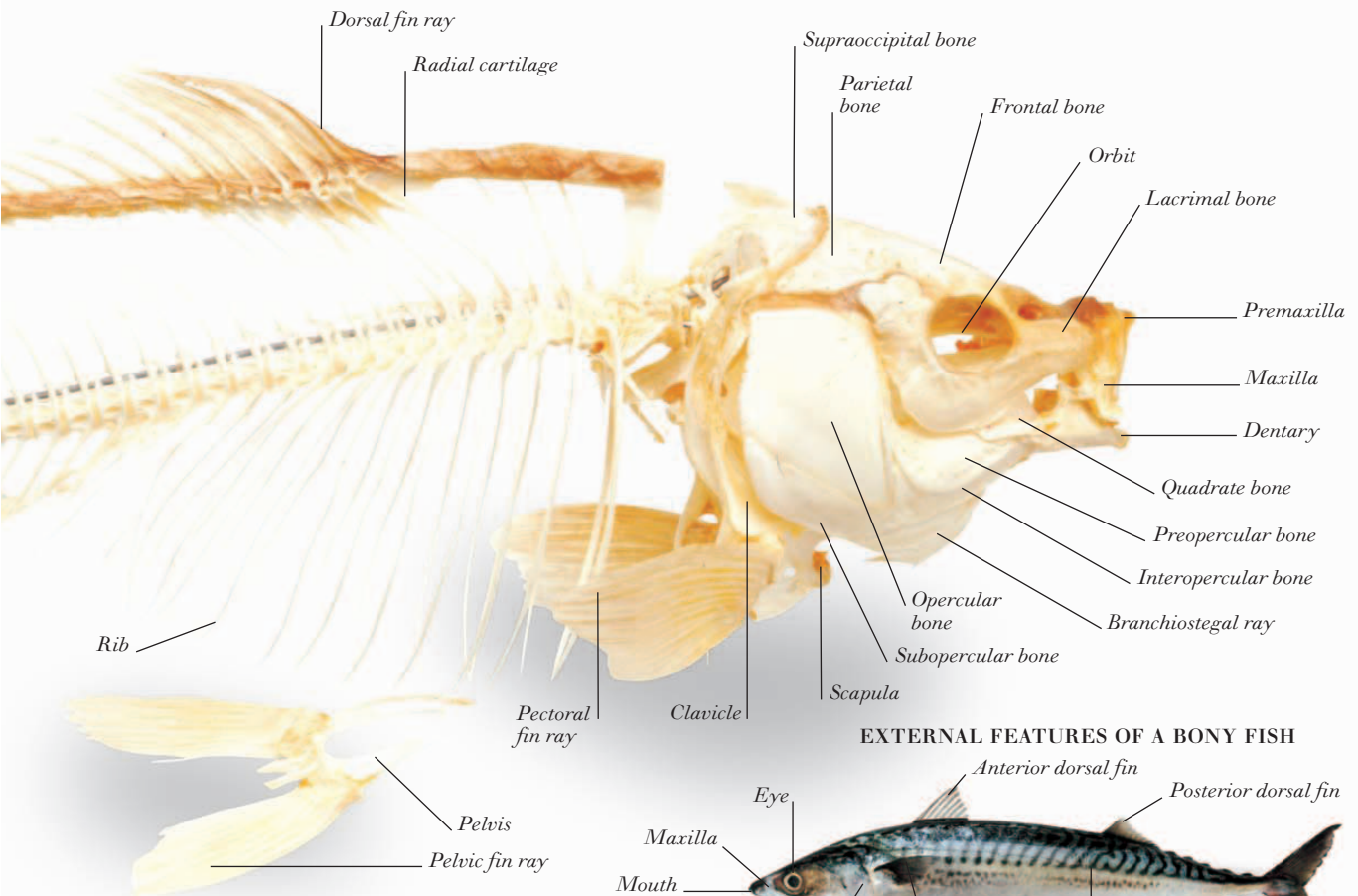
Fish “breathe” by extracting oxygen from water through their gills. Water is sucked in through the mouth; simultaneously, the opercula close to prevent the water from escaping. The mouth is then closed, and muscles in the walls of the mouth, pharynx, and opercular cavity contract to pump the water inside over the gills and out through the opercula. Some fish rely on swimming with their mouths open to keep water flowing over the gills.



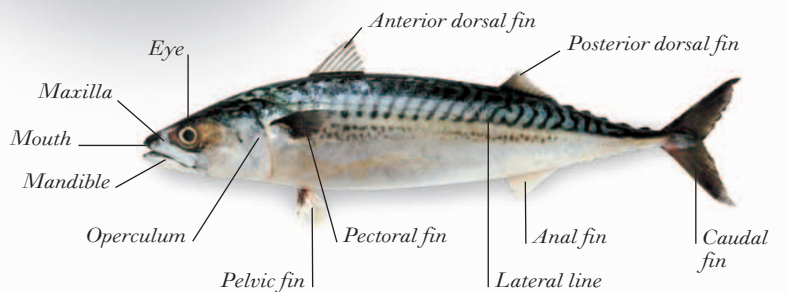
INTERNAL ANATOMY OF A FEMALE BONY FISH



SKELETON OF A BONY FISH



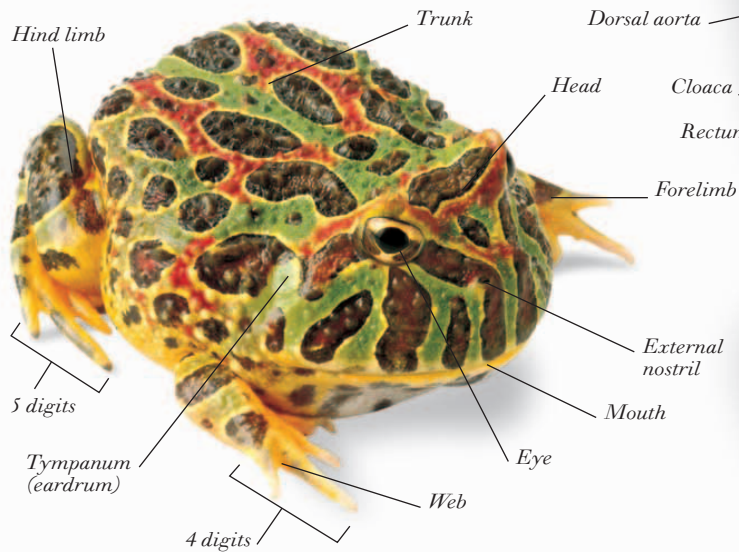
EXTERNAL FEATURES OF A BONY FISH



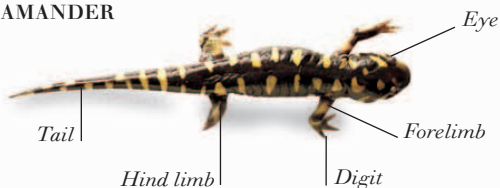
Amphibians

THE CLASS AMPHIBIA INCLUDES FROGS and toads (which make up the order Anura), and newts and salamanders (which make up the order Urodela). Amphibians typically have moist, scaleless, hairless skin; lungs; and are cold-blooded. They also undergo complete metamorphosis, from eggs laid in water through various water-living larval stages (such as tadpoles) to land-living adults. Typical features of adult frogs and toads include a squat body with no tail; long, powerful hind legs; and large, often bulging, eyes. Adult newts and salamanders typically have a long body with a well-developed tail; and relatively short, equal-sized legs. However, newts and salamanders show considerable variation; for example, in some species the adults have minute legs, external gills rather than lungs, and spend their entire lives in water.

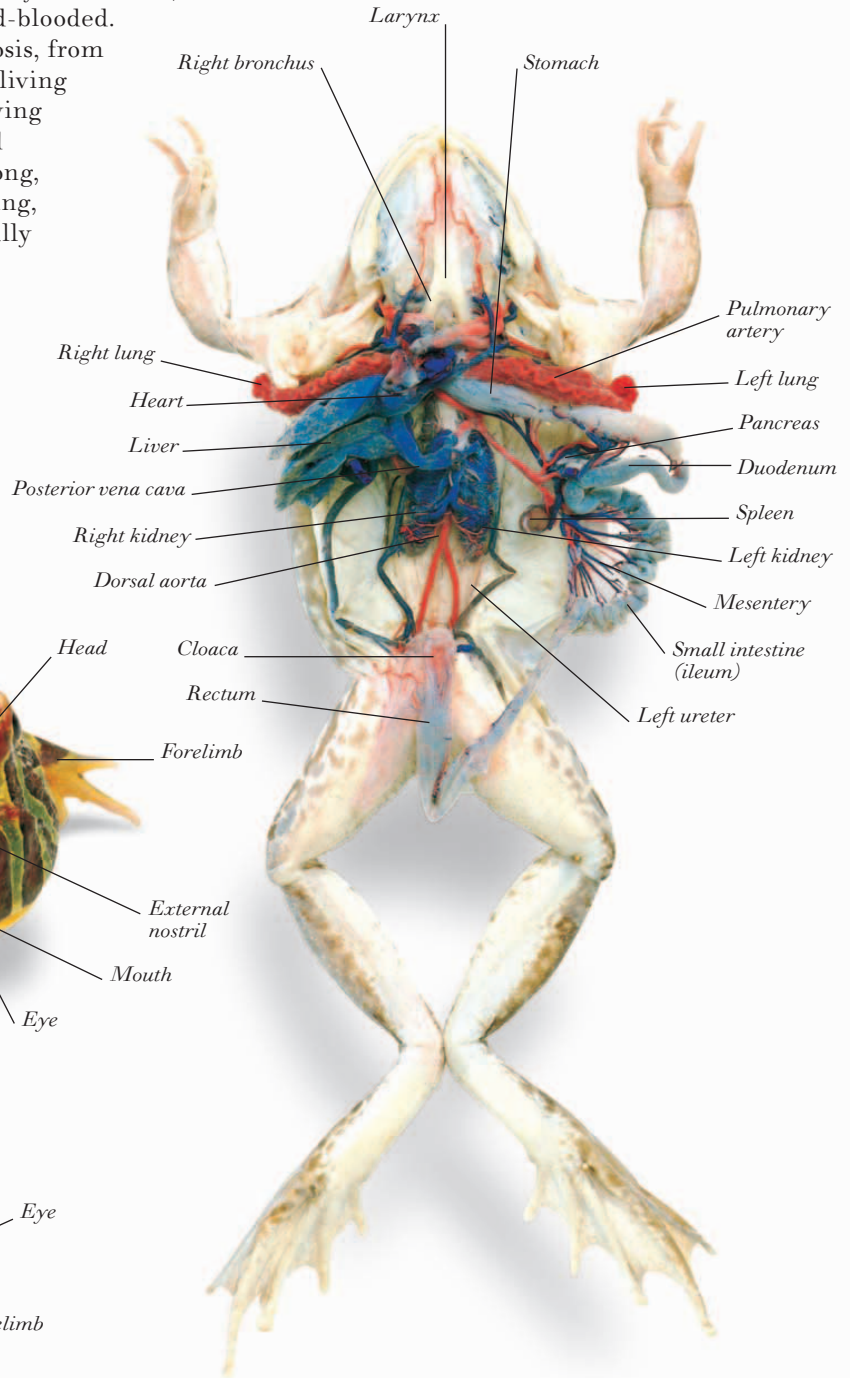
EXTERNAL FEATURES OF A FROG



EXTERNAL FEATURES OF A SALAMANDER



INTERNAL ANATOMY OF A FEMALE FROG





EGGS (SPAWN)



YOUNG TADPOLES



MATURE TADPOLE

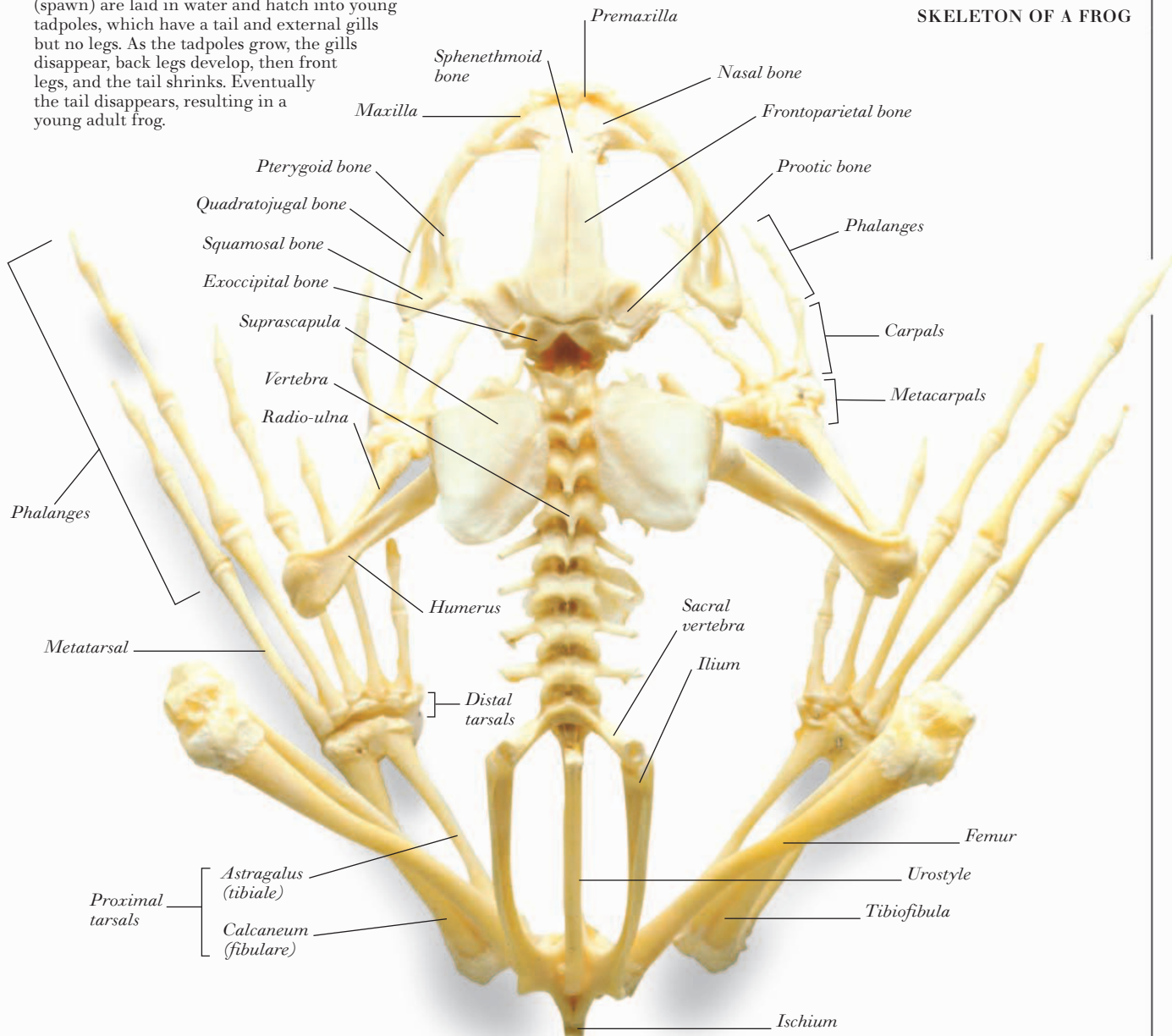


YOUNG FROG

METAMORPHOSIS OF FROGS

Frogs undergo complete metamorphosis. Eggs (spawn) are laid in water and hatch into young tadpoles, which have a tail and external gills but no legs. As the tadpoles grow, the gills disappear, back legs develop, then front legs, and the tail shrinks. Eventually the tail disappears, resulting in a young adult frog.

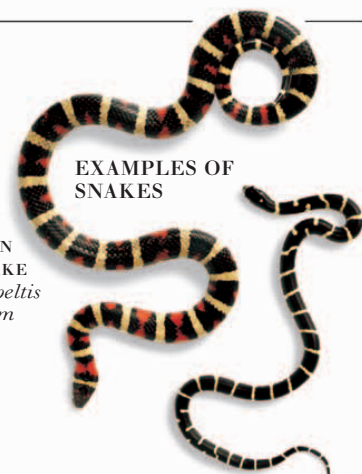
SKELETON OF A FROG



Lizards and snakes

LIZARDS AND SNAKES BELONG to the order Squamata, a division of the class Reptilia. Characteristic reptilian features include scaly skin, lungs, and cold-bloodedness. Most reptiles lay leathery-shelled eggs, although some hatch the eggs inside their bodies and give birth to live young. Lizards belong to the suborder Lacertilia. Typically, they have long tails, and shed their skin in several pieces. Many lizards can regenerate a tail if it is lost; some can change color; and some are limbless.

Snakes make up the suborder Ophidia (also called Serpentes). All snakes have long, limbless bodies; can dislocate their lower jaw to swallow large prey; and have eyelids that are joined together to form a single transparent covering over the front of the eye. Most snakes shed their skin in a single piece. Constrictor snakes kill their prey by squeezing; venomous snakes poison their prey.

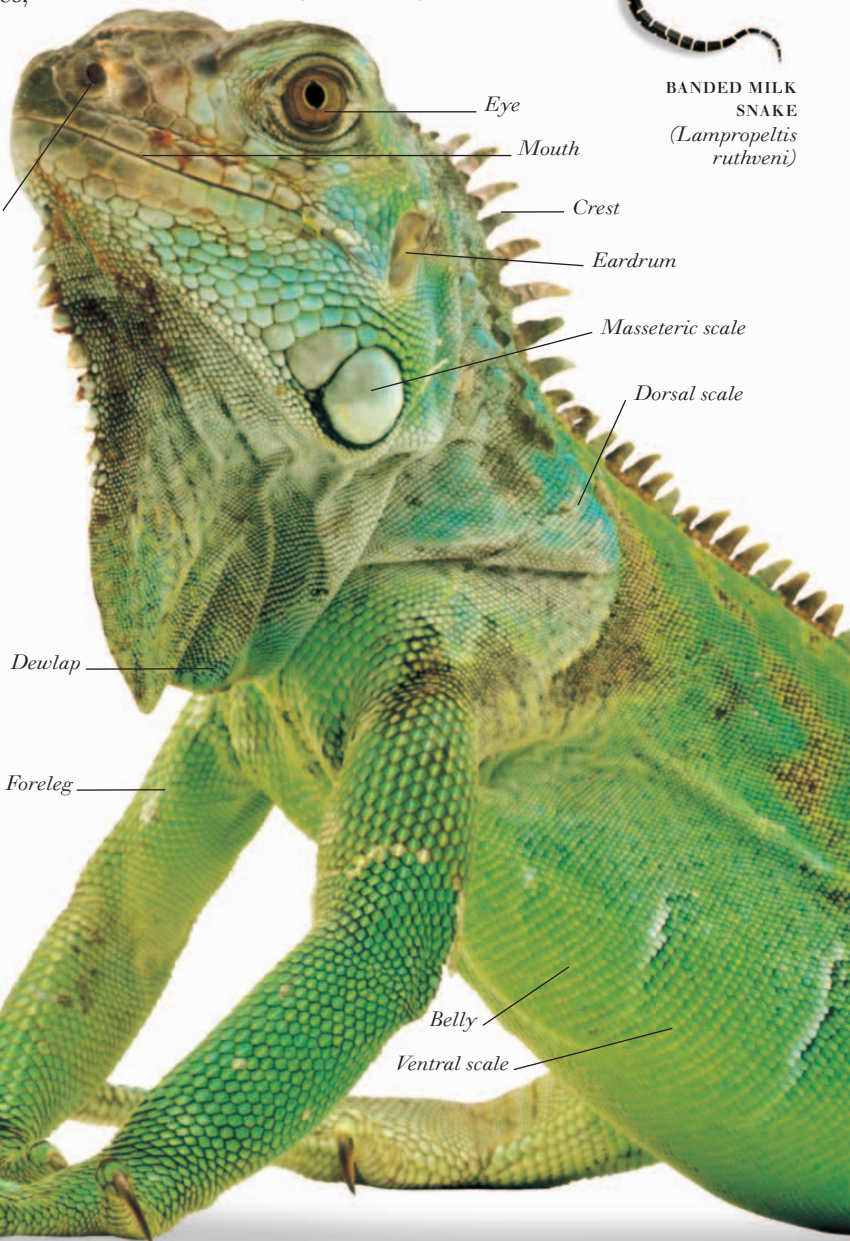


EXAMPLES OF SNAKES

MEXICAN MOUNTAIN KING SNAKE
(Lampropeltis triangulum annulata)

BANDED MILK SNAKE
(Lampropeltis ruthveni)

EXTERNAL FEATURES OF A LIZARD



External nostril

Eye

Mouth

Crest

Eardrum

Masseteric scale

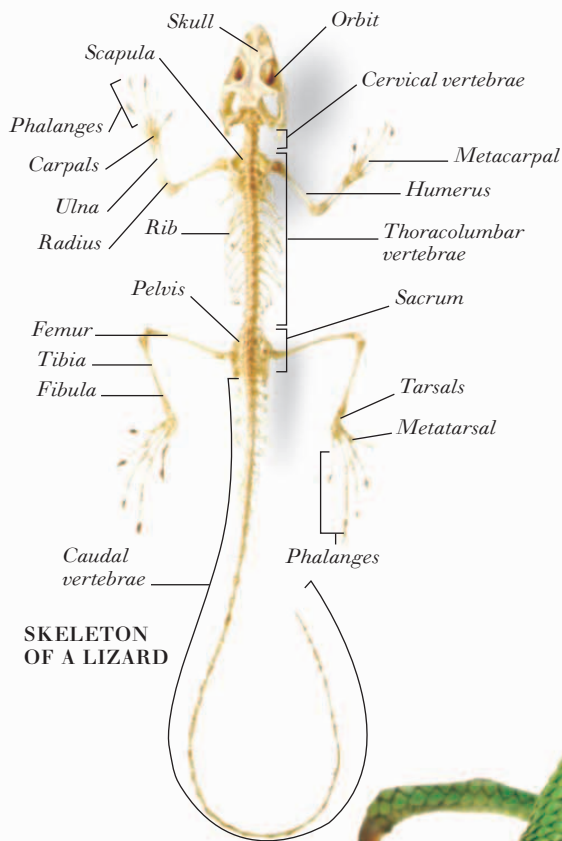
Dorsal scale

Dewlap

Foreleg

Belly

Ventral scale



SKELETON OF A LIZARD

Skull

Orbit

Scapula

Cervical vertebrae

Phalanges

Carpals

Metacarpal

Ulna

Humerus

Radius

Rib

Thoracolumbar vertebrae

Pelvis

Sacrum

Femur

Tibia

Fibula

Tarsals

Metatarsal

Caudal vertebrae

Phalanges

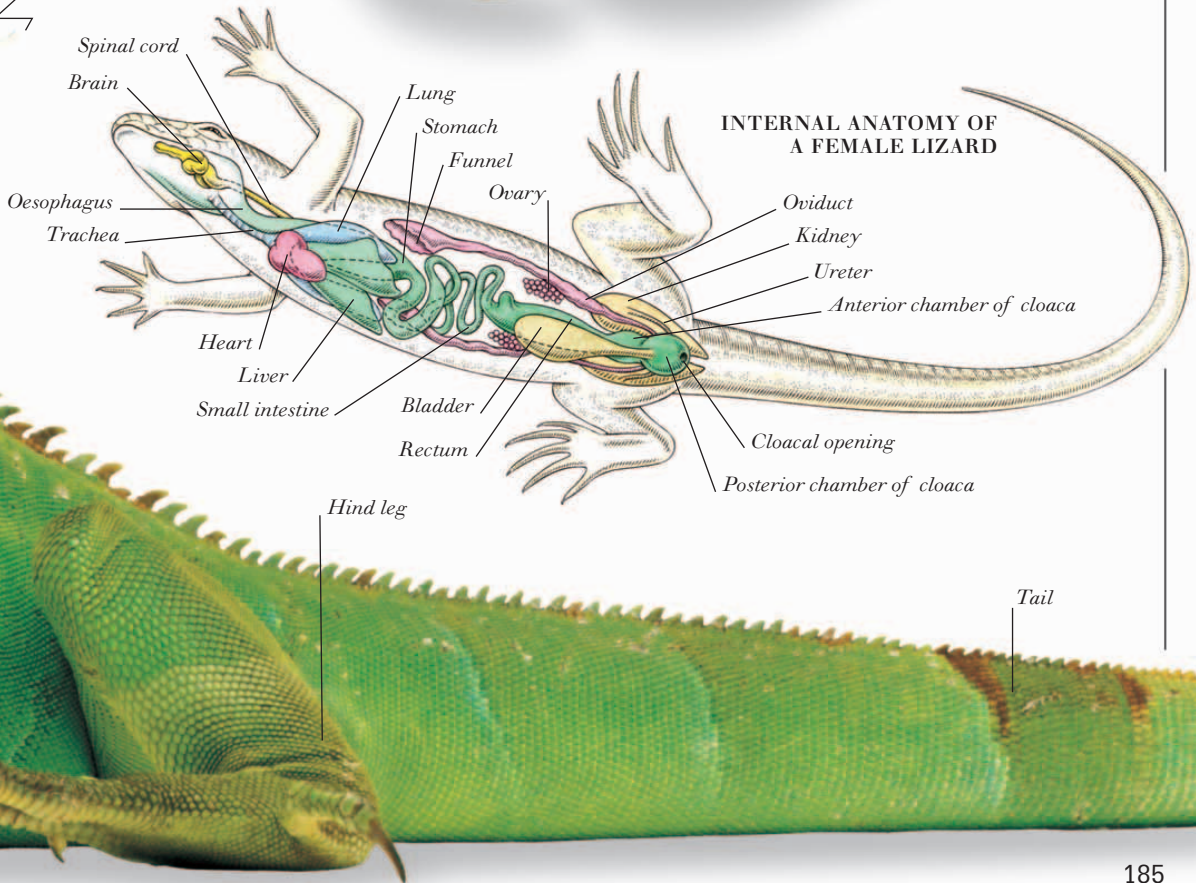
Toe

Claw



SKELETON OF A SNAKE

EXTERNAL FEATURES OF A RATTLESNAKE



INTERNAL ANATOMY OF A FEMALE LIZARD

Crocodylians and turtles

CROCODYLIANS AND TURTLES BELONG to different orders in the class Reptilia. The order Crocodylia includes crocodiles, alligators, caimans, and gharials. Typically, crocodylians are carnivores (flesh-eaters), and have a long snout, sharp teeth for gripping prey, and hard, square scales. All crocodylians are adapted to living on land and in water: they have four strong legs for moving on land; a powerful tail for swimming; and their eyes and nostrils are high on the head so that they stay above water while the rest of the body is submerged. The order Chelonia includes marine turtles, terrapins (freshwater turtles), and tortoises (land turtles). Characteristically, chelonians have a short, broad body encased in a bony shell with an outer horny covering, into which the head and limbs can be withdrawn; and a horny beak instead of teeth.

SKULLS OF CROCODYLIANS



GHARIAL
(*Gavialis gangeticus*)

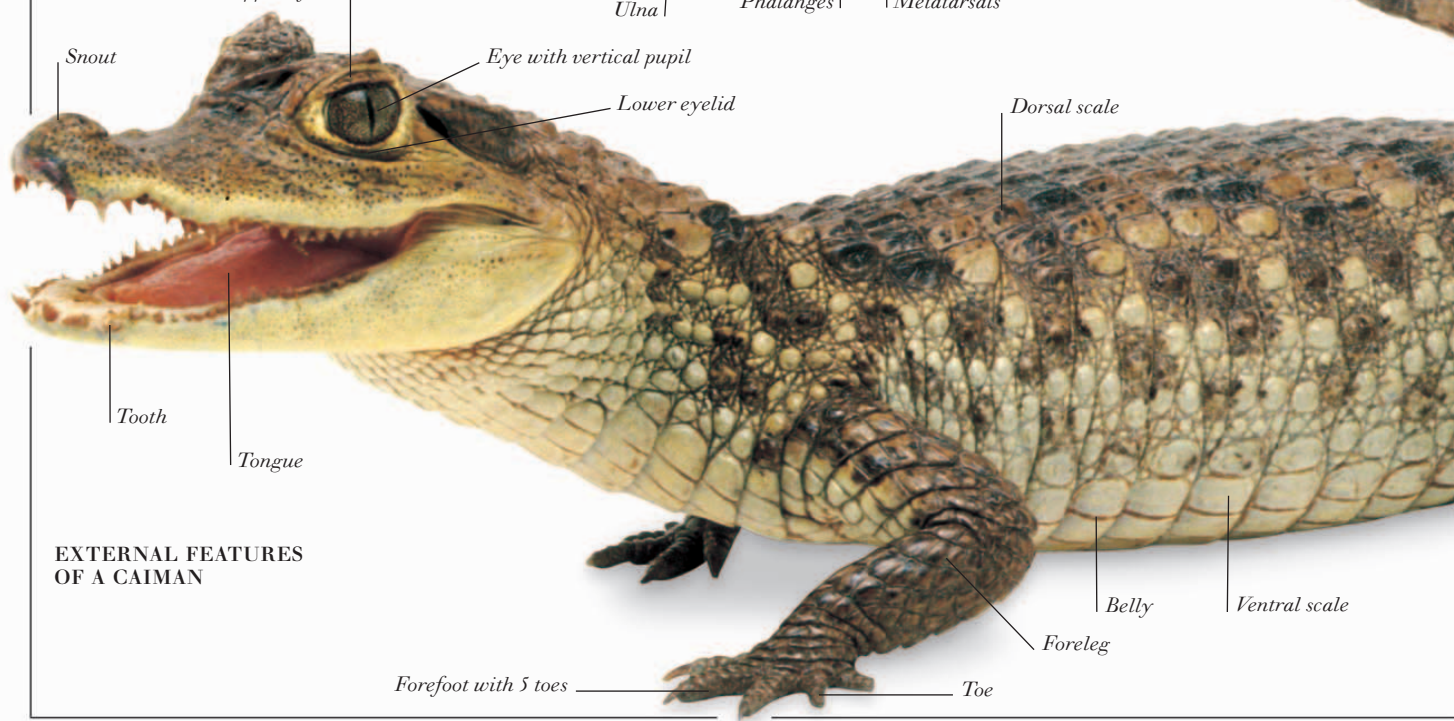
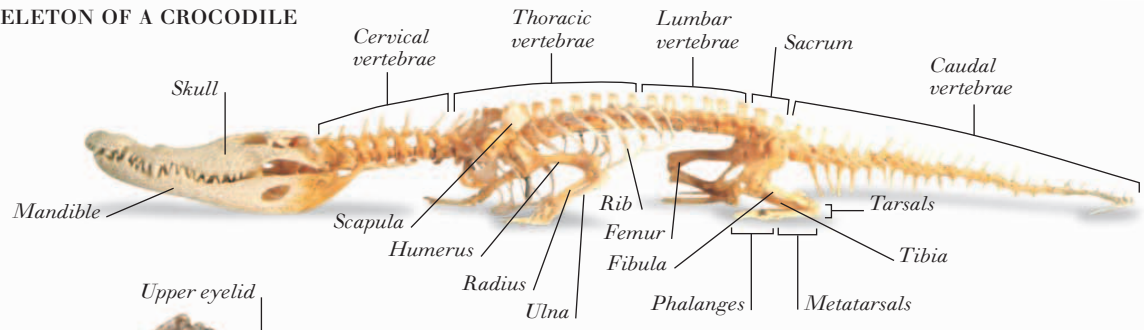


NILE CROCODILE
(*Crocodylus niloticus*)



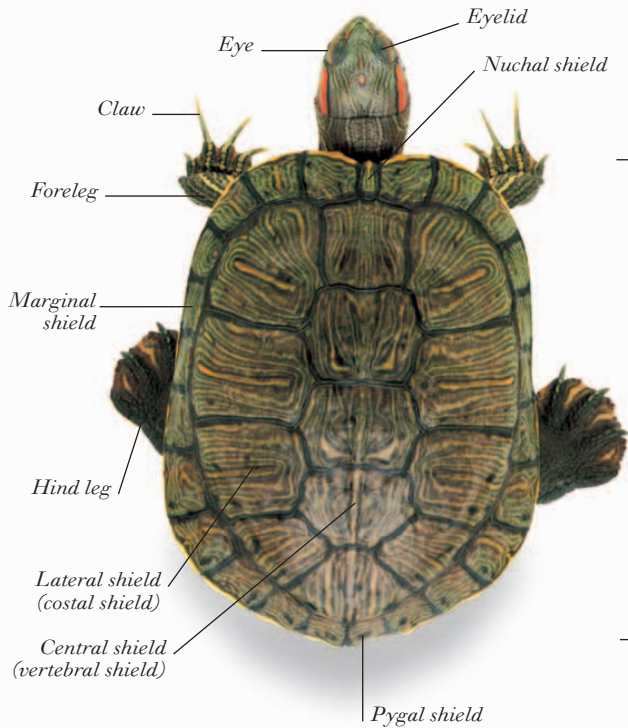
AMERICAN ALLIGATOR
(*Alligator mississippiensis*)

SKELETON OF A CROCODILE

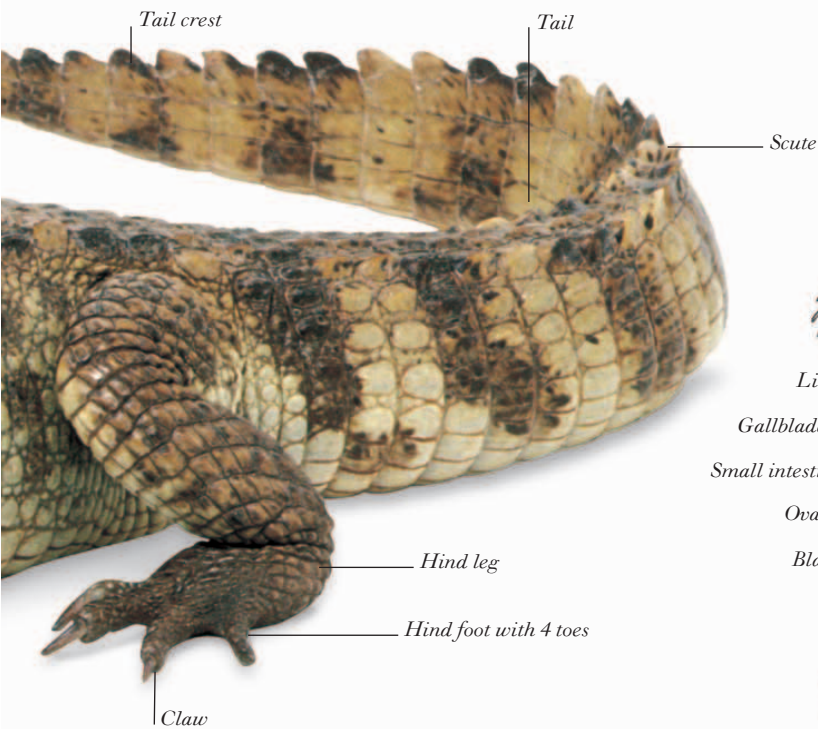
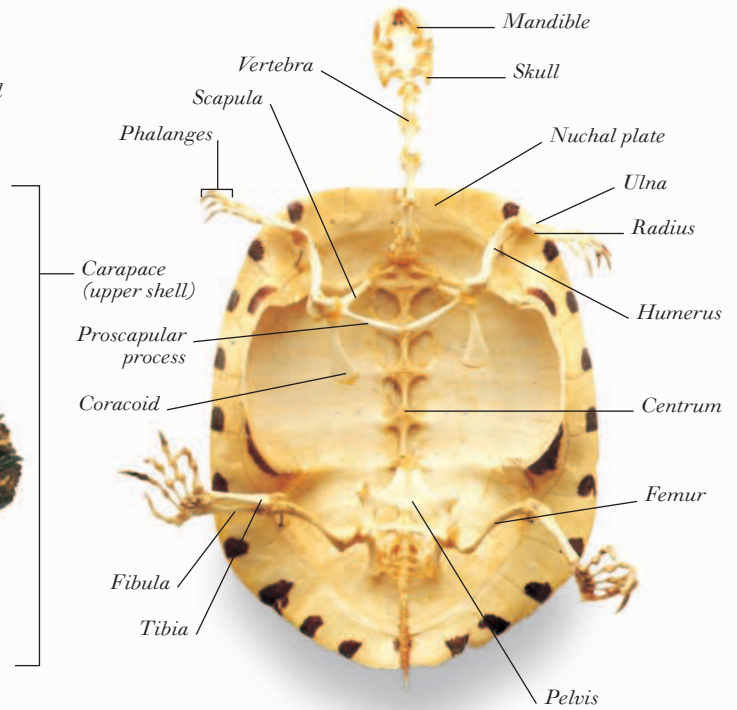


EXTERNAL FEATURES OF A CAIMAN

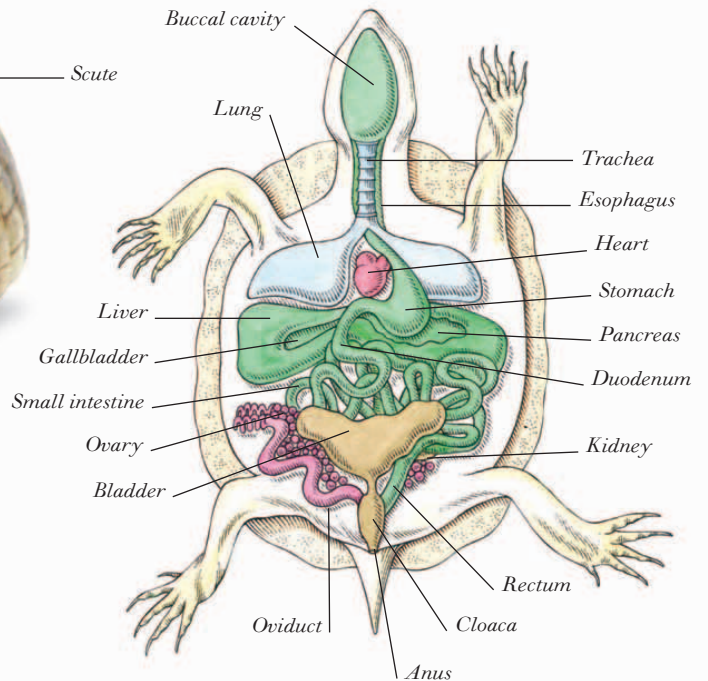
EXTERNAL FEATURES OF A TERRAPIN



SKELETON OF A TURTLE



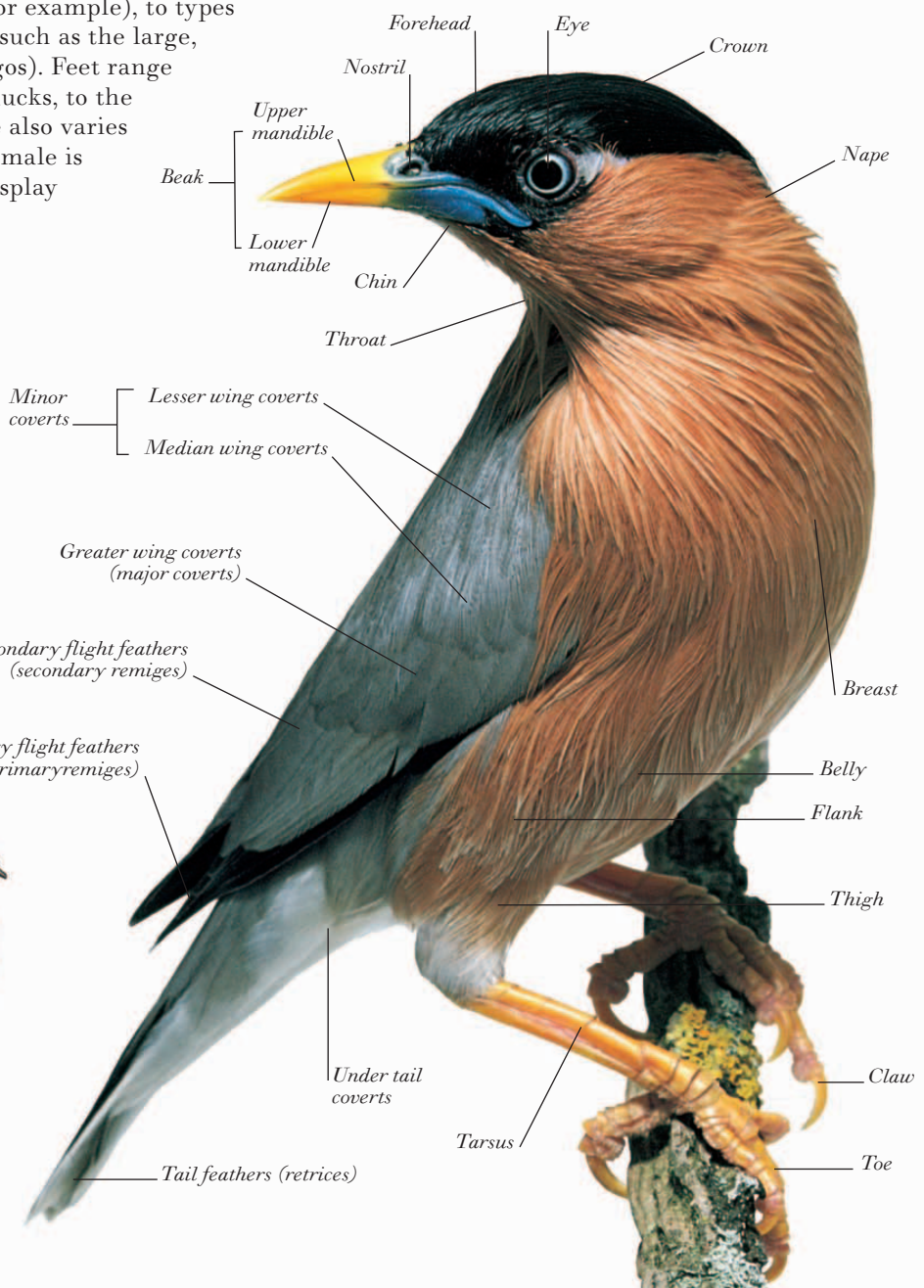
INTERNAL ANATOMY OF A FEMALE TORTOISE



Birds 1

BIRDS MAKE UP THE CLASS AVES. There are more than 9,000 species, almost all of which can fly (the only flightless birds are penguins, ostriches, rheas, cassowaries, and kiwis). The ability to fly is reflected in the typical bird features: forelimbs modified as wings; a streamlined body; and hollow bones to reduce weight. All birds lay hard-shelled eggs, which the parents incubate. Birds' beaks and feet vary according to diet and way of life. Beaks range from general-purpose types suitable for a mixed diet (those of thrushes, for example), to types specialized for particular foods (such as the large, curved, sieving beaks of flamingos). Feet range from the webbed "paddles" of ducks, to the talons of birds of prey. Plumage also varies widely, and in many species the male is brightly colored for courtship display whereas the female is drab.

EXTERNAL FEATURES OF A BIRD



EXAMPLES OF BIRDS



MALE TUFTED DUCK
(Aythya fuligula)

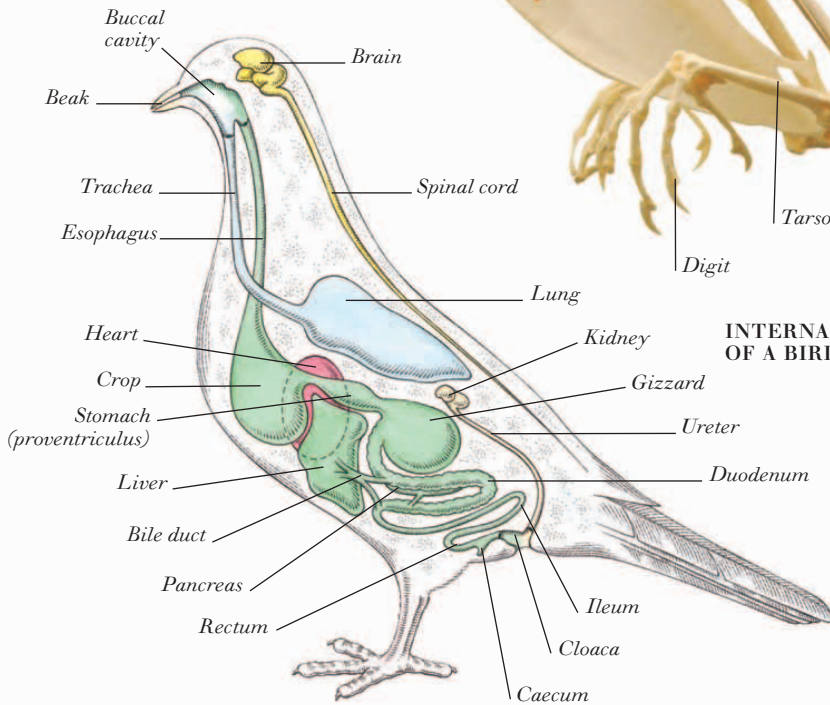
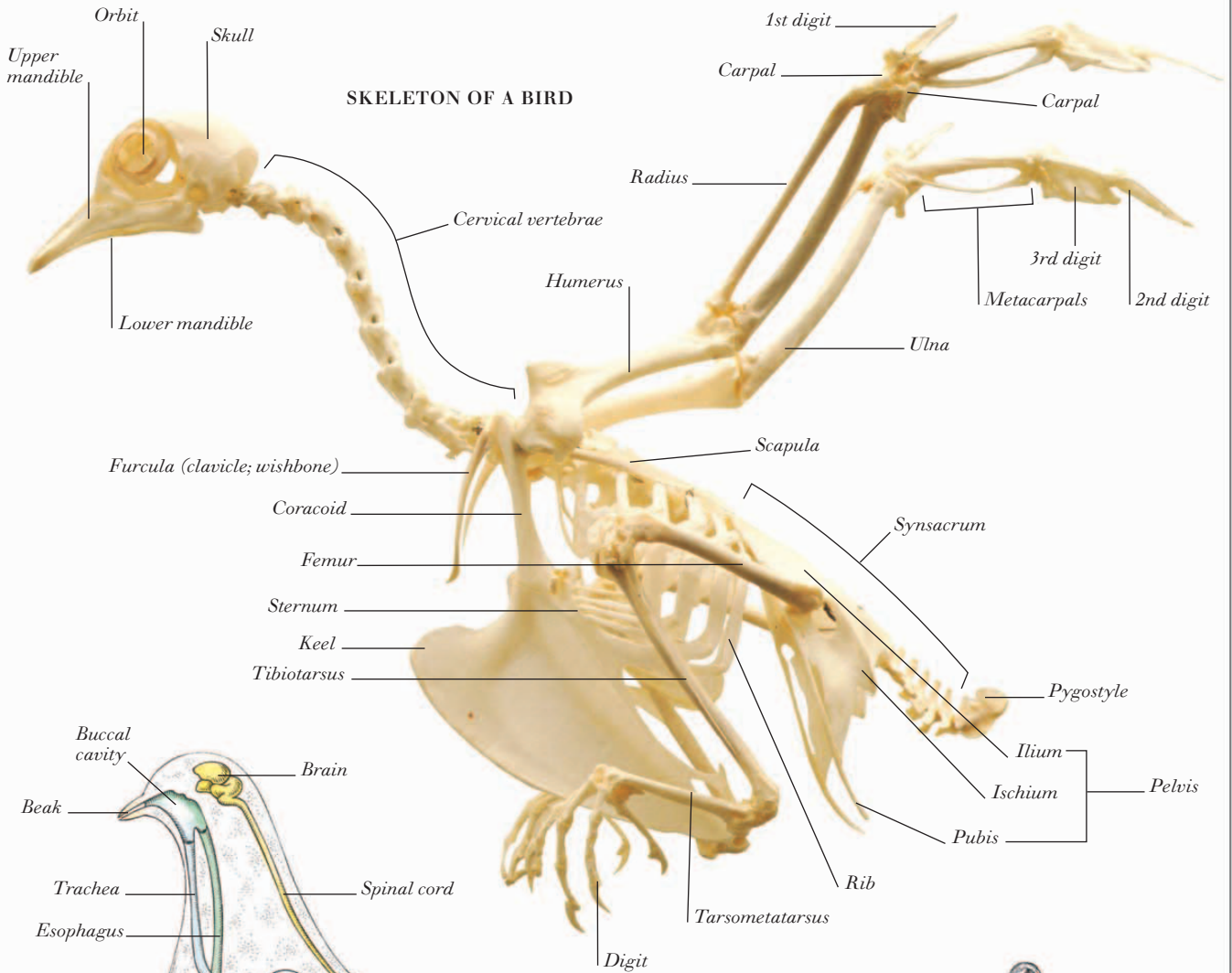


WHITE STORK
(Ciconia ciconia)



MALE OSTRICH
(Struthio camelus)

SKELETON OF A BIRD



INTERNAL ANATOMY OF A BIRD



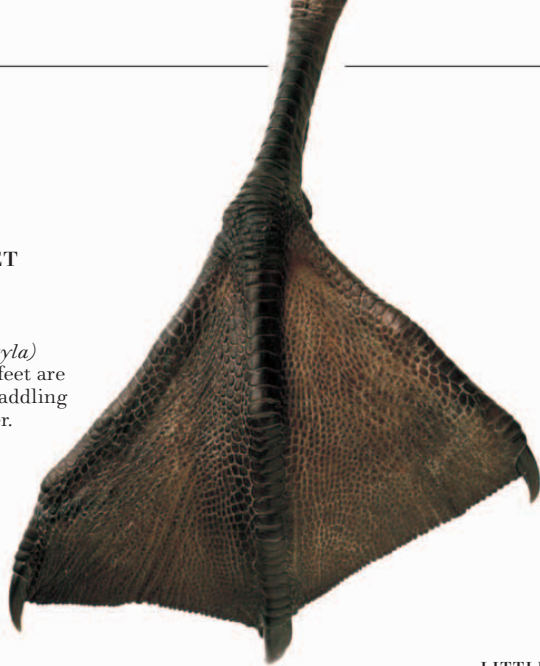
Birds 2

EXAMPLES OF BIRDS' FEET

KITTIWAKE

(Rissa tridactyla)

The webbed feet are adapted for paddling through water.



LITTLE GREBE

(Tachybaptus ruficollis)

The lobed, flattened feet are adapted for swimming underwater.



TAWNY OWL

(Strix aluco)

The clawed feet are adapted for gripping prey.



EXAMPLES OF BIRDS' BEAKS

GREATER FLAMINGO

(Phoenicopterus ruber)

In the living bird, the large, curved beak contains a cartilaginous "strainer" for filtering food particles from water.



MISTLE THRUSH

(Turdus viscivorus)

The general-purpose beak is suitable for a wide range of animal and plant foods.



KING VULTURE

(Sarcorhamphus papa)

The hooked beak is adapted for pulling apart flesh.

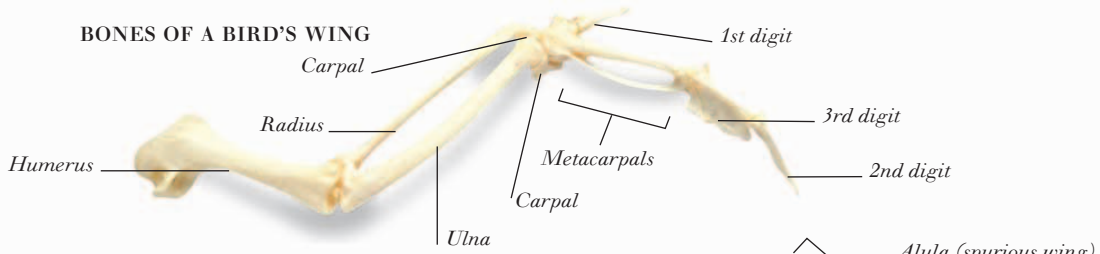


BLUE-AND-YELLOW MACAW

(Ara ararauna)

The broad, powerful, hooked beak is adapted for crushing seeds and eating fruit.

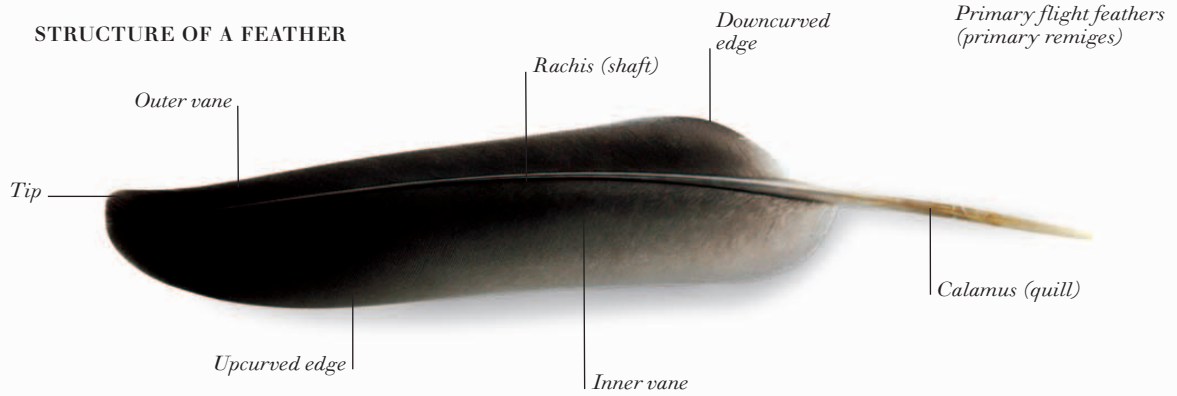
BONES OF A BIRD'S WING



FEATHERS OF A BIRD'S WING

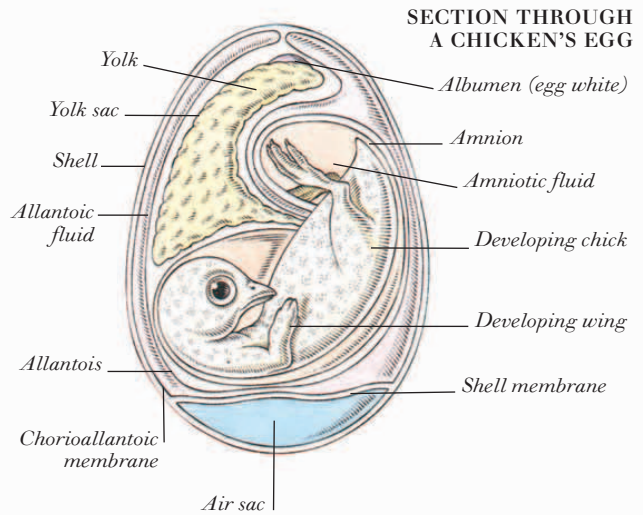


STRUCTURE OF A FEATHER



Eggs

AN EGG IS A SINGLE CELL, produced by the female, with the capacity to develop into a new individual. Development may take place inside the mother's body (as in most mammals) or outside, in which case the egg has a protective covering such as a shell. Egg yolk nourishes the growing young. Eggs developing inside the mother generally have little yolk, because the young are nourished from her body. Eggs developing outside may also have little yolk if they are produced by animals whose young go through a larval stage (such as a caterpillar) that feeds itself while developing into the adult form. The shelled eggs of birds and reptiles contain enough yolk to sustain the young until it hatches into a juvenile version of the adult.



VARIETY OF EGGS

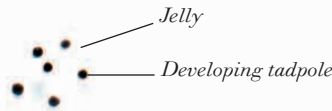
LEAF INSECT EGGS



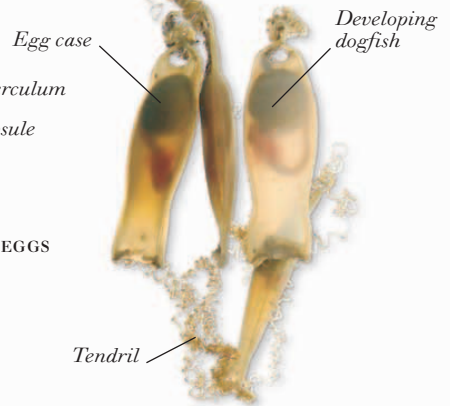
GIANT STICK INSECT EGGS



INDIAN STICK INSECT EGGS



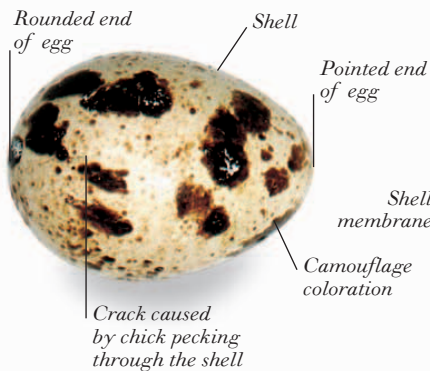
DOG FISH EGGS (MERMAID'S PURSES)



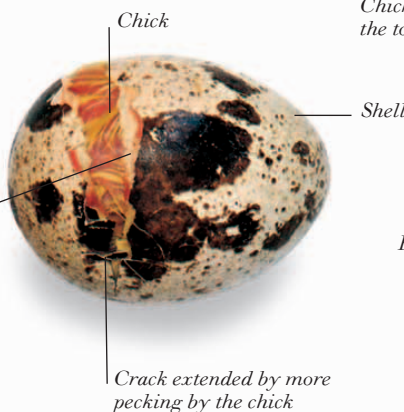
FROG EGGS (FROG SPAWN)

HATCHING OF A QUAIL'S EGG

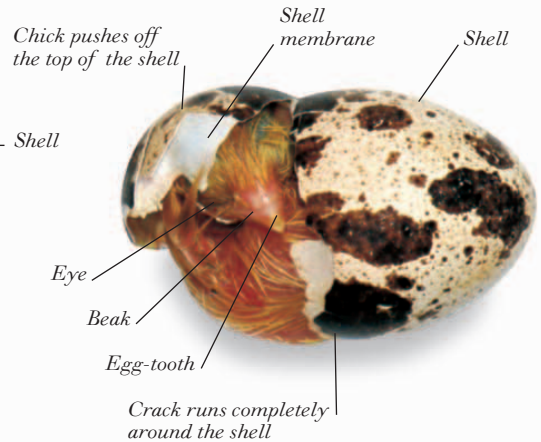
EGG AT THE POINT OF HATCHING



CUTTING THROUGH THE EGG



BREAKING OUT OF THE EGG



EXAMPLES OF BIRDS' EGGS



BEE HUMMINGBIRD
(Calypte helenae)

GREATER BLACKBACKED GULL
(Larus marinus)



BALTIMORE ORIOLE
(Icterus galbula)

WILLOW GROUSE
(Lagopus lagopus)



COMMON TERN
(Sterna hirundo)

CARRION CROW
(Corvus corone)

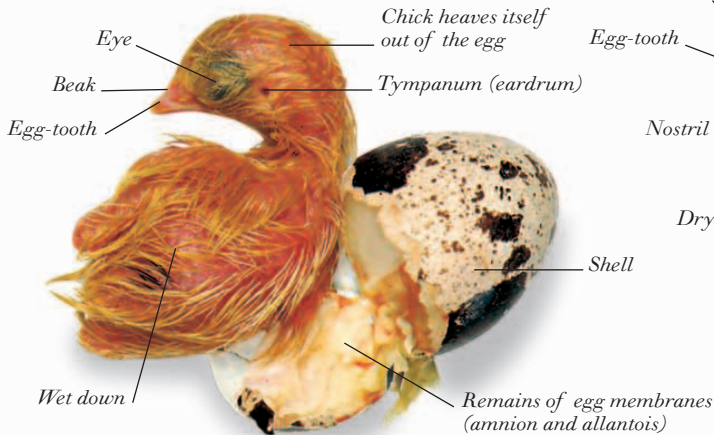


CHAFFINCH
(Fringilla coelebs)

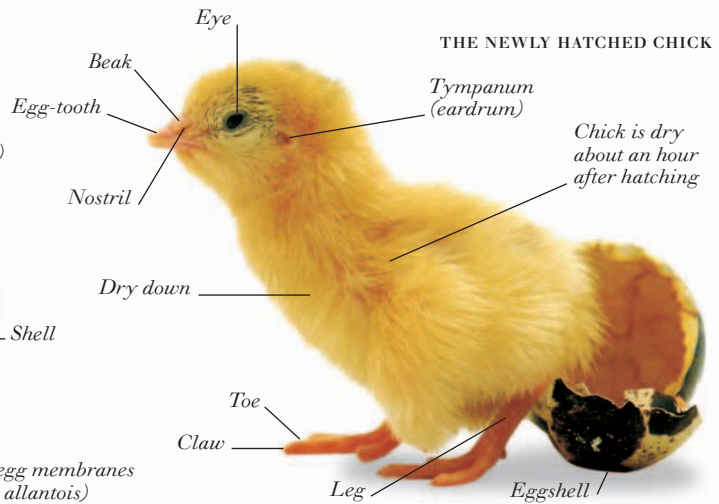


OSTRICH
(Struthio camelus)

EMERGING FROM THE EGG



THE NEWLY HATCHED CHICK

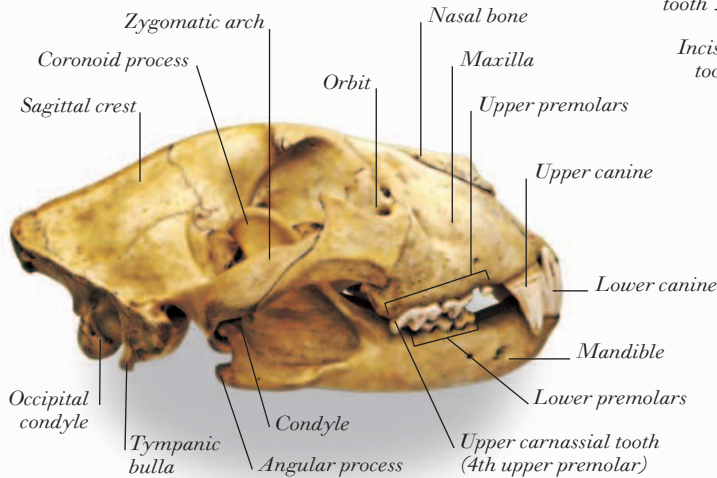


Carnivores

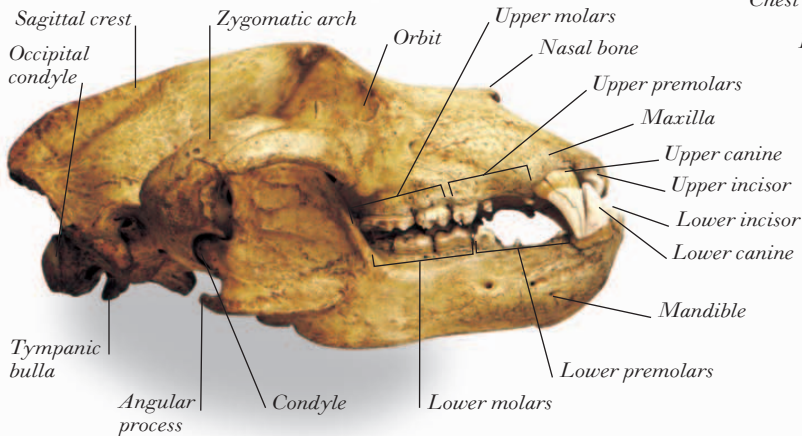
THE MAMMALIAN ORDER CARNIVORA includes cats, dogs, bears, raccoons, pandas, weasels, badgers, skunks, otters, civets, mongooses, and hyenas. The order's name is derived from the fact that most of its members are carnivores (flesh-eaters). Typical carnivore features therefore reflect a hunting life-style: speed and agility; sharp claws and well-developed canine teeth for holding and killing prey; carnassial teeth (cheek teeth) for cutting flesh; and forward-facing eyes for good distance judgment. However, some members of the order—bears, badgers, and foxes, for example—have a more mixed diet, and a few are entirely herbivorous (plant-eating), notably pandas. Such animals have no carnassial teeth and tend to be slower moving than pure flesh-eaters.

EXTERNAL FEATURES OF A MALE LION

SKULL OF A LION



SKULL OF A BEAR



EXAMPLES OF CARNIVORES



ALSATIAN DOG
(*Canis familiaris*)



MANED WOLF
(*Chrysocyon brachyurus*)

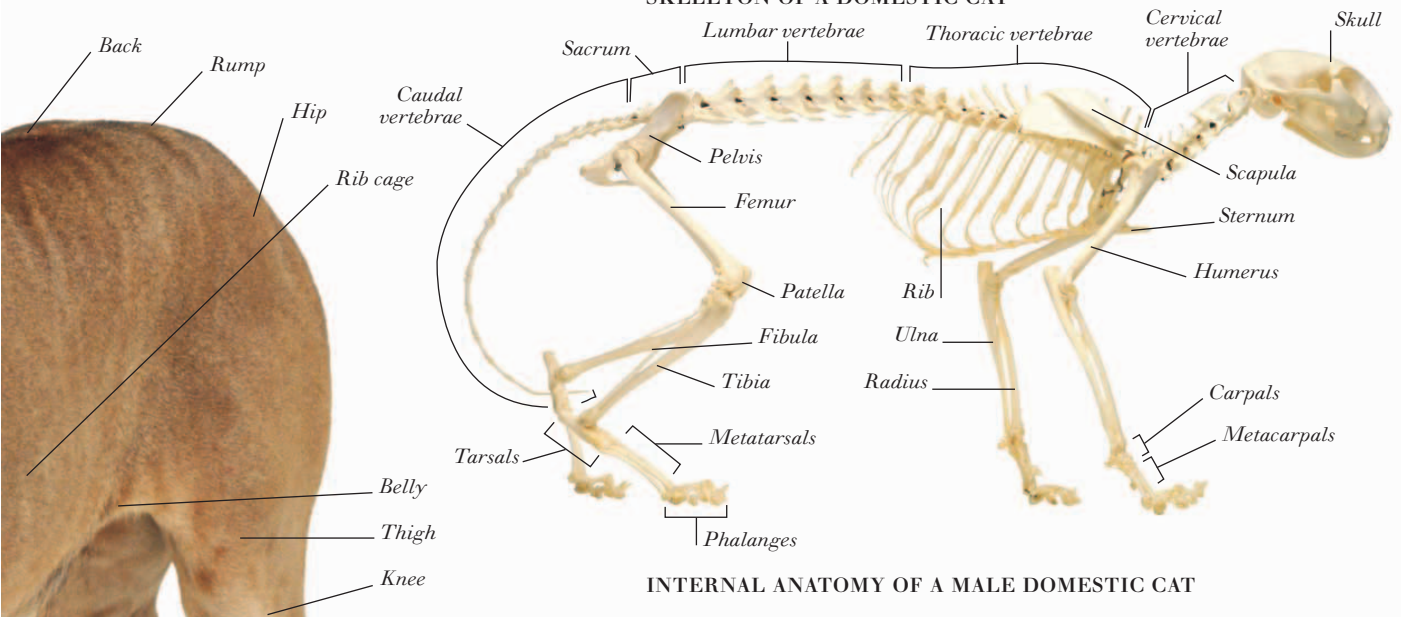


RACCOON
(*Procyon lotor*)

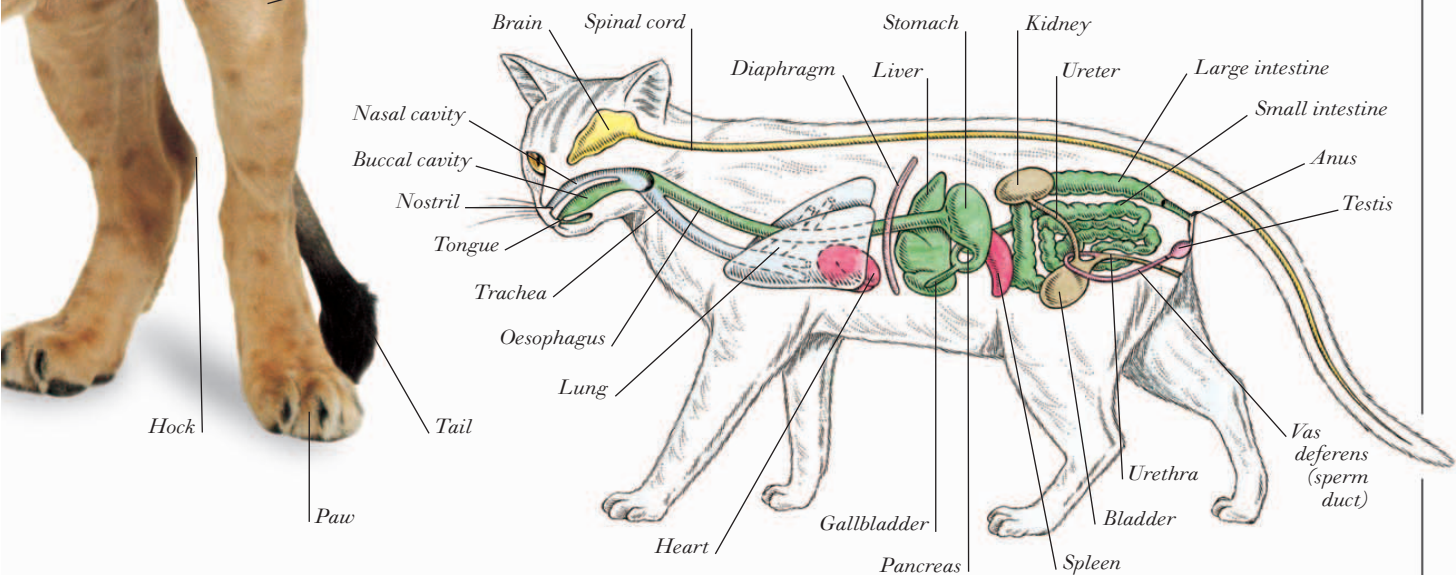


AMERICAN BLACK BEAR
(*Ursus americanus*)

SKELETON OF A DOMESTIC CAT



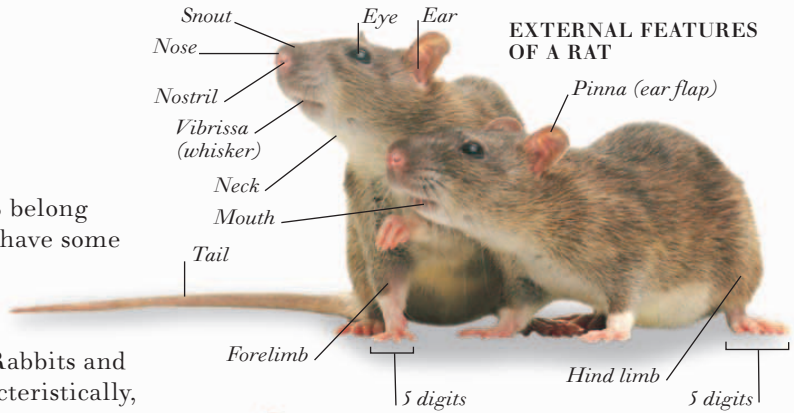
INTERNAL ANATOMY OF A MALE DOMESTIC CAT



Rabbits and rodents

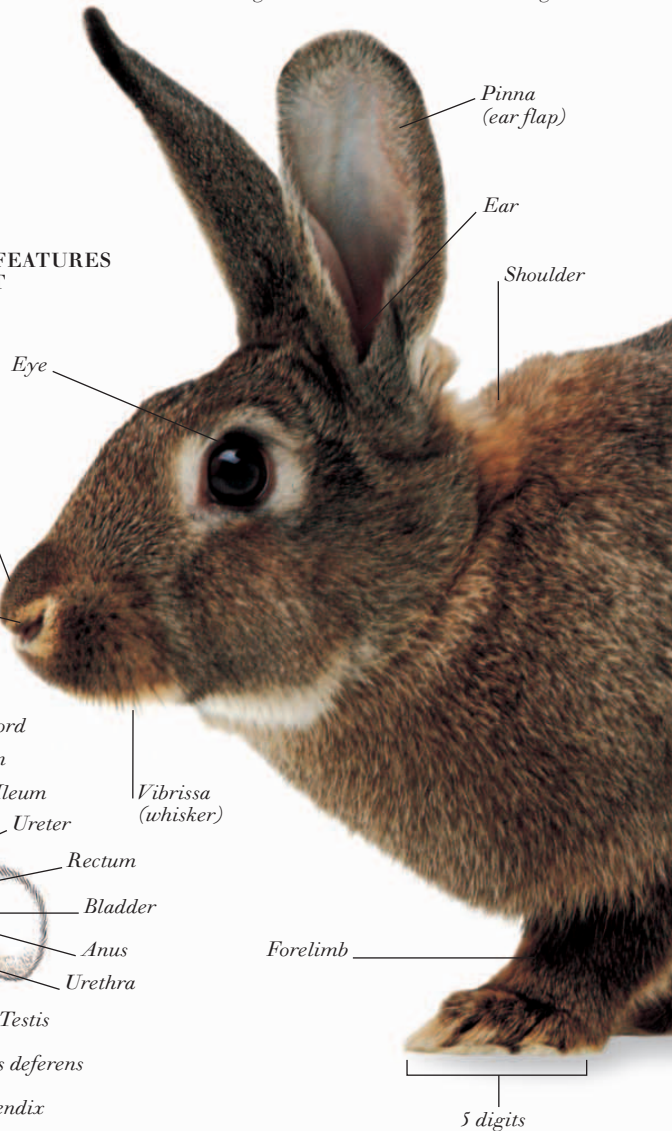


ALTHOUGH RABBITS AND RODENTS belong to different orders of mammals, they have some features in common. These features include chisel-shaped incisor teeth that grow continually, and eating their feces to extract more nutrients from their plant diet. Rabbits and hares belong to the order Lagomorpha. Characteristically, they have four incisors in the upper jaw and two in the lower jaw; powerful hind legs for jumping; forelimbs adapted for burrowing; long ears; and a small tail. Rodents make up the order Rodentia. This is the largest order of mammals, with more than 1,700 species, including squirrels, beavers, chipmunks, gophers, rats, mice, lemmings, gerbils, porcupines, cavies, and the capybara. Typical rodent features include two incisors in each jaw; short forelimbs for manipulating food; and cheek pouches for storing food.

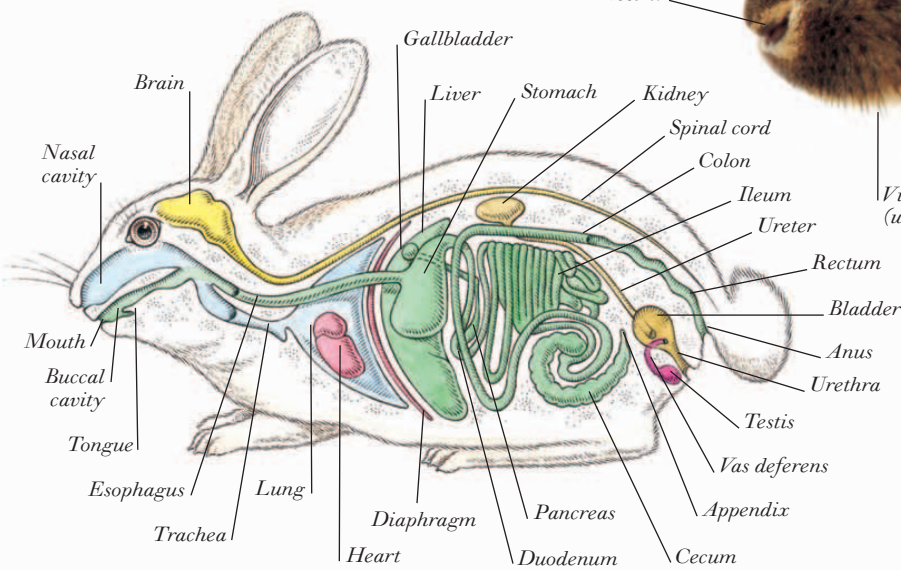


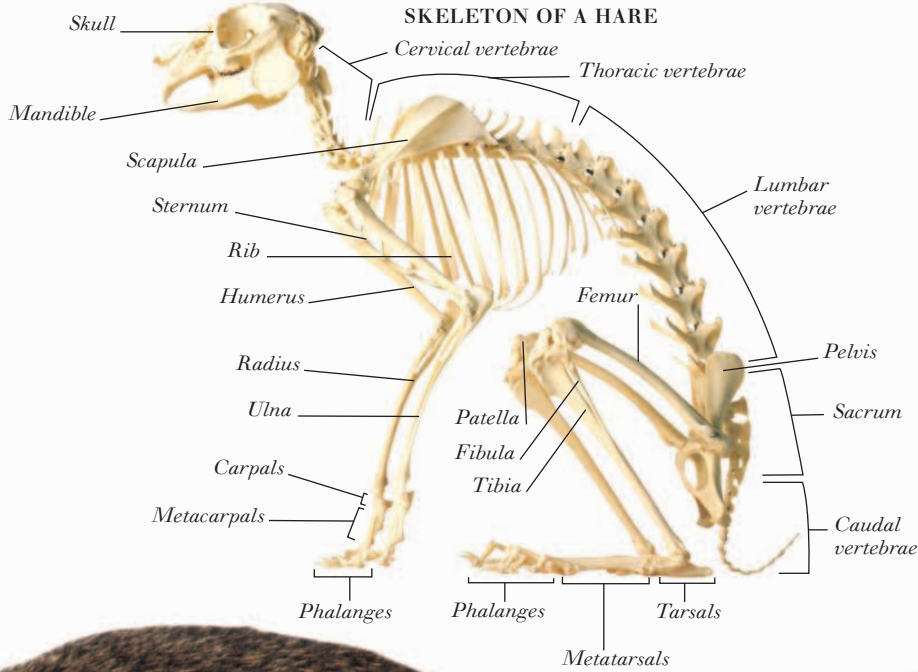
EXTERNAL FEATURES OF A RAT

EXTERNAL FEATURES OF A RABBIT



INTERNAL ANATOMY OF A MALE RABBIT





EXAMPLES OF RODENTS



GRAY SQUIRREL
(*Sciurus carolinensis*)



PLAINS VISCACHA
(*Lagostomus maximus*)

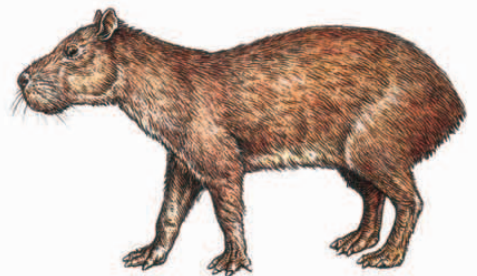


CRESTED PORCUPINE
(*Hystrix africaeustralis*)

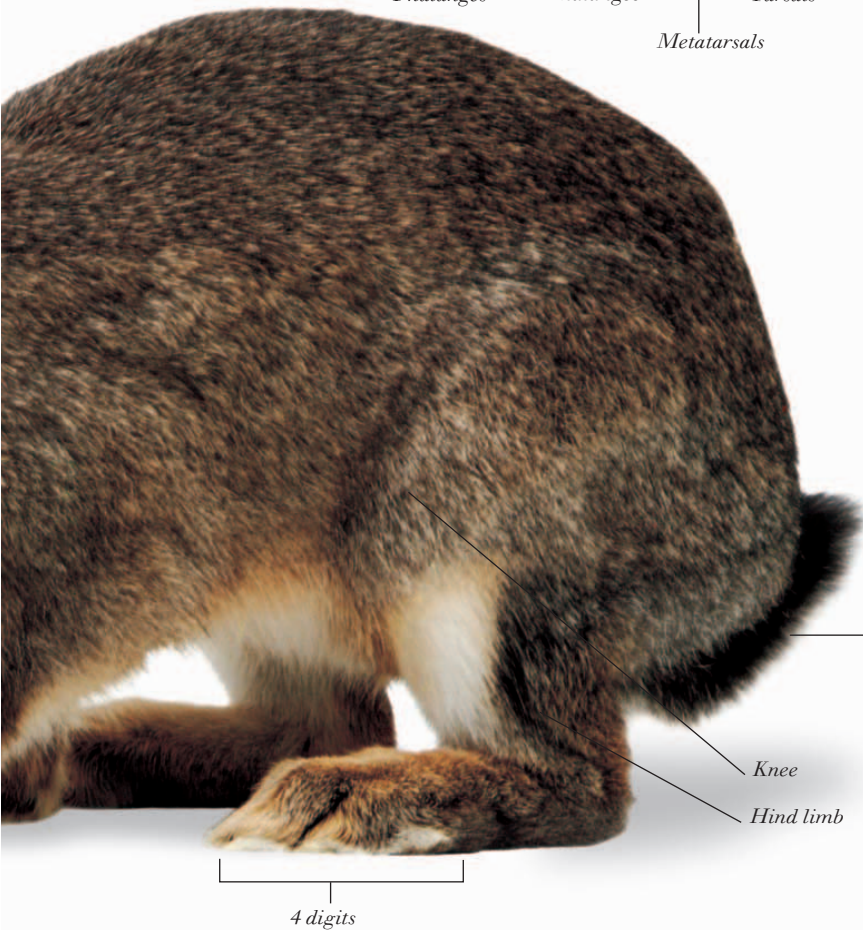


AMERICAN BEAVER
(*Castor canadensis*)

Tail

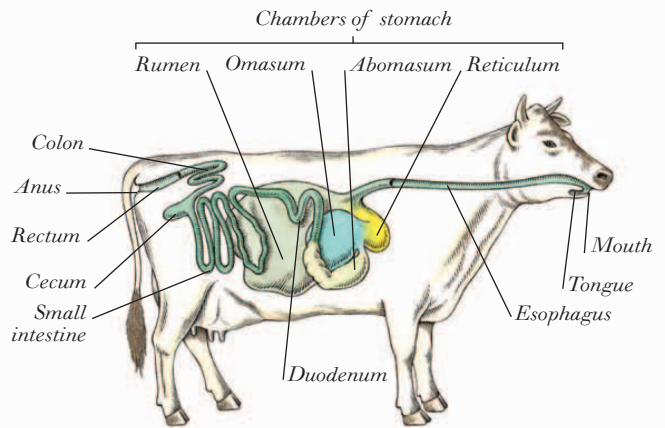


CAPYBARA
(*Hydrochoerus hydrochaeris*)



Ungulates

UNGULATES IS A GENERAL TERM FOR a large, varied group of mammals that includes horses, cattle, and their relatives. The ungulates are divided into two orders on the basis of the number of toes. Members of the order Perissodactyla (odd-toed ungulates) have one or three toes. Perissodactyls include horses, onagers, and zebras (all of which are one-toed), and rhinoceroses and tapirs (which are three-toed). Members of the order Artiodactyla (even-toed ungulates) have two or four toes. Most artiodactyls have two toes, which are typically encased in hooves to give the so-called cloven hoof. Two-toed, cloven-hoofed artiodactyls include cows and other cattle, sheep, goats, antelopes, deer, and giraffes. The other main two-toed artiodactyls are camels and llamas. Most two-toed artiodactyls are ruminants; that is, they have a four-chambered stomach and chew the cud. The principal four-toed artiodactyls are pigs, peccaries, and hippopotamuses.

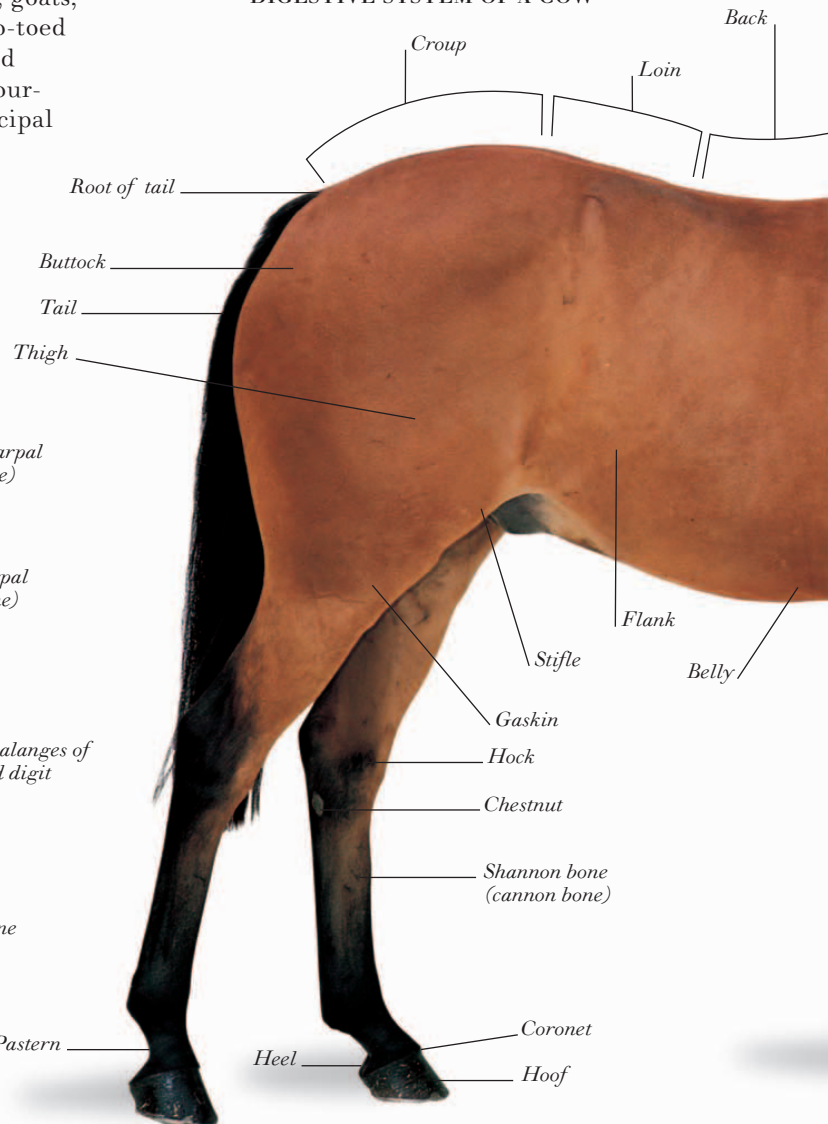
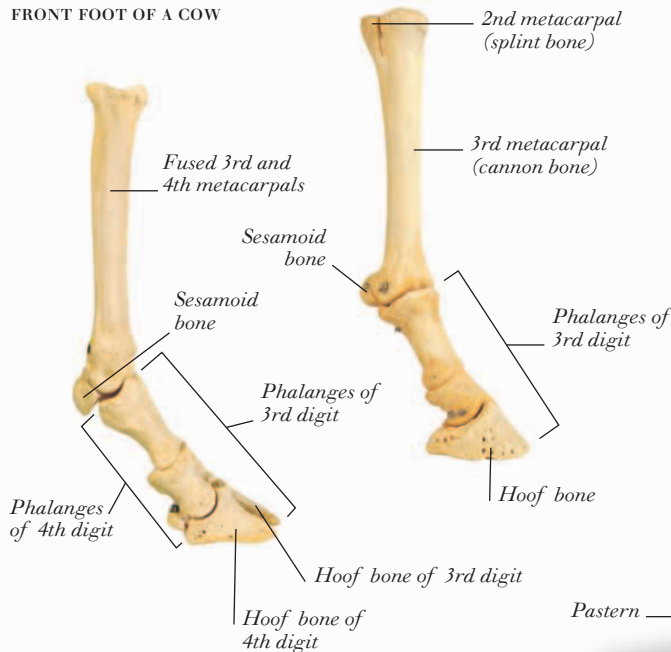


DIGESTIVE SYSTEM OF A COW

COMPARISON OF THE FRONT FEET OF A HORSE AND A COW

SKELETON OF THE LEFT FRONT FOOT OF A HORSE

SKELETON OF THE RIGHT FRONT FOOT OF A COW



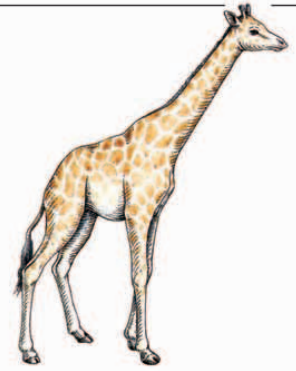
EXAMPLES OF UNGULATES



MALE RED DEER
(Cervus elephas)
An even-toed ungulate
(order Artiodactyla)



BACTRIAN CAMEL
(Camelus ferus)
An even-toed ungulate
(order Artiodactyla)

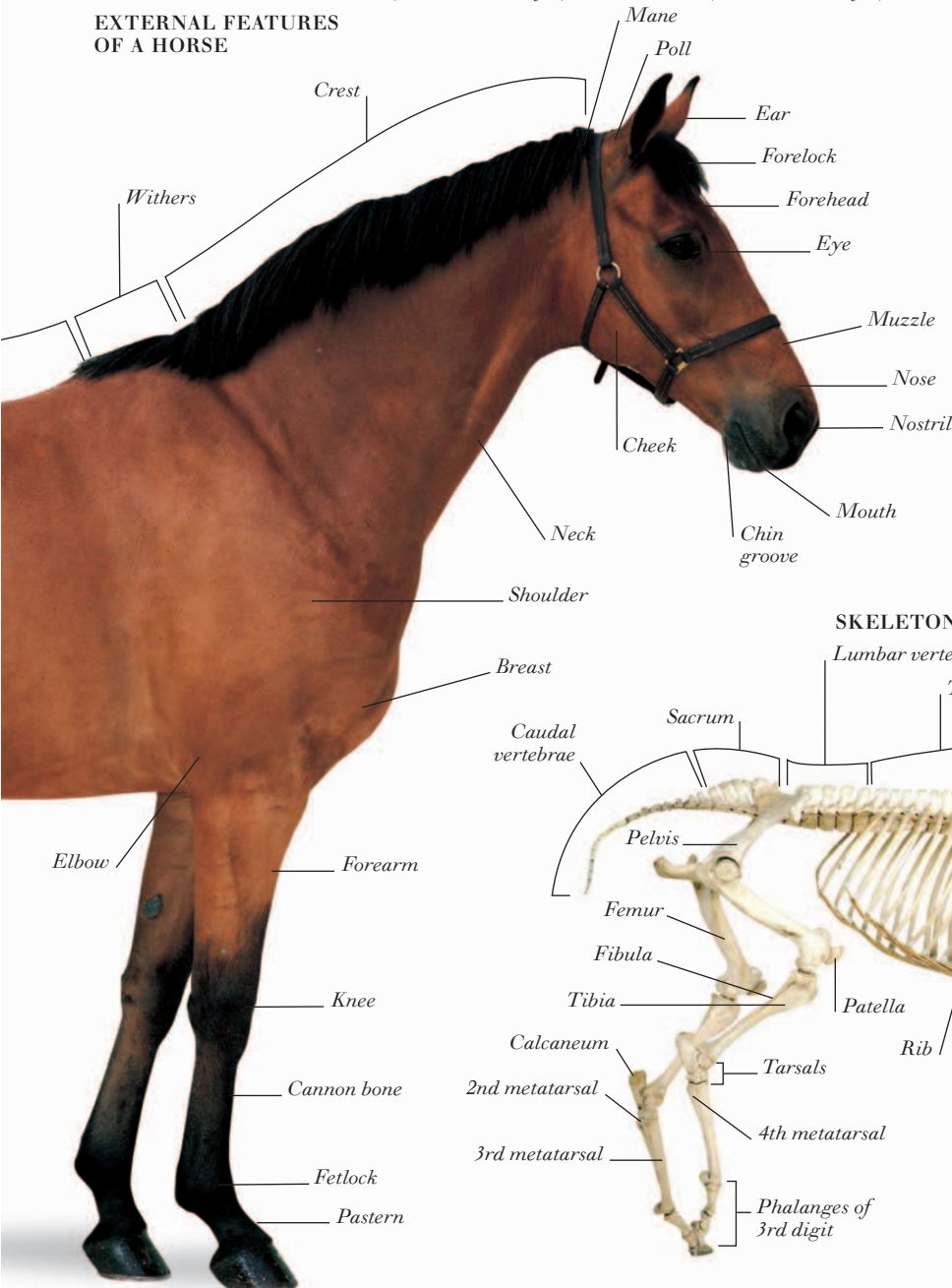


GIRAFFE
(Giraffa camelopardalis)
An even-toed ungulate
(order Artiodactyla)

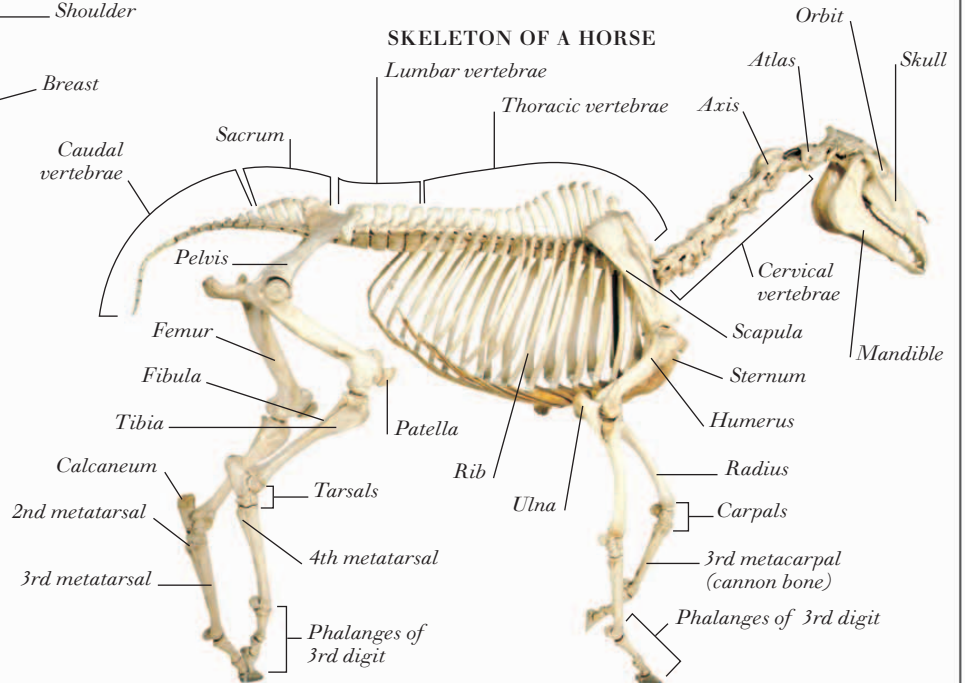


BLACK RHINOCEROS
(Diceros bicornis)
An odd-toed ungulate
(order Perissodactyla)

EXTERNAL FEATURES OF A HORSE



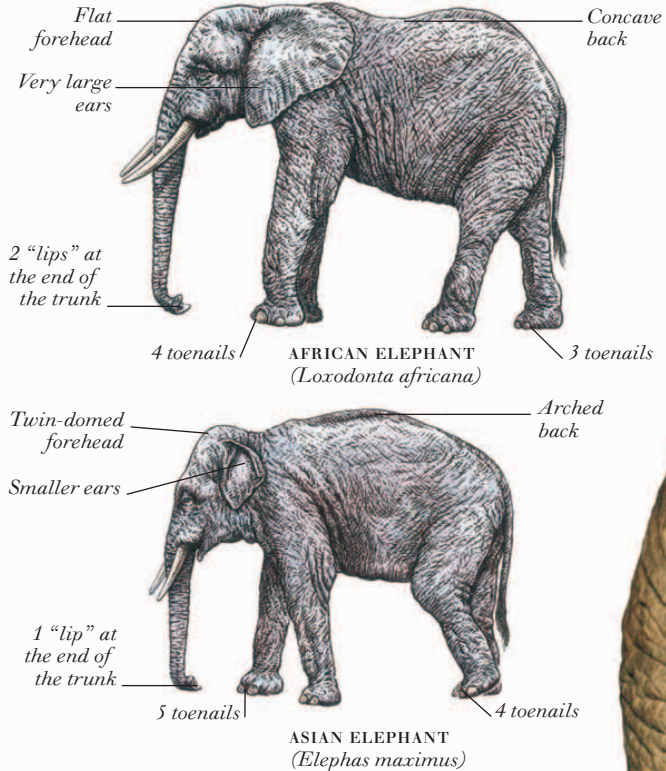
SKELETON OF A HORSE



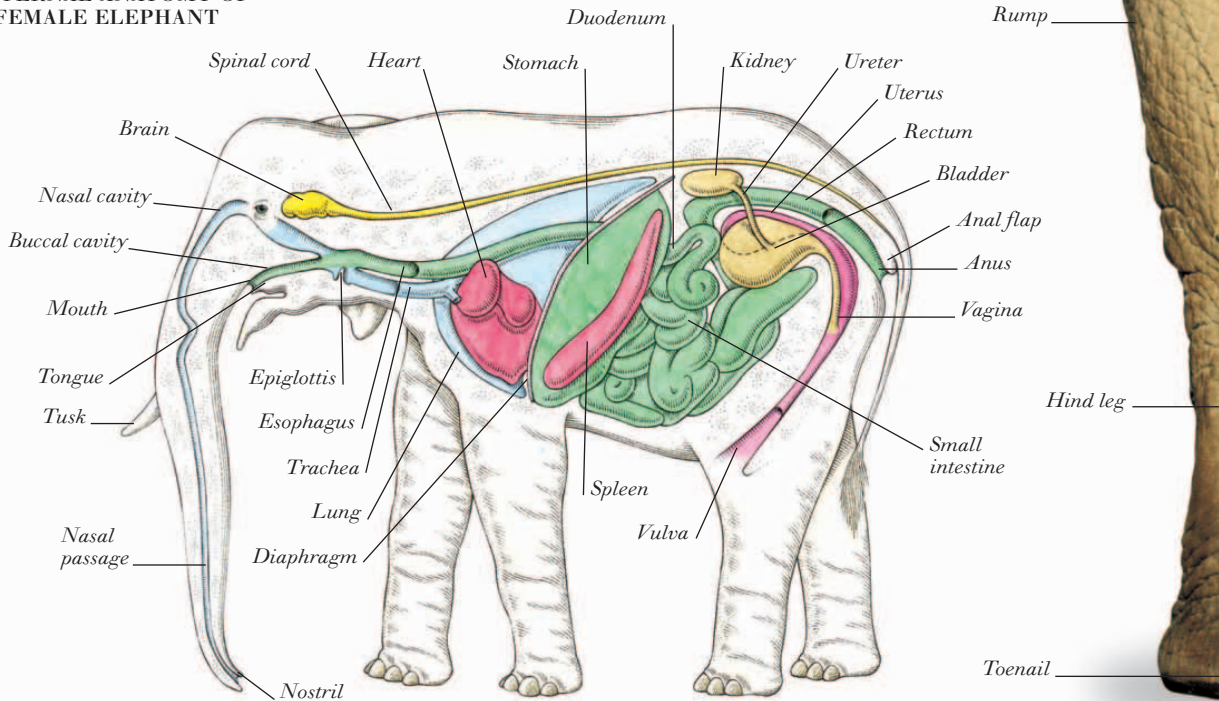
Elephants

THE TWO SPECIES OF elephant—African and Asian—are the only members of the mammalian order Proboscidea. The bigger African elephant is the largest land animal: a fully grown male may be up to 13 ft (4 m) tall and weigh nearly 8 tons (7 metric tons). A fully grown male Asian elephant may be 11 ft (3.3 m) tall and weigh 6 tons (5.4 metric tons). The trunk—an extension of the nose and upper lip—is the elephant’s other most obvious feature. It is used for manipulating and lifting, feeding, drinking and spraying water, smelling, touching, and producing trumpeting sounds. Other characteristic features include a pair of tusks, used for defense and for crushing vegetation; thick, pillarlike legs and broad feet to support the massive body; and large ear flaps that act as radiators to keep the elephant cool.

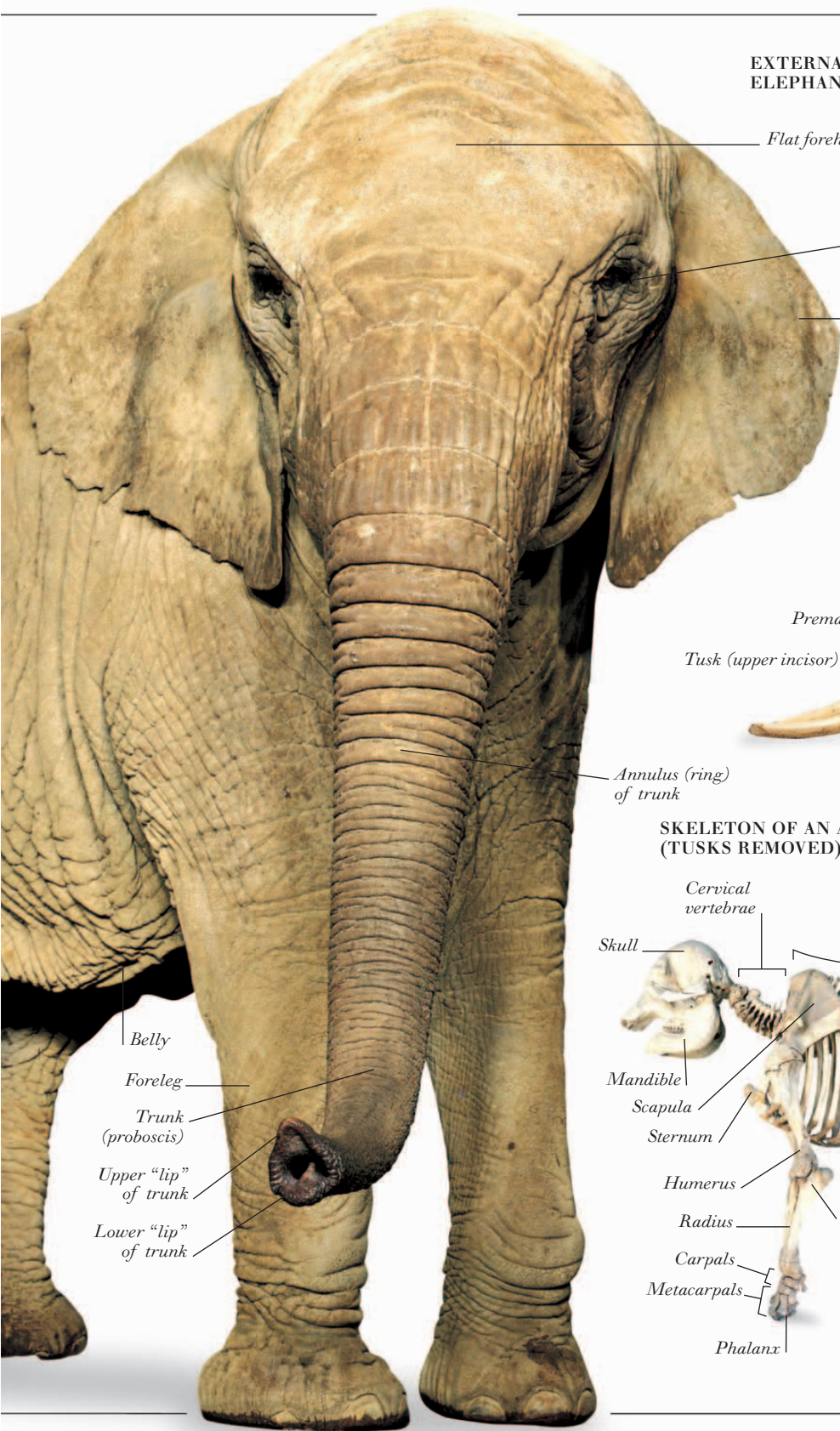
DIFFERENCES BETWEEN AFRICAN AND ASIAN ELEPHANTS



INTERNAL ANATOMY OF A FEMALE ELEPHANT



EXTERNAL FEATURES OF A FEMALE AFRICAN ELEPHANT (TUSKS REMOVED)



Flat forehead

Eye

Pinna (ear flap)

Annulus (ring) of trunk

Belly

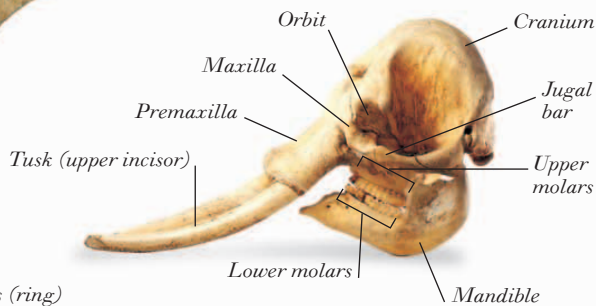
Foreleg

Trunk (proboscis)

Upper "lip" of trunk

Lower "lip" of trunk

SKULL OF AN ASIAN ELEPHANT



Orbit

Cranium

Maxilla

Jugal bar

Premaxilla

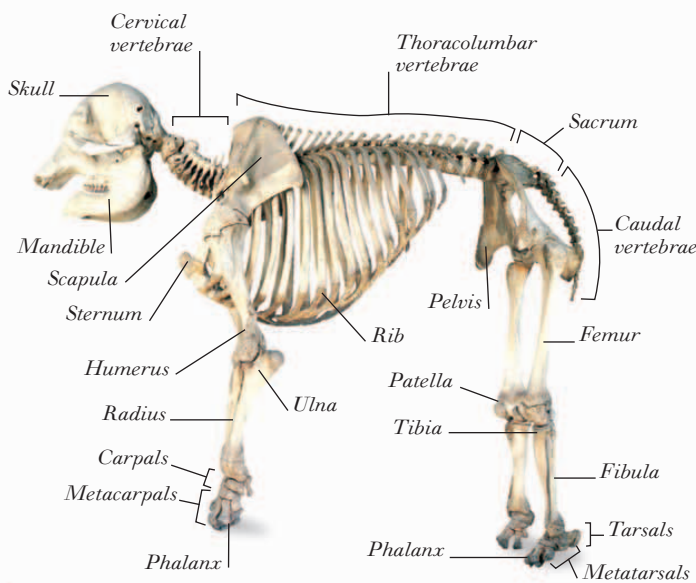
Upper molars

Tusk (upper incisor)

Lower molars

Mandible

SKELETON OF AN AFRICAN ELEPHANT (TUSKS REMOVED)



Cervical vertebrae

Thoracolumbar vertebrae

Skull

Sacrum

Mandible

Caudal vertebrae

Scapula

Sternum

Rib

Pelvis

Femur

Humerus

Patella

Radius

Ulna

Tibia

Carpals

Fibula

Metacarpals

Phalanx

Tarsals

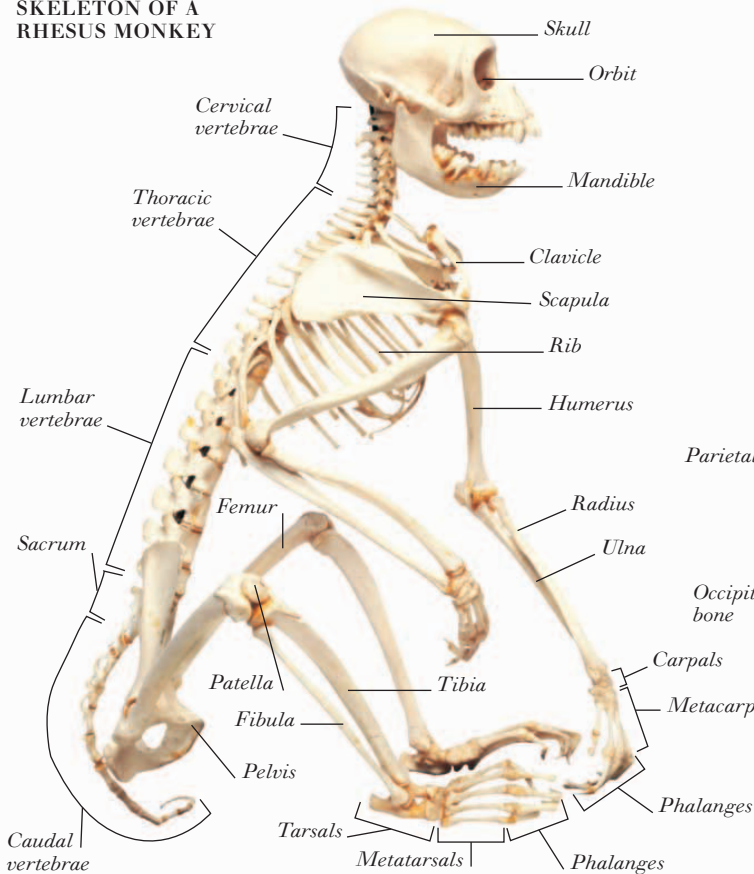
Phalanx

Metatarsals

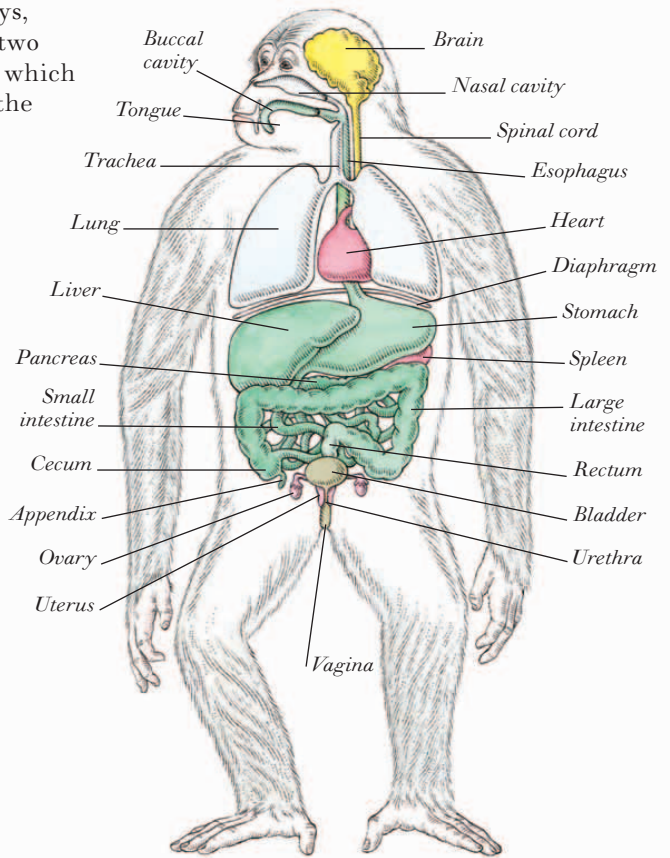
Primates

THE MAMMALIAN ORDER PRIMATES consists of monkeys, apes, and their relatives (including humans). There are two suborders of primates: Prosimii, the primitive primates, which include lemurs, tarsiers, and lorises; and Anthropoidea, the advanced primates, which include monkeys, apes, and humans. The anthropoids are divided into New World monkeys, Old World monkeys, and hominids. New World monkeys typically have wide-apart nostrils that open to the side; and long tails, which are prehensile (grasping) in some species. This group of monkeys lives in South America, and includes marmosets, tamarins, and howler monkeys. Old World monkeys typically have close-set nostrils that open forward or downward; and non-prehensile tails. This group of monkeys lives in Africa and Asia, and includes langurs, mandrills, macaques, and baboons. Hominids typically have large brains, and no tail. This group includes the apes—chimpanzees, gibbons, gorillas, and orangutans—and humans.

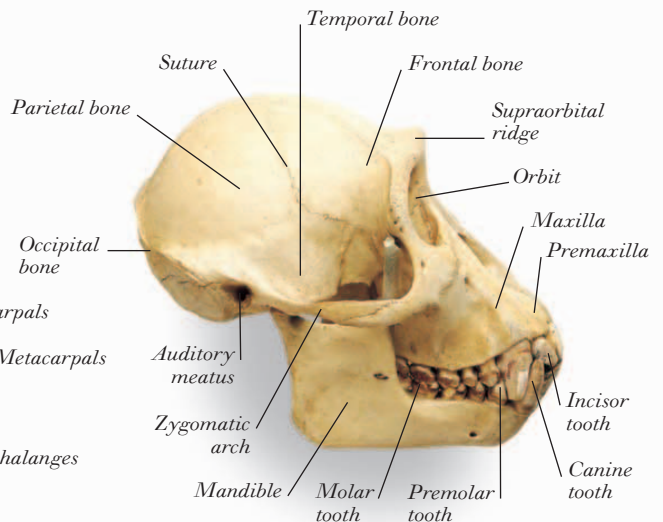
SKELETON OF A RHESUS MONKEY



INTERNAL ANATOMY OF A FEMALE CHIMPANZEE



SKULL OF A CHIMPANZEE



EXAMPLES OF PRIMATES



RING-TAILED LEMUR
(Lemur catta)
A prosimian



MALE RED HOWLER MONKEY
(Alouatta seniculus)
A New World monkey



MALE MANDRILL
(Mandrillus sphinx)
An Old World monkey

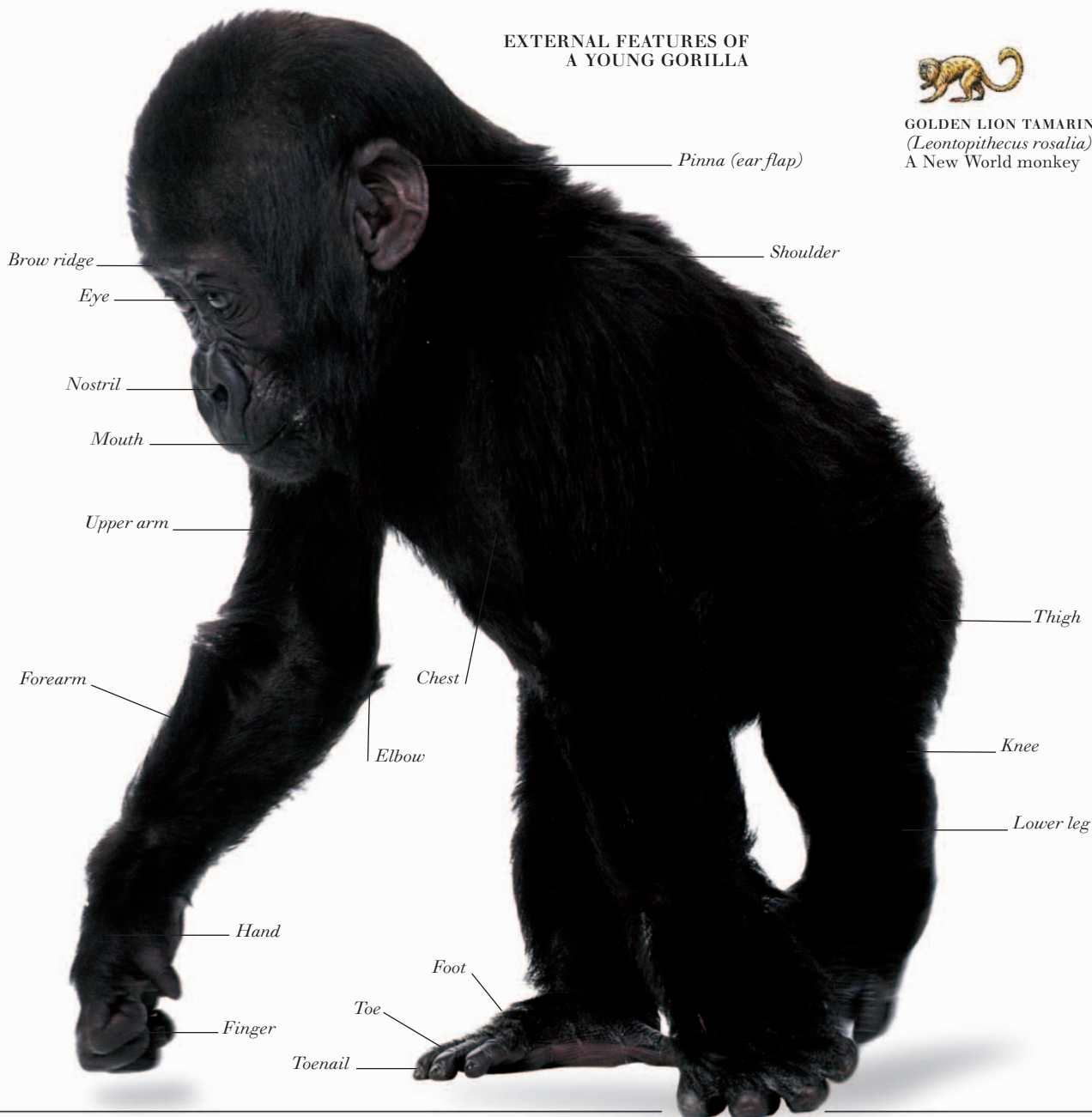


CHIMPANZEE
(Pan troglodytes)
An ape

EXTERNAL FEATURES OF
A YOUNG GORILLA

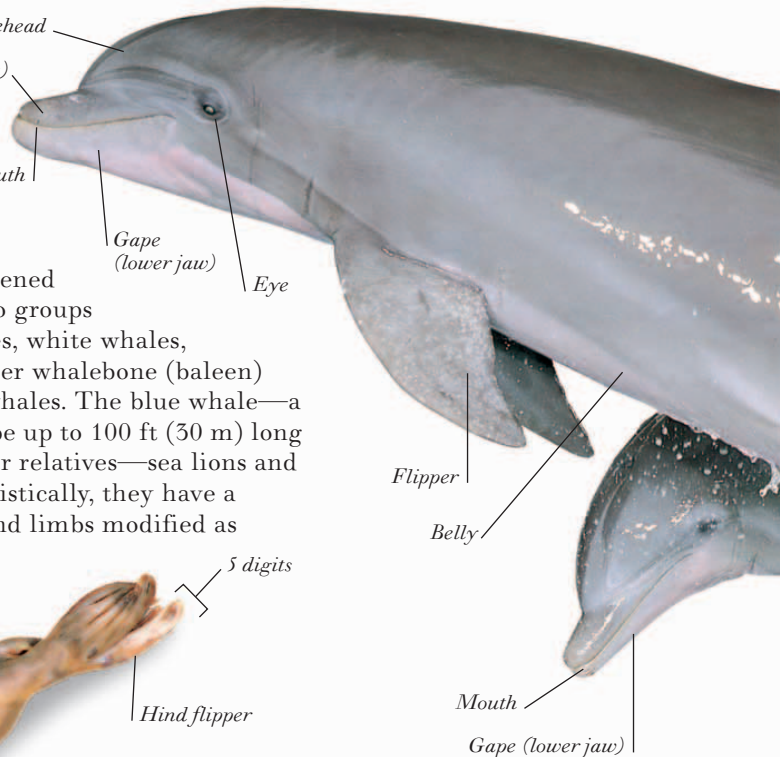


GOLDEN LION TAMARIN
(Leontopithecus rosalia)
A New World monkey

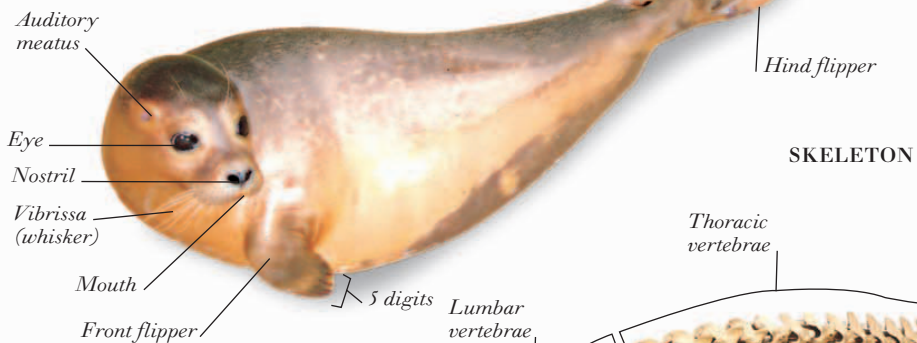


Dolphins, whales, and seals

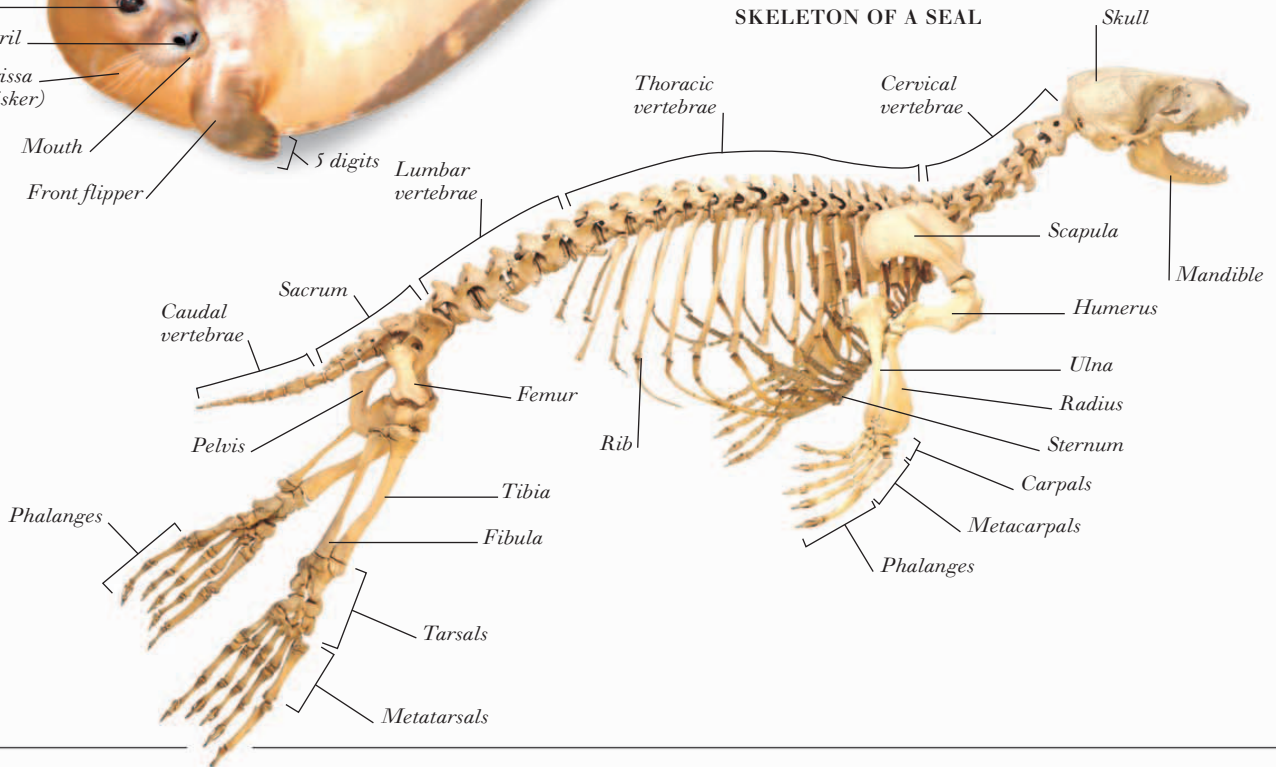
DOLPHINS, WHALES, AND SEALS belong to two orders of mammal adapted to living in water. Dolphins and whales make up the order Cetacea. Typical cetacean features include a streamlined, fishlike shape; forelimbs in the form of flippers; no visible hind limbs; a horizontally flattened tail; and thick blubber under the skin. There are two groups of cetaceans: toothed whales, including sperm whales, white whales, beaked whales, dolphins, and porpoises; and the larger whalebone (baleen) whales, including rorquals, gray whales, and right whales. The blue whale—a rorqual—is the largest living animal: an adult may be up to 100 ft (30 m) long and weigh 145 tons (130 metric tons). Seals and their relatives—sea lions and walruses—make up the order Pinnipedia. Characteristically, they have a streamlined, torpedo-shaped body; forelimbs and hind limbs modified as flippers; thick blubber; and no external ears.



EXTERNAL FEATURES OF A SEAL

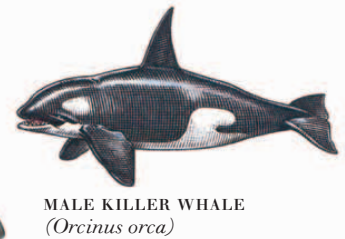
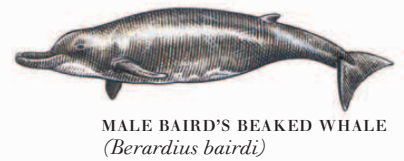
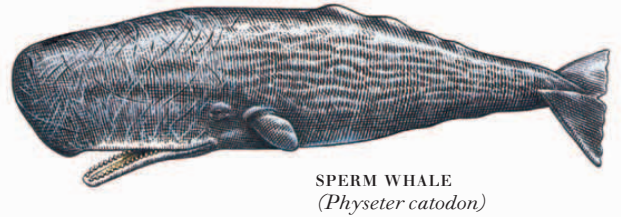
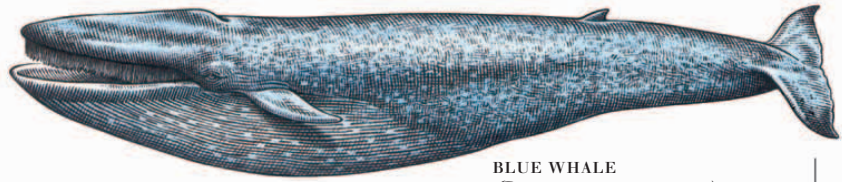
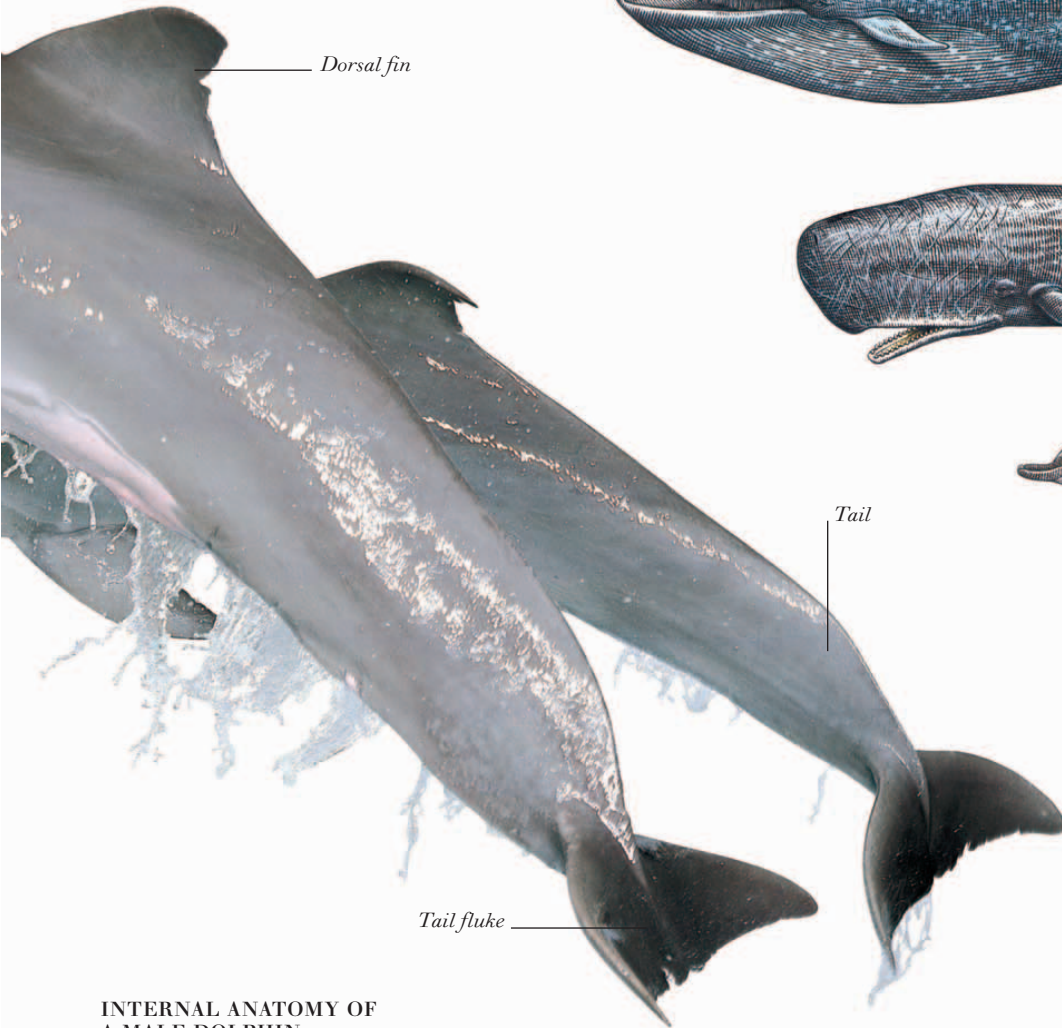


SKELETON OF A SEAL



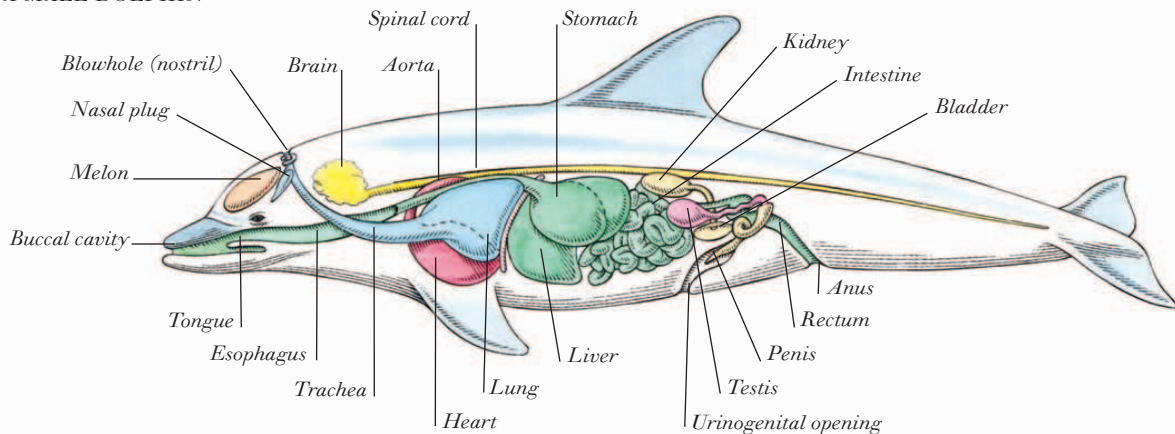
EXAMPLES OF CETACEANS

EXTERNAL FEATURES OF A DOLPHIN



Tail

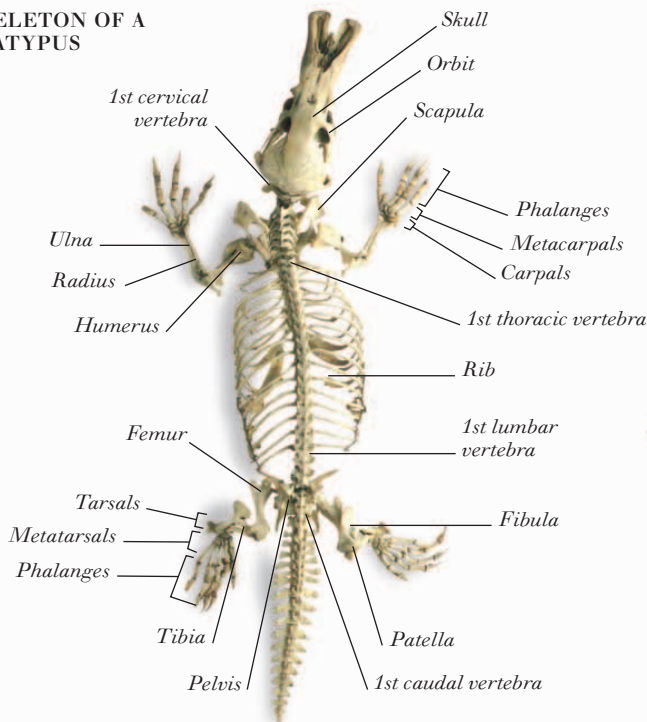
INTERNAL ANATOMY OF A MALE DOLPHIN



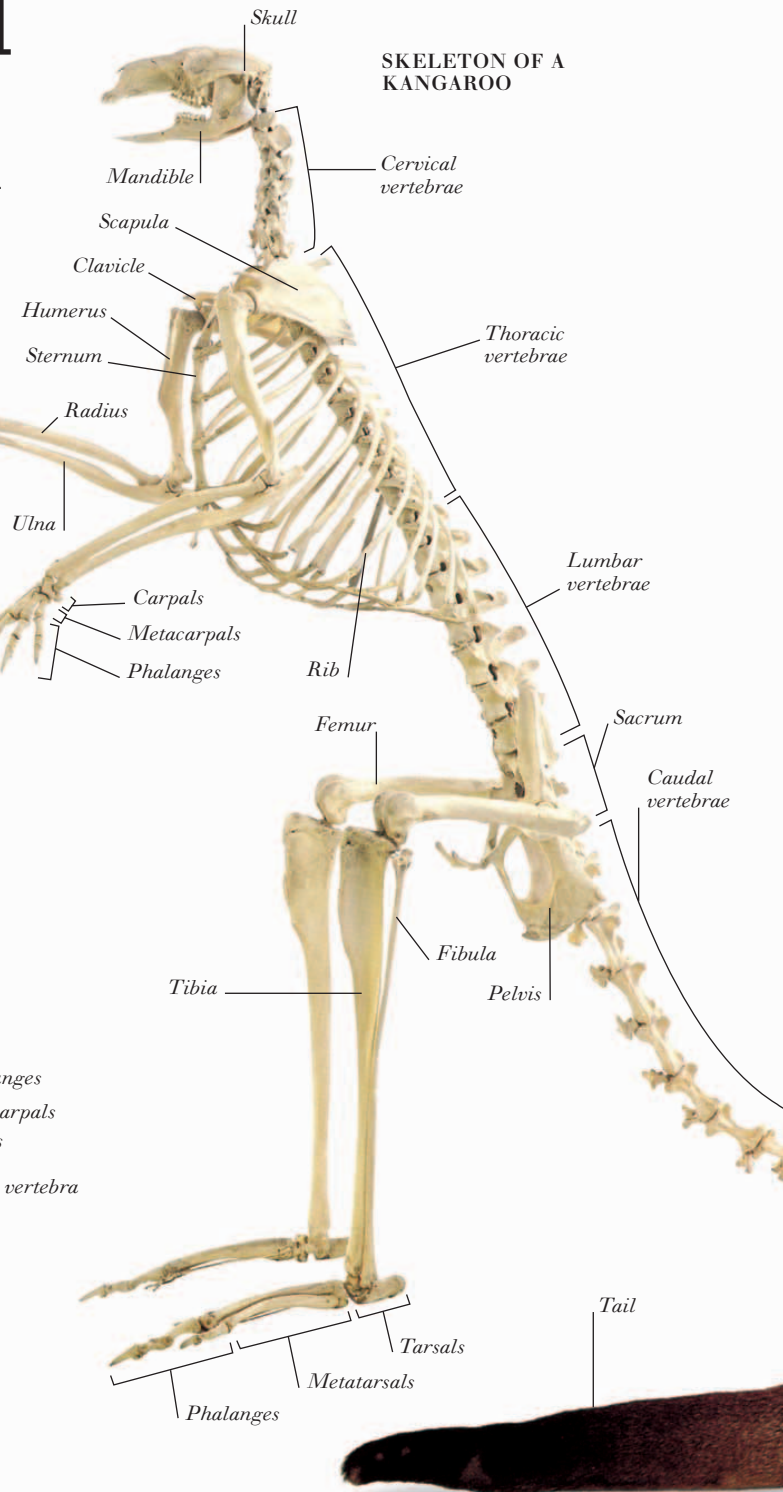
Marsupials and Monotremes

MARSUPIALS AND MONOTREMES are two orders of mammal that differ from other mammalian groups in the ways that their young develop. The order Marsupalia, the pouched mammals, is made up of kangaroos and their relatives. Typically, marsupials give birth to their young at a very early stage of development. The young then crawls to the mother's pouch (which is on the outside of her abdomen), where it attaches itself to a nipple and remains until fully developed. Most marsupials live in Australia, although the opossums—which are classified as marsupials despite not having a pouch—live in the Americas. The order Monotremata is made up of the platypus and its relatives (the echidnas, or spiny anteaters). The monotremes are primitive mammals that lay eggs, which the mother incubates. The monotremes are found only in Australia and New Guinea.

SKELETON OF A PLATYPUS



SKELETON OF A KANGAROO



**EXAMPLES OF MARSUPIALS
AND MONOTREMES**



KOALA
(Phascolarctos cinereus)
A marsupial



DUCK-BILLED PLATYPUS
(Ornithorhynchus anatinus)
A monotreme

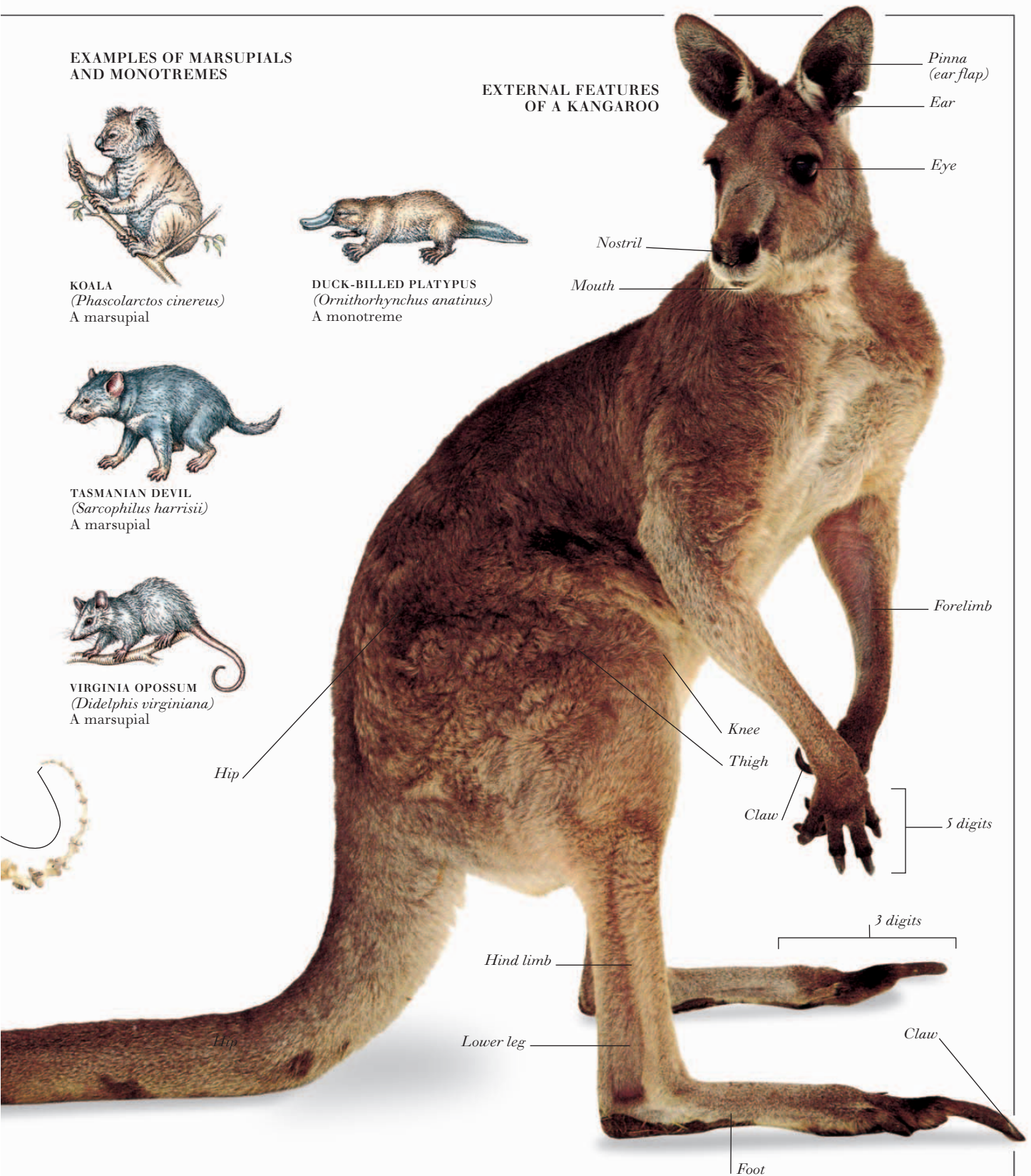


TASMANIAN DEVIL
(Sarcophilus harrisi)
A marsupial



VIRGINIA OPOSSUM
(Didelphis virginiana)
A marsupial

**EXTERNAL FEATURES
OF A KANGAROO**



Pinna
(ear flap)

Ear

Eye

Nostril

Mouth

Forelimb

Knee

Thigh

Claw

5 digits

3 digits

Hind limb

Lower leg

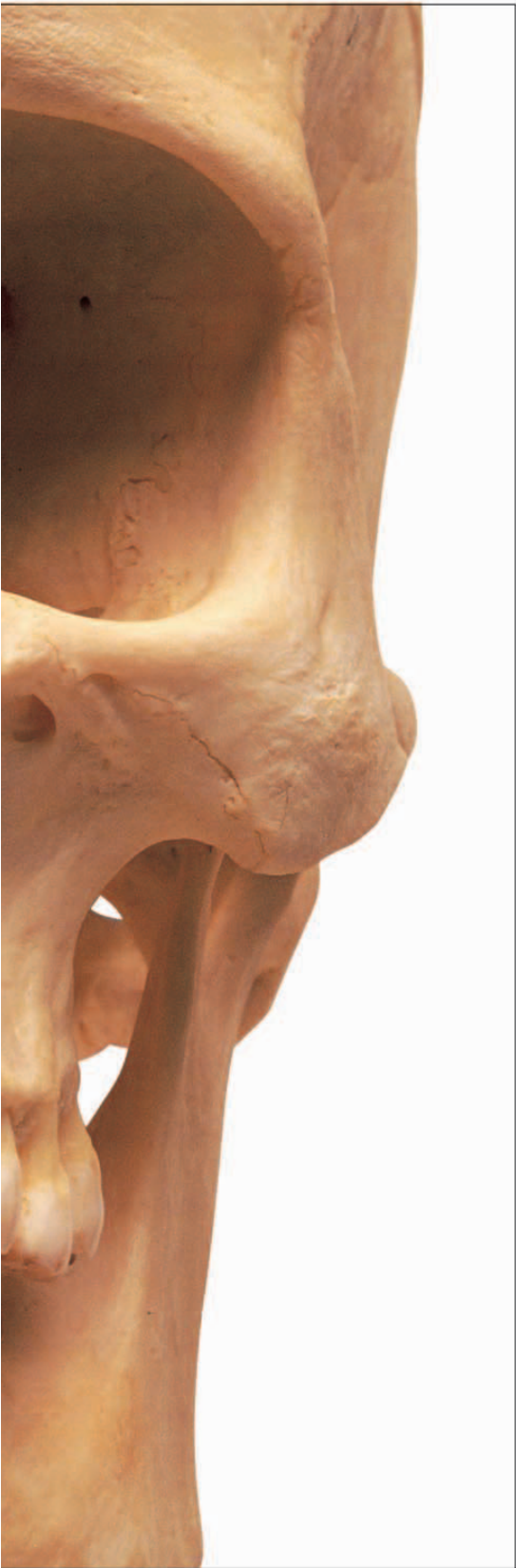
Claw

Foot

Hip

Hip





THE HUMAN BODY

BODY FEATURES.....	210
HEAD.....	212
BODY ORGANS.....	214
BODY CELLS.....	216
SKELETON.....	218
SKULL.....	220
SPINE.....	222
BONES AND JOINTS.....	224
MUSCLES 1.....	226
MUSCLES 2.....	228
HANDS.....	230
FEET.....	232
SKIN AND HAIR.....	234
BRAIN.....	236
NERVOUS SYSTEM.....	238
EYE.....	240
EAR.....	242
NOSE, MOUTH, AND THROAT.....	244
TEETH.....	246
DIGESTIVE SYSTEM.....	248
HEART.....	250
CIRCULATORY SYSTEM.....	252
RESPIRATORY SYSTEM.....	254
URINARY SYSTEM.....	256
REPRODUCTIVE SYSTEM.....	258
DEVELOPMENT OF A BABY.....	260

Body features

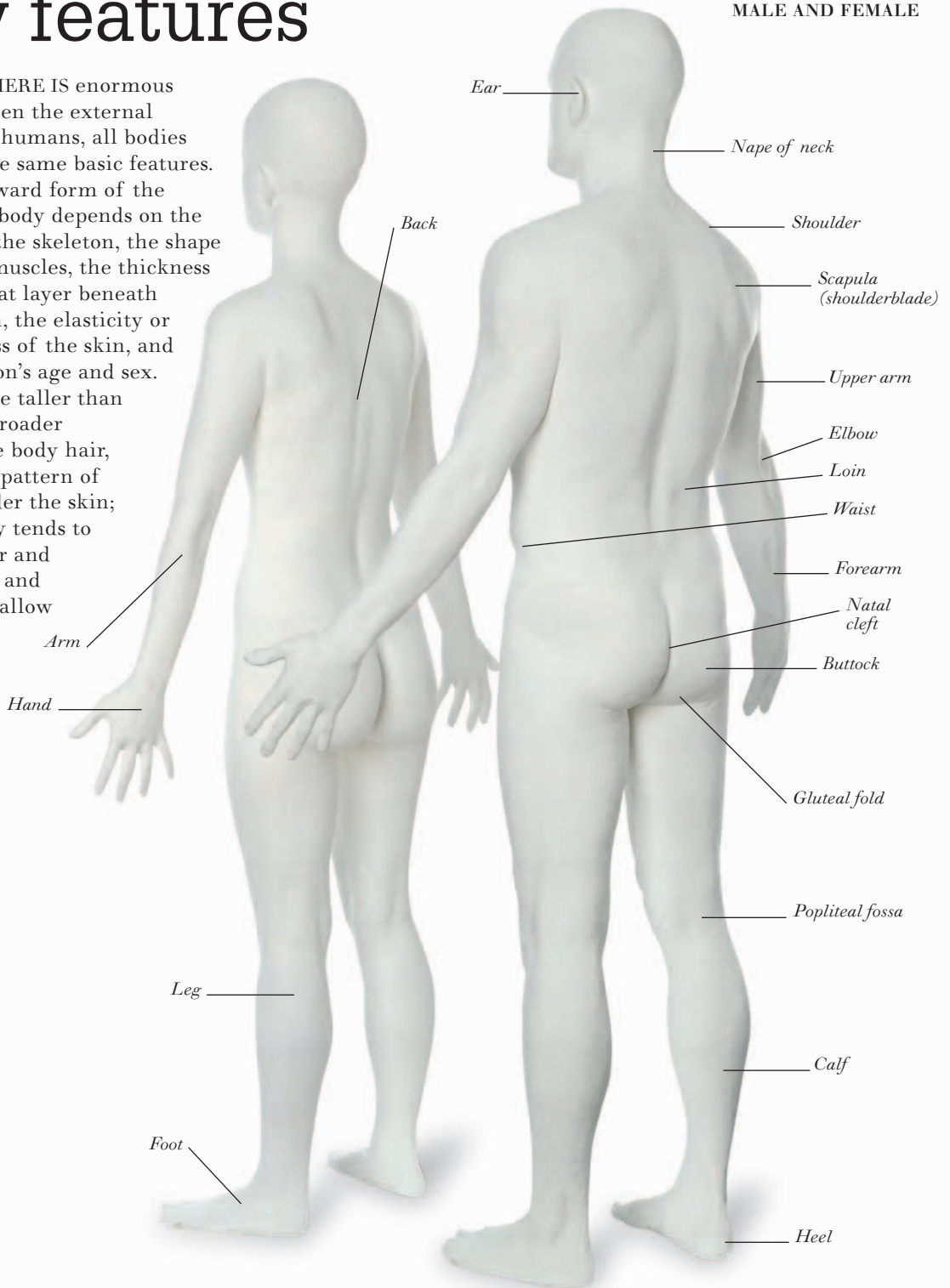
BACK VIEWS OF
MALE AND FEMALE

ALTHOUGH THERE IS enormous variation between the external appearances of humans, all bodies contain the same basic features.

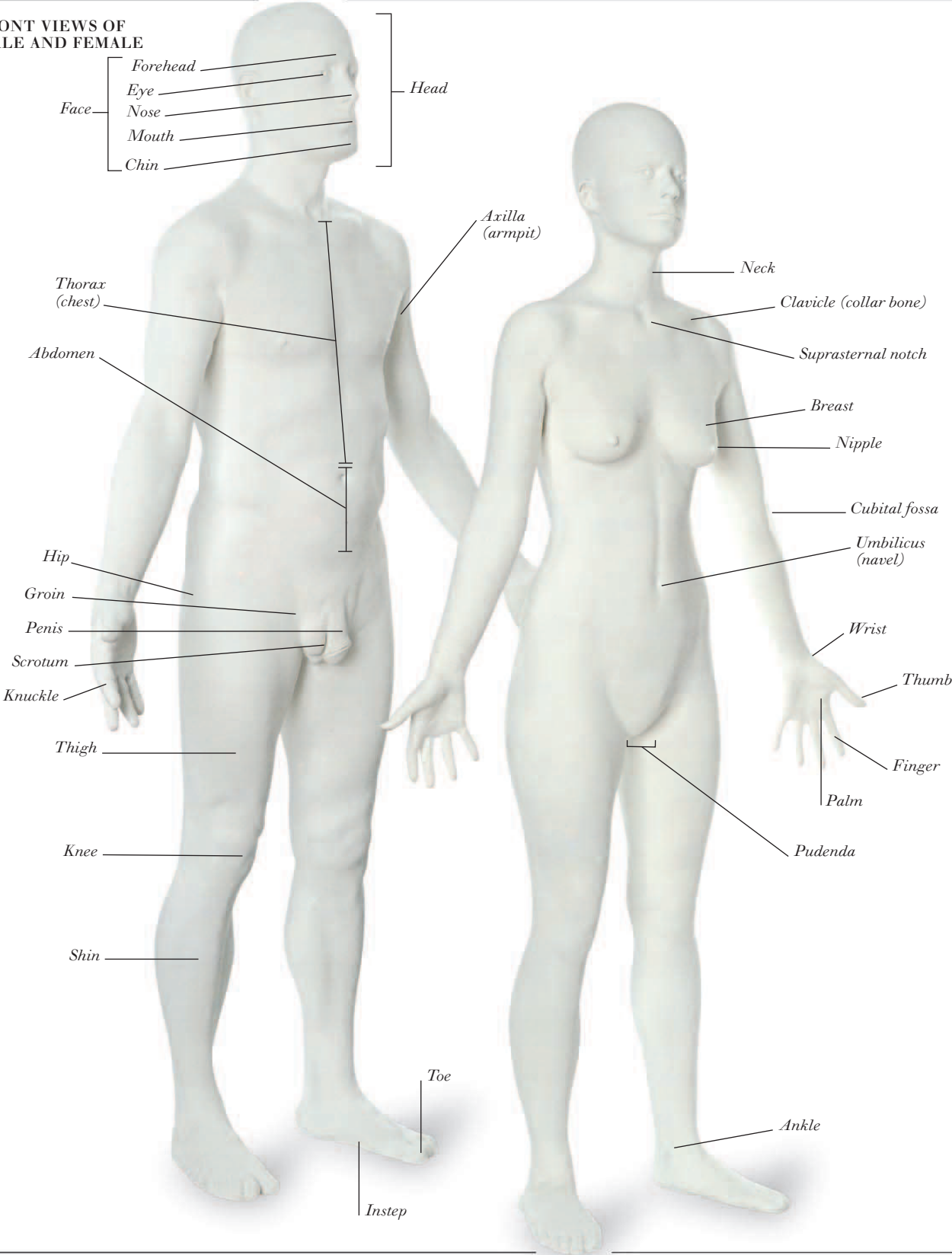


The outward form of the human body depends on the size of the skeleton, the shape of the muscles, the thickness of the fat layer beneath the skin, the elasticity or sagginess of the skin, and the person's age and sex.

Males tend to be taller than females, with broader shoulders, more body hair, and a different pattern of fat deposits under the skin; the female body tends to be less muscular and has a shallower and wider pelvis to allow for childbirth.



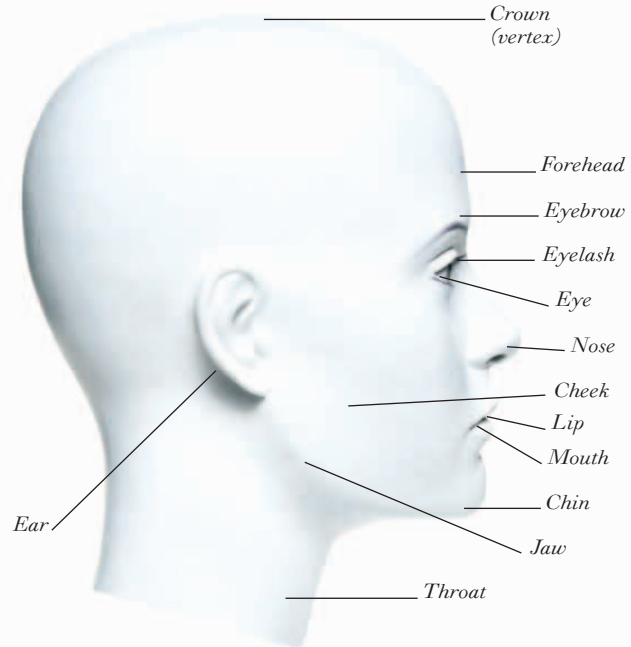
FRONT VIEWS OF MALE AND FEMALE



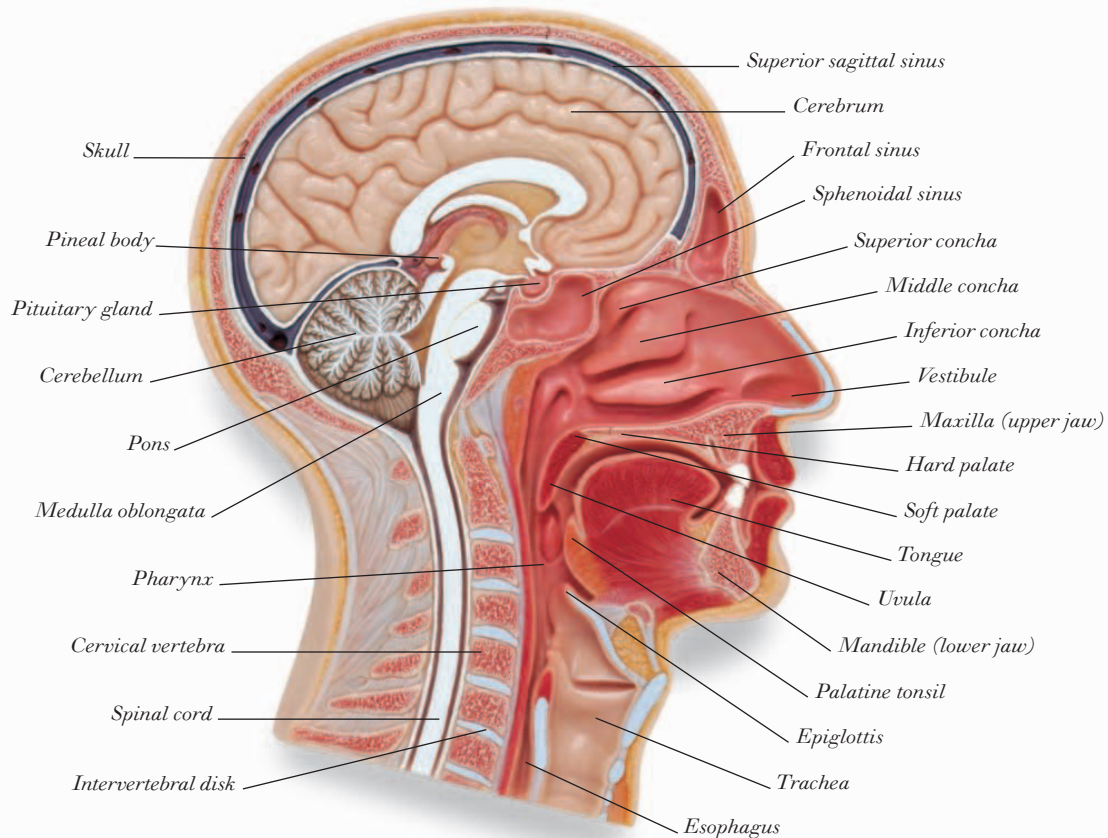
Head

IN A NEWBORN BABY, the head accounts for one-quarter of the total body length; by adulthood, the proportion has reduced to one-eighth. Contained in the head are the body's main sense organs: eyes, ears, olfactory nerves that detect smells, and the taste buds of the tongue. Signals from these organs pass to the body's great coordination center: the brain, housed in the protective, bony dome of the skull. Hair on the head insulates against heat loss, and adult males also grow thick facial hair. The face has three important openings: two nostrils through which air passes, and the mouth, which takes in nourishment and helps form speech. Although all heads are basically similar, differences in the size, shape, and color of features produce an infinite variety of appearances.

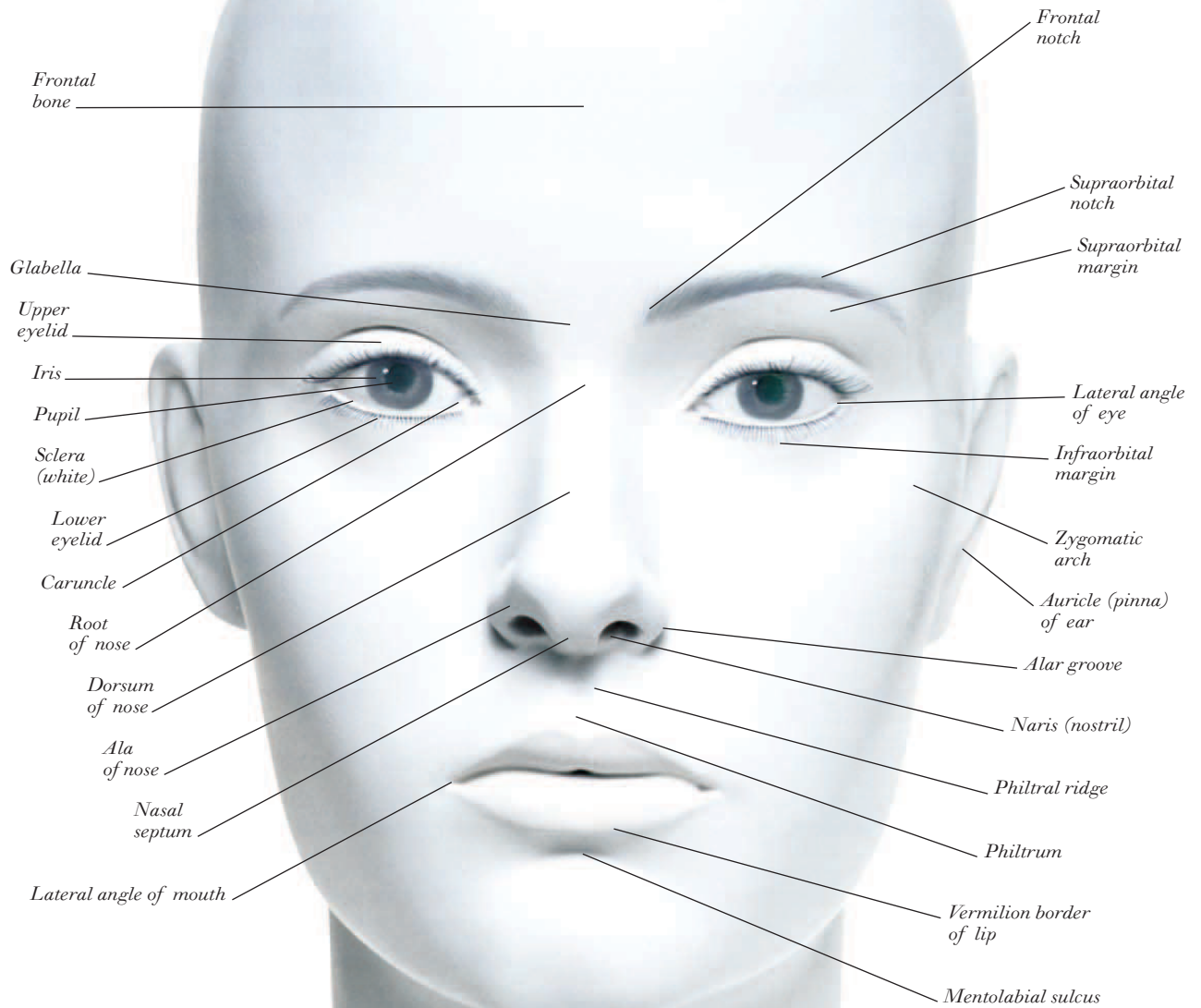
SIDE VIEW OF EXTERNAL FEATURES OF HEAD



SECTION THROUGH HEAD



FRONT VIEW OF EXTERNAL
FEATURES OF HEAD

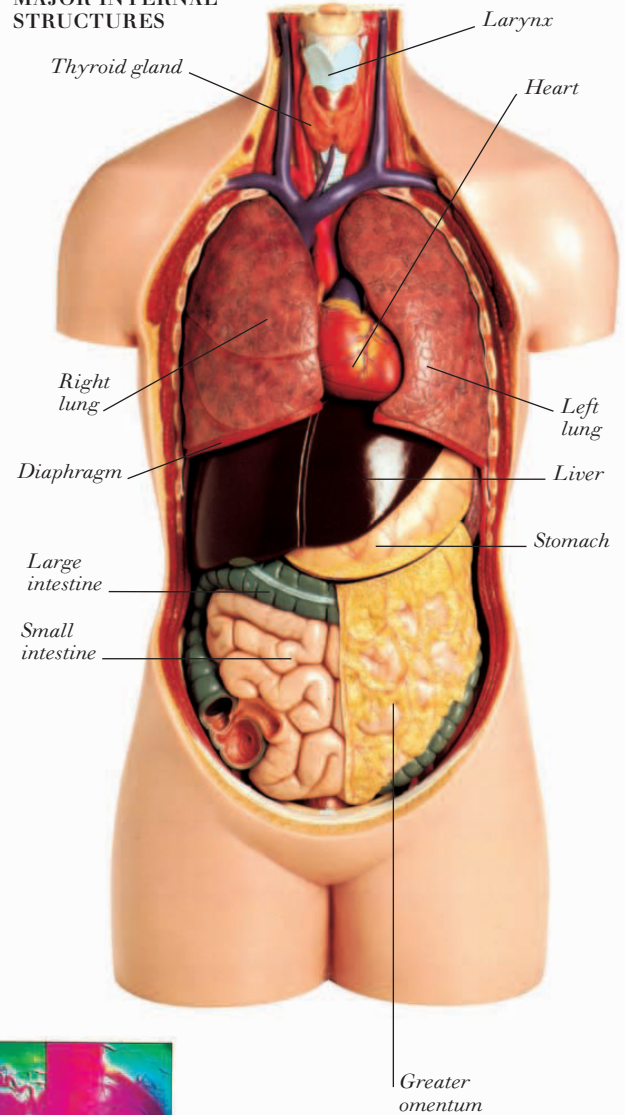


Body organs

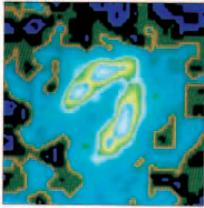


ALL THE VITAL BODY ORGANS except for the brain are enclosed within the trunk or torso (the body apart from the head and limbs). The trunk contains two large cavities separated by a muscular sheet called the diaphragm. The upper cavity, known as the thorax or chest cavity, contains the heart and lungs. The lower cavity, called the abdominal cavity, contains the stomach, intestines, liver, and pancreas, which all play a role in digesting food. Also within the trunk are the kidneys and bladder, which are part of the urinary system, and the reproductive organs, which hold the seeds of new human life. Modern imaging techniques, such as contrast X-rays and different types of scans, make it possible to see and study body organs without the need to cut through their protective coverings of skin, fat, muscle, and bone.

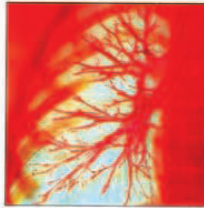
MAJOR INTERNAL STRUCTURES



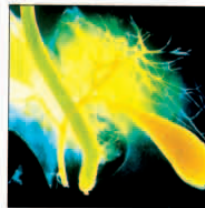
IMAGING THE BODY



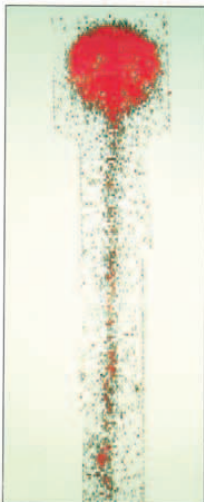
SCINTIGRAM OF HEART CHAMBERS



ANGIOGRAM OF RIGHT LUNG



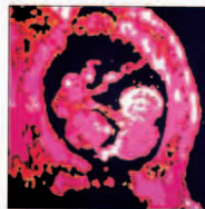
CONTRAST X-RAY OF GALLBLADDER



SCINTIGRAM OF NERVOUS SYSTEM



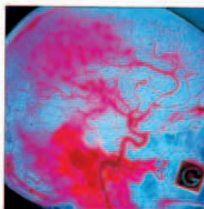
DOUBLE CONTRAST X-RAY OF COLON



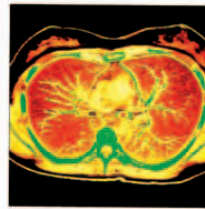
ULTRASOUND SCAN OF TWINS IN UTERUS



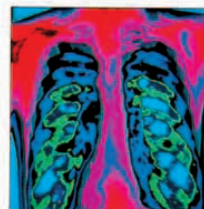
ANGIOGRAM OF KIDNEYS



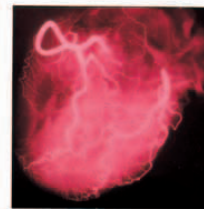
ANGIOGRAM OF ARTERIES OF HEAD



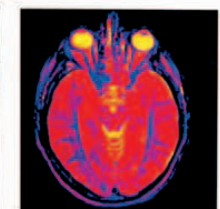
CT SCAN THROUGH FEMALE CHEST



THERMOGRAM OF CHEST REGION

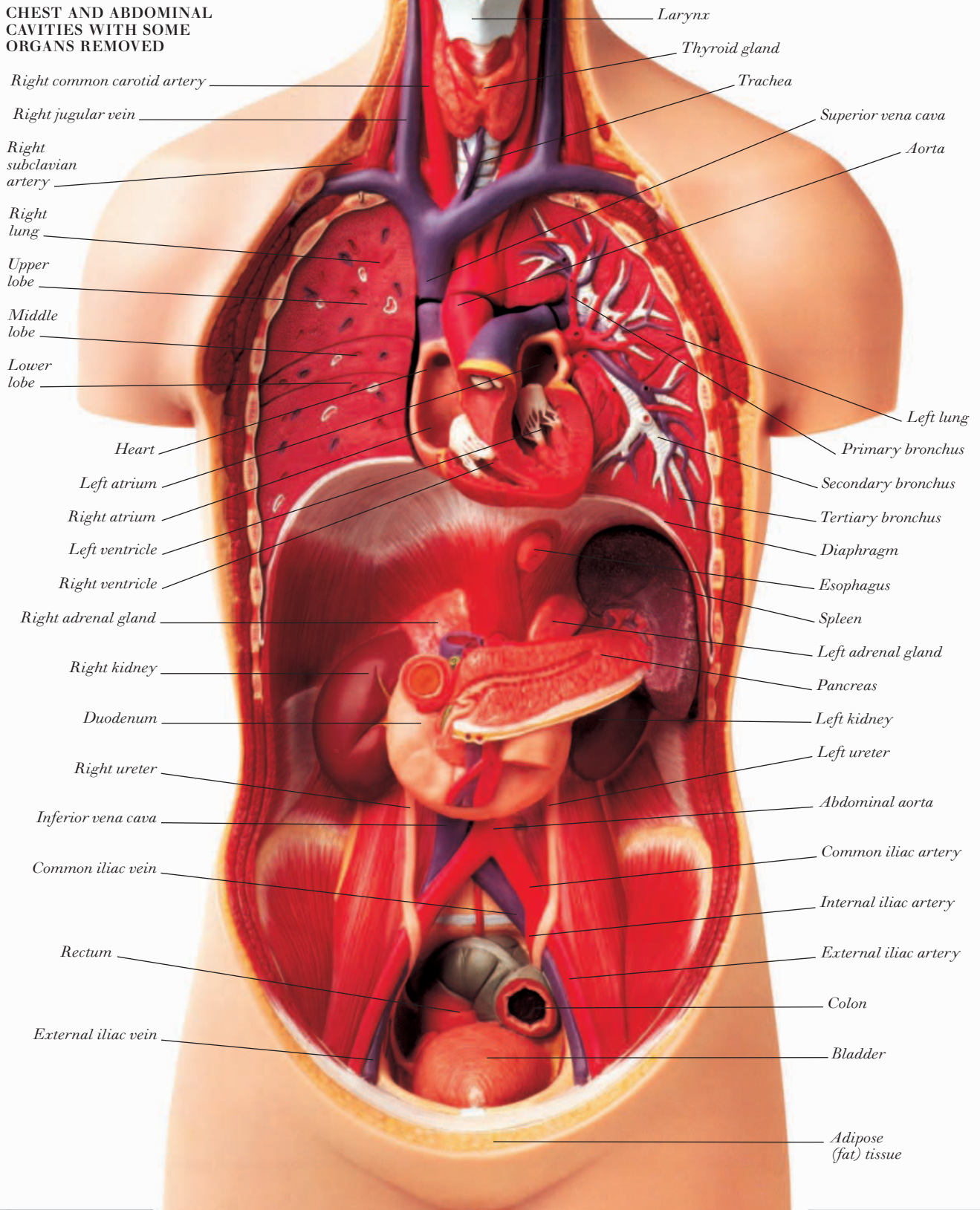


ANGIOGRAM OF ARTERIES OF HEART



MRI SCAN THROUGH HEAD AT EYE LEVEL

CHEST AND ABDOMINAL CAVITIES WITH SOME ORGANS REMOVED

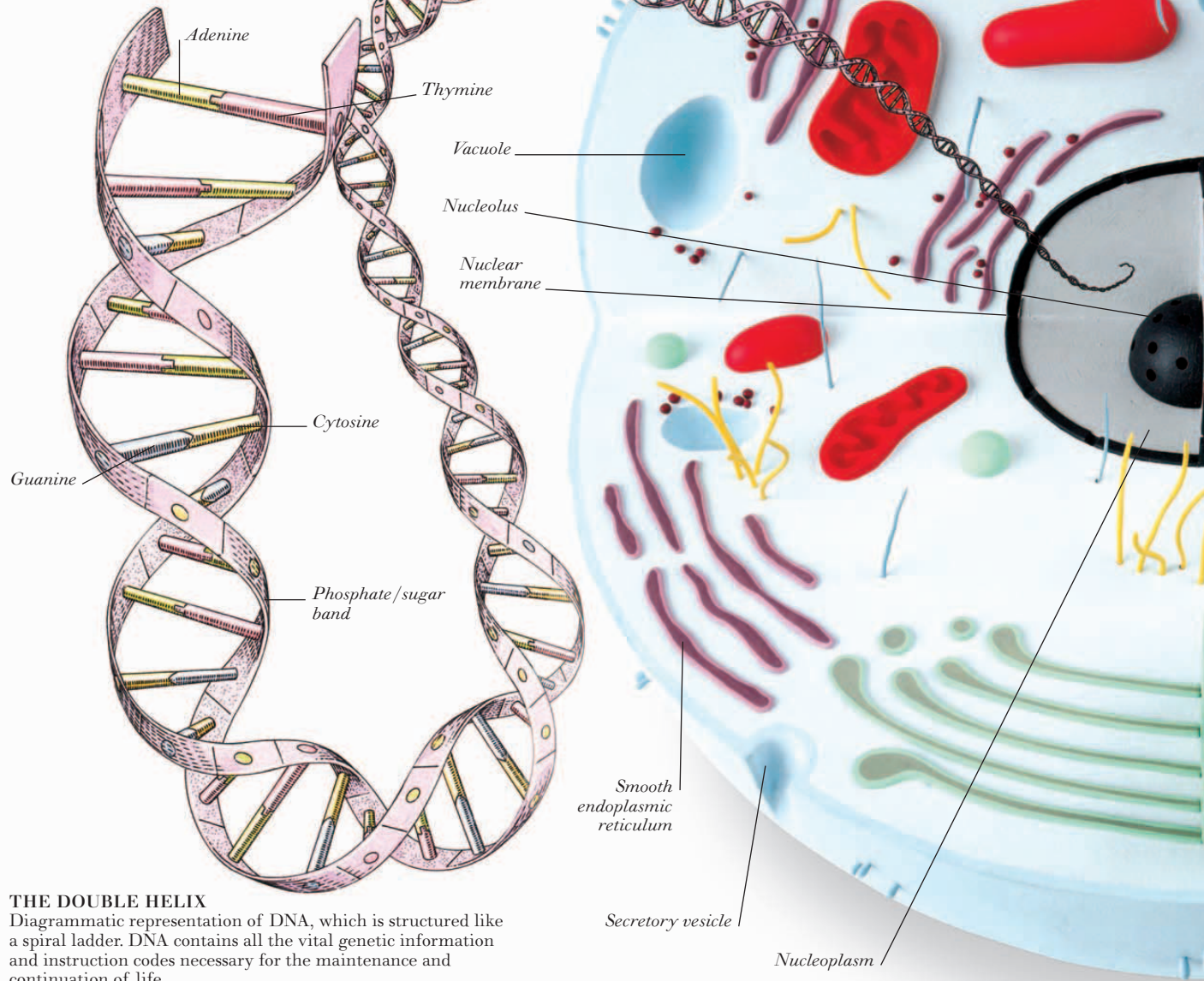


Right common carotid artery
Right jugular vein
Right subclavian artery
Right lung
Upper lobe
Middle lobe
Lower lobe
Heart
Left atrium
Right atrium
Left ventricle
Right ventricle
Right adrenal gland
Right kidney
Duodenum
Right ureter
Inferior vena cava
Common iliac vein
Rectum
External iliac vein

Larynx
Thyroid gland
Trachea
Superior vena cava
Aorta
Left lung
Primary bronchus
Secondary bronchus
Tertiary bronchus
Diaphragm
Esophagus
Spleen
Left adrenal gland
Pancreas
Left kidney
Left ureter
Abdominal aorta
Common iliac artery
Internal iliac artery
External iliac artery
Colon
Bladder
Adipose (fat) tissue

Body cells

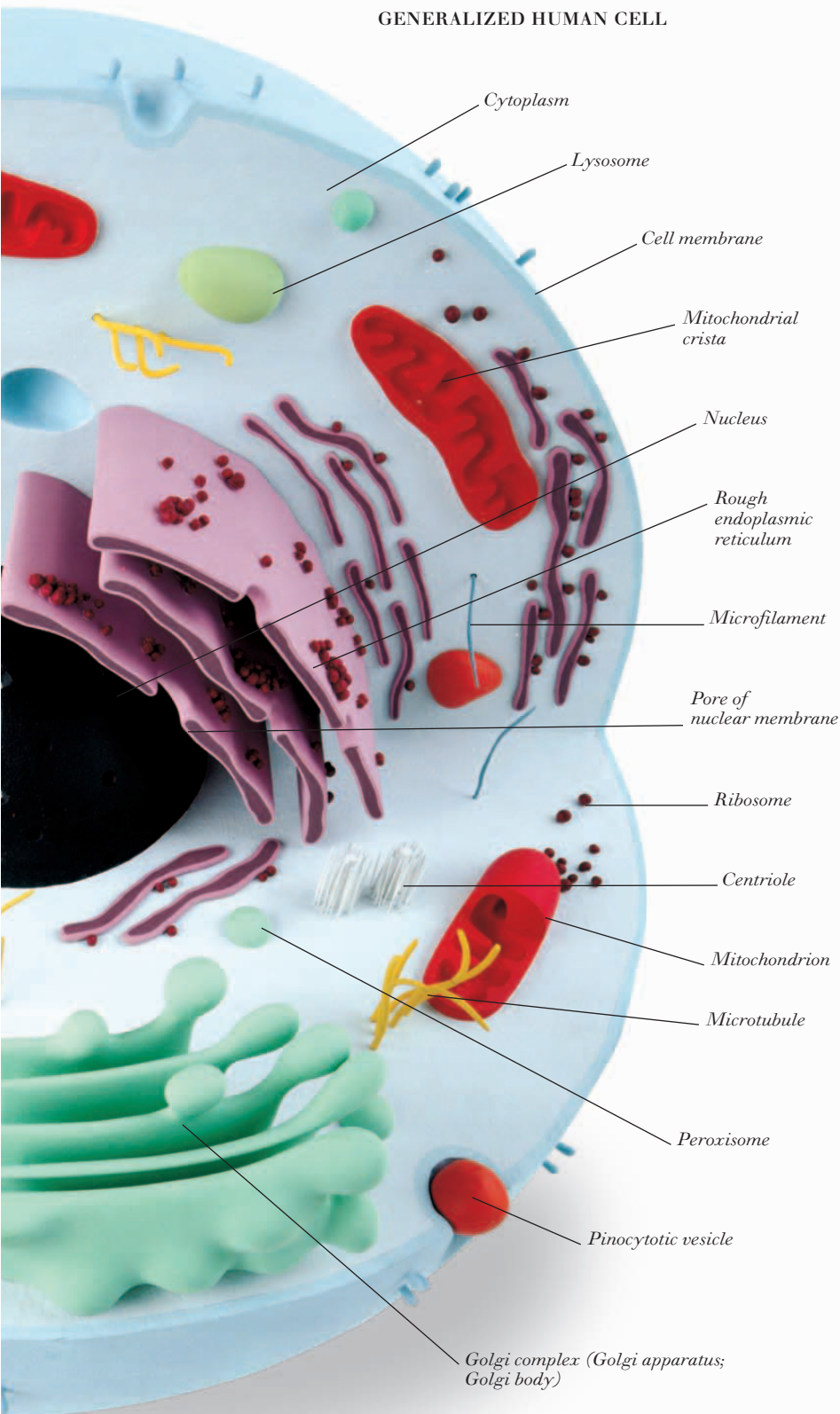
EVERYONE IS MADE UP OF BILLIONS OF CELLS, which are the basic structural units of the body. Bones, muscles, nerves, skin, blood, and all other body tissues are formed from different types of cells. Each cell has a specific function but works with other types of cells to perform the enormous number of tasks needed to sustain life. Most body cells have a similar basic structure. Each cell has an outer layer (called the cell membrane) and contains a fluid material (cytoplasm). Within the cytoplasm are many specialized structures (organelles). The most important organelle is the nucleus, which contains vital genetic material and acts as the cell's control center.



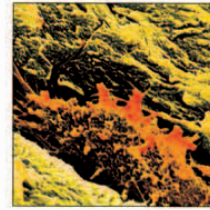
THE DOUBLE HELIX

Diagrammatic representation of DNA, which is structured like a spiral ladder. DNA contains all the vital genetic information and instruction codes necessary for the maintenance and continuation of life.

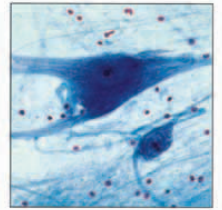
GENERALIZED HUMAN CELL



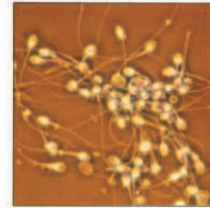
TYPES OF CELLS



BONE-FORMING CELL



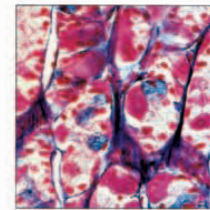
NERVE CELLS IN SPINAL CORD



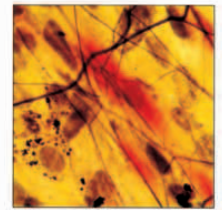
SPERM CELLS IN SEMEN



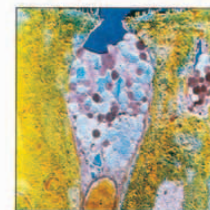
SECRETORY THYROID GLAND CELLS



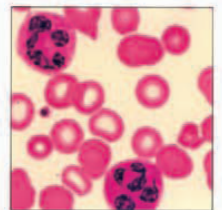
ACID-SECRETING STOMACH CELLS



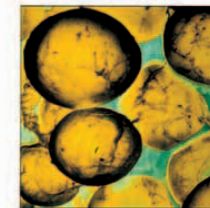
CONNECTIVE TISSUE CELLS



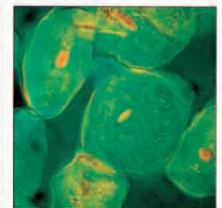
MUCUS-SECRETING DUODENAL CELLS



RED AND TWO WHITE BLOOD CELLS



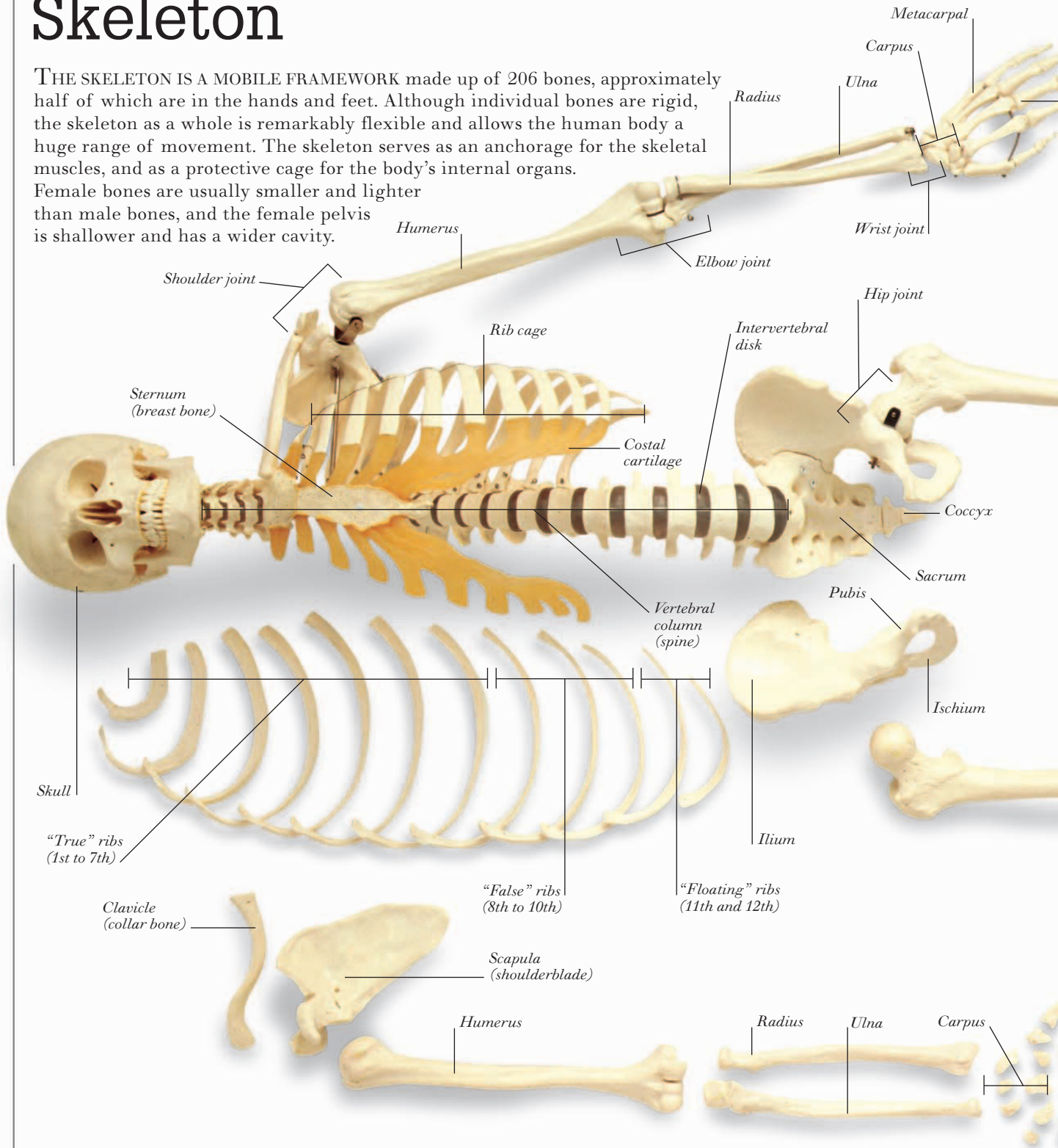
FAT CELLS IN ADIPOSE TISSUE

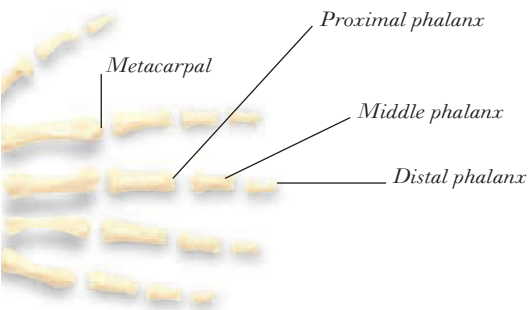
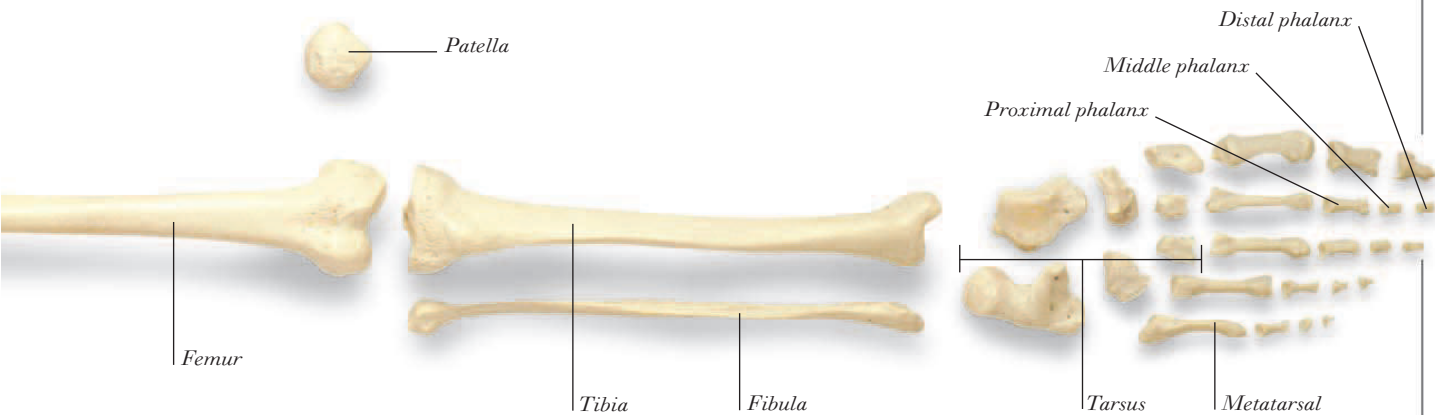
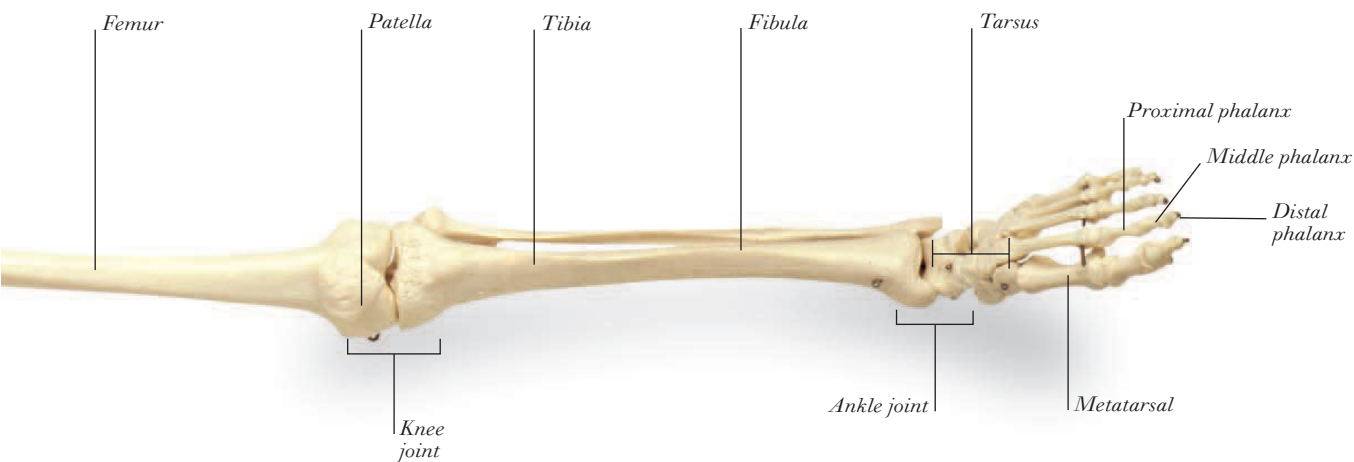
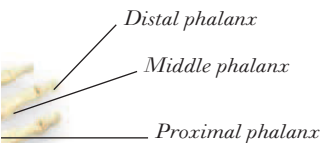


EPITHELIAL CELLS IN CHEEK

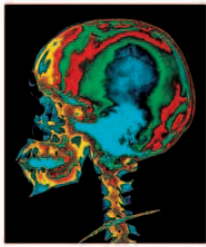
Skeleton

THE SKELETON IS A MOBILE FRAMEWORK made up of 206 bones, approximately half of which are in the hands and feet. Although individual bones are rigid, the skeleton as a whole is remarkably flexible and allows the human body a huge range of movement. The skeleton serves as an anchorage for the skeletal muscles, and as a protective cage for the body's internal organs. Female bones are usually smaller and lighter than male bones, and the female pelvis is shallower and has a wider cavity.



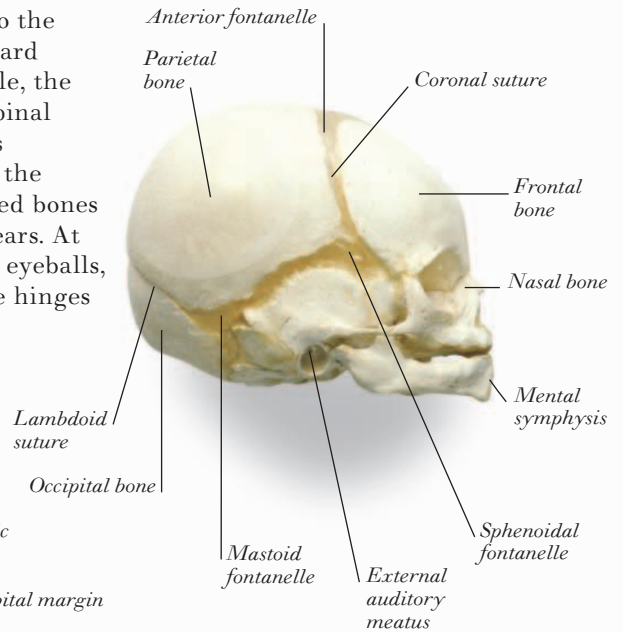


Skull

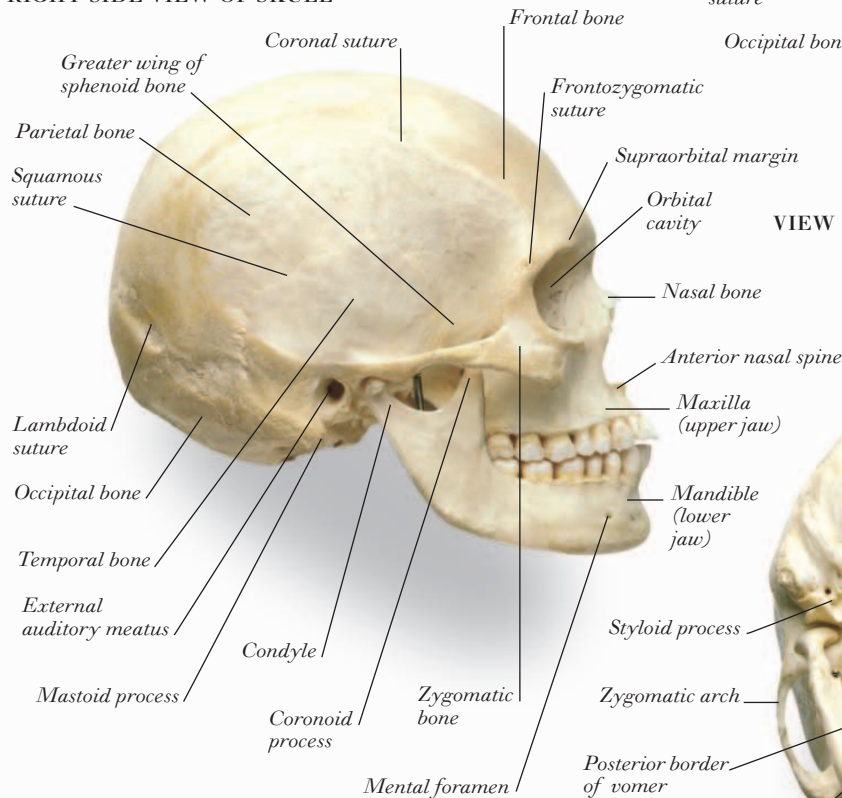


THE SKULL is the most complicated bony structure of the body but every feature serves a purpose. Internally, the main hollow chamber of the skull has three levels that support the brain, with every bump and hollow corresponding to the shape of the brain. Underneath and toward the back of the skull is a large round hole, the foramen magnum, through which the spinal cord passes. To the front of this are many smaller openings through which nerves, arteries, and veins pass to and from the brain. The roof of the skull is formed from four thin, curved bones that are firmly fixed together from the age of about two years. At the front of the skull are the two orbits, which contain the eyeballs, and a central hole for the airway of the nose. The jaw bone hinges on either side at ear level.

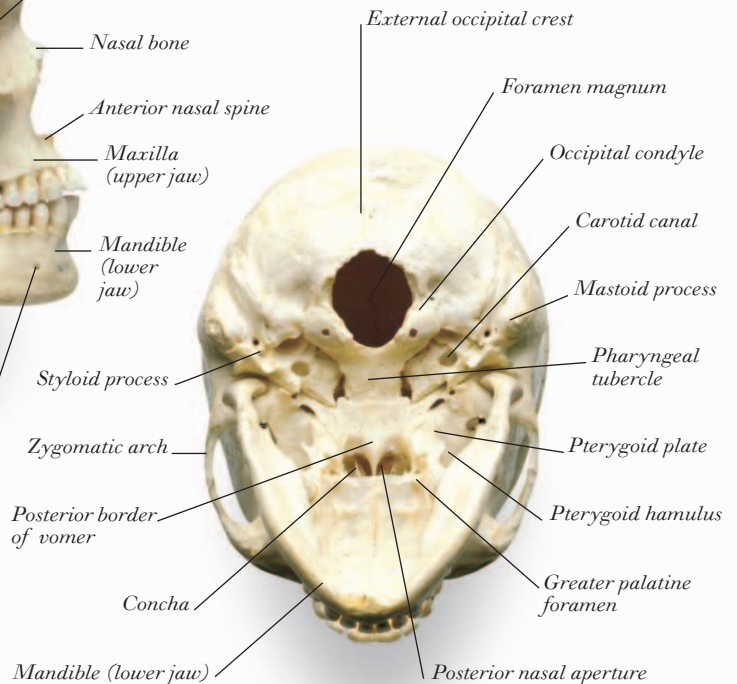
RIGHT SIDE VIEW OF A FETAL SKULL



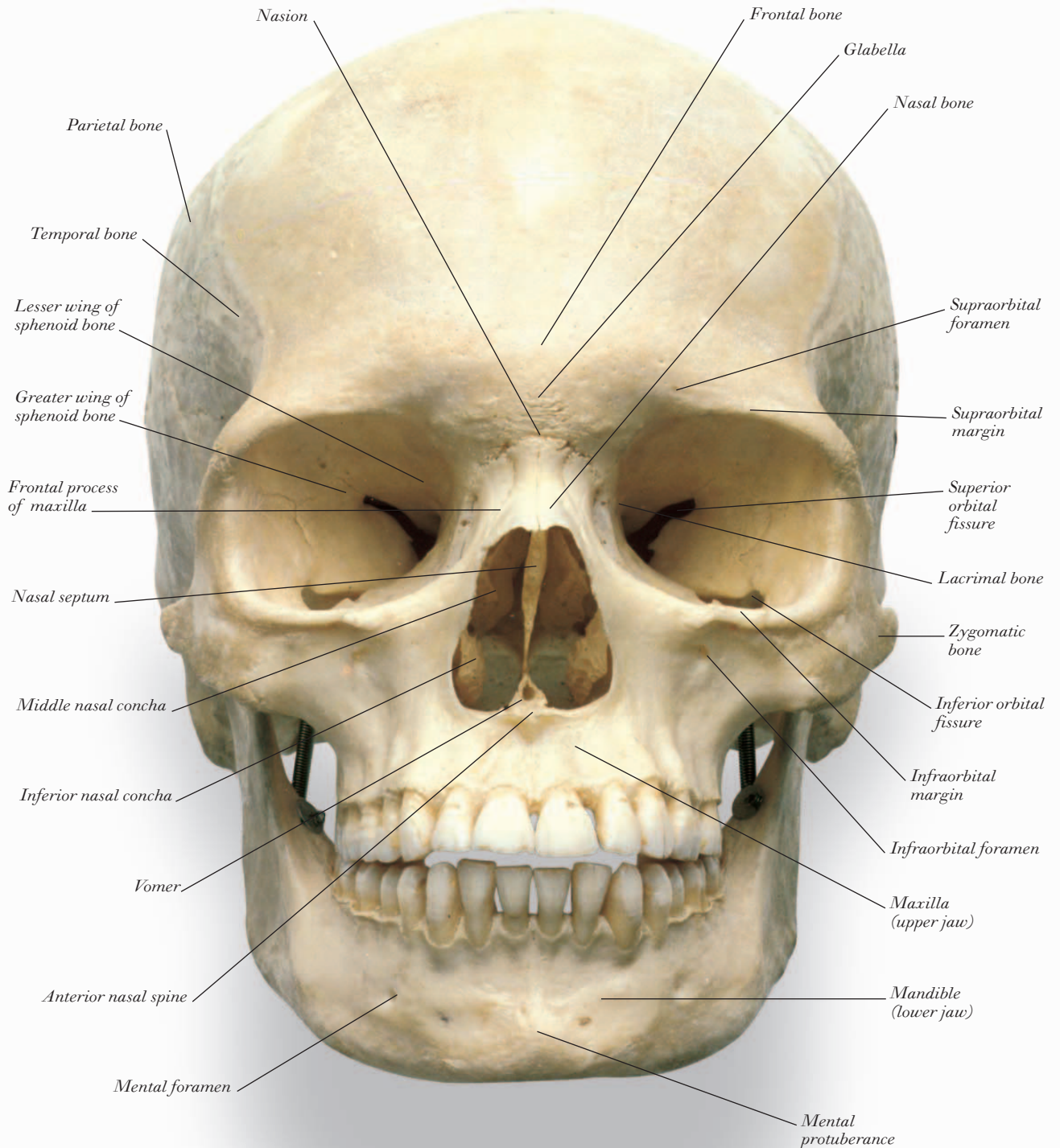
RIGHT SIDE VIEW OF SKULL



VIEW OF SKULL FROM BELOW



FRONT VIEW OF SKULL

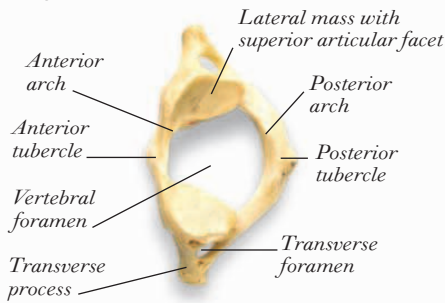


Spine

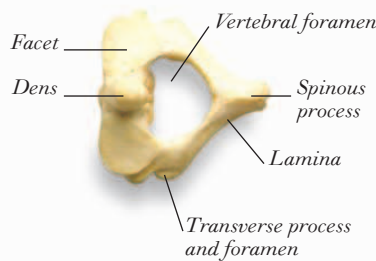
THE SPINE (OR VERTEBRAL COLUMN) has two main functions: it serves as a protective surrounding for the delicate spinal cord and forms the supporting back bone of the skeleton. The spine consists of 24 separate differently shaped bones (vertebrae) with a curved, triangular bone (the sacrum) at the bottom. The sacrum is made up of fused vertebrae; at its lower end is a small tail-like structure made up of tiny bones collectively called the coccyx. Between each pair of vertebrae is a disk of cartilage that cushions the bones during movement. The top two vertebrae differ in appearance from the others and work as a pair: the first, called the atlas, rotates around a stout vertical peg on the second, the axis. This arrangement allows the skull to move freely up and down, and from side to side.

TYPES OF VERTEBRAE (VIEWED FROM ABOVE)

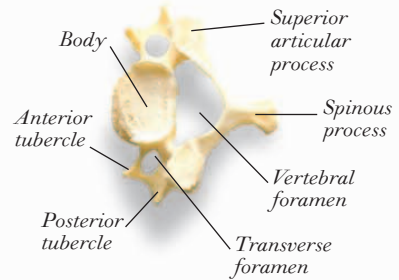
ATLAS



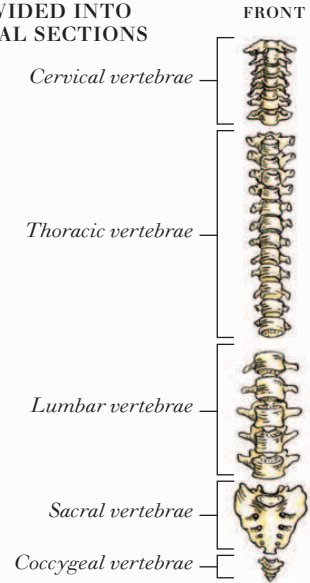
AXIS



CERVICAL VERTEBRA

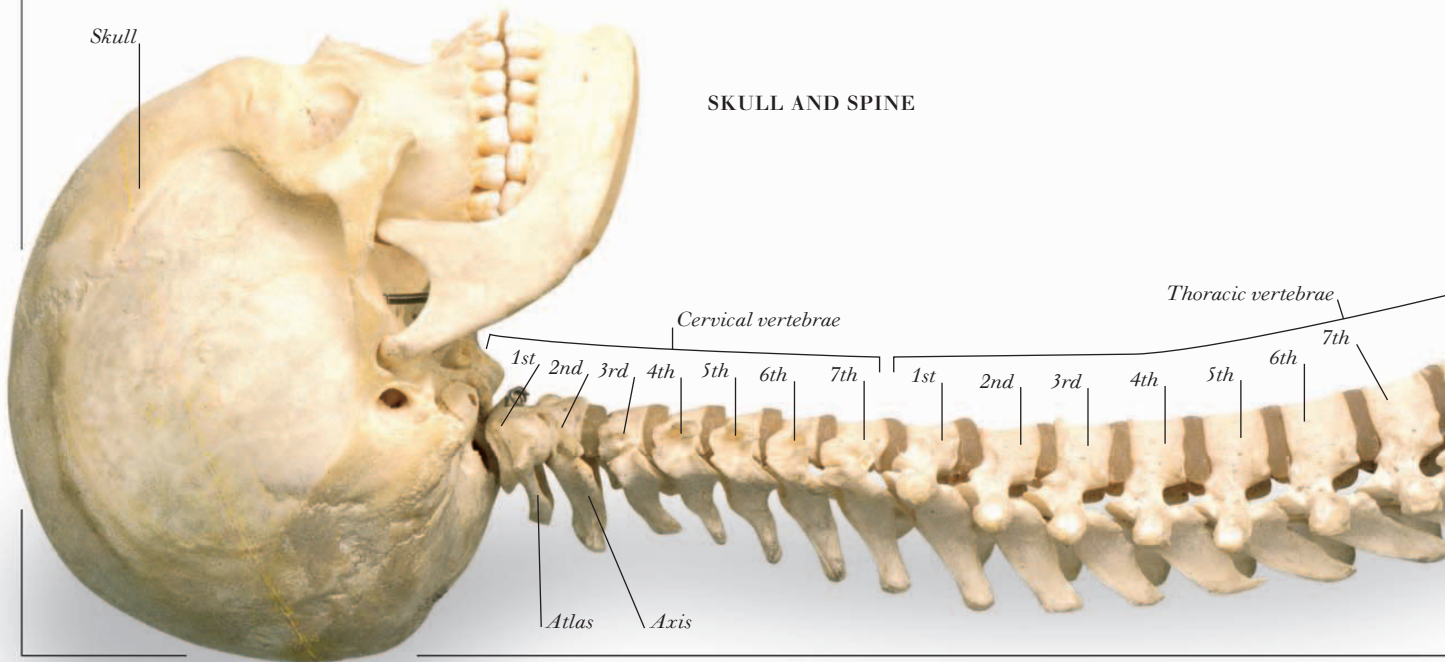


SPINE DIVIDED INTO VERTEBRAL SECTIONS



Skull

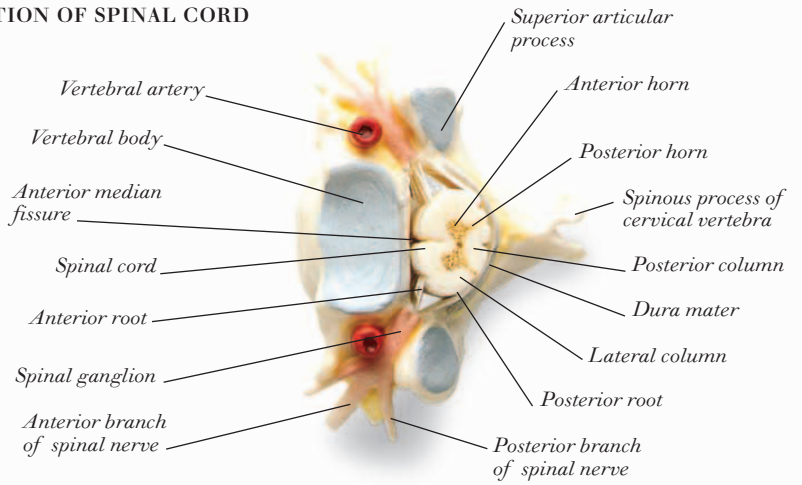
SKULL AND SPINE



CERVICAL VERTEBRA AND SECTION OF SPINAL CORD

RIGHT SIDE

BACK

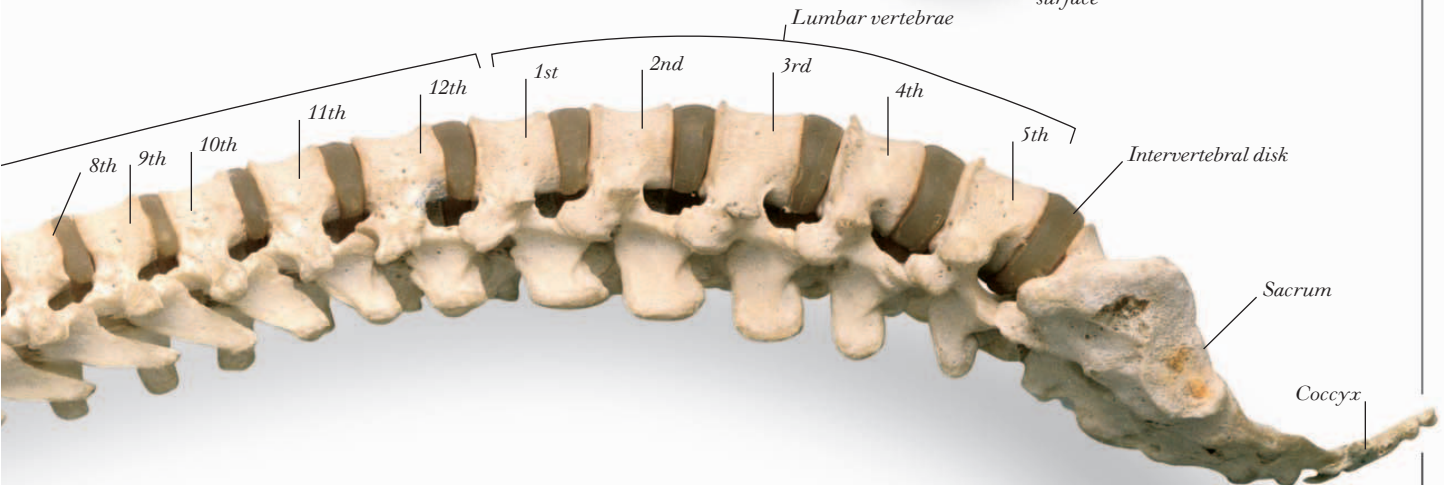
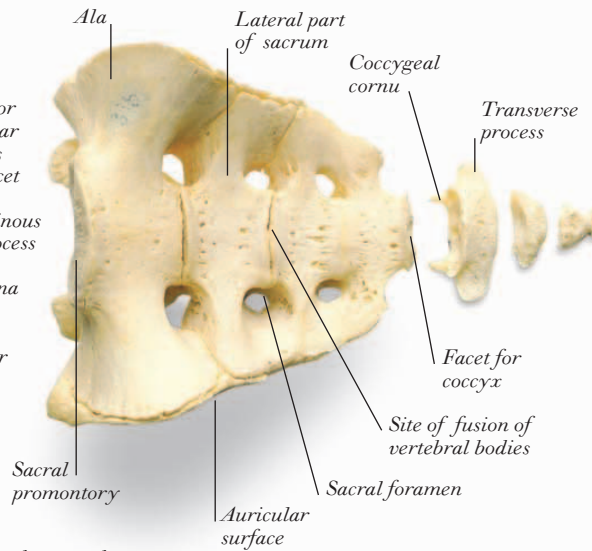
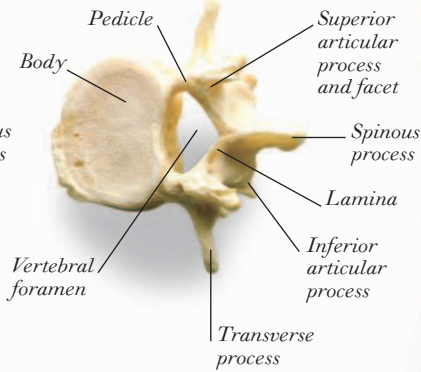
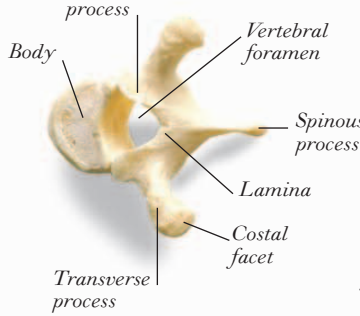


SACRUM

COCCYX

THORACIC VERTEBRA
Superior articular process

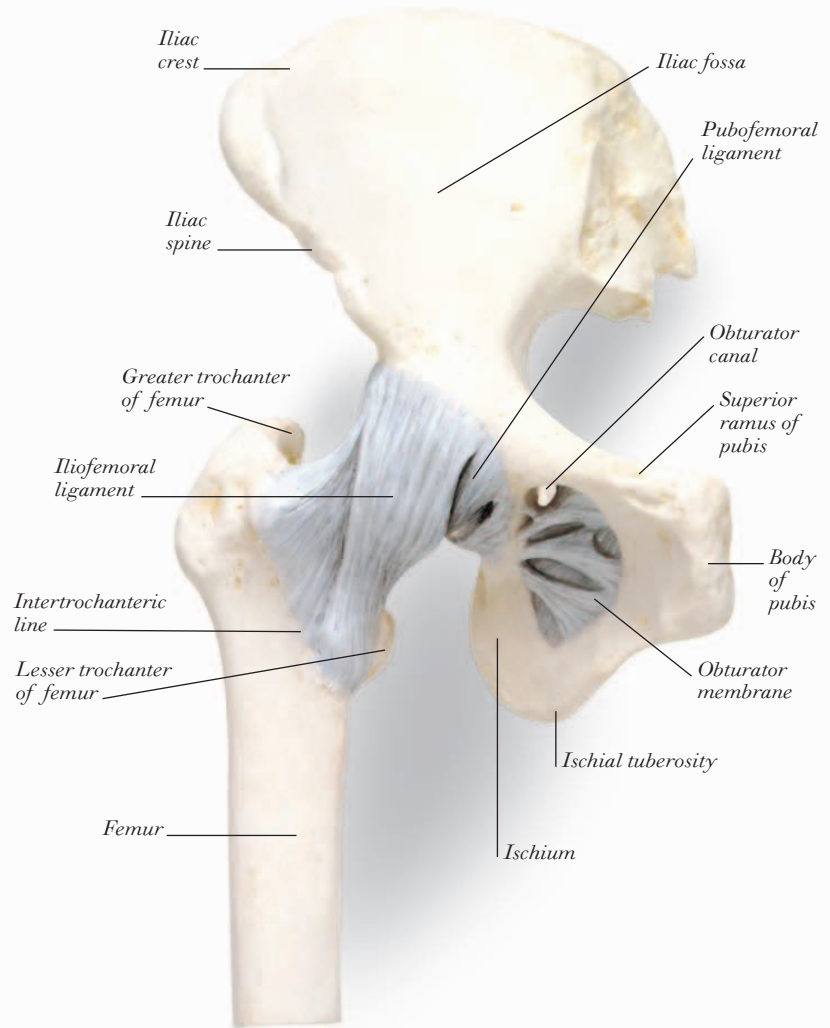
LUMBAR VERTEBRA



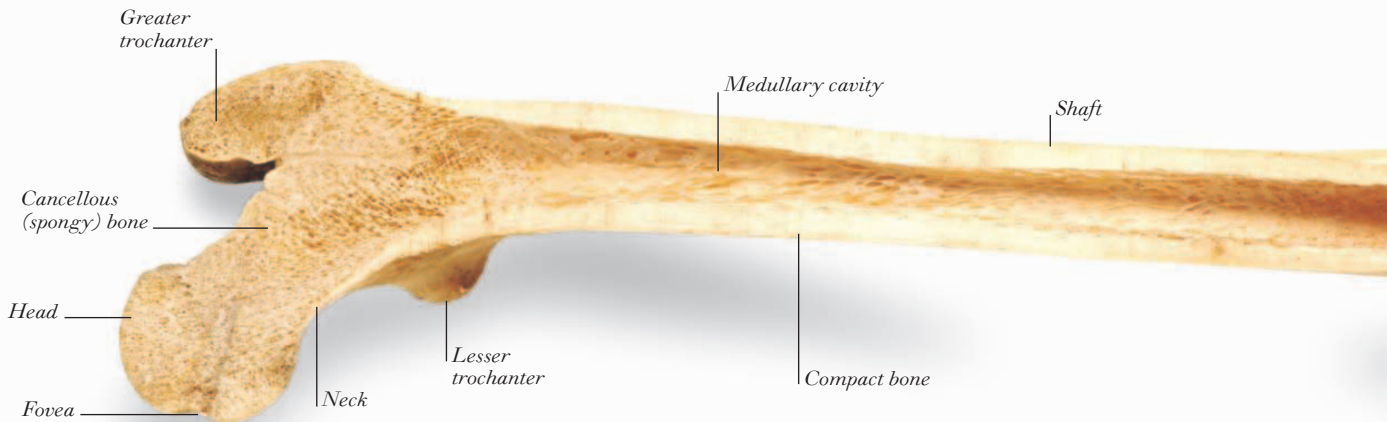
Bones and joints

BONES FORM the body's hard, strong skeletal framework. Each bone has a hard, compact exterior surrounding a spongy, lighter interior. The long bones of the arms and legs, such as the femur (thigh bone), have a central cavity containing bone marrow. Bones are composed chiefly of calcium, phosphorus, and a fibrous substance known as collagen. Bones meet at joints, which are of several different types. For example, the hip is a ball-and-socket joint that allows the femur a wide range of movement, whereas finger joints are simple hinge joints that allow only bending and straightening. Joints are held in place by bands of tissue called ligaments. Movement of joints is facilitated by the smooth hyaline cartilage that covers the bone ends and by the synovial membrane that lines and lubricates the joint.

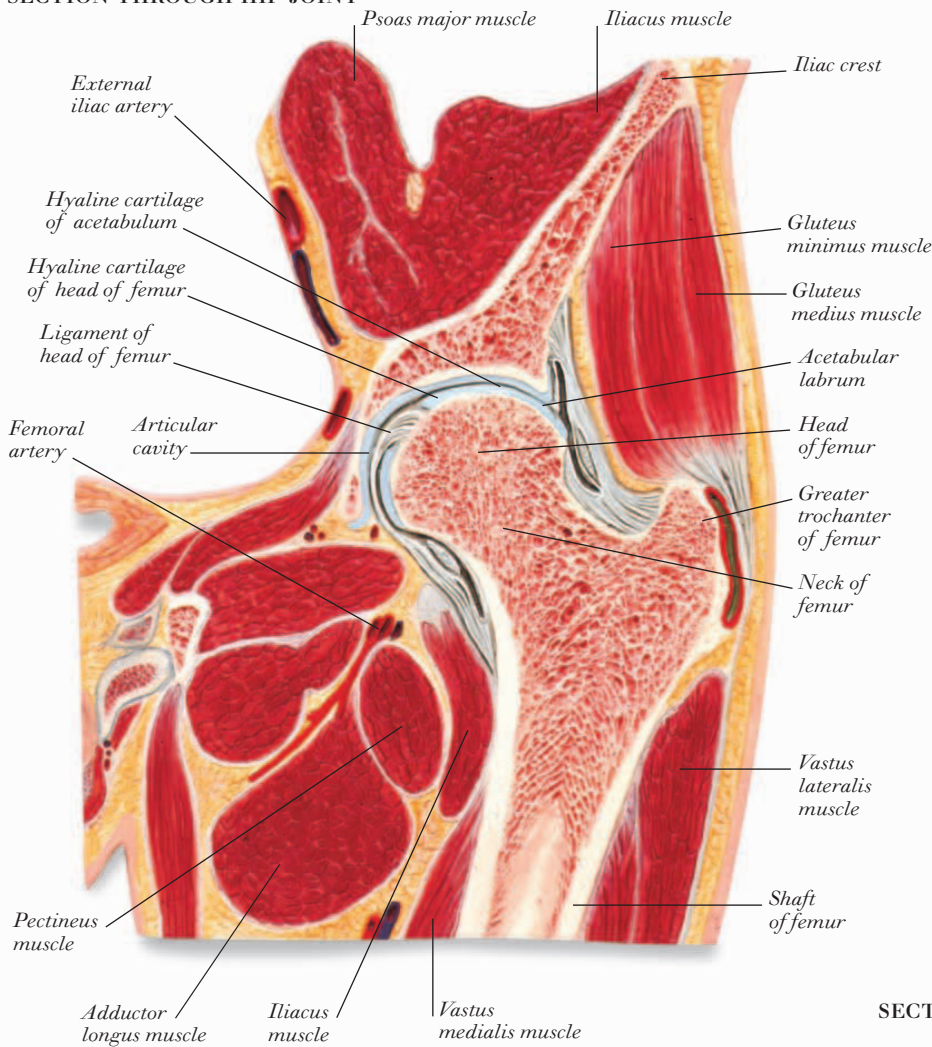
LIGAMENTS SURROUNDING HIP JOINT



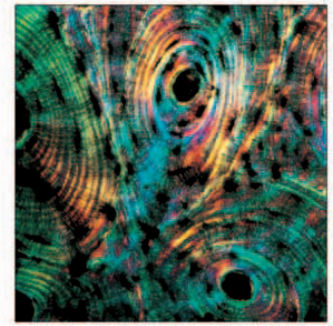
SECTION THROUGH LEFT FEMUR



SECTION THROUGH HIP JOINT

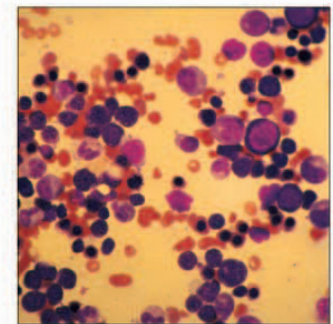


SECTION OF COMPACT BONE



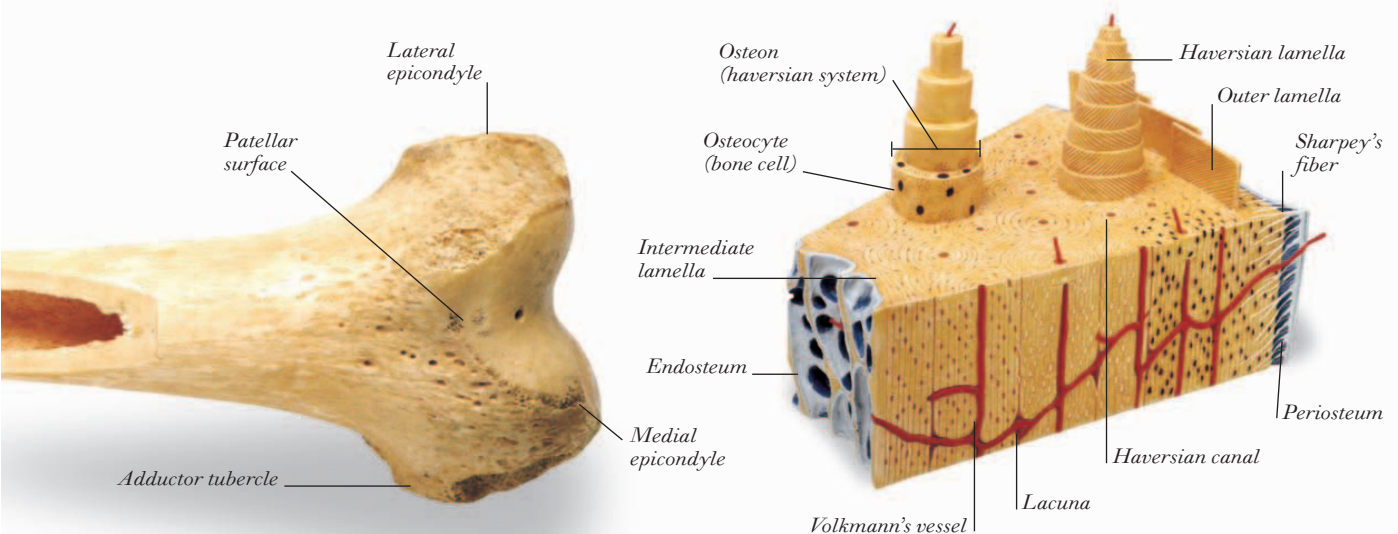
Parallel rows of concentric bony layers make up this strong material.

BONE MARROW SMEAR



Composed mainly of red and white blood cells, marrow fills the cavities of bones.

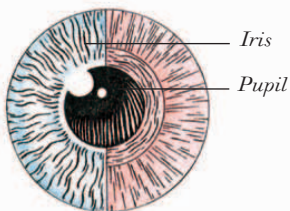
SECTION THROUGH LONG BONE



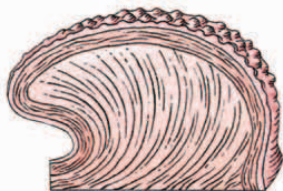
Muscles 1

THERE ARE THREE MAIN TYPES OF MUSCLE: skeletal muscle (also called voluntary muscle because it can be consciously controlled); smooth muscle (also called involuntary muscle because it is not under voluntary control); and the specialized muscle tissue of the heart. Humans have more than 600 skeletal muscles, which differ in size and shape according to the jobs they do. Skeletal muscles are attached either directly or indirectly (via tendons) to bones, and work in opposing pairs (one muscle in the pair contracts while the other relaxes) to produce body movements as diverse as walking, threading a needle, and an array of facial expressions. Smooth muscles occur in the walls of internal body organs and perform actions such as forcing food through the intestines, contracting the uterus (womb) in childbirth, and pumping blood through the blood vessels.

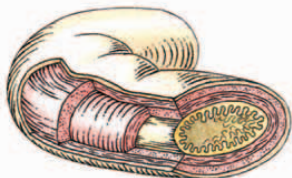
SOME OTHER MUSCLES IN THE BODY



IRIS
The muscle fibers contract and dilate (expand) to alter pupil size.



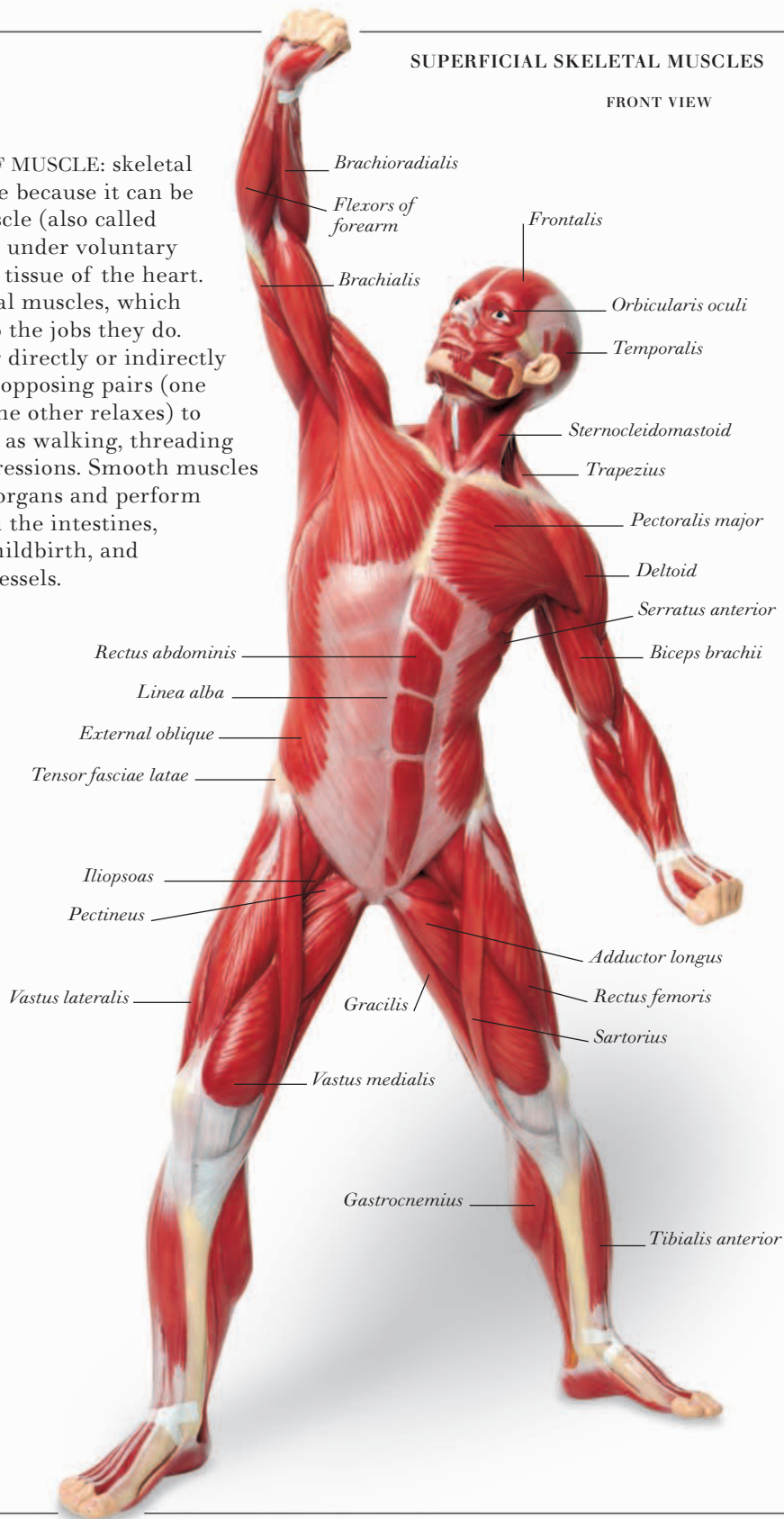
TONGUE
Interlacing layers of muscle allow great mobility.



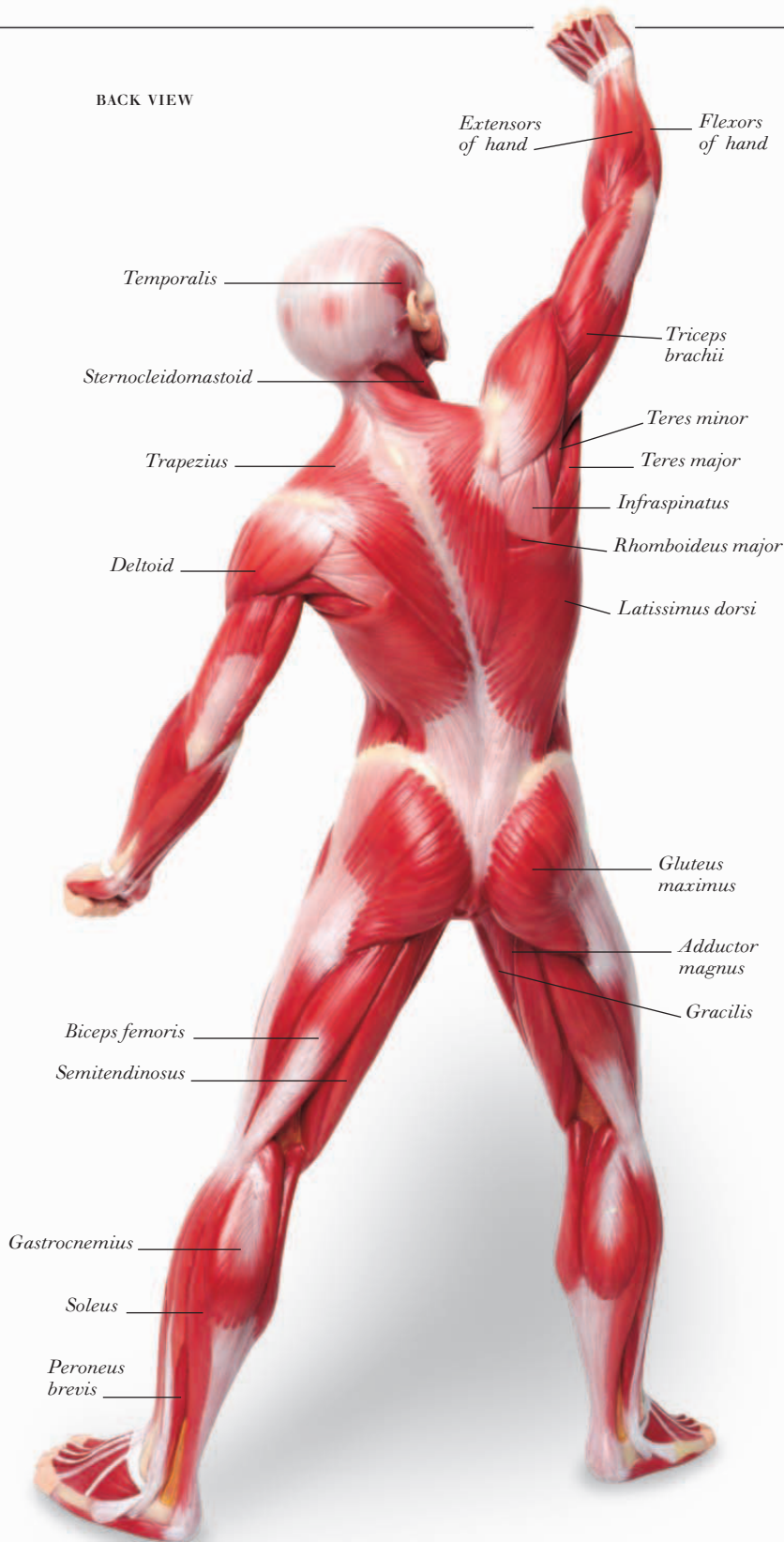
ILEUM
Opposing muscle layers transport semidigested food.

SUPERFICIAL SKELETAL MUSCLES

FRONT VIEW

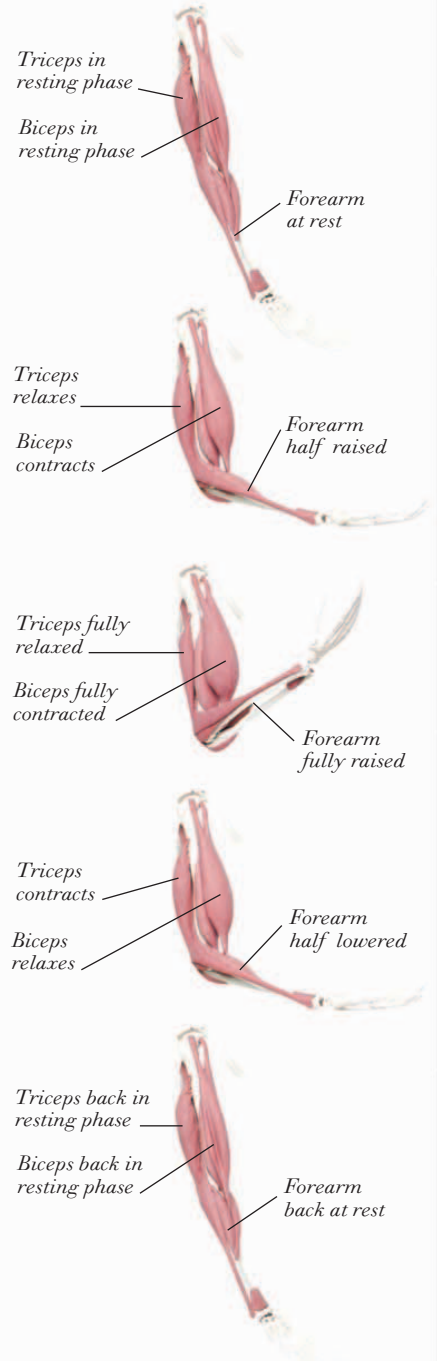


BACK VIEW



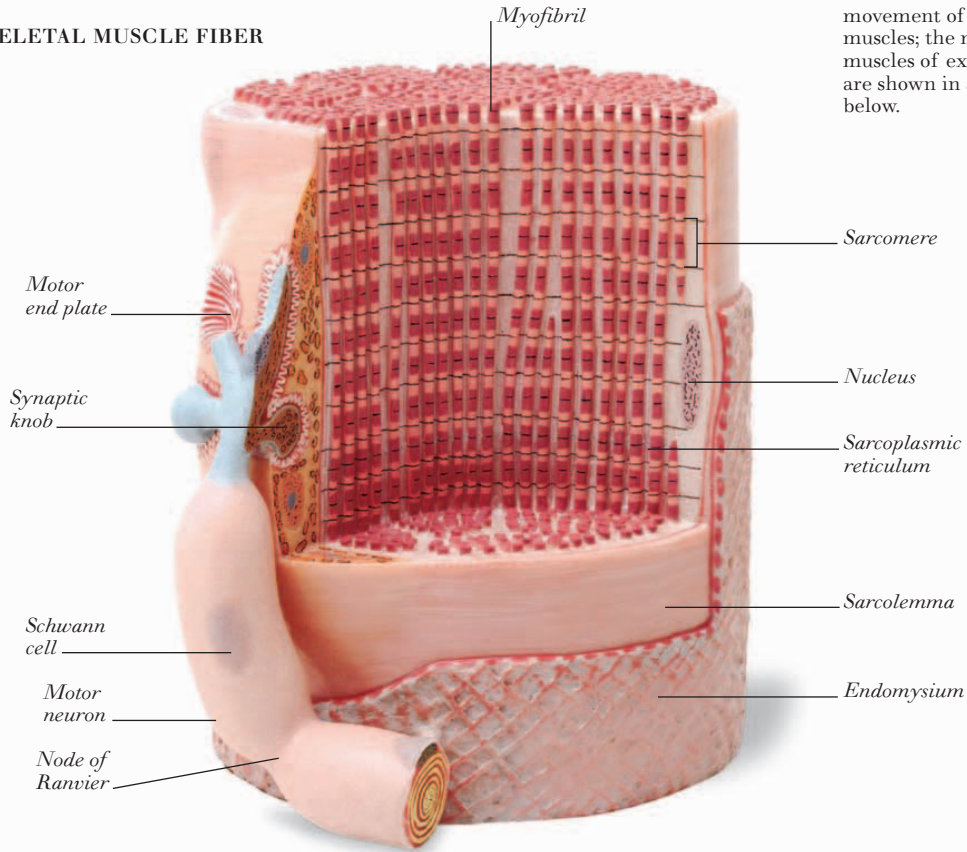
MOVEMENT OF THE FOREARM

Controlled movement of the limbs relies on coordinated relaxation and contraction of opposing muscles. To raise the forearm, the biceps (two-rooted muscle) contracts and shortens while the triceps (three-rooted muscle) relaxes; the reverse occurs when the forearm is lowered.



Muscles 2

SKELETAL MUSCLE FIBER



MUSCLES OF FACIAL EXPRESSION

A single expression is the result of movement of many muscles; the main muscles of expression are shown in action below.



FRONTALIS



CORRUGATOR SUPERCILII



ORBICULARIS ORIS

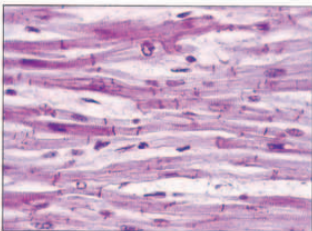


ZYGOMATICUS MAJOR

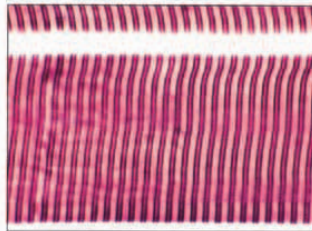


DEPRESSOR ANGULI ORIS

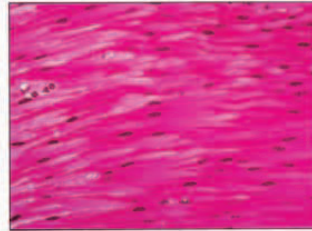
TYPES OF MUSCLE



CARDIAC MUSCLE

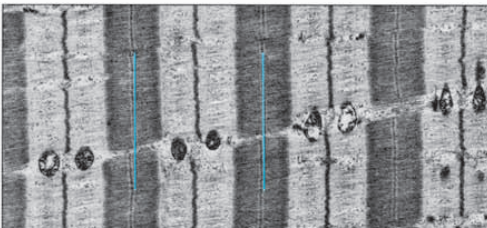


SKELETAL MUSCLE

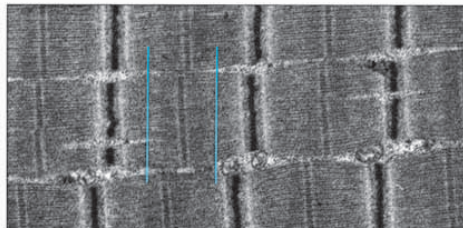


SMOOTH MUSCLE

CONTRACTION OF SKELETAL MUSCLE

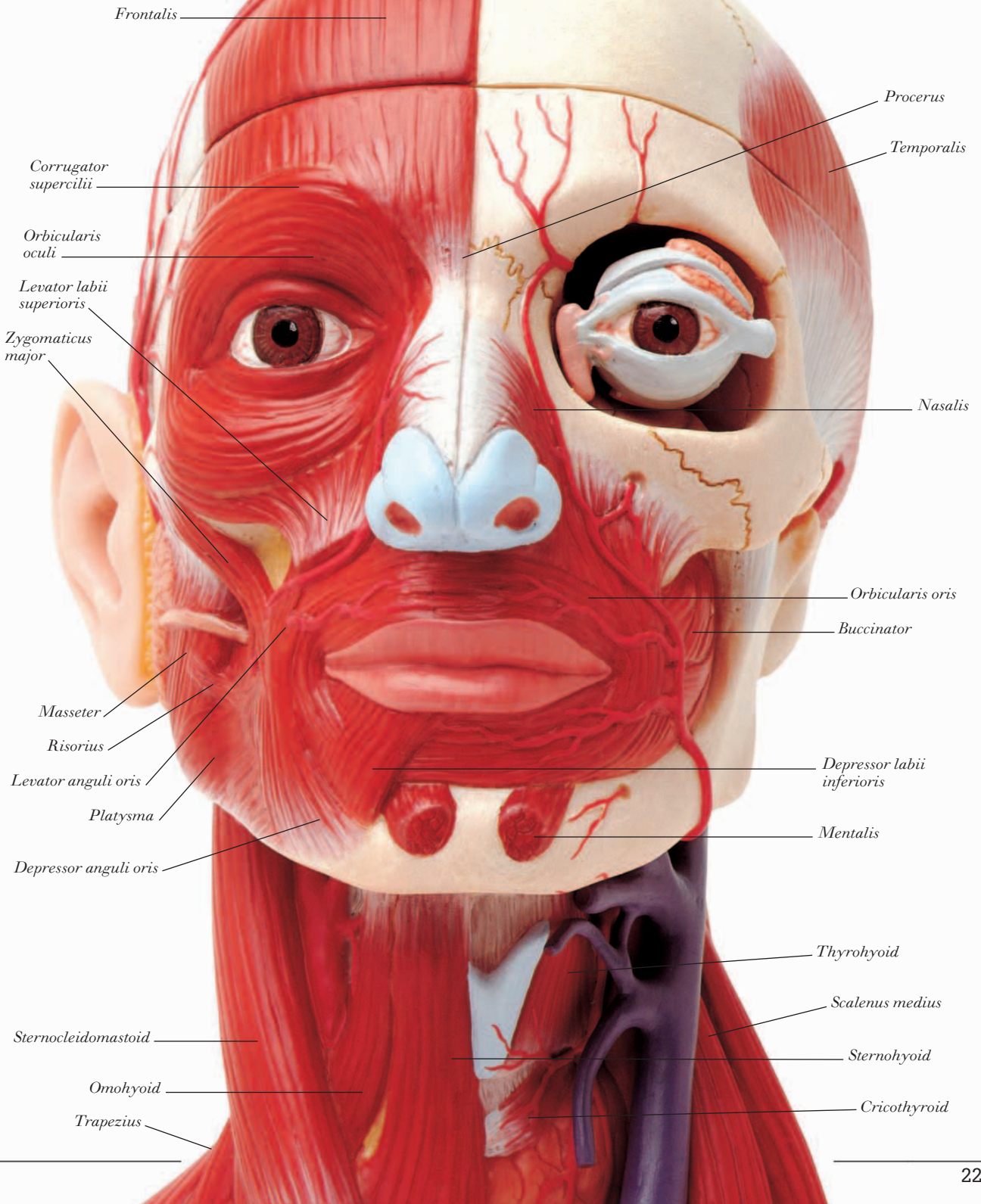


RELAXED STATE



CONTRACTED STATE

MUSCLES OF HEAD AND NECK

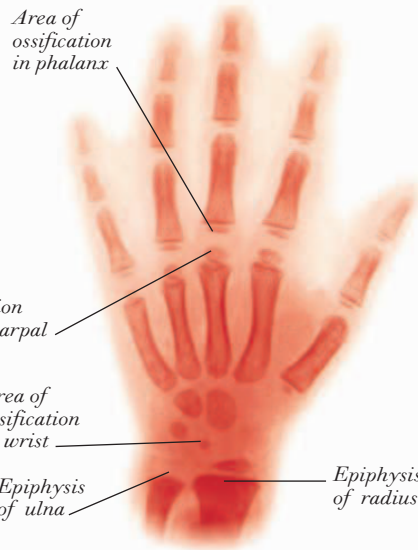


Hands



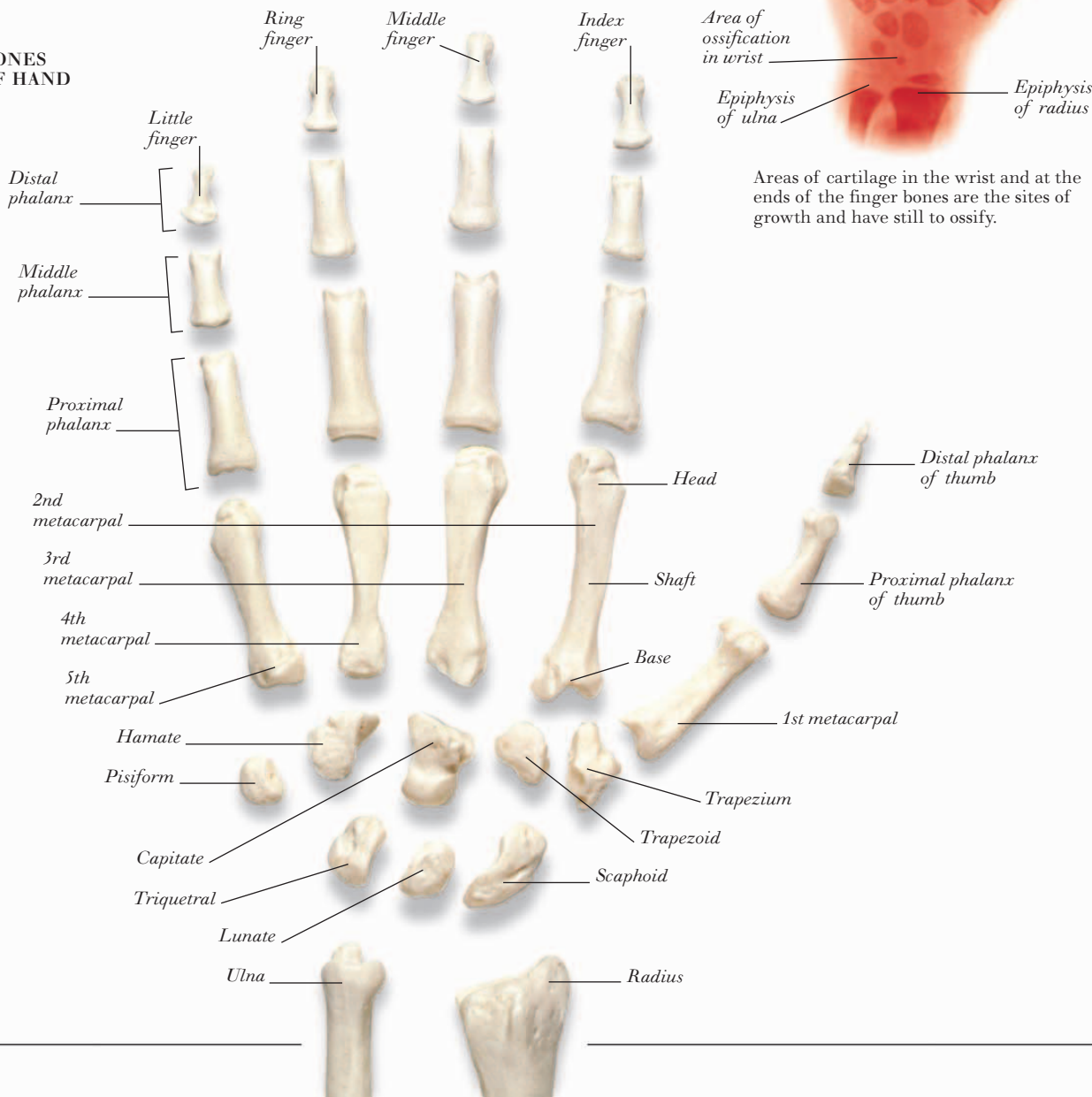
THE HUMAN HAND is an extremely versatile tool, capable of delicate manipulation as well as powerful gripping actions. The arrangement of its 27 small bones, moved by 37 skeletal muscles that are connected to the bones by tendons, allows a wide range of movements. Our ability to bring the tips of our thumbs and fingers together, combined with the extraordinary sensitivity of our fingertips due to their rich supply of nerve endings, makes our hands uniquely dextrous.

X-RAY OF LEFT HAND OF A YOUNG CHILD

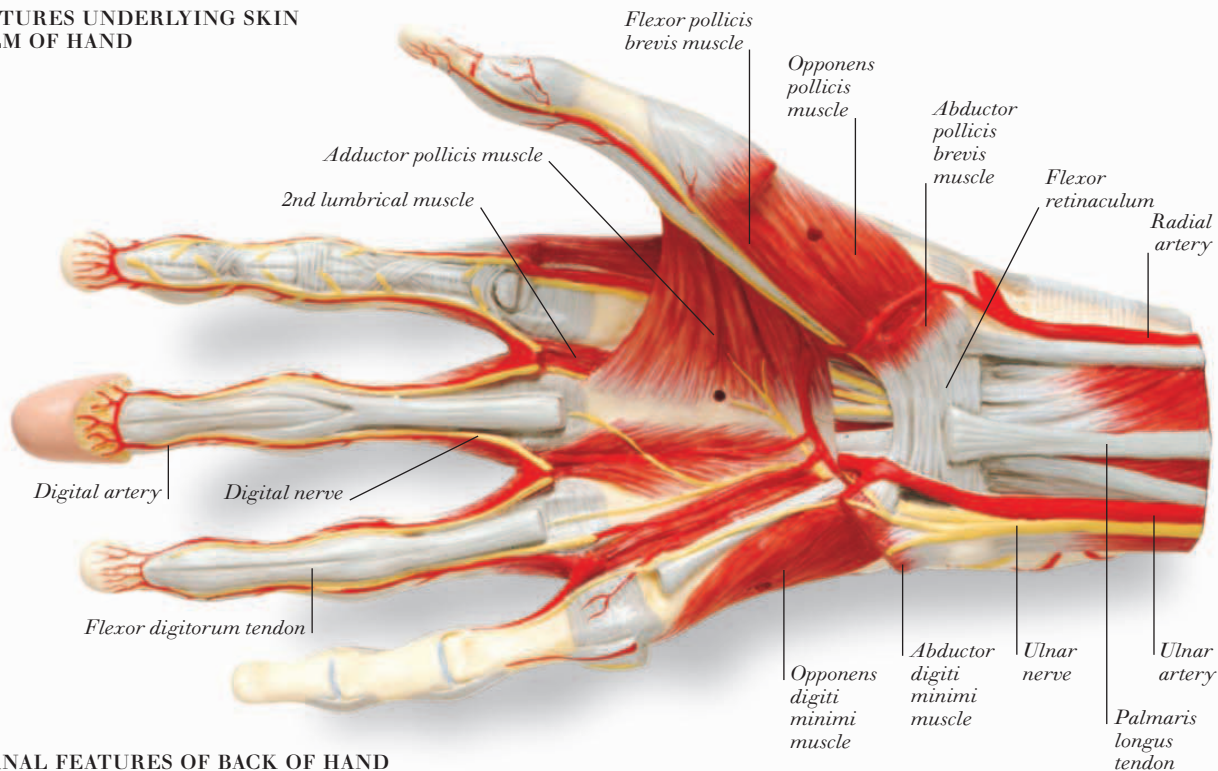


Areas of cartilage in the wrist and at the ends of the finger bones are the sites of growth and have still to ossify.

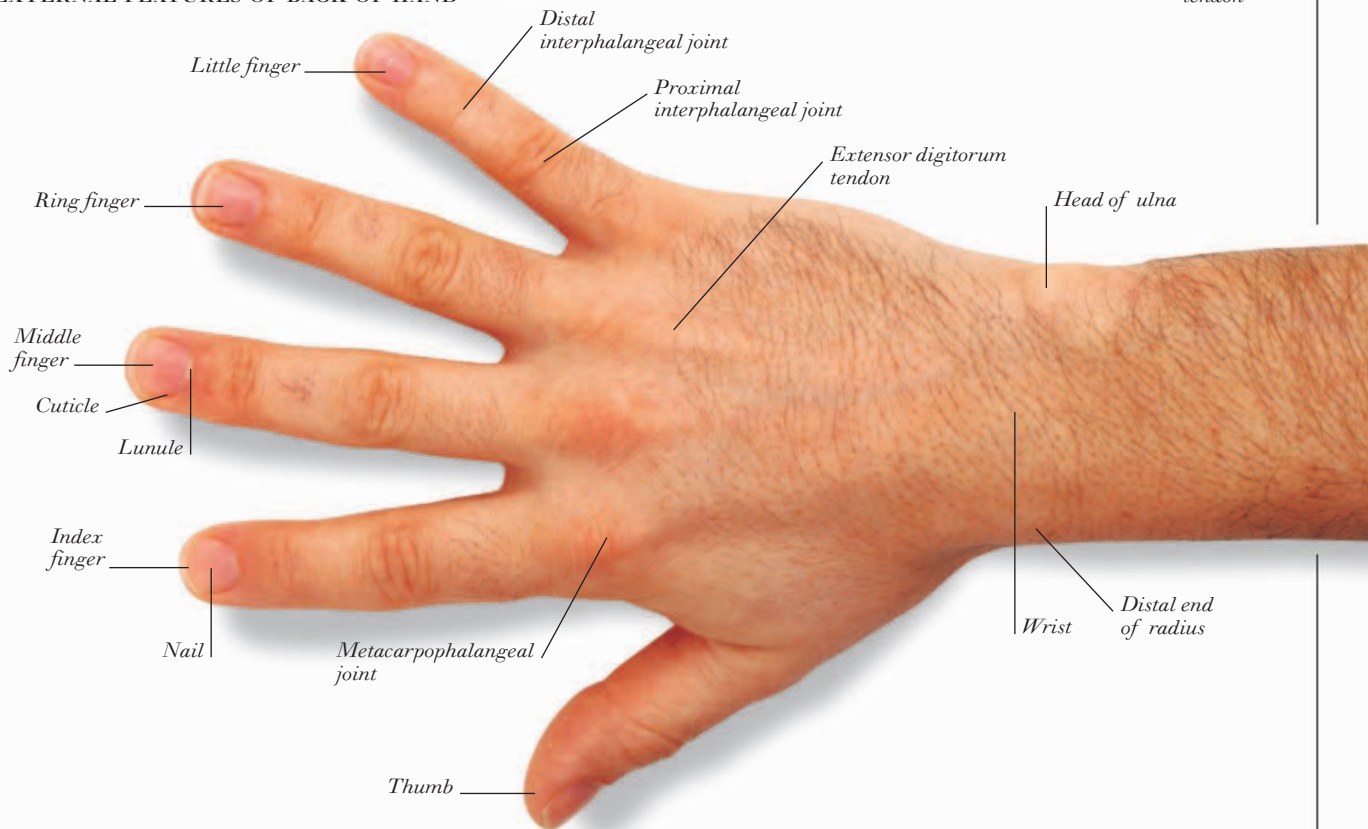
BONES OF HAND



STRUCTURES UNDERLYING SKIN OF PALM OF HAND



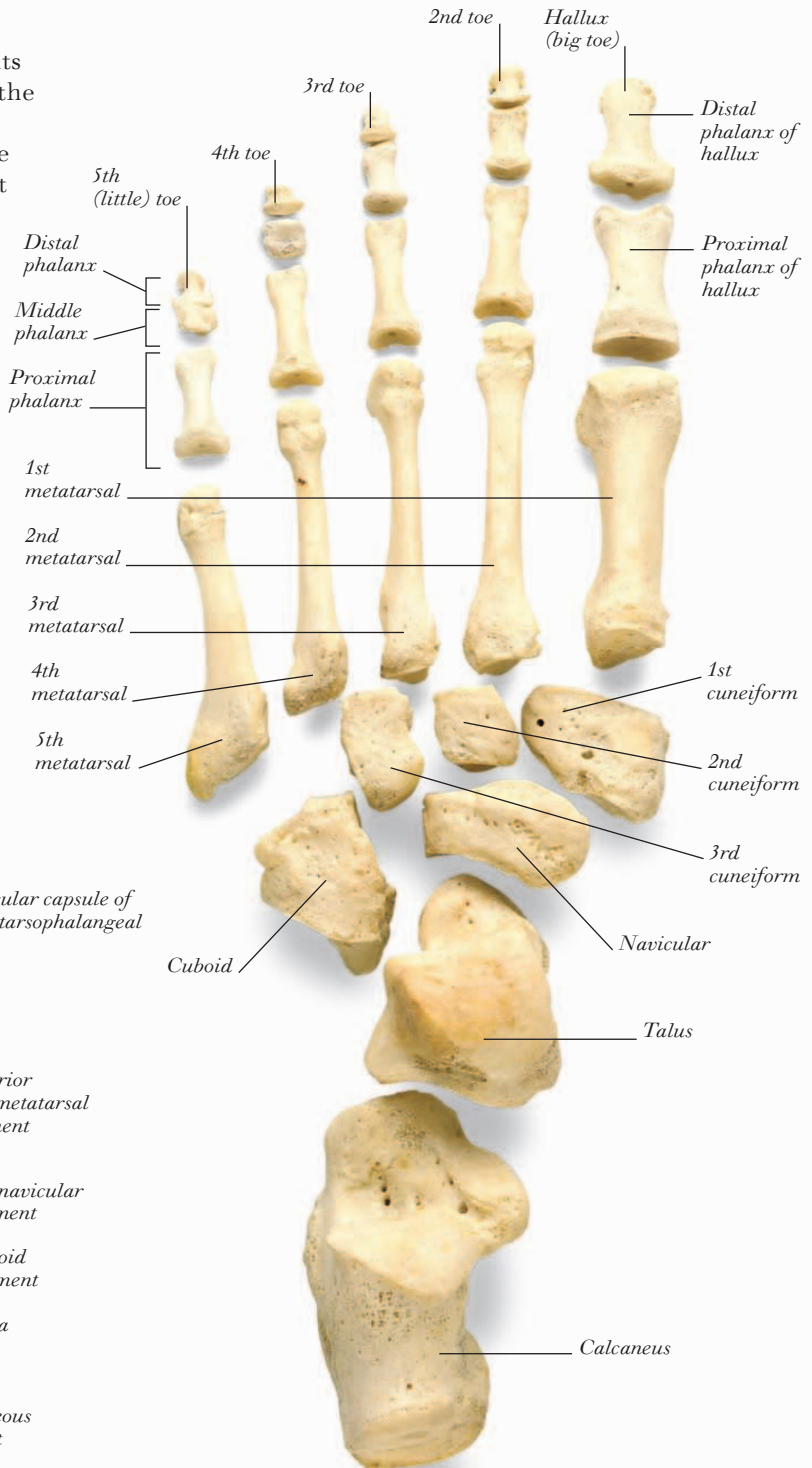
EXTERNAL FEATURES OF BACK OF HAND



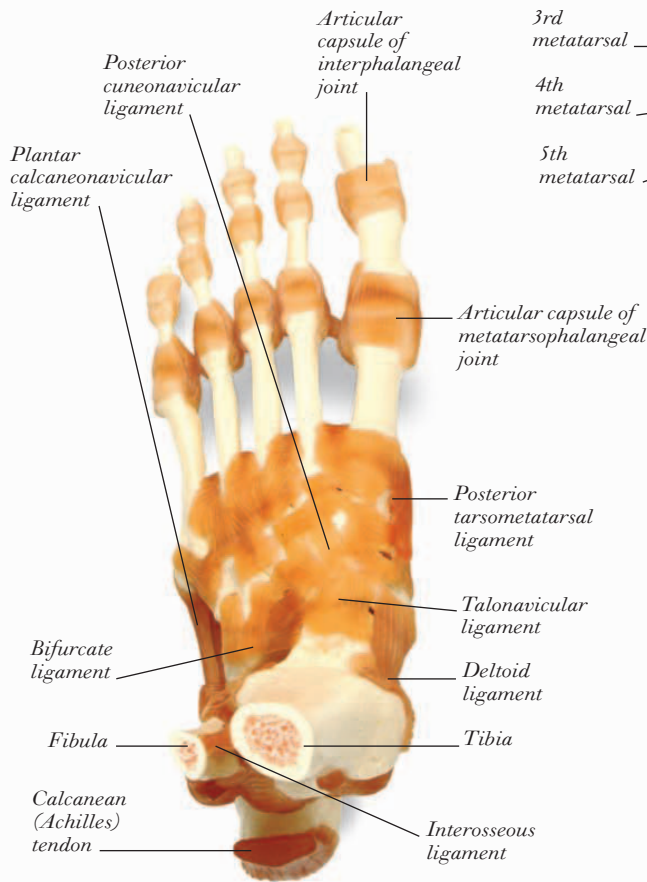
Feet

THE FEET AND TOES are essential elements in body movement. They bear and propel the weight of the body during walking and running, and also help to maintain balance during changes of body position. Each foot has 26 bones, more than 100 ligaments, and 33 muscles, some of which are attached to the lower leg. The heel pad and the arch of the foot act as shock absorbers, providing a cushion against the jolts that occur with every step.

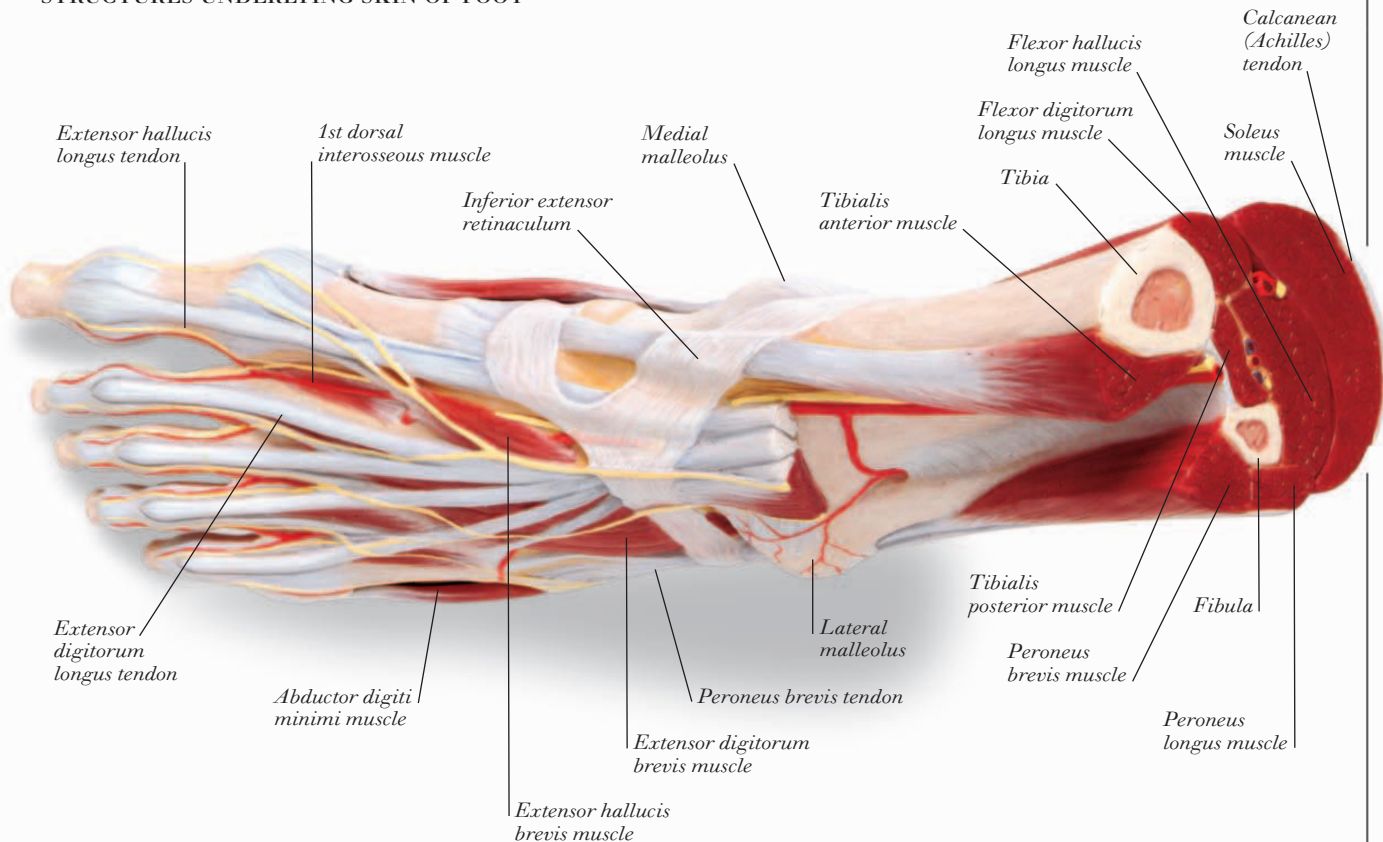
BONES OF FOOT



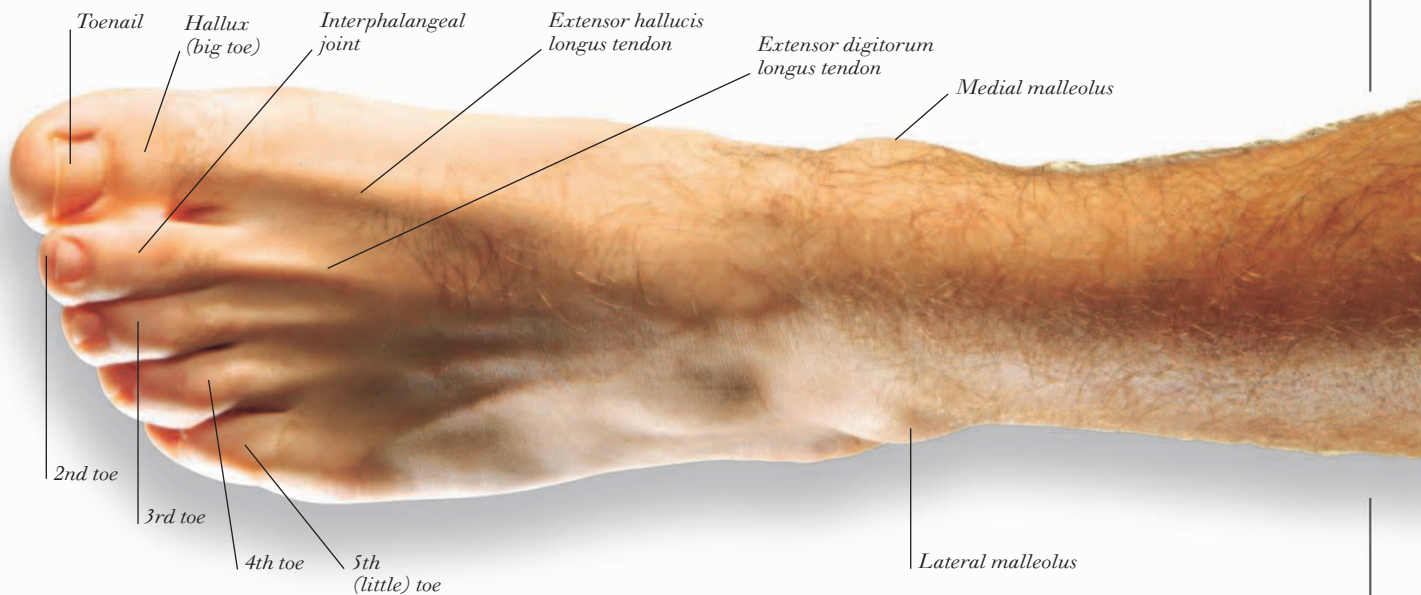
LIGAMENTS OF FOOT



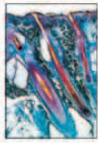
STRUCTURES UNDERLYING SKIN OF FOOT



EXTERNAL FEATURES OF FOOT

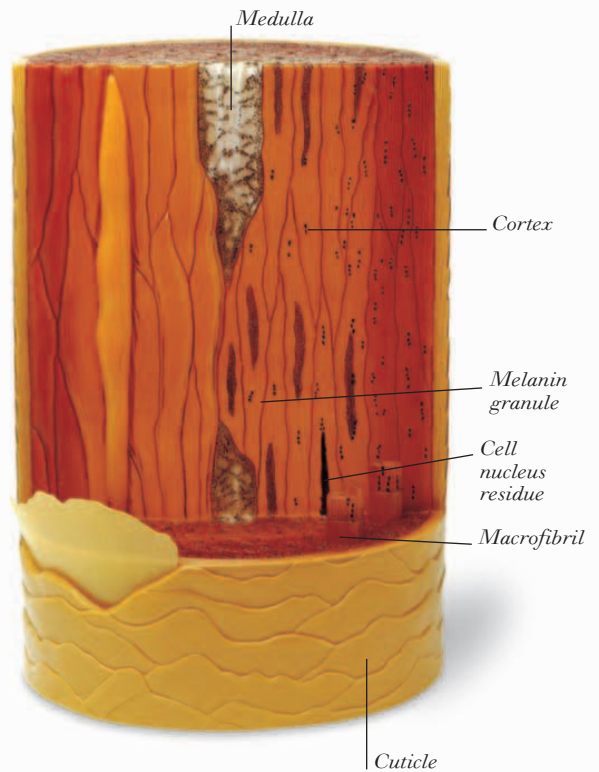


Skin and hair

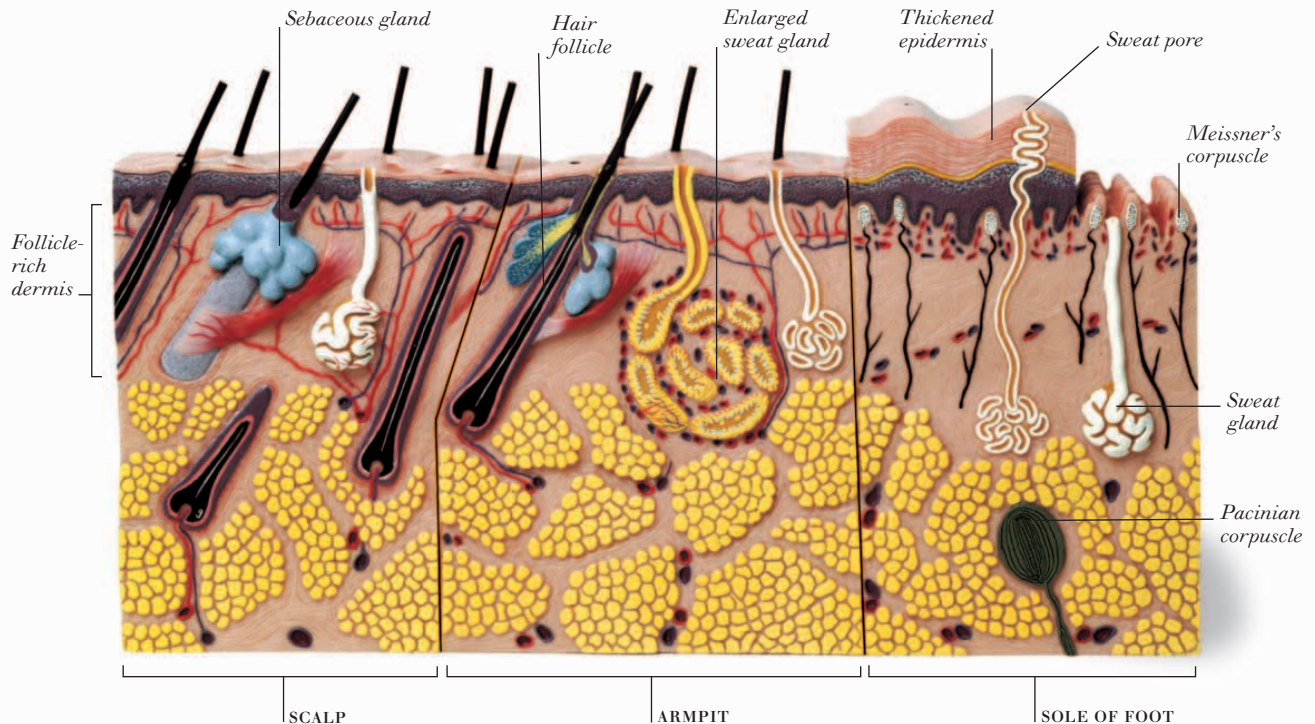


SKIN IS THE BODY'S LARGEST ORGAN, a waterproof barrier that protects the internal organs against infection, injury, and harmful sun rays. The skin is also an important sensory organ and helps to control body temperature. The outer layer of the skin, known as the epidermis, is coated with keratin, a tough, horny protein that is also the chief constituent of hair and nails. Dead cells are shed from the skin's surface and are replaced by new cells from the base of the epidermis, the region that also produces the skin pigment, melanin. The dermis contains most of the skin's living structures, and includes nerve endings, blood vessels, elastic fibers, sweat glands that cool the skin, and sebaceous glands that produce oil to keep the skin supple. Beneath the dermis lies the subcutaneous tissue (hypodermis), which is rich in fat and blood vessels. Hair shafts grow from hair follicles situated in the dermis and subcutaneous tissue. Hair grows on every part of the skin apart from the palms of the hands and soles of the feet.

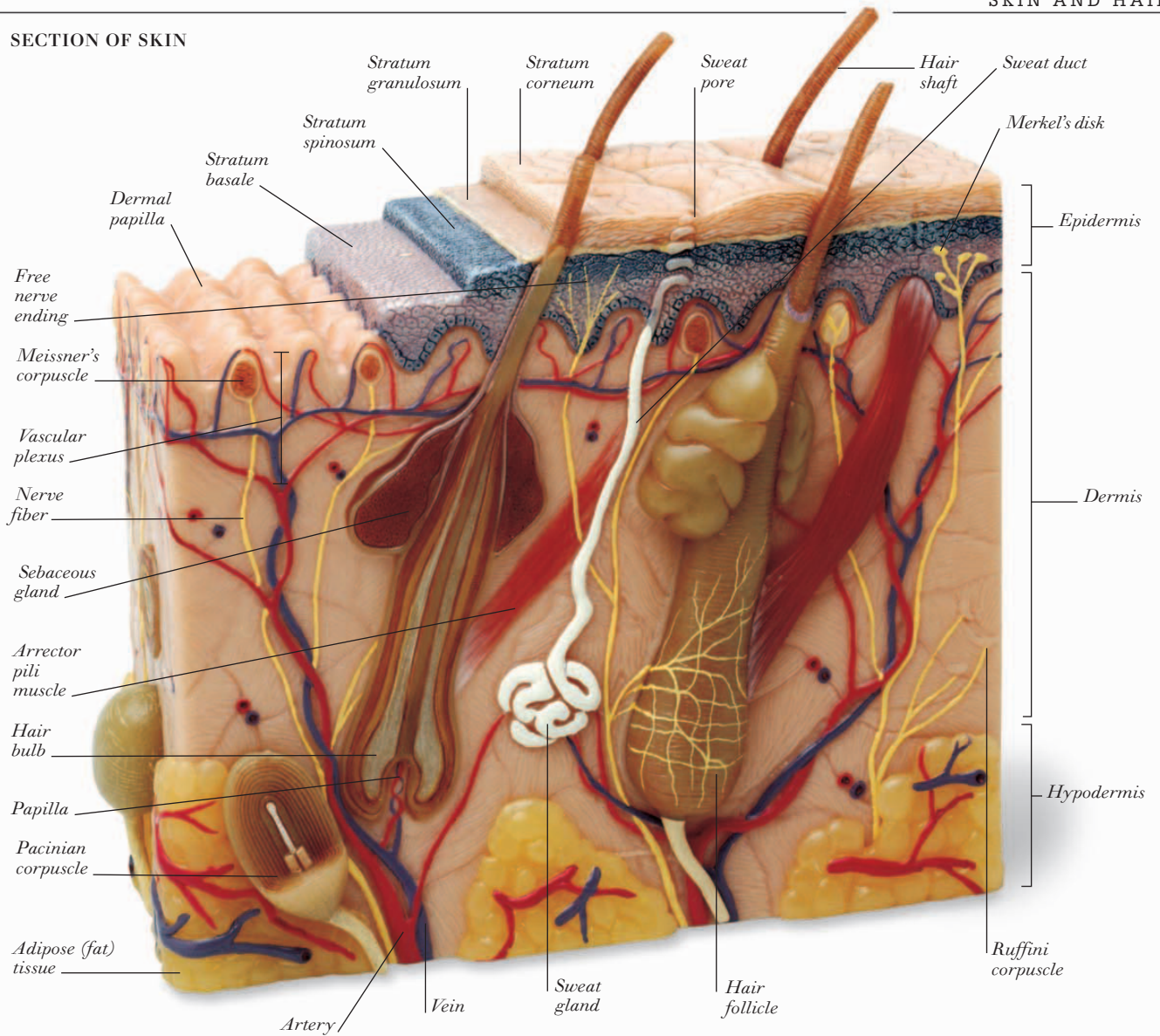
SECTION OF HAIR



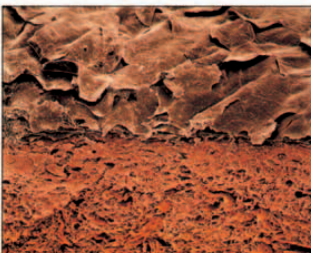
SECTIONS OF DIFFERENT TYPES OF SKIN



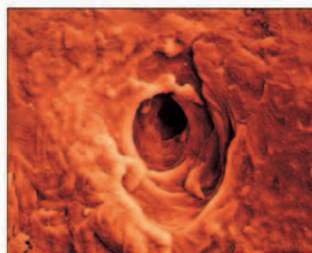
SECTION OF SKIN



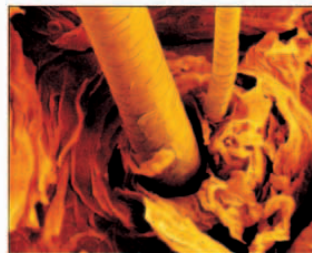
PHOTOMICROGRAPHS OF SKIN AND HAIR



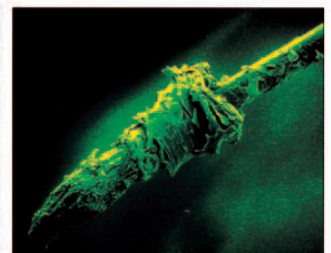
SECTION OF SKIN
The flaky cells at the skin's surface are shed continuously.



SWEAT PORE
This allows loss of fluid as part of temperature control.



SKIN HAIR
Two hairs pushing through the outer layer of skin.

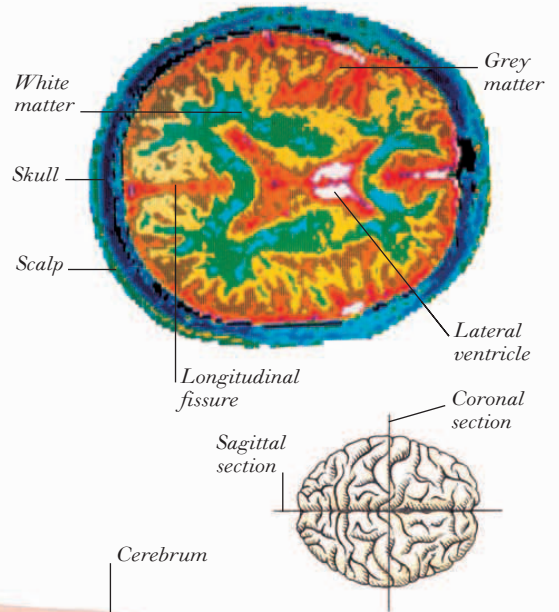


HEAD HAIR
The root and part of the shaft of a hair from the scalp.

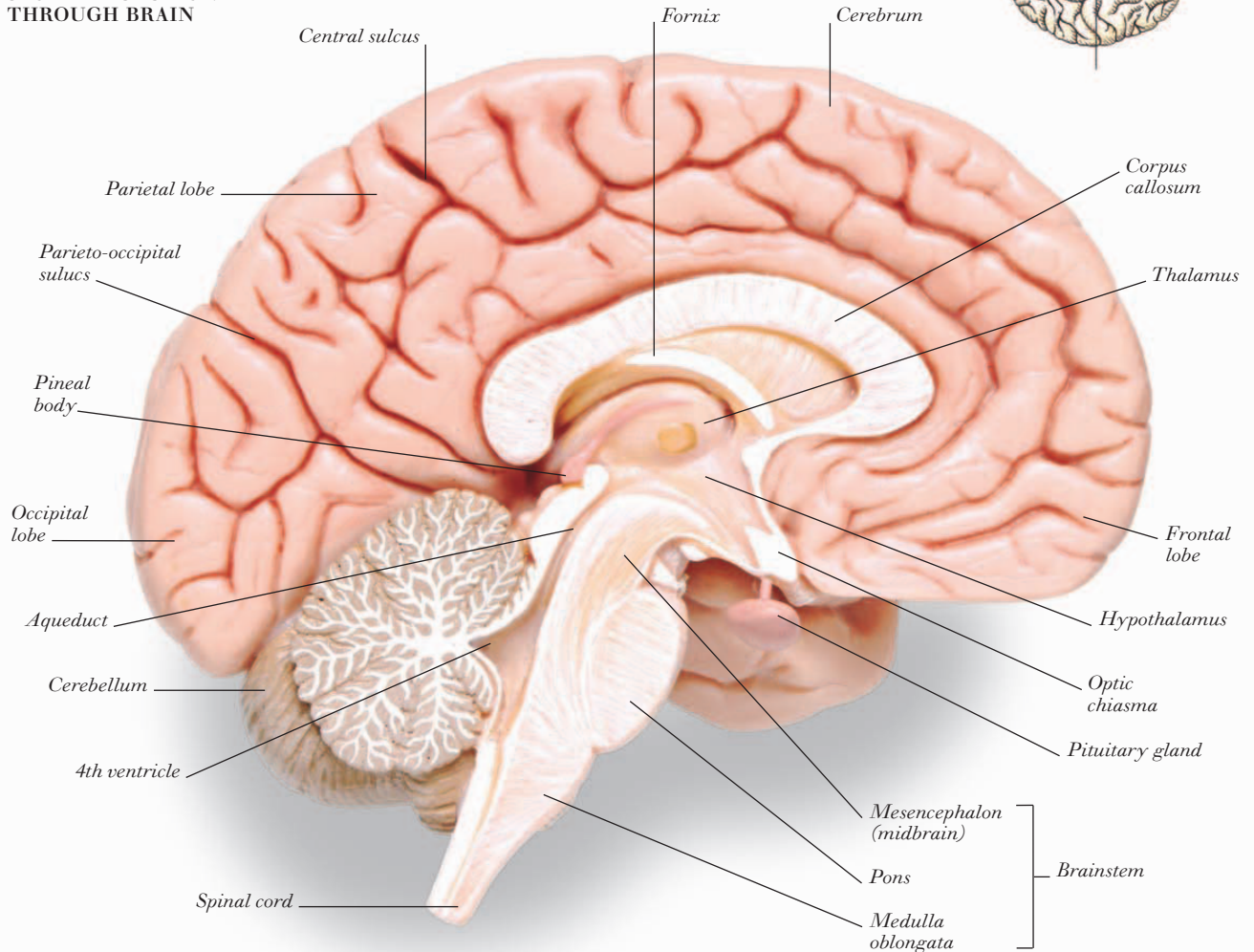
Brain

THE BRAIN IS THE MAJOR ORGAN of the central nervous system and the control center for all the body's voluntary and involuntary activities. It is also responsible for the complexities of thought, memory, emotion, and language. In adults, this complex organ is a mere 3 lb (1.4 kg) in weight, containing over 10 billion nerve cells. Three distinct regions can easily be seen—the brainstem, the cerebellum, and the large cerebrum. The brainstem controls vital body functions, such as breathing and digestion. The cerebellum's main functions are the maintenance of posture and the coordination of body movements. The cerebrum, which consists of the right and left cerebral hemispheres joined by the corpus callosum, is the site of most conscious and intelligent activities.

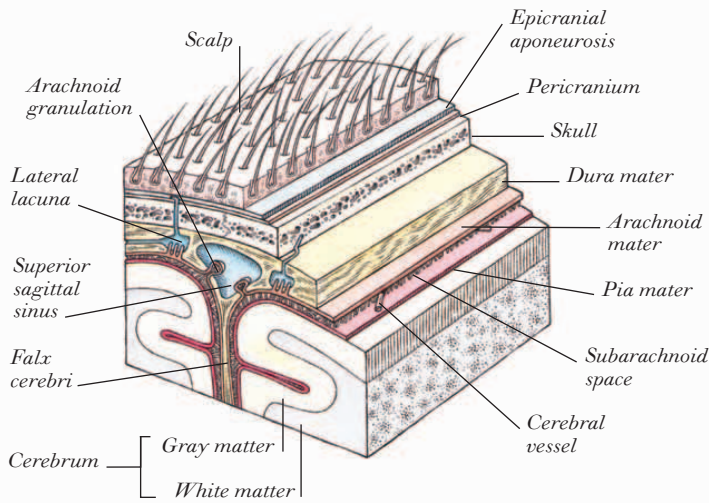
MRI SCAN OF TRANSVERSE SECTION THROUGH BRAIN



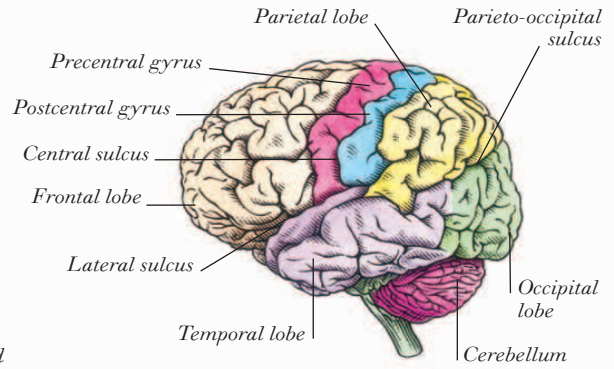
SAGITTAL SECTION THROUGH BRAIN



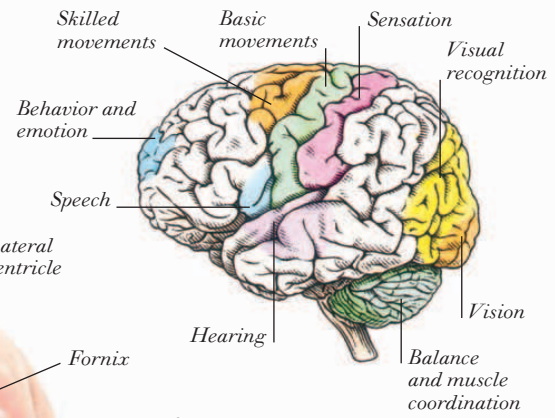
SECTION THROUGH SKULL AND BRAIN



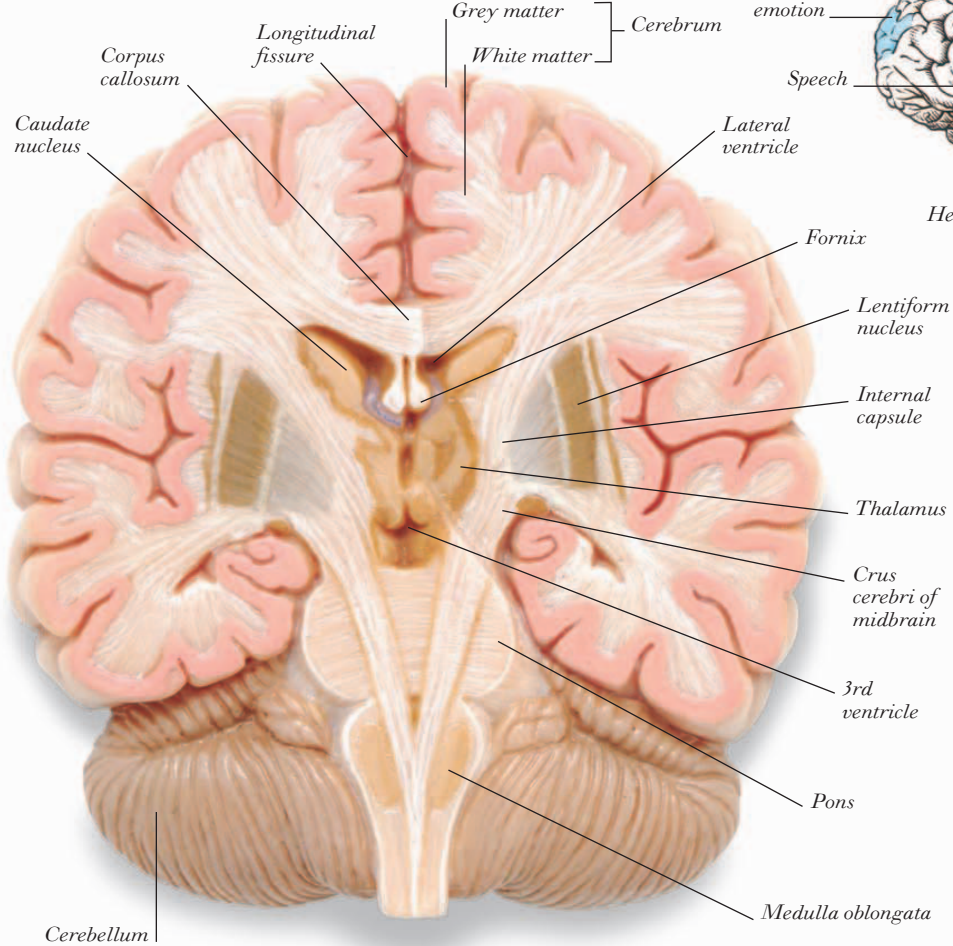
EXTERNAL ANATOMY OF BRAIN



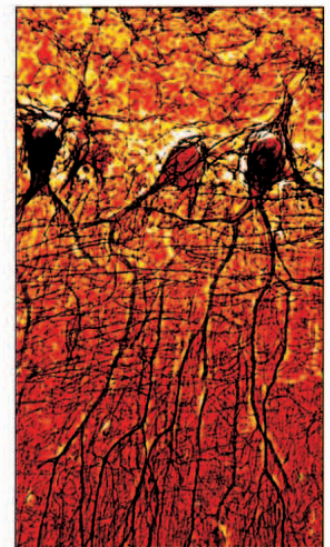
SPECIFIC ROLES OF AREAS OF CEREBRUM



CORONAL SECTION THROUGH BRAIN

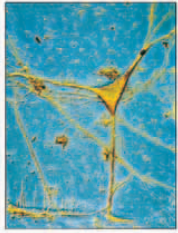


NERVE CELLS IN BRAIN



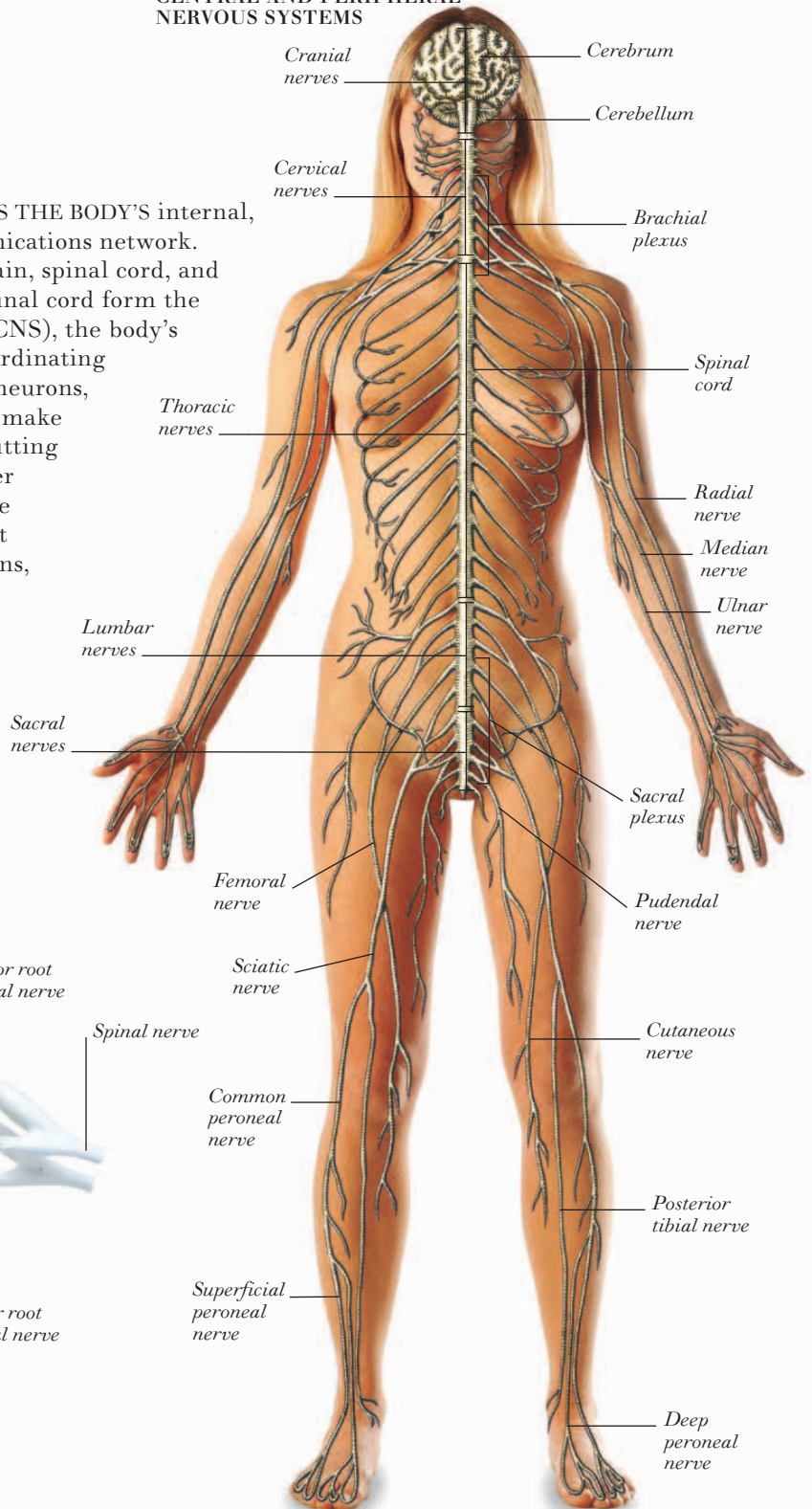
The dark cells are Purkinje's cells, which are among the largest nerve cells in the body.

Nervous system

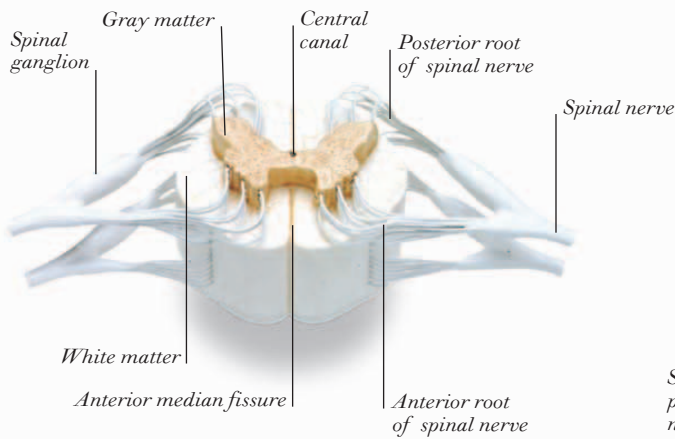


THE NERVOUS SYSTEM IS THE BODY'S internal, electrochemical, communications network. Its main parts are the brain, spinal cord, and nerves. The brain and spinal cord form the central nervous system (CNS), the body's chief controlling and coordinating centers. Billions of long neurons, many grouped as nerves, make up the peripheral nervous system, transmitting nerve impulses between the CNS and other regions of the body. Each neuron has three parts: a cell body, branching dendrites that receive chemical signals from other neurons, and a tubelike axon that conveys these signals as electrical impulses.

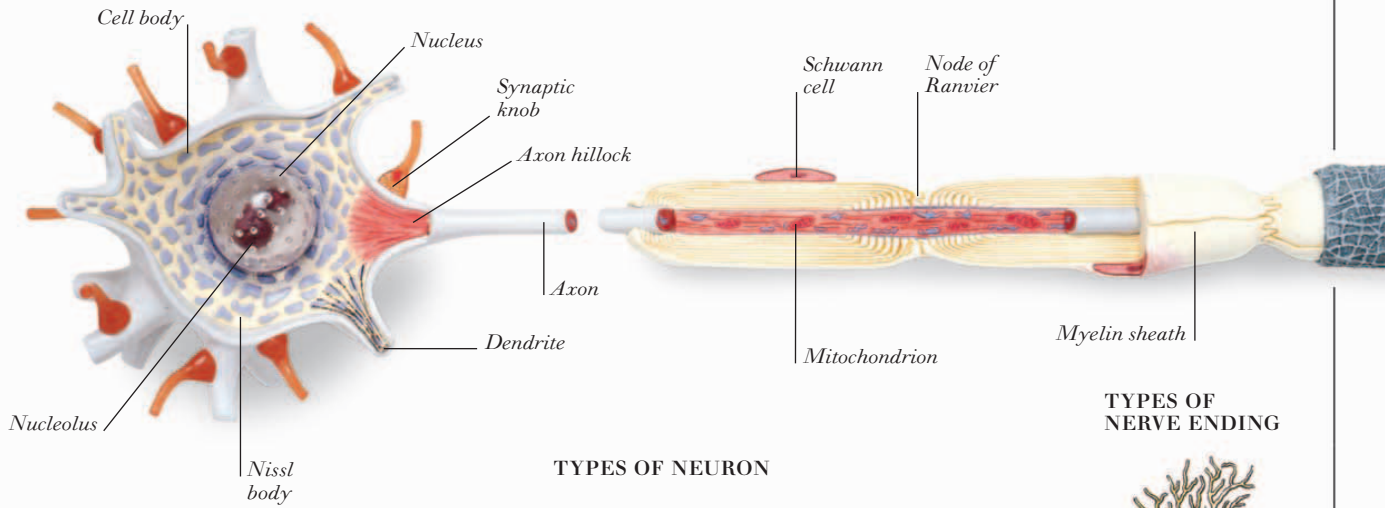
CENTRAL AND PERIPHERAL NERVOUS SYSTEMS



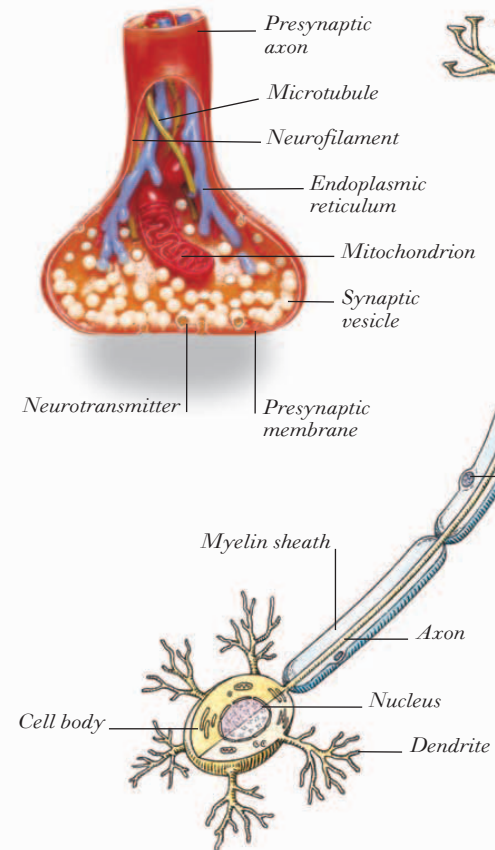
SECTION THROUGH SPINAL CORD



STRUCTURE OF A MOTOR NEURON



STRUCTURE OF A SYNAPTIC KNOB

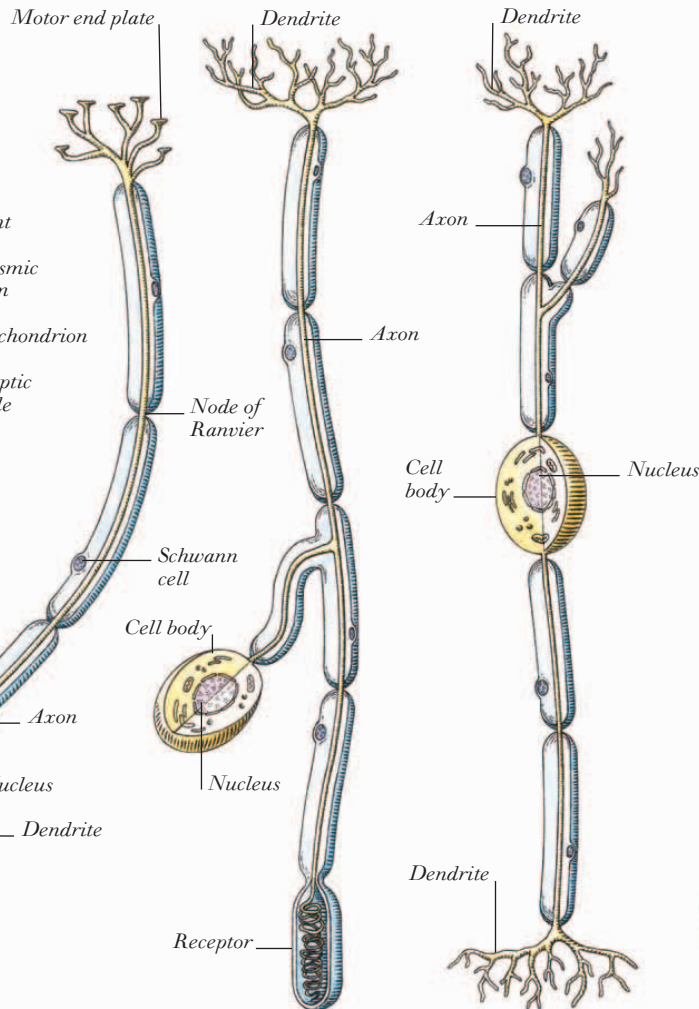


TYPES OF NEURON

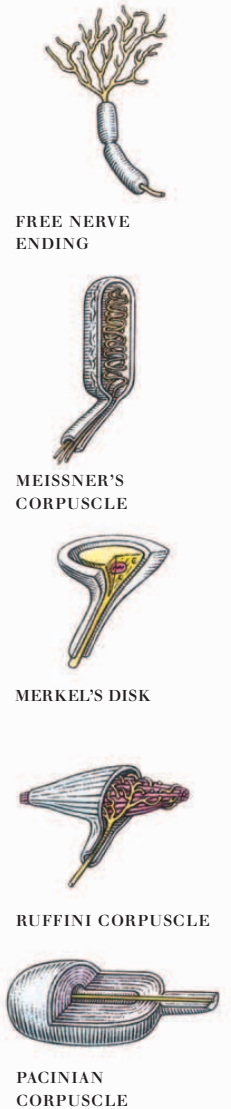
MULTIPOLAR

UNIPOLAR

BIPOLAR

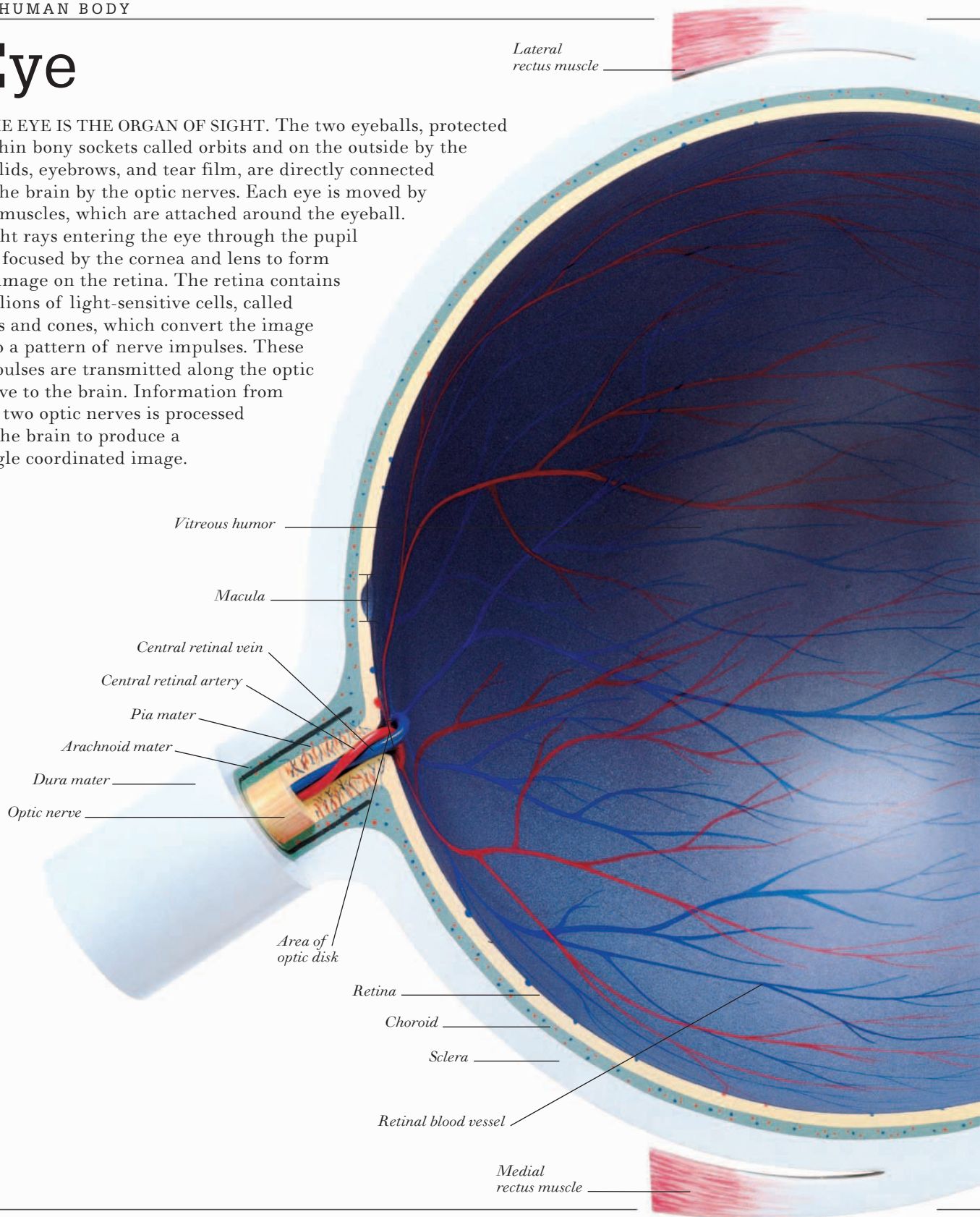


TYPES OF NERVE ENDING

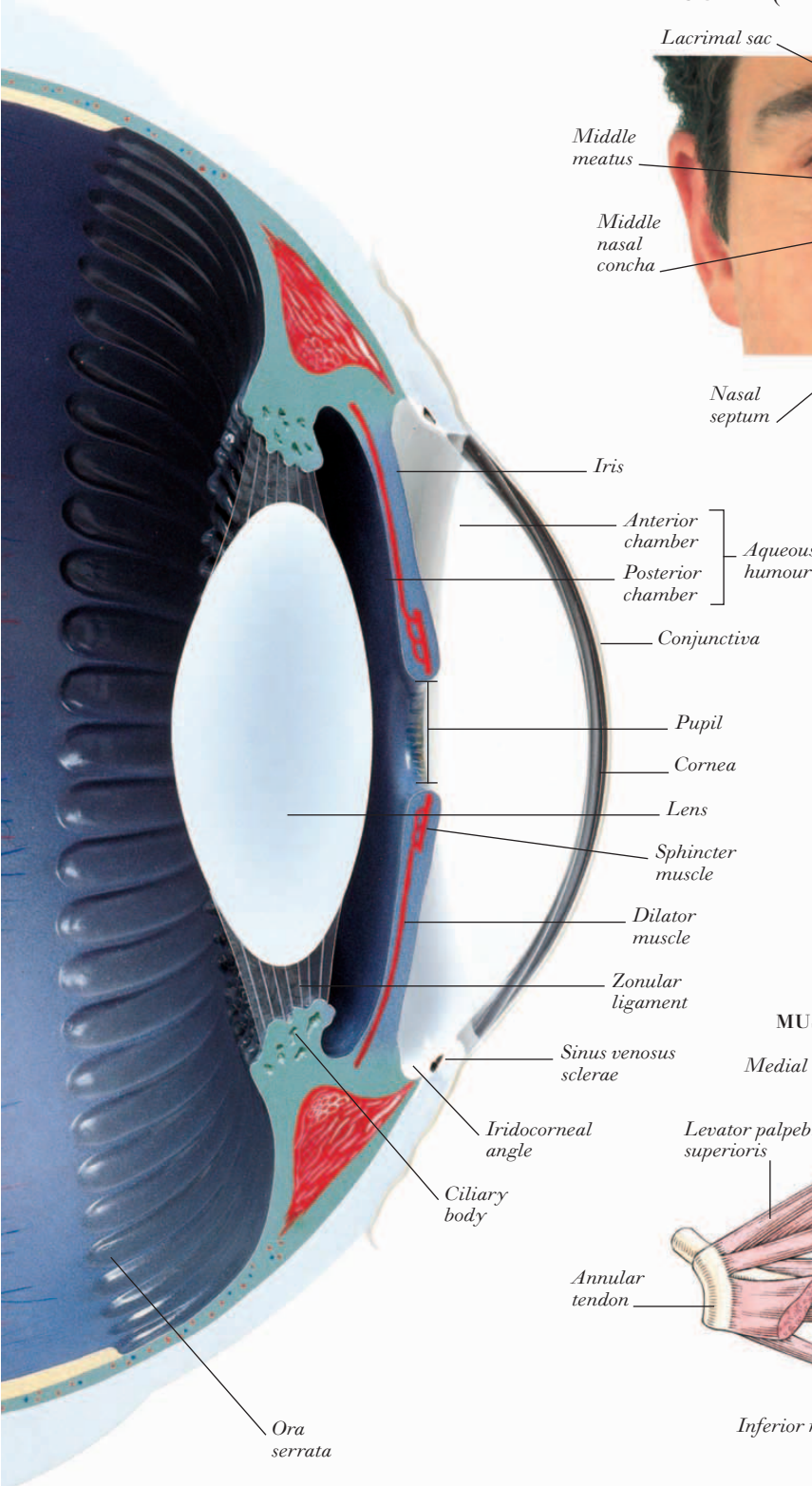


Eye

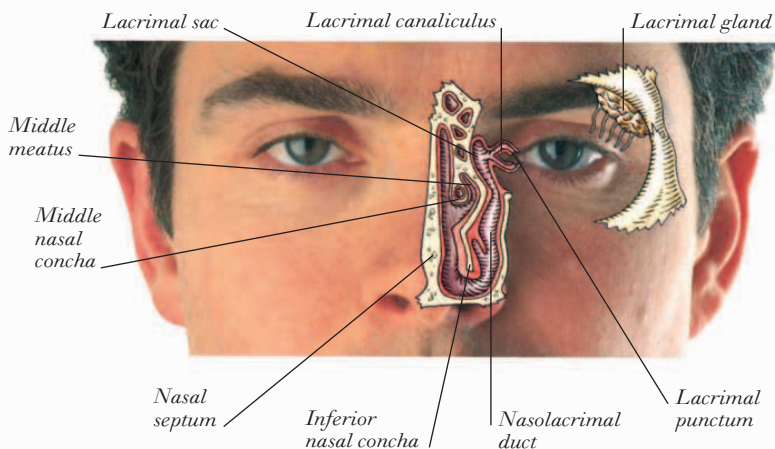
THE EYE IS THE ORGAN OF SIGHT. The two eyeballs, protected within bony sockets called orbits and on the outside by the eyelids, eyebrows, and tear film, are directly connected to the brain by the optic nerves. Each eye is moved by six muscles, which are attached around the eyeball. Light rays entering the eye through the pupil are focused by the cornea and lens to form an image on the retina. The retina contains millions of light-sensitive cells, called rods and cones, which convert the image into a pattern of nerve impulses. These impulses are transmitted along the optic nerve to the brain. Information from the two optic nerves is processed in the brain to produce a single coordinated image.



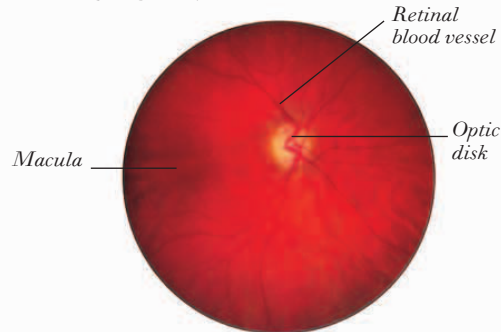
SECTION THROUGH LEFT EYE



LACRIMAL (TEAR-PRODUCING) APPARATUS

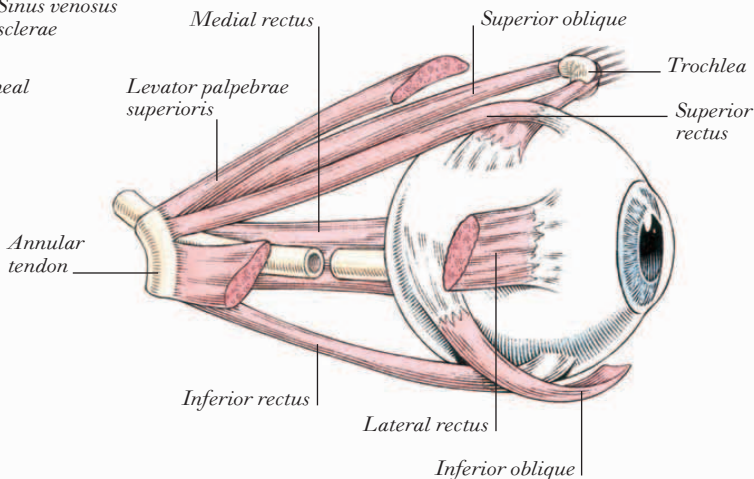


OPHTHALMOSCOPIC VIEW OF RETINA



The blind spot, where the optic nerve leaves the eye, can be clearly seen as a light circular area toward the center of the image.

MUSCLES SURROUNDING RIGHT EYE

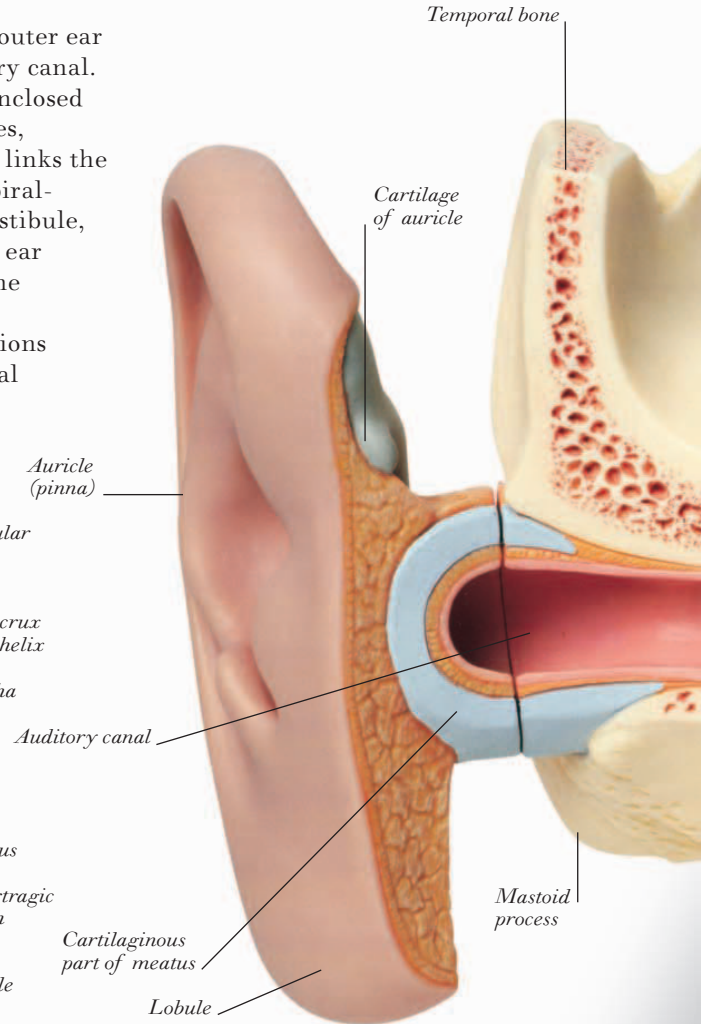
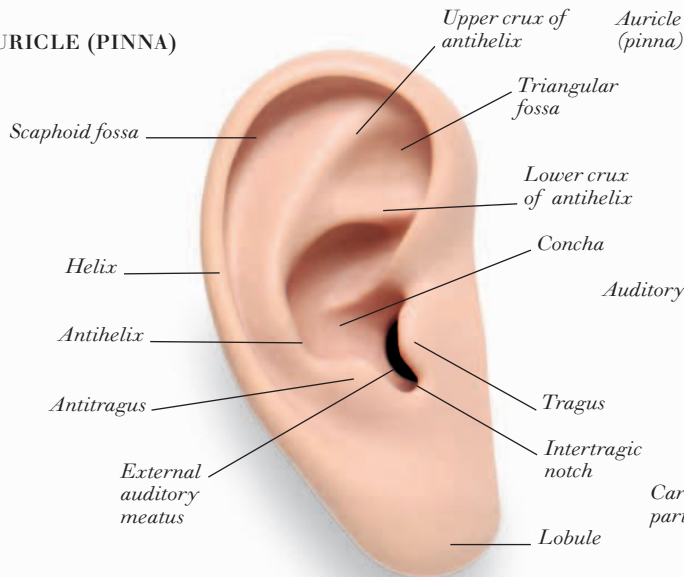


Ear

THE EAR IS THE ORGAN OF HEARING AND BALANCE. The outer ear consists of a flap called the auricle or pinna and the auditory canal. The main functional parts—the middle and inner ears—are enclosed within the skull. The middle ear consists of three tiny bones, known as auditory ossicles, and the eustachian tube, which links the ear to the back of the nose. The inner ear consists of the spiral-shaped cochlea, and also the semicircular canals and the vestibule, which are the organs of balance. Sound waves entering the ear travel through the auditory canal to the tympanic membrane (eardrum), where they are converted to vibrations that are transmitted via the ossicles to the cochlea. Here, the vibrations are converted by millions of microscopic hairs into electrical nerve signals to be interpreted by the brain.

STRUCTURE OF EAR

RIGHT AURICLE (PINNA)



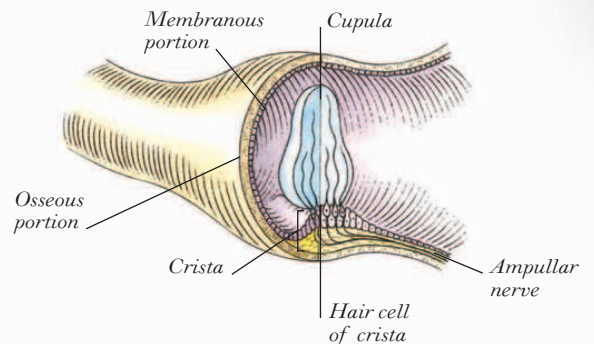
OSSICLES OF MIDDLE EAR

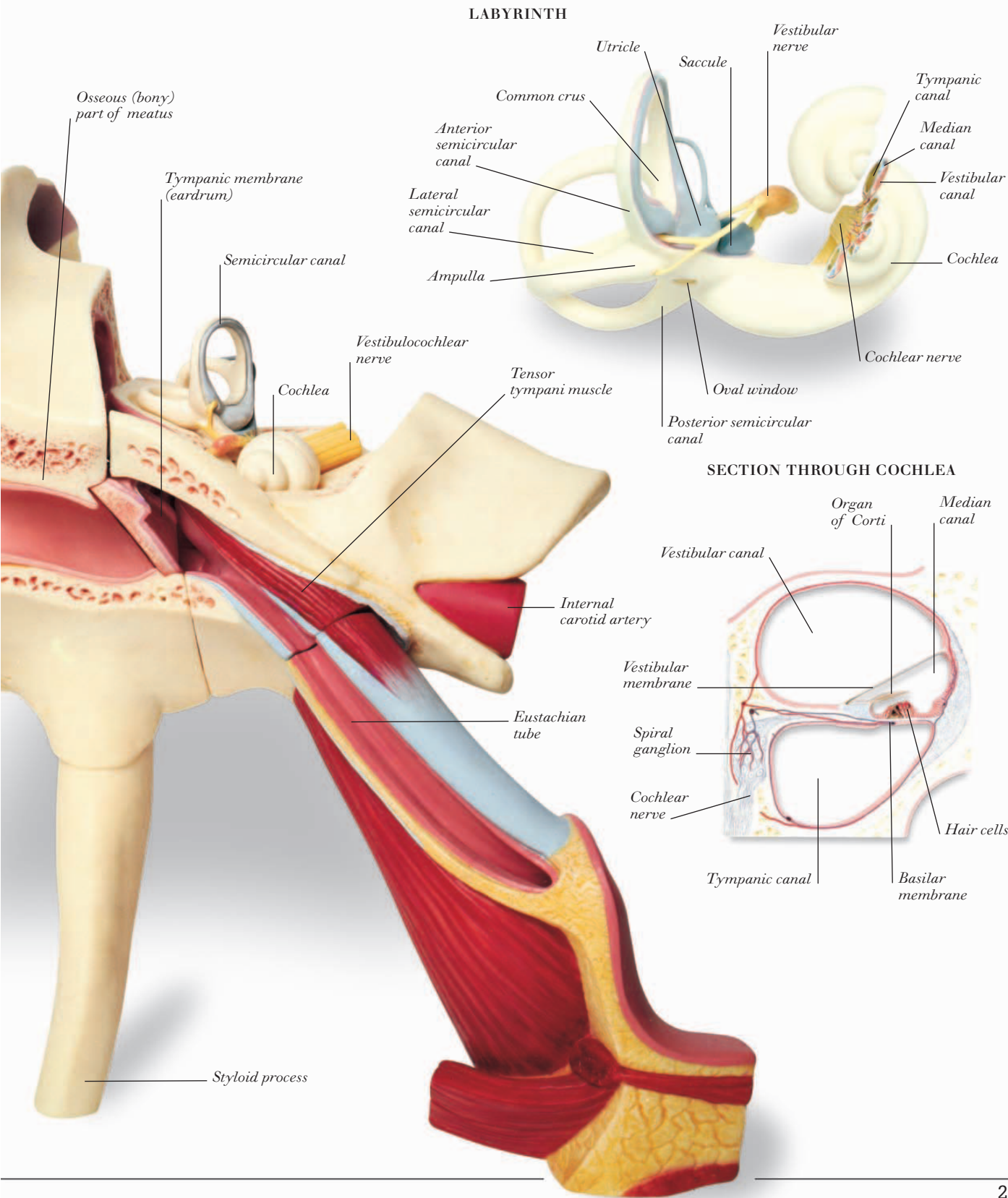


MALLEUS (HAMMER) INCUS (ANVIL) STAPES (STIRRUP)

These three tiny bones connect to form a bridge between the tympanic membrane and the oval window. With a system of membranes they convey sound vibrations to the inner ear.

INTERNAL STRUCTURE OF AMPULLA

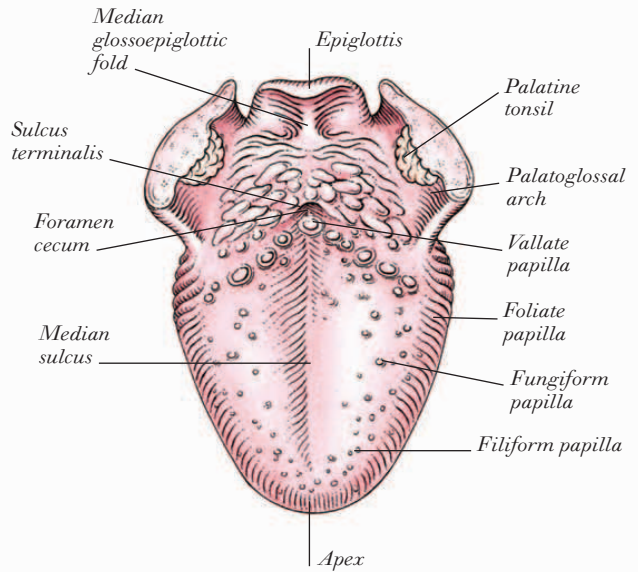




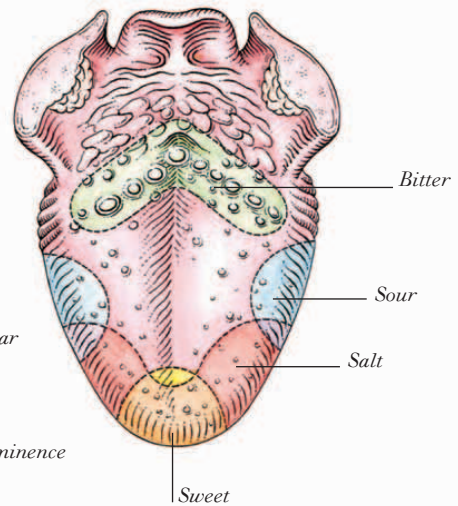
Nose, mouth, and throat

WITH EVERY BREATH, air passes through the nasal cavity down the pharynx (throat), larynx (“voice box”), and trachea (windpipe) to the lungs. The nasal cavity warms and moistens air, and the tiny layers in its lining protect the airway against damage by foreign bodies. During swallowing, the tongue moves up and back, the larynx rises, the epiglottis closes off the entrance to the trachea, and the soft palate separates the nasal cavity from the pharynx. Saliva, secreted from three pairs of salivary glands, lubricates food to make swallowing easier; it also begins the chemical breakdown of food, and helps to produce taste. The senses of taste and smell are closely linked. Both depend on the detection of dissolved molecules by sensory receptors in the olfactory nerve endings of the nose and in the taste buds of the tongue.

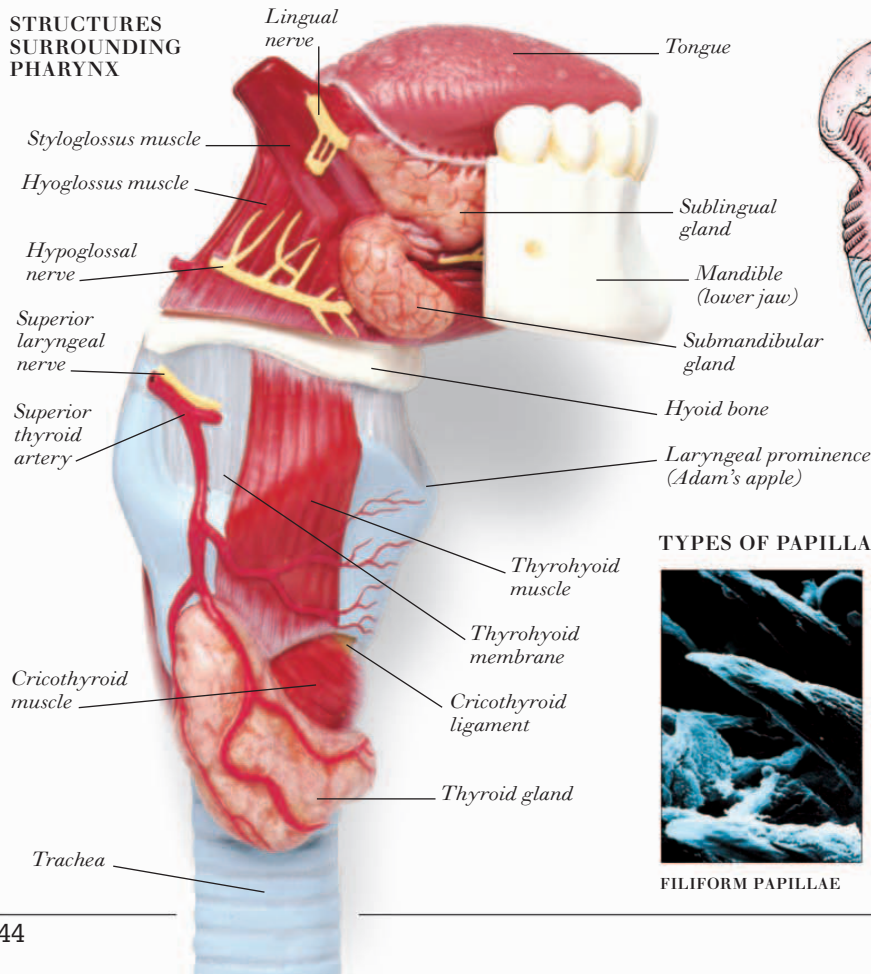
STRUCTURE OF TONGUE



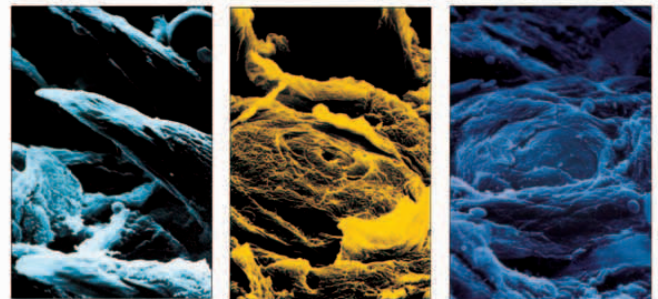
TASTE AREAS ON TONGUE



STRUCTURES SURROUNDING PHARYNX



TYPES OF PAPILLAE

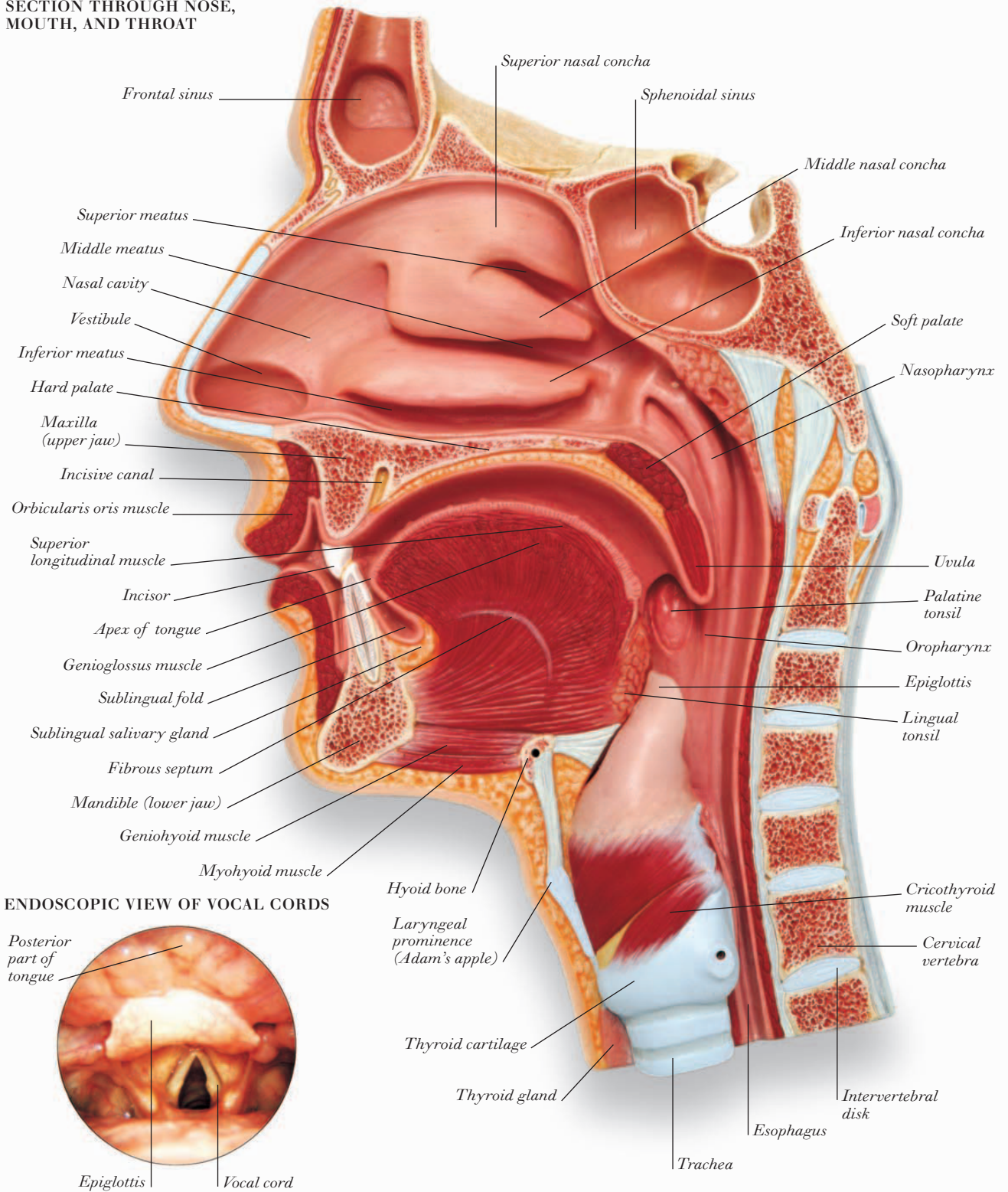


FILIFORM PAPILLAE

FUNGIFORM PAPILLAE

VALLATE PAPILLAE

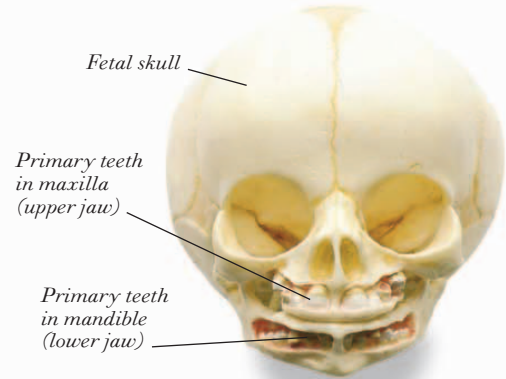
SECTION THROUGH NOSE,
MOUTH, AND THROAT



Teeth

THE 20 PRIMARY TEETH (also called deciduous or baby teeth) usually begin to erupt when a baby is about six months old. They start to be replaced by the permanent teeth when the child is about six years old. By the age of 20, most adults have a full set of 32 teeth although the third molars (commonly called wisdom teeth) may never erupt. While teeth help people to speak clearly and give shape to the face, their main function is the chewing of food. Incisors and canines shear and tear the food into pieces; premolars and molars crush and grind it further. Although tooth enamel is the hardest substance in the body, it tends to be eroded and destroyed by acid produced in the mouth during the breakdown of food.

DEVELOPMENT OF TEETH IN A FETUS



FETAL JAWS

By the sixth week of embryonic development areas of thickening occur in each jaw; these areas give rise to tooth buds. By the time the fetus is six months old, enamel has formed on the tooth buds.

DEVELOPMENT OF JAW AND TEETH



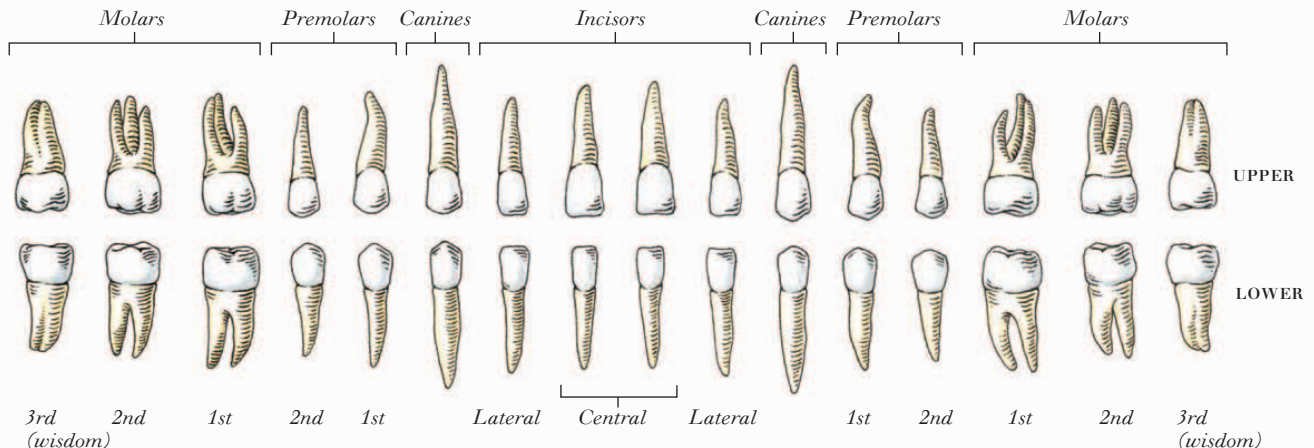
A NEWBORN BABY'S JAWS
The primary teeth can be seen developing in the jaw bones; they begin to erupt around the age of six months.

A FIVE-YEAR-OLD CHILD'S TEETH
There is a full set of 20 erupted primary teeth; the permanent teeth can be seen developing in the upper and lower jaws.

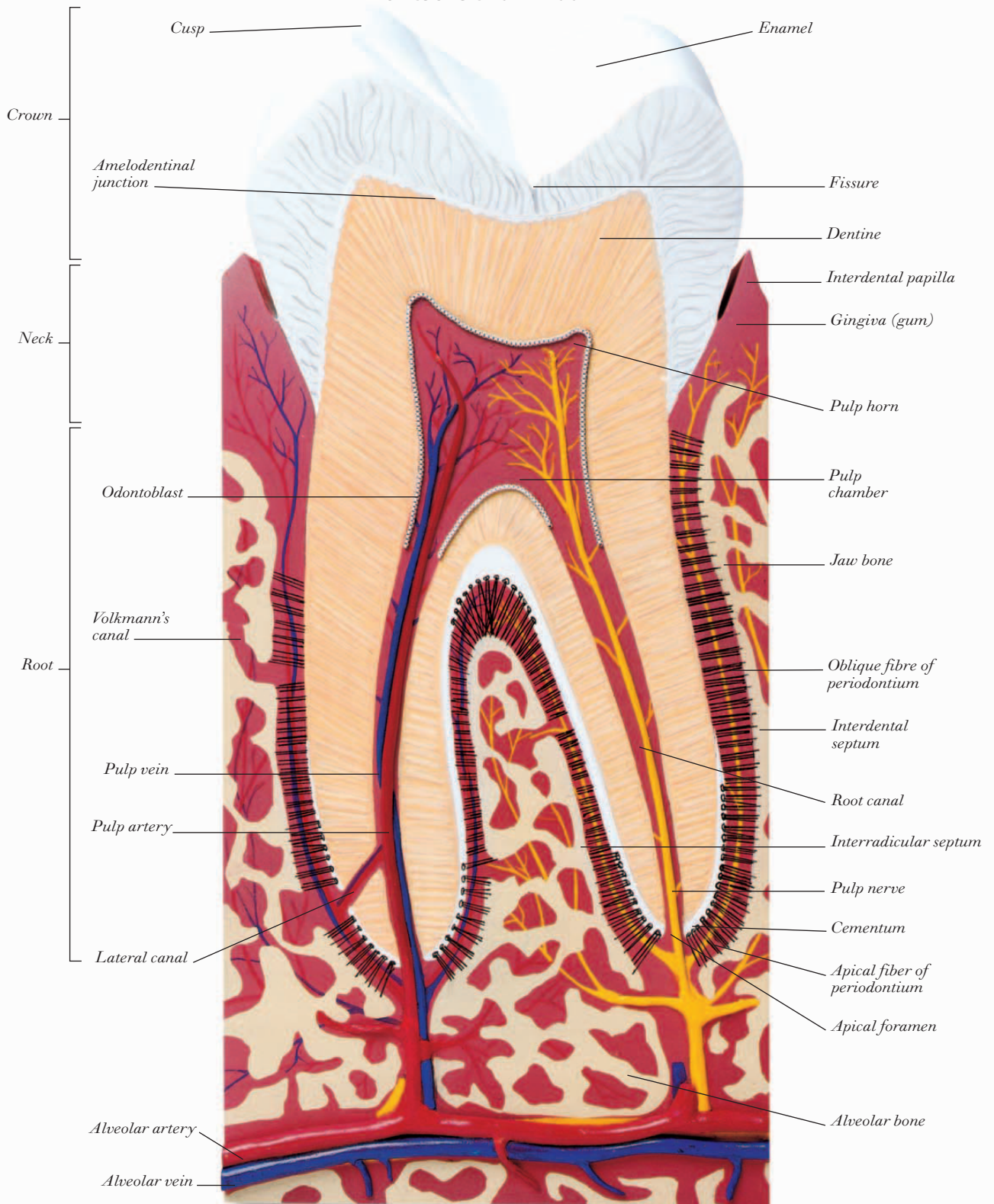
A NINE-YEAR-OLD CHILD'S TEETH
Most of the teeth are primary teeth but the permanent incisors and first molars have now emerged.

AN ADULT'S TEETH
By the age of 20, the full set of 32 permanent teeth (including the wisdom teeth) should be in position.

THE PERMANENT TEETH

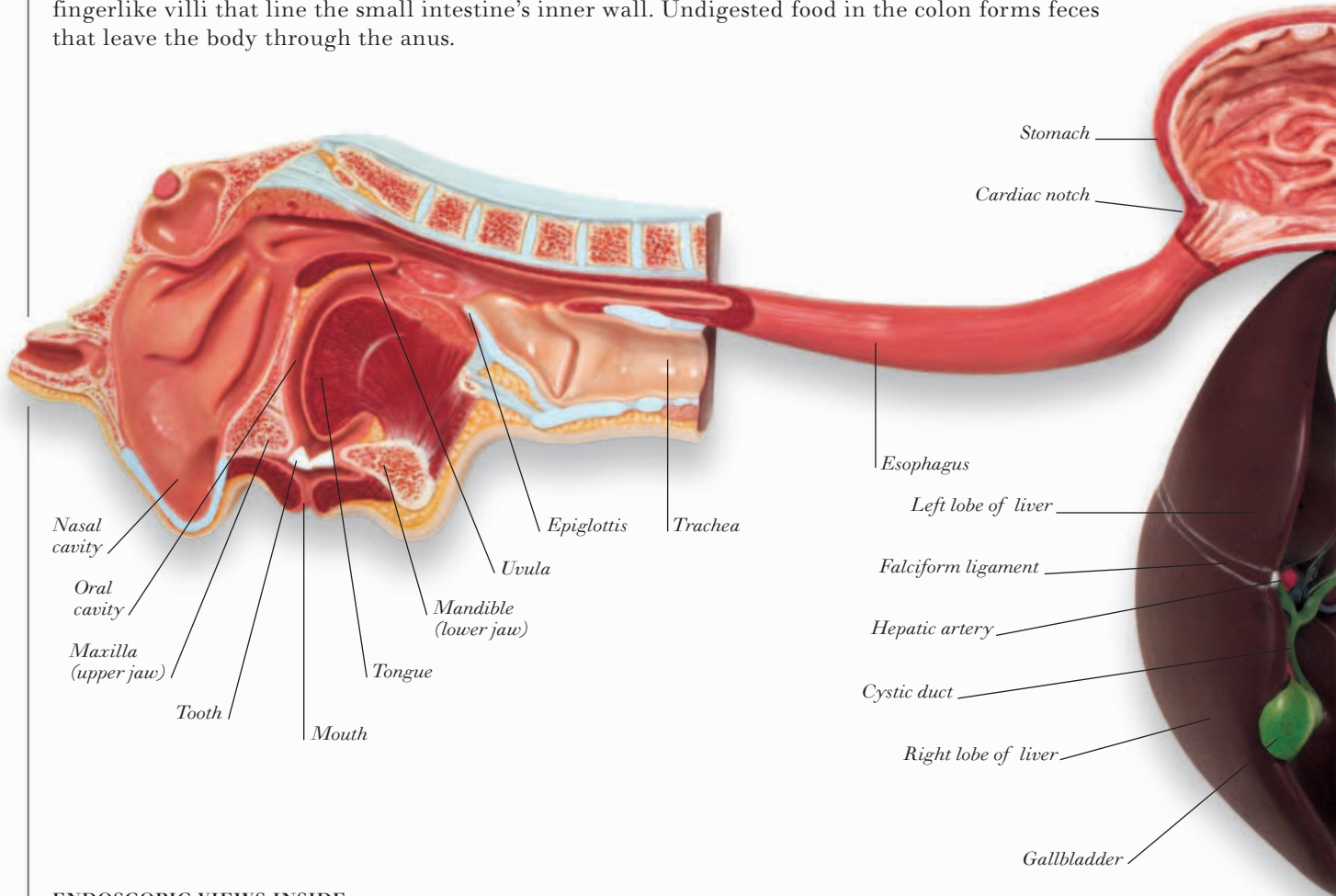


STRUCTURE OF A TOOTH

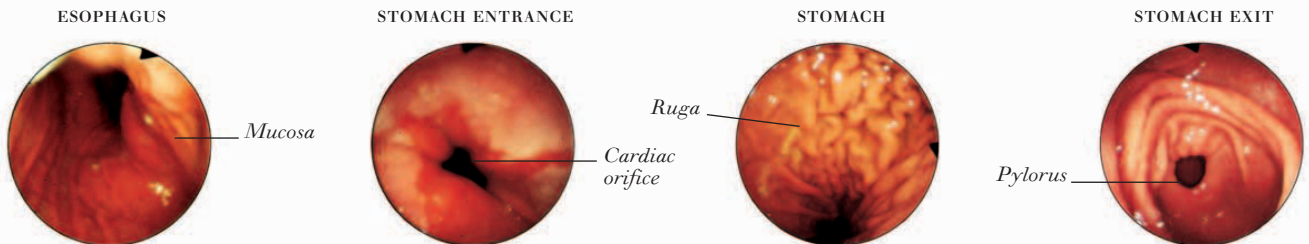


Digestive system

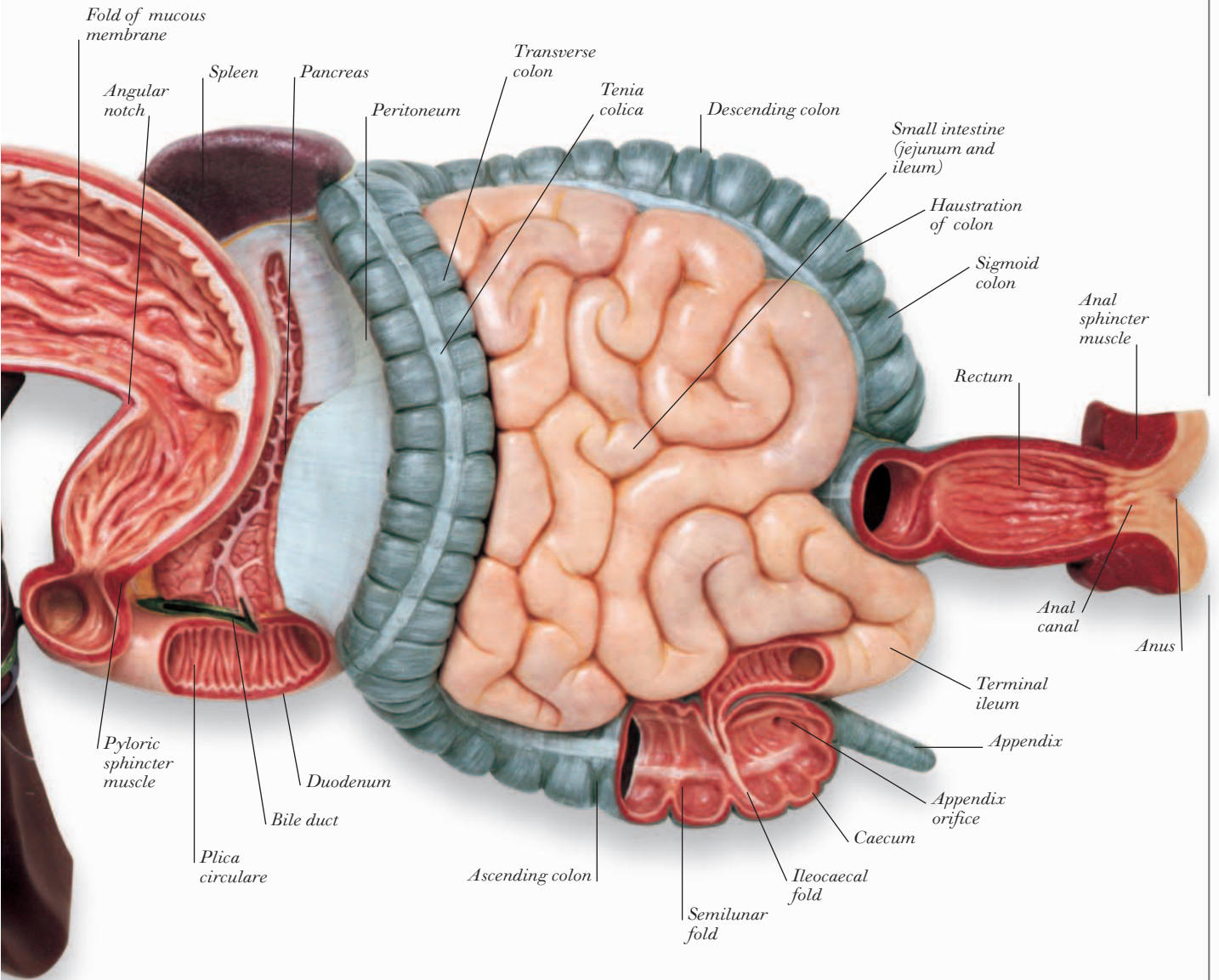
THE DIGESTIVE SYSTEM BREAKS DOWN FOOD into particles so tiny that blood can take nourishment to all parts of the body. The system's main part is a 30 ft (9 m) tube from mouth to rectum; muscles in this alimentary canal force food along. Chewed food first travels through the esophagus to the stomach, which churns and liquidizes food before it passes through the duodenum, jejunum, and ileum—the three parts of the long, convoluted small intestine. Here, digestive juices from the gallbladder and pancreas break down food particles; many filter out into the blood through tiny fingerlike villi that line the small intestine's inner wall. Undigested food in the colon forms feces that leave the body through the anus.



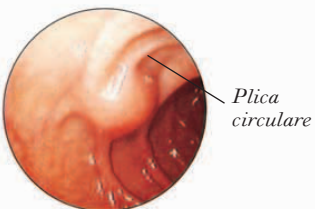
ENDOSCOPIC VIEWS INSIDE ALIMENTARY CANAL



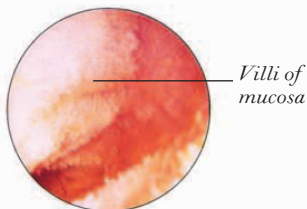
ALIMENTARY CANAL



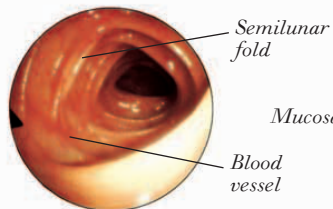
DUODENUM



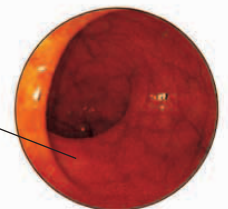
ILEUM



COLON

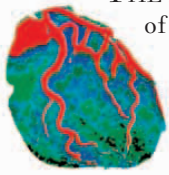


RECTUM



Heart

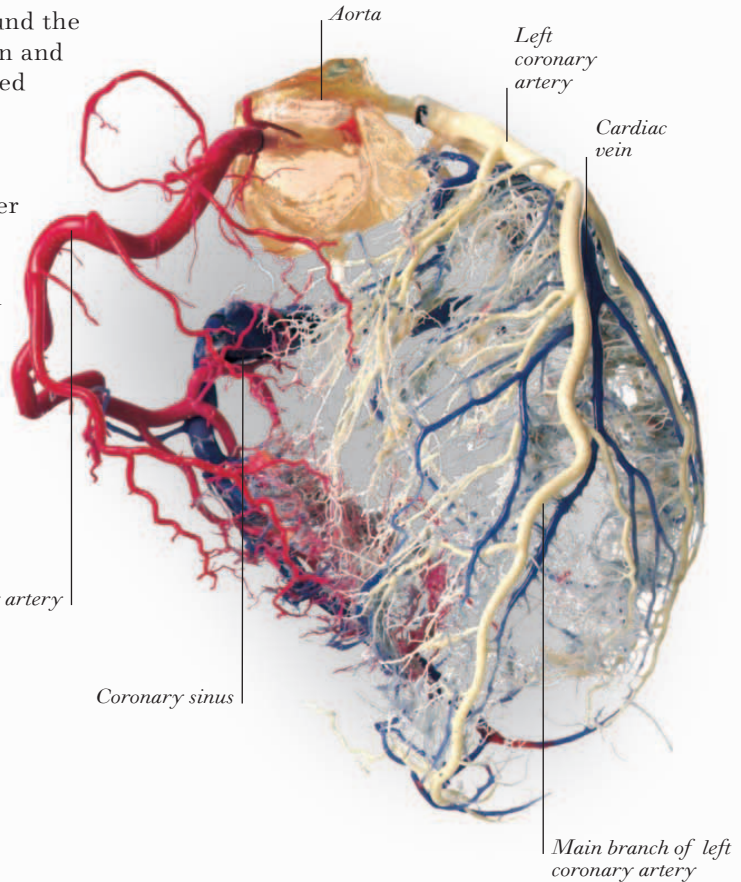
ARTERIES AND VEINS SURROUNDING HEART



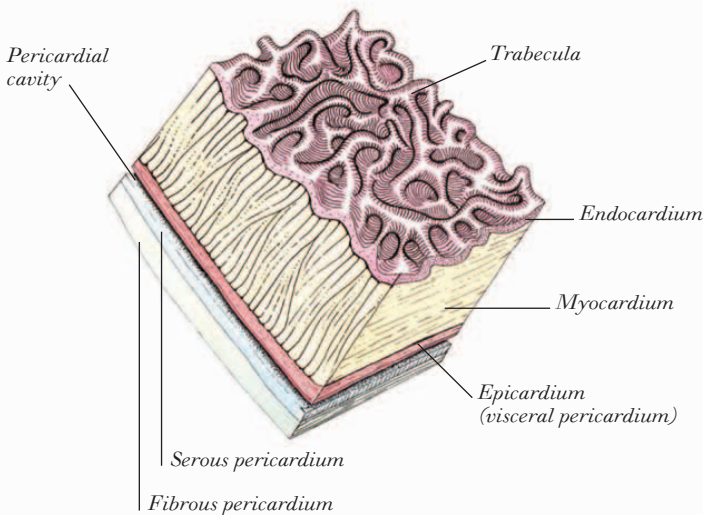
THE HEART IS A HOLLOW MUSCLE in the middle of the chest that pumps blood around the body, supplying cells with oxygen and nutrients. A muscular wall, called the septum, divides the heart lengthwise into left and right sides. A valve divides each side

into two chambers: an upper atrium and a lower ventricle. When the heart muscle contracts, it squeezes blood through the atria and then through the ventricles. Oxygenated blood from the lungs flows from the pulmonary veins into the left atrium, through the left ventricle, and then out via the aorta to all parts of the body. Deoxygenated blood returning from the body flows from the vena cava into the right atrium, through the right ventricle, and then out via the pulmonary artery to the lungs for reoxygenation.

At rest the heart beats between 60 and 80 times a minute; during exercise or at times of stress or excitement the rate may increase to 200 beats a minute.

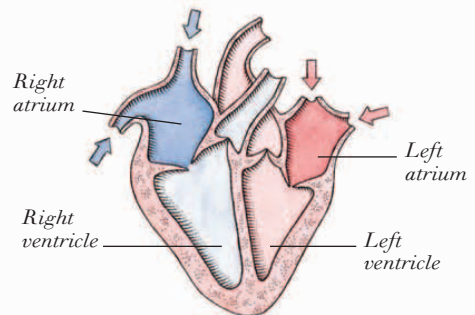


SECTION THROUGH HEART WALL



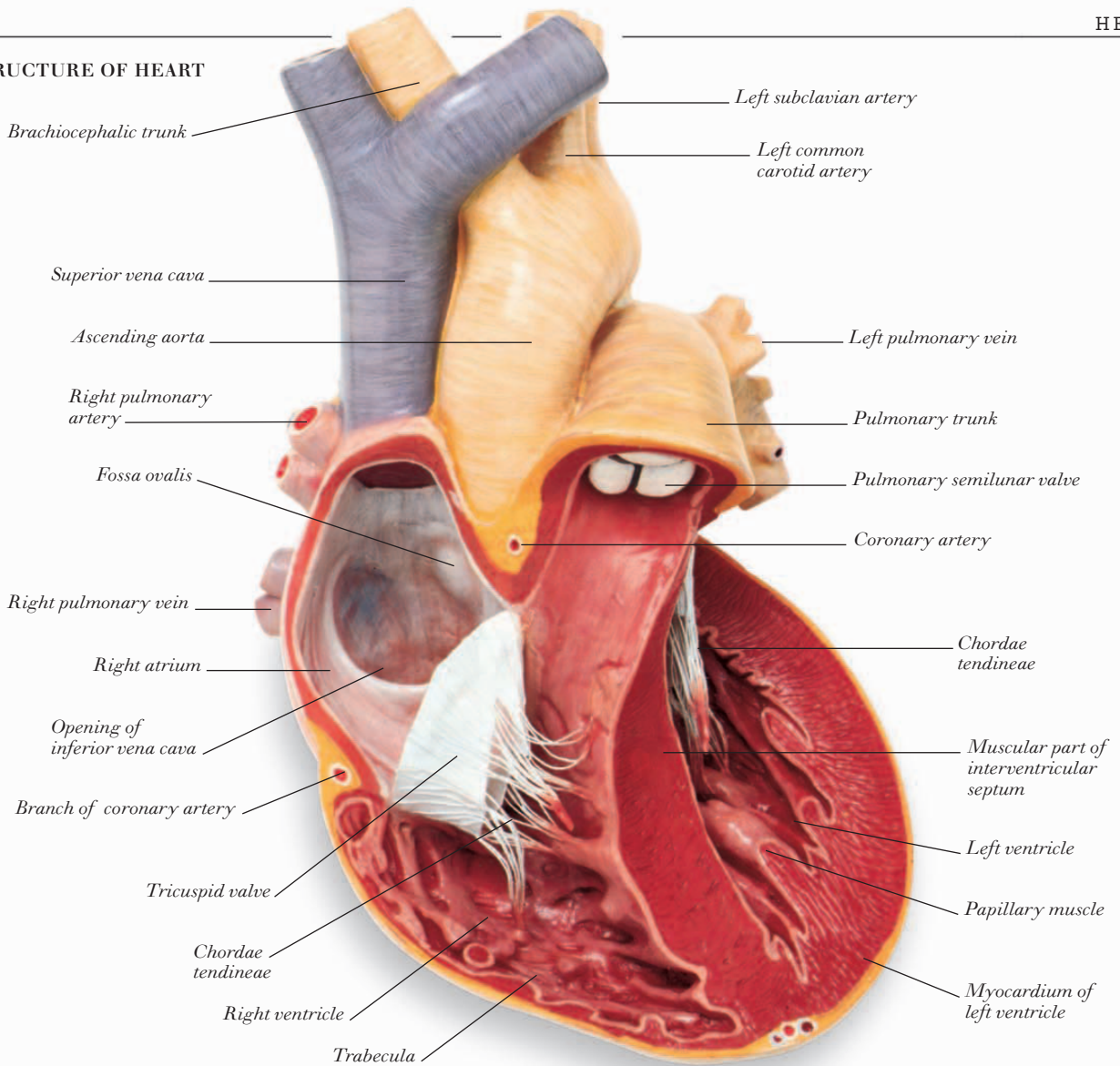
HEARTBEAT SEQUENCE

ATRIAL DIASTOLE

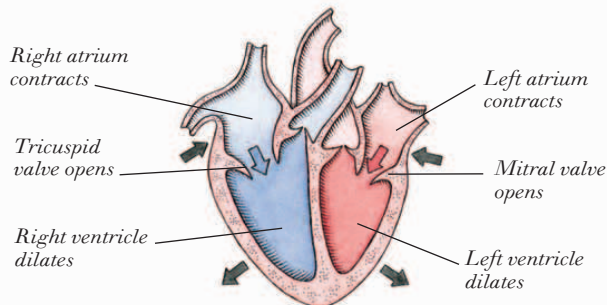


Deoxygenated blood enters the right atrium while the left atrium receives oxygenated blood.

STRUCTURE OF HEART

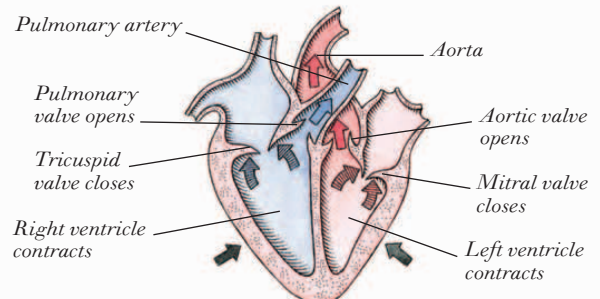


ATRIAL SYSTOLE (VENTRICULAR DIASTOLE)



Left and right atria contract, forcing blood into the relaxed ventricles.

VENTRICULAR SYSTOLE



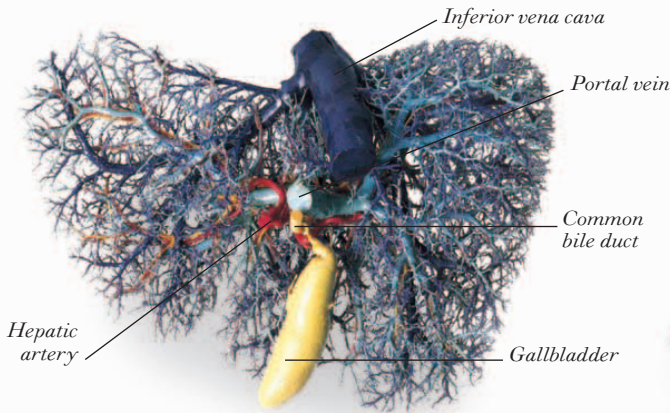
Ventricles contract and force blood to the lungs for oxygenation and via the aorta to the rest of the body.

Circulatory system

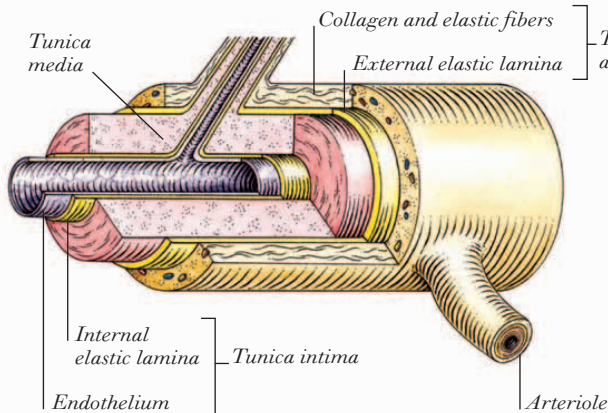


THE CIRCULATORY SYSTEM consists of the heart and blood vessels, which together maintain a continuous flow of blood around the body. The heart pumps oxygen-rich blood from the lungs to all parts of the body through a network of tubes called arteries, and smaller branches called arterioles. Blood returns to the heart via small vessels called venules, which lead in turn into larger tubes called veins. Arterioles and venules are linked by a network of tiny vessels called capillaries, where the exchange of oxygen and carbon dioxide between blood and body cells takes place. Blood has four main components: red blood cells, white blood cells, platelets, and liquid plasma.

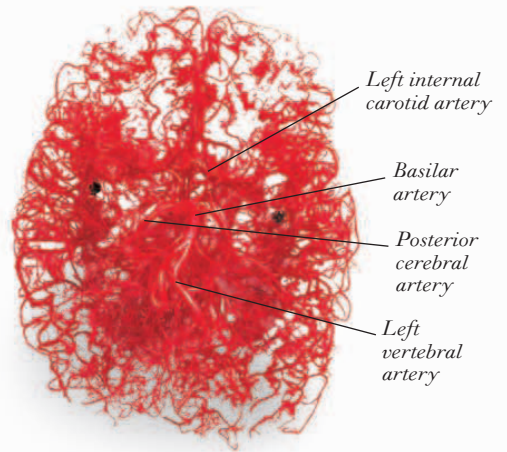
CIRCULATORY SYSTEM OF LIVER



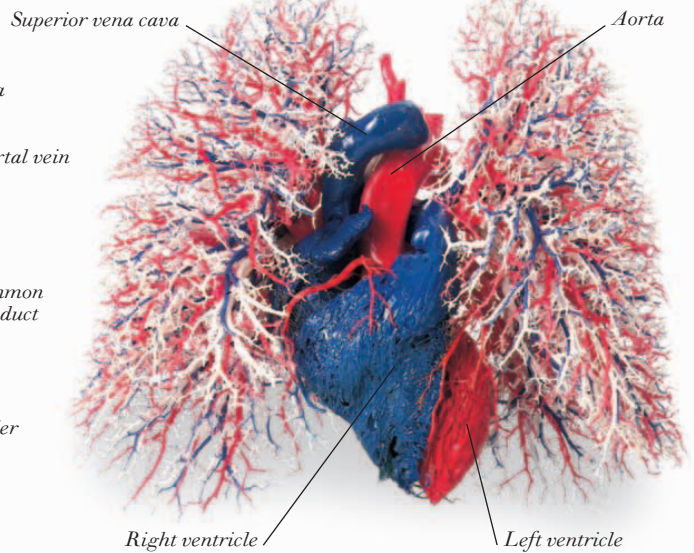
SECTION OF MAIN ARTERY



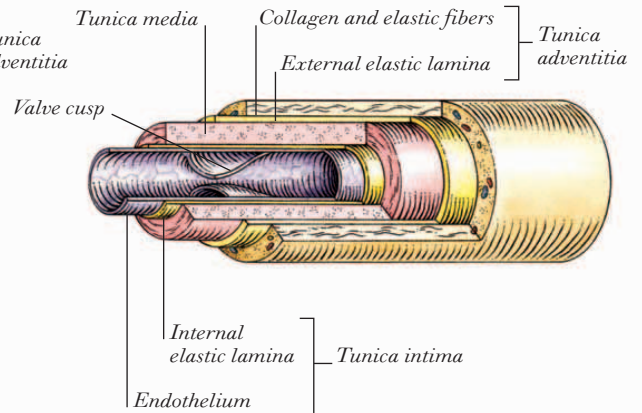
ARTERIAL SYSTEM OF BRAIN



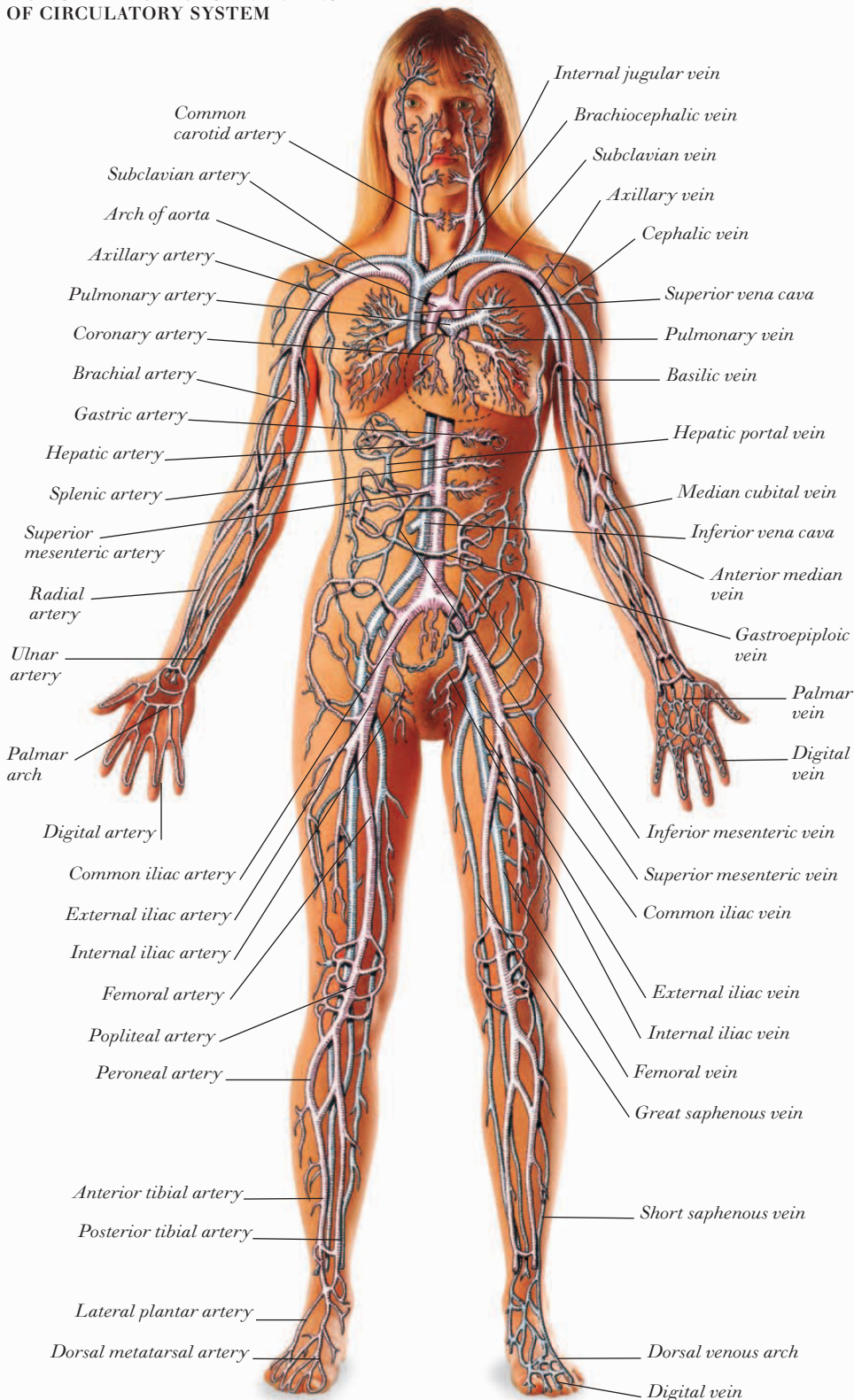
CIRCULATORY SYSTEM OF HEART AND LUNGS



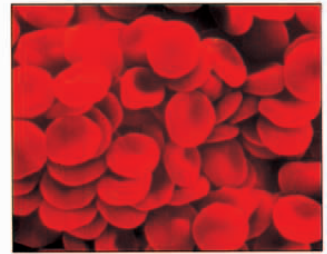
SECTION OF MAIN VEIN



PRINCIPAL ARTERIES AND VEINS OF CIRCULATORY SYSTEM

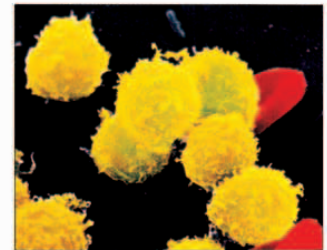


TYPES OF BLOOD CELLS



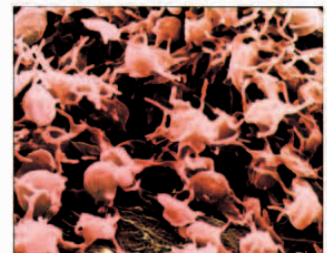
RED BLOOD CELLS

These cells are biconcave in shape to maximize their oxygen-carrying capacity.



WHITE BLOOD CELLS

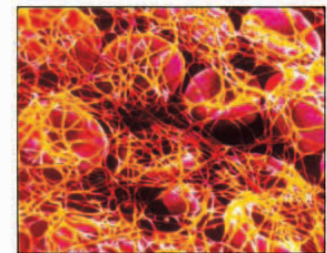
Lymphocytes are the smallest white blood cells; they form antibodies against disease.



PLATELETS

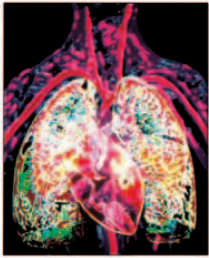
Tiny cells that are activated whenever blood clotting or repair to vessels is necessary.

BLOOD CLOTTING



Filaments of fibrin enmesh red blood cells as part of the process of blood clotting.

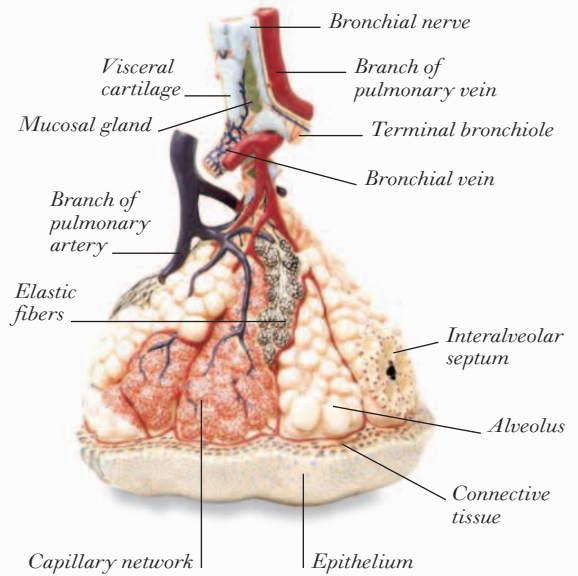
Respiratory system



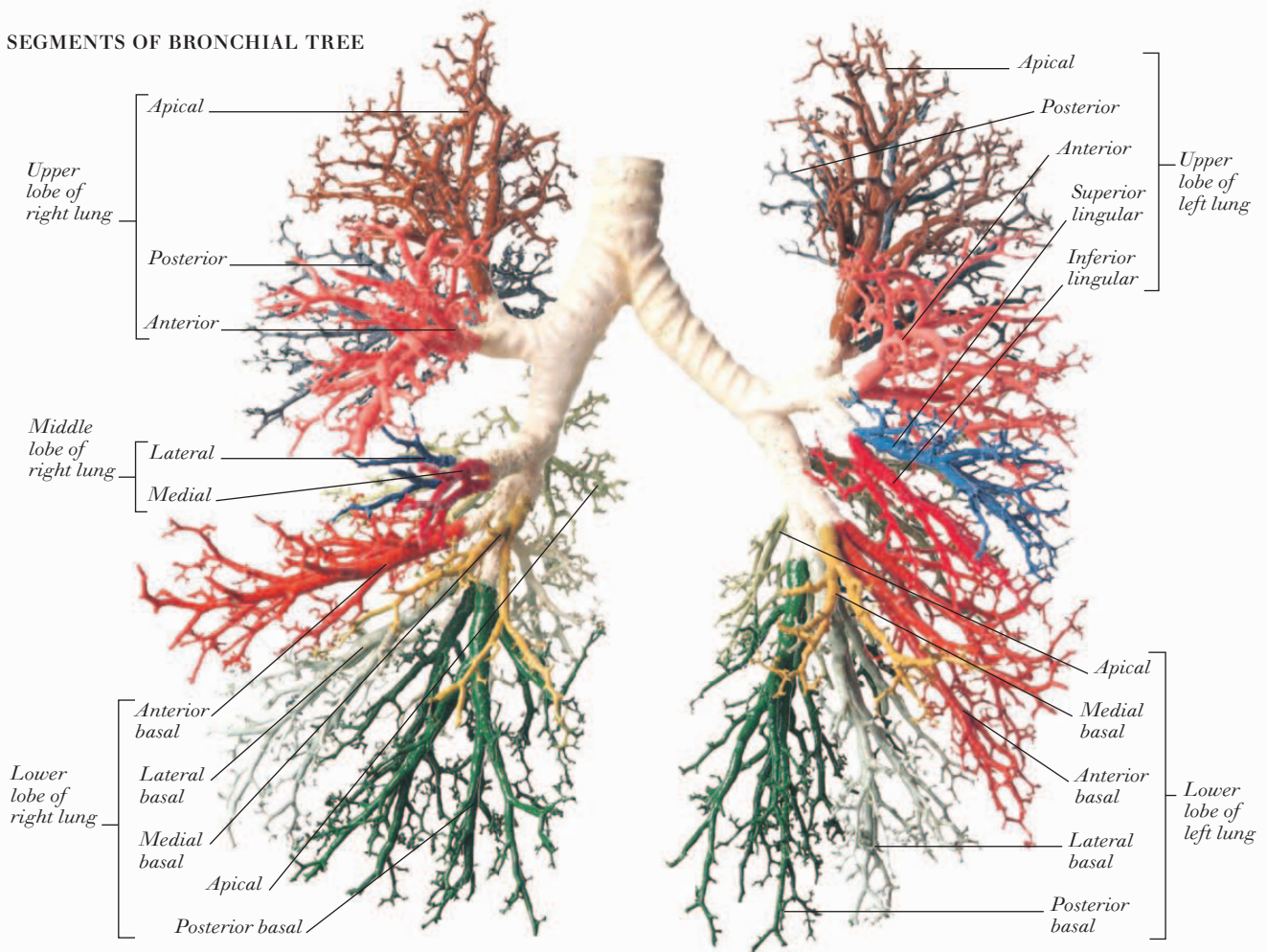
THE RESPIRATORY SYSTEM supplies the oxygen needed by body cells and carries off their carbon dioxide waste. Inhaled air passes via the trachea (windpipe) through two narrower tubes, the bronchi, to the lungs. Each lung comprises many fine, branching tubes called bronchioles that end in tiny clustered chambers called alveoli. Gases cross the thin

alveolar walls to and from a network of tiny blood vessels. Intercostal (rib) muscles and the muscular diaphragm below the lungs operate the lungs like bellows, drawing air in and forcing it out at regular intervals.

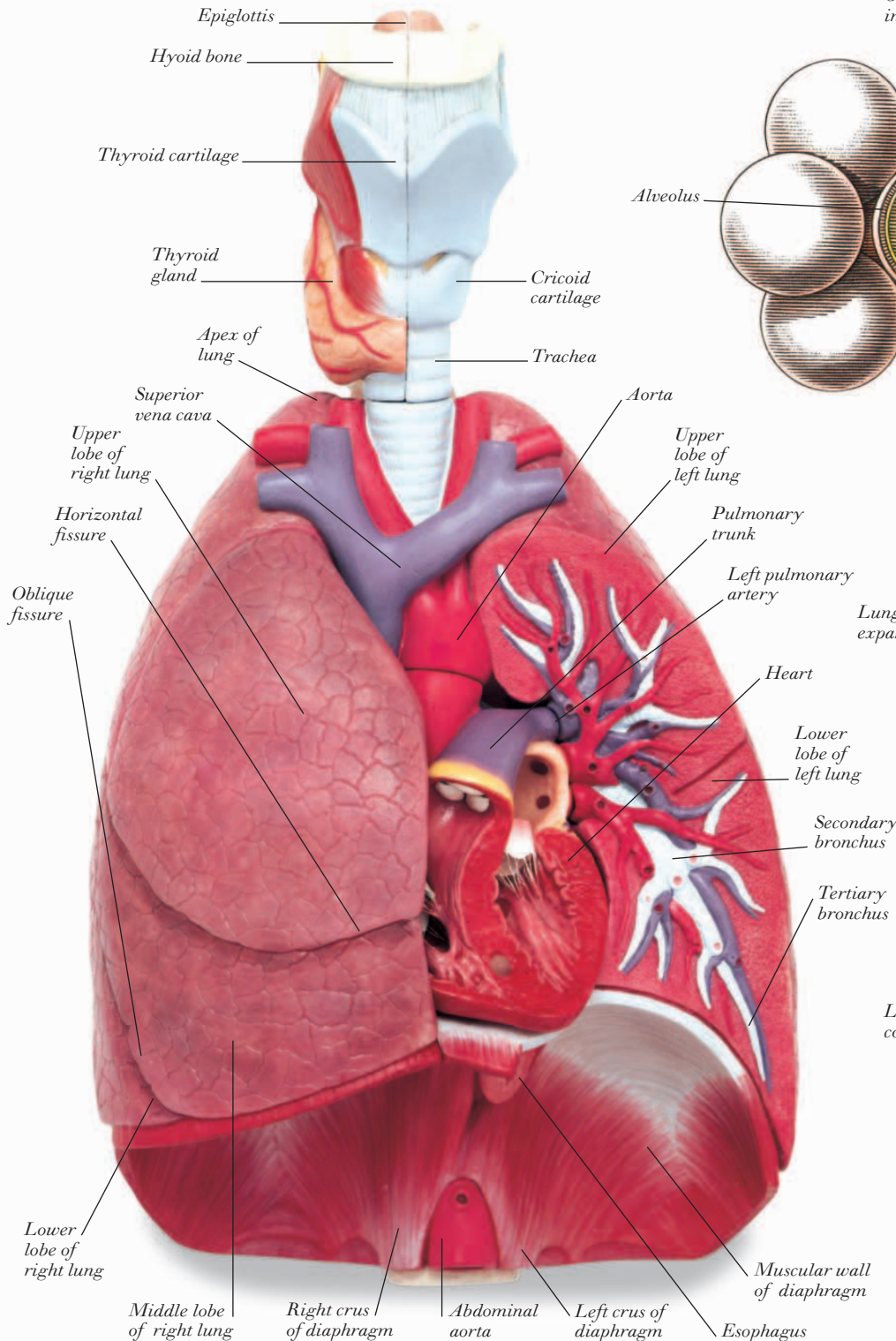
BRONCHIOLE AND ALVEOLI



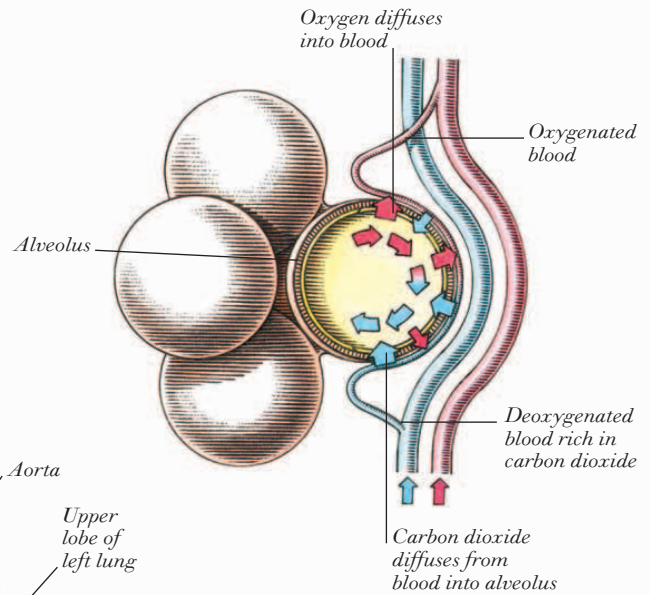
SEGMENTS OF BRONCHIAL TREE



STRUCTURES OF THORACIC CAVITY

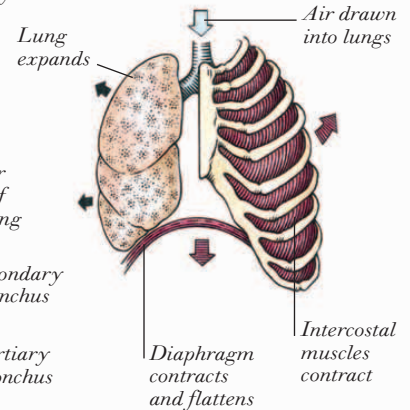


GASEOUS EXCHANGE IN ALVEOLUS

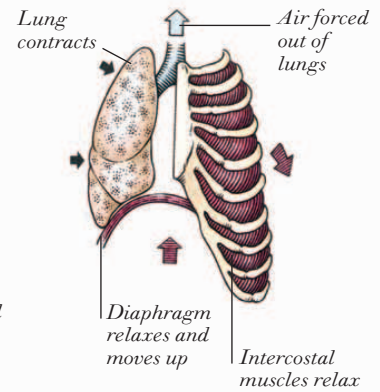


MECHANISM OF RESPIRATION

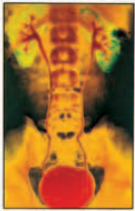
INSPIRATION



EXPIRATION

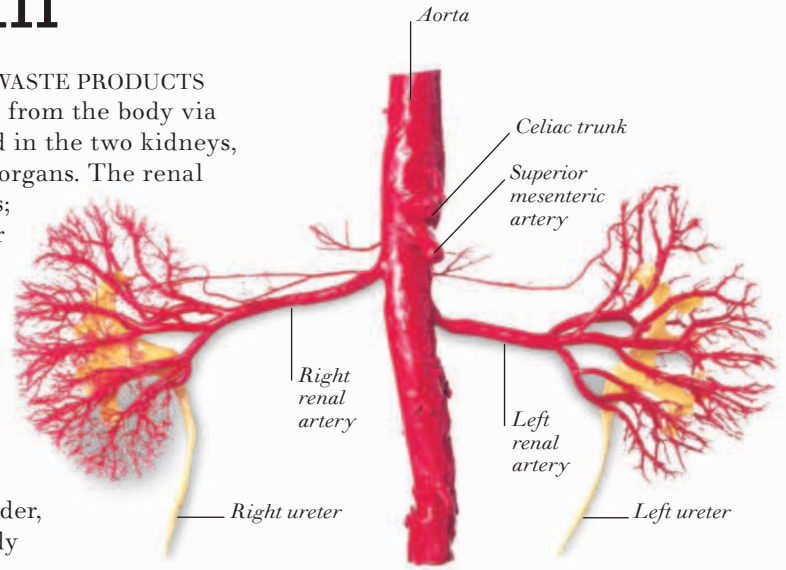


Urinary system

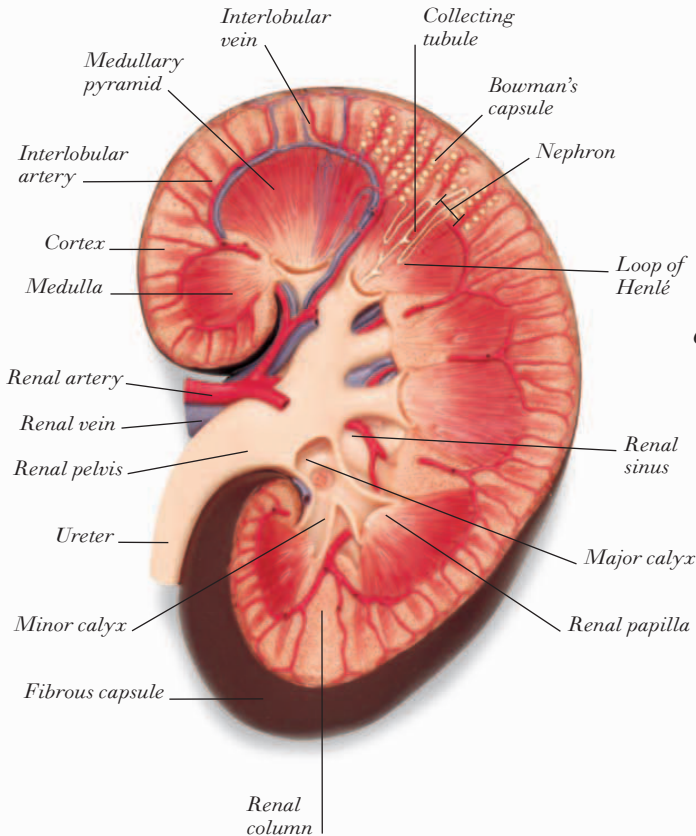


THE URINARY SYSTEM FILTERS WASTE PRODUCTS from the blood and removes them from the body via a system of tubes. Blood is filtered in the two kidneys, which are fist-sized, bean-shaped organs. The renal arteries carry blood to the kidneys; the renal veins remove blood after filtering. Each kidney contains about one million tiny units called nephrons. Each nephron is made up of a tubule and a filtering unit called a glomerulus, which consists of a collection of tiny blood vessels surrounded by the hollow Bowman's capsule. The filtering process produces a watery fluid that leaves the kidney as urine. The urine is carried via two tubes called ureters to the bladder, where it is stored until its release from the body through another tube called the urethra.

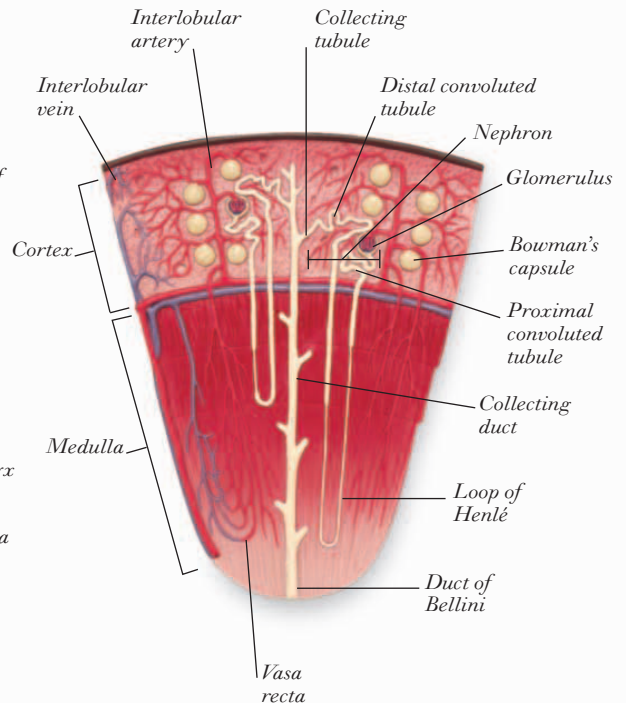
ARTERIAL SYSTEM OF KIDNEYS



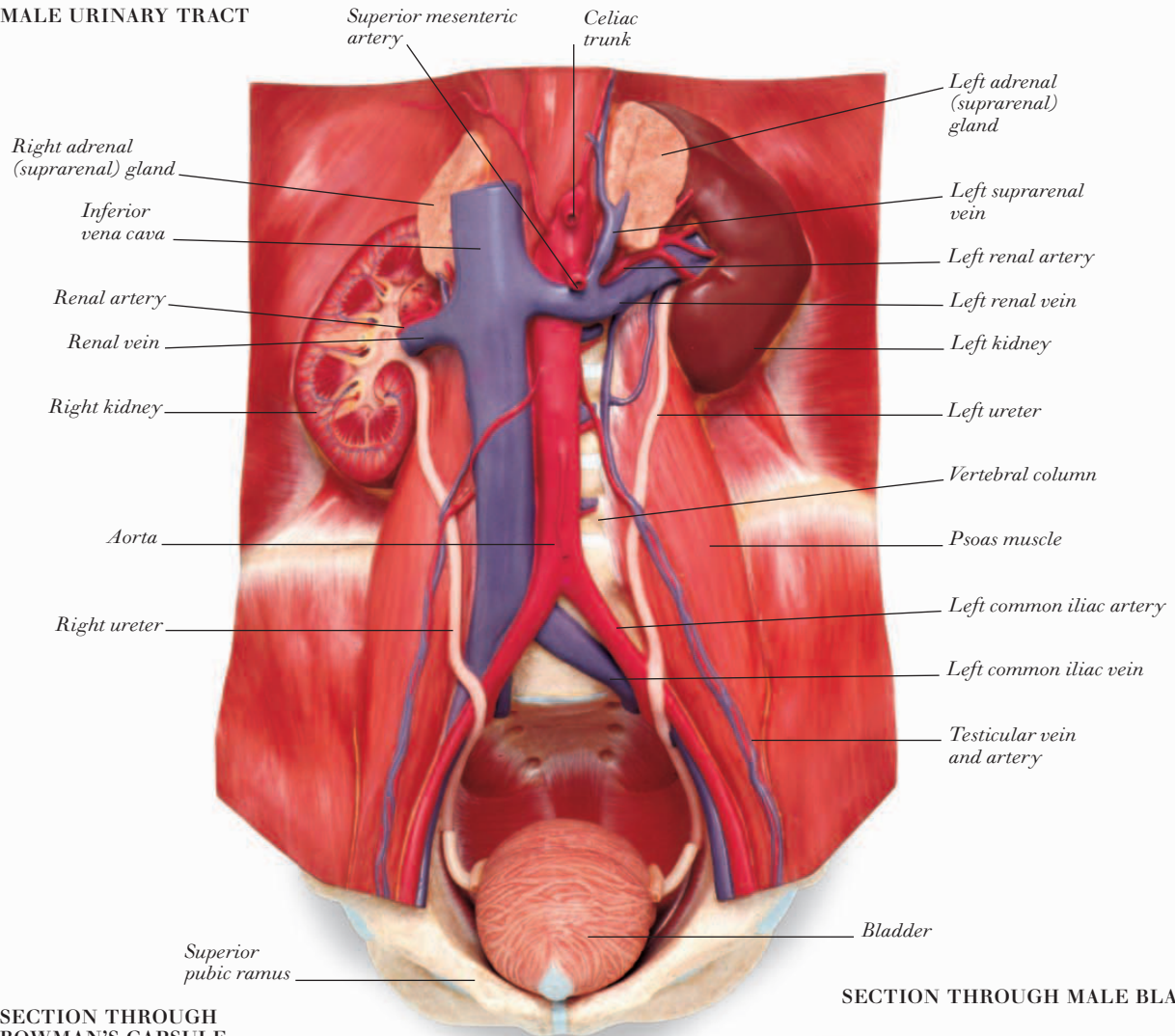
SECTION THROUGH LEFT KIDNEY



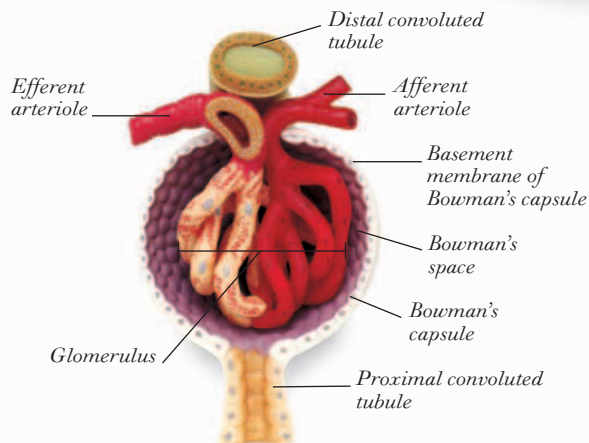
SECTION OF KIDNEY



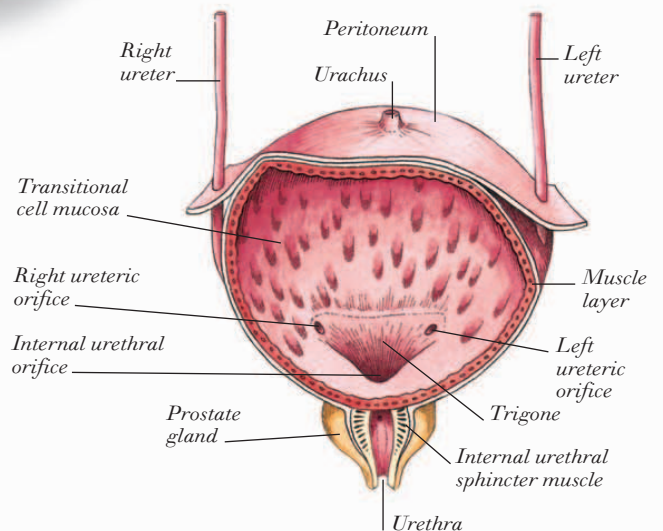
MALE URINARY TRACT



SECTION THROUGH BOWMAN'S CAPSULE



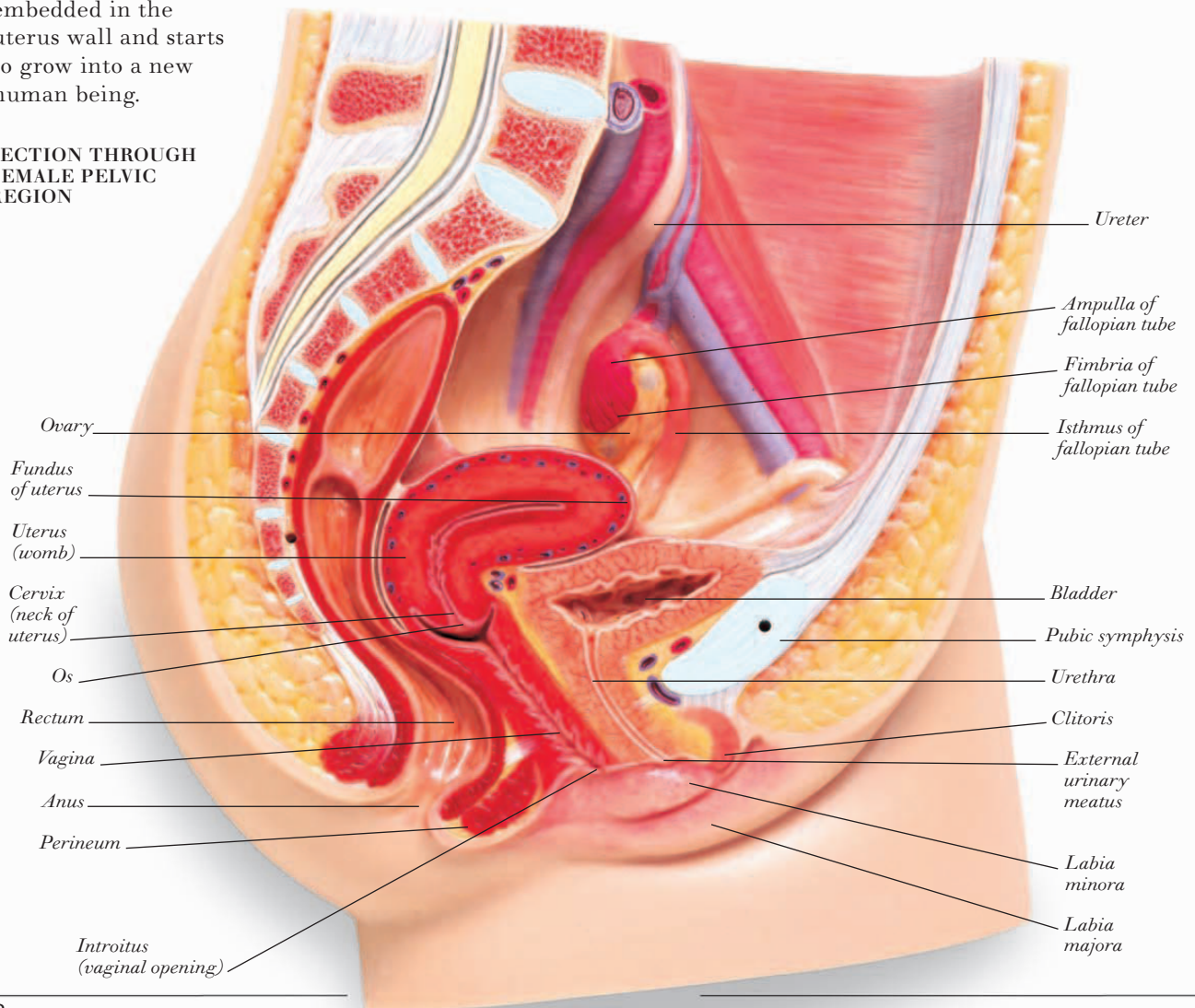
SECTION THROUGH MALE BLADDER



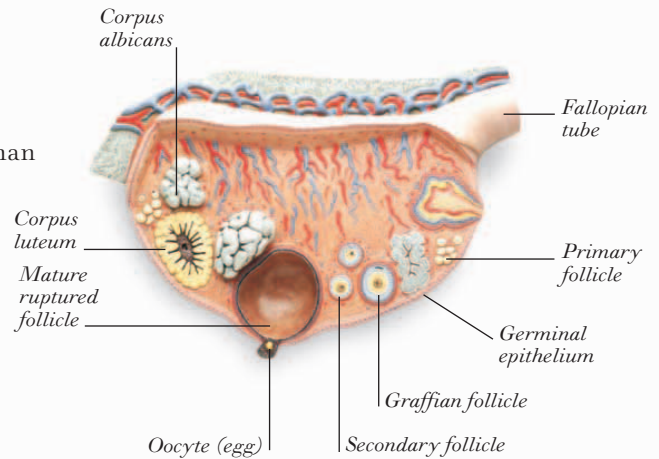
Reproductive system

SEX ORGANS LOCATED IN THE PELVIS create new human lives. Each month a ripe egg is released from one of the female's ovaries into a fallopian tube leading to the uterus (womb), a muscular pear-sized organ. A male produces minute tadpolelike sperm in two oval glands called testes. When the male is ready to release sperm into the female's vagina, many millions pass into his urethra and leave his body through the fleshy penis. The sperm travel up through the vagina into the uterus and fallopian tubes, and one sperm may enter and fertilize an egg. The fertilized egg becomes embedded in the uterus wall and starts to grow into a new human being.

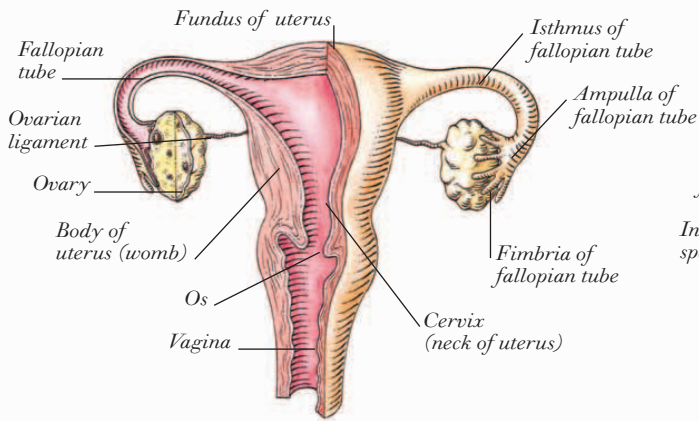
SECTION THROUGH FEMALE PELVIC REGION



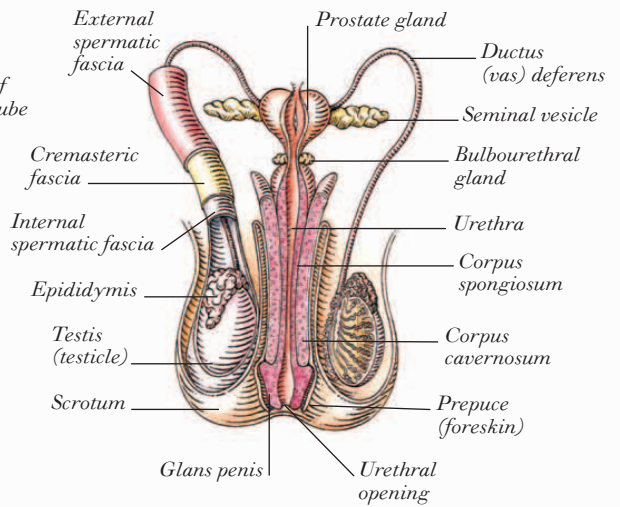
SECTION THROUGH OVARY



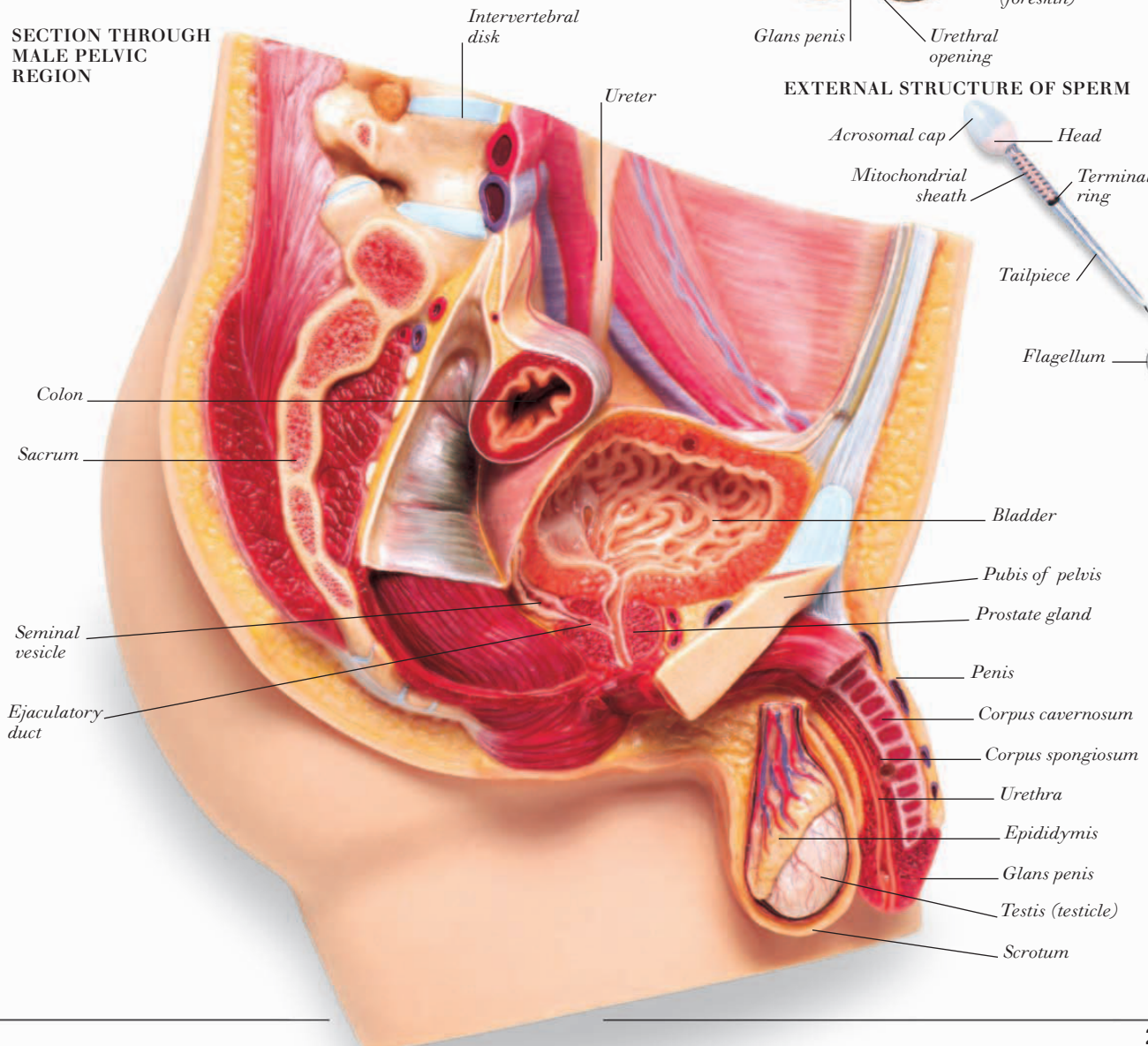
FEMALE REPRODUCTIVE ORGANS



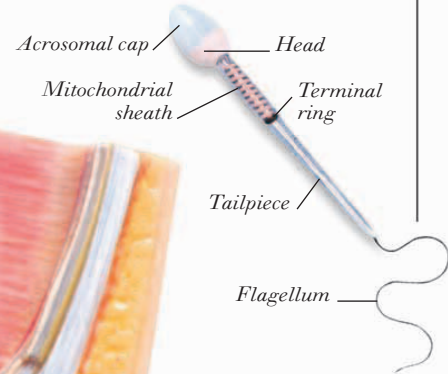
MALE REPRODUCTIVE ORGANS



SECTION THROUGH MALE PELVIC REGION



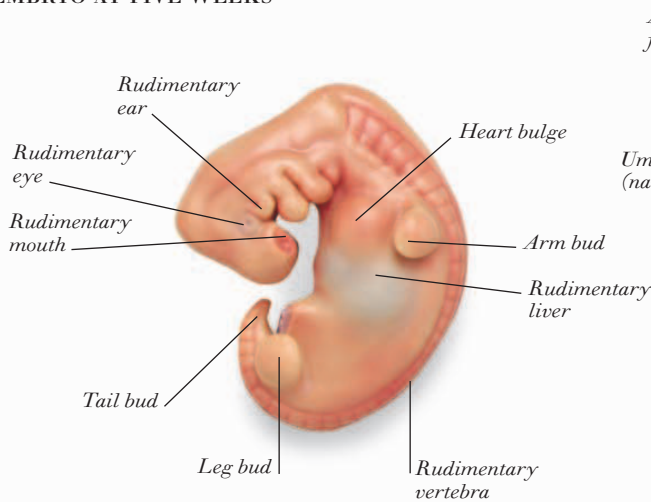
EXTERNAL STRUCTURE OF SPERM



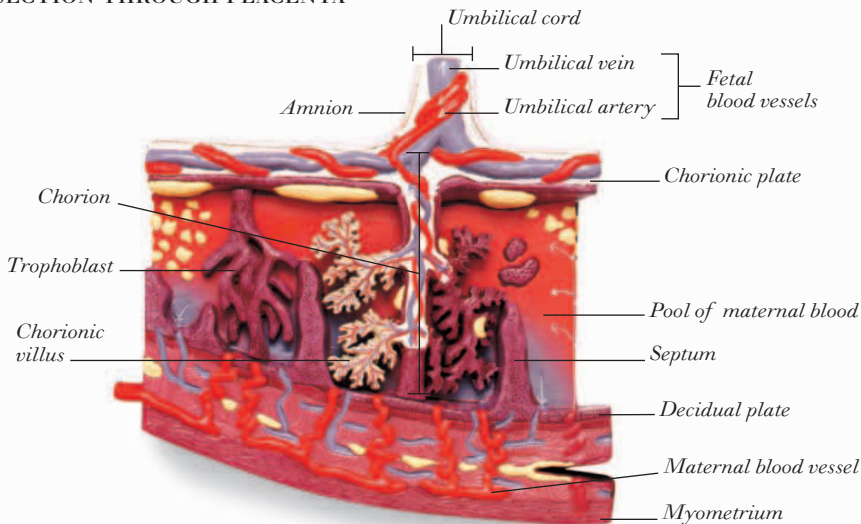
Development of a baby

A FERTILIZED EGG IS NOURISHED AND PROTECTED as it develops into an embryo and then a fetus during the 40 weeks of pregnancy. The placenta, a mass of blood vessels implanted in the uterus lining, delivers nourishment and oxygen, and removes waste through the umbilical cord. Meanwhile, the fetus lies snugly in its amniotic sac, a bag of fluid that protects it against any sudden jolts. In the last weeks of the pregnancy, the rapidly growing fetus turns head-down: a baby ready to be born.

EMBRYO AT FIVE WEEKS



SECTION THROUGH PLACENTA



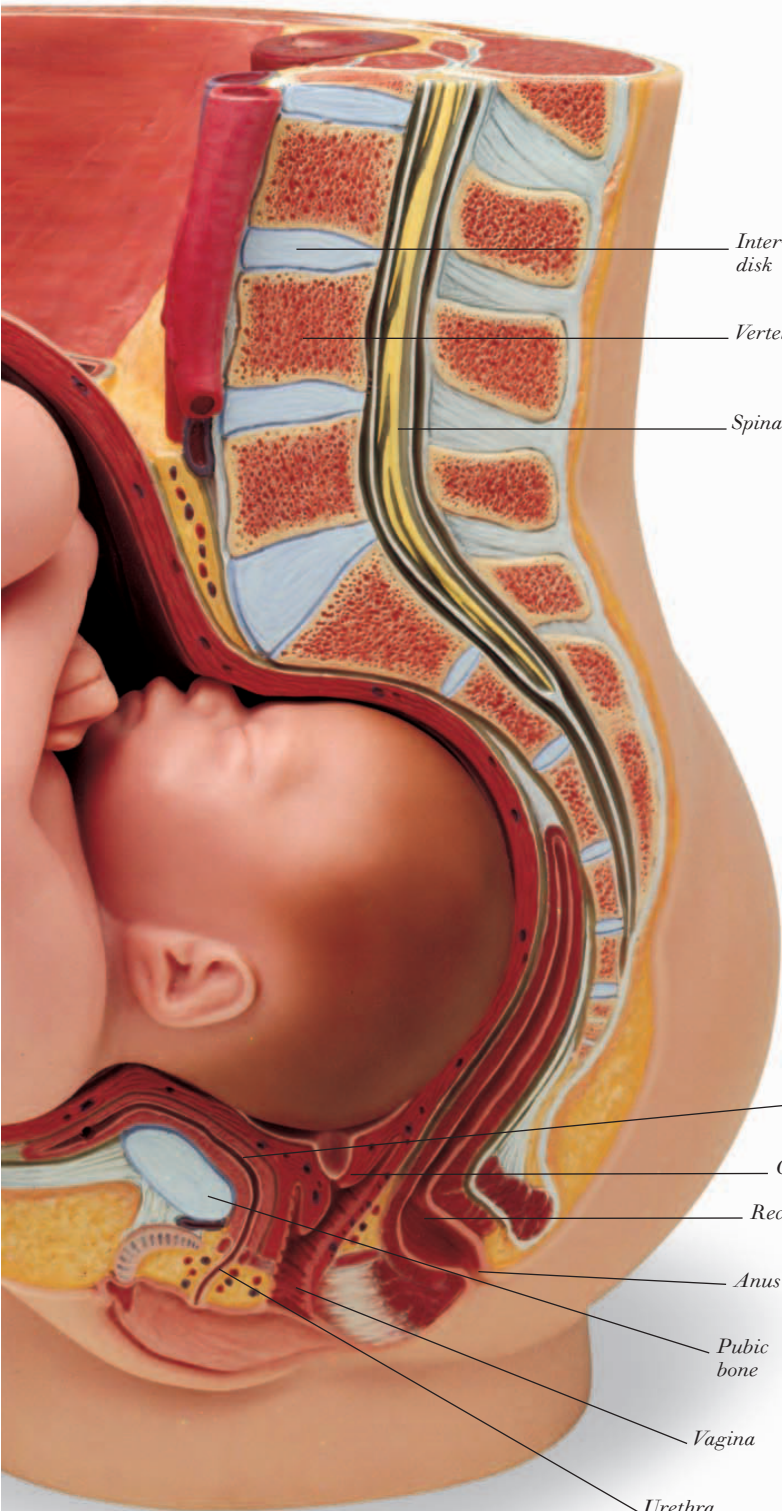
Amniotic fluid

Umbilicus (navel)

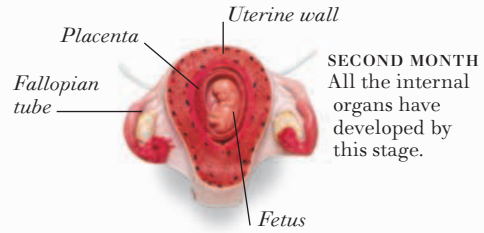
Uterine wall

Fetus

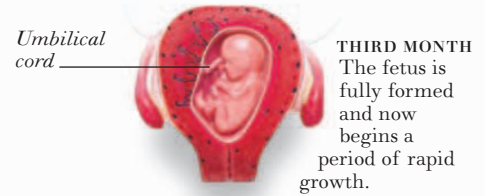
SECTION THROUGH PELVIS IN NINTH MONTH OF PREGNANCY



THE DEVELOPING FETUS

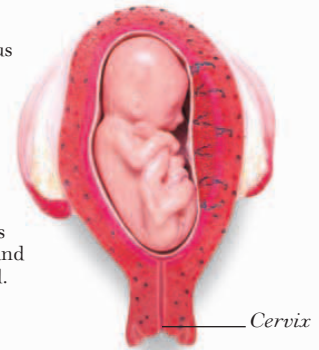


SECOND MONTH
All the internal organs have developed by this stage.

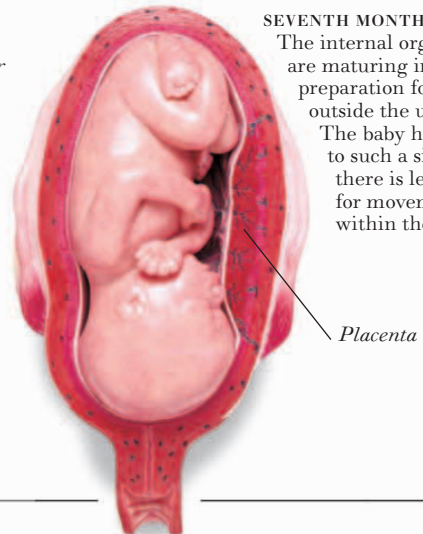


THIRD MONTH
The fetus is fully formed and now begins a period of rapid growth.

FIFTH MONTH
Although the fetus is here in breech (bottom down) position, it will probably turn by 180° before birth. By the fifth month the baby is moving actively and responds to sound.



SEVENTH MONTH
The internal organs are maturing in preparation for life outside the uterus. The baby has grown to such a size that there is less room for movement within the uterus.



Intervertebral disk

Vertebra

Spinal cord

Bladder

Cervix

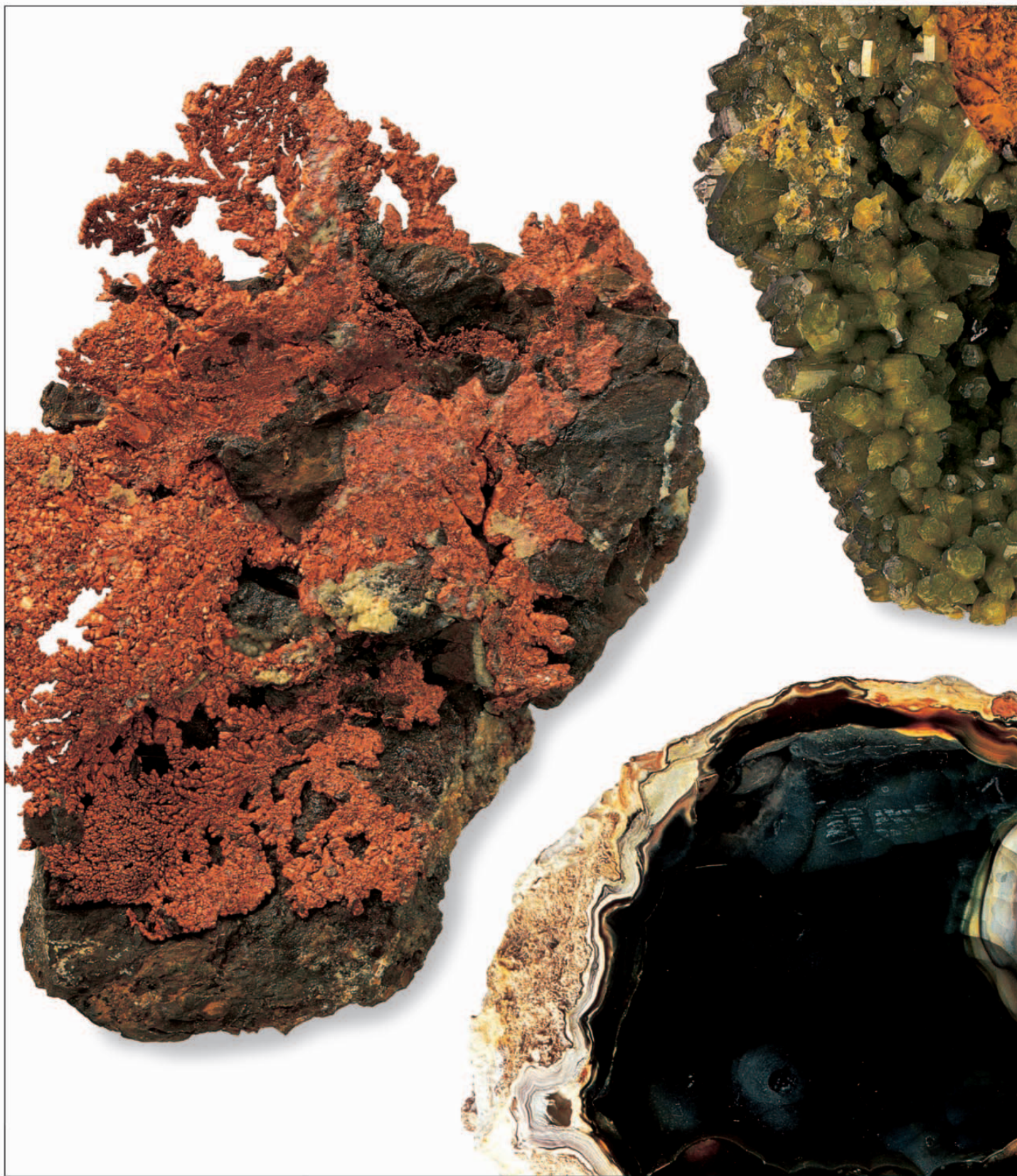
Rectum

Anus

Pubic bone

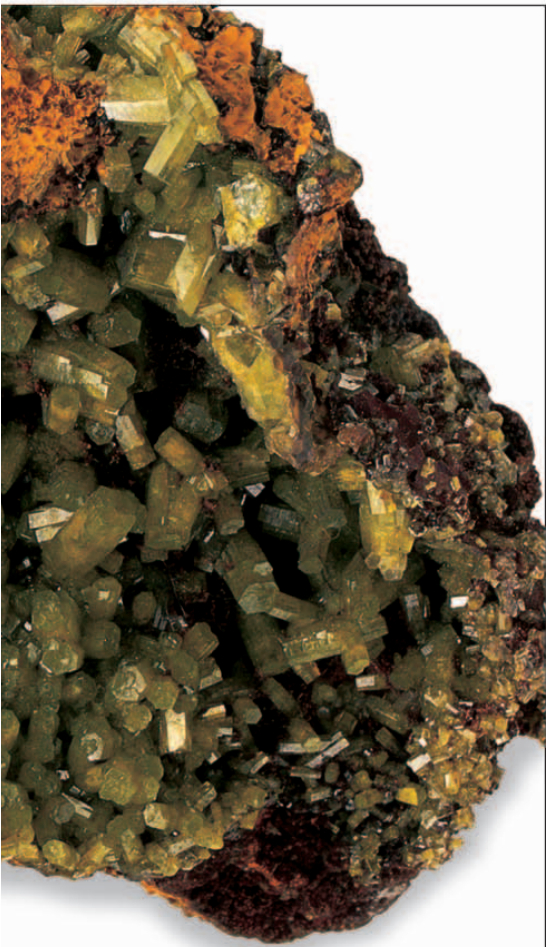
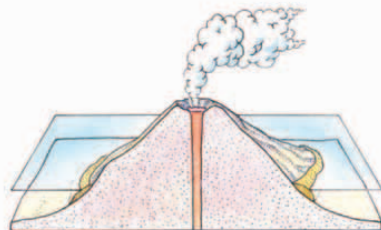
Vagina

Urethra



GEOLOGY, GEOGRAPHY, AND METEOROLOGY

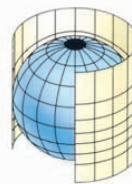
EARTH'S PHYSICAL FEATURES	264
THE ROCK CYCLE	266
MINERALS	268
MINERAL FEATURES	270
VOLCANOES	272
IGNEOUS AND METAMORPHIC ROCKS	274
SEDIMENTARY ROCKS	276
FOSSILS	278
MINERAL RESOURCES	280
WEATHERING AND EROSION	282
CAVES	284
GLACIERS	286
RIVERS	288
RIVER FEATURES	290
LAKES AND GROUNDWATER	292
COASTLINES	294
OCEANS AND SEAS	296
THE OCEAN FLOOR	298
THE ATMOSPHERE	300
WEATHER	302



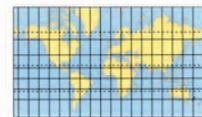
Earth's physical features

MOST OF THE EARTH'S SURFACE (about 70 percent) is covered with water. The largest single body of water, the Pacific Ocean, alone covers about 30 percent of the surface. Most of the land is distributed as seven continents; these are (from largest to smallest) Asia, Africa, North America, South America, Antarctica, Europe, and Australasia. The physical features of the land are remarkably varied. Among the most notable are mountain ranges, rivers, and deserts. The largest mountain ranges—the Himalayas in Asia and the Andes in South America—extend for thousands of miles. The Himalayas include the world's highest mountain, Mount Everest (29,029 ft/8,848 m). The longest rivers are the Nile River in Africa (4,160 miles/6,695 km) and the Amazon River in South America (4,000 miles/6,437 km). Deserts cover about 20 percent of the total land area. The largest is the Sahara, which covers nearly a third of Africa. The Earth's surface features can be represented in various ways. Only a globe can correctly represent areas, shapes, sizes, and directions, because there is always distortion when a spherical surface—the Earth's, for example—is projected on to the flat surface of a map. Each map projection is therefore a compromise; it shows some features accurately but distorts others. Even satellite mapping does not produce completely accurate maps, although they can show physical features with great clarity.

EXAMPLES OF MAP PROJECTIONS



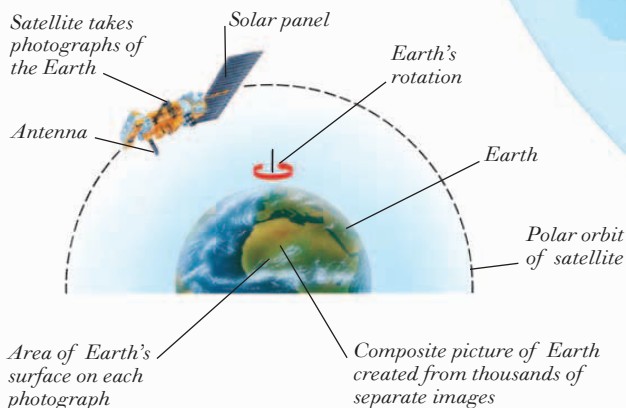
CYLINDRICAL PROJECTION

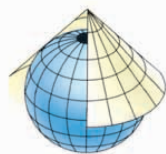


CYLINDRICAL-PROJECTION MAP

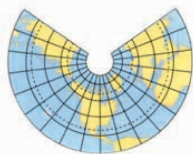


SATELLITE MAPPING OF THE EARTH

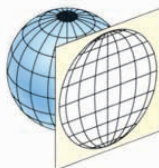




CONICAL PROJECTION



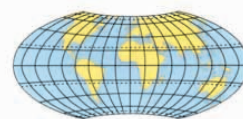
CONICAL-PROJECTION MAP



AZIMUTHAL PROJECTION

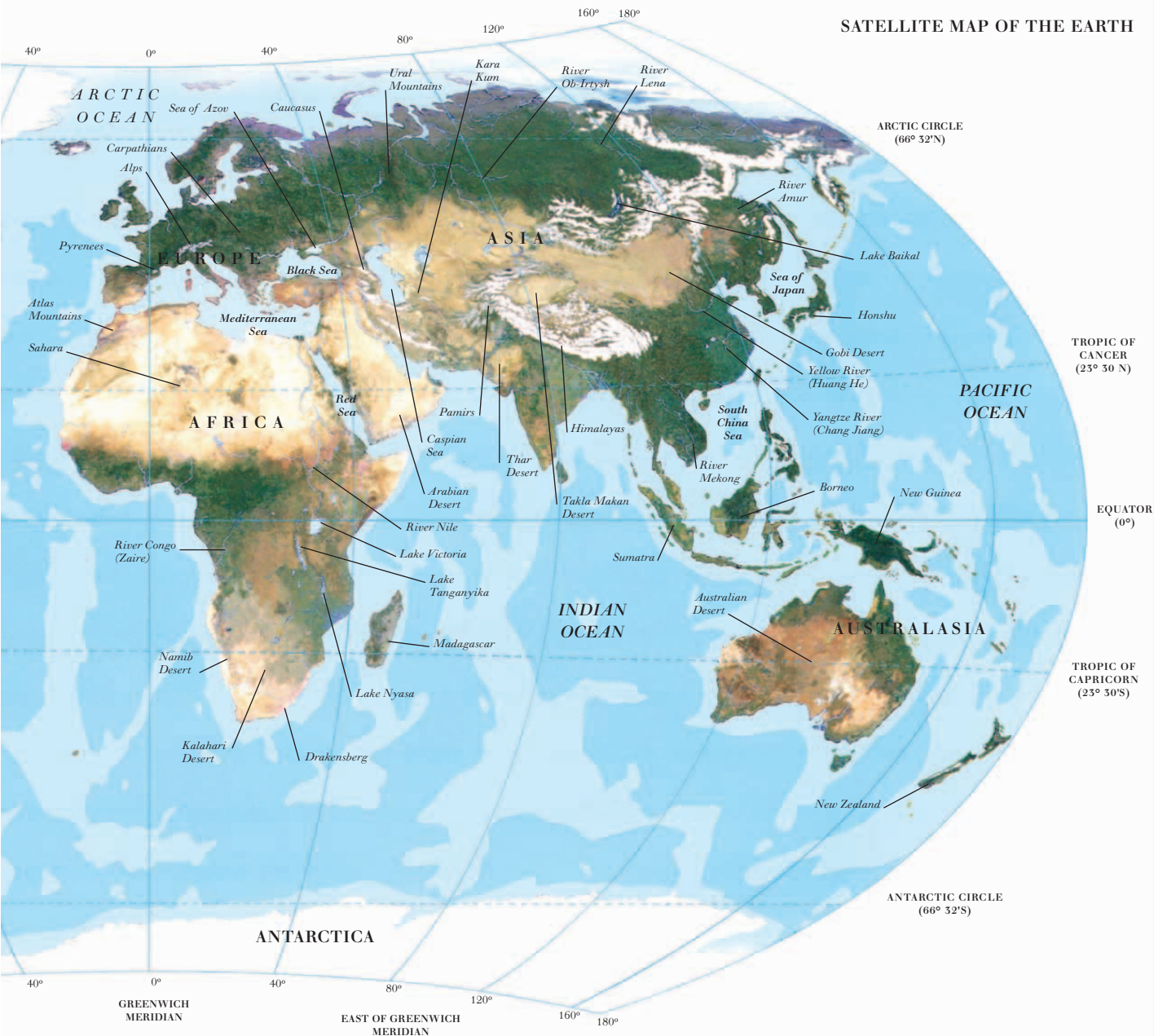


AZIMUTHAL-PROJECTION MAP

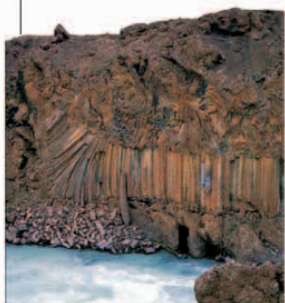


MODIFIED AZIMUTHAL-PROJECTION MAP

SATELLITE MAP OF THE EARTH



The rock cycle

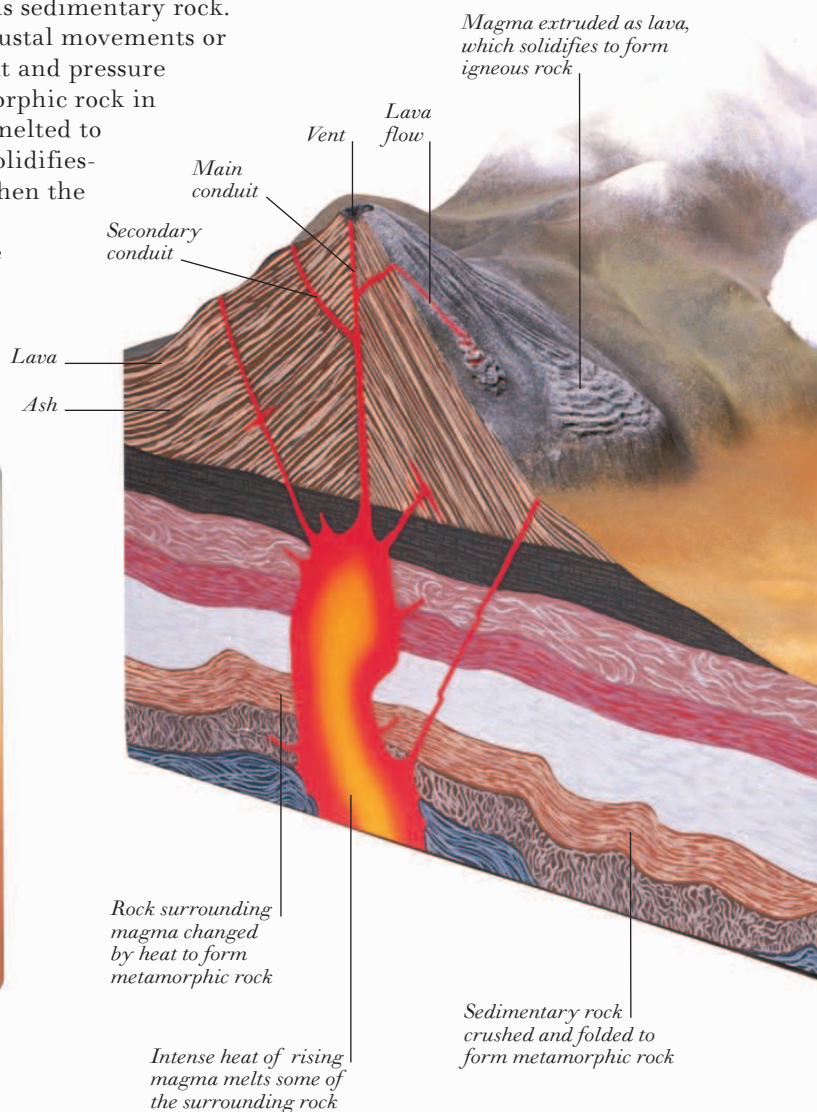


HEXAGONAL BASALT COLUMNS, ICELAND

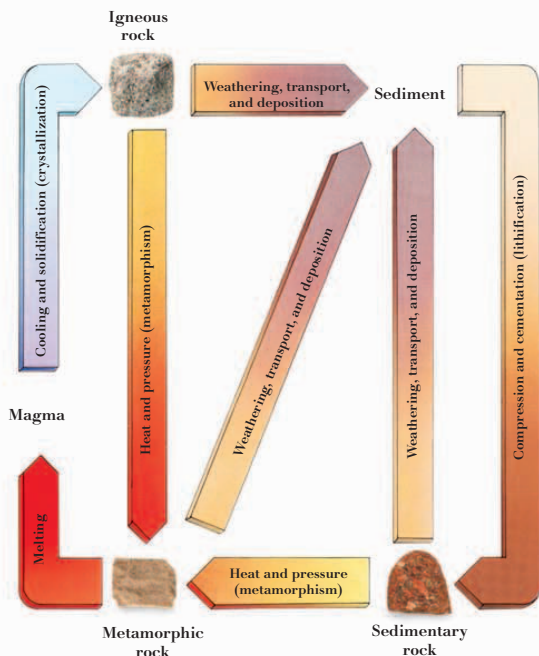
THE ROCK CYCLE IS A CONTINUOUS PROCESS through which old rocks are transformed into new ones. Rocks can be divided into three main groups: igneous, sedimentary, and metamorphic. Igneous rocks are formed when magma (molten rock) from the Earth's interior cools and solidifies (see pp. 274-275). Sedimentary rocks are formed when sediment (rock particles, for example) becomes compressed and cemented together in a process known as lithification (see pp. 276-277). Metamorphic rocks are formed when igneous, sedimentary, or other metamorphic rocks are changed by heat or pressure (see pp. 274-275). Rocks are added to the Earth's surface by crustal movements and volcanic activity. Once exposed on the surface, the rocks are broken down into rock particles by weathering (see pp. 282-283). The particles are then transported by glaciers, rivers, and wind, and deposited as sediment in lakes, deltas, deserts, and on the ocean floor. Some

of this sediment undergoes lithification and forms sedimentary rock. This rock may be thrust back to the surface by crustal movements or forced deeper into the Earth's interior, where heat and pressure transform it into metamorphic rock. The metamorphic rock in turn may be pushed up to the surface or may be melted to form magma. Eventually, the magma cools and solidifies—below or on the surface—forming igneous rock. When the sedimentary, igneous, and metamorphic rocks are exposed once more on the Earth's surface, the cycle begins again.

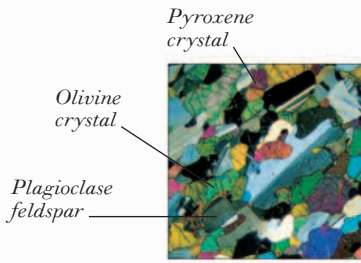
STAGES IN THE ROCK CYCLE



THE ROCK CYCLE



IGNEOUS ROCK

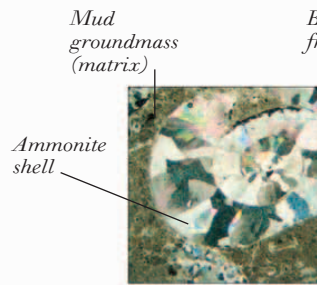


PHOTOMICROGRAPH OF GABBRO

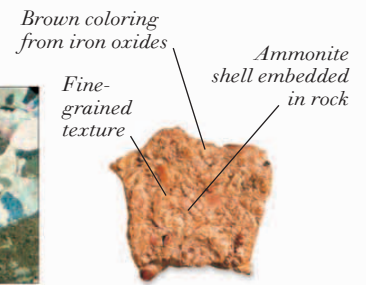


PIECE OF GABBRO

SEDIMENTARY ROCK

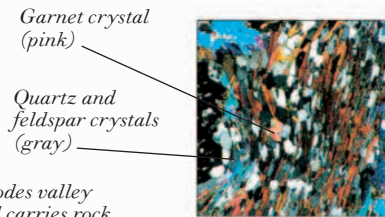


PHOTOMICROGRAPH OF SHELLY LIMESTONE

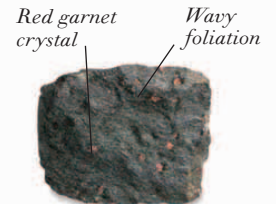


PIECE OF SHELLY LIMESTONE

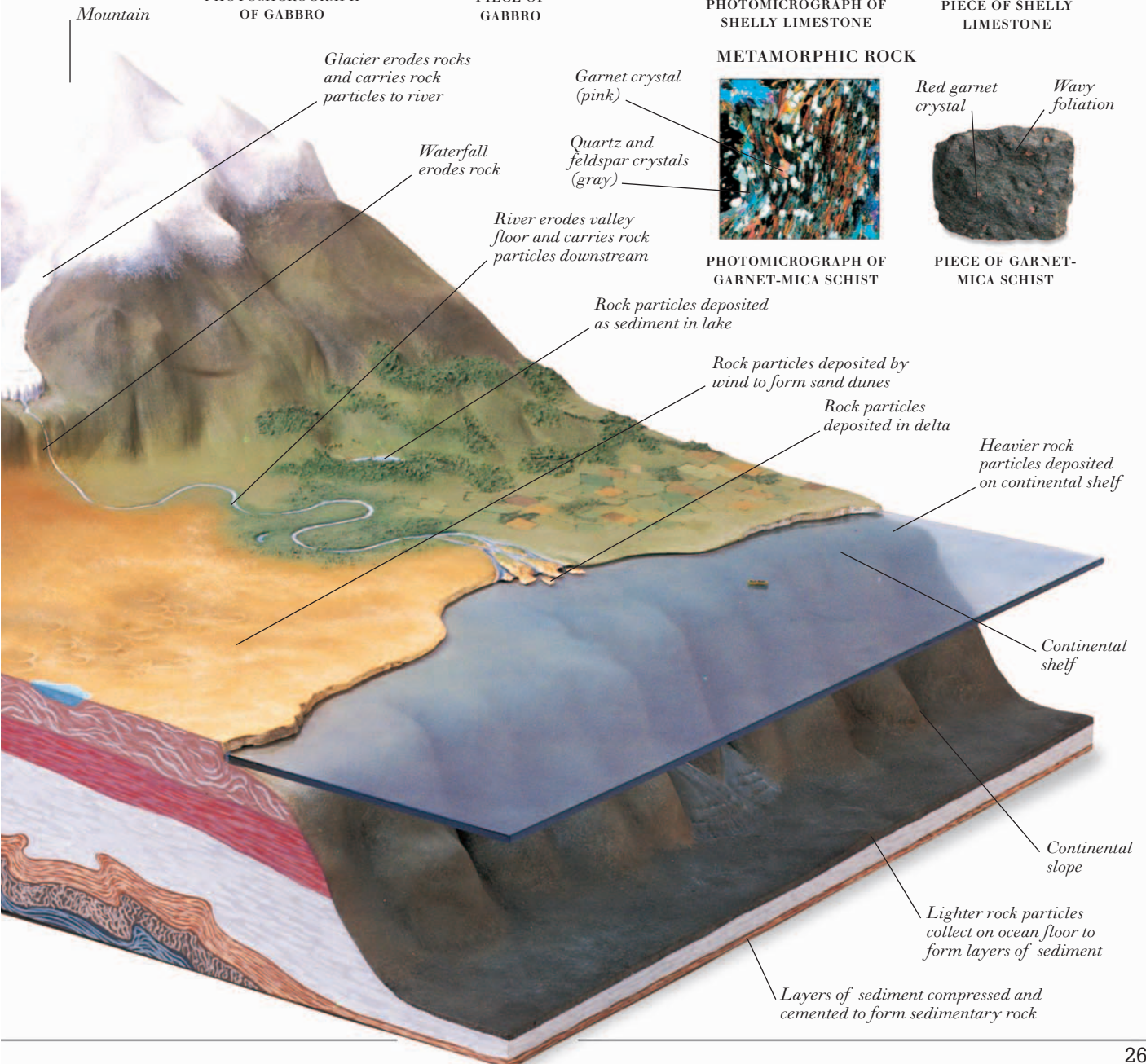
METAMORPHIC ROCK



PHOTOMICROGRAPH OF GARNET-MICA SCHIST



PIECE OF GARNET-MICA SCHIST



Minerals

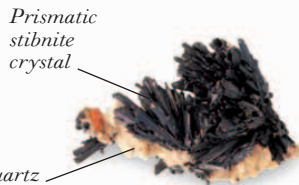
A MINERAL IS A NATURALLY OCCURRING SUBSTANCE that has a characteristic chemical composition and specific physical properties, such as habit and streak (see pp. 270-271). A rock, by comparison, is an aggregate of minerals and need not have a specific chemical composition. Minerals are made up of elements (substances that cannot be broken down chemically into simpler substances), each of which can be represented by a chemical symbol. Minerals can be divided into two main groups: native elements and compounds. Native elements are made up of a pure element. Examples include gold (chemical symbol Au), silver (Ag), copper (Cu), and carbon (C); carbon occurs as a native element in two forms, diamond and graphite. Compounds are combinations of two or more elements. For example, sulfides are compounds of sulfur (S) and one or more other elements, such as lead (Pb) in the mineral galena, or antimony (Sb) in the mineral stibnite.

SULFIDES



Cubic galena crystal

GALENA (PbS)



Prismatic stibnite crystal

STIBNITE (Sb₂S₃)

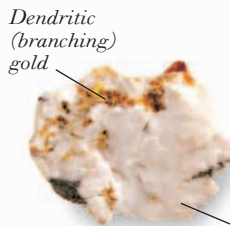
Quartz groundmass (matrix)

Perfect octahedral pyrites crystal



PYRITES (FeS₂)

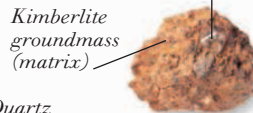
Quartz crystal



Dendritic (branching) gold

GOLD (Au)

Quartz vein



White diamond

DIAMOND (C)

Kimberlite groundmass (matrix)

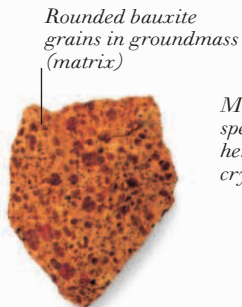
OXIDES/HYDROXIDES



Milky quartz groundmass (matrix)

Smoky quartz crystal

SMOKY QUARTZ (SiO₂)



Rounded bauxite grains in groundmass (matrix)

BAUXITE (FeO(OH) and Al₂O₃·2H₂O)



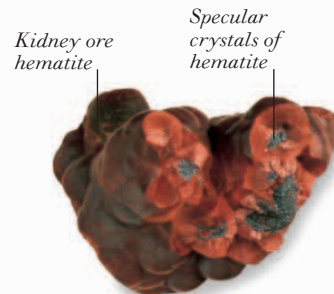
Mass of specular hematite crystals

SPECULAR HEMATITE (Fe₂O₃)



Parallel bands of onyx

ONYX (SiO₂)

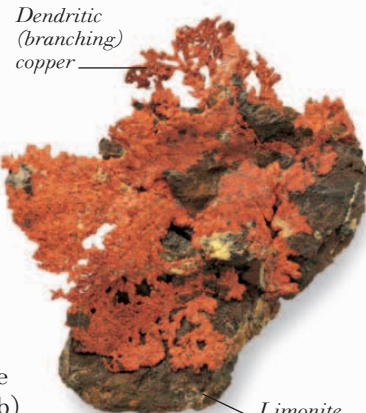


Kidney ore hematite

Specular crystals of hematite

KIDNEY ORE HEMATITE (Fe₂O₃)

NATIVE ELEMENTS



Dendritic (branching) copper

Limonite groundmass (matrix)

COPPER (Cu)



Hexagonal graphite crystal

GRAPHITE (C)

PHOSPHATES

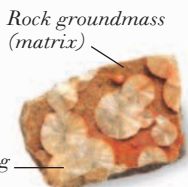


Limonite groundmass (matrix)

Radiating wavellite crystals

Prismatic pyromorphite crystals

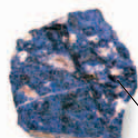
PYROMORPHITE
($Pb_5(PO_4)_3Cl$)



Rock groundmass (matrix)

WAVELLITE
($Al_3(PO_4)_2(OH,F)_5 \cdot 5H_2O$)

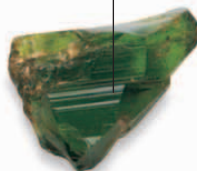
SILICATES



Dodecahedral sodalite crystal

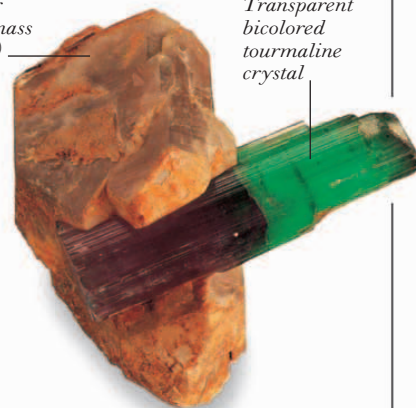
SODALITE
($Na_8Al_6Si_6O_{24}Cl_2$)

Striated surface of olivine crystal



OLIVINE
($Fe_2SiO_4 - Mg_2SiO_4$)

Feldspar groundmass (matrix)



Transparent bicolored tourmaline crystal

TOURMALINE
($Na(Mg,Fe,Li,Mn,Al)_3Al_6(BO_3)_3Si_6O_{18}(OH,F)_4$)

CARBONATES



Striated cerussite crystal

CERUSSITE
($PbCO_3$)



Dog tooth calcite crystal

CALCITE
($CaCO_3$)

Striated surface of olivine crystal

Tabular muscovite crystal



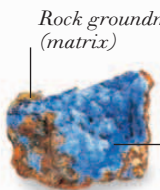
MUSCOVITE
($KAl_2(Si_3Al)O_{10}(OH,F)_2$)

Striated prismatic epidote crystal



EPIDOTE
($Ca_2(Al,Fe)_3(SiO_4)_3(OH)$)

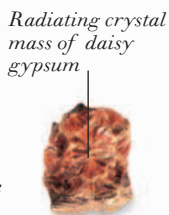
SULFATES



Rock groundmass (matrix)

Radiating cyanotrichite crystals

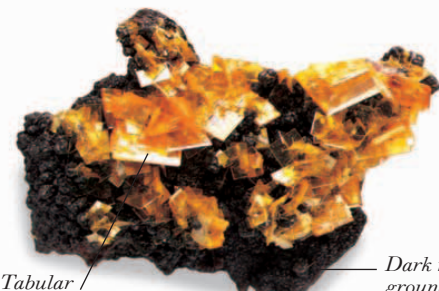
CYANOTRICHITE
($Cu_4Al_2(SO_4)(OH)_{12} \cdot 2H_2O$)



Radiating crystal mass of daisy gypsum

DAISY GYPSUM
($CaSO_4 \cdot 2H_2O$)

MOLYBDATE



Tabular wulfenite crystal

WULFENITE
($PbMoO_4$)

Dark rock groundmass (matrix)

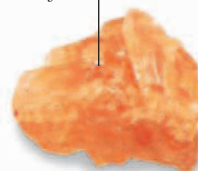
HALIDES



Cubic fluorite crystal

GREEN FLUORITE
(CaF_2)

Cubic rock salt crystal



ORANGE HALITE (ROCK SALT)
($NaCl$)

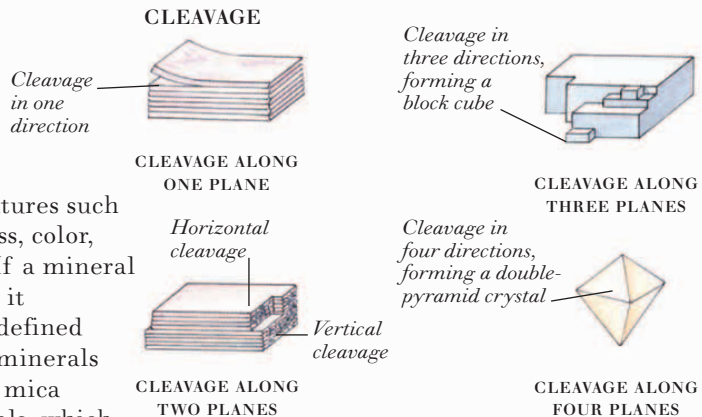
Orthoclase crystal



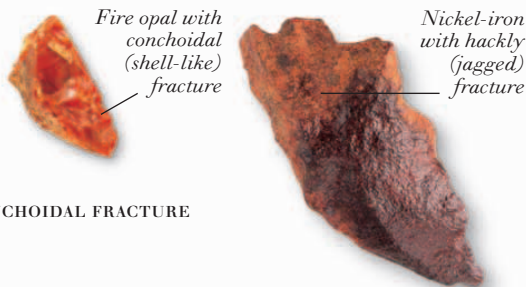
ORTHOCLASE
($KAlSi_3O_8$)

Mineral features

MINERALS CAN BE IDENTIFIED BY STUDYING features such as fracture, cleavage, crystal system, habit, hardness, color, and streak. Minerals can break in different ways. If a mineral breaks in an irregular way, leaving rough surfaces, it possesses fracture. If a mineral breaks along well-defined planes of weakness, it possesses cleavage. Specific minerals have distinctive patterns of cleavage; for example, mica cleaves along one plane. Most minerals form crystals, which can be categorized into crystal systems according to their symmetry and number of faces. Within each system, several different but related forms of crystal are possible; for example, a cubic crystal can have six, eight, or 12 sides. A mineral's habit is the typical form taken by an aggregate of its crystals. Examples of habit include botryoidal (like a bunch of grapes) and massive (no definite form). The relative hardness of a mineral may be assessed by testing its resistance to scratching. This property is usually measured using Mohs scale, which increases in hardness from 1 (talc) to 10 (diamond). The color of a mineral is not a dependable guide to its identity as some minerals have a range of colors. Streak (the color the powdered mineral makes when rubbed across an unglazed tile) is a more reliable indicator.

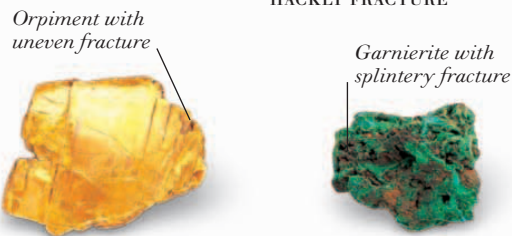


FRACTURE



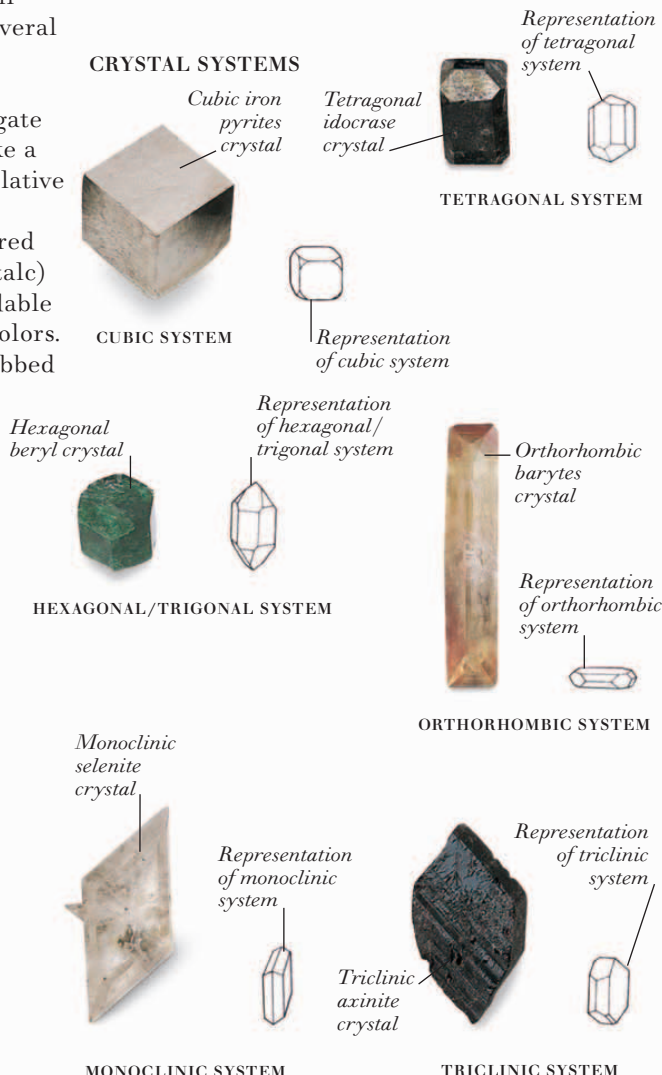
CONCHOIDAL FRACTURE

HACKLY FRACTURE



UNEVEN FRACTURE

SPLINTERY FRACTURE



HABIT



Kunzite with prismatic habit



Silver with twisted wire habit

TWISTED WIRE HABIT

PRISMATIC HABIT



Haematite with tabular habit (flattened structure)

TABULAR HABIT



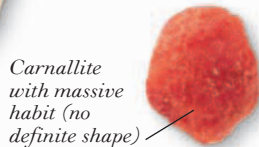
Wollastonite with fibrous habit

FIBROUS HABIT



Chalcedony with botryoidal habit (like a bunch of grapes)

BOTRYOIDAL HABIT



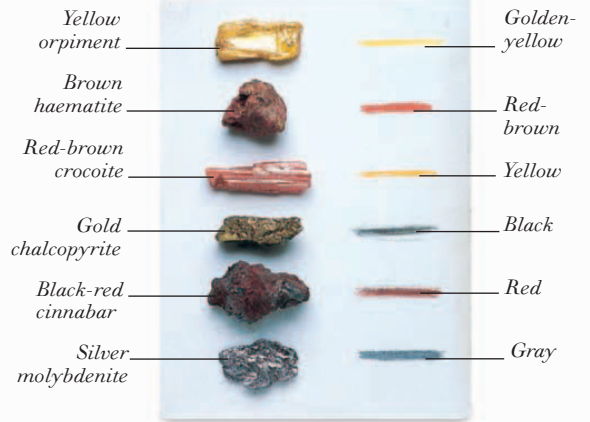
Carnallite with massive habit (no definite shape)

MASSIVE HABIT

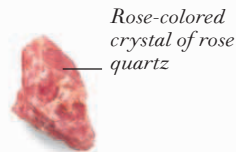
STREAK

COLOR OF MINERAL

COLOR OF STREAK



COLOR



Rose-colored crystal of rose quartz

ROSE, PINK



Translucent white-gray crystal of milky quartz

WHITE-GRAY



Translucent crystal of orange citrine

ORANGE

Transparent glassy crystal of rock crystal



BEIGE, TRANSPARENT

MOHS SCALE OF HARDNESS



Volcanoes

VOLCANOES ARE VENTS OR FISSURES in the Earth's crust through which magma (molten rock that originates from deep beneath the crust) is forced on to the surface as lava. They occur most commonly along the boundaries of crustal plates; most volcanoes lie in a belt called the "Ring of Fire," which runs along the edge of the Pacific Ocean. Volcanoes can be classified according to the violence and frequency of their eruptions.



HORU GEYSER,
NEW ZEALAND

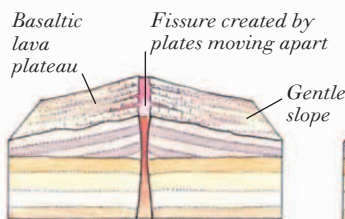
Nonexplosive volcanic eruptions generally occur where crustal plates pull apart. These eruptions produce runny basaltic lava that spreads quickly over a wide area to form relatively flat cones. The most violent eruptions take place where plates collide. Such eruptions produce thick rhyolitic lava and may also blast out clouds of dust and pyroclasts (lava fragments). The lava does not flow far before cooling and therefore builds up steep-sided, conical volcanoes. Some volcanoes produce lava and ash eruptions, which build up composite volcanic cones. Volcanoes that erupt frequently are described as active; those that erupt rarely are termed dormant; and those that have stopped erupting altogether are termed extinct. As well as the volcanoes themselves, other features associated with volcanic regions include geysers, hot mineral springs, solfataras, fumaroles, and bubbling mud pools.



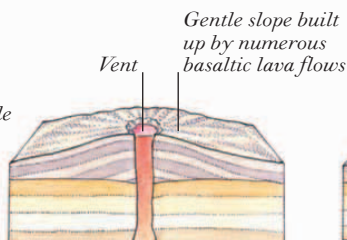
Folded, rope-like surface

PAHOEHOE
(ROPY LAVA)

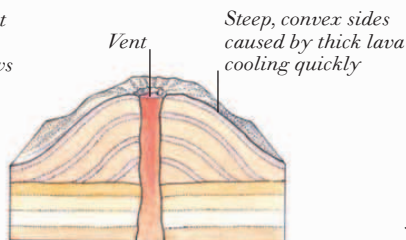
VOLCANO TYPES



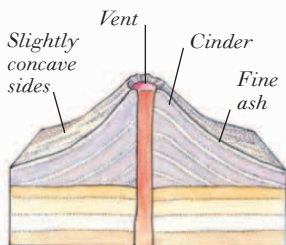
FISSURE VOLCANO



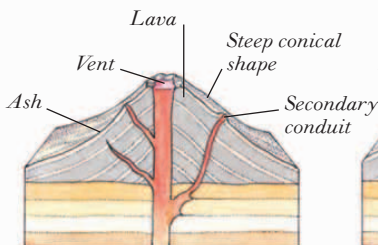
BASIC SHIELD VOLCANO



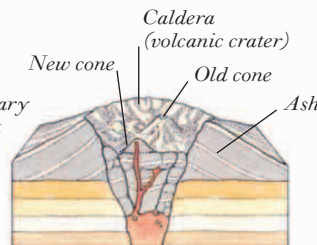
DOME VOLCANO



ASH-CINDER VOLCANO



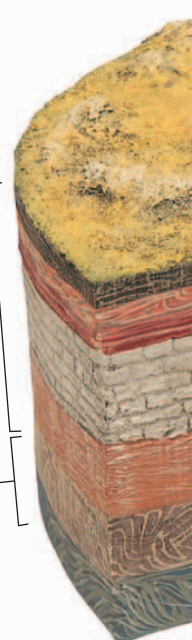
COMPOSITE VOLCANO



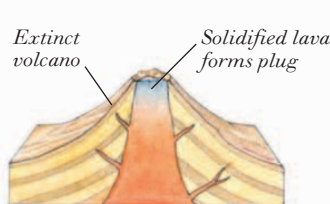
CALDERA VOLCANO

Layers of sedimentary rocks

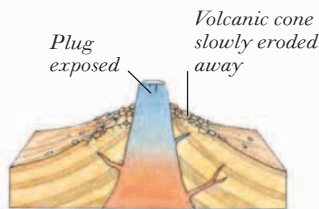
Metamorphic rocks (rocks altered by heat and pressure)



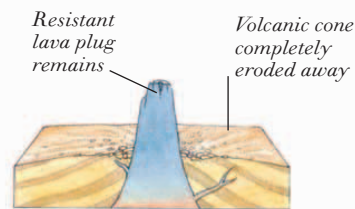
HOW VOLCANIC PLUGS BECOME EXPOSED



PLUG FORMATION



INITIAL EROSION AROUND PLUG



COMPLETE DENUDATION OF PLUG

LAPILLI
(LAVA FRAGMENTS)



Small piece of solidified lava

TYPES OF LAVA

Scoria (*sharp, angular chunks*)



AA (BLOCKY LAVA)

Dribblets of lava from roof of tunnel



REMELTED LAVA

LOCATION OF VOLCANOES



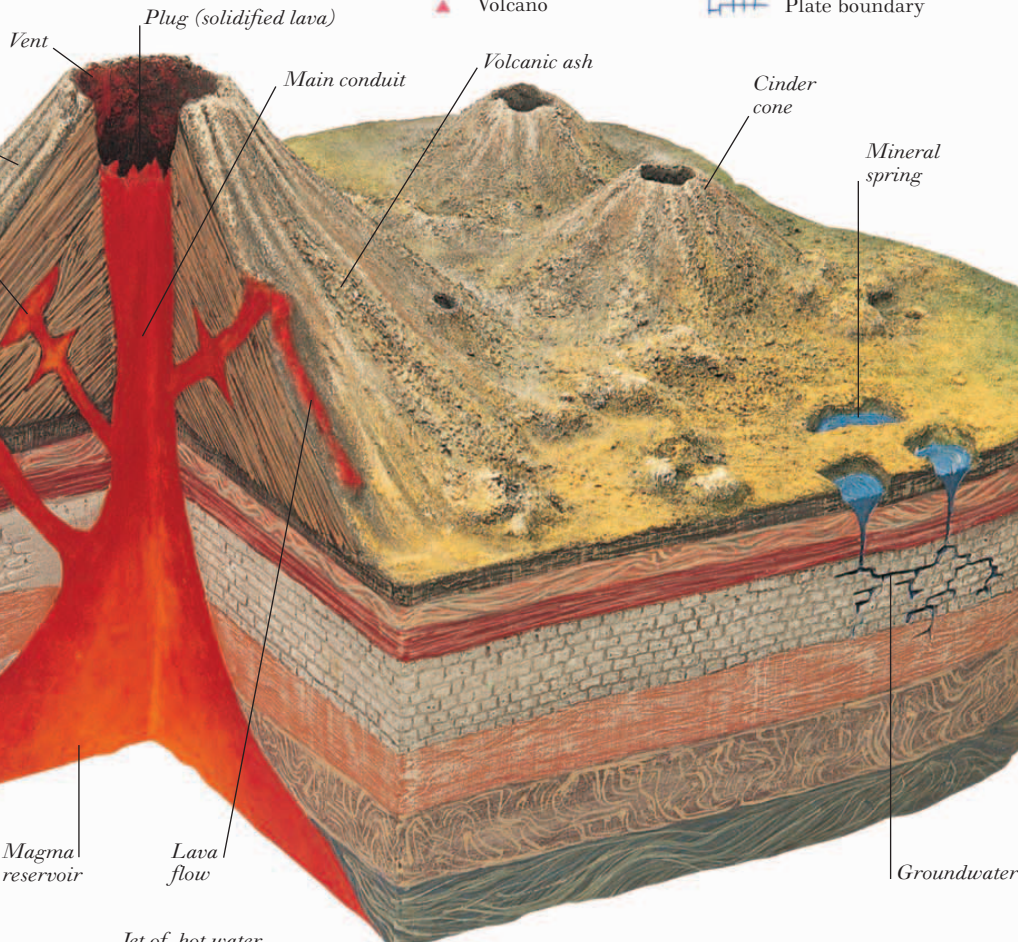
▲ Volcano

||||| Plate boundary

STRUCTURE OF A VOLCANO

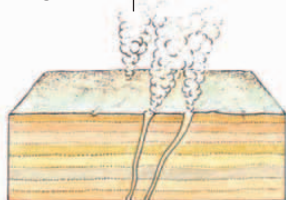
Steeply sloping cone consisting of numerous layers of ash and lava

Laccolith
Secondary conduit



VOLCANIC FEATURES

Sulfurous gases

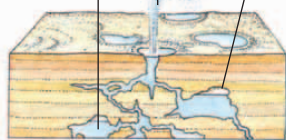


SOLFATARA

Jet of hot water and steam

Water heated by hot rocks

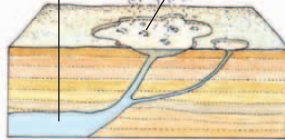
Steam pressure builds up



GEYSER

Hot water

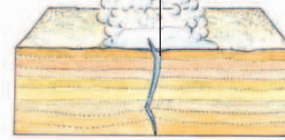
Mud and surface deposits mixed with hot water



MUD POOL

Superheated water

Steam

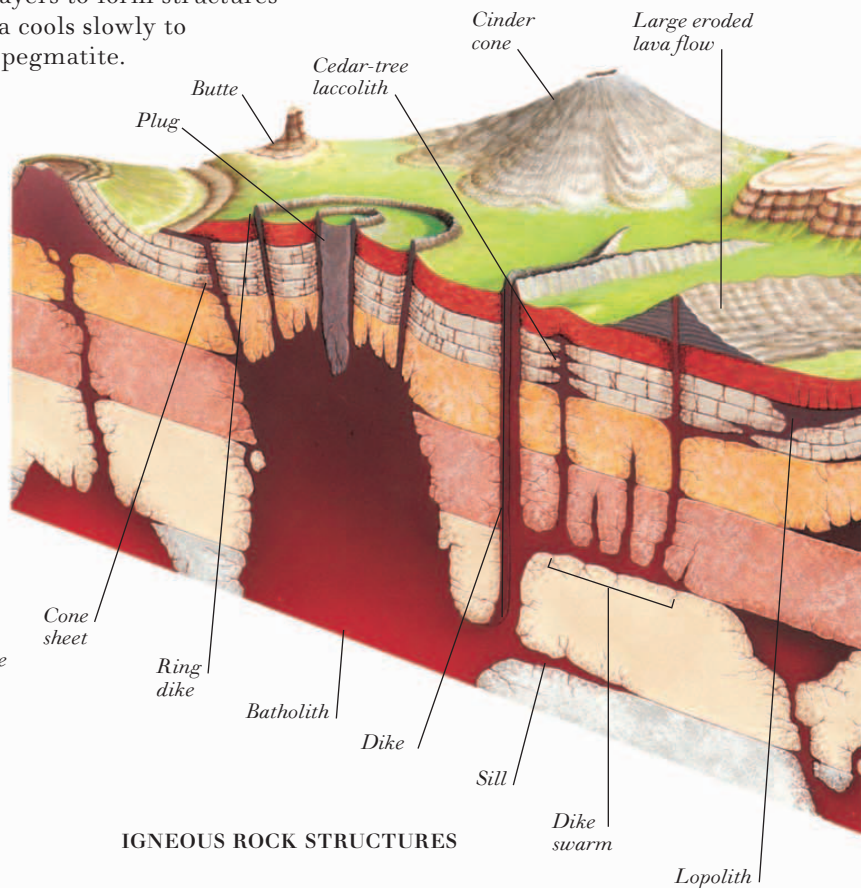


FUMAROLE

Igneous and metamorphic rocks

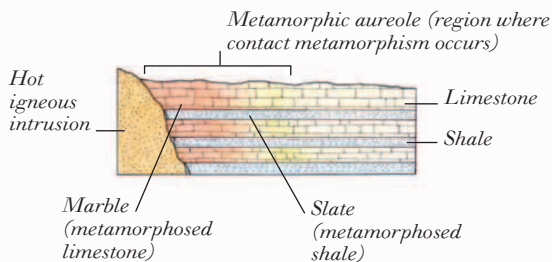
IGNEOUS ROCKS ARE FORMED WHEN MAGMA (molten rock that originates from deep beneath the Earth's crust) cools and solidifies. There are two main types of igneous rock: intrusive and extrusive. Intrusive rocks are formed deep underground where magma is forced into cracks or between rock layers to form structures such as sills, dikes, and batholiths. The magma cools slowly to form coarse-grained rocks such as gabbro and pegmatite. Extrusive rocks are formed above the Earth's surface from lava (magma that has been ejected in a volcanic eruption). The molten lava cools quickly, producing fine-grained rocks such as rhyolite and basalt. Metamorphic rocks are those that have been altered by intense heat (contact metamorphism) or extreme pressure (regional metamorphism). Contact metamorphism occurs when rocks are changed by heat from, for example, an igneous intrusion or lava flow. Regional metamorphism occurs when rock is crushed in the middle of a folding mountain range. Metamorphic rocks can be formed from igneous rocks, sedimentary rocks, or even from other metamorphic rocks.

BASALT COLUMNS

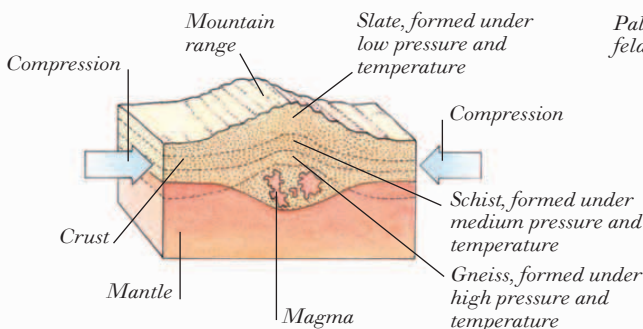


IGNEOUS ROCK STRUCTURES

CONTACT METAMORPHISM



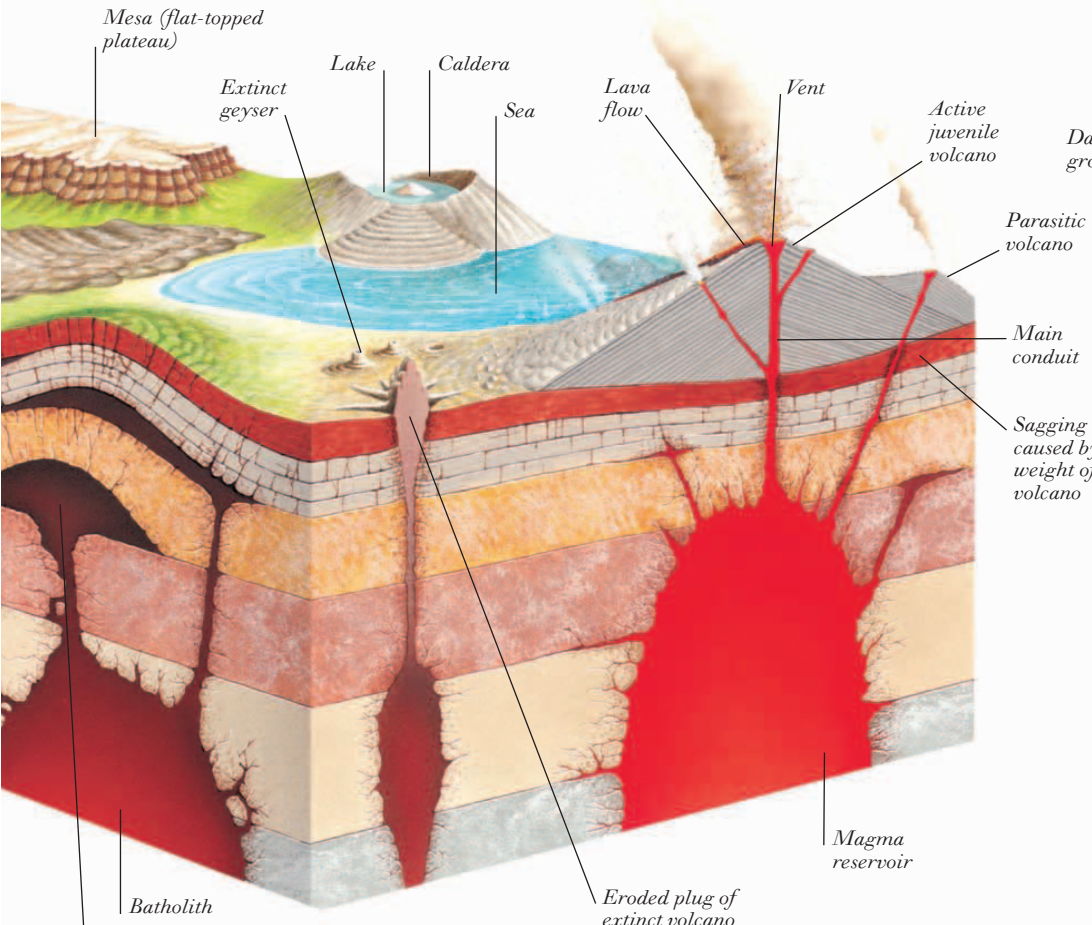
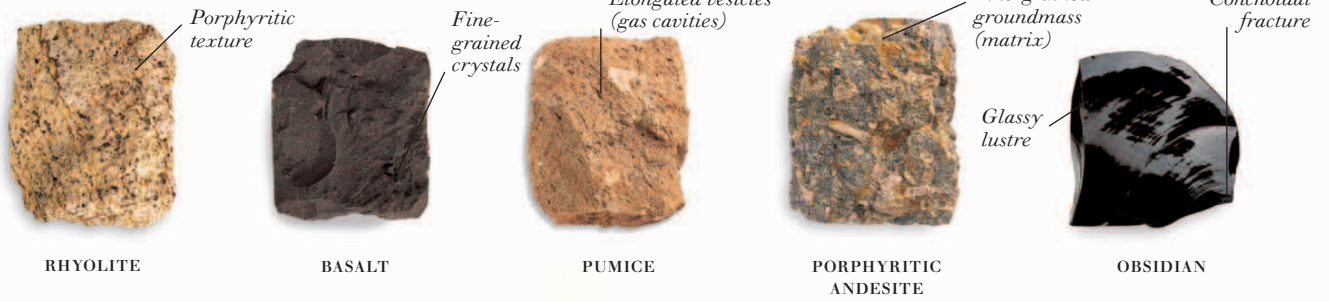
REGIONAL METAMORPHISM



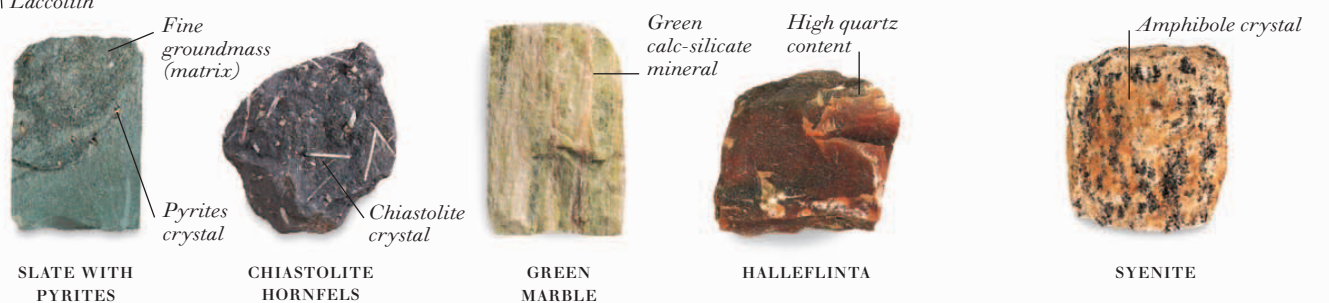
EXAMPLES OF METAMORPHIC ROCKS



EXAMPLES OF EXTRUSIVE IGNEOUS ROCKS



EXAMPLES OF INTRUSIVE IGNEOUS ROCKS



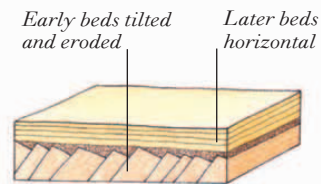
Sedimentary rocks

SEDIMENTARY ROCKS ARE FORMED BY THE ACCUMULATION and consolidation of sediments (see pp. 266-267). There are three main types of sedimentary rock. Clastic sedimentary rocks, such as breccia or sandstone, are formed from other rocks that have been broken down into fragments by weathering (see pp. 282-283), which have then been transported and deposited elsewhere. Organic sedimentary rocks—for example, coal (see pp. 280-281)—are derived from plant and animal remains. Chemical sedimentary rocks are formed by chemical processes. For example, rock salt is formed when salt dissolved in water is deposited as the water evaporates. Sedimentary rocks are laid down in layers, called beds or strata. Each new layer is laid down horizontally over older ones. There are usually some gaps in the sequence, called unconformities. These represent periods in which no new sediments were being laid down, or when earlier sedimentary layers were raised above sea level and eroded away.

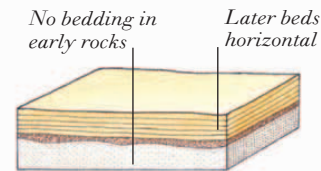


THE GRAND CANYON, USA

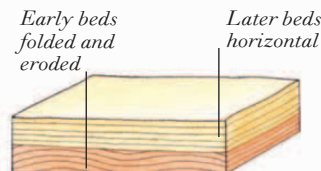
EXAMPLES OF UNCONFORMITIES



ANGULAR UNCONFORMITY

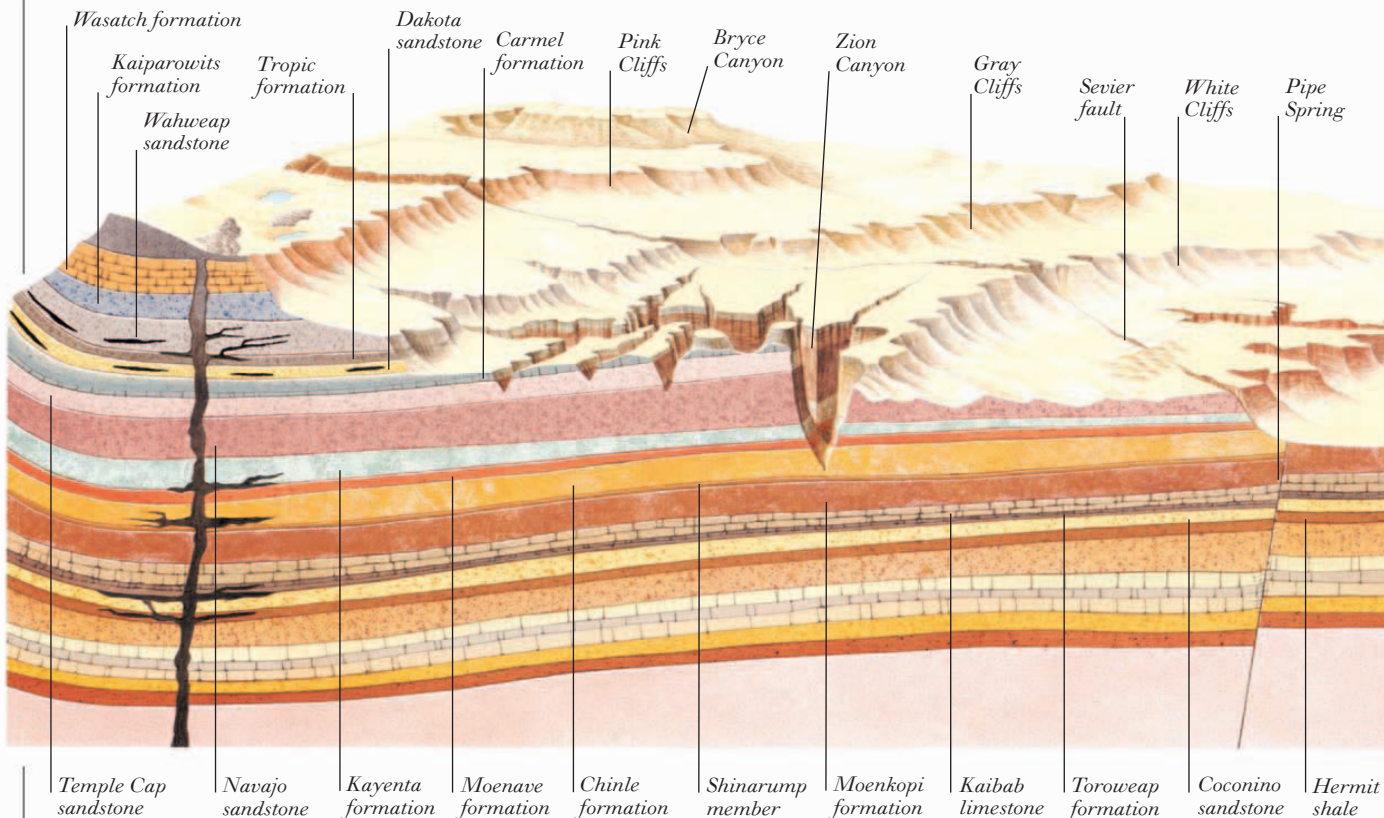


NONCONFORMITY

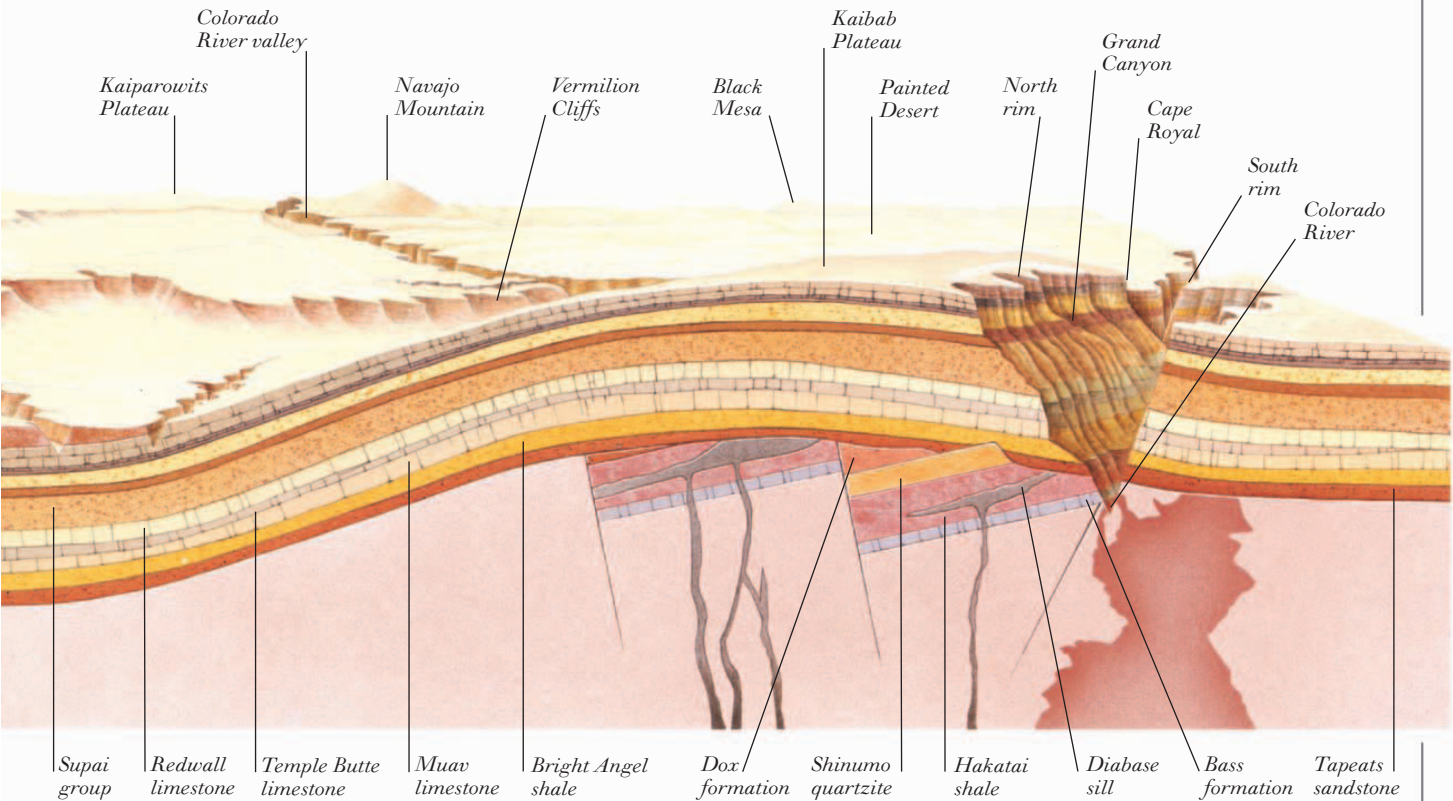
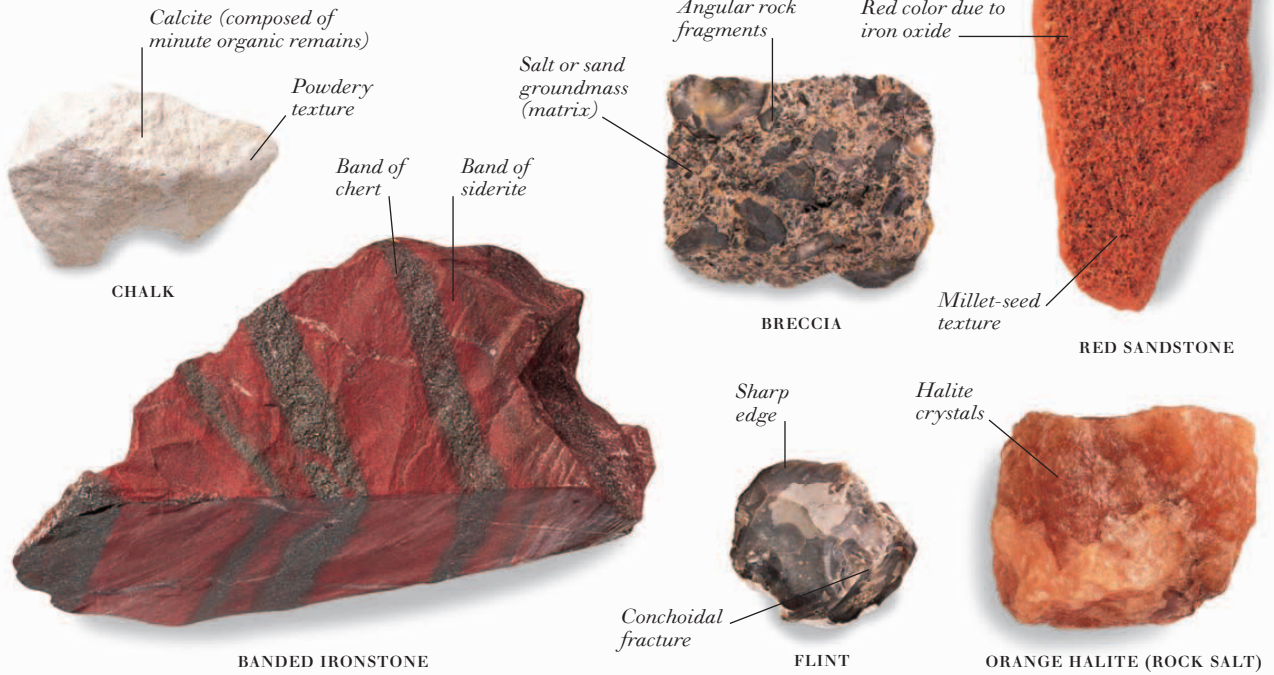


DISCONFORMITY

SEDIMENTARY LAYERS OF THE GRAND CANYON REGION



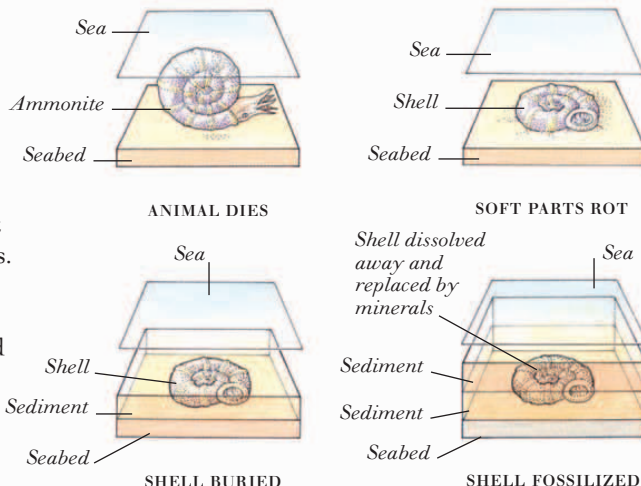
EXAMPLES OF SEDIMENTARY ROCKS



Fossils

FOSSILS ARE THE REMAINS of plants and animals that have been preserved in rock. A fossil may be the preserved remains of an organism itself, an impression of it in rock, or preserved traces (known as trace fossils) left by an organism while it was alive, such as organic carbon outlines, fossilized footprints, or droppings. Most dead organisms soon rot away or are eaten by scavengers. For fossilization to occur, rapid burial by sediment is necessary. The organism decays, but the harder parts—bones, teeth, and shells, for example—may be preserved and hardened by minerals from the surrounding sediment. Fossilization may also occur even when the hard parts of an organism are dissolved away to leave an impression called a mold. The mold is filled by minerals, thereby creating a cast of the organism. The study of fossils (paleontology) can not only show how living things have evolved, but can also help to reveal the Earth's geological history—for example, by aiding in the dating of rock strata.

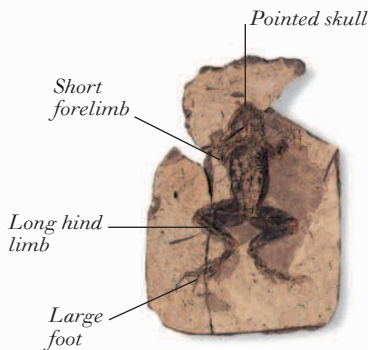
PROCESS OF FOSSILIZATION



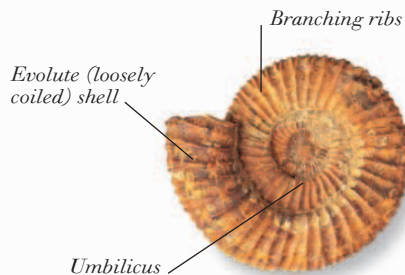
EXAMPLES OF FOSSILS



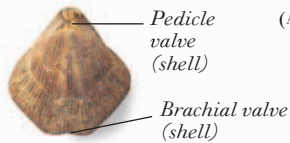
ALETHOPTERIS (SEED FERN)



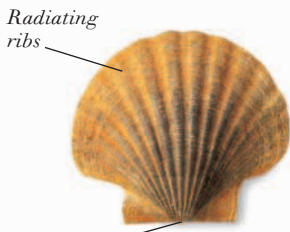
FROG (AMPHIBIAN)



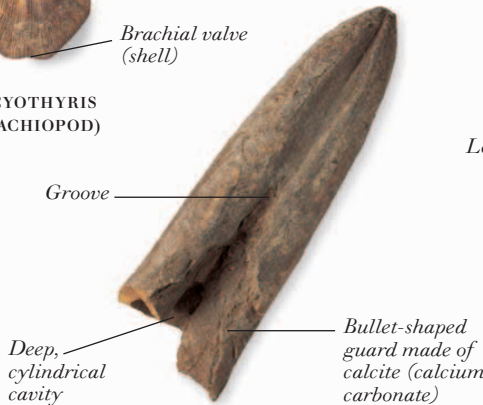
PAVLOVIA (AMMONITE MOLLUSK)



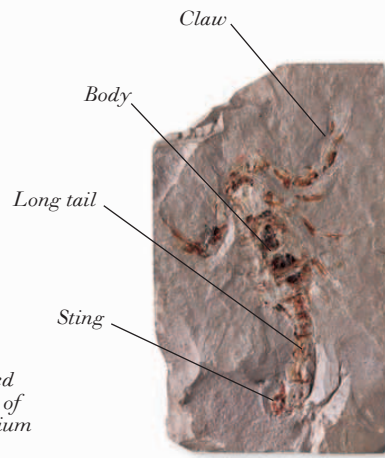
DICYOTHYRIS (BRACHIOPOD)



SCALLOP (BIVALVE MOLLUSK)

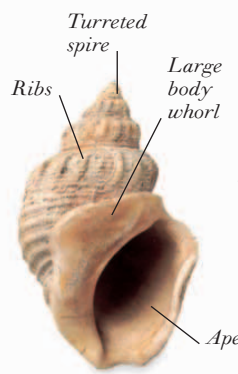
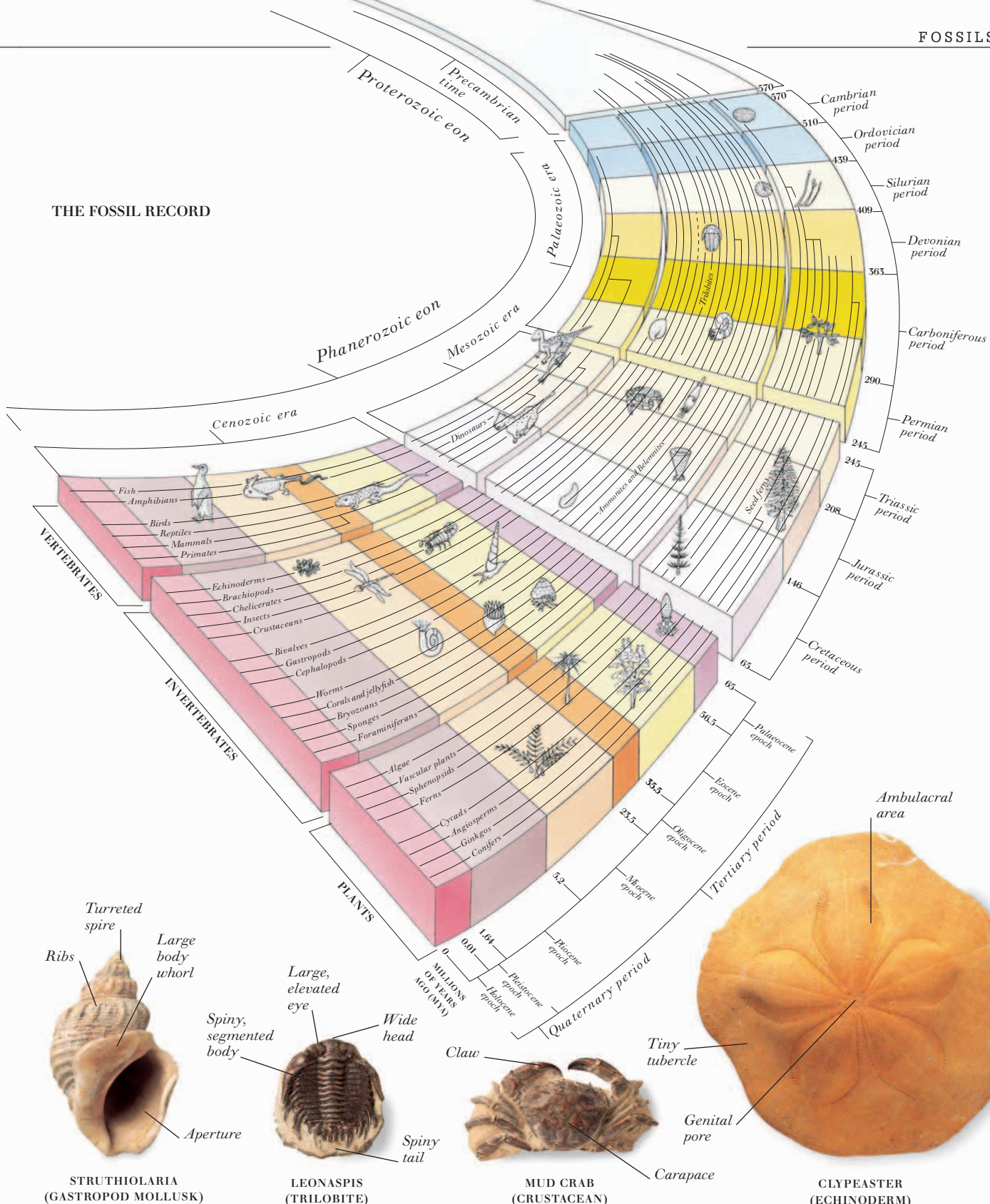


ACROTEUTHIS (BELEMNITE MOLLUSK)

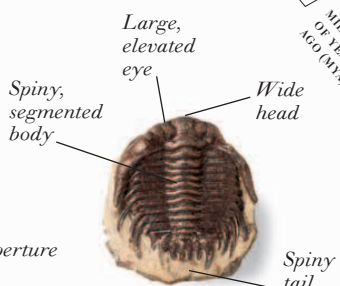


SCORPION (ARTHROPOD)

THE FOSSIL RECORD



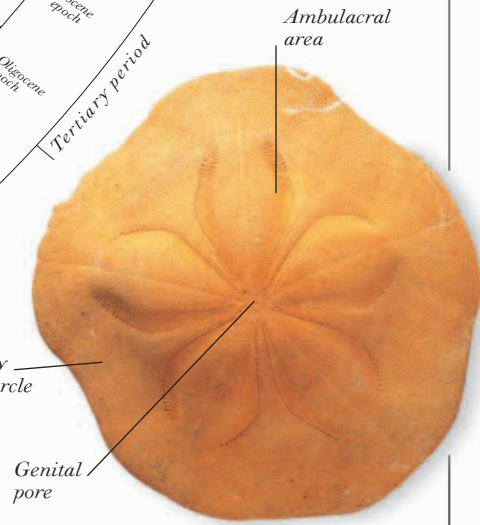
STRUTHIOLARIA (GASTROPOD MOLLUSK)



LEONASPIS (TRILOBITE)



MUD CRAB (CRUSTACEAN)



CLYPEASTER (ECHINODERM)

Mineral resources

MINERAL RESOURCES CAN BE DEFINED AS naturally occurring substances that can be extracted from the Earth and are useful as fuels and raw materials. Coal, oil, and gas – collectively called fossil fuels – are commonly included in this group, but are not strictly minerals, because they are of organic origin. Coal formation begins when vegetation is buried and partly decomposed to form peat. Overlying sediments compress the peat and transform it into lignite (soft brown coal).



OIL RIG, NORTH SEA

As the overlying sediments accumulate, increasing pressure and temperature eventually transform the lignite into bituminous and hard anthracite coals. Oil and gas are usually formed from organic matter that was deposited in marine sediments. Under the effects of heat and pressure, the compressed organic matter undergoes complex chemical changes to form oil and gas. The oil and gas percolate upwards through water-saturated, permeable rocks and they may rise to the Earth's surface or accumulate below an impermeable layer of rock that has been folded or faulted to form a trap – an anticline (upfold) trap, for example. Minerals are inorganic substances that may consist of a single chemical element, such as gold, silver, or copper, or combinations of elements (see pp. 268-269). Some minerals are concentrated in mineralization zones in rock associated with crustal movements or volcanic activity. Others may be found in sediments as placer deposits – accumulations of high-density minerals that have been weathered out of rocks, transported, and deposited (on riverbeds, for example).

STAGES IN THE FORMATION OF COAL



PLANT MATTER



About 60% carbon

PEAT

About 70% carbon



Crumbly texture

LIGNITE (BROWN COAL)

Powdery texture



About 80% carbon

BITUMINOUS COAL

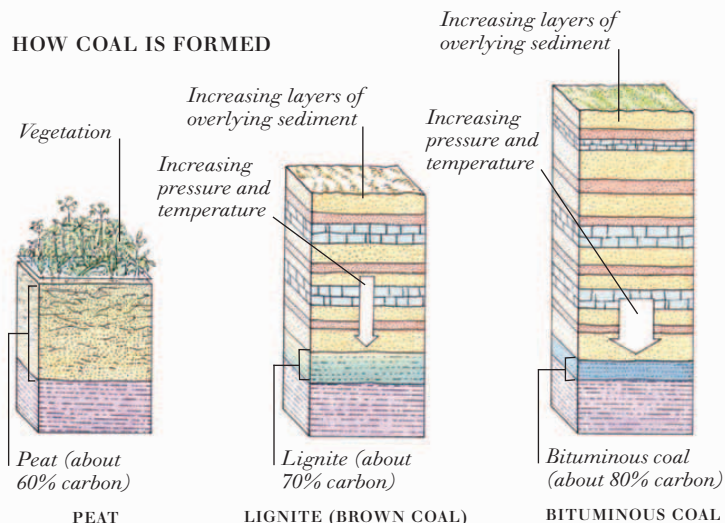
Shiny surface

About 95% carbon

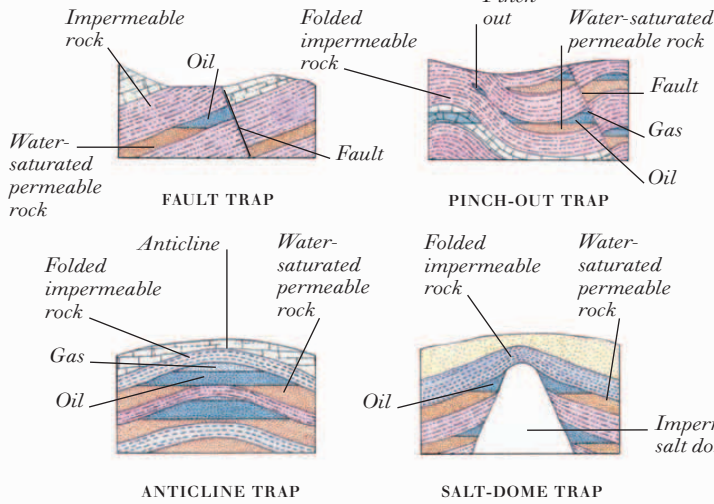


ANTHRACITE COAL

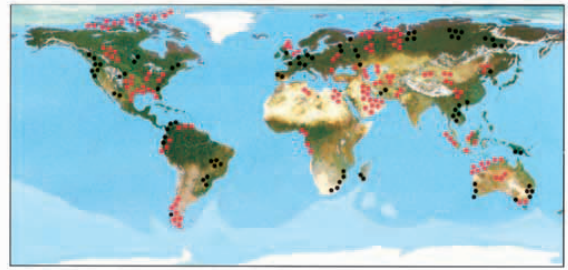
HOW COAL IS FORMED



EXAMPLES OF OIL AND GAS TRAPS

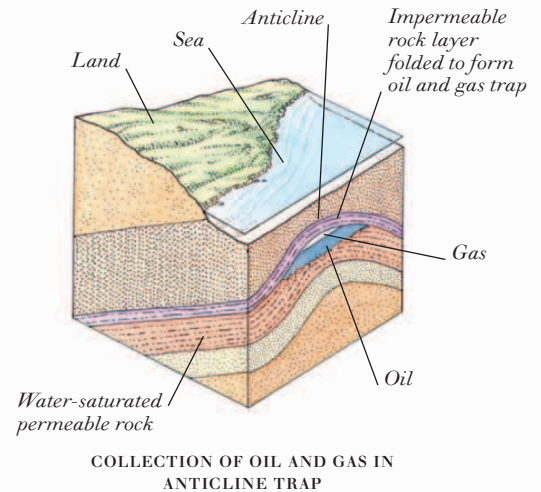
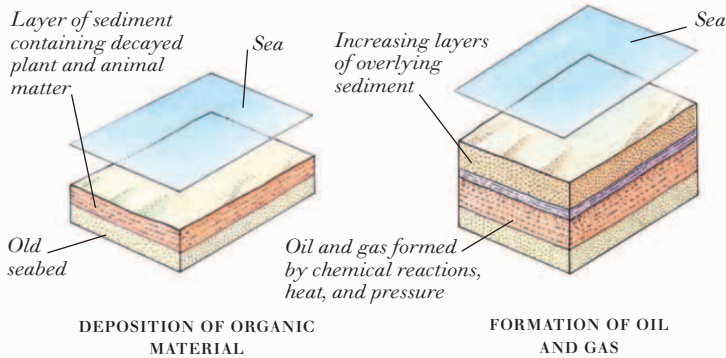


MAJOR COAL, OIL, AND GAS DEPOSITS

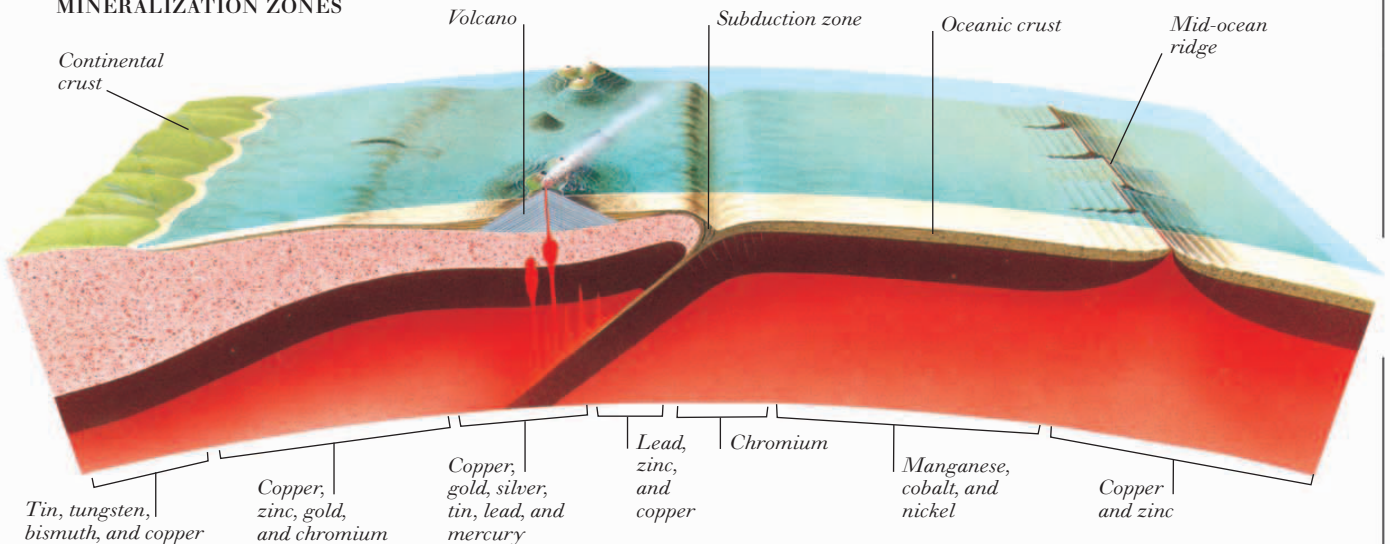


● Coal ● Oil and gas

HOW AN ANTICLINE TRAP IS FORMED



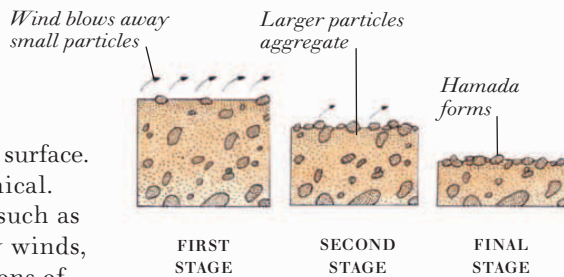
MINERALIZATION ZONES



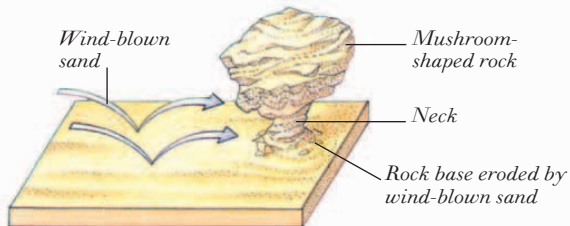
Weathering and erosion

WEATHERING IS THE BREAKING DOWN of rocks on the Earth's surface. There are two main types: physical (or mechanical) and chemical. Physical weathering may be caused by temperature changes, such as freezing and thawing, or by abrasion from material carried by winds, rivers, or glaciers. Rocks may also be broken down by the actions of animals and plants, such as the burrowing of animals and the growth of roots. Chemical weathering causes rocks to decompose by changing their chemical composition—for example, rainwater may dissolve certain minerals in a rock. Erosion is the wearing away and removal of land surfaces by water, wind, or ice. It is greatest in areas of little or no surface vegetation, such as deserts, where sand dunes may form.

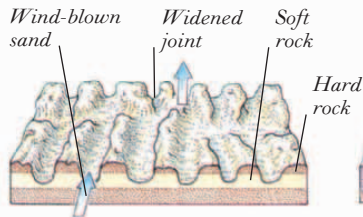
FORMATION OF A HAMADA (ROCK PAVEMENT)



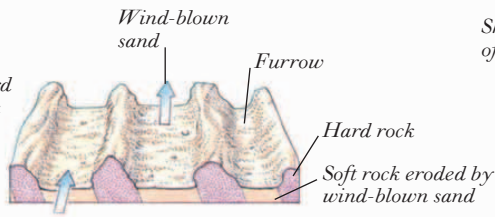
FEATURES PRODUCED BY WIND ACTION



ROCK PEDESTAL

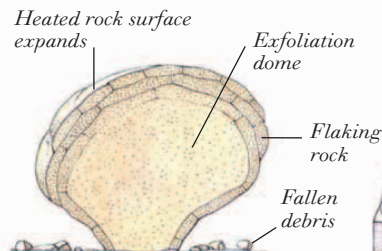


ZEUGEN

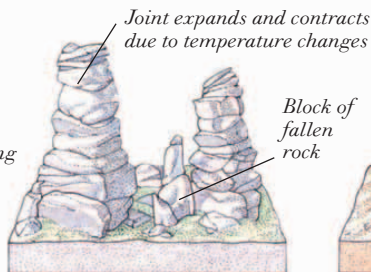


YARDANG

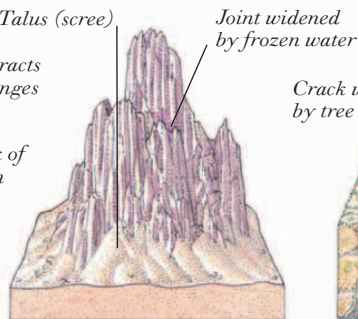
EXAMPLES OF PHYSICAL WEATHERING PROCESSES



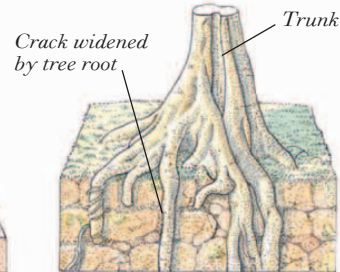
EXFOLIATION (ONION-SKIN WEATHERING)



BLOCK DISINTEGRATION

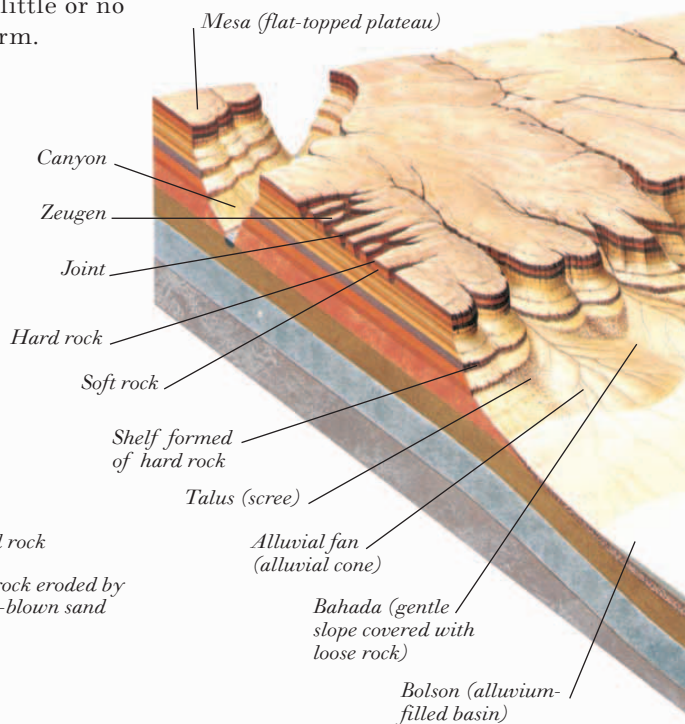


FROST WEDGING

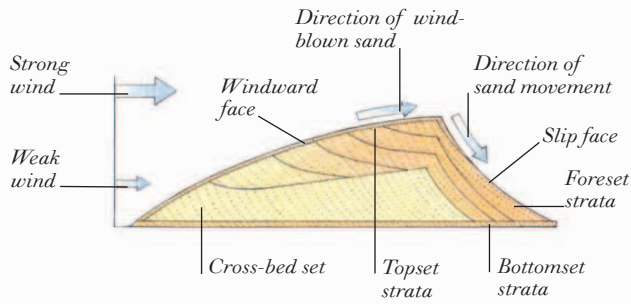


TREE ROOT ACTION

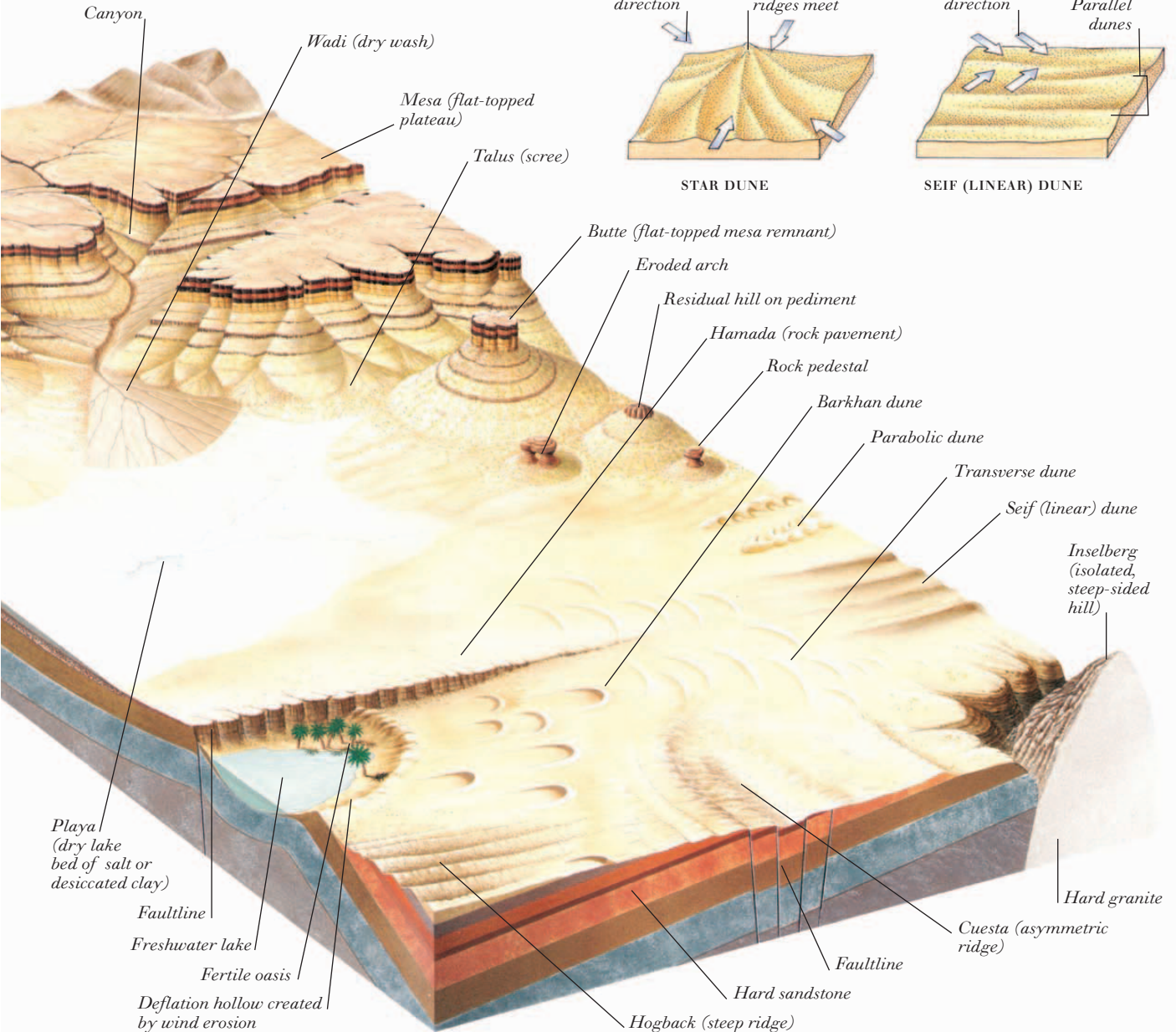
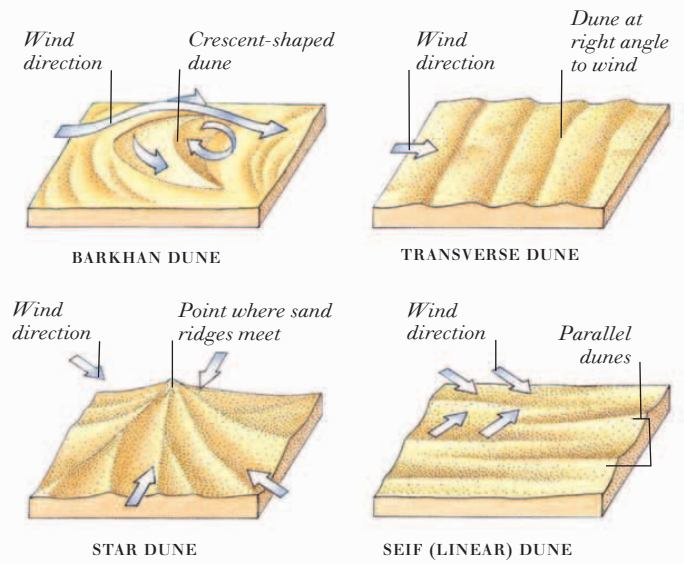
FEATURES OF WEATHERING AND EROSION



SECTION THROUGH A BARKHAN DUNE



EXAMPLES OF SAND DUNES



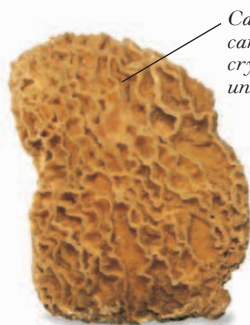
Caves

CAVES COMMONLY FORM in areas of limestone, although on coastlines they also occur in other rocks. Limestone is made of calcite (calcium carbonate), which dissolves in the carbonic acid naturally present in rainwater, and in humic acids from the decay of vegetation. The acidic water trickles down through cracks and joints in the limestone and between rock layers, breaking up the surface terrain into clints (blocks of rock), separated by grikes (deep cracks), and punctuated by sink-holes (also called swallow-holes or potholes) into

MERGED STALACTITES

which surface streams may disappear. Underground, the acidic water dissolves the rock around crevices, opening up a network of passages and caves, which can become large caverns if the roofs collapse. Various features are formed when the dissolved calcite is redeposited; for example, it may be redeposited along an underground stream to form a gour (series of calcite ridges), or in caves and passages to form stalactites and stalagmites. Stalactites develop where calcite is left behind as water drips from the roof; where the drops land, stalagmites build up.

STALAGMITE FORMATIONS



CRYSTALLINE STALAGMITIC FLOOR

Calcite (calcium carbonate) crystallized under water



CALCAREOUS TUFFA

Thin encrustations of calcite (calcium carbonate)



STALAGMITIC FLOOR

Encrustations on dead stems of small plants

Calcite (calcium carbonate)

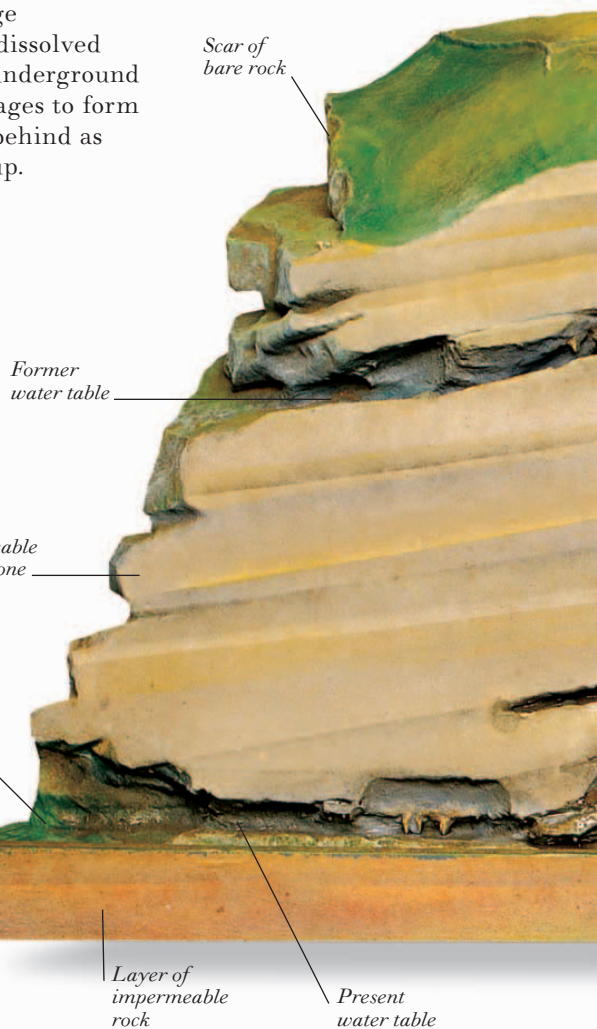
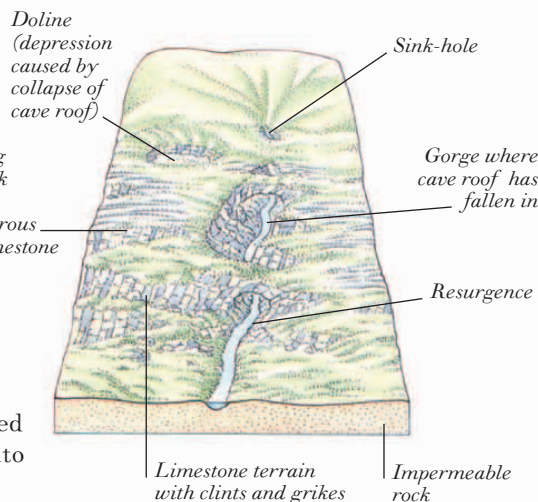
Calcite (calcium carbonate)



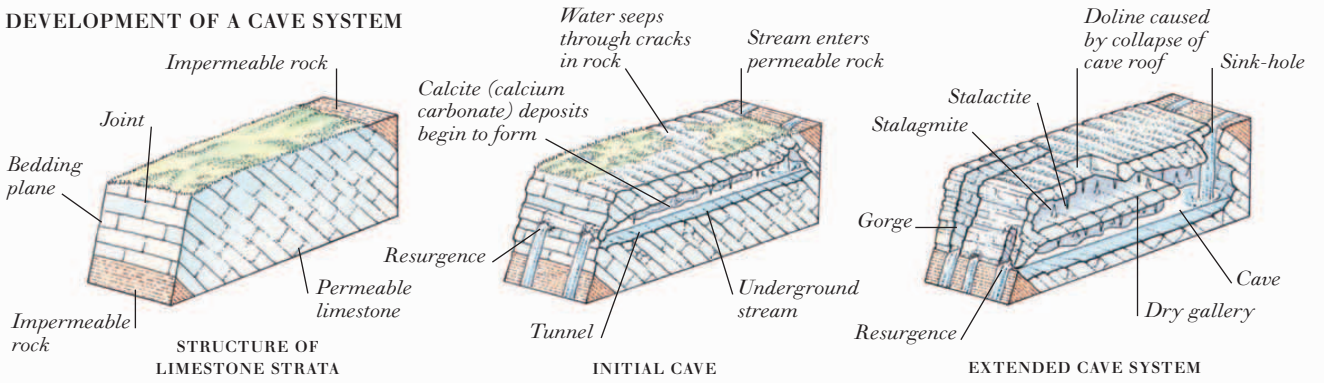
STALAGMITIC BOSS

Encrustations with fungoid structure

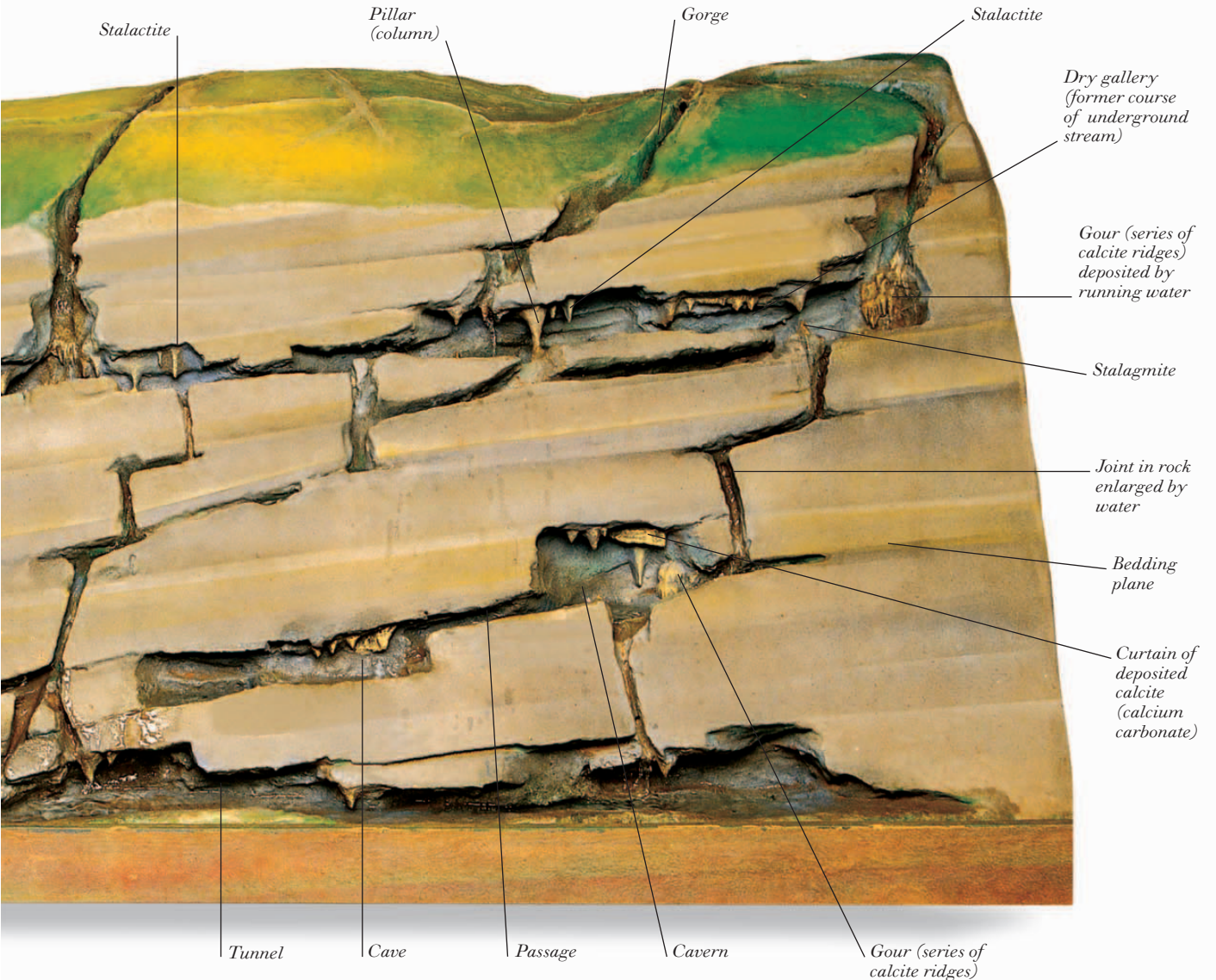
SURFACE TOPOGRAPHY OF A CAVE SYSTEM



DEVELOPMENT OF A CAVE SYSTEM



INTERCONNECTED CAVE SYSTEM



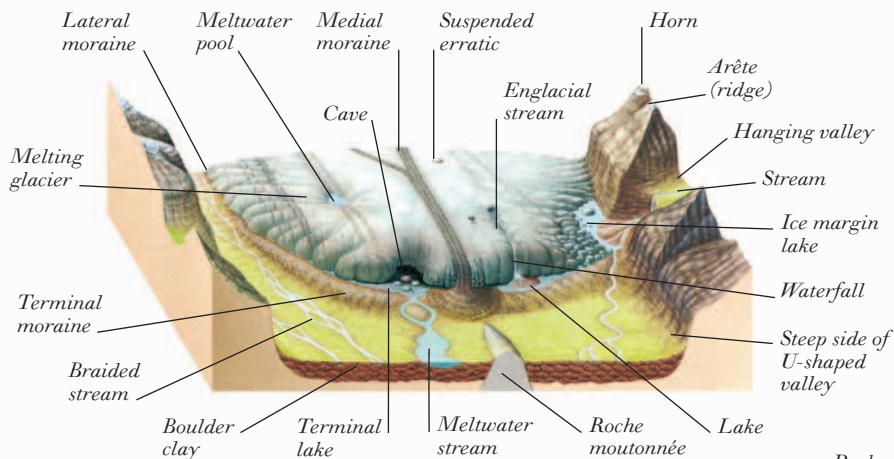
Glaciers



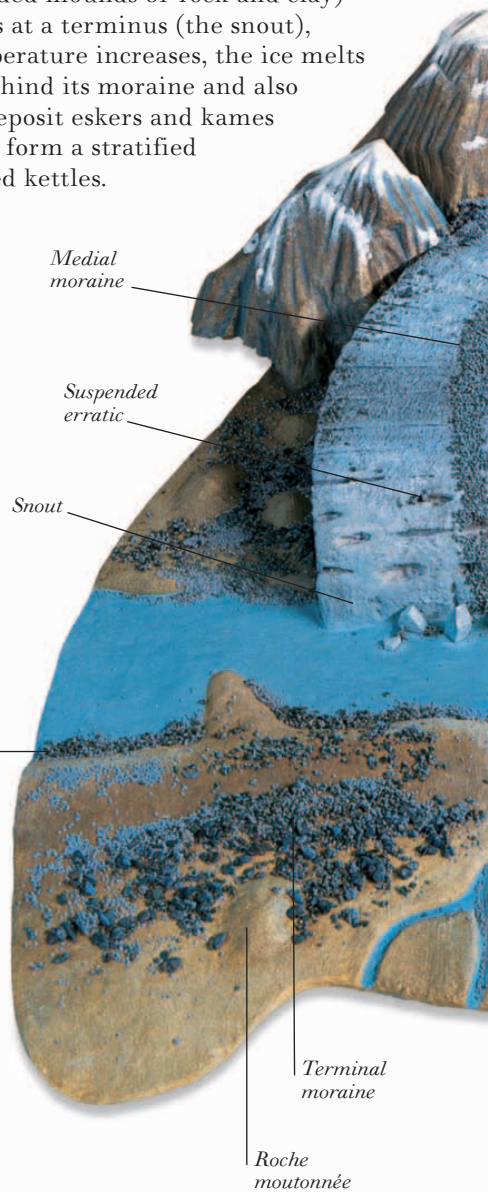
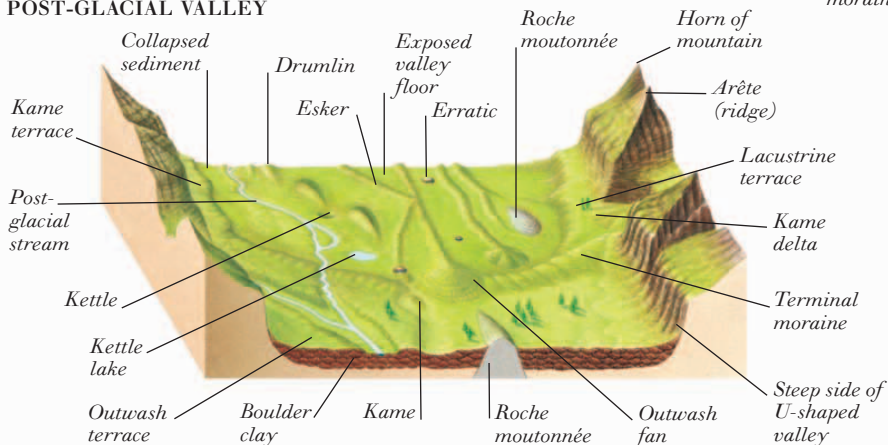
GLACIER BAY, ALASKA

A VALLEY GLACIER IS A LARGE MASS OF ICE that forms on land and moves slowly downhill under its own weight. It is formed from snow that collects in cirques (mountain hollows also known as corries) and compresses into ice as more and more snow accumulates. The cirque is deepened by frost wedging and abrasion (see pp. 282-283), and arêtes (sharp ridges) develop between adjacent cirques. Eventually, so much ice builds up that the glacier begins to move downhill. As the glacier moves it collects moraine (debris), which may range in size from particles of dust to large boulders. The rocks at the base of the glacier erode the glacial valley, giving it a U-shaped cross-section. Under the glacier, *roches moutonnées* (eroded outcrops of hard rock) and drumlins (rounded mounds of rock and clay) are left behind on the valley floor. The glacier ends at a terminus (the snout), where the ice melts as fast as it arrives. If the temperature increases, the ice melts faster than it arrives, and the glacier retreats. The retreating glacier leaves behind its moraine and also erratics (isolated single boulders). Glacial streams from the melting glacier deposit eskers and kames (ridges and mounds of sand and gravel), but carry away the finer sediment to form a stratified outwash plain. Lumps of ice carried on to this plain melt, creating holes called kettles.

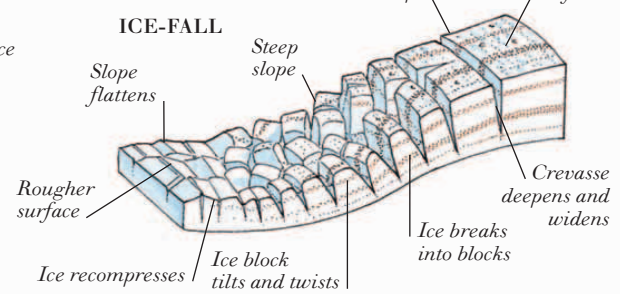
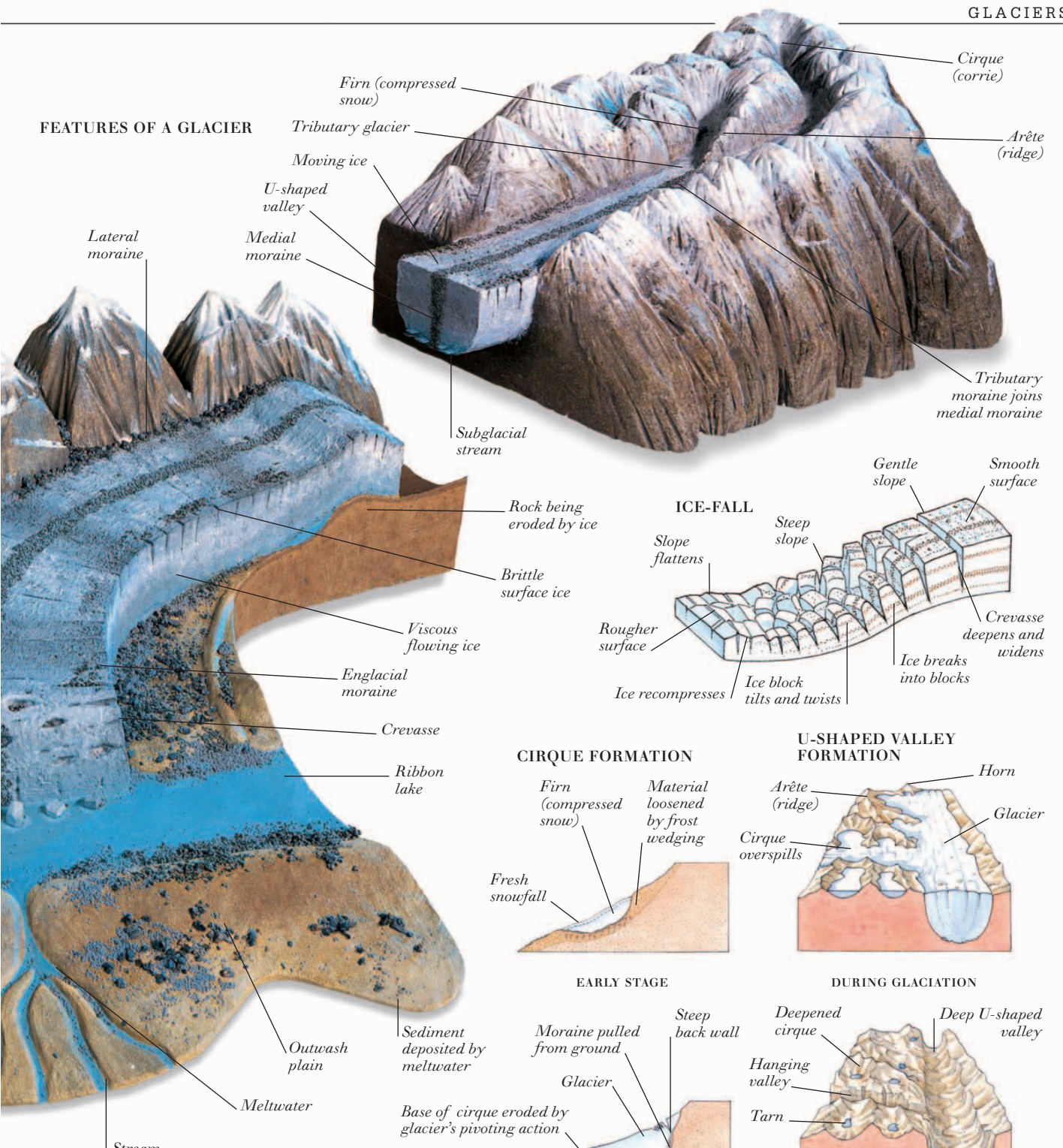
VALLEY GLACIER



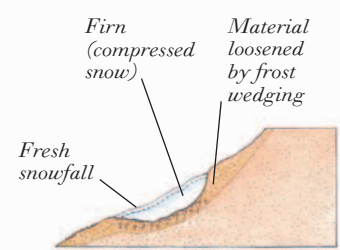
POST-GLACIAL VALLEY



FEATURES OF A GLACIER

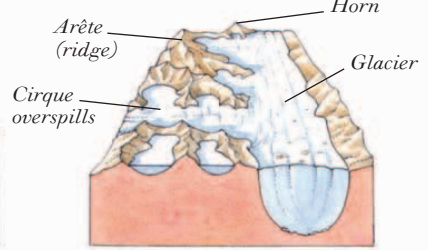


CIRQUE FORMATION

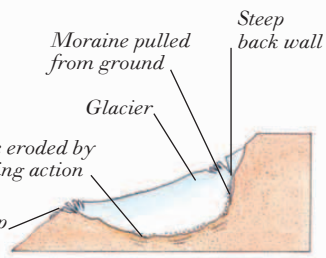


EARLY STAGE

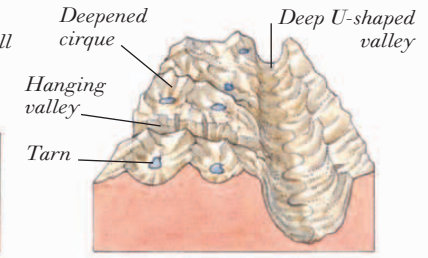
U-SHAPED VALLEY FORMATION



DURING GLACIATION



LATER STAGE

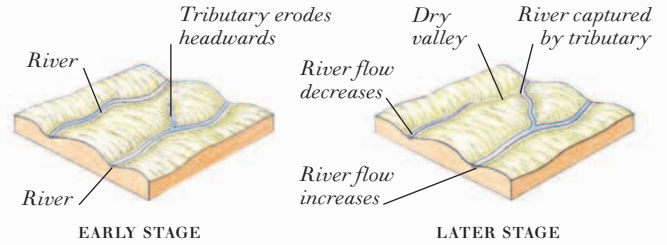


AFTER GLACIATION

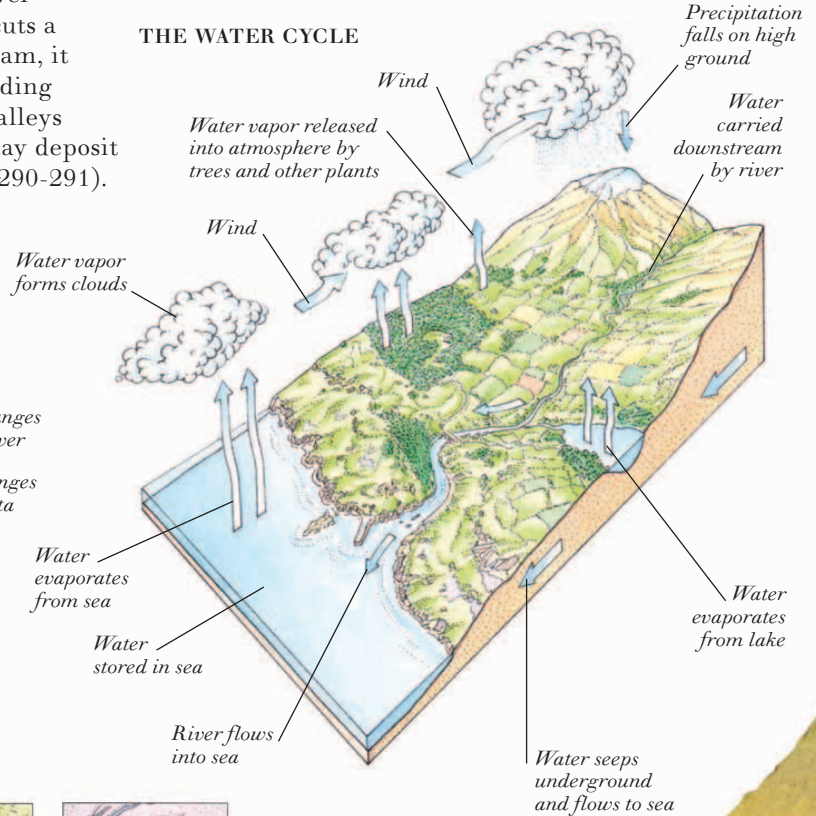
Rivers

RIVERS FORM PART of the water cycle—the continuous circulation of water between the land, sea, and atmosphere. The source of a river may be a mountain spring or lake, or a melting glacier. The course that the river subsequently takes depends on the slope of the terrain and on the rock types and formations over which it flows. In its early, upland stages, a river tumbles steeply over rocks and boulders and cuts a steep-sided V-shaped valley. Farther downstream, it flows smoothly over sediments and forms winding meanders, eroding sideways to create broad valleys and plains. On reaching the coast, the river may deposit sediment to form an estuary or delta (see pp. 290-291).

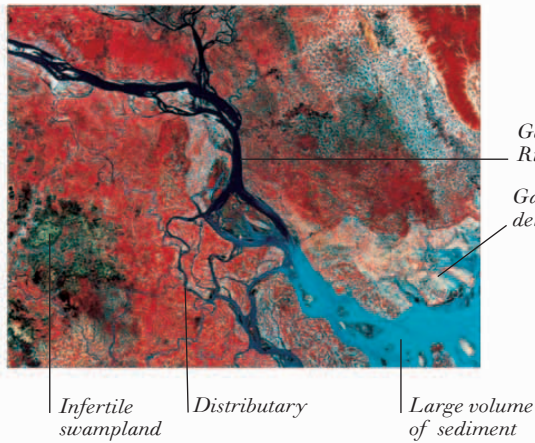
RIVER CAPTURE



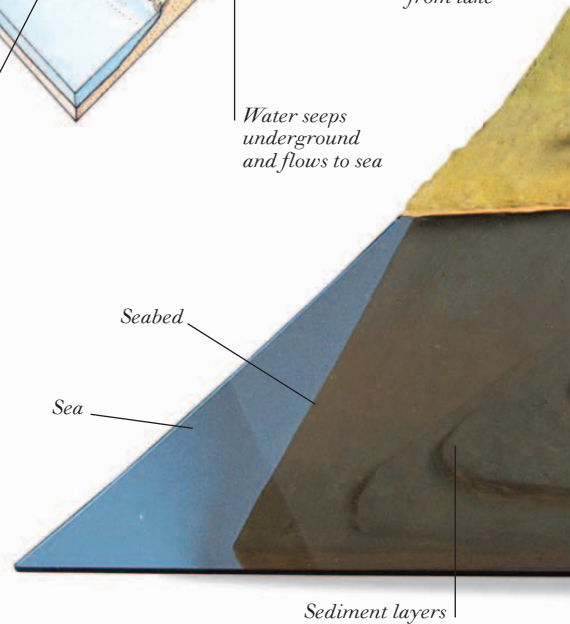
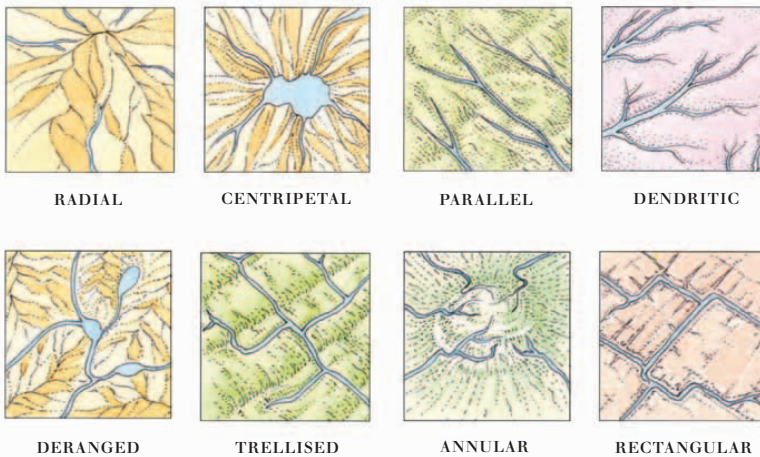
THE WATER CYCLE



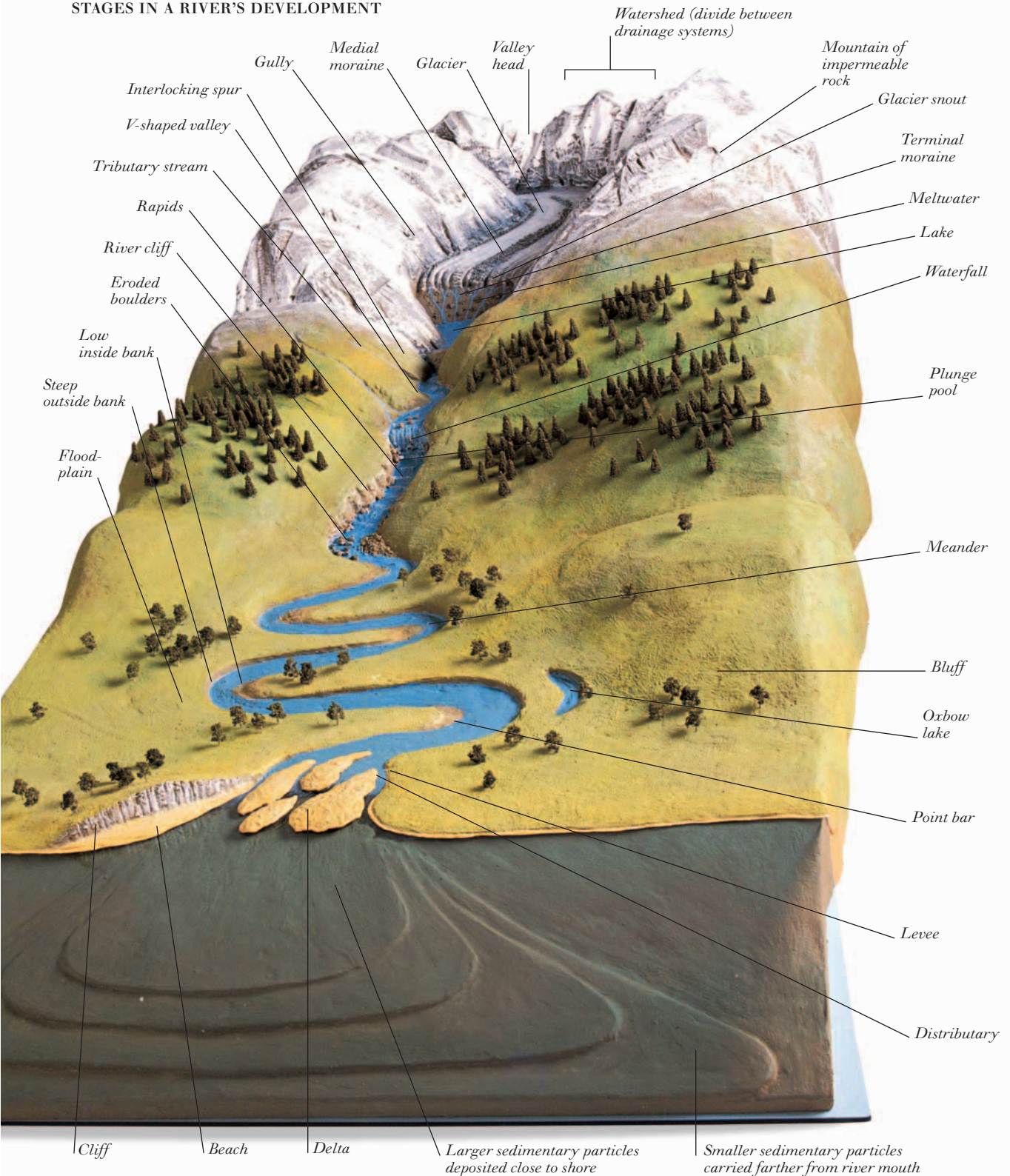
SATELLITE IMAGE OF GANGES RIVER DELTA, BANGLADESH



RIVER DRAINAGE PATTERNS



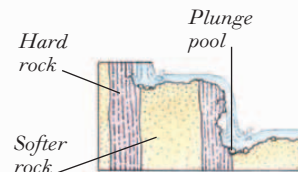
STAGES IN A RIVER'S DEVELOPMENT



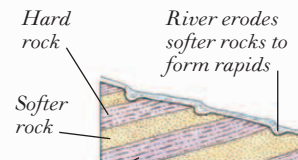
River features

RIVERS ARE ONE OF THE MAJOR FORCES that shape the landscape. Near its source, a river is steep (see pp. 288-289). It erodes downward, carving out V-shaped valleys and deep gorges. Waterfalls and rapids are formed where the river flows from hard rock to softer, more easily eroded rock. Farther downstream, meanders may form and there is greater sideways erosion, resulting in a broad river valley. The river sometimes erodes through the neck of a meander to form an oxbow lake. Sediment deposited on the valley floor by meandering rivers and during floods helps to create a floodplain. Floods may also deposit sediment on the banks of the river to form levees. As a river spills into the sea or a lake, it deposits large amounts of sediment, and may form a delta. A delta is an area of sand bars, swamps, and lagoons through which the river flows in several channels called distributaries—the Mississippi delta, for example. Often, a rise in sea level may have flooded the river mouth to form a broad estuary, a tidal section where seawater mixes with fresh water.

HOW WATERFALLS AND RAPIDS ARE FORMED



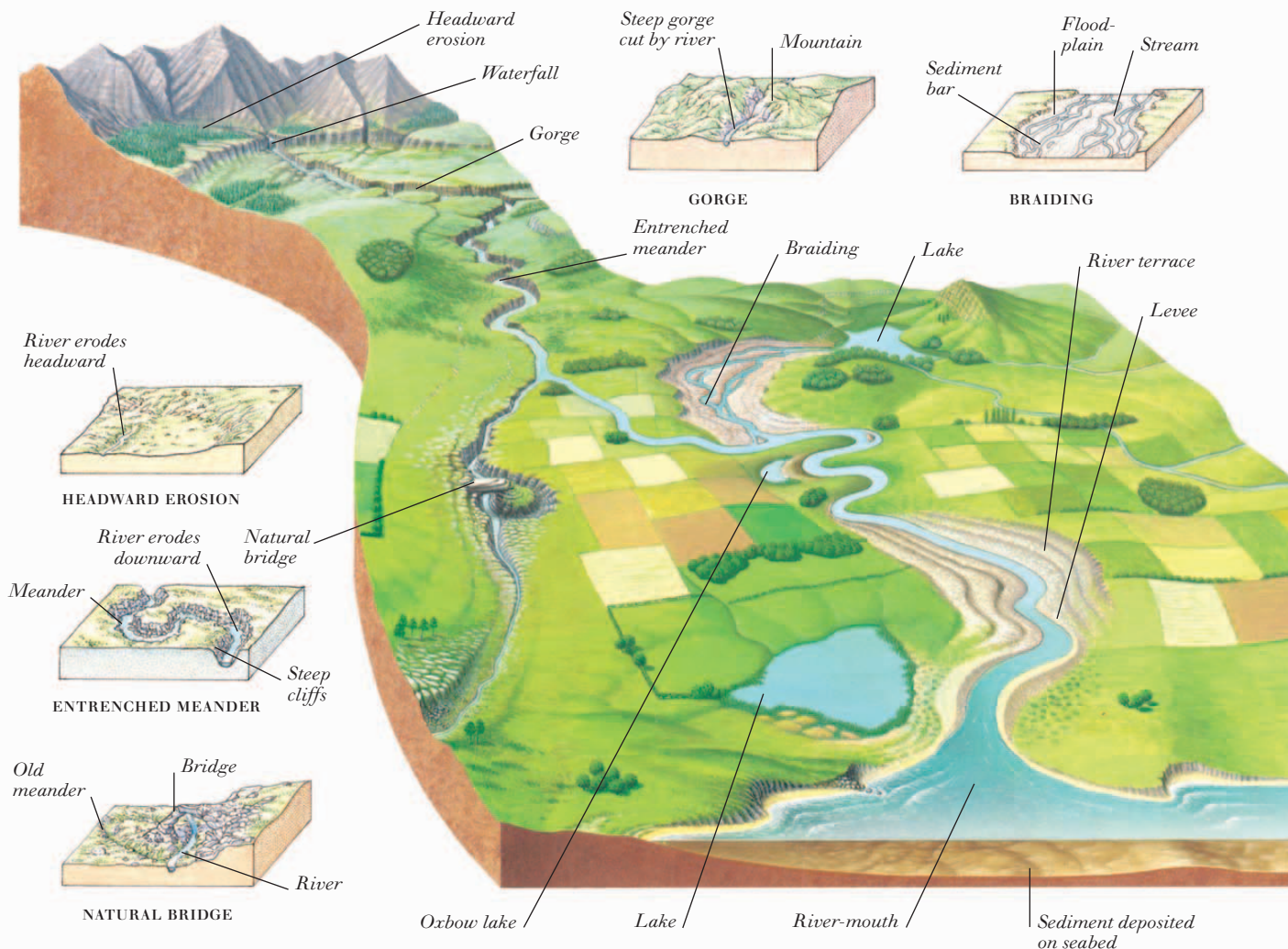
WATERFALL



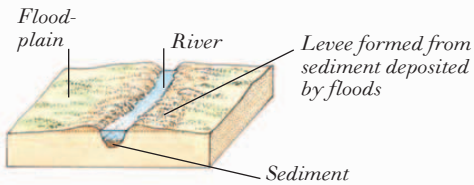
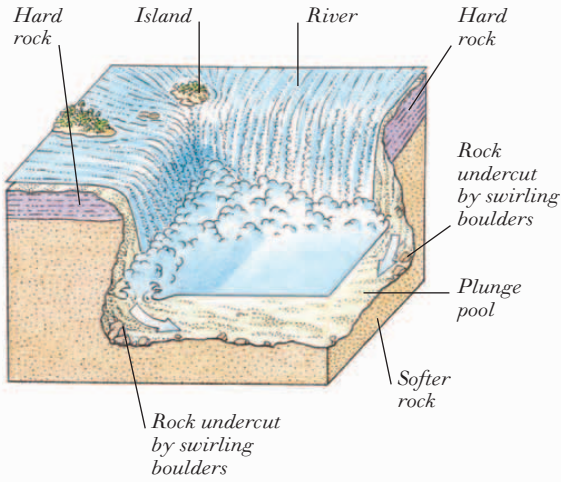
RAPIDS

Gently sloping rock strata

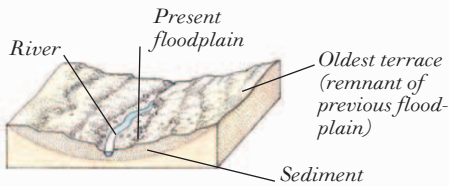
A RIVER VALLEY DRAINAGE SYSTEM



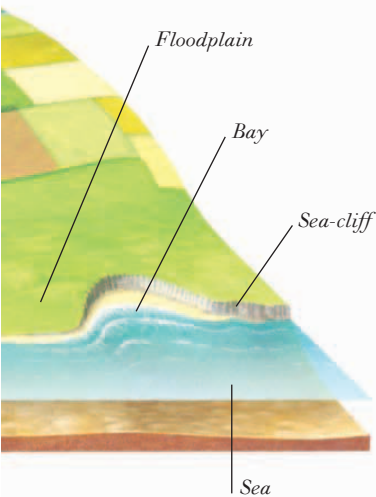
WATERFALL FEATURES



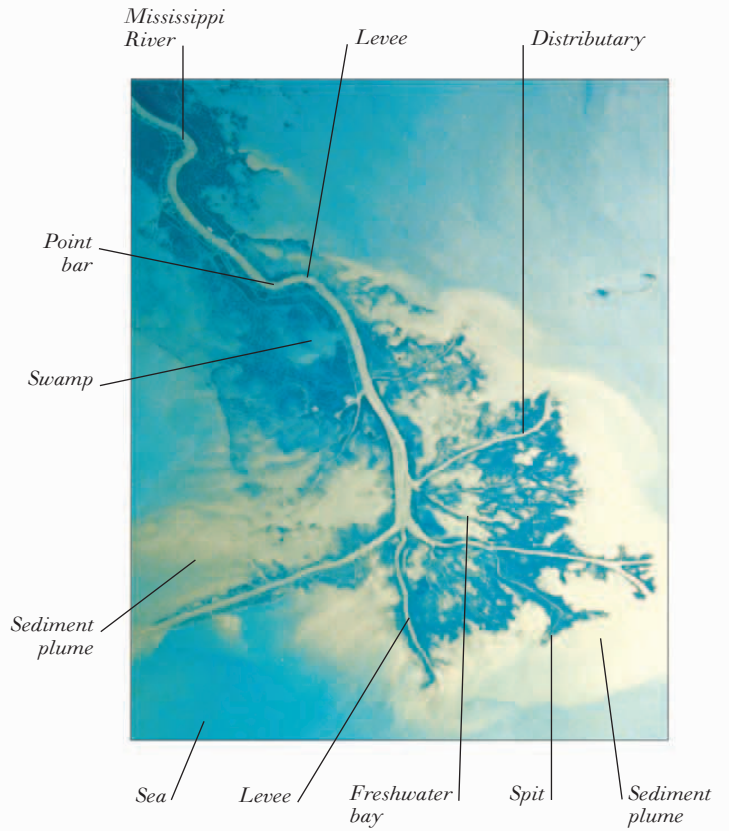
LEVEE



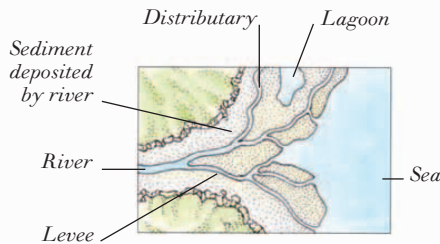
RIVER TERRACE



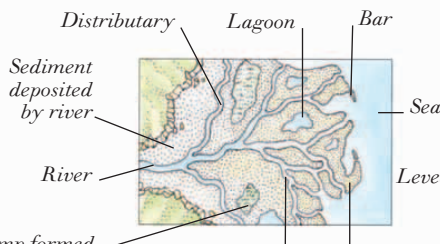
THE MISSISSIPPI DELTA



FORMATION OF A DELTA

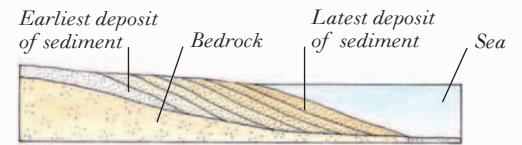


EARLY STAGE

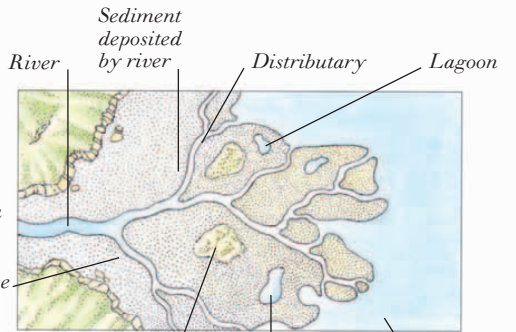


MIDDLE STAGE

Swamp formed by deposition of sediment in lagoon



SECTION THROUGH DELTA



LATE STAGE

Lakes and groundwater

NATURAL LAKE OCCUR WHERE a large quantity of water collects in a hollow in impermeable rock, or is prevented from draining away by a barrier, such as moraine (glacial deposits) or solidified lava. Lakes are often relatively short-lived landscape features, as they tend to become silted up by sediment from the streams and rivers that feed them. Some of the more long-lasting

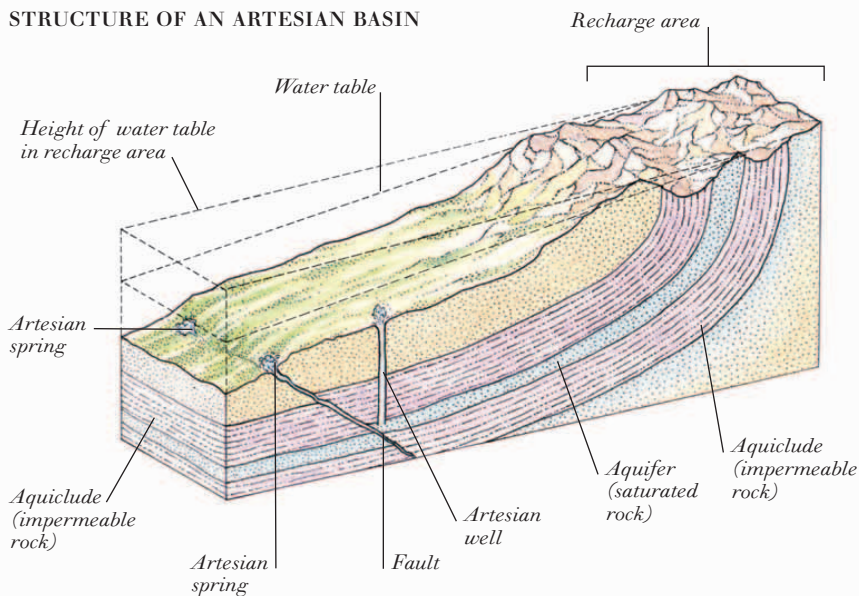


LAKE BAIKAL, RUSSIA

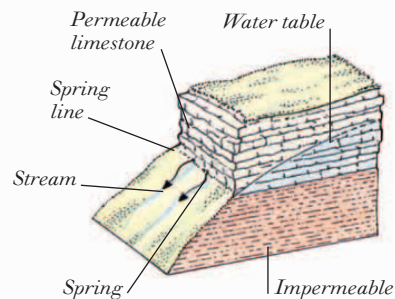
lakes are found in deep rift valleys formed by vertical movements of the Earth's crust (see pp. 58-59)—for example, Lake Baikal in Russia, the world's largest freshwater lake, and the Dead Sea in the Middle East, one of the world's saltiest lakes. Where water is able to drain away, it sinks into the ground until it reaches a layer of impermeable rock, then accumulates in the permeable rock above it; this water-saturated permeable rock is called an aquifer. The saturated zone varies in depth according to seasonal and climatic changes. In wet conditions, the water

stored underground builds up, while in dry periods it becomes depleted. Where the upper edge of the saturated zone—the water table—meets the ground surface, water emerges as springs. In an artesian basin, where the aquifer is below an aquiclude (layer of impermeable rock), the water table throughout the basin is determined by its height at the rim. In the center of such a basin, the water table is above ground level. The water in the basin is thus trapped below the water table and can rise under its own pressure along faultlines or well shafts.

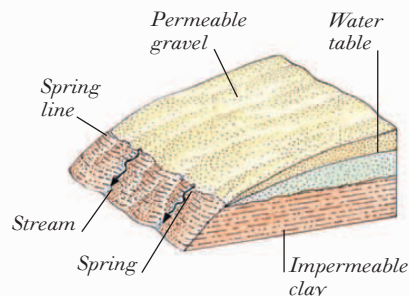
STRUCTURE OF AN ARTESIAN BASIN



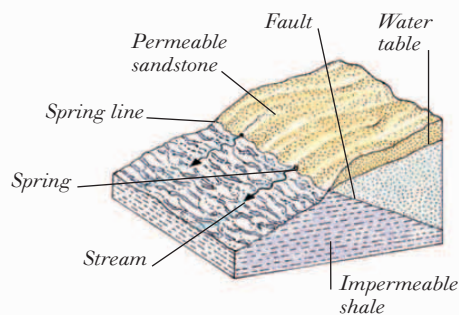
EXAMPLES OF SPRINGS



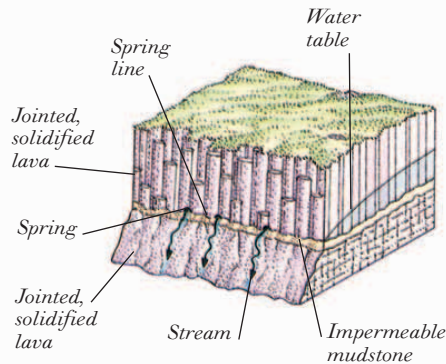
LIMESTONE SPRING



COASTAL (VALLEY) SPRING

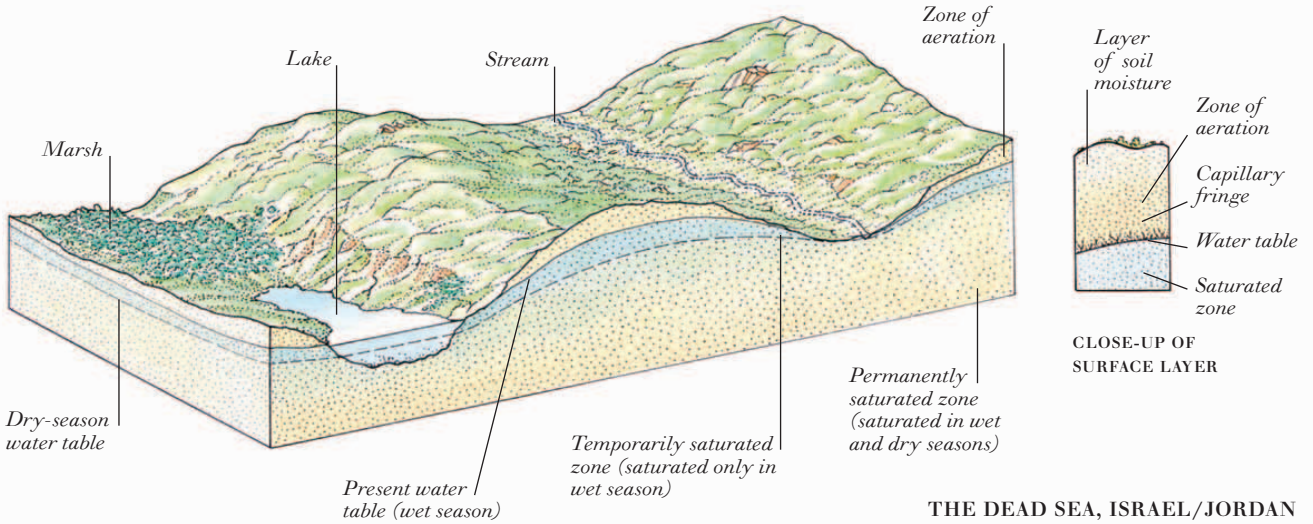


FAULT SPRING

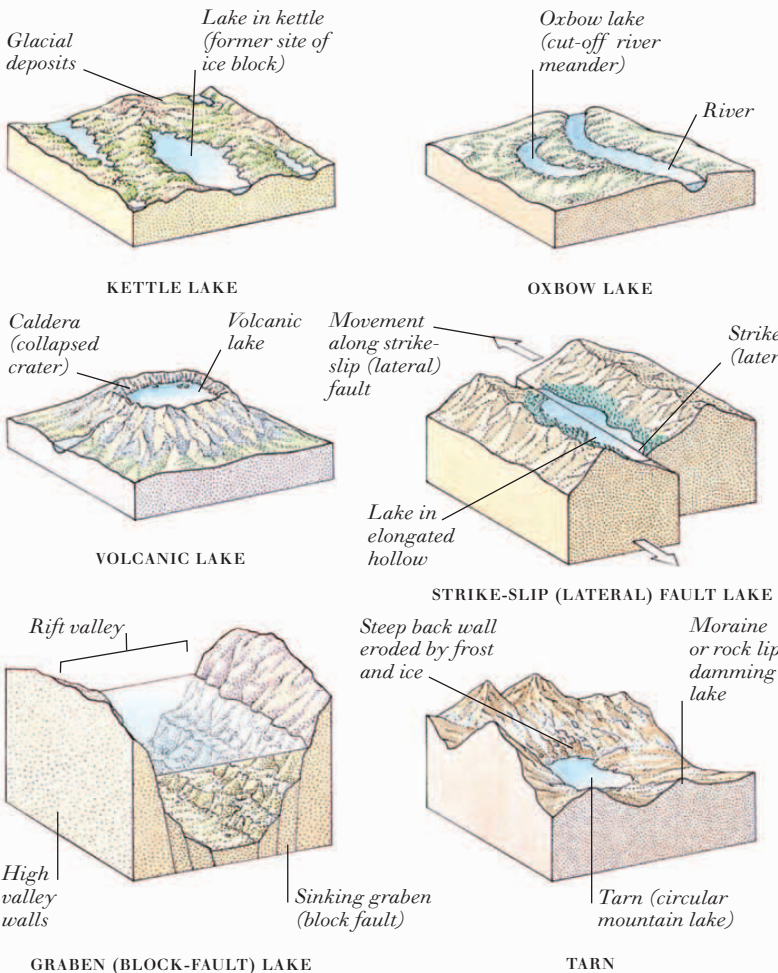


LAVA SPRING

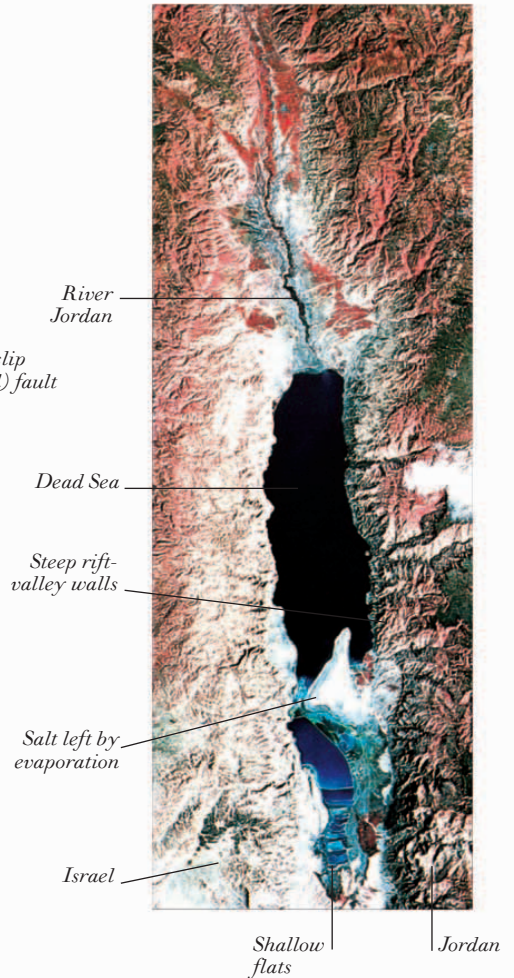
FEATURES OF A GROUNDWATER SYSTEM



EXAMPLES OF LAKES



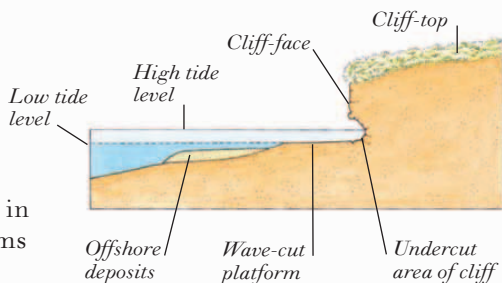
THE DEAD SEA, ISRAEL/JORDAN



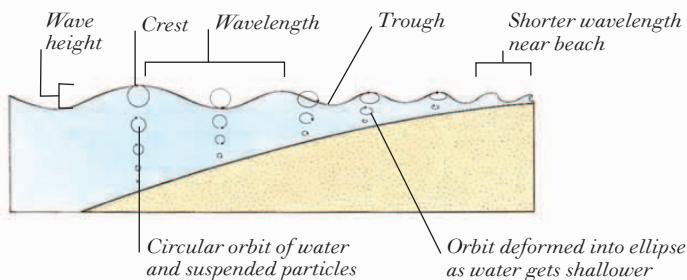
Coastlines

COASTLINES ARE AMONG THE MOST RAPIDLY changing landscape features. Some are eroded by waves, wind, and rain, causing cliffs to be undercut and caves to be hollowed out of solid rock. Others are built up by waves transporting sand and small rocks in a process known as longshore drift, and by rivers depositing sediment in deltas. Additional influences include the activities of living organisms such as coral, crustal movements, and sea-level variations due to climatic changes. Rising land or a drop in sea level creates an emergent coastline, with cliffs and beaches stranded above the new shoreline. Sinking land or a rise in sea level produces a drowned coastline, typified by fjords (submerged glacial valleys) or submerged river valleys.

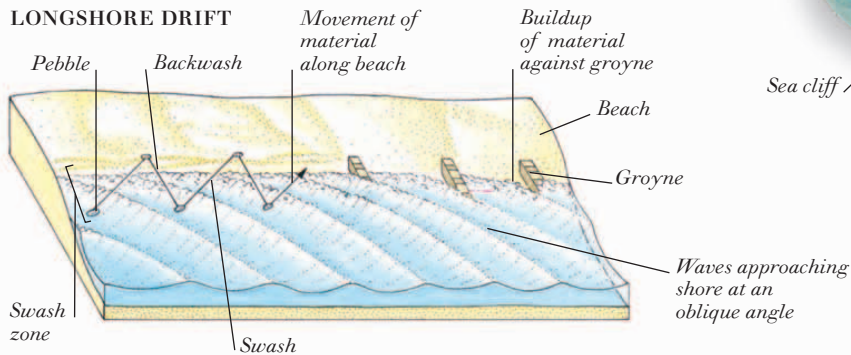
FEATURES OF A SEA CLIFF



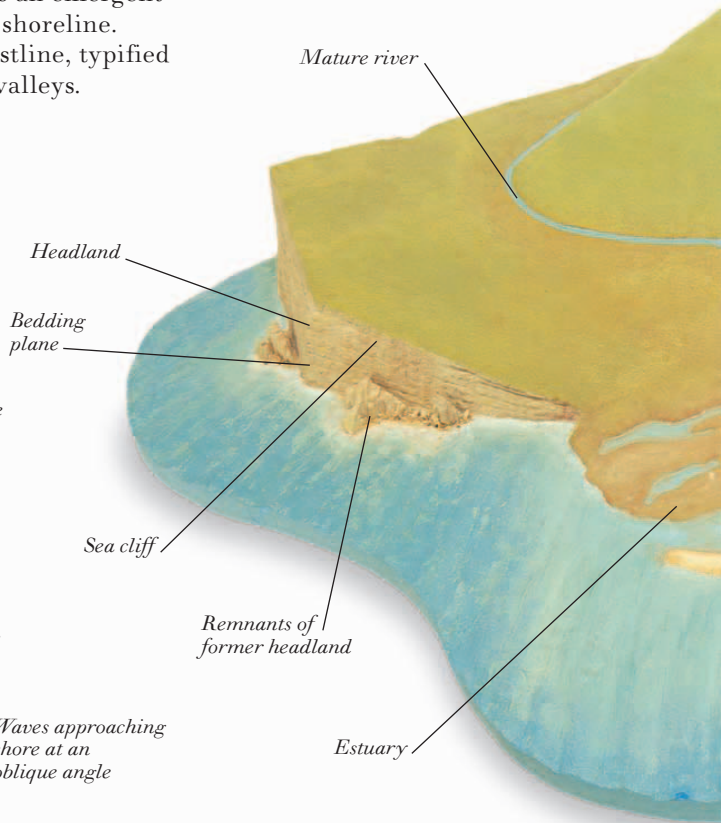
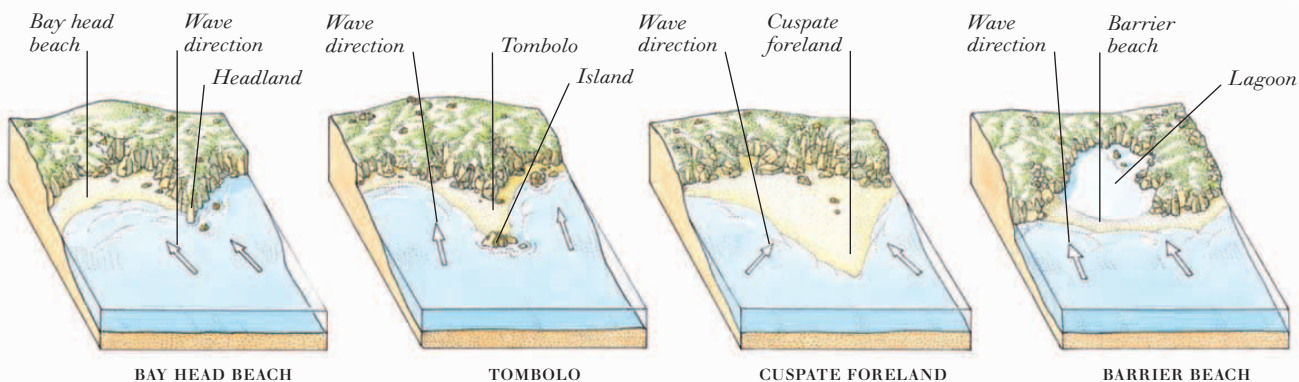
FEATURES OF WAVES



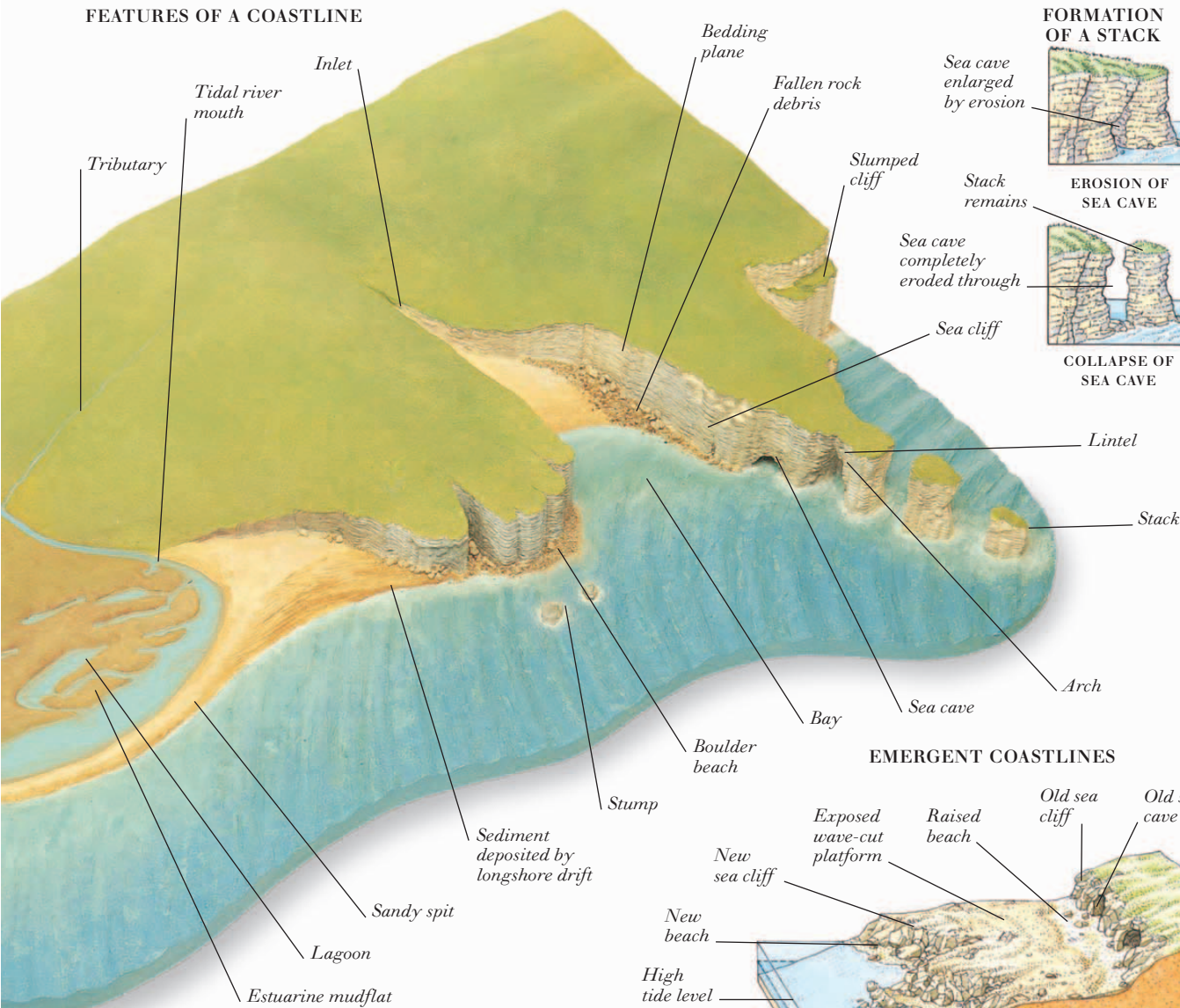
LONGSHORE DRIFT



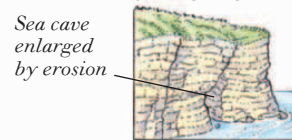
DEPOSITIONAL FEATURES OF COASTLINES



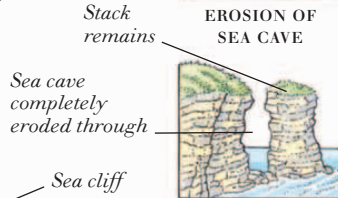
FEATURES OF A COASTLINE



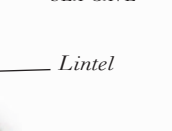
FORMATION OF A STACK



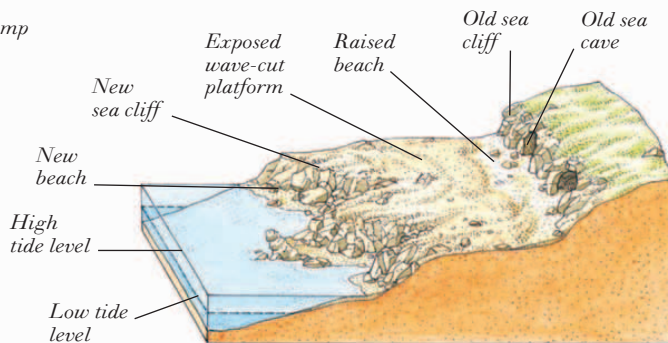
EROSION OF SEA CAVE



COLLAPSE OF SEA CAVE



EMERGENT COASTLINES



HIGHLAND COASTLINE

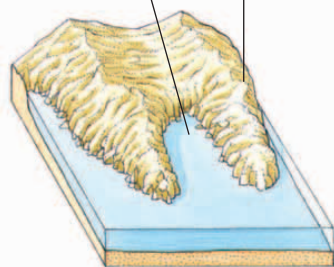
DROWNED COASTLINES

Fjord (submerged glacial valley)

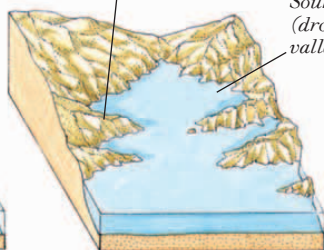
Angular mountain ridge

Mountain ridge parallel to coast

Sound (drowned valley)



FJORD COASTLINE



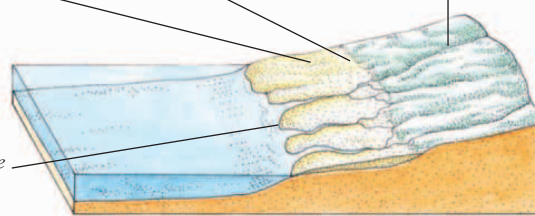
DALMATIAN/PACIFIC COASTLINE

Valley deepened by river downcutting toward new sea level

New coastal plain

Old coastline

New coastline

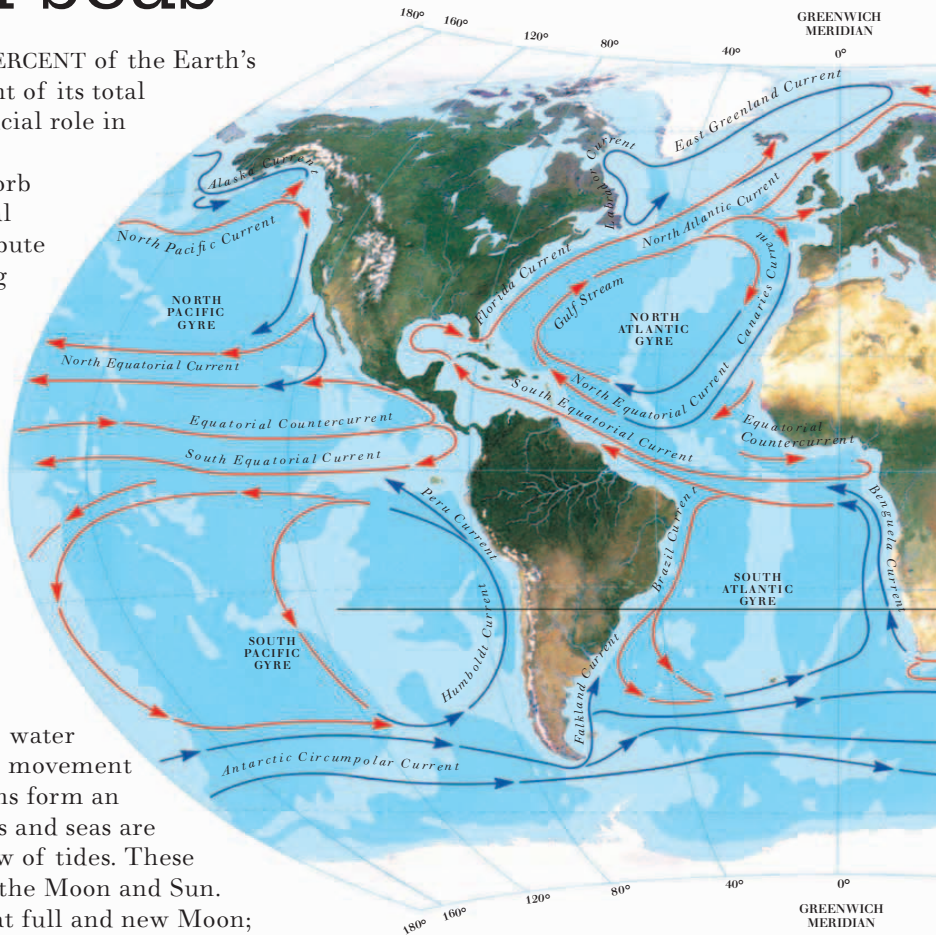


LOWLAND COASTLINE

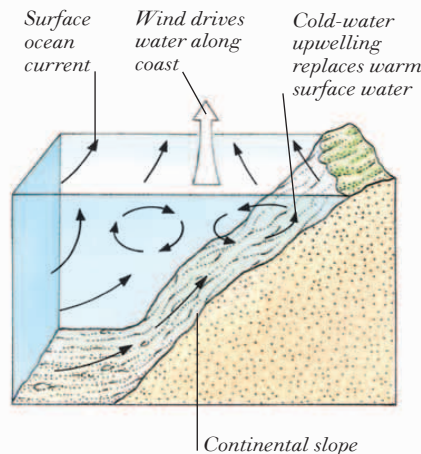
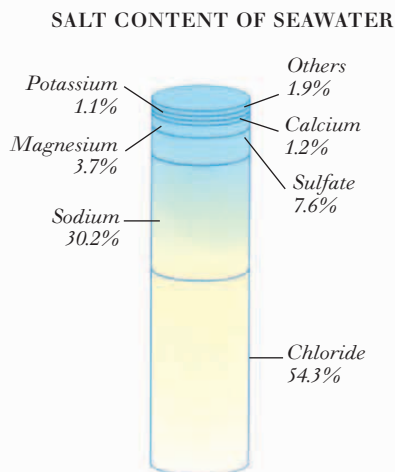
Oceans and seas

OCEANS AND SEAS COVER ABOUT 70 PERCENT of the Earth's surface and account for about 97 percent of its total water. These oceans and seas play a crucial role in regulating temperature variations and determining climate. Their waters absorb heat from the Sun, especially in tropical regions, and the surface currents distribute it around the Earth, warming overlying air masses and neighboring land in winter and cooling them in summer. The oceans are never still. Differences in temperature and salinity drive deep current systems, while surface currents are generated by winds blowing over the oceans. All currents are deflected—to the right in the Northern Hemisphere, to the left in the Southern Hemisphere—as a result of the Earth's rotation. This deflective factor is known as the Coriolis force. A current that begins on the surface is immediately deflected. This current in turn generates a current in the layer of water beneath, which is also deflected. As the movement is transmitted downward, the deflections form an Ekman spiral. The waters of the oceans and seas are also moved by the constant ebb and flow of tides. These are caused by the gravitational pull of the Moon and Sun. The highest tides (Spring tides) occur at full and new Moon; the lowest tides (neap tides) occur at first and last quarter.

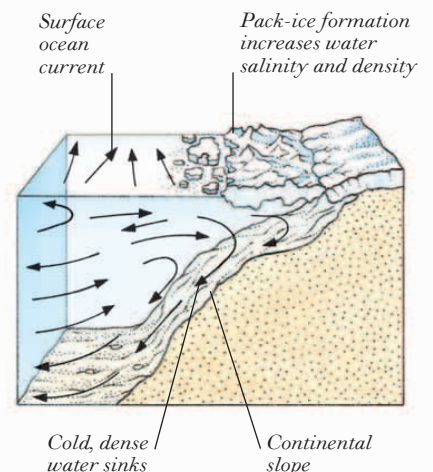
SURFACE CURRENTS



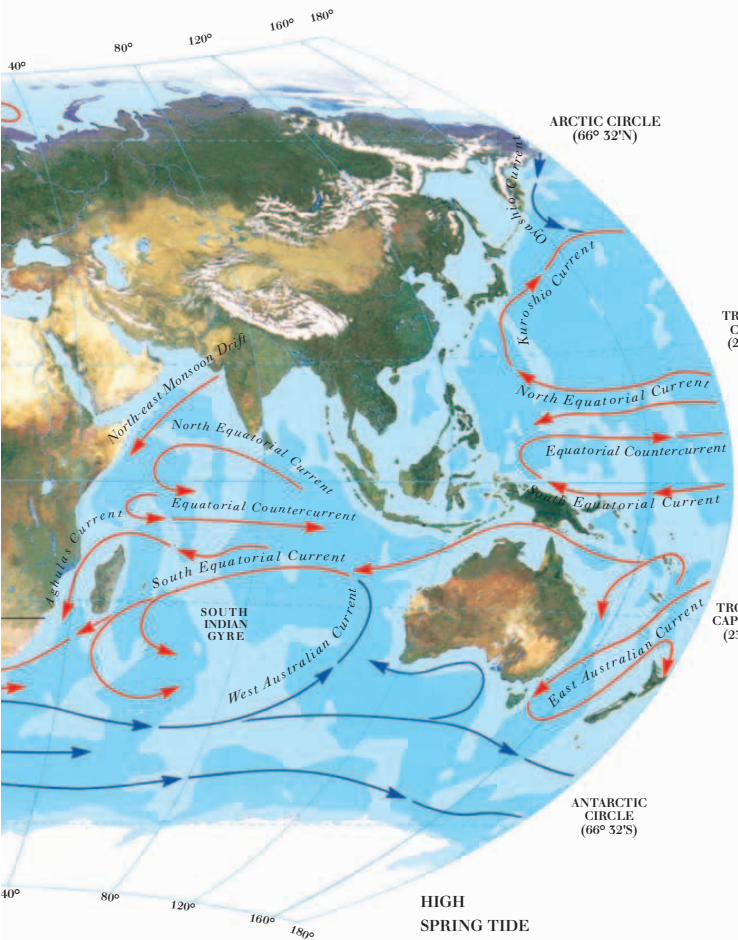
OFFSHORE CURRENTS



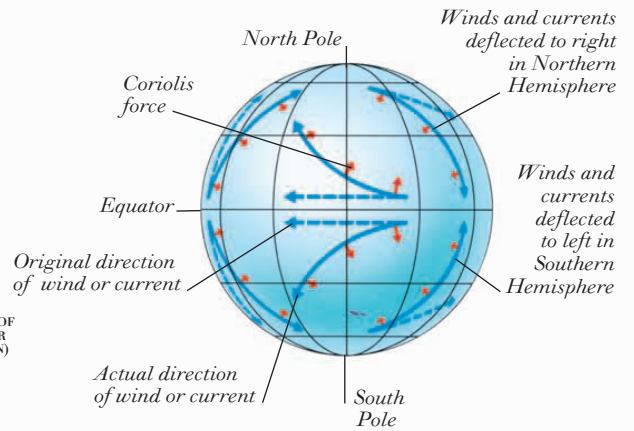
COLD-WATER UPWELLING (SOUTHERN HEMISPHERE)



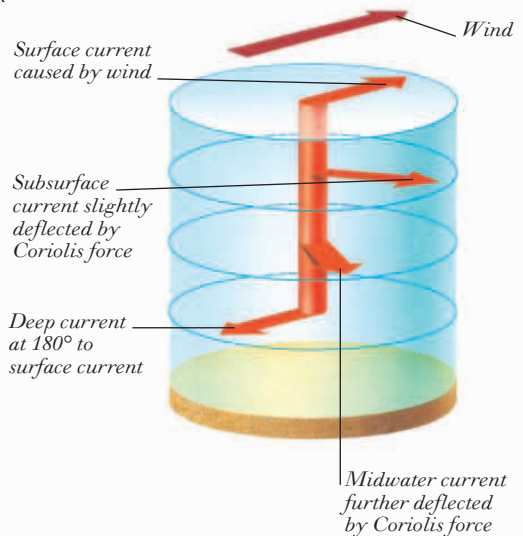
POLAR BOTTOM WATER



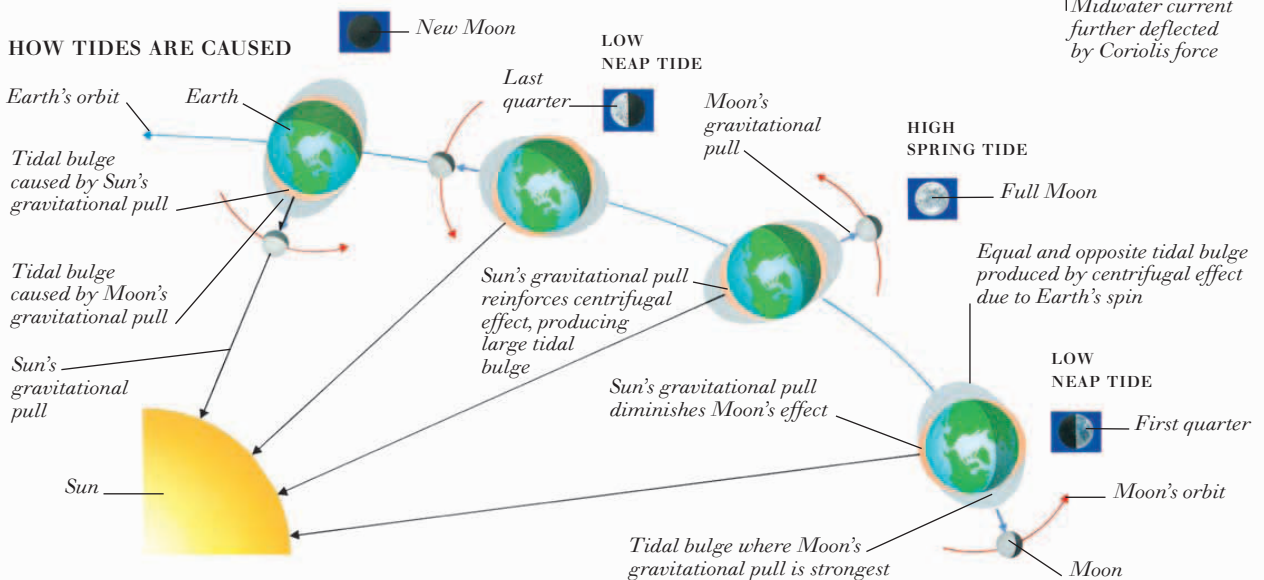
EFFECT OF CORIOLIS FORCE



EKMAN SPIRAL (NORTHERN HEMISPHERE)



HOW TIDES ARE CAUSED

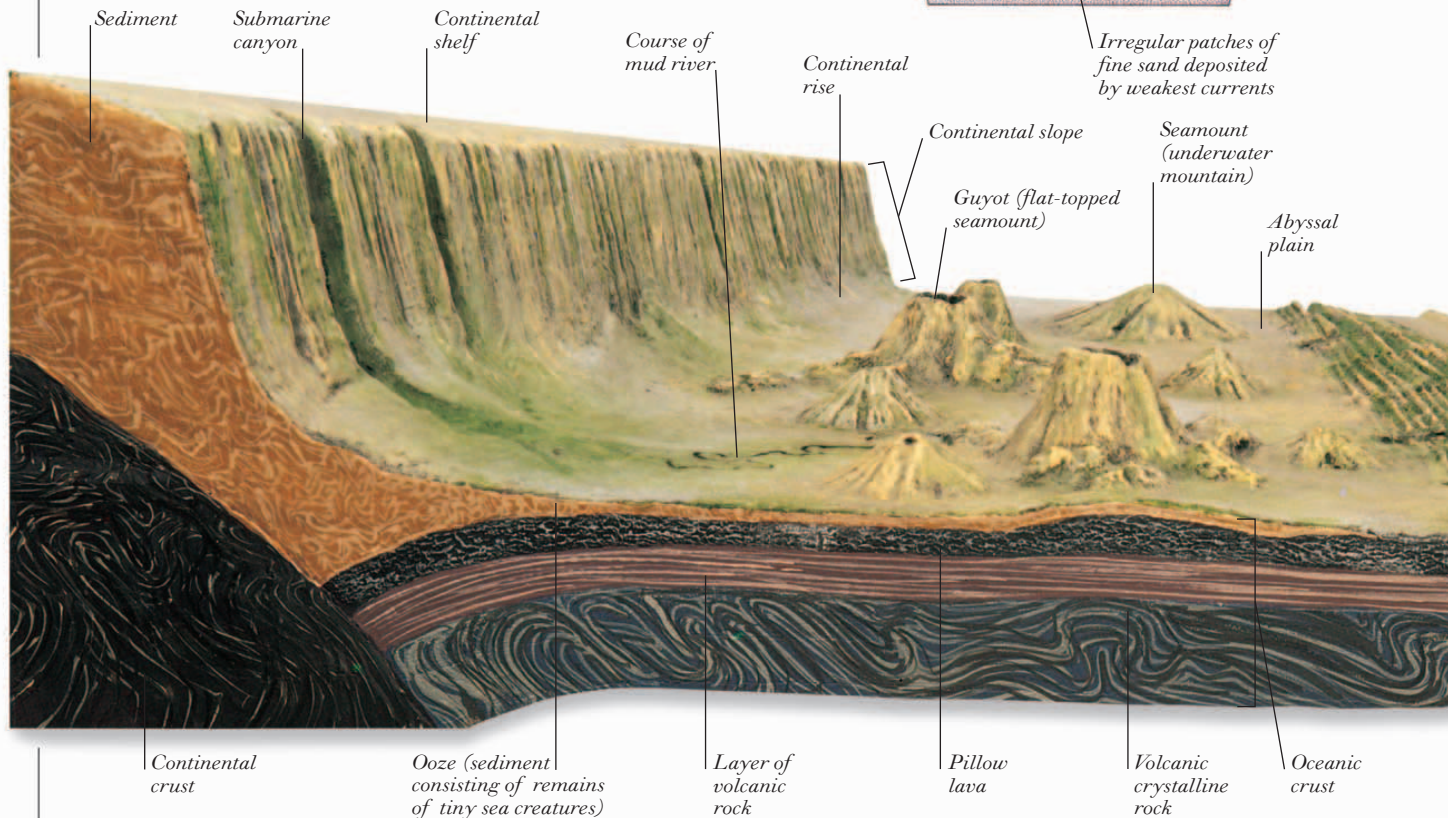
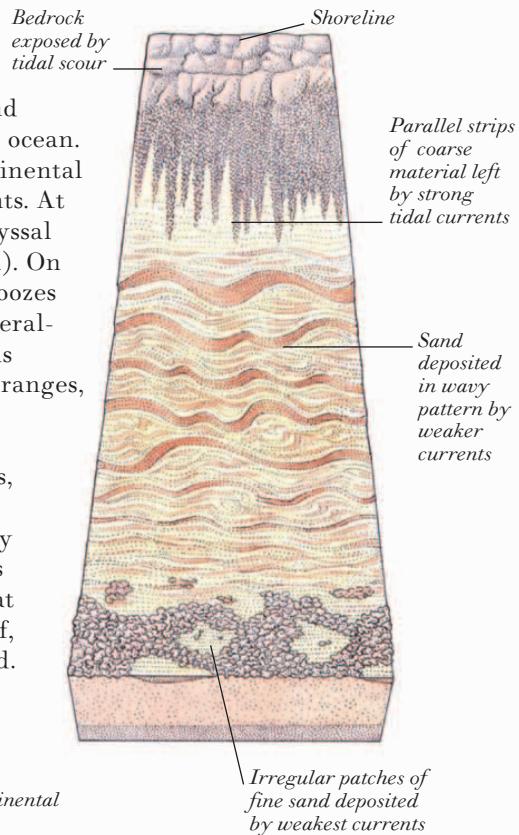


The ocean floor



THE OCEAN FLOOR COMPRISES TWO SECTIONS: the continental shelf and slope, and the deep-ocean floor. The continental shelf and slope are part of the continental crust, but may extend far into the ocean. Sloping quite gently to a depth of about 460 feet (140 m), the continental shelf is covered in sandy deposits shaped by waves and tidal currents. At the edge of the continental shelf, the seabed slopes down to the abyssal plain, which lies at an average depth of about 12,500 feet (3,800 m). On this deep-ocean floor is a layer of sediment made up of clays, fine oozes formed from the remains of tiny sea creatures, and occasional mineral-rich deposits. Echo-sounding and remote sensing from satellites has revealed that the abyssal plain is divided by a system of mountain ranges, far bigger than any on land—the mid-ocean ridge. Here, magma (molten rock) wells up from the Earth's interior and solidifies, widening the ocean floor (see pp. 58-59). As the ocean floor spreads, volcanoes that have formed over hot spots in the crust move away from their magma source; they become extinct and are increasingly submerged and eroded. Volcanoes eroded below sea level remain as seamounts (underwater mountains). In warm waters, a volcano that projects above the ocean surface often acquires a fringing coral reef, which may develop into an atoll as the volcano becomes submerged.

FEATURES OF THE OCEAN FLOOR

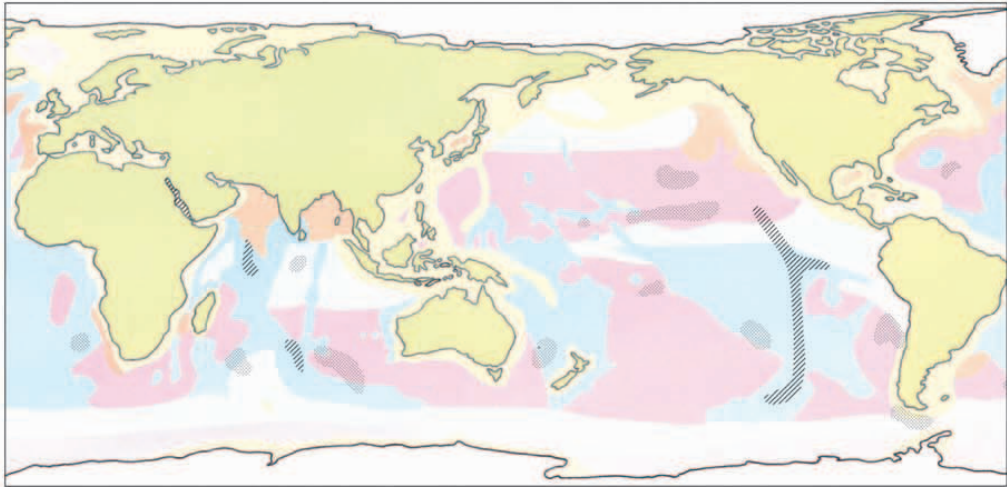
CONTINENTAL-SHELF FLOOR



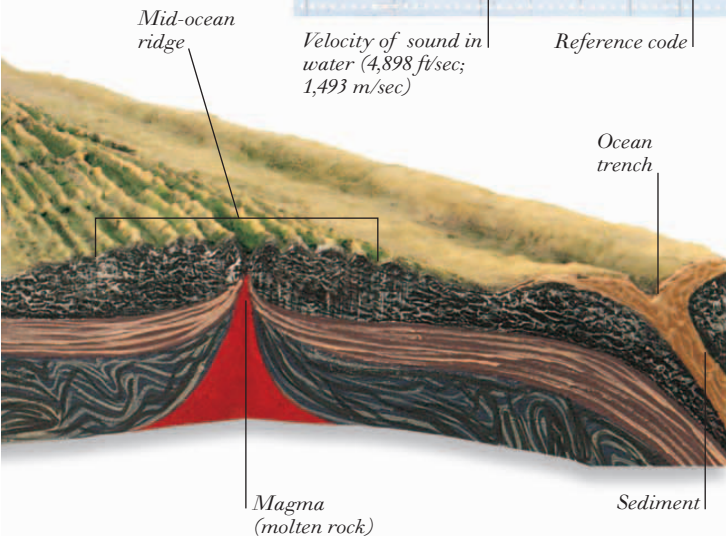
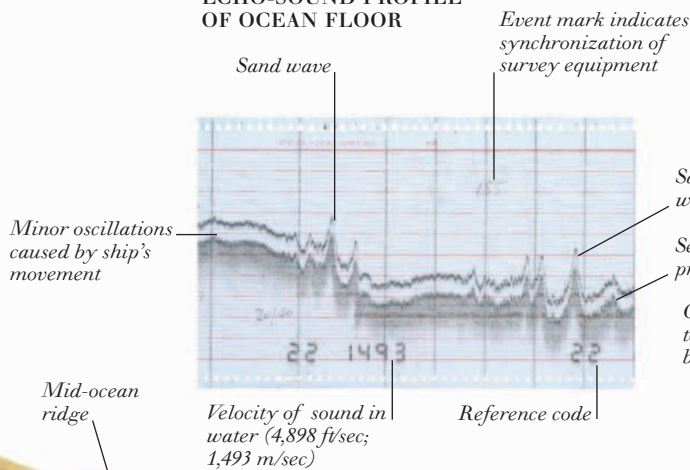
KEY

-  Calcareous ooze
-  Pelagic clay
-  Glacial sediments
-  Siliceous ooze
-  Terrigenous sediments
-  Continental margin sediments
-  Metalliferous muds
-  Major nodule fields

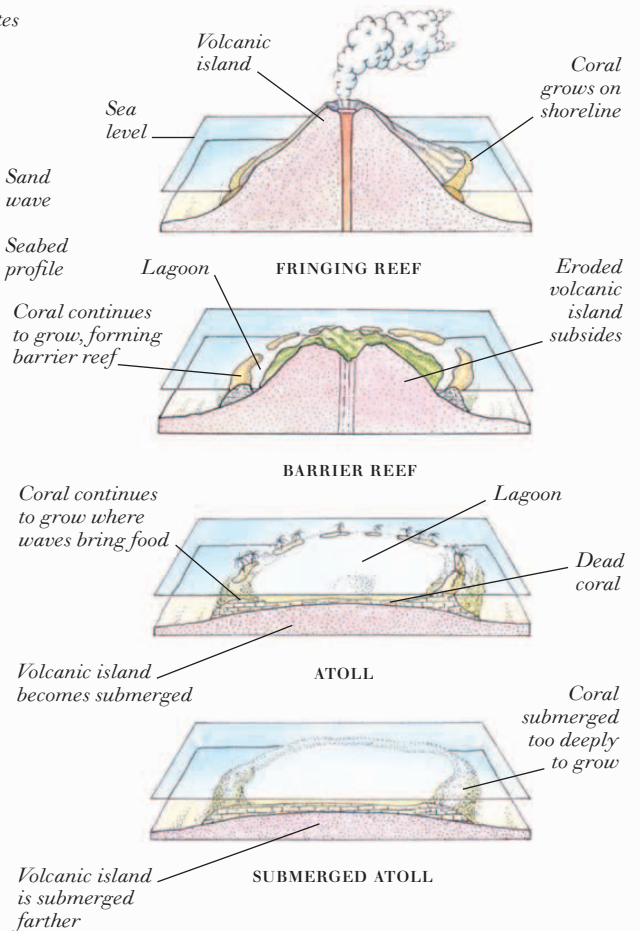
DEEP-OCEAN FLOOR SEDIMENTS



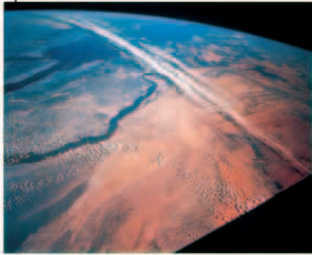
ECHO-SOUND PROFILE OF OCEAN FLOOR



DEVELOPMENT OF AN ATOLL



The atmosphere

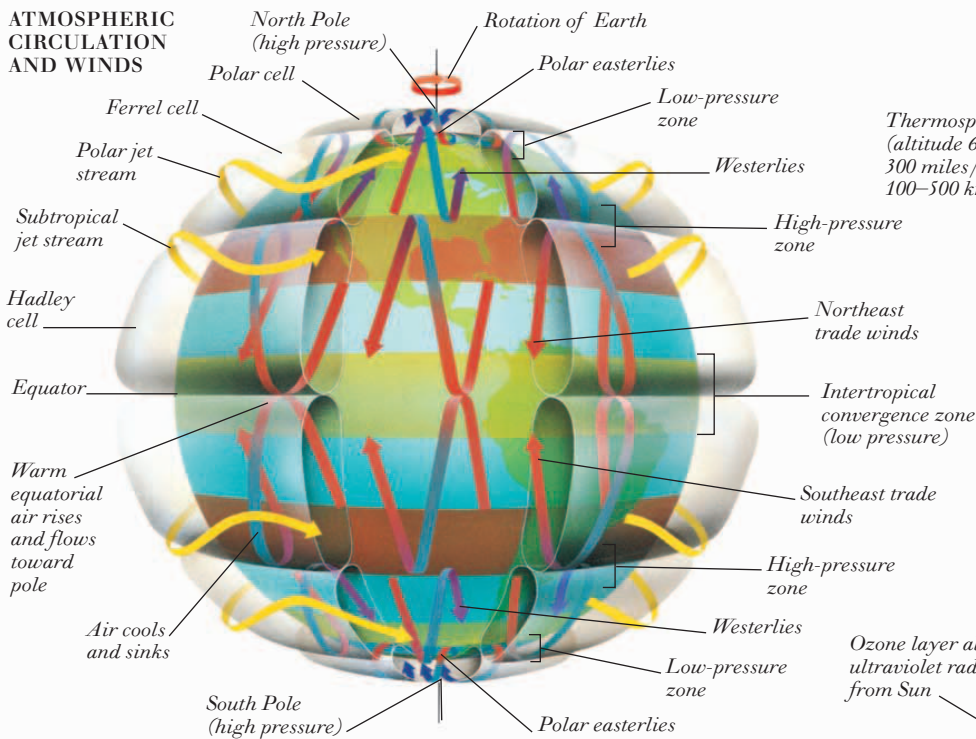


JET STREAM

THE EARTH IS SURROUNDED BY ITS ATMOSPHERE, a blanket of gases that enables life to exist on the planet. This layer has no definite outer edge, gradually becoming thinner until it merges into space, but over 80 percent of atmospheric gases are held by gravity within about 12 miles (20 km) of the Earth's surface. The atmosphere blocks out much harmful ultraviolet solar radiation, and insulates the Earth against extremes of temperature by limiting both incoming solar radiation and the escape of reradiated heat into space.

This natural balance may be distorted by the greenhouse effect, as gases such as carbon dioxide have built up in the atmosphere, trapping more heat. Close to the Earth's surface, differences in air temperature and pressure cause air to circulate between the equator and poles. This circulation, together with the Coriolis force, gives rise to the prevailing surface winds and the high-level jet streams.

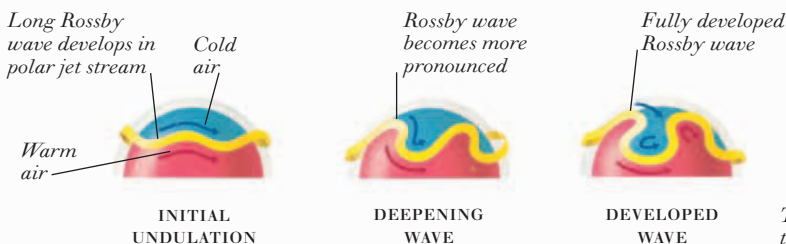
ATMOSPHERIC CIRCULATION AND WINDS



Thermosphere
(altitude 60–300 miles / 100–500 km)

Ozone layer absorbs ultraviolet radiation from Sun

FORMATION OF ROSSBY WAVES IN THE JET STREAM



Mesosphere
(altitude 30–60 miles / 50–100 km)

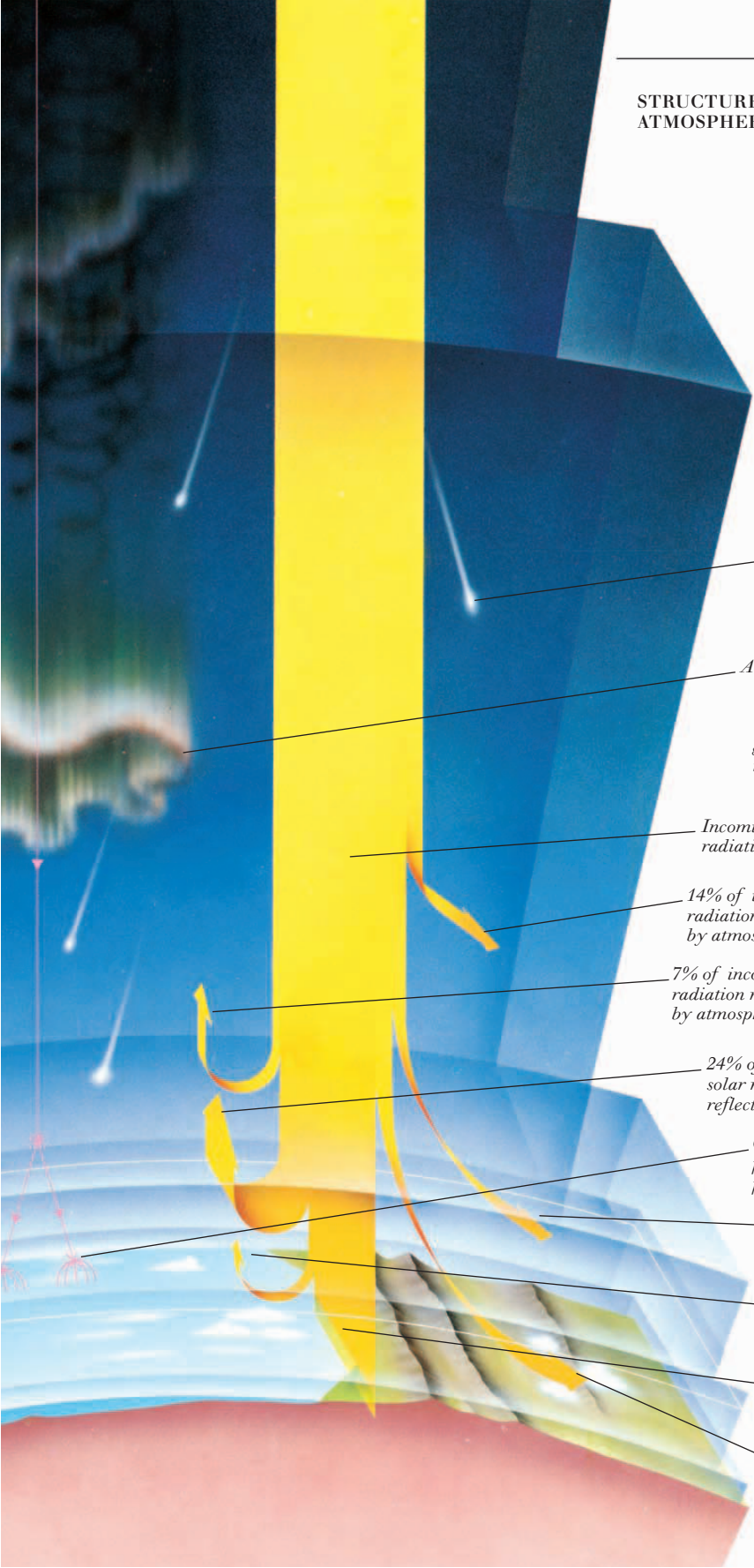
Stratosphere
(6–30 miles / 10–50 km)

Troposphere
(altitude to 6 miles / 10 km)

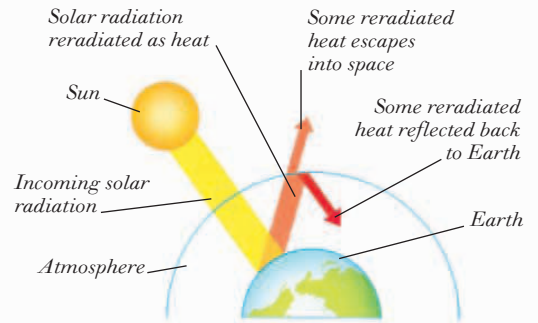
Exosphere
(altitude above 300 miles / 500 km)

Corona

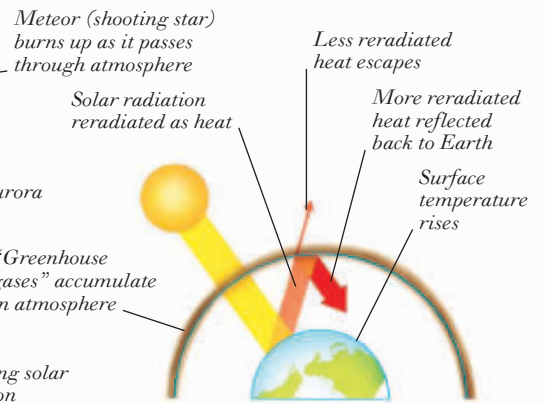
STRUCTURE OF THE ATMOSPHERE



GLOBAL WARMING

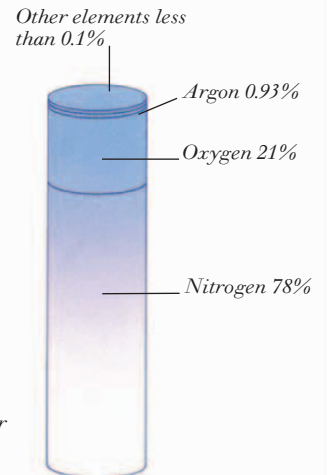


NATURALLY MODERATED GREENHOUSE EFFECT



UNBALANCED GREENHOUSE EFFECT

COMPOSITION OF THE LOWER ATMOSPHERE

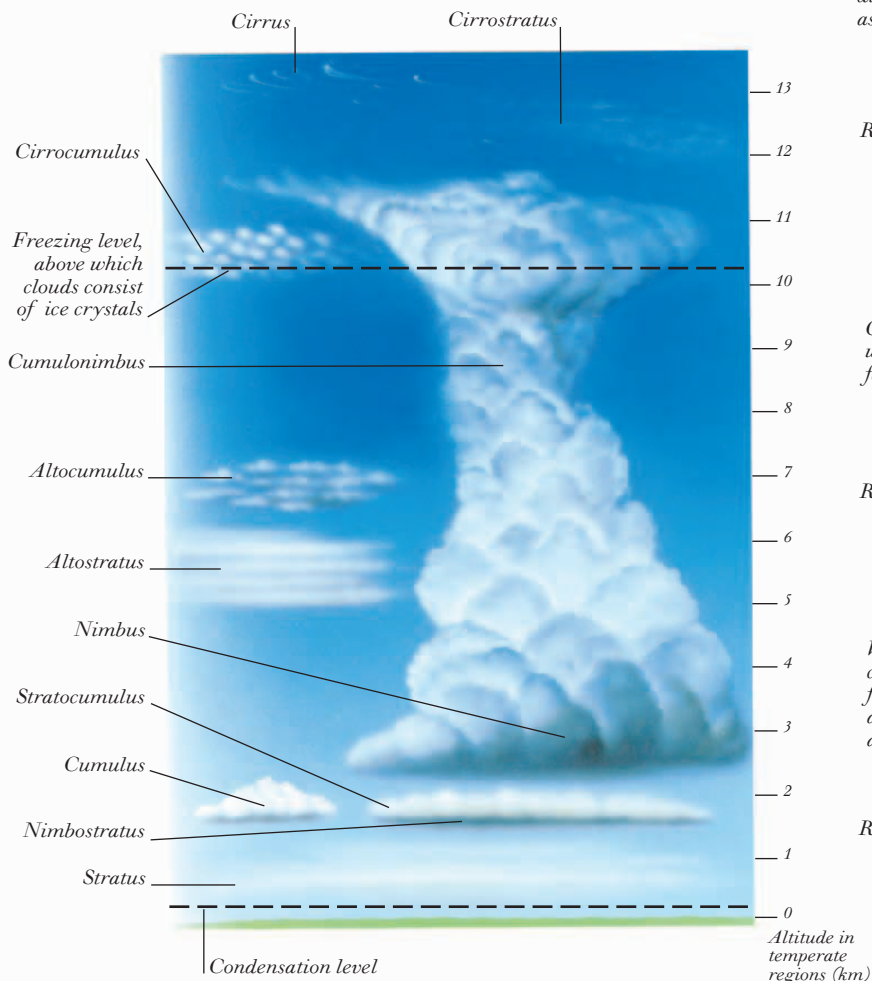


- Incoming solar radiation
- 14% of incoming solar radiation absorbed by atmosphere
- 7% of incoming solar radiation reflected by atmosphere
- 24% of incoming solar radiation reflected by clouds
- Cosmic rays (high-energy particles from space) penetrate to stratosphere
- Some absorbed heat reradiated by atmosphere
- 4% of incoming solar radiation reflected by oceans and land
- 51% of incoming solar radiation absorbed by Earth's surface
- Some absorbed heat re-radiated by clouds

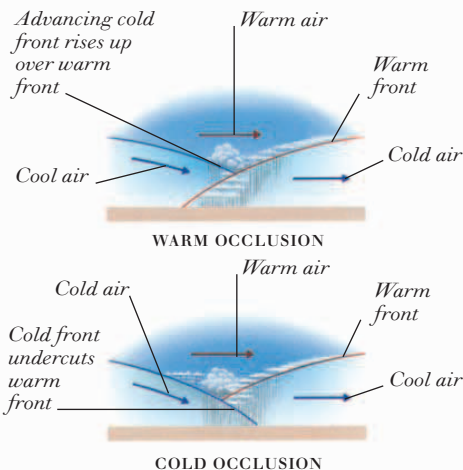
Weather

WEATHER IS DEFINED AS THE ATMOSPHERIC CONDITIONS at a particular time and place; climate is the average weather conditions for a given region over time. Weather is assessed in terms of temperature, wind, cloud cover, and precipitation, such as rain or snow. Good weather is associated with high-pressure areas, where air is sinking. Cloudy, wet, changeable weather is common in low-pressure zones with rising, unstable air. Such conditions occur at temperate latitudes, where warm air meets cool air along the polar fronts. Here, spiraling low-pressure cells known as depressions (mid-latitude cyclones) often form. A depression usually contains a sector of warmer air, beginning at a warm front and ending at a cold front. If the two fronts merge, forming an occluded front, the warm air is pushed upward. An extreme form of low-pressure cell is a hurricane (also called a typhoon or tropical cyclone), which brings torrential rain and exceptionally strong winds.

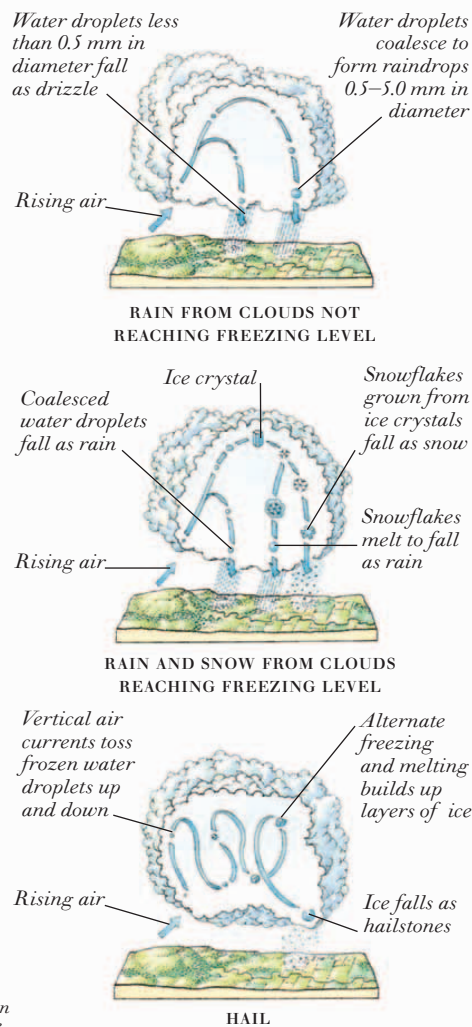
TYPES OF CLOUD



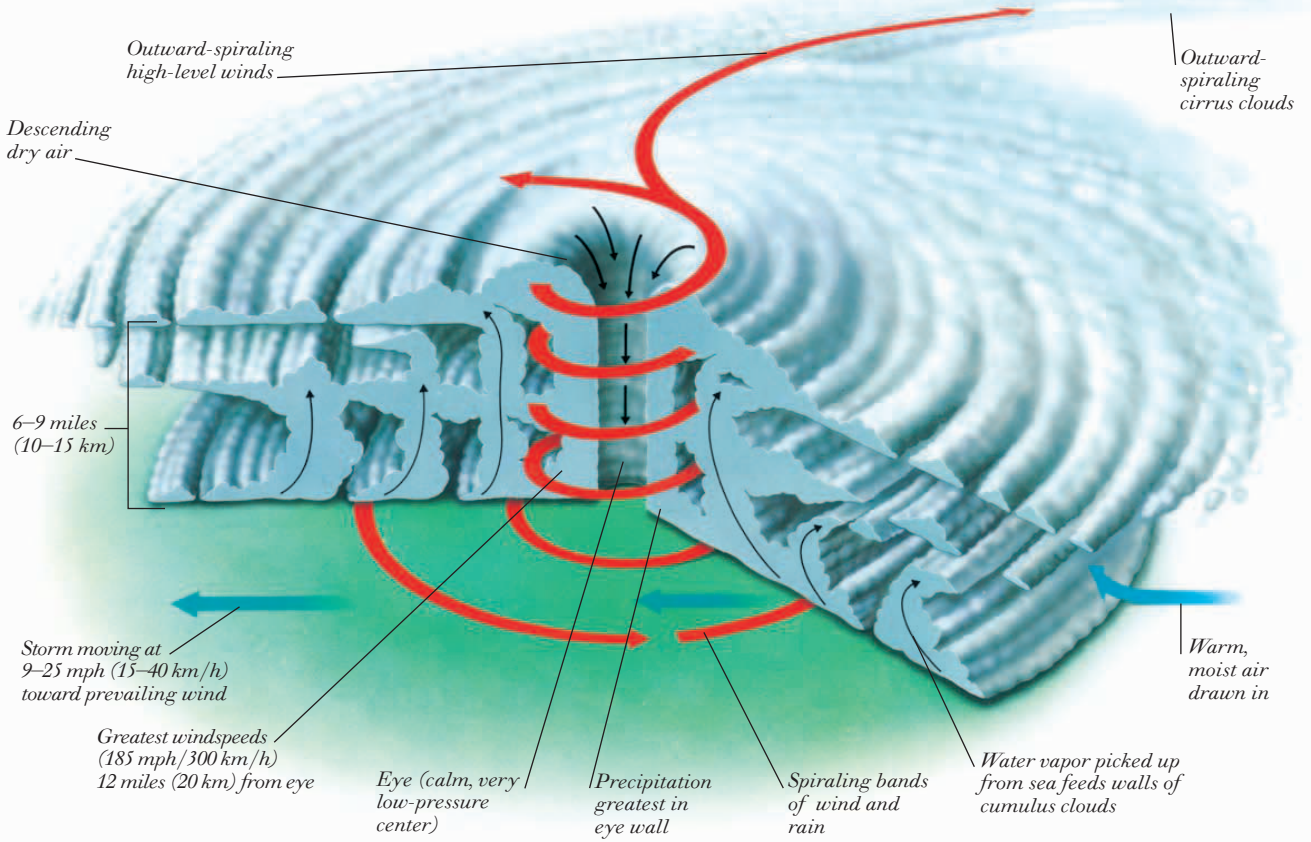
TYPES OF OCCLUDED FRONT



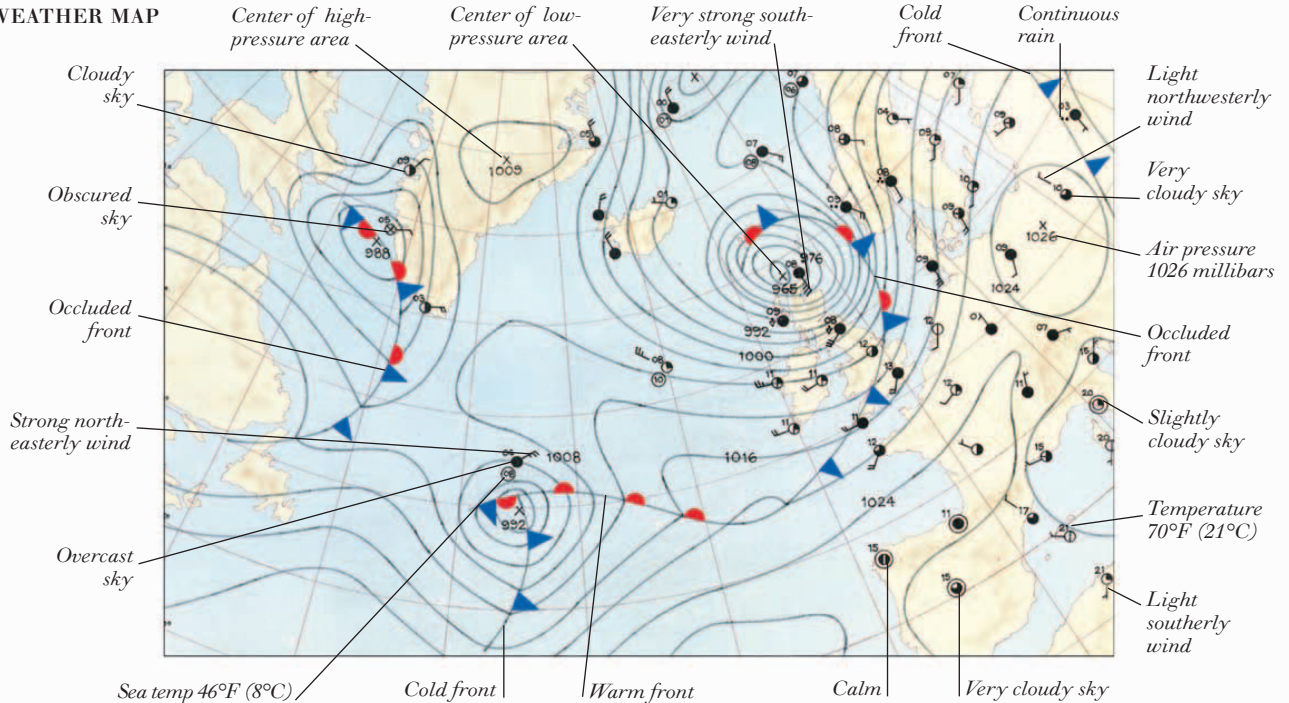
FORMS OF PRECIPITATION

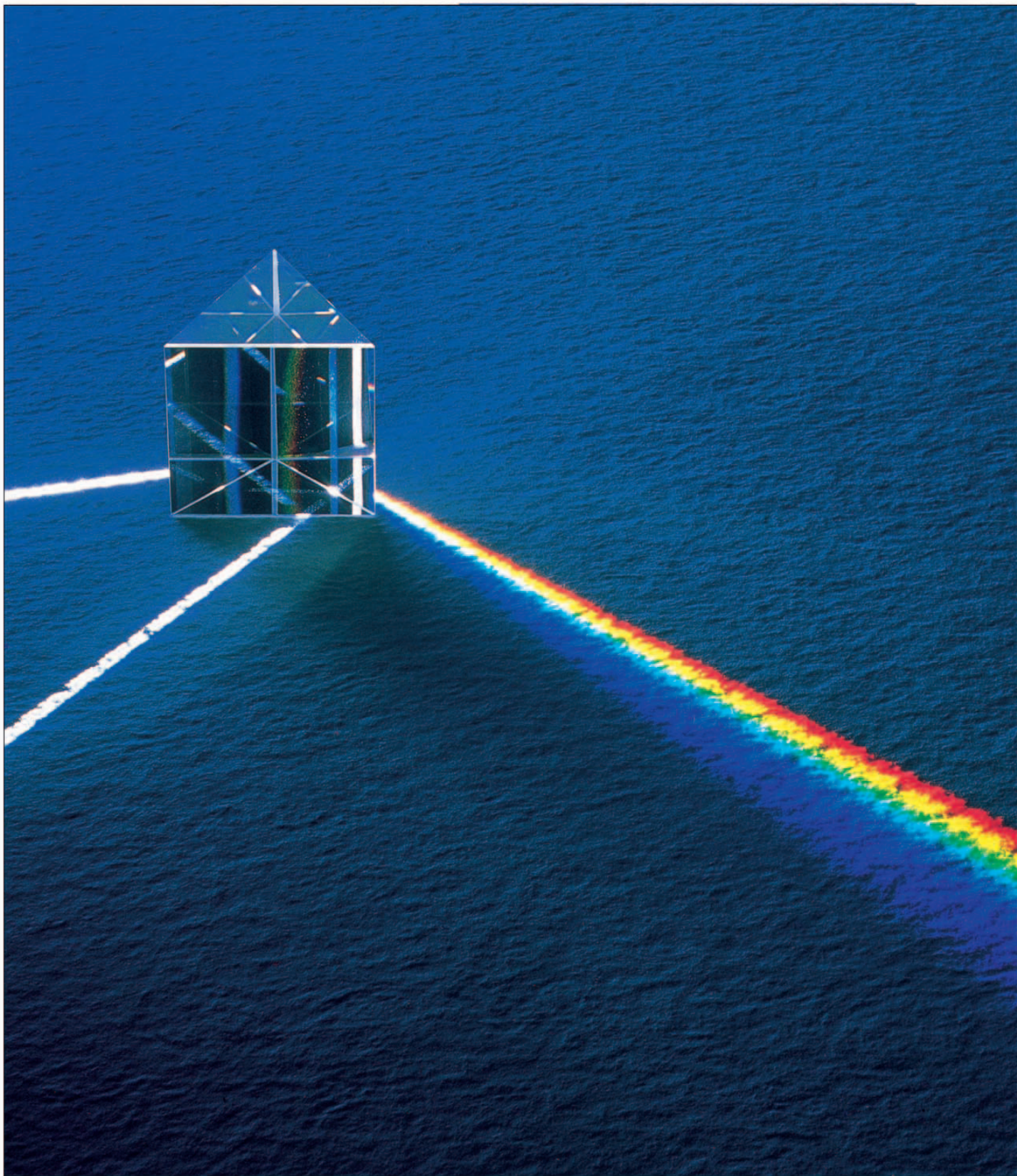


STRUCTURE OF A HURRICANE



WEATHER MAP





PHYSICS AND CHEMISTRY

THE VARIETY OF MATTER.....	306
ATOMS AND MOLECULES.....	308
THE PERIODIC TABLE.....	310
CHEMICAL REACTIONS.....	312
ENERGY.....	314
ELECTRICITY AND MAGNETISM.....	316
LIGHT.....	318
FORCE AND MOTION.....	320



The variety of matter



PLANT AND INSECT
(LIVING MATTER)

MATTER IS ANYTHING THAT HAS A MASS. It includes everything from natural substances, such as minerals or living organisms, to synthetic materials. Matter can exist in three distinct states—solid, liquid, and gas. A solid is rigid and retains its shape. A liquid is fluid, has a definite volume, and will take the shape of its container. A gas (also fluid) fills a space, so its volume will be the same as the volume of its container. Most substances can exist as a solid, a liquid, or a gas: the state is determined by temperature. At very high temperatures, matter becomes plasma, often considered to be a fourth state of matter. All matter is composed of microscopic particles, such as atoms and molecules (see pp. 308-309).

The arrangement and interactions of these particles give a substance its physical and chemical properties, by which matter can be identified. There is a huge variety of matter because particles can arrange themselves in countless ways, in one substance or by mixing with others. Natural glass, for example, seems to be a solid but is, in fact, a supercool liquid: the atoms are not locked into a pattern and can flow. Pure substances known as elements (see p. 310) combine to form compounds or mixtures. Mixtures called colloids are made up of larger particles of matter suspended in a solid, liquid, or gas, while a solution is one substance dissolved in another.

TYPES OF COLLOID



HAIR GEL (SOLID IN LIQUID)



SHAVING CREAM
(AIR IN LIQUID)



MIST
(LIQUID IN GAS)

EXAMPLES OF MATTER



POLYETHYLENE
(SYNTHETIC POLYMER)

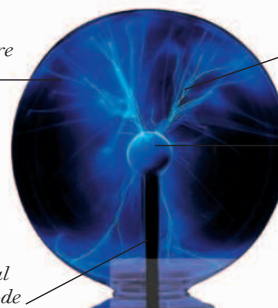
The element silicon in pure crystalline form

Poly-ethylene combines natural materials in new ways



PURE SILICON
(SEMICONDUCTOR)

Low pressure gases



Central electrode

BALL CONTAINING
HIGH-TEMPERATURE GAS
(PLASMA)

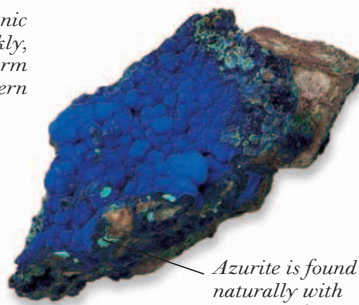
Streaks of plasma (mixture of electrons and charged atoms)

Voltage tears electrons from atoms of low pressure gases inside



OBSIDIAN
(NATURAL GLASS)

Obsidian is molten volcanic rock that cools quickly, so atoms cannot form a regular pattern



AZURITE
(CRYSTALLINE MINERAL)

Azurite is found naturally with deposits of copper ore



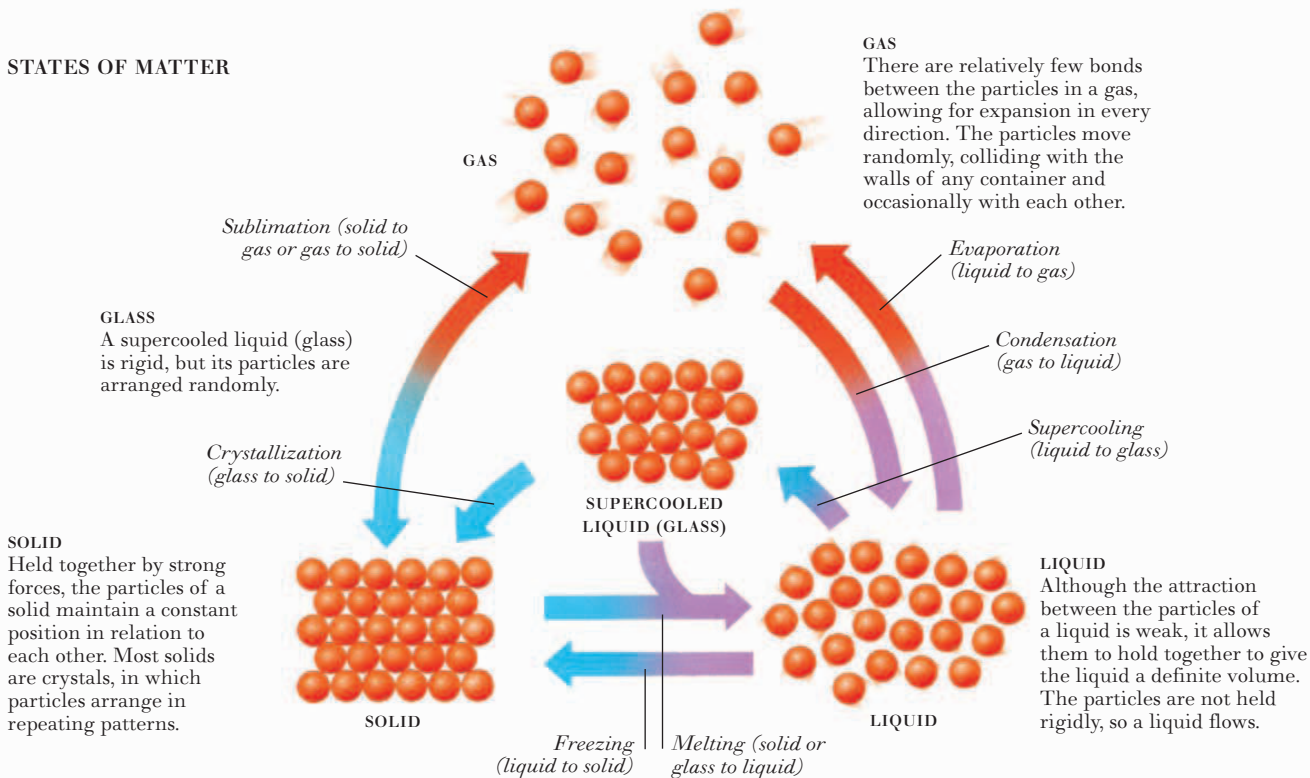
Solid crystals dissolve in liquid water

Water

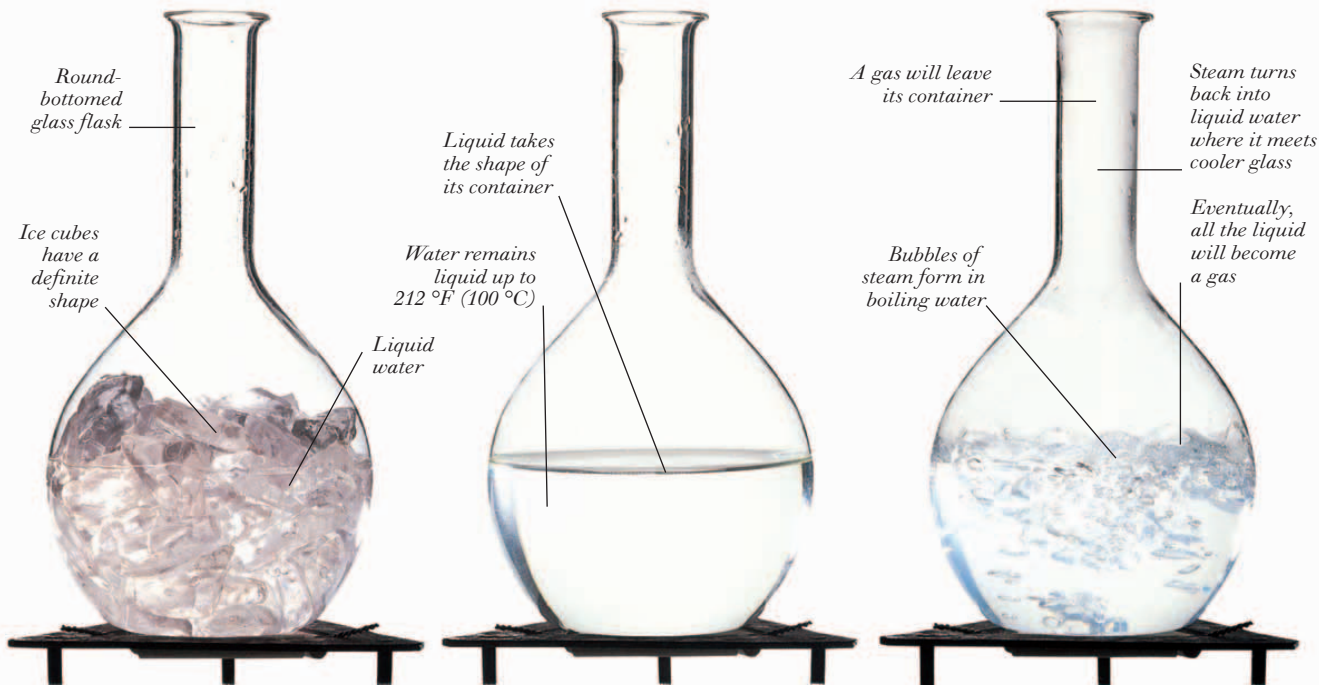
Potassium permanganate crystals

POTASSIUM PERMANGANATE AND WATER
(SOLUTION)

STATES OF MATTER



CHANGING STATES OF WATER



SOLID STATE: ICE

The solid state of water, ice, forms when liquid water is cooled sufficiently. Ice cubes are rigid, with a definite shape and volume.

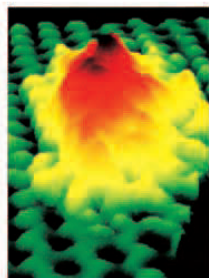
LIQUID STATE: WATER

When the temperature of a substance rises above its freezing point, it melts to become a liquid. Ice changes to water.

GASEOUS STATE: STEAM

Above its boiling point, a substance will become a gas. When heated sufficiently, liquid water turns to steam, a colorless gas.

Atoms and molecules

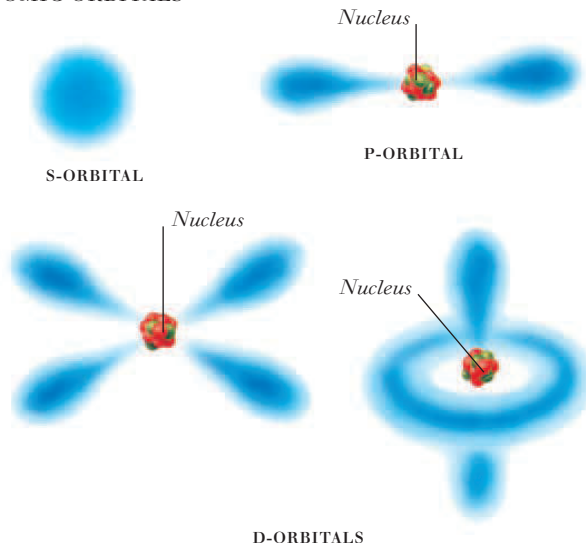


FALSE-COLOR
IMAGE OF ACTUAL
GOLD ATOMS

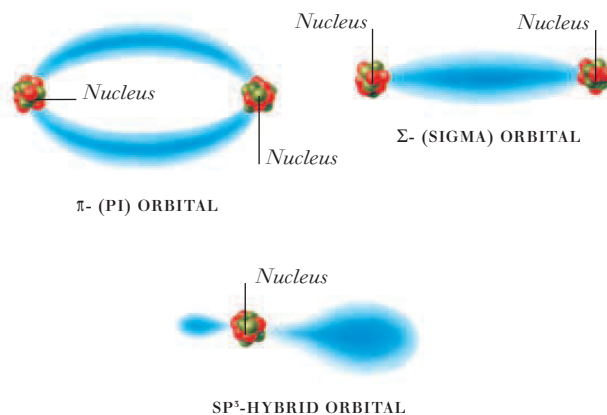
ATOMS ARE THE smallest individual parts of an element (see pp. 310-311). They are tiny, with diameters in the order of one ten-thousand-millionth of a meter (10^{-10} m). Two or more atoms join together (bond) to form a molecule of a substance known as a compound. For example, when atoms of the elements hydrogen and fluorine join together, they form a molecule of the compound hydrogen fluoride. So molecules are the smallest

individual parts of a compound. Atoms themselves are not indivisible—they possess an internal structure. At their center is a dense nucleus, consisting of protons, which have a positive electric charge (see p. 316), and neutrons, which are uncharged. Around the nucleus are the negatively charged electrons. It is the electrons that give a substance most of its physical and chemical properties. They do not follow definite paths around the nucleus. Instead, electrons are said to be found within certain regions, called orbitals. These are arranged around the nucleus in “shells,” each containing electrons of a particular energy. For example, the first shell (1) can hold up to two electrons, in a so-called s-orbital (1s). The second shell (2) can hold up to eight electrons, in s-orbitals (2s) and p-orbitals (2p). If an atom loses an electron, it becomes a positive ion (cation). If an electron is gained, an atom becomes a negative ion (anion). Ions of opposite charges will attract and join together, in a type of bonding known as ionic bonding. In covalent bonding, the atoms bond by sharing their electrons in what become molecular orbitals.

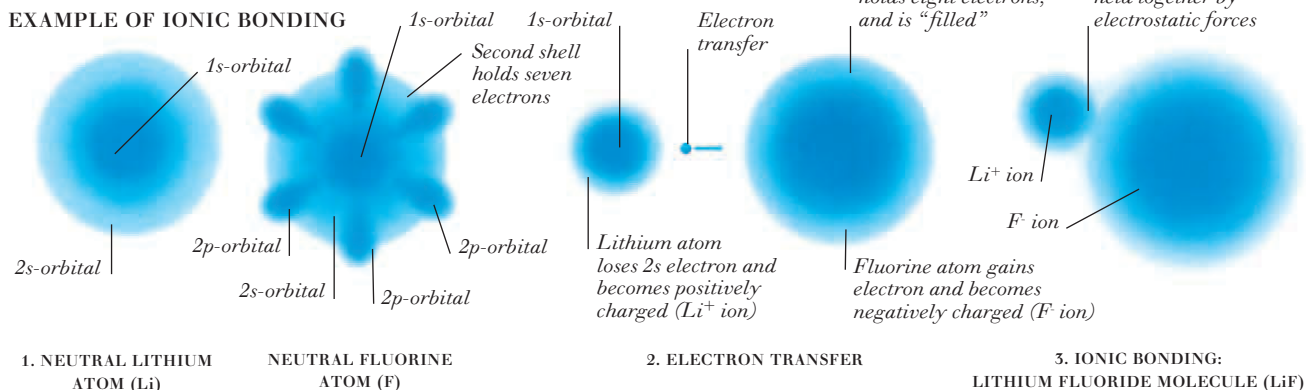
ATOMIC ORBITALS



MOLECULAR ORBITALS

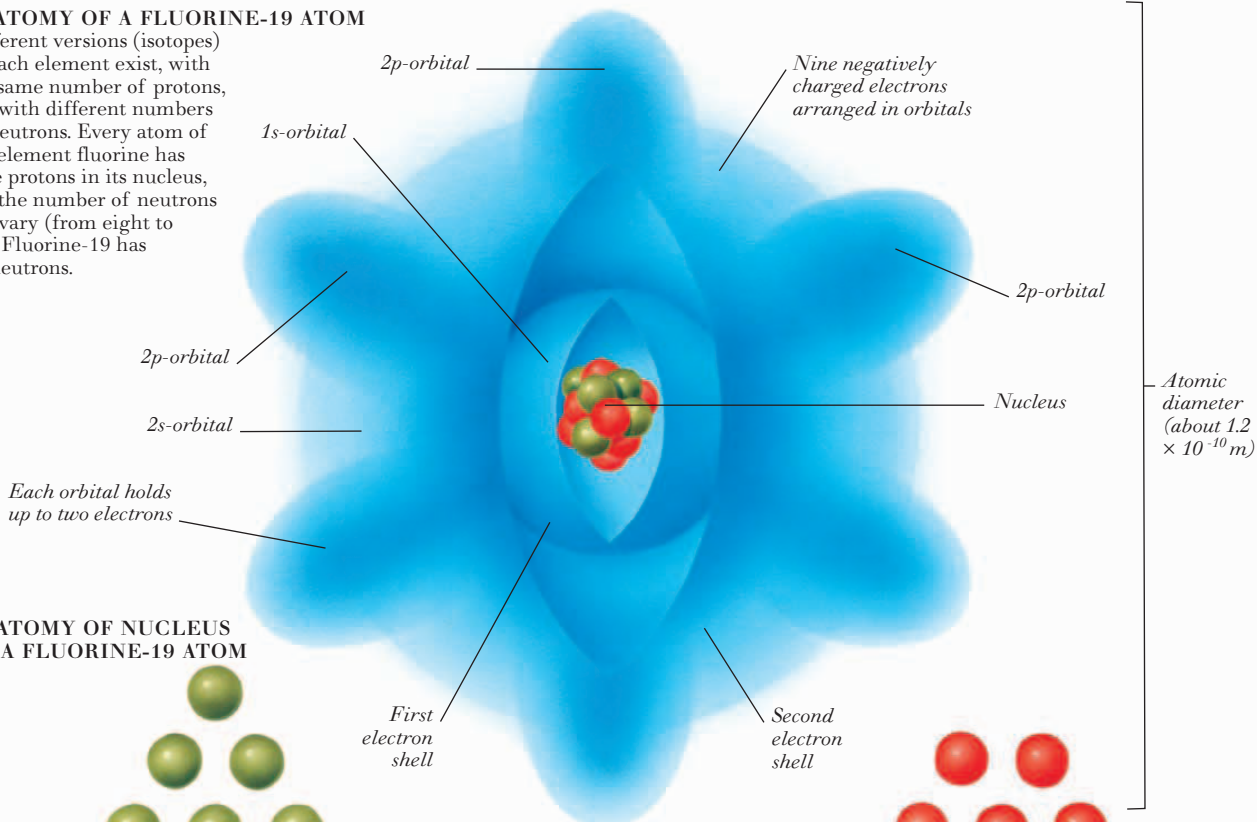


EXAMPLE OF IONIC BONDING

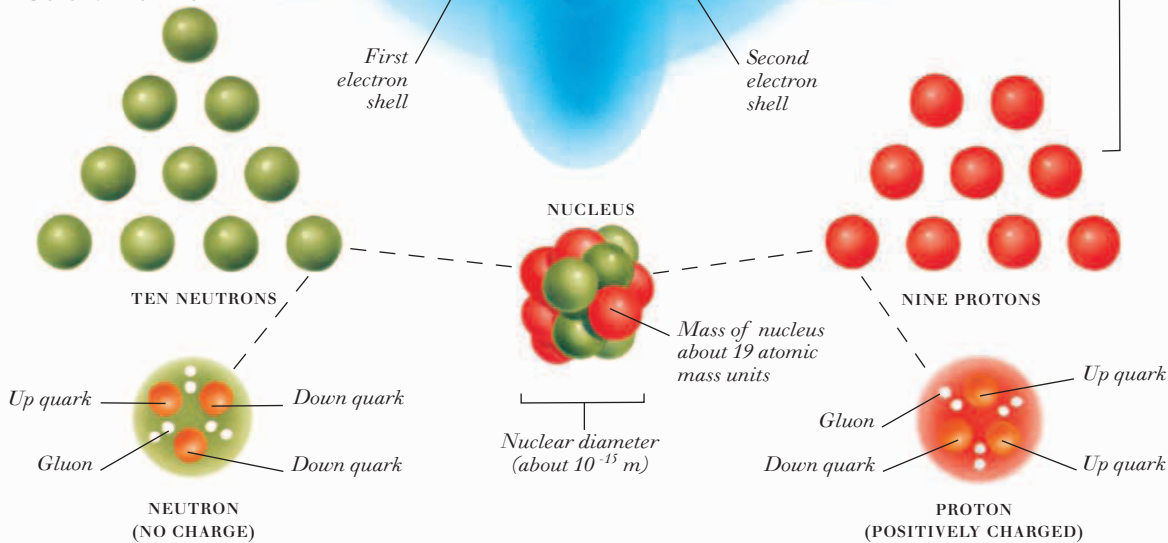


ANATOMY OF A FLUORINE-19 ATOM

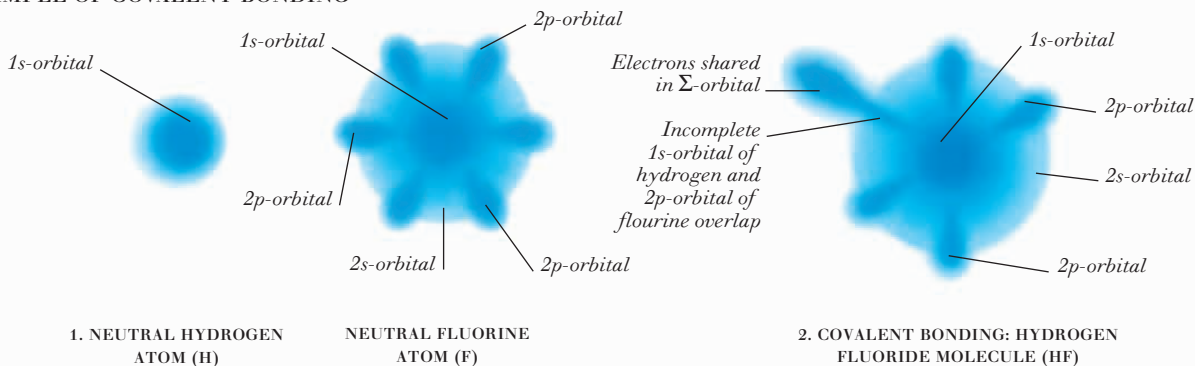
Different versions (isotopes) of each element exist, with the same number of protons, but with different numbers of neutrons. Every atom of the element fluorine has nine protons in its nucleus, but the number of neutrons can vary (from eight to 11). Fluorine-19 has 10 neutrons.



ANATOMY OF NUCLEUS OF A FLUORINE-19 ATOM



EXAMPLE OF COVALENT BONDING



The periodic table

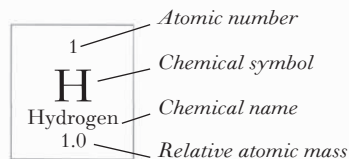
AN ELEMENT is a substance that consists of atoms of one type only. The 92 elements that occur naturally, and the 17 elements created artificially, are often arranged into a chart called the periodic table. Each element is defined by its atomic number—the number of protons in the nucleus of each of its atoms (it is also the number of electrons present). Atomic number increases along each row (period) and down each column (group). The shape of the table is determined by the way in which electrons arrange themselves around the nucleus: the positioning of elements in order of increasing atomic number brings together atoms with a similar pattern of orbiting electrons (orbitals). These appear in blocks. Electrons occupy shells of a certain energy (see pp. 308-309). Periods are ordered according to the filling of successive shells with electrons, while groups reflect the number of electrons in the outer shell (valency electrons). These outer electrons are important—they decide the chemical properties of the atom. Elements that appear in the same group have similar properties because they have the same number of electrons in their outer shell. Elements in Group 0 have “filled shells,” where the outer shell holds its maximum number of electrons, and are stable. Atoms of Group I elements have just one electron in their outer shell. This makes them unstable—and ready to react with other substances.

METALS AND NON-METALS

Elements at the left-hand side of each period are metals. Metals easily lose electrons and form positive ions. Non-metals, on the right of a period, tend to become negative ions. Semimetals, which have properties of both metals and non-metals, are between the two.

TYPES OF ELEMENT KEY:

- Alkali metals
- Alkaline earth metals
- Transition metals
- Lanthanides
- Actinides
- Poor metals
- Semi-metals
- Non-metals
- Noble gases
- Unknown chemical properties



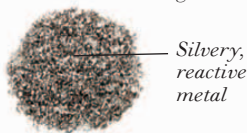
Group I						
1 H Hydrogen 1.0						
Group II						
3 Li Lithium 6.9	4 Be Beryllium 9.0					
11 Na Sodium 23.0	12 Mg Magnesium 24.3					
		1st transition metals				
19 K Potassium 39.1	20 Ca Calcium 40.1	21 Sc Scandium 45.0	22 Ti Titanium 47.9	23 V Vanadium 50.9	24 Cr Chromium 52.0	25 Mn Manganese 54.9
37 Rb Rubidium 85.5	38 Sr Strontium 87.6	39 Y Yttrium 88.9	40 Zr Zirconium 91.2	41 Nb Niobium 92.9	42 Mo Molybdenum 95.9	43 Tc Technetium (98)
55 Cs Cesium 132.9	56 Ba Barium 137.3	57-71	72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.8	75 Re Rhenium 186.2
87 Fr Francium 223.0	88 Ra Radium 226.0	89-103	104 Rf Rutherfordium (267)	105 Db Dubnium (268)	106 Sg Seaborgium (271)	107 Bh Bohrium (270)
s-block		Two series always separated out from the table to give it a coherent shape			d-block	

RELATIVE ATOMIC MASS

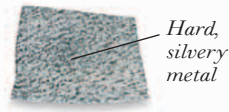
Atomic mass (formerly atomic weight) is the mass of each atom of an element. It is equal to the number of protons plus the number of neutrons (electrons have negligible mass). The figures given are the averages for all the different versions (isotopes) of each element, measured relative to the mass of carbon-12.



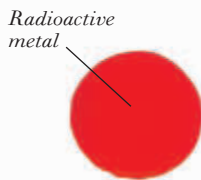
SODIUM:
GROUP 1 METAL



MAGNESIUM:
GROUP 2 METAL

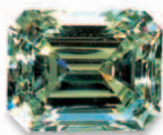


CHROMIUM:
1ST TRANSITION METAL



PLUTONIUM:
ACTINIDE SERIES METAL

57 La Lanthanum 138.9	58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2
89 Ac Actinium (227)	90 Th Thorium 232.0	91 Pa Protactinium 231.0	92 U Uranium 238.0



DIAMOND

ALLOTROPE OF CARBON
Some elements exist in more than one form—these are known as allotropes. Carbon powder, graphite, and diamond are allotropes of carbon. They all consist of carbon atoms, but have very different physical properties.



GRAPHITE



CARBON POWDER



Bright yellow crystal

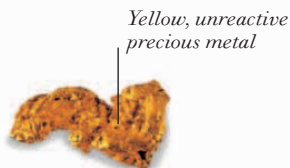
SULFUR:
GROUP 6 SOLID NON-METAL



IODINE:
GROUP 7
SOLID NON-METAL

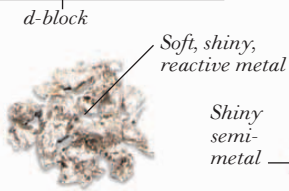
Purple-black solid turns to gas easily

					Boron and carbon groups					Nitrogen and oxygen groups					Halogens	Group 0
					Group III		Group IV		Group V		Group VI		Group VII		2 He Helium 4.0	Period
					5 B Boron 10.8		6 C Carbon 12.0		7 N Nitrogen 14.0		8 O Oxygen 16.0		9 F Fluorine 19.0		10 Ne Neon 20.2	Short period
					13 Al Aluminum 27.0		14 Si Silicon 28.1		15 P Phosphorus 31.0		16 S Sulfur 32.1		17 Cl Chlorine 35.5		18 Ar Argon 40.0	
2nd transition metals					3rd transition metals											
26 Fe Iron 55.8	27 Co Cobalt 58.9	28 Ni Nickel 58.7	29 Cu Copper 63.5	30 Zn Zinc 65.4	31 Ga Gallium 69.7	32 Ge Germanium 72.6	33 As Arsenic 74.9	34 Se Selenium 79.0	35 Br Bromine 79.9	36 Kr Krypton 83.8	Long period					
44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 151.3						
76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)						
108 Hs Hassium (269)	109 Mt Meitnerium (278)	110 Ds Darmstadtium (281)	111 Rg Roentgenium (281)	112 Cn Copernicium (285)	113 Uut Ununtrium (286)	114 Uuq Ununquadium (289)	115 Uup Ununpentium (289)	116 Uuh Ununhexium (293)	117 Uus Ununseptium (294)	118 Uuo Ununoctium (294)	Unreactive, colorless gas glows red in discharge tube					



Yellow, unreactive precious metal

GOLD:
3RD TRANSITION METAL



d-block Soft, shiny, reactive metal

TIN:
GROUP 4 POOR METAL

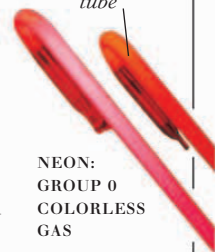


Shiny semi-metal

ANTIMONY:
GROUP 5 SEMI-METAL

NOBLE GASES

Group 0 contains elements that have a filled (complete) outer shell of electrons, which means the atoms do not need to lose or gain electrons by bonding with other atoms. This makes them stable and they do not easily form ions or react with other elements. Noble gases are also called rare or inert gases.



NEON:
GROUP 0
COLORLESS GAS

f-block										
61 Pm Promethium (145)	62 Sm Samarium 150.4	63 Eu Europium 152.0	64 Gd Gadolinium 157.3	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 Lu Lutetium 175.0
93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

Chemical reactions

A CHEMICAL REACTION TAKES PLACE whenever bonds between atoms are broken or made. In each case, atoms or groups of atoms rearrange, making new substances (products) from the original ones (reactants). Reactions happen naturally, or can be made to happen; they may take years, or only an instant. Some of the main types are shown here. A reaction usually involves a change in energy (see pp. 314-315). In a burning reaction, for example, the making of new bonds between atoms releases energy as heat and light. This type of reaction, in which heat is given off, is an exothermic reaction. Many reactions, like burning, are irreversible, but some can take place in either direction, and are said to be reversible. Reactions can be used to form solids from solutions: in a double decomposition reaction, two compounds in solution break down and re-form into two new substances, often creating a precipitate (insoluble solid); in displacement, an element (e.g., copper) displaces another element (e.g., silver) from a solution. The rate (speed) of a reaction is determined by many different factors, such as temperature, and the size and shape of the reactants. To describe and keep track of reactions, internationally recognized chemical symbols and equations are used. Reactions are also used in the laboratory to identify matter. An experiment with candle wax, for example, demonstrates that it contains carbon and hydrogen.

BURNING MATTER

Ammonium dichromate
($(\text{NH}_4)_2\text{Cr}_2\text{O}_7$)

Flame

In this burning reaction, atoms form simpler substances and give off heat and light

Ammonium dichromate ($(\text{NH}_4)_2\text{Cr}_2\text{O}_7$) converts to chromium oxide (Cr_2O_3)

Nitrogen monoxide (NO) and water vapor (H_2O) given off as colorless gases

THE REACTION

When lit, ammonium dichromate combines with oxygen from air.
 $(\text{NH}_4)_2\text{Cr}_2\text{O}_7 + \text{O}_2 \rightarrow \text{Cr}_2\text{O}_3 + 4\text{H}_2\text{O} + 2\text{NO}$

A REVERSIBLE REACTION

Flat-bottomed glass flask
Potassium Chromate solution (K_2CrO_4)
Bright yellow solution contains potassium and chromate ions

Pipette
Hydrochloric acid (HCl) added in drops
Acid causes reaction to take place
Chromate ions converted to orange dichromate ions
Potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) forms

1. THE REACTANT

Potassium chromate dissolves in water to form potassium ions and chromate ions.
 $\text{K}_2\text{CrO}_4 \rightarrow 2\text{K}^+ + \text{CrO}_4^{2-}$

2. THE REACTION

Addition of hydrochloric acid changes chromate ions into dichromate ions.
 $2\text{CrO}_4^{2-} \rightarrow \text{Cr}_2\text{O}_7^{2-}$

Pipette
Sodium hydroxide (NaOH) added in drops
Sodium hydroxide (NaOH) neutralizes the acid
Solution turns to bright orange of potassium dichromate
Potassium dichromate ($\text{K}_2\text{Cr}_2\text{O}_7$) re-forms to potassium chromate (K_2CrO_4)
Solution returns to original bright yellow color

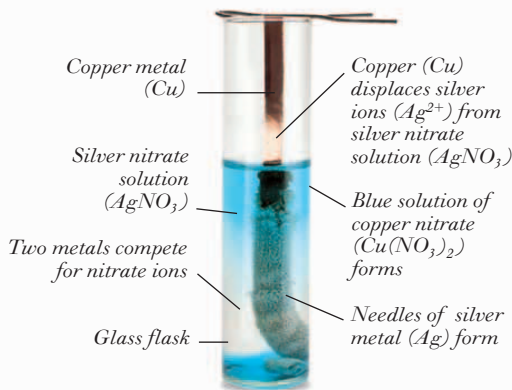
SALT FORMATION (ACID ON METAL)



THE REACTION

Hydrochloric acid added to zinc produces zinc chloride and hydrogen.
 $\text{Zn} + 2\text{HCl} \rightarrow \text{ZnCl}_2 + \text{H}_2$

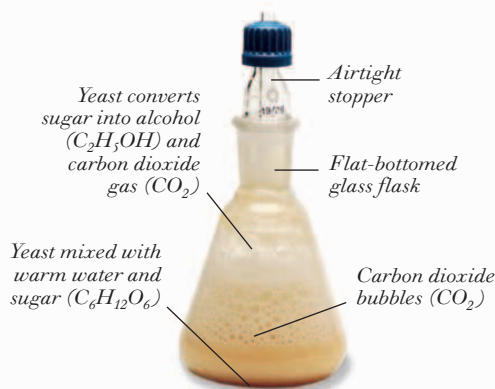
DISPLACEMENT



THE REACTION

Copper metal added to silver nitrate solution produces copper nitrate and silver metal.
 $\text{Cu} + 2\text{AgNO}_3 \rightarrow \text{Cu(NO}_3)_2 + 2\text{Ag}$

FERMENTATION

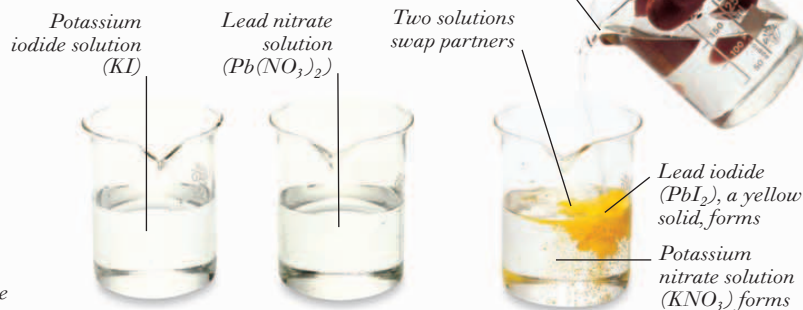


THE REACTION

Yeast converts sugar and warm water into alcohol and carbon dioxide.



DOUBLE DECOMPOSITION

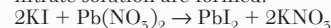


1. THE REACTANTS

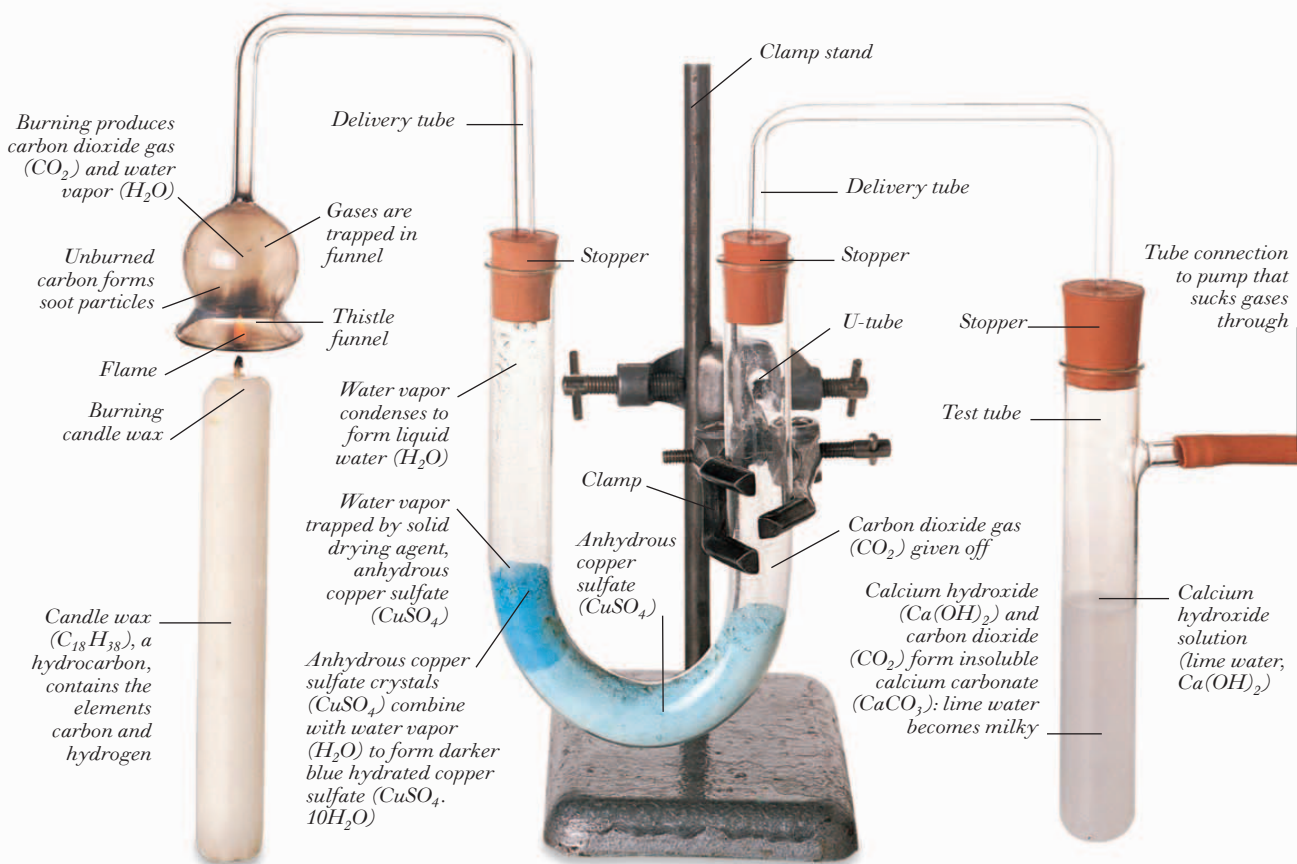
Potassium iodide in water (KI) and lead nitrate in water ($Pb(NO_3)_2$) each form colorless solutions.

2. THE REACTION

When the solutions are mixed, lead iodide, a precipitate, and potassium nitrate solution are formed.

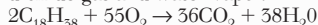


TESTING CANDLE WAX, AN ORGANIC COMPOUND



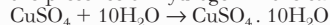
1. THE BURNING REACTION

Burning wax produces carbon dioxide gas and water vapor.



2. TESTING FOR WATER VAPOR

A solid drying agent traps water vapor, proving the presence of hydrogen in the candle wax.



3. TESTING FOR CARBON DIOXIDE

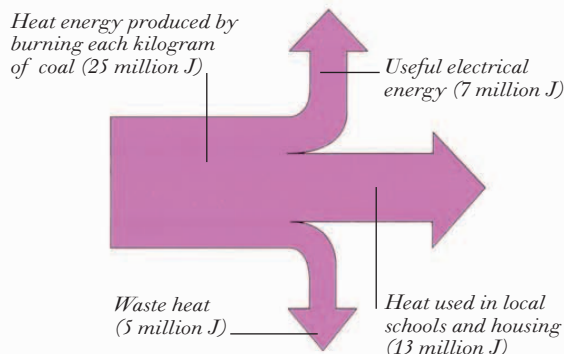
Calcium hydroxide in solution reacts with carbon dioxide, forming a carbonate and turning milky.



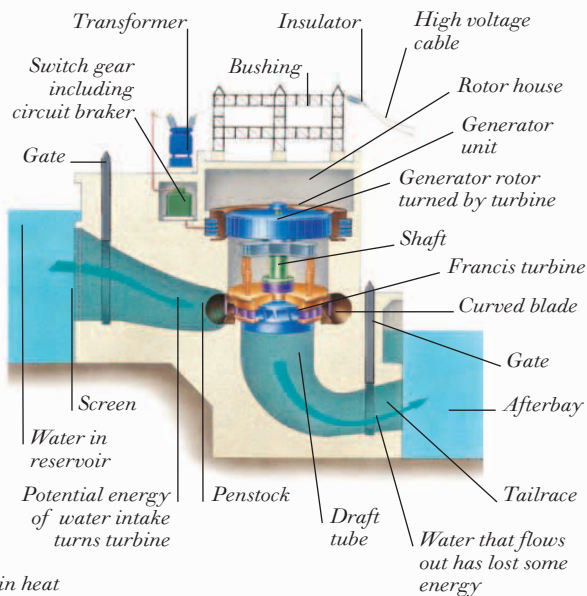
Energy

ANYTHING THAT HAPPENS—from a pin-drop to an explosion—requires energy. Energy is the capacity for “doing work” (making something happen). Various forms of energy exist, including light, heat, sound, electrical, chemical, nuclear, kinetic, and potential energies. The Law of Conservation of Energy states that the total amount of energy in the universe is fixed—energy cannot be created or destroyed. It means that energy can only change from one form to another (energy transfer). For example, potential energy is energy that is “stored,” and can be used in the future. An object gains potential energy when it is lifted; as the object is released, potential energy changes into the energy of motion (kinetic energy). During transference, some of the energy converts into heat. A combined heat and power station can put some of the otherwise “waste” heat to useful effect in local schools and housing. Most of the Earth’s energy is provided by the Sun, in the form of electromagnetic radiation (see pp. 316-317). Some of this energy transfers to plant and animal life, and ultimately to fossil fuels, where it is stored in chemical form. Our bodies obtain energy from the food we eat, while energy needed for other tasks, such as heating and transport, can be obtained by burning fossil fuels—or by harnessing natural forces like wind or moving water—to generate electricity. Another source is nuclear power, where energy is released by reactions in the nucleus of an atom. All energy is measured by the international unit, the joule (J). As a guide, one joule is about equal to the amount of energy needed to lift an apple one meter.

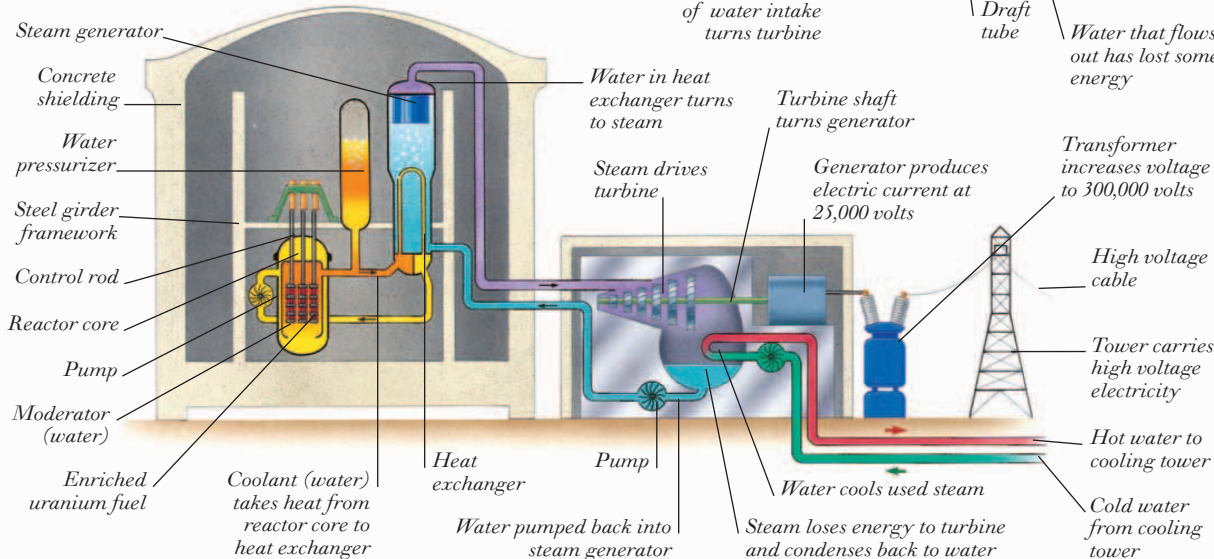
SANKEY DIAGRAM SHOWING ENERGY FLOW IN A COAL-FIRED COMBINED HEAT AND POWER STATION



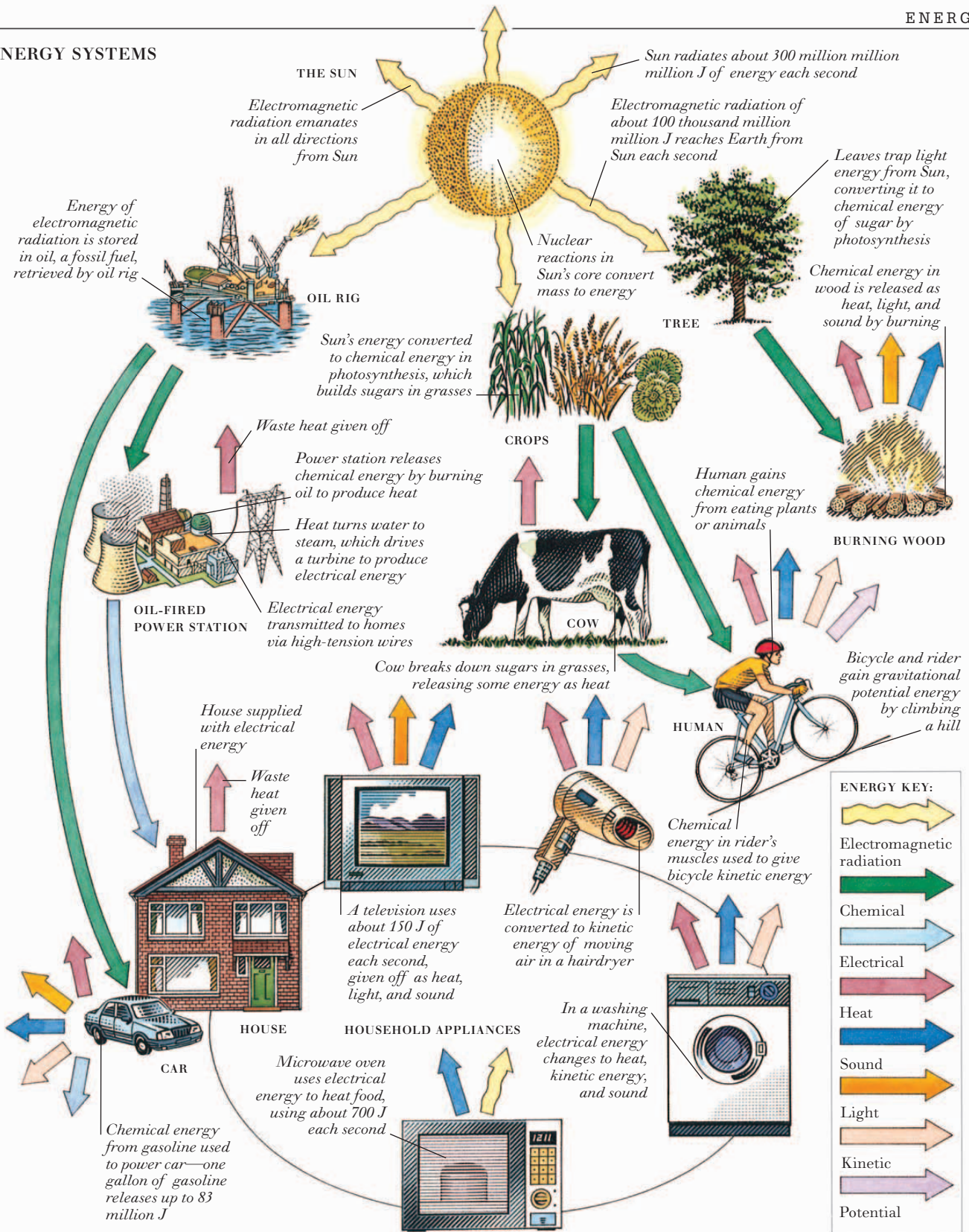
CROSS-SECTION OF HYDROELECTRIC POWER STATION WITH FRANCIS TURBINE



CROSS-SECTION OF NUCLEAR POWER STATION WITH PRESSURIZED WATER REACTOR



ENERGY SYSTEMS



Electricity and magnetism

VAN DE GRAAFF (ELECTROSTATIC) GENERATOR

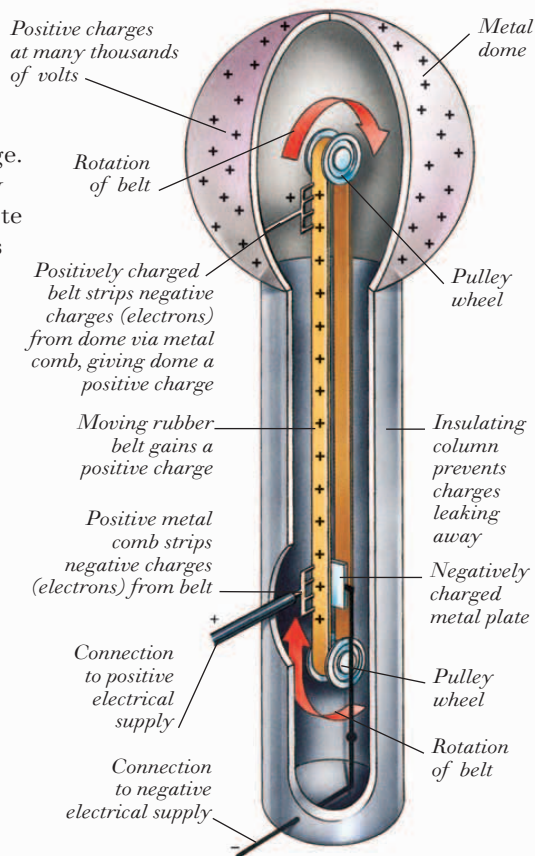
ELECTRICAL EFFECTS result from an imbalance of electric charge. There are two types of electric charge, named positive (carried by protons) and negative (carried by electrons). If charges are opposite (unlike), they attract one another, while like charges repel. Forces of attraction and repulsion (electrostatic forces) exist between any two charged particles. Matter is normally uncharged, but if



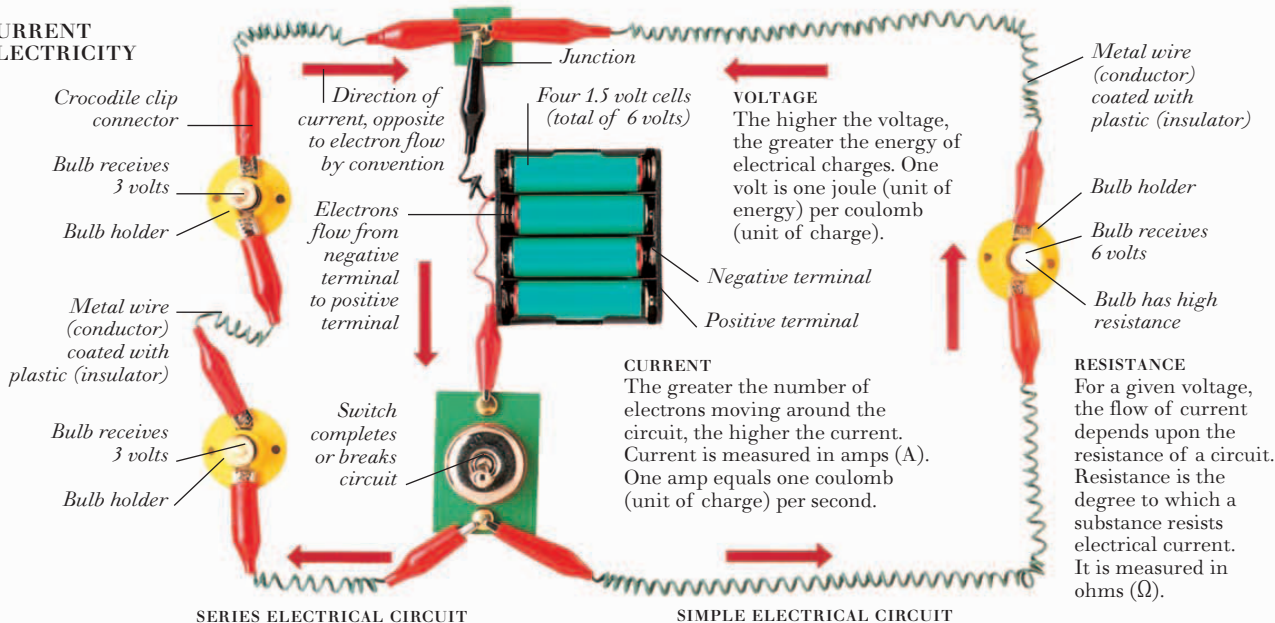
LIGHTNING

electrons are gained, an object will gain an overall negative charge; if they are removed, it becomes positive. Objects with an overall negative or positive charge are said to have an imbalance of charge, and exert the same forces as individual negative and positive charges. On this larger scale, the forces will always act to regain the balance of charge. This causes static electricity. Lightning, for example, is produced by clouds discharging a huge excess of negative electrons. If charges are “free”—in a wire or material that allows

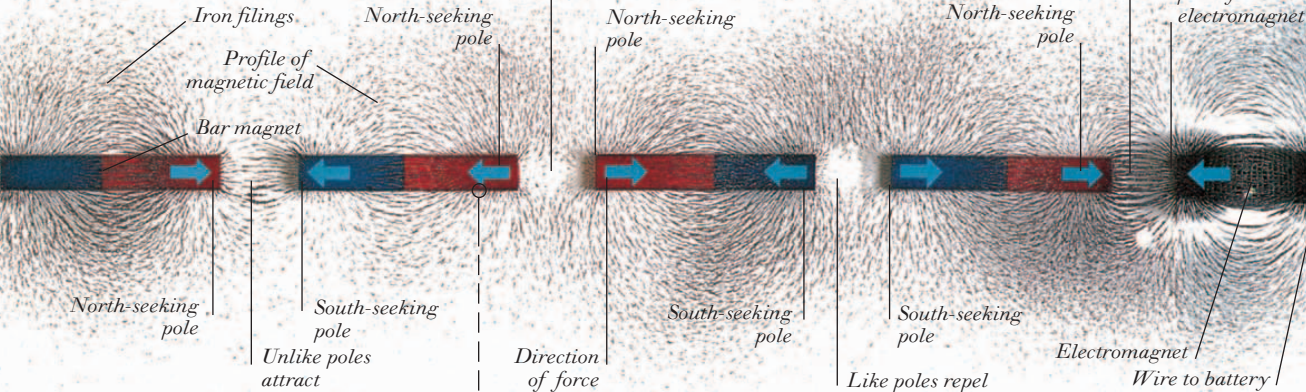
electrons to pass through it—the forces cause a flow of charge called an electric current. Some substances exhibit the strange phenomenon of magnetism—which also produces attractive and repulsive forces. Magnetic substances consist of small regions called domains. Normally unmagnetized, they can be magnetized by being placed in a magnetic field. Magnetism and electricity are inextricably linked, a fact put to use in motors and generators.



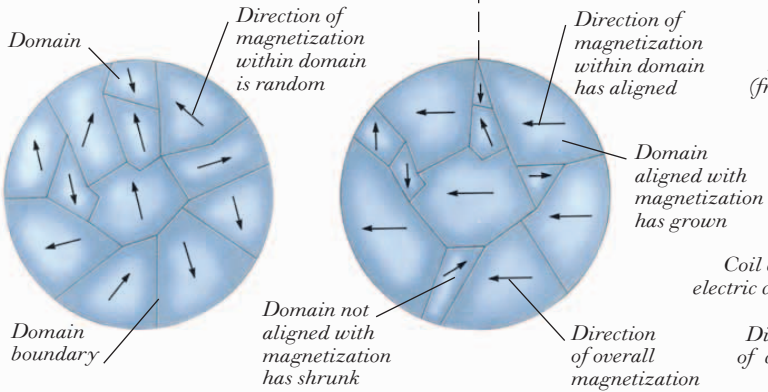
CURRENT ELECTRICITY



MAGNETIC FIELDS AND FORCES



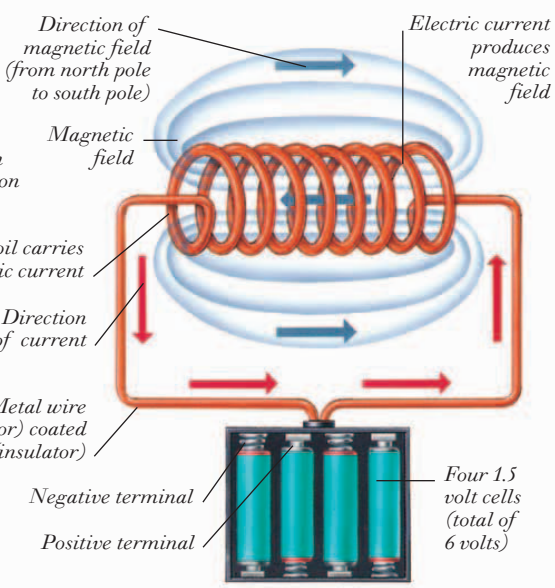
MAGNETIC DOMAINS



UNMAGNETIZED IRON

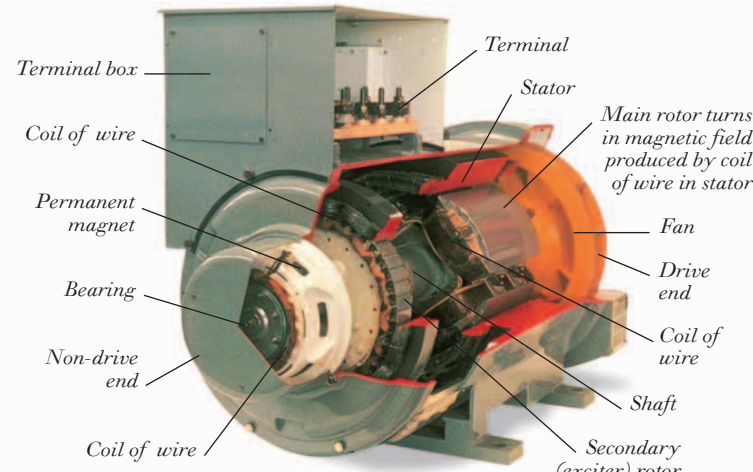
MAGNETIZED IRON IN A MAGNETIC FIELD

GENERATING MAGNETISM FROM ELECTRICITY



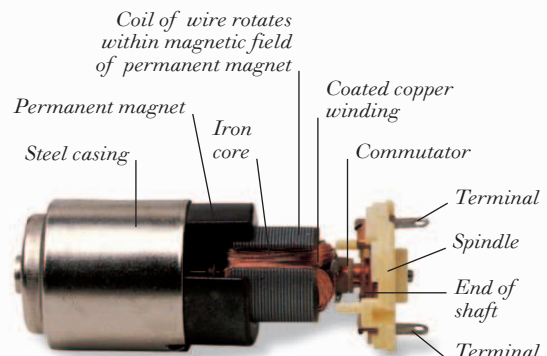
CIRCUIT WITH ELECTROMAGNET

GENERATING ELECTRICITY FROM MAGNETISM



ELECTRIC GENERATOR

In a generator, the rotor rotates within the magnetic field of the stator to produce an electric current.



ELECTRIC MOTOR

In a motor, magnetic forces between the winding and permanent magnet produce a rotary motion.

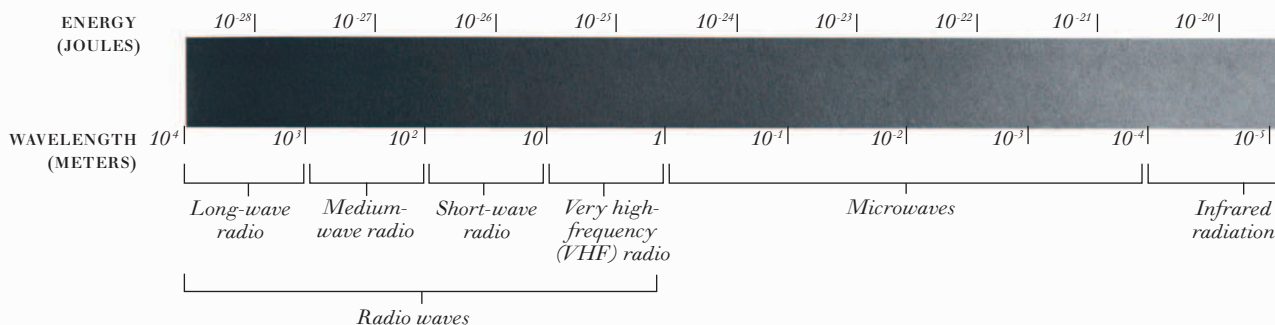


INFRARED IMAGE OF A HOUSE

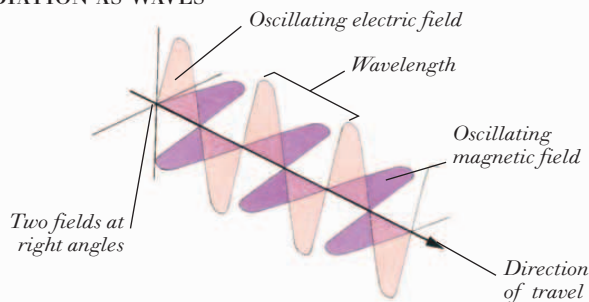
Light

LIGHT IS A FORM OF ENERGY. It is a type of electromagnetic radiation, like X-rays or radio waves. All electromagnetic radiation is produced by electric charges (see pp. 316-317): it is caused by the effects of oscillating electric and magnetic fields as they travel through space. Electromagnetic radiation is considered to have both wave and particle properties. It can be thought of as a wave of electricity and magnetism. In that case, the difference between the various forms of radiation is their wavelength. Radiation can also be said to consist of particles, or packets of energy, called photons. The difference between light and X-rays, for instance, is the amount of energy that each photon carries. The complete range of radiation is referred to as the electromagnetic spectrum, extending from low energy, long wavelength radio waves to high energy, short wavelength gamma rays. Light is the only part of the electromagnetic spectrum that is visible. White light from the Sun is made up of all the visible wavelengths of radiation, which can be seen when it is separated by using a prism. Light, like all forms of electromagnetic radiation, can be reflected (bounced back) and refracted (bent). Different parts of the electromagnetic spectrum are produced in different ways. Sometimes visible light—and infrared radiation—is generated by the vibrating particles of warm or hot objects. The emission of light in this way is called incandescence. Light can also be produced by fluorescence, a phenomenon in which electrons gain and lose energy within atoms.

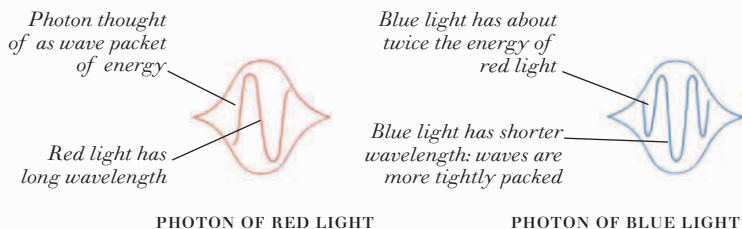
THE ELECTROMAGNETIC SPECTRUM



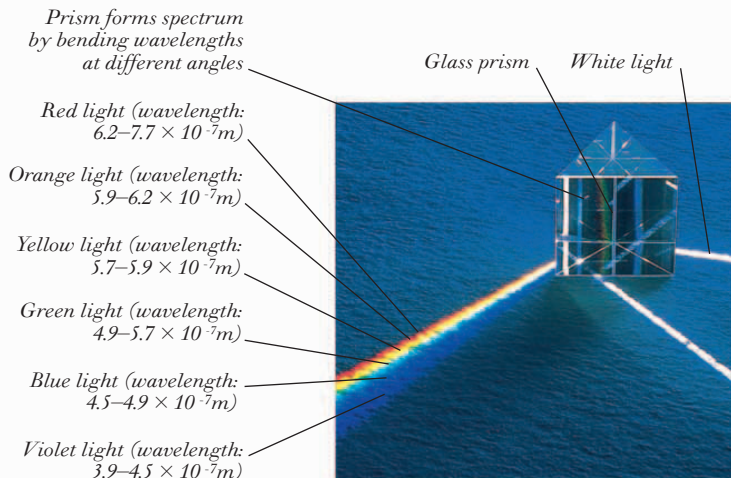
MAXWELLIAN DIAGRAM OF ELECTROMAGNETIC RADIATION AS WAVES



ELECTROMAGNETIC RADIATION AS PARTICLES

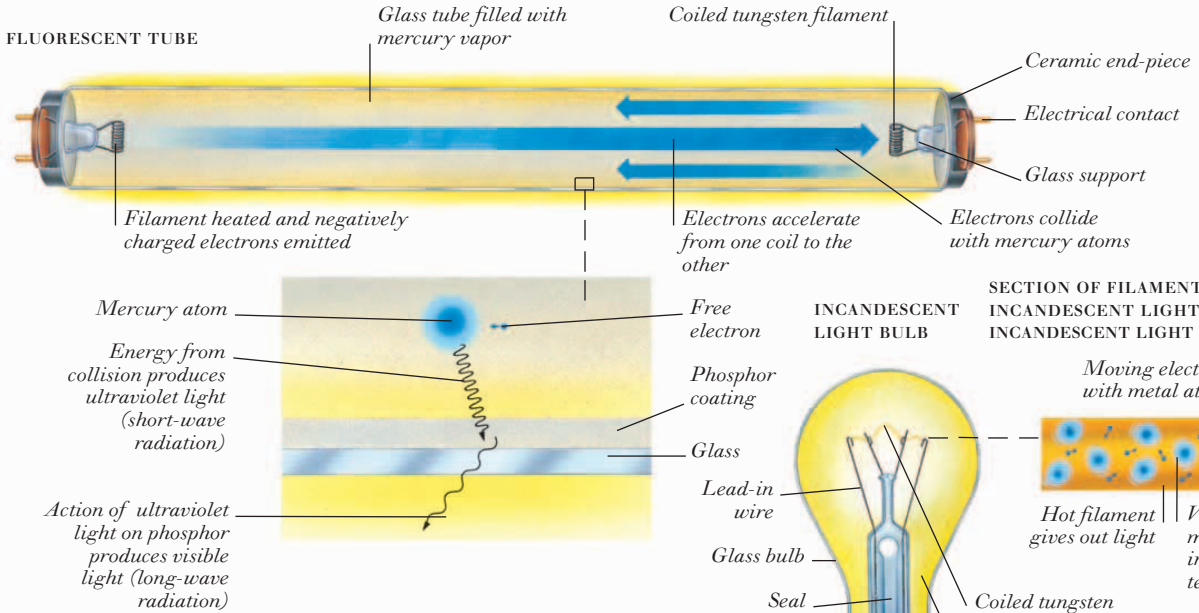


SPLITTING WHITE LIGHT INTO THE SPECTRUM



ARTIFICIAL LIGHT SOURCES

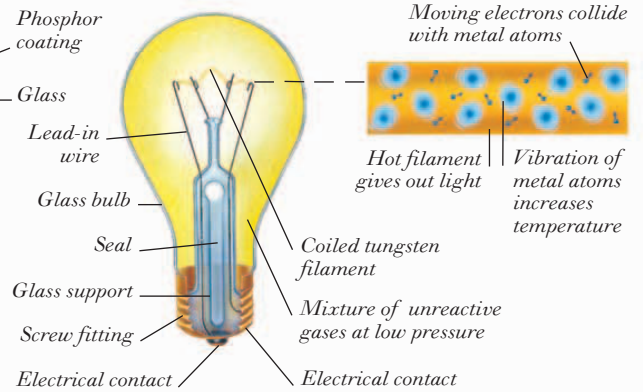
FLUORESCENT TUBE



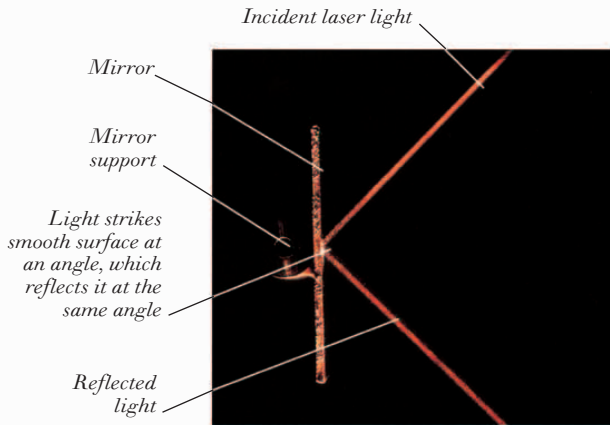
SECTION OF PHOSPHOR COATING OF FLUORESCENT TUBE: HOW FLUORESCENT LIGHT IS PRODUCED

INCANDESCENT LIGHT BULB

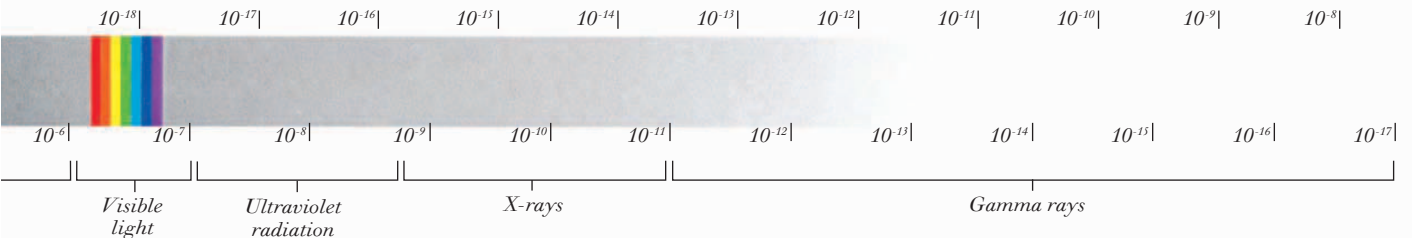
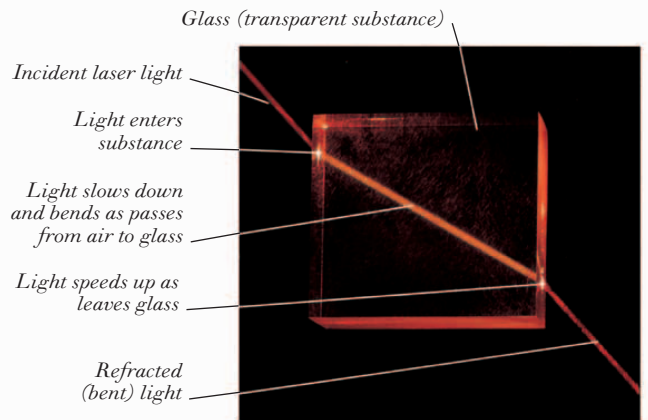
SECTION OF FILAMENT OF INCANDESCENT LIGHT BULB: HOW INCANDESCENT LIGHT IS PRODUCED



REFLECTION OF LIGHT



REFRACTION OF LIGHT



Force and motion

FORCES ARE PUSHES OR PULLS that change the motion of objects. To make a stationary object move, or a moving object stop, a force is needed. A force is also required to change the speed or direction of an object. This change in speed or direction is known as acceleration. Acceleration depends on the size (magnitude) of the force, and on the mass of the object. The effects of forces were first summarized by Isaac Newton in his three laws of motion. The international unit of force, named after him, is the newton (N), which is approximately equal to the weight of one apple. Gravity—the force of attraction between any two masses—can be measured using a newton meter (spring balance). Forces are put to useful effect in machines. A simple machine, such as a wheel and axle, is a device that changes the size or direction of an applied force. It allows an applied force (the effort) to produce another force (the load). A lever uses a bar that turns on a fulcrum to exert force. In all simple machines, there is a relationship between force and distance. A small force (in a compound pulley, for instance) moves through a large distance to lift a heavy object a small distance. This is called the Law of Simple Machines.

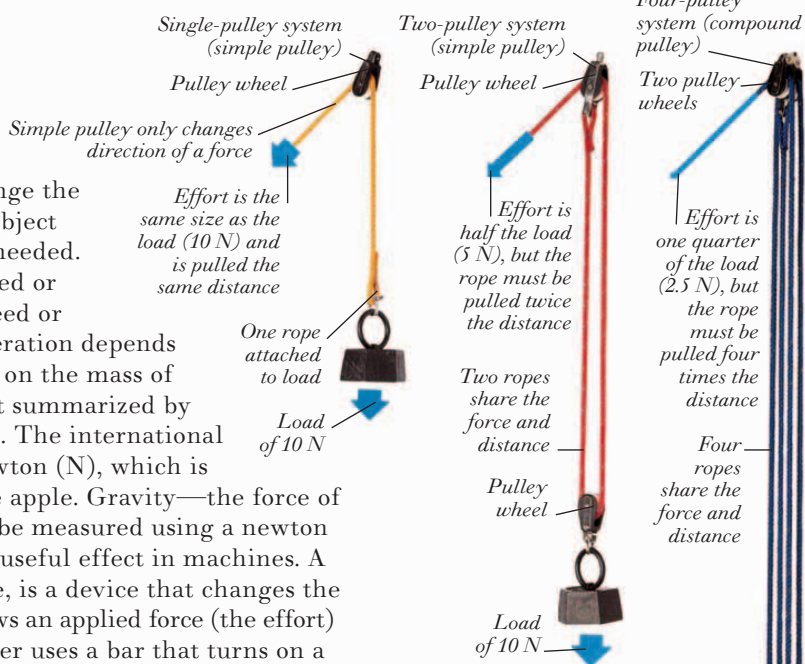
NEWTON METERS (SPRING BALANCES)



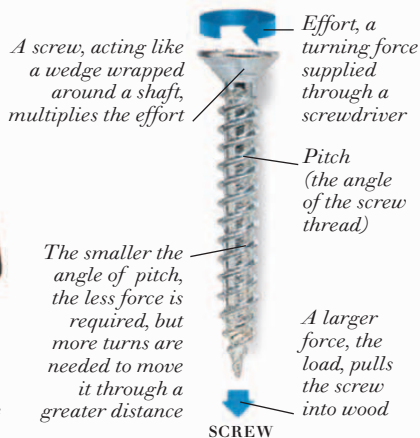
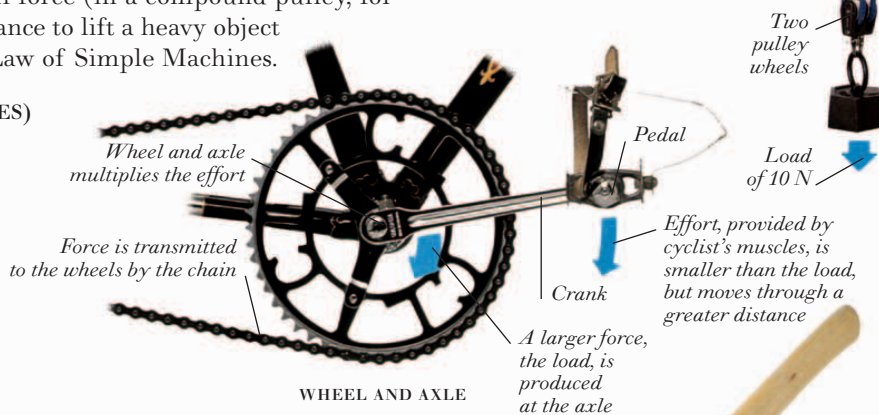
WEIGHT AND MASS

The “mass” of an object is a measure of the quantity of matter that it possesses. Mass is usually measured in grams (g) or kilograms (kg). The “weight” of an object is the force exerted on the object’s mass by gravity. Since weight is a force, its unit is the newton (N).

SIMPLE MACHINES



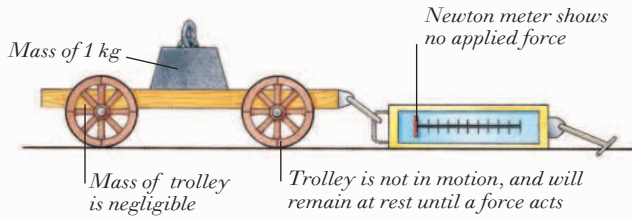
SIMPLE AND COMPOUND PULLEYS



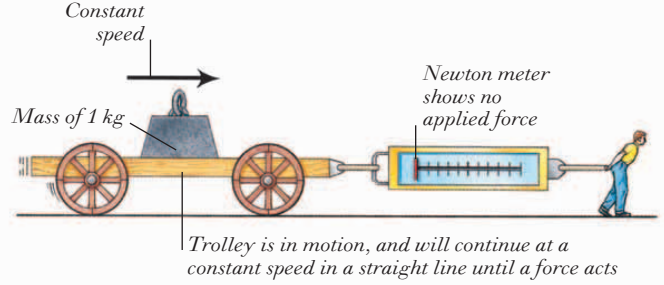
NEWTON'S THREE LAWS OF MOTION

NEWTON'S FIRST LAW

When no force acts on a body, it will continue in a state of rest or uniform motion.



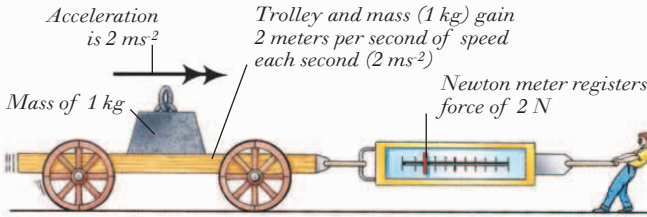
NO FORCE, NO ACCELERATION: STATE OF REST



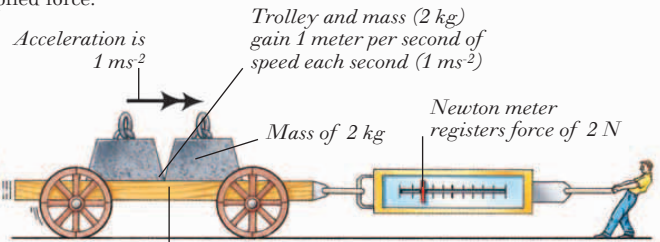
NO FORCE, NO ACCELERATION: UNIFORM MOTION

NEWTON'S SECOND LAW

When a force acts on a body, the motion of the body will change. The size of the change will depend upon the mass of the object and the magnitude of the applied force.



FORCE AND ACCELERATION: SMALL MASS, LARGE ACCELERATION



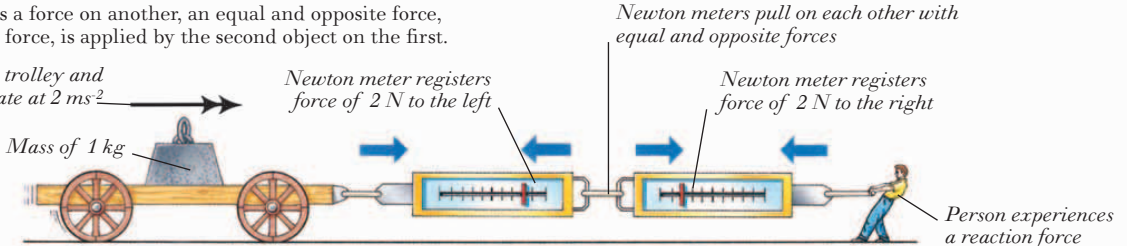
FORCE AND ACCELERATION: LARGE MASS, SMALL ACCELERATION

With the same applied force, an object with 2 kg mass accelerates at half the rate of object with 1 kg mass

NEWTON'S THIRD LAW

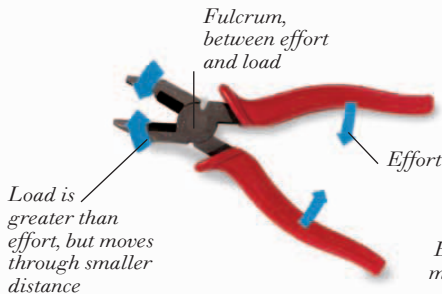
If one object exerts a force on another, an equal and opposite force, called the reaction force, is applied by the second object on the first.

Acceleration: the trolley and mass accelerate at 2 ms^{-2}

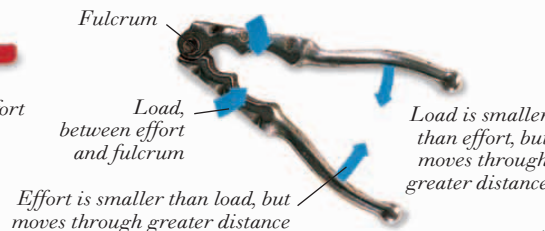


ACTION AND REACTION

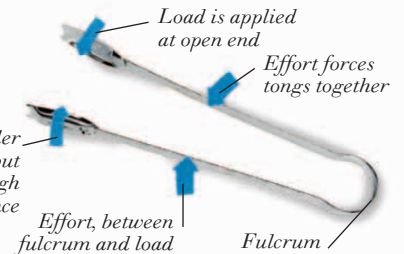
THREE CLASSES OF LEVER



CLASS 1 LEVER
Pliers consist of two class 1 levers.



CLASS 2 LEVER
Nutcrackers consist of two class 2 levers.



CLASS 3 LEVER
Tongs consist of two class 3 levers.





RAIL AND ROAD

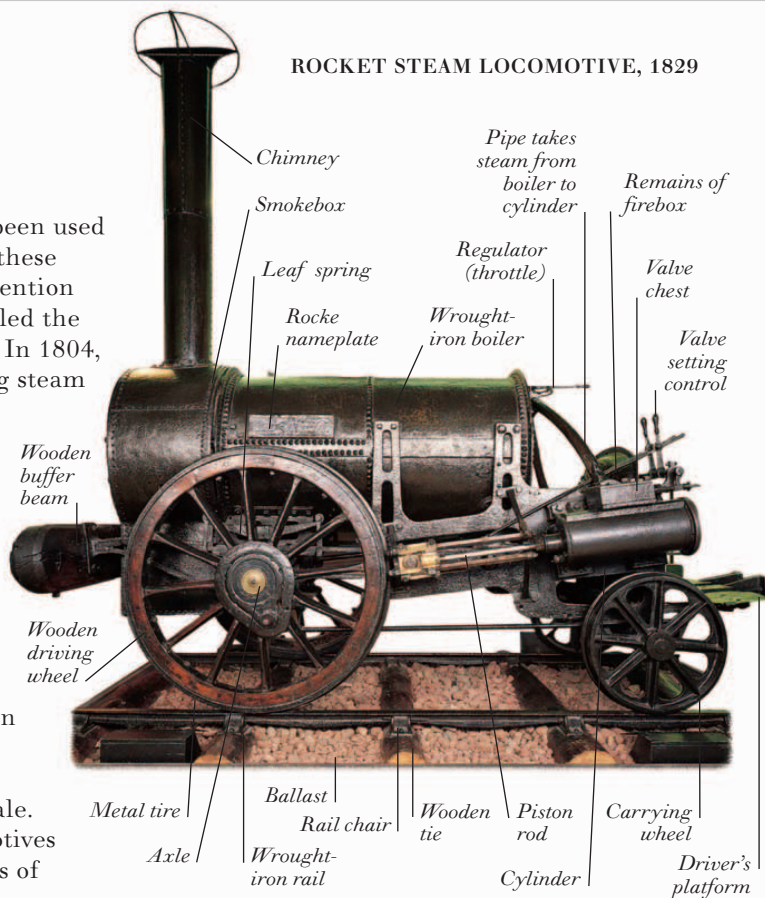
STEAM LOCOMOTIVES	324
DIESEL TRAINS	326
ELECTRIC AND HIGH-SPEED TRAINS	328
TRAIN EQUIPMENT	330
TROLLEYS AND BUSES	332
THE FIRST CARS	334
ELEGANCE AND UTILITY	336
MASS-PRODUCTION	338
THE "PEOPLE'S CAR"	340
EARLY ENGINES	342
MODERN ENGINES	344
ALTERNATIVE ENGINES	346
BODYWORK	348
MECHANICAL COMPONENTS	350
CAR TRIM	352
HYBRID CAR	354
RACE CARS	356
BICYCLE ANATOMY	358
BICYCLES	360
THE MOTORCYCLE	362
THE MOTORCYCLE CHASSIS	364
MOTORCYCLE ENGINES	366
COMPETITION MOTORCYCLES	368



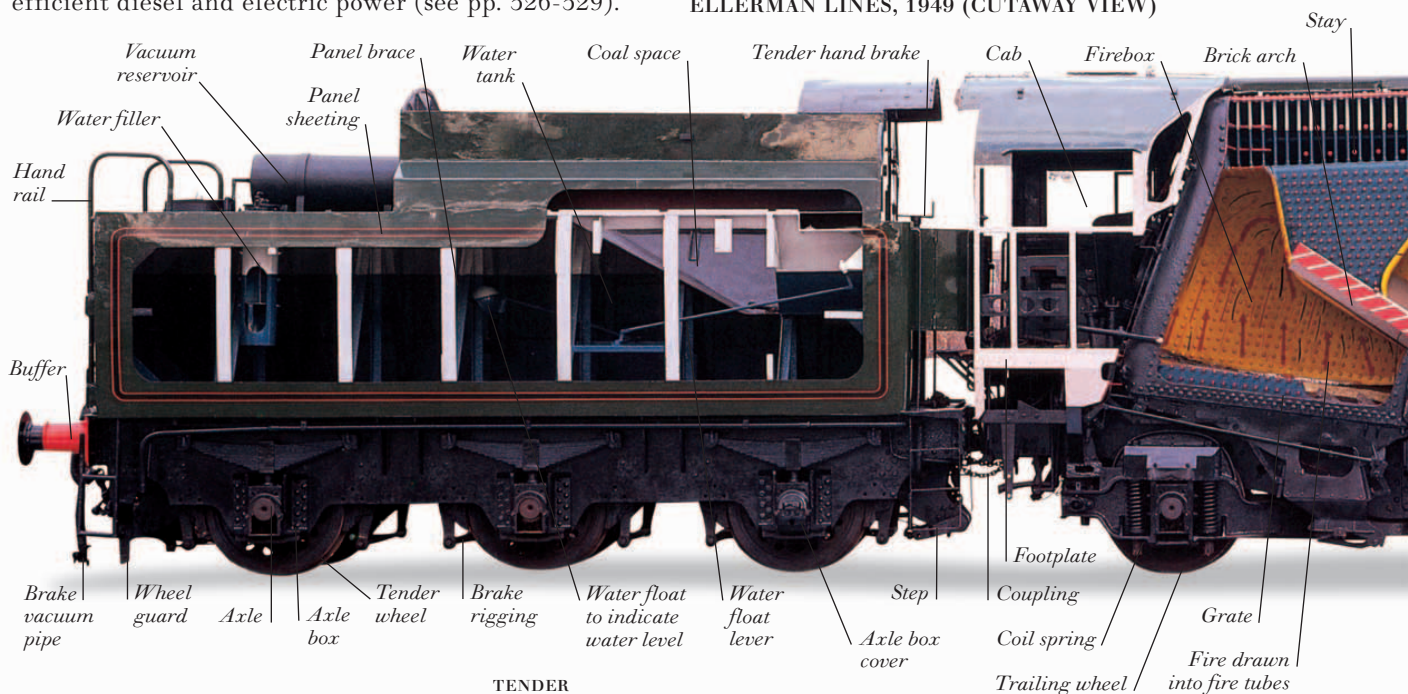
Steam locomotives

WAGONS THAT ARE PULLED along tracks have been used to transport material since the 16th century, but these trains were drawn by men or horses until the invention of the steam locomotive. Steam locomotives enabled the basic railroad system to realize its true potential. In 1804, Richard Trevithick built the world's first working steam locomotive in South Wales. It was not entirely successful, but it encouraged others to develop new designs. By 1829, the British engineer Robert Stephenson had built the Rocket, considered to be the forerunner of the modern locomotive. The Rocket was a self-sufficient unit, carrying coal to heat the boiler and a water supply for generating steam. Steam passed from the boiler to force the pistons back and forth, propelling the train forward. Used steam was then expelled in characteristic puffs. Later steam locomotives, like Ellerman Lines and the Mallard, worked in a similar way, but on a much larger scale. The simple design and reliability of steam locomotives ensured that they changed very little in 120 years of use, before being replaced from the 1950s by more efficient diesel and electric power (see pp. 326-329).

ROCKET STEAM LOCOMOTIVE, 1829

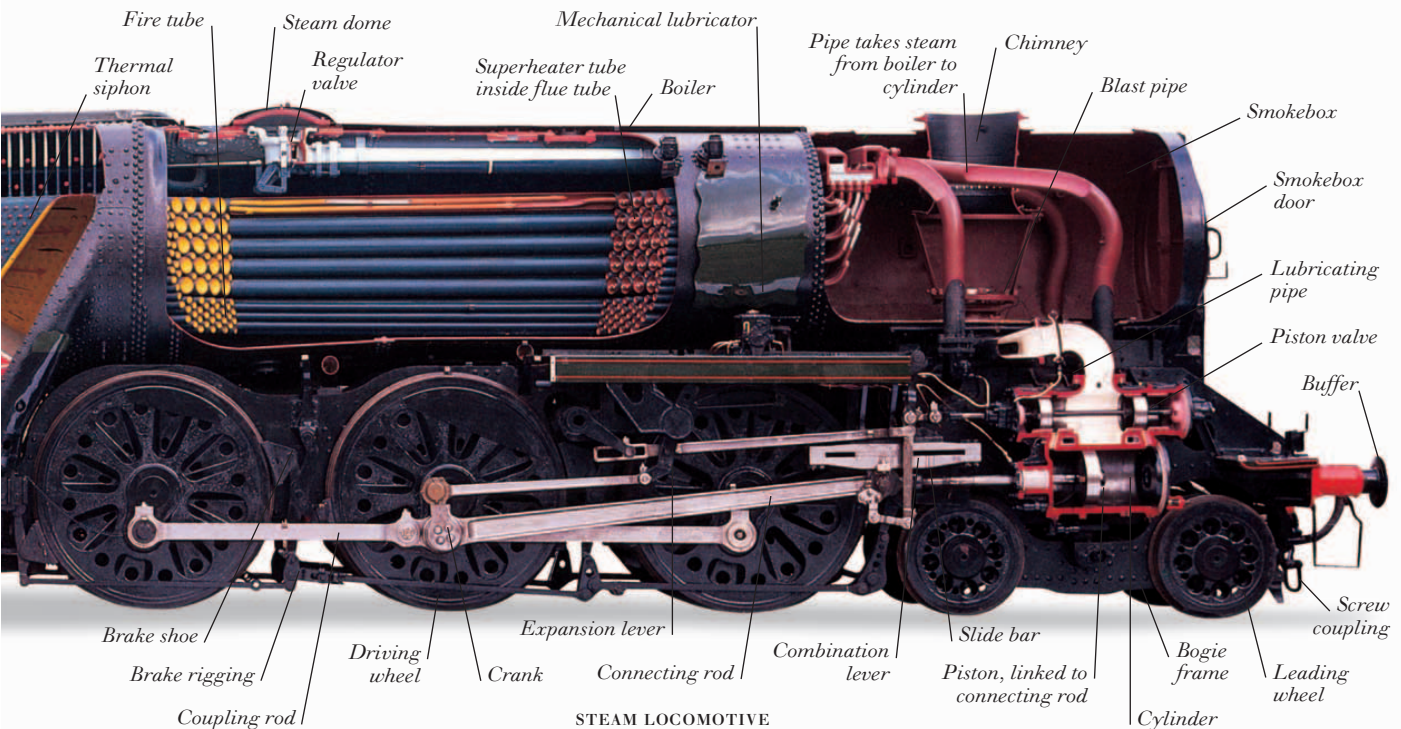
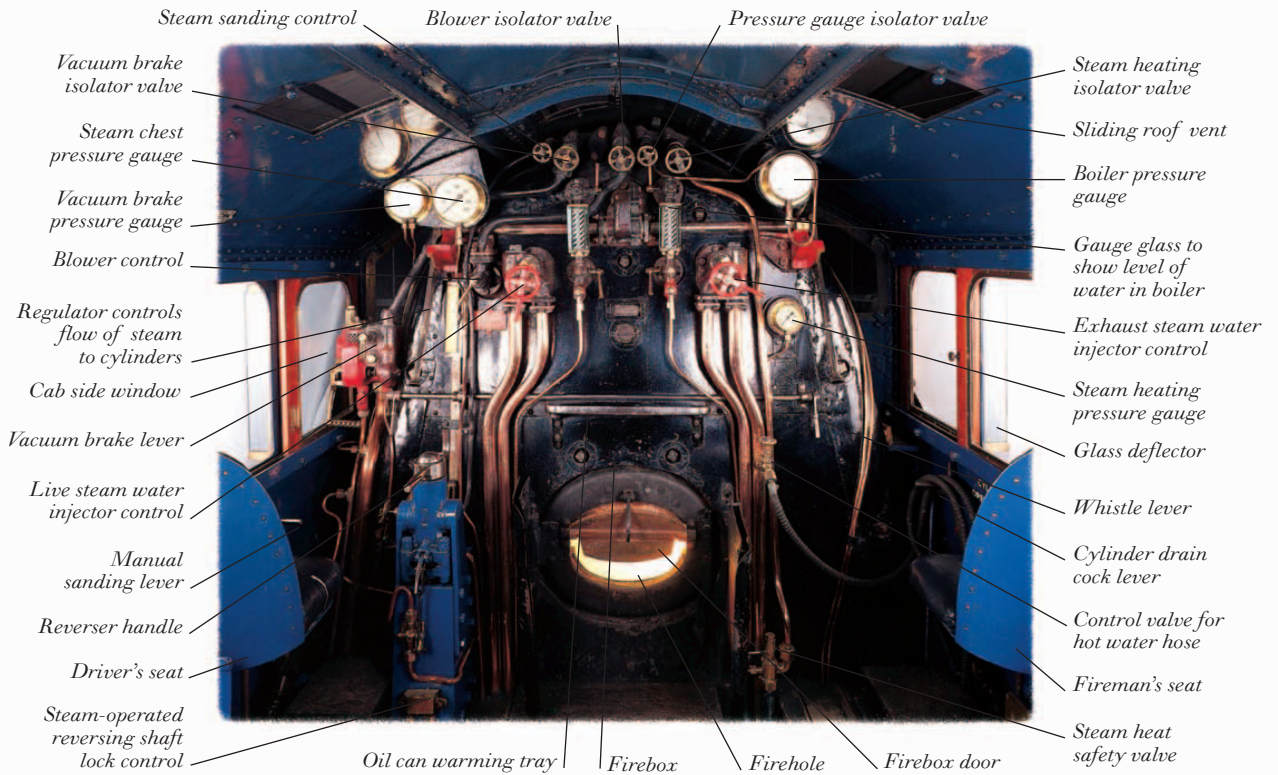


ELLERMAN LINES, 1949 (CUTAWAY VIEW)



TENDER

CAB INTERIOR OF MALLARD EXPRESS STEAM LOCOMOTIVE, 1938

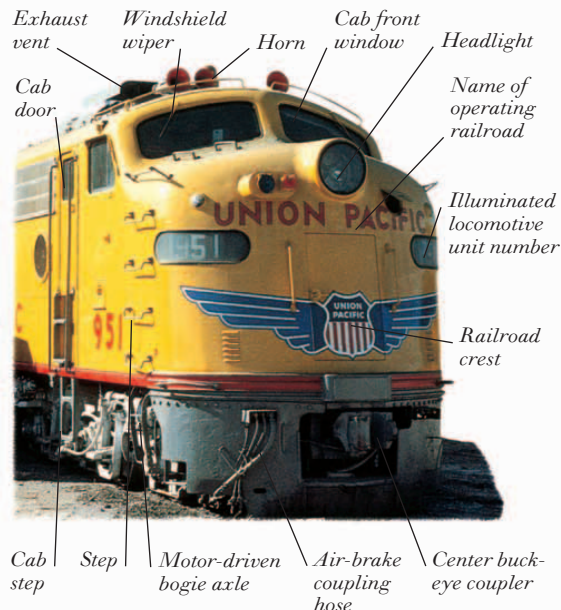


STEAM LOCOMOTIVE

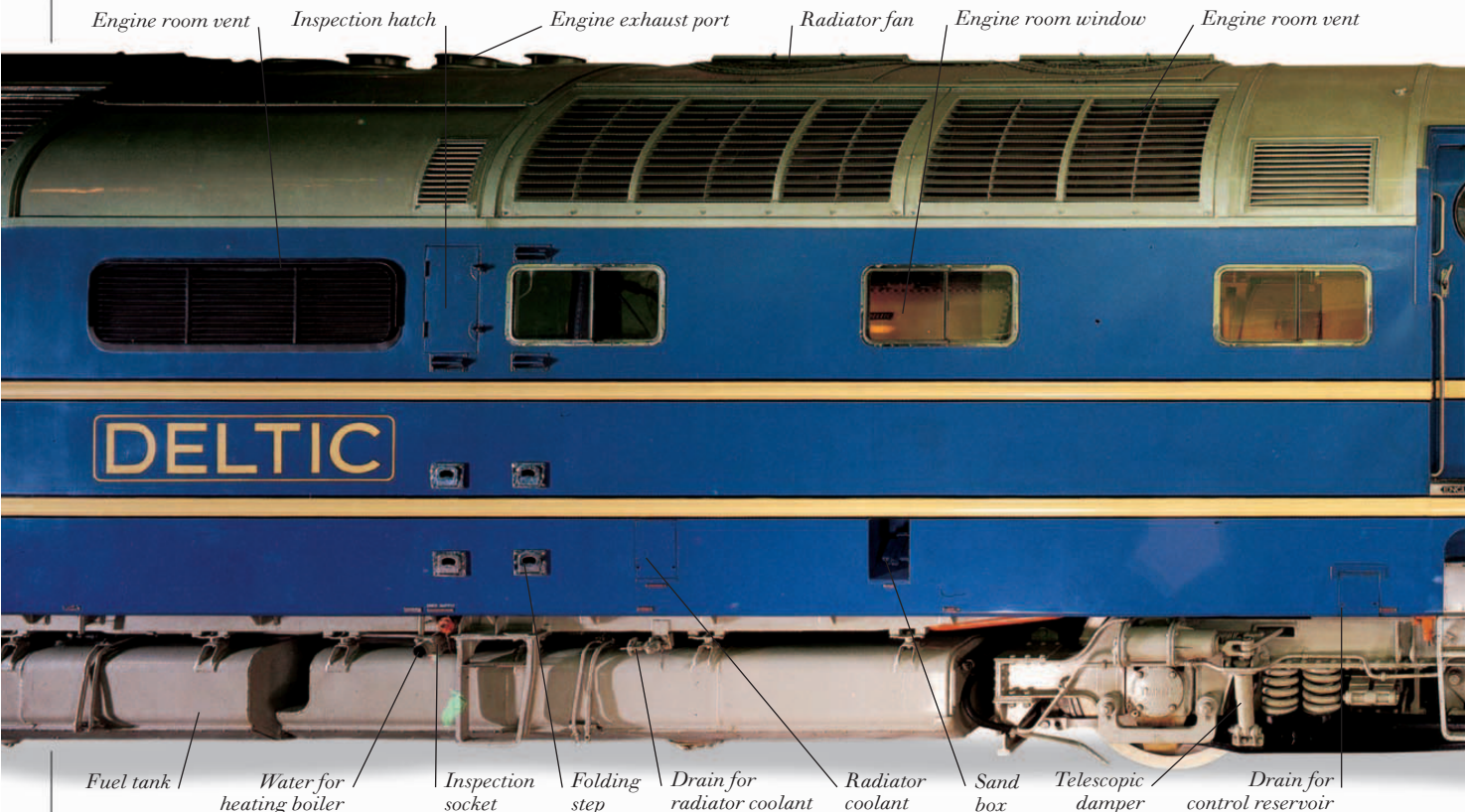
Diesel trains

RUDOLF DIESEL FIRST DEMONSTRATED the diesel engine in Germany in 1898, but it was not until the 1940s that diesel locomotives were successfully established on both passenger and freight services in the US. Early diesel locomotives like the Union Pacific were more expensive to build than steam locomotives, but were more efficient and cheaper to operate, especially where oil was plentiful. One feature of diesel engines is that the power output cannot be coupled directly to the wheels. To convert the mechanical energy produced by diesel engines, a transmission system is needed. Almost all diesel locomotives have electric transmissions, and are known as diesel-electric locomotives. The diesel engine works by drawing air into the cylinders and compressing it to increase its temperature; a small quantity of diesel fuel is then injected into it. The resulting combustion drives the generator (more recently an alternator) to produce electricity, which is fed to electric motors connected to the wheels. Diesel-electric locomotives are essentially electric locomotives that carry their own power plants, and are used worldwide today. The Deltic diesel-electric locomotive, similar to the one shown here, replaced classic express steam locomotives, and ran at speeds up to 100 mph (160 kph).

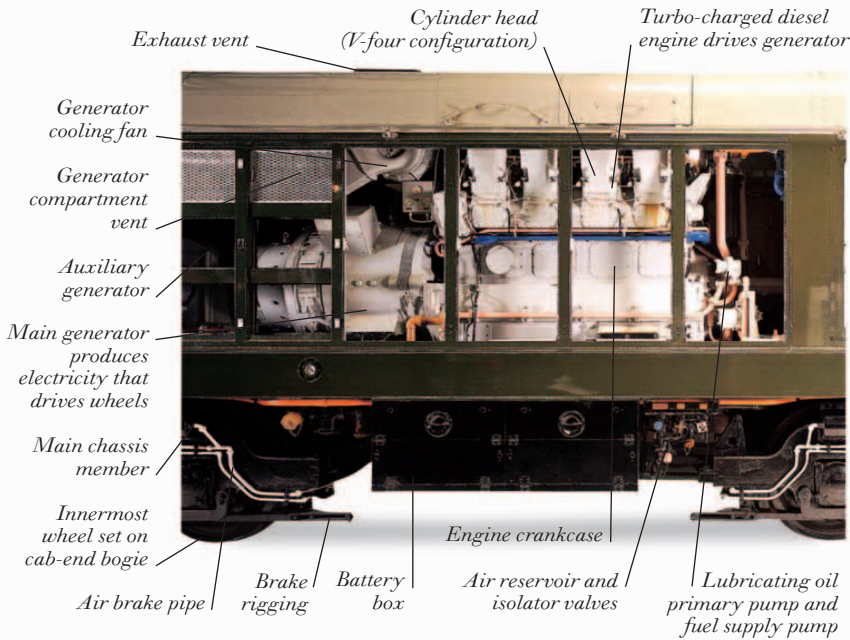
FRONT VIEW OF UNION PACIFIC
DIESEL-ELECTRIC LOCOMOTIVE, 1950s



PROTOTYPE DELTIC DIESEL-ELECTRIC LOCOMOTIVE, 1956



**DIESEL ENGINE OF BRITISH RAIL CLASS 20
DIESEL-ELECTRIC LOCOMOTIVE**



EXAMPLES OF FREIGHT CARS



BOX CAR



HOPPER CAR



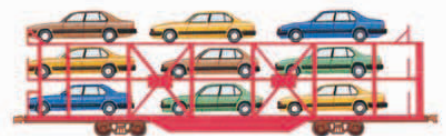
REFRIGERATOR CAR



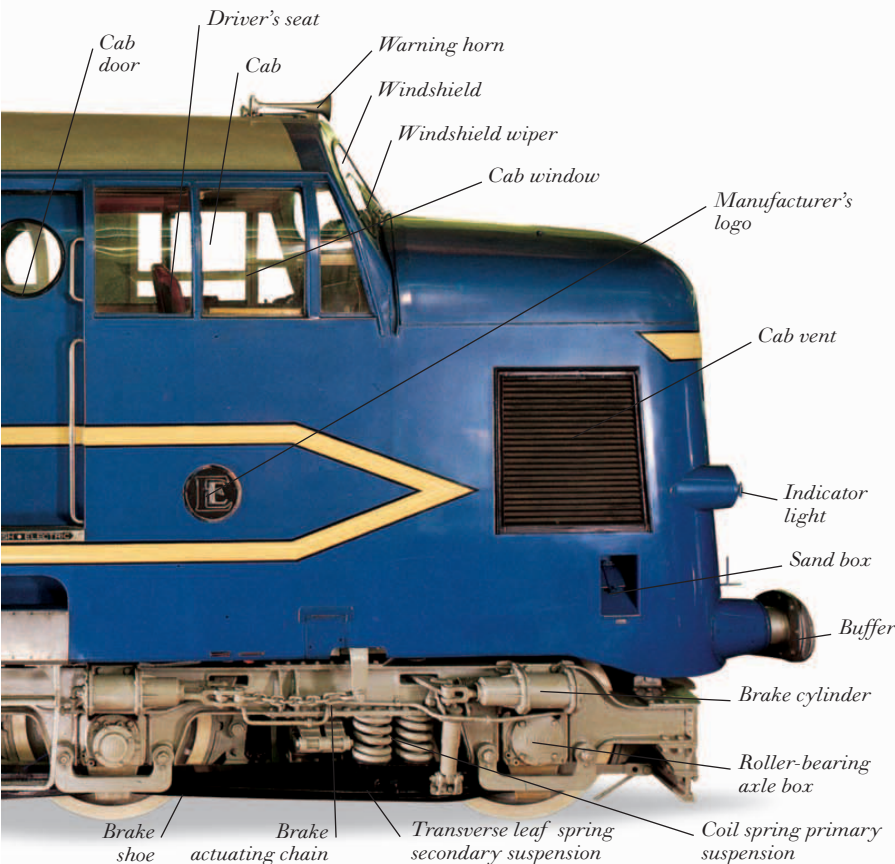
LIVESTOCK CAR



FLAT CAR WITH BULKHEADS



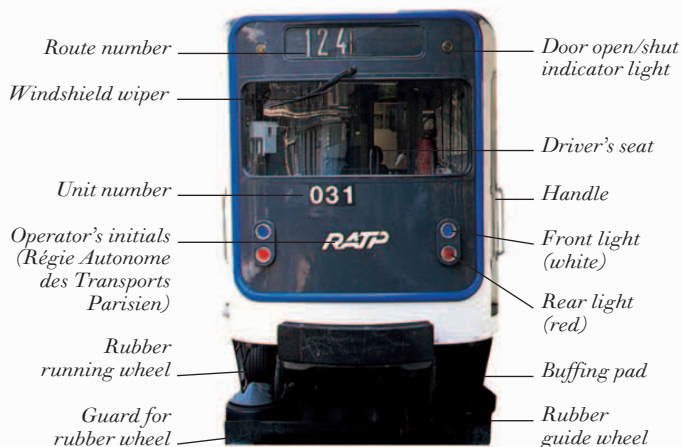
AUTOMOBILE CAR



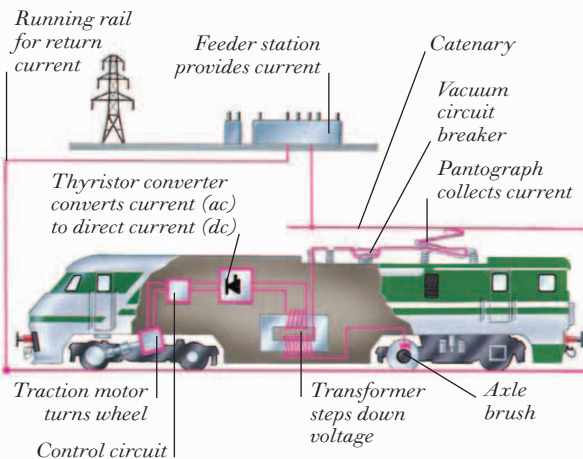
Electric and high-speed trains

THE FIRST ELECTRIC LOCOMOTIVE ran in 1879 in Berlin, Germany. In Europe, electric trains developed as a more efficient alternative to the steam locomotive and diesel-electric power. Like diesels, electric trains employ electric motors to drive the wheels but, unlike diesels, the electricity is generated externally at a power station. Electric current is picked up either from a catenary (overhead cable) via a pantograph, or from a third rail. Since it does not carry its own power-generating equipment, an electric locomotive has a better power-to-weight ratio and greater acceleration than its diesel-electric equivalent. This makes electric trains suitable for urban routes with many stops. They are also faster, quieter, and cause less pollution. The latest electric French TGV (Train à Grande Vitesse) reaches 185 mph (300 kph); other trains, like the London to Paris and Brussels Eurostar, can run at several voltages and operate between different countries. Simpler electric trains perform special duties—the “People Mover” at Gatwick Airport in London runs between terminals.

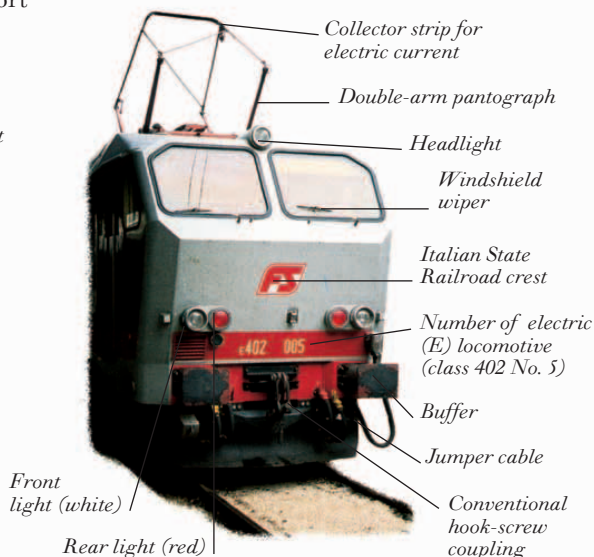
FRONT VIEW OF PARIS METRO



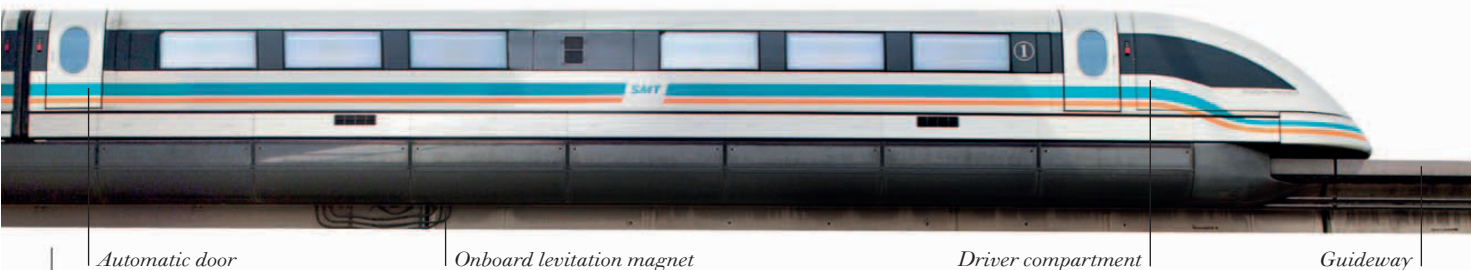
HOW ALTERNATING CURRENT (AC) ELECTRIC TRAINS WORK



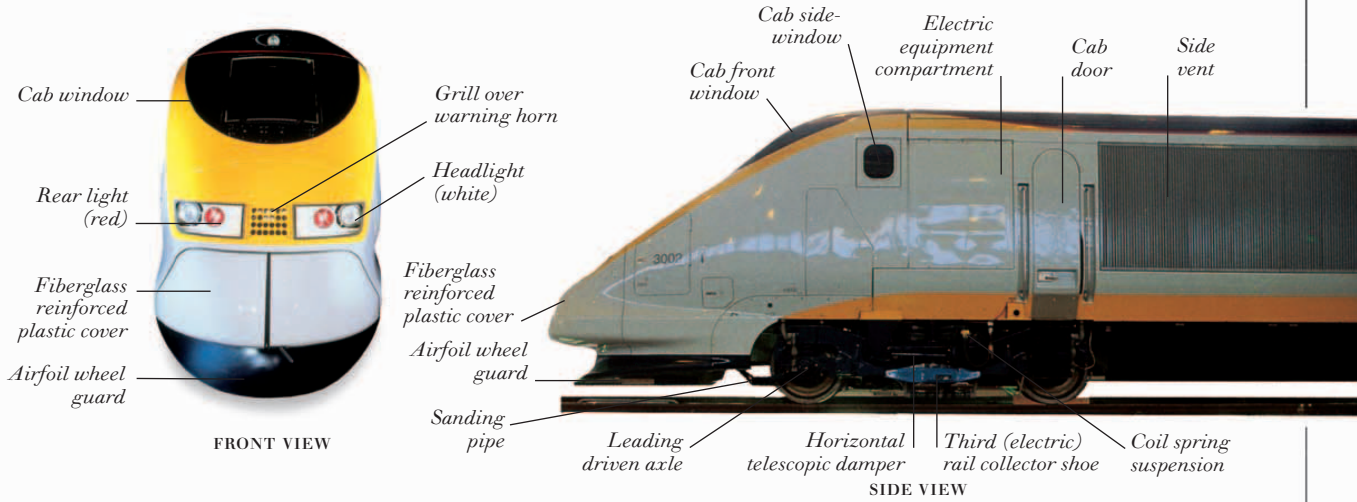
FRONT VIEW OF ITALIAN STATE RAILROADS CLASS 402 ELECTRIC LOCOMOTIVE



SIDE VIEW OF SHANGHAI MAGLEV TRAIN



EUROSTAR MULTIVOLTAGE ELECTRIC TRAIN



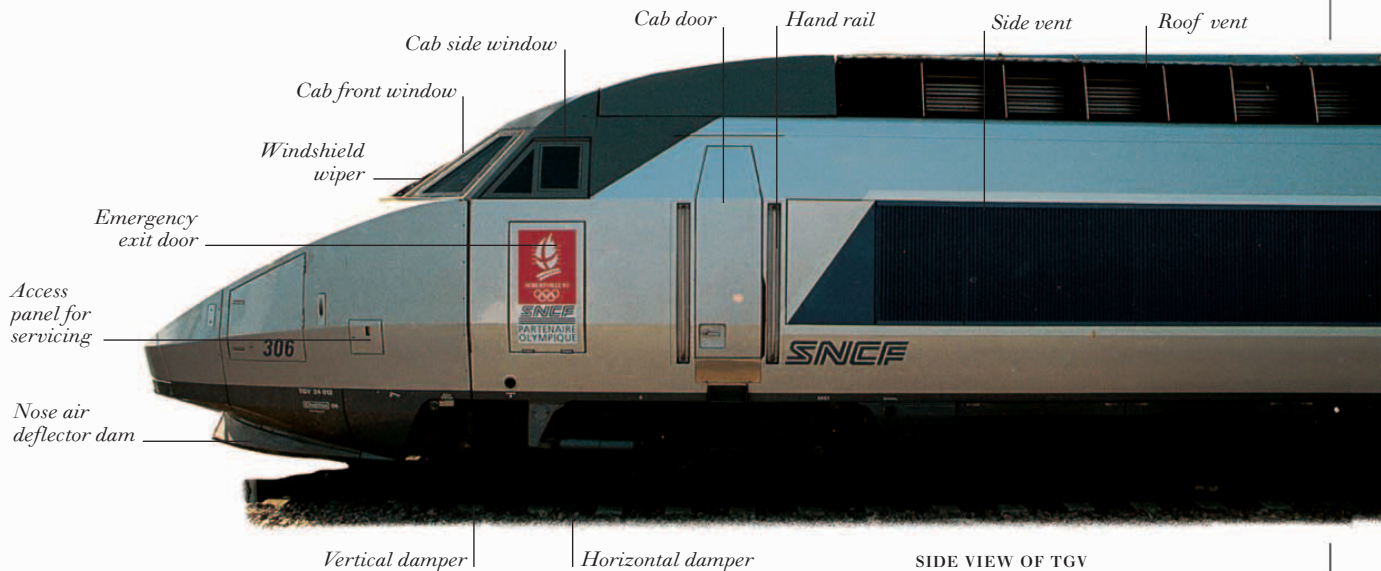
FRONT VIEW

SIDE VIEW

TGV ELECTRIC HIGH-SPEED TRAIN



INTERIOR OF TGV

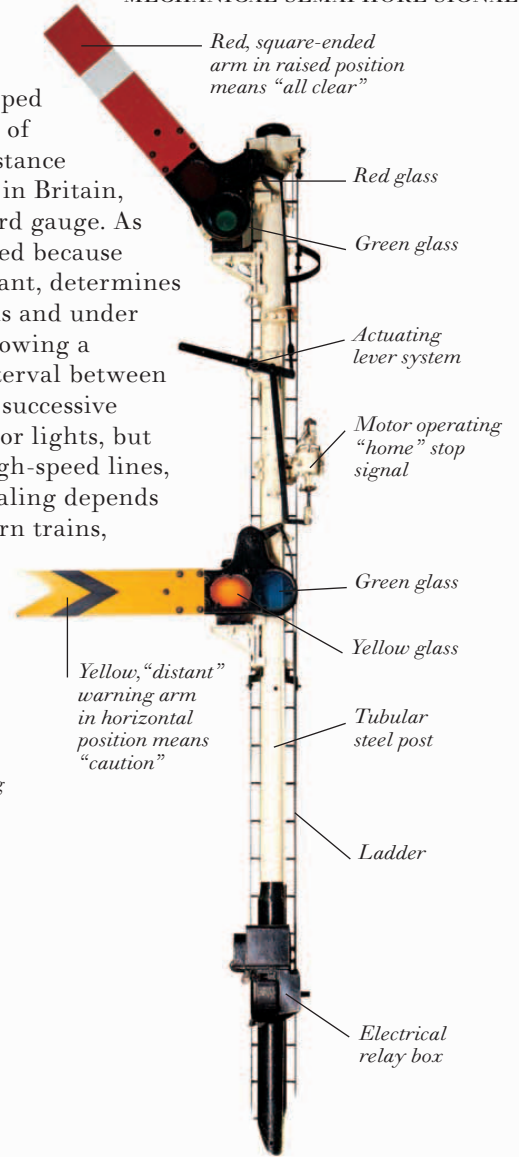


SIDE VIEW OF TGV

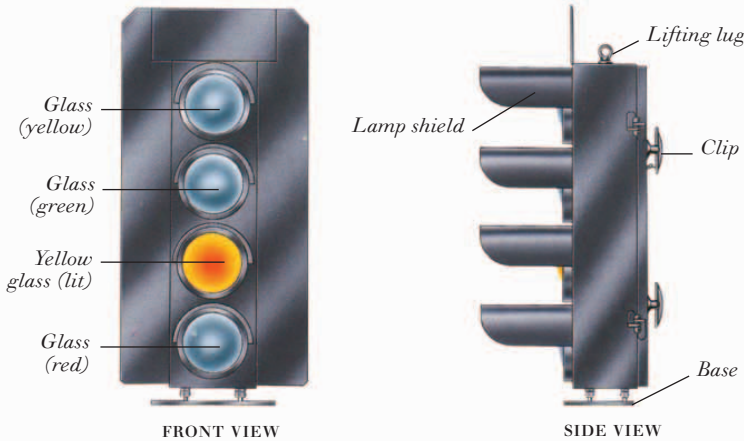
Train equipment

MODERN RAILROAD TRACK consists of two parallel steel rails clipped on to a support called a railroad tie. Railroad ties are usually made of reinforced concrete, although wood and steel are still used. The distance between the inside edges of the rails is the track gauge. It evolved in Britain, which uses a gauge of 4 ft 8½ in (1,435 mm), known as the standard gauge. As engineering grew more sophisticated, narrower gauges were adopted because they cost less to build. The loading gauge, which is equally important, determines the size of the largest loaded vehicle that may pass through tunnels and under bridges with adequate clearance. Safe train operation relies on following a signaling system. At first, signaling was based on a simple time interval between trains, but it now depends on maintaining a safe distance between successive trains traveling in the same direction. Most modern signals are color lights, but older mechanical semaphore signals are still used. On the latest high-speed lines, train drivers receive control instructions by electronic means. Signaling depends on reliable control of the train by effective braking. For fast, modern trains, which have considerable momentum, it is essential that each vehicle in the train can be braked by the driver or by a train control system, such as Automatic Train Protection (ATP). Braking is achieved by the brake shoe acting on the wheel rim (rim brakes), by disc brakes, or, increasingly, by electrical braking.

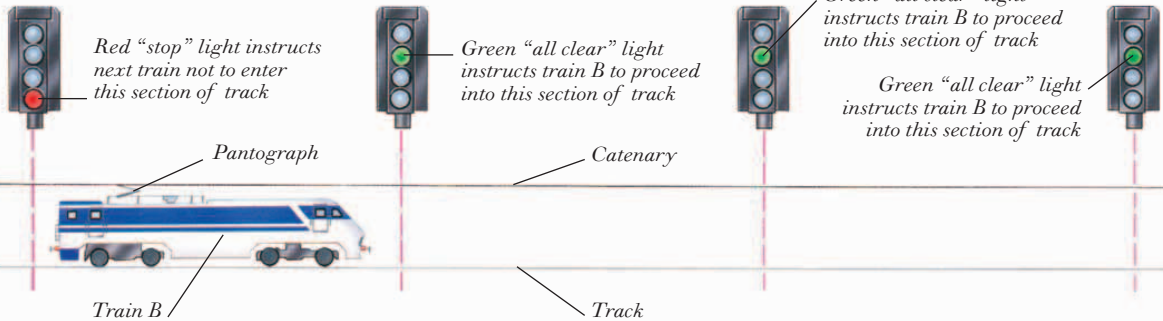
MECHANICAL SEMAPHORE SIGNAL



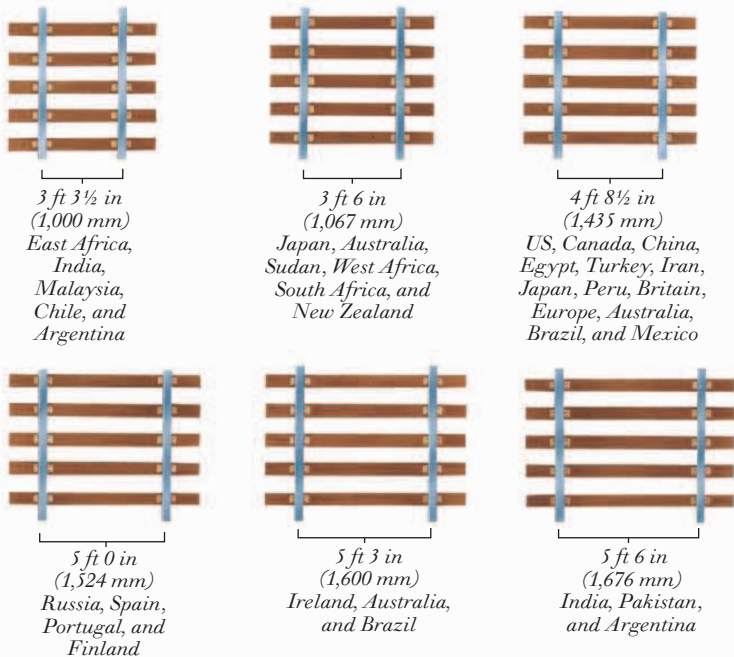
FOUR-ASPECT COLOR LIGHT SIGNAL



HOW A MODERN MAIN-LINE SIGNALING SYSTEM WORKS

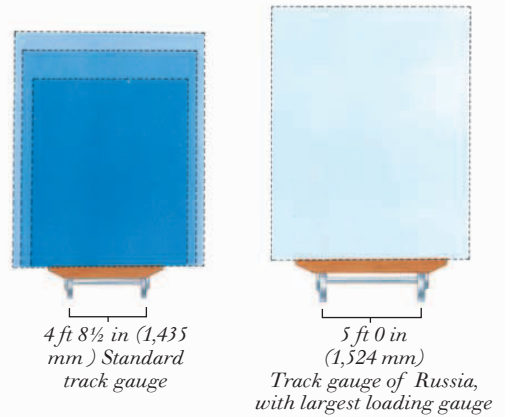


EXAMPLES OF INTERNATIONAL TRACK GAUGES

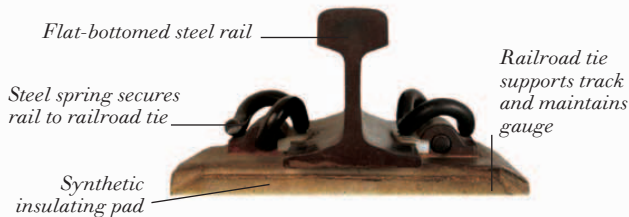


EXAMPLES OF INTERNATIONAL LOADING GAUGES

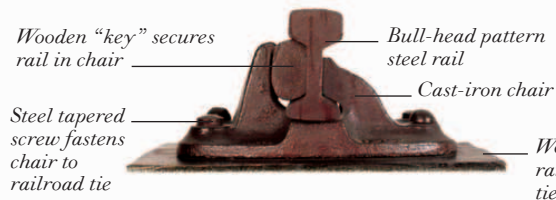
- Britain: 9 ft 0 in (2.75 m) × 12 ft 11 in (3.95 m)
- Europe: 10 ft 2 in (3.1 m) × 14 ft 9 in (4.5 m)
- US: 10 ft 10 in (3.3 m) × 16 ft 2 in (4.9 m)
- Russia: 11 ft 2 in (3.4 m) × 17 ft 4 in (5.3 m)



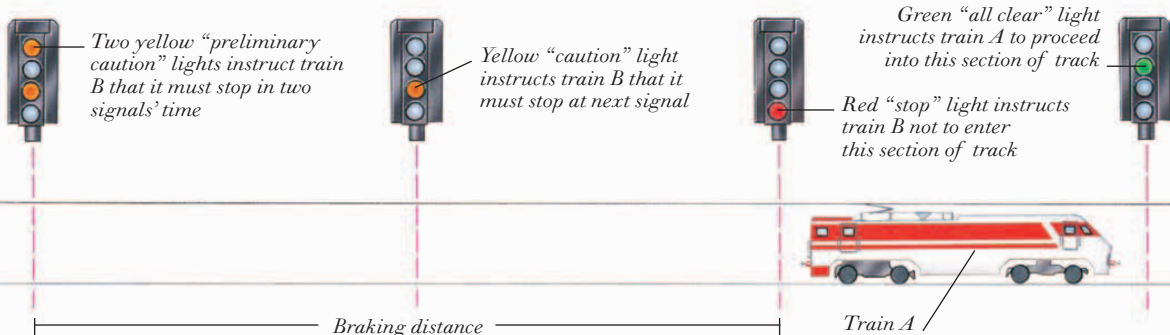
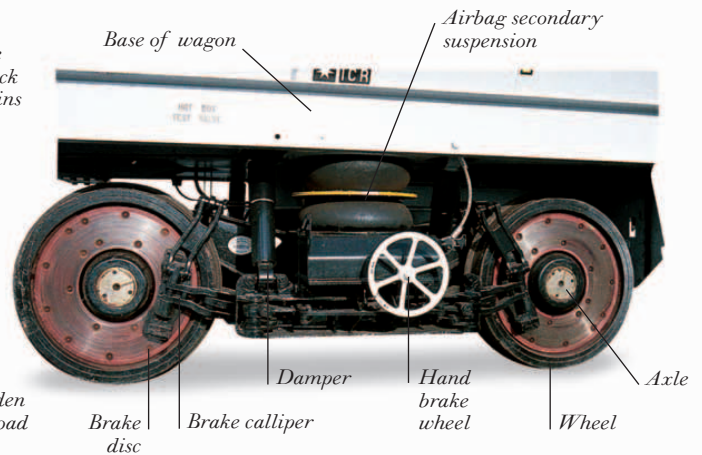
FLAT-BOTTOMED RAIL



BULL-HEAD RAIL



DISC BRAKES ON MODERN WAGON BOGIE

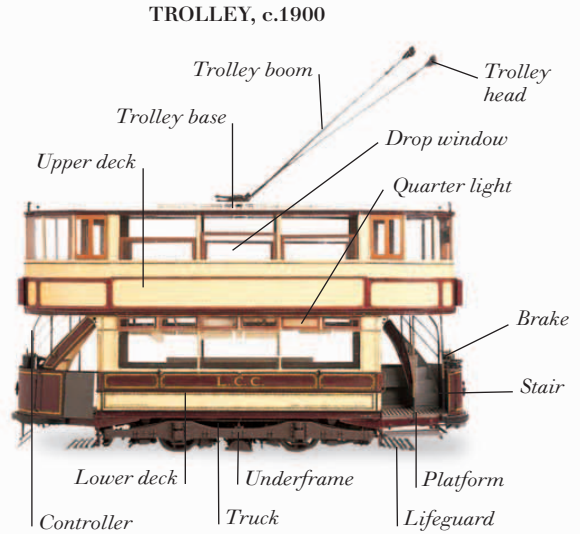


Trolleys and buses



**METROLINK
TROLLEY,
MANCHESTER, UK**

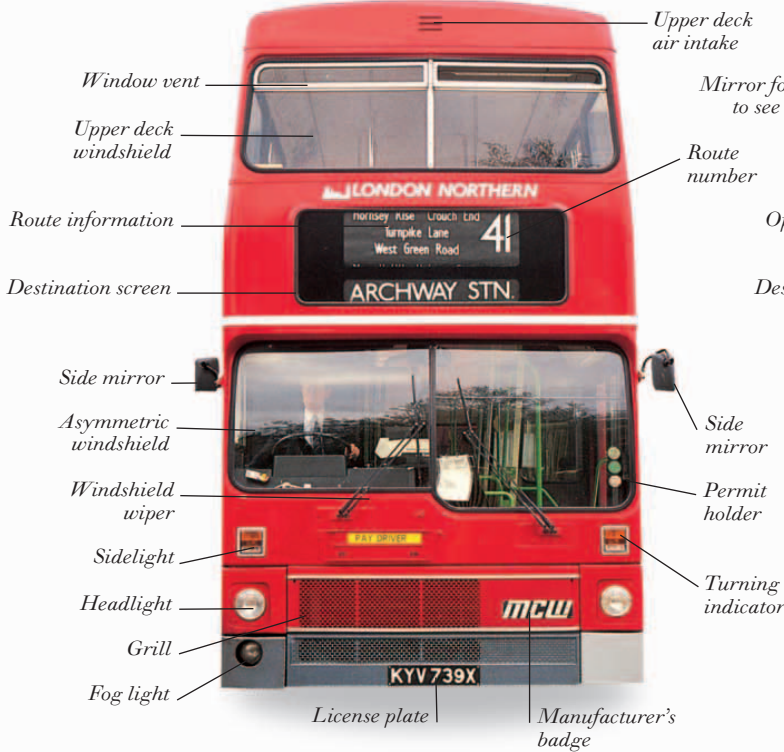
AS CITY POPULATIONS exploded in the 1800s, there was an urgent need for mass transportation. Trolleys were an early solution. The first trolleys, like buses, were horse-drawn, but in 1881, electric streetcars appeared in Berlin, Germany. Electric streetcars soon became widespread throughout Europe and North America. Trolleys run on rails along a fixed route, using electric motors that receive power from overhead cables. As road networks developed, motorized buses offered a flexible alternative to trolleys. By the 1930s, they had replaced trolley systems in many cities. City buses typically have doors at both front and rear to make loading and unloading easier. Double-decker designs are popular, occupying the same amount of street space as single-decker buses but able to transport twice the number of people. Buses are also commonly used for inter-city travel and touring. Tour buses have reclining seats, large windows, luggage space, and toilets. Recently, as city traffic has become increasingly congested, many city planners have designed new electric streetcar routes to run alongside bus routes as part of an integrated transportation system.



TROLLEY, c.1900

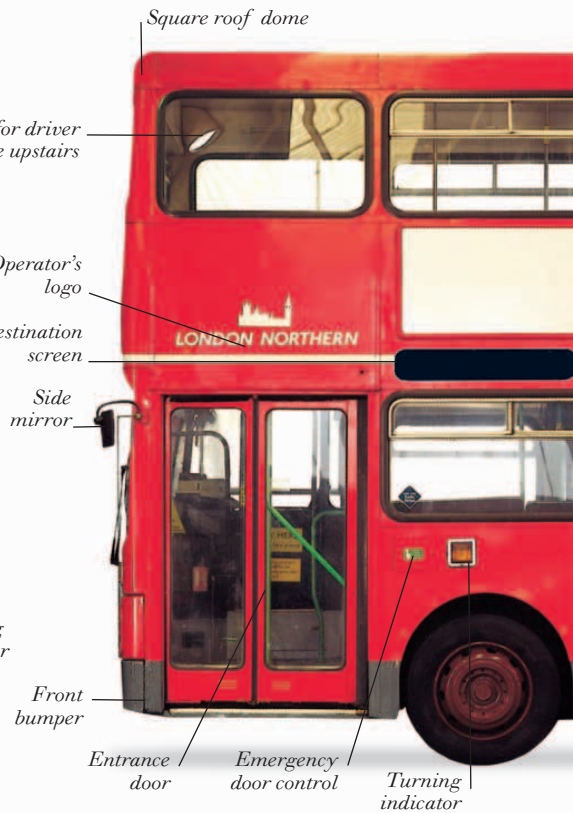
- Trolley boom
- Trolley head
- Drop window
- Quarter light
- Upper deck
- Trolley base
- Lower deck
- Underframe
- Platform
- Truck
- Lifeguard
- Controller
- Brake
- Stair

MCW METROBUS, LONDON, UK



FRONT VIEW

- Upper deck air intake
- Mirror for driver to see upstairs
- Route number
- Operator's logo
- Destination screen
- Side mirror
- Side mirror
- Permit holder
- Turning indicator
- Window vent
- Upper deck windshield
- Route information
- Destination screen
- Side mirror
- Asymmetric windshield
- Windshield wiper
- Sidelight
- Headlight
- Grill
- Fog light
- License plate
- Manufacturer's badge

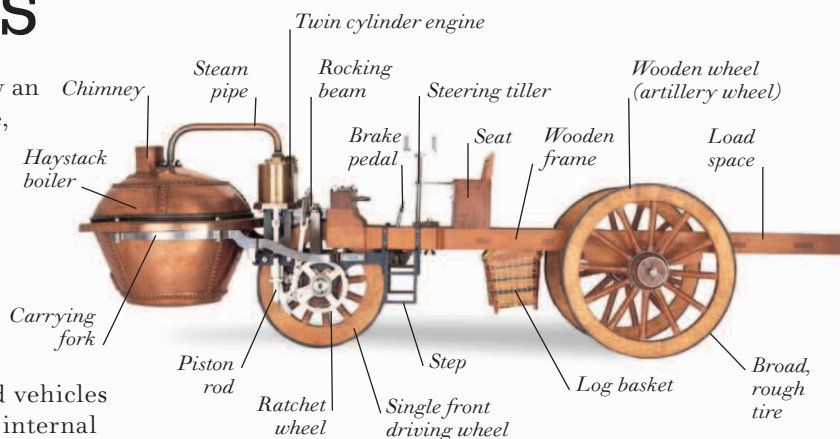


- Square roof dome
- Front bumper
- Entrance door
- Emergency door control
- Turning indicator

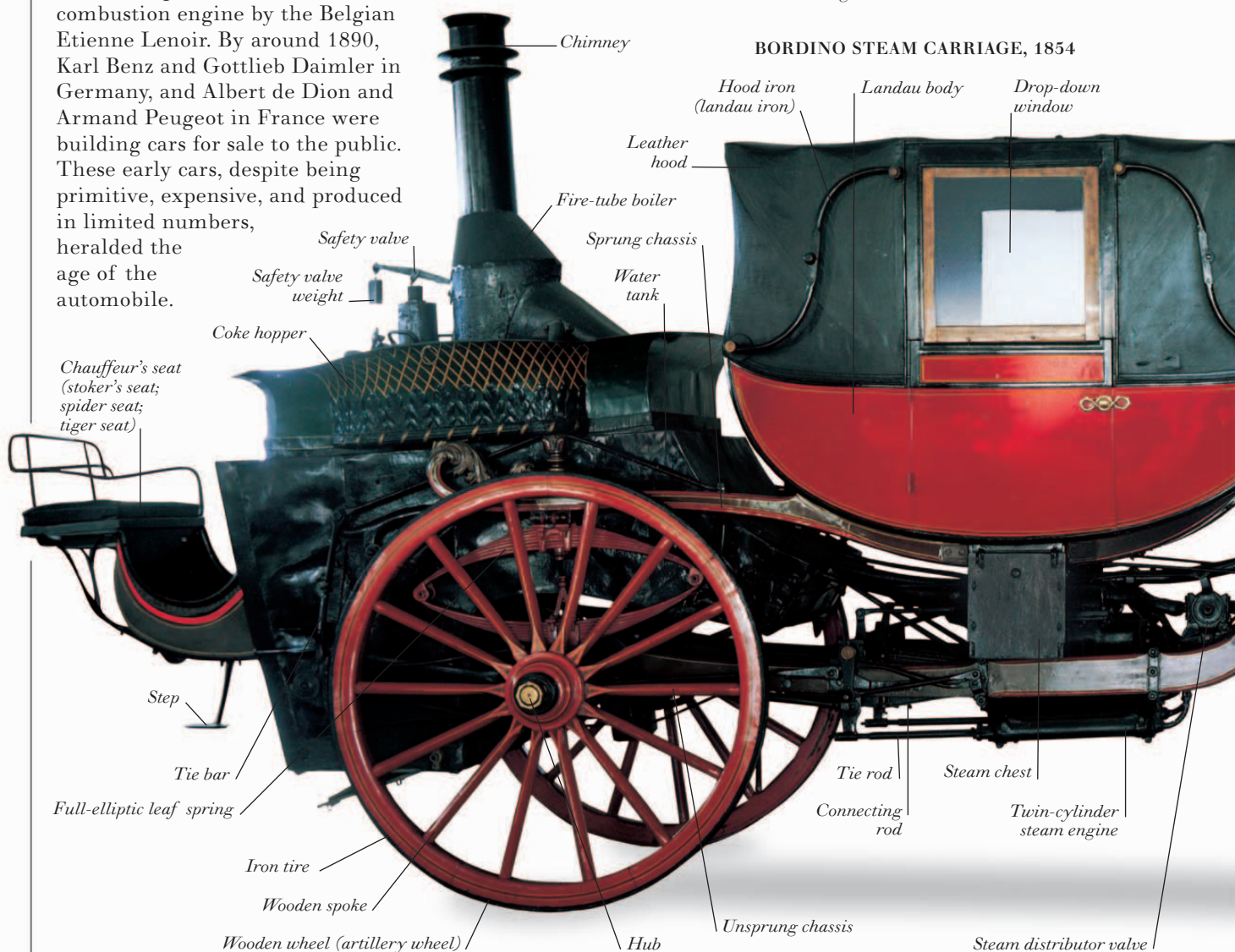
The first cars

THE EARLIEST ROAD VEHICLE powered by an engine, the Cugnot steam traction engine, was built in 1770. More practical steam carriages, such as the Bordino, were available in the early 19th century, but they were heavy and cumbersome. Restrictive laws and the introduction of railroads, faster and able to carry more passengers, saw the decline of “cars” powered by steam. It was not until 1860 that the first practical power unit for road vehicles was developed, with the invention of the internal combustion engine by the Belgian Etienne Lenoir. By around 1890, Karl Benz and Gottlieb Daimler in Germany, and Albert de Dion and Armand Peugeot in France were building cars for sale to the public. These early cars, despite being primitive, expensive, and produced in limited numbers, heralded the age of the automobile.

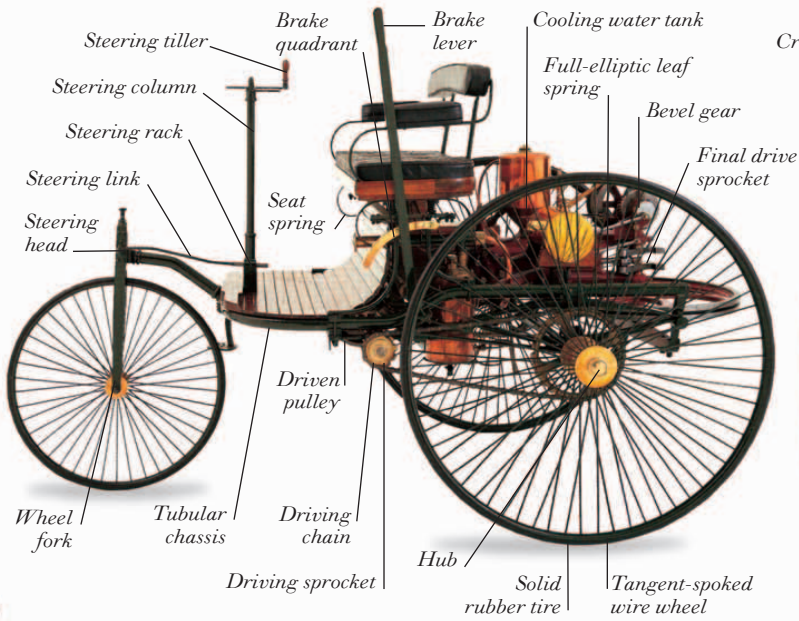
STEAM-POWERED CUGNOT FARDIER, 1770



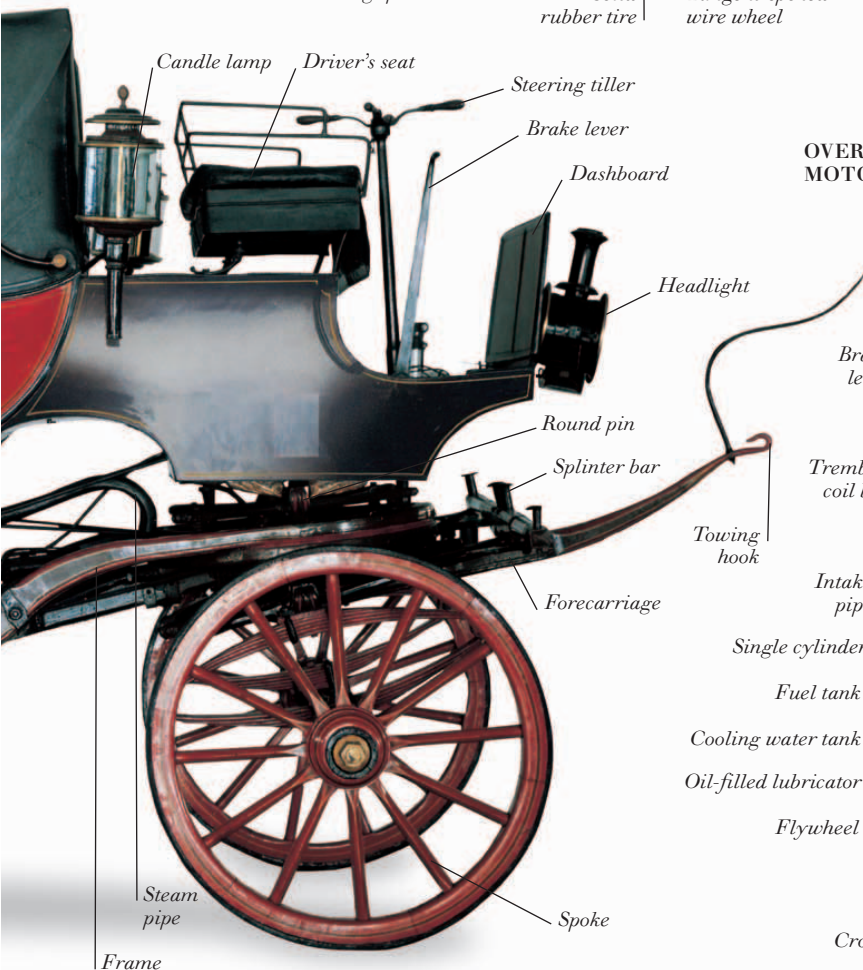
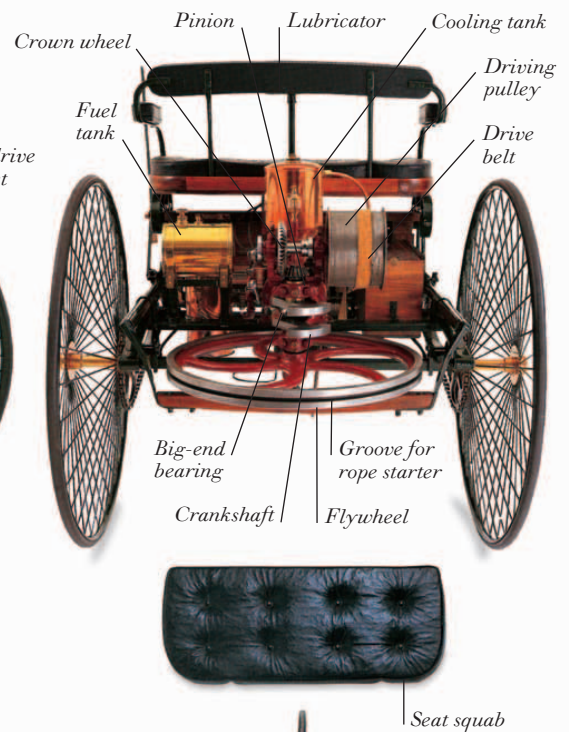
BORDINO STEAM CARRIAGE, 1854



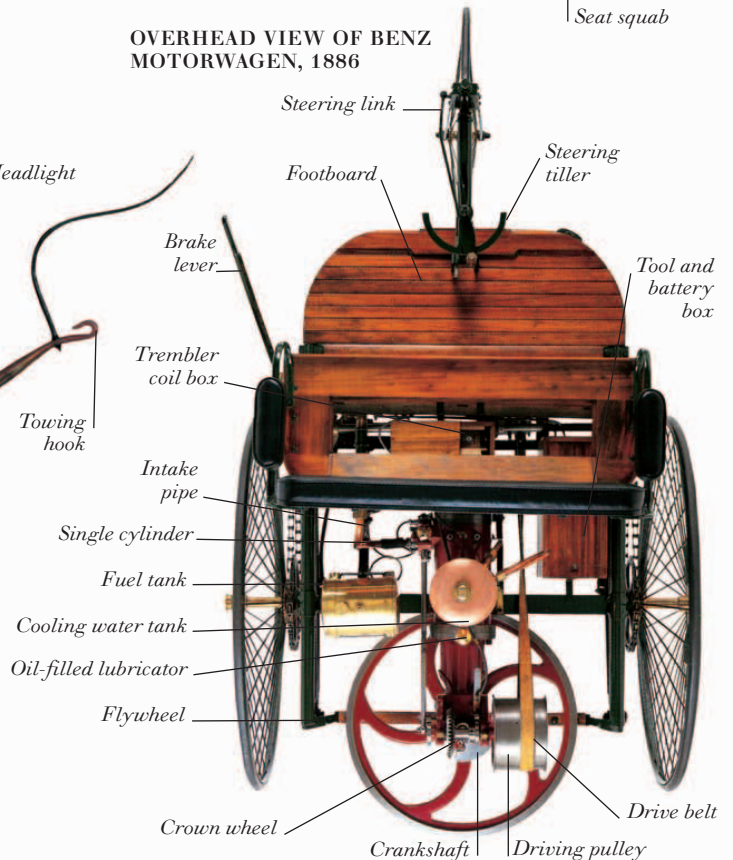
SIDE VIEW OF GAS-DRIVEN BENZ MOTORWAGEN, 1886



REAR VIEW OF BENZ MOTORWAGEN, 1886



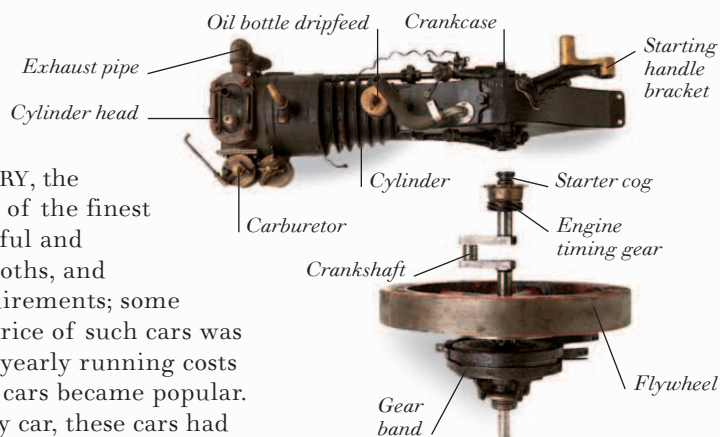
OVERHEAD VIEW OF BENZ MOTORWAGEN, 1886



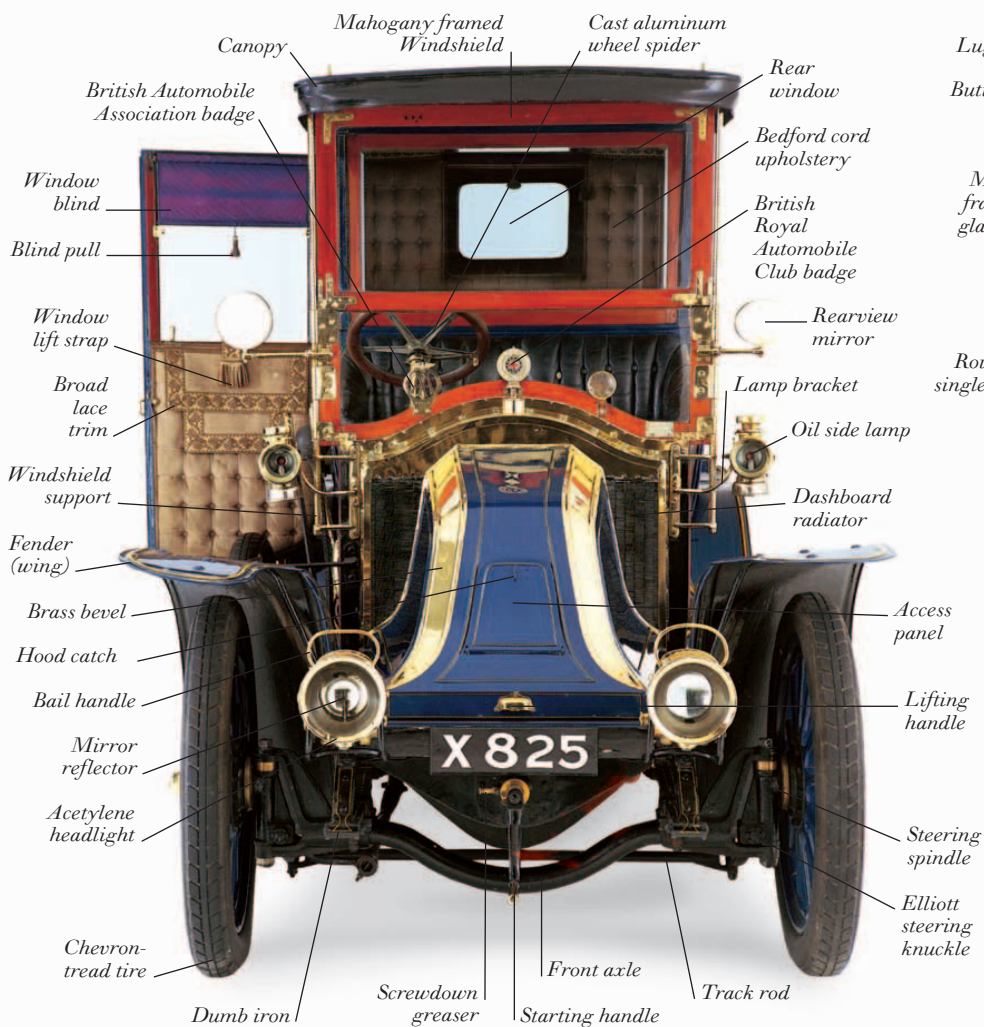
Elegance and utility

DURING THE FIRST DECADE OF THE 20TH CENTURY, the motorist who could afford it had a choice of some of the finest cars ever made. These handbuilt cars were powerful and luxurious, using the finest woods, leathers, and cloths, and bodywork made to the customer's individual requirements; some had six-cylinder engines as big as 15 liters. The price of such cars was several times that of an average house, and their yearly running costs were also very high. As a result, basic, utilitarian cars became popular. Costing perhaps one-tenth of the price of a luxury car, these cars had very little trim and often had only single-cylinder engines.

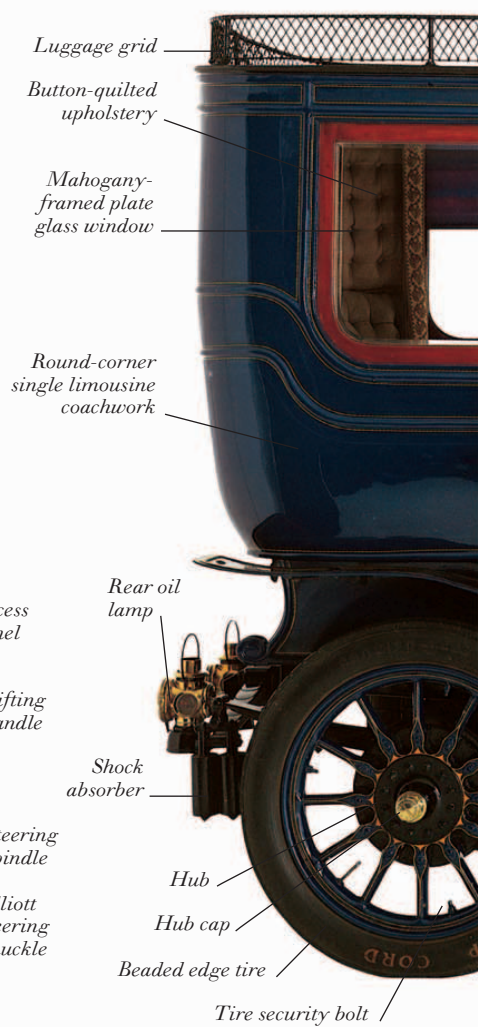
1904 OLDSMOBILE SINGLE-CYLINDER ENGINE



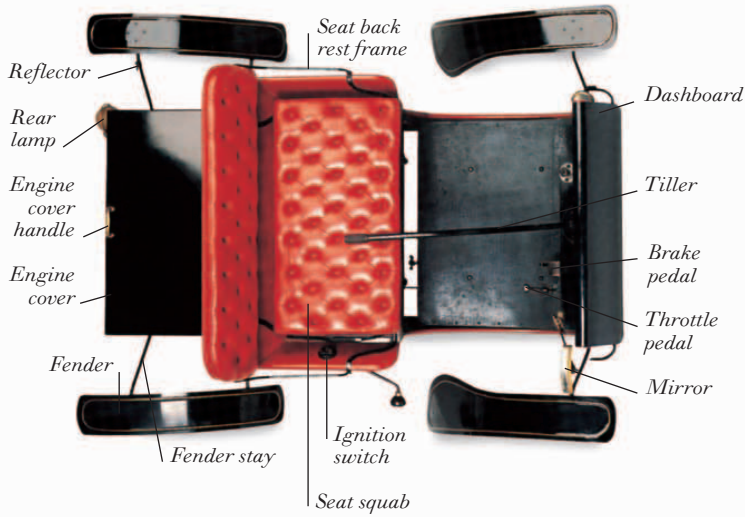
FRONT VIEW OF 1906 RENAULT



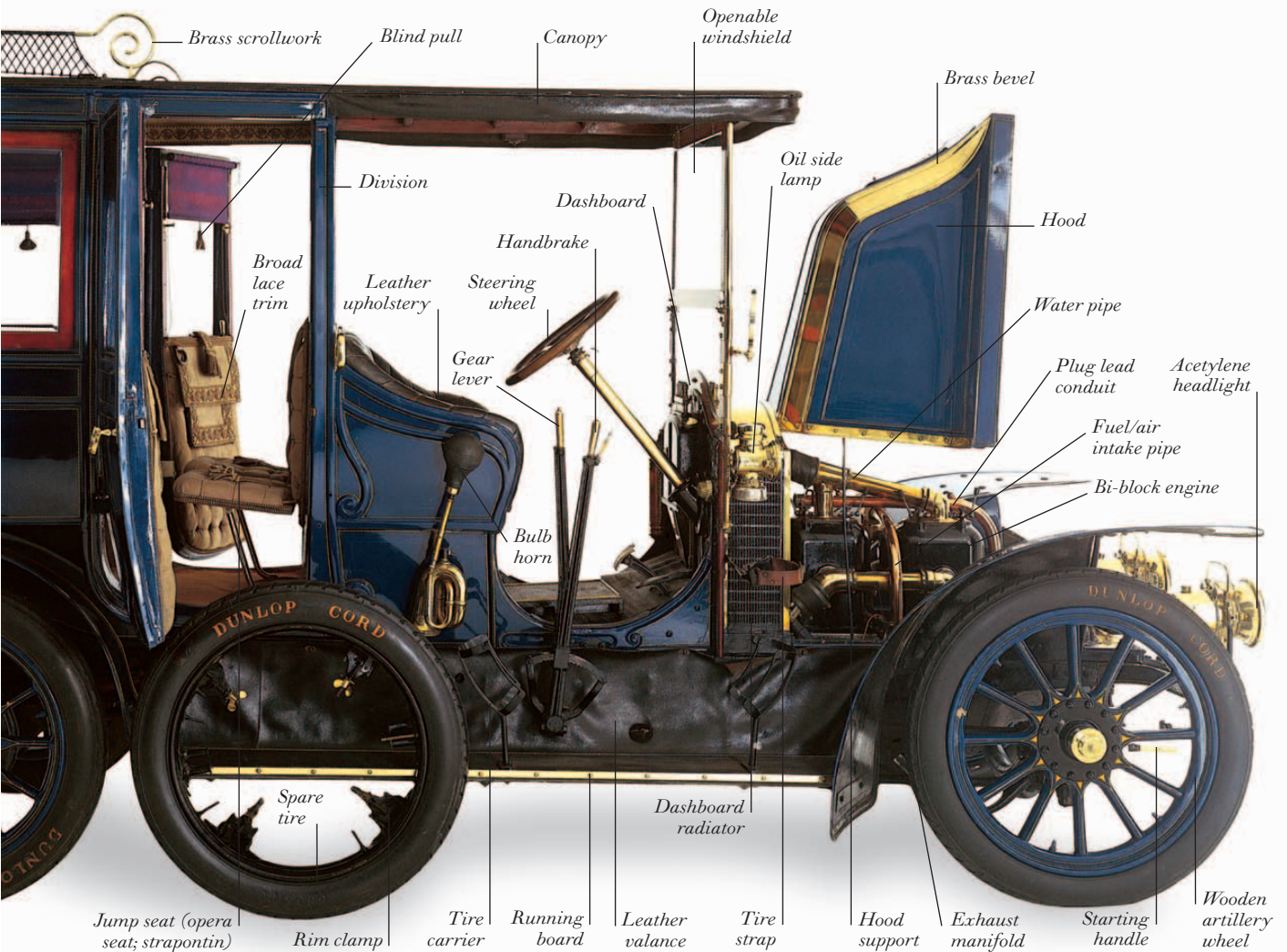
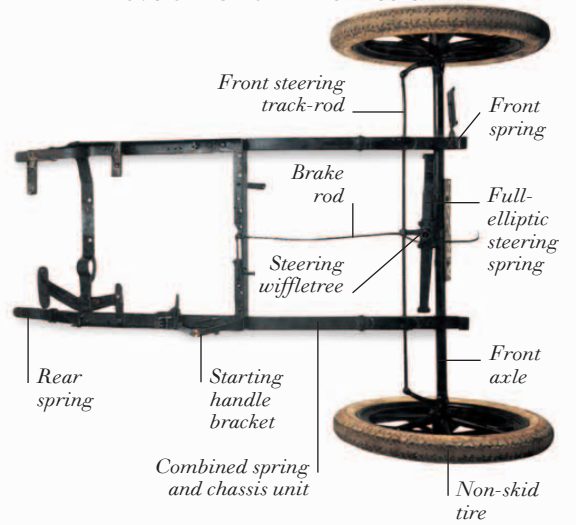
SIDE VIEW OF 1906 RENAULT



1904 OLDSMOBILE TRIM AND BODYWORK



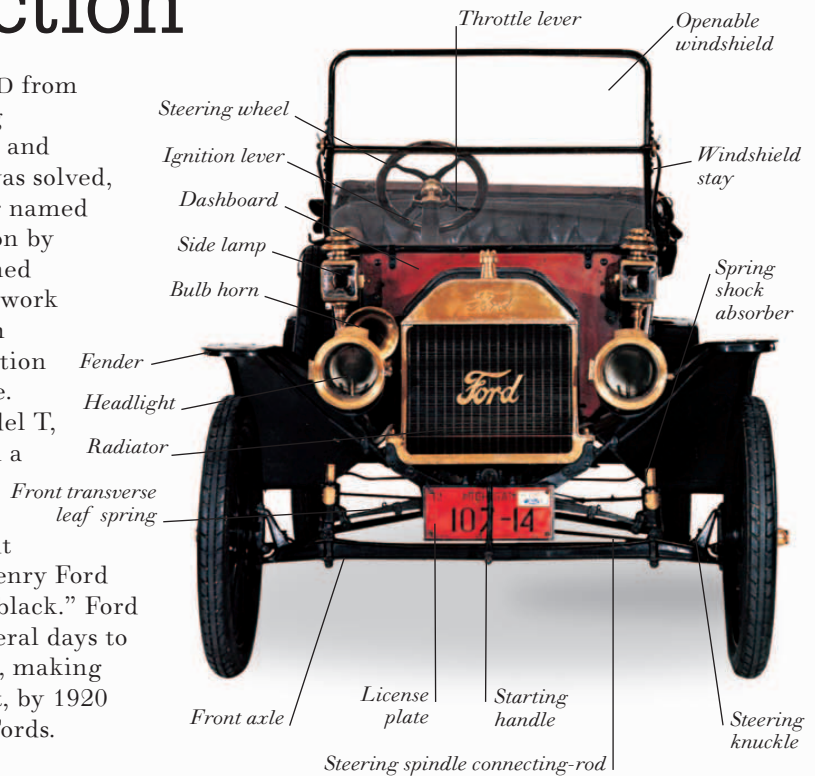
1904 OLDSMOBILE CHASSIS



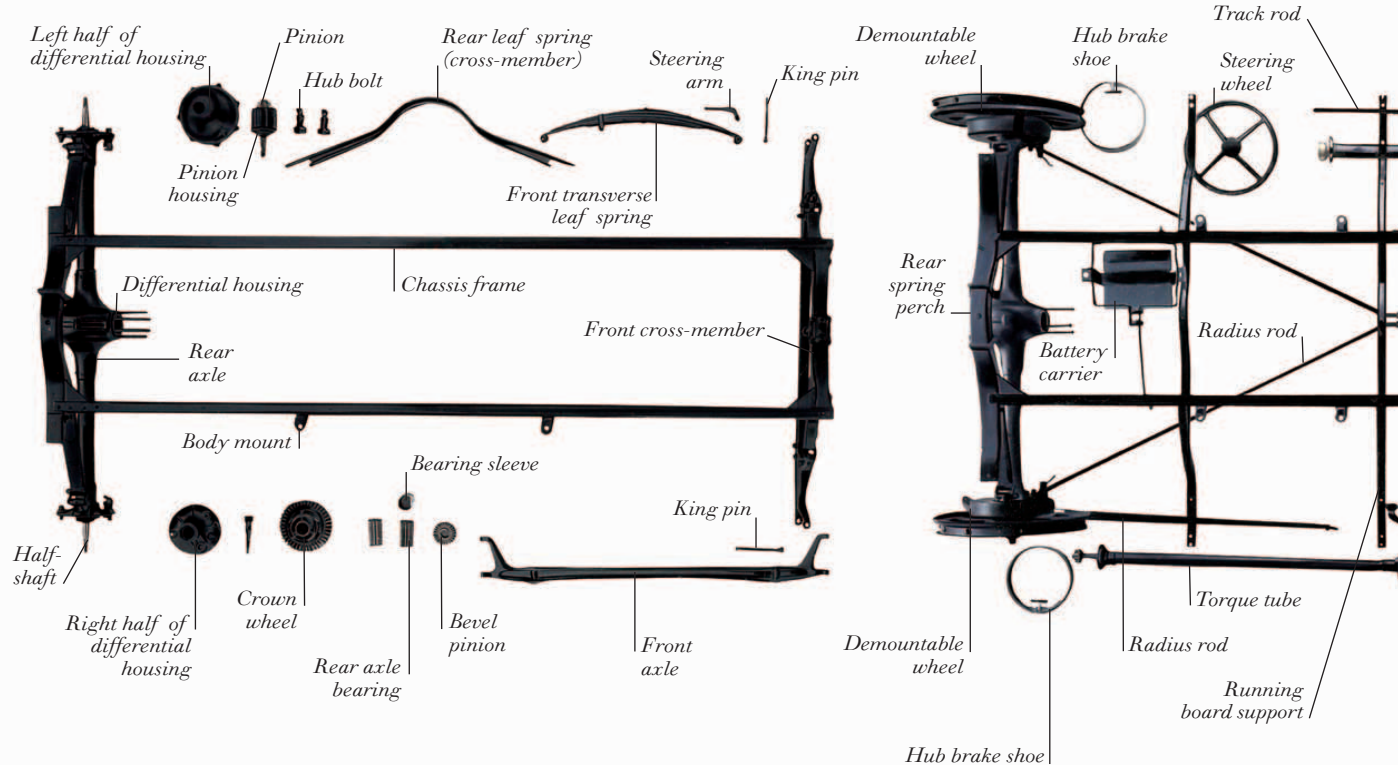
Mass-production

THE FIRST CARS WERE HAND-ASSEMBLED from individually built parts, a time-consuming procedure that required skilled mechanics and made cars very expensive. This problem was solved, in America, by a Detroit car manufacturer named Henry Ford; he introduced mass-production by using standardized parts, and later combined these with a moving production line. The work was brought to the workers, each of whom performed one simple task in the construction process as the chassis moved along the line. The first mass-produced car, the Ford Model T, was launched in 1908 and was available in a limited range of body styles and colors. However, when the production line was introduced in 1914, the color range was cut back; the Model T became available, as Henry Ford said, in "any color you like, so long as it's black." Ford cut the production time for a car from several days to about 12 hours, and eventually to minutes, making cars much cheaper than before. As a result, by 1920 half the cars in the world were Model T Fords.

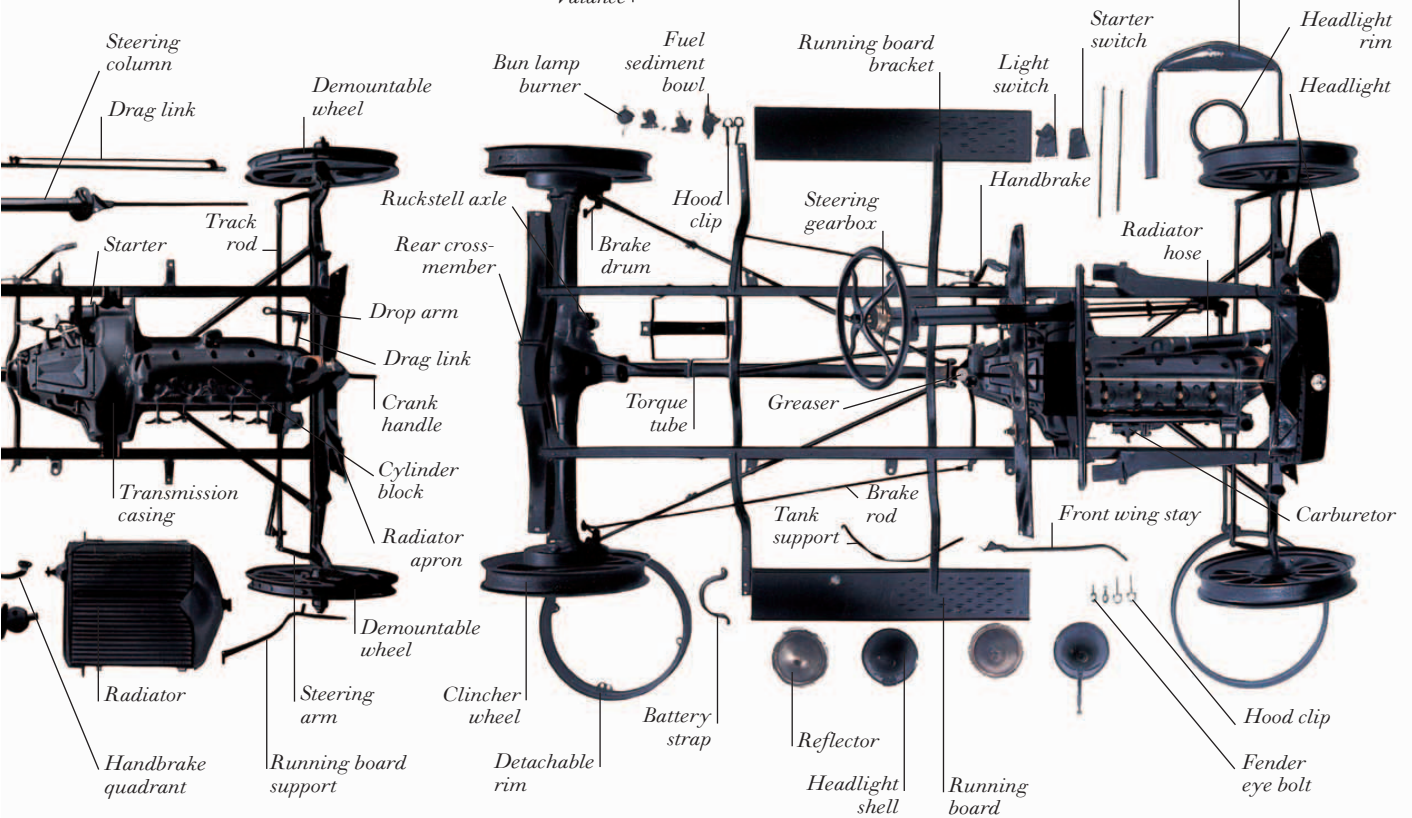
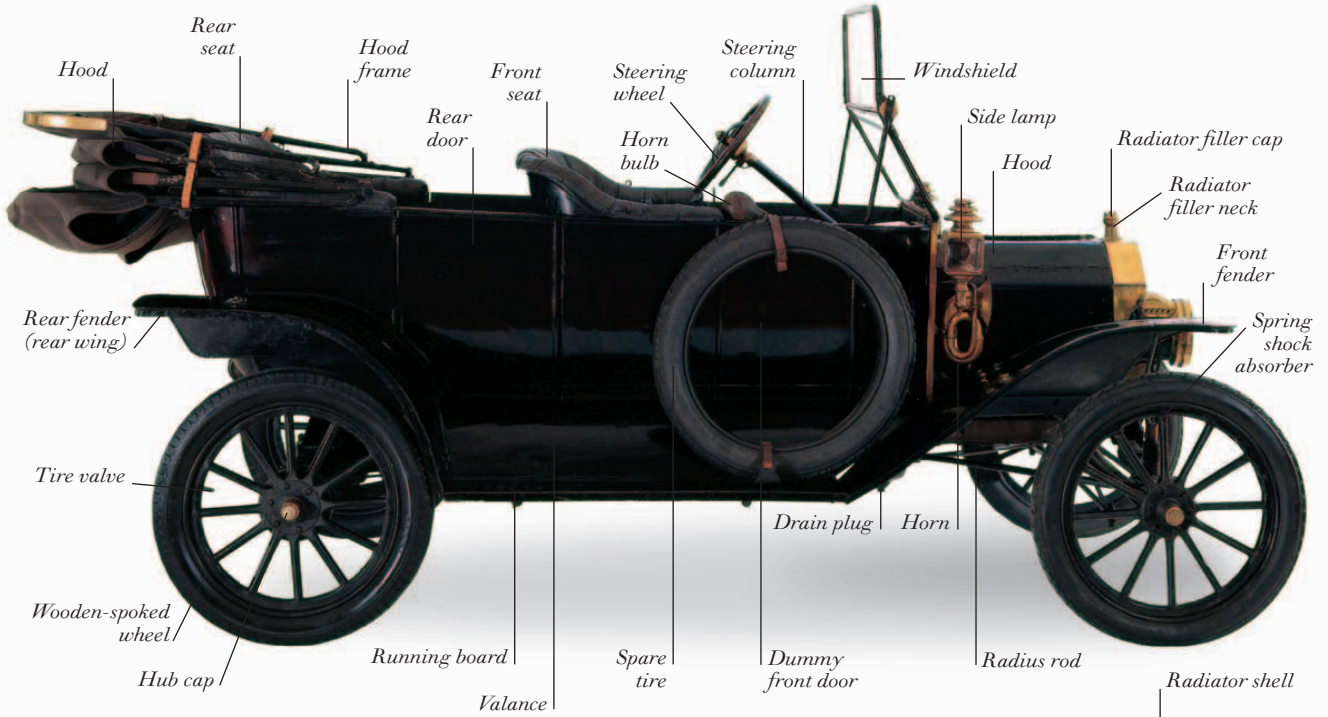
FRONT VIEW OF 1913 FORD MODEL T



STAGES OF FORD MODEL T PRODUCTION



SIDE VIEW OF 1913 FORD MODEL T

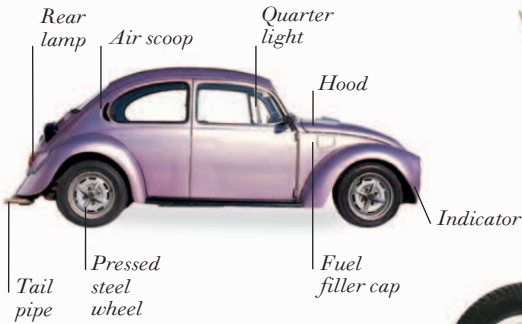


The "people's car"

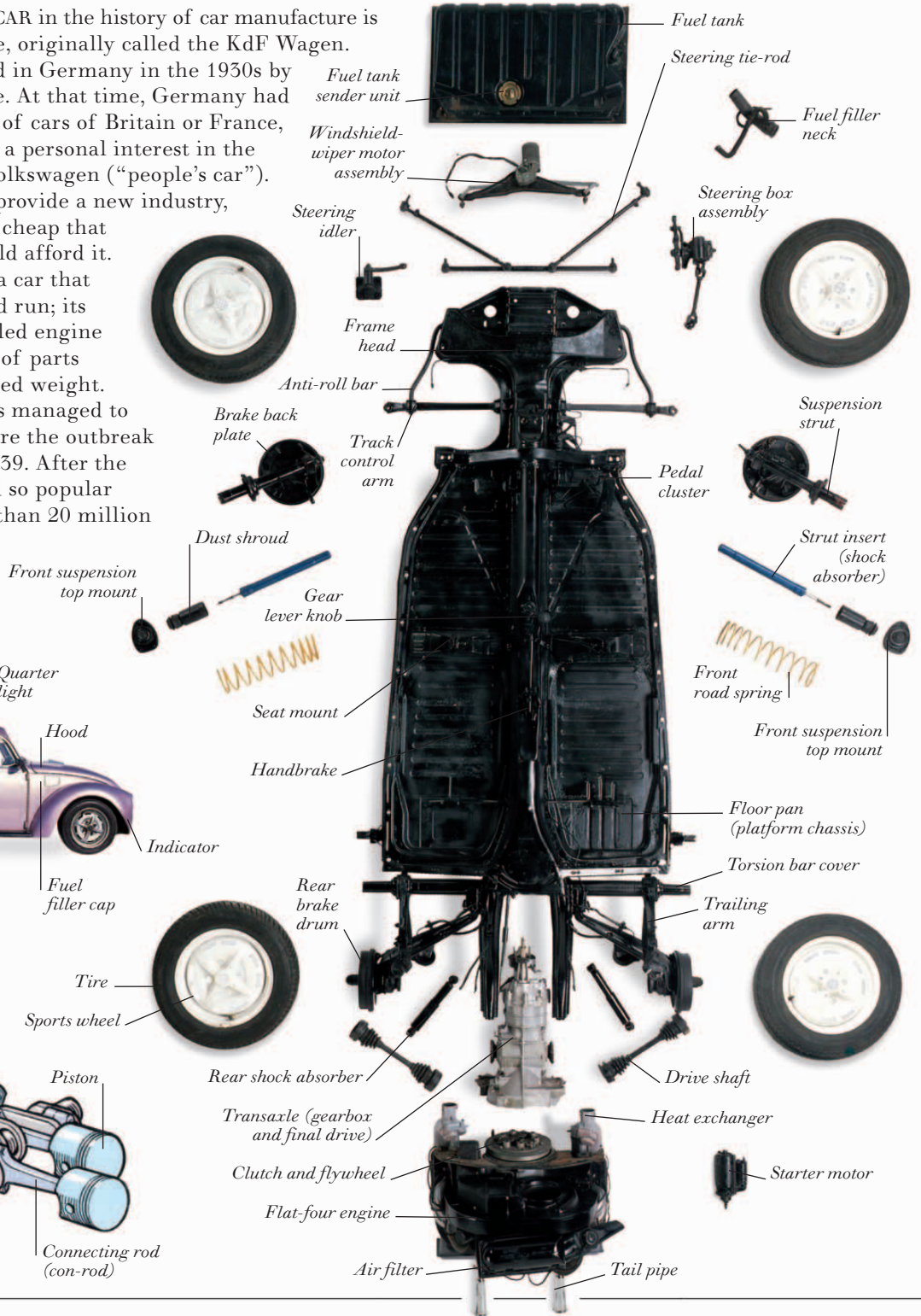
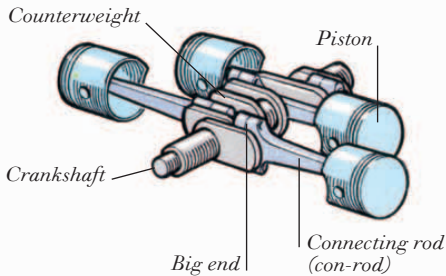
THE MOST POPULAR CAR in the history of car manufacture is the Volkswagen Beetle, originally called the KdF Wagen. The car was developed in Germany in the 1930s by Dr. Ferdinand Porsche. At that time, Germany had only half the number of cars of Britain or France, and Adolf Hitler took a personal interest in the development of the Volkswagen ("people's car"). The intention was to provide a new industry, new jobs, and a car so cheap that anyone with a job could afford it. Dr. Porsche designed a car that was cheap to build and run; its rear-mounted, air-cooled engine cut down the number of parts needed and also reduced weight. However, few civilians managed to obtain the Beetle before the outbreak of World War II in 1939. After the war, the Beetle proved so popular that eventually more than 20 million were sold.

WORKING PARTS OF VOLKSWAGEN BEETLE

CUSTOMIZED VOLKSWAGEN BEETLE



FLAT-FOUR CYLINDER ARRANGEMENT



Early engines

STEAM AND ELECTRICITY were used to power cars until early this century, but neither power source was ideal. Electric cars had to stop frequently to recharge their heavy batteries, and steam cars gave smooth power delivery but were too complicated for the average driver to use. A rival power source, the internal combustion engine, was invented in 1860 by Etienne Lenoir (see pp. 334-335). This engine converted the force of a controlled explosion into rotary motion, to turn the wheels of a vehicle. Early variations on this basic model included sleeve valves, separately cast cylinders, and the two-stroke combustion cycle. Today, many internal combustion engines, including the Wankel rotary and diesels (see pp. 346-347), use the four-stroke cycle, first demonstrated by Nikolaus Otto in 1876. The Otto cycle, often described as “suck, squeeze, bang, blow,” has proved the best method of ensuring that the engine turns over smoothly and that exhaust emissions are controllable.

BERSEY ELECTRIC CAB, 1896

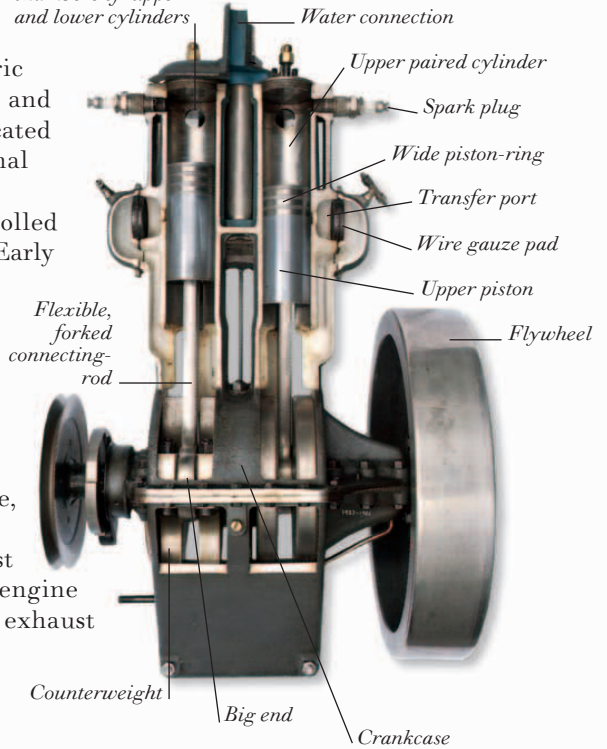


Mounting for tray of 40 batteries

Housing for electric motors

TROJAN TWO-STROKE ENGINE, 1927

Port linking combustion chambers of upper and lower cylinders



Water connection

Upper paired cylinder

Spark plug

Wide piston-ring

Transfer port

Wire gauze pad

Upper piston

Flywheel

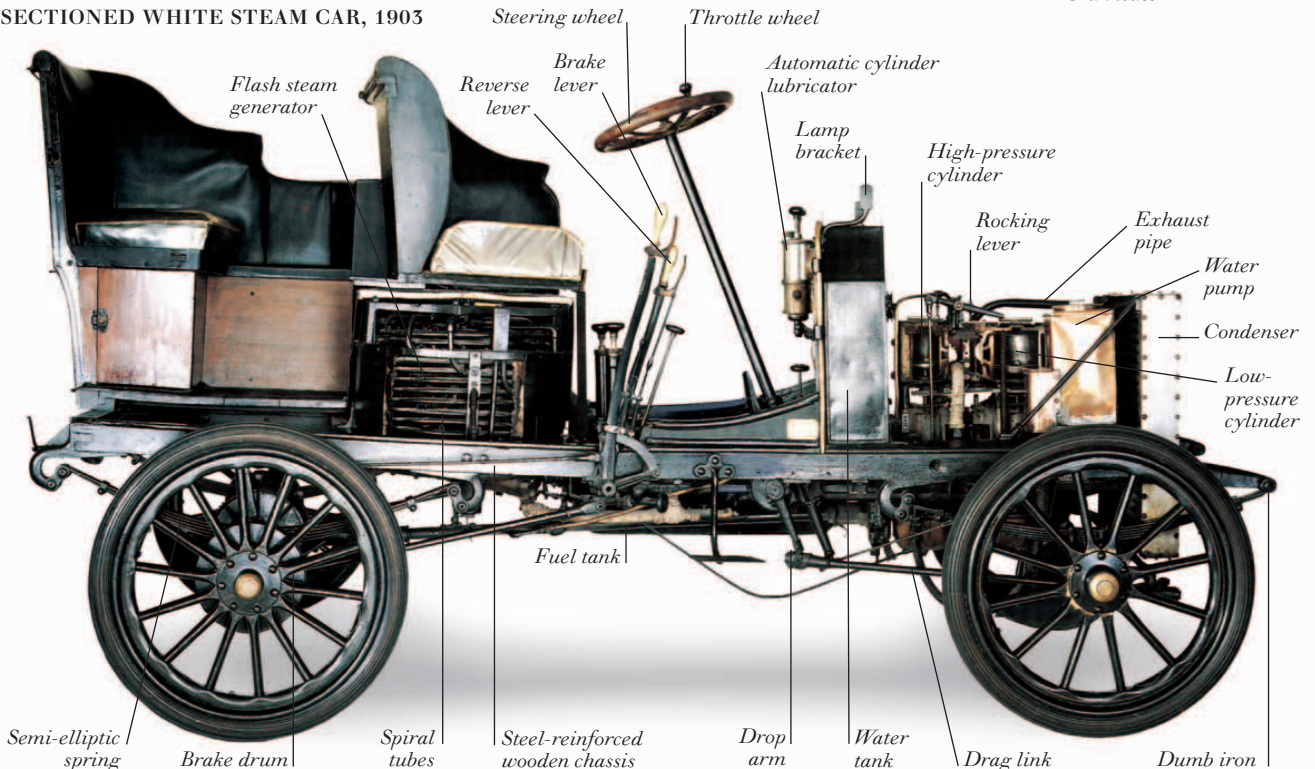
Flexible, forked connecting-rod

Counterweight

Big end

Crankcase

SECTIONED WHITE STEAM CAR, 1903



Steering wheel

Throttle wheel

Flash steam generator

Reverse lever

Brake lever

Automatic cylinder lubricator

Lamp bracket

High-pressure cylinder

Rocking lever

Exhaust pipe

Water pump

Condenser

Low-pressure cylinder

Fuel tank

Semi-elliptic spring

Brake drum

Spiral tubes

Steel-reinforced wooden chassis

Drop arm

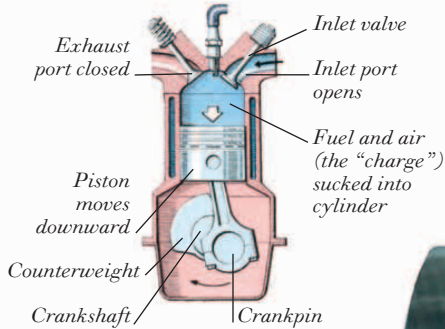
Water tank

Drag link

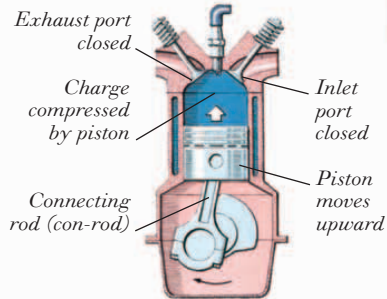
Dumb iron

CYCLE OF A FOUR-STROKE INTERNAL COMBUSTION ENGINE

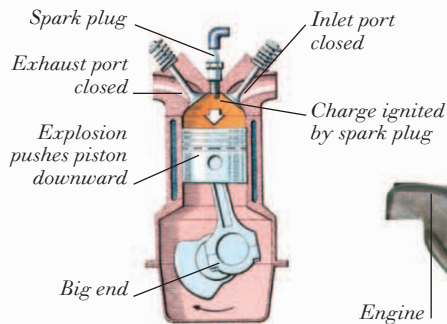
INDUCTION STROKE ("SUCK")



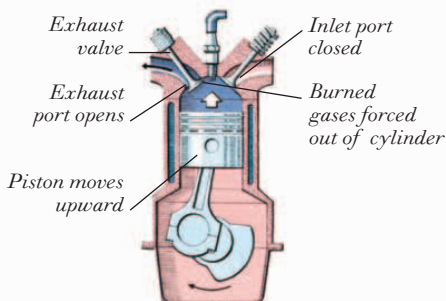
COMPRESSION STROKE ("SQUEEZE")



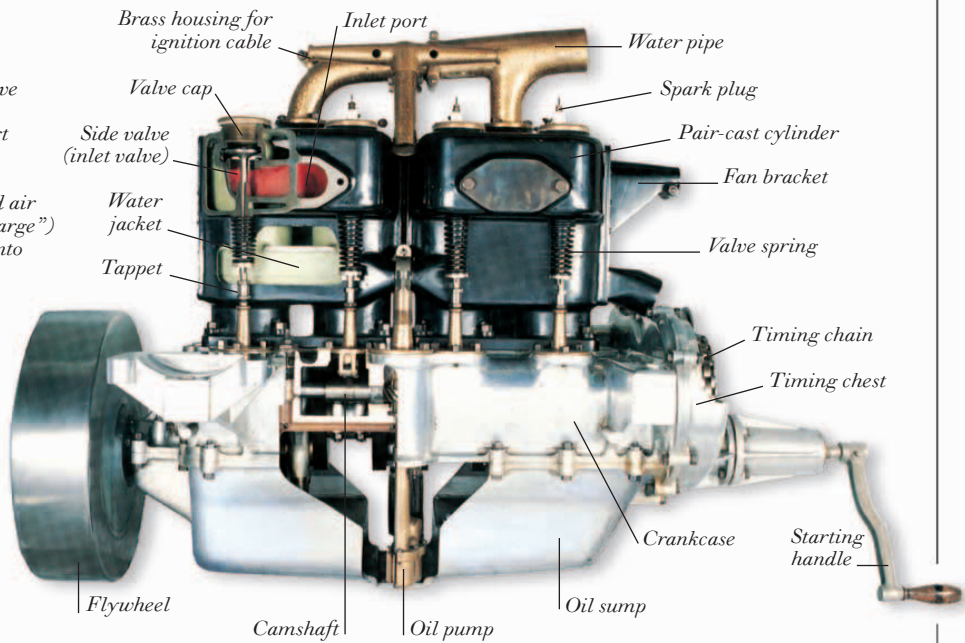
POWER STROKE ("BANG")



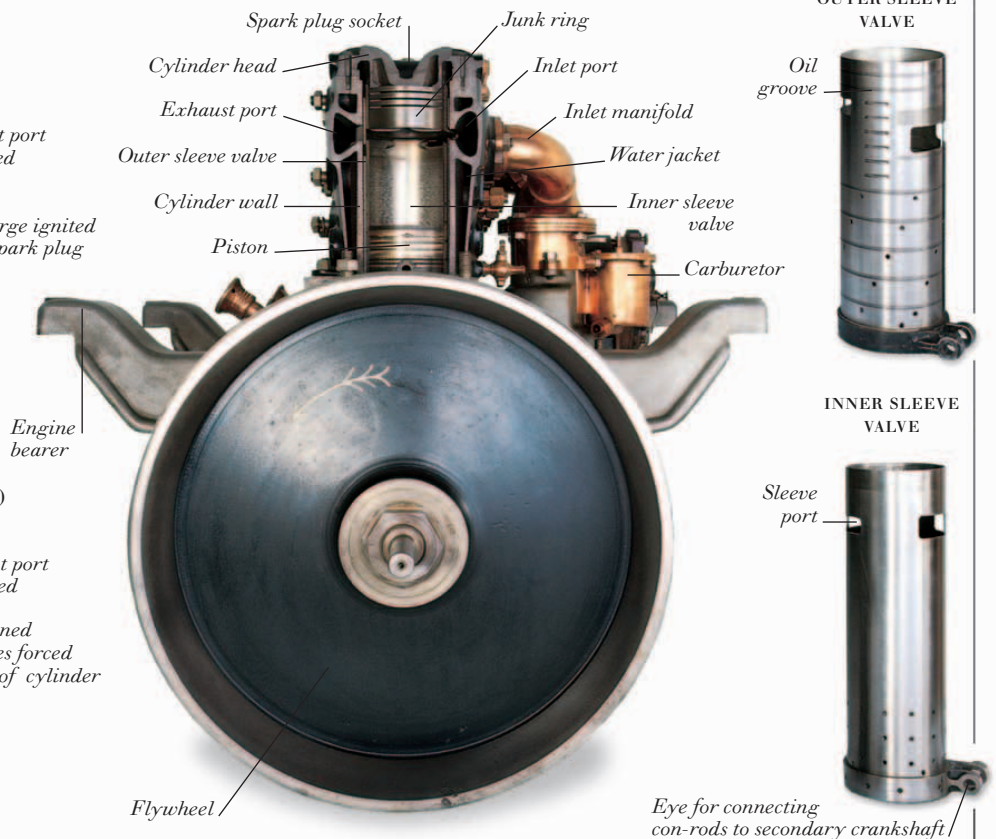
EXHAUST STROKE ("BLOW")



16-HORSEPOWER HUMBER ENGINE, 1911



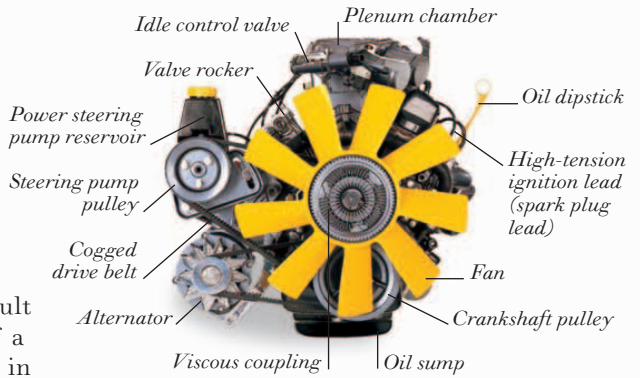
DAIMLER DOUBLE-SLEEVE VALVE ENGINE, 1910



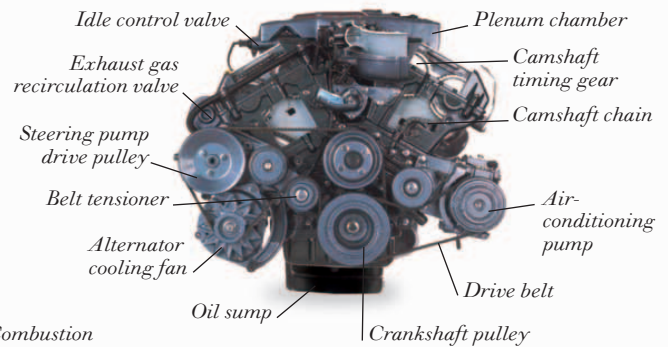
Modern engines

TODAY'S GASOLINE ENGINE WORKS on the same basic principles as the first car engines of a century ago, although it has been greatly refined. Modern engines, often made from special metal alloys, are much lighter than earlier engines. Computerized ignition systems, fuel injectors, and multivalve cylinder heads achieve a more efficient combustion of the fuel/air mixture (the charge) so that less fuel is wasted. As a result of this greater efficiency, the power and performance of a modern engine are increased, and the level of pollution in the exhaust gases is reduced. Exhaust pollution levels today are also lowered by the increasing use of special filters called catalytic converters, which absorb many exhaust pollutants. The need to produce ever more efficient engines means that it can take up to seven years to develop a new engine for a family car, at a cost of many millions of dollars.

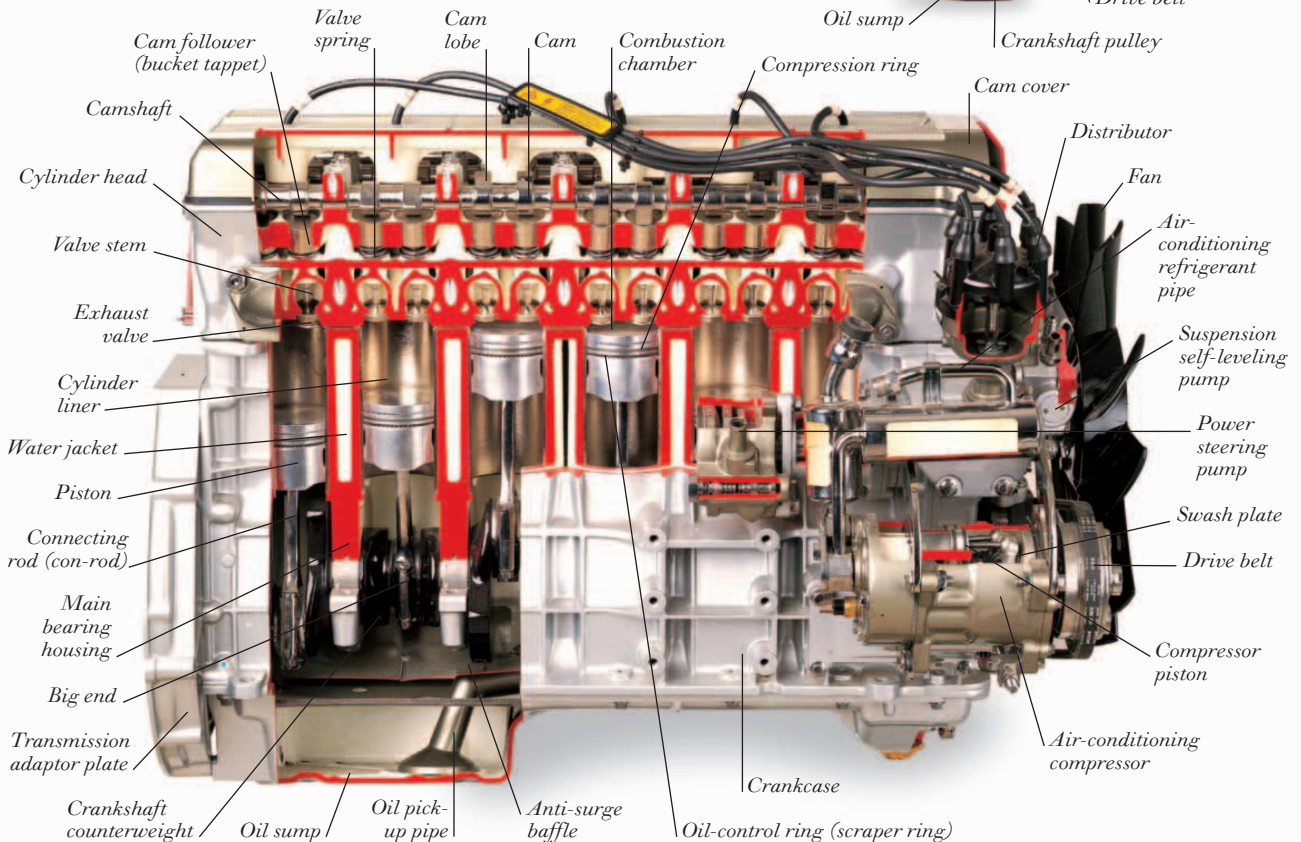
FRONT VIEW OF A FORD COSWORTH V6 12-VALVE



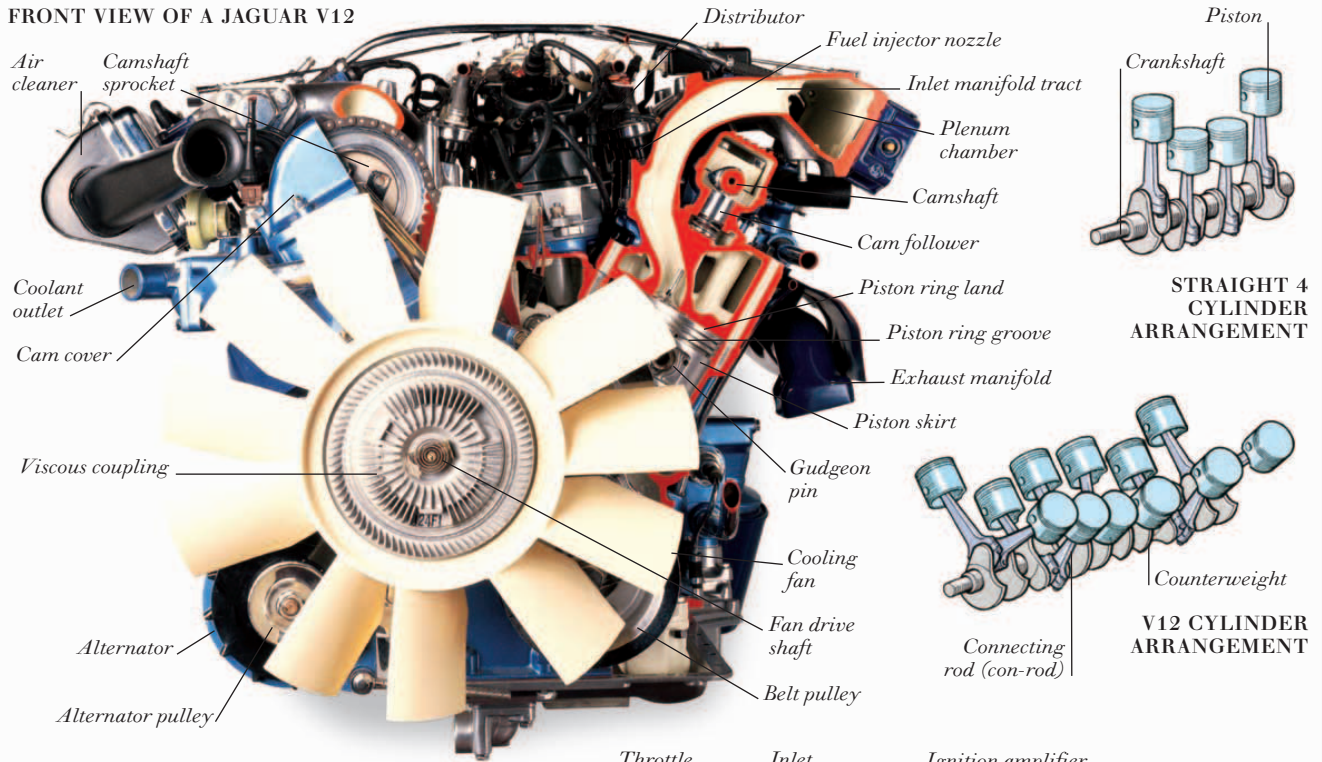
FRONT VIEW OF A FORD COSWORTH V6 24-VALVE



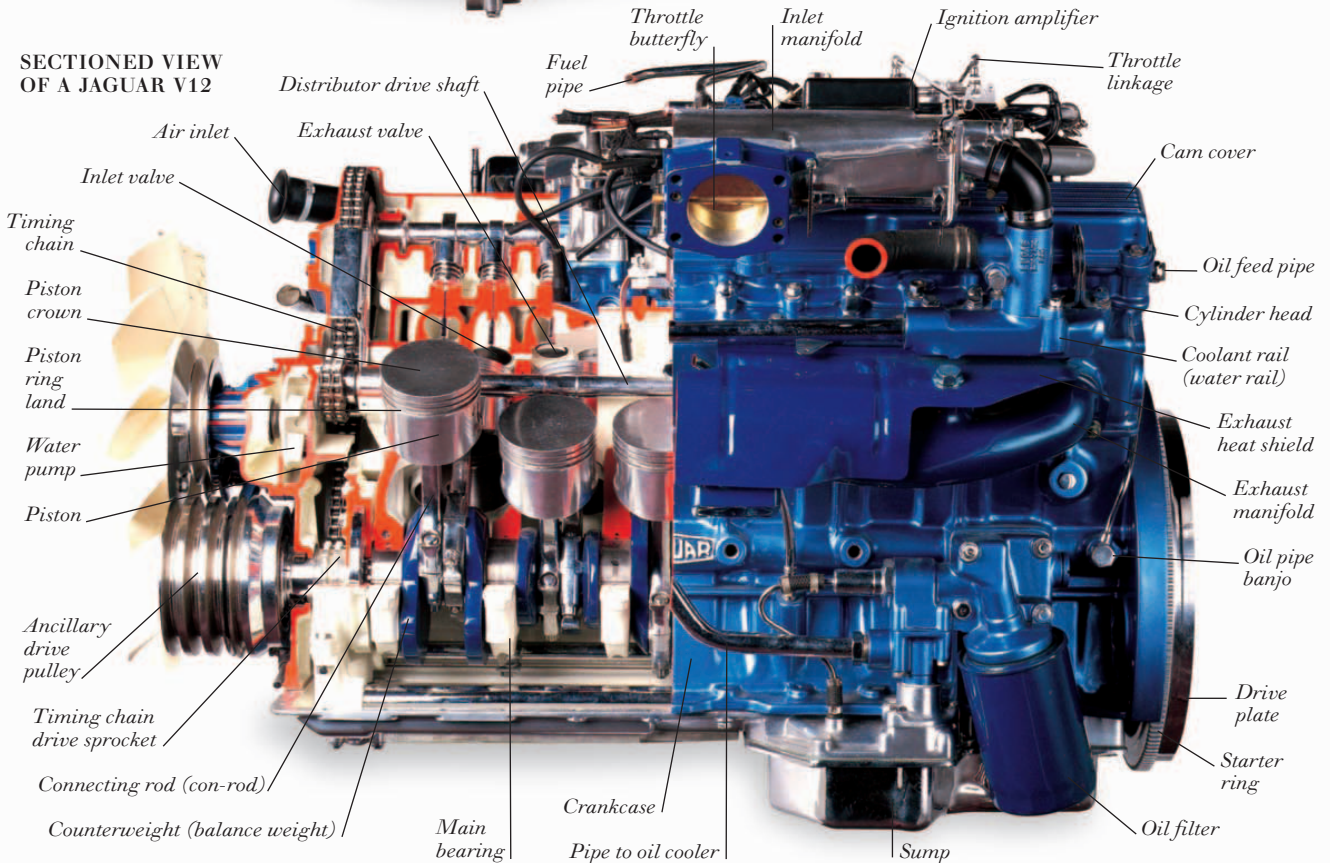
SECTIONED VIEW OF A JAGUAR STRAIGHT 6



FRONT VIEW OF A JAGUAR V12



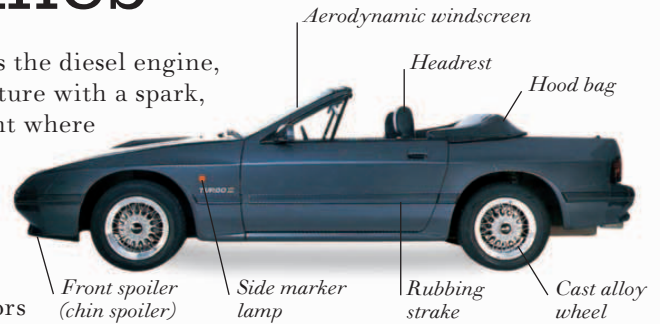
SECTIONED VIEW OF A JAGUAR V12



Alternative engines

THE MOST COMMON TYPE OF ALTERNATIVE ENGINE is the diesel engine, which, instead of igniting the compressed fuel/air mixture with a spark, uses compression alone, heating the mixture to the point where it explodes. A diesel engine's fuel consumption is low in comparison with similarly sized piston engines, despite its heavier, reinforced moving parts and cylinder block. Another type of engine is the rotary-combustion, first successfully developed by Felix Wankel in the 1950s. Its two trilobate (three-sided) rotors revolve in housings shaped in a fat figure-eight. The four sequences of the four-stroke cycle, which occur consecutively in a piston engine, occur simultaneously in a rotary engine, producing power in a continuous stream.

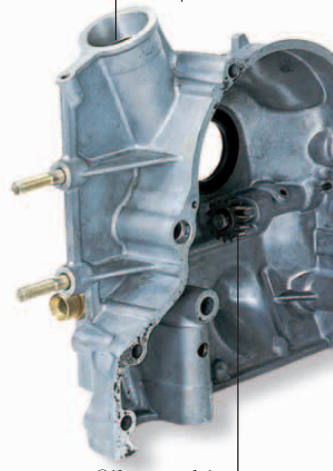
ROTARY-ENGINE MAZDA RX-7



WANKEL ROTARY ENGINE

OIL-PUMP HOUSING

Distributor fixing point (drive point)



Oil-pump drive

FRONT SIDE HOUSING



Coolant passage

FRONT ROTOR CHAMBER



Leading spark-plug hole

INTERMEDIATE HOUSING



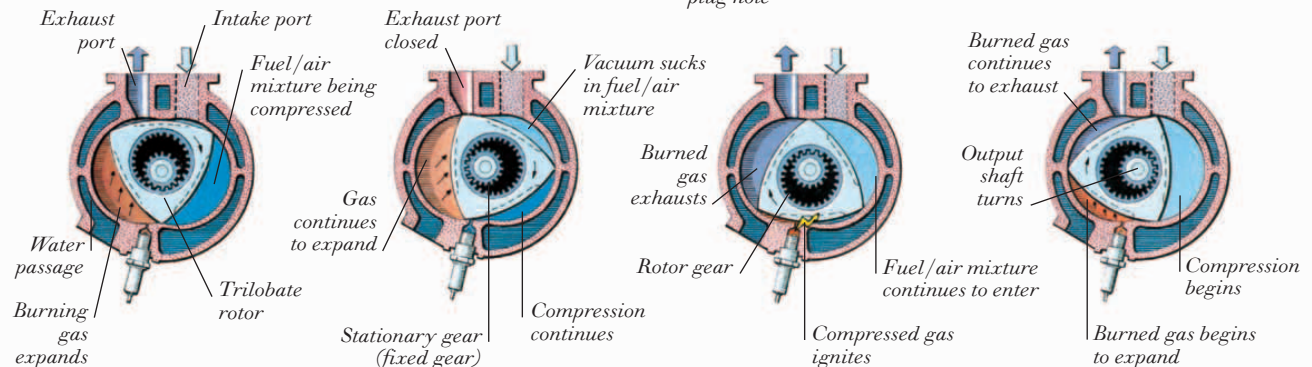
Water drain bolt

REAR ROTOR CHAMBER

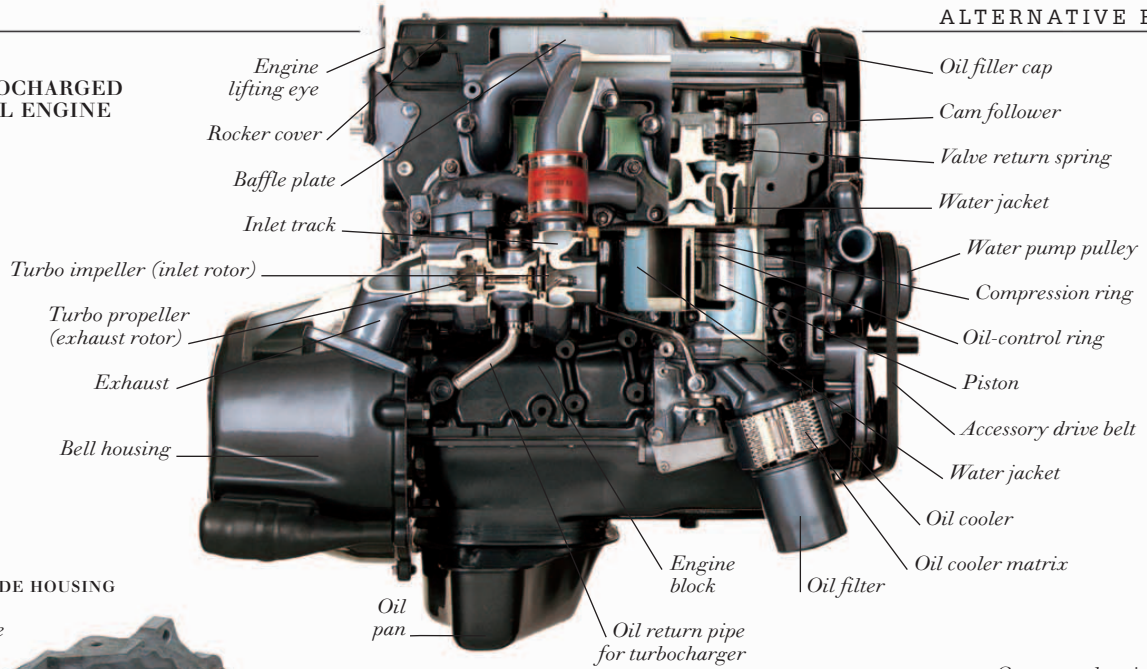


Trailing spark-plug hole

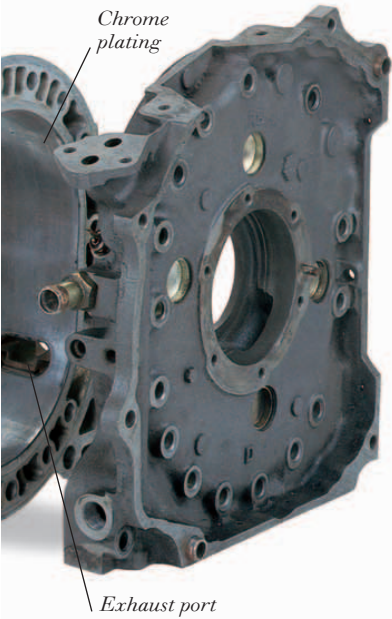
THE WANKEL ROTARY CYCLE



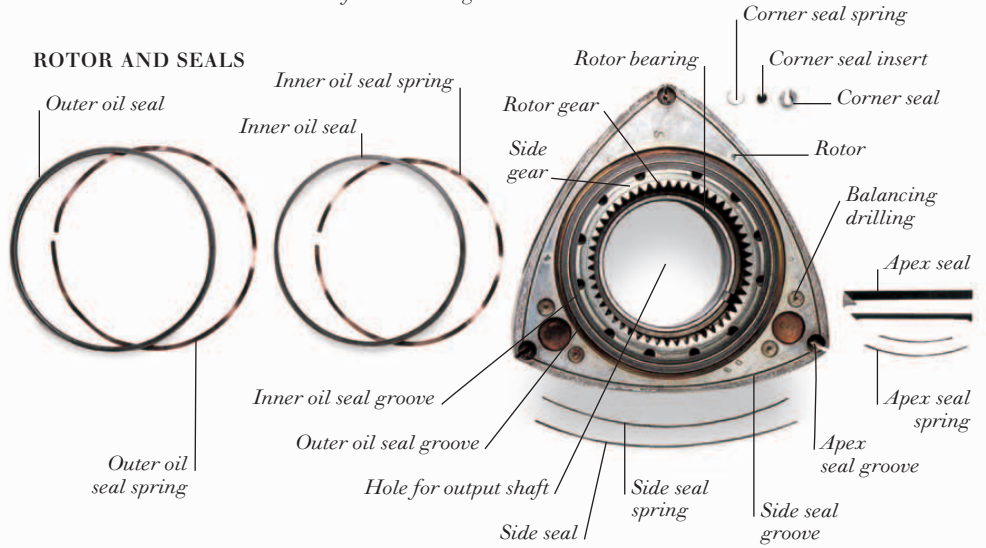
**FORD
TURBOCHARGED
DIESEL ENGINE**



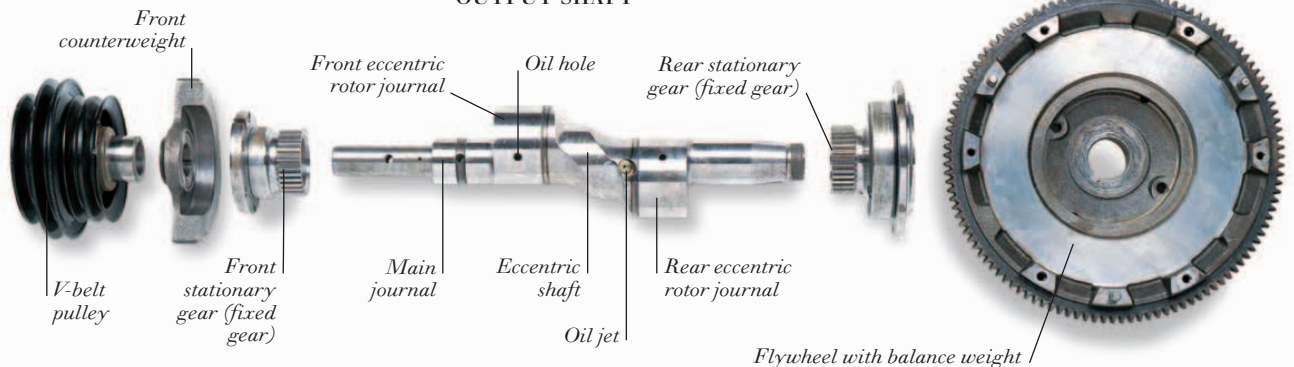
REAR SIDE HOUSING



ROTOR AND SEALS



OUTPUT SHAFT



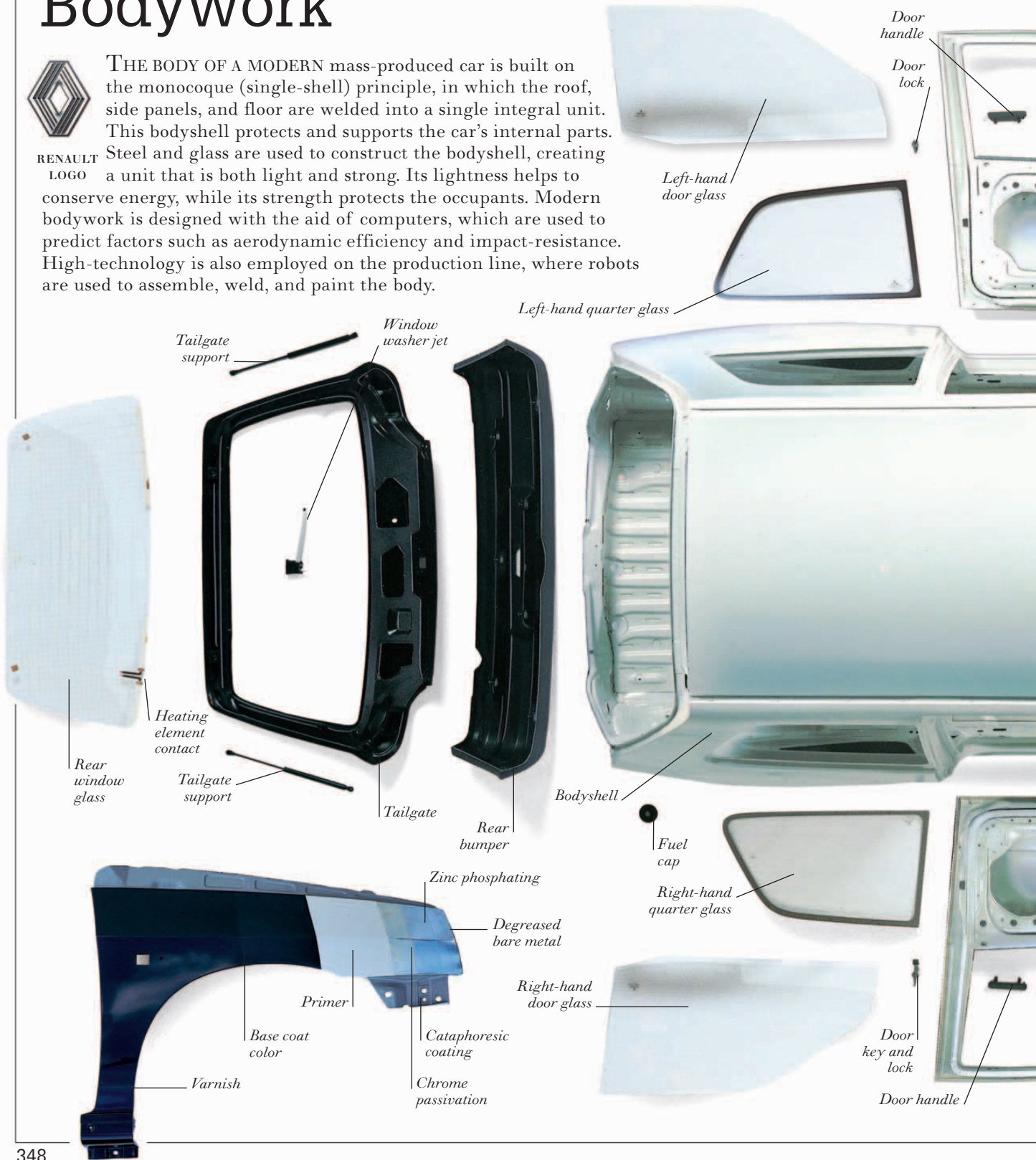
Bodywork

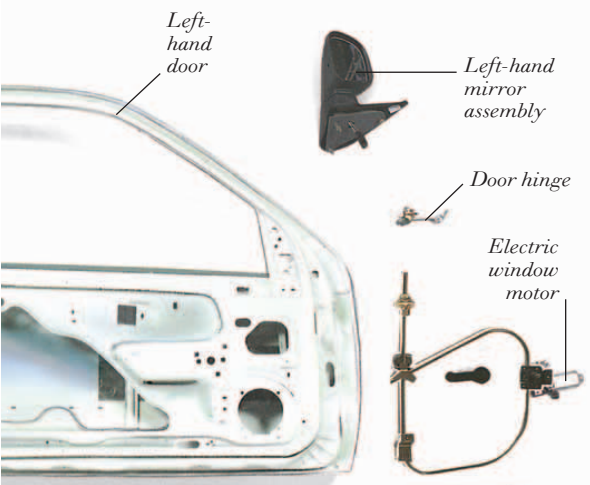


RENAULT
LOGO

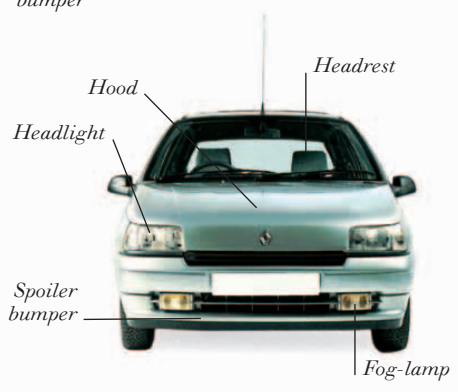
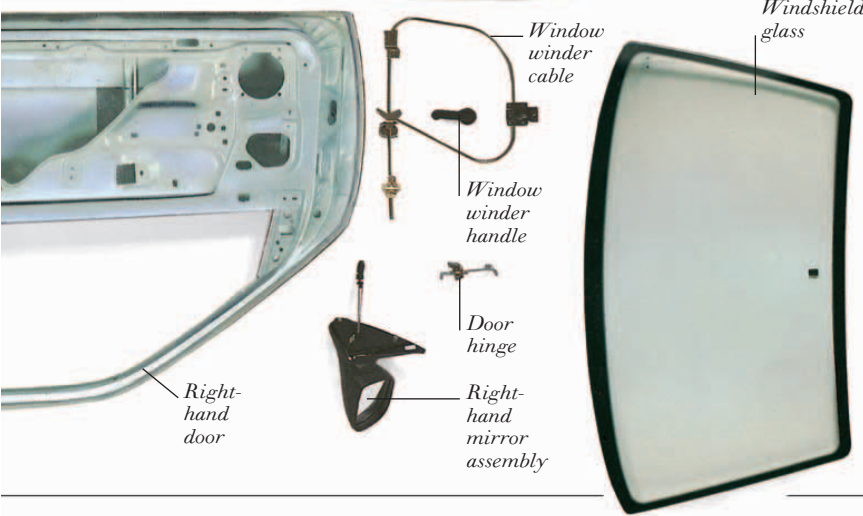
THE BODY OF A MODERN mass-produced car is built on the monocoque (single-shell) principle, in which the roof, side panels, and floor are welded into a single integral unit. This bodyshell protects and supports the car's internal parts. Steel and glass are used to construct the bodyshell, creating a unit that is both light and strong. Its lightness helps to conserve energy, while its strength protects the occupants. Modern bodywork is designed with the aid of computers, which are used to predict factors such as aerodynamic efficiency and impact-resistance. High-technology is also employed on the production line, where robots are used to assemble, weld, and paint the body.

BODYWORK OF A RENAULT CLIO





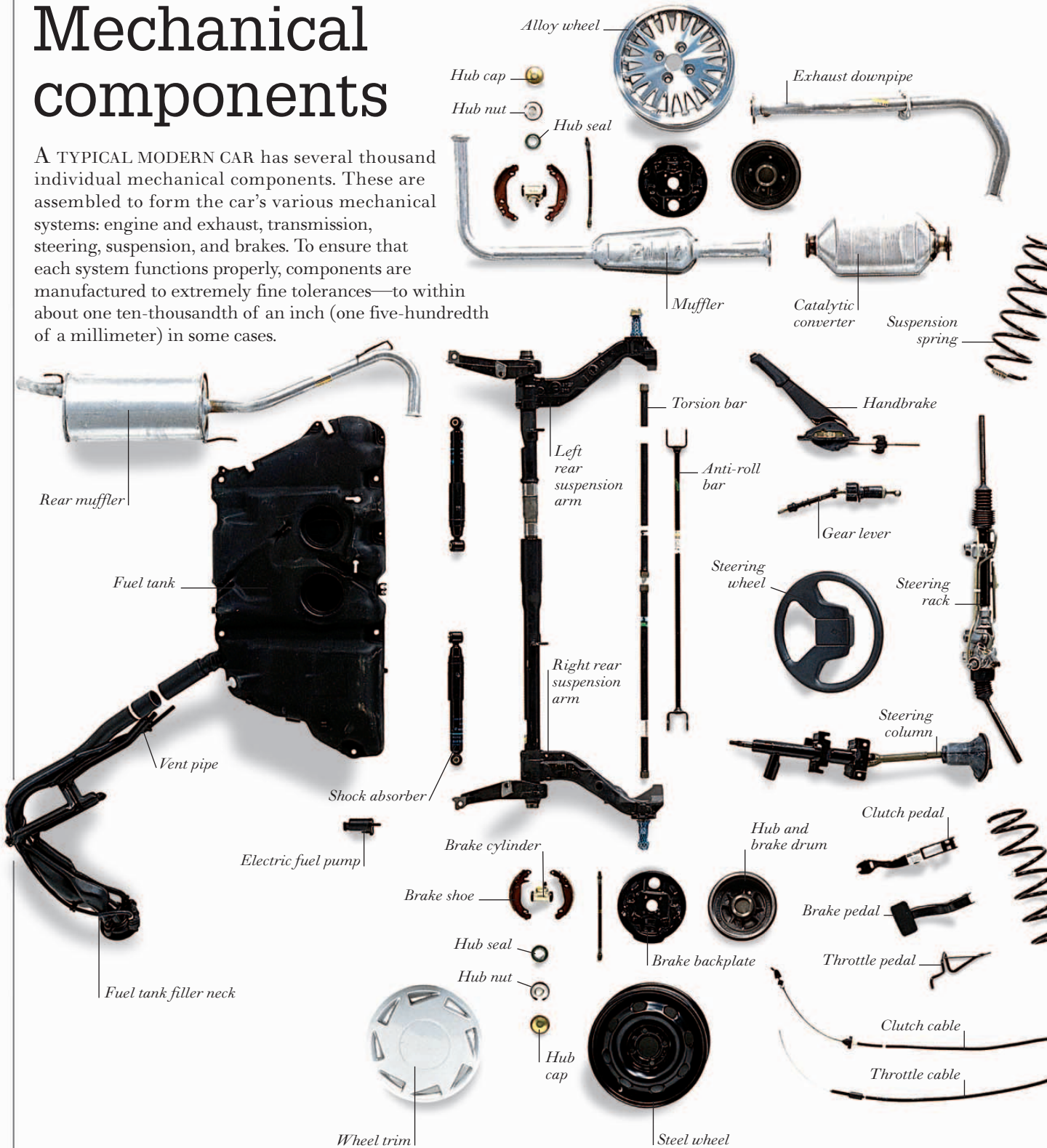
SIDE VIEW OF A RENAULT CLIO

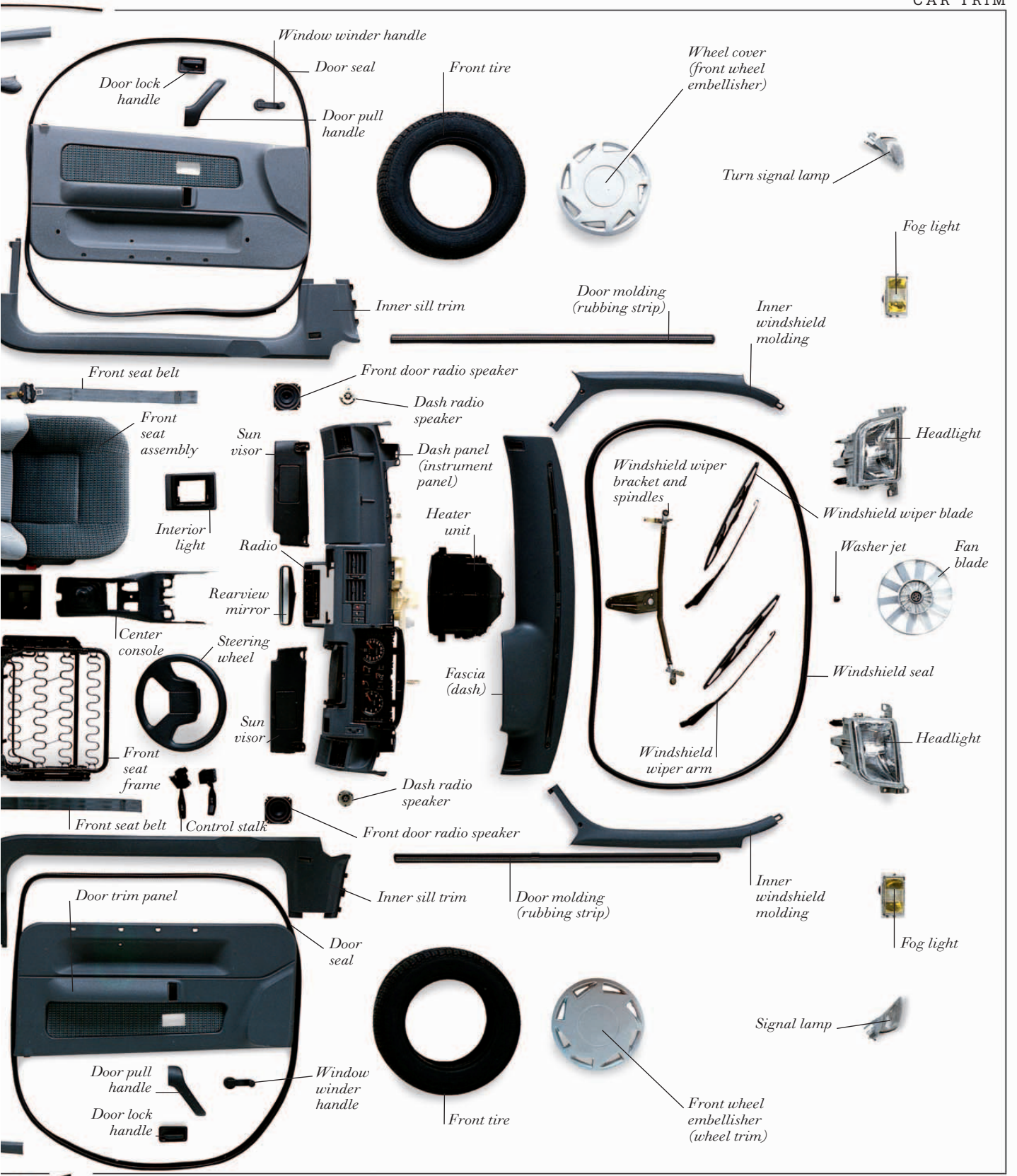


FRONT VIEW OF A RENAULT CLIO

Mechanical components

A TYPICAL MODERN CAR has several thousand individual mechanical components. These are assembled to form the car's various mechanical systems: engine and exhaust, transmission, steering, suspension, and brakes. To ensure that each system functions properly, components are manufactured to extremely fine tolerances—to within about one ten-thousandth of an inch (one five-hundredth of a millimeter) in some cases.

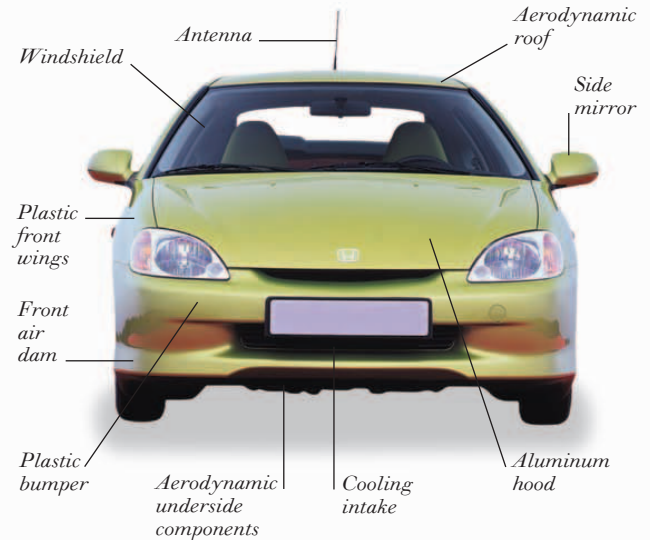




Hybrid car

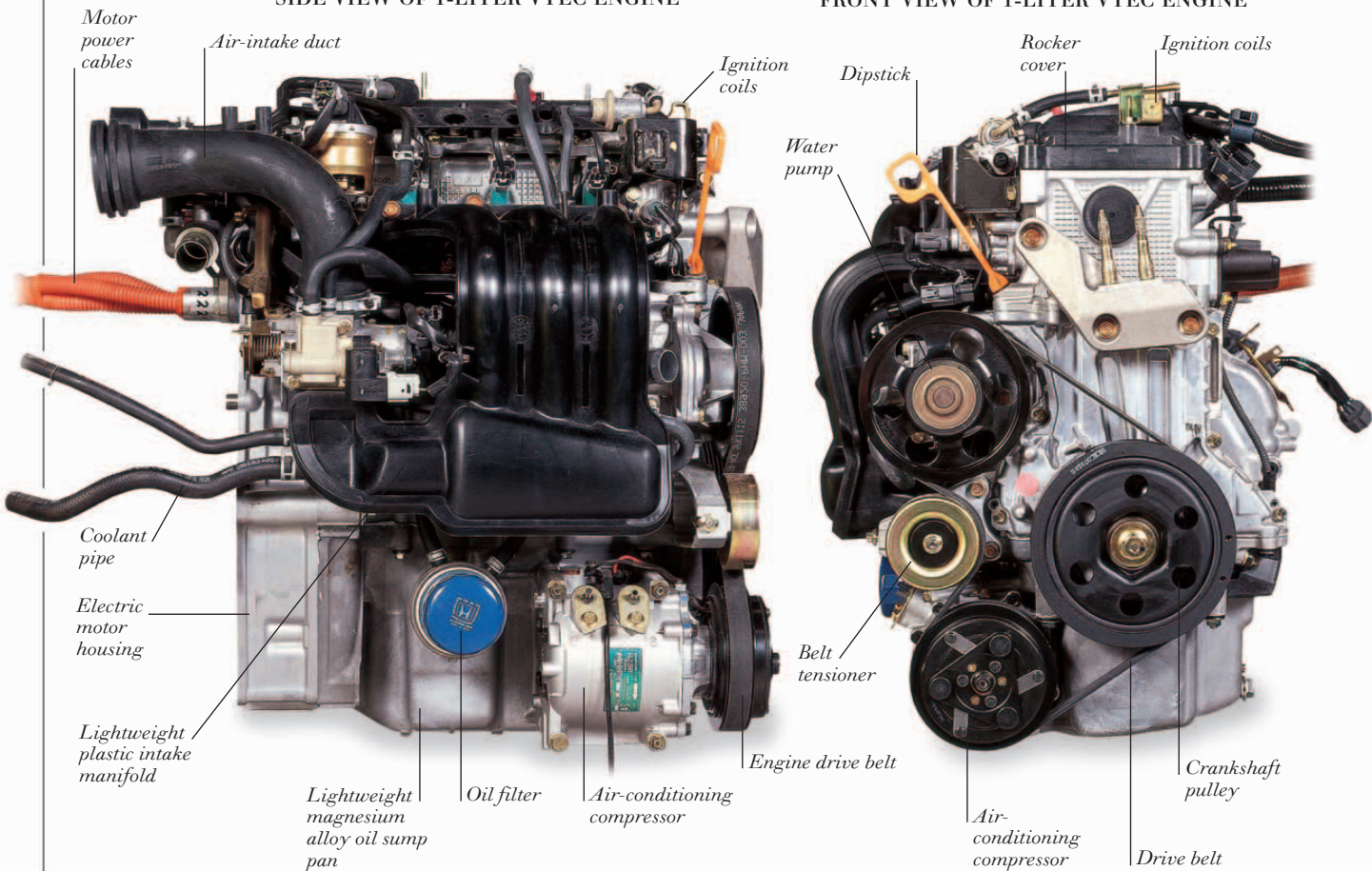
THERE HAVE BEEN SEVERAL proposed alternatives to conventional gas- or diesel-powered cars, including cars that use solar or battery power. The object is to lower harmful emissions and conserve natural resources. One of the alternatives already in production is the hybrid car. A hybrid vehicle uses two or more fuels. Examples include diesel-electric trains and mopeds. The latter combine the power of a gasoline engine with pedal power. In a hybrid car, gas consumption is reduced by the provision of additional power by an electric motor during acceleration. The motor is driven by power from on-board batteries that are recharged by an engine-driven generator when the car is decelerating or cruising. Some hybrid cars transfer energy from the wheels to a flywheel during braking. The flywheel drives the generator, which recharges the batteries.

HONDA INSIGHT



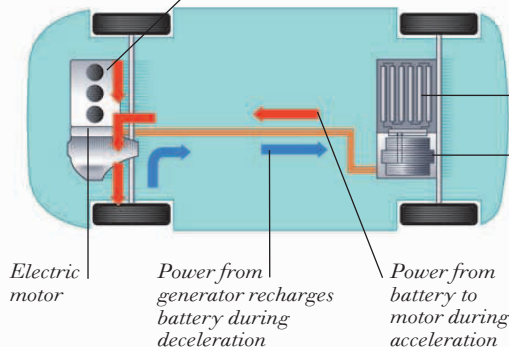
SIDE VIEW OF 1-LITER VTEC ENGINE

FRONT VIEW OF 1-LITER VTEC ENGINE



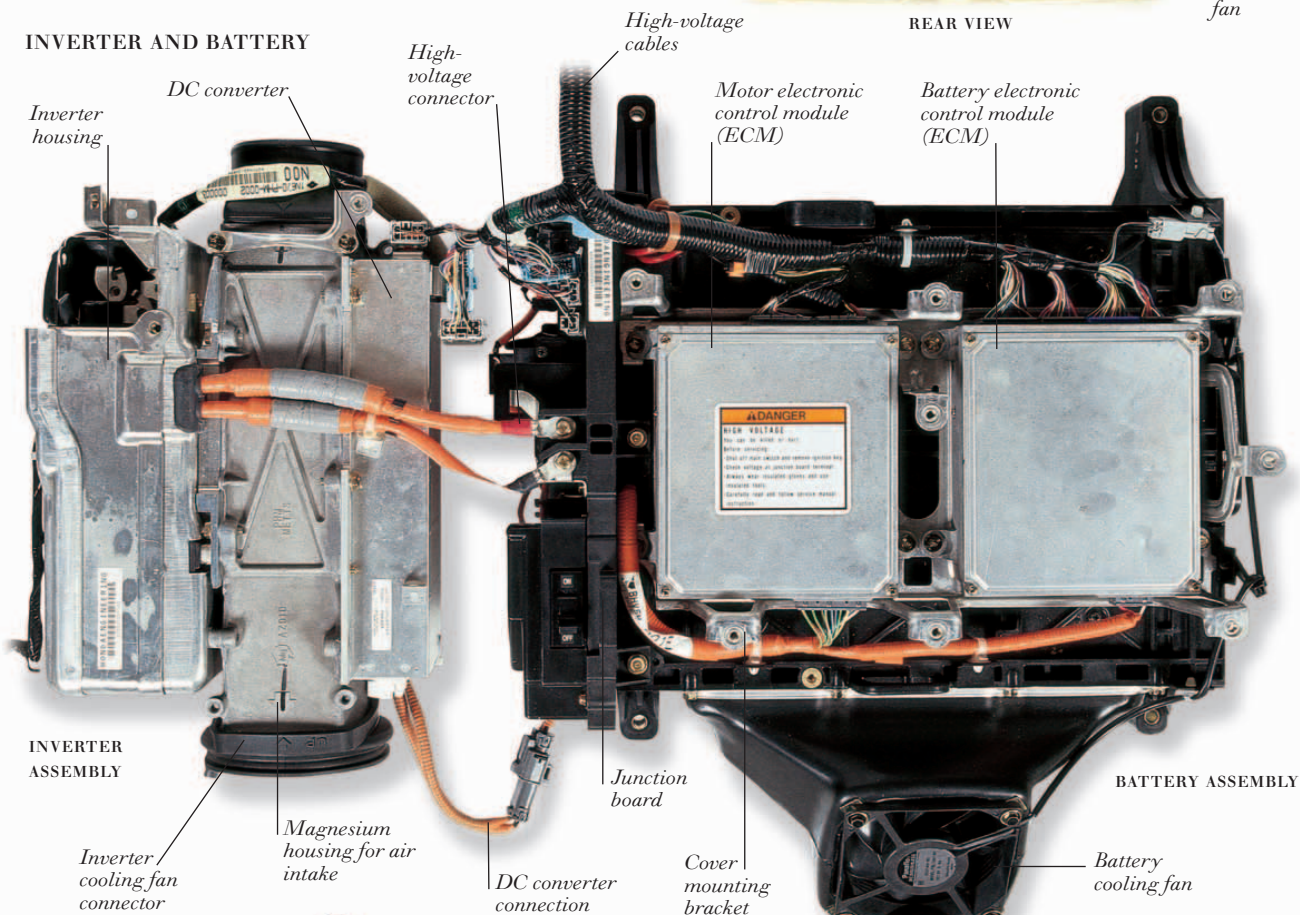
HOW HYBRID POWER WORKS

Gasoline engine provides power for acceleration and to generator



REAR VIEW

INVERTER AND BATTERY

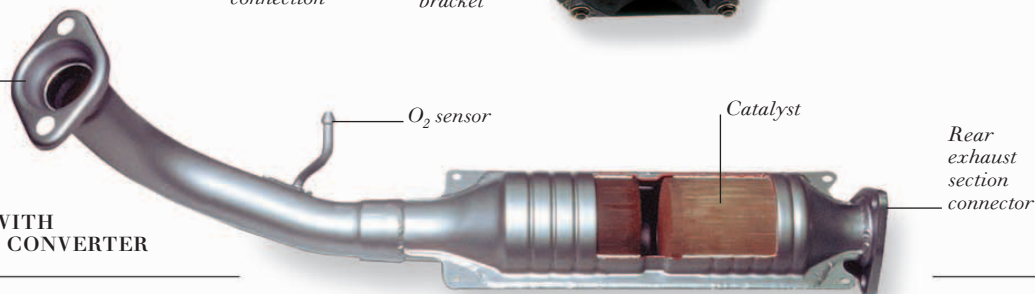


INVERTER ASSEMBLY

BATTERY ASSEMBLY

Manifold connector

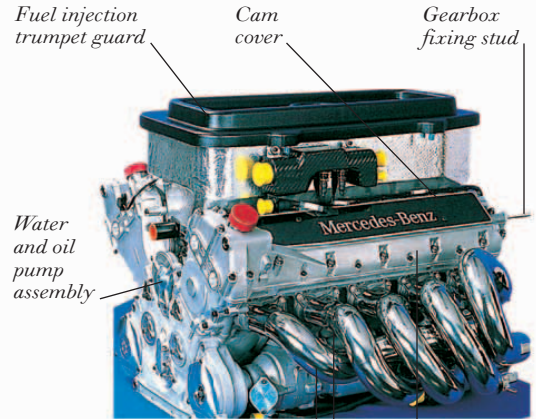
EXHAUST WITH CATALYTIC CONVERTER



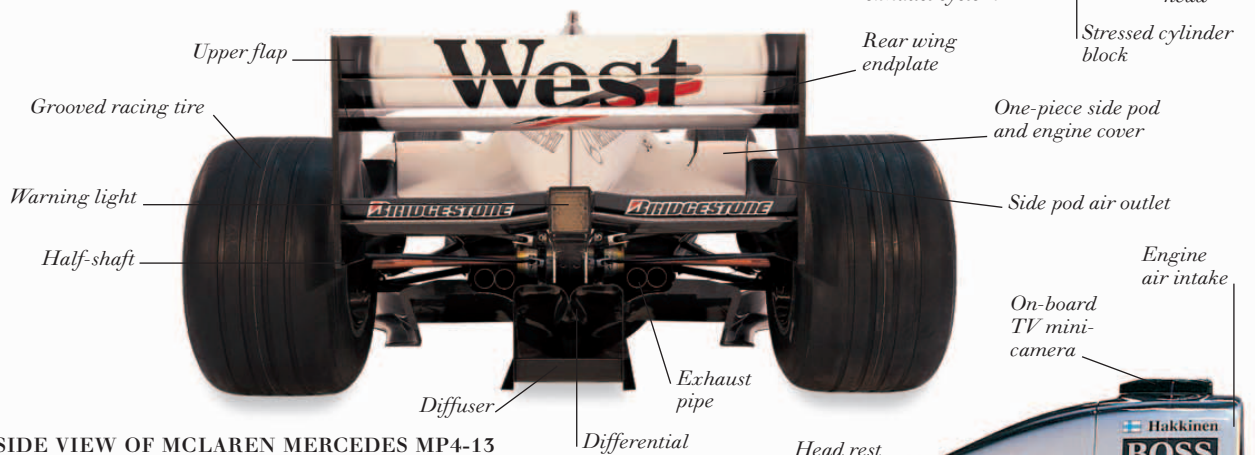
Race cars

SINCE THE ADVENT OF DRIVING, race cars have been a major focus of innovation in car design. Features that are now commonplace, such as disc brakes, turbochargers, and even safety belts, were used first on competition cars. Research into race cars has contributed to a new understanding of engine performance, aerodynamics, and tire adhesion, and has led to the development of ultralight materials such as carbon fiber for car bodies. A modern McLaren Formula One car has a low, streamlined body and an open cockpit but, unlike its forerunner, it also has front and rear wings that push the wheels firmly on to the track, huge tires for extra grip, and electronic sensors that continually relay information to the pits about the car's performance.

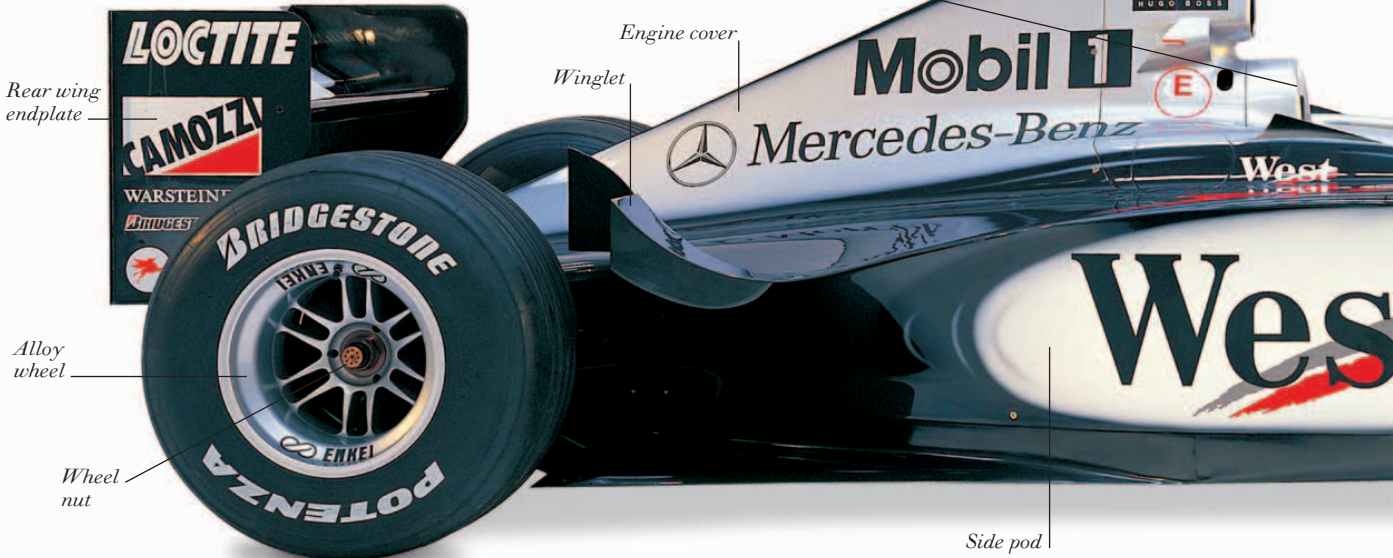
72° V10 ENGINE



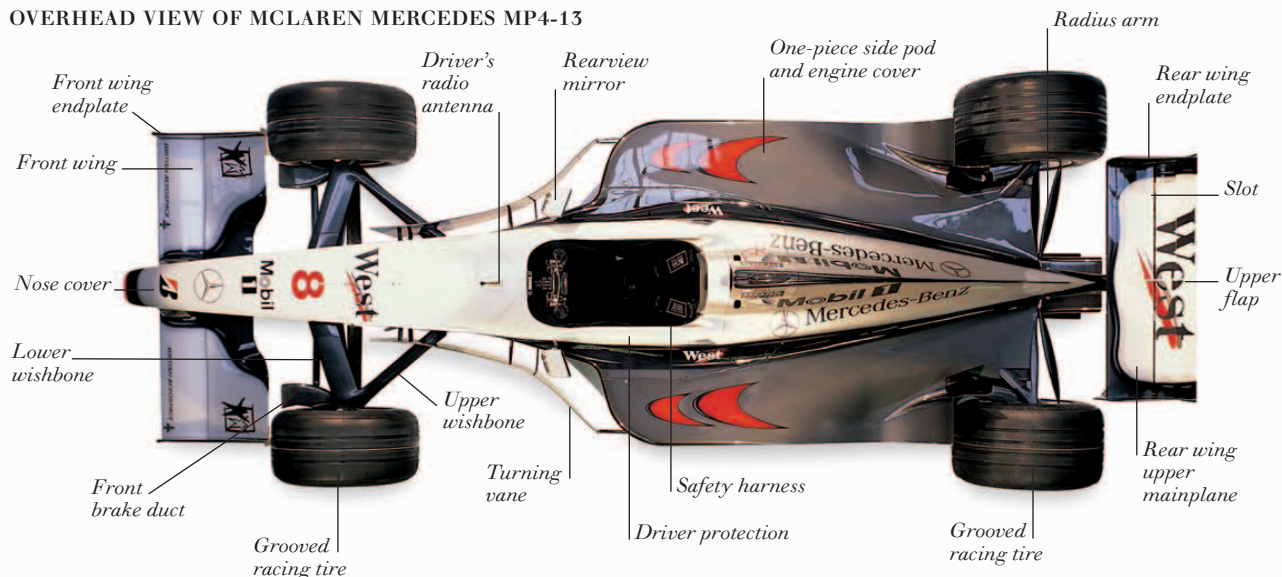
BACK VIEW OF MCLAREN MERCEDES MP4-13



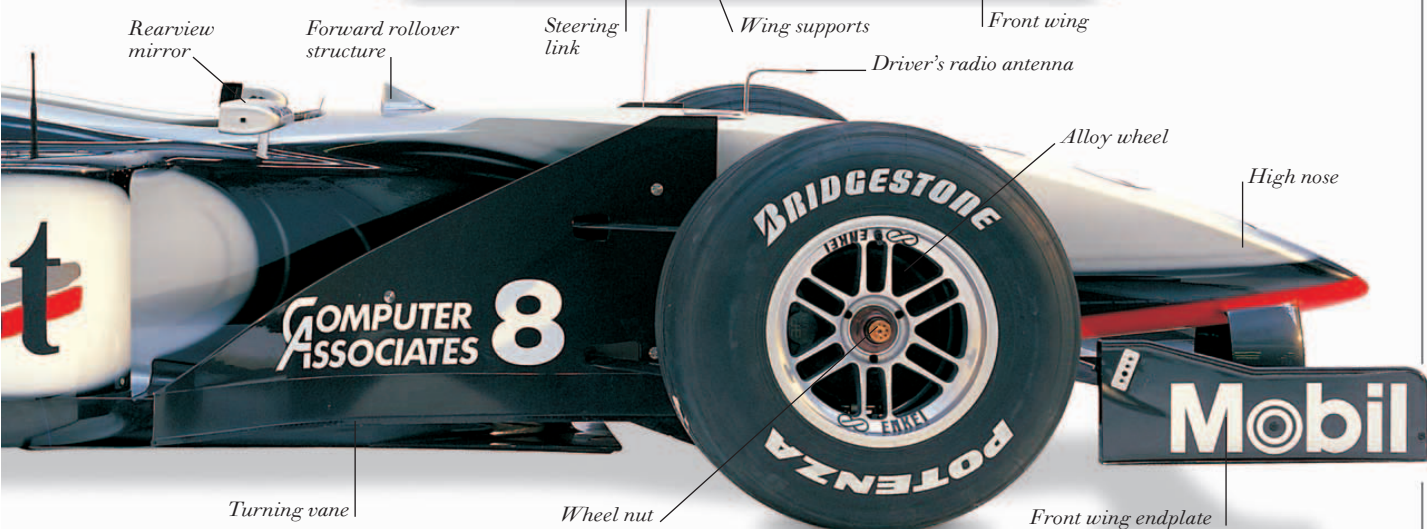
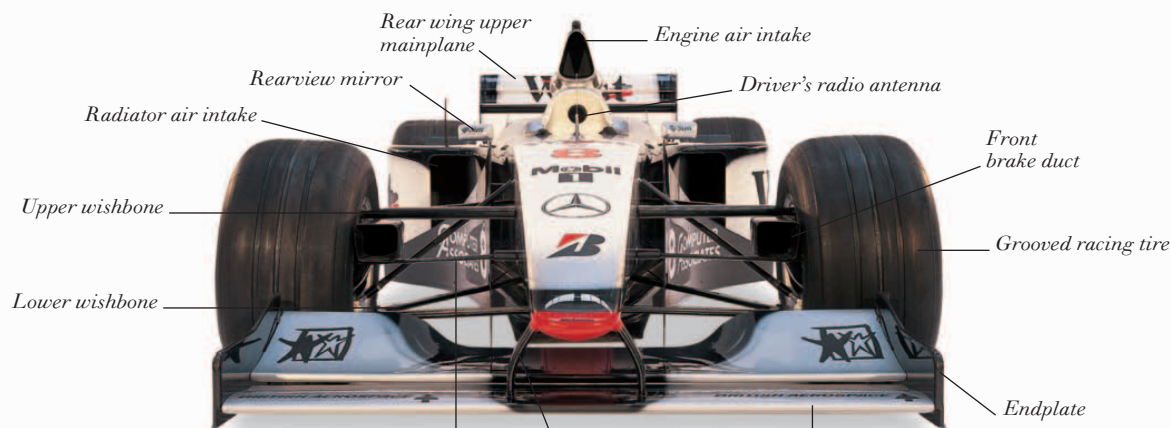
SIDE VIEW OF MCLAREN MERCEDES MP4-13



OVERHEAD VIEW OF MCLAREN MERCEDES MP4-13



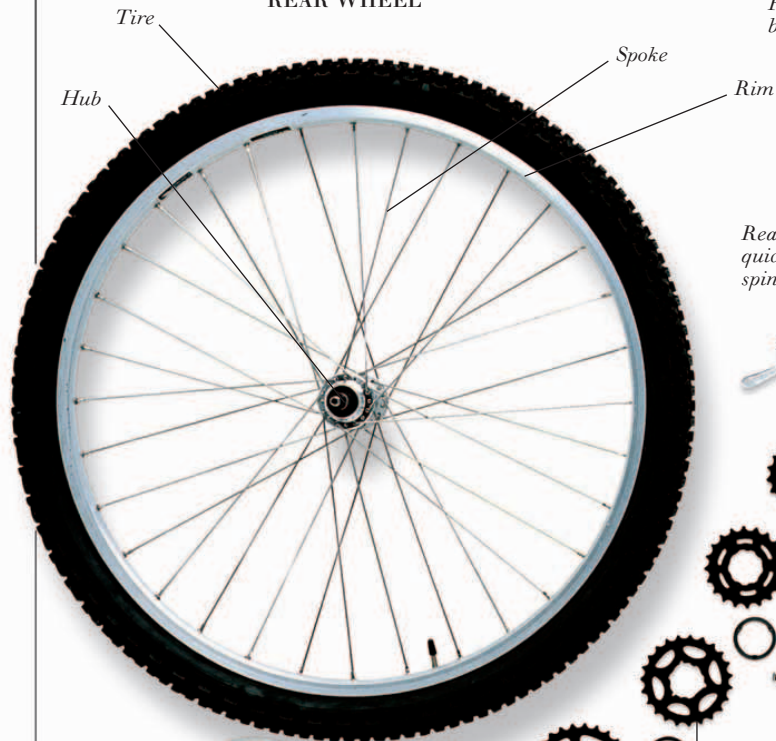
FRONT VIEW OF MCLAREN MERCEDES MP4-13



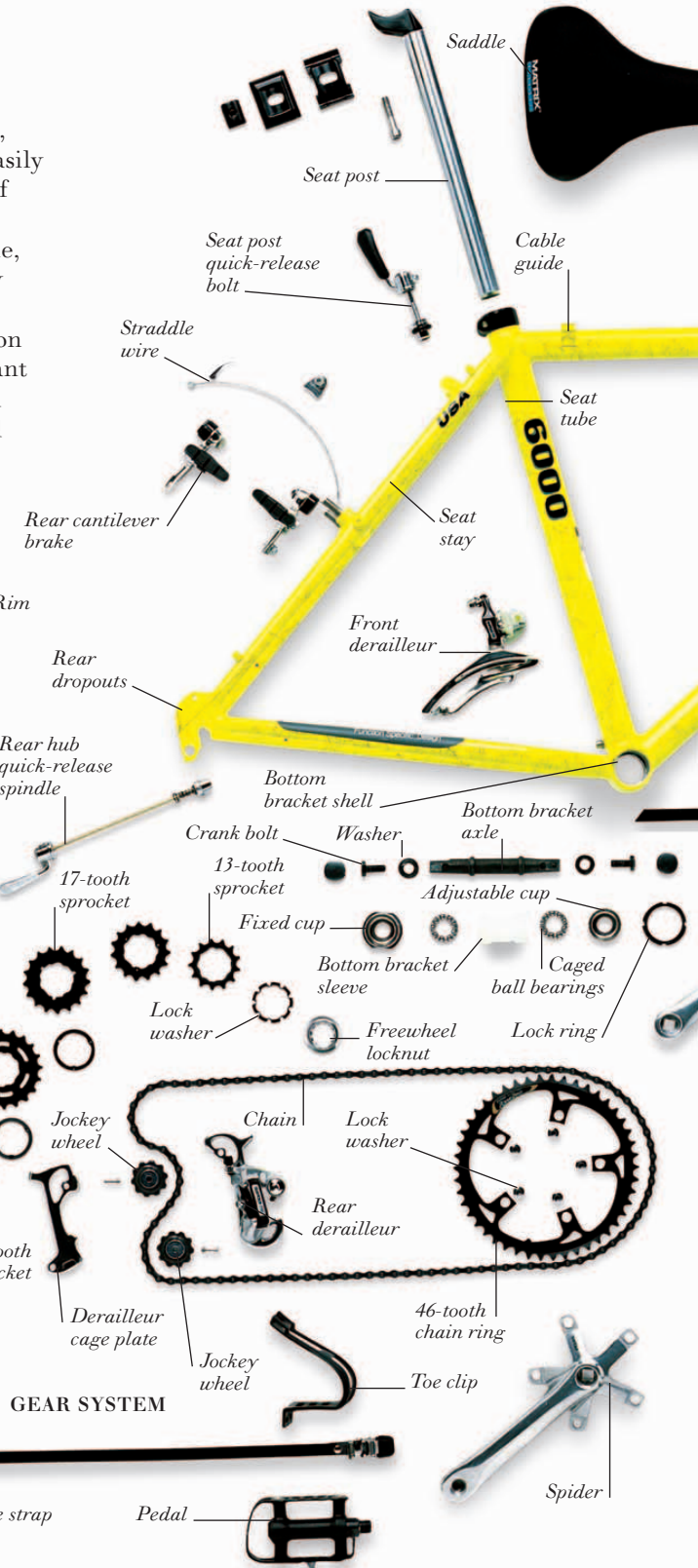
Bicycle anatomy

THE BICYCLE IS A TWO-WHEELED, light-weight machine, which is propelled by human power. It is efficient, cheap, easily manufactured, and one of the world's most popular forms of transportation. The first pedal-driven bicycle was built in Scotland in 1839. Since then the basic design—of a frame, wheels, brakes, handlebars, and saddle—has been gradually improved, with the addition of a chain, gear system, and pneumatic tires (tires inflated with air). The recent invention of the mountain bike (all-terrain bike) has been an important development. With its strong, rugged frame, wide tires, and 21 gears, a mountain bike enables riders to reach rough and hilly areas that were previously inaccessible to cyclists.

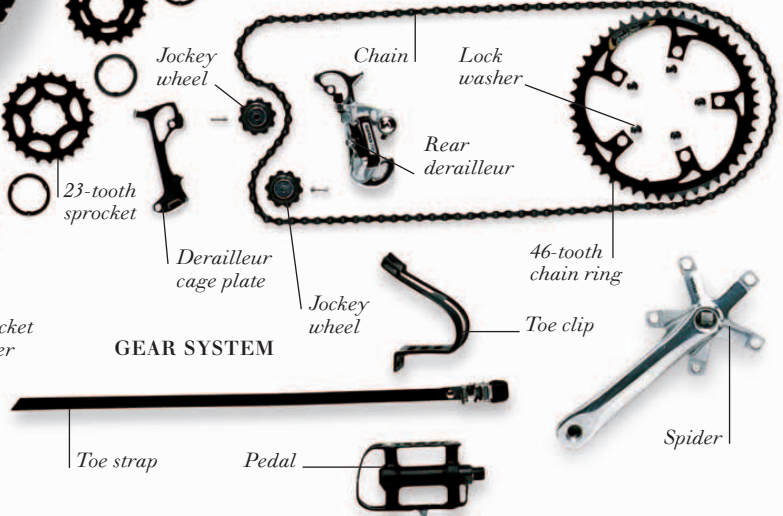
REAR WHEEL

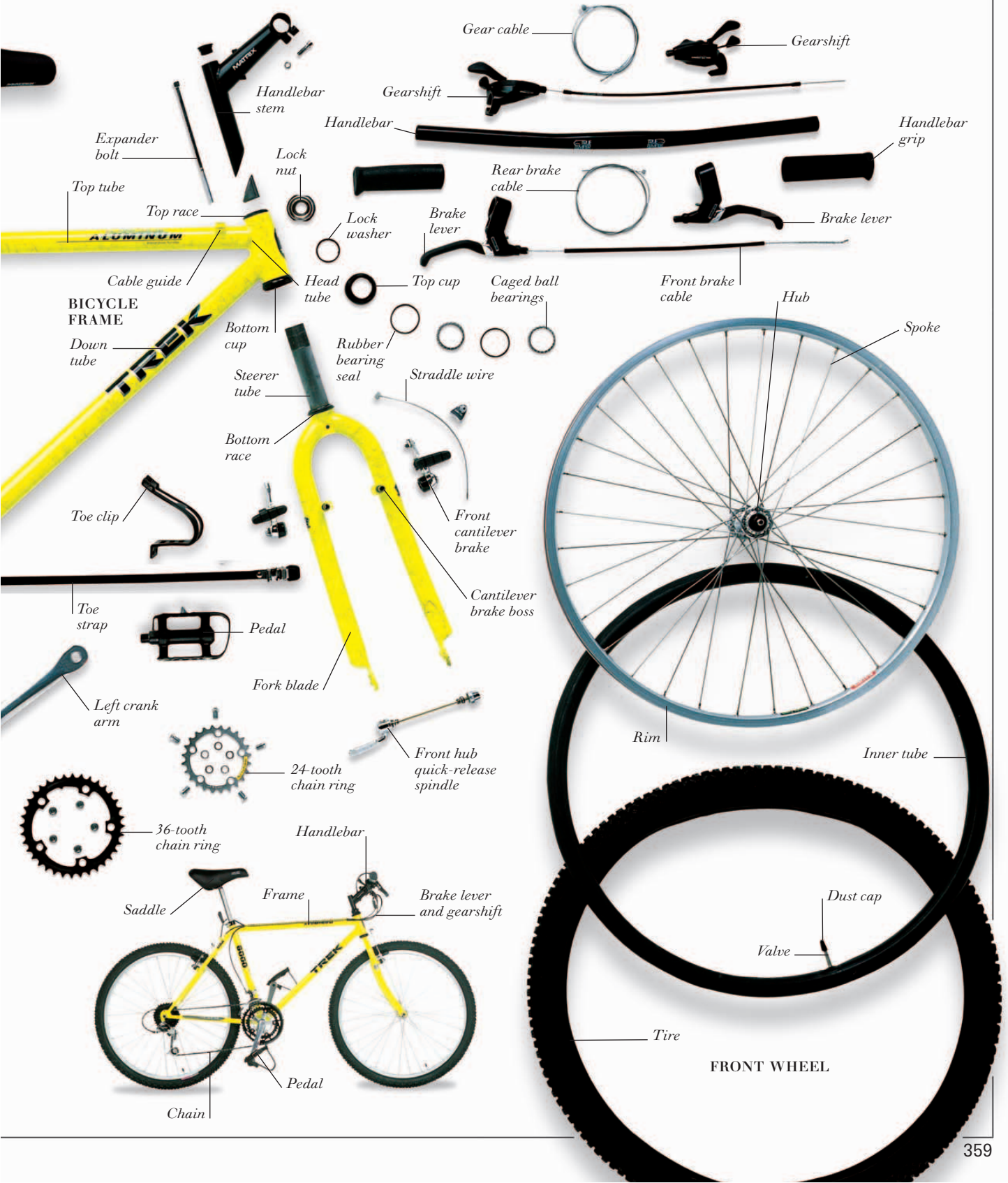


FREEWHEEL SPROCKETS



GEAR SYSTEM





Bicycles

ALTHOUGH ALL BICYCLES are made up of the same basic components, they can vary greatly in design. A racing bike, such as the Eddy Merckx model, with its light frame and steep head- and seat-angles, is built for speed. Its design forces the rider to adopt the “aerotuck,” a crouched, aerodynamic position. While a touring bike resembles the racing bike in many respects, it is designed for comfort and stability on long-distance journeys. Touring bikes are characterized by more relaxed frame angles, heavy chain stays that support the rear panniers, and a long wheelbase (the distance between the wheel axles) for reliable handling. All-round bicycles, known as “hybrids,” combine the light weight and speed of sports bikes with the rugged durability of mountain bikes (see pp. 358-359). Bicycles that are not designed for conventional road use include time-trial bikes, which have a short head tube, sloping top tube, “aero” handlebars, and aerodynamic tubing. Most Human Powered Vehicles (HPVs) are recumbents—the rider has a recumbent position—which maximize power output and minimize drag (resistance). Essential to the safety of all riders are helmets, and both front and rear lights; locks protect against theft.

FRONT AND REAR LIGHTS



White front light

Hard outer shell

Red rear light

HELMET

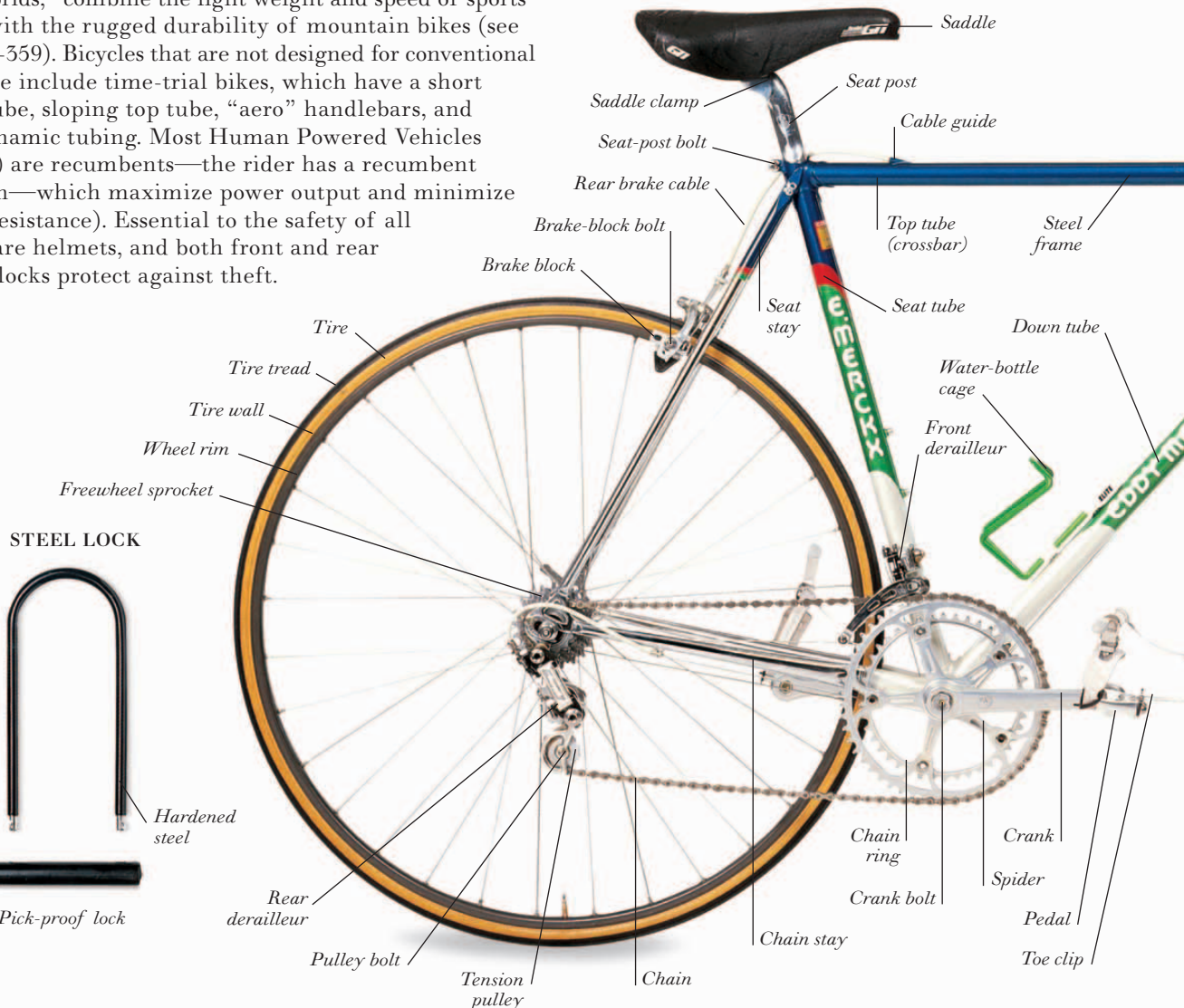


Air vent

Polystyrene padding

Quick-release strap

EDDY MERCKX RACING BICYCLE



Saddle

Seat post

Saddle clamp

Seat-post bolt

Cable guide

Rear brake cable

Top tube (crossbar)

Steel frame

Brake-block bolt

Brake block

Seat stay

Seat tube

Down tube

Tire

Tire tread

Tire wall

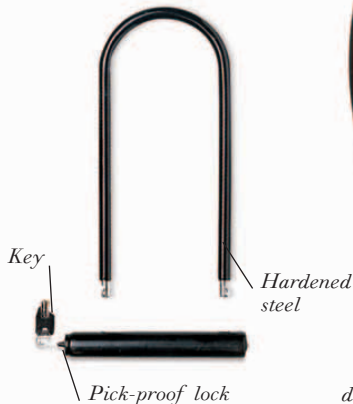
Wheel rim

Freewheel sprocket

Water-bottle cage

Front derailleur

STEEL LOCK



Key

Hardened steel

Pick-proof lock

Rear derailleur

Pulley bolt

Tension pulley

Chain

Chain ring

Crank bolt

Crank

Spider

Pedal

Toe clip

Chain stay

CANNONDALE SH600 HYBRID BICYCLE



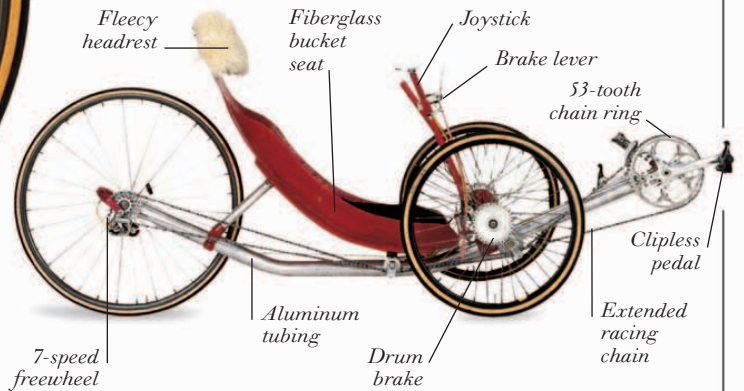
CANNONDALE ST1000 TOURING BICYCLE



ROSSIN ITALIAN TIME-TRIAL BICYCLE



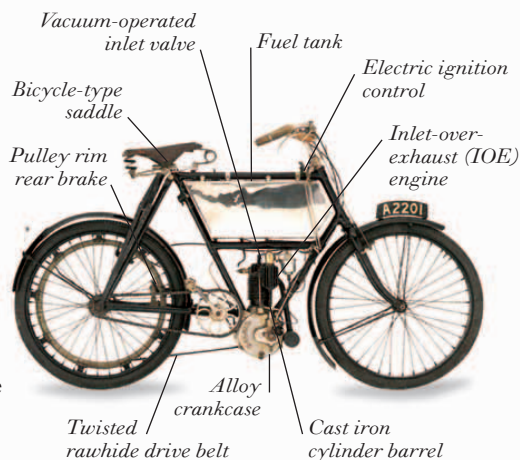
WINDCHEETAH SL MARK VI "SPEEDY" RACING HPV BICYCLE



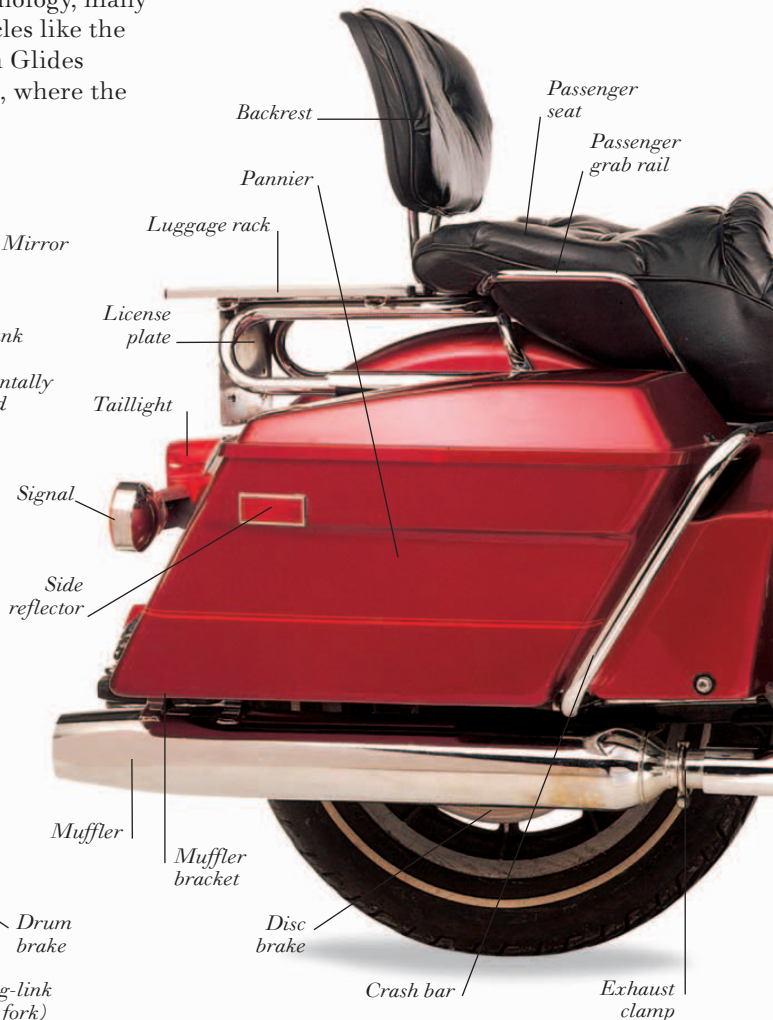
The motorcycle

THE MOTORCYCLE HAS EVOLVED from a motorized cycle—a basic bicycle with an engine—into a sophisticated, high-performance machine. In 1901, the Werner brothers established the most viable location for the engine by positioning it low in the center of the chassis (see pp. 364-365): the new Werner became the basis for the modern motorcycle. Motorcycles are used for many purposes—for commuting, delivering messages, touring, and racing—and different machines have been developed according to the demands of different types of rider. The Vespa scooter, for instance, which is small-wheeled, economical, and easy-to-ride, was designed to meet the needs of the commuter. Sidecars provided transportation for the family until the arrival of cheap cars caused their popularity to decline. Enthusiast riders generally favor larger capacity machines that are capable of greater performance and offer more comfort. Four-cylinder machines have been common since the Honda CB750 appeared in 1969. Despite advances in motorcycle technology, many riders are attracted to the traditional looks of motorcycles like the twin-cylinder Harley-Davidson. The Harley-Davidson Glides exploit the style of the classic American V-twin engine, where the cylinders are placed in a V-formation.

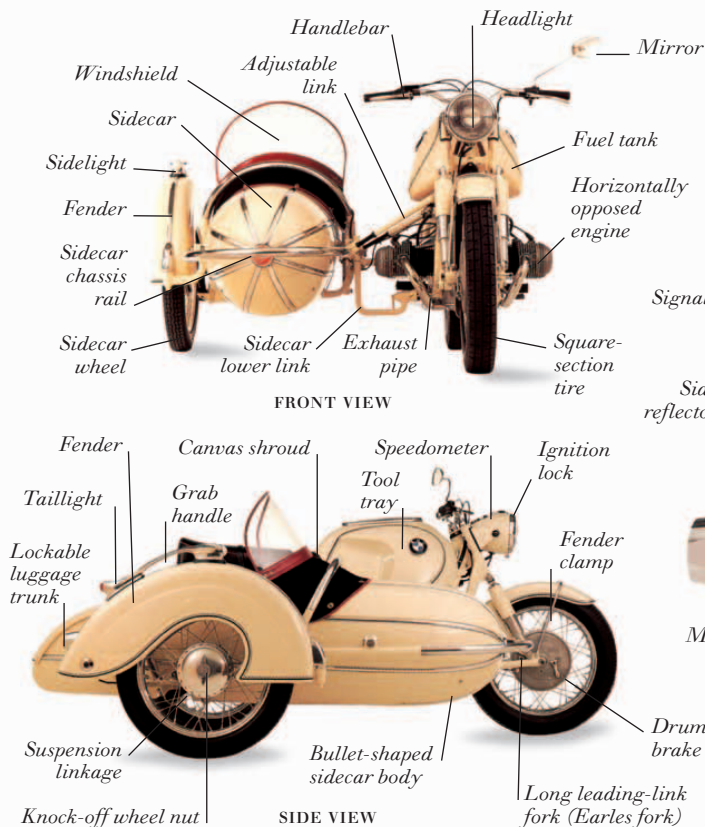
1901 WERNER MOTORCYCLE



1988 HARLEY-DAVIDSON FLH8 ELECTRA GLIDE

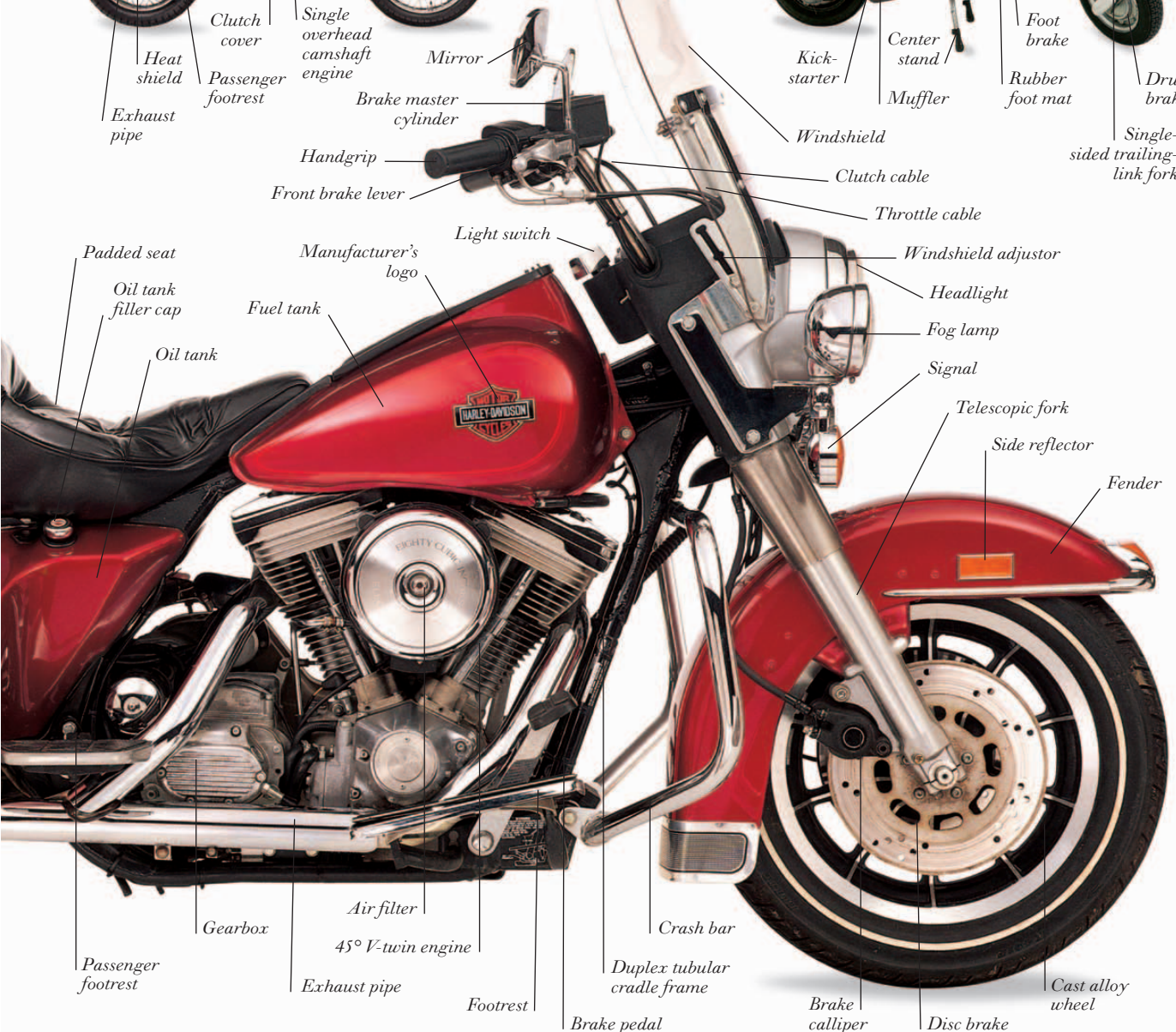
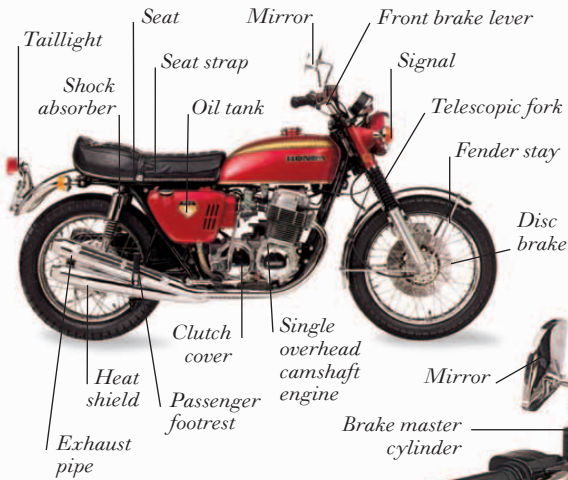


1965 BMW R/60 WITH 1952 STEIB CHAIR



1969 HONDA CB750

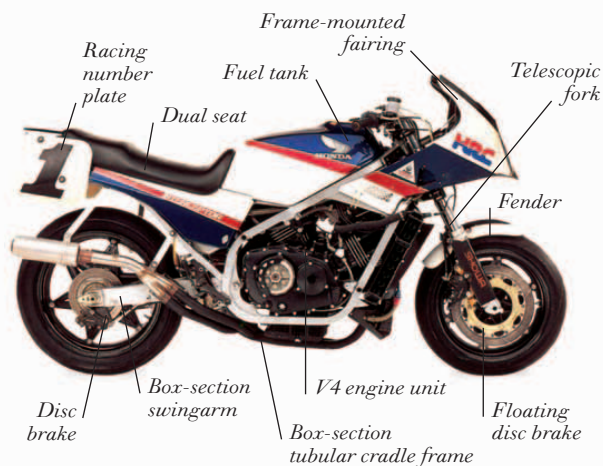
1963 VESPA GRAND SPORT 160 MARK 1



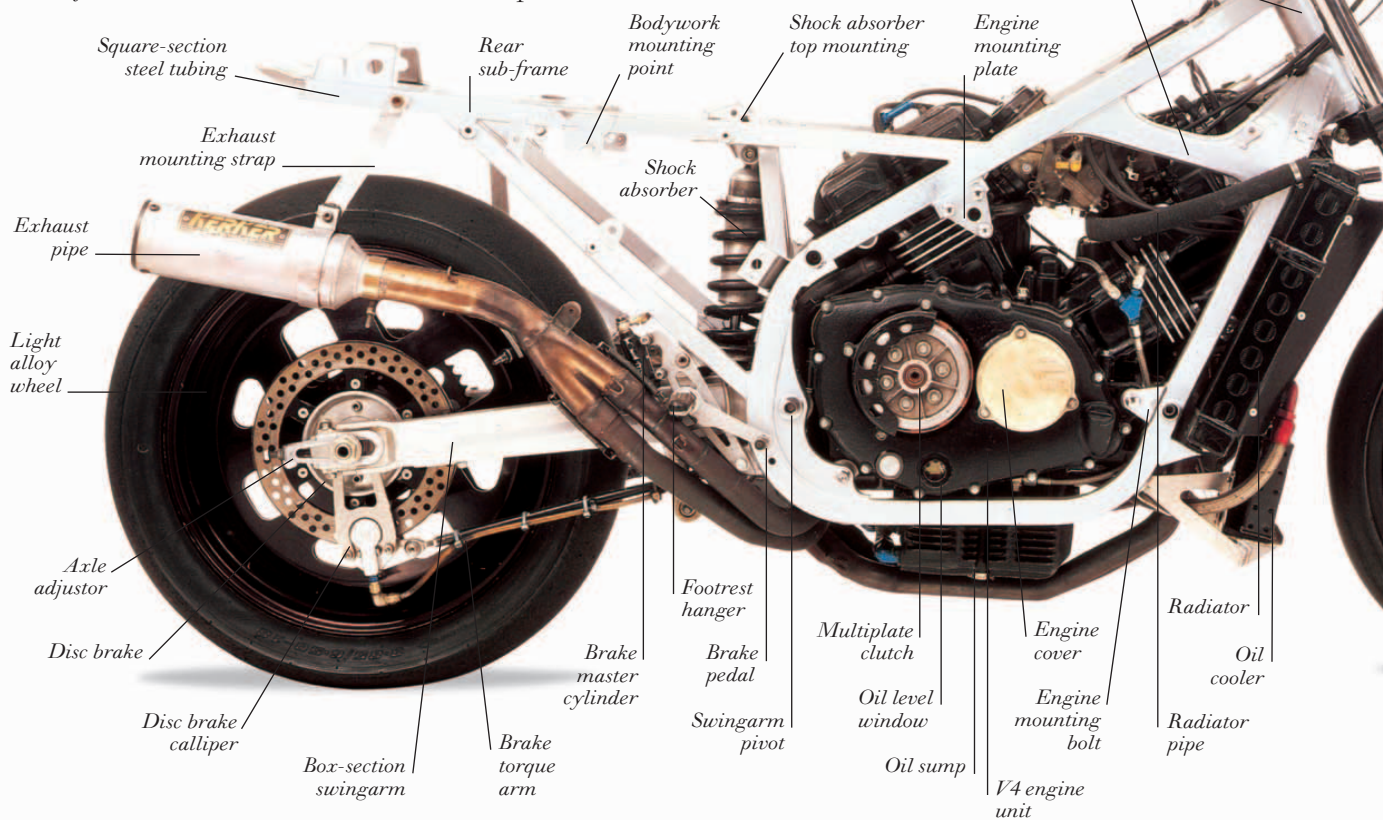
The motorcycle chassis

THE MOTORCYCLE CHASSIS is the main “body” of the motorcycle, to which the engine is attached. Consisting of the frame, wheels, suspension, and brakes, the chassis performs various functions. The frame, which is built from steel or alloy, keeps the wheels in line to maintain the handling of the motorcycle, and serves as a structure for mounting other components. The engine and gearbox unit is bolted into place, while items such as the seat, the fenders, and the fairing are more easily removable. Suspension cushions the rider from irregularities in the road surface. In most suspension systems, coil springs controlled by an oil damper separate the main mass of the motorcycle from the wheels. At the front, the spring and damper are usually incorporated in a telescopic fork; the rear employs a pivoted swingarm. The suspension also helps to retain maximum contact between the tires and the road, necessary for effective braking and steering. Drum brakes were common until the 1970s, but modern motorcycles use disc brakes, which are more powerful.

1985 HONDA VF750 WITH BODYWORK

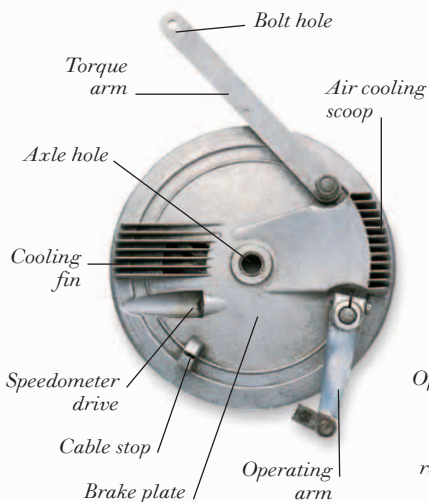


1985 HONDA VF750 WITH BODYWORK REMOVED

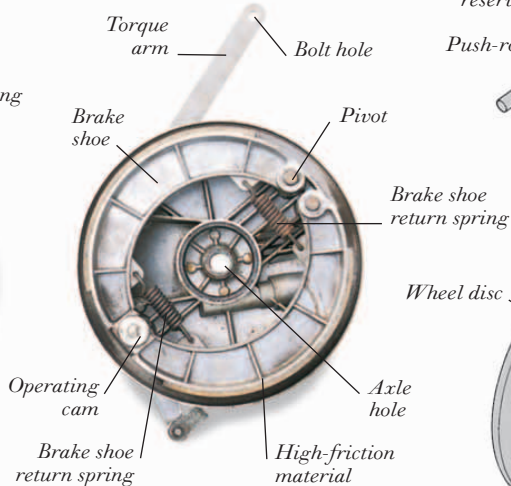


DRUM BRAKE

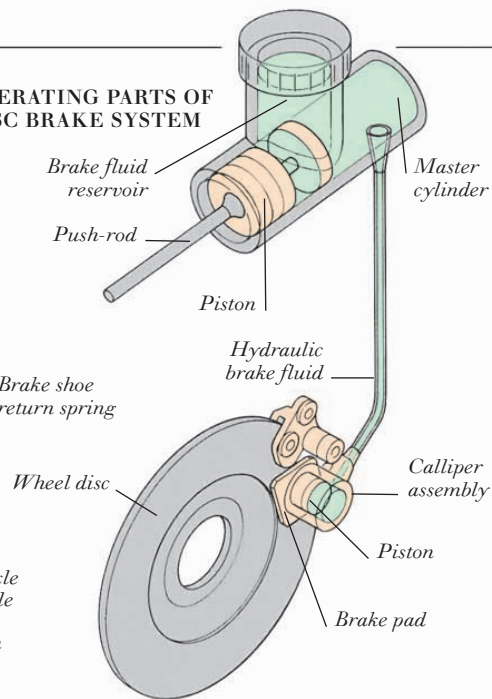
EXTERIOR OF DRUM BRAKE



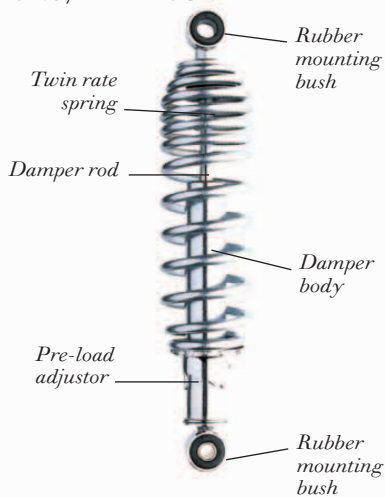
INTERIOR OF DRUM BRAKE



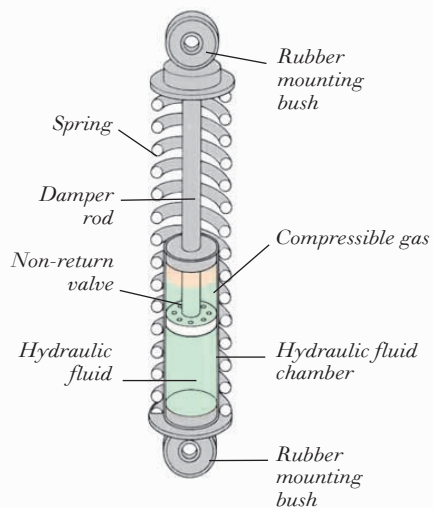
OPERATING PARTS OF DISC BRAKE SYSTEM



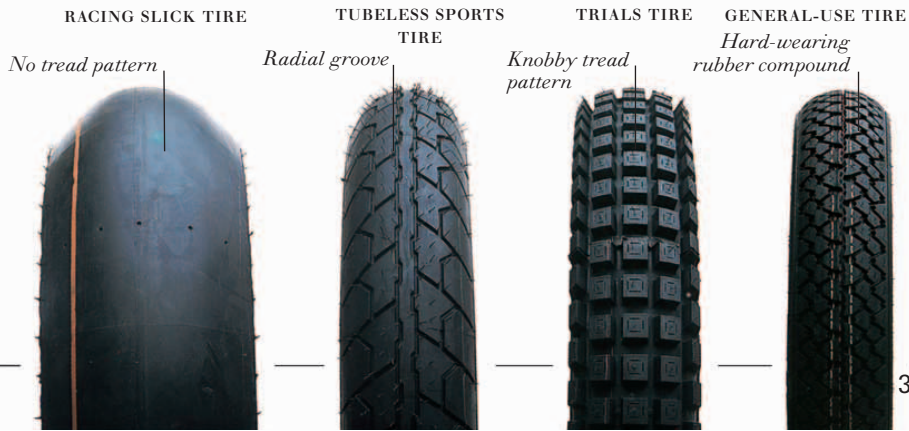
SPRING/DAMPER UNIT



HOW A SPRING/DAMPER UNIT WORKS



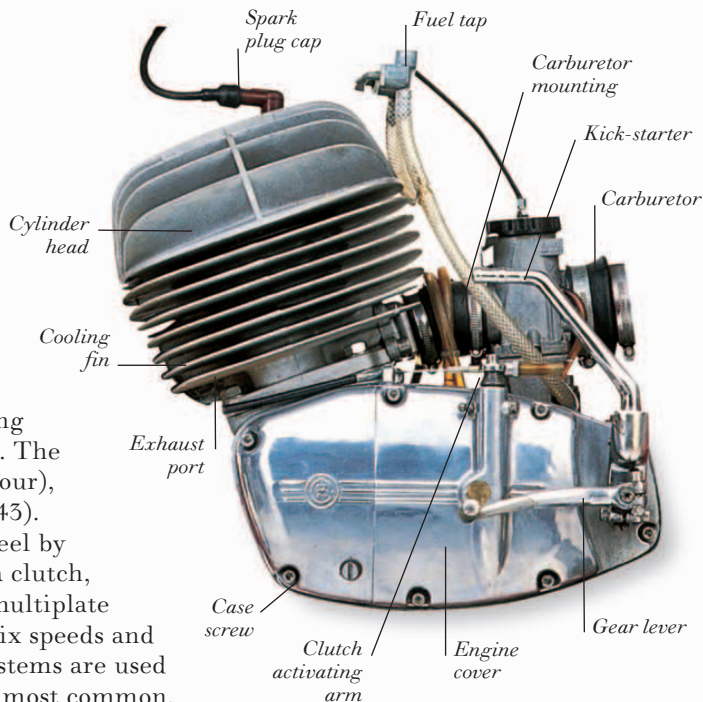
TYPES OF TIRE



Motorcycle engines

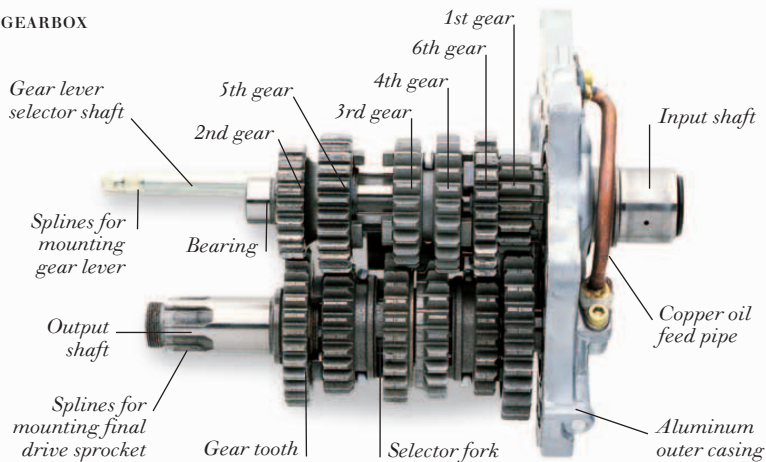
MOTORCYCLE ENGINES must be lightweight and compact and have a good power output. They have between one and six cylinders, can be cooled by air or water, and the capacity of the combustion chamber varies from 49cc (cubic centimeters) to 1500cc. Two types of internal combustion engine are common: the four-stroke, which is used in cars (see pp. 342-343), and the two-stroke. A basic two-stroke engine has only three moving parts—the crankshaft, the connecting rod, and the piston—but the power output is high. The engine fires every two strokes (rather than every four), giving a “power stroke” every revolution (see p. 343). Power is conveyed from the engine to the rear wheel by the transmission system. This usually consists of a clutch, a gearbox, and a final drive system. Clutches are multiplate devices, which run in oil. Gearboxes have five or six speeds and are operated by foot pedal. Shaft and belt drive systems are used in some cases, but chain drive to the rear wheel is most common.

EXTERIOR OF STANDARD TWO-STROKE ENGINE

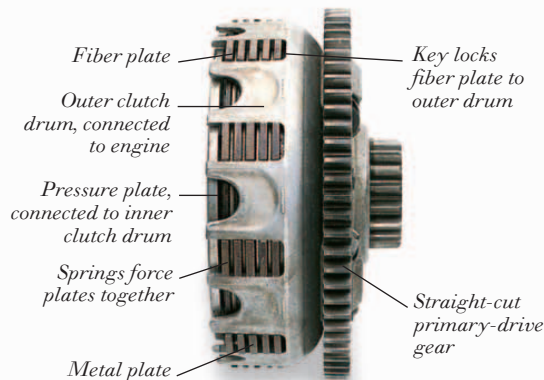


TRANSMISSION SYSTEM

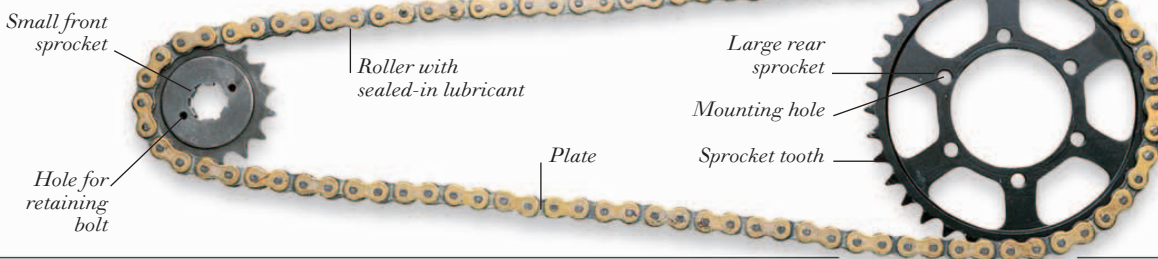
GEARBOX



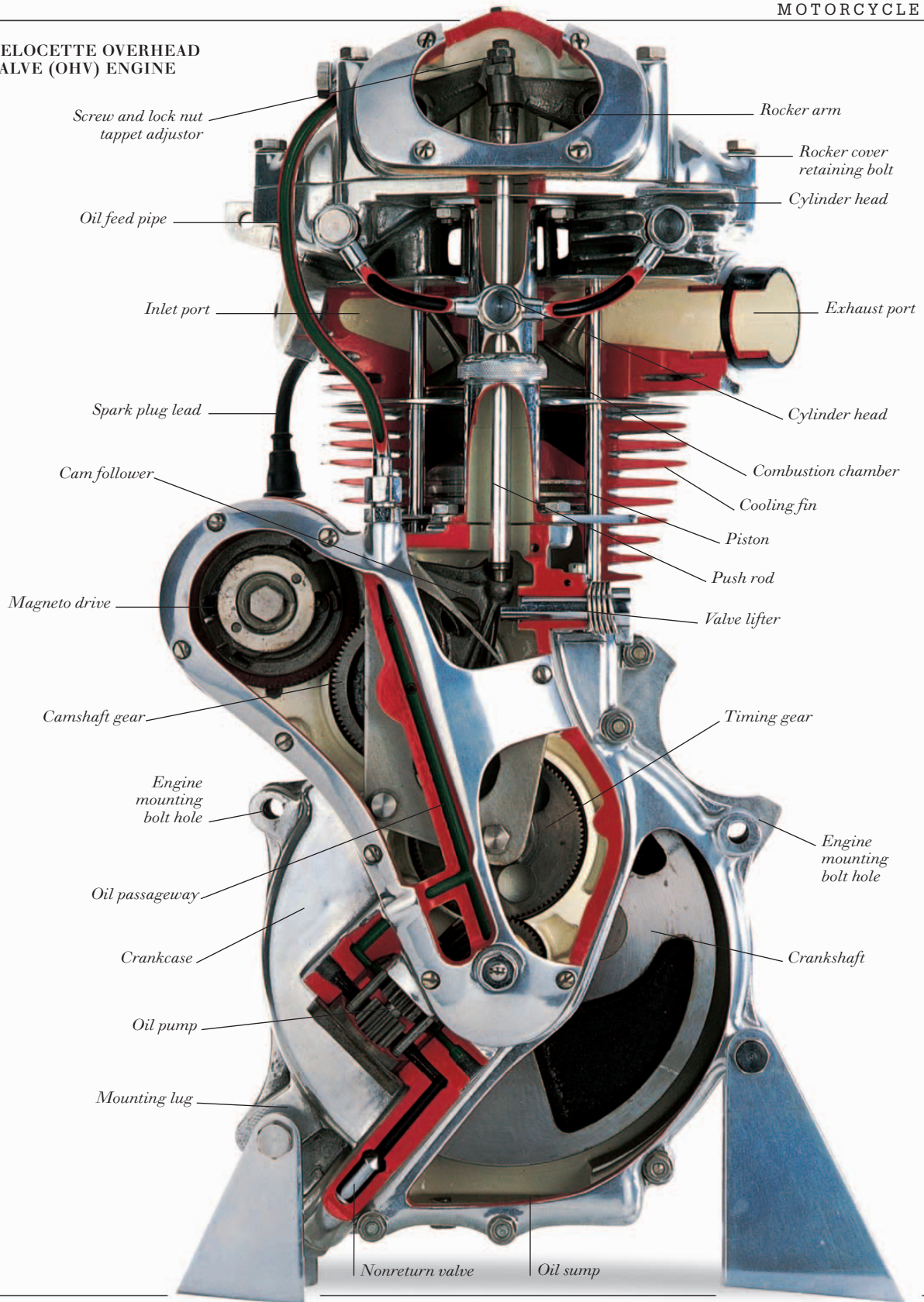
MULTIPLATE CLUTCH



MODERN “O RING” DRIVE CHAIN



VELOCETTE OVERHEAD VALVE (OHV) ENGINE



Screw and lock nut
tappet adjustor

Rocker arm

Rocker cover
retaining bolt

Oil feed pipe

Cylinder head

Inlet port

Exhaust port

Spark plug lead

Cylinder head

Cam follower

Combustion chamber

Cooling fin

Piston

Push rod

Magneto drive

Valve lifter

Camshaft gear

Timing gear

Engine
mounting
bolt hole

Engine
mounting
bolt hole

Oil passageway

Crankcase

Crankshaft

Oil pump

Mounting lug

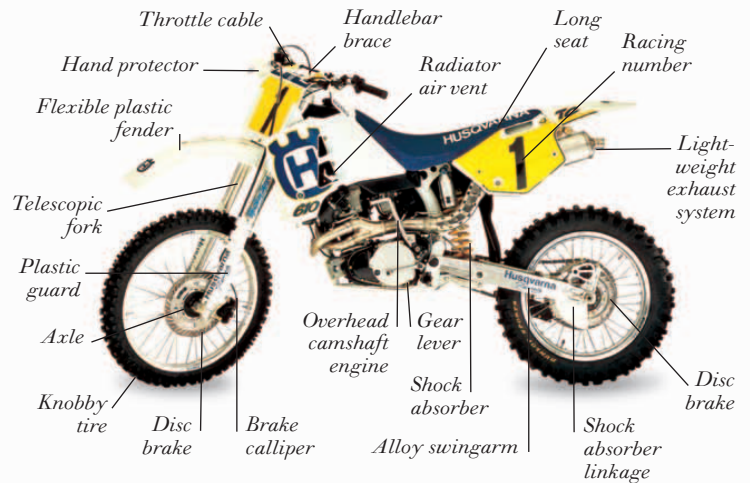
Nonreturn valve

Oil sump

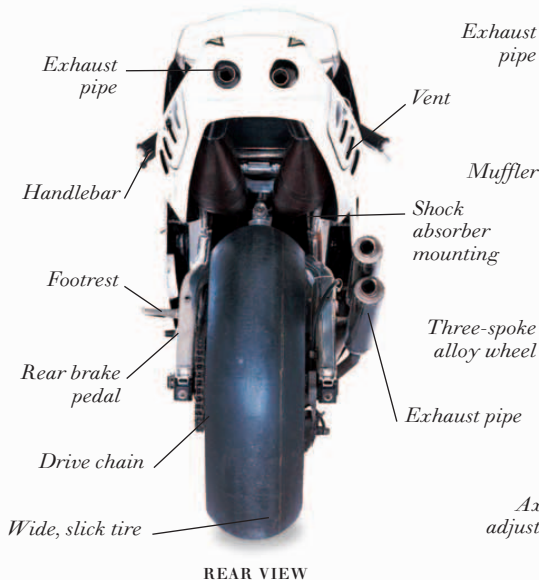
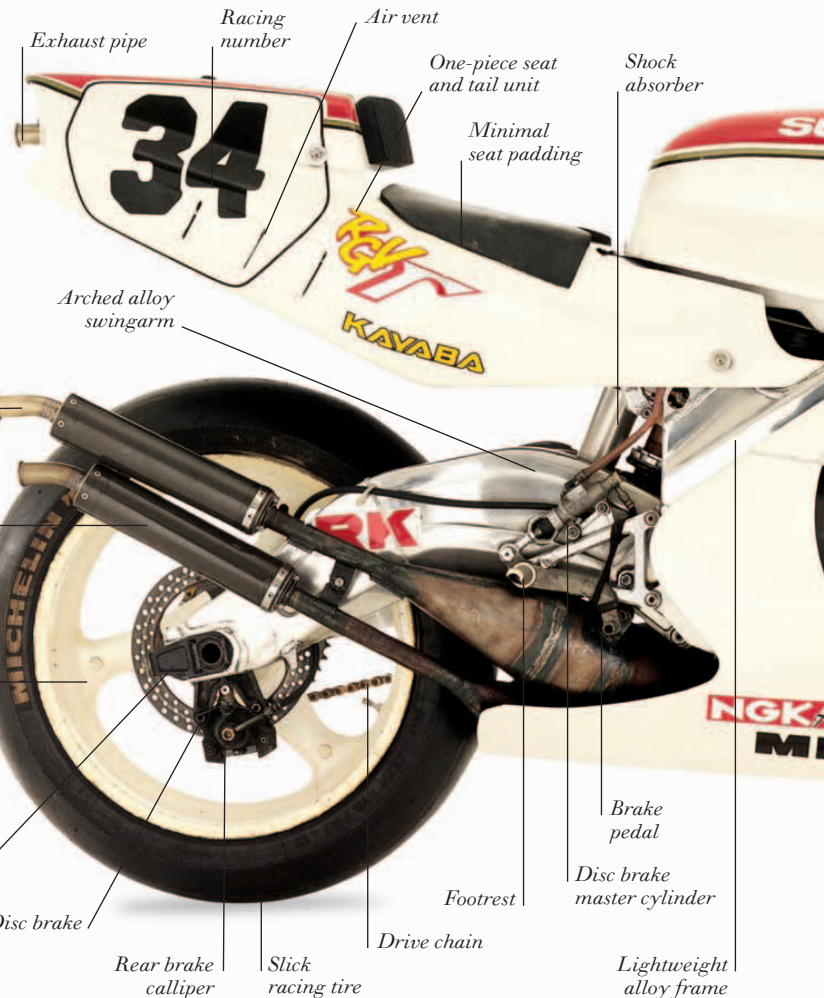
Competition motorcycles

THERE ARE MANY TYPES of motorcycle sport and in each, a specialized machine has evolved to perform to specific requirements. Races take place on roads or tracks or “off-road,” in fields, dirt tracks, and even the desert. “Grand Prix” world championships in road-racing are contested by three classes: 125cc, 250cc two-strokes; the top class of 500cc two-strokes; and 900cc four-stroke machines. The latest racing sidecars have more in common with racing cars than motorcycles. The rider and passenger operate within an all-enclosing, aerodynamic fairing. The Suzuki RGV500 shown here, like other Grand Prix machines, carries advertising, which helps to cover the cost of developing motorcycle technology. In Speedway, which originated in the US in 1902, motorcycles operate without brakes or a gearbox. Off-road competition motorcycles have less emphasis on high power output. In Motocross, for example, which is held on rough terrain, they must have high ground clearance, flexible long-travel suspension, and tires with a chunky tread pattern.

1992 HUSQVARNA MOTOCROSS TC610



1992 SUZUKI RGV500
SIDE VIEW



REAR VIEW



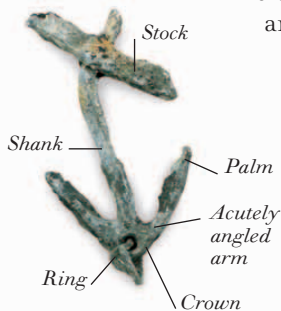


SEA AND AIR

SHIPS OF GREECE AND ROME	372
VIKING SHIPS	374
MEDIEVAL WARSHIPS AND TRADERS	376
THE EXPANSION OF SAIL	378
A SHIP OF THE LINE	380
RIGGING	382
SAILS	384
MOORING AND ANCHORING	386
ROPES AND KNOTS	388
PADDLE WHEELS AND PROPELLERS	390
ANATOMY OF AN IRON SHIP	392
THE BATTLESHIP	394
FRIGATES AND SUBMARINES	396
PIONEERS OF FLIGHT	398
EARLY MONOPLANES	400
BIPLANES AND TRIPLANES	402
WORLD WAR I AIRCRAFT	404
EARLY PASSENGER AIRCRAFT	406
WORLD WAR II AIRCRAFT	408
MODERN PISTON AERO-ENGINES	410
MODERN JETLINERS 1	412
MODERN JETLINERS 2	414
SUPERSONIC JETLINERS	416
JET ENGINES	418
MODERN MILITARY AIRCRAFT	420
HELICOPTERS	422
LIGHT AIRCRAFT	424
GLIDERS, HANG-GLIDERS, AND ULTRALIGHTS	426

Ships of Greece and Rome

ROMAN ANCHOR

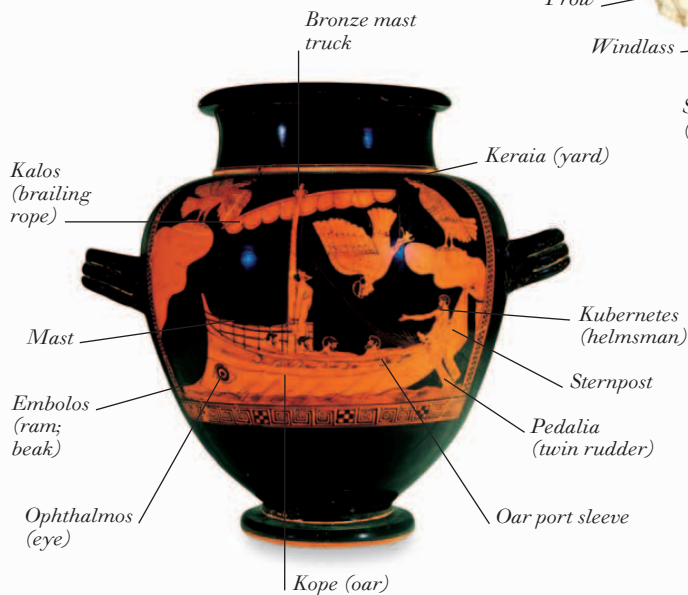


IN THE EXPANSIVE EMPIRES OF GREECE AND ROME, powerful fleets were needed for battle, trade, and communication. Greek galleys were powered by a sail and many oars. A new armament, the embolos (ram), was fitted on to the galley bow. Since ramming duels required fast and maneuverable boats, extra rows of oarsmen were added, culminating in the trireme. During the fifth and fourth centuries BC, the trireme dominated the Mediterranean. It was powered by 170 oarsmen, rowing with one oar each. The oarsmen were ranged on three levels, as the model opposite shows. The trireme also carried archers and soldiers for boarding.

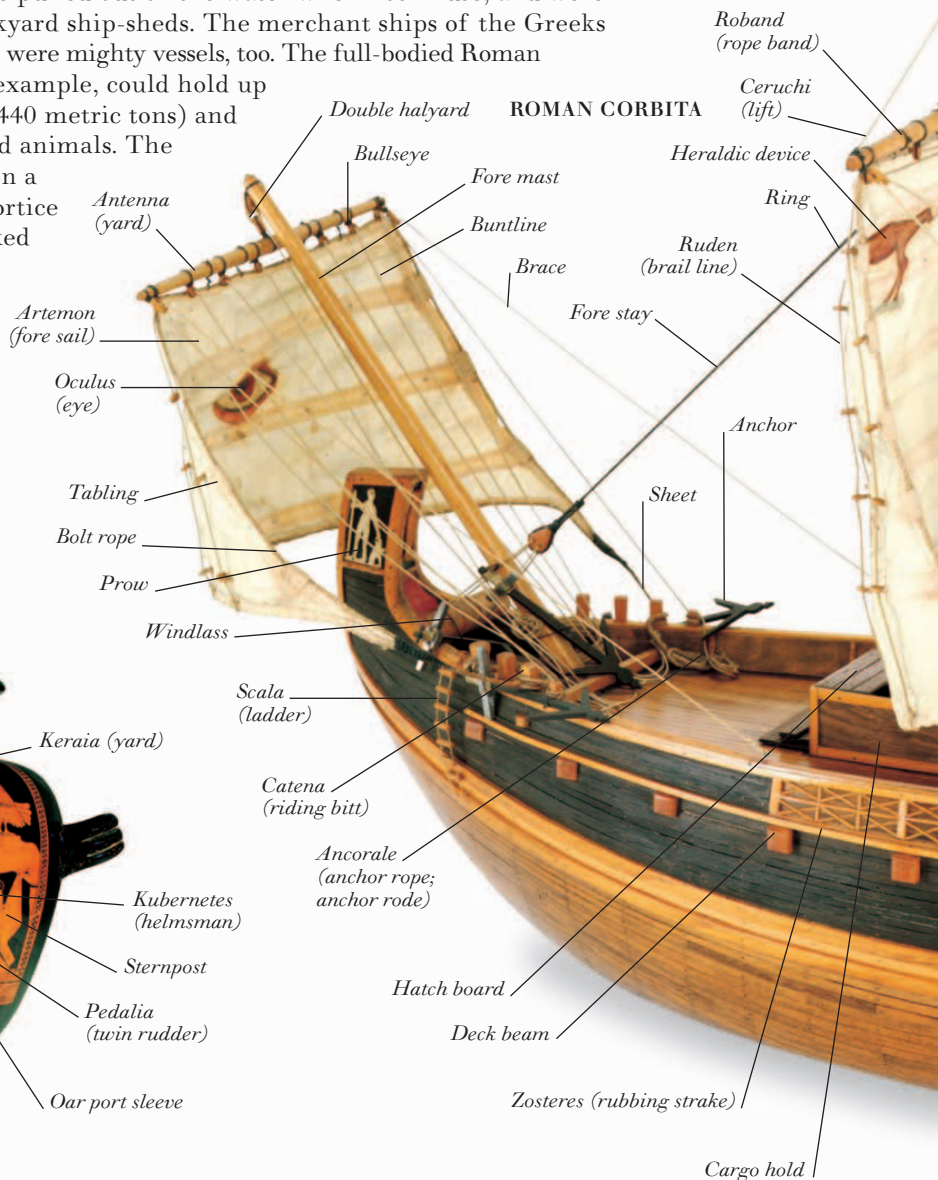
Galleys were pulled out of the water when not in use, and were kept in dockyard ship-sheds. The merchant ships of the Greeks and Romans were mighty vessels, too. The full-bodied Roman corbita, for example, could hold up to 400 tons (440 metric tons) and

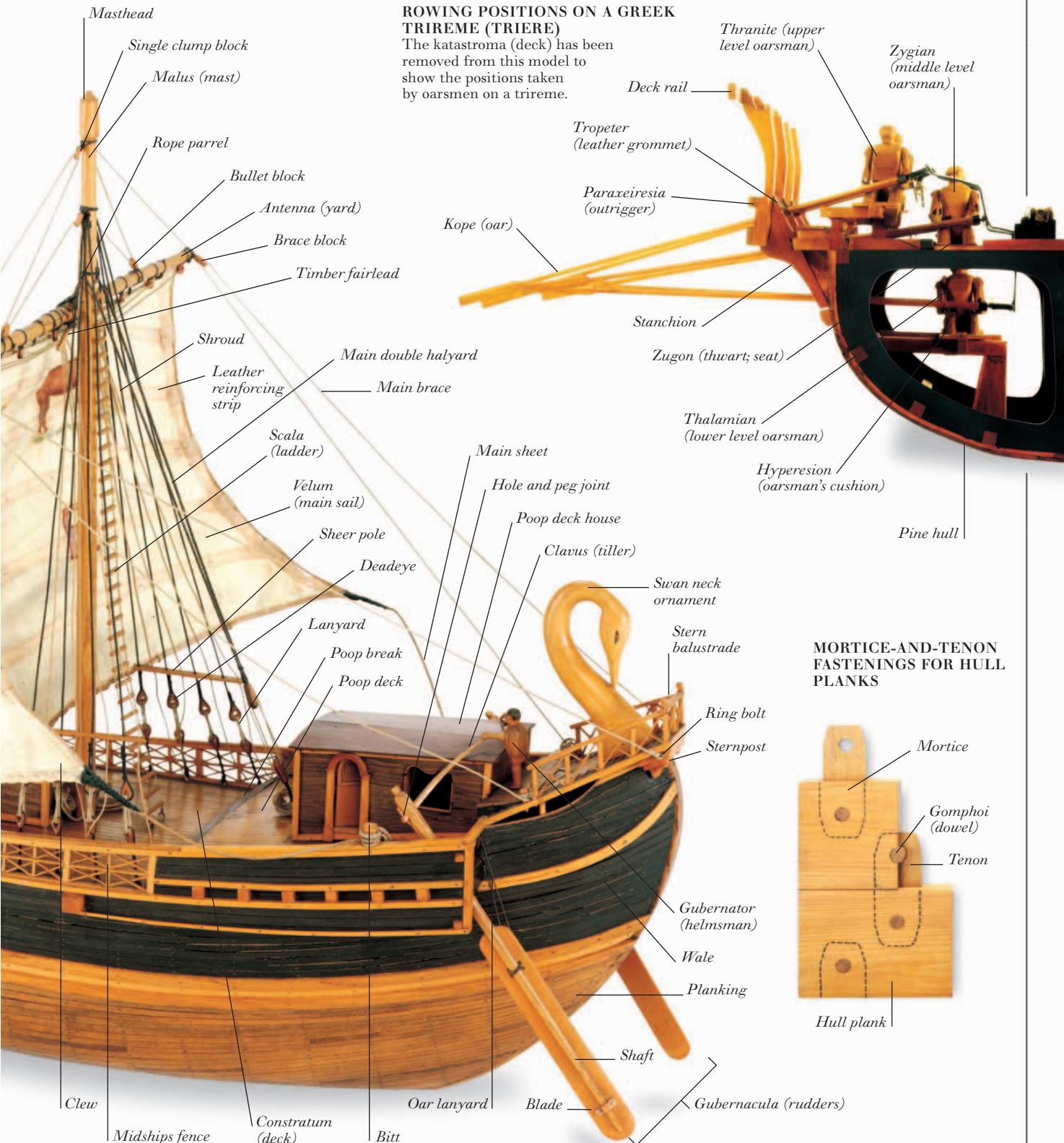
carried a cargo of spices, gems, silk, and animals. The construction of these boats was based on a stout hull with planking secured by mortice and tenon. Some of these ships embarked on long voyages, sailing even as far as India. To make them easier to steer, corbitas set a fore sail called an "artemon." It flew from a forward-leaning mast that was a forerunner of the long bowsprits carried by the great clipper ships of the 19th century.

ATTIC VASE SHOWING A GALLEY



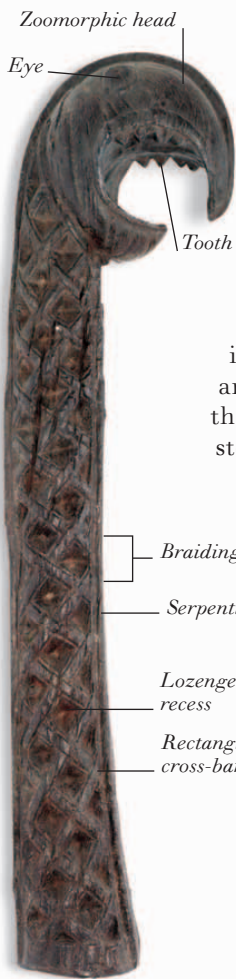
ROMAN CORBITA



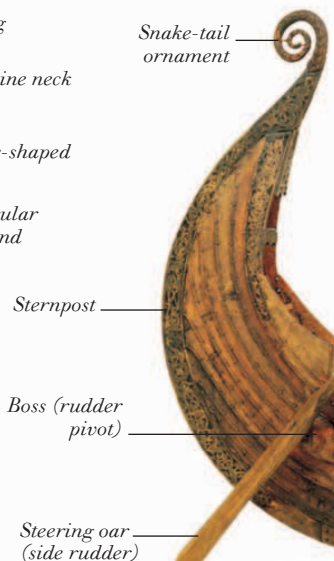


Viking ships

IN THE DARK AGES and early medieval times, the longships of Scandinavia were one of the most feared sights for people of northern Europe. The Vikings launched raids from Scandinavia every summer in longships equipped with a single steering oar on the right, or “steerboard,” side (hence “starboard”). A longship had one row of oars on each side and a single sail. The hull had clinker (overlapping) planks. Prowheads adorned fighting ships during campaigns of war. The sailing longship was also used for local coastal travel. The karv below was probably built as transport for an important family, while the smaller faering (top right) was a rowing boat only. The fleet of William of Normandy that invaded England in 1066 owed much to the Viking boatbuilding tradition, and has been depicted in the Bayeux Tapestry (above). Seals used by port towns and royal courts through the ages provide an excellent record of contemporary ship design. The seal opposite shows how ships changed from the Viking period to the end of the Middle Ages. The introduction of the fighting platform—the castle—and the addition of extra masts and sails changed the character of the medieval ship. Note also that the steering oar has been replaced by a centered rudder.



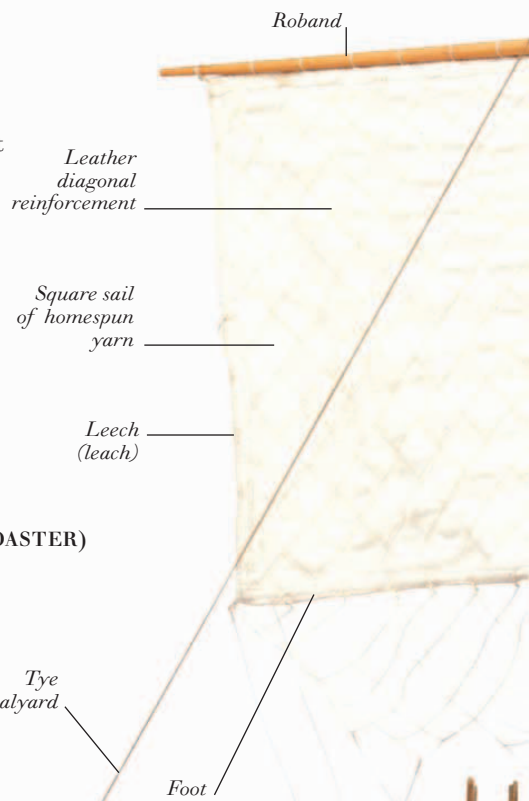
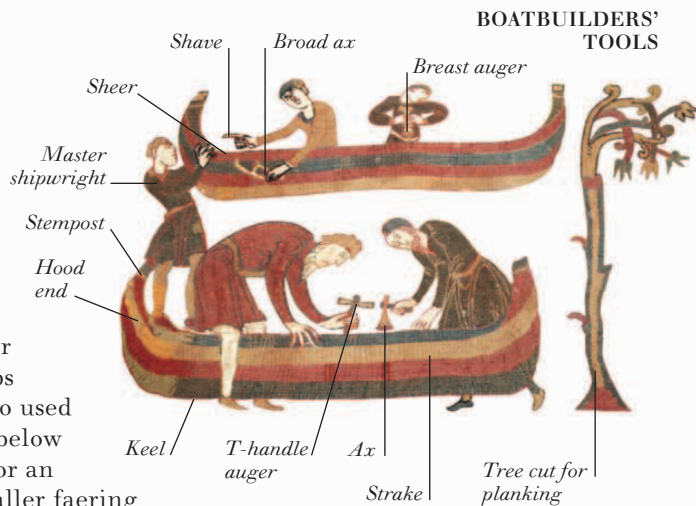
DRAGON PROWHEAD



Oar

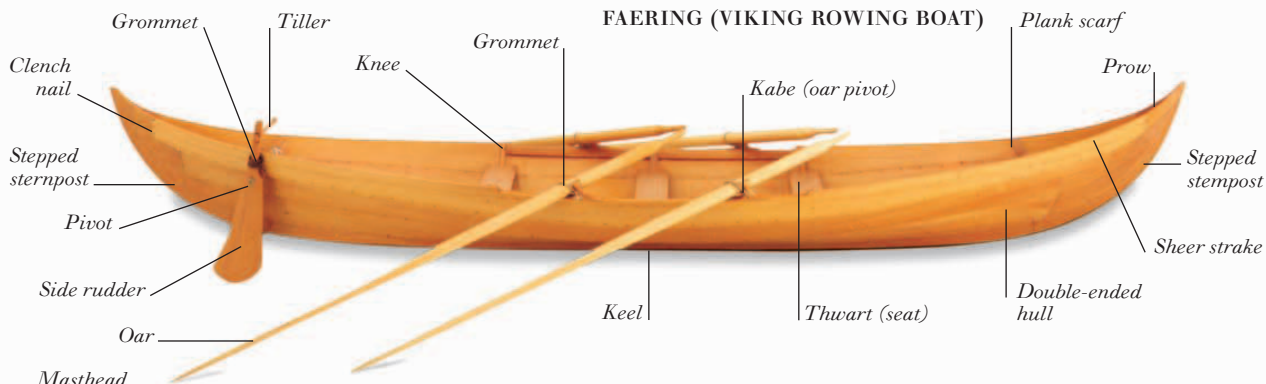
Starboard (steerboard) side

Keel

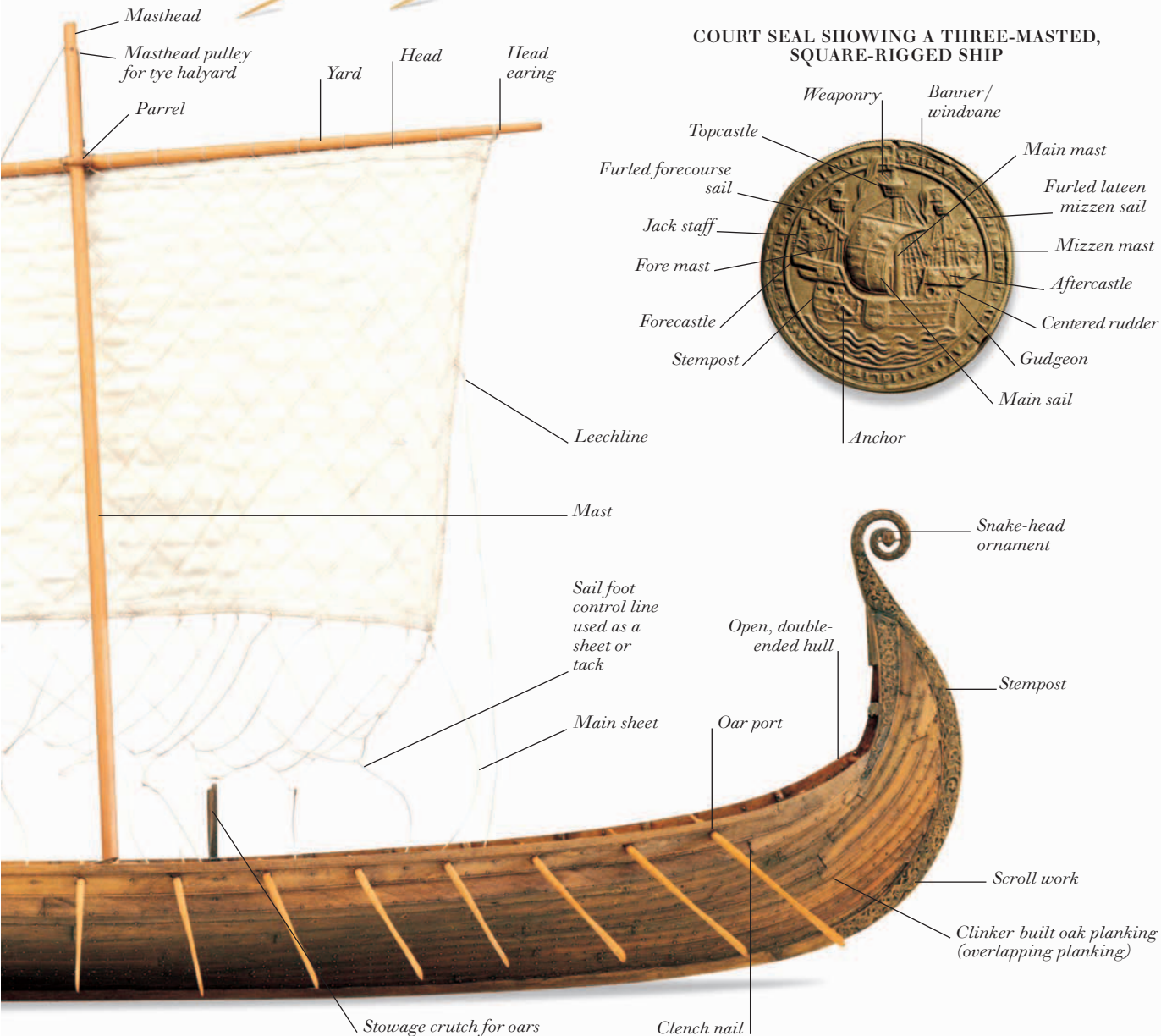
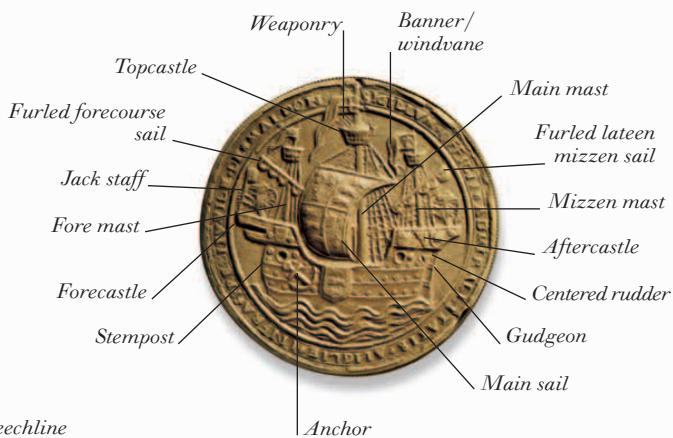


VIKING KARV (COASTER)

Tye halyard



COURT SEAL SHOWING A THREE-MASTED, SQUARE-RIGGED SHIP

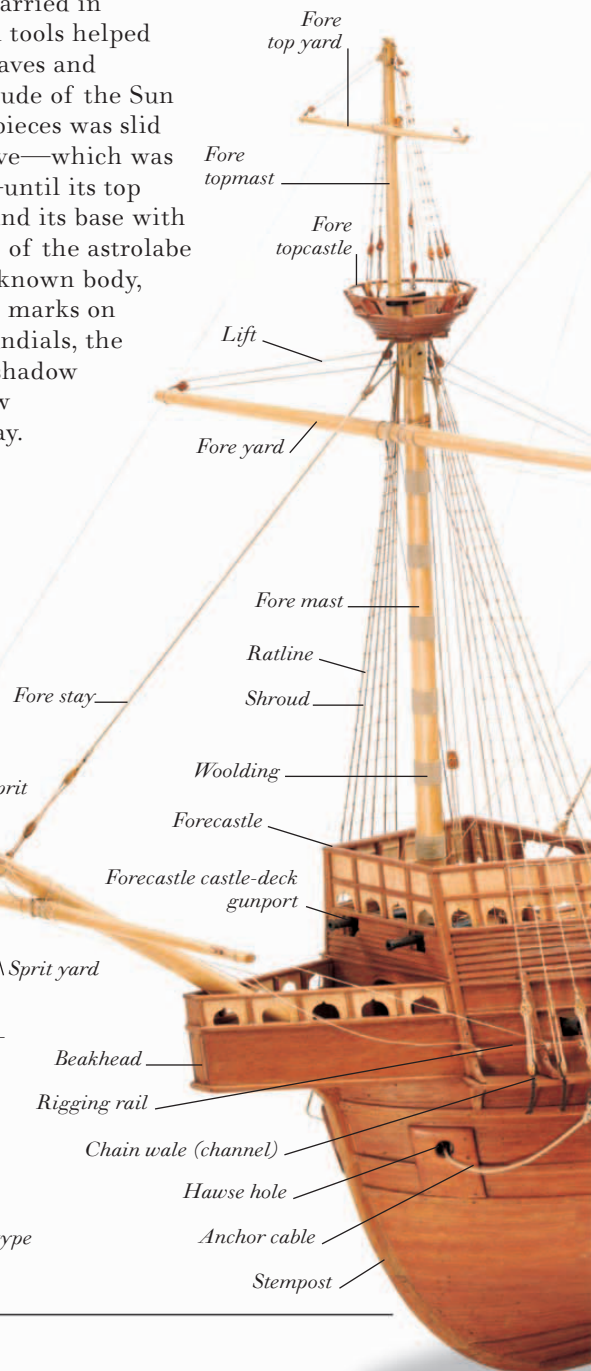
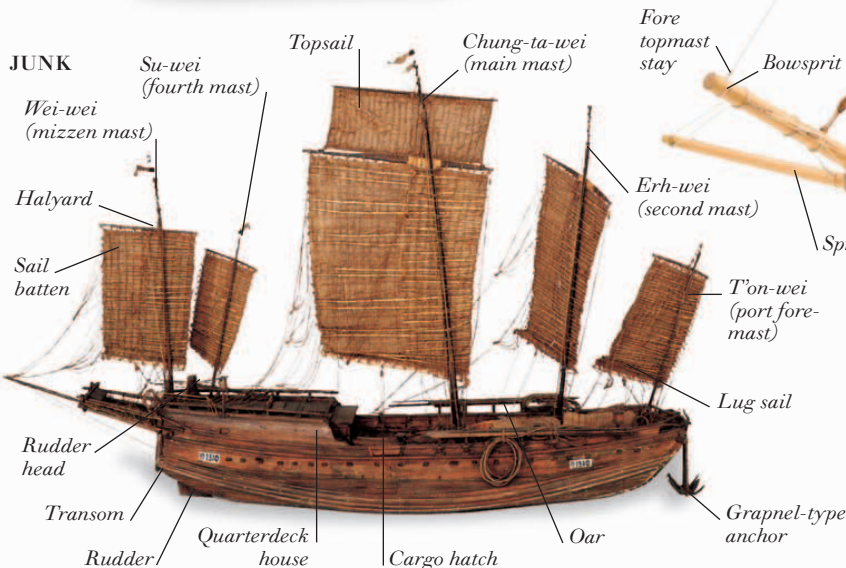
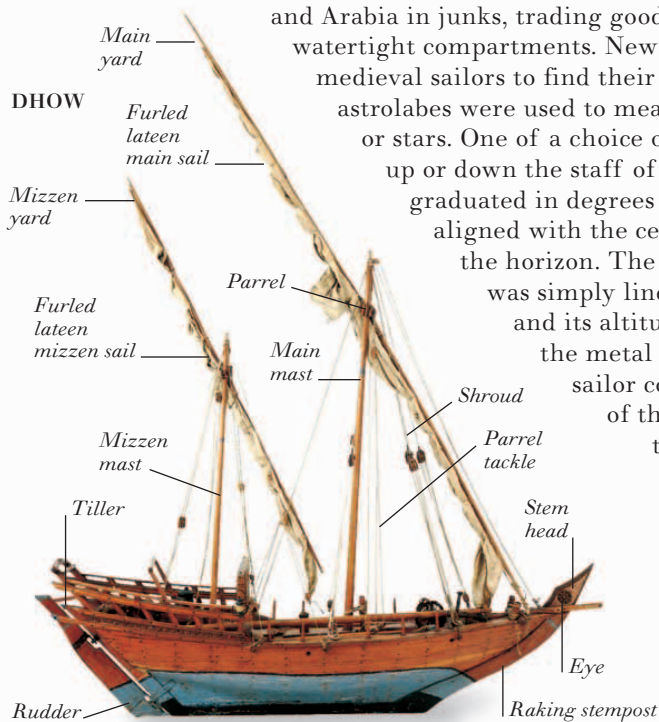


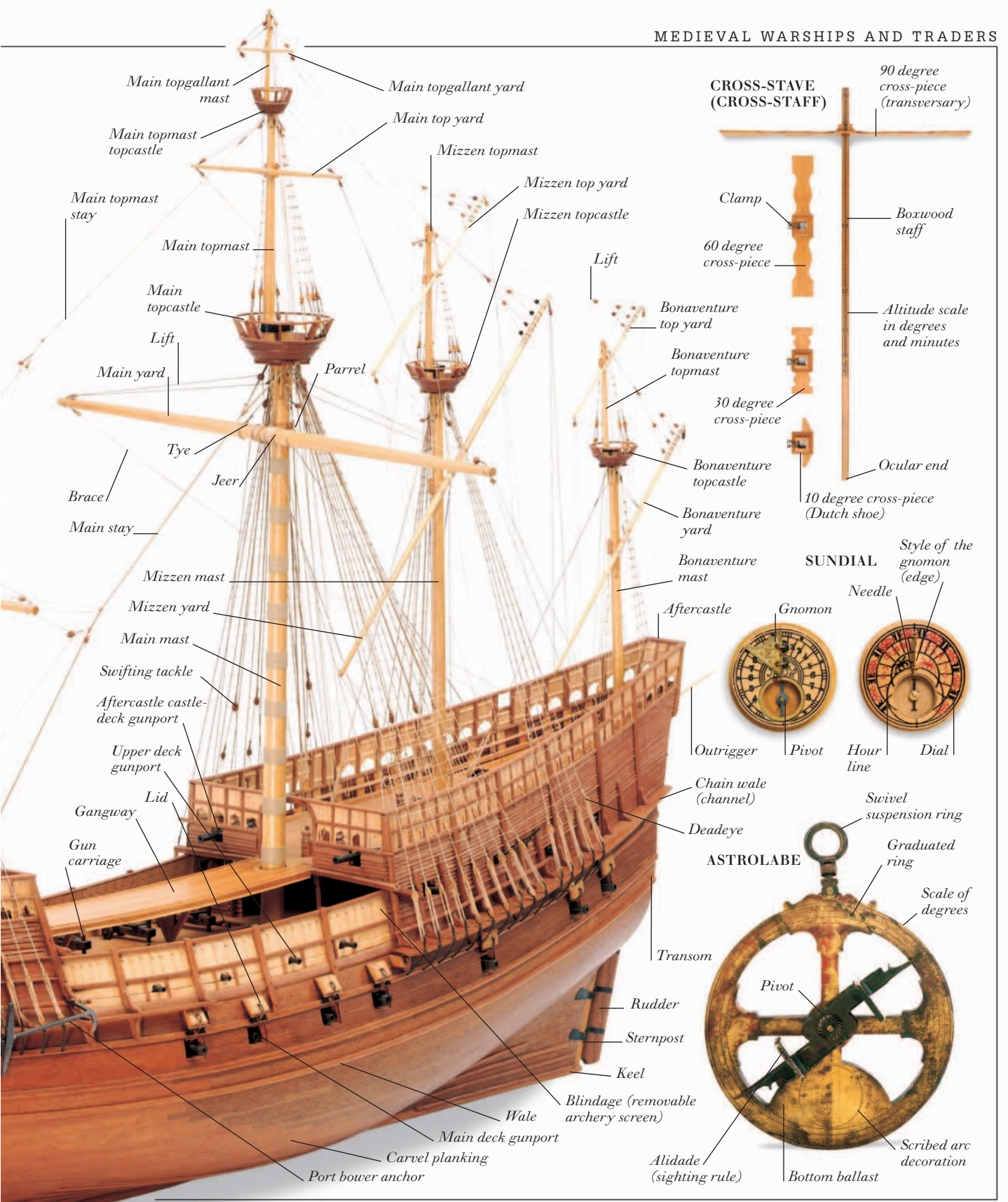
Medieval warships and traders

FROM THE 16TH CENTURY, SHIPS WERE BUILT WITH A NEW FORM OF HULL, constructed from carvel (edge-to-edge) planking. Warships of the time, like King Henry VIII of England's *Mary Rose*, boasted awesome fire power. This ship carried both long-range cannon in bronze, and short-range, anti personnel guns in iron. Elsewhere, ships took on a multiformity of shapes. Dhows transported slaves from East Africa to Arabia, their fore-and-aft rigged lateen sails allowing them to sail close to the wind around the

lands of the Indian Ocean. The Chinese sailed to East Africa and Arabia in junks, trading goods that were carried in watertight compartments. New astronomical tools helped medieval sailors to find their way. Cross-staves and astrolabes were used to measure the altitude of the Sun or stars. One of a choice of four cross-pieces was slid up or down the staff of the cross-stave—which was graduated in degrees of altitude—until its top aligned with the celestial body and its base with the horizon. The sighting rule of the astrolabe was simply lined up with a known body, and its altitude read from marks on the metal disk. With sundials, the sailor could use the shadow of the Sun to show the time of day.

SAILING WARSHIP





Main topgallant mast Main topgallant yard

Main topmast Main top yard

CROSS-STAFF (CROSS-STAFF)
90 degree cross-piece (transversary)

Clamp Boxwood staff

60 degree cross-piece

Altitude scale in degrees and minutes

30 degree cross-piece

10 degree cross-piece (Dutch shoe)

Ocular end

SUNDIAL
Style of the gnomon (edge)

Needle

Gnomon

Hour line Dial

Swivel suspension ring

ASTROLABE
Graduated ring

Scale of degrees

Pivot

Alidade (sighting rule)

Bottom ballast

Main topmast stay

Main topmast

Main topcastle

Lift

Main yard

Parrel

Tye

Jeer

Brace

Main stay

Mizzen mast

Mizzen yard

Main mast

Swiftling tackle

Aftercastle castle-deck gunport

Upper deck gunport

Gangway

Lid

Gun carriage

Carvel planking

Main deck gunport

Port bower anchor

Mizzen topmast

Mizzen top yard

Mizzen topcastle

Lift

Bonaventure top yard

Bonaventure topmast

30 degree cross-piece

Bonaventure topcastle

Bonaventure yard

Bonaventure mast

Aftercastle

Chain wale (channel)

Deadeye

Outrigger

Pivot

Hour line

Chain wale (channel)

Deadeye

Transom

Rudder

Sternpost

Keel

Blindage (removable archery screen)

Wale

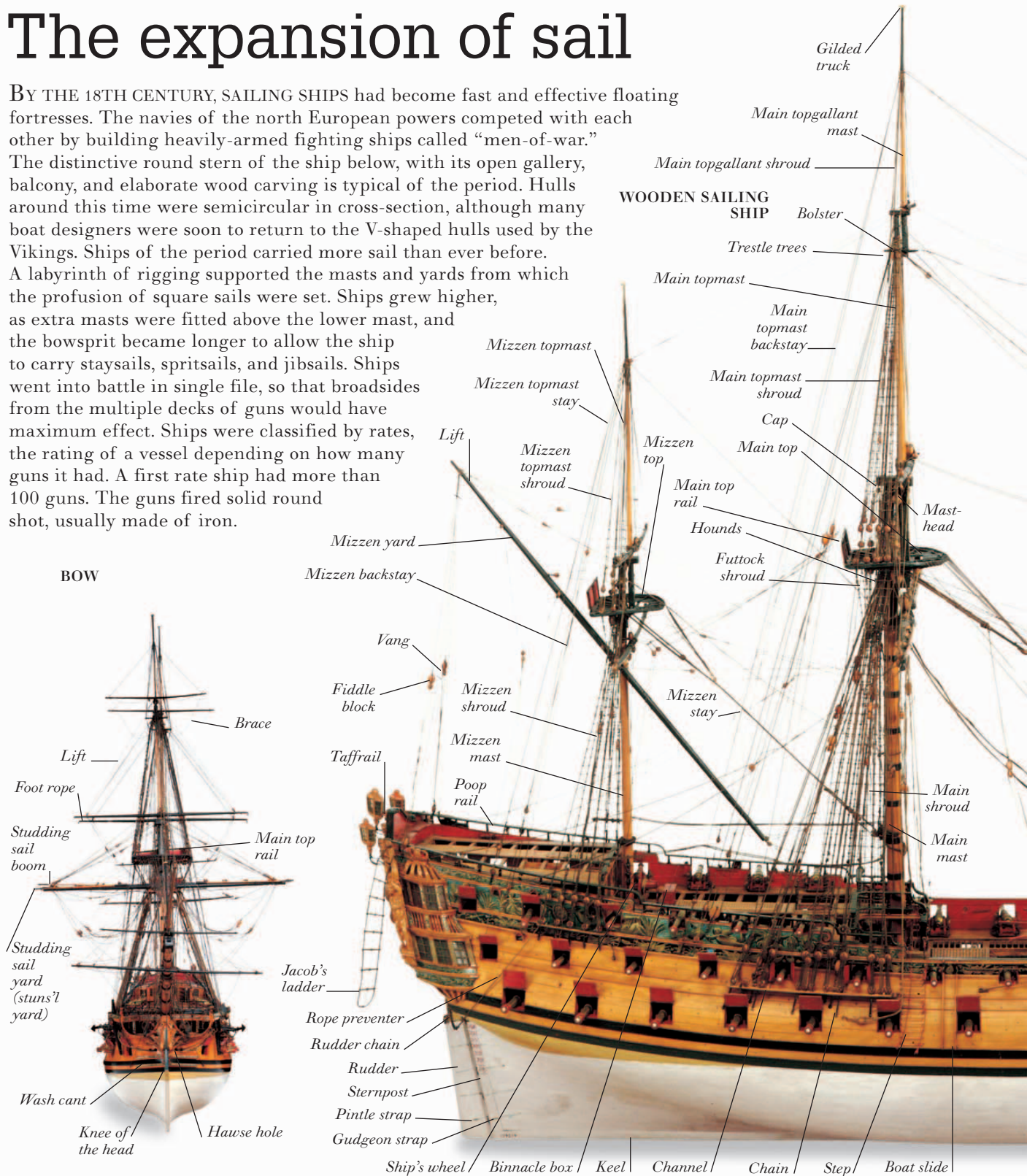
Main deck gunport

Carvel planking

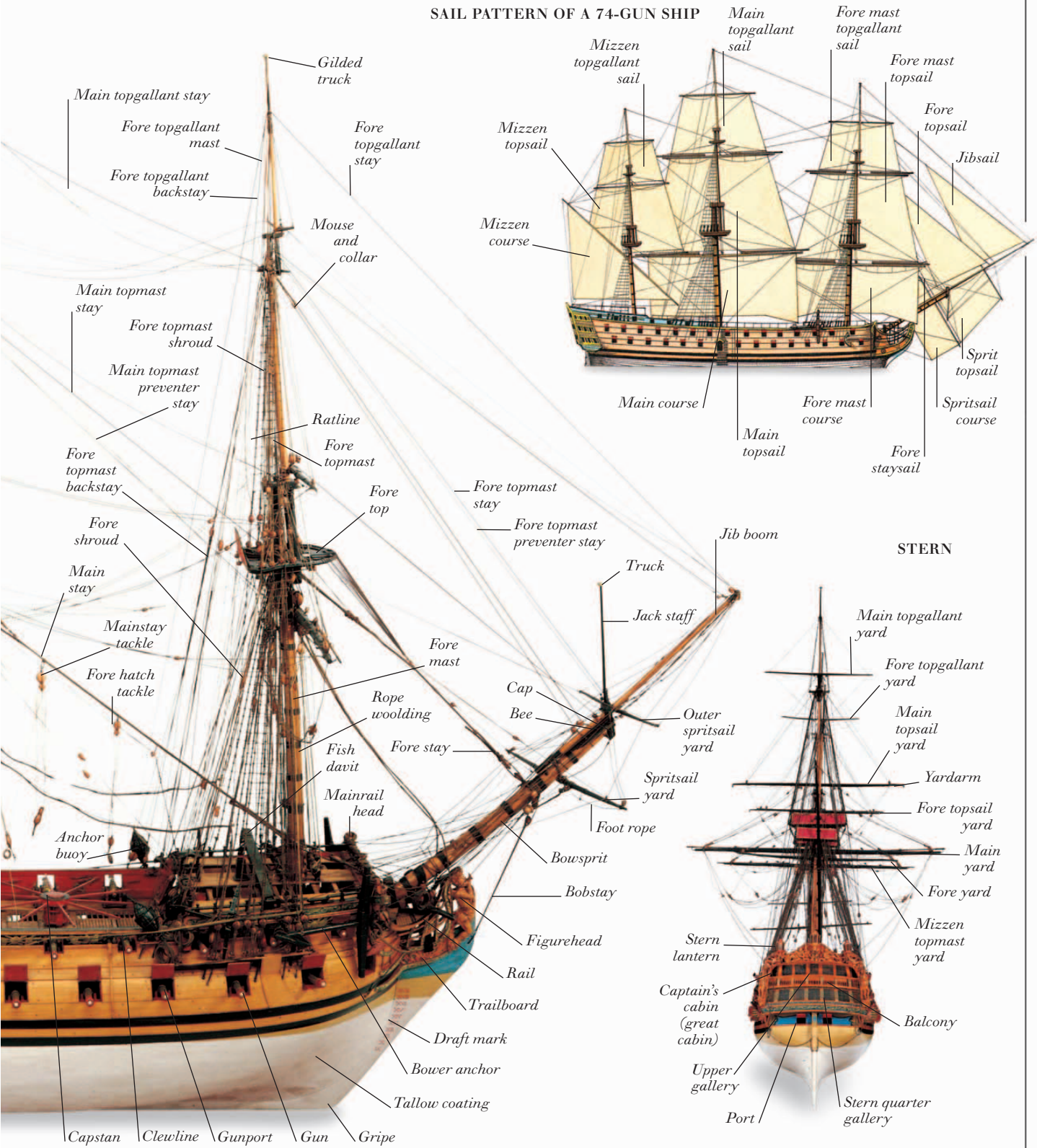
Port bower anchor

The expansion of sail

BY THE 18TH CENTURY, SAILING SHIPS had become fast and effective floating fortresses. The navies of the north European powers competed with each other by building heavily-armed fighting ships called “men-of-war.” The distinctive round stern of the ship below, with its open gallery, balcony, and elaborate wood carving is typical of the period. Hulls around this time were semicircular in cross-section, although many boat designers were soon to return to the V-shaped hulls used by the Vikings. Ships of the period carried more sail than ever before. A labyrinth of rigging supported the masts and yards from which the profusion of square sails were set. Ships grew higher, as extra masts were fitted above the lower mast, and the bowsprit became longer to allow the ship to carry staysails, spritsails, and jibsails. Ships went into battle in single file, so that broadsides from the multiple decks of guns would have maximum effect. Ships were classified by rates, the rating of a vessel depending on how many guns it had. A first rate ship had more than 100 guns. The guns fired solid round shot, usually made of iron.



SAIL PATTERN OF A 74-GUN SHIP



Main topgallant stay
Fore topgallant mast
Fore topgallant backstay

Main topmast stay
Fore topmast shroud
Main topmast preventer stay

Fore topmast backstay

Fore shroud
Main stay

Mainstay tackle
Fore hatch tackle

Anchor buoy

Capstan Clewline Gunport Gun Gripe

Gilded truck
Fore topgallant stay
Mouse and collar

Ratline
Fore topmast
Fore top

Rope woolding
Fish davit
Mainrail head

Bowsprit
Bobstay
Figurehead
Rail
Trailboard
Draft mark
Bower anchor
Tallow coating

Mizzen topsail
Mizzen course

Fore topmast stay
Fore topmast preventer stay

Cap
Bee

Foot rope

Mizzen topgallant sail
Main topgallant sail
Fore mast topgallant sail
Fore mast topsail
Fore topsail
Jibsail
Sprit topsail
Spritsail course
Main course
Fore mast course
Fore staysail

Jib boom

Truck
Jack staff

Outer spritsail yard
Spritsail yard

Stern lantern
Captain's cabin (great cabin)

Upper gallery

Port

STERN

Main topgallant yard
Fore topgallant yard
Main topsail yard
Yardarm
Fore topsail yard
Main yard
Fore yard
Mizzen topmast yard

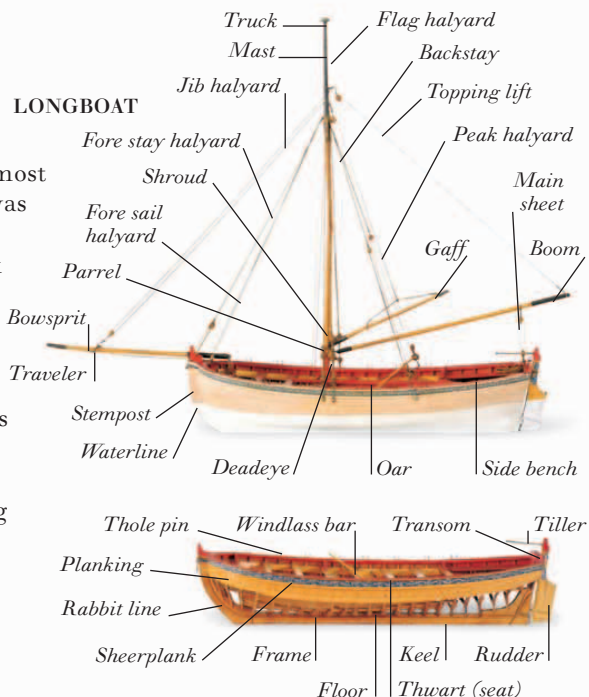
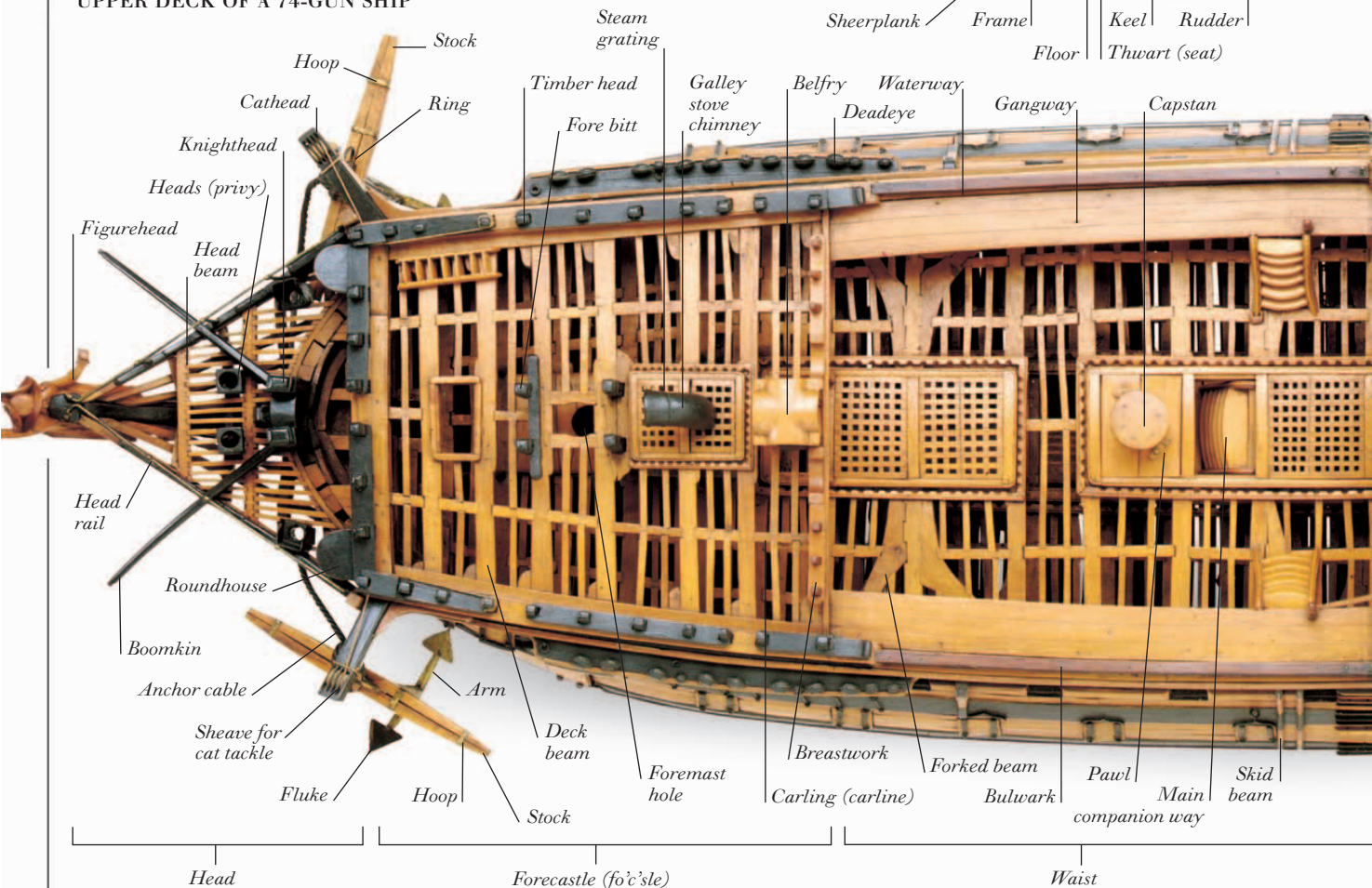
Balcony

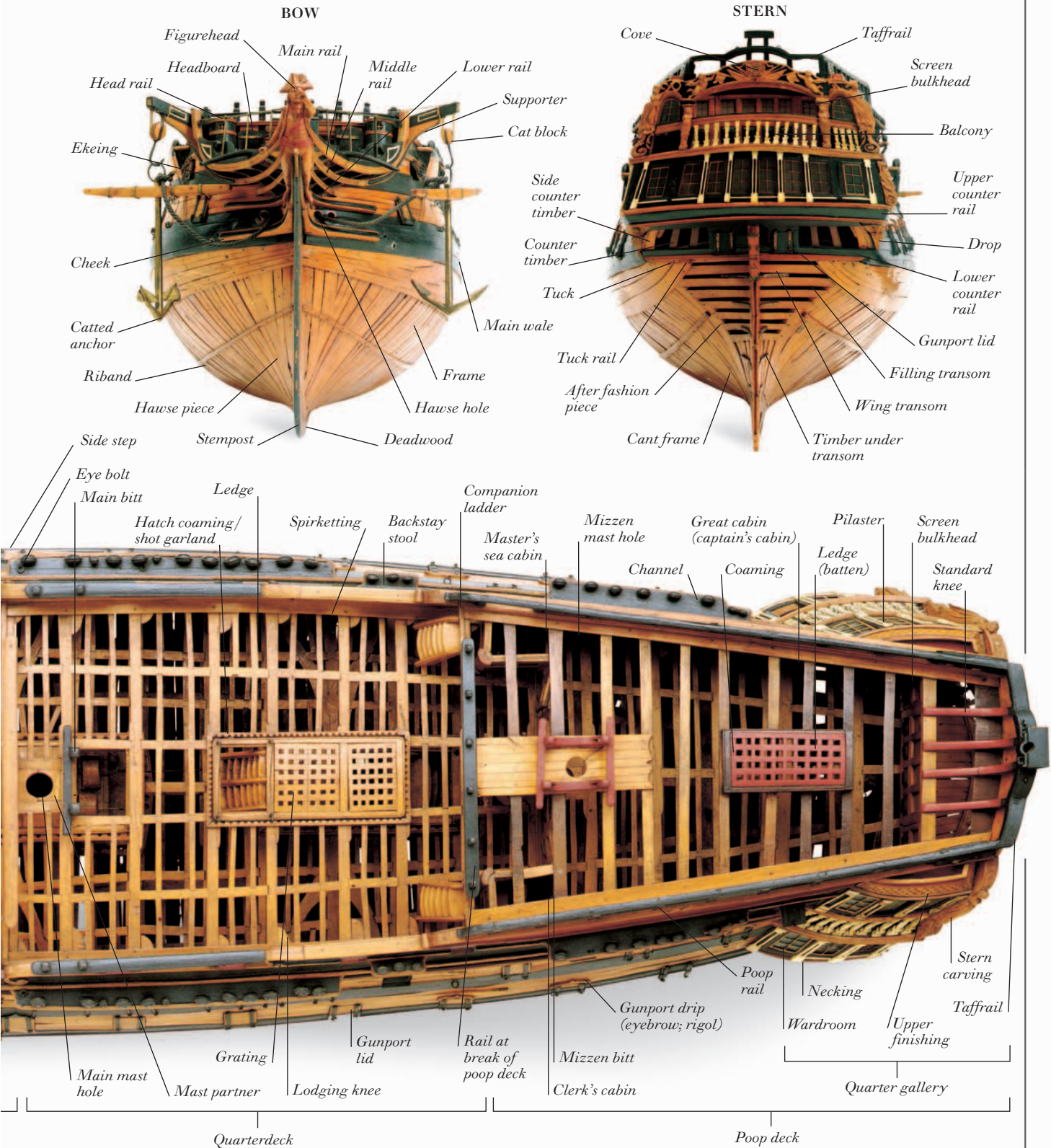
Stern quarter gallery

A ship of the line

THE 74-GUN WOODEN SHIP WAS A MAINSTAY of British and French battlefleets in the late 18th and early 19th centuries. This “ship of the line” was heavy enough to fight with the most potent of rivals, yet nimble, too. The length of such a ship was determined by the number of guns required for each deck, allowing enough room for crews to man them. The gun deck was about 170 ft (52 m) long. The decks had to be very strong to carry the weight of the guns. The deck planks have been removed on the vessel pictured below, to show just how close together the beams had to be to make the hull strong enough. Only timber with a perfect grain was used. The upper deck was open at the waist, but afore and abaft were officers’ cabins. The forecastle and quarterdeck carried light guns and acted as platforms for working rigging and for reconnaissance. The ship’s longboats (launches) were carried on booms between the gangways.

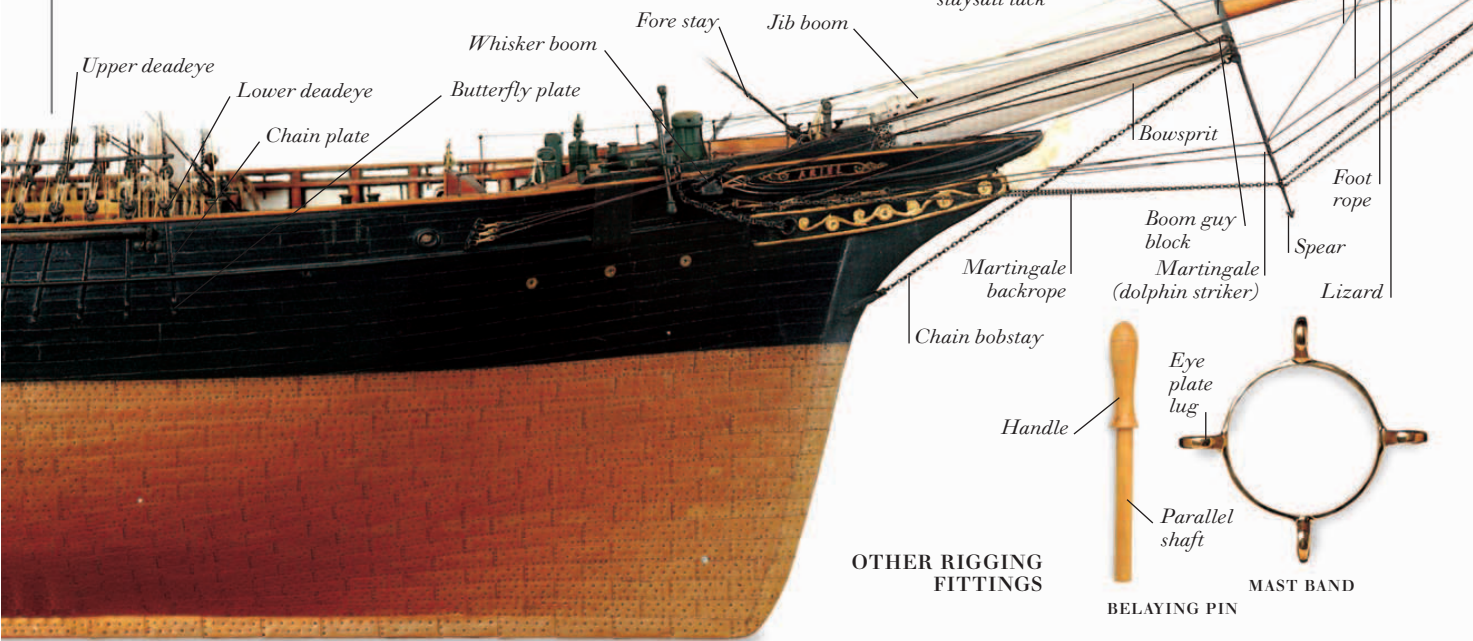
UPPER DECK OF A 74-GUN SHIP





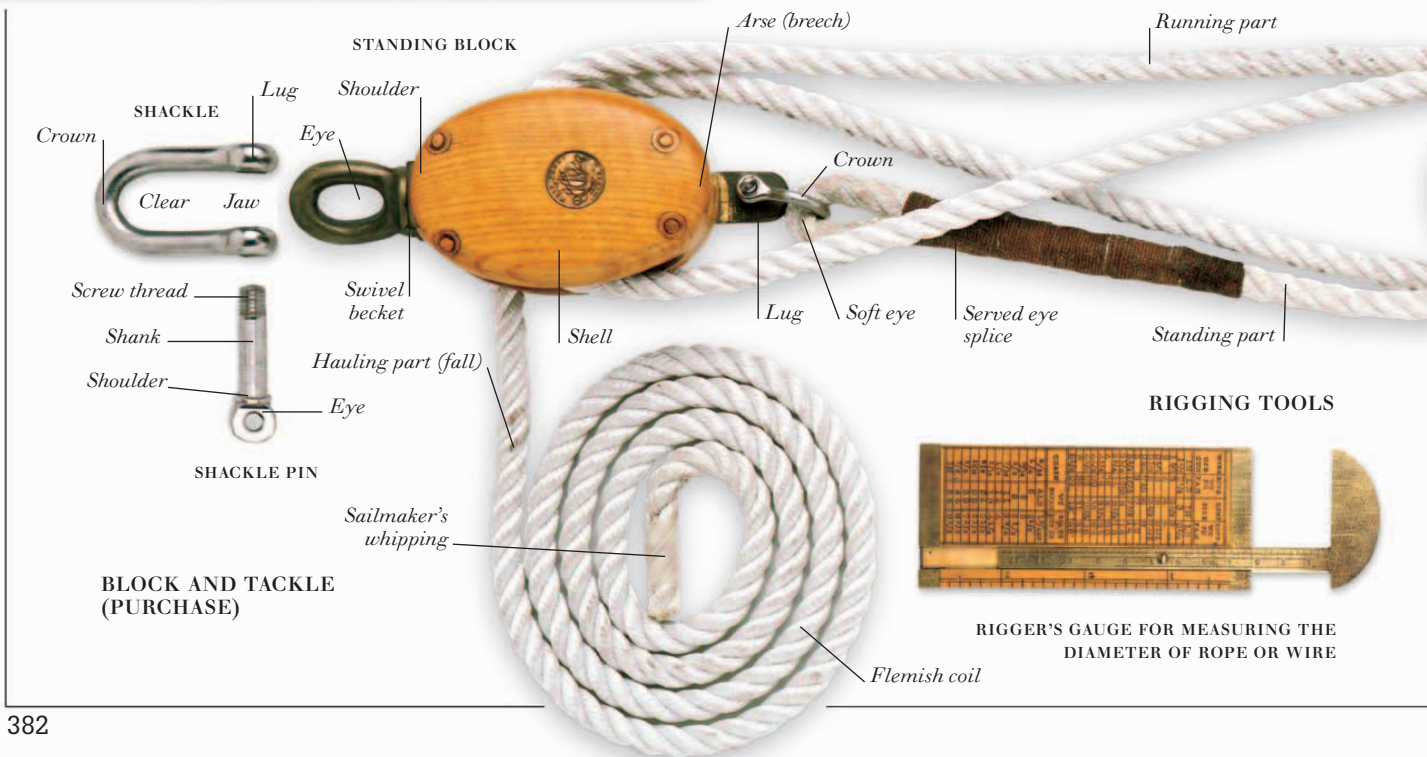
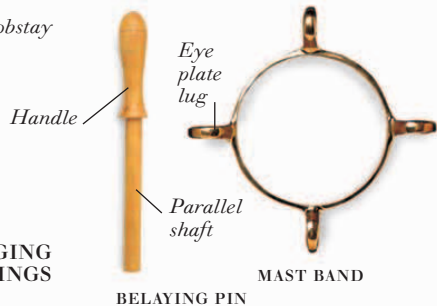
Rigging

MOST SAILING SHIPS HAVE TWO TYPES OF RIGGING. Standing rigging—kept taut by rigging screws or old-fashioned lanyards and deadeyes—refers to the ropes, wires, and chains that support the masts and yards (horizontal spars). Running rigging, which includes types of block and tackle, halyards, and sheets, is used to hoist, lower, or trim sails.



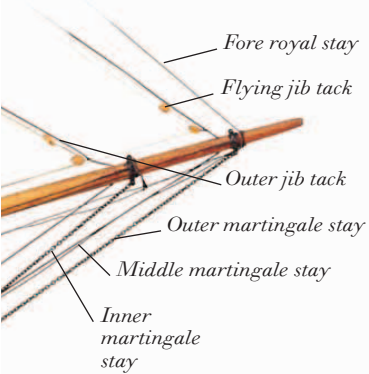
BOWSPRIT AND JIB BOOM

OTHER RIGGING FITTINGS

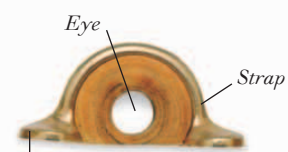


RIGGING TOOLS

RIGGER'S GAUGE FOR MEASURING THE DIAMETER OF ROPE OR WIRE

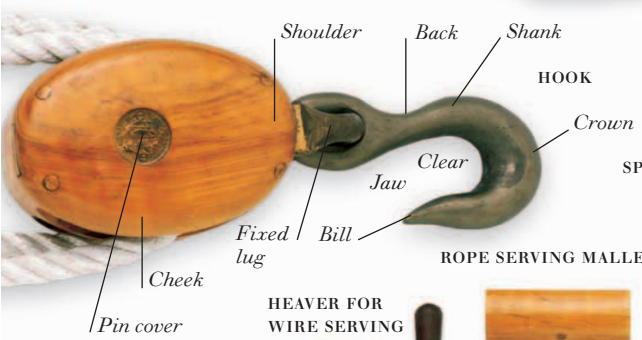


SCORED BULLSEYE FAIRLEAD



SHEET LEAD
Base

RUNNING BLOCK



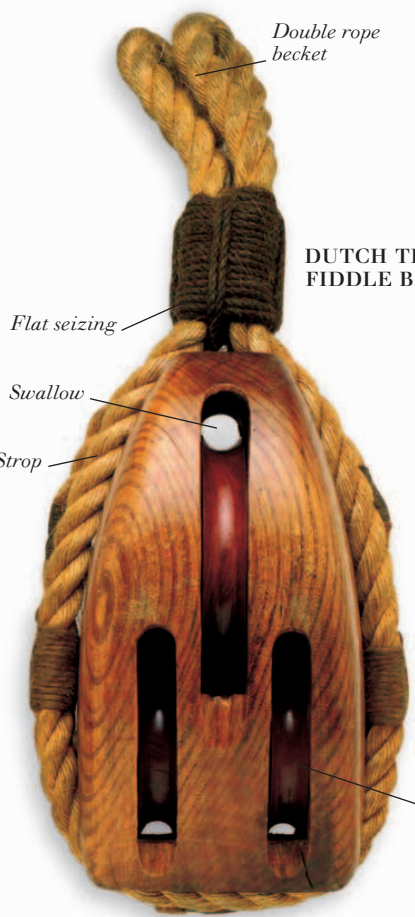
SPLICING FID

ROPE SERVING Mallet

HEAVER FOR WIRE SERVING



HOLLOW SPIKE FOR WIRE



DUTCH TRIPLE FIDDLE BLOCK

LANYARD AND DEADEYES

Leather pointing

Turk's head

Hitched hauling end

UPPER DEADEYE

Swallow

Standing part

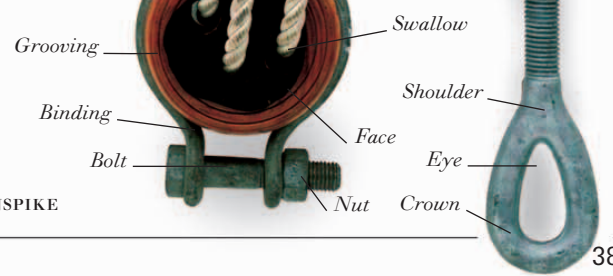
LANYARD

LOWER DEADEYE

Grooving

Binding

Bolt



RIGGING SCREW (TURNBUCKLE)

Shroud

Spun yarn serving

Flat wire seizing

Solid heart thimble

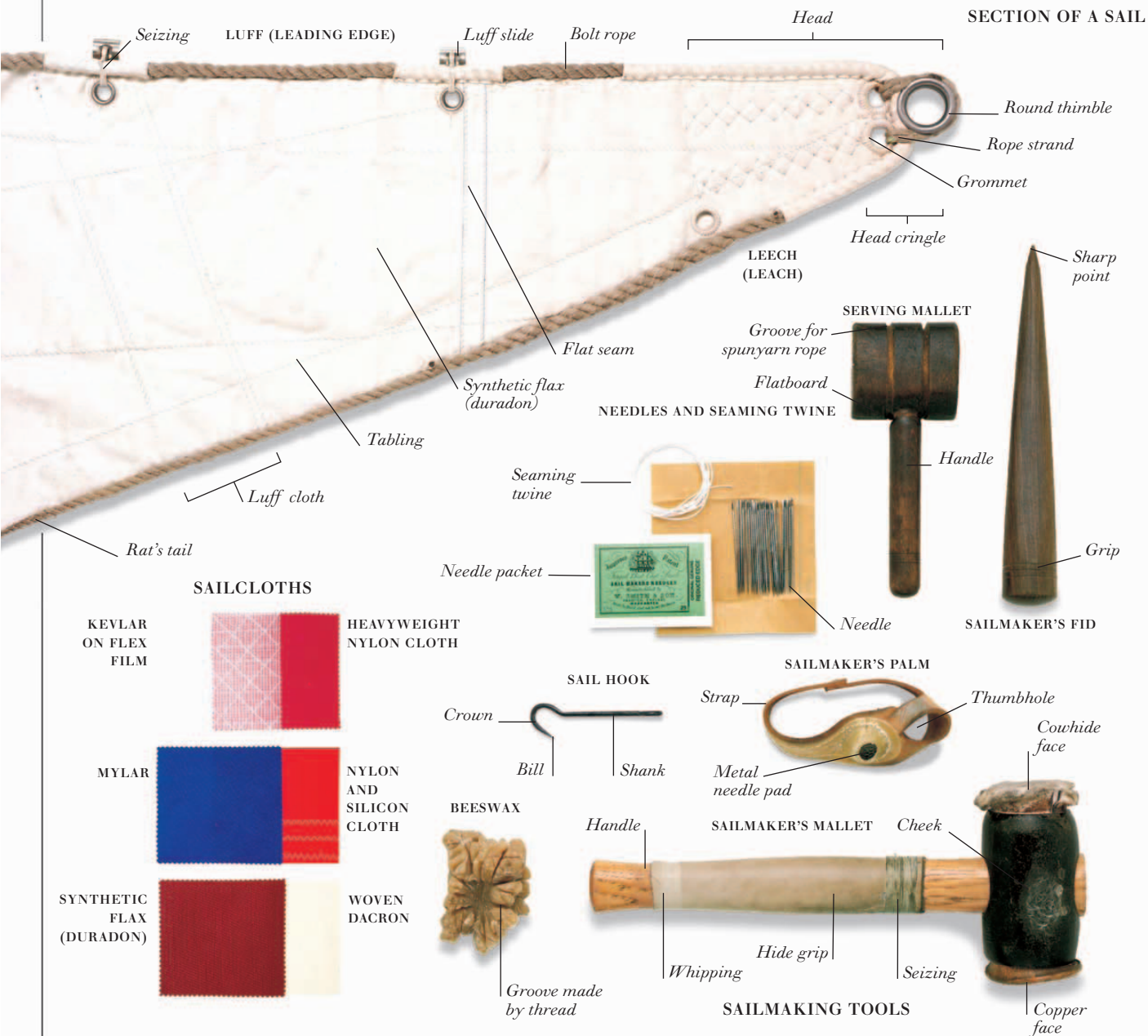
Cotter pin

Fork end

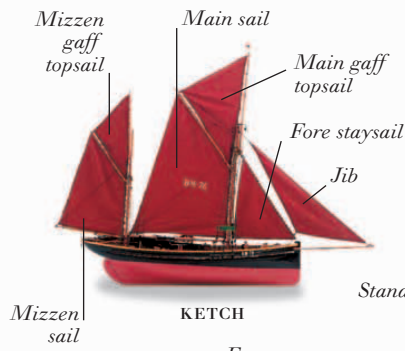
Tail

Sails

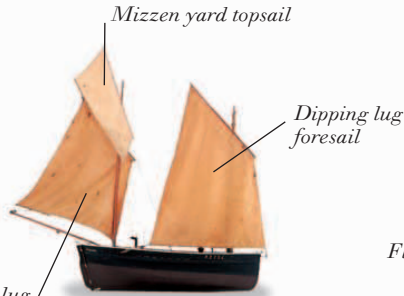
THERE ARE TWO MAIN TYPES OF SAIL, often used in combination. Square sails are driving sails. They are usually attached by parrels to yards, square to the mast to catch the following wind. On fore-and-aft sails, such as lateen and lug sails, the luff (leading edge) usually abuts a mast or a stay. The head of the sail may abut a gaff, and the foot a boom. Around the world, a great range of rigs (sail patterns), such as the ketch, lugger, and schooner, have evolved to suit local needs. Sails are made from strips of cloth, cut to give the sail a belly and strong enough to resist the most violent of winds. Cotton and flax are the traditional sail materials, but synthetic fabrics are now commonly used.



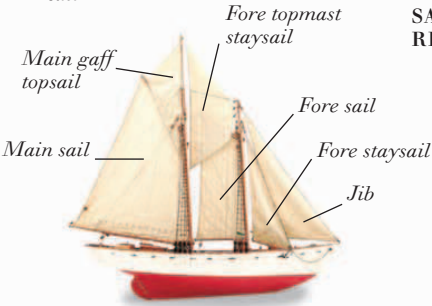
SAILS AND RUNNING RIGGING OF A DOUBLE TOPSAIL SCHOONER



KETCH

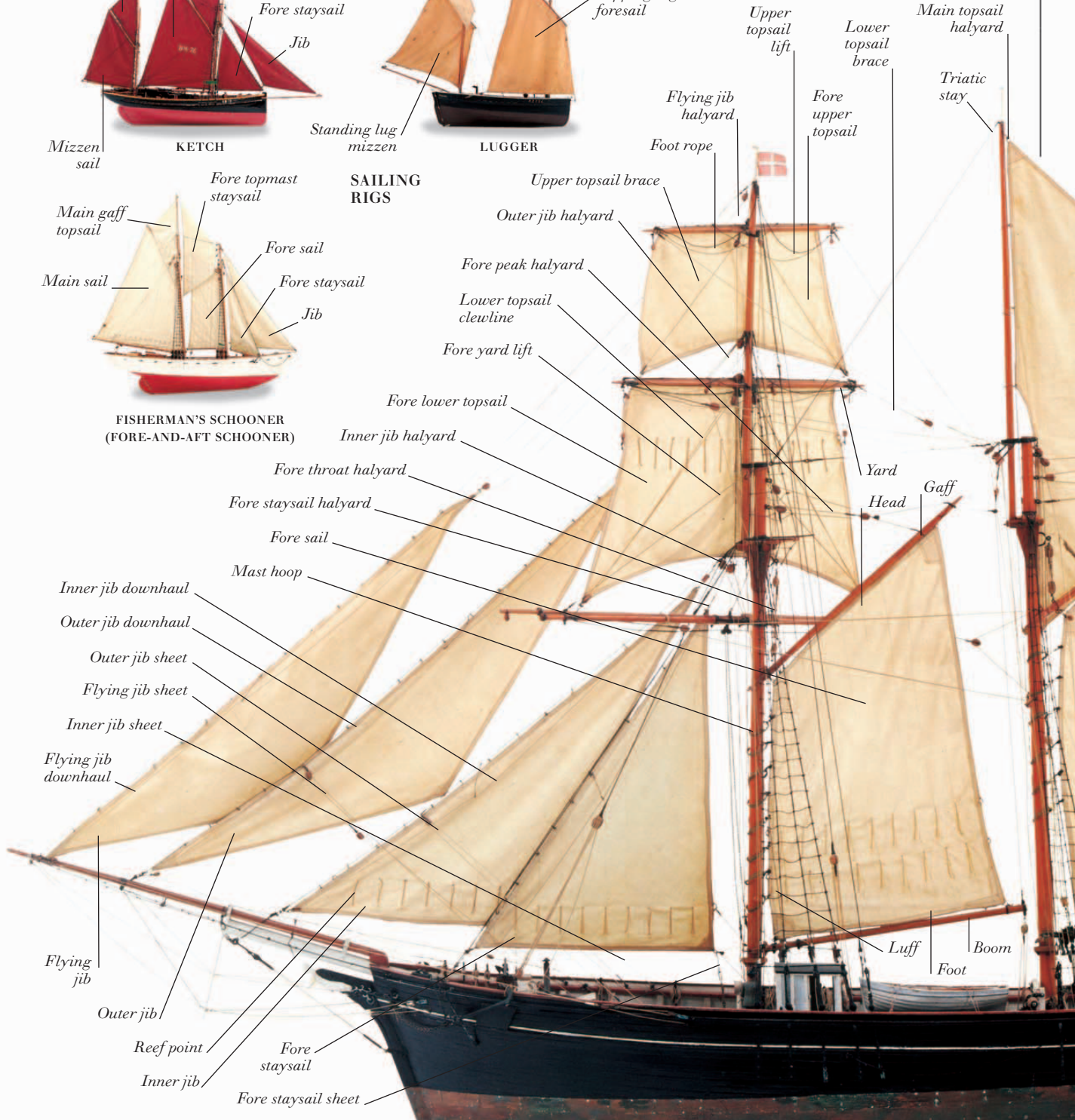


LUGGER



FISHERMAN'S SCHOONER (FORE-AND-AFT SCHOONER)

SAILING RIGS



Mooring and anchoring

FOR LARGE VESSELS IN OPEN WATER, ANCHORAGE IS ESSENTIAL. By holding a ship securely to the seabed, an anchor prevents the vessel from being at the mercy of wave, tide, and current. The earliest anchors were nothing more than stones. In later years, many anchors had a standard design, much like the Admiralty pattern anchor shown on this page. The Danforth anchor is somewhat different.

STONE ANCHOR (KILLICK)



TYPES OF ANCHOR

It has particularly deep flukes to give it great holding power. On large sailing ships, anchors were worked by teams of sailors.

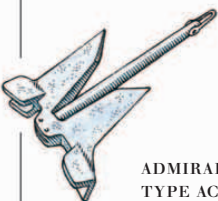
They turned the drum of a capstan by pushing on bars slotted into the revolving cylinder. This, in turn, lifted or lowered the anchor chain. In calm harbors and estuaries, ships can moor (make fast) without using anchors. Berthing ropes can be attached to bollards both inboard and on the quayside. Berthing ropes are joined to each other by bends, like those opposite.



CLOSE-STOWING ANCHOR



CQR ANCHOR (SECURE ANCHOR; PLOW ANCHOR)



ADMIRALTY ANCHOR TYPE ACH



ADMIRALTY PATTERN ANCHOR



STOCKLESS ANCHOR



MUSHROOM ANCHOR (PERMANENT MOORING ANCHOR)



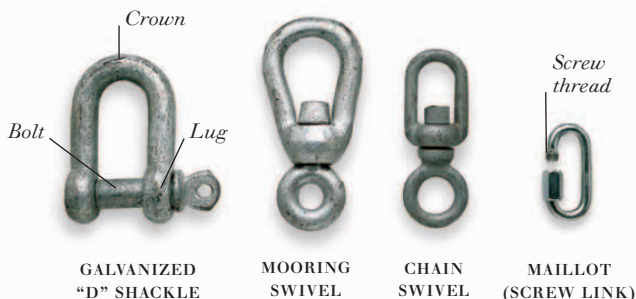
End link

ANCHOR CHAIN

Common link

Patent link

SHACKLE, SWIVELS, AND LINK



Crown

Bolt

Lug

GALVANIZED "D" SHACKLE

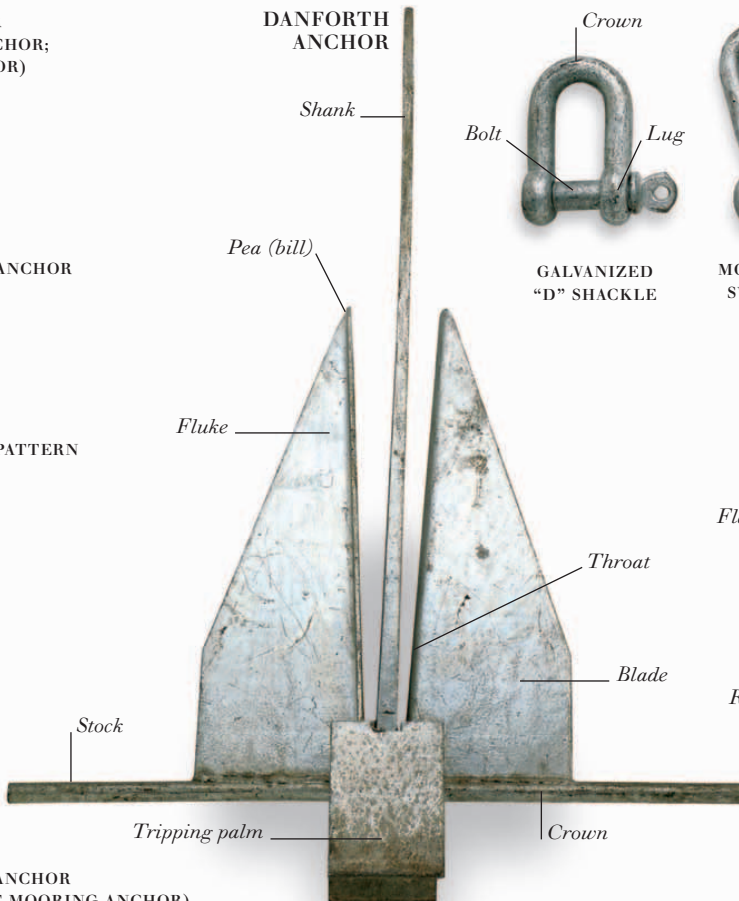
MOORING SWIVEL

CHAIN SWIVEL

MAILLET (SCREW LINK)

Screw thread

DANFORTH ANCHOR



Shank

Pea (bill)

Fluke

Throat

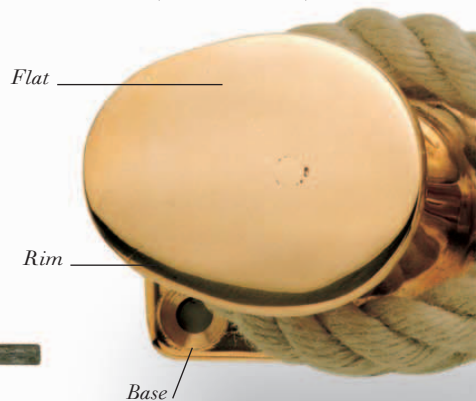
Blade

Stock

Tripping palm

Crown

TWIN BOLLARDS WITH RAKED PILLARS AND A HAWSER (HEAVY ROPE)

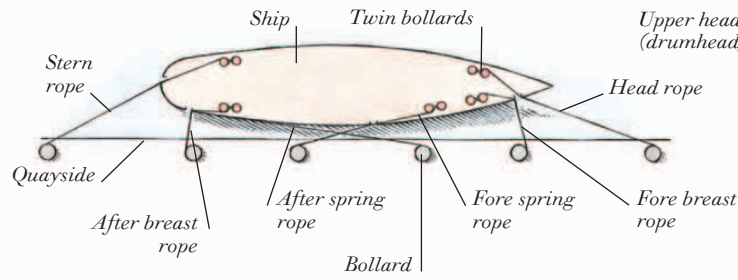


Flat

Rim

Base

BERTHING ROPES (HAWSERS)



MOORING ROPE BENDS

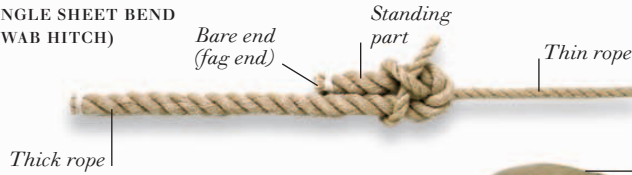
HAWSER BEND
(TWO DOUBLE ROUND TURNS AND DOUBLE HALF HITCHES)



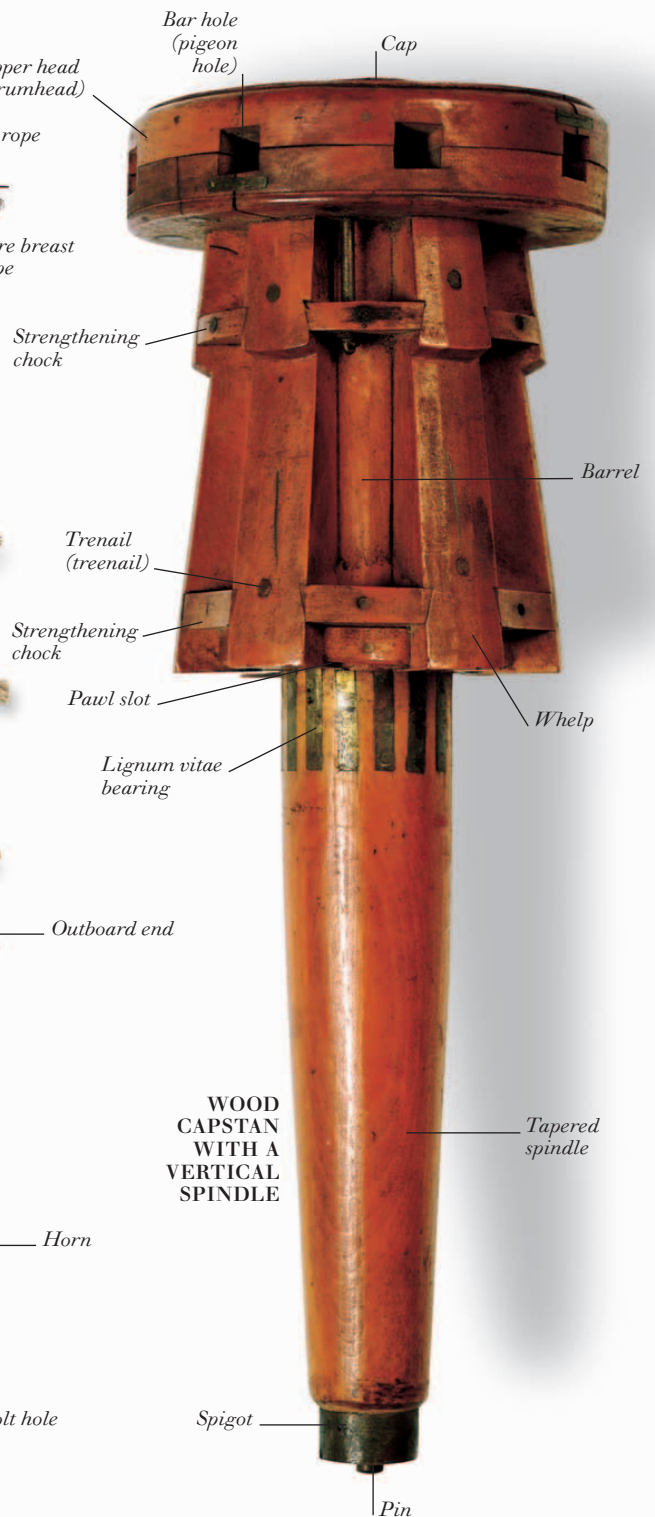
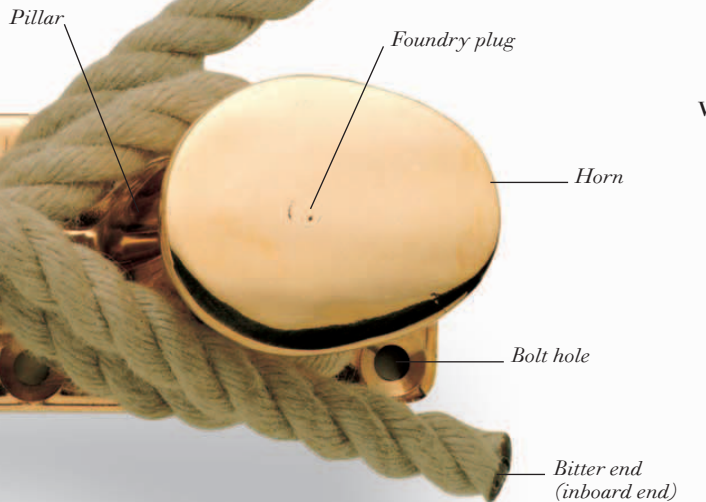
CARRICK BEND



SINGLE SHEET BEND
(SWAB HITCH)



Three-strand hawser
belayed with
figure-eight
turns

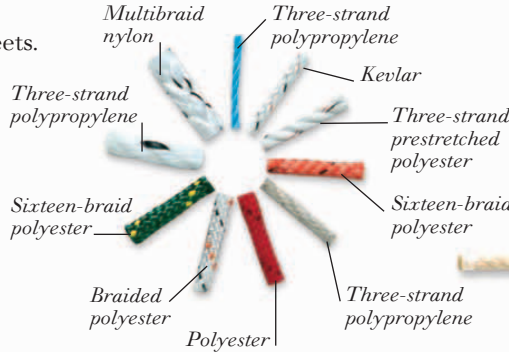


Ropes and knots

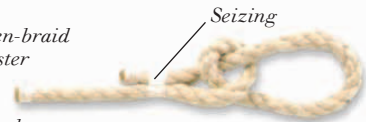
ALL KINDS OF ROPES ARE USED AT SEA, from thin twines and yarns to thick hawsers. Synthetic fibers have been developed specifically for use at sea. Nylon ropes stretch, and so are ideal for anchoring; polyester (frequently called by the trade name Dacron) has little stretch, so is ideal for halyards and sheets. Different knots have different uses. Knots that join two ropes are called bends; hitches join a rope to another object; and bowlines produce an eye (loop) in the end of a rope. Ropes can be joined by splicing (unraveling the ends and weaving them together) or seizing (lashing the ropes together side by side).

ROPEWORK

SYNTHETIC ROPES



FRENCH BOWLINE (PORTUGUESE BOWLINE)



HALF HITCH WITH SEIZING



HUNTER'S BEND



MARLINSPIKE HITCH



BOWLINE



REEF KNOT (SQUARE KNOT)



Eye

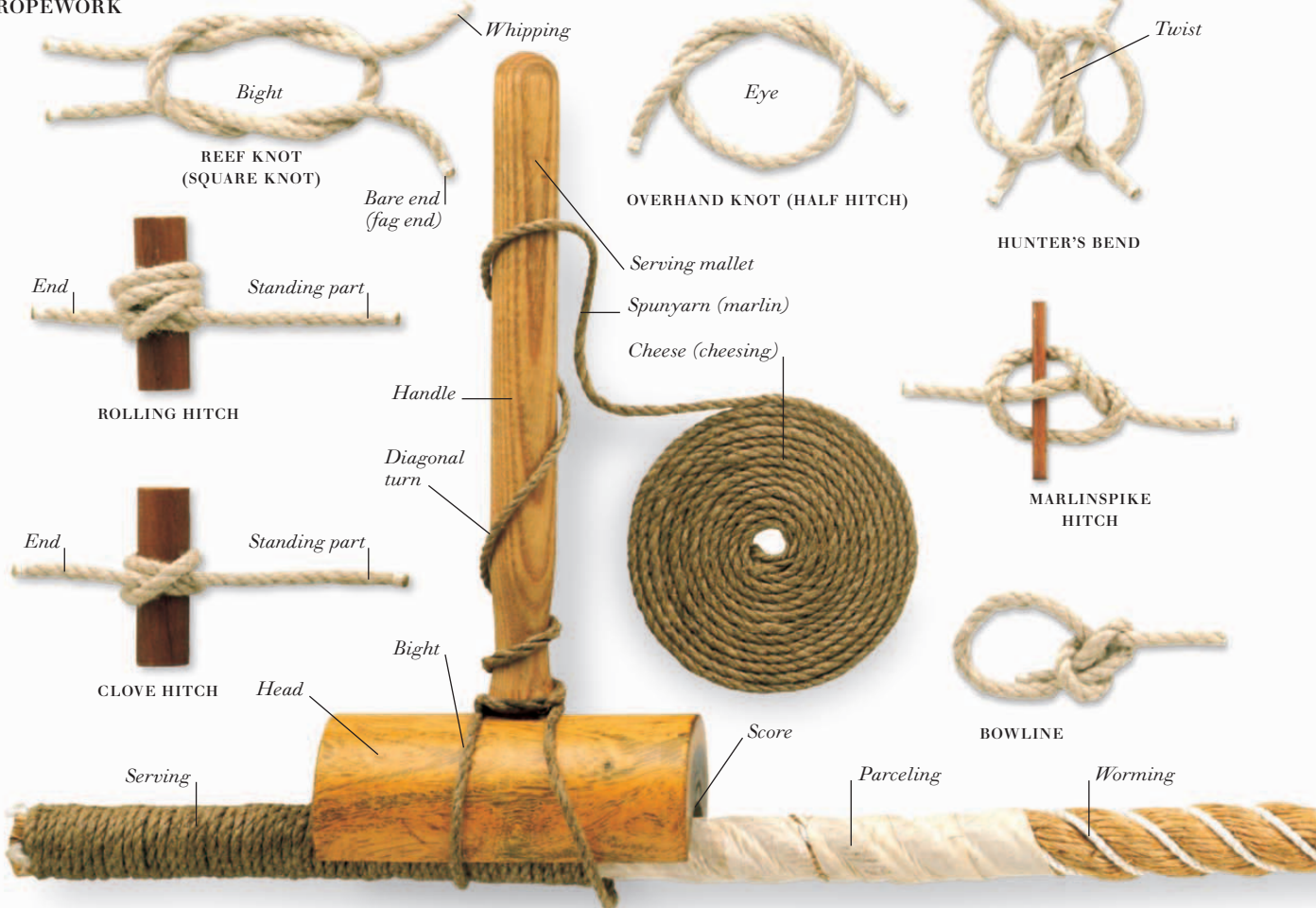
OVERHAND KNOT (HALF HITCH)



ROLLING HITCH



CLOVE HITCH



WORMING, PARCELING, AND SERVING



THUMB KNOT



SPANISH BOWLINE



FLAT SEIZING
(ROUND SEIZING)



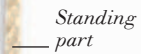
DOUBLE CARRICK BEND



LIGHTERMAN'S HITCH



JURY MAST KNOT
(MAST HEAD BEND)



SHEET BEND (SWAB HITCH)



HEAVING LINE BEND



MANHARNNESS KNOT
(BUTTERFLY KNOT;
ARTILLERY LOOP)



Flemish coil (*cheesing*)

HEAVING LINE



PINNED SHEEPSHANK



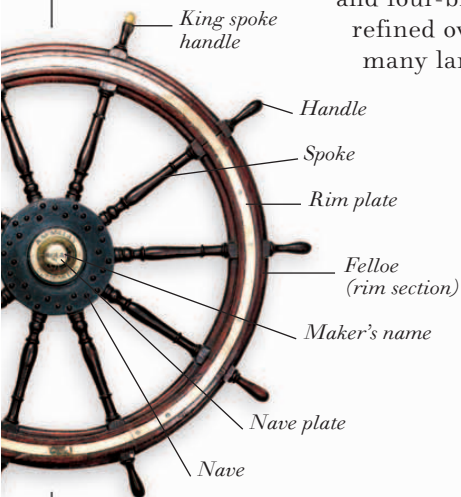
Hawser laid three-strand manilla rope with right-handed lay



Paddle wheels and propellers

THE INVENTION OF THE STEAM ENGINE IN THE 18TH CENTURY made mechanically driven ships fitted with paddle wheels or propellers a viable alternative to sails. Paddle wheels have fixed or feathered floats, and the model shown below features both types. Feathered floats give more propulsive power than fixed floats because they are almost upright at all times in the water. Paddle wheels were superseded by the propeller on oceangoing vessels in the mid-19th century. Propellers are more efficient, work better in rough water, and are less vulnerable in collisions. The first propellers were two-bladed but later three- and four-bladed versions are more powerful; the shape and pitch of blades have also been refined over the years. At the beginning of the 18th century, tillers were superseded on many larger ships by the ship's wheel as a means of steering.

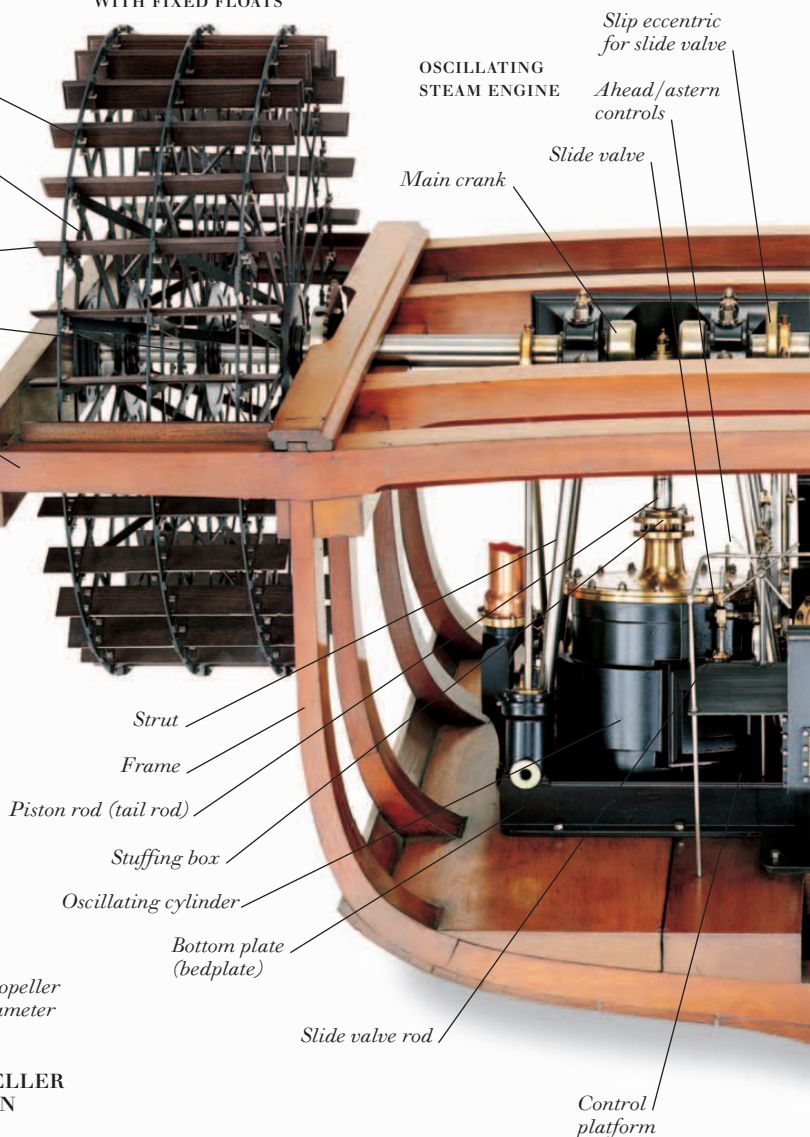
SHIP'S WHEEL



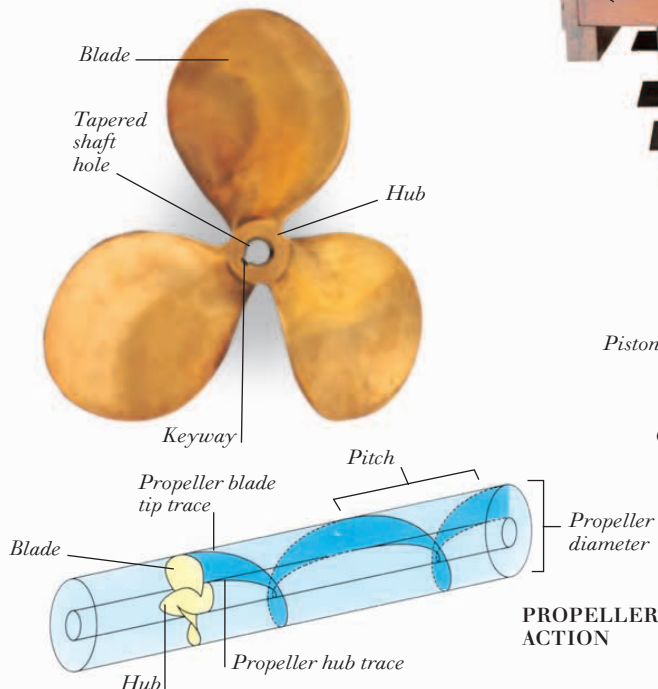
PADDLE WHEEL WITH FIXED FLOATS



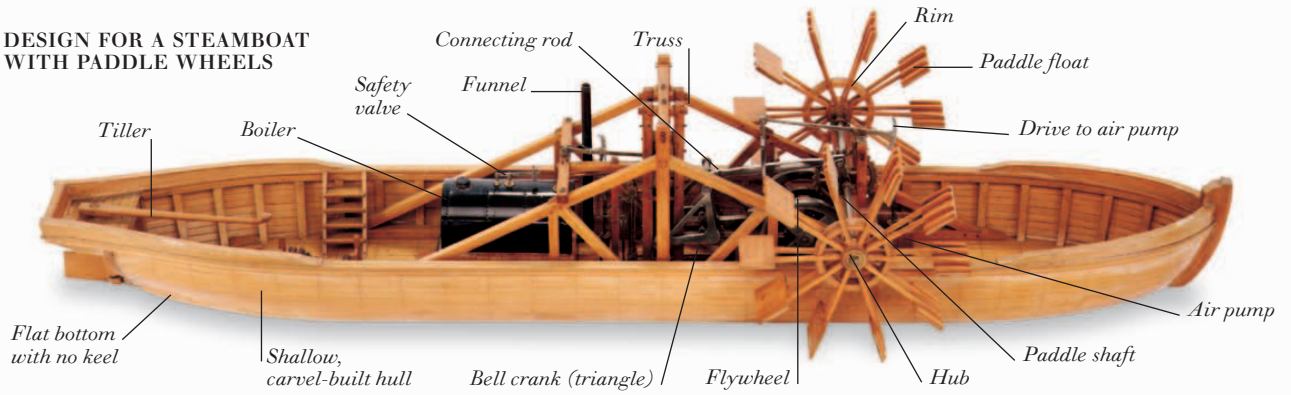
OSCILLATING STEAM ENGINE



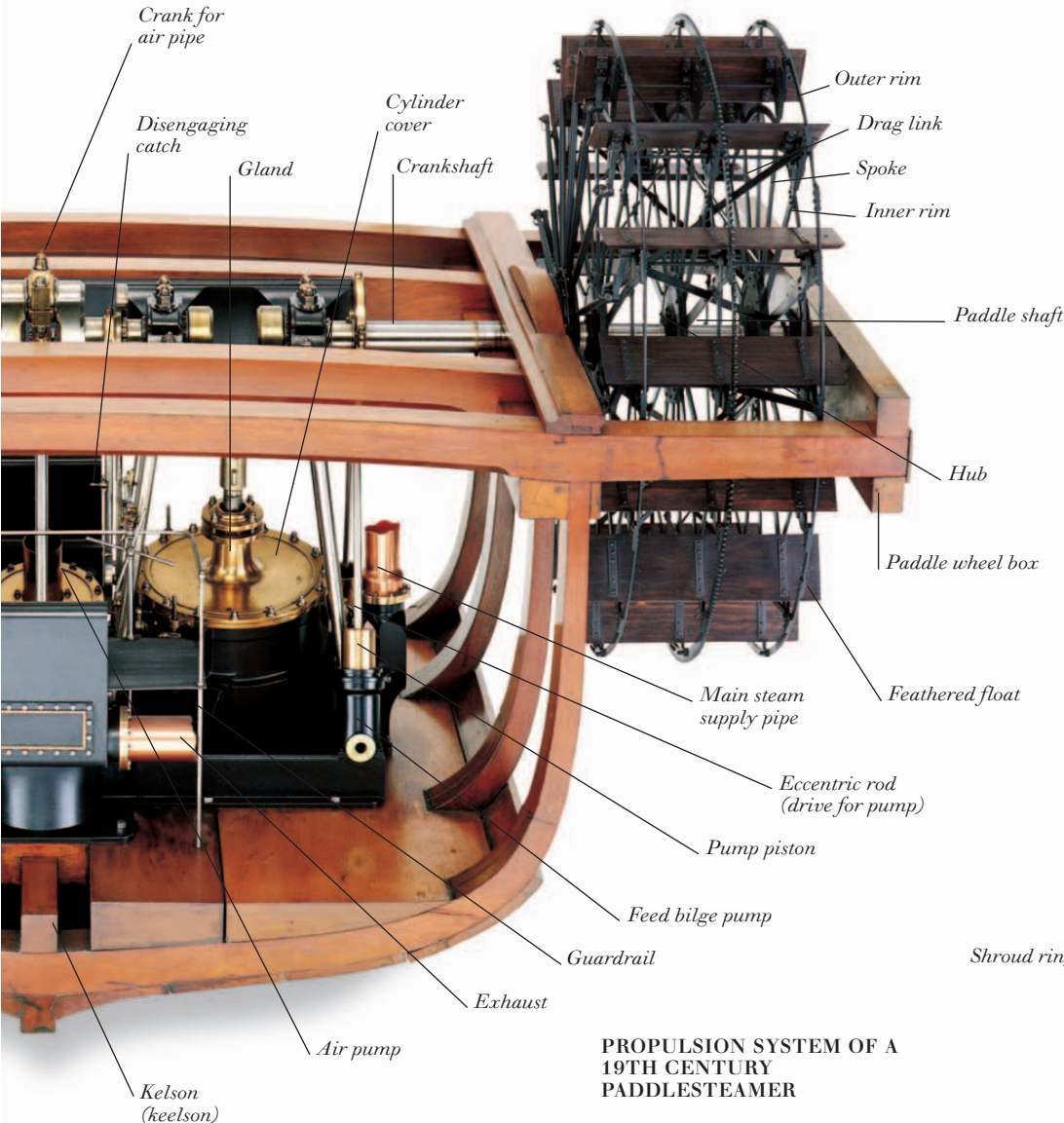
THREE-BLADED PROPELLER



DESIGN FOR A STEAMBOAT WITH PADDLE WHEELS



PADDLE WHEEL WITH FEATHERED FLOATS



PROPULSION SYSTEM OF A 19TH CENTURY PADDLESTEAMER

TYPES OF PROPELLER



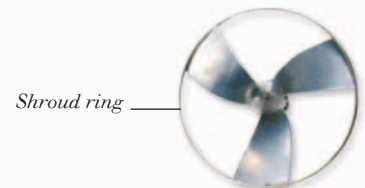
FROUDE'S EARLY TEST PROPELLER



TUG PROPELLER



THREE-BLADED PROPELLER



SHROUD RING PROPELLER

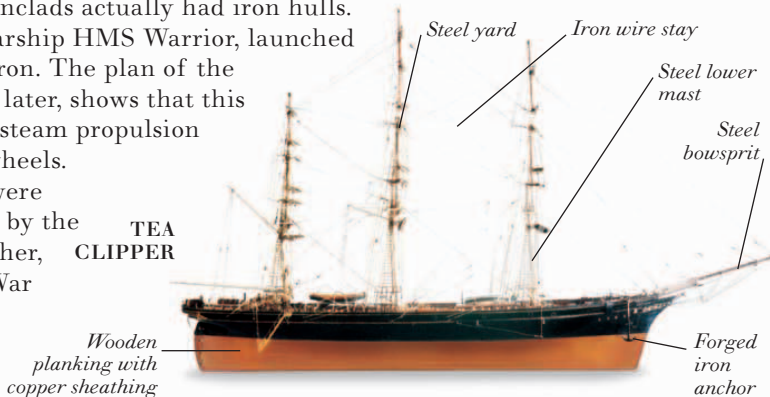
Anatomy of an iron ship

IRON PARTS WERE USED IN THE HULLS OF WOODEN SHIPS AS EARLY AS 1675, often in the same form as the wooden parts that they replaced. Eventually, as on the tea clipper *Cutty Sark* (below), iron rigging was found to be stronger than the traditional rope. The first "ironclads" were warships whose wooden hulls were protected by iron armor plates. Later ironclads actually had iron hulls.

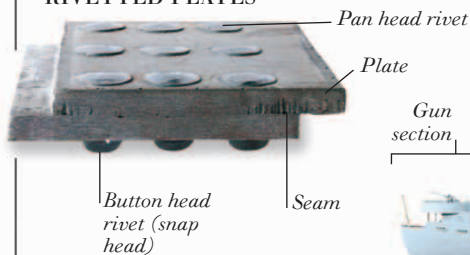
The model opposite is based on the British warship *HMS Warrior*, launched in 1860, the first battleship built entirely of iron. The plan of the iron paddlesteamer (bottom), built somewhat later, shows that this vessel was a sailing ship; but it also boasted a steam propulsion plant amidships that turned two side paddlewheels.

Early iron hulls were made from plates that were painstakingly riveted together (as below), but by the 20th century vessels began to be welded together, whole sections at a time. The Second World War "liberty ship" was one of the first of these "production-line vessels."

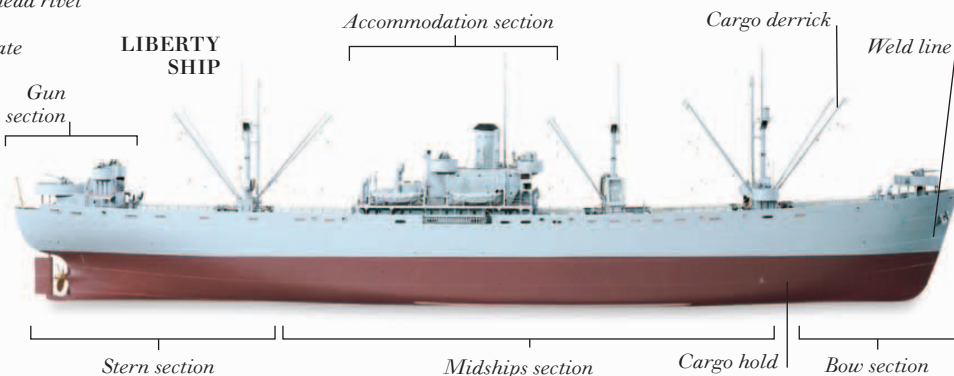
TEA CLIPPER



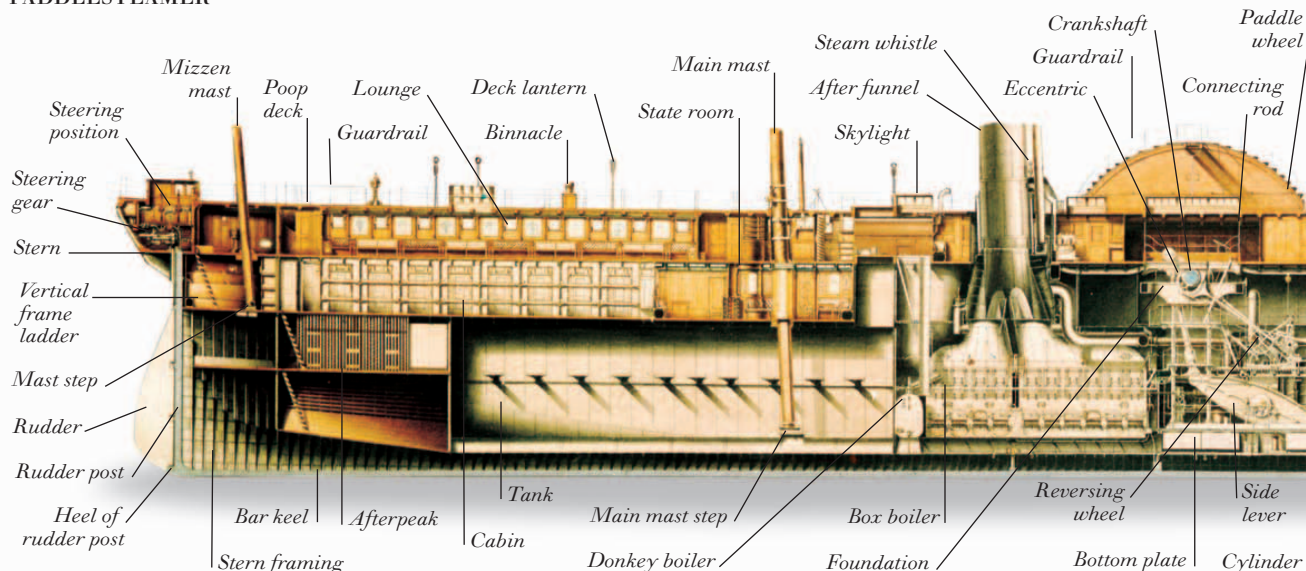
RIVETTED PLATES



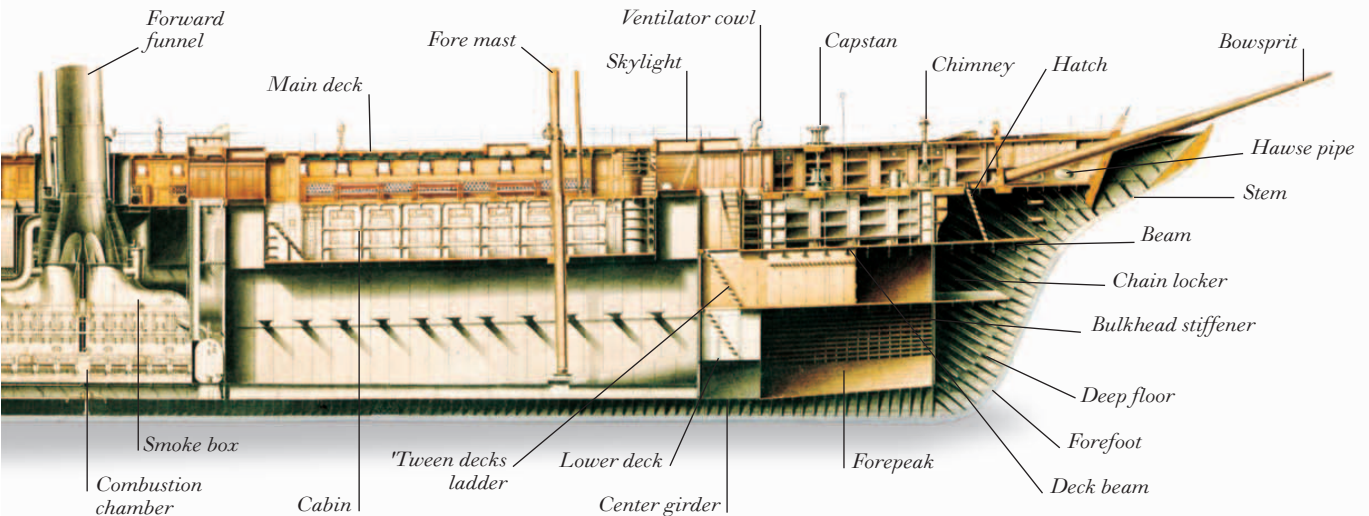
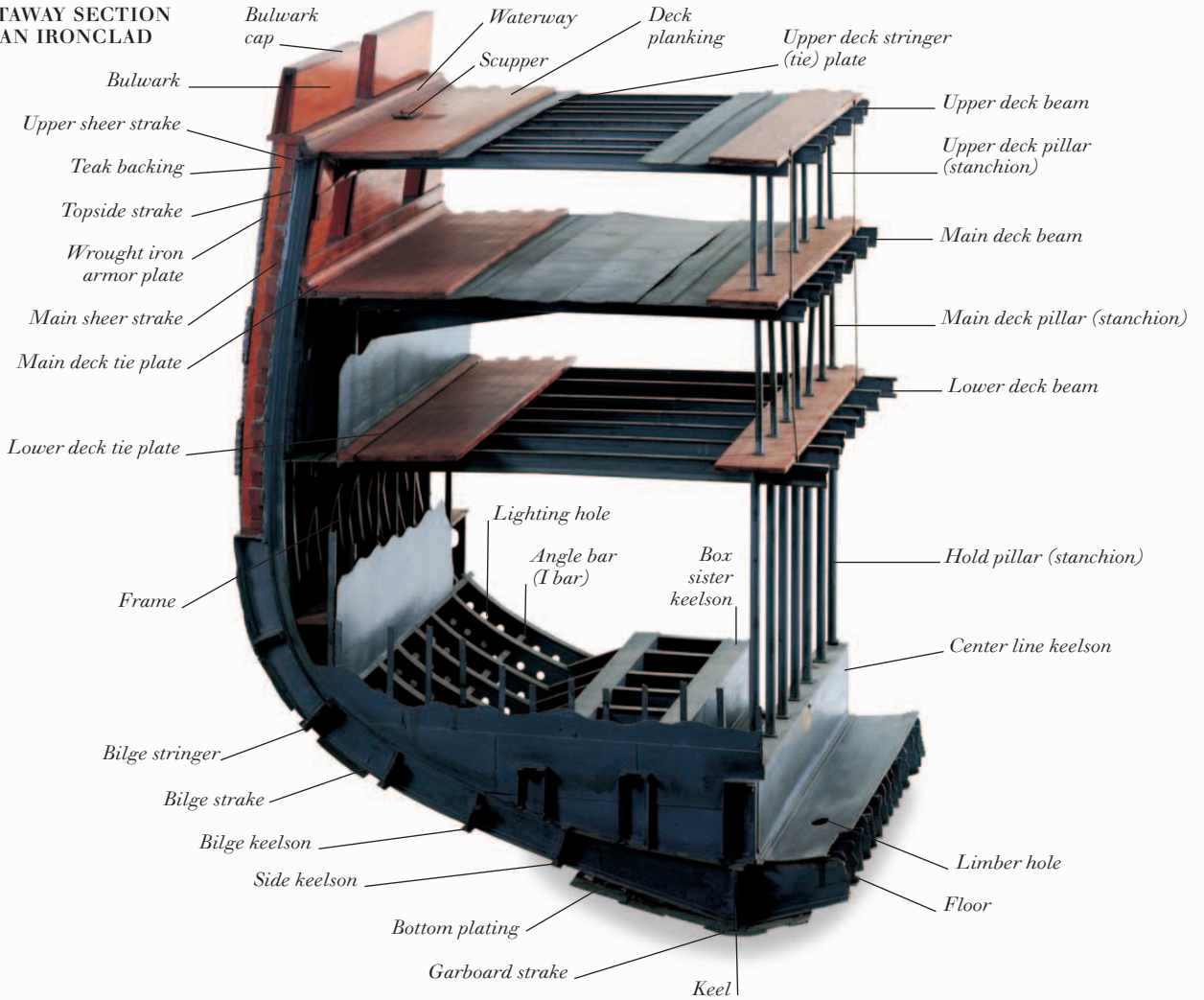
LIBERTY SHIP



PLAN OF AN IRON PADDLESTEAMER



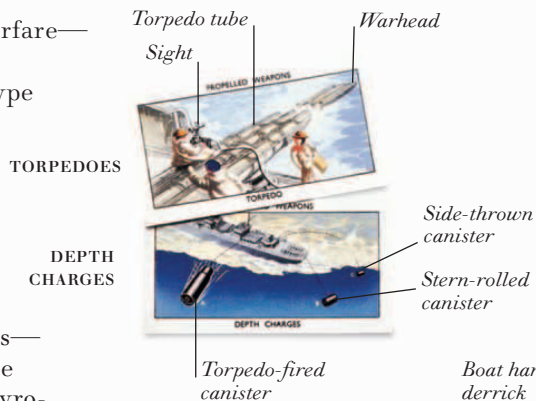
CUTAWAY SECTION OF AN IRONCLAD



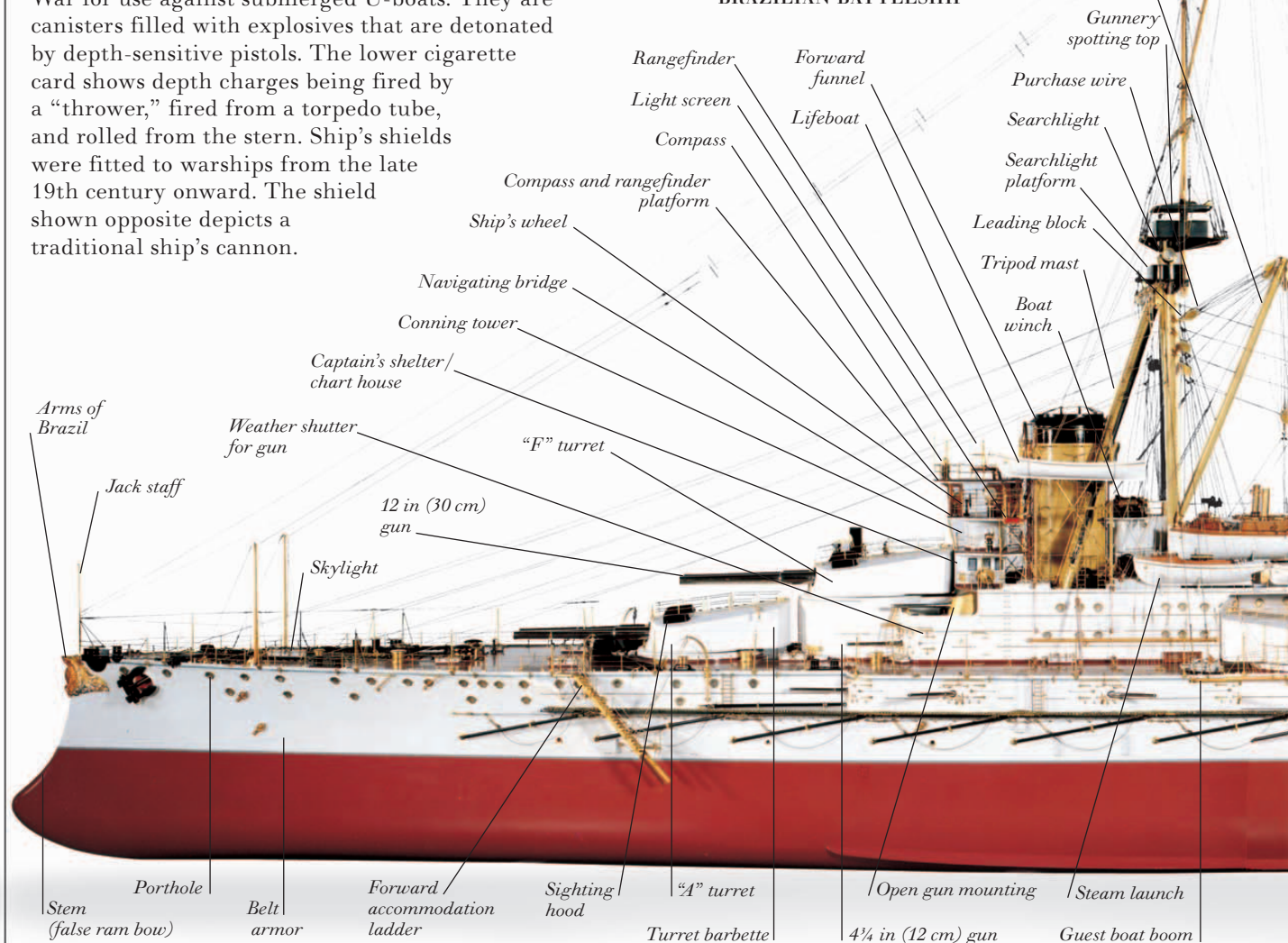
The battleship

IN THE EARLY YEARS OF THE 20TH CENTURY, sea warfare—attacking enemy vessels or defending a ship—was revolutionized by the introduction of Dreadnought-type battleships like the Brazilian vessel below. These new ships combined the latest advances in steam propulsion, gunnery, and armor plating. The gun turret was designed to fire shells over huge distances. It was protected by armor 12 in (30 cm) thick. The measurements given for the guns of this ship refer to the bore diameter. Where “weight” is quoted, this is the weight of the shell that the gun fires. Torpedoes—as portrayed on the upper cigarette card (right)—were self-propelled underwater missiles, often steered by gyro-control. Depth charges were designed in the First World War for use against submerged U-boats. They are canisters filled with explosives that are detonated by depth-sensitive pistols. The lower cigarette card shows depth charges being fired by a “thrower,” fired from a torpedo tube, and rolled from the stern. Ship’s shields were fitted to warships from the late 19th century onward. The shield shown opposite depicts a traditional ship’s cannon.

20TH CENTURY WEAPONRY

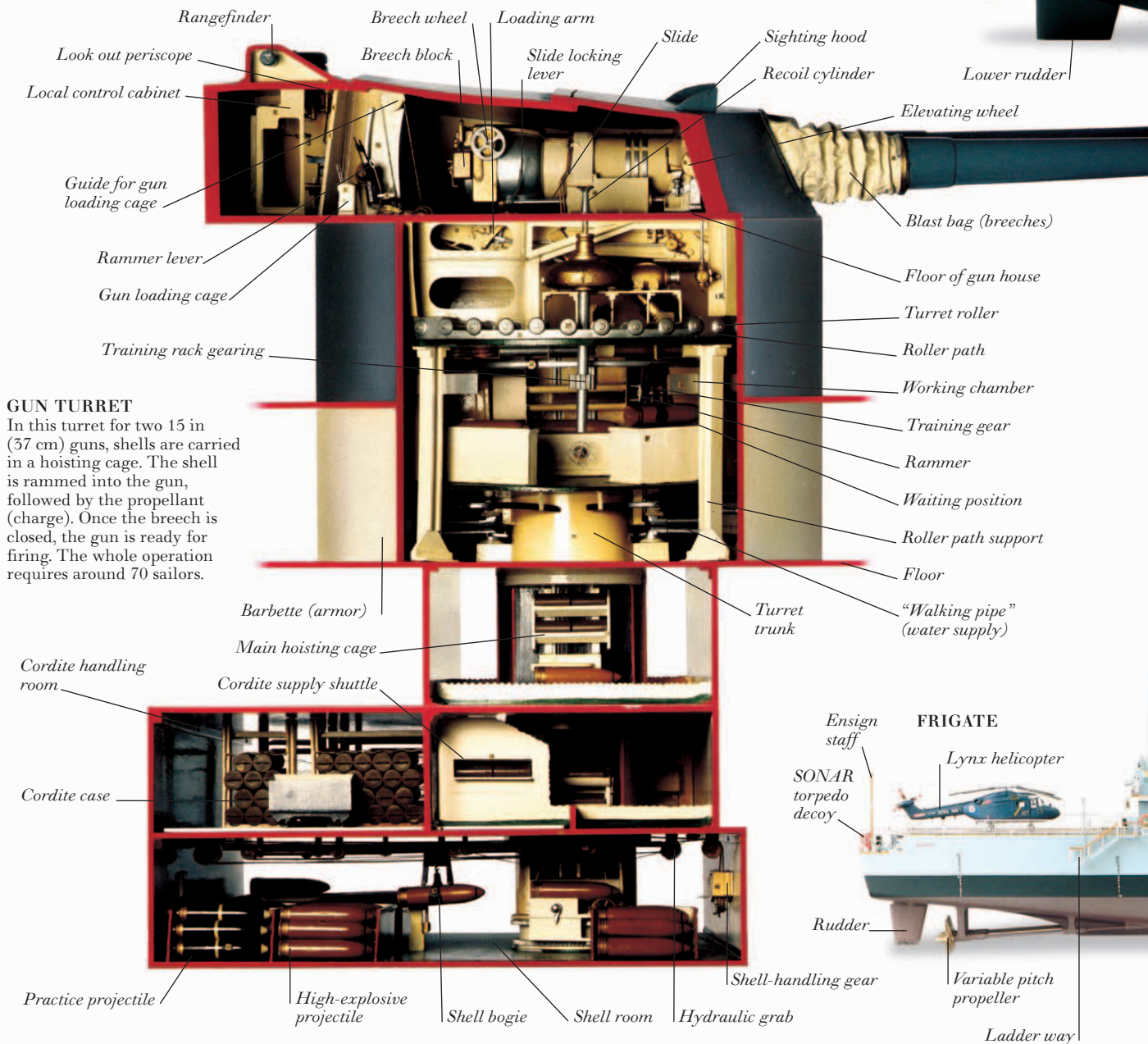


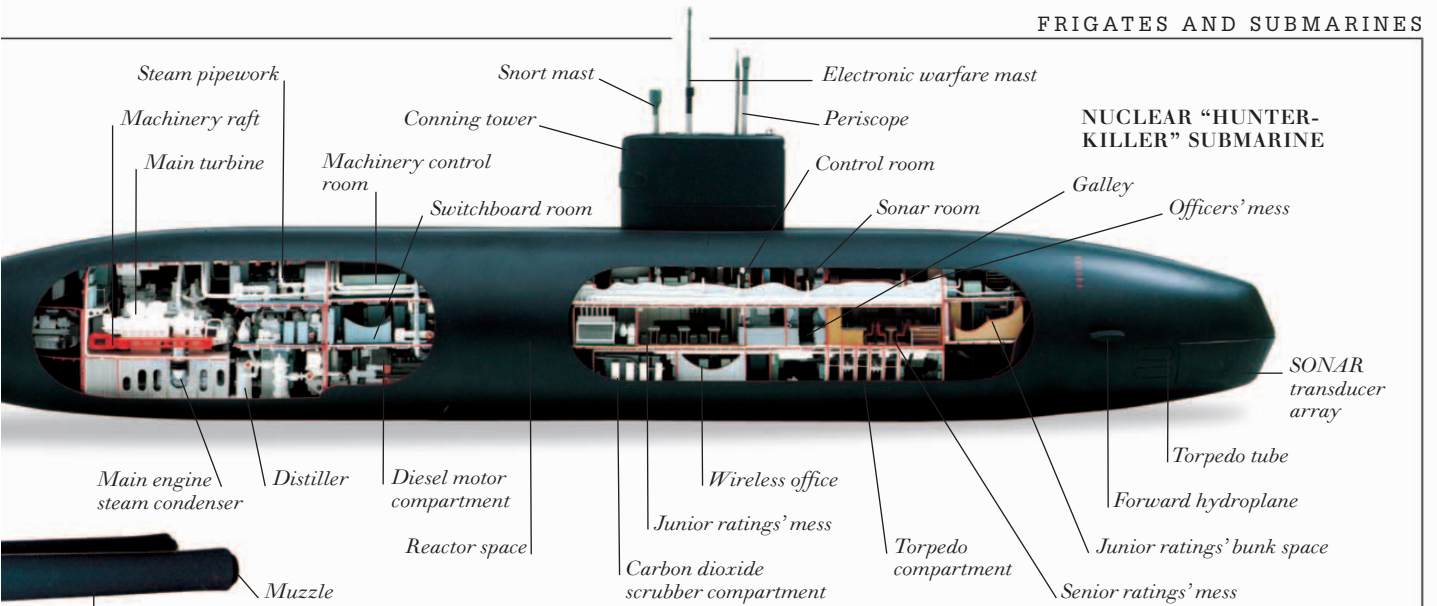
BRAZILIAN BATTLESHIP



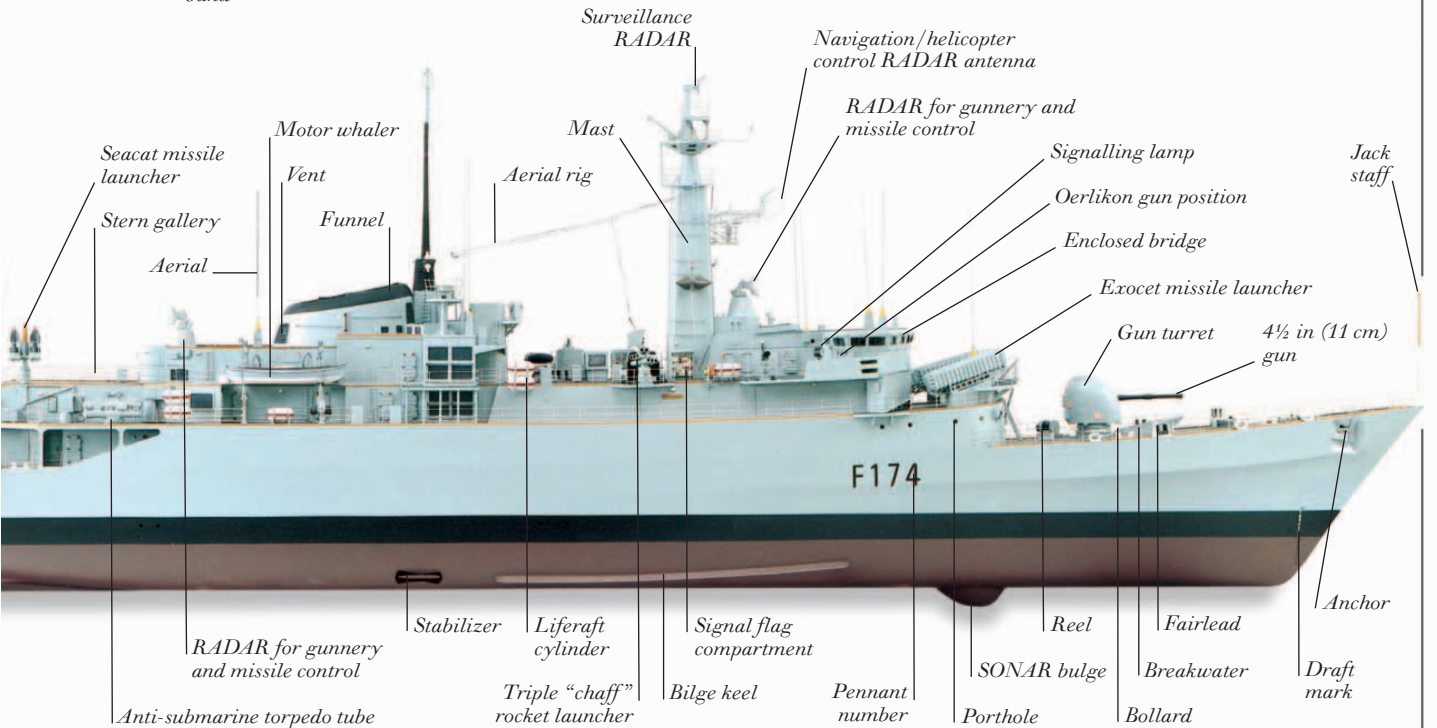
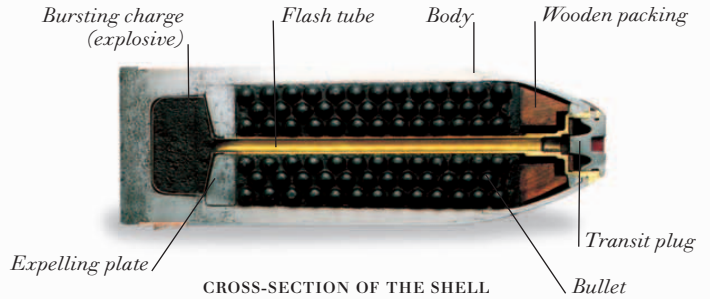
Frigates and submarines

FROM THE MID-19TH CENTURY, ARMORED SHIPS provided a new challenge to enemy craft. In response, huge revolving gun turrets were developed. These could fire in any direction, could be loaded from the breech very rapidly, and, instead of cannonballs, they discharged exploding shells. Modern fighting ships, like the frigate, combine heavy ship-borne armament with light helicopter weaponry. Submarines function below the surface of the sea. Their speed and ability to fire missiles from under water are their major assets. The nuclear submarine can stay under water for several years without refueling.





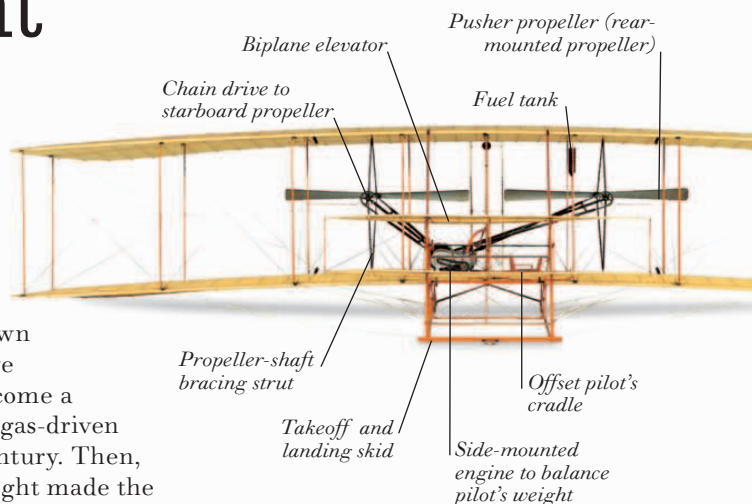
6 in (15 cm) SHELL
This shell is designed to burst in the air above its target.



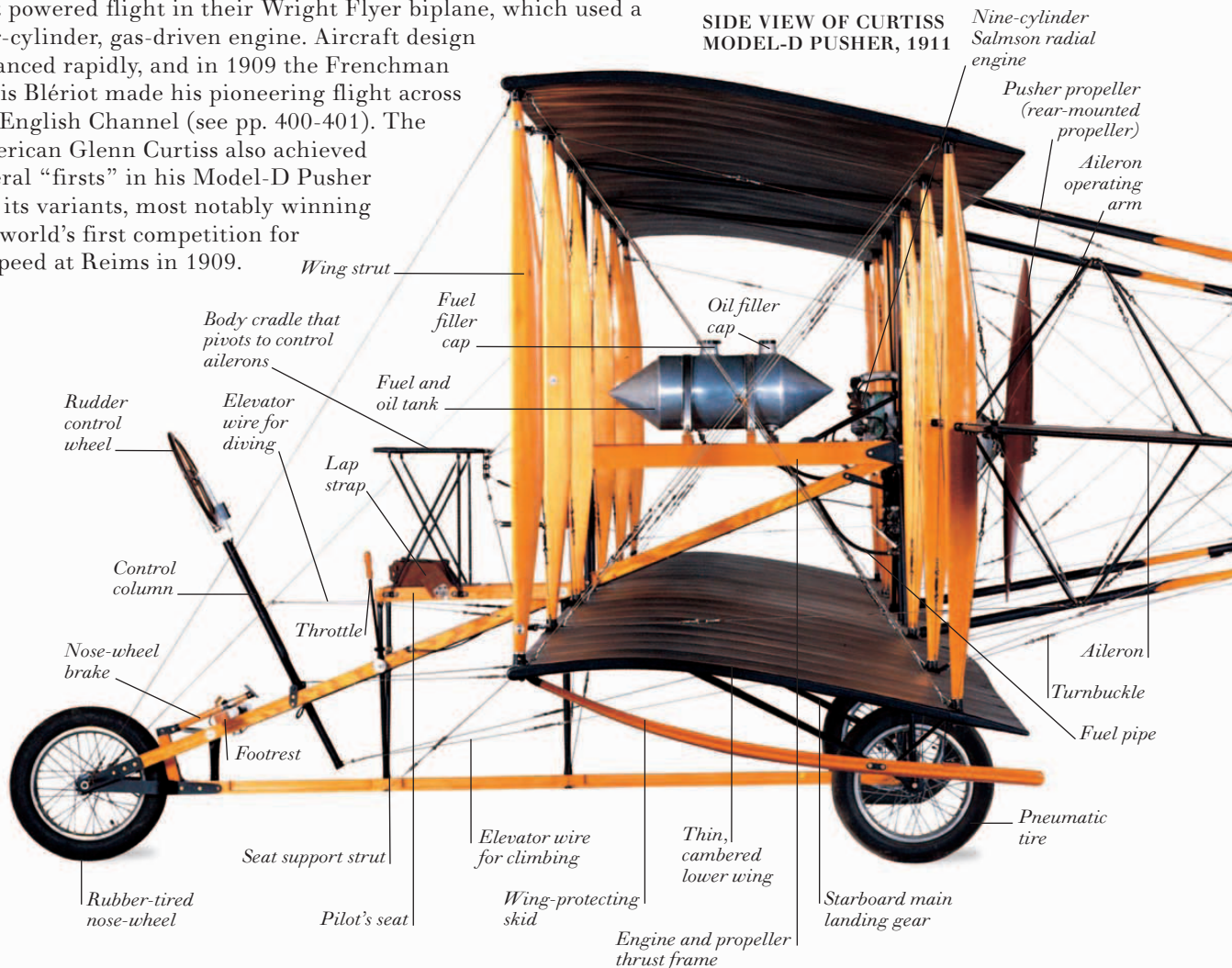
Pioneers of flight

FLIGHT HAS FASCINATED MANKIND for centuries, and countless unsuccessful flying machines have been designed. The first successful flight was made by the French Montgolfier brothers in 1783, when they flew a balloon over Paris. The next major advance was the development of gliders, notably by the Englishman Sir George Cayley, who in 1845 designed the first glider to make a sustained flight, and by the German Otto Lilienthal, who became known as the world's first pilot because he managed to achieve controlled flights. However, powered flight did not become a practical possibility until the invention of lightweight, gas-driven internal combustion engines at the end of the 19th century. Then, in 1903, the American brothers Orville and Wilbur Wright made the first powered flight in their Wright Flyer biplane, which used a four-cylinder, gas-driven engine. Aircraft design advanced rapidly, and in 1909 the Frenchman Louis Blériot made his pioneering flight across the English Channel (see pp. 400-401). The American Glenn Curtiss also achieved several "firsts" in his Model-D Pusher and its variants, most notably winning the world's first competition for airspeed at Reims in 1909.

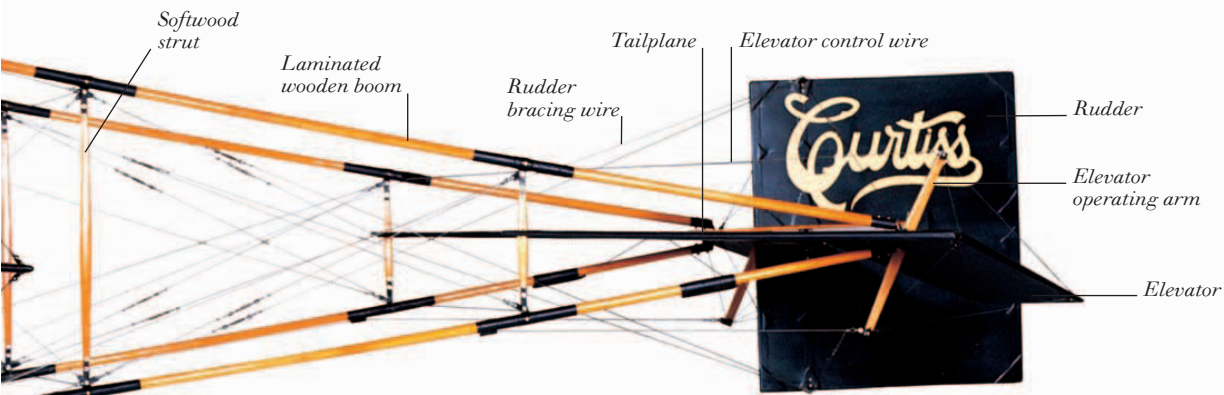
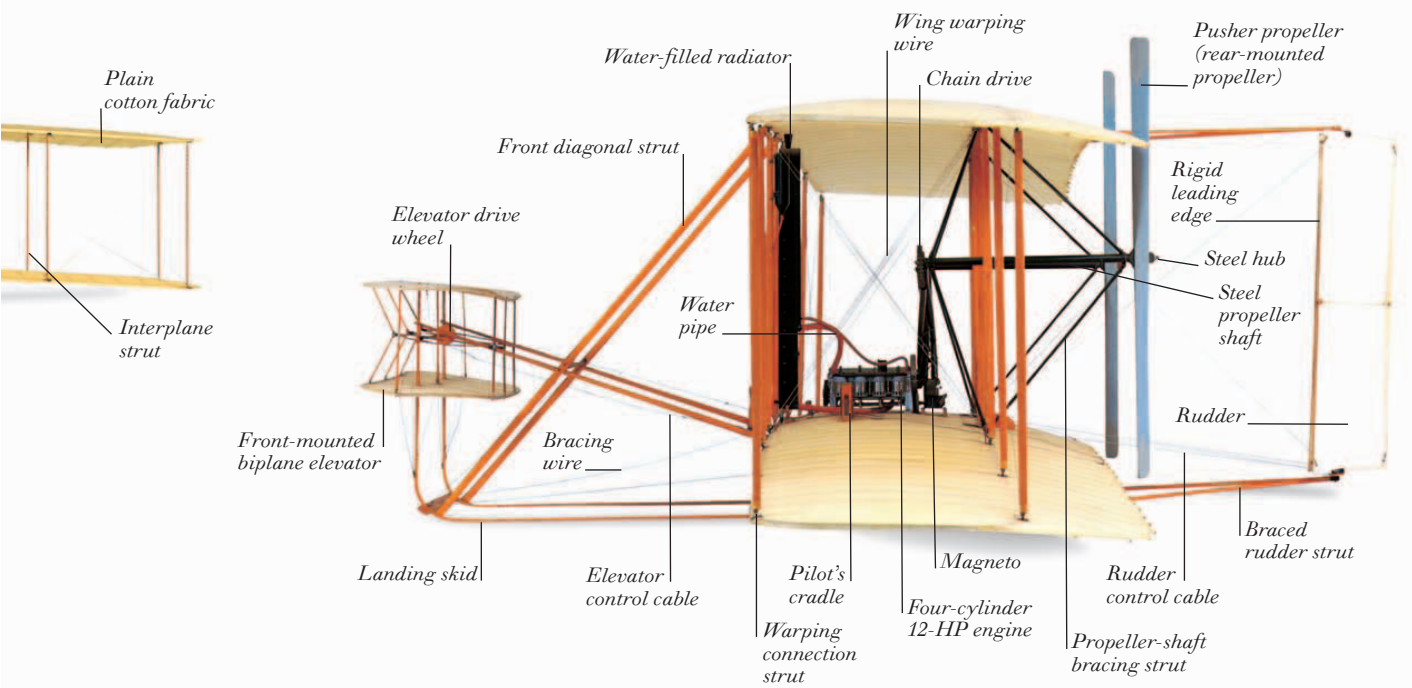
FRONT VIEW OF WRIGHT FLYER, 1903



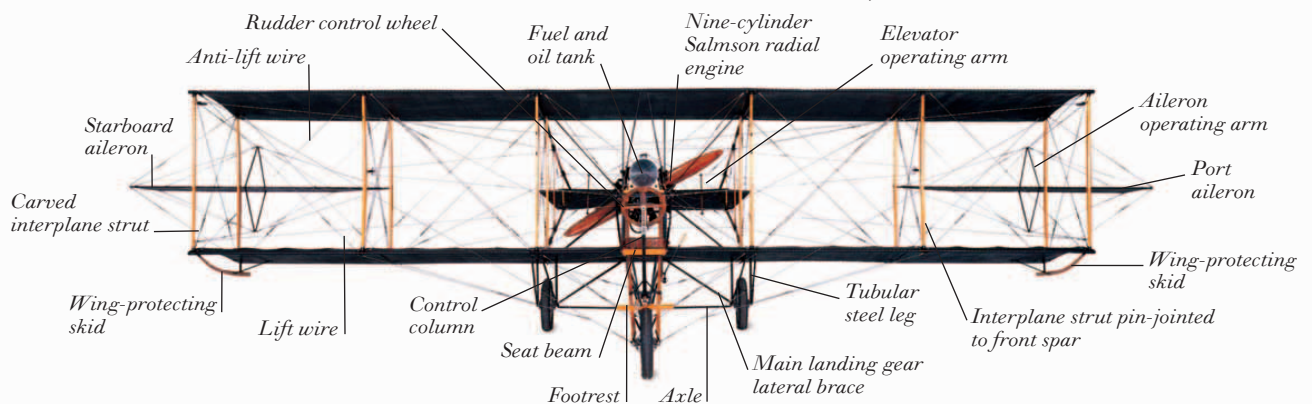
SIDE VIEW OF CURTISS MODEL-D PUSHER, 1911



SIDE VIEW OF WRIGHT FLYER, 1903



FRONT VIEW OF CURTISS MODEL-D PUSHER, 1911



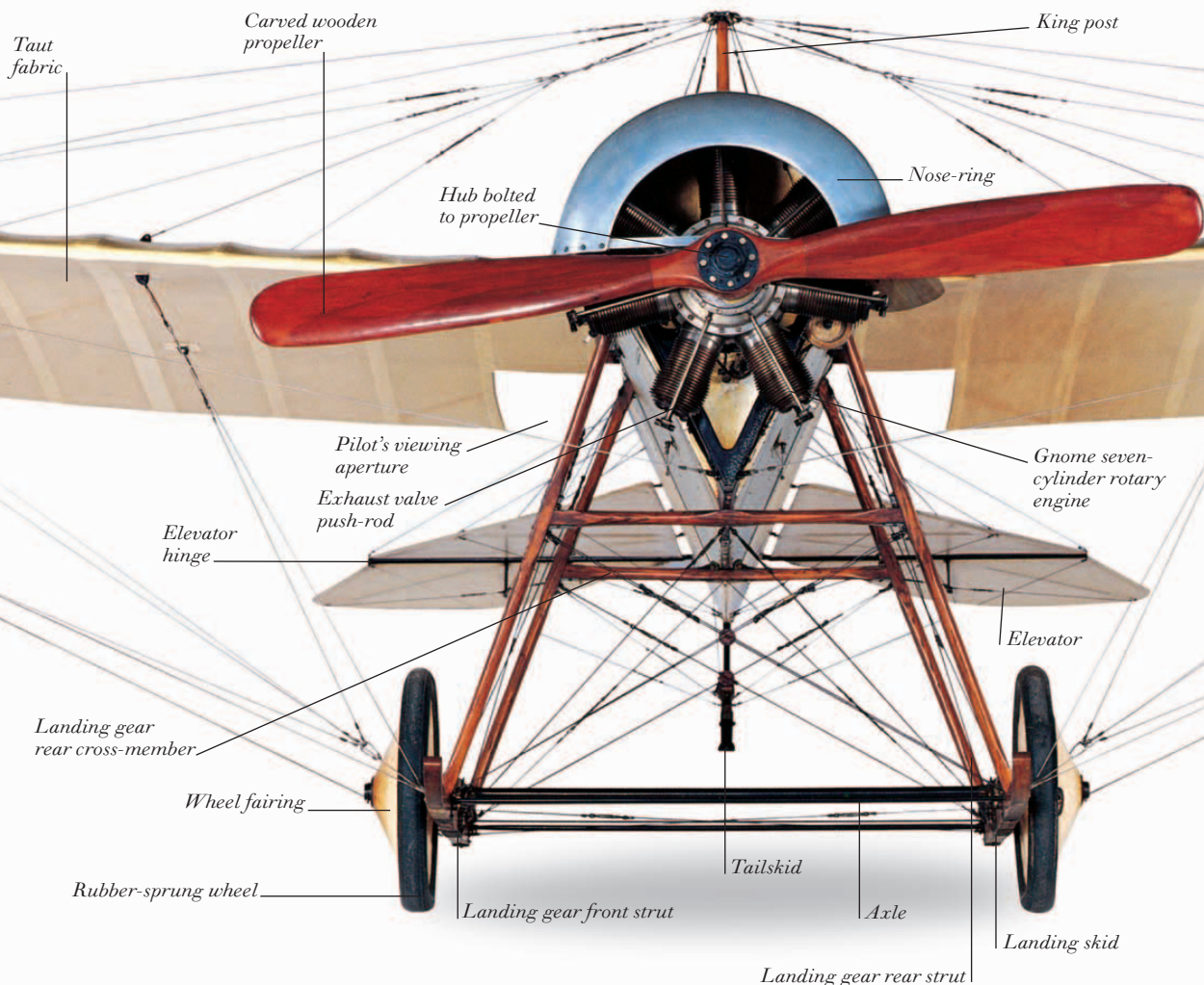
Early monoplanes

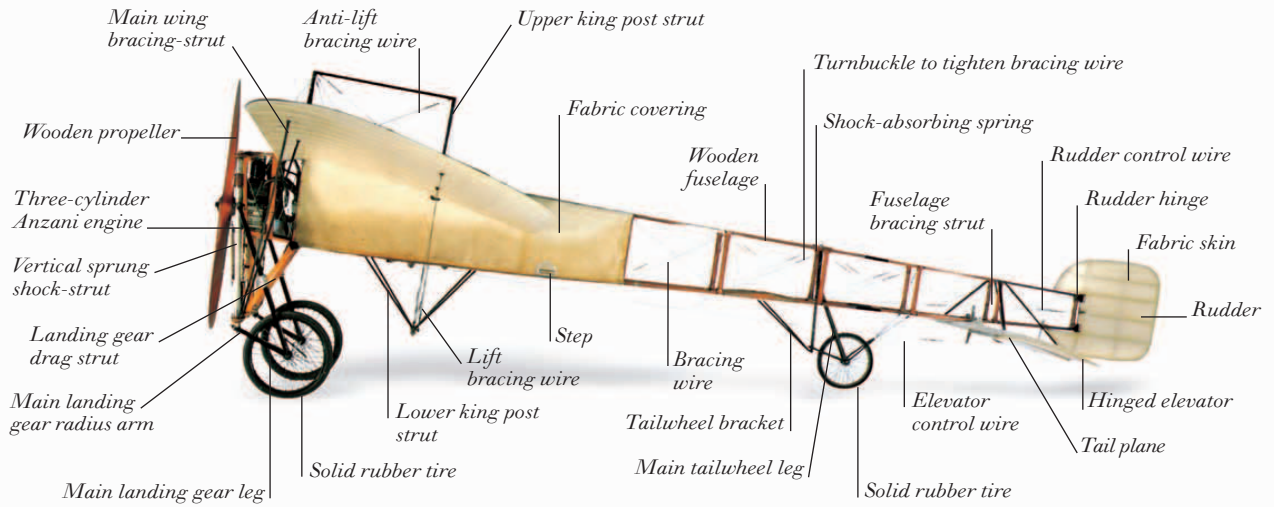


RUMPLER MONOPLANE, 1908

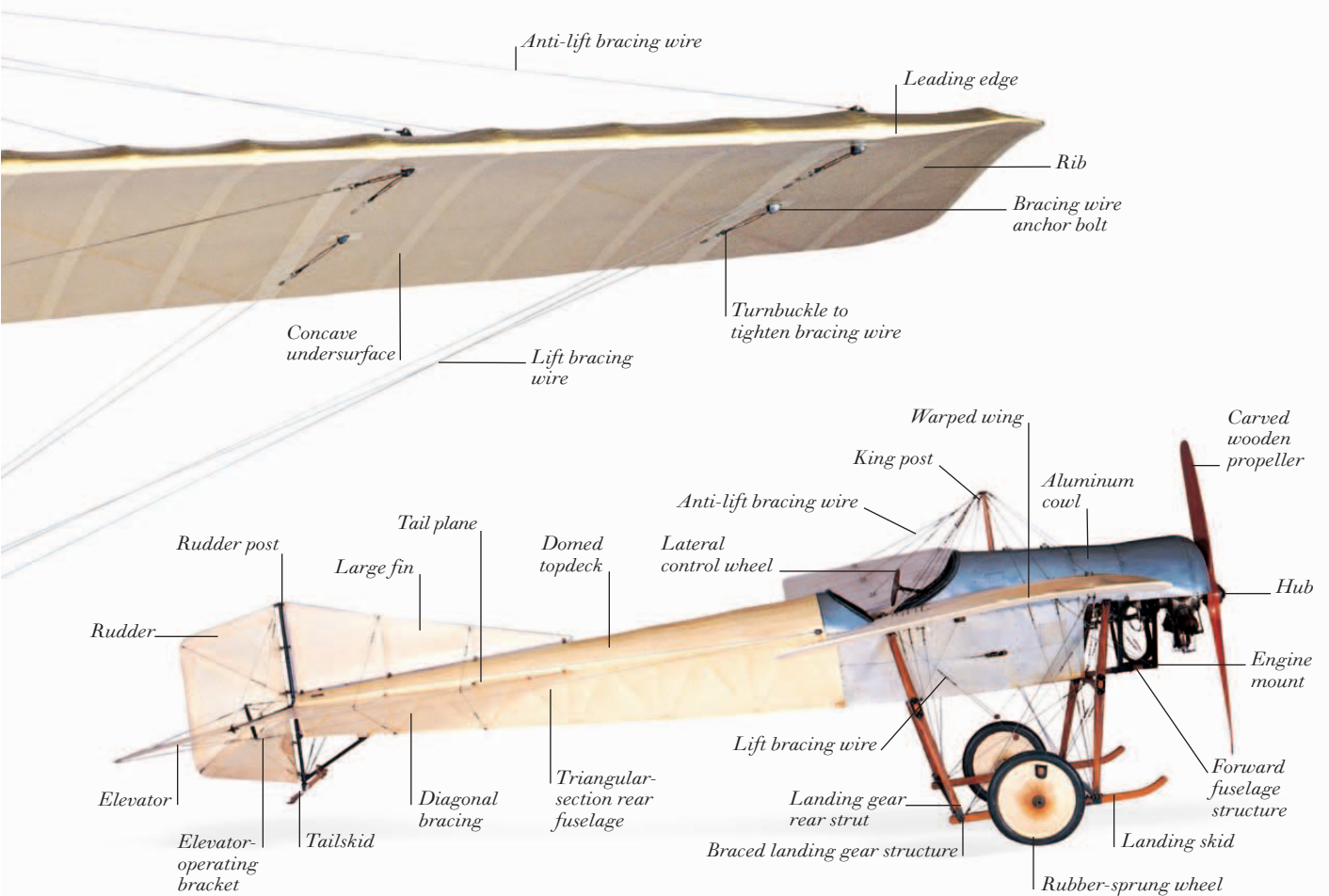
MONOPLANES HAVE ONE WING on each side of the fuselage. The principal disadvantage of this arrangement in early, wooden-framed aircraft was that single wings were weak and required strong wires to brace them to king posts above and below the fuselage. However, single wings also had advantages: they experienced less drag than multiple wings, allowing greater speed; they also made aircraft more manoeuvrable because single wings were easier to warp (twist) than double wings, and warping the wings was how pilots controlled the roll of early aircraft. By 1912, the French pilot Louis Blériot had used a monoplane to make the first flight across the English Channel, and the Briton Robert Blackburn and the Frenchman Armand Deperdussin had proved the greater speed of monoplanes. However, a spate of crashes caused by broken wings discouraged monoplane production, except in Germany, where all-metal monoplanes were developed in 1917. The wings of all-metal monoplanes did not need strengthening by struts or bracing wires, but despite this, such planes were not widely adopted until the 1930s.

FRONT VIEW OF BLACKBURN MONOPLANE, 1912





SIDE VIEW OF BLÉRIOT XI, 1909



SIDE VIEW OF BLACKBURN MONOPLANE, 1912

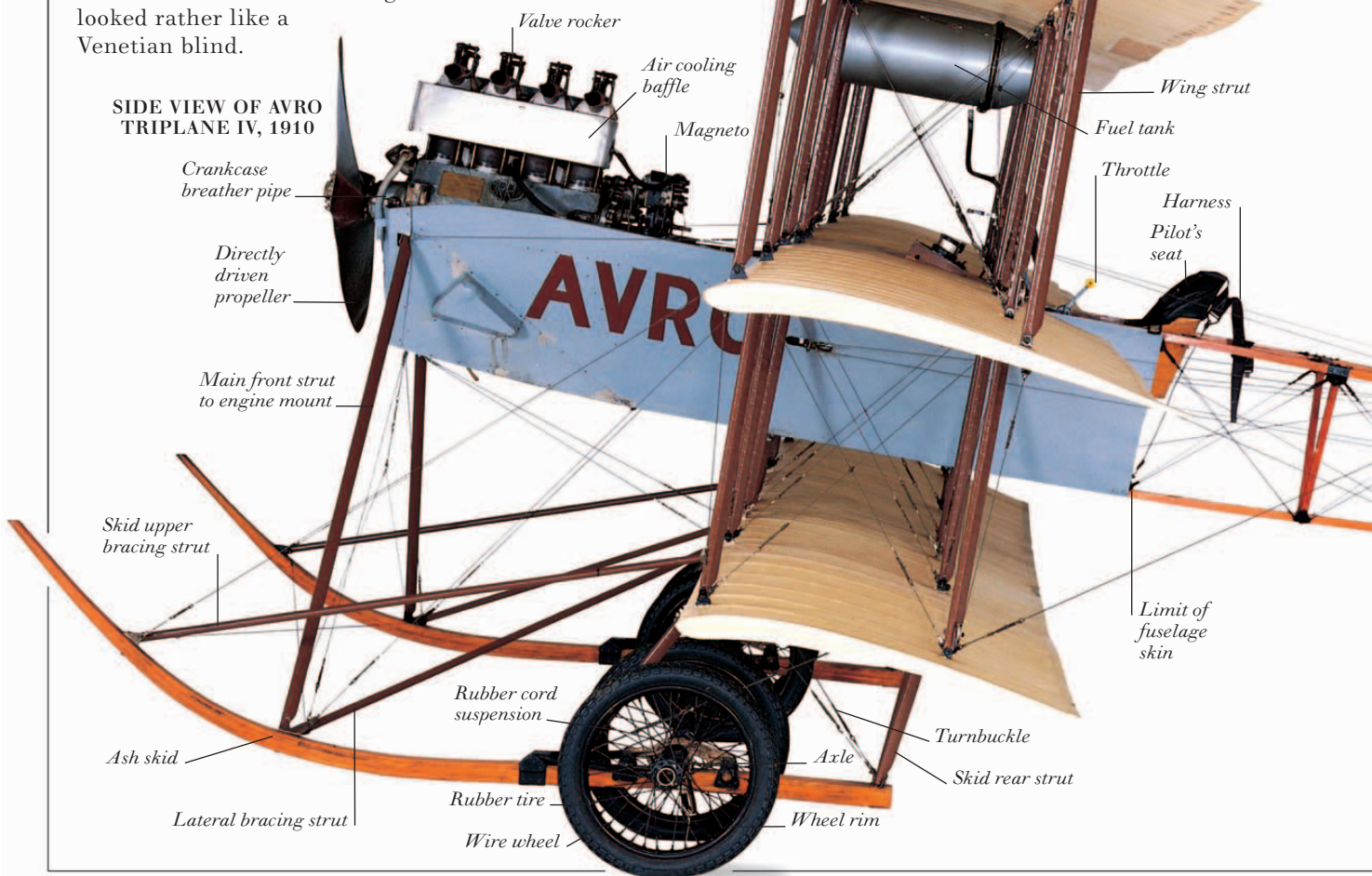
Biplanes and triplanes



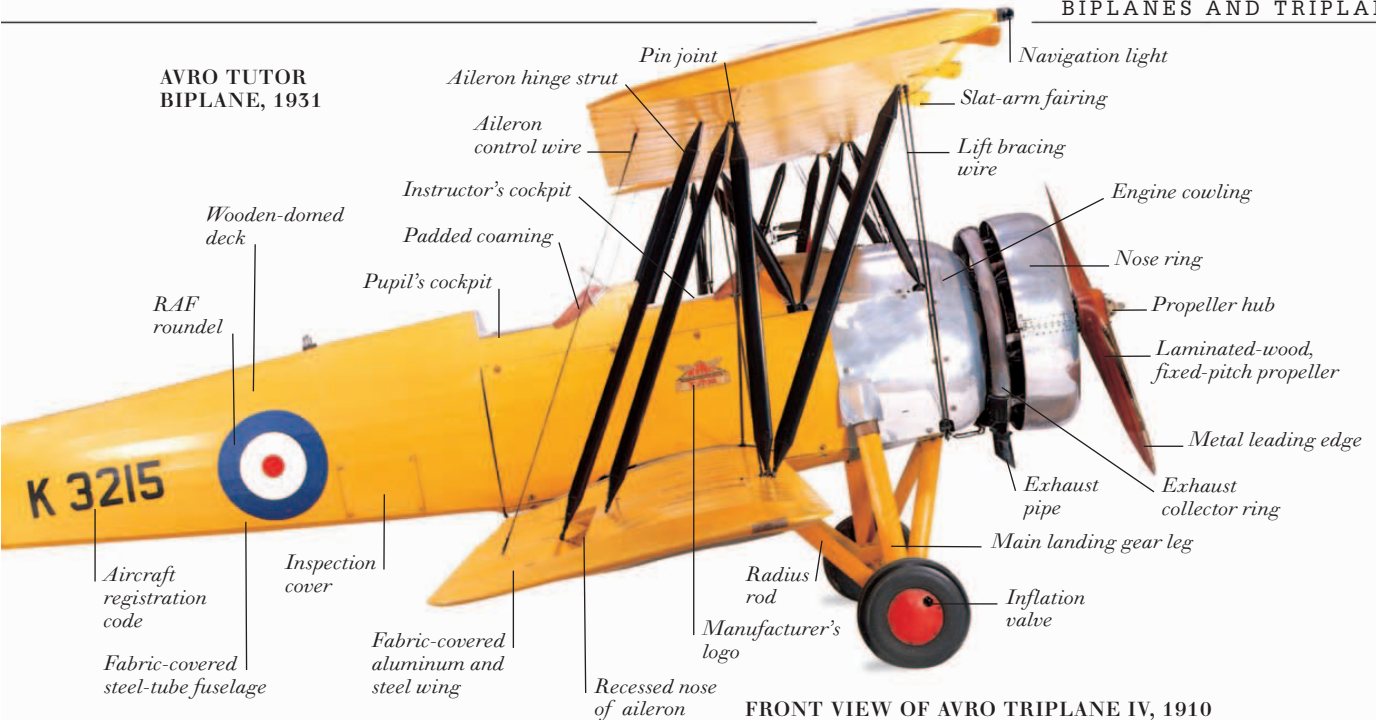
LAMINATED PROPELLER

BIPLANES DOMINATED AIRCRAFT DESIGN until the 1930s, largely because some early monoplanes (see pp. 400-401) were too fragile to withstand the stresses of flight. The struts between biplanes' wings made the wings strong compared with those of early monoplanes, although the greater surface area of biplanes' wings increased drag and reduced speed. Many aircraft designers also developed triplanes, which had a particular advantage over biplanes: more wings meant a shorter wingspan to achieve the same lifting power, and a shorter wingspan gave greater manoeuvrability. Triplanes were most successful as fighters during World War I, the German Fokker triplane being a notable example. However, the greater maneuverability of triplanes was no advantage for normal flying and so most manufacturers continued to make biplanes. Many other aircraft designs were attempted. Some were quadruplanes, with four pairs of wings (two pairs of monoplane wings, one behind the other). One of the most bizarre designs was by the Englishman Horatio Phillips: it had 20 sets of narrow wings and looked rather like a Venetian blind.

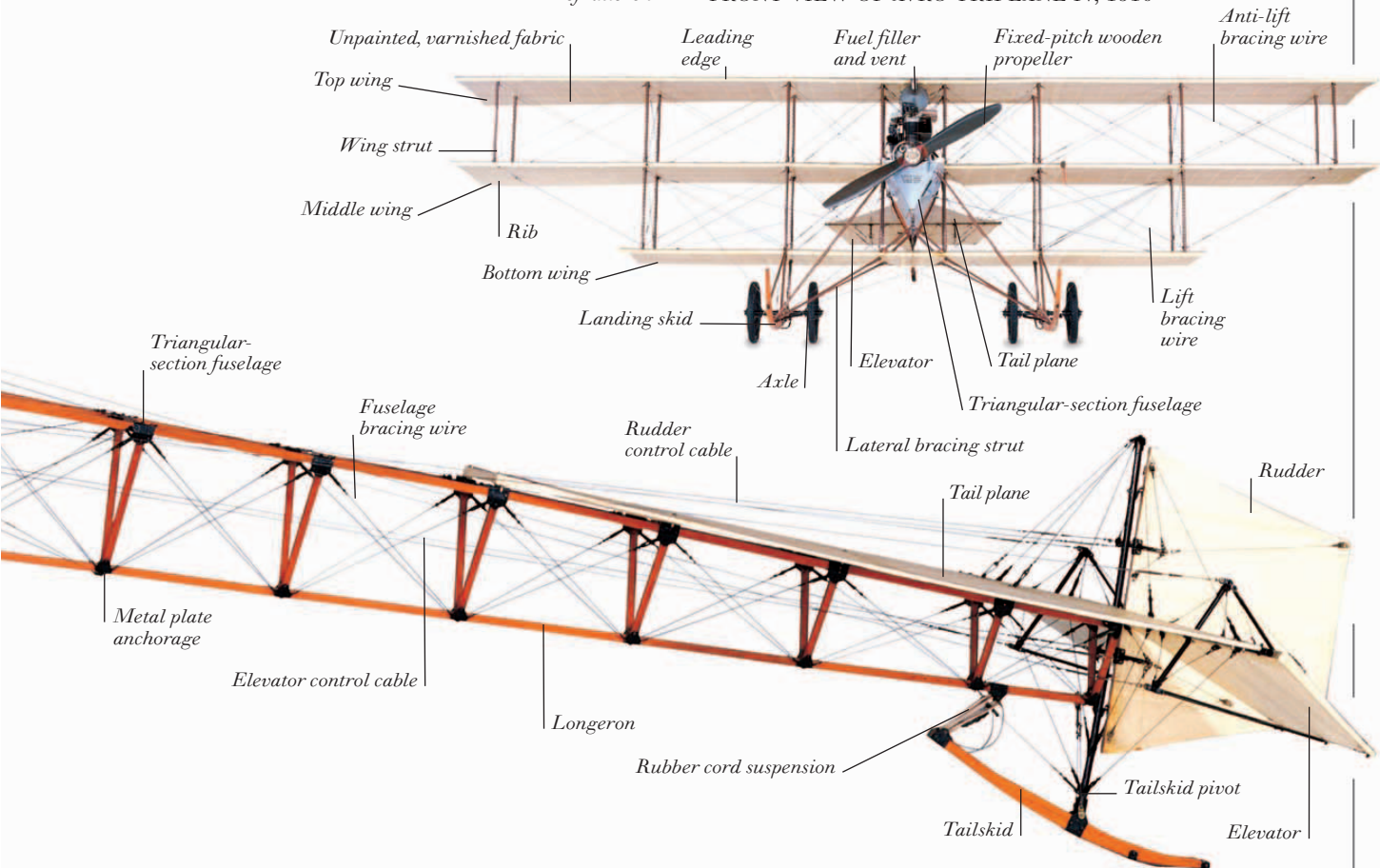
SIDE VIEW OF AVRO TRIPLANE IV, 1910



**AVRO TUTOR
BIPLANE, 1931**



FRONT VIEW OF AVRO TRIPLANE IV, 1910



World War I aircraft

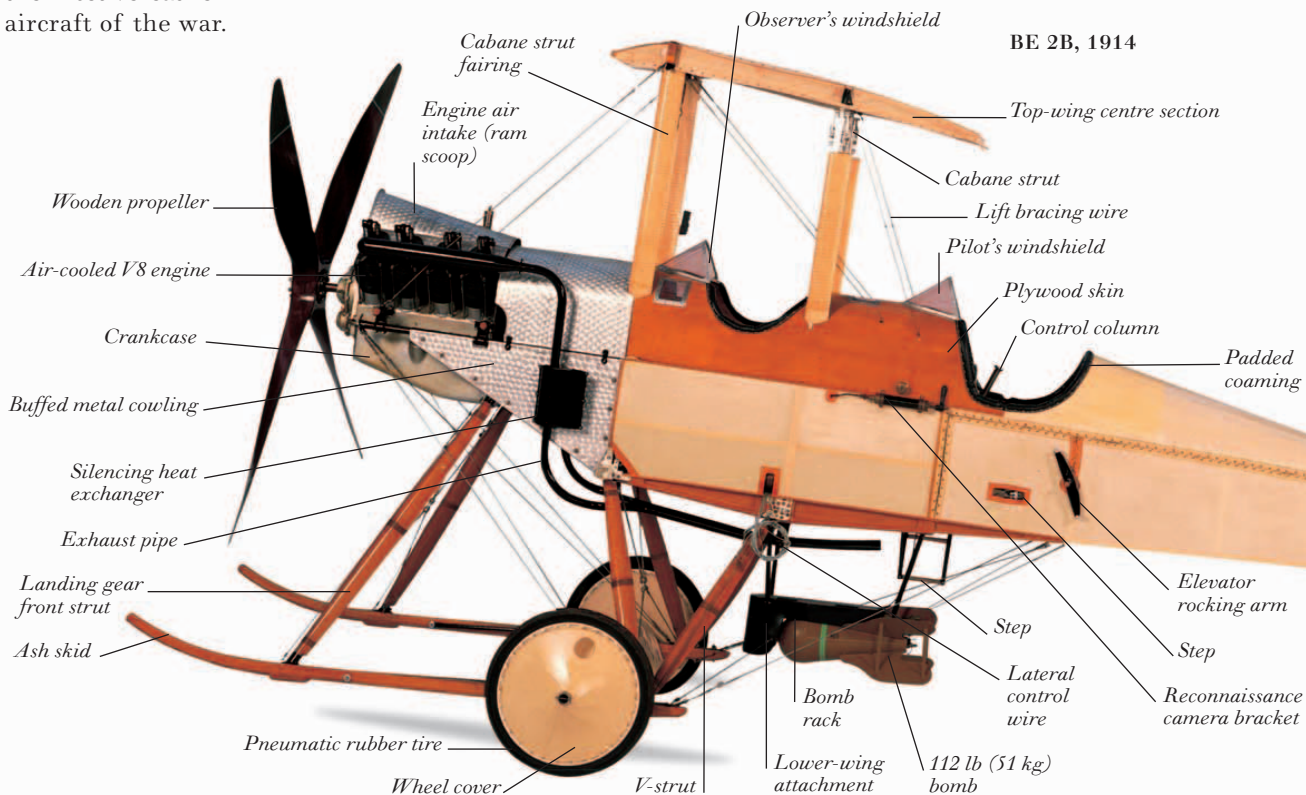
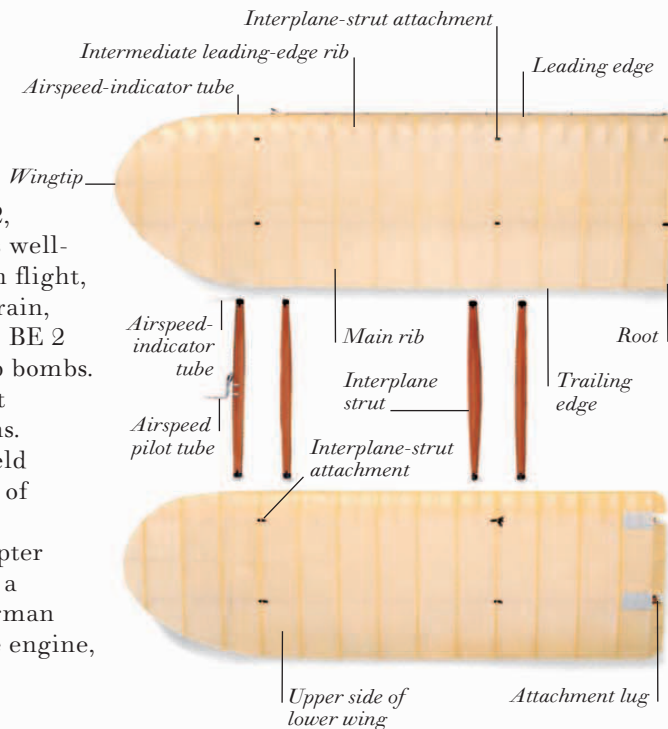


FLYING
HELMET

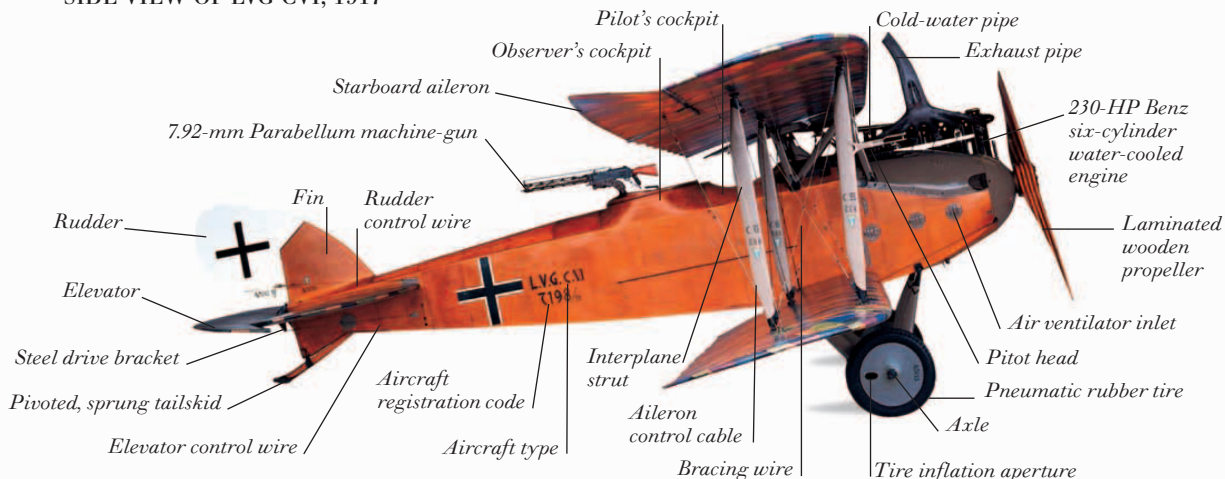
WHEN WORLD WAR I STARTED in 1914, the main purpose of military aircraft was reconnaissance. The British-built BE 2, of which the BE 2B was a variant, was well-suited to this duty; it was very stable in flight, allowing the occupants to study the terrain, take photographs, and make notes. The BE 2 was also one of the first aircraft to drop bombs.

One of the biggest problems for aircraft designers during the war was mounting machine-guns. On aircraft that had front-mounted propellers, the field of fire was restricted by the propeller and other parts of the aircraft. The problem was solved in 1915 by the Dutchman Anthony Fokker, who designed an interrupter gear that prevented a machine-gun from firing when a propeller blade passed in front of the barrel. The German LVG CVI had a forward-firing gun to the right of the engine, as well as a rear-cockpit gun, and a bombing capability. It was one of the most versatile aircraft of the war.

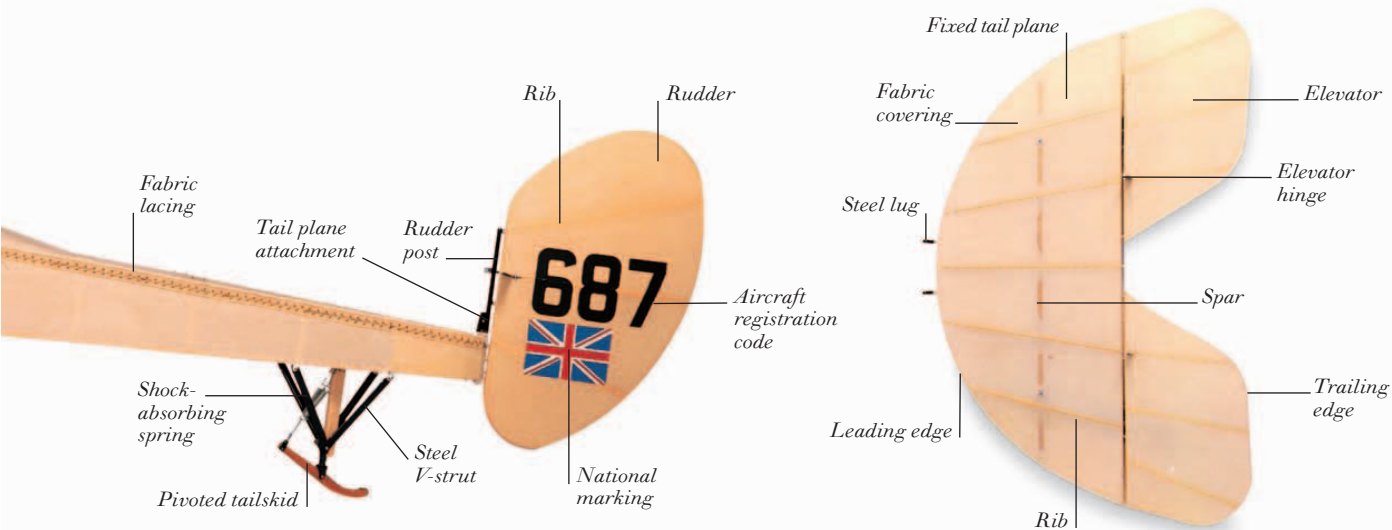
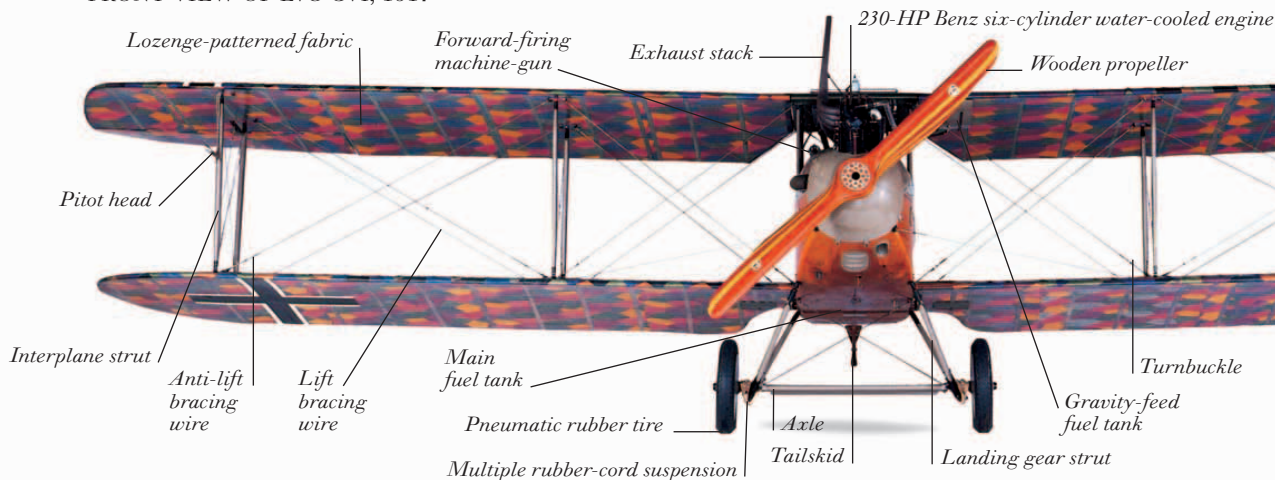
PORT WINGS FROM A BE 2B



SIDE VIEW OF LVG CVI, 1917



FRONT VIEW OF LVG CVI, 1917



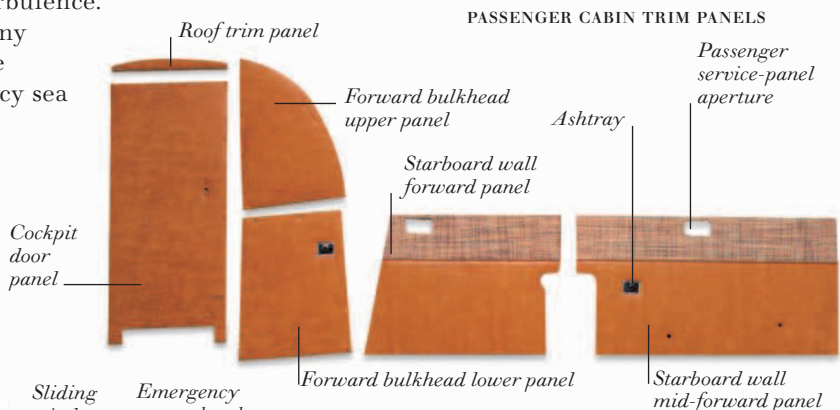
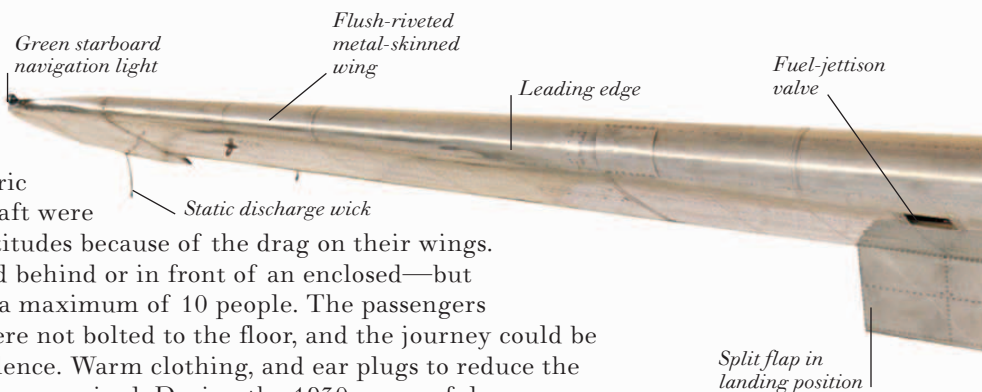
HORIZONTAL TAIL OF A BE 2B

Early passenger aircraft

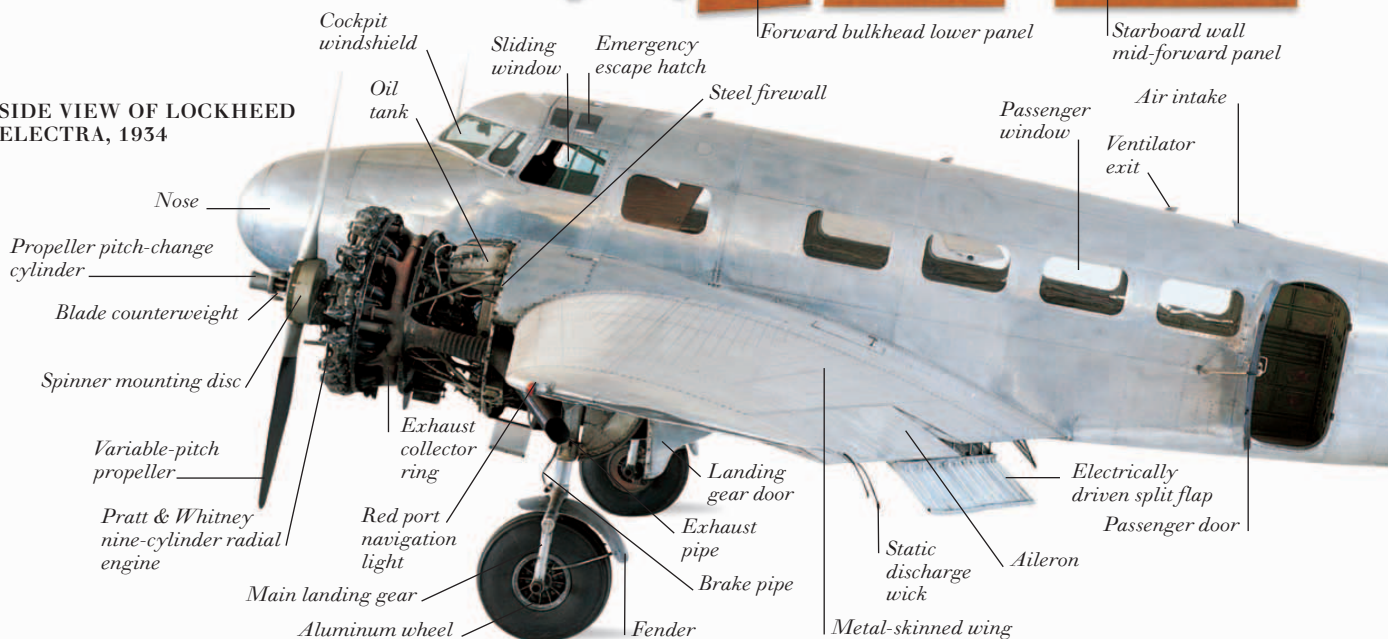
FRONT VIEW OF LOCKHEED ELECTRA, 1934

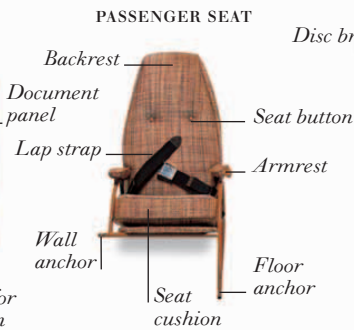
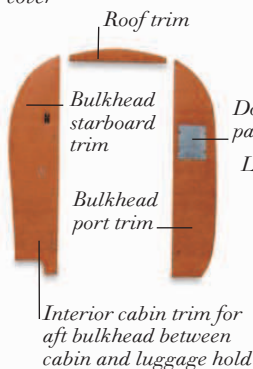
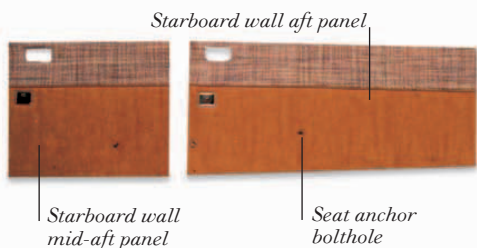
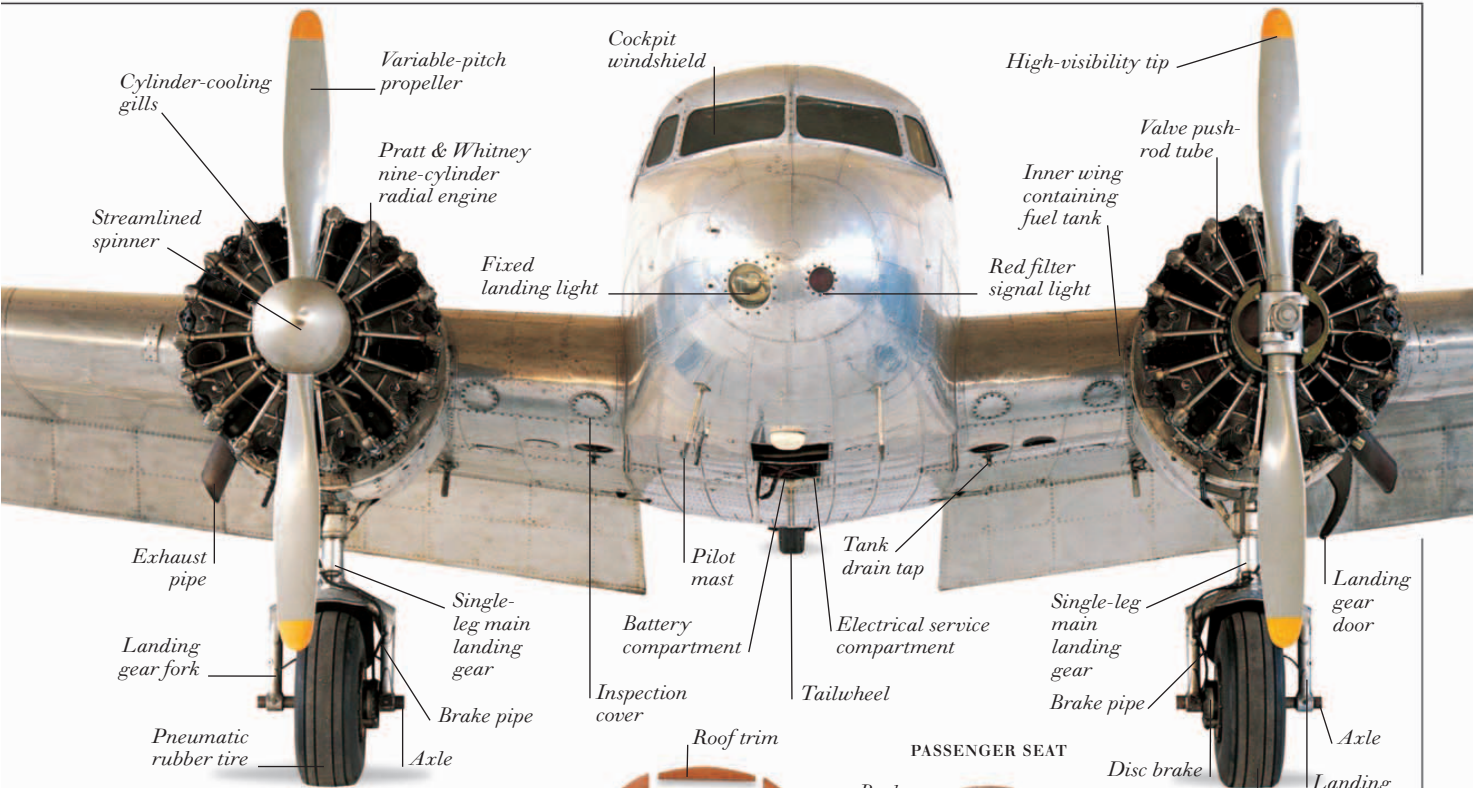
UNTIL THE 1930s, most passenger aircraft were biplanes, with two pairs of wings and a wooden or metal framework covered with fabric or, sometimes, plywood. Such aircraft were restricted to low speeds and low altitudes because of the drag on their wings. Many had an open cockpit, situated behind or in front of an enclosed—but unpressurized—cabin that carried a maximum of 10 people. The passengers usually sat in wicker chairs that were not bolted to the floor, and the journey could be bumpy when flying through turbulence. Warm clothing, and ear plugs to reduce the effects of prolonged noise, were often required. During the 1930s, powerful, streamlined, all-metal monoplanes, such as the Lockheed Electra shown here, became widespread. By 1939, the advent of pressurized cabins allowed fast flights at high altitudes, where there is less turbulence.

Flying boats were still necessary on many routes until 1945 because of inadequate runways and the frequency of emergency sea landings. World War II, however, resulted in enough good runways being built for land-planes to become standard on all major airline routes.

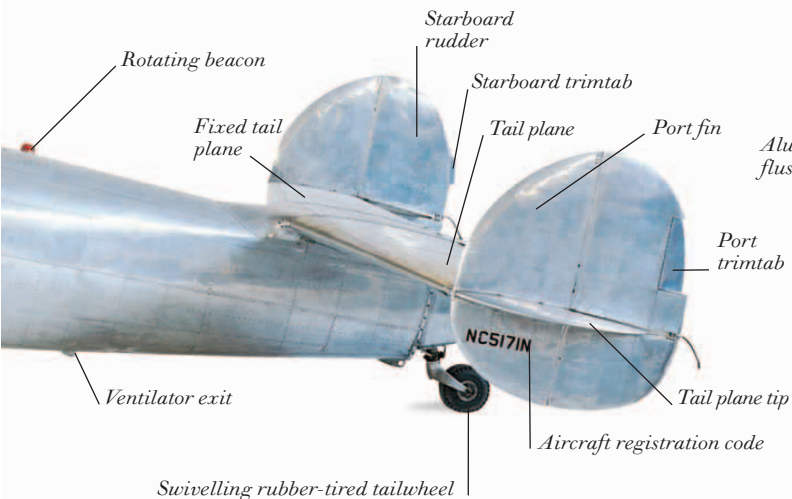
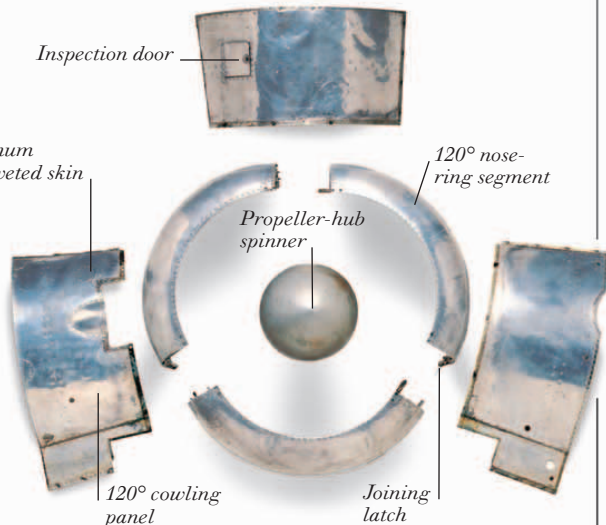


SIDE VIEW OF LOCKHEED ELECTRA, 1934



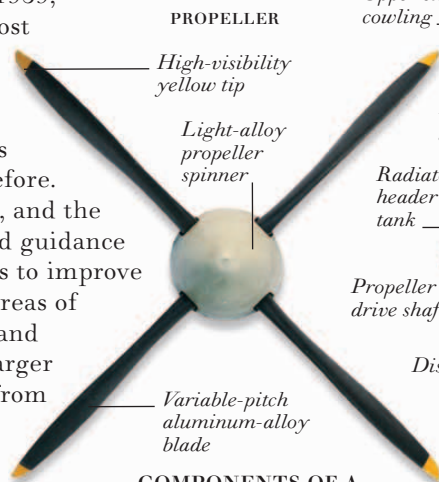


PORT ENGINE COWLINGS

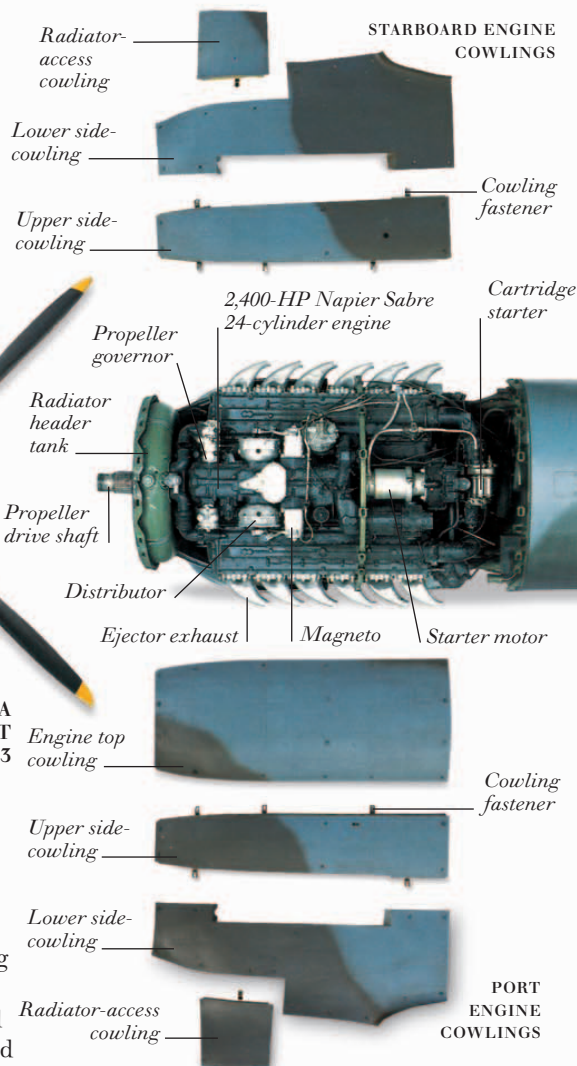


World War II aircraft

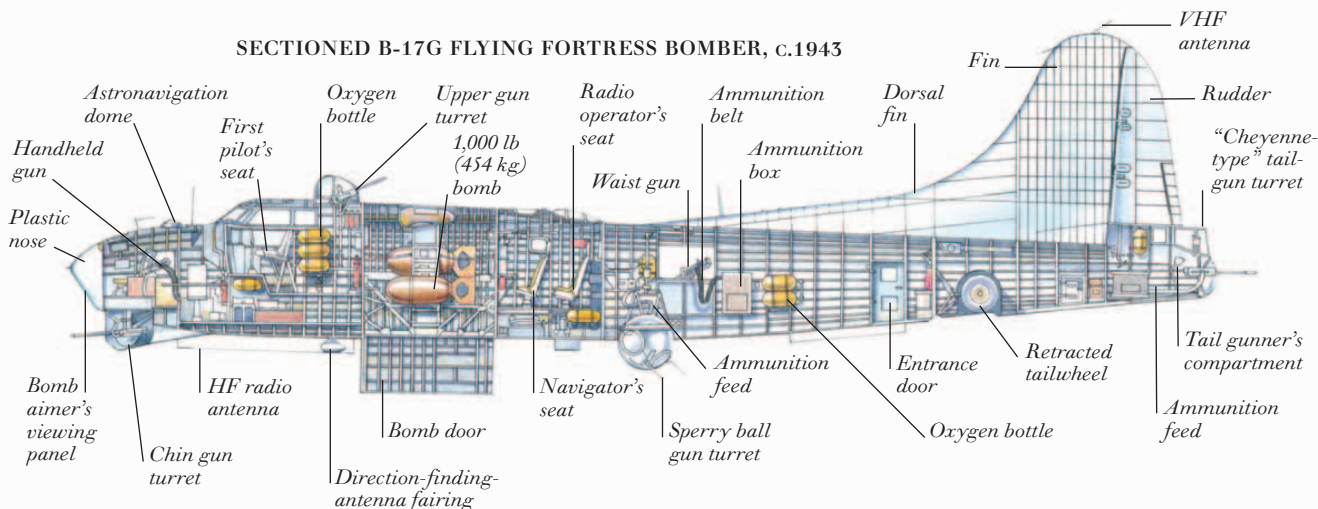
WHEN WORLD WAR II began in 1939, air forces had already replaced most of their fabric-skinned biplanes with all-metal, stressed-skin monoplanes. Aircraft played a far greater role in military operations during World War II than ever before. The wide range of aircraft duties, and the introduction of radar tracking and guidance systems, put pressure on designers to improve aircraft performance. The main areas of improvement were speed, range, and engine power. Bombers became larger and more powerful—converting from two to four engines—in order to carry a heavier bomb load; the US B-17 Flying Fortress could carry up to 6.8 tons (6.2 metric tons) of bombs over a distance of about 2,000 miles (3,200 km). Some aircraft increased their range by using drop tanks (fuel tanks that were jettisoned when empty to reduce drag). Fighters needed speed and manoeuvrability: the Hawker Tempest shown here had a maximum speed of 435 mph (700 km/h), and was one of the few Allied aircraft capable of catching the German jet-powered V1 “flying bomb.” By 1944, Britain had introduced its first turbojet-powered aircraft, the Gloster Meteor fighter, and Germany had introduced the fastest fighter in the world, the turbojet-powered Me 262, which had a maximum speed of 540 mph (868 km/h).

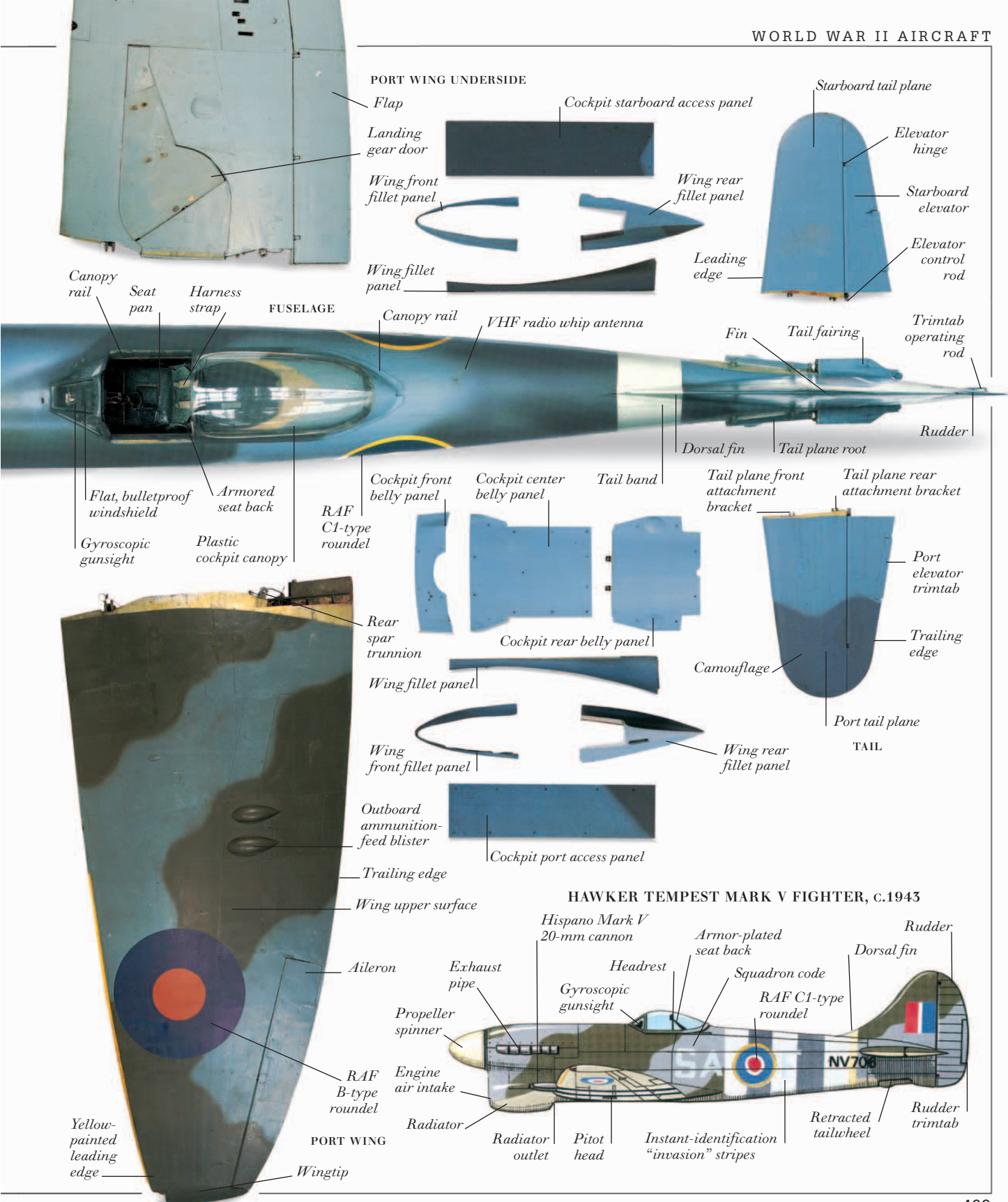


COMPONENTS OF A HAWKER TEMPEST MARK V, c.1943



SECTIONED B-17G FLYING FORTRESS BOMBER, c.1943





PORT WING UNDERSIDE

- Flap
- Landing gear door
- Wing front fillet panel
- Wing fillet panel
- Cockpit starboard access panel
- Wing rear fillet panel
- Leading edge

- Starboard tail plane
- Elevator hinge
- Starboard elevator
- Elevator control rod

FUSELAGE

- Canopy rail
- Seat pan
- Harness strap
- Flat, bulletproof windshield
- Gyroscopic gunsight
- Armored seat back
- Plastic cockpit canopy

- Canopy rail
- VHF radio whip antenna
- Fin
- Tail fairing
- Trimtab operating rod
- Dorsal fin
- Tail plane root
- Rudder

- Cockpit front belly panel
- Cockpit center belly panel
- Tail band
- Tail plane front attachment bracket
- Tail plane rear attachment bracket
- RAF C1-type roundel

- Rear spar trunnion
- Cockpit rear belly panel
- Wing fillet panel
- Wing front fillet panel
- Wing rear fillet panel
- Port elevator trimtab
- Trailing edge
- Port tail plane

TAIL

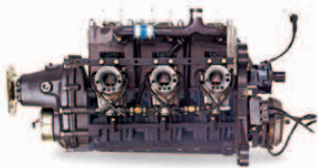
- Outboard ammunition-feed blister
- Trailing edge
- Wing upper surface
- Cockpit port access panel

- Aileron
- RAF B-type roundel
- Engine air intake
- Radiator
- Radiator outlet
- Pitot head
- Instant-identification "invasion" stripes
- Retracted tailwheel
- Rudder trimtab
- Yellow-painted leading edge
- Wingtip

HAWKER TEMPEST MARK V FIGHTER, c.1943

- Hispano Mark V 20-mm cannon
- Armor-plated seat back
- Squadron code
- RAF C1-type roundel
- Rudder
- Dorsal fin
- Headrest
- Gyroscopic gunsight
- Exhaust pipe
- Propeller spinner
- Engine air intake
- Radiator
- Radiator outlet
- Pitot head
- Instant-identification "invasion" stripes
- Retracted tailwheel
- Rudder trimtab

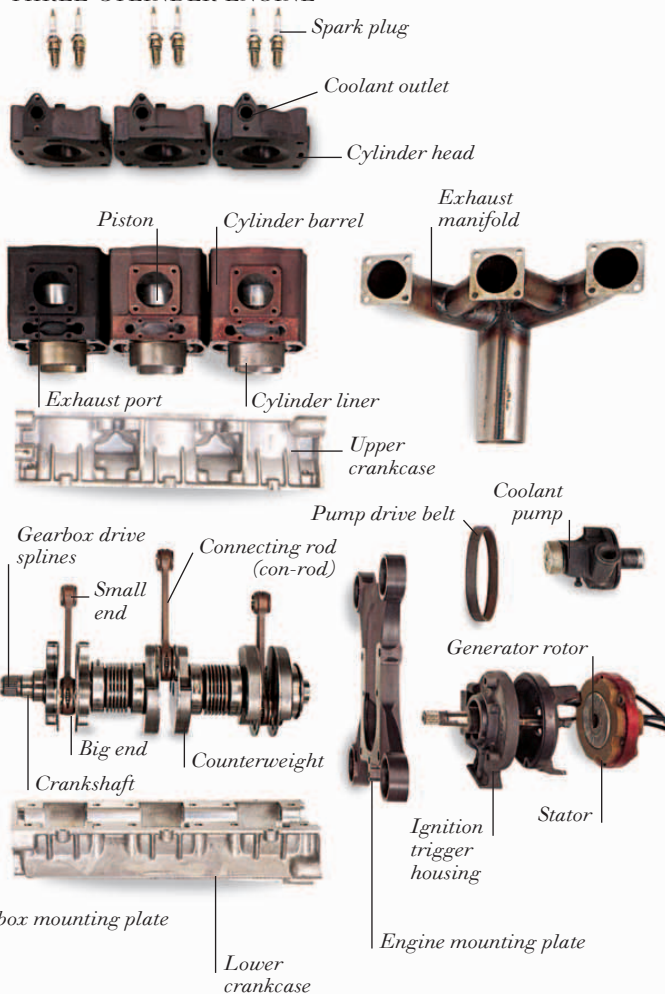
Modern piston aero-engines



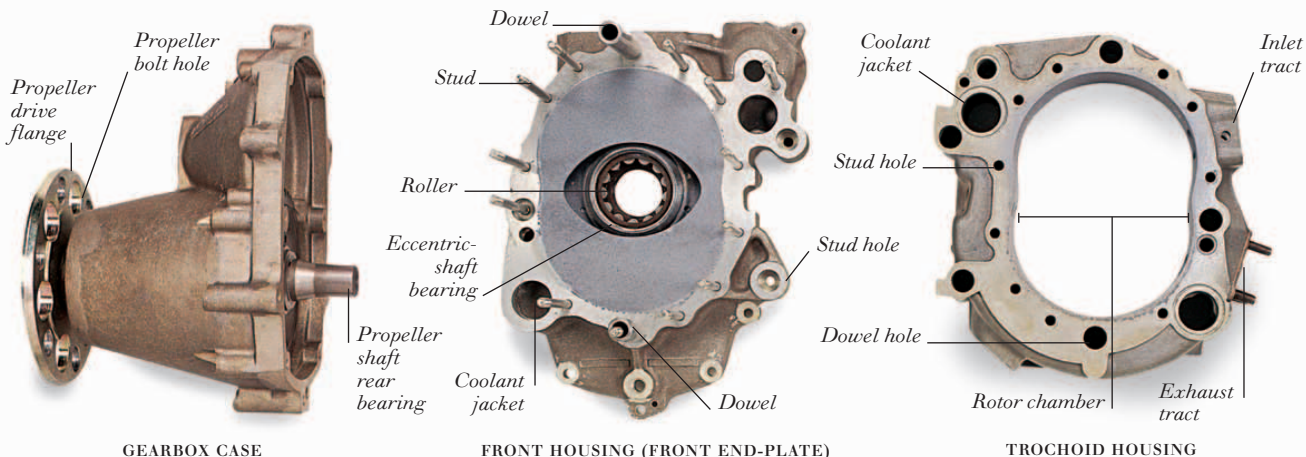
MID WEST TWO-STROKE, THREE-CYLINDER ENGINE

PISTON ENGINES today are used mainly to power the vast numbers of light aircraft and microlights, as well as crop-sprayers and crop-dusters, small helicopters, and fire-bombers (which dump water on large fires). Virtually all heavier aircraft are now powered by jet engines. Modern piston aero-engines work on the same basic principles as the engine used by the Wright brothers in the first powered flight in 1903. However, today's engines are more sophisticated than earlier engines. For example, modern aero-engines may use a two-stroke or a four-stroke combustion cycle; they may have from one to nine air- or water-cooled cylinders, which may be arranged horizontally, in-line, in V formation, or radially; and they may drive the aircraft's propeller either directly or through a reduction gearbox. One of the more unconventional types of modern aero-engine is the rotary engine shown here, which has a trilobate (three-sided) rotor spinning in a chamber shaped like a fat figure-eight.

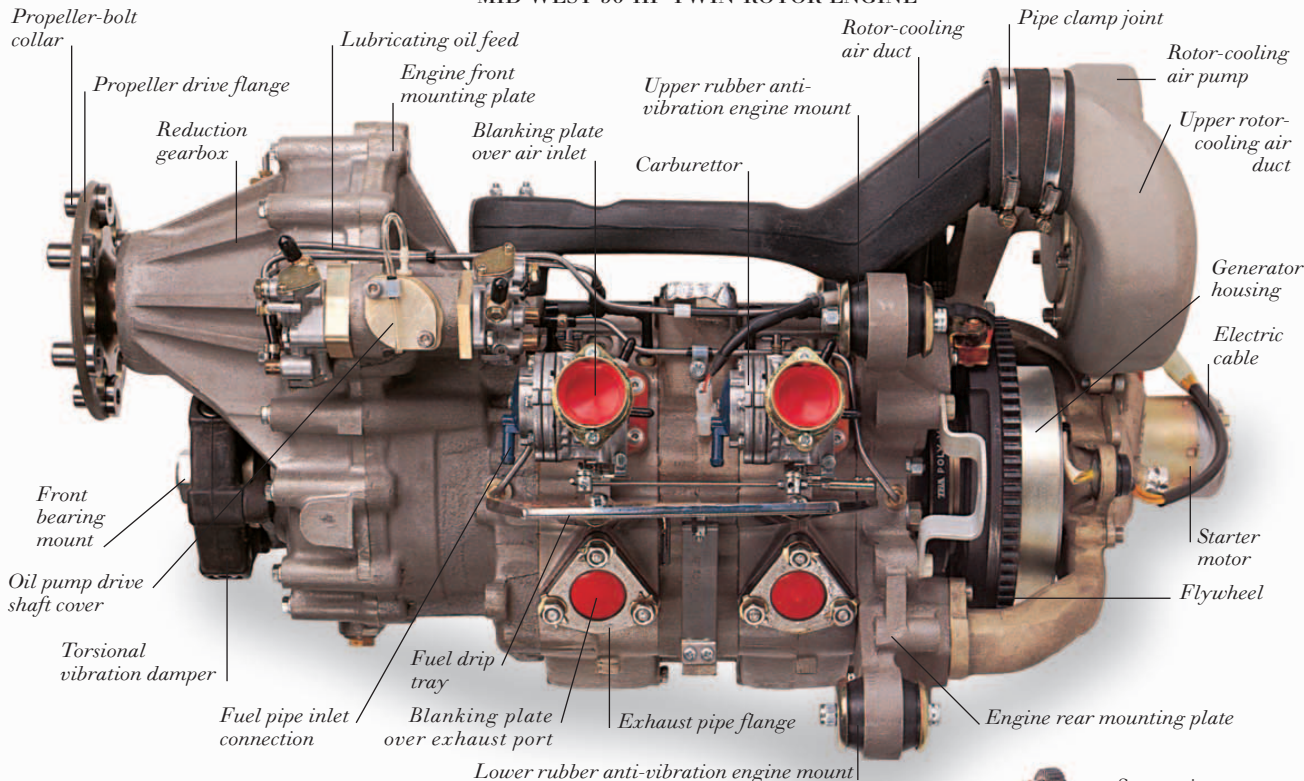
MID WEST 75-HP TWO-STROKE, THREE-CYLINDER ENGINE



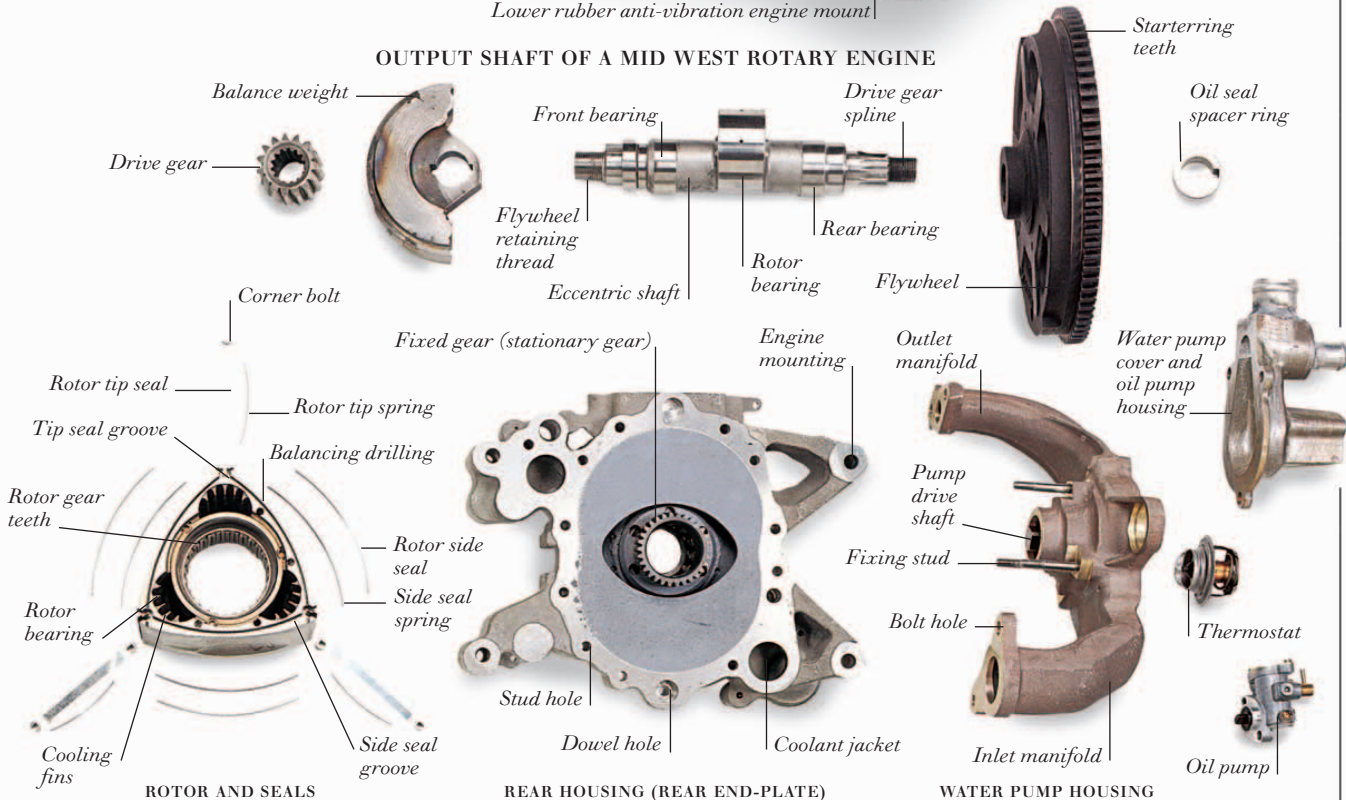
ROTOR AND HOUSINGS OF A MID WEST SINGLE-ROTOR ENGINE



MID WEST 90-HP TWIN-ROTOR ENGINE



OUTPUT SHAFT OF A MID WEST ROTARY ENGINE



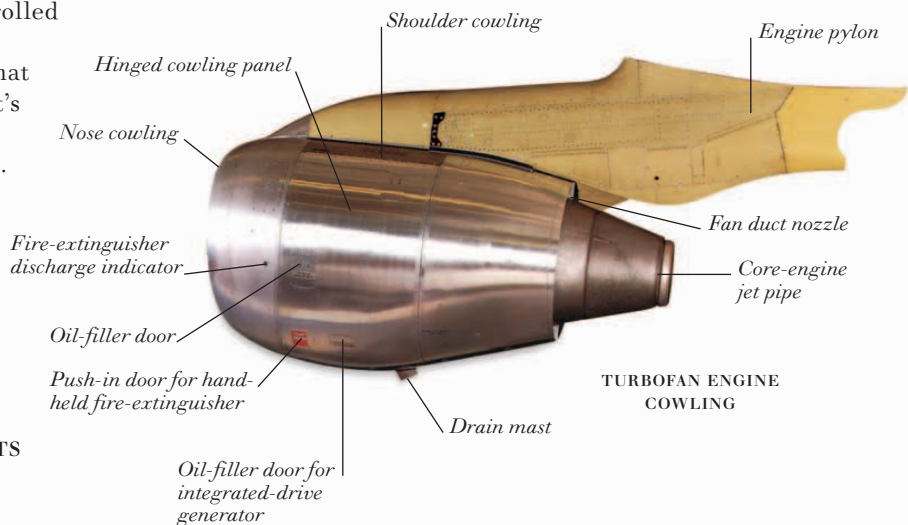
Modern jetliners 1



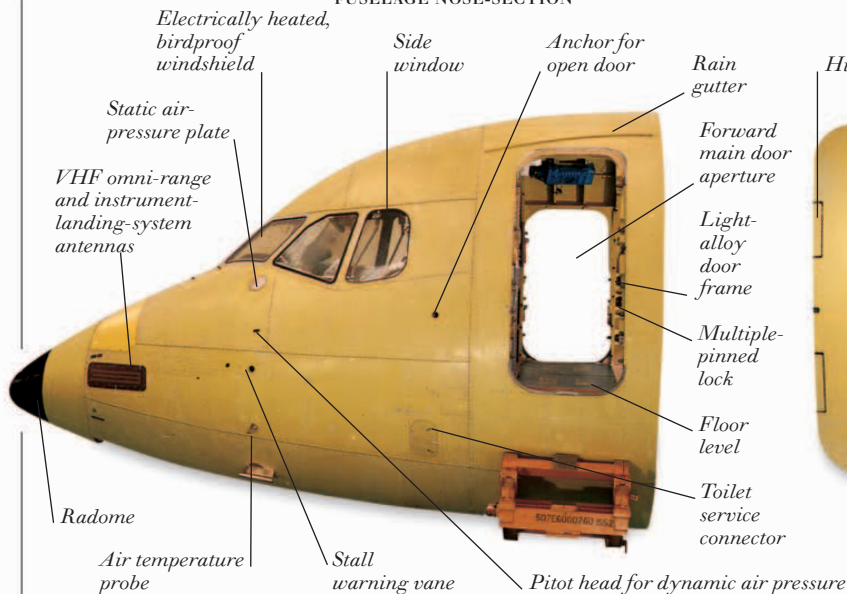
BAE-146 JETLINER

MODERN JETLINERS HAVE ENABLED ordinary people to travel to places where once only the wealthy could afford to go. Compared with the first jetliners (which were introduced in the 1940s), modern ones are much quieter, burn fuel more efficiently, and produce less air pollution. These advances are largely due to the replacement of turbojet engines with turbofan engines (see pp. 418-419). The greater power of turbofan engines at low speeds enables modern jetliners to carry more fuel and passengers than turbojet aircraft; a modern Boeing 747-400 (popularly known as a “jumbo jet”) can fly 400 people for 8,500 miles (13,700 km) without needing to refuel. Jetliners fly at high altitudes, typically cruising at 26,000-36,000 ft (8000-11,000 m), where they can use fuel efficiently and usually avoid bad weather. The pilot always controls the aircraft during takeoff and landing, but at other times the aircraft is usually controlled by an autopilot. Autopilots are complex on-board mechanisms that detect deviations from an aircraft’s route and make appropriate adjustments to the flight controls. Flight decks are also equipped with radars that warn pilots of approaching hazards, such as mountain ranges, bad weather, and other aircraft.

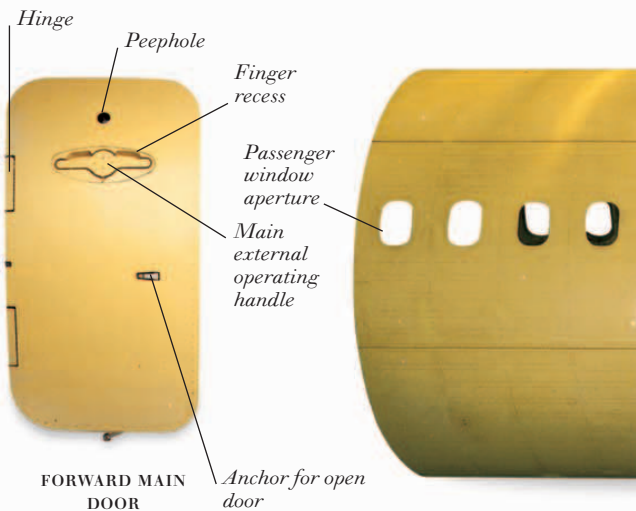
STRUCTURAL COMPONENTS
OF A BAE-146 JETLINER

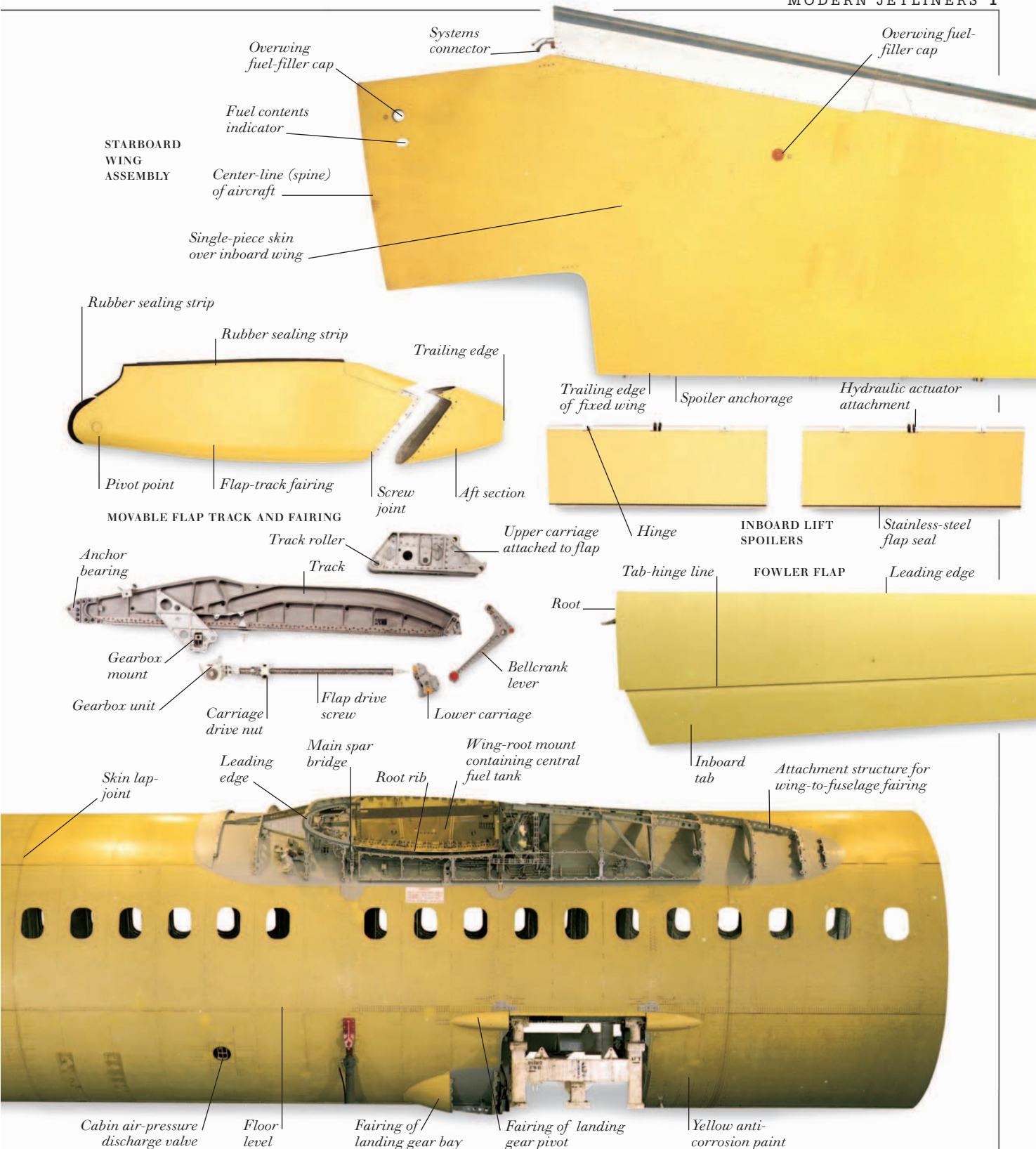


FUSELAGE NOSE-SECTION



FUSELAGE MID-SECTION





STARBOARD WING ASSEMBLY

Overwing fuel-filler cap

Systems connector

Overwing fuel-filler cap

Fuel contents indicator

Center-line (spine) of aircraft

Single-piece skin over inboard wing

Rubber sealing strip

Rubber sealing strip

Trailing edge

Trailing edge of fixed wing

Spoiler anchorage

Hydraulic actuator attachment

Pivot point

Flap-track fairing

Screw joint

Aft section

MOVABLE FLAP TRACK AND FAIRING

Upper carriage attached to flap

INBOARD LIFT SPOILERS

Stainless-steel flap seal

Anchor bearing

Track roller

Track

Hinge

FOWLER FLAP

Leading edge

Gearbox mount

Gearbox unit

Carriage drive nut

Flap drive screw

Lower carriage

Bellcrank lever

Root

Tab-hinge line

Skin lap-joint

Leading edge

Main spar bridge

Root rib

Wing-root mount containing central fuel tank

Inboard tab

Attachment structure for wing-to-fuselage fairing

Cabin air-pressure discharge valve

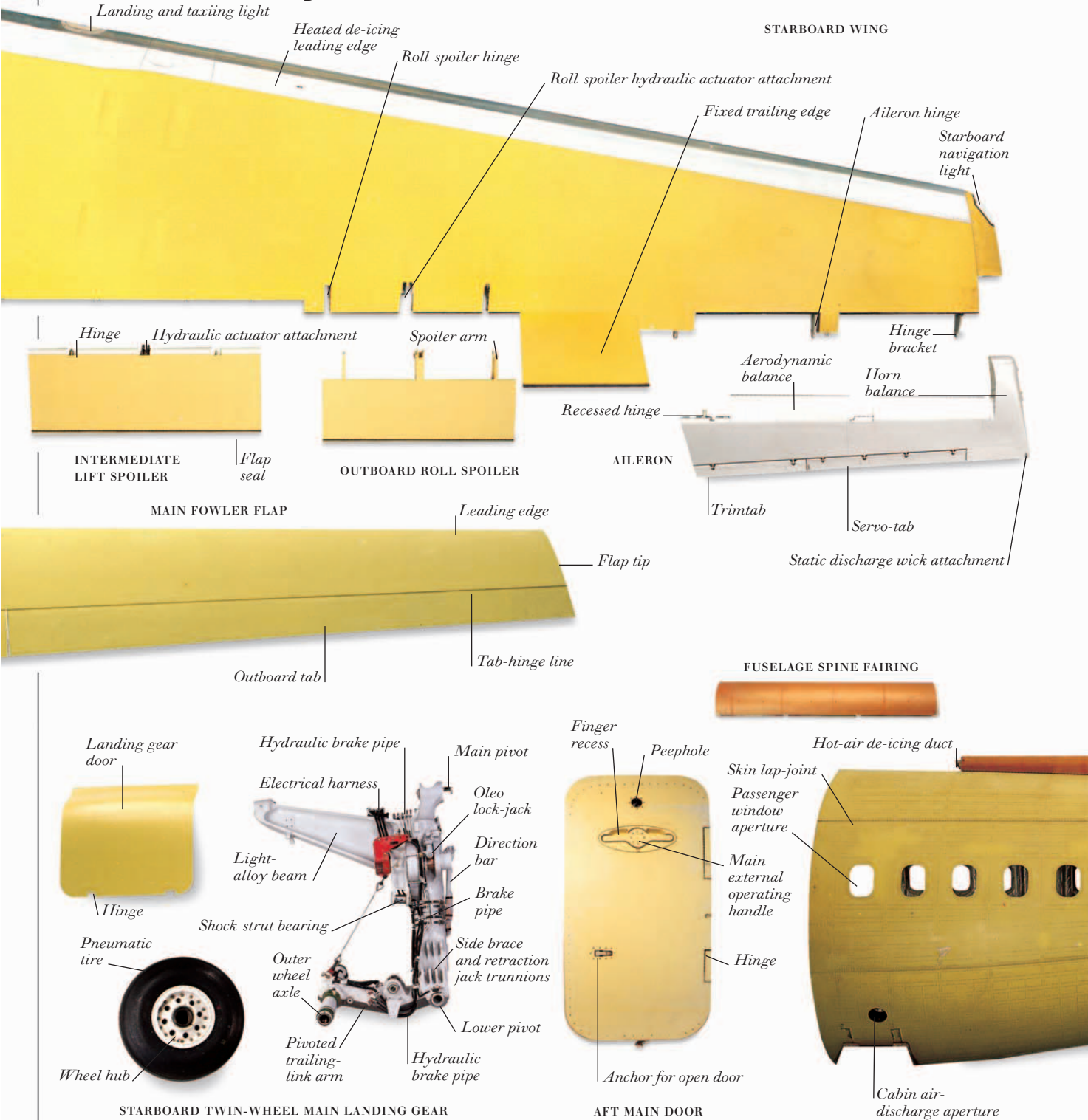
Floor level

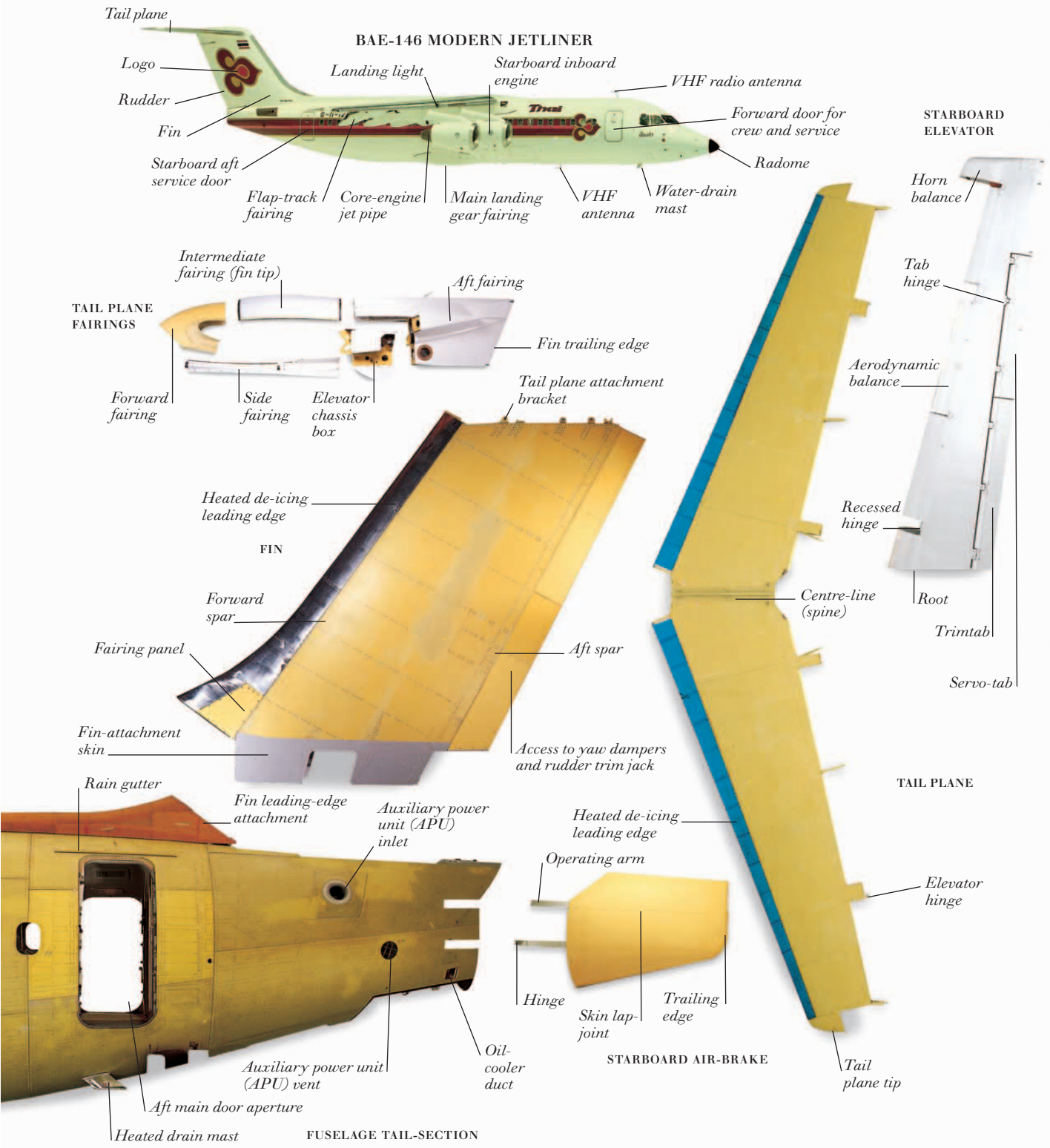
Fairing of landing gear bay

Fairing of landing gear pivot

Yellow anti-corrosion paint

Modern jetliners 2





BAE-146 MODERN JETLINER

TAIL PLANE FAIRINGS

STARBOARD ELEVATOR

TAIL PLANE

FUSELAGE TAIL-SECTION

STARBOARD AIR-BRAKE

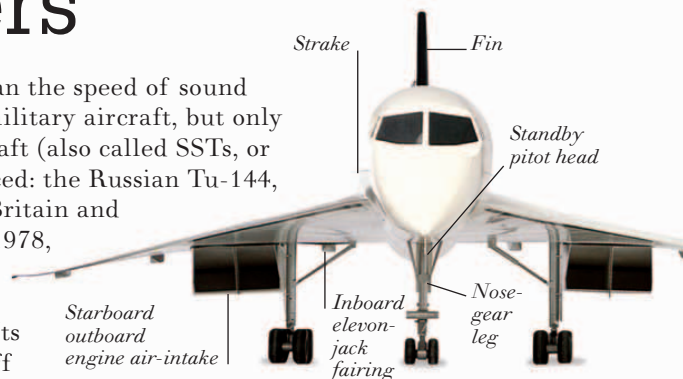
Supersonic jetliners



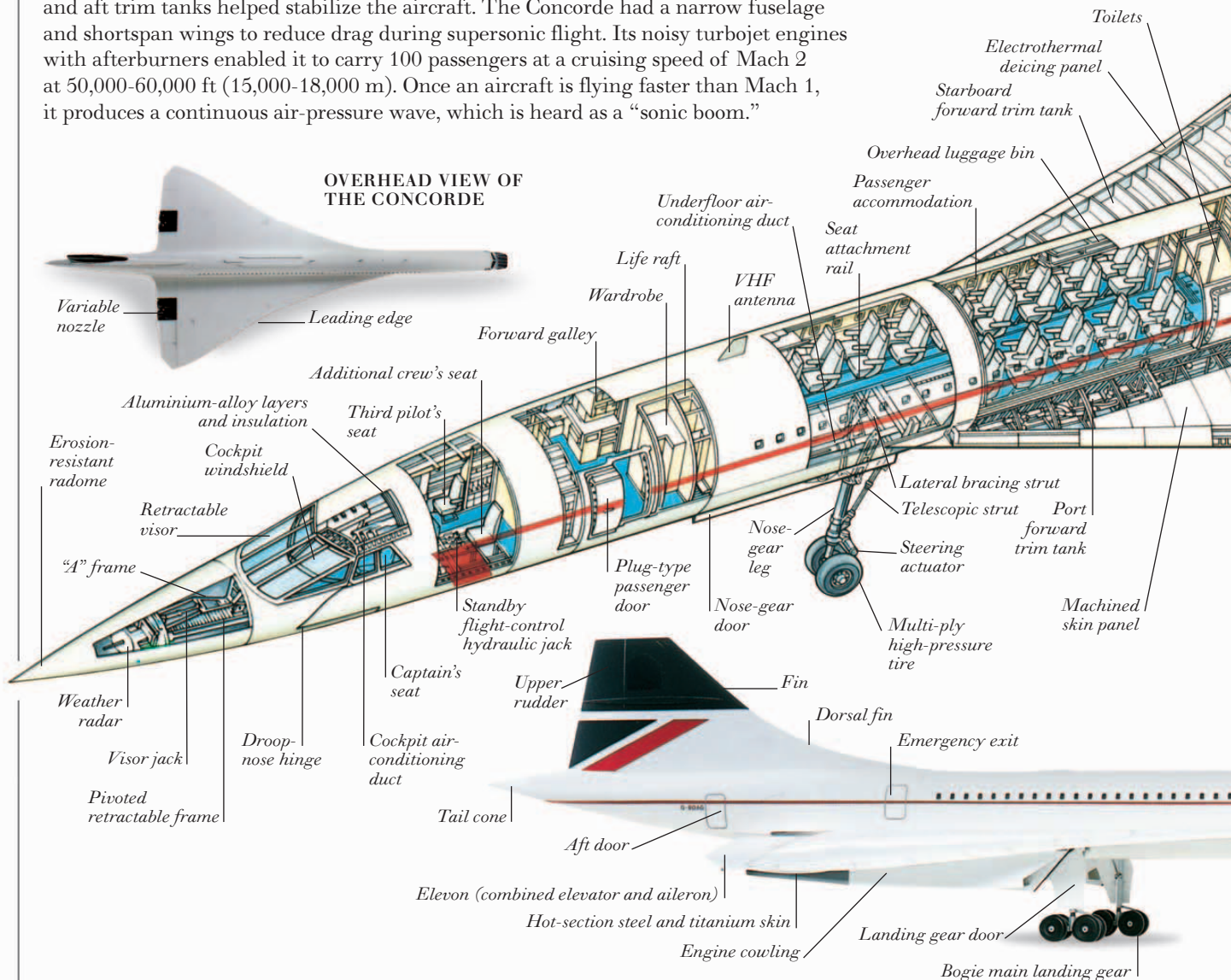
COMPUTER-DESIGNED SST

SUPERSONIC AIRCRAFT FLY FASTER than the speed of sound (Mach 1). There are many supersonic military aircraft, but only two supersonic passenger-carrying aircraft (also called SSTs, or supersonic transports) have been produced: the Russian Tu-144, and the Concorde, produced jointly by Britain and France. The Tu-144 was withdrawn in 1978, after only seven months in service. The

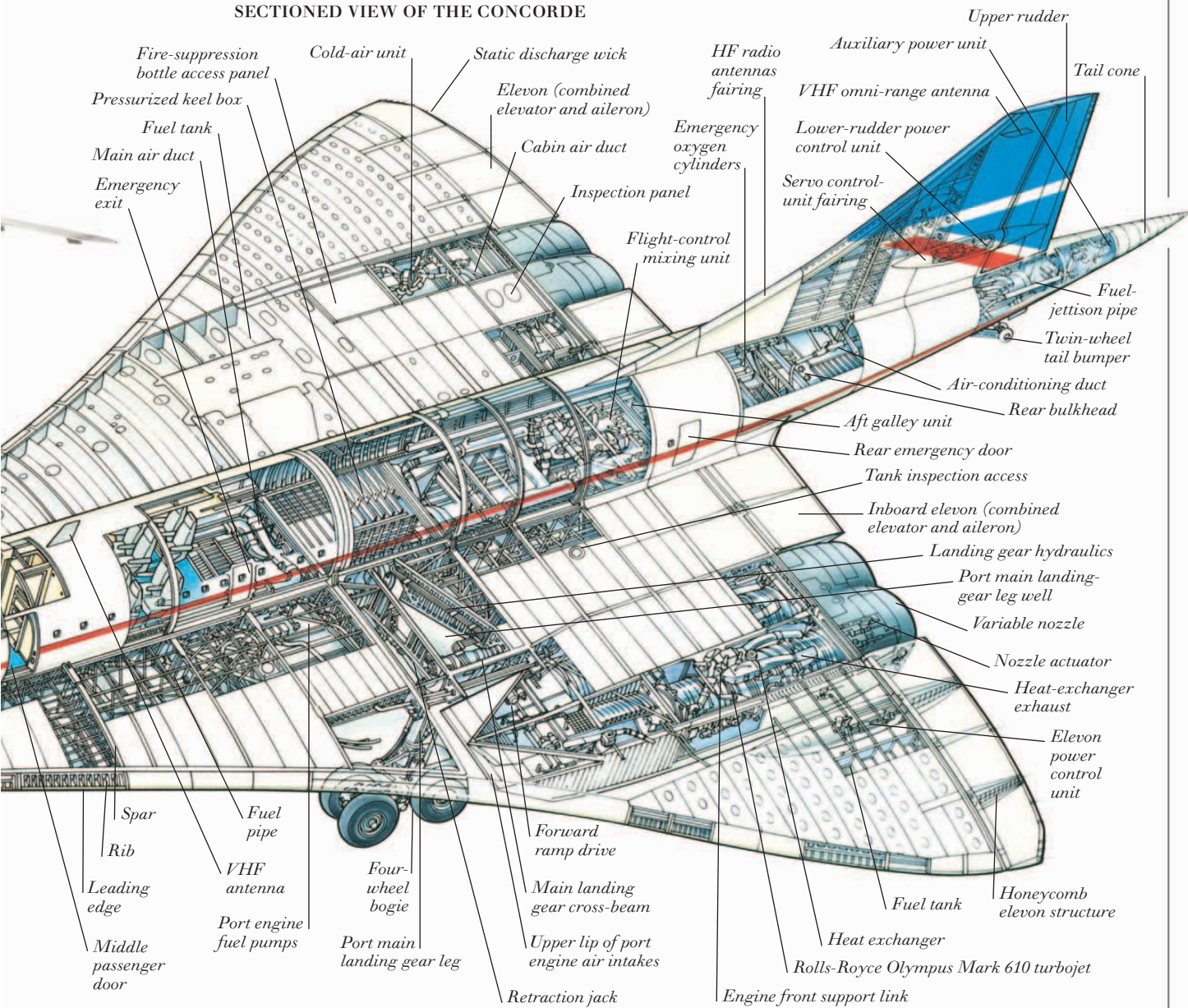
Concorde remained in service from 1976 until 2003, with a break for modifications from July 2000 until October 2001. Its features included a droop nose, which lowered during takeoff and landing to aid visibility from the cockpit; the pumping of fuel between forward and aft trim tanks helped stabilize the aircraft. The Concorde had a narrow fuselage and shortspan wings to reduce drag during supersonic flight. Its noisy turbojet engines with afterburners enabled it to carry 100 passengers at a cruising speed of Mach 2 at 50,000-60,000 ft (15,000-18,000 m). Once an aircraft is flying faster than Mach 1, it produces a continuous air-pressure wave, which is heard as a "sonic boom."



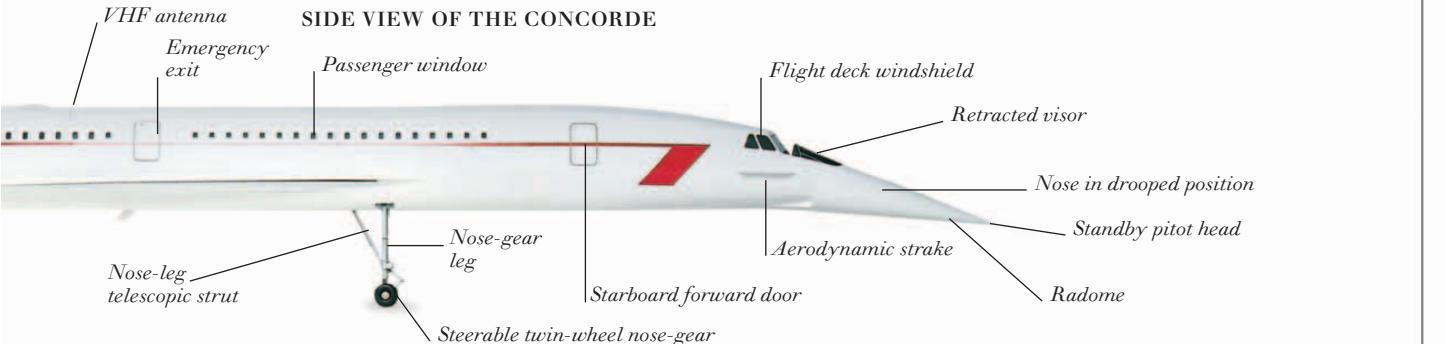
FRONT OF THE CONCORDE



SECTIONED VIEW OF THE CONCORDE



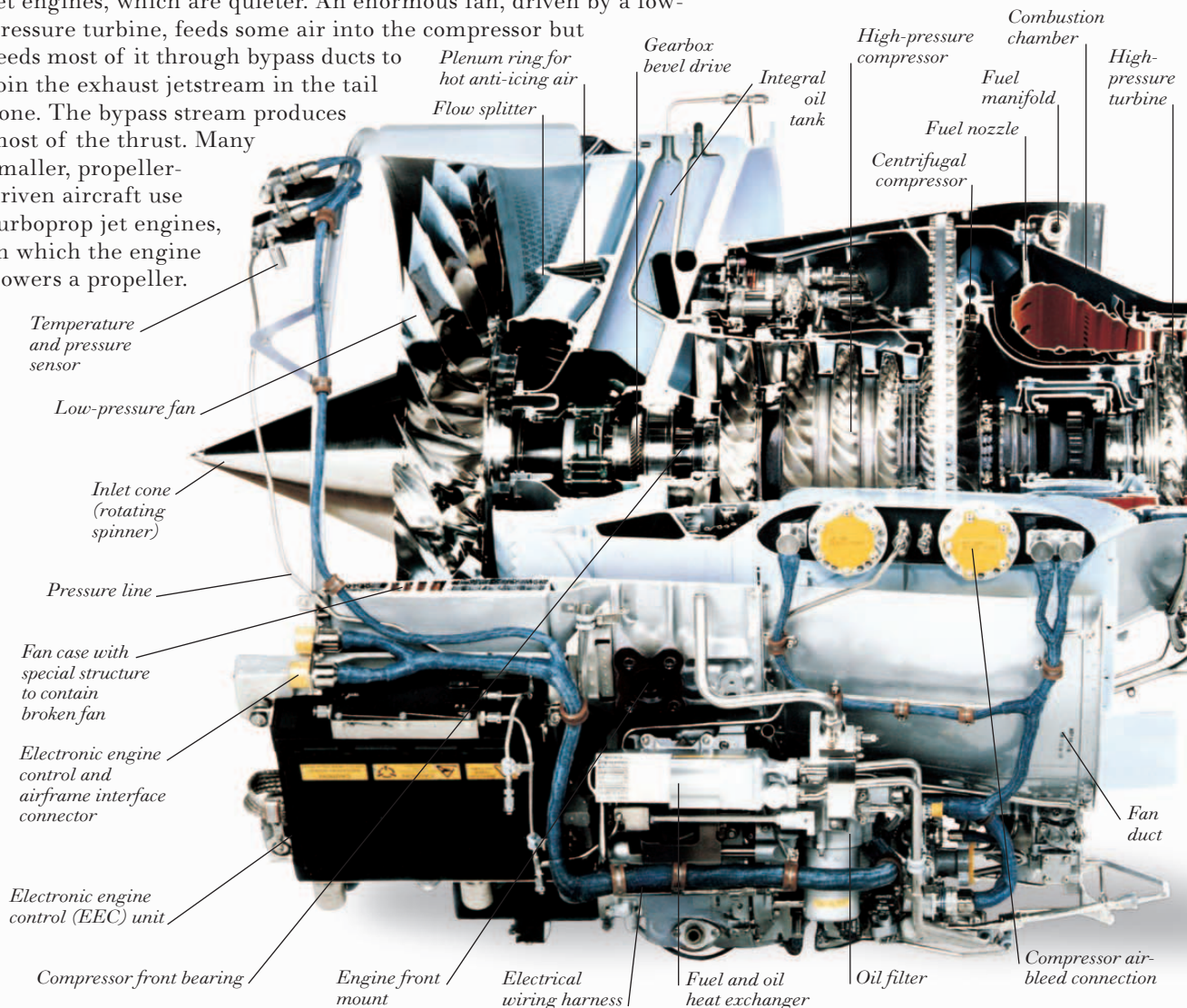
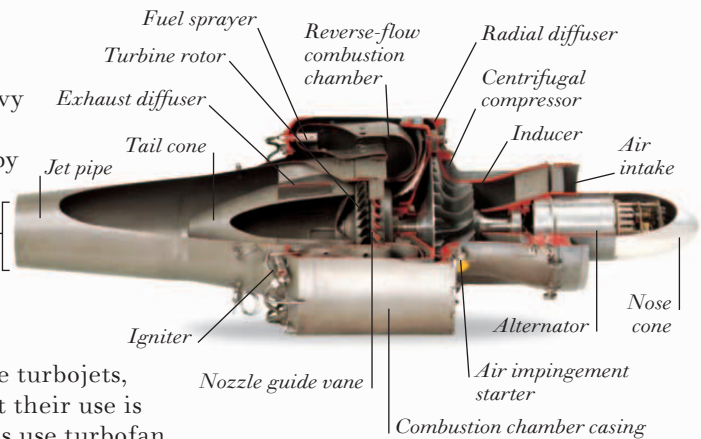
SIDE VIEW OF THE CONCORDE



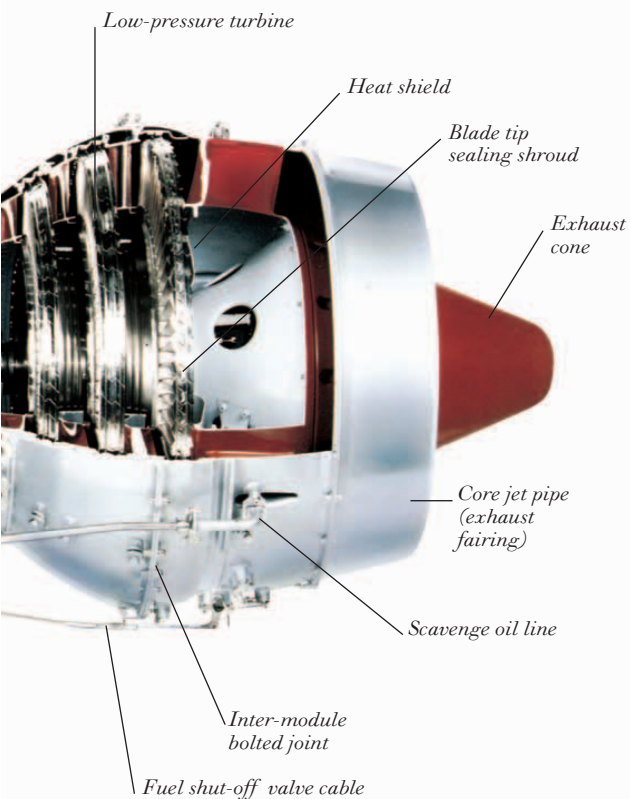
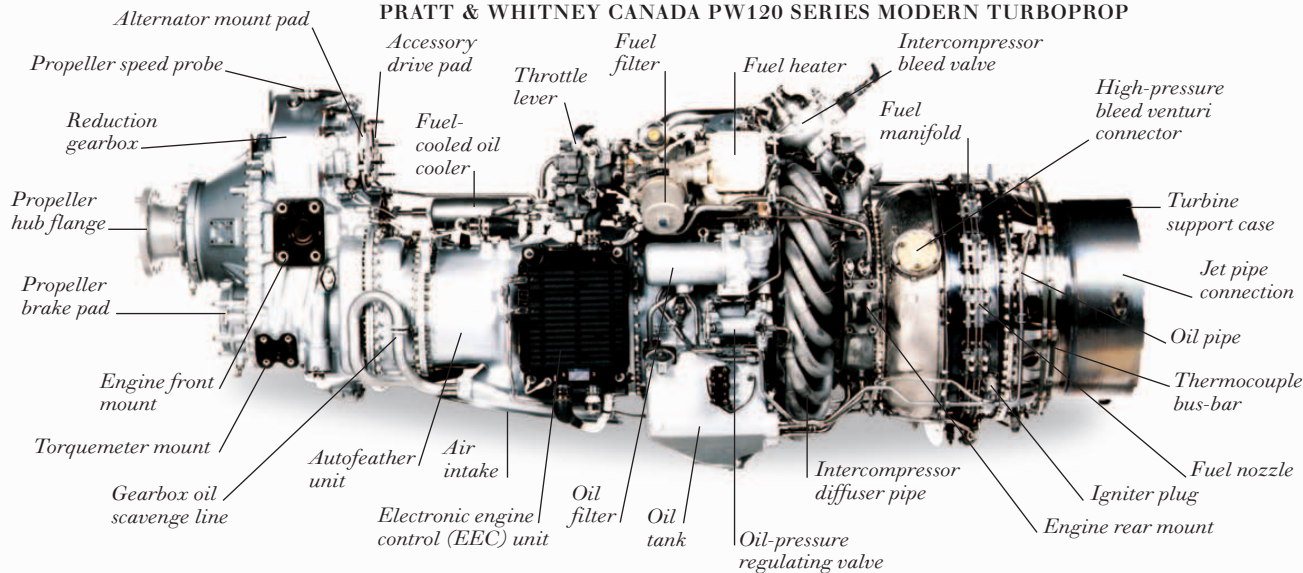
Jet engines

JET ENGINES ARE USED BY MOST MILITARY and heavy aircraft, and by many helicopters. The simplest type of jet engine, or gas turbine, is the turbojet. It works by continuously burning a mixture of fuel and air in a combustion chamber to produce a jet of hot exhaust gas that is expelled through a nozzle to produce thrust. The hot gas also spins turbine blades, which, in turn, spin the blades of an air compressor; the compressor forces air into the combustion chamber. Many of the fastest aircraft use turbojets, with additional booster units called afterburners, but their use is restricted by their high noise emission. Most jetliners use turbofan jet engines, which are quieter. An enormous fan, driven by a low-pressure turbine, feeds some air into the compressor but feeds most of it through bypass ducts to join the exhaust jetstream in the tail cone. The bypass stream produces most of the thrust. Many smaller, propeller-driven aircraft use turboprop jet engines, in which the engine powers a propeller.

NPT 301 MODERN TURBOJET

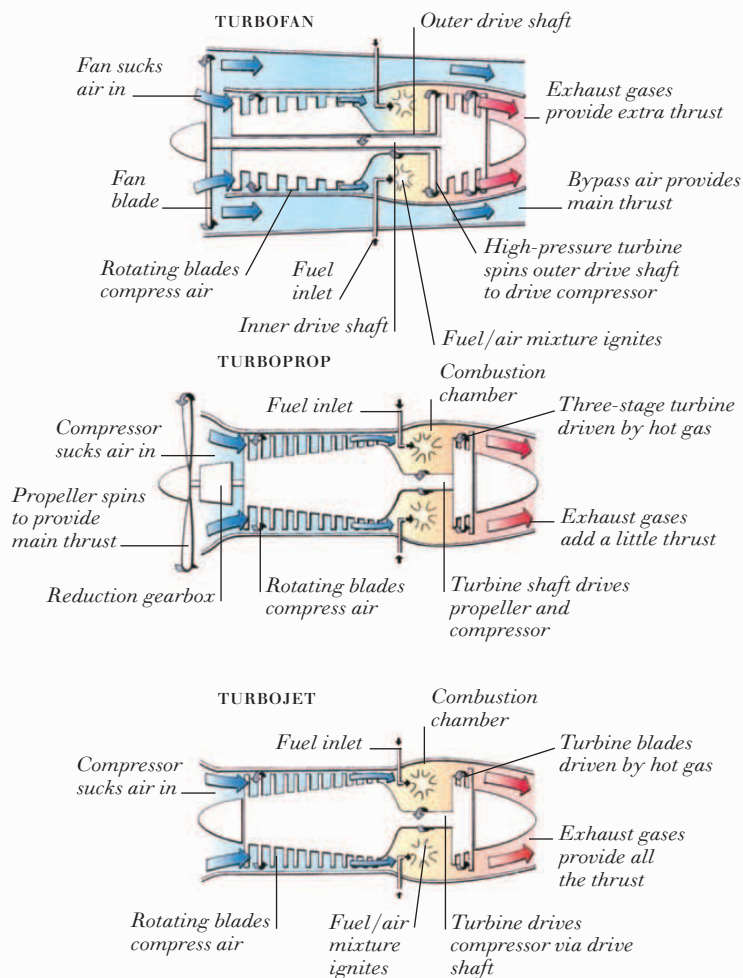


PRATT & WHITNEY CANADA PW120 SERIES MODERN TURBOPROP



SECTIONED PRATT & WHITNEY CANADA PW305 MODERN TURBOFAN

HOW JET ENGINES WORK

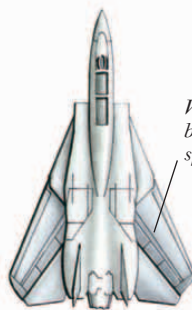


Modern military aircraft

MODERN MILITARY AIRCRAFT ARE AMONG THE MOST SOPHISTICATED and expensive products of the 21st century. Fighters need computer-operated controls for maneuverability, powerful engines, and effective air-to-air weapons. Most modern fighters also have guided missiles, radar, and passive, infrared sensors. These developments enable today's fighters to engage in combat with adversaries that are outside visual range. Bombers carry a large weapon load and enough fuel for long-range flights. A few military aircraft, such as the Tornado and the F-14 Tomcat, have variable-sweep ("swing") wings. During takeoff and landing their wings are fully extended, but for high-speed flight and low-level attacks the wings are pivoted fully back. A recent development is the "stealth" bomber, which is designed to absorb or deflect enemy radar in order to remain undetected. Earlier bombers, such as the Tornado, use terrain-following radars to fly so close to the ground that they avoid enemy radar detection.



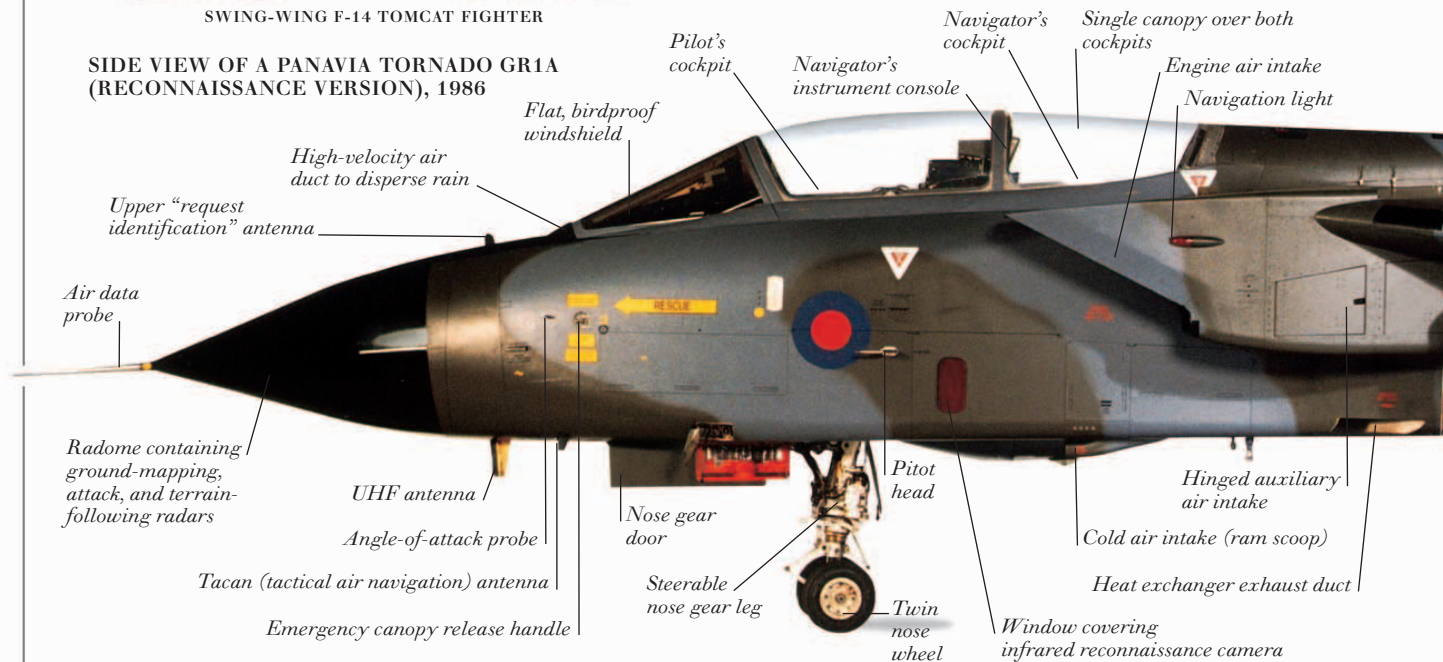
Wing extended for takeoff and landing



Wing pivoted back for high-speed flight

SWING-WING F-14 TOMCAT FIGHTER

SIDE VIEW OF A PANAVIA TORNADO GR1A (RECONNAISSANCE VERSION), 1986



Pilot's cockpit

Navigator's instrument console

Navigator's cockpit

Single canopy over both cockpits

Engine air intake

Navigation light

Flat, birdproof windshield

High-velocity air duct to disperse rain

Upper "request identification" antenna

Air data probe

Radome containing ground-mapping, attack, and terrain-following radars

UHF antenna

Angle-of-attack probe

Tacan (tactical air navigation) antenna

Emergency canopy release handle

Nose gear door

Steerable nose gear leg

Pitot head

Twin nose wheel

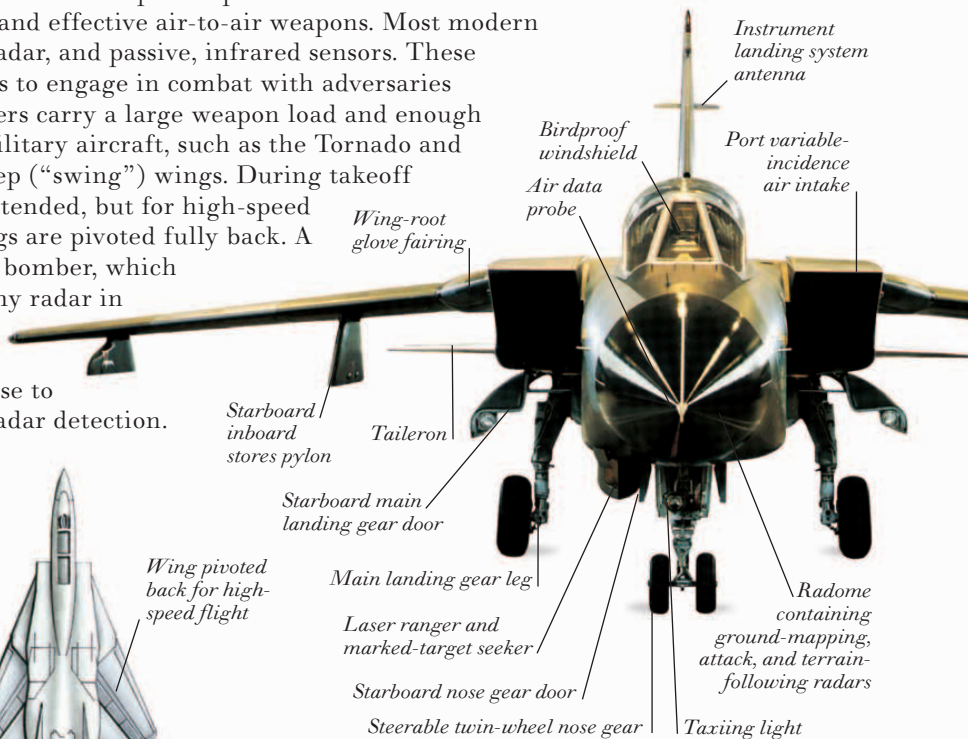
Hinged auxiliary air intake

Cold air intake (ram scoop)

Heat exchanger exhaust duct

Window covering infrared reconnaissance camera

FRONT VIEW OF A PANAVIA TORNADO



Instrument landing system antenna

Port variable-incidence air intake

Birdproof windshield

Air data probe

Wing-root glove fairing

Starboard inboard stores pylon

Taileron

Starboard main landing gear door

Main landing gear leg

Laser ranger and marked-target seeker

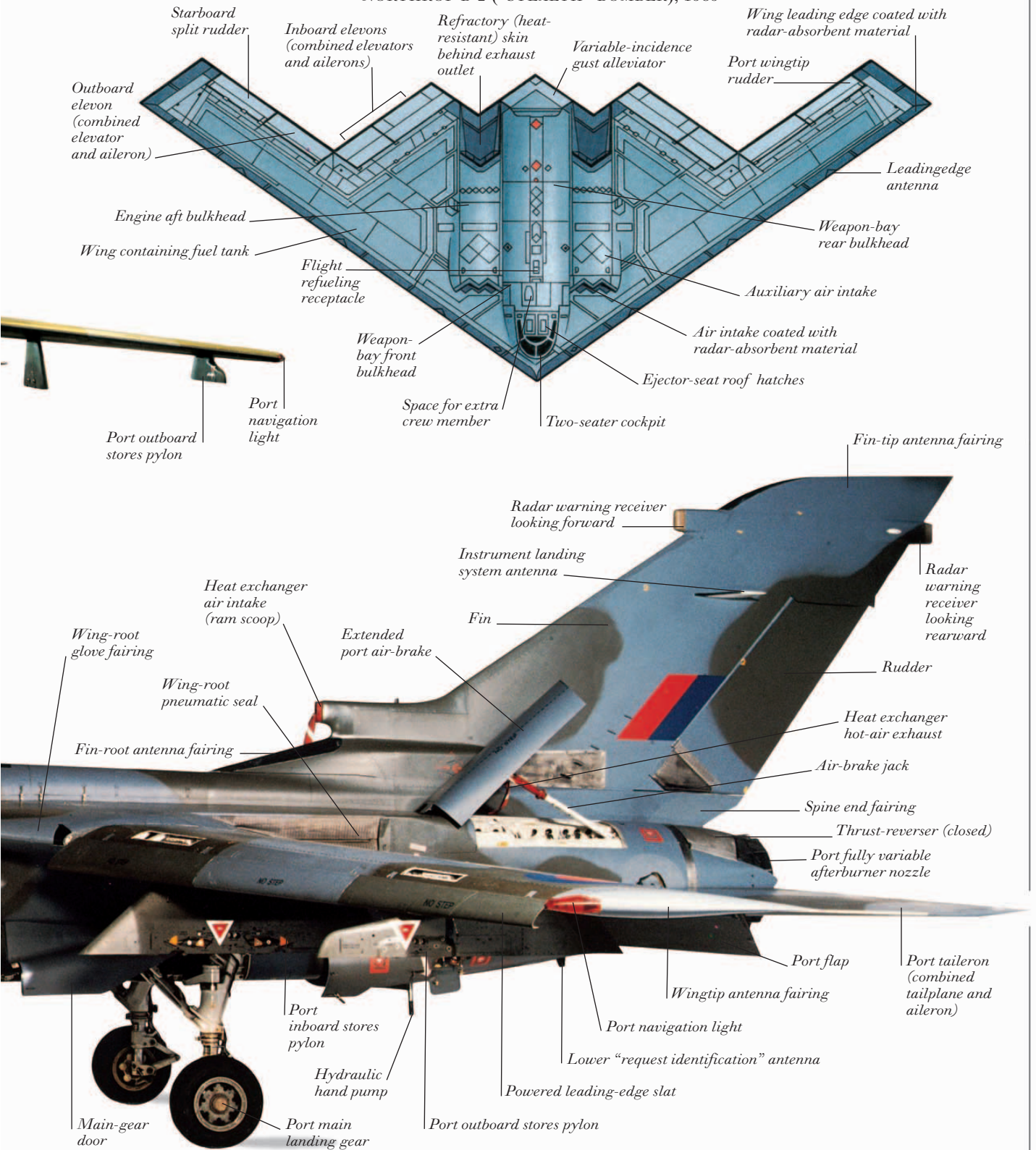
Starboard nose gear door

Steerable twin-wheel nose gear

Radome containing ground-mapping, attack, and terrain-following radars

Taxiing light

NORTHROP B-2 ("STEALTH" BOMBER), 1989

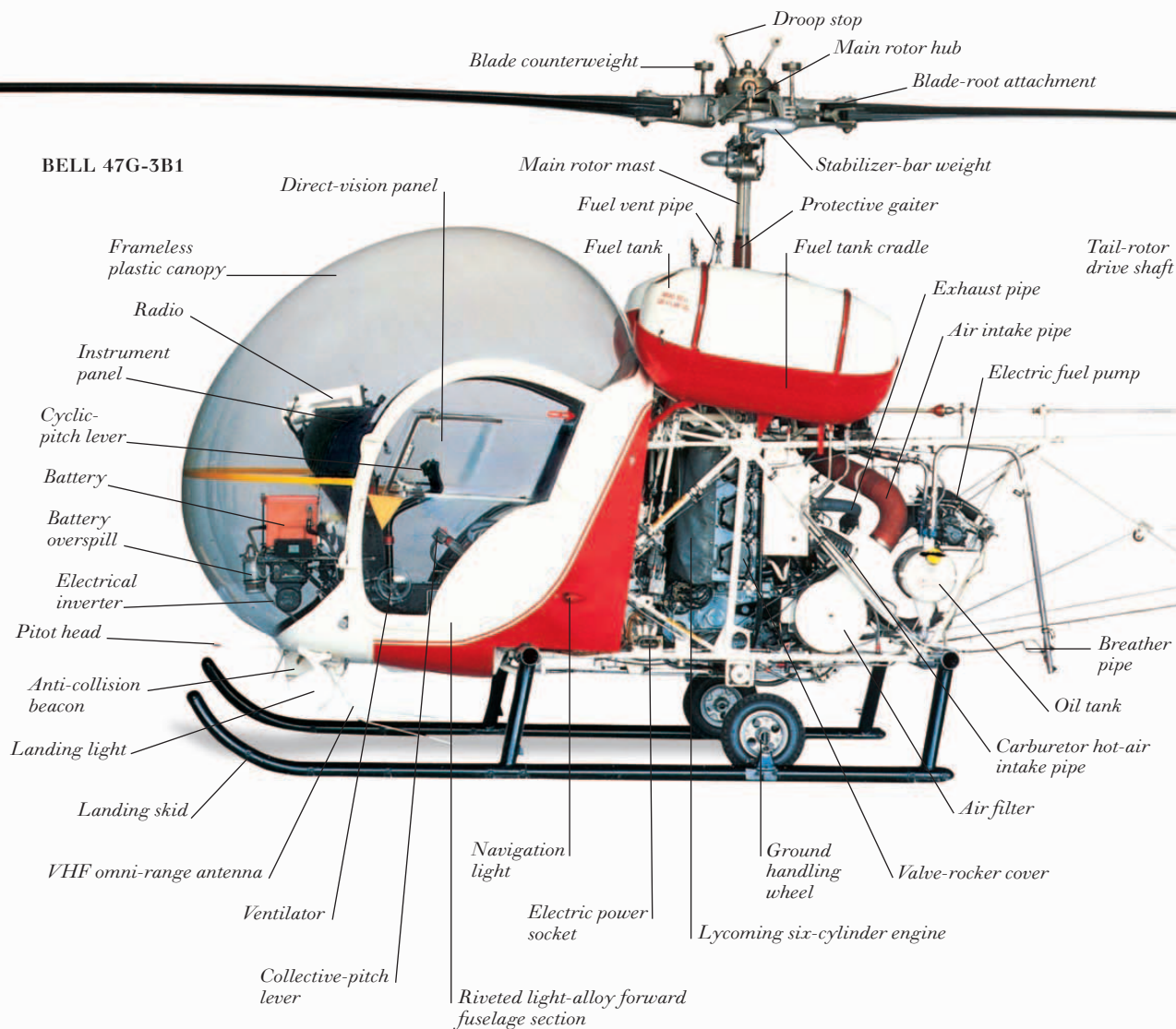


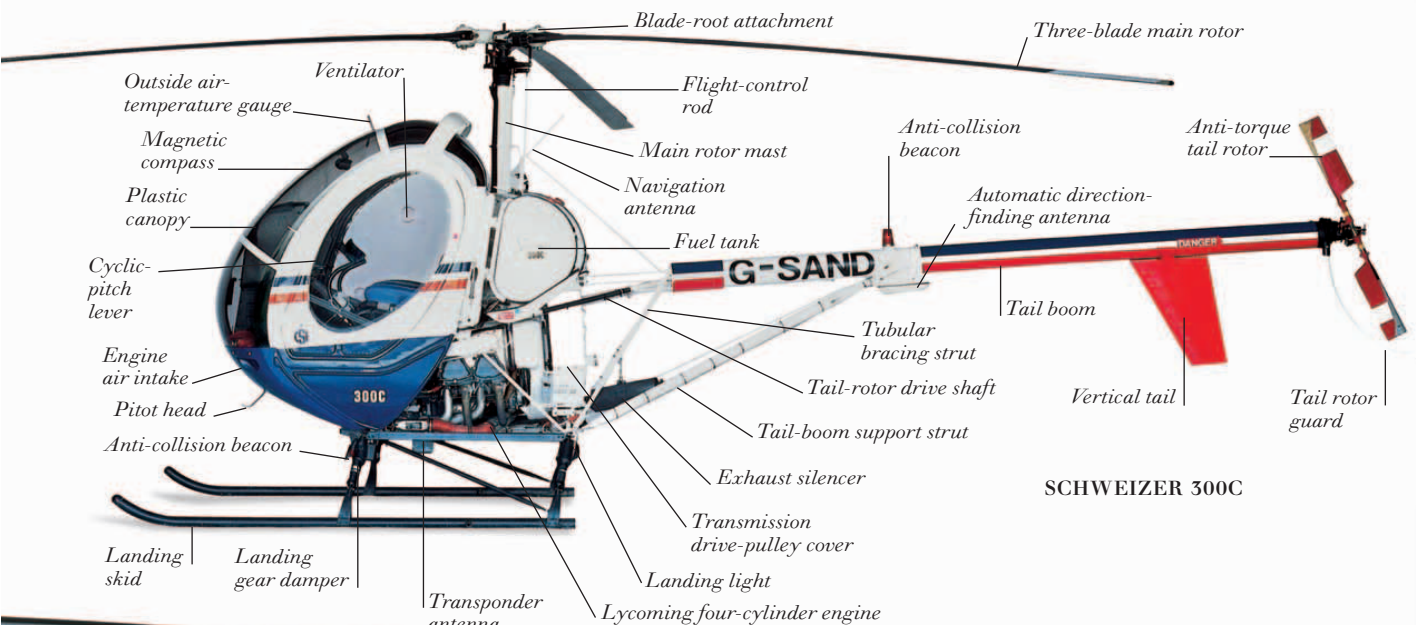
Helicopters



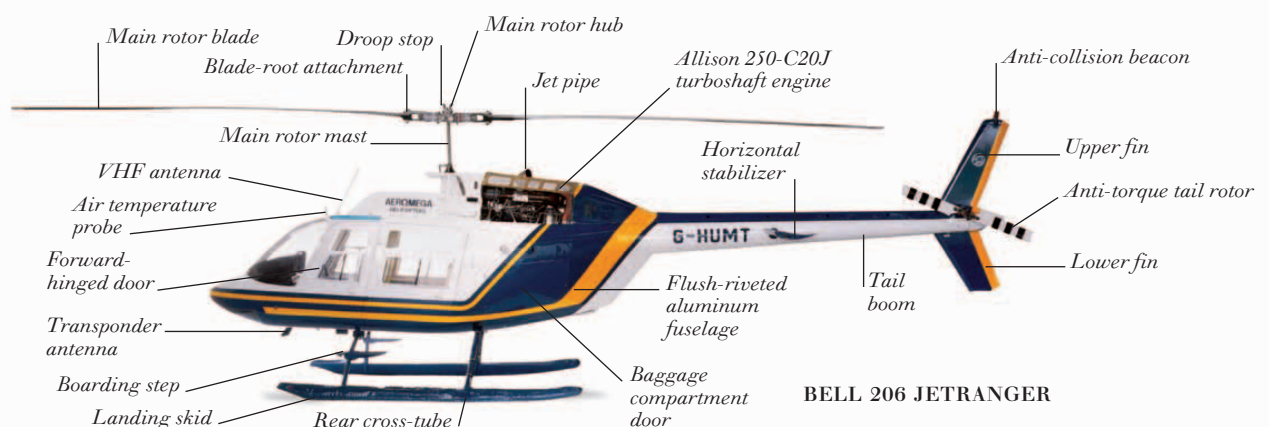
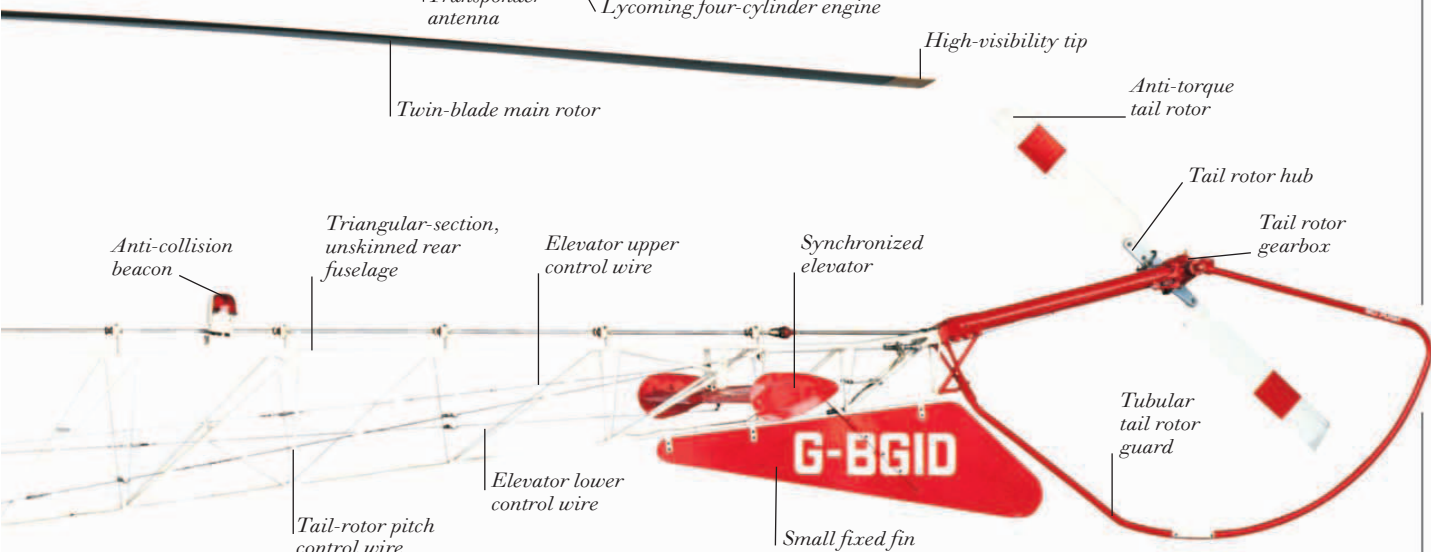
BELL 47G-3B1

HELICOPTERS USE ROTATING BLADES for lift, propulsion, and steering. The first machine to achieve sustained, controlled flight using rotating blades was the autogiro built in the 1920s by the Spaniard Juan de la Cierva. His machine had unpowered blades above the fuselage that relied on the flow of air to rotate them and provide lift as the autogiro was driven forward by a conventional propeller. Then, in 1939, the Russian-born American Igor Sikorsky produced his VS-300, the forerunner of modern helicopters. Its engine-driven blades provided lift, propulsion, and steering. It could take off vertically, hover, and fly in any direction, and had a tail rotor to prevent the helicopter body from spinning. The introduction of gas turbine jet engines to helicopters in 1955 produced quieter, safer, and more powerful machines. Because of their versatility in flight, helicopters are today used for many purposes, including crop spraying, traffic surveillance, and transporting crews to deep-sea oil rigs, as well as acting as gunships, air ambulances, and air taxis.





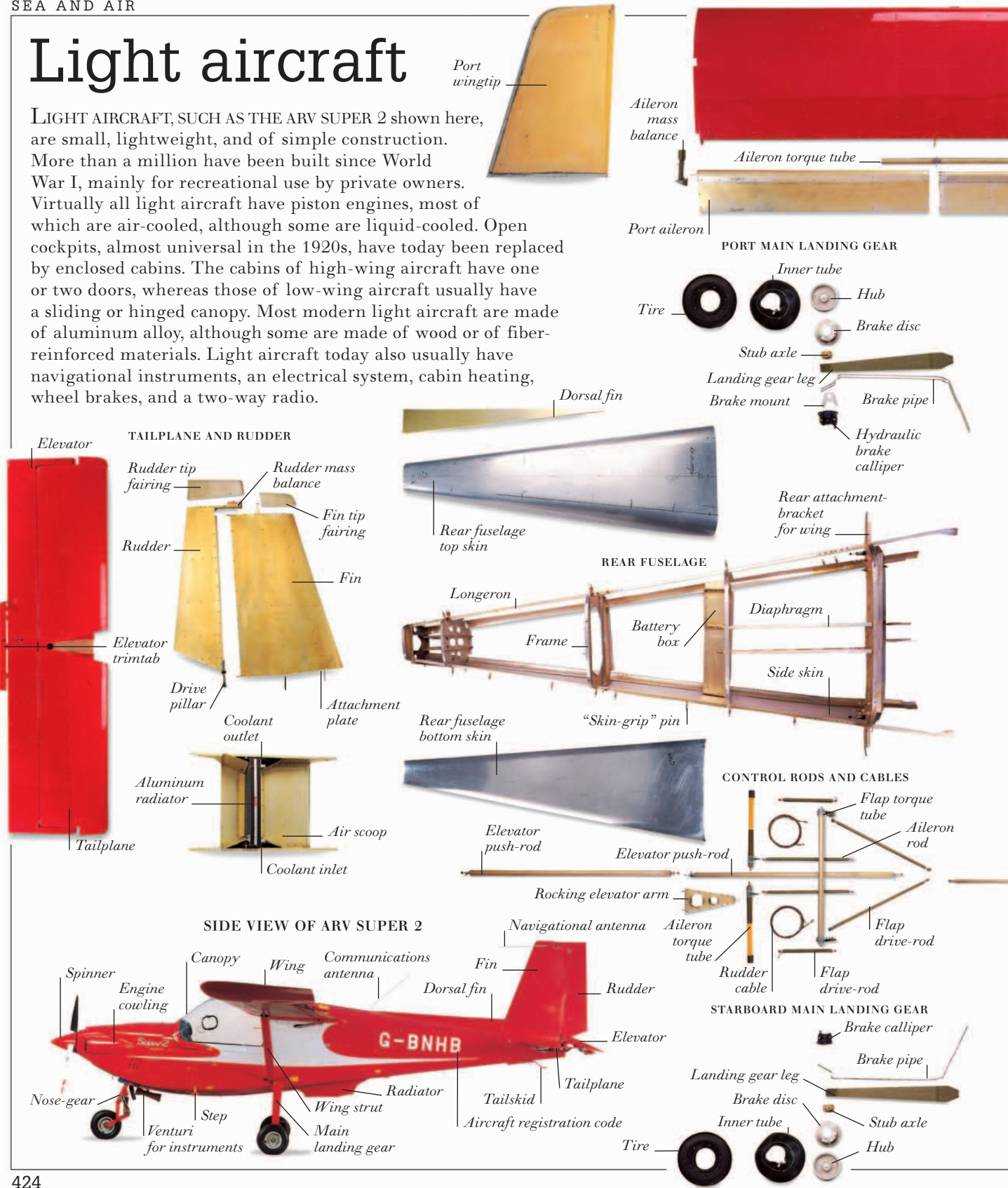
SCHWEIZER 300C



BELL 206 JETRANGER

Light aircraft

LIGHT AIRCRAFT, SUCH AS THE ARV SUPER 2 shown here, are small, lightweight, and of simple construction. More than a million have been built since World War I, mainly for recreational use by private owners. Virtually all light aircraft have piston engines, most of which are air-cooled, although some are liquid-cooled. Open cockpits, almost universal in the 1920s, have today been replaced by enclosed cabins. The cabins of high-wing aircraft have one or two doors, whereas those of low-wing aircraft usually have a sliding or hinged canopy. Most modern light aircraft are made of aluminum alloy, although some are made of wood or of fiber-reinforced materials. Light aircraft today also usually have navigational instruments, an electrical system, cabin heating, wheel brakes, and a two-way radio.



SIDE VIEW OF ARV SUPER 2

Spinner
Engine cowling
Nose-gear
Venturi for instruments
Step
Wing
Communications antenna
Main landing gear
Wing strut
Radiator
Tailskid
Tailplane
Aircraft registration code
G-BNHB
Dorsal fin
Fin
Rudder
Elevator
Tailplane

TAILPLANE AND RUDDER

Elevator
Rudder tip fairing
Rudder mass balance
Fin tip fairing
Rudder
Fin
Elevator trimtab
Drive pillar
Attachment plate
Coolant outlet
Aluminum radiator
Air scoop
Coolant inlet
Tailplane

Port wingtip

Aileron mass balance

Aileron torque tube

Port aileron

PORT MAIN LANDING GEAR

Inner tube
Hub
Tire
Brake disc
Stub axle
Landing gear leg
Brake mount
Brake pipe
Hydraulic brake calliper
Rear attachment-bracket for wing

Dorsal fin
Rear fuselage top skin

REAR FUSELAGE

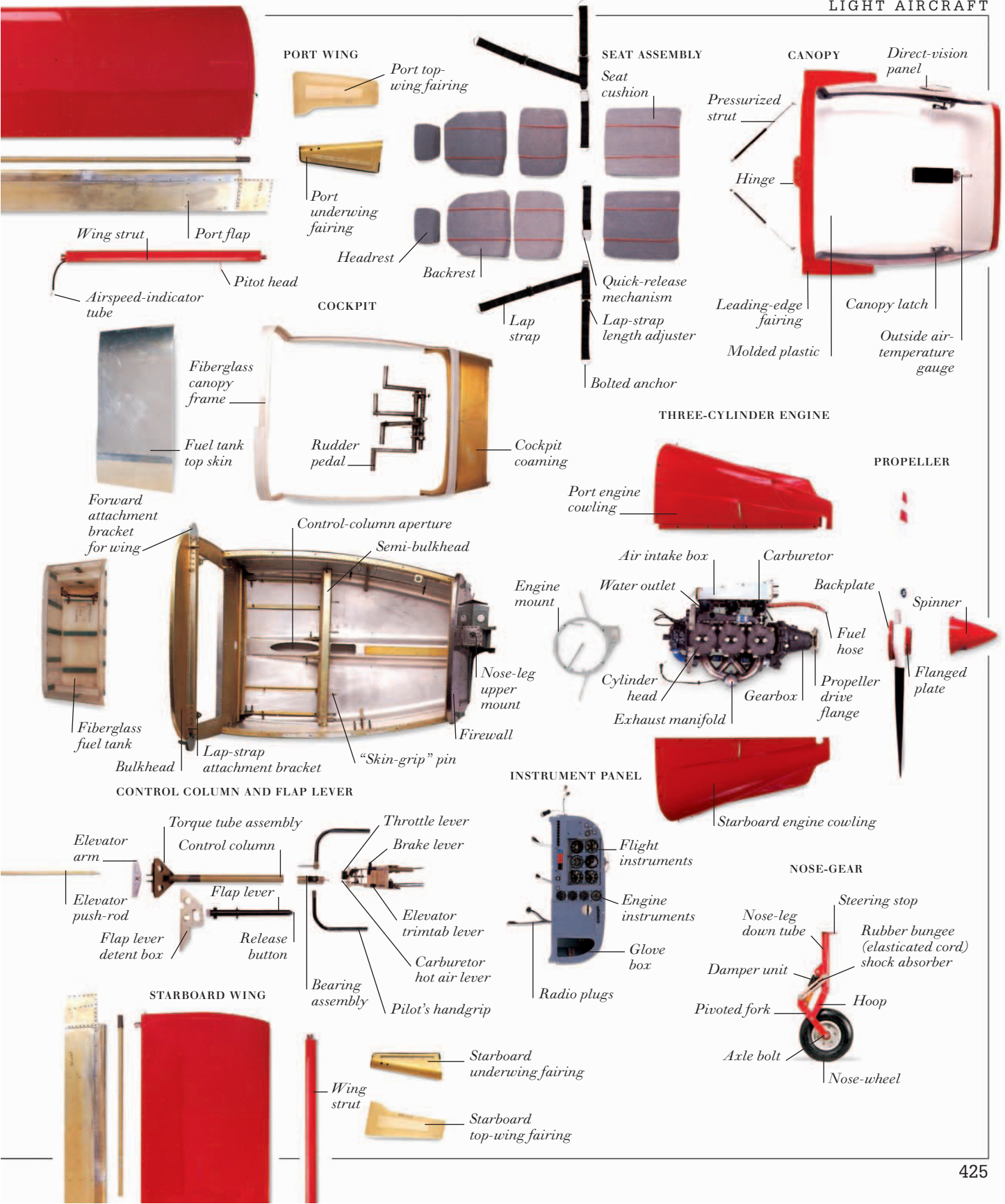
Longeron
Frame
Battery box
Diaphragm
Side skin
"Skin-grip" pin
Rear fuselage bottom skin

CONTROL RODS AND CABLES

Flap torque tube
Aileron rod
Elevator push-rod
Rocking elevator arm
Elevator push-rod
Rudder cable
Flap drive-rod
Flap drive-rod

STARBOARD MAIN LANDING GEAR

Brake calliper
Brake pipe
Landing gear leg
Brake disc
Stub axle
Hub
Tire



PORT WING

Port top-wing fairing
Port underwing fairing
Headrest
Backrest

SEAT ASSEMBLY

Seat cushion
Quick-release mechanism
Lap-strap length adjuster
Bolted anchor

CANOPY

Direct-vision panel
Pressurized strut
Hinge
Leading-edge fairing
Molded plastic
Canopy latch
Outside air-temperature gauge

COCKPIT

Rudder pedal
Cockpit coaming
Fiberglass canopy frame
Fuel tank top skin

THREE-CYLINDER ENGINE

Port engine cowling
Air intake box
Carburetor
Water outlet
Backplate
Spinner
Flanged plate

PROPELLER

Fuel hose
Propeller drive flange
Gearbox
Cylinder head
Exhaust manifold

CONTROL COLUMN AND FLAP LEVER

Control-column aperture
Semi-bulkhead
Nose-leg upper mount
Firewall
"Skin-grip" pin
Bulkhead
Lap-strap attachment bracket

ENGINE MOUNT

Engine mount

INSTRUMENT PANEL

Flight instruments
Engine instruments
Glove box
Radio plugs

Starboard engine cowling

NOSE-GEAR

Steering stop
Nose-leg down tube
Rubber bungee (elasticated cord) shock absorber
Damper unit
Hoop
Pivoted fork
Axle bolt
Nose-wheel

STARBOARD WING

Starboard underwing fairing
Wing strut
Starboard top-wing fairing

Gliders, hang-gliders, and ultralights



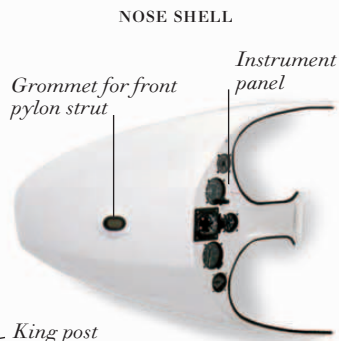
HANG-GLIDER

MODERN GLIDERS ARE AMONG the most graceful and aerodynamically efficient of all aircraft. Unpowered but with a large wingspan (up to about 82 ft, or 25 m), gliders use currents of hot, rising air (thermals) to stay aloft, and a rudder, elevators, and ailerons for control.

Modern gliders have achieved flights of more than 900 miles (1,450 km) and altitudes above 49,000 ft (15,000 m).

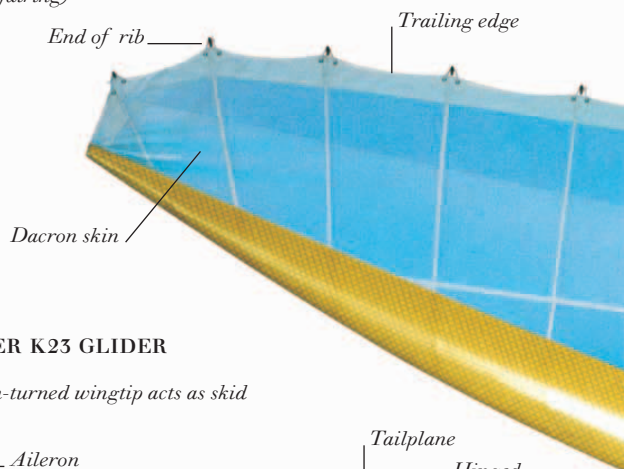
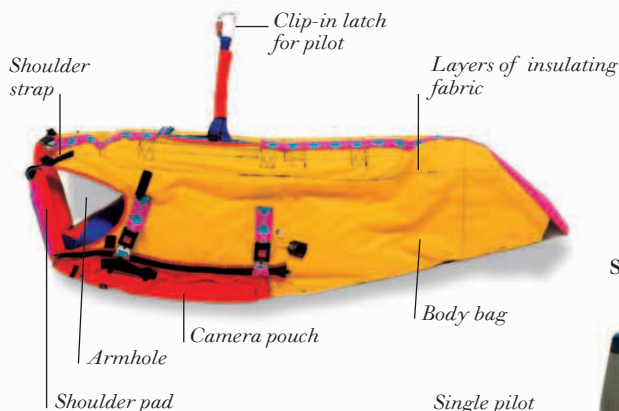
Hang-gliders consist of a simple frame across which rigid or flexible material is stretched to form the wings. The pilot is suspended below the wings in a harness or body bag, and gripping a triangular A-frame, steers by shifting weight from side to side. Like gliders, hang-gliders rely on thermals for lift. Ultralights are basically powered hang-gliders.

A small engine and an open fiberglass car (trike), which can hold a crew of two, are suspended beneath a stronger version of a hang-glider frame; the frame may have rigid or flexible wings. Ultralight pilots, like hang-glider pilots, steer by shifting their weight against an A-frame. Ultralights can reach speeds of up to 100 mph (160 kph).

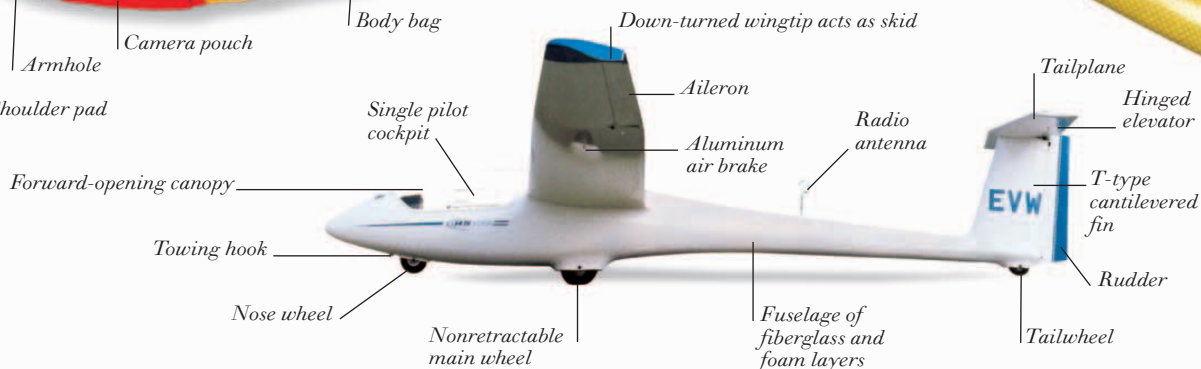


PEGASUS XL SE ULTRALIGHT

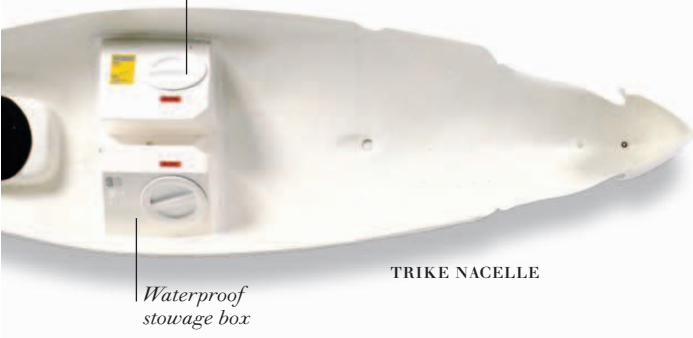
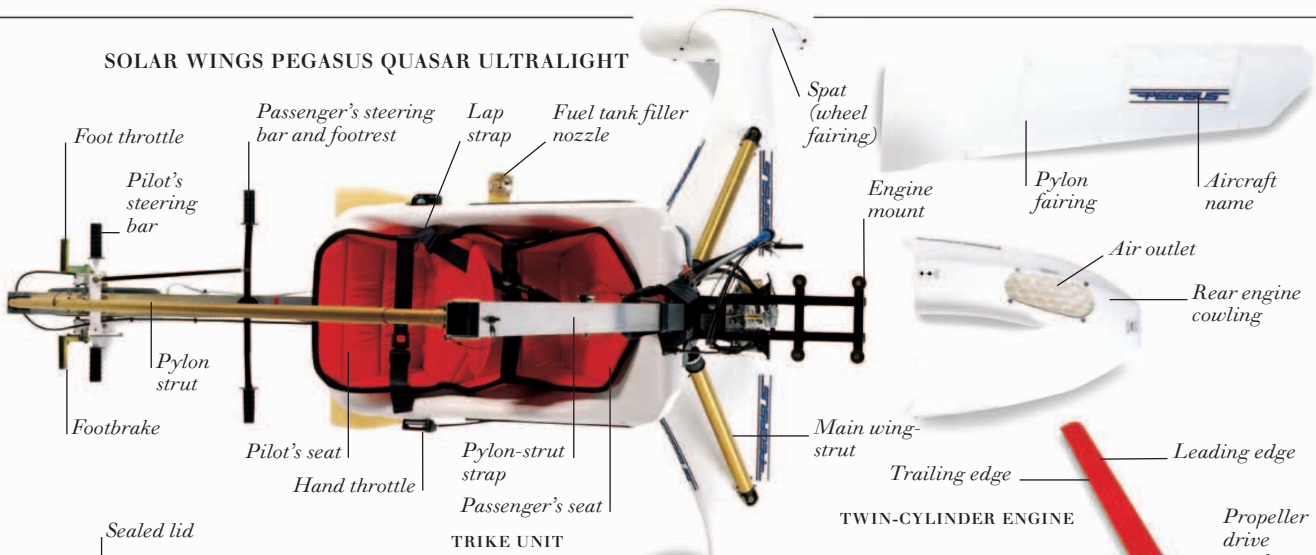
HANG-GLIDER BODY BAG



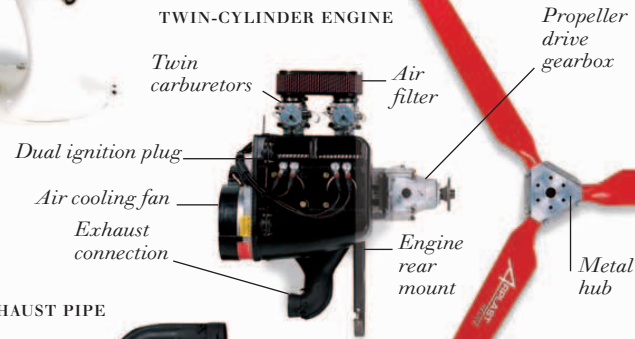
SCHLEICHER K23 GLIDER



SOLAR WINGS PEGASUS QUASAR ULTRALIGHT



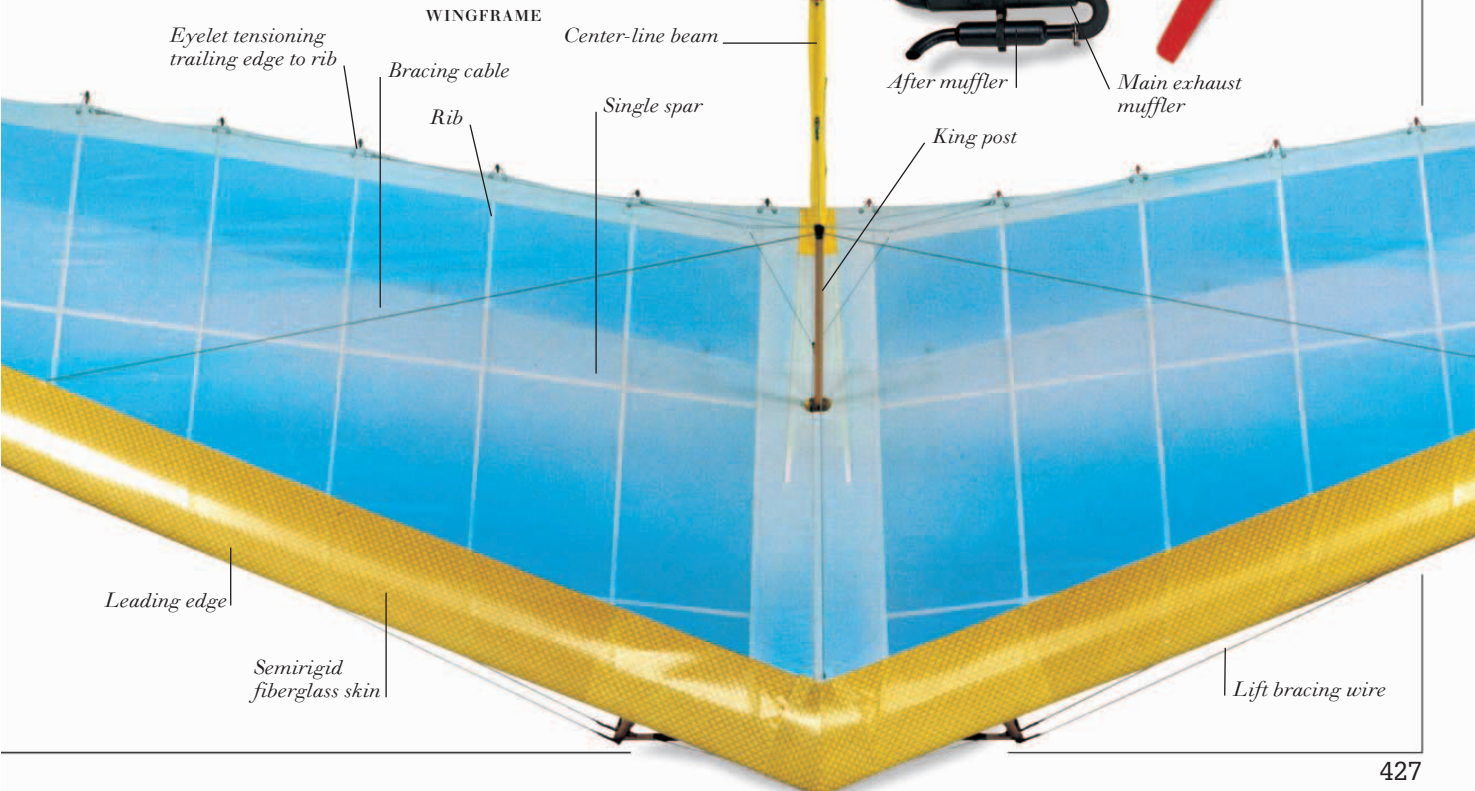
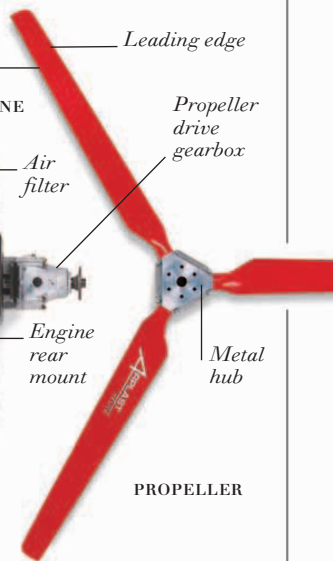
TRIKE NACELLE



EXHAUST PIPE



PROPELLER



75 Moosgrün 1 ***
 moss green 1
 vert de mousse 1

85 Olivengrün 1 ***
 olive green 1
 vert d'olive 1

71 Hellgrün ***
 light green
 vert clair

71 H... ***
 M

05 Echtorange 1 ***
 orange 1
 orange solide 1

42 Permanentrot 1 hell ***
 permanent red 1 pale
 rouge permanent 1 clair

05 Echtorange 1 ***
 permanent orange 1
 rouge permanent 1 clair

42 Permanentrot 1 hell ***
 permanent red 1 pale
 rouge permanent 1 clair

75 Mo... ***
 D vert de m...

76 Moosgrün 2 ***
 moss green 2
 vert de mousse 2

71 Hellgrün ***
 light green
 vert clair

73 Laubgrün 2 ****
 leaf green 2
 vert d'herbe 2

80 Kaltgrün 1 ****
 cold green 1
 vert cru 1

30 Umbra grün ****
 swedish umber
 terre d'ombre verte

03 Echtgelb 2 hell ***
 sunproof yellow 2 light
 jaune solide 2 clair

03 Echtgelb 2 hell ***
 sunproof yellow 2 light
 jaune solide 2 clair

03 Echtgelb 2 hell ***
 sunproof yellow 2 light
 jaune solide 2 clair

04 Echtgelb 3 dkl. ***
 sunproof yellow 3 deep
 jaune solide 3 foncé

04 Echtgelb 3 dkl. ***
 sunproof yellow 3 deep
 jaune solide 3 foncé

04 Echtgelb 3 dkl. ***
 sunproof yellow 3 deep
 jaune solide 3 foncé

05 Echtorange 1 ***
 orange 1
 orange solide 1

42 Permanentrot 1 hell ***
 permanent red 1 pale
 rouge permanent 1 clair

05 Echtorange 1 ***
 permanent orange 1
 rouge permanent 1 clair

42 Permanentrot 1 hell ***
 permanent red 1 pale
 rouge permanent 1 clair

91 Graublau 1 ****
 grey blue 1
 gris bleu 1

66 Kobaltblau limit ****
 cobalt blue limit
 bleu de cobalt limit

66 Preußischblau ****
 Prussian blue
 bleu de Prusse

57 Violett bläulich ***
 bluish violet
 violet bläulich

19 ... ***
 H ...

24 Caput mortuum dkl. ***
 caput mortuum deep
 tête morte foncé

23 Caput mortuum hell ****
 caput mortuum pale
 tête morte clair

42 Permanentrot 1 hell ***
 permanent red 1 pale
 rouge permanent 1 clair

45 Krapplack ***
 madder lake
 laque de garance

44 Permanentrot 3 dkl. ***
 permanent red 3 deep
 rouge permanent 3 foncé

44 Permanentrot 3 dkl. ***
 permanent red 3 deep
 rouge permanent 3 foncé

45 Krapplack ***
 madder lake
 laque de garance

46 Karminrot ***
 carmine red
 rouge carmine

49 Purpur 1 ***
 purple 1
 pourpre 1

47 Krapprosa ***
 rose madder
 rose de garance

66 Preußischblau ****
 ultramarine blue
 bleu de Prusse

63 Ultramarin dkl. ***
 ultramarine deep
 ultramarine foncé

59 Violett hell ***
 demm violet
 violet clair

66 Preußischblau ****
 ultramarine blue
 bleu de Prusse

68 Grün bläulich ***
 bluish green
 vert bläulich



THE VISUAL ARTS

DRAWING	430
TEMPERA	432
FRESCO	434
OILS	436
WATERCOLOR	438
PASTELS	440
ACRYLICS	442
CALLIGRAPHY	444
PRINTMAKING 1	446
PRINTMAKING 2	448
MOSAIC	450
SCULPTURE 1	452
SCULPTURE 2	454



Drawing

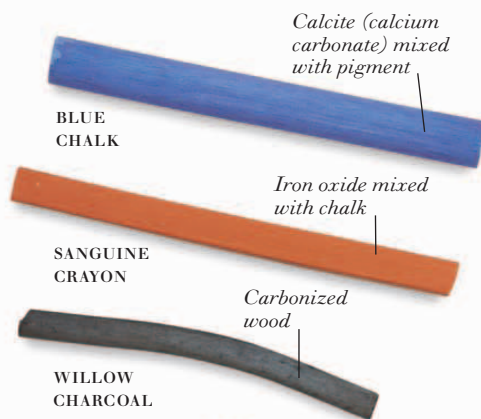
DRAWINGS CAN BE FINISHED WORKS OF ART, or preparatory studies for paintings and other visual arts. They can be made using a wide variety of drawing instruments such as pencils, graphite sticks, chalks, charcoal, pens and inks, and silver wires. The most common drawing instrument is the graphite pencil. A graphite pencil consists of a thin rod of graphite mixed with clay, encased in wood. Charcoal is one of the oldest drawing instruments. It is produced by firing twigs of willow, vine, or other woods at high temperatures in airtight containers. Erasers can be used to rub out marks made by drawing materials such as graphite pencils or charcoal, or to achieve a particular effect—such as smudging. Fixative is often applied—using a mouth diffuser or aerosol spray fixative—to prevent smudging once a drawing is finished. Silver lines can be produced by drawing silver wire across specially prepared paper—a technique known as silverpoint. The lines are permanent and cannot be erased. In time, the silver lines oxidize and turn brown.

FIXATIVE AND MOUTH DIFFUSER

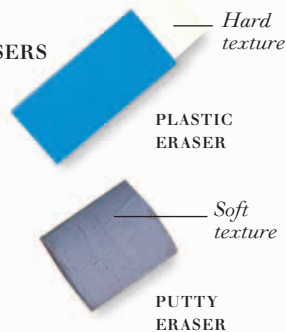


Fixative is sucked into tube and sprayed on to drawing

CHALK, CRAYON, AND CHARCOAL



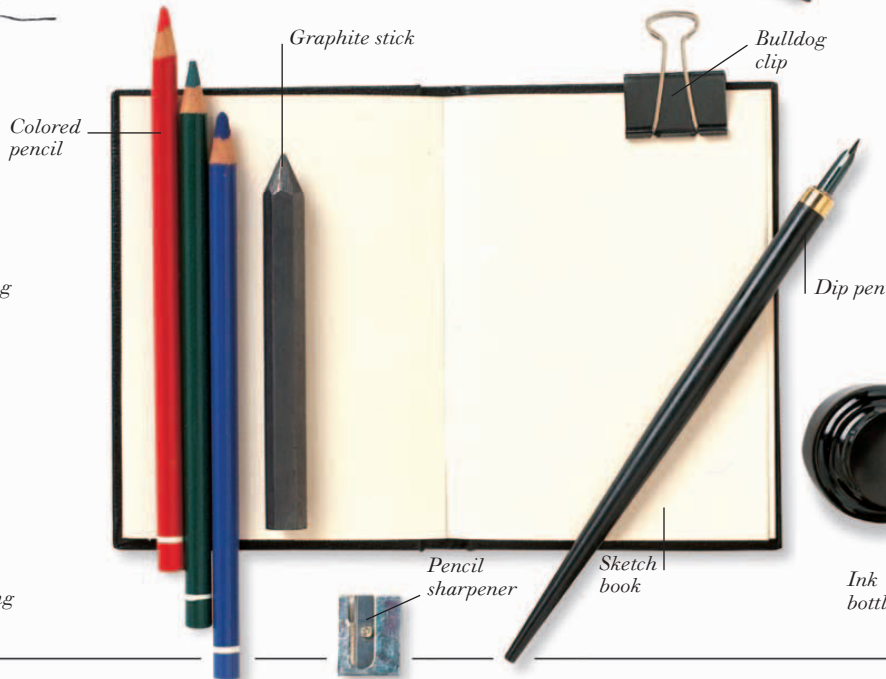
ERASERS



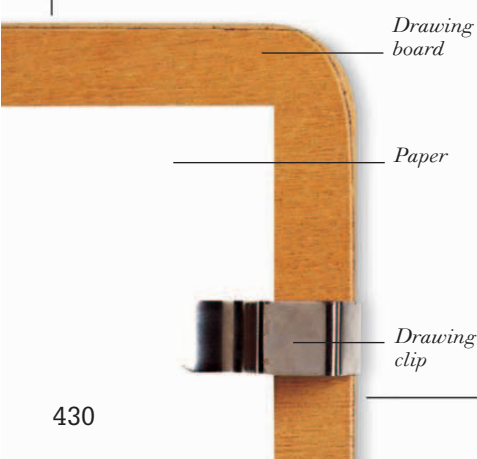
DRAWING INSTRUMENTS

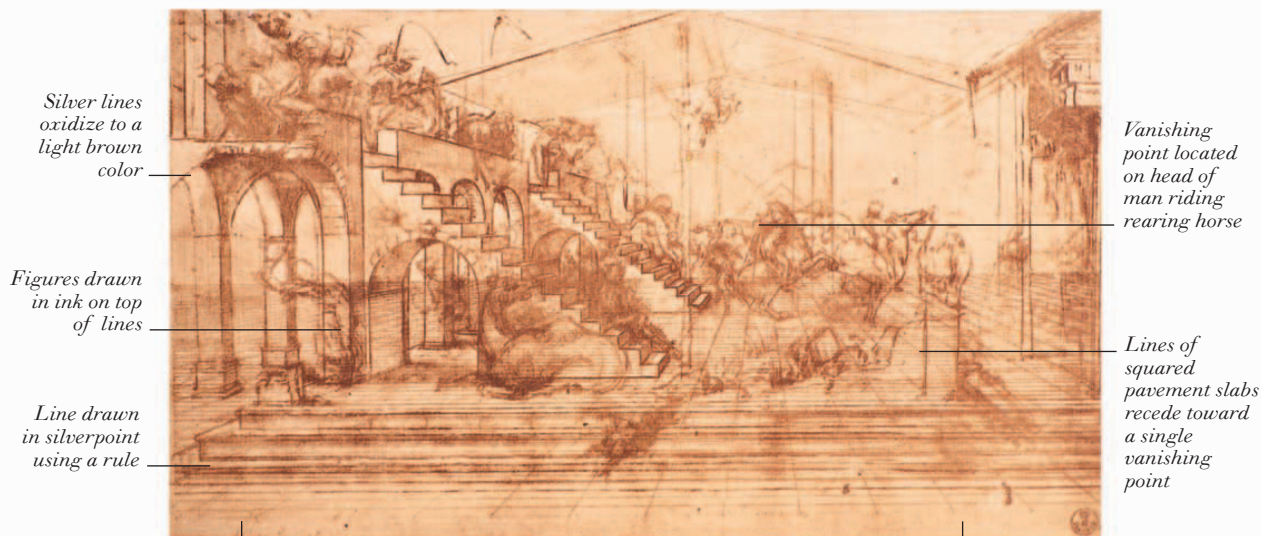


DRAWING MATERIALS



DRAWING BOARD





Silver lines
oxidize to a
light brown
color

Figures drawn
in ink on top
of lines

Line drawn
in silverpoint
using a rule

Vanishing
point located
on head of
man riding
rearing horse

Lines of
squared
pavement slabs
recede toward
a single
vanishing
point

Complex perspective
drawing done as a
preparatory study
for a painting

EXAMPLE OF A SILVERPOINT DRAWING
The Adoration of the Magi, Leonardo da Vinci, 1481
Pen and ink over silverpoint on paper
6½ × 11½ in (16.5 × 29.2 cm)

Paper prepared
with size (glue)
and pigment

One of a series
of drawings
recording
London during
1944–1945

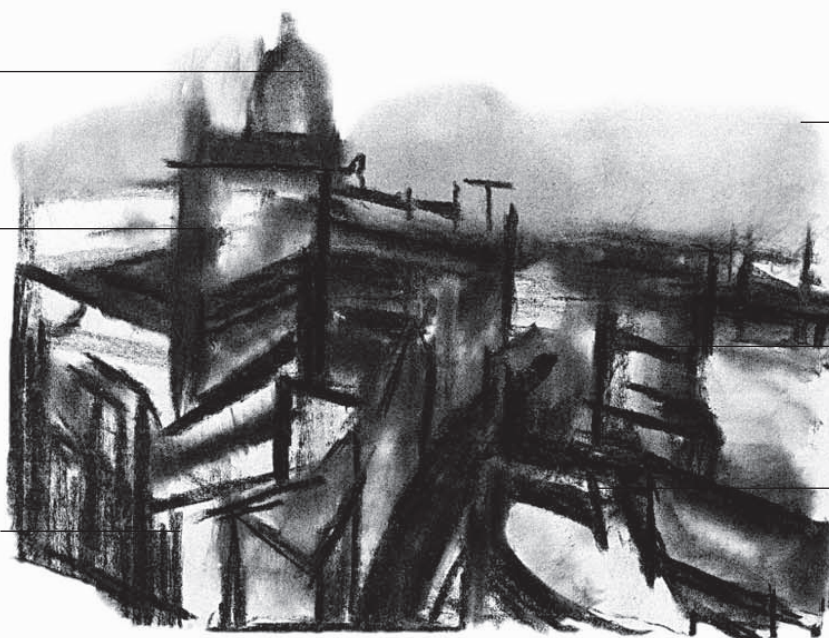
Charcoal lines
softened by
rubbing and
smudging

Charcoal
gives strong,
expressive lines

Handmade, tinted
paper

Broad charcoal
mark

Lines rapidly
drawn on site



EXAMPLE OF A CHARCOAL DRAWING
St. Paul's and the River, David Bomberg, 1945
Charcoal on paper
20 × 25½ in (50.8 × 65.8 cm)

Tempera

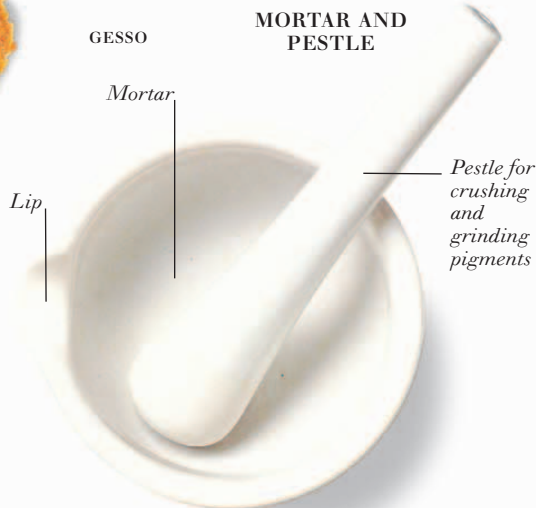


ILLUMINATED
MANUSCRIPT

THE TERM TEMPERA is applied to any paint in which pigment is tempered (mixed) with a water-based binding medium—usually egg yolk. Egg tempera is applied to a smooth surface such as vellum (for illuminated manuscripts) or more commonly to hardwood panels prepared with gesso—a mixture of chalk and size

(glue). Hog hair brushes are used to apply the gesso. A layer of gesso grosso (coarse gesso) is followed by successive layers of gesso sottile (fine gesso) that are sanded between coats to provide a smooth, yet absorbent ground. The paint is applied with fine sable brushes in thin layers, using light brushstrokes. Tempera dries quickly to form a tough skin with a satin sheen. The luminous white surface of the gesso combined with the overlaid paint produces the brilliant crispness and rich colors particular to this medium. Egg tempera paintings are frequently gilded with gold. Leaves of finely beaten gold are applied to a bole (reddish-brown clay) base and polished by burnishing.

MATERIALS FOR TEMPERA PANEL PAINTING



MATERIALS FOR GILDING



EXAMPLES OF BRUSHES



EXAMPLE OF A TEMPERA PAINTING
 Presentation in the Temple, Ambrogio Lorenzetti, 1342
 Tempera on wood, 8 ft 5 1/8 in x 5 ft 6 1/8 in (257 x 168 cm)

PIGMENTS FOR FLESH-COLOR PAINTING



VERDACCIO



VERMILION AND LEAD WHITE



VERMILION



RED EARTH (IRON OXIDE)

Altarpiece commissioned for Siena Cathedral, Italy

Textured gold ornament made by punching motifs into the gilded surface

The red tinge of the bole is just visible beneath the gold

Edge of a sheet of gold leaf

Crisp edge characteristic of tempera painting

Vine black used to create the dim cathedral interior

Highlights on the beard made by applying thin layers of white over dried paint

Red drapery painted in vermilion

Raised right hand and pointing finger is the gesture of prophecy

Receding floor tiles create the impression of depth

Patch of discolored varnish, left from last cleaning

EXAMPLES OF PIGMENTS



MALACHITE



ULTRAMARINE LAPIS LAZULI



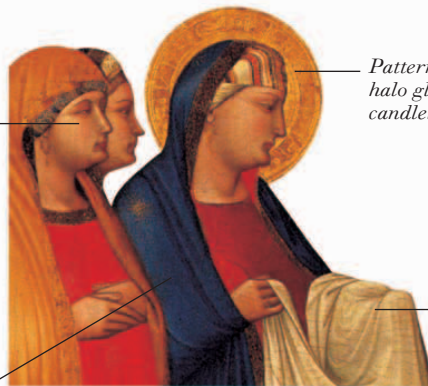
VINE BLACK



LEAD TIN YELLOW

Warm flesh tones achieved by layering vermilion and white over an undercoat of verdaccio

Ultramarine lapis lazuli, as costly as gold, was reserved for significant figures such as the Virgin Mary



Patterned gold halo glitters in candlelight

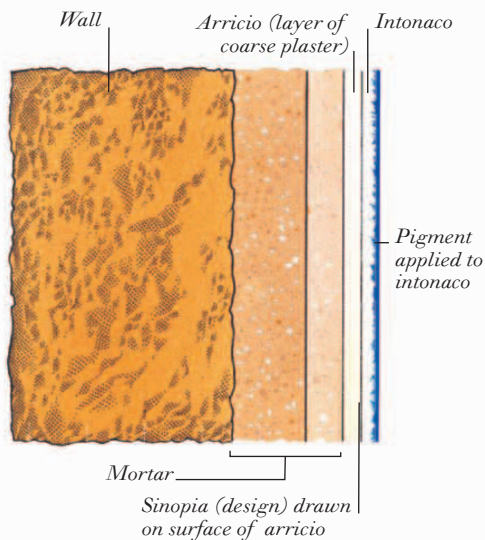
Craquelure (pattern of cracks in the paint)

DETAIL FROM "PRESENTATION IN THE TEMPLE"

Fresco

FRESCO IS A METHOD OF WALL PAINTING. In buon fresco (true fresco), pigments are mixed with water and applied to an intonaco (layer of fresh, damp lime-plaster). The intonaco absorbs and binds the pigments as it dries making the picture a permanent part of the wall surface. The intonaco is applied in sections called giornate (daily sections). The size of each giornata depends on the artist's estimate of how much can be painted before the plaster sets. The junctions between giornate are sometimes visible on a finished fresco. The range of colors used in buon fresco are limited to lime-resistant pigments such as earth colors (below). Slaked lime (burnt lime mixed with water), bianco di San Giovanni (slaked lime that has been partly exposed to air), and chalk can be used to produce fresco whites. In fresco secco (dry fresco), pigments are mixed with a binding medium and applied to dry plaster. The pigments are not completely absorbed into the plaster and may flake off over time.

CROSS-SECTION SHOWING FRESCO LAYERS



EXAMPLES OF EARTH COLOR PIGMENTS



RAW UMBER



RED EARTH (IRON OXIDE)



GREEN EARTH



RAW SIENNA

EXAMPLES OF FRESCO BRUSHES



Round hog hair brush
Rust-resistant twine binding

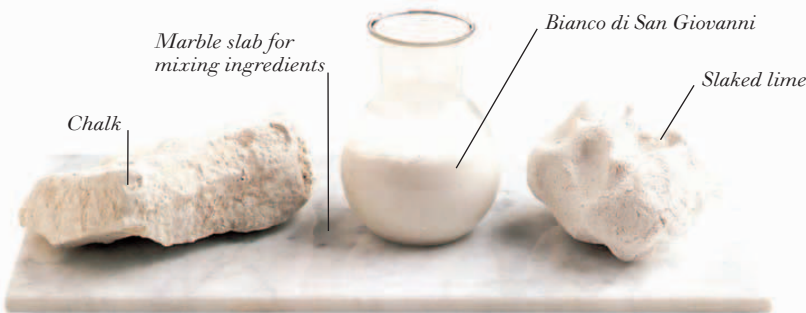


Dome-shaped hog hair brush



Pointed hog hair brush

INGREDIENTS FOR FRESCO WHITES



EXAMPLE OF A FRESCO
The Expulsion of the Merchants from the Temple, Giotto, c.1306
Fresco, 78 x 72 in (200 x 185 cm)



One of a series of frescoes in the Arena Chapel, Padua, Italy

Patches of azurite blue have turned green due to reaction with carbon dioxide

Hairline junction between giornate is visible

Red earth pigment applied in buon fresco has retained rich hue

Temple acts as a backdrop for the action

Bianco di San Giovanni often used for fresco whites

Gold leaf applied to apostle's halo

Green earth pigment applied to robe

Child painted on top of apostle's robe

Azurite blue applied in fresco secco has flaked off to reveal the plaster beneath

Dry, matte surface characteristic of buon fresco

Artist has to finish giornata before plaster dries

Junction between giornate

A fresco was generally worked in zones from the top down

Area with little detail can be painted quickly, allowing a larger giornata to be completed

Highly detailed area takes a longer time to paint, restricting the size of the giornata

Paint applied in buon fresco to child's face

White dove represents the Holy Ghost

Paint applied in fresco secco to child's body has flaked off

Sinopia (design) sketched in red earth

DETAIL FROM "THE EXPULSION"



GIORNATE (DAILY SECTIONS) IN "THE EXPULSION"

Oils



KIDNEY-SHAPED PALETTE

OIL PAINTS ARE MADE BY MIXING and grinding pigment with a drying vegetable oil such as linseed oil. The paint can be applied to many different surfaces and textures—the most common being canvas. Before painting, the canvas is stretched on a wooden frame and its surface is prepared with layers of size (glue) and primer. The two main types of brushes used in oil painting are stiff hog hair bristle brushes—generally used for covering large areas; and soft hair brushes made from sable or synthetic material—generally used for fine detail. Other tools, including painting knives, can also be used to achieve different effects. Oil paint can be applied thickly (a technique known as impasto), or can be thinned down using a solvent—such as turpentine. Varnishes are sometimes applied to finished paintings to protect their surface and to give them a matte or gloss finish.

LINSEED OIL



Oil derived from seeds of flax plant

EXAMPLES OF PIGMENTS



CADMIUM RED



CERULEAN BLUE

DOUBLE DIPPER (PALETTE ATTACHMENT)



Container for storing solvent or drying oil

DAMMAR RESIN VARNISH



Crystals are dissolved and applied to painting to protect its surface

COMMERCIAL OIL PAINTS



CADMIUM RED

ULTRAMARINE

Lightfast opaque color

Transparent color

EQUIPMENT FOR MAKING OIL PAINT



Airtight jar for storing paint

Palette knife for mixing drying oil and pigment

PAINTING KNIVES

TROWEL-SHAPED PAINTING KNIFE

Blade

DIAMOND-SHAPED PAINTING KNIFE

Blade

Cranked, steel shank

Cranked, steel shank

Glass muller for grinding drying oil and pigment

Glass slab with abrasive surface

EXAMPLES OF BRUSHES

SABLE BRUSH



SYNTHETIC BRUSH



Round hog hair brush

HOG HAIR BRISTLE BRUSHES



Flat hog hair brush

Flat hog hair brush

Filbert hog hair brush

Long, wooden handle

Protective, plastic case

EXAMPLE OF AN OIL PAINTING
 Fritillarias, Vincent van Gogh, 1886 Oil on
 canvas, 29 × 24 in (73.5 × 60.5 cm)



Artist's signature
 scratched in wet
 paint with the
 end of the brush

Background
 enlivened by
 dabs of white
 and green

Each leaf
 painted
 in a single,
 rapid stroke

Orange and blue
 (complementary
 colors) placed
 together to
 give maximum
 contrast and
 enhance one
 another to
 appear brighter

Impasto
 (deep ridges
 of paint applied
 in thick strokes)

Strong
 directional
 brushstrokes
 on table draw
 attention to
 the vase

Features of vase highlighted
 by generous touches of yellow

**CANVAS STRETCHED
 ON WOODEN FRAME
 (VIEWED FROM
 THE BACK)**

Staple

Canvas prepared
 with glue (size)
 and primer

Wooden
 frame

Unprimed
 canvas

EXAMPLES OF CANVASES



COTTON DUCK



FINE LINEN



COARSE LINEN

Canvas
 support

Height
 adjustment
 key

Angle
 adjustment
 key

Tripod

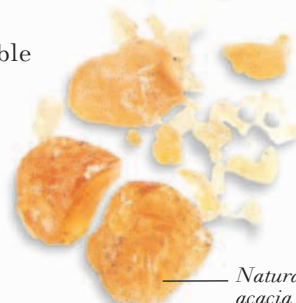
**RADIAL
 STUDIO
 EASEL**

Top sliding-
 block adjusts
 to canvas
 height

Watercolor

WATERCOLOR PAINT IS MADE OF GROUND PIGMENT mixed with a watersoluble binding medium, usually gum arabic. It is usually applied to paper using soft hair brushes such as sable, goat hair, squirrel, and synthetic brushes. Watercolors are often diluted and applied as overlaying washes (thin, transparent layers) to build up depth of color. Washes can be laid in a variety of ways to create a range of different effects. For example, a wet-in-wet wash can be achieved by laying a wash on top of another wet wash. The two washes blend together to give a fused effect. Sponges are used to modify washes by soaking up paint so that areas of pigment are lightened or removed from the paper. Watercolors can also be applied undiluted—a technique known as dry brush—to create a broken-color effect. Watercolors are generally transparent and allow light to reflect from the surface of the paper through the layers of paint to give a luminous effect. They can be thickened and made opaque by adding body color (Chinese white).

GUM ARABIC

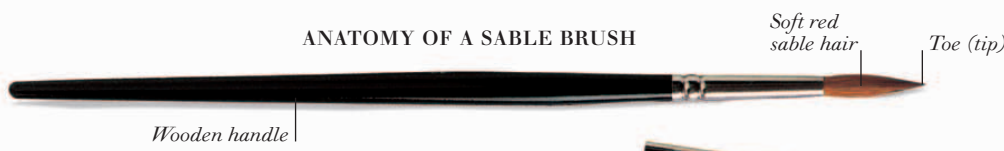


Natural sap from acacia tree

NATURAL SPONGE



ANATOMY OF A SABLE BRUSH



SOFT HAIR BRUSHES



ROUND SABLE BRUSH (NO. 6)



ROUND SABLE BRUSH (NO. 1)



SYNTHETIC WASH BRUSH



SQUIRREL MOP WASH BRUSH



LARGE GOAT HAKE WASH BRUSH



TUBES OF WATERCOLOR PAINT



WINSOR GREEN

CADMIUM YELLOW

PORTABLE BOX OF WATERCOLOR PAINTS



Painted color swatch

Chinese white

Pan of watercolor paint

Lid can be used for mixing colors

EXAMPLE OF A WATERCOLOR
 Burning of the Houses of Parliament, Turner, 1834
 Watercolor on paper, 11½ × 17½ in (29.2 × 44.5 cm)

Transparent washes laid on top of each other to create tonal depth

Transparent washes allow light to reflect off the surface of the paper to give a luminous effect

Highlight scratched out with a scalpel

Paper shows through thin wash to give flames added highlight

Crowd painted with thin strokes laid over a pale wash

Undiluted paint applied, then partly washed out, to create the impression of water



EXAMPLES OF WATERCOLOR PAPERS

SMOOTH-TEXTURED PAPER

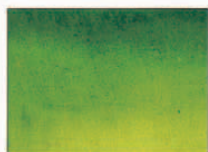
MEDIUM-TEXTURED PAPER

ROUGH-TEXTURED PAPER

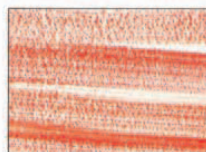
EXAMPLES OF WASHES



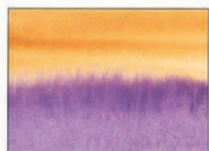
WASH OVER DRY BRUSH
 Wash laid over paint applied with dry brush gives two-tone effect



GRADED WASH
 Strong wash applied to tilted paper gives graded effect

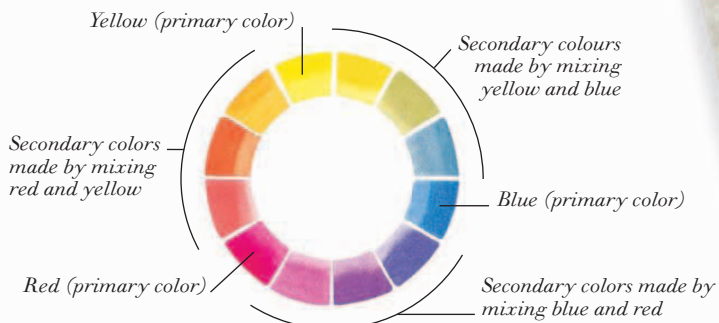


DRY BRUSH
 Undiluted paint dragged across surface of paper gives broken effect



WET-IN-WET
 Two diluted washes left to run together to give fused effect

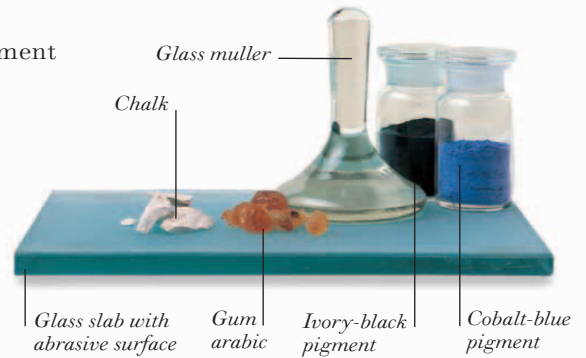
COLOR WHEEL OF WATERCOLOR PAINTS



Pastels

PASTELS ARE STICKS OF PIGMENT made by mixing ground pigment with chalk and a binding medium, such as gum arabic. They vary in hardness depending on the proportion of the binding medium to the chalk. Soft pastel—the most common form of pastel—contains just enough binding medium to hold the pigment in stick form. Pastels can be applied directly to any support (surface) with sufficient tooth (texture). When a pastel is drawn over a textured surface, the pigment crumbles and lodges in the fibers of the support. Pastel marks have a particular soft, matte quality and are suitable for techniques such as blending, scumbling, and feathering. Blending is a technique of rubbing and fusing two or more colors on the support using fingers or various tools such as tortillons (paper stumps), soft hair brushes, putty erasers, and soft bread. Scumbling is a technique of building up layers of pastel colors. The side or blunted tip of a soft pastel is lightly drawn over an underpainted area so that patches of the color beneath show through. Feathering is a technique of applying parallel strokes of color with the point of a pastel, usually over an existing layer of pastel color. A thin spray of fixative can be applied—using a mouth diffuser (see pp. 430-431) or aerosol spray fixative—to a finished pastel painting, or in between layers of color, to prevent smudging.

EQUIPMENT FOR MAKING PASTELS



EXAMPLES OF SOFT PASTELS



BOXED PASTEL SET



Boxed set containing a mixture of portrait and landscape colors

Foam compartments protect the pastels

Soft pastel

Wooden tray

EQUIPMENT USED WITH PASTELS



PUTTY ERASER

BREAD

AEROSOL SPRAY FIXATIVE

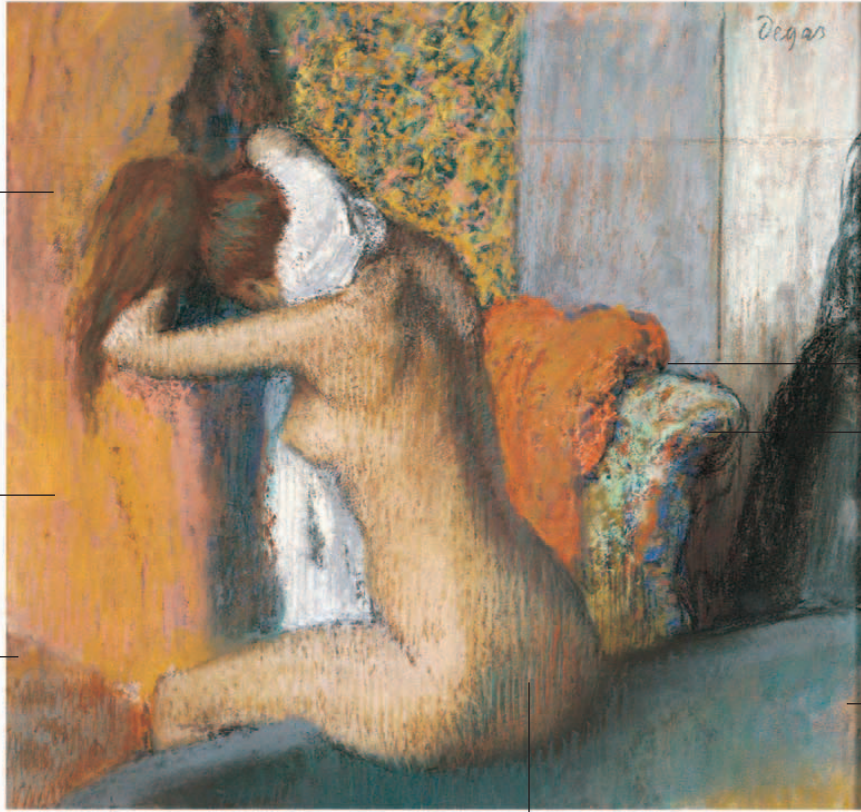
SOFT HAIR BRUSH

TORTILLONS (PAPER STUMPS)

Soft point used for blending

Tight roll of paper

EXAMPLE OF A PASTEL PAINTING
 Woman Drying her Neck, Edgar Degas, c.1898
 Pastel on cardboard, 24½ x 25½ in (62.5 x 65.5 cm)



Pastels applied directly to support

Colors are blended together using fingers or tools such as tortillons

Built up layers of pastel

Rich color of fabric created by overlaying yellows and oranges

Broken colors, characteristic of scumbling technique

Toned color of paper visible beneath thinly applied pastels

Pure bright colors laid side by side produce strong contrasts

DETAIL FROM "WOMAN DRYING HER NECK"



Feathering technique used to produce skin tones

EXAMPLES OF TEXTURED PAPERS AND PASTEL BOARDS



WATERCOLOR PAPER (ROUGH TEXTURE)



GLASS PAPER



WATERCOLOR PAPER (MEDIUM TEXTURE)



INGRES PAPER

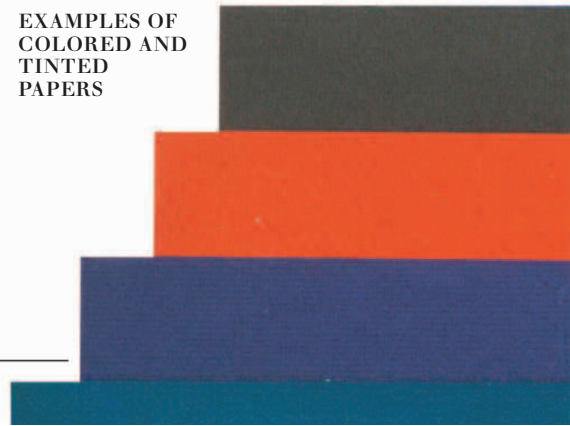


FLOCKED PASTEL BOARD



CANSON PAPER

EXAMPLES OF COLORED AND TINTED PAPERS



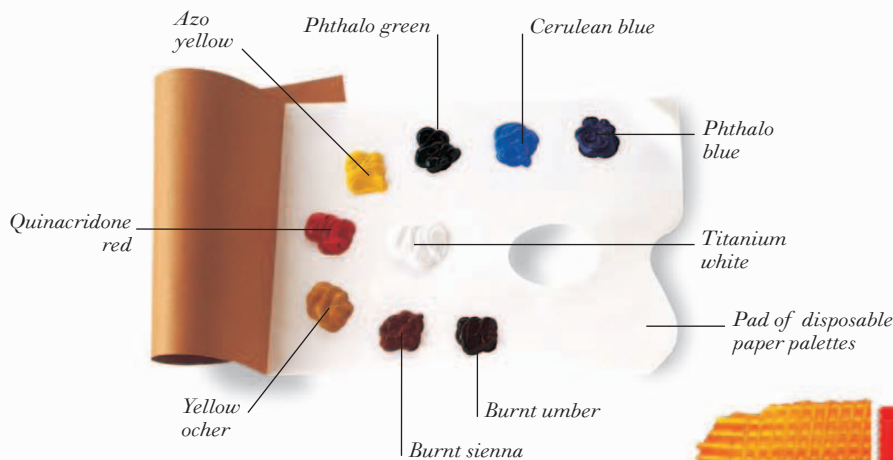
Acrylics

ACRYLIC PAINT IS MADE BY MIXING PIGMENT with a synthetic resin. It can be thinned with water but dries to become water insoluble. Acrylics are applied to many surfaces, such as paper and acrylic-primed board and canvas. A variety of brushes, painting knives, rollers, air-brushes, plastic scrapers, and other tools are used in acrylic painting. The versatility of acrylics makes them suitable for a wide range of techniques. They can be used opaquely or—by adding water—in a transparent, watercolor style. Acrylic mediums can be added to the paint to adjust its consistency for special effects such as glazing and impasto (ridges of paint applied in thick strokes) or to make it more matt or glossy. Acrylics are quick-drying, which allows layers of paint to be applied on top of each other almost immediately.

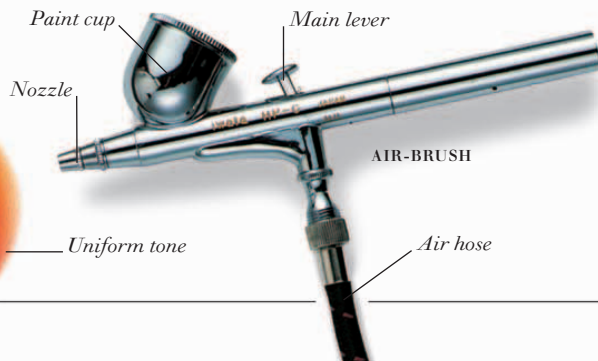
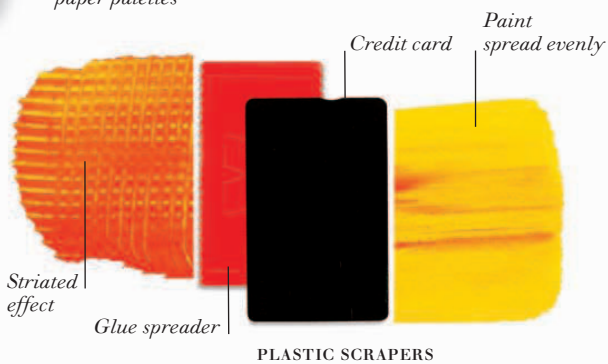
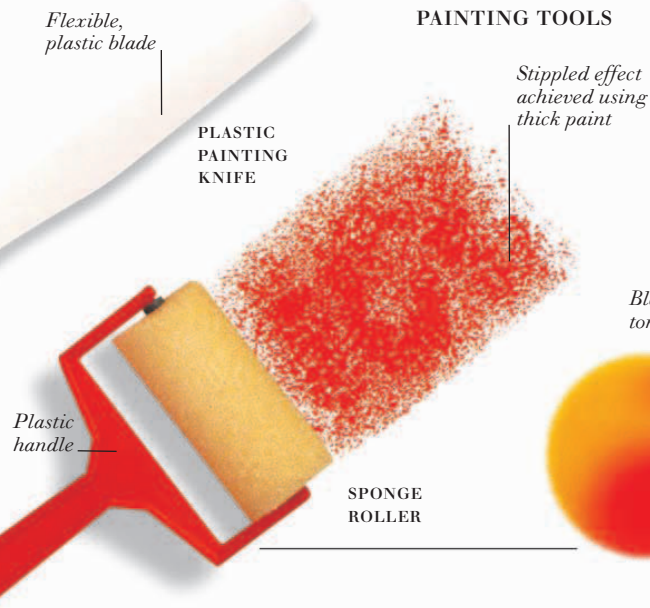
EXAMPLES OF BRUSHES



EXAMPLES OF PAINTS USED IN ACRYLICS



PAINTING TOOLS



EXAMPLE OF AN ACRYLIC PAINTING
A Bigger Splash, David Hockney, 1967
Acrylic on canvas, 95½ x 96 in (242.5 x 243.8 cm)



EXAMPLES OF ACRYLIC PAINTS AND TECHNIQUES



Calligraphy

CALLIGRAPHY IS BEAUTIFULLY FORMED LETTERING. The term applies to written text and illumination (the decoration of manuscripts using gold leaf and color). The essential materials needed to practice calligraphy are a writing tool, ink, and a writing surface. Quills are among the oldest writing tools. They are usually made from goose or turkey feathers, and are noted for their flexibility and ability to produce fine lines. A quill point, however, is not very durable and constant recutting and trimming is required. The most commonly used writing instrument in Western calligraphy is a detachable, metal nib held in a penholder. The metal nib is very durable, and there are a wide range of different types. Particular types of nibs—such as copperplate, speedball, and round-hand nibs—are used for specific styles of lettering. Some nibs have integral ink reservoirs and others have reservoirs that are detachable. Brushes are also used for writing, and for filling in outlined letters and painting decoration. Other writing tools used in calligraphy are fountain pens, felt-tip pens, rotring pens, and reed pens. Calligraphy inks may come in liquid form, or as a solid ink stick. Ink sticks are ground down in distilled water to form a liquid ink. The most common writing surfaces for calligraphy are good quality, smooth-surfaced papers. To achieve the best writing position, the calligrapher places the paper on a drawing board set at an angle.

EQUIPMENT USED IN BRUSH LETTERING

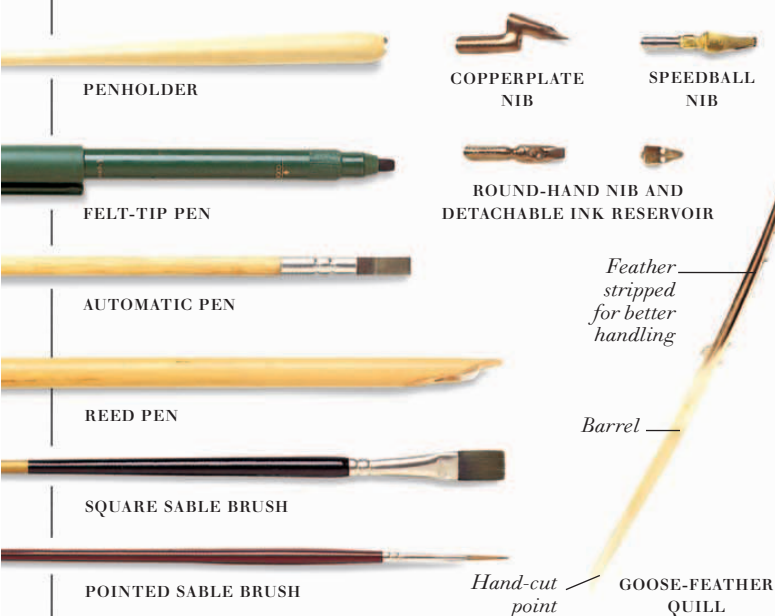


BRUSHES AND BRUSH REST



INK STICK AND STONE

PENS, NIBS, AND BRUSHES USED IN CALLIGRAPHY



GOAT HAIR BRUSH

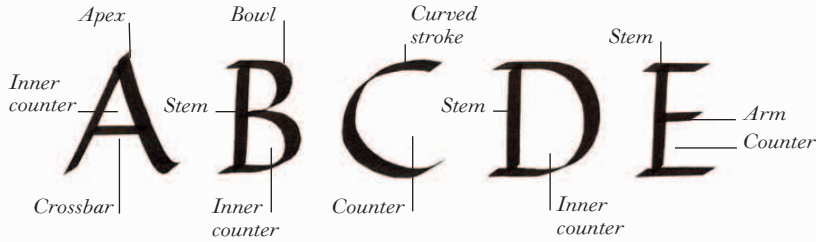


WOLF HAIR BRUSH

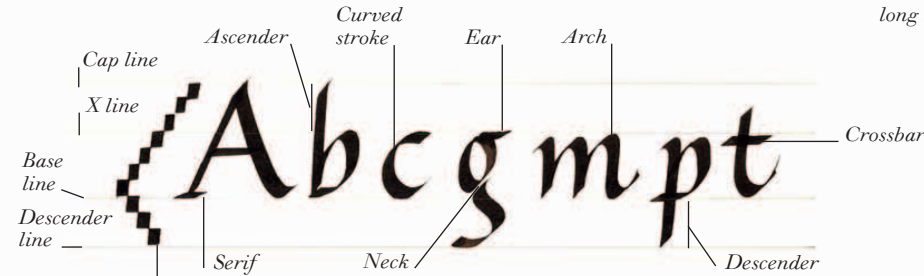
FOUNTAIN PEN AND INK



EXAMPLES OF LETTERING STYLES

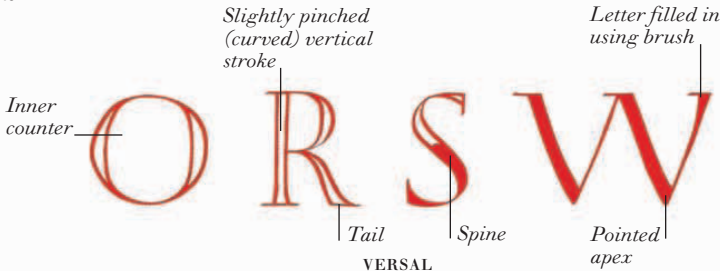


ROMAN CAPITALS



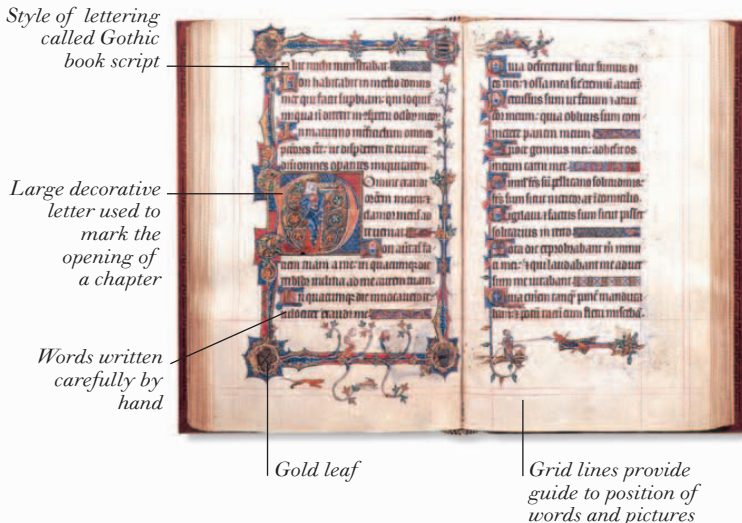
ITALIC ROMAN

Height of letter determined by ladder of nib widths



VERSAL

AN ILLUMINATED MANUSCRIPT



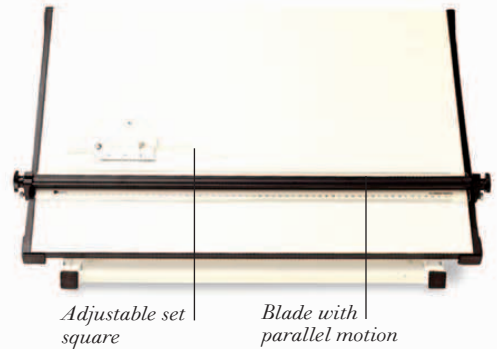
CHINESE LETTERING



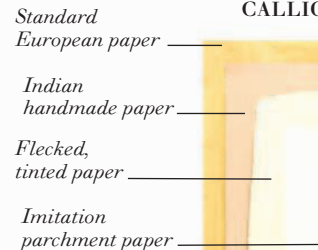
ARTIST'S STAMP



DRAWING BOARD



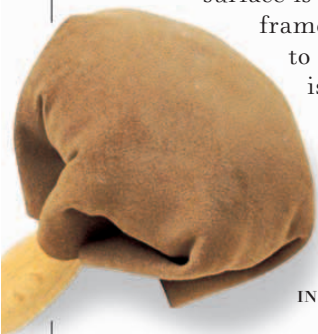
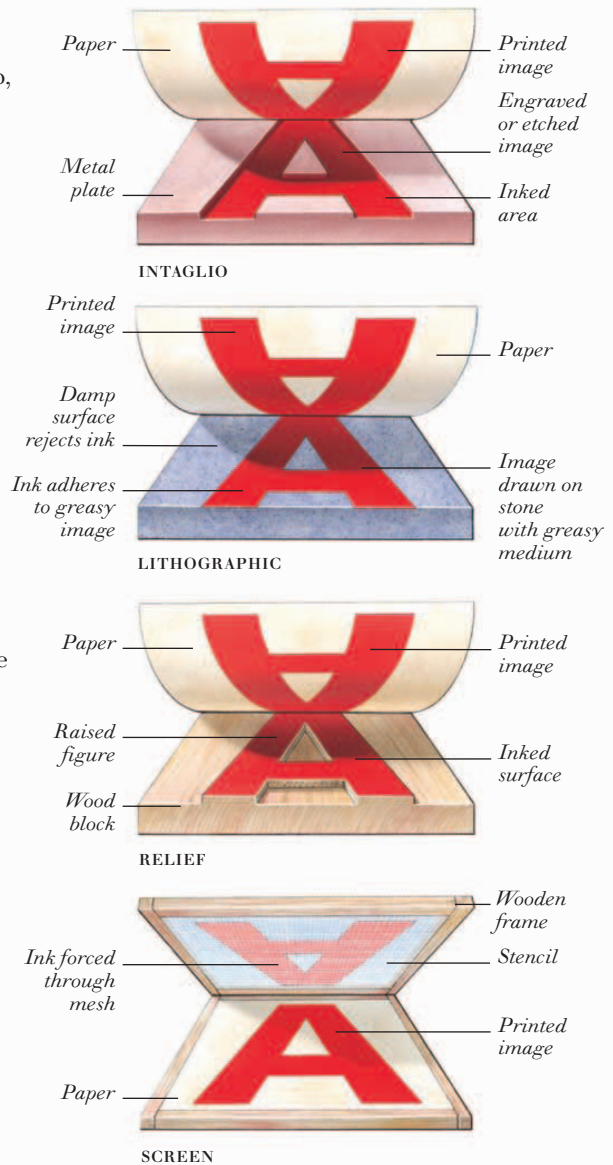
EXAMPLES OF CALLIGRAPHY PAPERS



Printmaking 1

PRINTS ARE MADE BY FOUR BASIC printing processes—intaglio, lithographic, relief, and screen. In intaglio printing, lines are engraved or etched into the surface of a metal plate. Lines are engraved by hand using sharp metal tools. They are etched by corroding the metal plate with acid, using acid-resistant ground to protect the areas not to be etched. The plate is then inked and wiped, leaving the grooves filled with ink and the surface clean. Dampened paper is laid over the plate, and both paper and plate are passed through the rollers of an etching press. The pressure of the rollers forces the paper into the grooves, so that it takes up the ink, leaving an impression on the paper. Lithographic printing is based on the antipathy between grease and water. An image is drawn on a surface—usually a stone or metal plate—with a greasy medium, such as tusche (lithographic ink). The greasy drawing is fixed on to the plate by applying an acidic solution, such as gum arabic. The surface is then dampened and rolled with ink. The ink adheres only to the greasy areas and is repelled by the water. Paper is laid on the plate and pressure is applied by means of a press. In relief printing, the nonprinting areas of a wood or linoleum block are cut away using gouges, knives, and other tools. The printing areas are left raised in relief and are rolled with ink. Paper is laid on the inked block and pressure is applied by means of a press or by burnishing (rubbing) the back of the paper. The most common forms of relief printing are woodcut, wood engraving, and linocut. In screen printing, the printing surface is a mesh stretched across a wooden frame. A stencil is applied to the mesh to seal the nonprinting areas and ink is scraped through the mesh to produce an image.

THE FOUR MAIN PRINTING PROCESSES



LEATHER INK DABBER

EQUIPMENT USED IN INTAGLIO PRINTING



ROCKER

SCRIBER

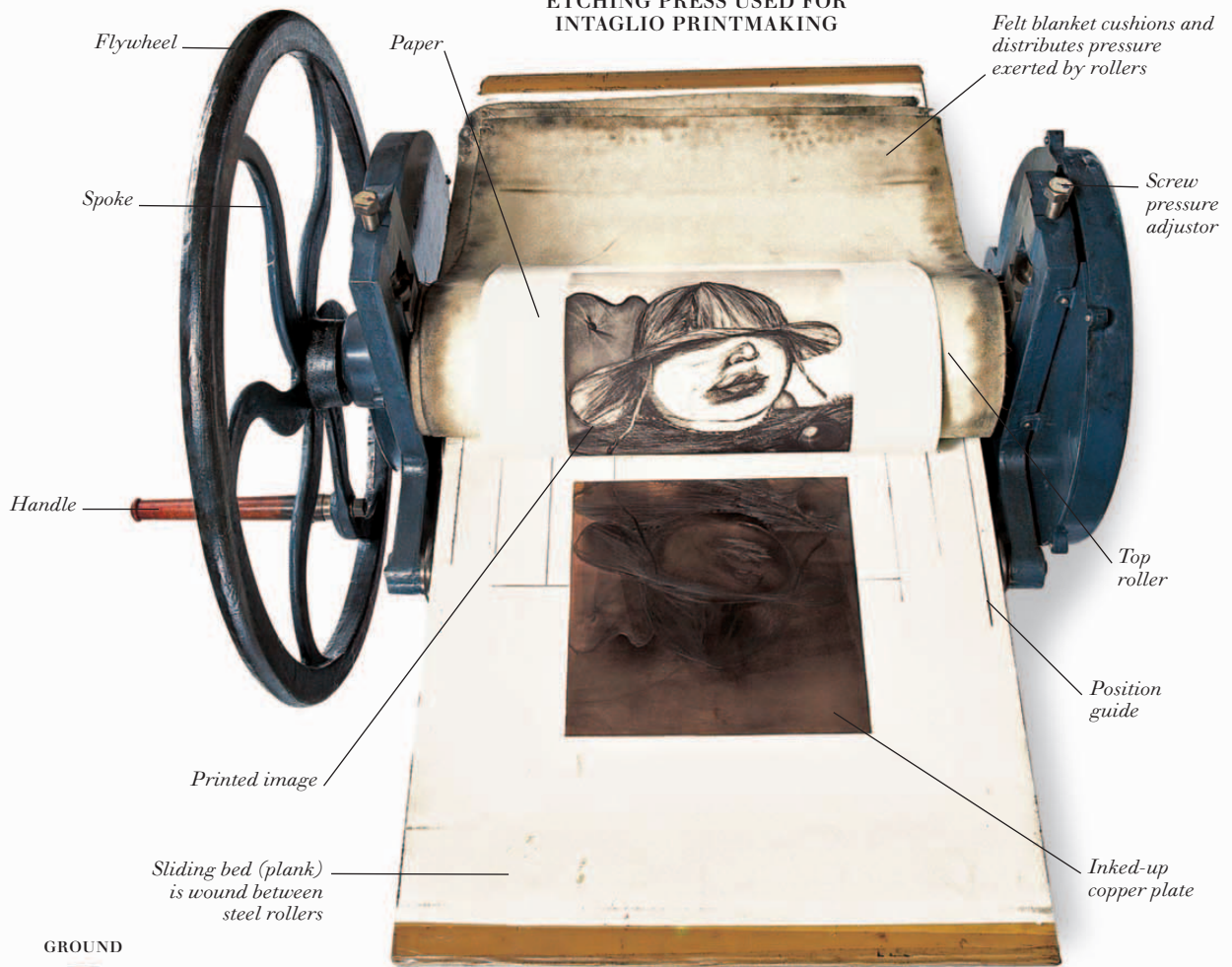
ROULETTE

SCRAPER

BURNISHER

CLAMP

ETCHING PRESS USED FOR INTAGLIO PRINTMAKING

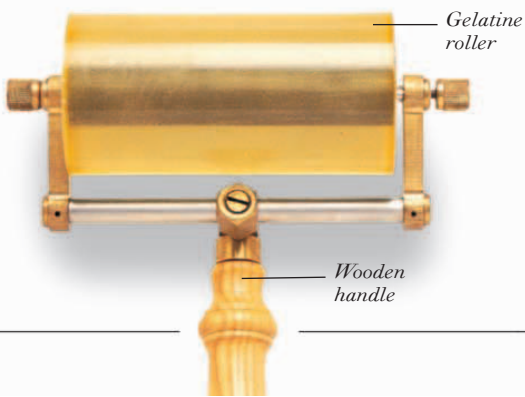


GROUND



Acid-resistant ground rolled onto metal plate before etching

GROUND ROLLER



EXAMPLES OF PRINTING PAPERS



EXAMPLE OF AN INTAGLIO PRINT
 Annie with a Sun Hat, Jock McFadyen, 1993
 Etched copper plate, 16 × 15¼ in (41 × 40 cm)



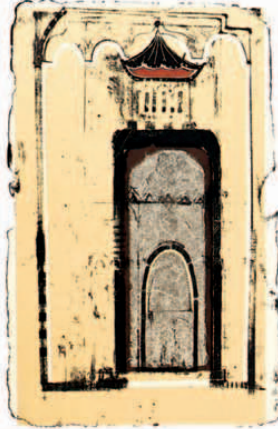
Printmaking 2

EXAMPLE OF A LITHOGRAPHIC STONE AND PRINT

Crown Gateway 2, Mandy Bonnell, 1987
Lithograph, 19½ × 15¾ in (50 × 40 cm)



IMAGE DRAWN ON STONE



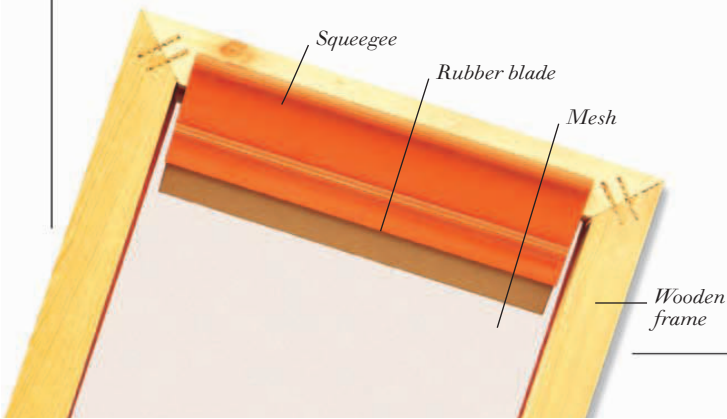
LITHOGRAPHIC PRINT

EXAMPLE OF A SCREEN PRINT

Sea Change, Patrick Hughes, 1992
Screen print, 30 × 37 in (77 × 94.5 cm)



SCREEN AND SQUEEGEE



EQUIPMENT USED IN LITHOGRAPHIC PRINTING



CRAYON AND HOLDER



LITHOGRAPHIC PENCIL



TUSCHE (LITHOGRAPHIC INK) PEN



ERASING STICK



EXPANDABLE SPONGE



TUSCHE (LITHOGRAPHIC INK) STICK



RUBBING INK



INK ROLLER



MILD ACIDIC SOLUTION



GUM ARABIC SOLUTION

WATER-BASED SCREEN PRINTING INKS



BLUE ACRYLIC INK



RED ACRYLIC INK



BROWN TEXTILE INK

EQUIPMENT USED IN RELIEF PRINTING



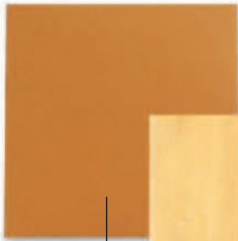
V-SHAPED GOUGE



INK ROLLER

Rubber roller

LINOLEUM AND WOODCUT BLOCK



Linoleum



Side-grain wood block



U-SHAPED GOUGE



GRAVER



KNIFE



SCORPER

WOOD ENGRAVING



END-GRAIN WOOD BLOCK

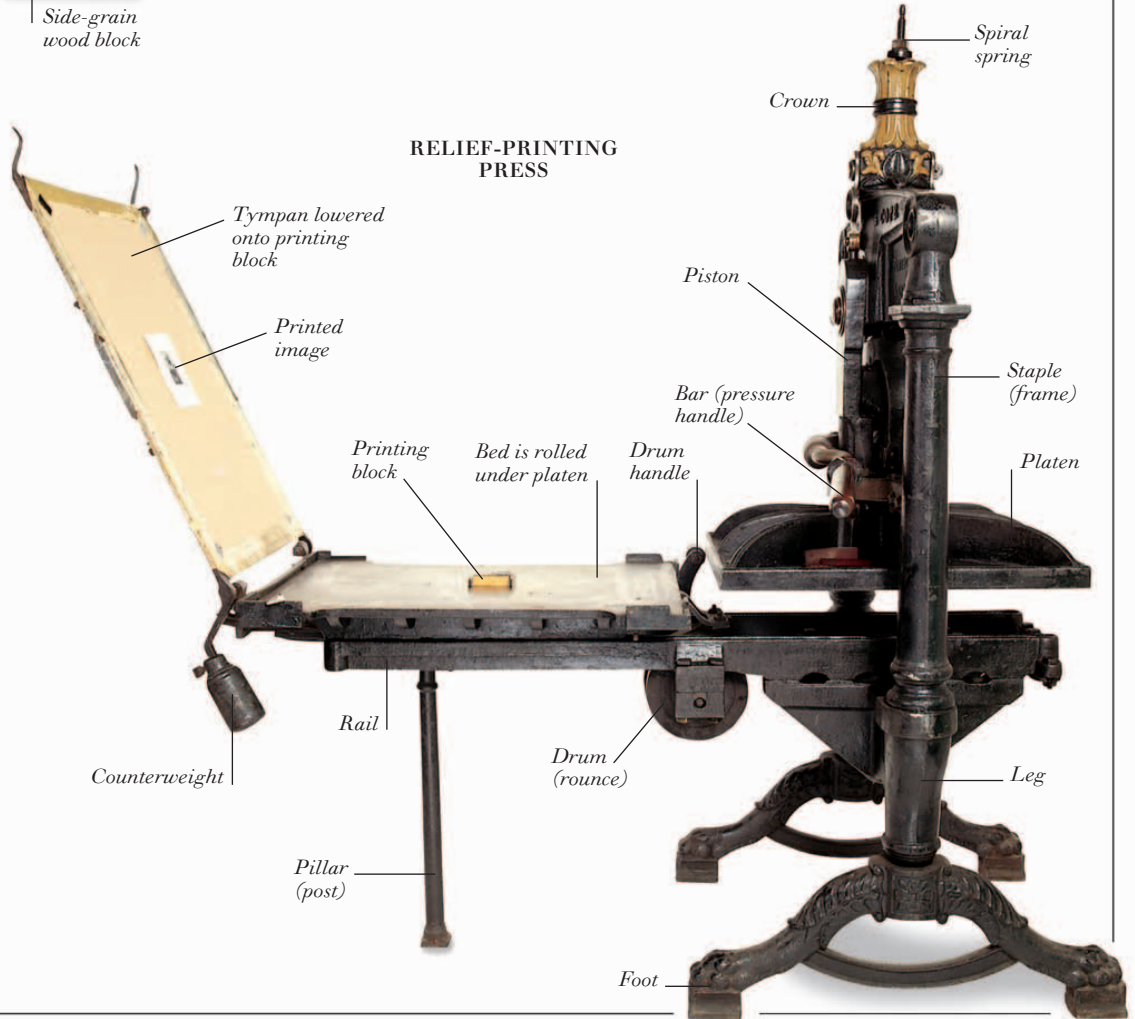


INKED-UP ENGRAVED BLOCK



WOOD ENGRAVING PRINT

RELIEF-PRINTING PRESS



Spiral spring

Crown

Piston

Staple (frame)

Platen

Bar (pressure handle)

Drum handle

Bed is rolled under platen

Printing block

Tympan lowered onto printing block

Printed image

Leg

Drum (rounce)

Rail

Counterweight

Pillar (post)

Foot

Mosaic

MOSAIC IS THE ART OF MAKING patterns and pictures from tesserae (small, colored pieces of glass, marble, and other materials). Different materials are cut into tesserae using different tools. Smalti (glass enamel) and marble are cut into pieces using a hammer and a hardy (a pointed blade) embedded in a log. Vitreous glass is cut into pieces using a pair of pliers. Mosaics can be made using a direct or indirect method. In the direct method, the tesserae are laid directly into a bed of cement-based adhesive. In the indirect method, the design is drawn in reverse on paper or cloth. The tesserae are then stuck face-down on the paper or cloth using water-soluble glue. Adhesive is spread with a trowel on to a solid surface—such as a wall—and the back of the mosaic is laid into the adhesive. Finally, the paper or cloth is soaked off to reveal the mosaic. Gaps between tesserae can be filled with grout. Grout is forced into gaps by dragging a grouting squeegee across the face of the mosaic. Mosaics are usually used to decorate walls and floors, but they can also be applied to smaller objects.

EXAMPLE OF A MOSAIC (DIRECT METHOD)
 Seascape, Tessa Hunkin, 1995
 Smalti mosaic on board
 31½ in (80 cm) diameter



SMALTI (GLASS ENAMEL)

RED SMALTI



YELLOW SMALTI



BLUE SMALTI



Gold-leaf smalti

EQUIPMENT FOR BREAKING MARBLE

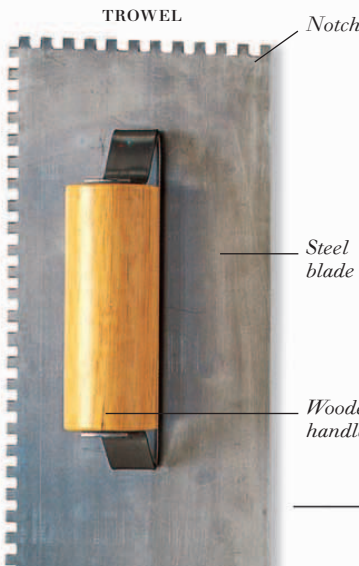


MOSAIC TOOLS

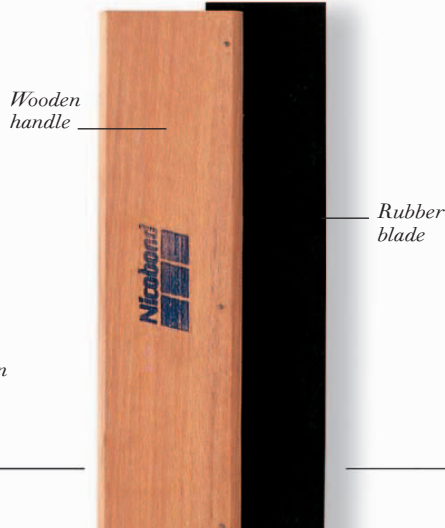
CEMENT-BASED ADHESIVE



GROUT



GROUTING SQUEEGEE



STAGES IN THE CREATION OF A MOSAIC (INDIRECT METHOD)

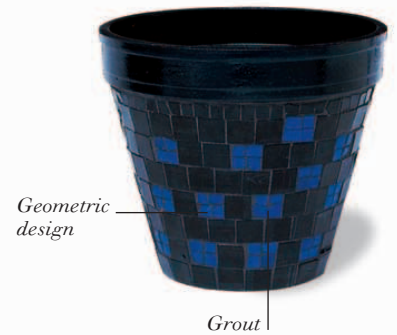


COLOR SKETCH
A color sketch is drawn in oil pastel to give a clear impression of how the finished mosaic will look.



REVERSE IMAGE
Tesserae are glued face-down on reverse image on paper. Mosaic is then attached to solid surface and paper is removed.

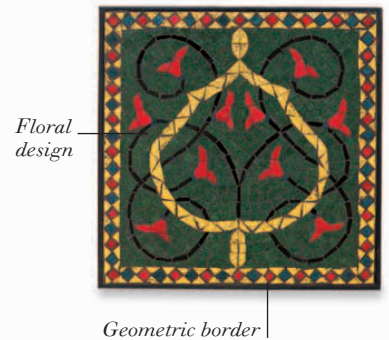
MOSAIC POT



Geometric design

Grout

MOSAIC MOSQUE DESIGN



Floral design

Geometric border



Andamenti (line along which tesserae are laid)

Grout fills the gaps between the tesserae

Mosaic mounted on board

Vitreous glass cut into triangular shape with pliers

Gold tessera with ripple finish

Gold tessera placed upside down

Plain finish

Ripple finish

BLUE VITREOUS GLASS

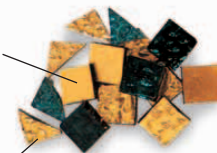
Border of square vitreous glass

VITREOUS GLASS

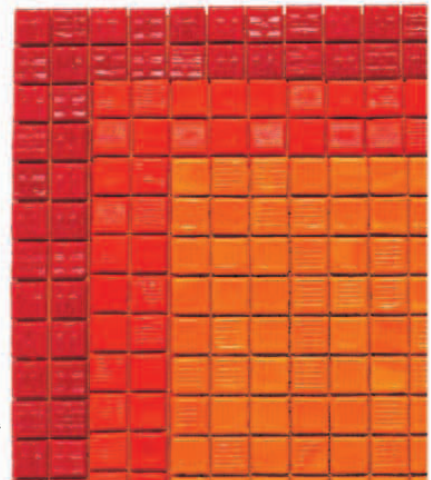
GREEN VITREOUS GLASS WITH GOLD LEAF



RED VITREOUS GLASS



SHEETS OF VITREOUS GLASS

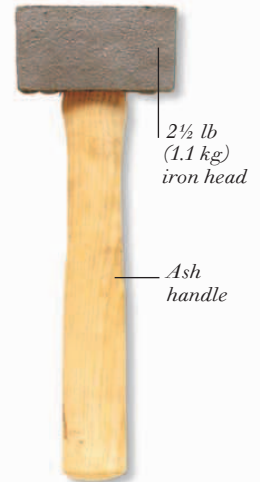


FINISHED MOSAIC
Goldfish, Tessa Hunkin, 1993
Vitreous glass mosaic on board
14 × 10 in (35.5 × 25.5 cm)

Sculpture 1

THE TWO TRADITIONAL METHODS OF MAKING SCULPTURE are carving and modeling. A carved sculpture is made by cutting away the surplus from a block of hard material such as stone, marble, or wood. The tools used for carving vary according to the material being carved. Heavy steel points, claws, and chisels that are struck with a lump hammer are generally used for stone and marble. Sharp gouges and chisels that are struck with a wooden mallet are used for wood. Sculptures formed from hard materials are generally finished by filing with rasps, rifflers, and other abrasive implements. Modeling is a process by which shapes are built up, using malleable materials such as clay, plaster, and wax. The material is cut with wire-ended tools and modeled with the fingers or a variety of hardwood and metal implements. For large or intricate modeled sculptures an armature (frame), made from metal or wood, is used to provide internal support. Sculptures formed in soft materials may harden naturally or can be made more durable by firing in a kiln. Modeled sculptures are often first designed in wax or another material to be cast later in a metal (see pp. 454-455) such as bronze. The development of many new materials in the 20th century has enabled sculptors to experiment with new techniques such as construction (joining preformed pieces of material such as machine components, mirrors, and furniture) and kinetic (mobile) sculpture.

EXAMPLES OF MARBLE CARVING TOOLS



2½ lb
(1.1 kg)
iron head

Ash
handle

LUMP HAMMER



WIDE
MARBLE
CLAW



NARROW
MARBLE
CLAW



POINT



FLAT CHISEL



BULLNOSE CHISEL



DIAMOND WHETSTONE

EXAMPLES OF WOOD-CARVING TOOLS



CABINET RASP



STRAIGHT GOUGE



SALMON BEND GOUGE



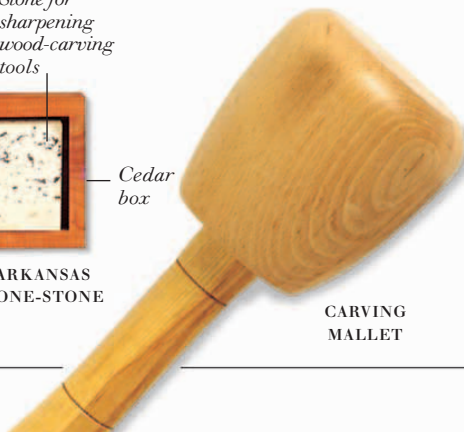
CHISEL

Stone for
sharpening
wood-carving
tools



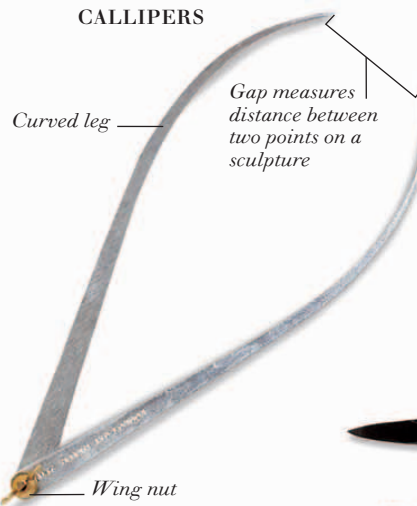
Cedar
box

ARKANSAS
HONE-STONE



CARVING
MALLET

CALLIPERS



Curved leg

Gap measures
distance between
two points on a
sculpture

Wing nut

EXAMPLES OF RIFFLERS (FOR STONE, MARBLE, AND WOOD)



12 IN (30 CM) RIFFLER

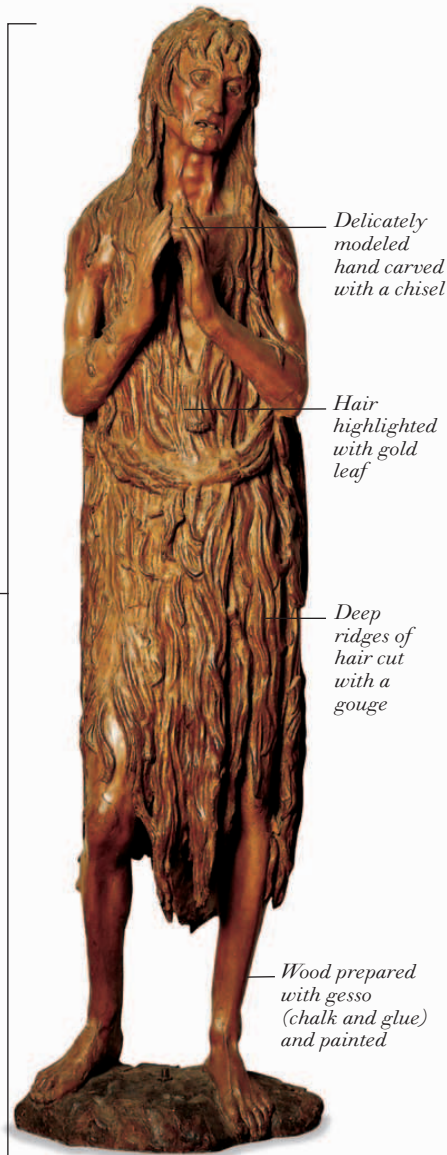


6 IN (15 CM) RIFFLER

Surface for
sharpening
stone-carving
tools

EXAMPLE OF A CARVED WOOD SCULPTURE

Mary Magdalene, Donatello, 1454-1455
Poplar wood, height 6 ft 2 in (188 cm)



Delicately modeled hand carved with a chisel

Hair highlighted with gold leaf

Deep ridges of hair cut with a gouge

Wood prepared with gesso (chalk and glue) and painted

Foot carved in deep relief



Rough surface made by driving a point into the marble at an oblique angle

DETAIL OF SLAVE'S FOOT

EXAMPLE OF A CARVED MARBLE SCULPTURE

The Rebel Slave, Michelangelo, 1513-1516
Marble, height 7 ft (213 cm)



Hair worked with a narrow claw

Soft skin texture tooled with a fine-toothed marble claw

Translucent white marble, quarried at Carrara, Italy

Surface rubbed smooth with rifflers and pumice

Base scored with jagged parallel cuts made with point and lump hammer

Strut gives added support to long slender limb

Series of tiny punch holes, made with a fine point, outline the form

The dimensions of the marble block determine the size of the sculpture

Tiny holes along the hairline made with a point



DETAIL OF SLAVE'S HEAD

Sculpture 2

EXAMPLES OF MODELING TOOLS



WIRE-ENDED CUTTING TOOL



CURVED MOLDING TOOL



SPATULA-ENDED WAX MODELING TOOL



ROUNDED WAX MODELING TOOL

EXAMPLES OF BRONZE FINISHING TOOLS



HOOKED RIFFLER



POINTED RIFFLER

SPIRIT LAMP (FOR HEATING WAX MODELING TOOLS)

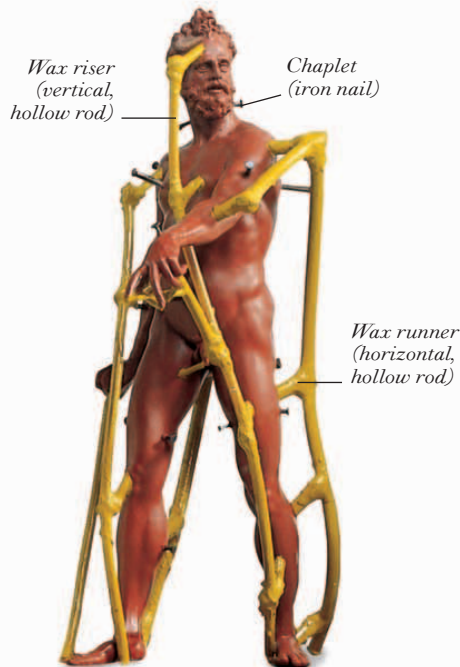


STAGES IN THE LOST-WAX METHOD OF CASTING

Based on Mars, Giambologna, c.1546



ORIGINAL MODEL
An original, solid wax model is made and preserved so that numerous replicas can be cast.



HOLLOW WAX FIGURE IS CAST
A new, hollow wax model is cast from the original model. It is filled with a plaster core that is held in place with nails. Wax runners and risers are attached.

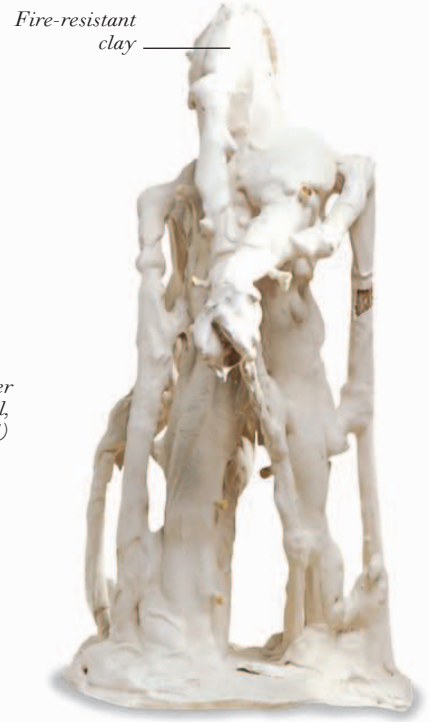
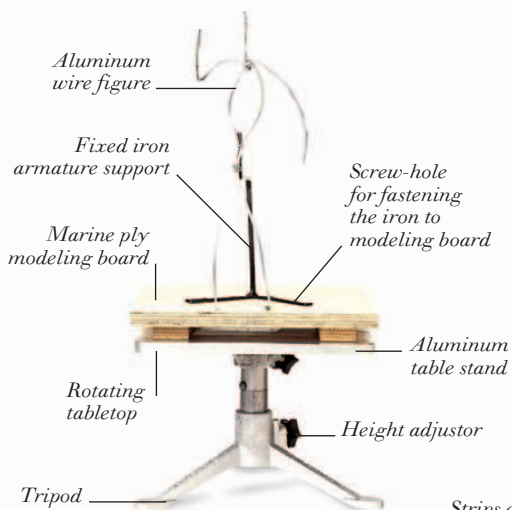


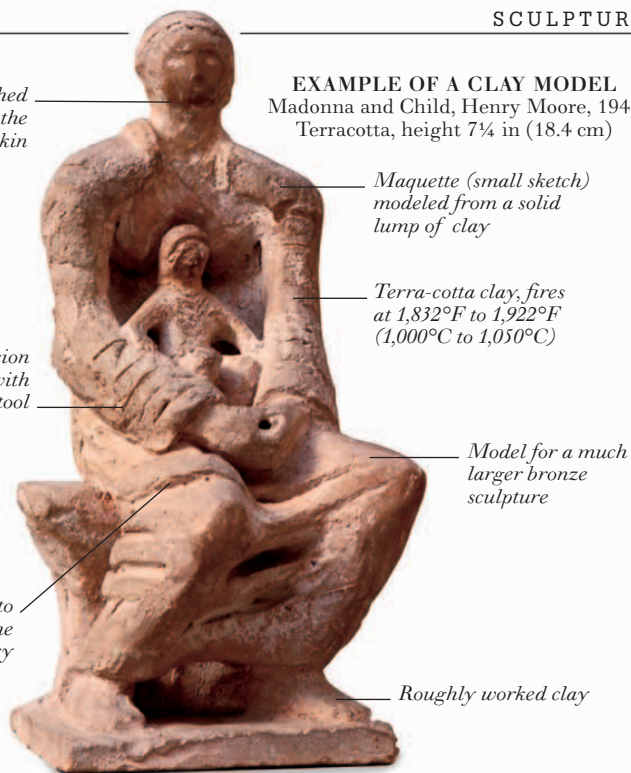
FIGURE IS BAKED IN CASTING MOLD
The model is encased in clay and baked. The wax melts away (through the channels made by the wax rods) and is replaced by molten bronze.

MODELING STAND AND ARMATURE



Clay smoothed to create the effect of soft skin

EXAMPLE OF A CLAY MODEL
Madonna and Child, Henry Moore, 1945
Terracotta, height 7¼ in (18.4 cm)



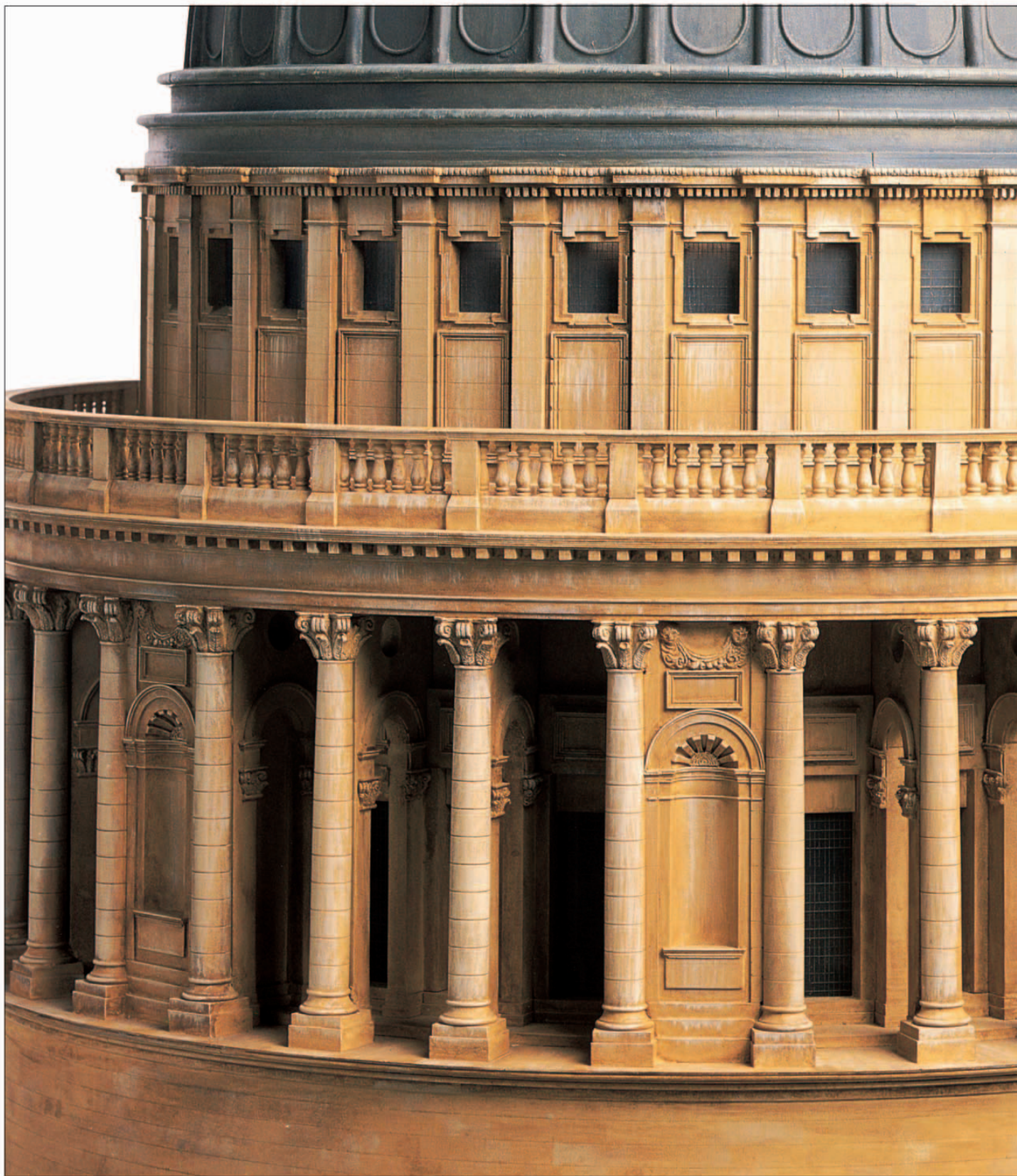
STATUE IS STRIPPED OF CLAY
When the bronze has cooled, the clay mold is broken open to reveal the bronze statue with solid metal runners and risers.



STATUE IS FINISHED
The nails are pulled out and a large hole is made to remove the plaster core. When the metal rods have been sawn off, the sculpture is filed to refine the surface.



STATUE IS CLEANED
Finally, the work is cleaned and polished. An artificial patina (coloring) is achieved by treating the surface with chemicals.



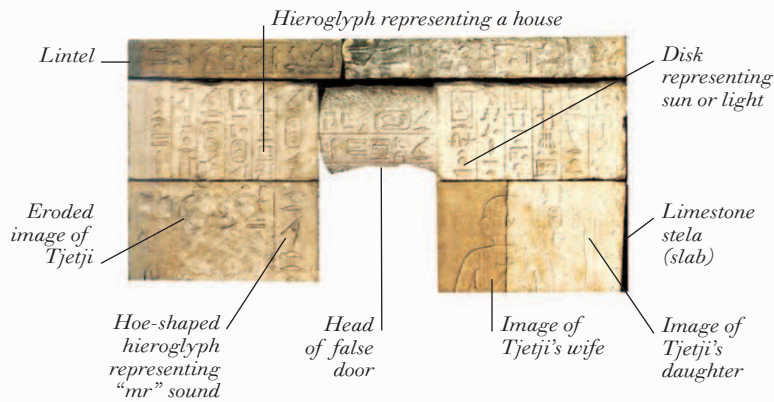


ARCHITECTURE

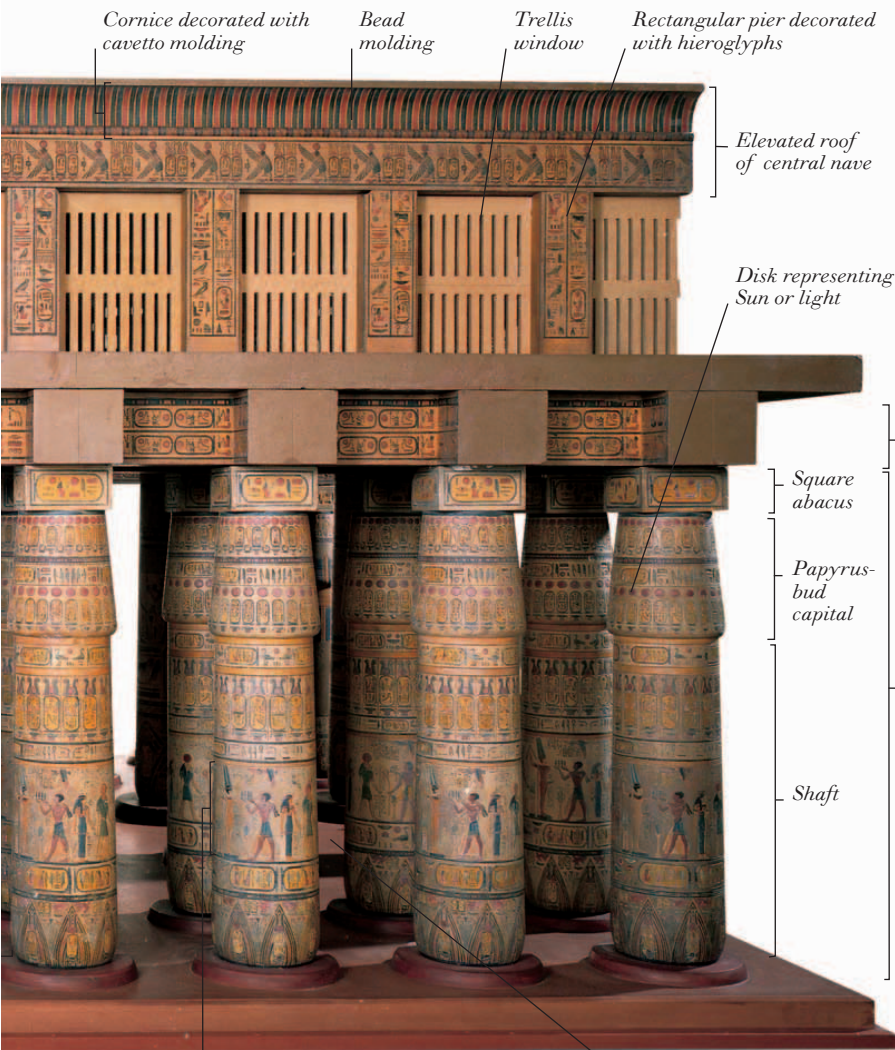
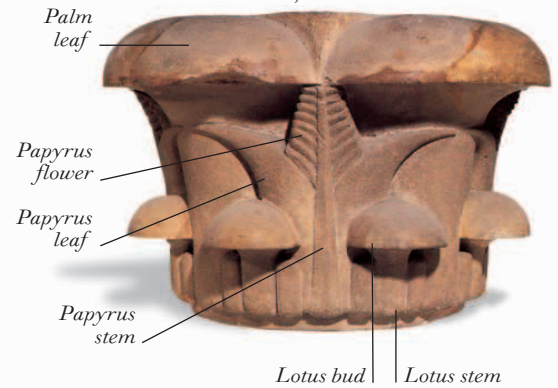
ANCIENT EGYPT.....	458
ANCIENT GREECE.....	460
ANCIENT ROME 1.....	462
ANCIENT ROME 2.....	464
MEDIEVAL CASTLES AND HOUSES.....	466
MEDIEVAL CHURCHES.....	468
GOthic 1.....	470
GOthic 2.....	472
RENAISSANCE 1.....	474
RENAISSANCE 2.....	476
BAROQUE AND NEOCLASSICAL 1.....	478
BAROQUE AND NEOCLASSICAL 2.....	480
BAROQUE AND NEOCLASSICAL 3.....	482
ARCHES AND VAULTS.....	484
DOMES.....	486
ISLAMIC BUILDINGS.....	488
SOUTH AND EAST ASIA.....	490
THE 19TH CENTURY.....	492
THE EARLY 20TH CENTURY.....	494
MODERN BUILDINGS 1.....	496
MODERN BUILDINGS 2.....	498



LIMESTONE FALSE DOOR WITH HIEROGLYPHS,
TOMB OF KING TJETJI, GIZA, EGYPT, c.2400 BC



PLANT CAPITAL OF THE
PTOLEMAIC-ROMAN PERIOD,
EGYPT, 332-30 BC



ANCIENT EGYPTIAN
BUILDING DECORATION



DECORATED WINDOW,
MEDINET HABU, EGYPT,
c.1198 BC



ROPE AND PATERAE
DECORATION



CAPITAL WITH THE HEAD OF THE
SKY-GODDESS HATHOR, TEMPLE
OF ISIS, PHILAE, EGYPT, 283-47 BC



LOTUS AND PAPYRUS
FRIEZE DECORATION

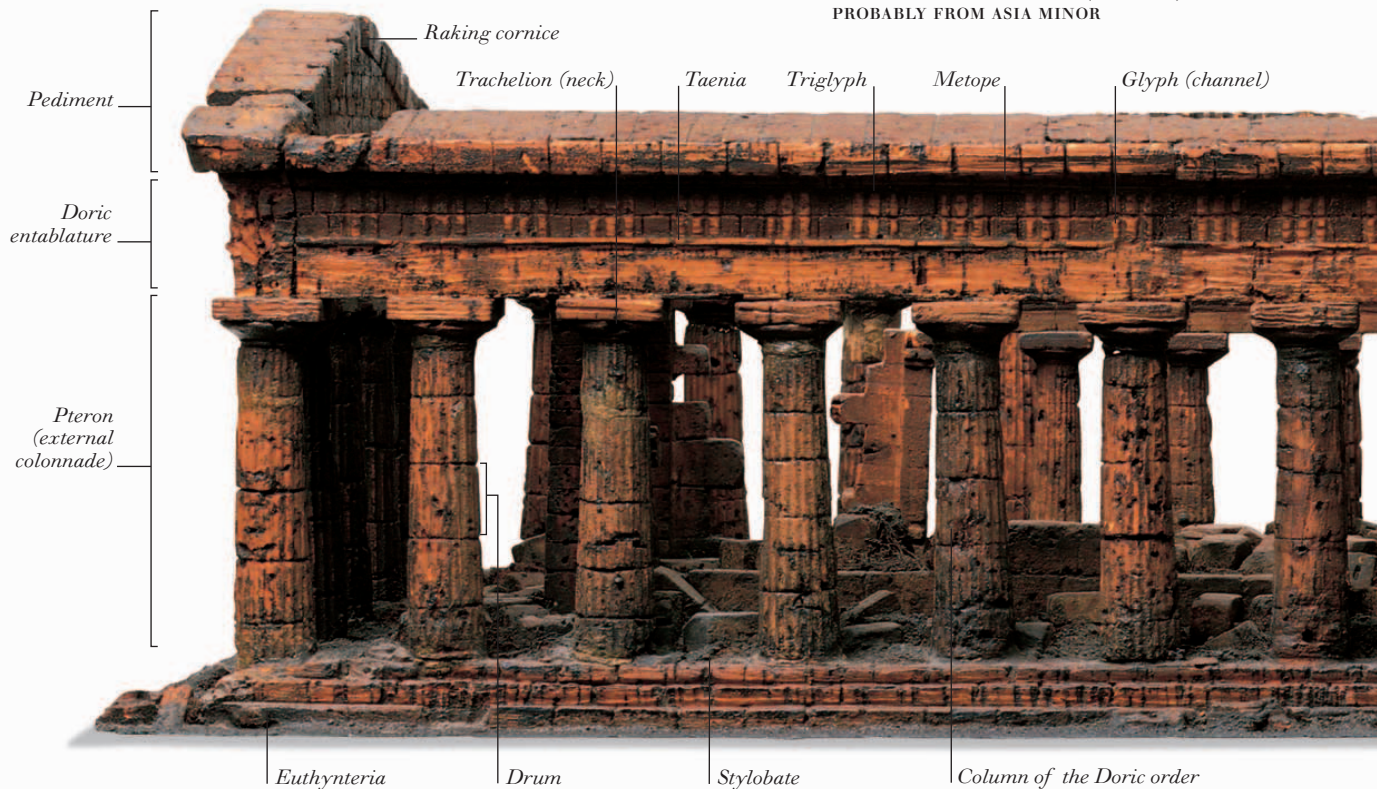
Scene depicting a Pharaoh (king)
paying homage to the god Amon-Re

Central nave

Ancient Greece

THE CLASSICAL TEMPLES OF ANCIENT GREECE were built according to the belief that certain forms and proportions were pleasing to the gods. There were three main ancient Greek architectural orders (styles), which can be distinguished by the decoration and proportions of their columns, capitals (column tops), and entablatures (structures resting on the capitals). The oldest is the Doric order, which dates from the seventh century BC and was used mainly on the Greek mainland and in the western colonies, such as Sicily and southern Italy. The Temple of Neptune, shown here, is a classic example of this order. It is hypaethral (roofless) and peripteral (surrounded by a single row of columns). About a century later, the more decorative Ionic order developed on the Aegean Islands. Features of this order include volutes (spiral scrolls) on capitals and acroteria (pediment ornaments). The Corinthian order was invented in Athens in the fifth century BC and is typically identified by an acanthus leaf on the capitals. This order was later widely used in ancient Roman architecture.

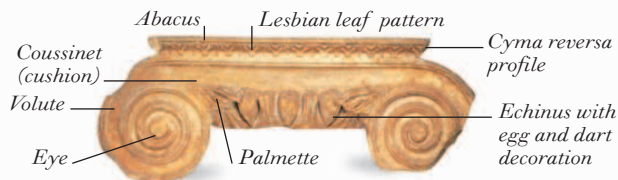
TEMPLE OF NEPTUNE, PAESTUM, ITALY, c.460 BC



CAPITALS OF THE THREE ORDERS OF ANCIENT GREEK ARCHITECTURE



DORIC CAPITAL, THE PROPYLAEUM (GATEWAY), THE ACROPOLIS, ATHENS, GREECE, 449 BC

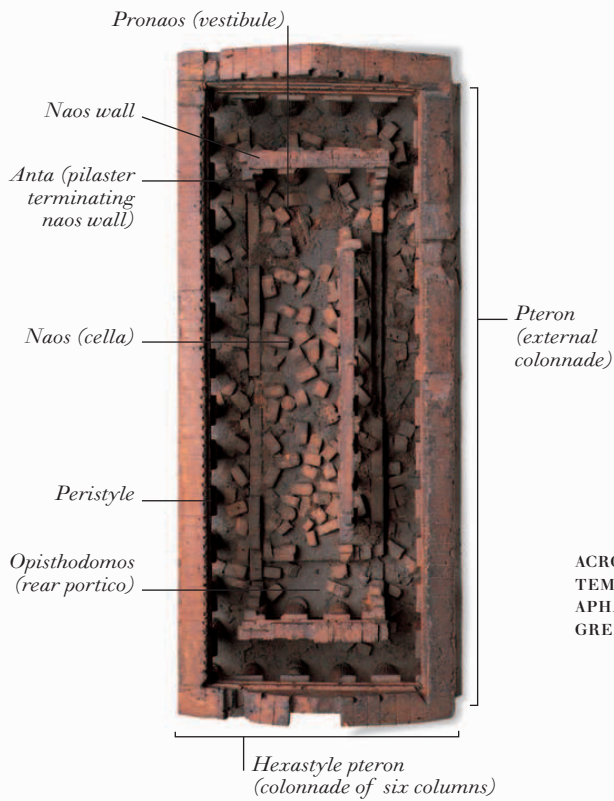


IONIC CAPITAL, THE PROPYLAEUM (GATEWAY), TEMPLE OF ATHENA POLIAS, PRIENE, GREECE, c.334 BC



CORINTHIAN CAPITAL FROM A STOA (PORTICO), PROBABLY FROM ASIA MINOR

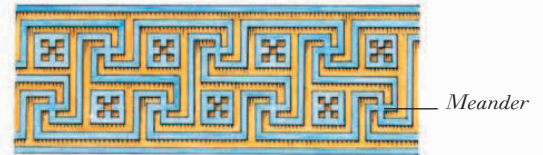
PLAN OF THE TEMPLE OF NEPTUNE, PAESTUM



ANCIENT GREEK BUILDING DECORATION



FACADE, TREASURY OF ATREUS, MYCENAE, GREECE, 1350-1250 BC



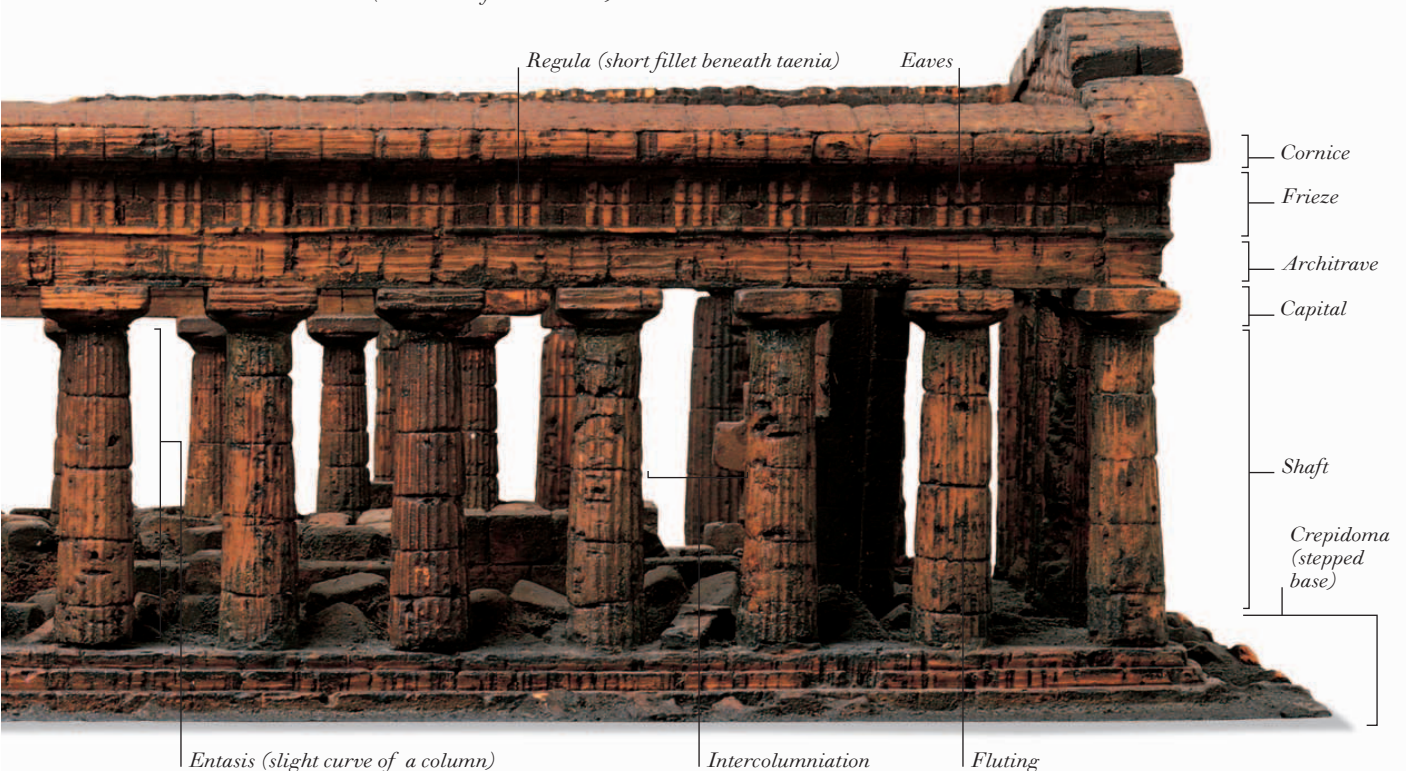
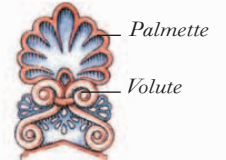
FRETWORK, PARTHENON, ATHENS, GREECE, 447-436 BC

ACROTHERION, TEMPLE OF APHAIA, AEGINA, GREECE, 490 BC



Raking cornice

ANTEFIXA, TEMPLE OF APHAIA, AEGINA, GREECE, 490 BC



Ancient Rome 1

IN THE EARLY PERIOD OF THE ROMAN EMPIRE extensive use was made of ancient Greek architectural ideas, particularly those of the Corinthian order (see pp. 460-461). As a result, many early Roman buildings—such as the Temple of Vesta (opposite)—closely resemble ancient Greek buildings. A distinctive Roman style began to evolve in the first century AD. This style developed the interiors of buildings (the Greeks had concentrated on the exterior) by using arches, vaults, and domes inside the buildings, and by ornamenting internal walls. Many of these features can be seen in the Pantheon. Exterior columns were often used for decorative, rather than structural, purposes, as in the Colosseum and the Porta Nigra (see pp. 464-465). Smaller buildings had timber frames with wattle-and-daub walls, as in the mill (see pp. 464-465). Roman architecture remained influential for many centuries, with some of its principles being used in the 11th century in Romanesque buildings (see pp. 468-469) and also in the 15th and 16th centuries in Renaissance buildings (see pp. 474-477).

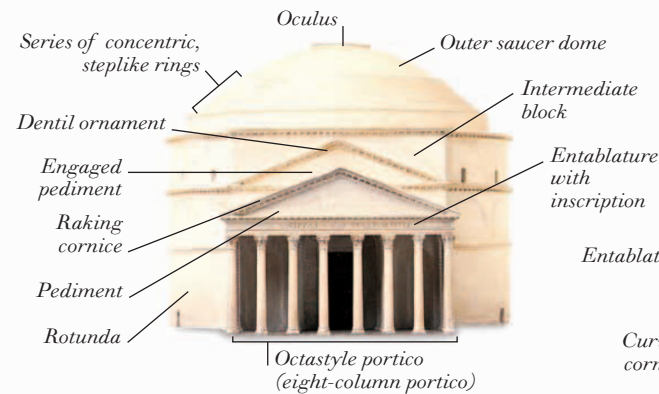
ANCIENT ROMAN BUILDING DECORATION



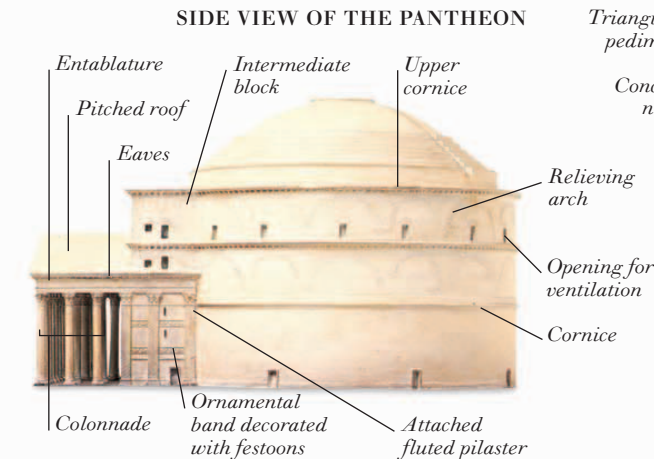
FESTOON, TEMPLE OF VESTA, TIVOLI, ITALY, C.80 BC



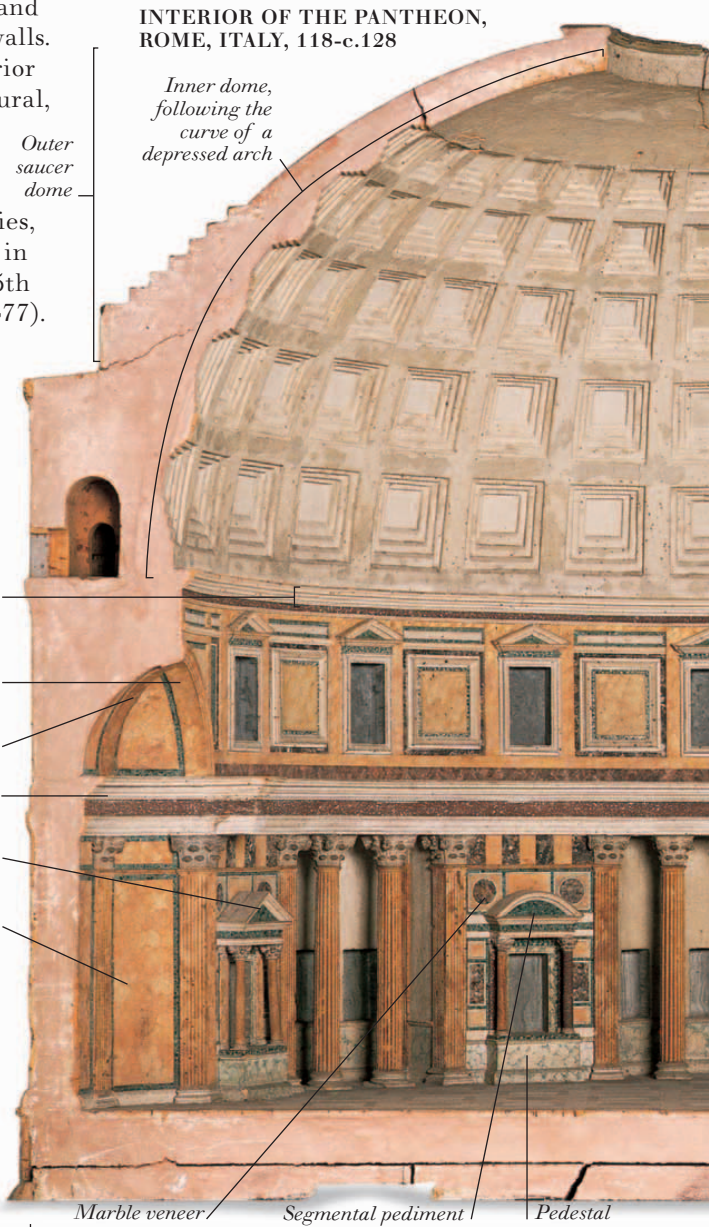
RICHLY DECORATED ROMAN OVUM



FRONT VIEW OF THE PANTHEON



SIDE VIEW OF THE PANTHEON



INTERIOR OF THE PANTHEON, ROME, ITALY, 118-c.128

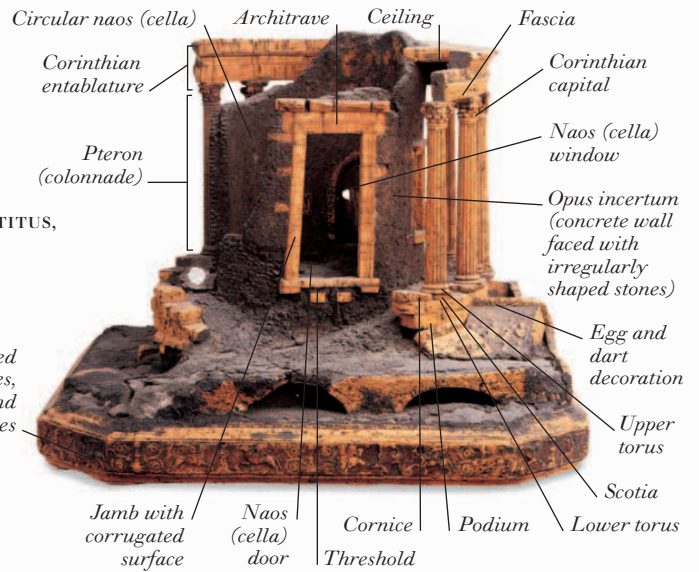


FRIEZE, FORUM OF TRAJAN, ROME, ITALY, 98-113



KEYSTONE, ARCH OF TITUS, ROME, ITALY, 81

TEMPLE OF VESTA, TIVOLI, ITALY, c.80 BC

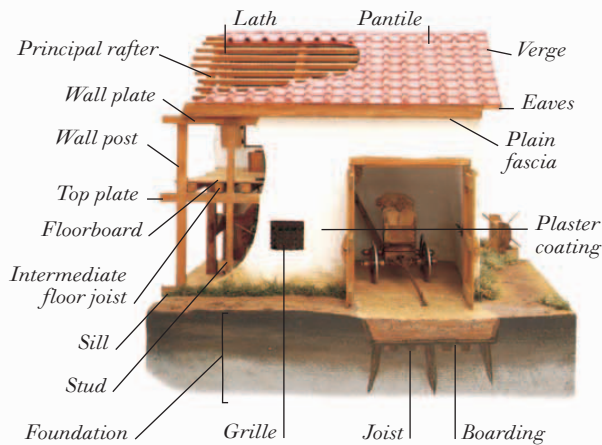


Oculus illuminating interior of rotunda

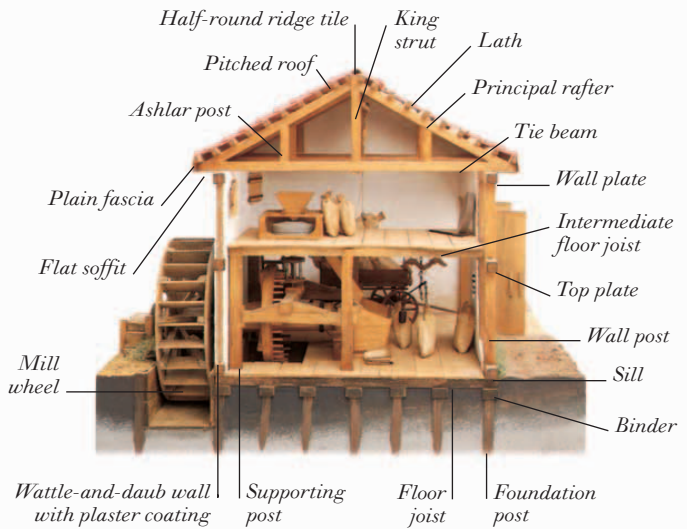


Ancient Rome 2

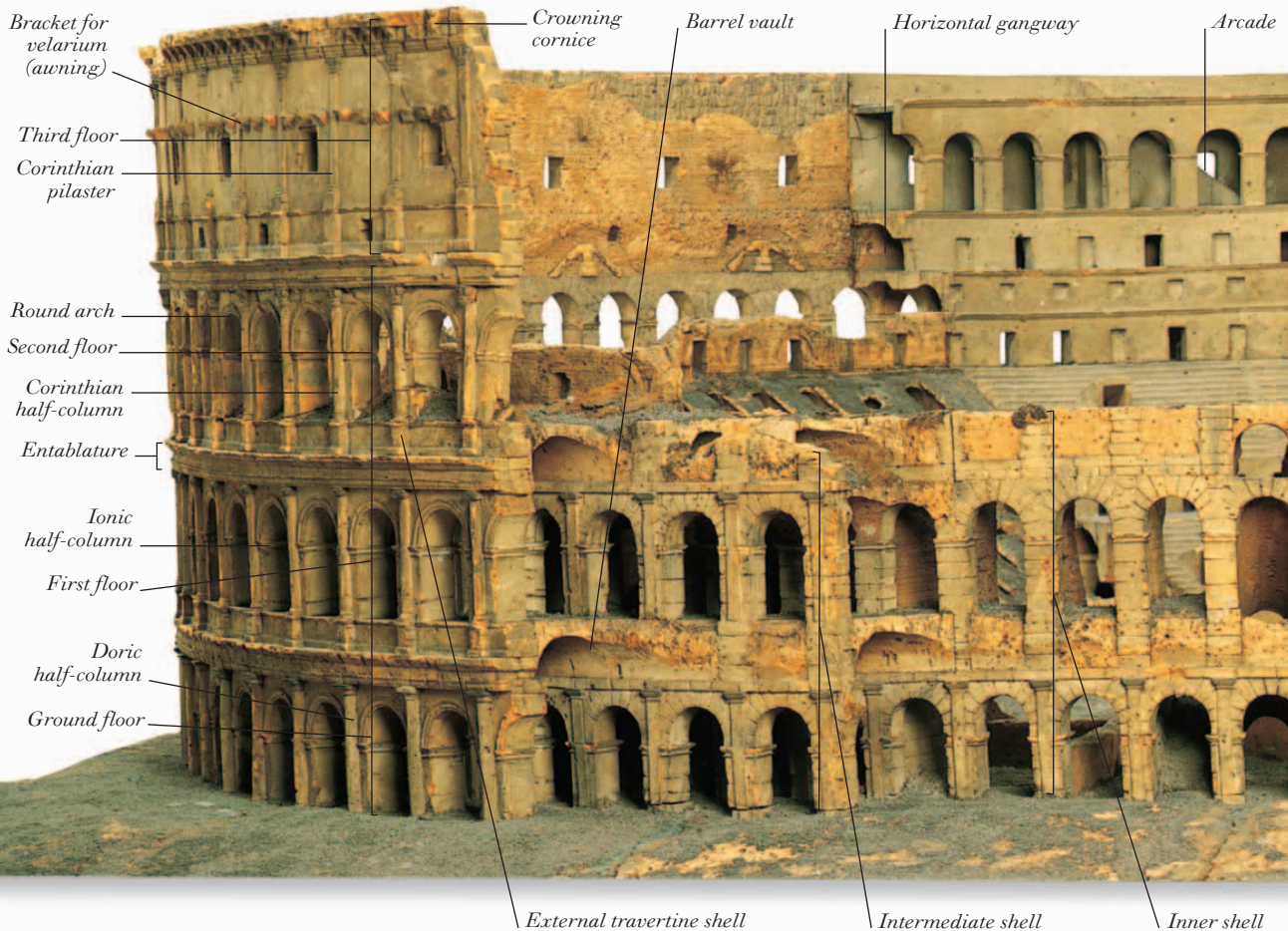
SIDE VIEW OF A ROMAN MILL



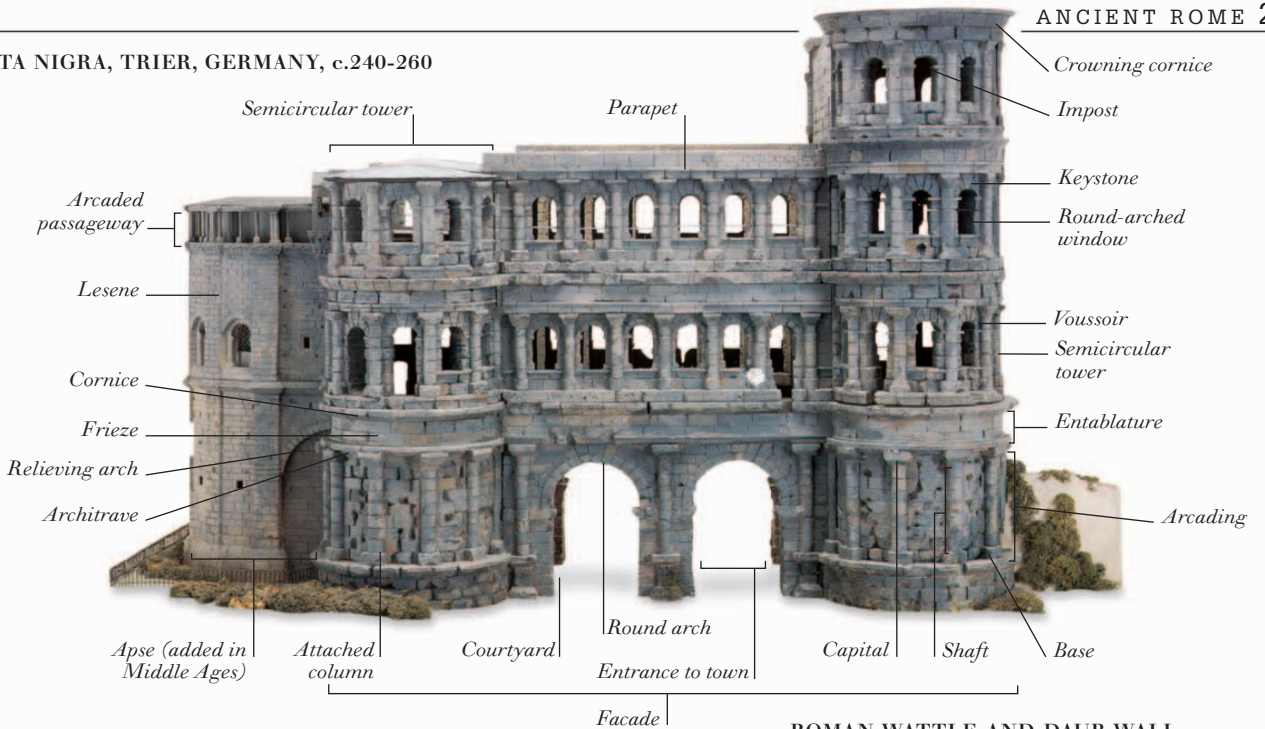
FRONT VIEW OF A ROMAN MILL, 1ST CENTURY BC



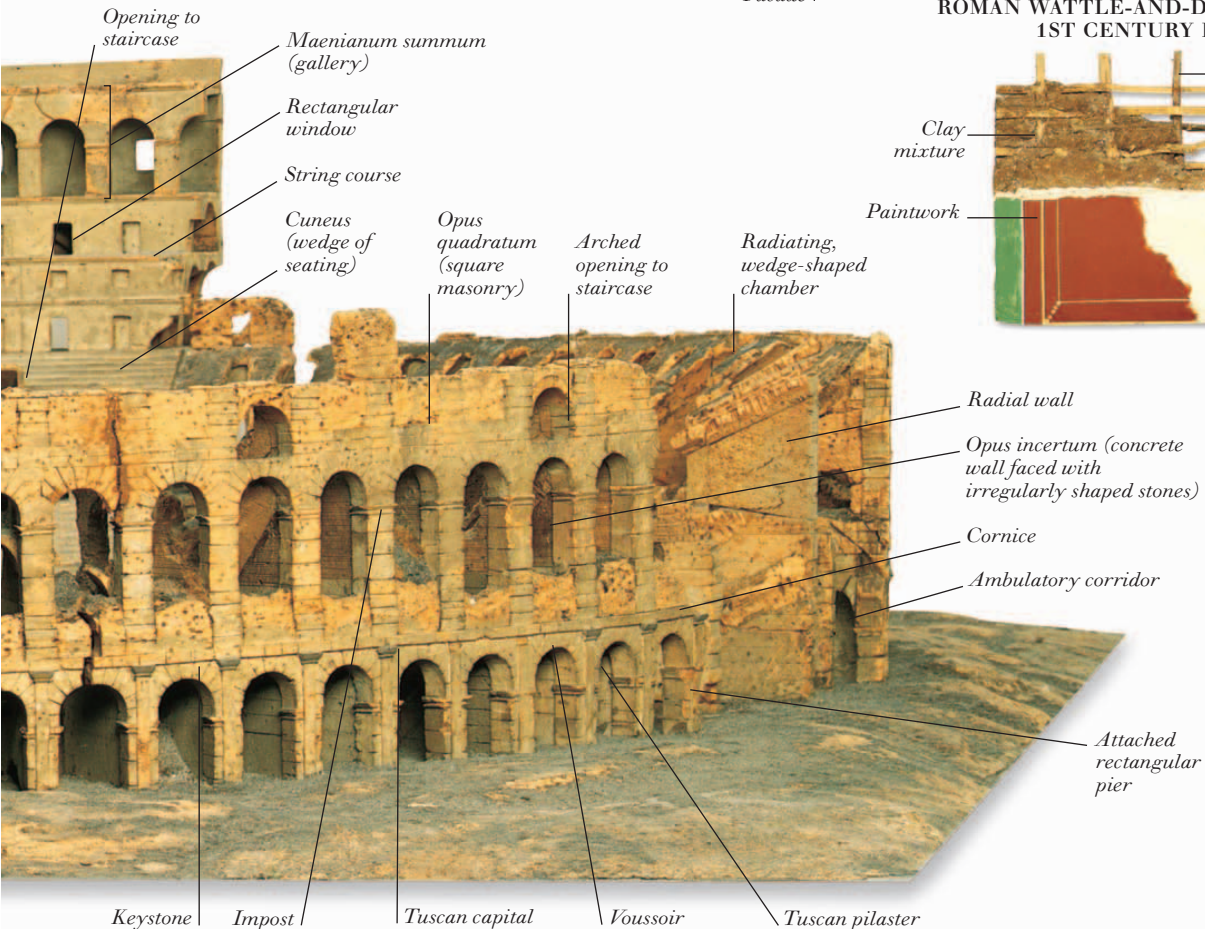
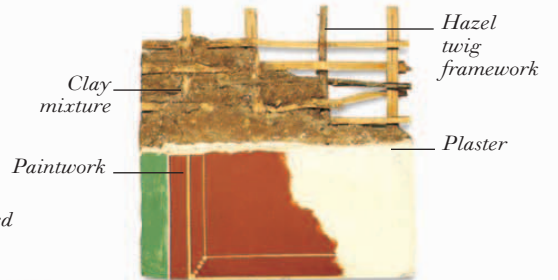
THE COLOSSEUM (FLAVIAN AMPHITHEATRE), ROME, ITALY, 70-82



PORTA NIGRA, TRIER, GERMANY, c.240-260



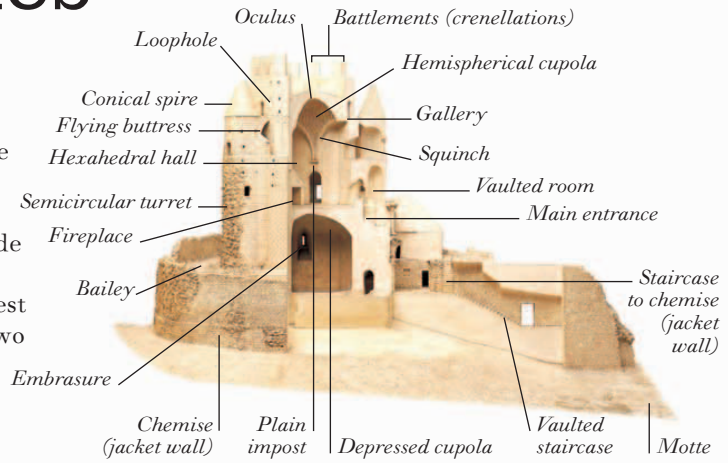
ROMAN WATTLE-AND-DAUB WALL, 1ST CENTURY BC



Medieval castles and houses

WARFARE WAS COMMON IN EUROPE in the Middle Ages, and many monarchs and nobles built castles as a form of defense. Typical medieval castles have outer walls surrounding a moat. Inside the moat is a bailey (courtyard), protected by a chemise (jacket wall). The innermost and strongest part of a medieval castle is the keep. There are two main types of keep: towers called donjons, such as the Tour de César and Coucy-le-Château, and rectangular keeps (“hall-keeps”), such as the Tower of London. Castles were often guarded by salients (projecting fortifications), like those of the Bastille. Medieval houses typically had timber cruck roofs, like those on medieval London Bridge (opposite).

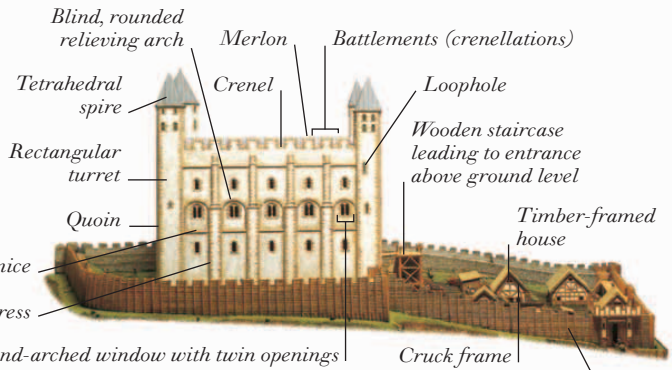
DONJON, TOUR DE CESAR, PROVINS, FRANCE, 12TH CENTURY



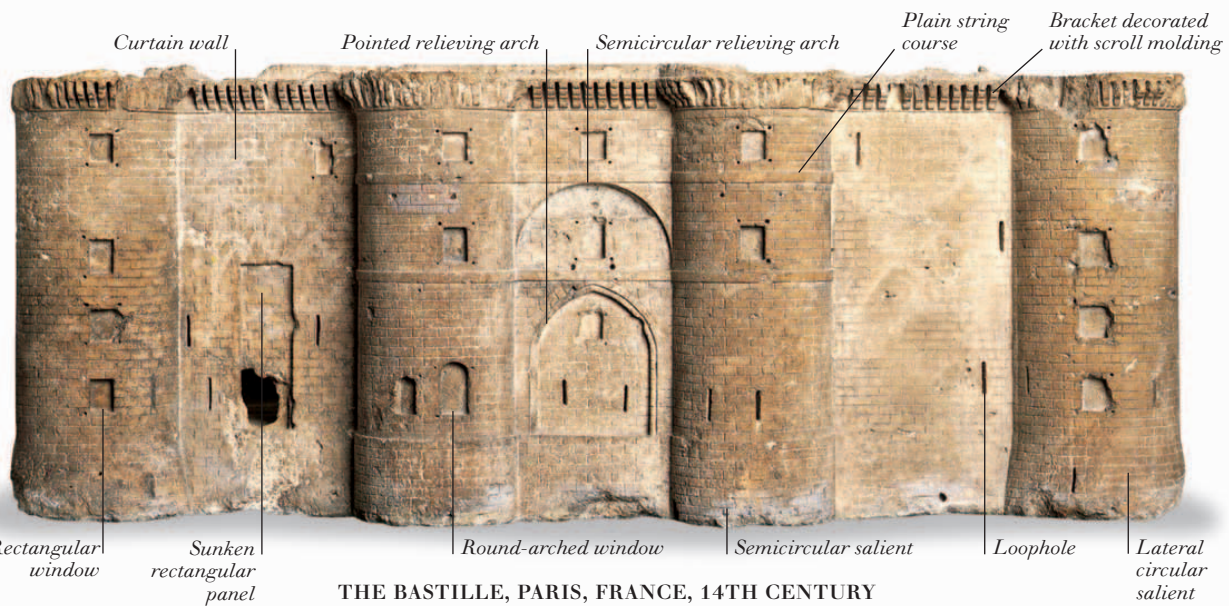
Salient, Caernarvon Castle, Britain, 1283-1323



CRUCK-FRAMED HOUSE, BRITAIN, c.1200

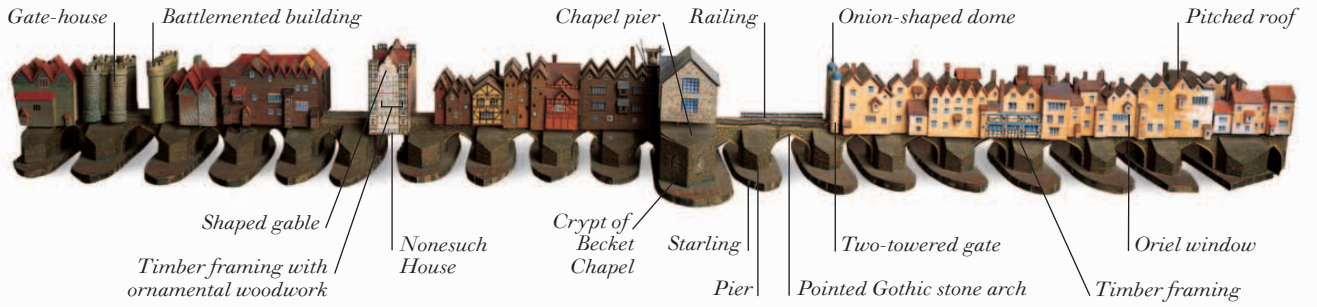


TOWER OF LONDON, BRITAIN, FROM 1070

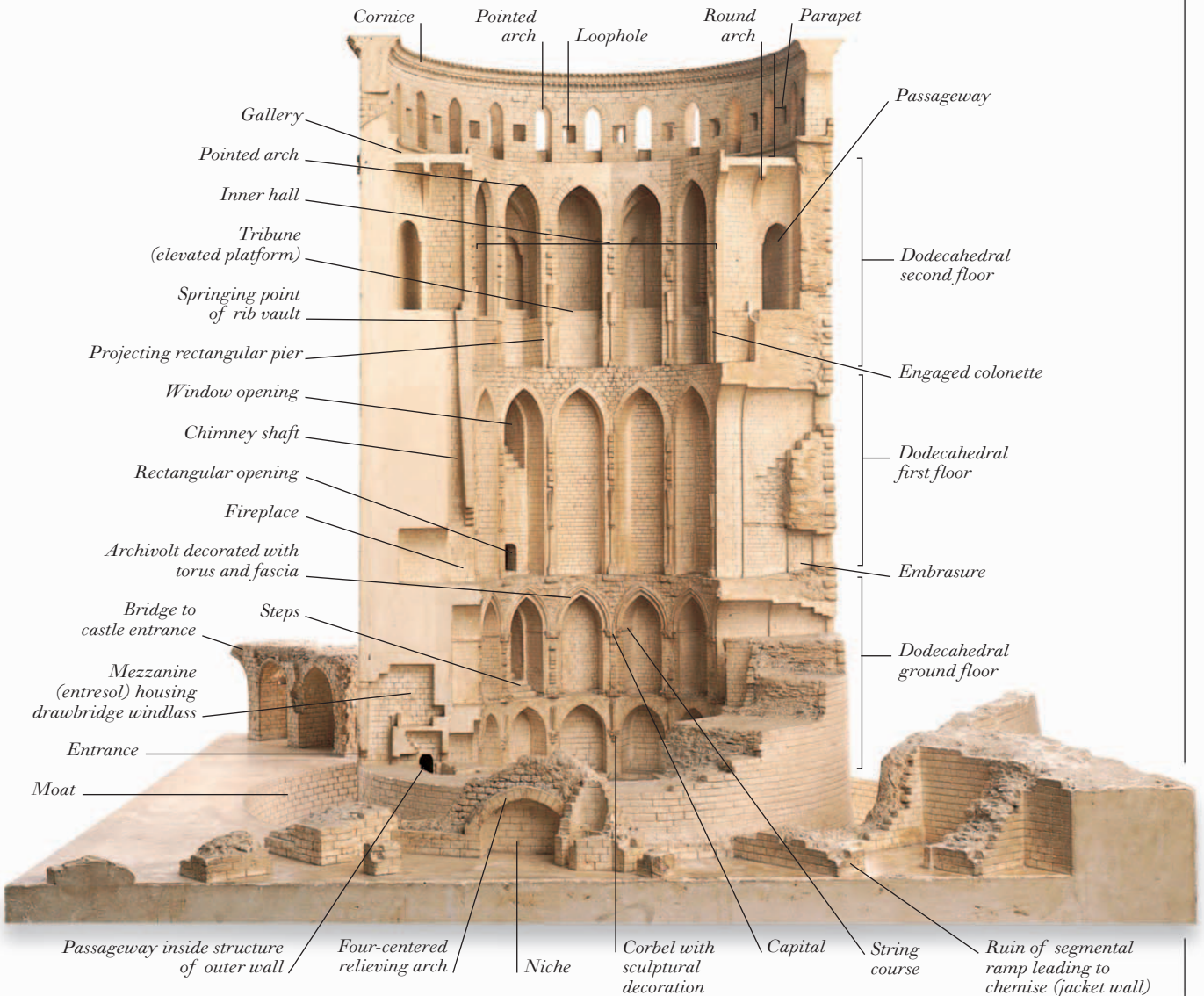


THE BASTILLE, PARIS, FRANCE, 14TH CENTURY

MEDIEVAL LONDON BRIDGE, BRITAIN, 1176 (WITH 14TH-CENTURY
BATTLEMENTED BUILDING, NONESUCH HOUSE, AND TWO-TOWERED GATE)



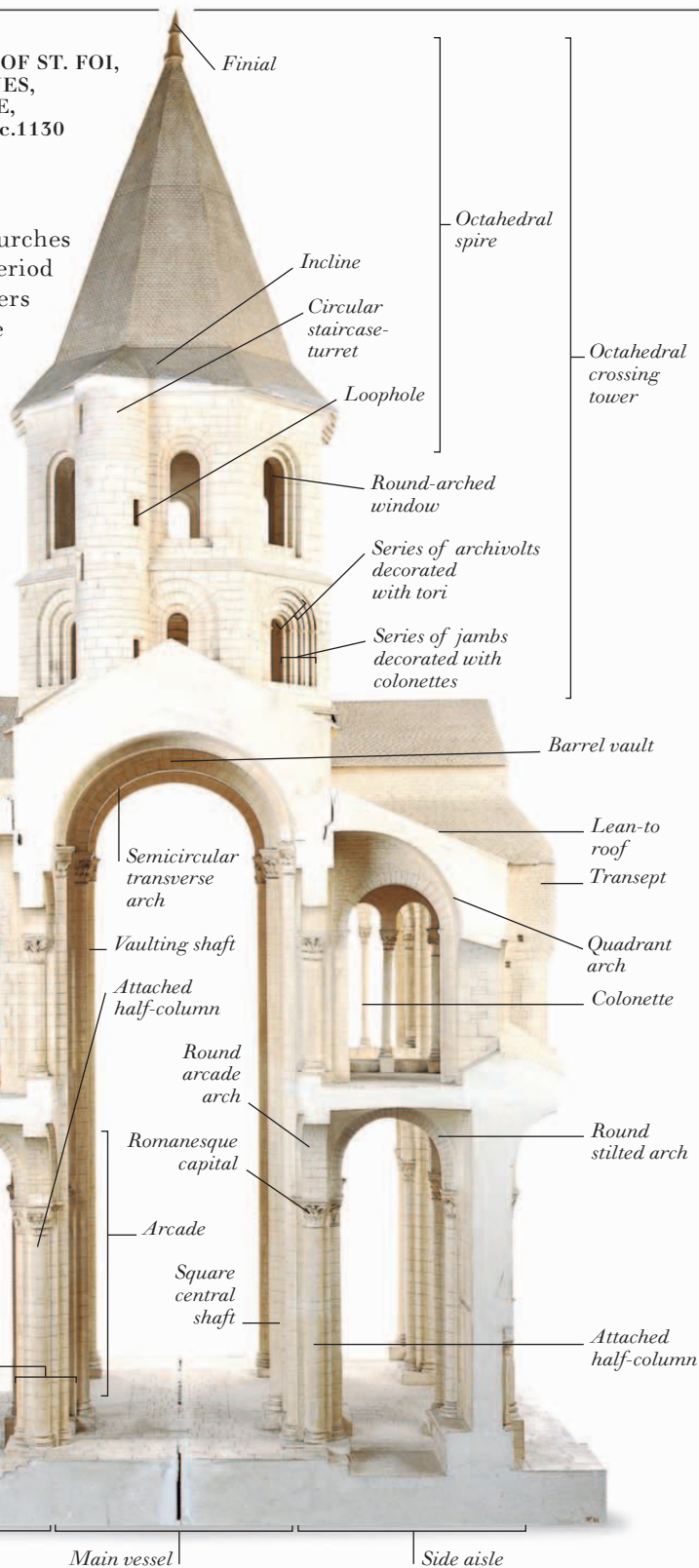
DONJON, COUCY-LE-CHATEAU, AISNE, FRANCE, 1225-1245



Medieval churches

ABBEY OF ST. FOI,
CONQUES,
FRANCE,
c.1050–c.1130

DURING THE MIDDLE AGES, large numbers of churches were built in Europe. European churches of this period typically have high vaults supported by massive piers and columns. In the 10th century, the Romanesque style developed. Romanesque architects adopted many Roman or early Christian architectural ideas, such as cross-shaped ground-plans—like that of Angoulême Cathedral (opposite)—and the basilican system of a nave with a central vessel and side aisles. In the mid-12th century, flying buttresses and pointed vaults appeared. These features later became widely used in Gothic architecture (see pp. 470-471). Bagneux Church (opposite) has both styles: a Romanesque tower, and a Gothic nave and choir.



CHURCH-ROOF BOSS, BRITAIN

ROMANESQUE CAPITALS

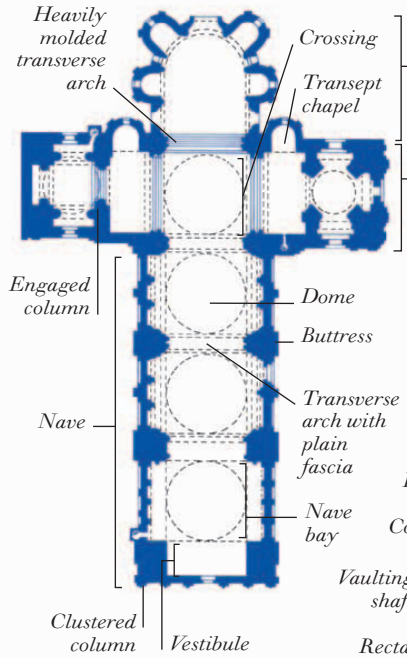


“THE FLIGHT INTO EGYPT” CAPITAL, CATHEDRAL OF ST. LAZARE, AUTUN, FRANCE, 1120-1130

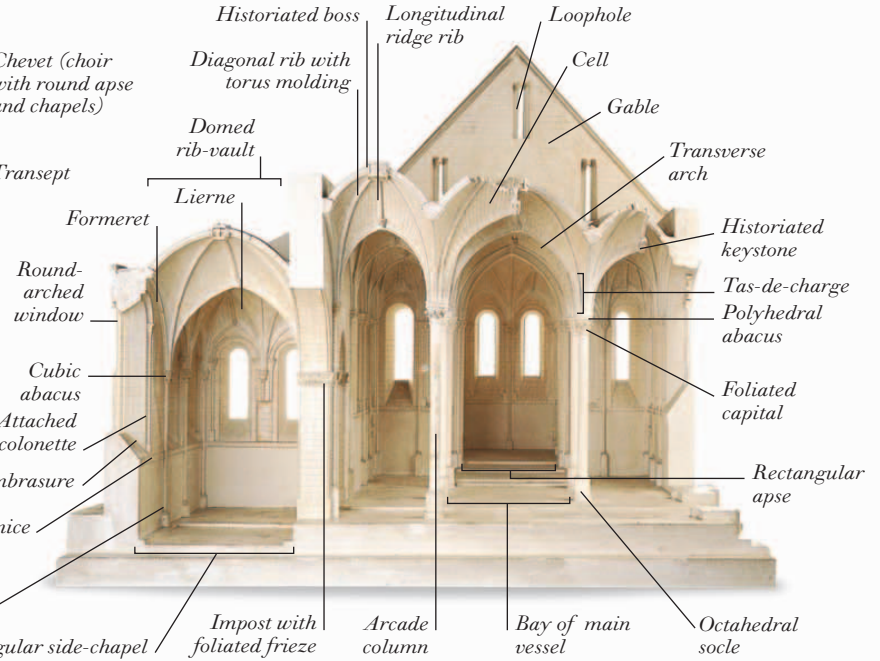


“CHRIST IN MAJESTY” CAPITAL, BASILICA OF ST. MADELEINE, VEZELAY, FRANCE, 1120-1140

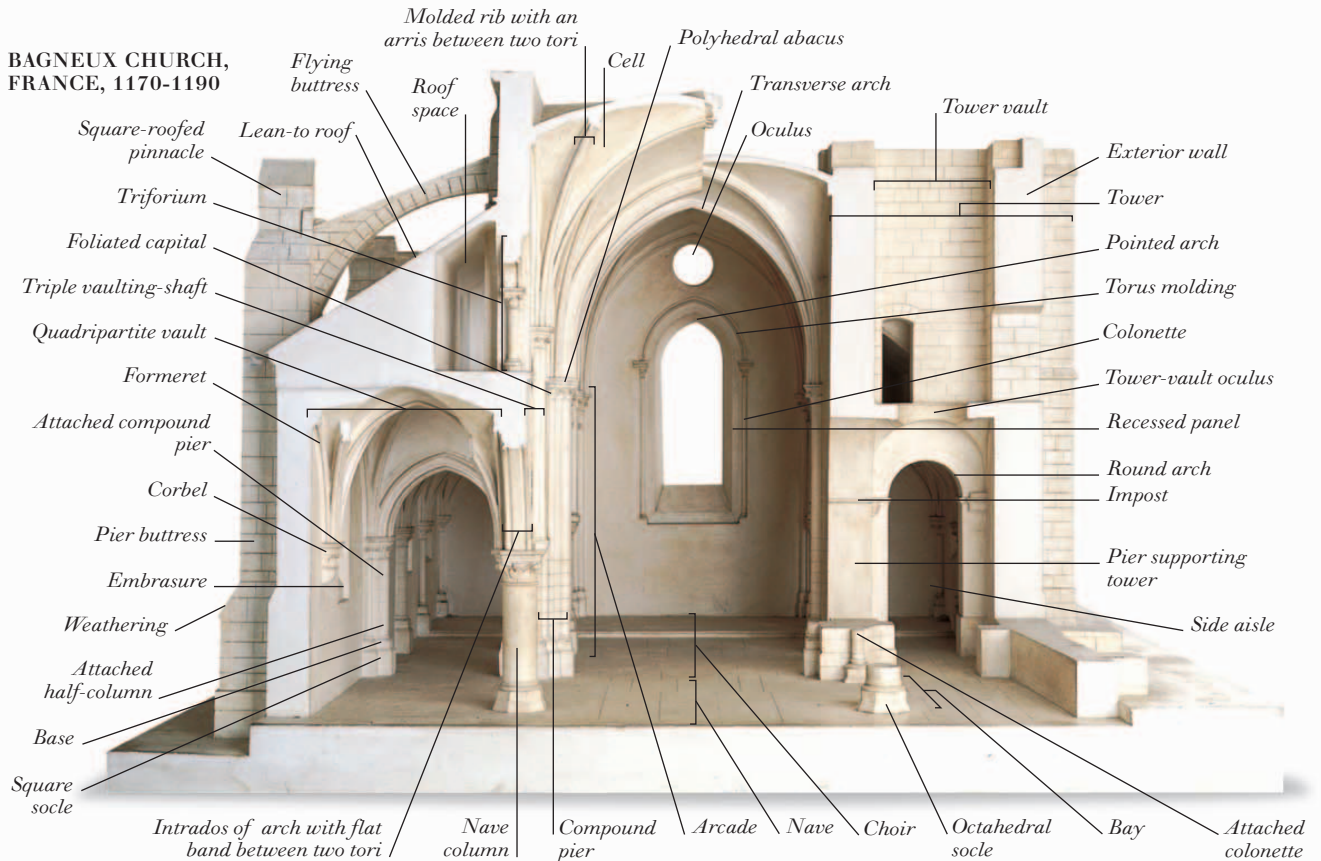
GROUND-PLAN OF ANGOULEME CATHEDRAL, FRANCE, FROM c.1105



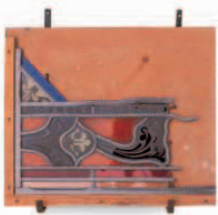
CHOIR, CHURCH OF ST. SERGE, ANGERS, FRANCE, c.1215-1220



BAGNEUX CHURCH, FRANCE, 1170-1190



Gothic 1

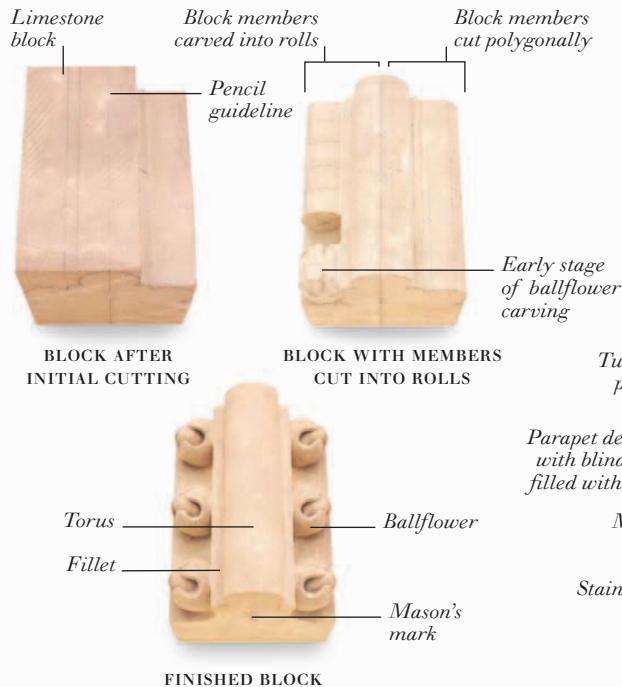


GOTHIC STAINED GLASS WITH FOLIATED SCROLL MOTIF, ON WOODEN FORM

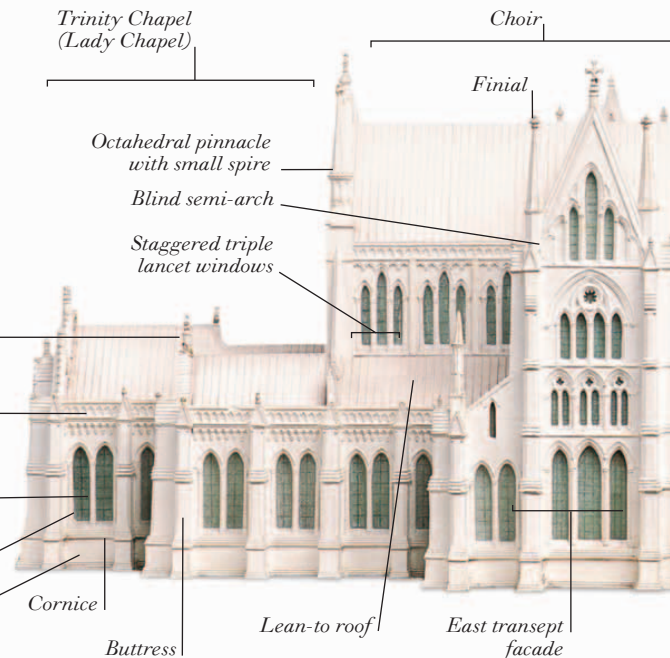
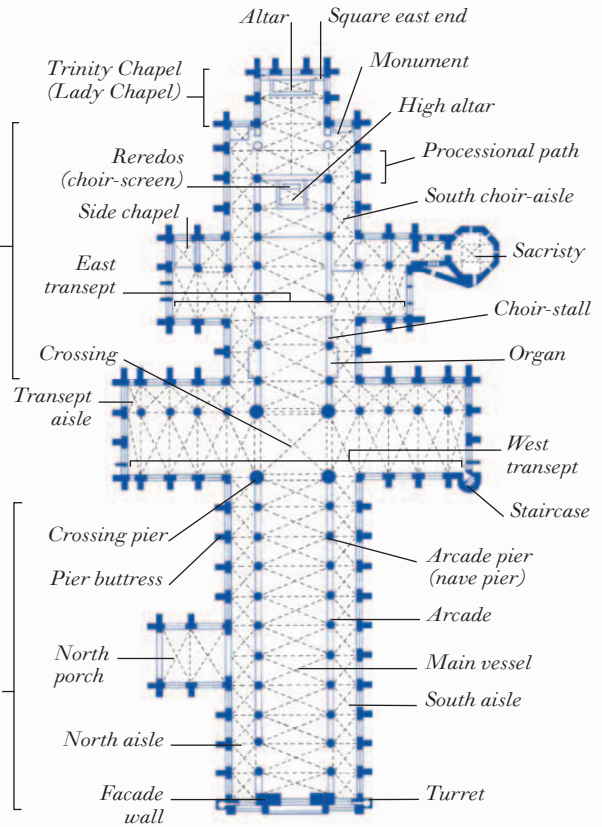
GOTHIC BUILDINGS are characterized by rib vaults, pointed or lancet arches, flying buttresses, decorative tracery and gables, and stained-glass windows. Typical Gothic buildings include the Cathedrals of Salisbury and old St. Paul's in England, and Notre Dame de Paris in France (see pp. 472-473). The Gothic style developed out of Romanesque architecture in France (see pp. 468-469) in the mid-

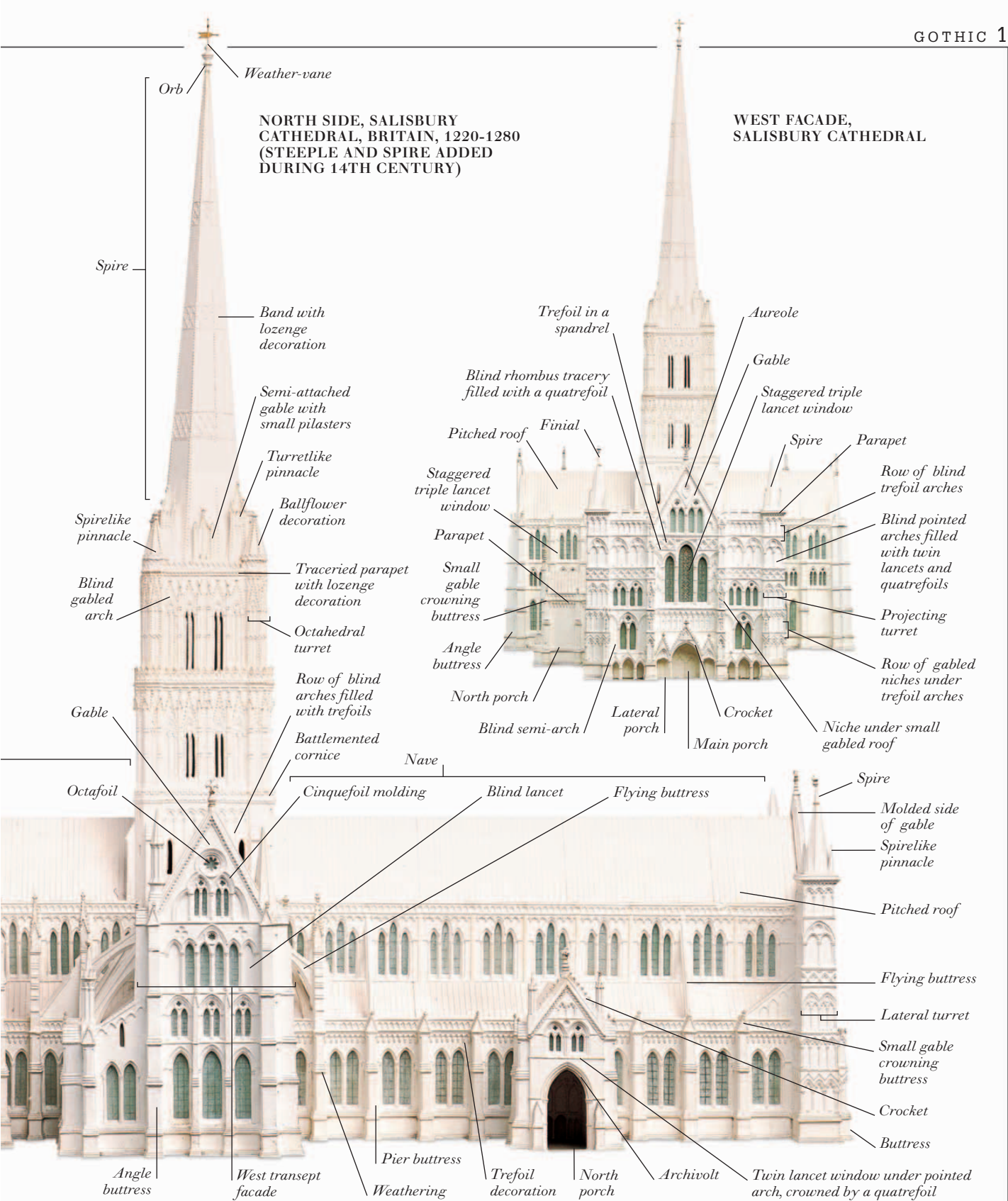
12th century, and then spread throughout Europe. The decorative elements of Gothic architecture became highly developed in buildings of the English Decorated style (late 13th-14th century) and the French Flamboyant style (15th-16th century). These styles are exemplified by the tower of Salisbury Cathedral and the staircase in the Church of St. Maclou (see pp. 472-473), respectively. In both of these styles, embellishments such as ballflowers and curvilinear (flowing) tracery were used liberally. The English Perpendicular style (late 14th-15th century), which followed the Decorated style, emphasized the vertical and horizontal elements of a building. A notable feature of this style is the hammer-beam roof.

GOTHIC TORUS WITH BALLFLOWERS



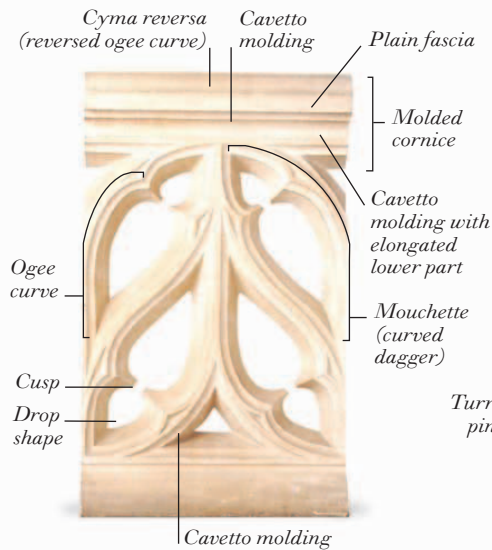
GROUND-PLAN OF SALISBURY CATHEDRAL



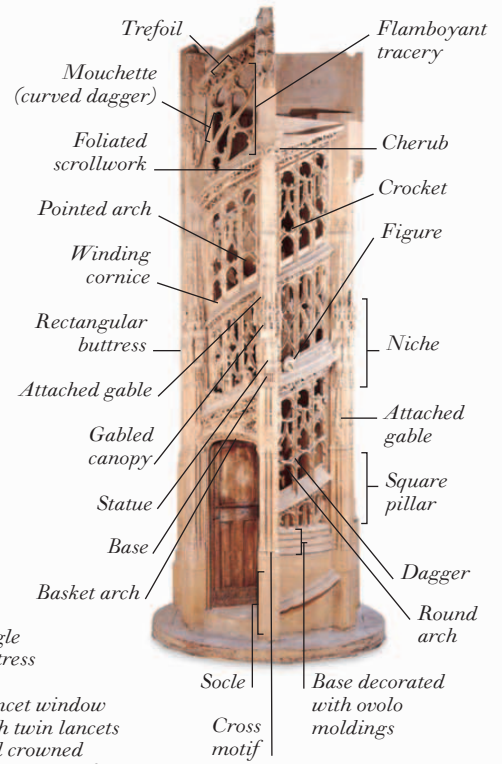


Gothic 2

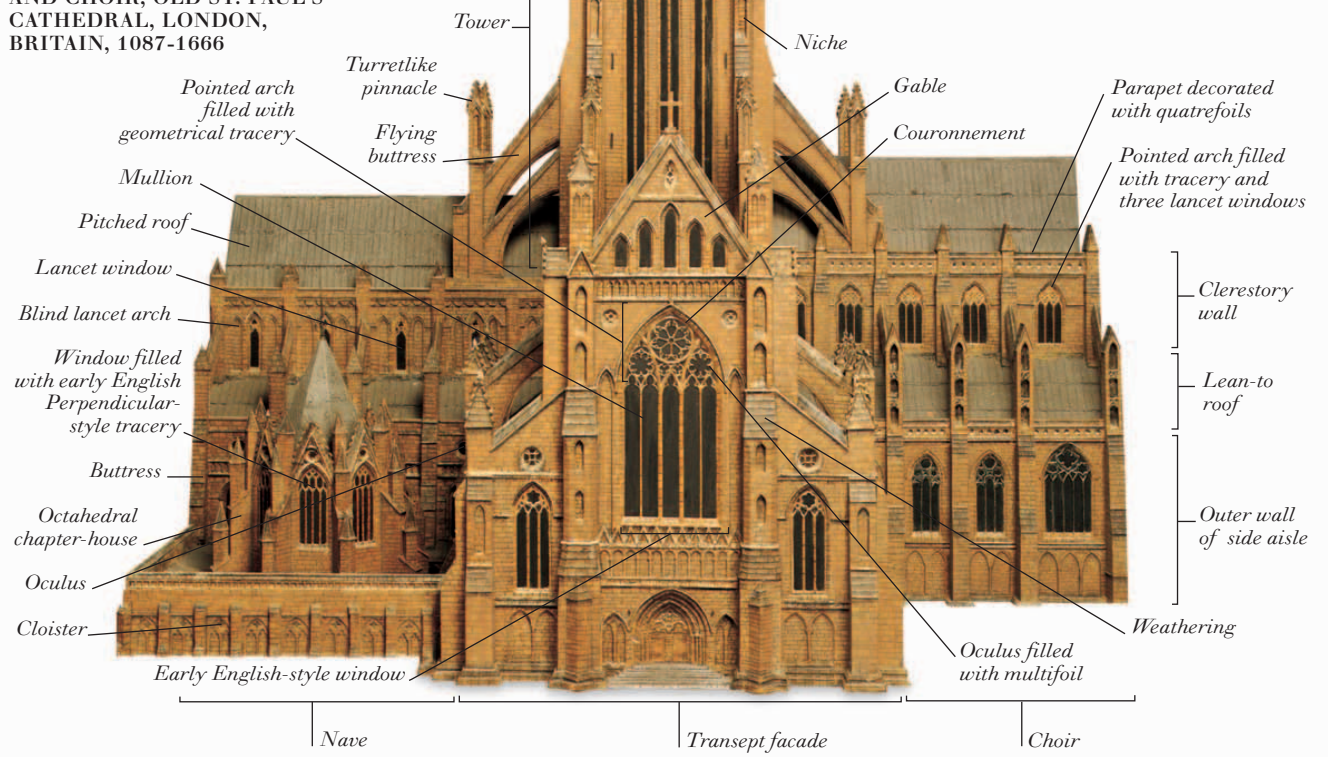
CURVILINEAR (FLOWING) TRACERY FROM A BALUSTRADE, 14TH OR 15TH CENTURY



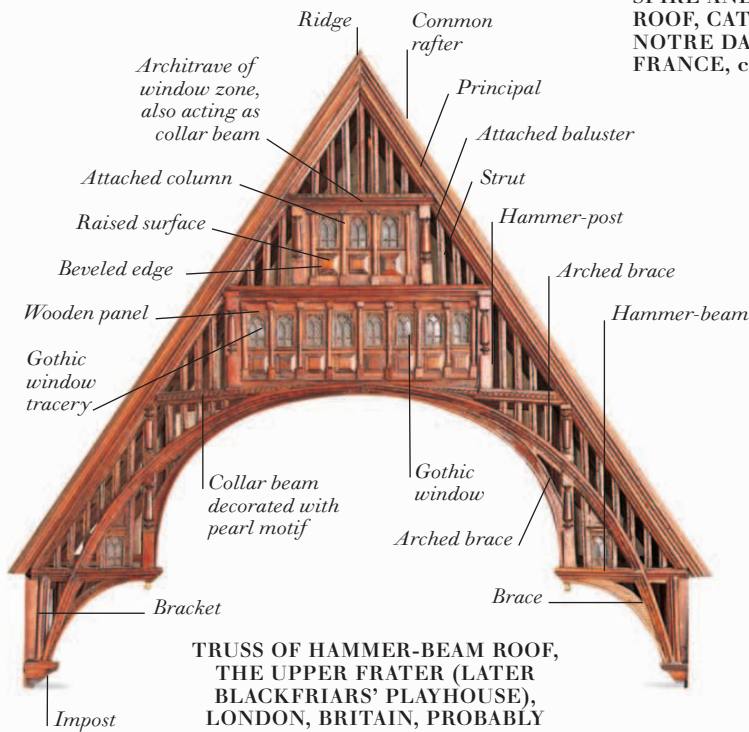
SPIRAL STAIRCASE TO ORGAN, CHURCH OF ST. MACLOU, ROUEN, FRANCE, c.1519



TOWER AND PART OF THE NAVE AND CHOIR, OLD ST. PAUL'S CATHEDRAL, LONDON, BRITAIN, 1087-1666

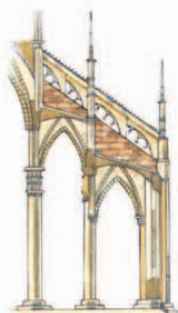


SPIRE AND TRANSEPT ROOF, CATHEDRAL OF NOTRE DAME DE PARIS, FRANCE, c.1163-1250



TRUSS OF HAMMER-BEAM ROOF, THE UPPER FRATER (LATER BLACKFRIARS' PLAYHOUSE), LONDON, BRITAIN, PROBABLY 14TH CENTURY

TYPICAL GOTHIC FEATURES



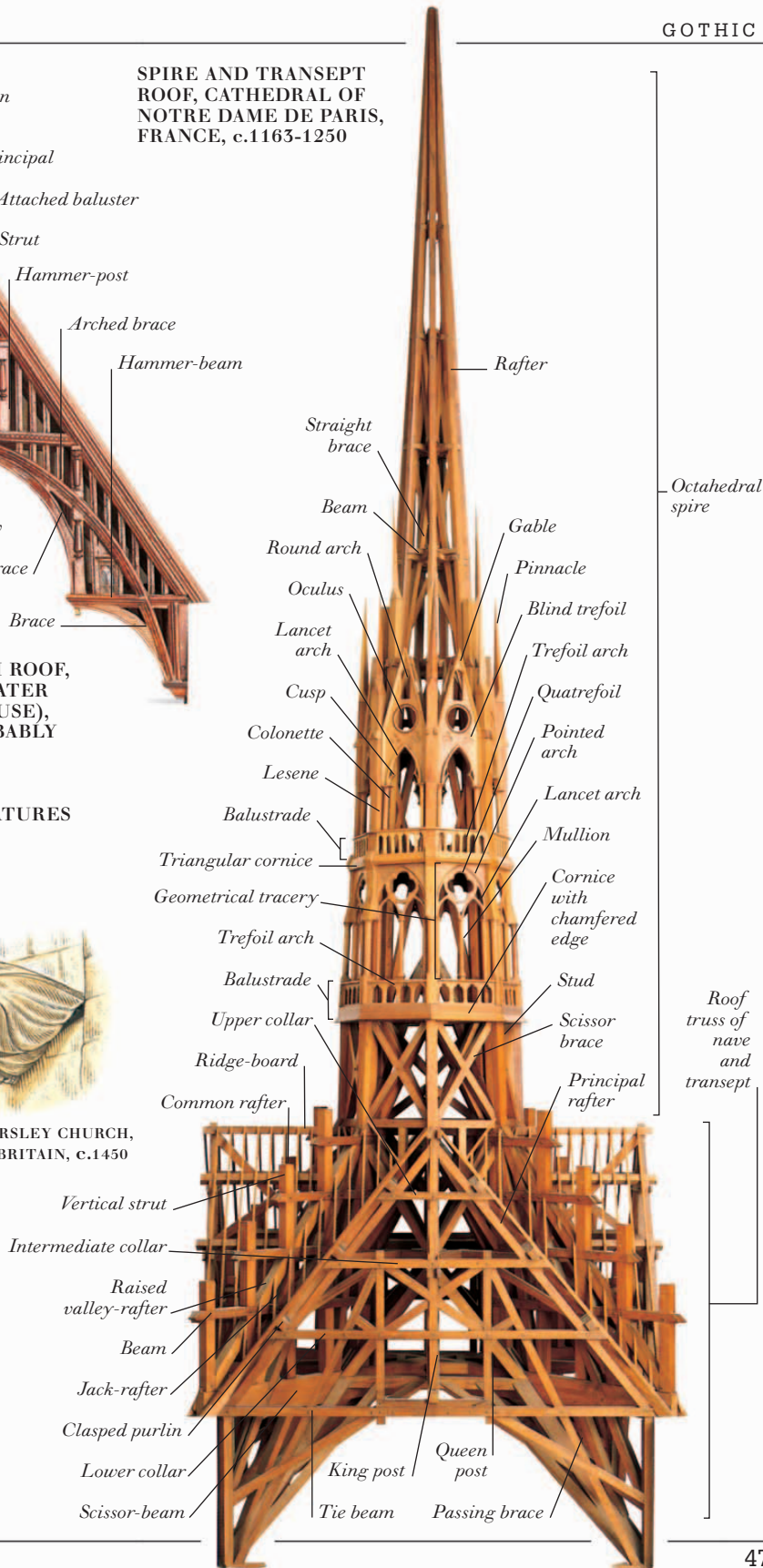
FLYING BUTTRESS OVER SIDE AISLES, MILAN CATHEDRAL, ITALY, c.1385-1485



GARGOYLE, HORSLEY CHURCH, DERBYSHIRE, BRITAIN, c.1450



HAMMER-BEAM ROOF, CHURCH OF ST. BOTOLPH, TRUNCH, NORFOLK, BRITAIN, 1360-1380



Octahedral spire

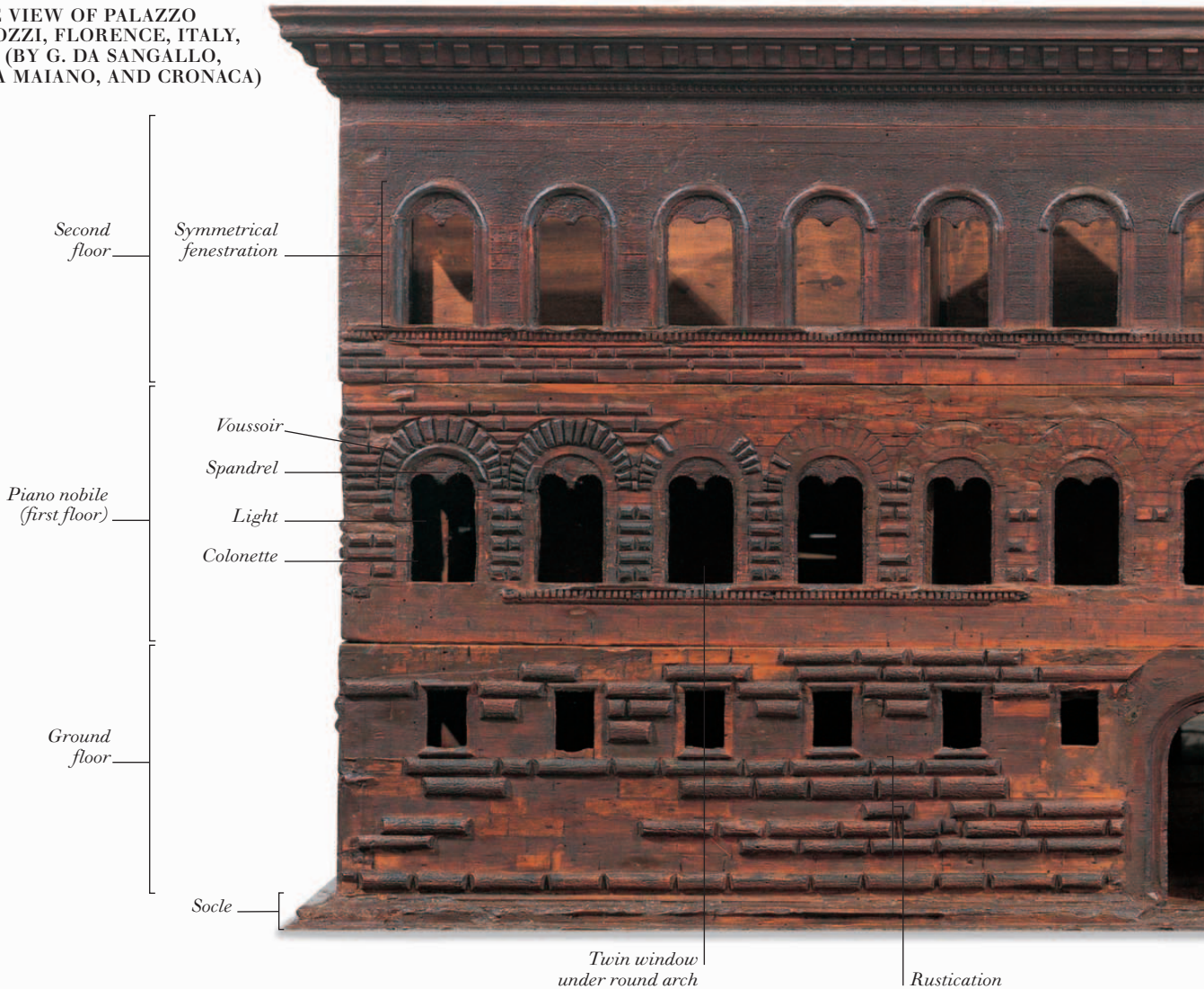
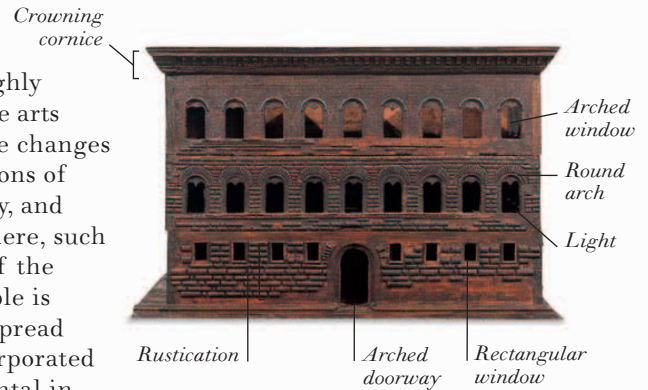
Roof truss of nave and transept

Renaissance 1

THE RENAISSANCE was a European movement—lasting roughly from the 14th century to the mid-17th century—in which the arts and sciences underwent great changes. In architecture, these changes were marked by a return to the classical forms and proportions of ancient Roman buildings. The Renaissance originated in Italy, and the buildings most characteristic of its style can be found there, such as the Palazzo Strozzi shown here. Mannerism is a branch of the Renaissance style that distorts the classical forms; an example is the Laurentian Library staircase. As the Renaissance style spread to other European countries, many of its features were incorporated into the local architecture; for example, the Château de Montal in France (see pp. 476-477) incorporates aedicules (tabernacles).

SIDE VIEW OF PALAZZO STROZZI, FLORENCE, ITALY, 1489 (BY G. DA SANGALLO, B. DA MAIANO, AND CRONACA)

FACADE ON TO PIAZZA, PALAZZO STROZZI



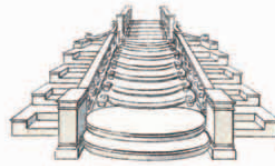
DETAILS FROM ITALIAN RENAISSANCE BUILDINGS



PANEL FROM DRUM OF DOME,
FLORENCE CATHEDRAL, 1420-1436



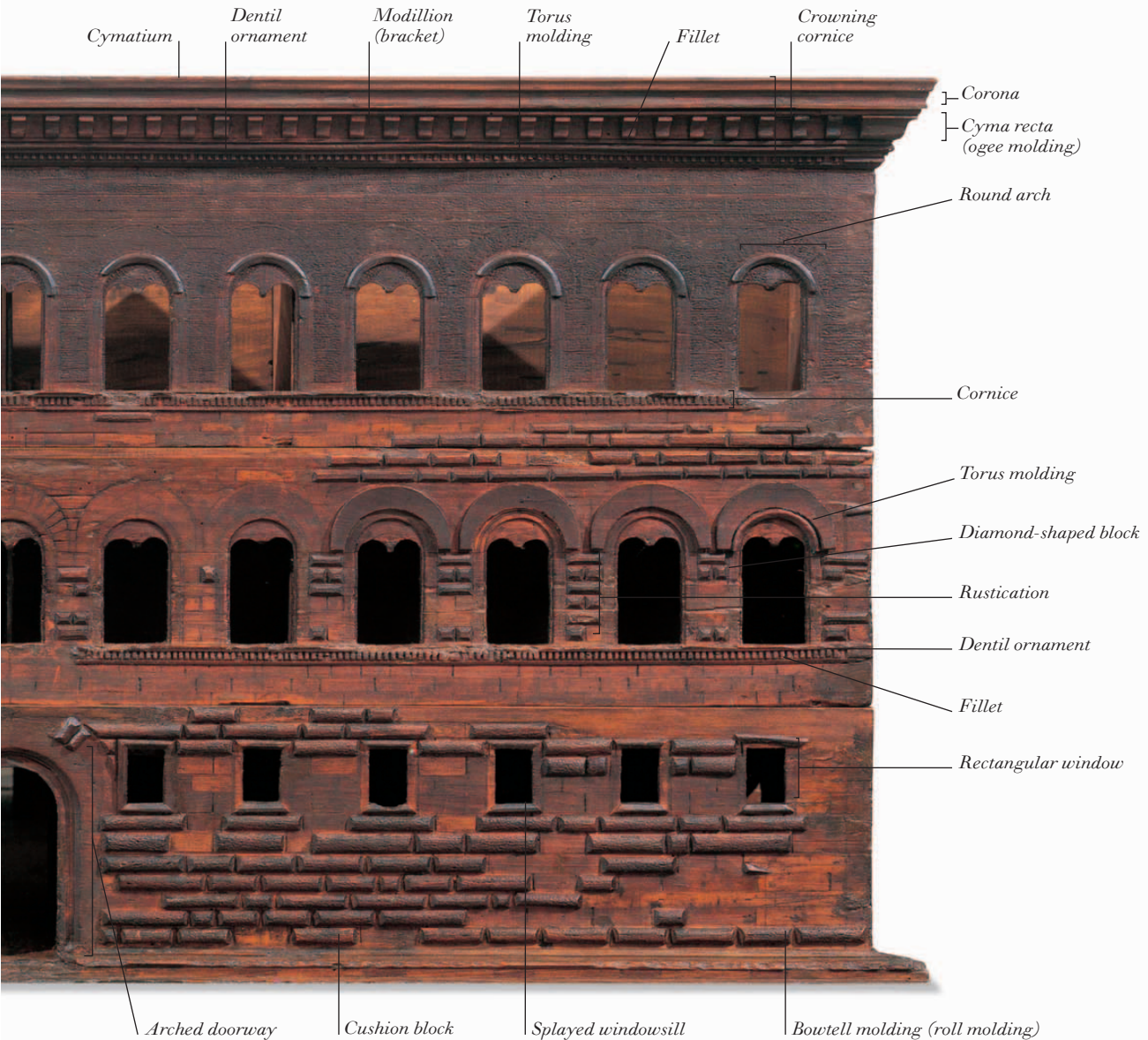
COFFERING IN DOME,
PAZZI CHAPEL,
FLORENCE, 1429-1461



STAIRCASE,
LAURENTIAN LIBRARY,
FLORENCE, 1559



PORTICO, VILLA ROTUNDA,
VICENZA, 1567-1569



Renaissance 2

NORTH WING, CHATEAU DE MONTAL, LOT, FRANCE, FROM 1523

DETAILS FROM EUROPEAN RENAISSANCE BUILDINGS



STONE WALL, QUOINS, AND SHELL DECORATION, CASA DE LAS CONCHAS, SALAMANCA, SPAIN, 1475-1483



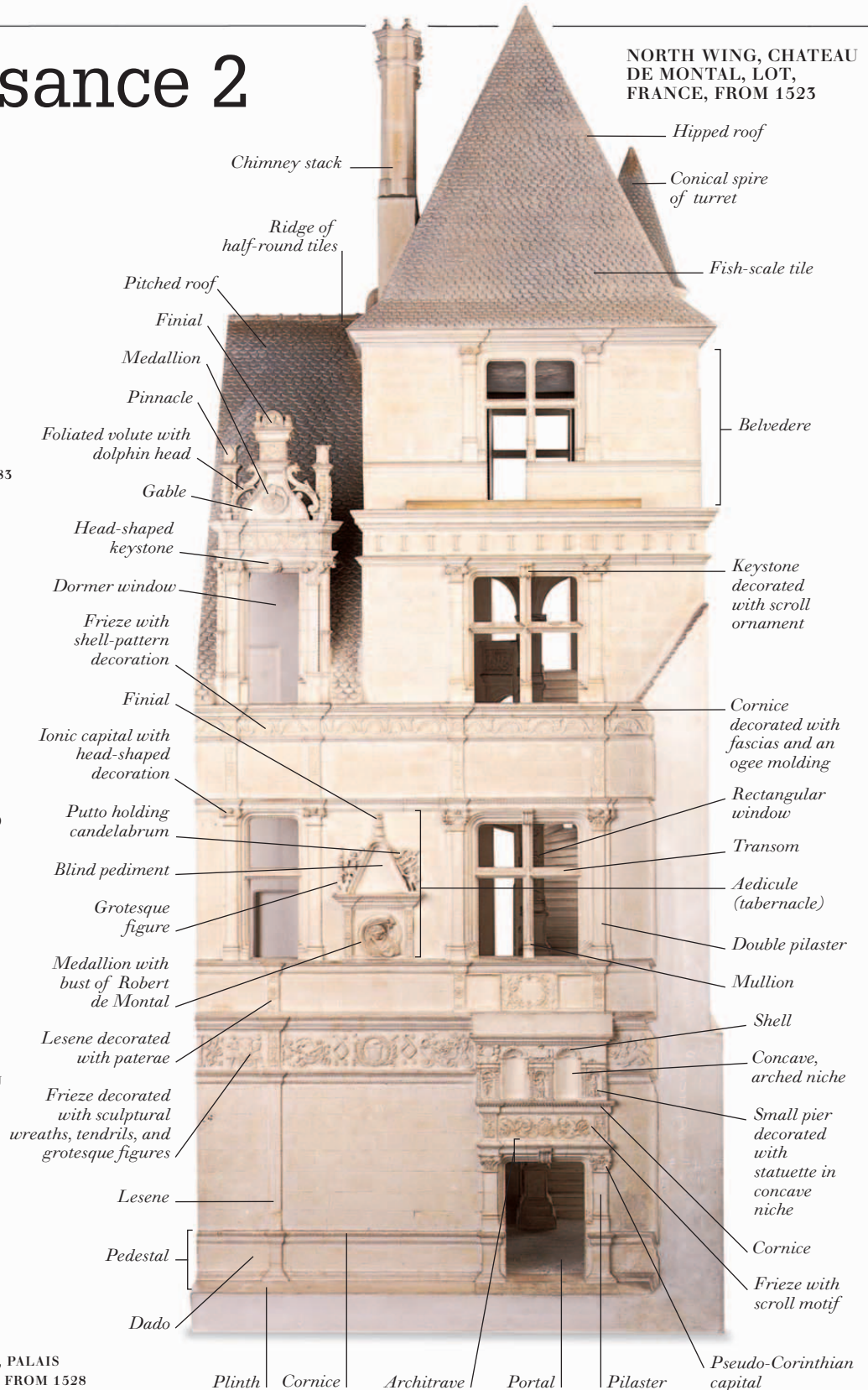
SPIRAL-STAIRCASE TOWER, CHATEAU DE BLOIS, FRANCE, 1514-1530



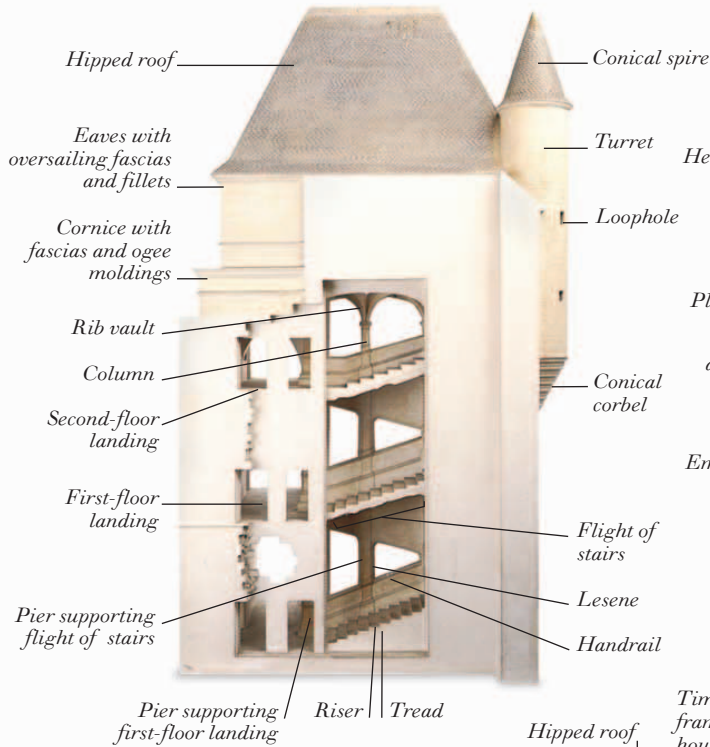
CONICAL DOME, CHATEAU DE CHAMBORD, FRANCE, 1519-1547



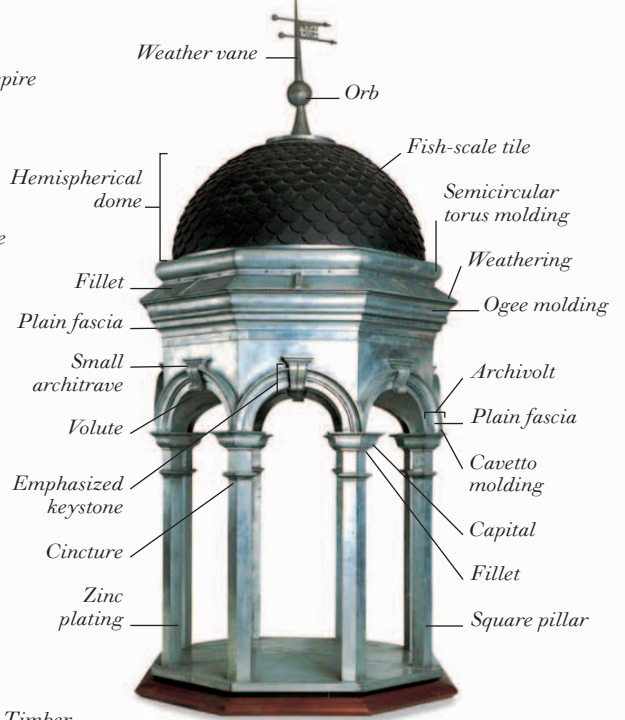
PAIR OF CHIMNEY-STACKS, PALAIS DE FONTAINEBLEAU, FRANCE, FROM 1528



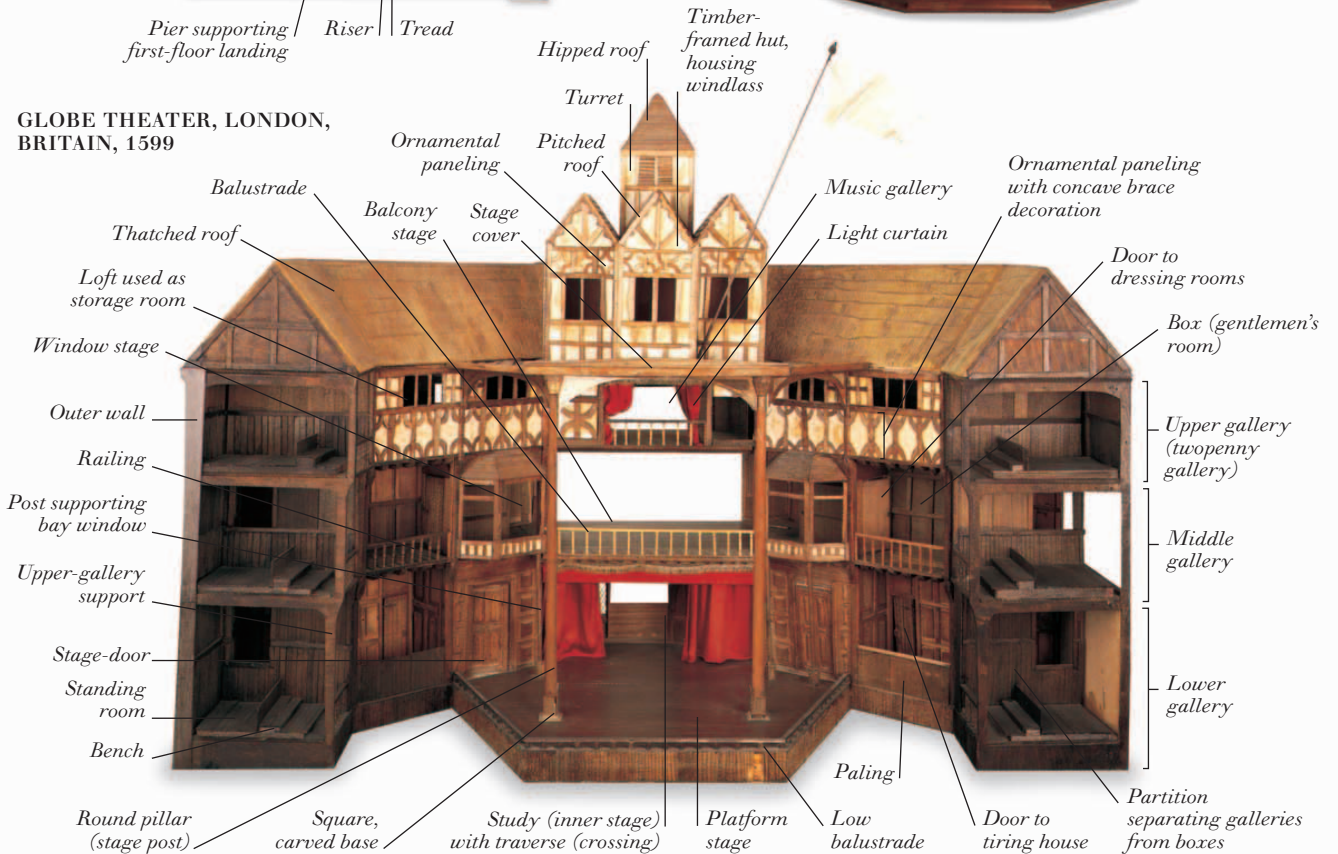
**NORTH-WING STAIRCASE,
CHATEAU DE MONTAL**



**CAMPANILE, CHURCH OF ST. EUSTACHE, PARIS,
FRANCE, 1532-1640**



**GLOBE THEATER, LONDON,
BRITAIN, 1599**



Baroque and neoclassical 1

THE BAROQUE STYLE EVOLVED IN THE EARLY 17TH CENTURY in Rome. It is characterized by curved outlines and ostentatious decoration, as can be seen in the Italian church details (right). The baroque style was particularly widely favored in Italy, Spain, and Germany. It was also adopted in Britain and France, but with adaptations. The British architects Sir Christopher Wren and Nicholas Hawksmoor, for example, used baroque features—such as the concave walls of St. Paul’s Cathedral and the curved buttresses of the Church of St. George in the East (see pp. 480-481)—but they did so with restraint. Similarly, the curved buttresses and volutes of the Parisian Church of St. Paul-St. Louis are relatively plain. In the second half of the 17th century, a distinct classical style (known as neoclassicism) developed in northern Europe as a reaction to the excesses of baroque. Typical of this new style were churches such as the Madeleine (a proposed facade is shown below), as well as secular buildings such as the Cirque Napoleon (opposite) and the buildings of the British architect Sir John Soane (see pp. 482-483). In early 18th-century France, an extremely lavish form of baroque developed, known as rococo. The balcony from Nantes (see pp. 482-483) with its twisted ironwork and head-shaped corbels is typical of this style.

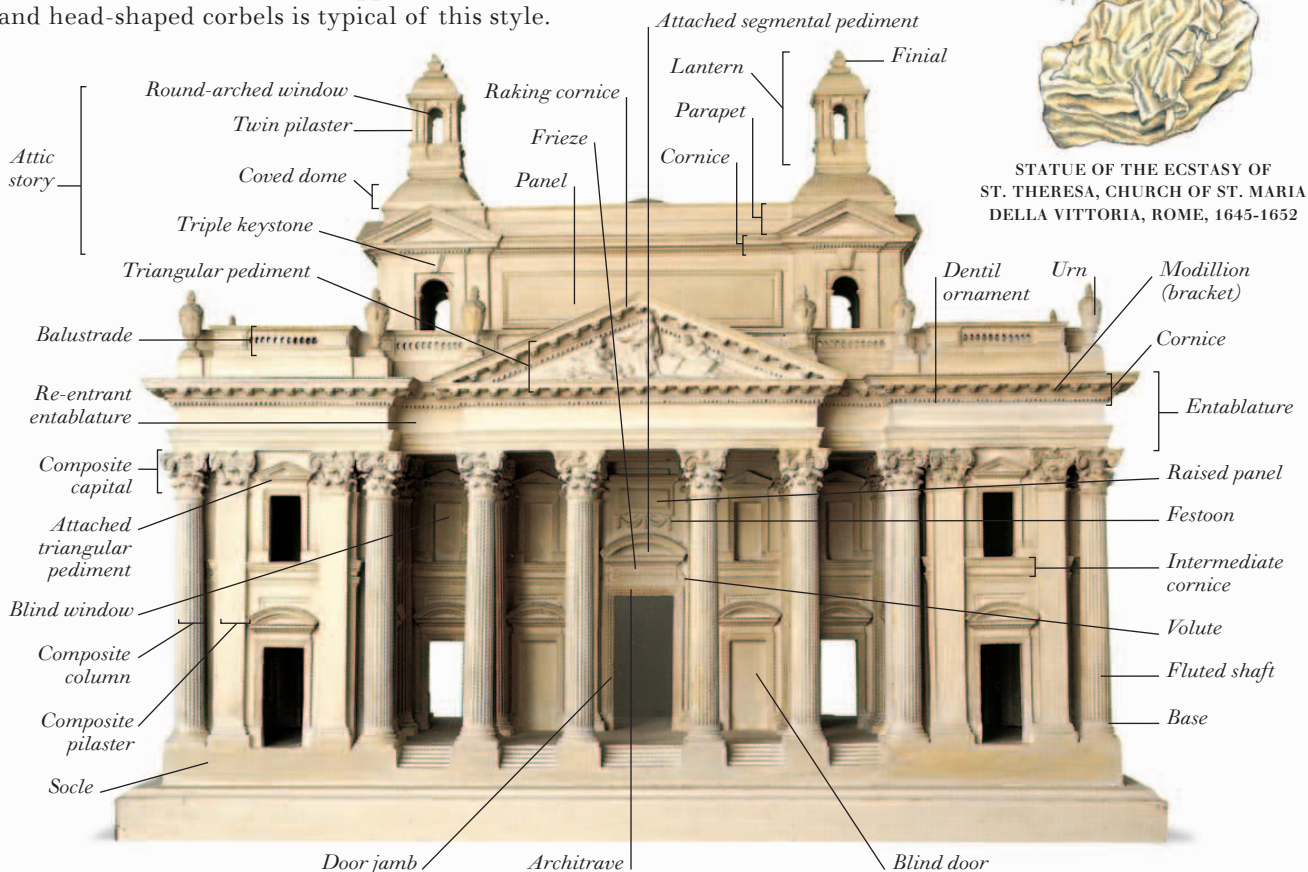
DETAILS FROM ITALIAN BAROQUE CHURCHES



SCROLLED BUTTRESS, CHURCH OF ST. MARIA DELLA SALUTE, VENICE, 1631-1682

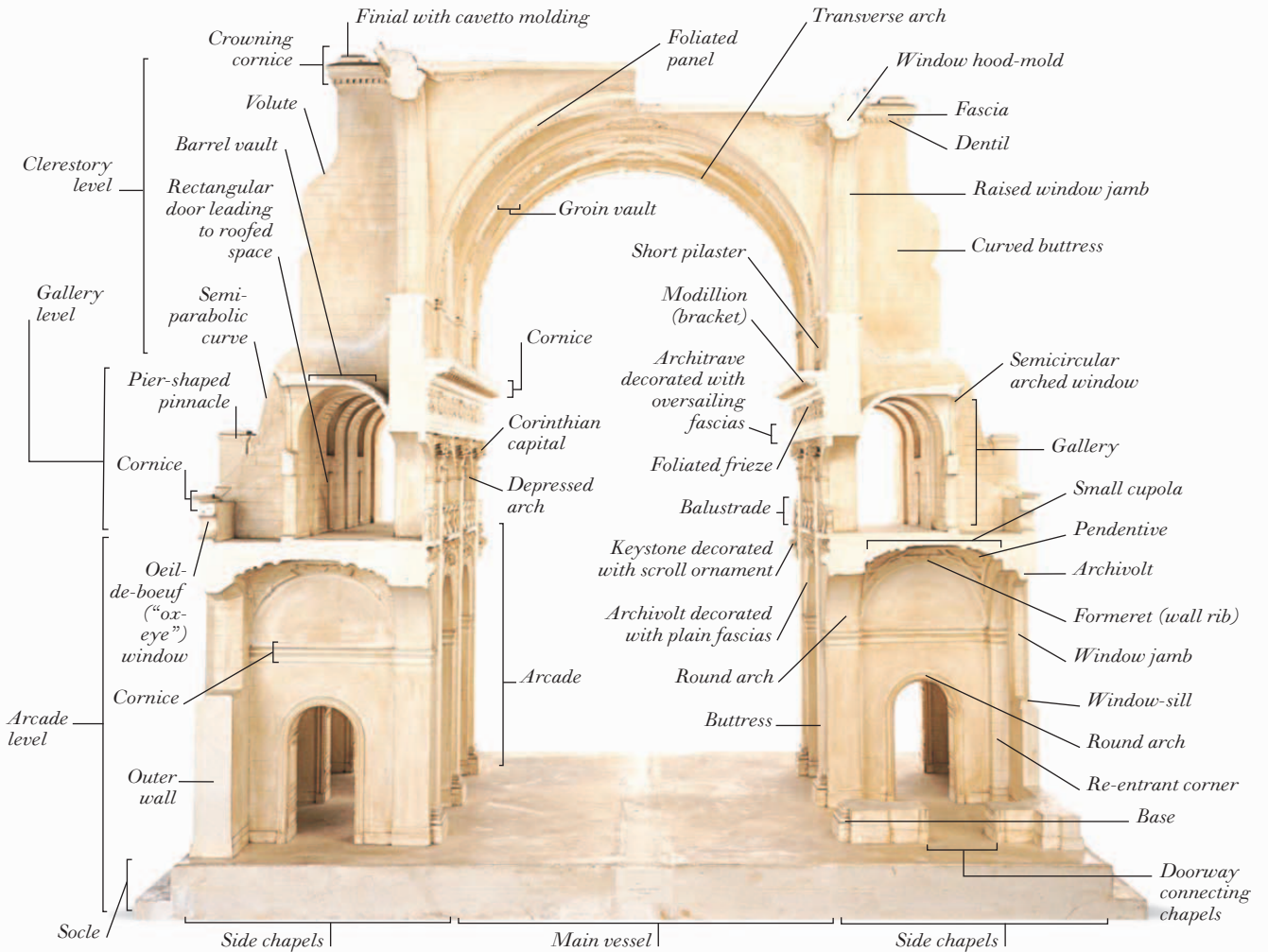
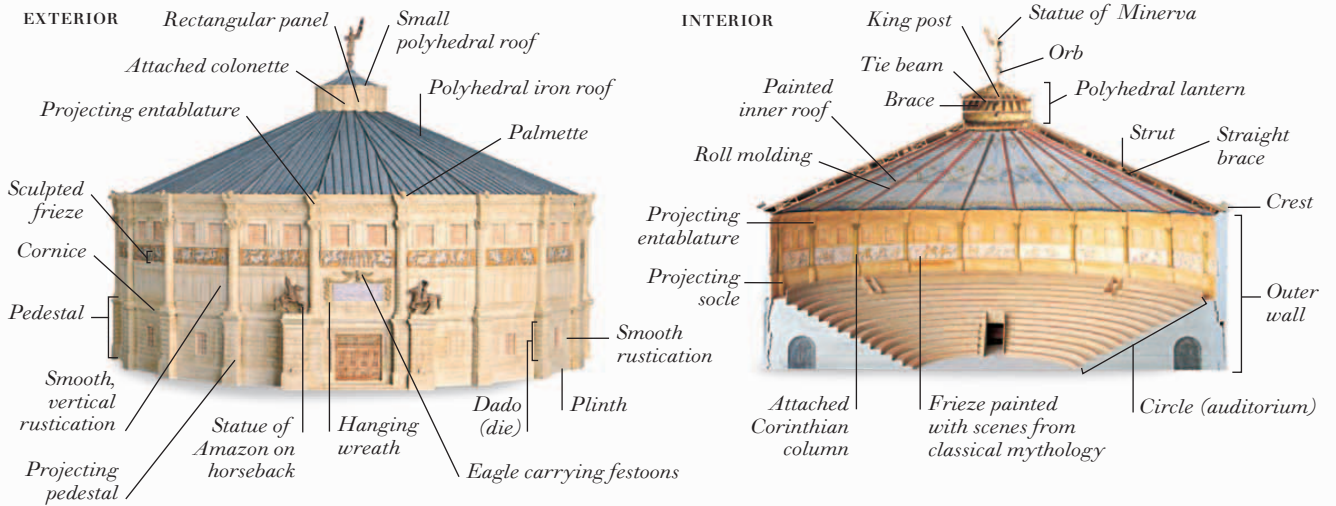


STATUE OF THE ECSTASY OF ST. THERESA, CHURCH OF ST. MARIA DELLA VITTORIA, ROME, 1645-1652



PROPOSED FACADE, THE MADELEINE (NEOCLASSICAL), PARIS, FRANCE, 1764 (BY P. CONTANT D'IVRY)

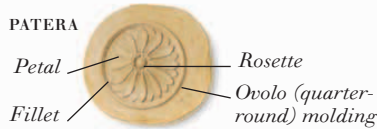
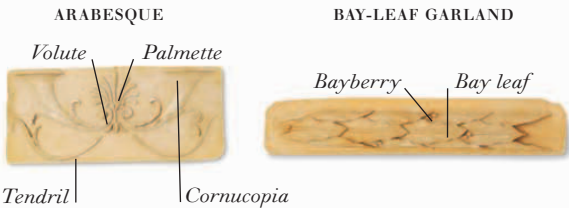
CIRQUE NAPOLEON (NEOCLASSICAL), PARIS, FRANCE, 1852 (BY J. I. HITTORFF)



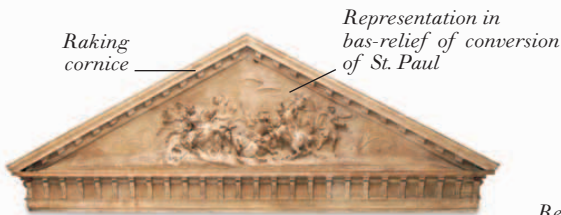
NAVE, CHURCH OF ST. PAUL-ST. LOUIS (FRENCH BAROQUE), PARIS, FRANCE, FROM 1627 (BY E. MARTELLANGE)

Baroque and neoclassical 2

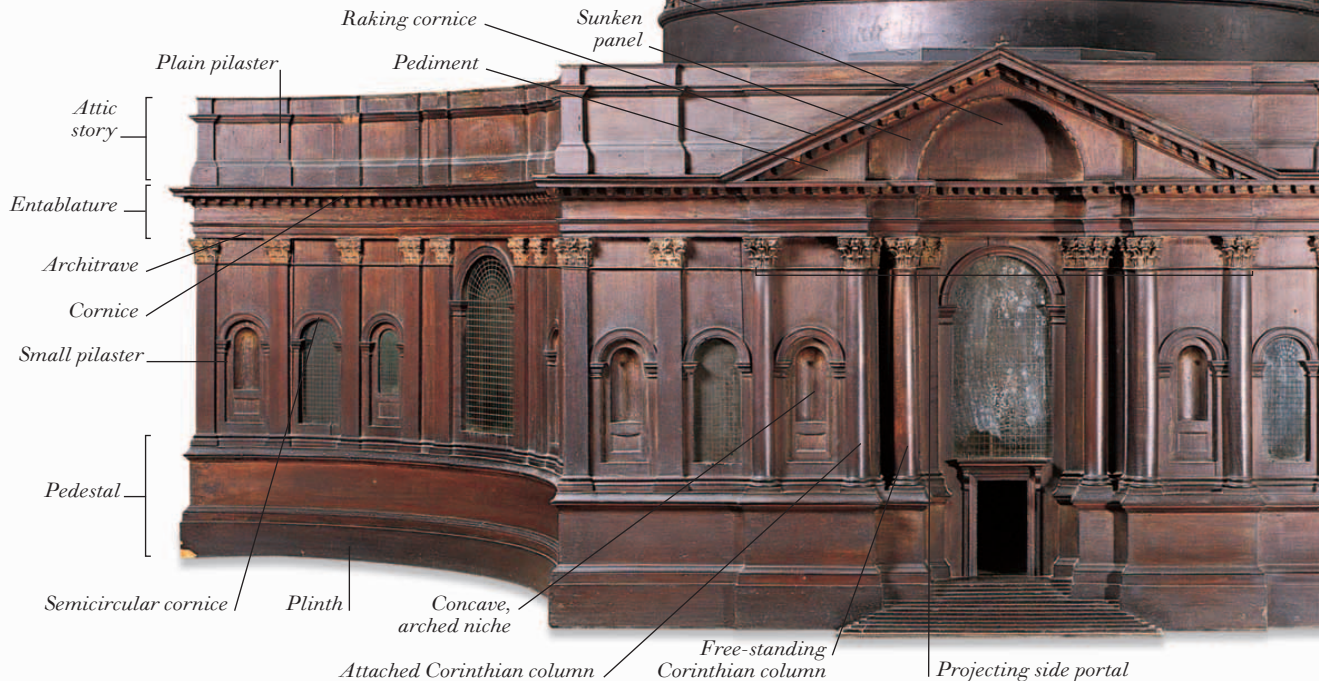
MODEL BUILT IN 1674 OF PROPOSED EXTERIOR OF ST. PAUL'S CATHEDRAL (ENGLISH BAROQUE), LONDON, BRITAIN (BY C. WREN)



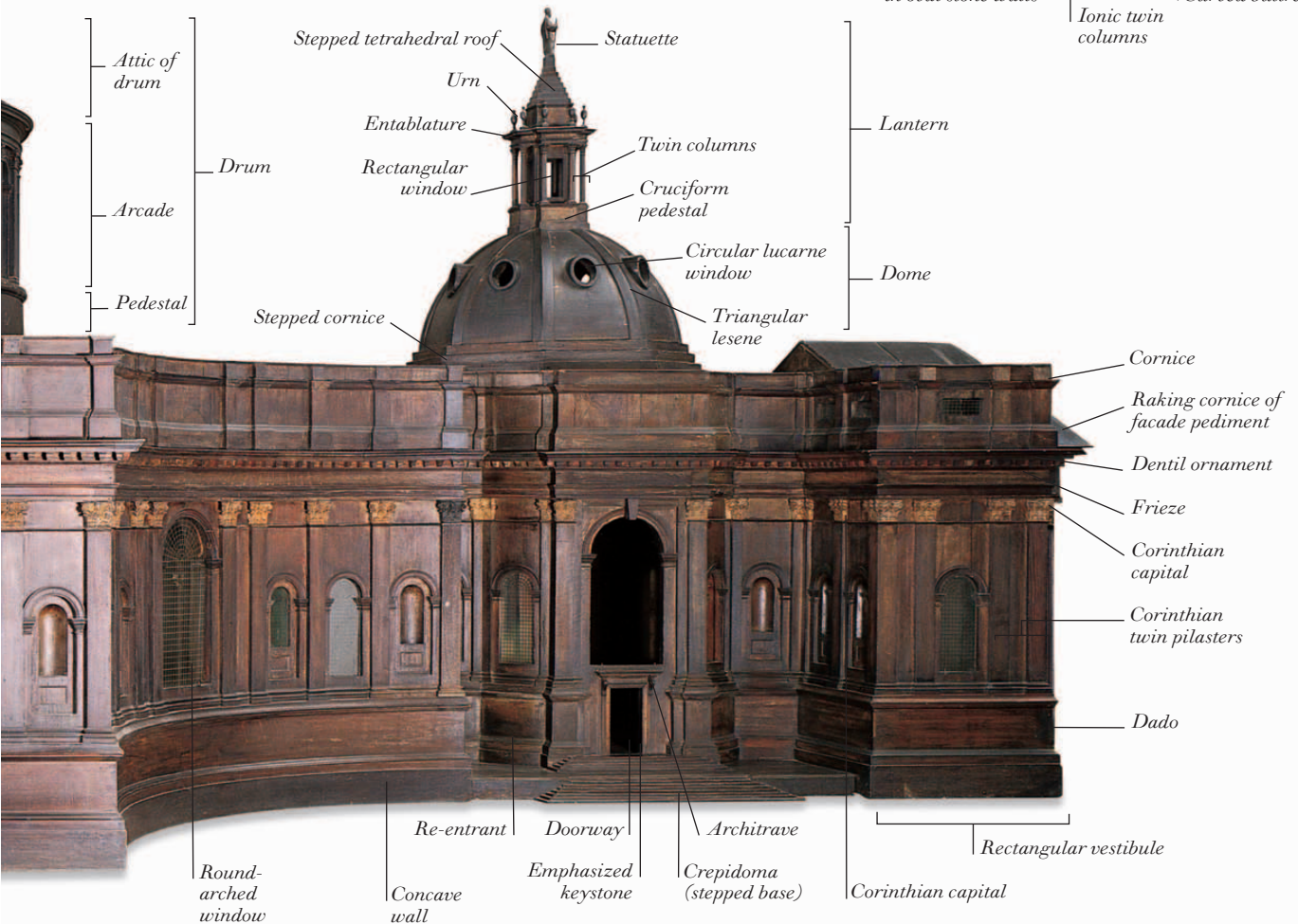
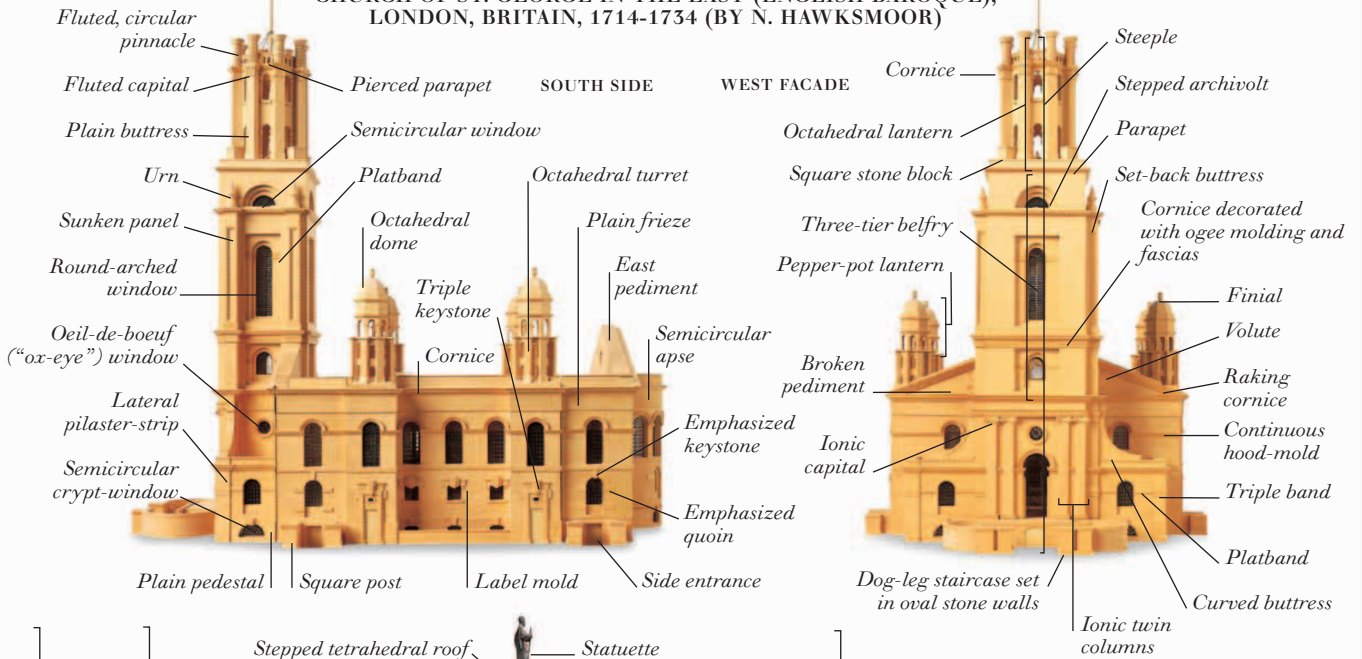
DECORATIVE MOLDINGS FROM ENGLISH NEOCLASSICAL BUILDINGS



TRIANGULAR PEDIMENT, WEST FACADE, ST. PAUL'S CATHEDRAL



CHURCH OF ST. GEORGE IN THE EAST (ENGLISH BAROQUE),
LONDON, BRITAIN, 1714-1734 (BY N. HAWKSMOOR)

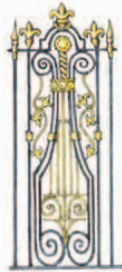


Baroque and neoclassical 3

DETAILS FROM BAROQUE, NEOCLASSICAL, AND ROCOCO BUILDINGS



PORTICO, THE VYNE, HAMPSHIRE, BRITAIN, 1654 (NEOCLASSICAL)



GILT IRONWORK FROM SCREEN, PALAIS DE VERSAILLES, FRANCE, 1669-1674 (FRENCH BAROQUE)



WINDOW, PALAZZO STANGA, CREMONA, ITALY, EARLY 18TH CENTURY (ROCOCO)

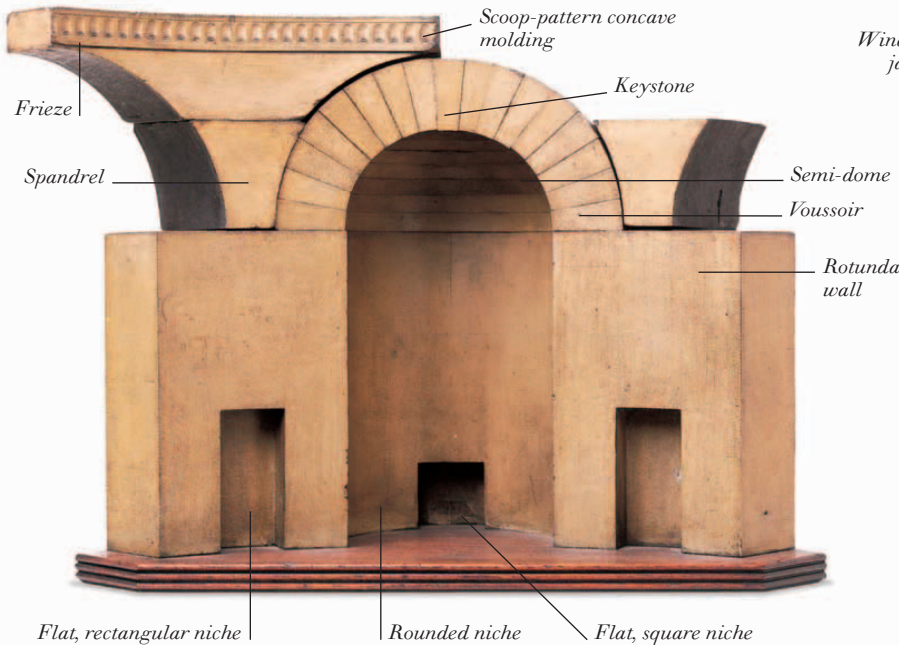


ATLAS (MALE CARYATID), UPPER BELVEDERE, VIENNA, AUSTRIA, 1721 (GERMAN-STYLE BAROQUE)

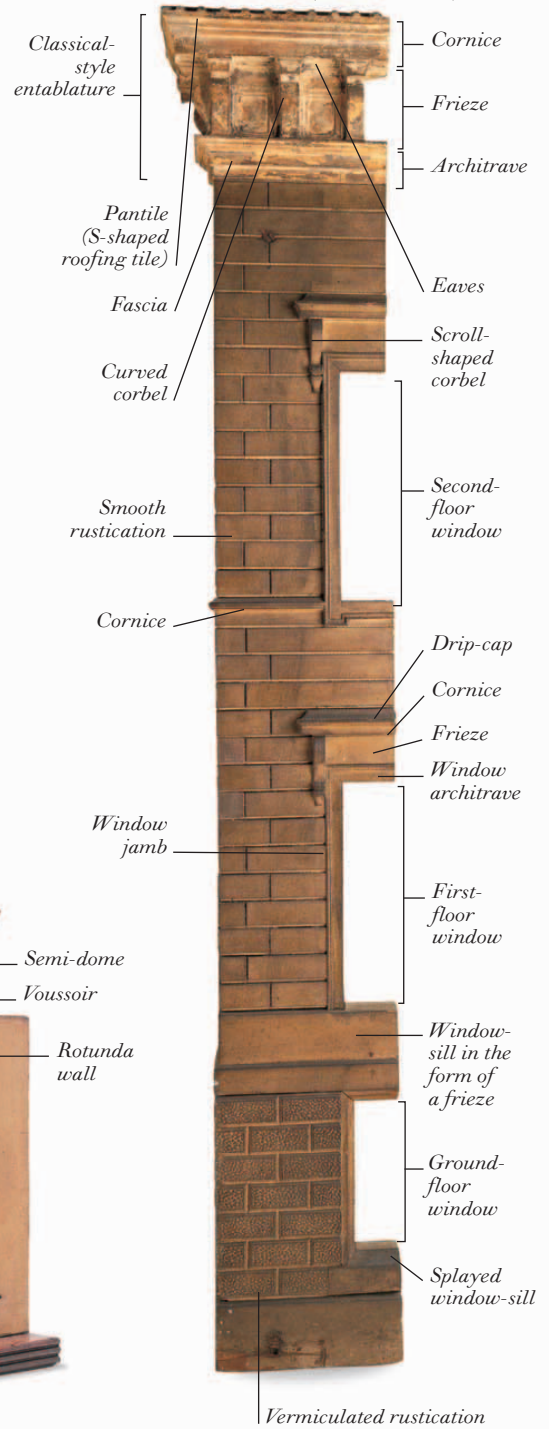


BALCONY, NANTES, FRANCE, 1730-1740 (ROCOCO)

MASONRY OF A NICHE IN THE ROTUNDA (NEOCLASSICAL), BANK OF ENGLAND, LONDON, BRITAIN, 1794 (BY J. SOANE)

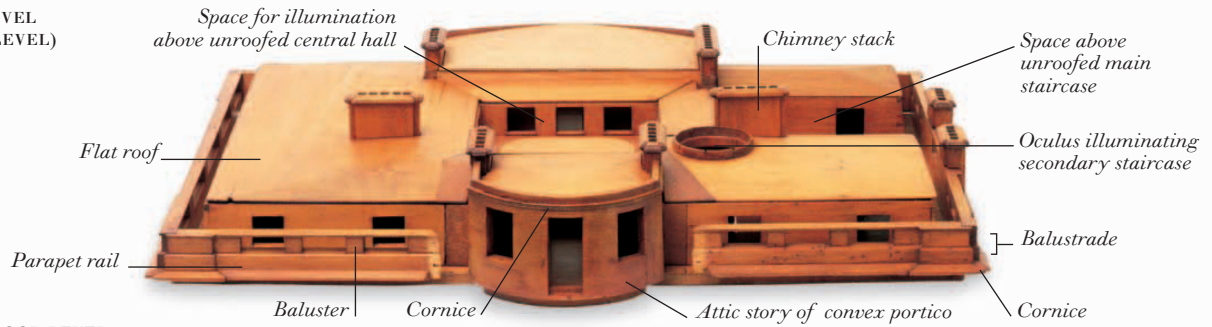


CORNER OF THE NEW STATE PAPER OFFICE (NEOCLASSICAL), LONDON, BRITAIN, 1830-1831 (BY J. SOANE)

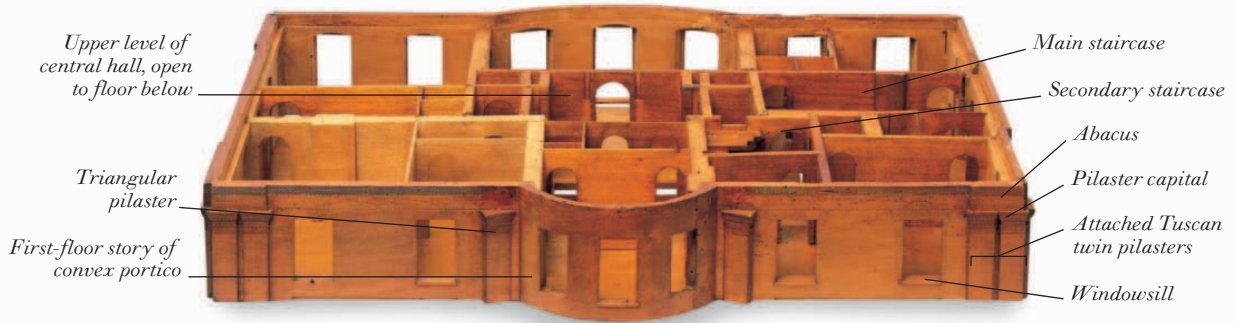


TYRINGHAM HOUSE (NEOCLASSICAL), BUCKINGHAMSHIRE, BRITAIN, 1793-1797 (BY J. SOANE)

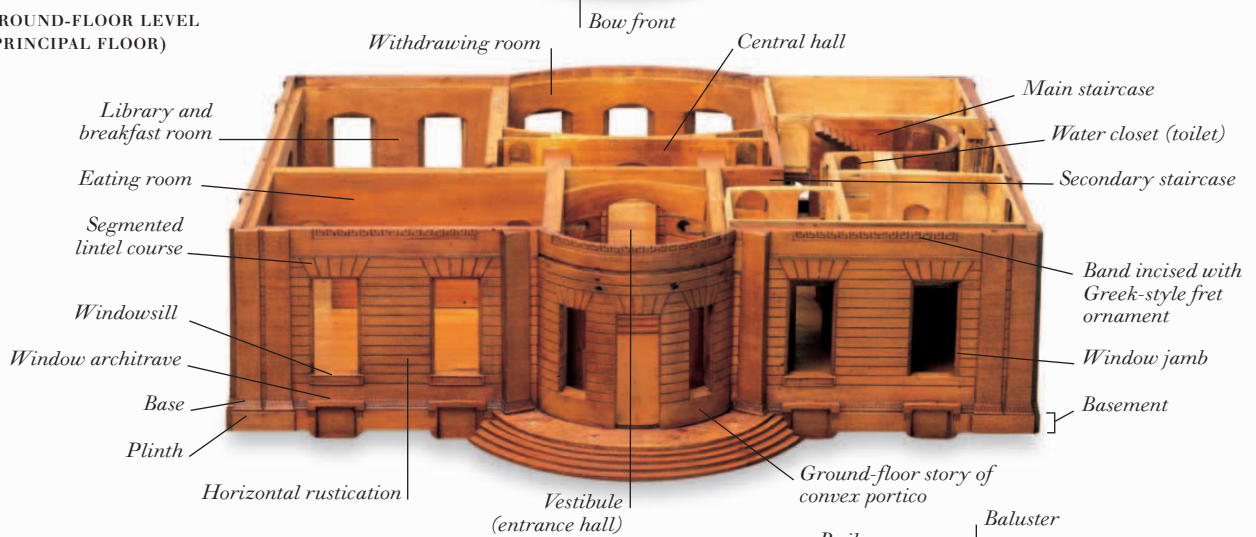
ROOF LEVEL
(ATTIC LEVEL)



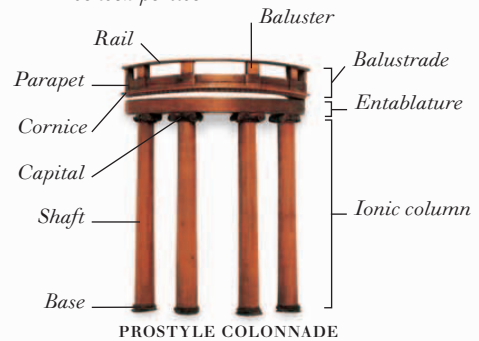
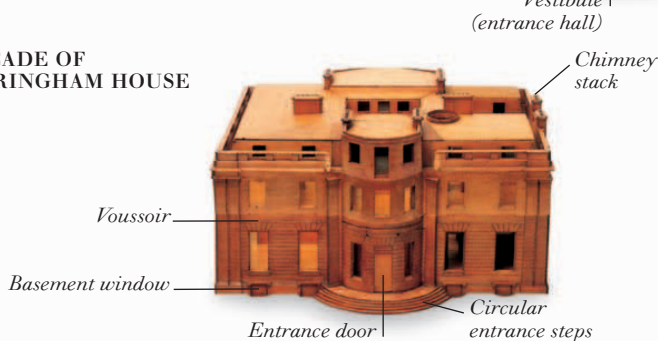
FIRST-FLOOR LEVEL
(CHAMBER FLOOR)



GROUND-FLOOR LEVEL
(PRINCIPAL FLOOR)



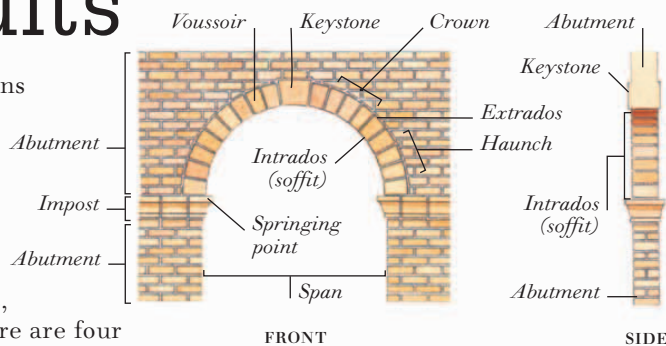
FACADE OF TYRINGHAM HOUSE



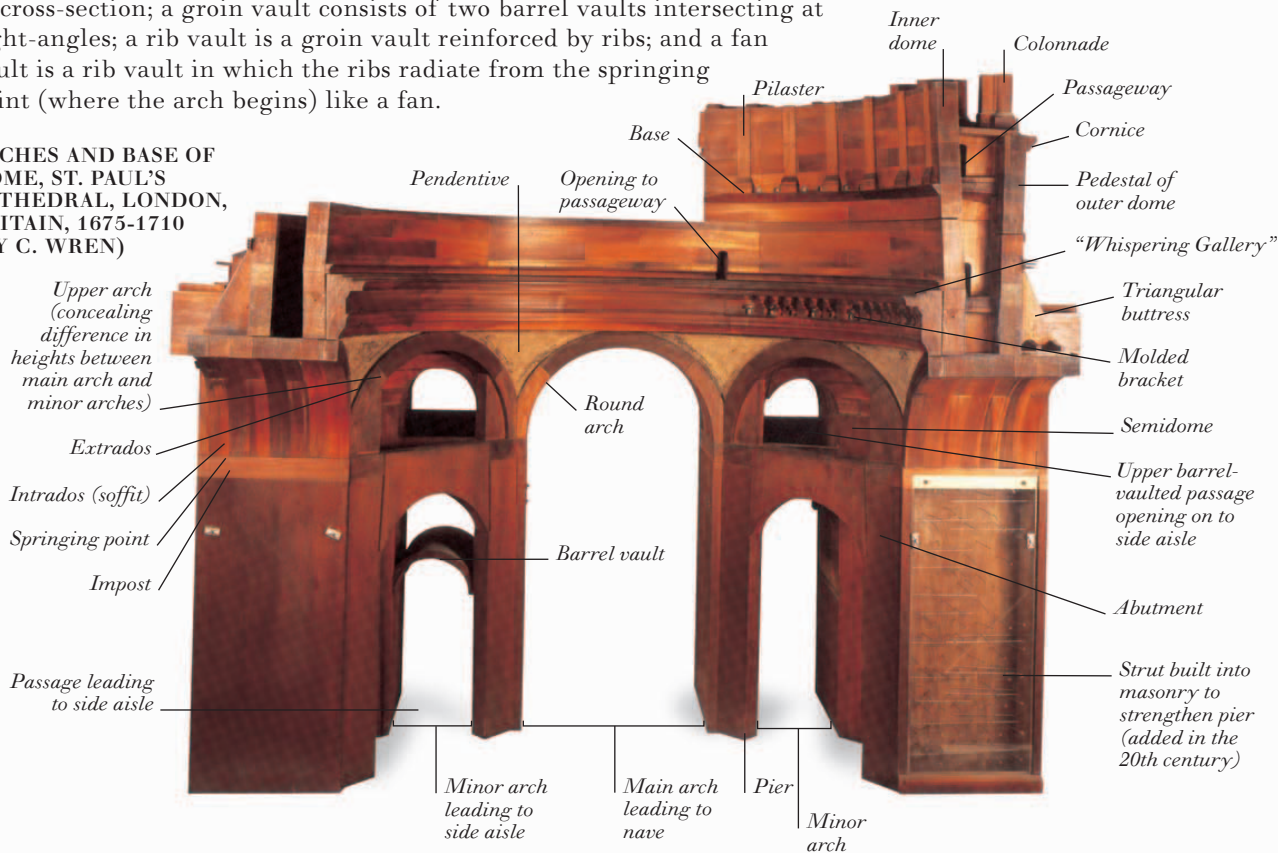
Arches and vaults

ARCHES ARE CURVED STRUCTURES used to bridge spans and to support the weight of upper parts of buildings, such as domes, as in St. Paul's Cathedral (below) and the antique temple (opposite). The voussoirs (wedge-shaped blocks) that form an arch (right) support each other and convert the downward force of the weight of the building into an outward force. This outward force is in turn transferred to buttresses, piers, or abutments. A vault is an arched roof or ceiling. There are four main types of vault (opposite). A barrel vault is a single vault, semicircular in cross-section; a groin vault consists of two barrel vaults intersecting at right-angles; a rib vault is a groin vault reinforced by ribs; and a fan vault is a rib vault in which the ribs radiate from the springing point (where the arch begins) like a fan.

PARTS OF AN ARCH



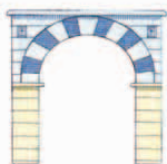
ARCHES AND BASE OF DOME, ST. PAUL'S CATHEDRAL, LONDON, BRITAIN, 1675-1710 (BY C. WREN)



TYPES OF ARCH



HORSESHOE ARCH (MOORISH ARCH), GREAT MOSQUE, CORDORA, SPAIN, 785



BASKET ARCH (SEMI-ELLIPTICAL ARCH), PALATINE CHAPEL, AIX-LA-CHAPELLE, FRANCE, 790-798



TUDOR ARCH, TOWER OF LONDON, BRITAIN, c.1086-1097

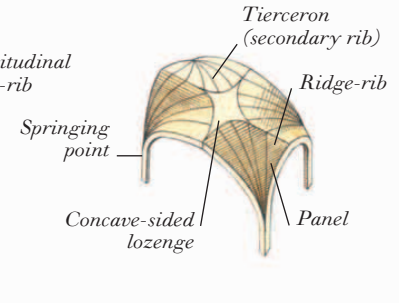
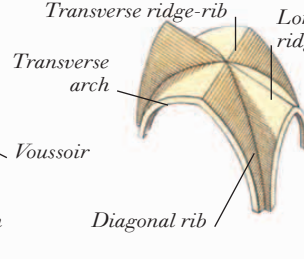
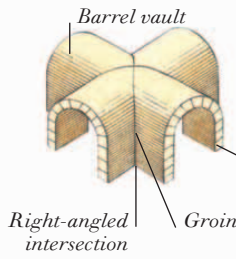
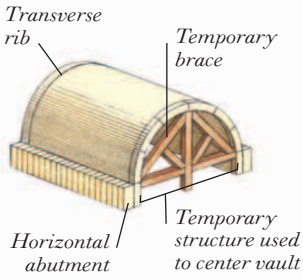


LANCET ARCH, WESTMINSTER ABBEY, LONDON, BRITAIN, 1503-1519



TREFOIL ARCH, BEVERLEY MINSTER, YORKSHIRE, BRITAIN, c.1300

TYPES OF VAULT



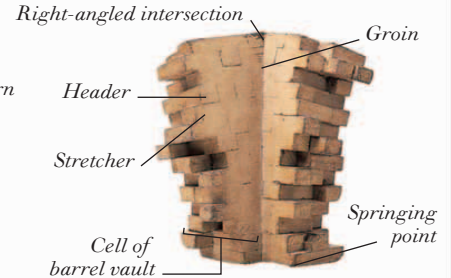
BARREL VAULT (TUNNEL VAULT; WAGON VAULT)

GROIN VAULT

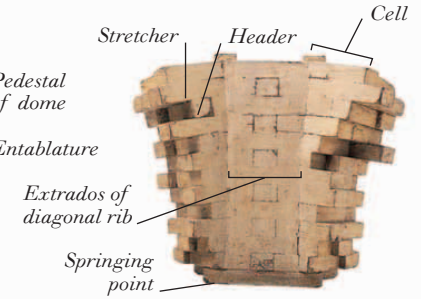
RIB VAULT

FAN VAULT

ENGLISH BOND BRICKWORK OF GROIN VAULT AND RIB VAULT

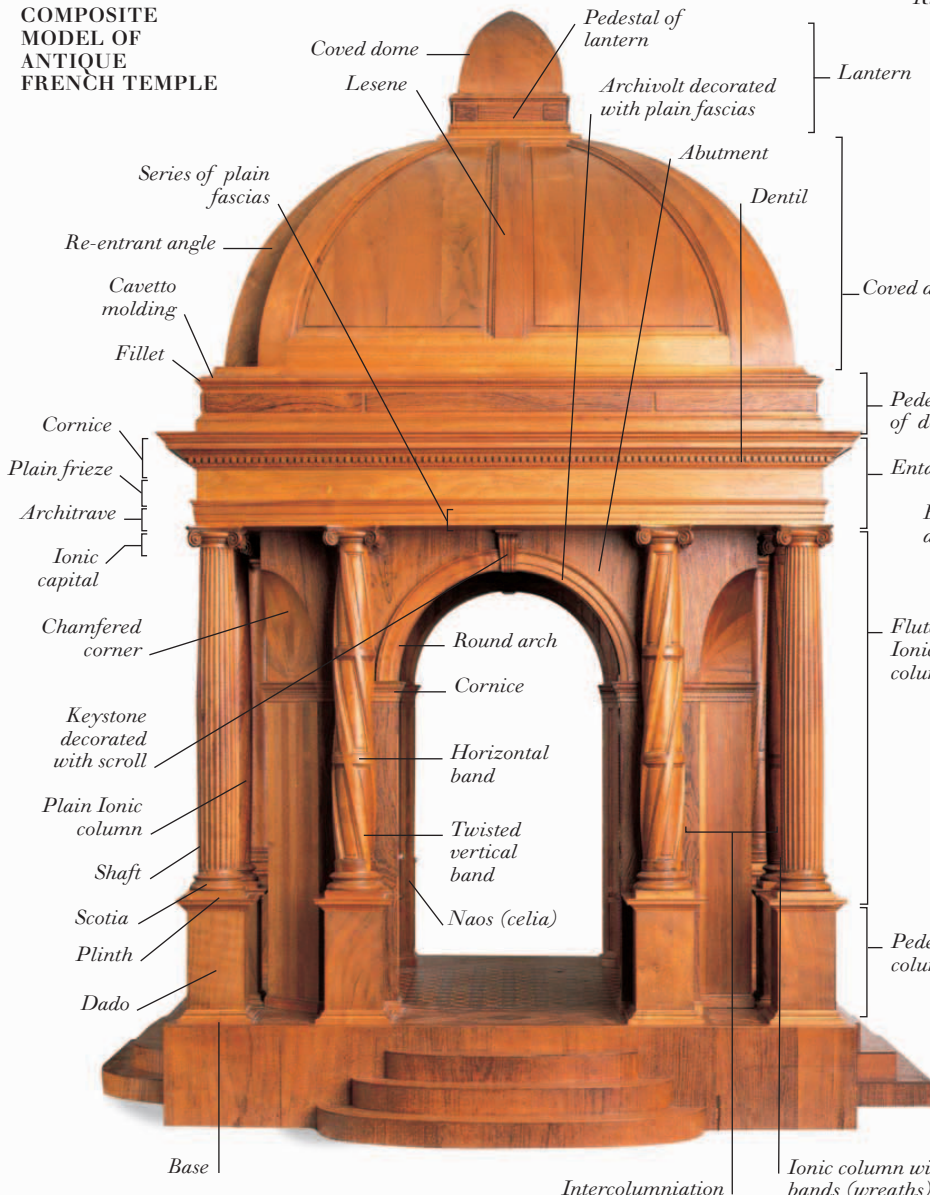


EXTRADOS OF GROIN VAULT



EXTRADOS OF RIB VAULT

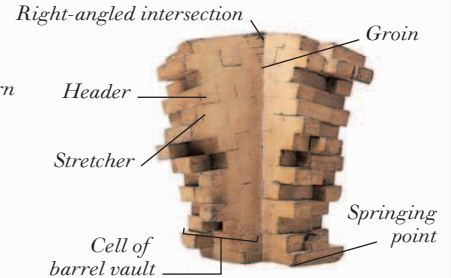
COMPOSITE MODEL OF ANTIQUE FRENCH TEMPLE



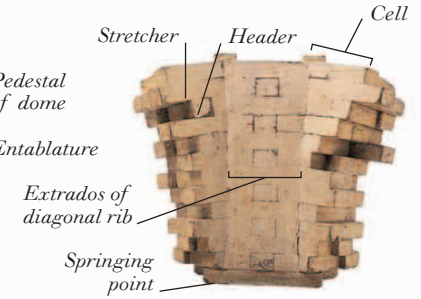
- Lesene
- Series of plain fascias
- Re-entrant angle
- Cavetto molding
- Fillet
- Cornice
- Plain frieze
- Architrave
- Ionic capital
- Chamfered corner
- Keystone decorated with scroll
- Plain Ionic column
- Shaft
- Scotia
- Plinth
- Dado
- Base

- Pedestal of lantern
- Archivolt decorated with plain fascias
- Abutment
- Dentil
- Round arch
- Cornice
- Horizontal band
- Twisted vertical band
- Naos (cellia)
- Intercolumniation
- Ionic column with twisted vertical bands (wreaths) and horizontal bands

ENGLISH BOND BRICKWORK OF GROIN VAULT AND RIB VAULT

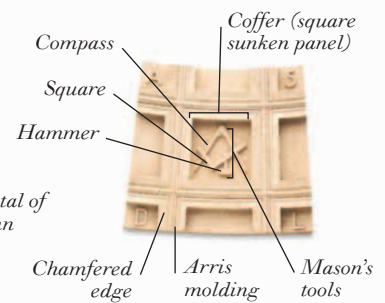


EXTRADOS OF GROIN VAULT



EXTRADOS OF RIB VAULT

INTERIOR DECORATION OF COFFERED VAULT

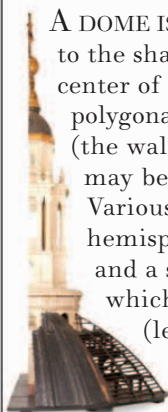


- Compass
- Square
- Hammer
- Chamfered edge
- Arries molding
- Mason's tools
- Coffer (square sunken panel)
- Pedestal of column

Domes

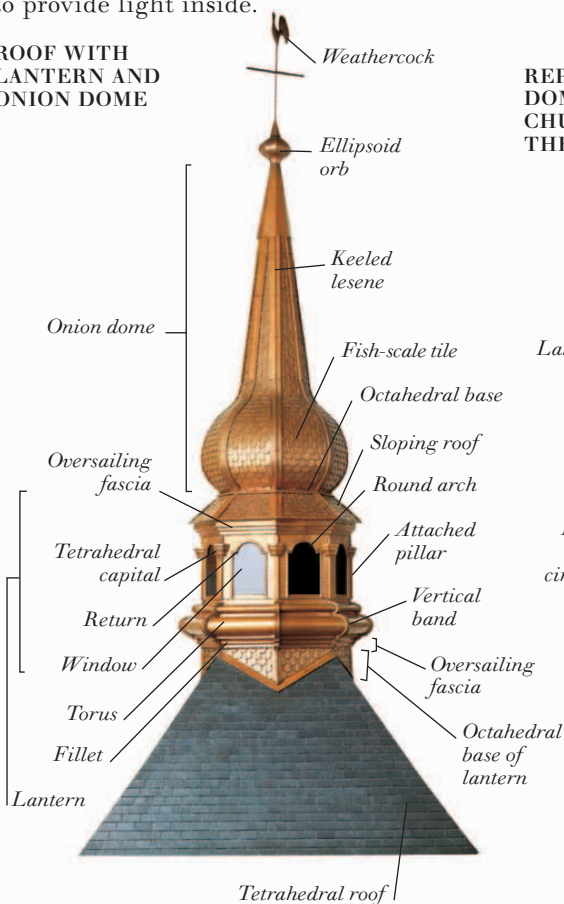
A DOME IS A CONVEX ROOF. Domes are categorized according to the shapes of both the base and the section through the center of the dome. The base may be circular, square, or polygonal (many-sided), depending on the plan of the drum (the walls on which the dome rests). The section of a dome may be the same shape as any arch (see pp. 484-485).

Various types of dome are illustrated here: a hemispherical dome, which has a circular base and a semicircular section; a saucer dome, which has a circular base and a segmental (less than a semicircle) section; a polyhedral dome, which is a dome on a polygonal base whose sides meet at the top of the dome; and an onion dome, which has a circular or polygonal base and an ogee-shaped section. Many domes have a lantern (a turret with windows) to provide light inside.

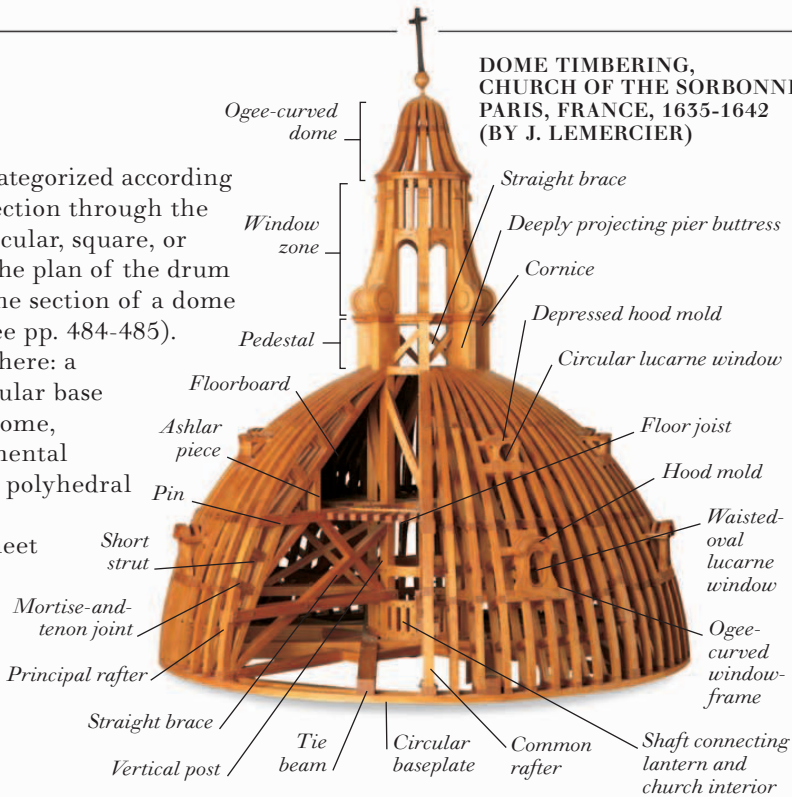


LANTERN AND UPPER DOME TIMBERING, ST. PAUL'S CATHEDRAL

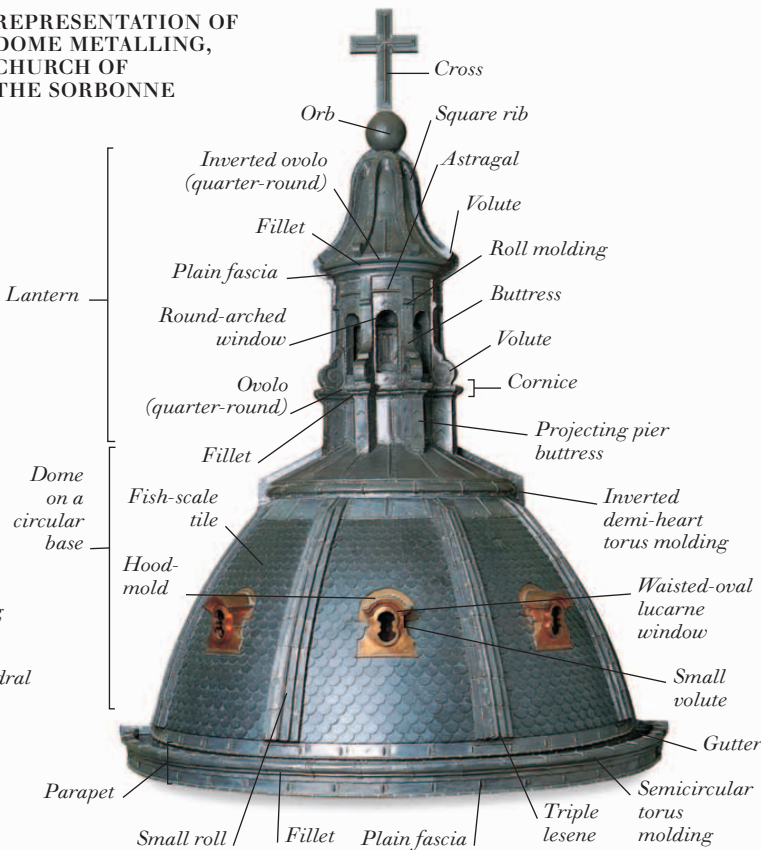
ROOF WITH LANTERN AND ONION DOME



DOME TIMBERING, CHURCH OF THE SORBONNE, PARIS, FRANCE, 1635-1642 (BY J. LEMERCIER)



REPRESENTATION OF DOME METALLING, CHURCH OF THE SORBONNE



TYPES OF DOME



DOME OF THE ROCK, JERUSALEM, ISRAEL, FROM c.684 (HEMISPHERICAL DOME)



CHURCH OF SANTA SOPHIA, ISTANBUL, TURKEY, 532-537 (SAUCER DOME)

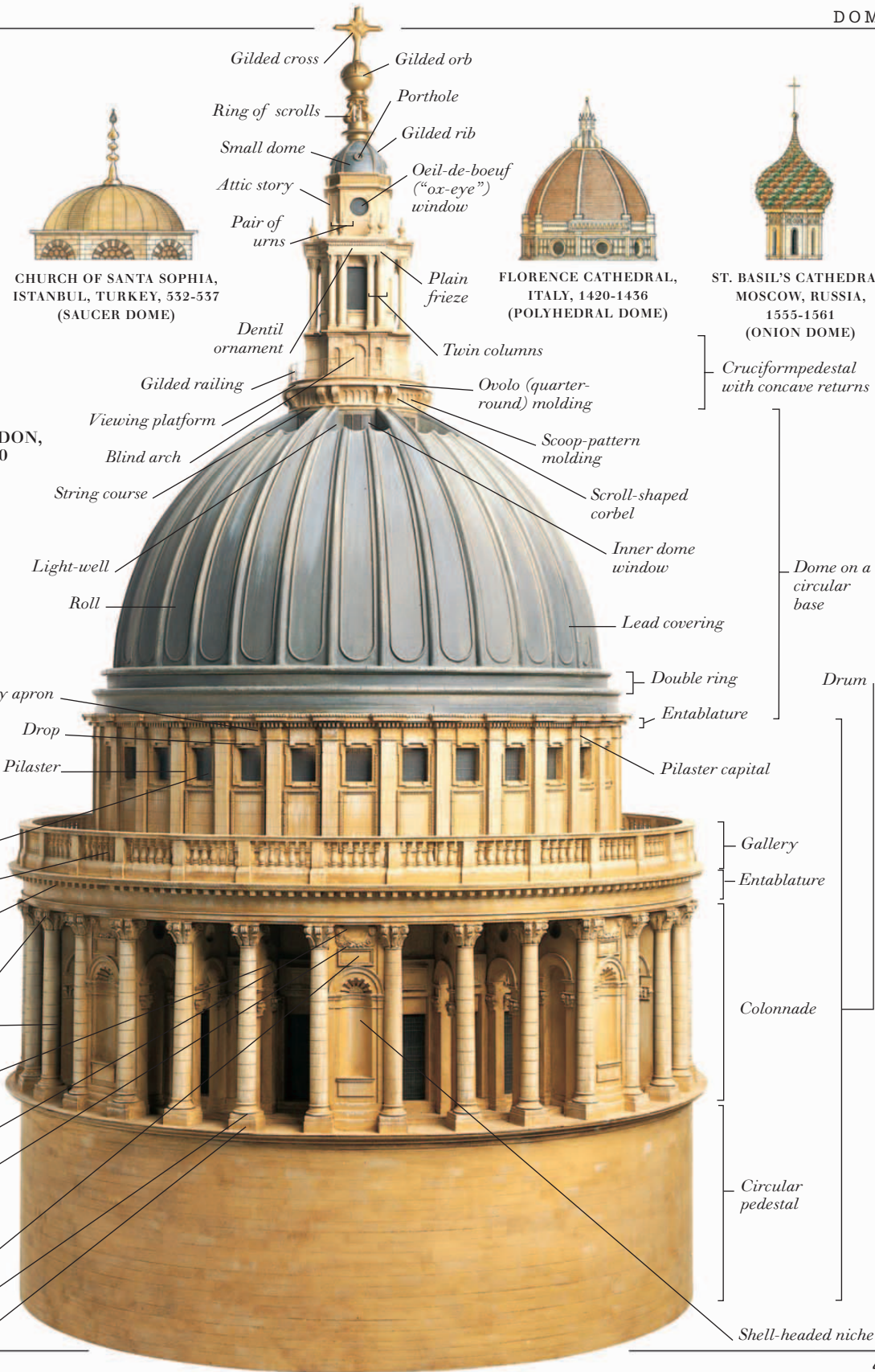


FLORENCE CATHEDRAL, ITALY, 1420-1436 (POLYHEDRAL DOME)



ST. BASIL'S CATHEDRAL, MOSCOW, RUSSIA, 1555-1561 (ONION DOME)

DOME, ST. PAUL'S CATHEDRAL, LONDON, BRITAIN, 1675-1710 (BY C. WREN)

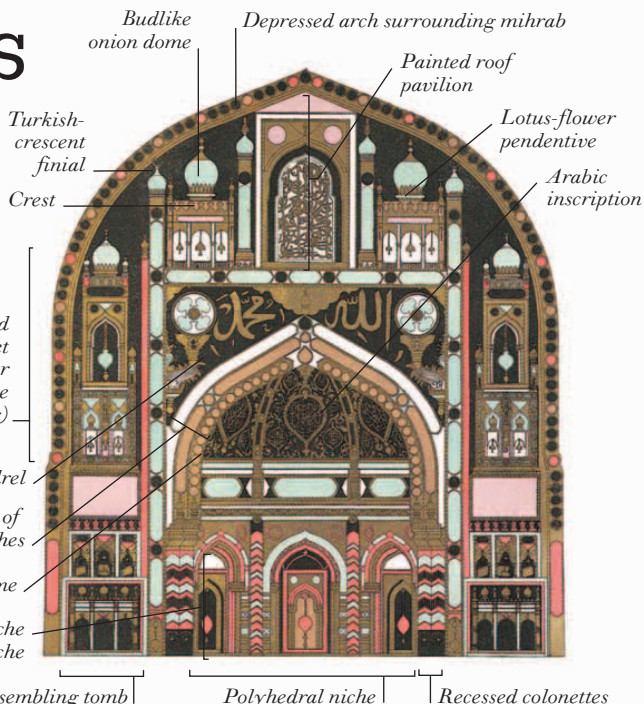


Islamic buildings

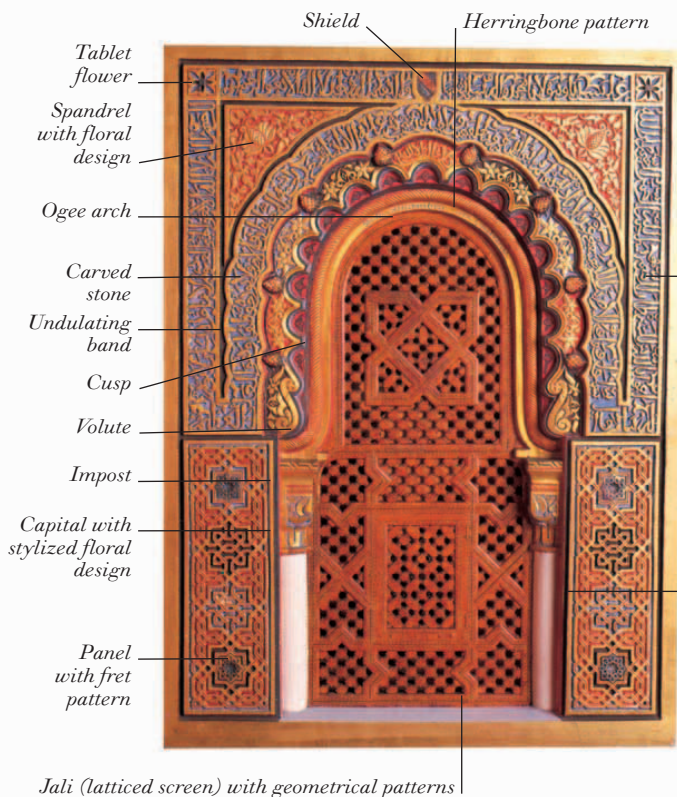


OPUS SECTILE
MOSAIC DESIGN

THE ISLAMIC RELIGION was founded by the prophet Mohammed, who was born in Mecca (in present-day Saudi Arabia) about 570 AD. In the following three centuries, Islam spread from Arabia to North Africa and Spain, as well as to India and much of the rest of Asia. The worldwide influence of Islam remains strong today. Common characteristics of Islamic buildings include ogee arches and roofs, onion domes, and walls decorated with carved stone, paintings, inlays, or mosaics. The most important type of Islamic building is the mosque—the place of worship—which generally has a minaret (tower) from which the muezzin (official crier) calls Muslims to prayer. Most mosques have a mihrab (decorative niche) that indicates the direction of Mecca. As figurative art is not allowed in Islam, buildings are ornamented with geometric and arabesque motifs, and inscriptions (frequently Koranic verses).

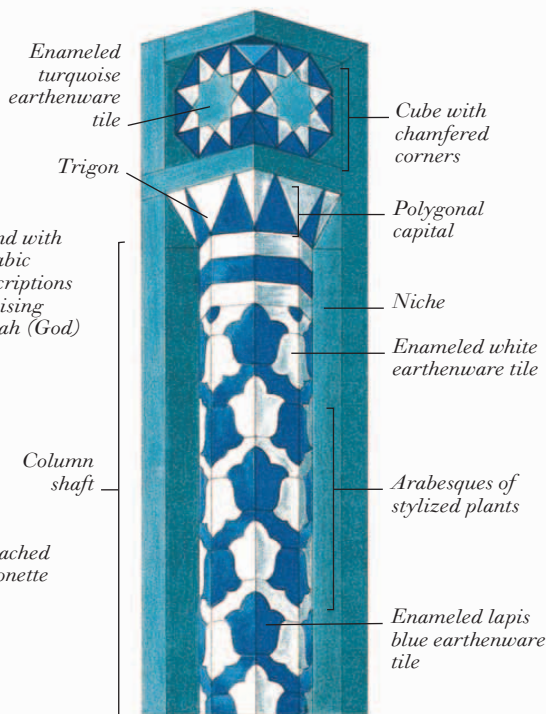


MIHRAB, JAMI MASJID (PRINCIPAL OR CONGREGATIONAL MOSQUE), BIJAPUR, INDIA, c.1636



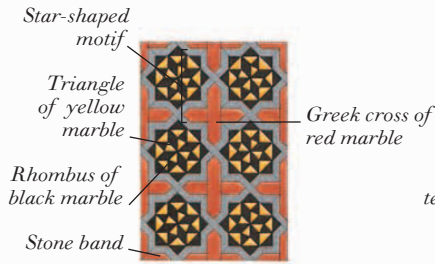
Jali (latticed screen) with geometrical patterns

ARCH, THE ALHAMBRA, GRANADA, SPAIN, 1333-1354

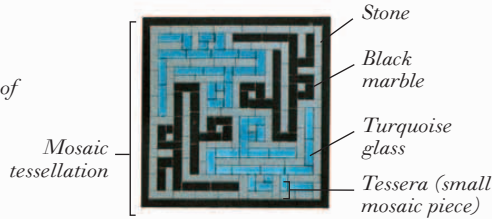


MIHRAB WITH COLUMN, EL-AINYI MOSQUE, CAIRO, EGYPT, 15TH CENTURY

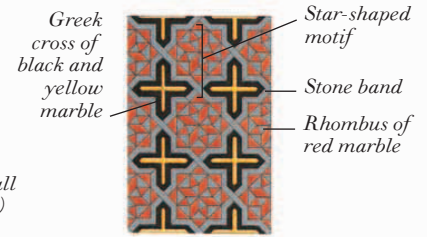
EXAMPLES OF ISLAMIC MOSAICS, EGYPT AND SYRIA



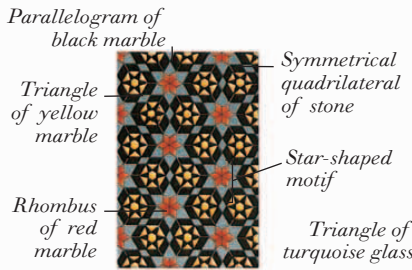
STAR AND GREEK-CROSS MOSAIC



FRET-PATTERN MOSAIC



STAR AND GREEK-CROSS MOSAIC



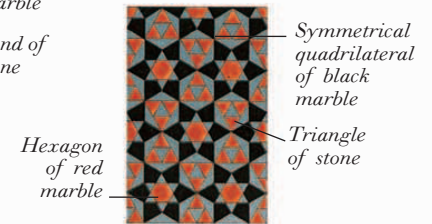
MOSAIC OF HEXAGONS, TRIANGLES, AND SYMMETRICAL QUADRILATERALS



HEXAGON AND BAND MOSAIC

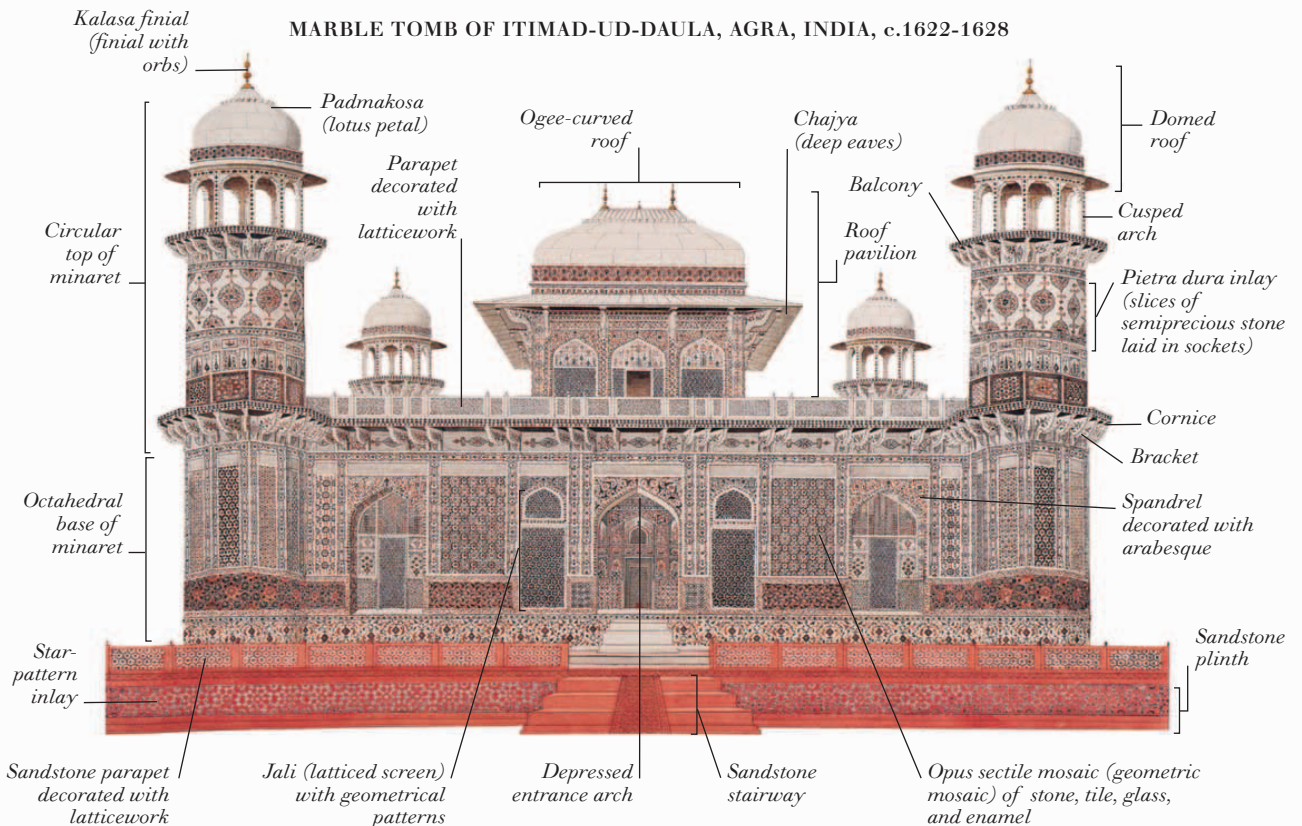


DANCETTE-PATTERN MOSAIC



MOSAIC OF HEXAGONS, TRIANGLES, AND SYMMETRICAL QUADRILATERALS

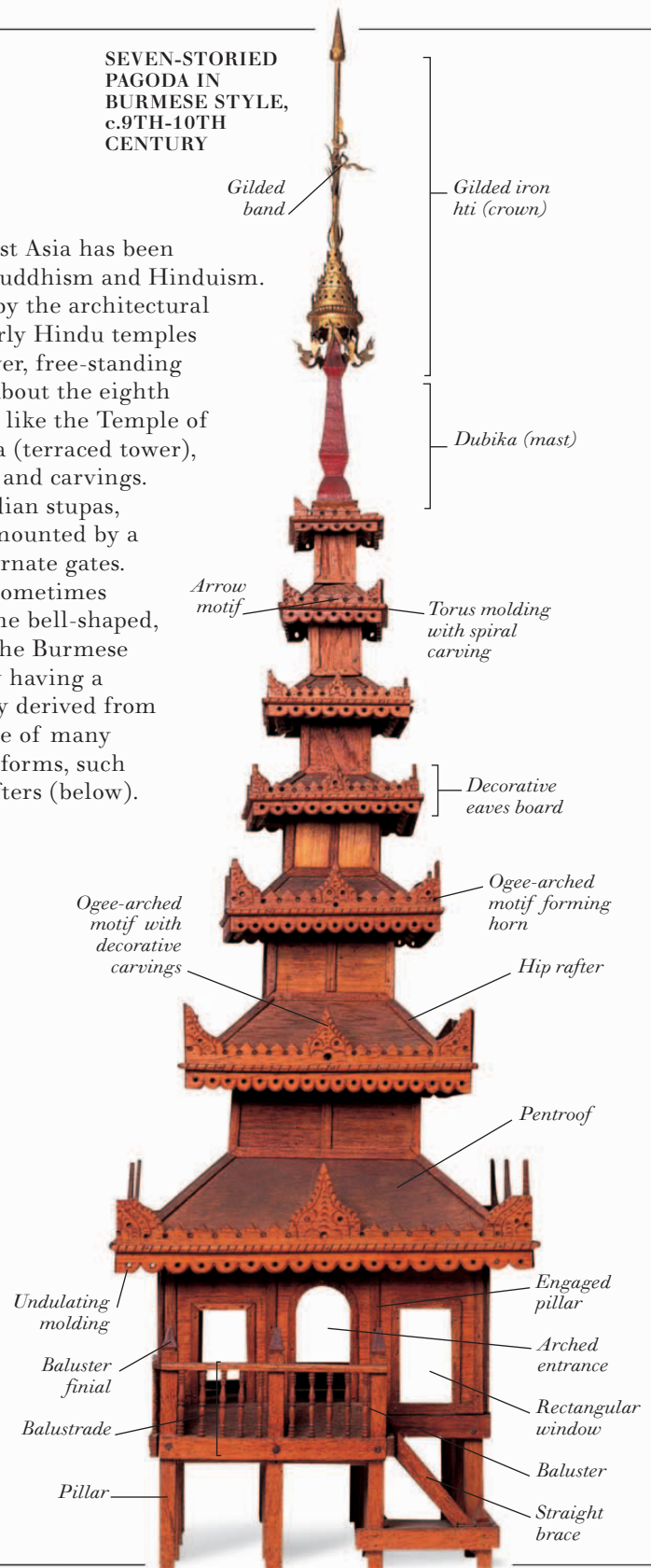
MARBLE TOMB OF ITIMAD-UD-DAULA, AGRA, INDIA, c.1622-1628



South and east Asia

THE TRADITIONAL ARCHITECTURE of south and east Asia has been profoundly influenced by the spread from India of Buddhism and Hinduism. This influence is shown both by the abundance and by the architectural styles of temples and shrines in the region. Many early Hindu temples consist of rooms carved from solid rock-faces. However, free-standing structures began to be built in southern India from about the eighth century AD. Many were built in the Dravidian style, like the Temple of Virupaksha (opposite) with its characteristic antarala (terraced tower), perforated windows, and numerous arches, pilasters, and carvings. The earliest Buddhist religious monuments were Indian stupas, which consisted of a single hemispherical dome surmounted by a chatravali (shaft) and surrounded by railings with ornate gates. Later Indian stupas and those built elsewhere were sometimes modified; for example, in Sri Lanka, the dome became bell-shaped, and was called a dagoba. Buddhist pagodas, such as the Burmese example (right), are multistoried temples, each story having a projecting roof. The form of these buildings probably derived from the yasti (pointed spire) of the stupa. Another feature of many traditional Asian buildings is their imaginative roof-forms, such as gambrel (mansard) roofs, and roofs with angle-rafters (below).

SEVEN-STORIED PAGODA IN BURMESE STYLE, c.9TH-10TH CENTURY



DETAILS FROM EAST ASIAN BUILDINGS



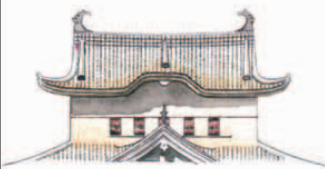
KASUGA-STYLE ROOF WITH SUMIGI (ANGLE-RAFTERS), KASUGADO SHRINE OF ENJOJI, NARA, JAPAN, 12TH-14TH CENTURY



TERRACES, TEMPLE OF HEAVEN, BEIJING, CHINA, 15TH CENTURY

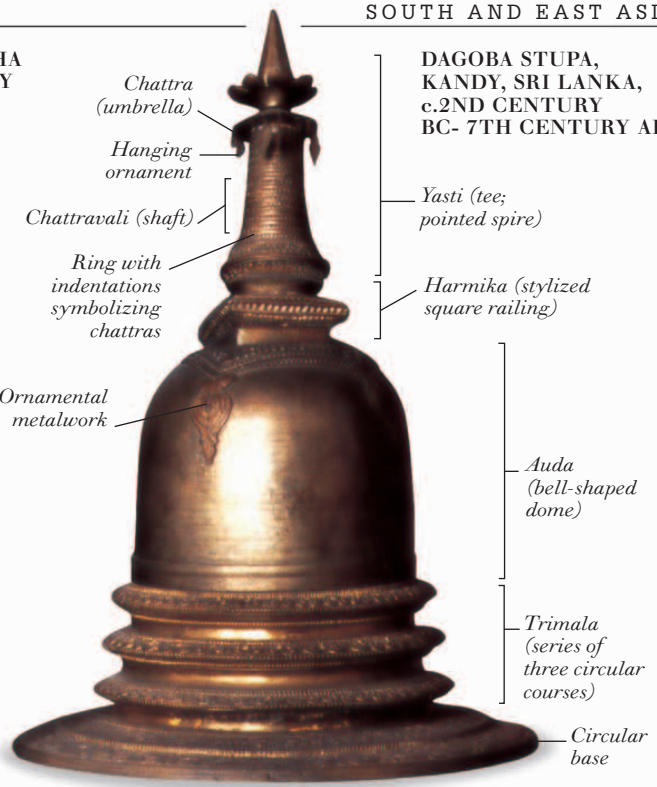
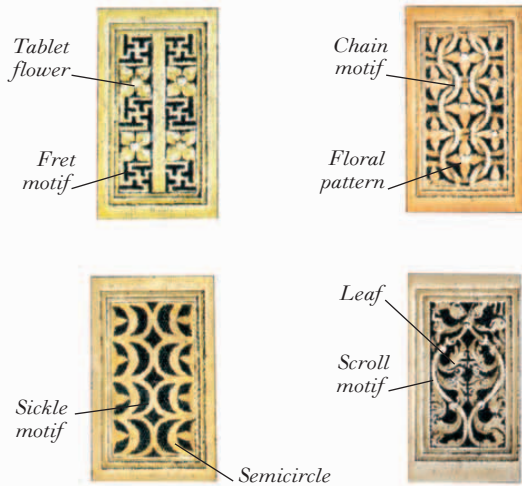


CORNER CAPITAL WITH ROOF BEAMS, POPCHU-SA TEMPLE, POPCHU-SA, SOUTH KOREA, 17TH CENTURY

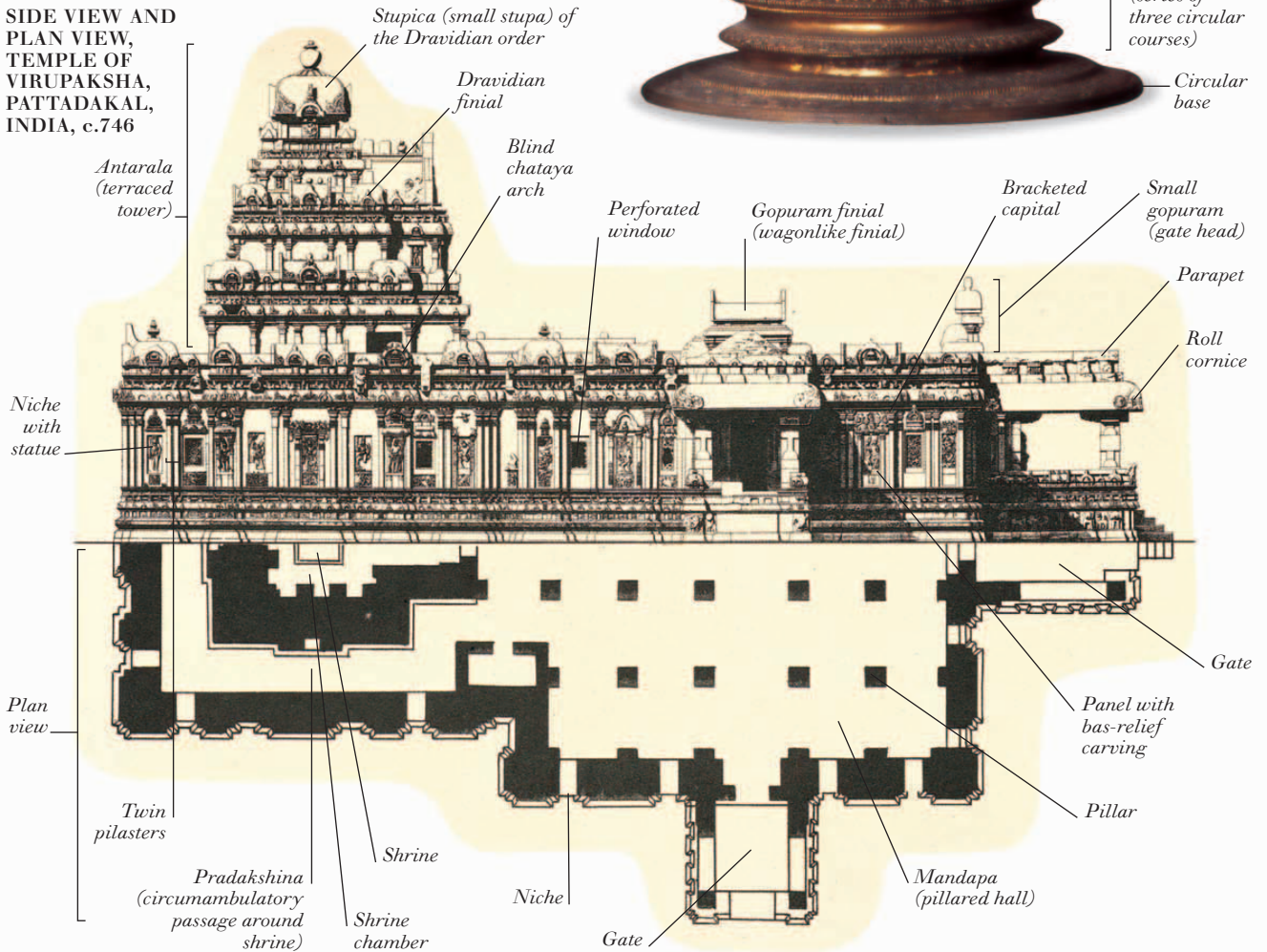


GAMBREL (MANSARD) ROOF WITH UPSWEPT EAVES AND UNDULATING GABLES, HIMEJI CASTLE, HIMEJI, JAPAN, 1608-1609

PERFORATED STONE WINDOWS, TEMPLES OF VIRUPAKSHA AND MALLIKARJUNA, PATTADAKAL, INDIA, 8TH CENTURY



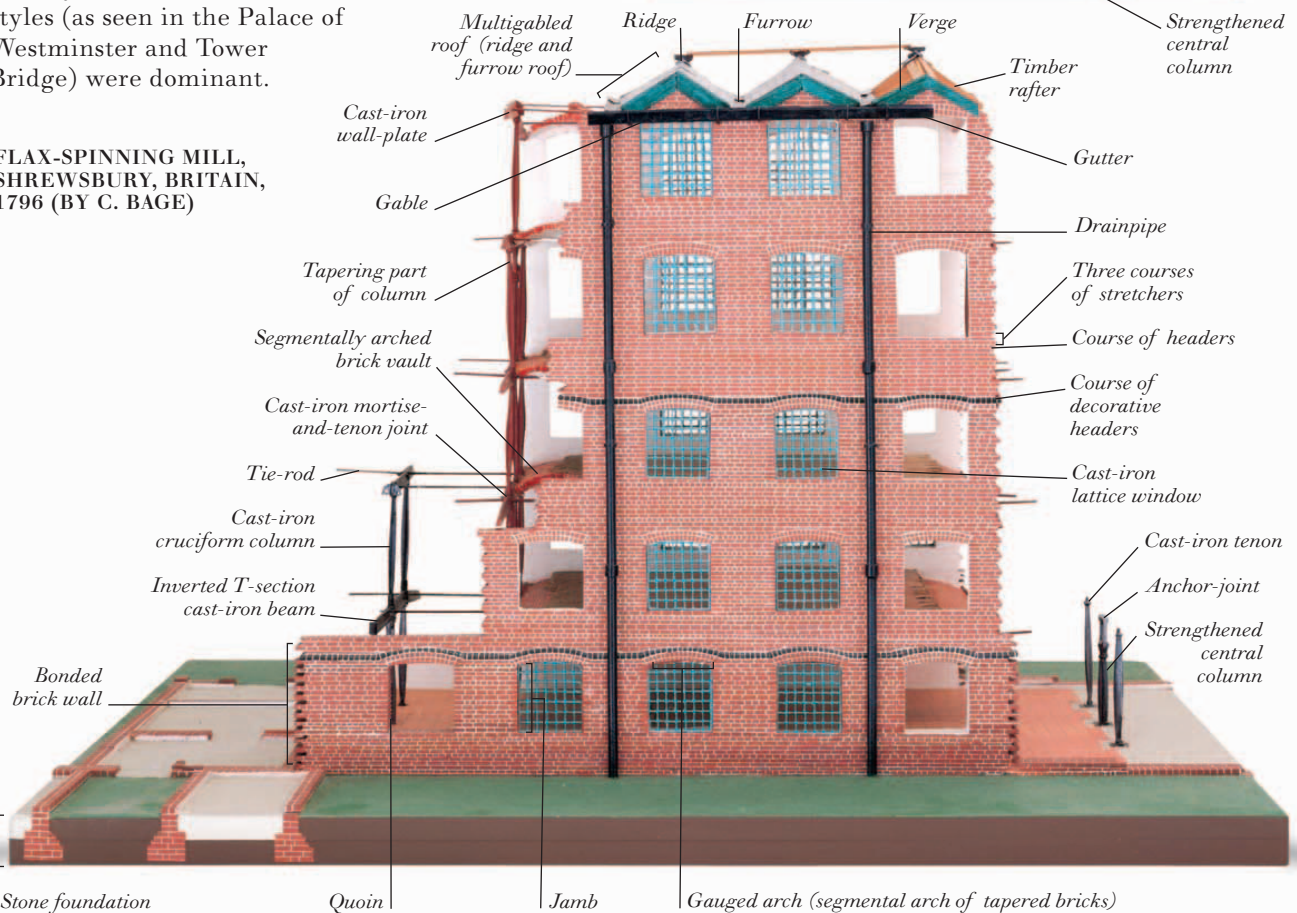
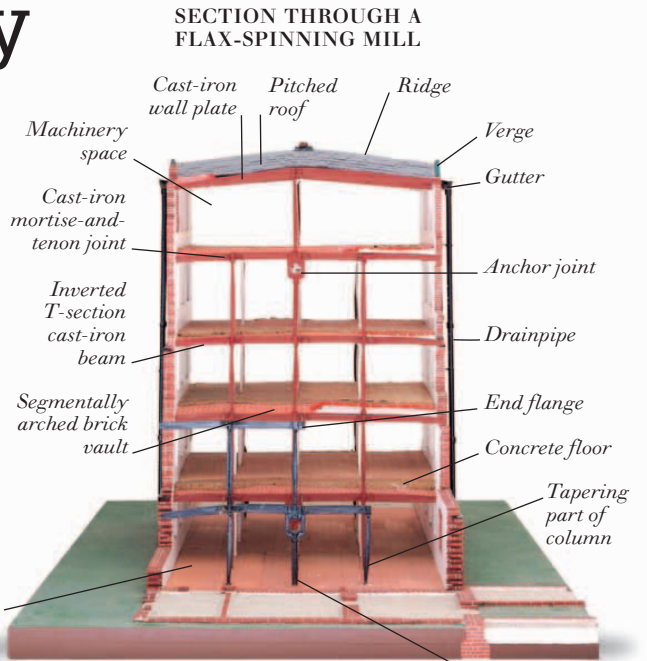
SIDE VIEW AND PLAN VIEW, TEMPLE OF VIRUPAKSHA, PATTADAKAL, INDIA, c.746



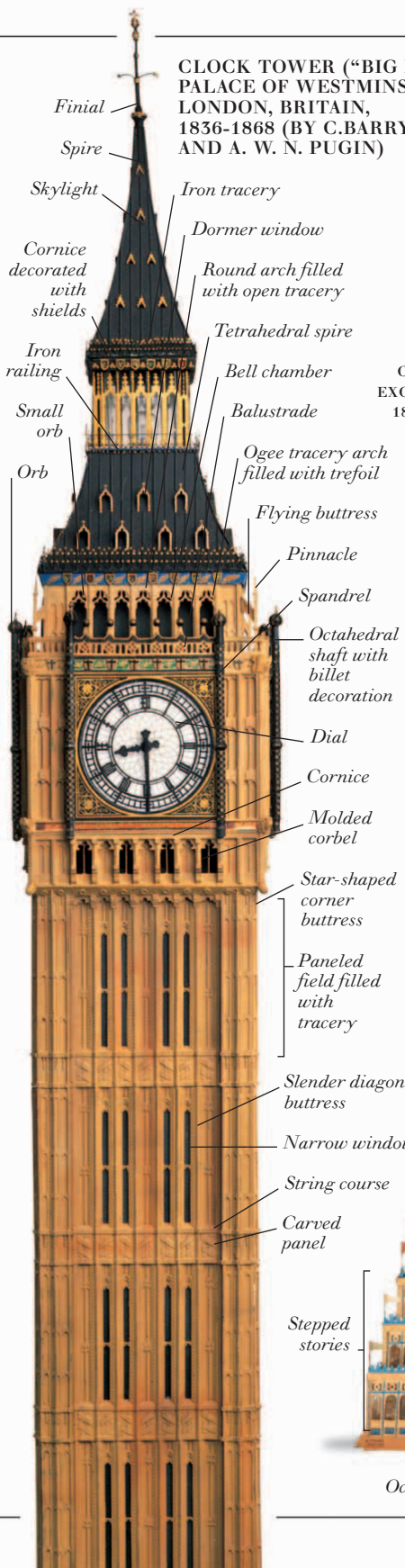
The 19th century

BUILDINGS OF THE 19TH CENTURY are characterized by the use of new materials and by a great diversity of architectural styles. From the end of the 18th century, iron and steel became widely used as alternatives to wood for the framework of buildings, as in the flax-spinning mill shown here. Built in Britain in 1796, this mill exemplifies an architectural style that became common throughout the industrialized world for more than a century. The Industrial Revolution also brought mass-production of building parts—a development that enabled the British architect Sir Joseph Paxton to erect London's Crystal Palace (a building made entirely of iron and glass) in only nine months, ready for the Great Exhibition of 1851. The 19th century saw a widespread revival of older architectural styles. For example, in the US and Germany, Neo-Greek architecture was fashionable; in Britain and France, Neo-Baroque, Neo-Byzantine, and Neo-Gothic styles (as seen in the Palace of Westminster and Tower Bridge) were dominant.

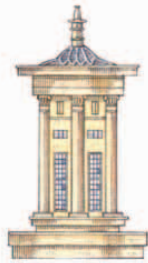
**FLAX-SPINNING MILL,
SHREWSBURY, BRITAIN,
1796 (BY C. BAGE)**



**CLOCK TOWER (“BIG BEN”),
PALACE OF WESTMINSTER,
LONDON, BRITAIN,
1836-1868 (BY C. BARRY
AND A. W. N. PUGIN)**



DETAILS FROM BUILDINGS IN REVIVALIST STYLES



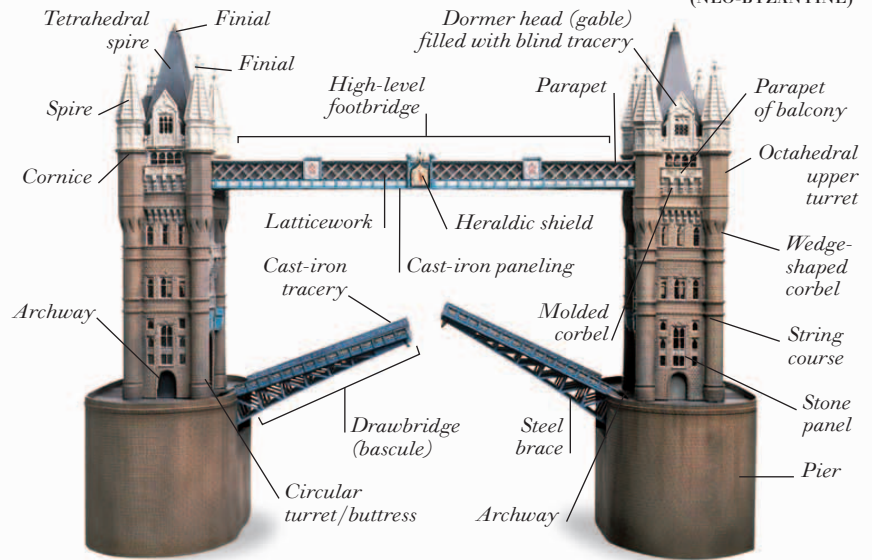
**CUPOLA, MERCHANTS’
EXCHANGE, PHILADELPHIA
1832-1834 (NEO-GREEK)**



**SCULPTURE AND PEDIMENT,
OPERA HOUSE, PARIS, FRANCE,
1861-1874 (NEO-BAROQUE)**

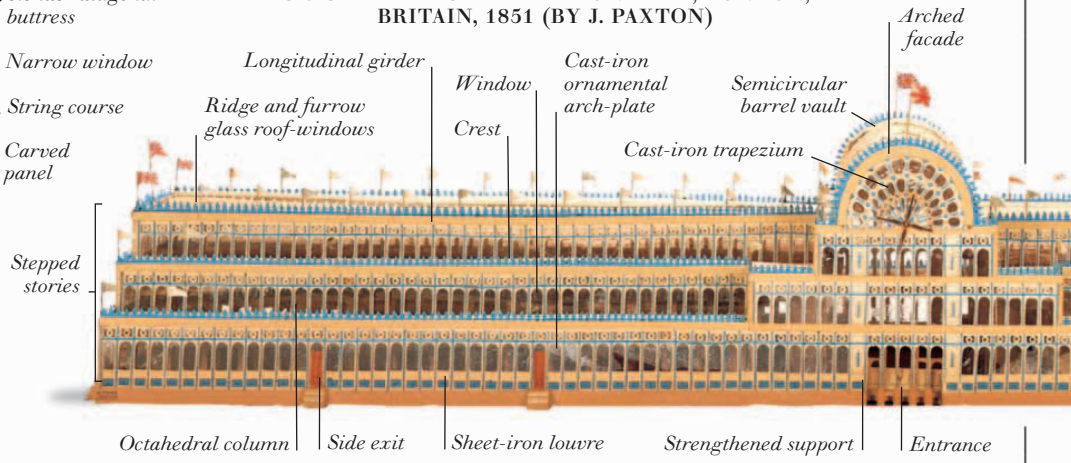


**DOMED TURRET,
WESTMINSTER
CATHEDRAL, LONDON,
BRITAIN, 1894-1903
(NEO-BYZANTINE)**



**TOWER BRIDGE, LONDON, BRITAIN,
1886-1894 (BY H. JONES)**

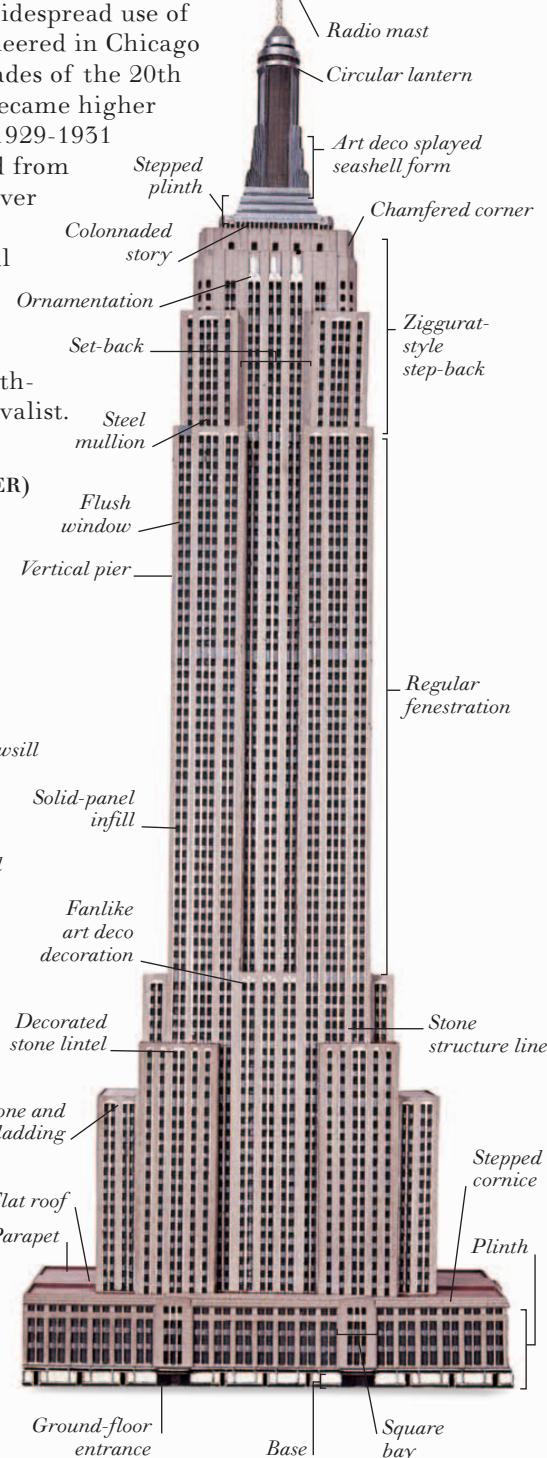
**CRYSTAL PALACE EXHIBITION HALL, LONDON,
BRITAIN, 1851 (BY J. PAXTON)**



The early 20th century

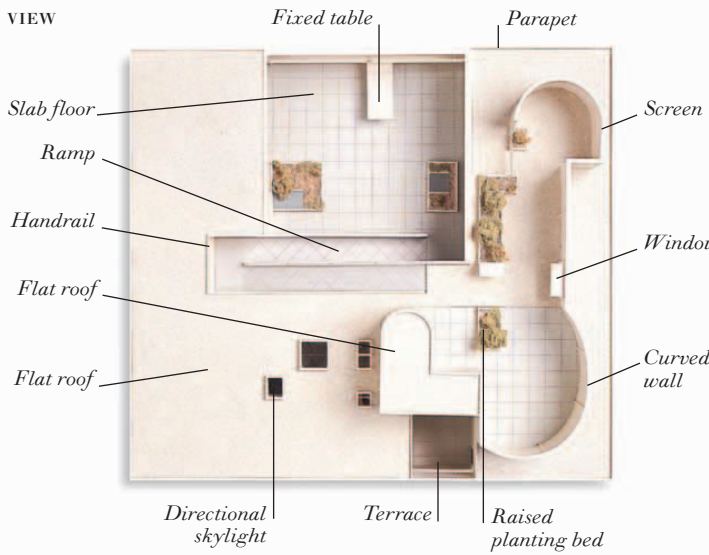
ARCHITECTURE OF THE EARLY 20TH CENTURY is notable for radical new types of steel-and-glass buildings—particularly skyscrapers—and the widespread use of steel-reinforced concrete. The steel-framed skyscraper was pioneered in Chicago in the 1880s, but did not become widespread until the first decades of the 20th century. As construction techniques were refined, skyscrapers became higher and higher; for example, the Empire State Building (right) of 1929-1931 has 102 storeys. Many buildings of this period were constructed from lightweight concrete slabs, which could be supported by cantilever beams or by pilotis (stilts), as in the Villa Savoye (below). The early 20th century also produced a great variety of architectural styles, some of which are illustrated opposite. Despite their diversity, the styles of this period generally had one thing in common: they were completely new, with few links to past architectural styles. This originality is in marked contrast to 19th-century architecture (see pp. 492-493), much of which was revivalist.

EMPIRE STATE BUILDING, NEW YORK, USA, 1929-1931 (BY R. H. SHREVE, T. LAMB, AND A. L. HARMON)

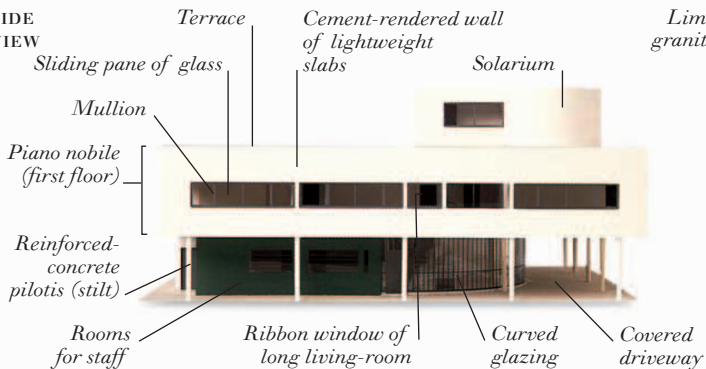


VILLA SAVOYE, POISSY, FRANCE, 1929-1931 (BY LE CORBUSIER)

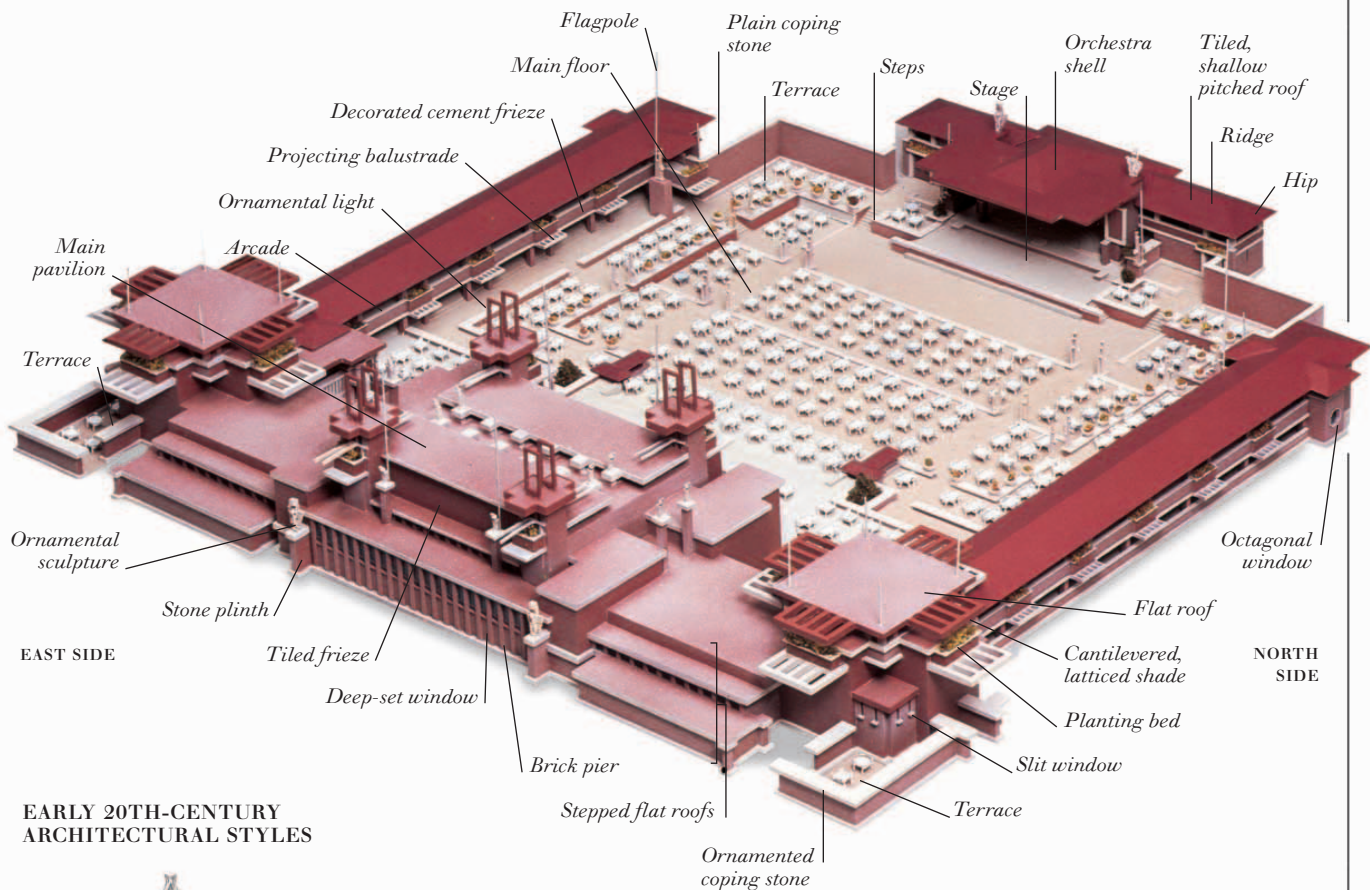
TOP VIEW



SIDE VIEW



MIDWAY GARDENS, CHICAGO, 1914 (BY F. L. WRIGHT)



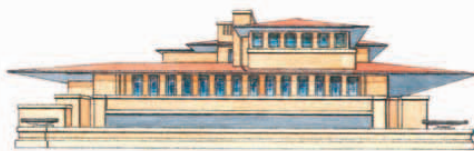
EARLY 20TH-CENTURY ARCHITECTURAL STYLES



DORMER WINDOW, STUDIO ELVIRA, MUNICH, GERMANY, 1902 (ART NOUVEAU)



AEG TURBINE HALL, BERLIN, GERMANY, 1909 (DEUTSCHER WERKBUND)



ROBIE HOUSE, CHICAGO, 1909-1910 (PRAIRIE STYLE)



GRUNDTVIG CHURCH, COPENHAGEN, DENMARK, 1920 (EXPRESSIONIST)



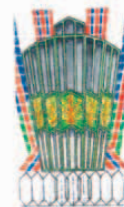
VERTEX, CHRYSLER BUILDING, NEW YORK CITY, 1928-1930 (ART DECO)



TOWER, TOWN HALL, HILVERSUM, NETHERLANDS, 1930 (DUTCH CUBIST)



CASA DEL FASCIO, COMO, ITALY, 1932-1936 (GRUPPO SEVEN CUBIST)

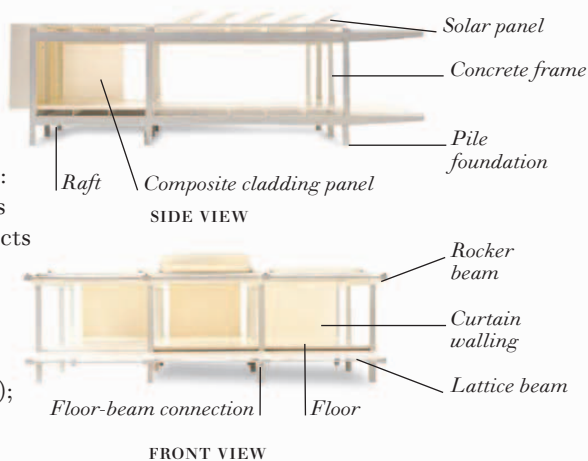


MOTIF ABOVE DOORWAY, HOOVER FACTORY, LONDON, BRITAIN, 1933 (ART DECO)

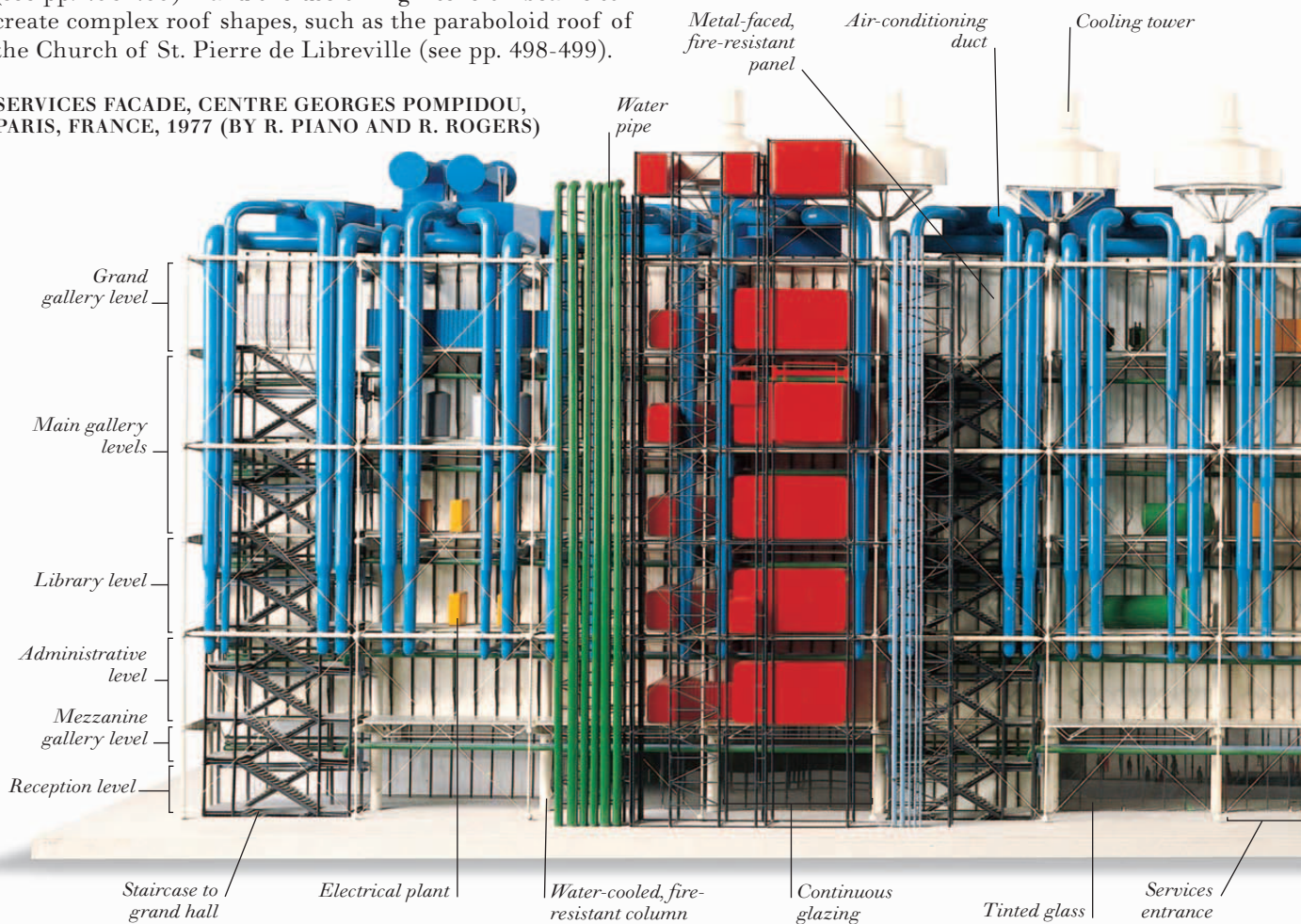
Modern buildings 1

KAWANA HOUSE, JAPAN,
FROM 1987 (BY N. FOSTER)

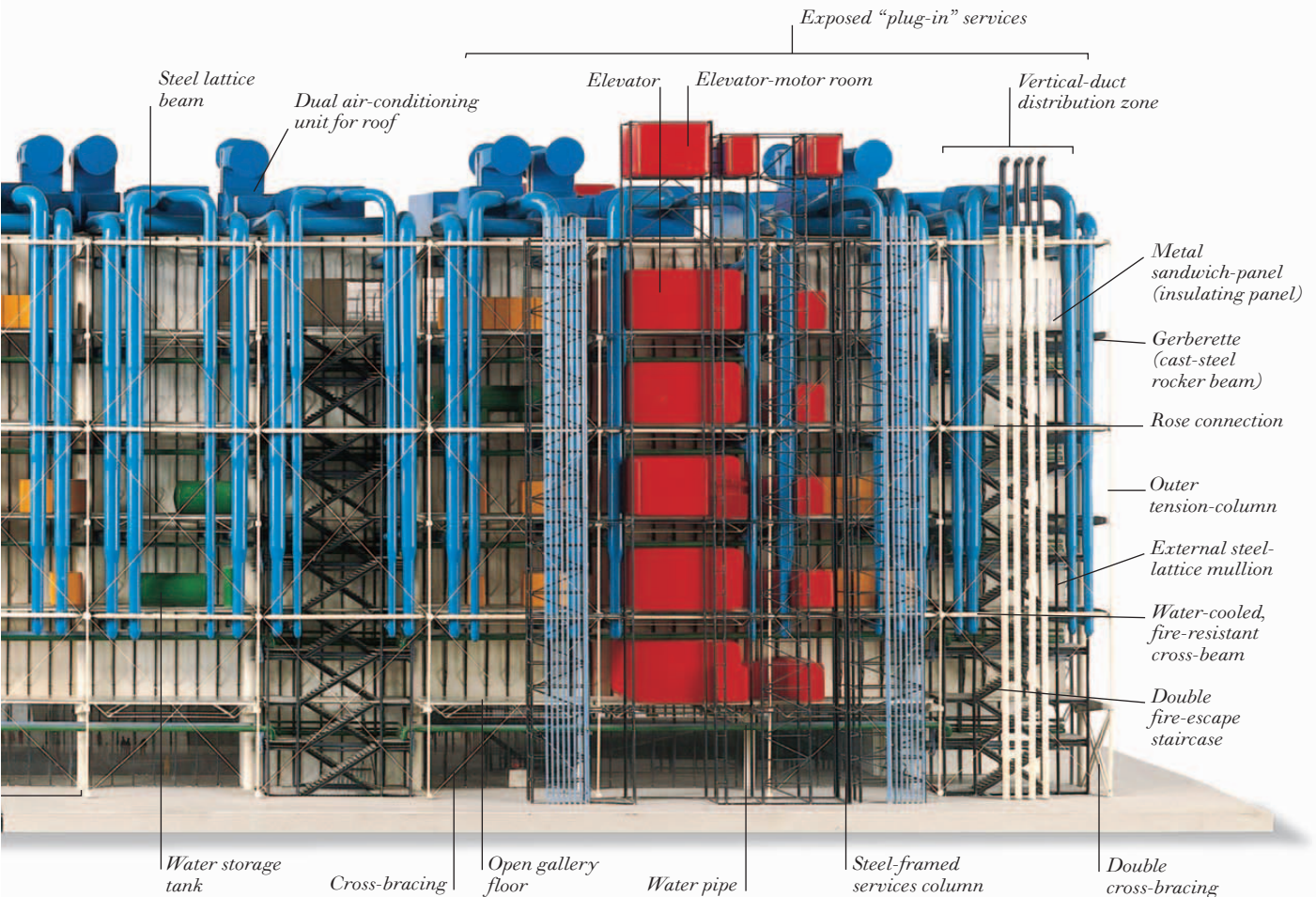
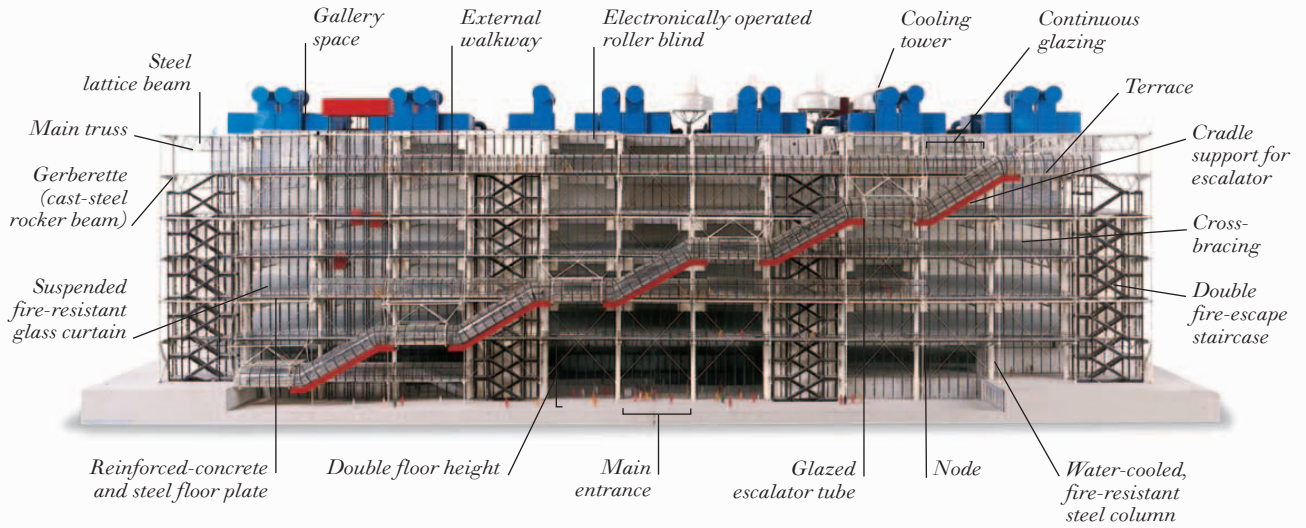
ARCHITECTURE SINCE ABOUT THE 1950s is generally known as modern architecture. One of its main influences has been functionalism—a belief that a building’s function should be apparent in its design. Both the Centre Georges Pompidou (below and opposite) and the Hong Kong and Shanghai Bank (see pp. 498-499) are functionalist buildings: on each, elements of engineering and the building’s services are clearly visible on the outside. In the 1980s, some architects rejected functionalism in favor of post-modernism, in which historical styles—particularly neoclassicism—were revived, using modern building materials and techniques. In many modern buildings, walls are made of glass or concrete hung from a frame, as in the Kawana House (right); this type of wall construction is known as curtain walling. Other modern construction techniques include the intricate interlocking of concrete vaults—as in the Sydney Opera House (see pp. 498-499)—and the use of high-tension beams to create complex roof shapes, such as the paraboloid roof of the Church of St. Pierre de Libreville (see pp. 498-499).



SERVICES FACADE, CENTRE GEORGES POMPIDOU,
PARIS, FRANCE, 1977 (BY R. PIANO AND R. ROGERS)

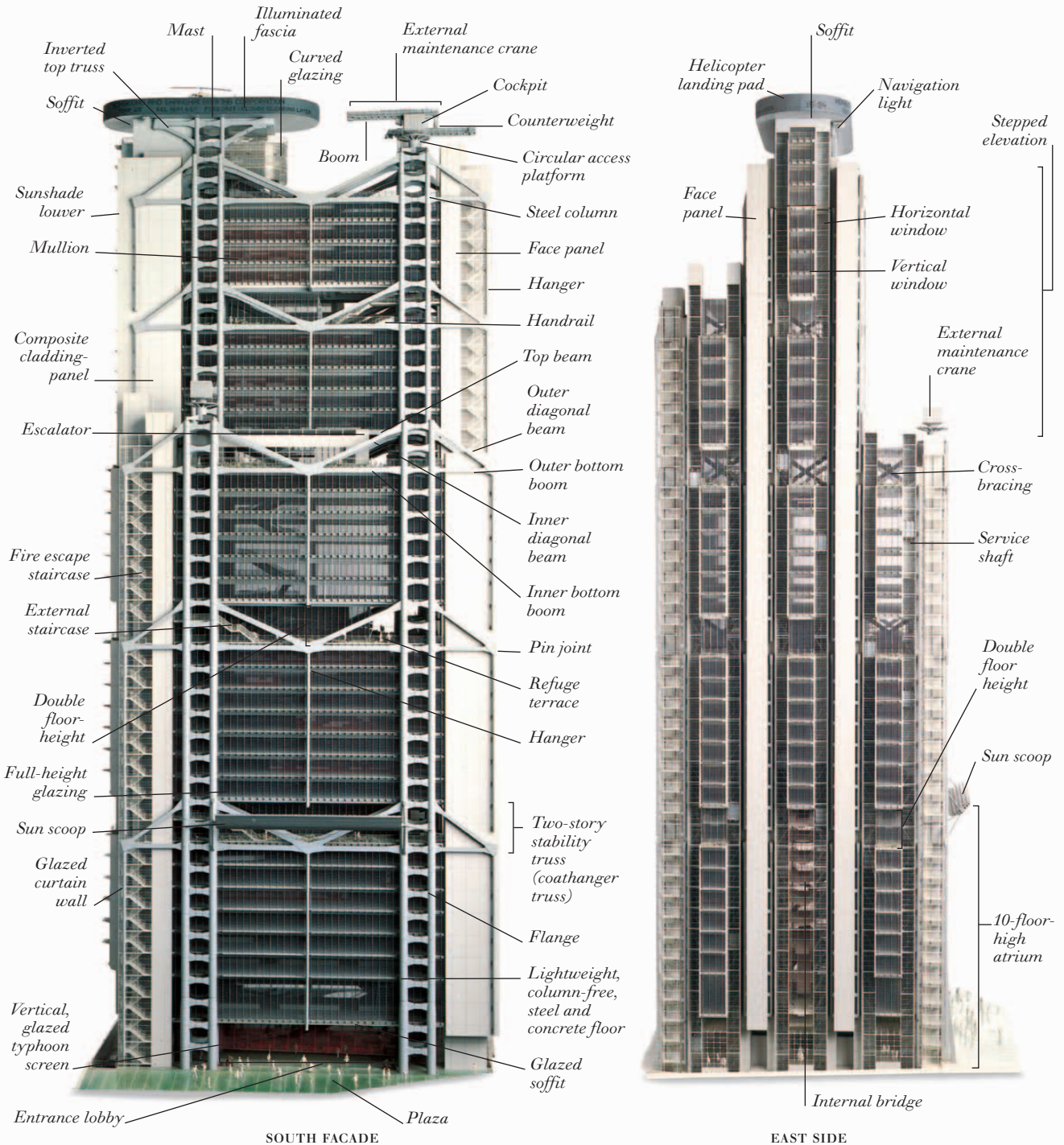


PRINCIPAL FACADE, CENTRE GEORGES POMPIDOU

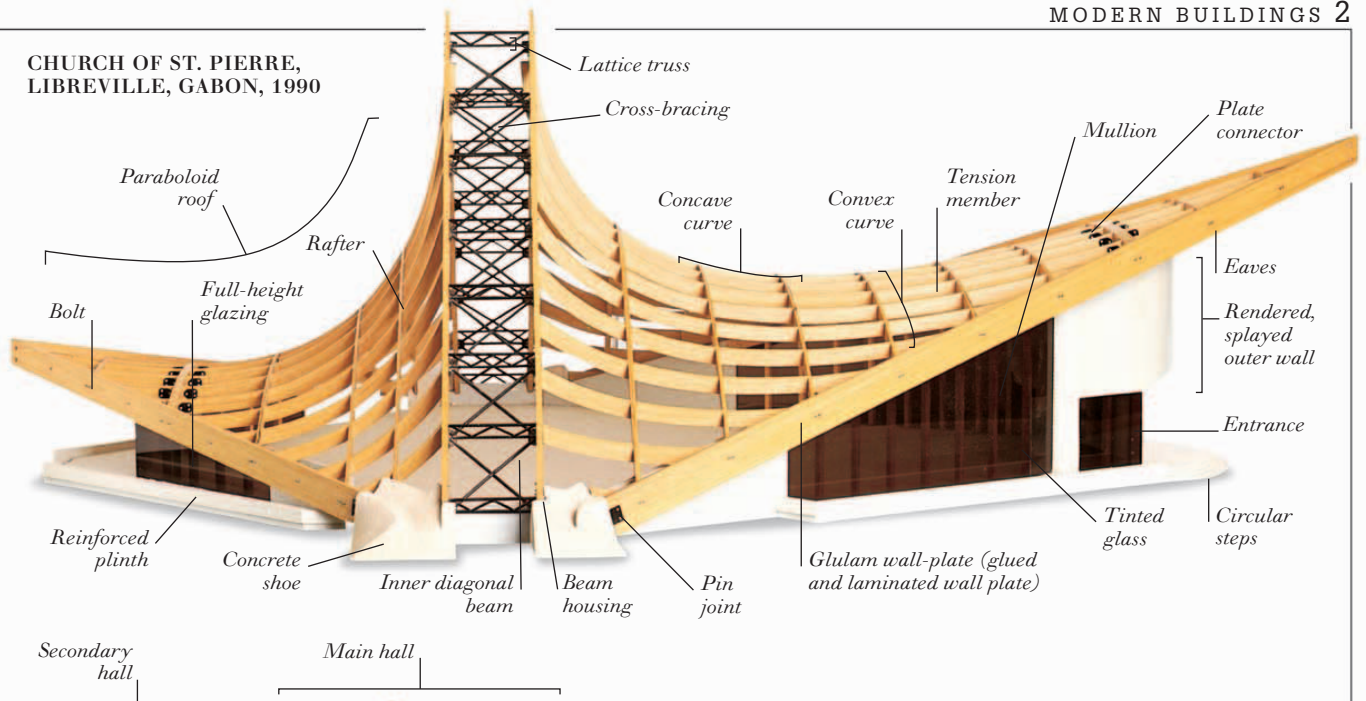


Modern buildings 2

HONG KONG AND SHANGHAI BANK, HONG KONG, 1981-1985 (BY N. FOSTER)

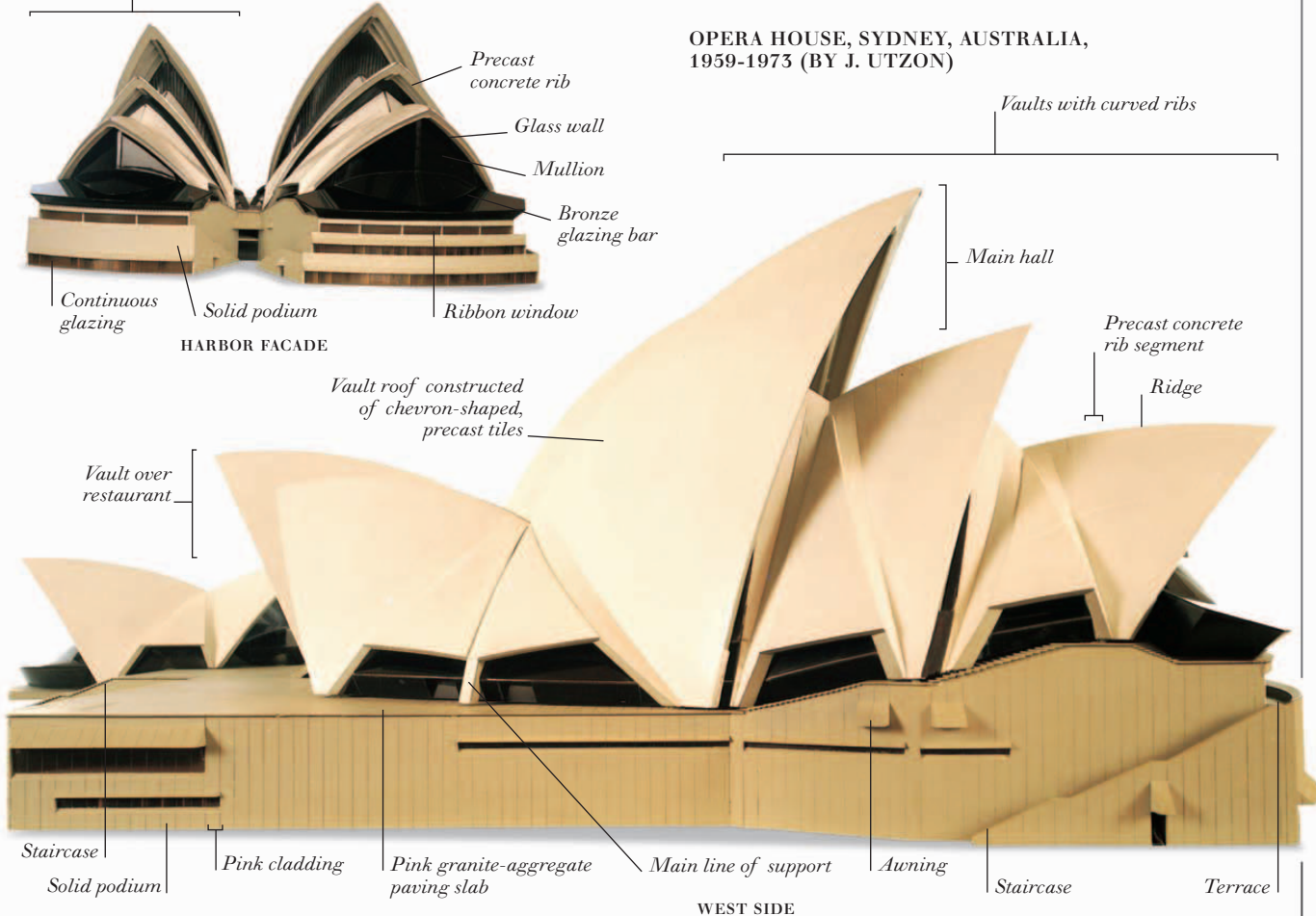


**CHURCH OF ST. PIERRE,
LIBREVILLE, GABON, 1990**



Secondary hall Main hall

**OPERA HOUSE, SYDNEY, AUSTRALIA,
1959-1973 (BY J. UTZON)**







MUSIC

MUSICAL NOTATION.....	502
ORCHESTRAS.....	504
BRASS INSTRUMENTS.....	506
WOODWIND INSTRUMENTS.....	508
STRINGED INSTRUMENTS.....	510
GUITARS.....	512
KEYBOARD INSTRUMENTS.....	514
PERCUSSION INSTRUMENTS.....	516
DRUMS.....	518
ELECTRONIC INSTRUMENTS.....	520



Musical notation

MUSICAL NOTATION IS ANY METHOD by which sounds are written down so that they can be read and performed by others. The present-day conventional system of notation uses a five-line staff (staff)—divided by vertical lines into sections known as bars—on which notes, rests, clefs, key signatures, time signatures, accidentals, and other symbols are written. A note indicates the duration of a sound and, according to its position on the staff, its pitch. Notes can be arranged on the staff in order of pitch to form a scale. A silence in the music is indicated by a rest. The clef, which is placed at the beginning of a staff, fixes the pitch. The key signature, which is placed after the clef, indicates the key. The time signature, placed after the key signature, shows the number of beats in a bar. Accidentals are used to indicate the raising or lowering of the pitch of a note.

ELEMENTS OF MUSICAL NOTATION

CLEFS Treble (or G) clef Alto (or C) clef Bass (or F) clef

TIME SIGNATURES Six-eight time Three-four time

Staff (staff)

NOTES Breve Minim Quaver

Semibreve Crotchet Semiquaver

RESTS Breve rest Minim rest Quaver rest

Semibreve rest Crotchet rest Semiquaver rest

SCALE

ACCIDENTALS Sharp Natural Double sharp

Flat Double flat Key signature

EXAMPLE OF AN ORIGINAL MANUSCRIPT: THE PRODIGAL SON, ARTHUR SULLIVAN, 1869

Moderately fast and quiet

Tie (bind)

Repeat the previous bar

Treble clef

Bass clef

Four-four time (common time)

Key signature

Alto clef

Treble voice

Alto voice

Tenor voice

Bass voice

Organ part for right hand

Organ part for left hand

Organ pedal line

Instruments of the orchestra written in Italian

Bar line

Bar

Bass clef

Crotchet

Orchestras

AN ORCHESTRA IS A GROUP of musicians that plays music written for a specific combination of instruments. The number and type of instruments included in the orchestra depends on the style of music being played. The modern orchestra (also known as a symphony orchestra) is made up of four sections of instruments—stringed, woodwind, brass, and percussion. The stringed section consists of violins, violas, cellos (violoncellos), double basses, and sometimes a harp (see pp. 510-511). The main instruments of the woodwind section are flutes, oboes, clarinets, and bassoons—the piccolo, cor anglais, bass clarinet, saxophone, and double bassoon (contrabassoon) can also be included if the music requires them (see pp. 508-509). The brass section usually consists of horns, trumpets, trombones, and the tuba (see pp. 506-507). The main instruments of the percussion section are the timpani (see pp. 518-519). The side drum, bass drum, cymbals, tambourine, triangle, tubular bells, xylophone, vibraphone, tam-tam (gong), castanets, and maracas can also be included in the percussion section (see pp. 516-517). The musicians are usually arranged in a semi-circle—strings spread along the front, woodwind and brass in the center, and percussion at the back. A conductor stands in front of the musicians and controls the tempo (speed) of the music and the overall balance of the sound, ensuring that no instruments are too loud or too soft in relation to the others.



EXAMPLE OF A LAYOUT OF THE INSTRUMENTS FOR A MODERN (SYMPHONY) ORCHESTRA



Brass instruments



BUGLE

BRASS INSTRUMENTS ARE WIND INSTRUMENTS that are made of metal, usually brass. Although they appear in many different shapes and sizes, all brass instruments have a mouthpiece, a length of hollow tube, and a flared bell.

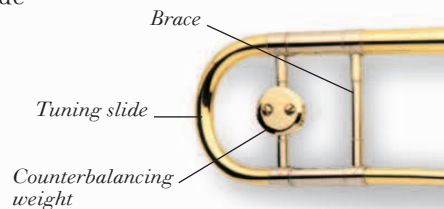
The mouthpiece of a brass instrument may be cup-shaped, as in the cornet, or cone-shaped, as in the

horn. The tube may be wide or narrow, mainly

conical, as in the horn and tuba, or mainly cylindrical, as in the trumpet and trombone. The sound of a brass instrument is made by the player's lips vibrating against the mouthpiece, so that the air vibrates in the tube. By changing lip tension, the player can vary the vibrations and produce notes of different pitches. The range of notes produced by a brass instrument can be extended by means of a valve system.

Most brass instruments, such as the trumpet, have piston valves that divert the air in the instrument along an extra piece of tubing (known as a valve slide) when pressed down.

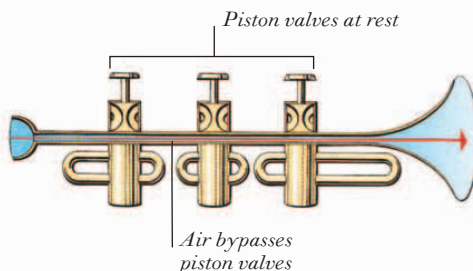
The total length of the tube is increased and the pitch of the note produced is lowered. Instead of valves, the trombone has a movable slide that can be pushed away from or drawn toward the player. The sound of a brass instrument can also be changed by inserting a mute into the bell of the instrument.



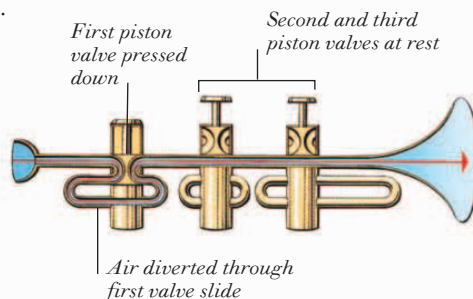
Tuning slide

Counterbalancing weight

SIMPLIFIED DIAGRAM SHOWING HOW A PISTON VALVE SYSTEM WORKS



PISTON VALVES AT REST



PISTON VALVE PRESSED DOWN

TRUMPET

Finger button

First piston valve

Spring returns piston valve to rest position

Second piston valve

Third piston valve

Holes divert air into valve slides

Cup-shaped mouthpiece

Mouthpiece receiver

Little finger support

Music stand holder

Narrow, cylindrical tube

Flared bell

Tuning slide

First valve slide

First valve slide thumb hook

Second valve slide

Third valve slide finger ring

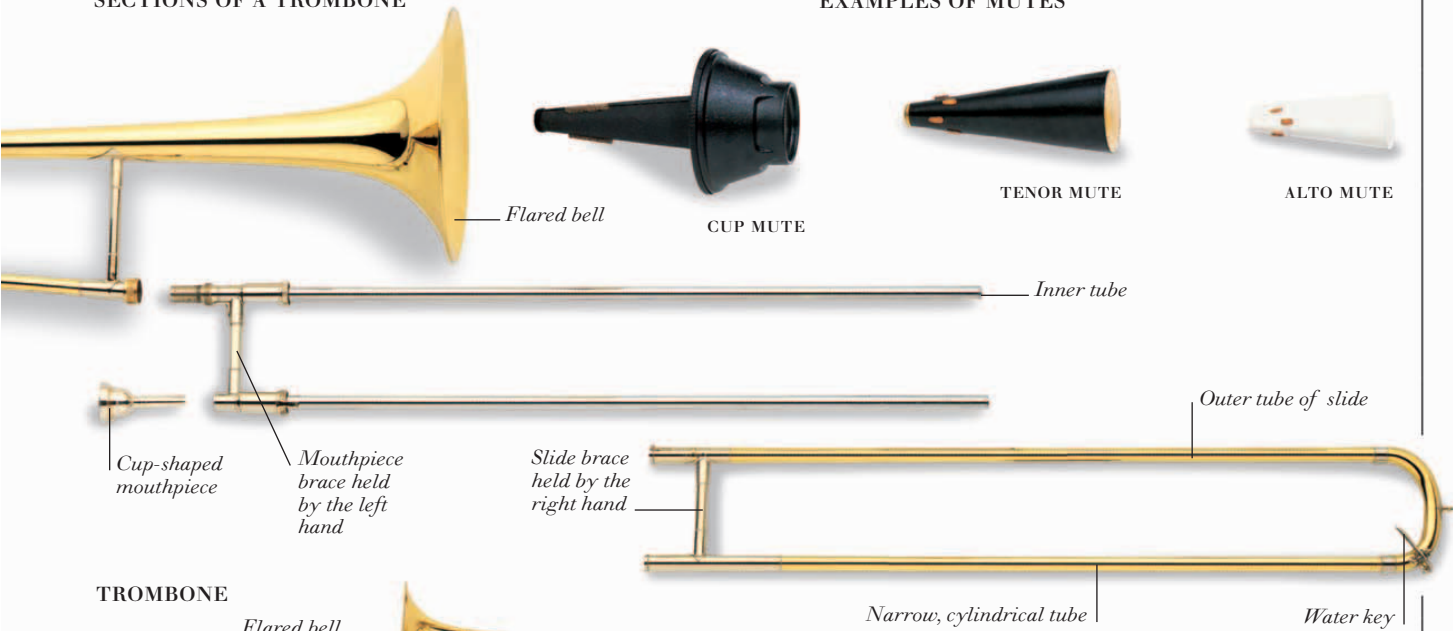
Third valve slide

Tuning slide water key

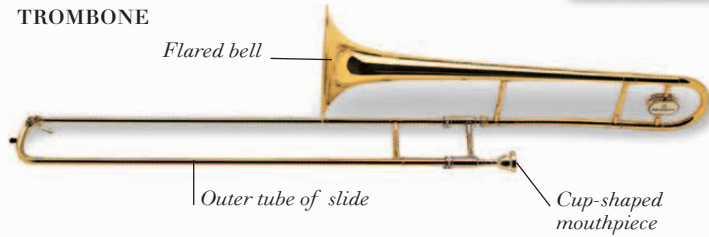
Third valve slide water key

SECTIONS OF A TROMBONE

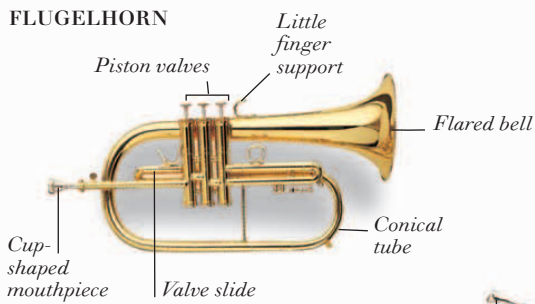
EXAMPLES OF MUTES



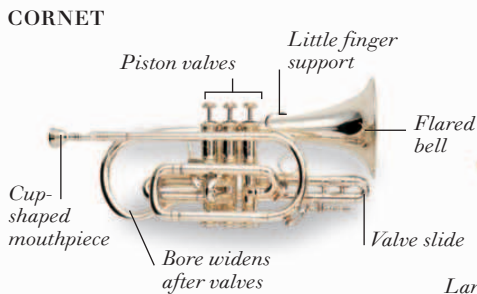
TROMBONE



FLUGELHORN



CORNET



HORN



TUBA



Woodwind instruments

WOODWIND INSTRUMENTS ARE wind instruments that are generally made of wood, although some are made of metal or plastic. The sound of a woodwind instrument is produced by the vibration of air in a hollow tube. The air is made to vibrate by blowing across a blow hole—as in the flute and piccolo—or by blowing through a single reed—as in the clarinet and saxophone—or a double reed—as in the bassoon, cor anglais, and oboe. The pitch of a woodwind instrument can be changed by opening or closing holes cut into the tube of the instrument.



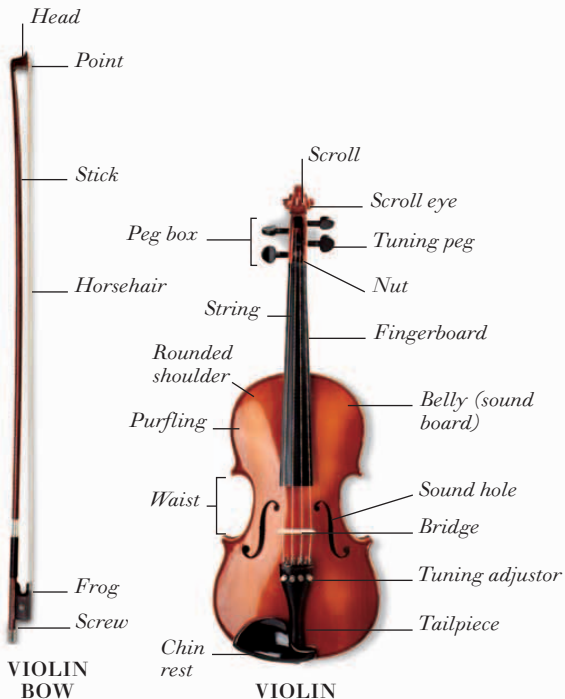
TENOR SAXOPHONE

SECTIONS OF A TENOR SAXOPHONE



Stringed instruments

STRINGED INSTRUMENTS PRODUCE SOUND by the vibration of stretched strings. This may be done by drawing a bow across the strings, as in the violin; or by plucking the strings, as in the harp and guitar (see pp. 512-513). The four modern members of the bowed string family are the violin, viola, cello (violoncello), and double bass. Each consists of a hollow, wooden body, a long neck, and four strings. The bow is a wooden stick with horsehair stretched across its length. The vibrations made by drawing the bow across the strings are transmitted to the hollow body, and this itself vibrates, amplifying and enriching the sound produced. The harp consists of a set of strings of different lengths stretched across a wooden frame. The strings are plucked by the player's thumbs and fingers—except the little finger of each hand—which produces vibrations that are amplified by the harp's sound board. The pitch of the note produced by any stringed instrument depends on the length, weight, and tension of the string. A shorter, lighter, or tighter string gives a higher note.





HARP

DOUBLE BASS BOW

VIOLA

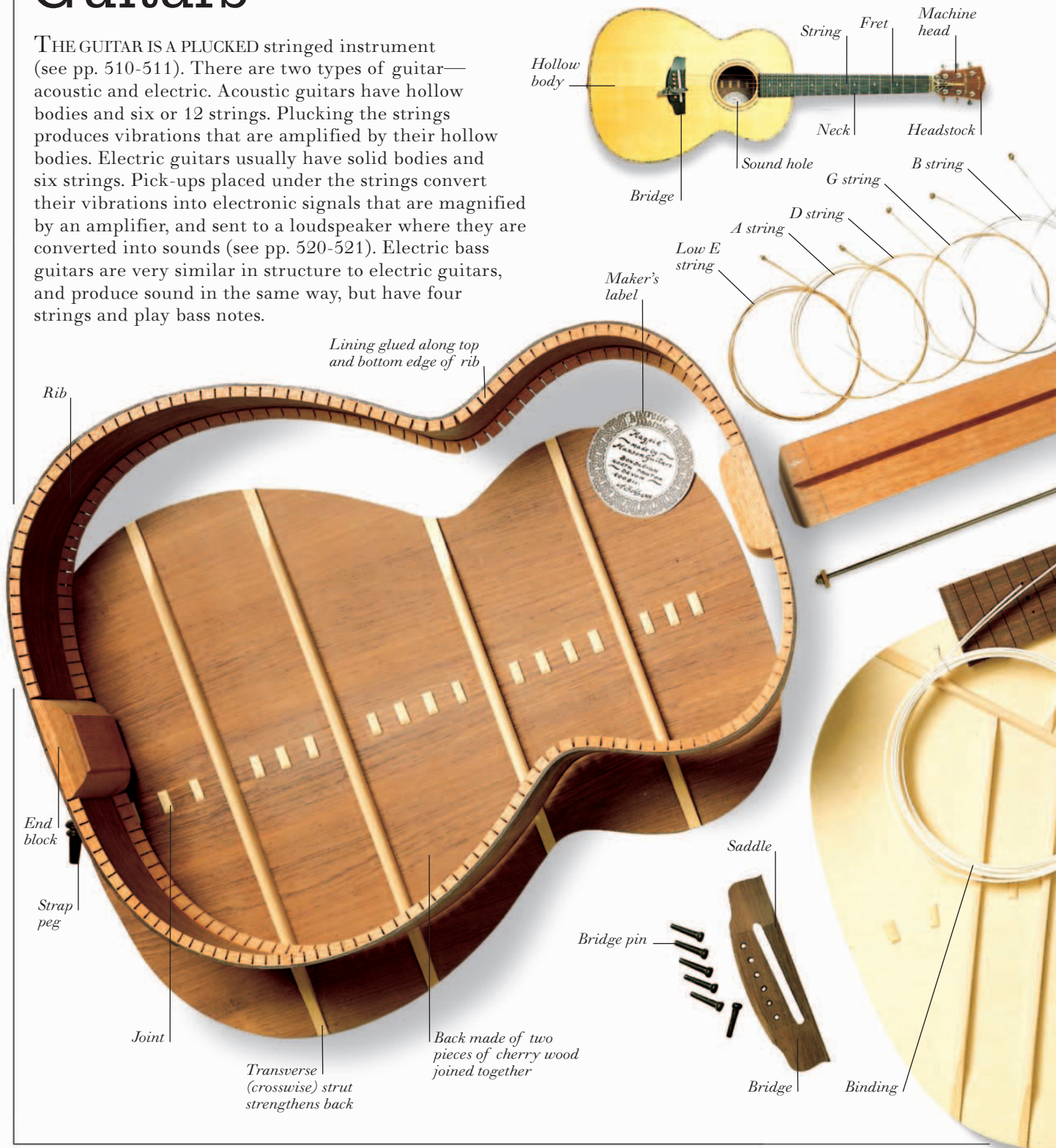
CELLO (VIOLONCELLO)

DOUBLE BASS

Guitars

THE GUITAR IS A PLUCKED stringed instrument (see pp. 510-511). There are two types of guitar—acoustic and electric. Acoustic guitars have hollow bodies and six or 12 strings. Plucking the strings produces vibrations that are amplified by their hollow bodies. Electric guitars usually have solid bodies and six strings. Pick-ups placed under the strings convert their vibrations into electronic signals that are magnified by an amplifier, and sent to a loudspeaker where they are converted into sounds (see pp. 520-521). Electric bass guitars are very similar in structure to electric guitars, and produce sound in the same way, but have four strings and play bass notes.

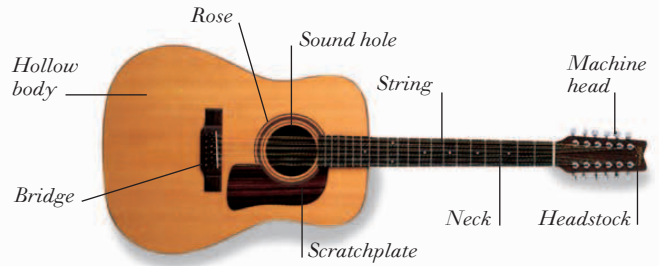
ACOUSTIC GUITAR



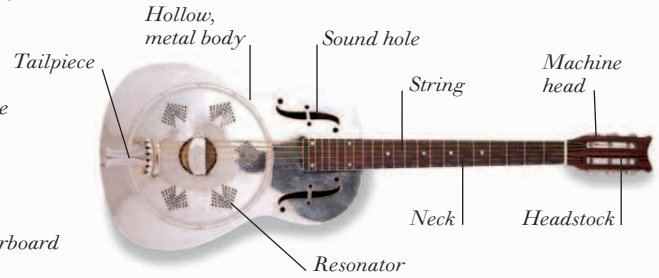
COMPONENTS OF AN ACOUSTIC GUITAR



EXAMPLES OF ACOUSTIC GUITARS

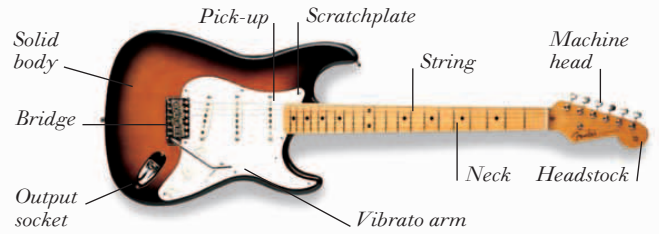


WASHBURN TWELVE-STRING

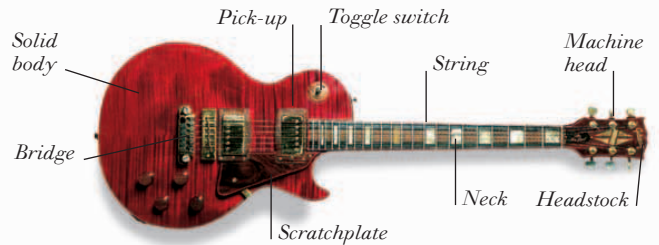


DOBRO RESONATOR

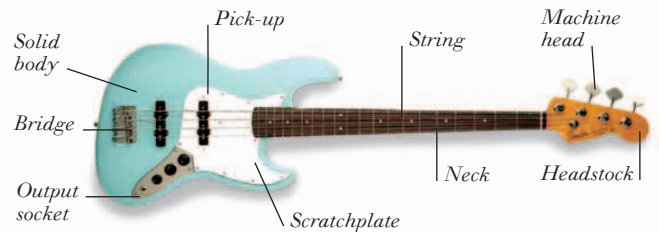
EXAMPLES OF ELECTRIC GUITARS



FENDER STRATOCASTER



GIBSON LES PAUL



FENDER JAZZ BASS

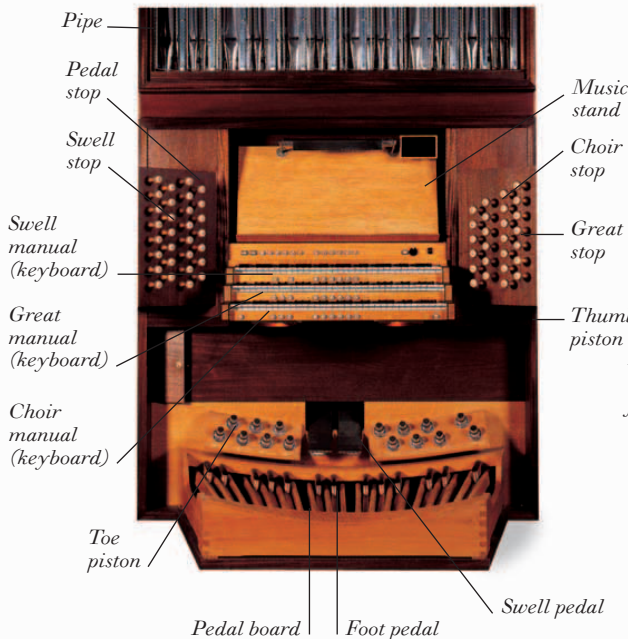
Keyboard instruments



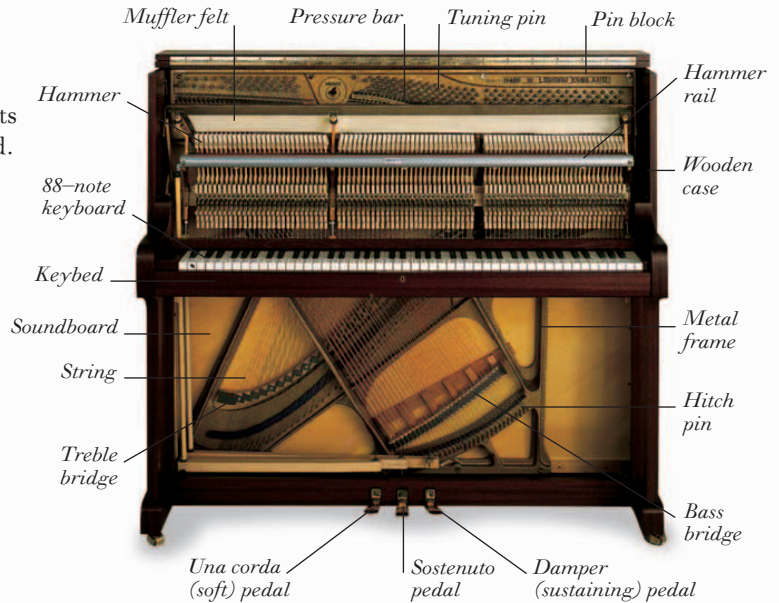
ORGAN PIPE

KEYBOARD INSTRUMENTS are instruments that are sounded by means of a keyboard. The organ and piano are two of the principal members of the keyboard family. The organ consists of pipes that are operated by one or more manuals (keyboards) and a pedal board. The pipes are lined up in rows (known as ranks or registers) on top of a wind chest. The sound of the organ is made when air is admitted into a pipe by pressing a key or pedal. The piano consists of wire strings stretched over a metal frame, and a keyboard and pedals that operate hammers and dampers. The piano frame is either vertical—as in the upright piano—or horizontal—as in the grand piano. When a key is at rest, a damper lies against the string to stop it from vibrating. When a key is pressed down, the damper moves away from the string as the hammer strikes it, causing the string to vibrate and sound a note.

ORGAN CONSOLE

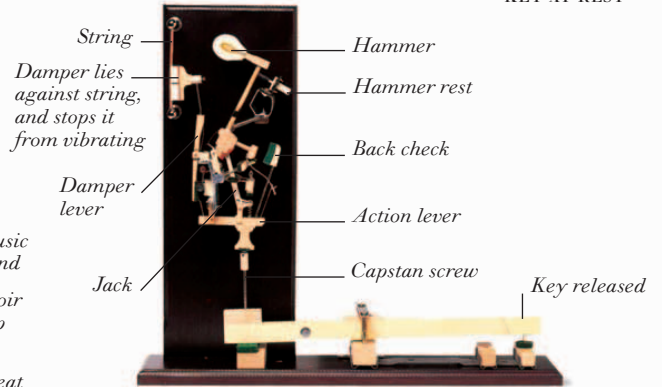


UPRIGHT PIANO

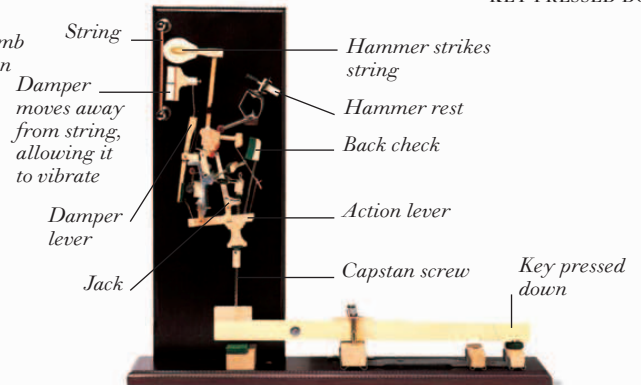


UPRIGHT PIANO ACTION

KEY AT REST

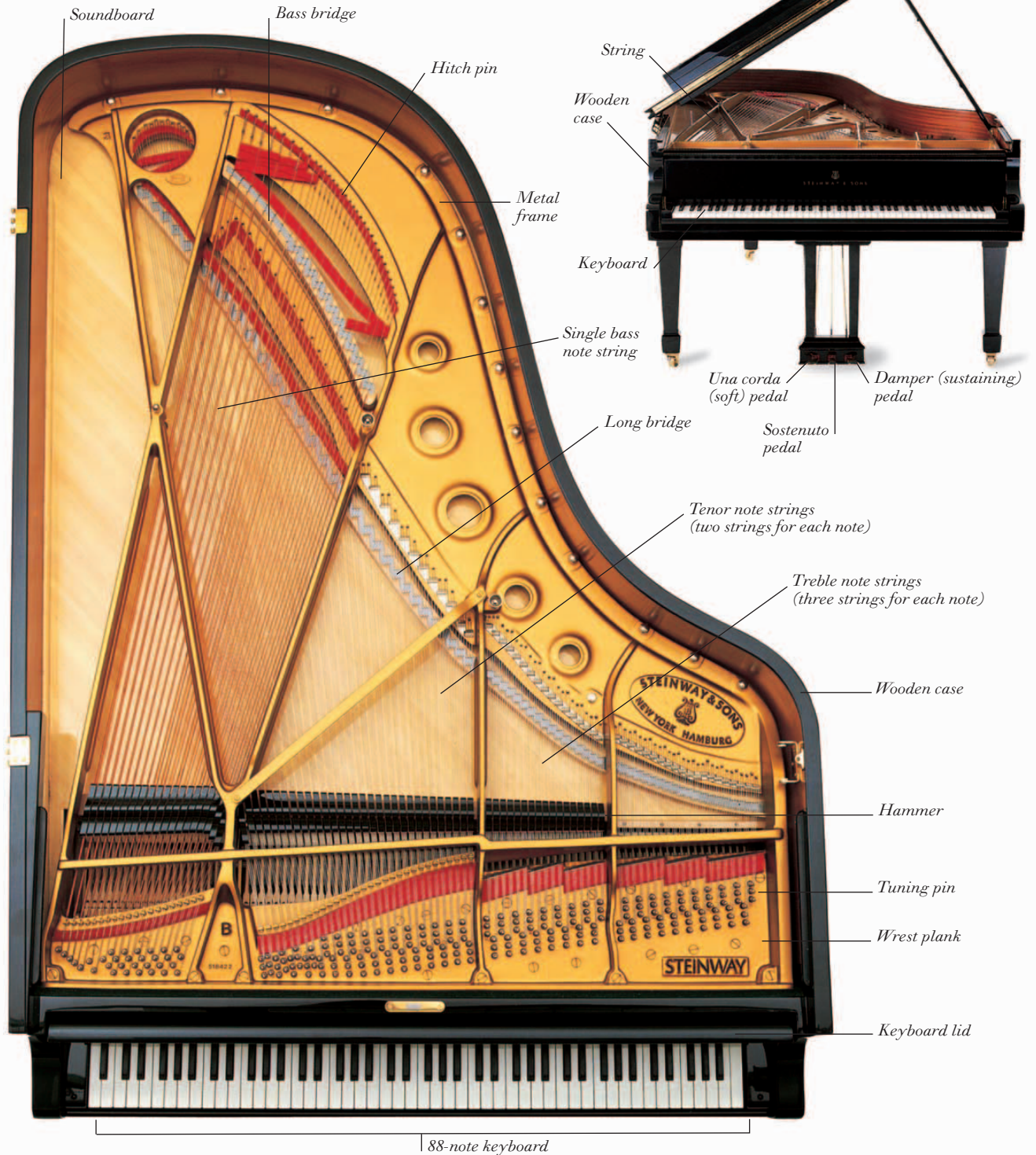


KEY PRESSED DOWN



CONCERT GRAND PIANO (VIEWED FROM ABOVE)

CONCERT GRAND PIANO (FRONT VIEW)



Percussion instruments



PERCUSSION INSTRUMENTS are a large group of instruments that produce sound by being struck, shaken, scraped, or clashed together. Most percussion instruments—such as the tam-tam (gong), cymbals, and maracas—do not have a definite pitch and are used for rhythm and impact, and the distinctive

timber (color) of their sound. Other percussion instruments—such as the xylophone, vibraphone, and tubular bells—are tuned to a definite pitch and can play melody, harmony, and rhythms. The xylophone and vibraphone each have two rows of bars that are arranged in a similar way to the black and white keys of a piano. Metal tubes are suspended below the bars to amplify the sound. The vibraphone has electrically operated fans that rotate in the tubes and produce a vibrato (wavering pitch) effect.

EXAMPLES OF BEATERS



SOFT-HEADED BEATER

Felt-covered head



HARD-HEADED BEATER

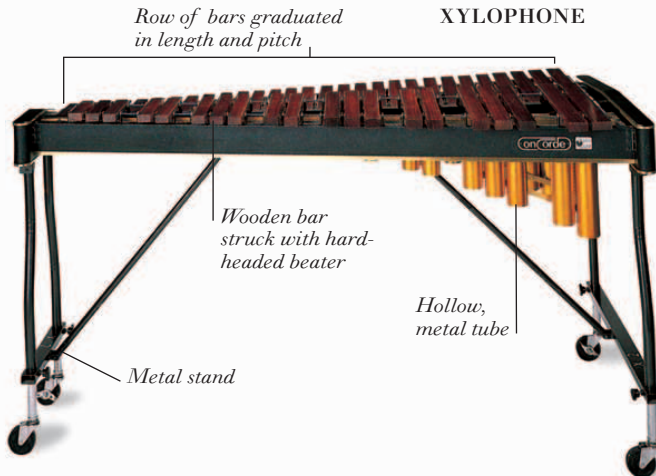
Rosewood head



MALLET

Leather-covered head

Tam-tam struck in center with soft-headed beater



XYLOPHONE

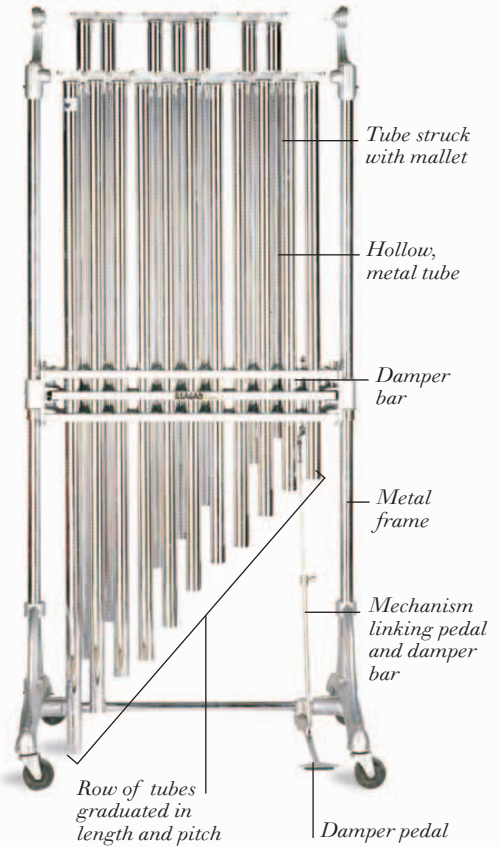
Row of bars graduated in length and pitch

Wooden bar struck with hard-headed beater

Hollow, metal tube

Metal stand

TUBULAR BELLS



Tube struck with mallet

Hollow, metal tube

Damper bar

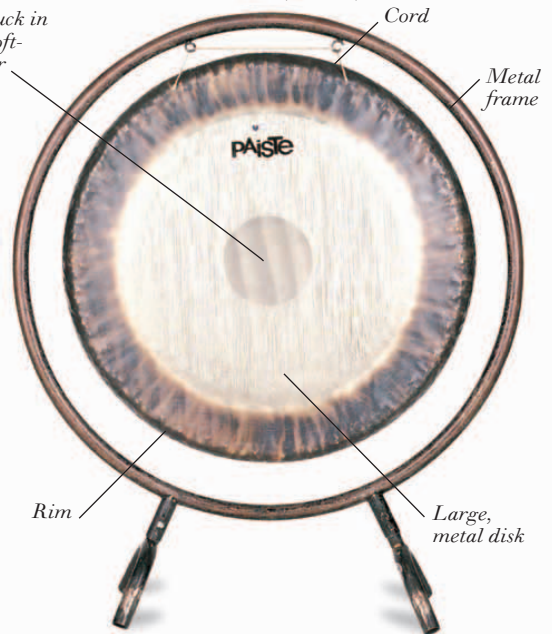
Metal frame

Mechanism linking pedal and damper bar

Row of tubes graduated in length and pitch

Damper pedal

TAM-TAM (GONG)

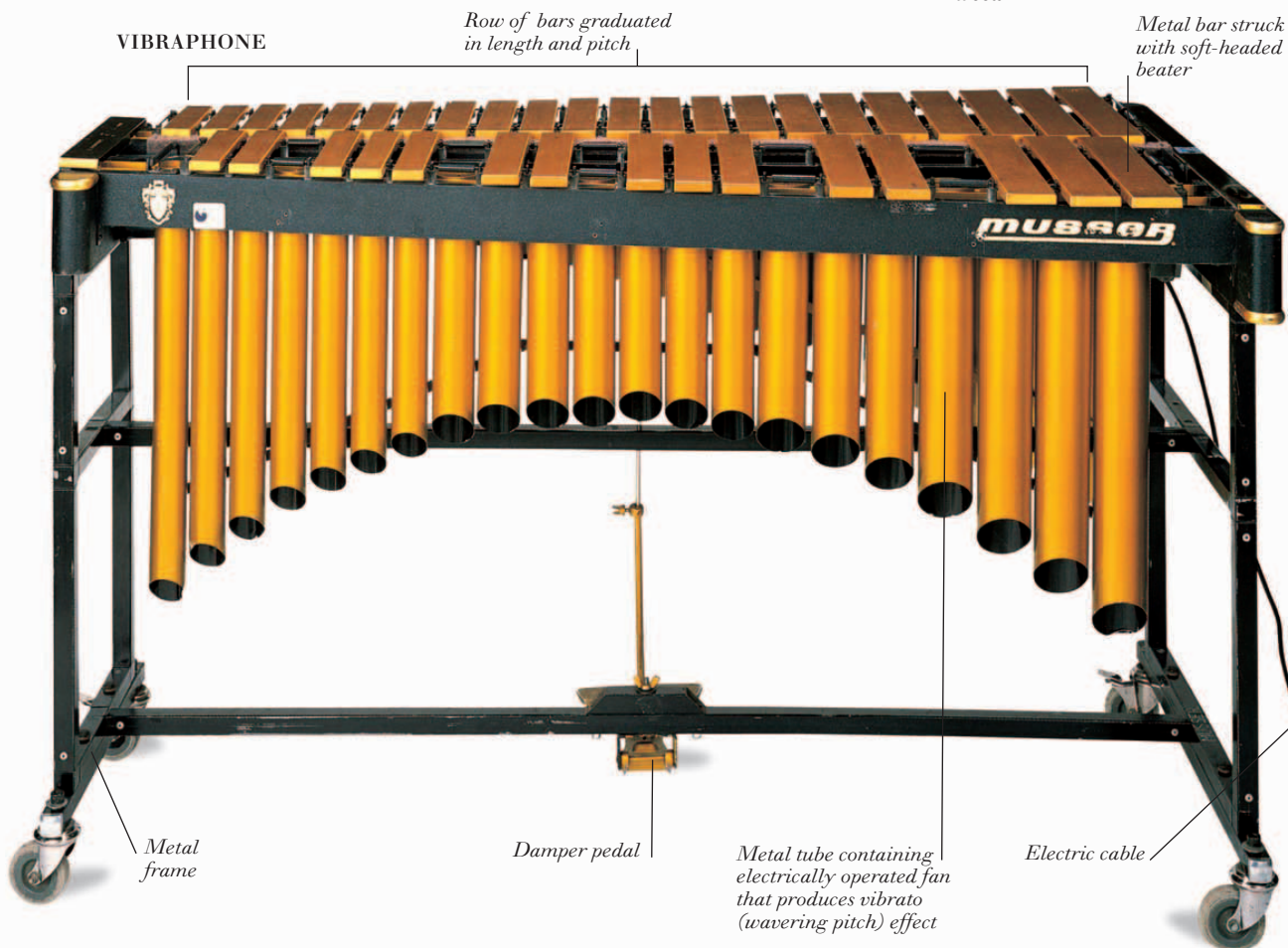
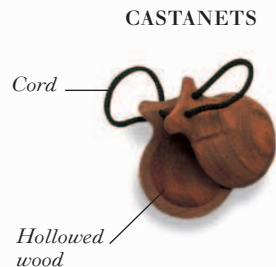
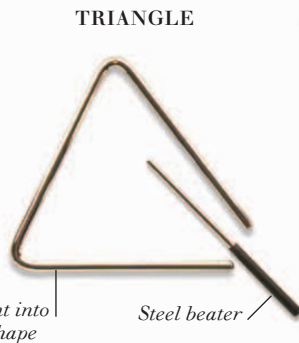
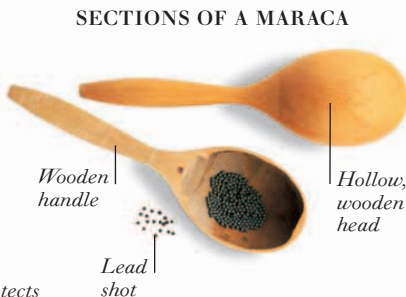
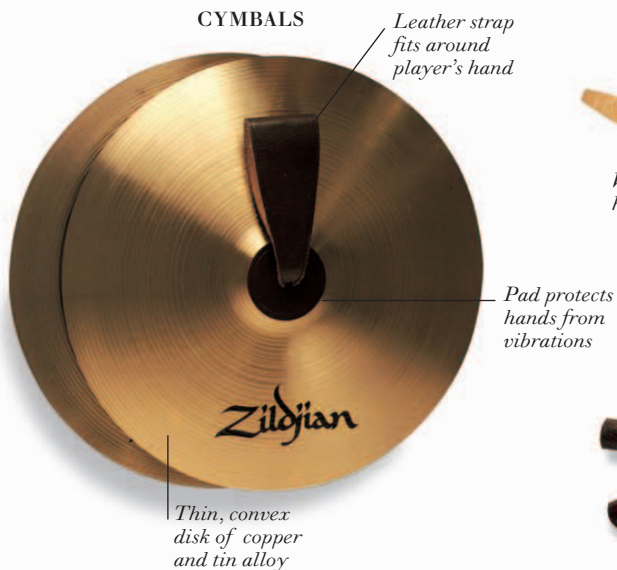


Cord

Metal frame

Rim

Large, metal disk



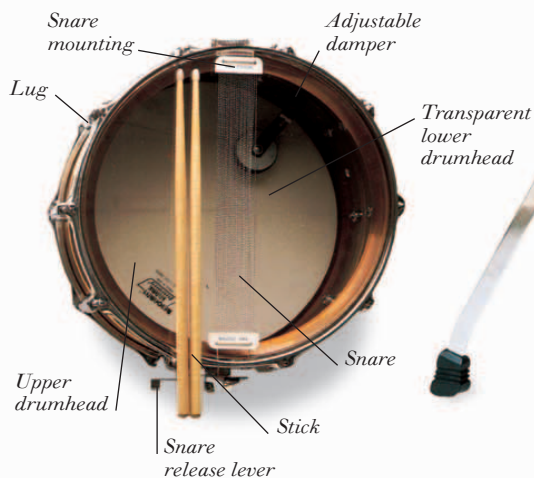
Drums

A DRUM IS a percussion instrument that consists of a drumhead, made of skin or plastic, stretched over one or both ends of a hollow vessel (the body shell). Drums are played in most parts of the world and are made in a number of different shapes and sizes. They can be divided into three

TAMBOURINE

groups according to the shape of the body-shell: frame drums (e.g., tambourines), bowl-shaped drums (e.g., timpani), and tubular drums (e.g., congas). Drums are usually sounded by striking the drumhead with the hands or with beaters, such as a hard-headed stick. The drumhead vibrates, and its vibrations are amplified by the hollow body shell. The snare drum has wires—known as snares—stretched across the lower drumhead; the snares vibrate against the lower drumhead when the drum is played. Most drums, such as congas, do not have a definite pitch and can play only rhythms (see pp. 516-517). Other drums, such as timpani, have a definite pitch and can play melody, harmony, and rhythms. They can be tuned by adjusting the tension of the drumhead. Different types of drum can be combined together with other percussion instruments to form a drum set. The basic components of the drum set are bass drum, tom-toms, floor tom (tenor drum), snare drum, and cymbals.

SNARE DRUM (VIEWED FROM BELOW)

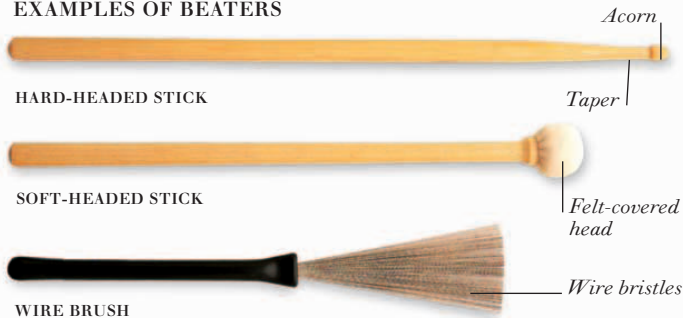


DRUM SET





EXAMPLES OF BEATERS



CONGAS



TIMPANUM (KETTLE DRUM)



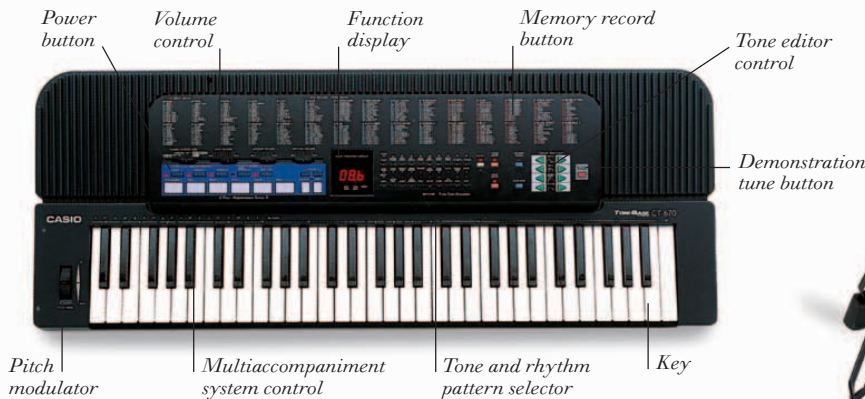
Electronic instruments

ELECTRONIC INSTRUMENTS generate electronic signals that are magnified by an amplifier and sent to a loudspeaker, where they are converted into sounds. Synthesizers, and other electronic instruments, simulate the characteristic sounds of conventional instruments, and also create entirely new sounds. Most electronic instruments are keyboard instruments, but electronic wind and percussion instruments are also popular. A digital sampler records and stores sounds from musical instruments or other sources. When the sound is played back, the pitch of the original sound can be altered. A keyboard can be connected to the sampler so that a tune can be played using the sampled sounds. With a MIDI (Musical Instrument Digital Interface) system, a computer can be linked with other electronic instruments, such as keyboards and electronic drums, to make sounds together or in sequence. It is also possible, using music software, to compose and play music on a home computer.

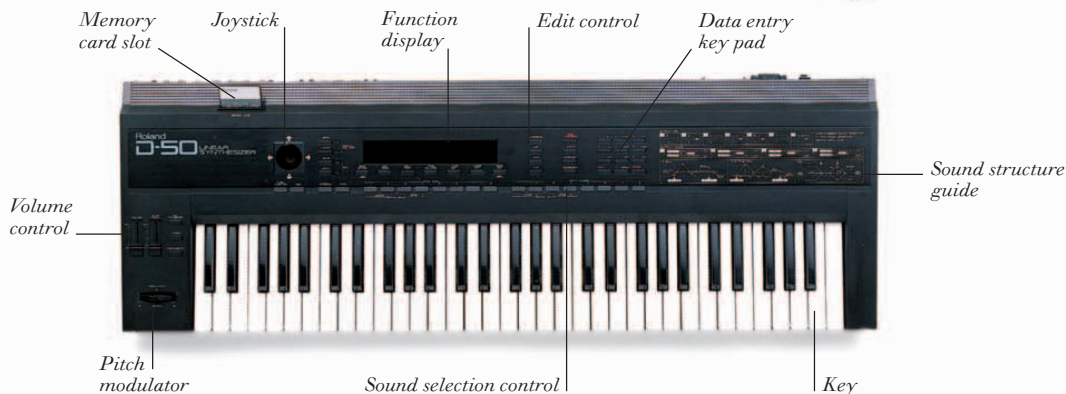
ELECTRONIC DRUMS



HOME KEYBOARD



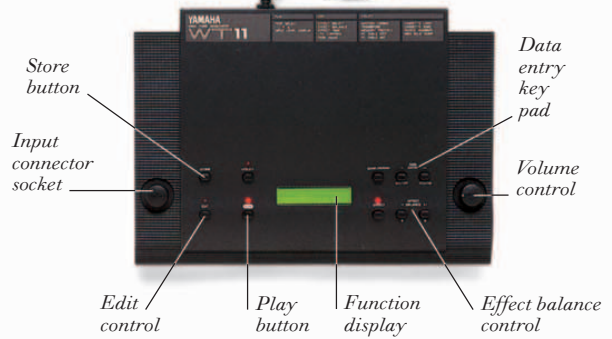
SYNTHESIZER



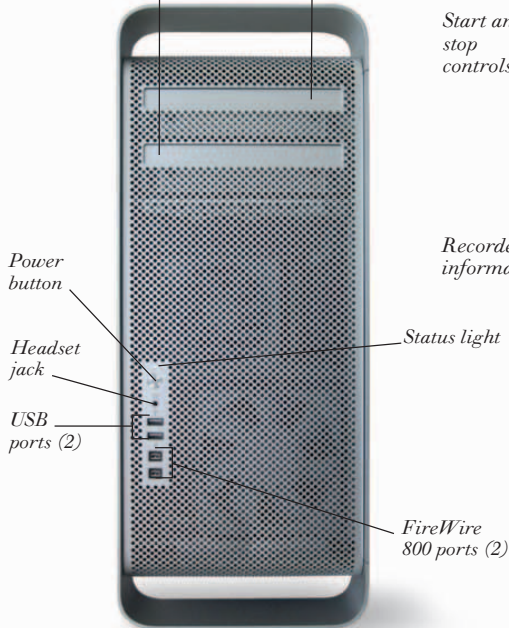
DIGITAL SAMPLER



WIND SYNTHESIZER



Second optical drive
Optical drive



SYSTEM UNIT

Audio clock settings
COMPUTER DISPLAY
Surround sound special effect plug-in



KEYBOARD

MOUSE

COMPUTER WITH MIDI AND AUDIO SOFTWARE SEQUENCER





SPORTS

SOCCER.....	524
FOOTBALL.....	526
AUSTRALIAN RULES AND GAELIC FOOTBALL.....	528
RUGBY.....	530
BASKETBALL.....	532
VOLLEYBALL, NETBALL, AND HANDBALL.....	534
BASEBALL.....	536
CRICKET.....	538
HOCKEY, LACROSSE, AND HURLING.....	540
TRACK AND FIELD.....	542
RACKET SPORTS.....	544
GOLF.....	546
ARCHERY AND SHOOTING.....	548
ICE HOCKEY.....	550
ALPINE SKIING.....	552
EQUESTRIAN SPORTS.....	554
JUDO AND FENCING.....	556
SWIMMING AND DIVING.....	558
CANOEING, ROWING, AND SAILING.....	560
ANGLING.....	562



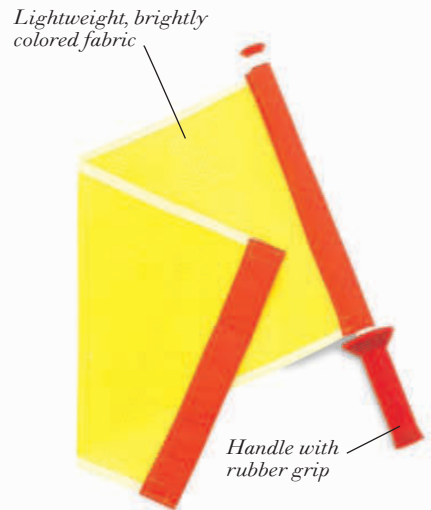
Soccer

GAMES INVOLVING KICKING A BALL have a long history and were recorded in China as early as 300 BC; in medieval Europe, street football was banned as a menace to the public; only in 1863 were the rules established, specifically banning carrying the ball for all players except the goalkeeper, and separating rugby from soccer. Soccer, officially termed association football, is a team sport in which players attempt to score goals by passing and dribbling the ball down the field past opposing defenders, and kicking or heading the ball into the goal net, outwitting the defending goalkeeper. Each team consists of 10 outfield players (defenders, midfielders, and strikers) and a goalkeeper. Players from the opposing team may challenge the player in possession of the ball, but an illegal or foul tackle results in a penalty if a foul occurs inside the penalty area or a free kick if outside the penalty area. The round ball used in soccer is more easily controlled than the oval balls used in American, Canadian, and Australian rules football and in rugby. The result is a more “open” or flowing game that is played and watched by millions of people worldwide.

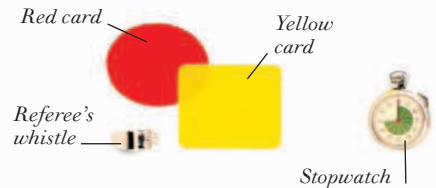
SOCCER FIELD



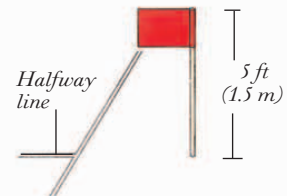
ASSISTANT REFEREE'S FLAG



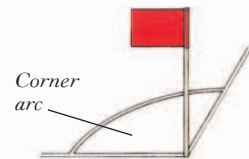
REFEREE'S EQUIPMENT



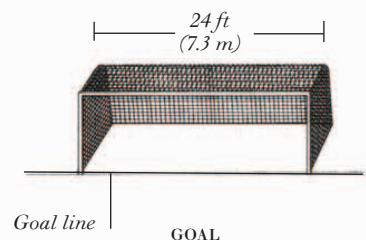
FIELD MARKINGS



HALFWAY-LINE FLAG



CORNER FLAG



GOALKEEPER



SOCCER STRIP



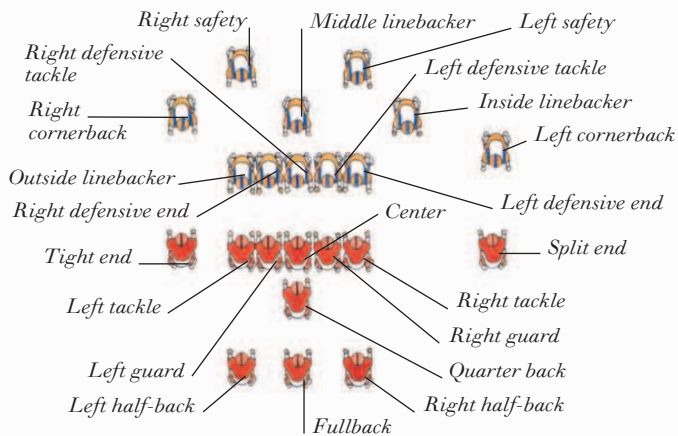
MAKING A SOCCER BALL



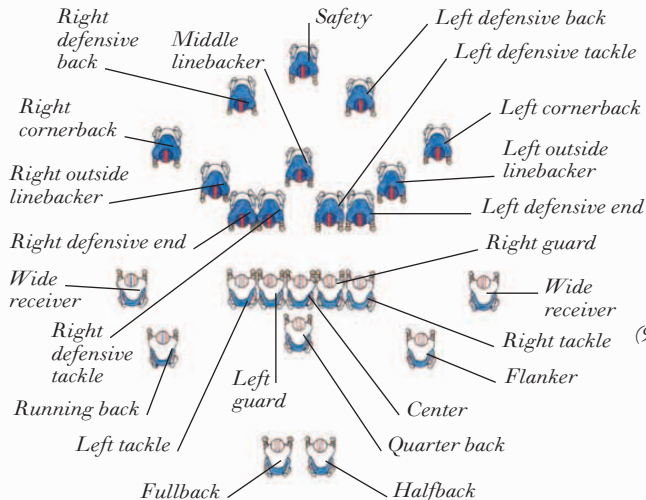
Football

IN AMERICAN AND CANADIAN FOOTBALL, the object of the game is to get the ball across the opponent's goal line, either by passing or carrying it across (a touchdown), or by kicking it between their goalposts (a field goal). An American football team has 11 players on the field at a time, although up to 40 players can appear for each side in a single game. The agile "offense" tries to score points, and the heavy hitting "defense" holds back the opposition. When in possession of the ball, a team has four chances ("downs"), to move it at least ten yards (nine meters) up the field to make a "first down." The opposition gains possession if they fail, or by tackling and intercepting the ball. Canadian football is played on a larger field, with 12 men on each side. A team has only three chances to achieve a first down. Otherwise, the game is very similar to American football. Helmets, face masks, and layers of body padding are worn by the players for protection.

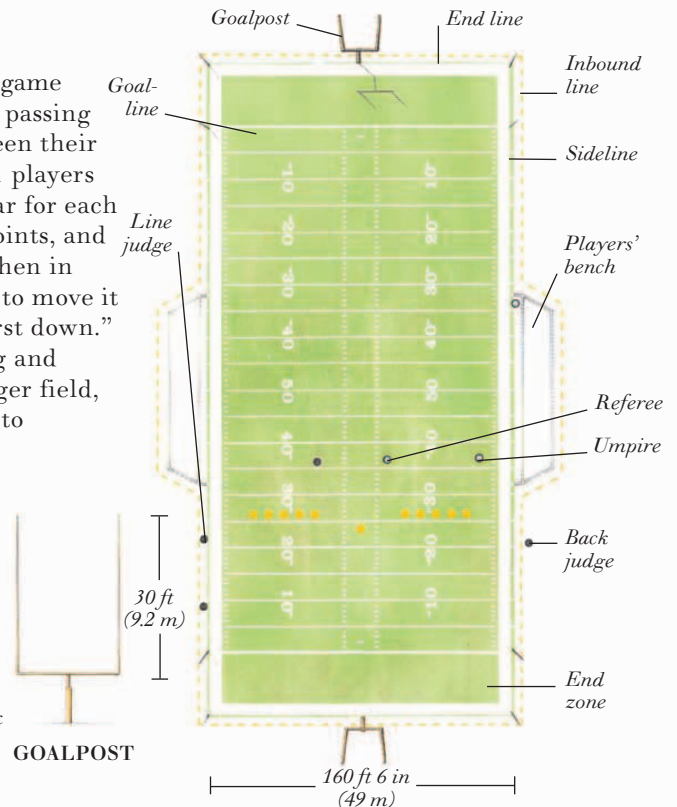
AMERICAN FOOTBALL PLAYING FORMATION



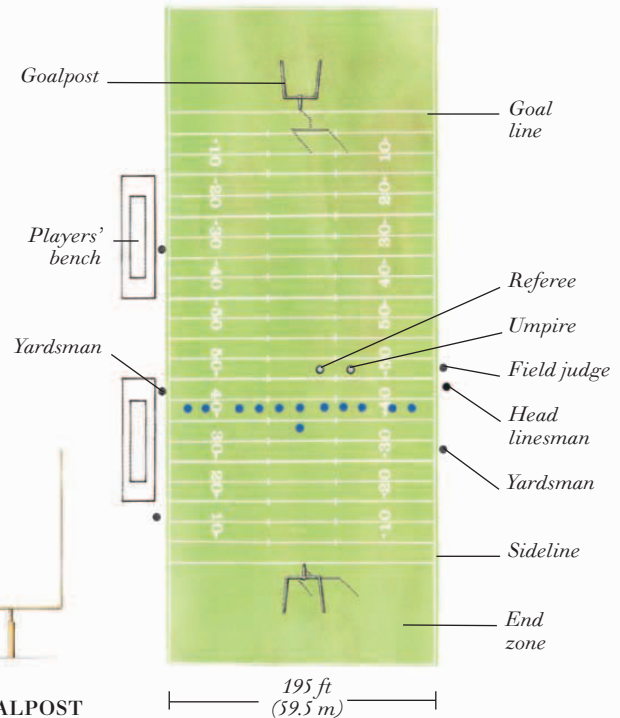
CANADIAN FOOTBALL PLAYING FORMATION

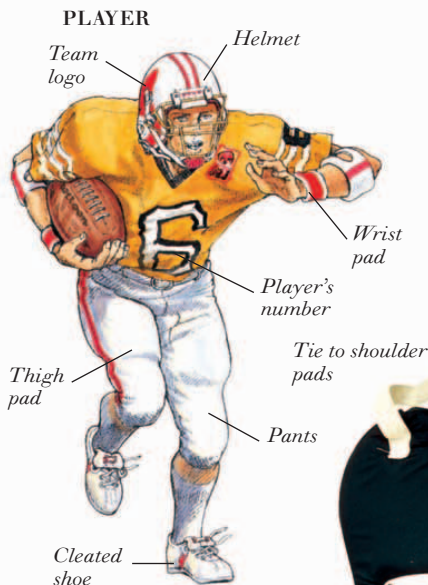


FOOTBALL FIELD



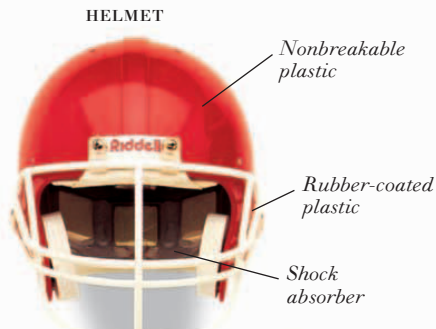
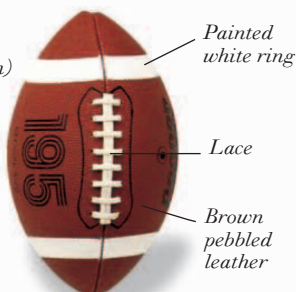
CANADIAN FOOTBALL FIELD





PROTECTIVE EQUIPMENT

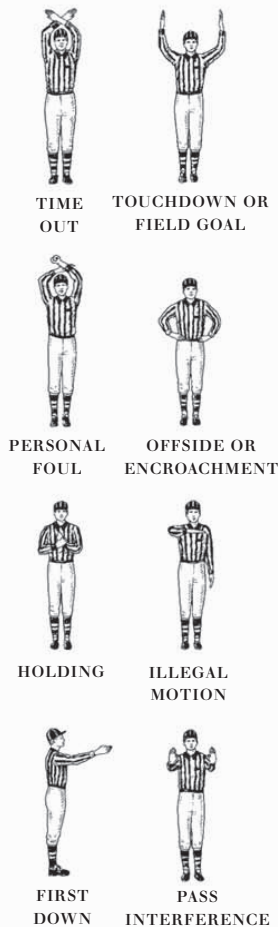
11 in
(28 cm)



Tie to shoulder pads



REFEREE'S SIGNALS



UPPER ARM PAD



Rigid plastic covering

Fold-over leather tongue

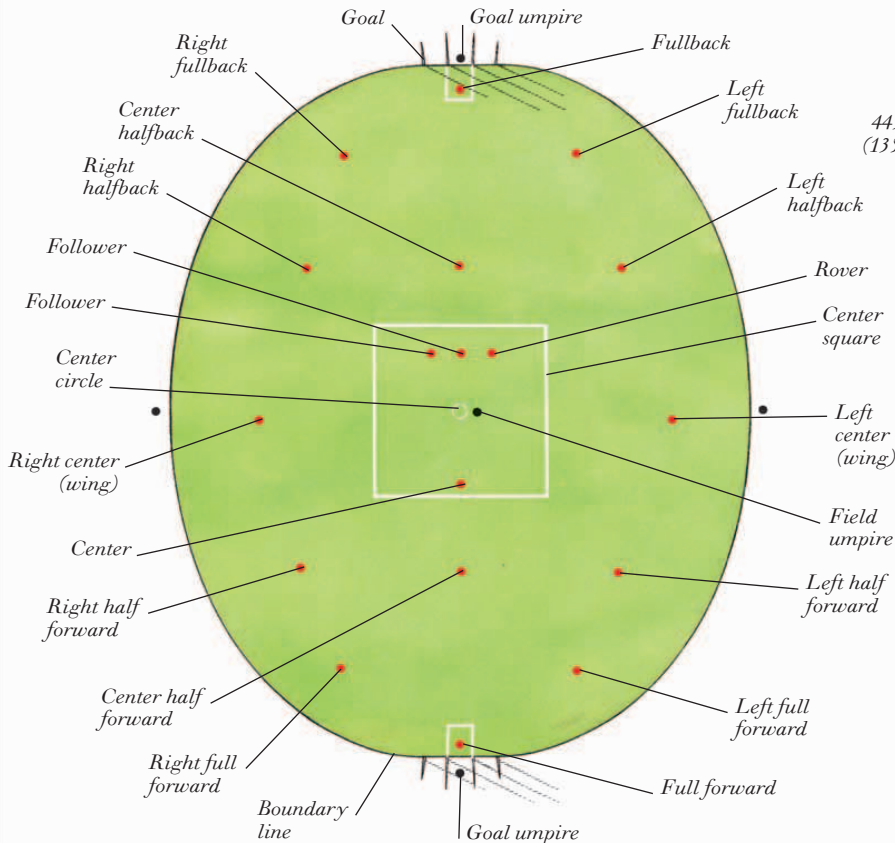
RIB PADS



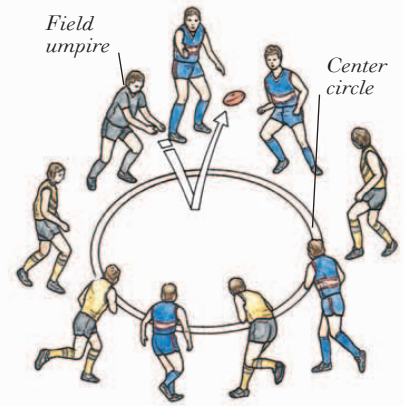
Australian rules and Gaelic football

VARIETIES OF FOOTBALL have developed all over the world and Australian rules football is considered to be one of the roughest versions, allowing full body tackles even though participants wear no protective padding. The game is played on a large, oval field by two sides, each of 18 players. Players can kick or punch the ball, which is shaped like a rugby ball, but cannot throw it. Running with the ball is permitted, as long as the ball touches the ground at least once every 10 meters. The fullbacks defend two sets of posts. Teams try to score “goals” (six points) between the inner posts or “behinds” (one point) inside the outer posts. Each game has four quarters of 25 minutes, and the team with the most points at the end of the allotted time is the winner. In Gaelic football, an Irish version of soccer (see pp. 524–525), a size 5 soccer ball is used. Each team can have 15 players on the field at a time. Players are allowed to catch, fist, and kick the ball, or dribble it using their hands or feet, but cannot throw it. Teams are awarded three points for getting the ball into the net, and one point for getting it through the posts above the crossbar. Gaelic football is rarely played outside of Ireland.

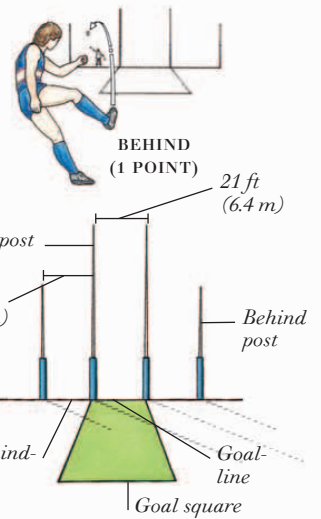
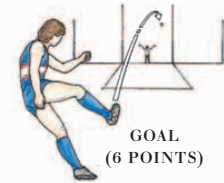
AUSTRALIAN RULES FOOTBALL FIELD



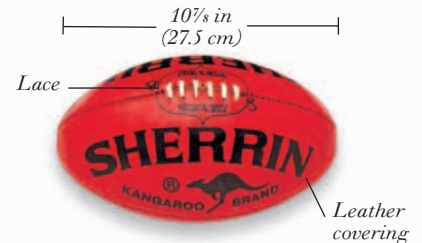
START OF PLAY



SCORING



GOALPOSTS



AUSTRALIAN RULES FOOTBALL

AUSTRALIAN RULES FOOTBALL SKILLS



RUNNING WITH THE BALL



KICKING



TACKLING



TAKING A MARK



PASSING THE BALL

AUSTRALIAN RULES FOOTBALL UNIFORM



Australian Football League logo

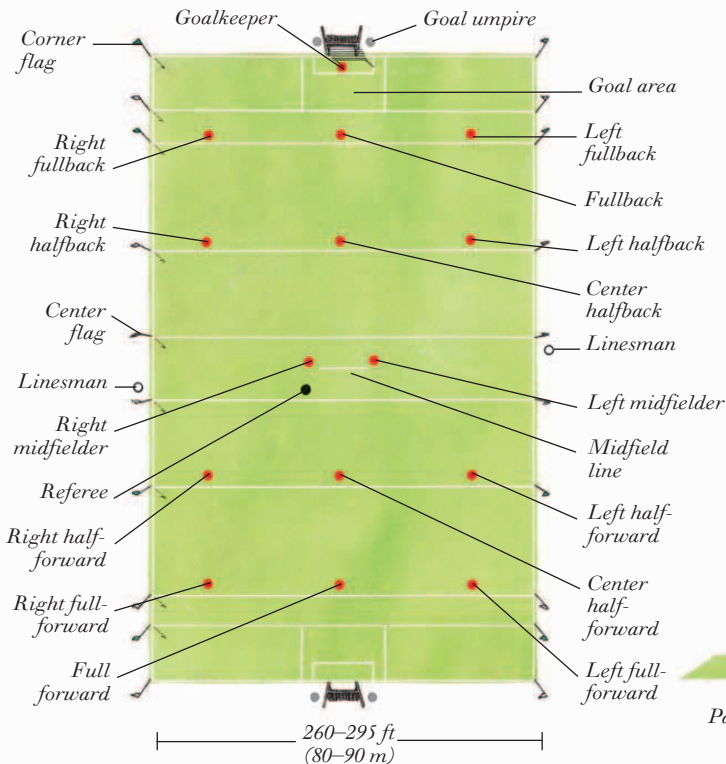
Team colors

Sleeveless team jersey

Sock

Shorts

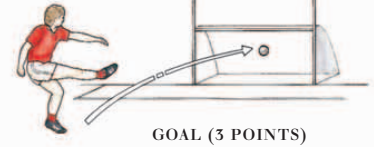
GAELIC FOOTBALL FIELD



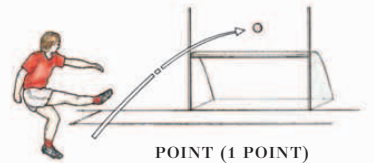
CONTROLLING THE BALL



SCORING IN GAELIC FOOTBALL

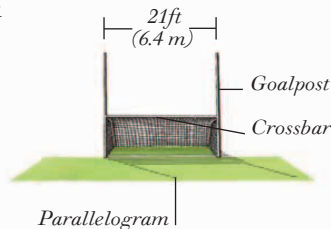


GOAL (3 POINTS)



POINT (1 POINT)

8½–9 in (22–23 cm)



Parallelogram

GOAL

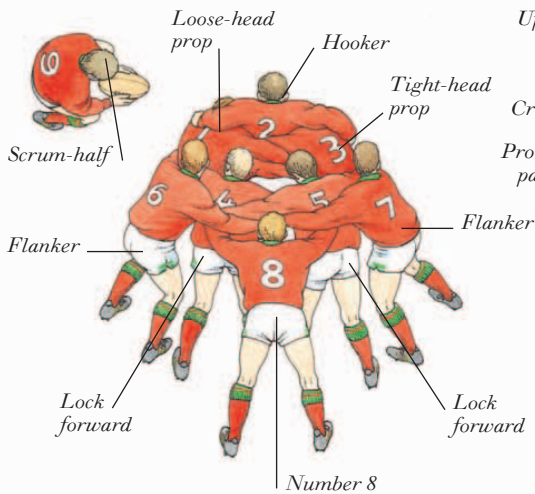


GAELIC FOOTBALL

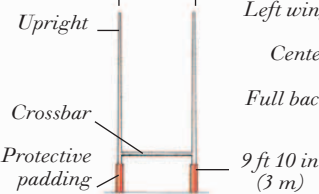
Rugby

RUGBY IS PLAYED WITH AN OVAL BALL, which may be carried, thrown, or kicked. There are two codes of rugby, both played at amateur and professional levels. Rugby Union is played by two teams of 15 players. They can score points in two ways: by placing the ball by hand over the opponents' goal line (a try, scoring four points) or by kicking it over the crossbar of the opponent's goal (a conversion of a try, scoring two points; a penalty kick, scoring three points; or a dropkick, scoring three points). Rugby League developed from the Union game but is played by 13 players. In League games, a try scores four points; a conversion scores two points; a drop goal scores one point, and a penalty kick scores two points. Scrummages occur in both codes when play stops following an infringement.

RUGBY UNION SCRUMMAGE

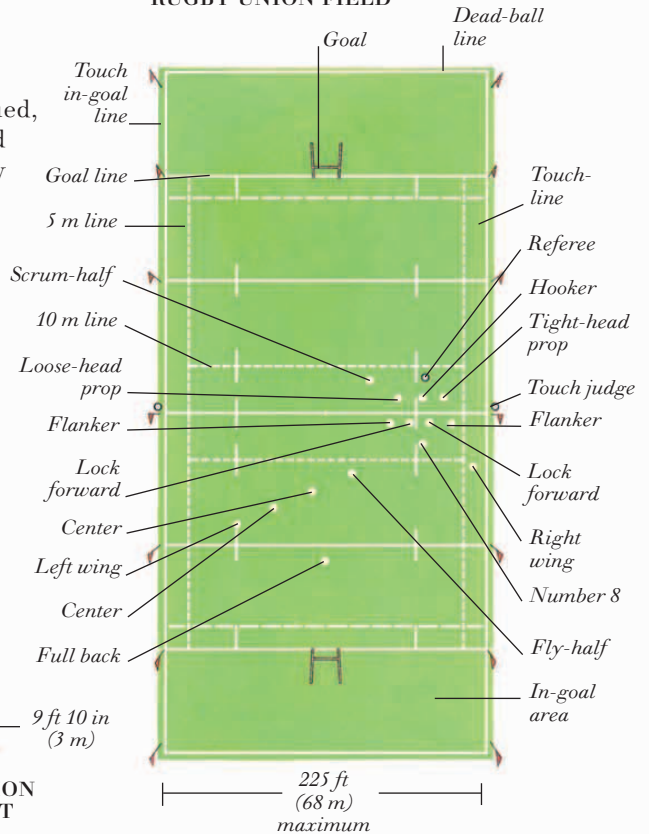


18 ft
(5.5 m)

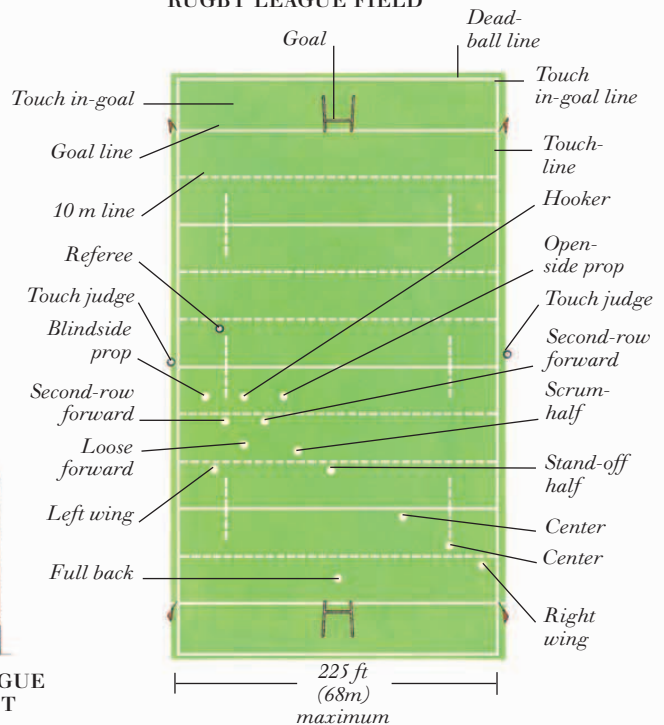


RUGBY UNION
GOALPOST

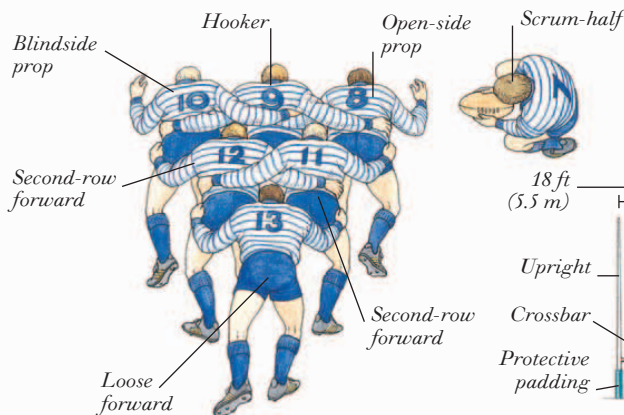
RUGBY UNION FIELD



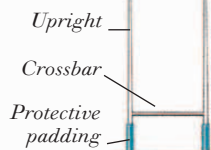
RUGBY LEAGUE FIELD



RUGBY LEAGUE SCRUMMAGE



18 ft
(5.5 m)



RUGBY LEAGUE
GOALPOST

RUGBY SCORING AND SKILLS



GOAL



TRY



PASS

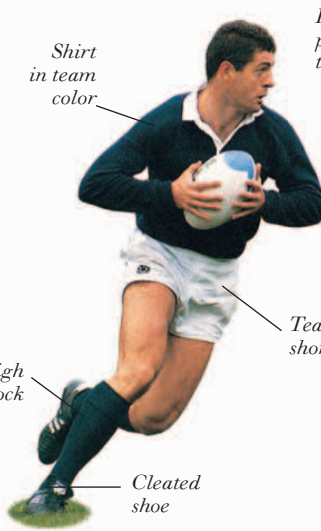


PLACE KICK



FLYING TACKLE

RUGBY UNION PLAYER



Shirt in team color

Knee-high sock

Cleated shoe

Team shorts

RUGBY UNION BALL

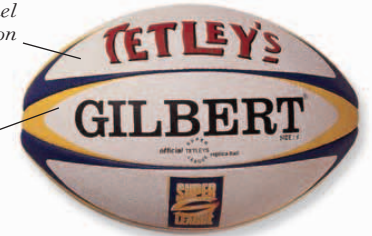


Laminated leather panel covered with textured plastic

Four-panel construction

11-12 in (28-30 cm)

RUGBY LEAGUE BALL



Eight-panel construction

Laminated leather panel covered with textured plastic

11 in (28 cm)

RUGBY LEAGUE SHIRT

Button-up collar

Team crest

Short sleeve



RUGBY UNION SHIRT

Team crest



Ankle support

Circular cleat

RUGBY SHOE

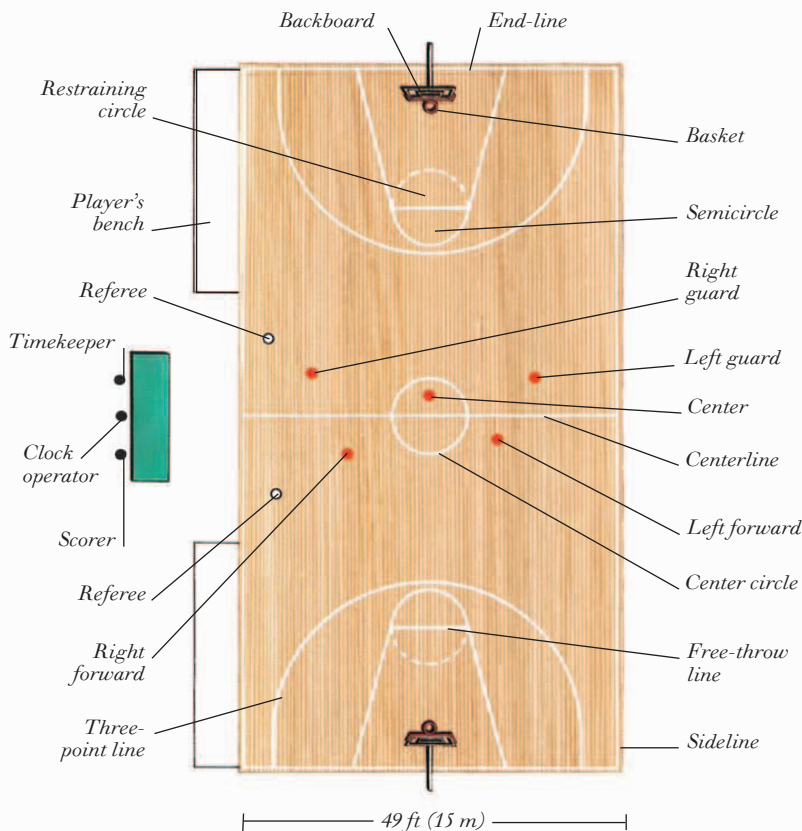
Team color

RUGBY SHIRTS

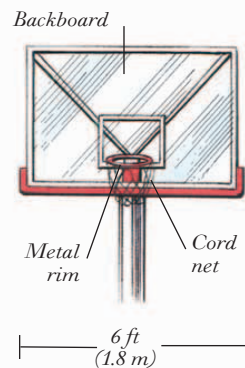
Basketball

BASKETBALL IS A BALL GAME for two teams of five players, originally devised in 1890 by James Naismath for the Y.M.C.A. in Springfield, Massachusetts. The object of the game is to take possession of the ball and score points by throwing the ball into the opposing team's basket. A player moves the ball up and down the court by bouncing it along the ground or "dribbling"; the ball may be passed between players by throwing, bouncing, or rolling. Players may not run with or kick the ball, although pivoting on one foot is allowed. The game begins with the referee throwing the ball into the air and a player from each team jumping up to try and "tip" the ball to a teammate. The length of the game and the number of periods played varies at different levels. There are amateur, professional, and international rules. No game ends in a draw. An extra period of five minutes is played, plus as many extra periods as are necessary to break the tie. In addition to the five players on court, each team has up to seven substitutes, but players may only leave the court with the permission of the referee. Basketball is a noncontact sport and fouls on other players are penalized by a throw-in awarded against the offending team; a free throw at the basket is awarded when a player is fouled in the act of shooting. Basketball is a fast-moving game, requiring both physical and mental coordination. Skillful tactical play matters more than simple physical strength and the agility of the players makes the game an excellent spectator sport.

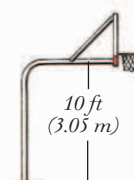
INTERNATIONAL BASKETBALL COURT



BASKET AND BACKBOARD



BASKET AND BACKBOARD STRUCTURE



BASKETBALL SKILLS



CHEST PASS



DRIBBLE



OVERHEAD PASS



LAY-UP SHOT

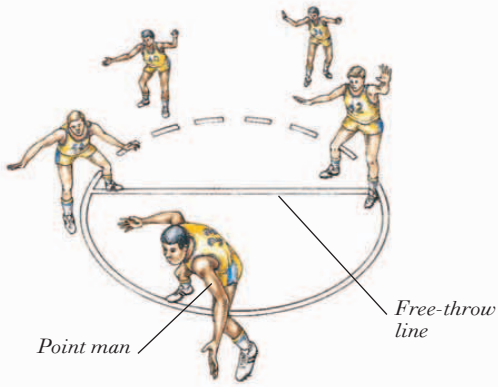


JUMP SHOT

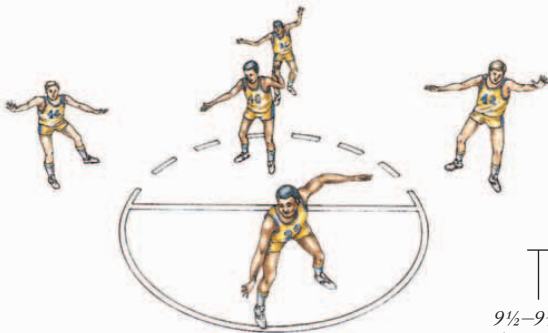


LONG PASS

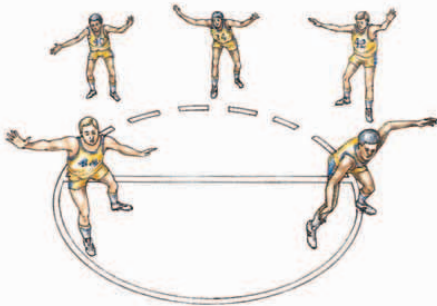
ZONE DEFENSES



1-2-2 ZONE



1-3-1 ZONE



2-3 ZONE

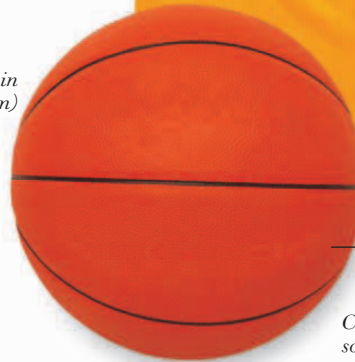
9½-9¼ in
(24-5 cm)

BASKETBALL JERSEY

Cool,
lightweight
fabric

Team name

Player's
number

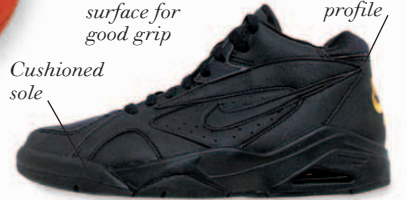


BASKETBALL

Textured
surface for
good grip

Cushioned
sole

Low heel
profile



BASKETBALL SHOE

INTERNATIONAL
REFEREE'S
SIGNALS



TECHNICAL
FOUL



INTENTIONAL
FOUL



JUMP BALL



STOP CLOCK
FOR FOUL



SUBSTITUTION



PERSONAL FOUL:
NO FREE THROWS



TRAVELLING



ILLEGAL
DRIBBLE



CHARGING WITH
THE BALL



ONE FREE
THROW

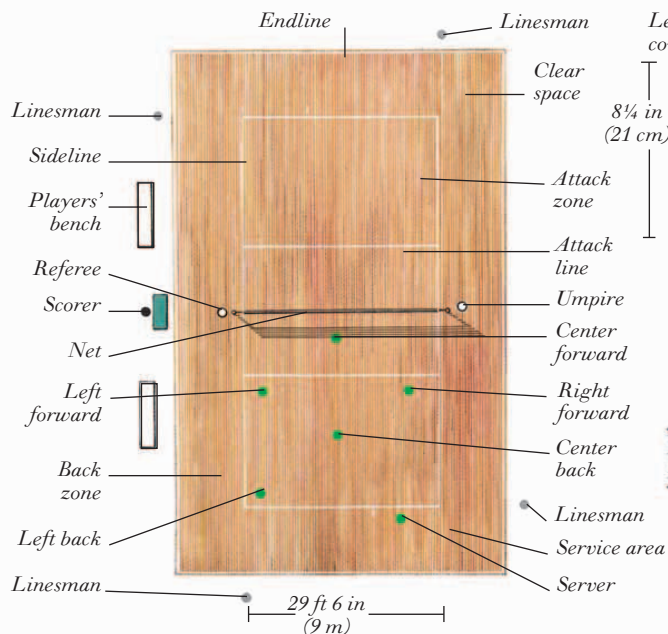


STOP CLOCK

Volleyball, netball, and handball

VOLLEYBALL, NETBALL, AND HANDBALL are fast-moving team sports played with balls on courts with a hard surface. In volleyball, the object of the game is to hit the ball over a net strung across the center of the court so that it touches the ground on the opponent's side. The team of six players can take three hits to direct the ball over the net, although the same player cannot hit the ball twice in a row. Players can hit the ball with their arms, hands, or any other part of their upper body. Teams score points only while serving. The first team to score 15 points, with a two-point margin over their opponent, wins the game. Netball is one of the few sports played exclusively by women. Similar to basketball (see pp. 532–533), it is played on a slightly larger court with seven players instead of five. A team moves the ball toward the goal by throwing, passing, and catching it with the aim of throwing the ball through the opponents' goal net. Players are confined by their playing position to specific areas of the court. Team handball is one of the world's fastest games. Each side has seven players. A team moves the ball by dribbling, passing, or bouncing it as they run. Players may stop, catch, throw, bounce, or strike the ball with any part of the body above the knees. Each team tries to score goals by directing the ball past the opposition's goalkeeper into the net, which is similar to a soccer net.

VOLLEYBALL COURT



VOLLEYBALL SHOTS



OVERHAND SERVE

SPIKE (SMASH)

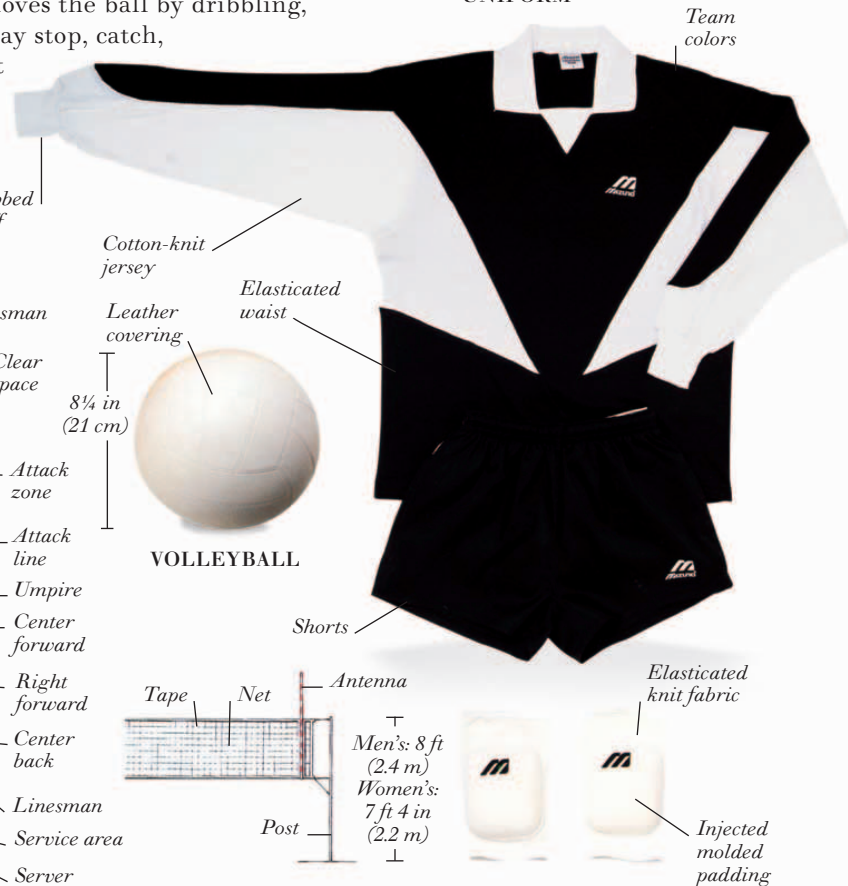


UNDERHAND SERVE



FOREARM PASS (DIG)

UNIFORM

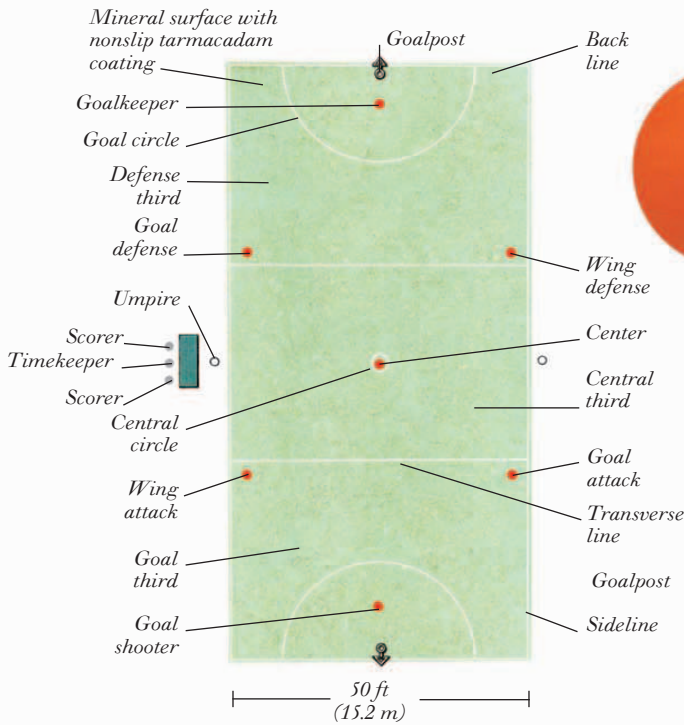


VOLLEYBALL

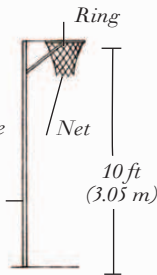
VOLLEYBALL NET

KNEE PADS

NETBALL COURT



NETBALL

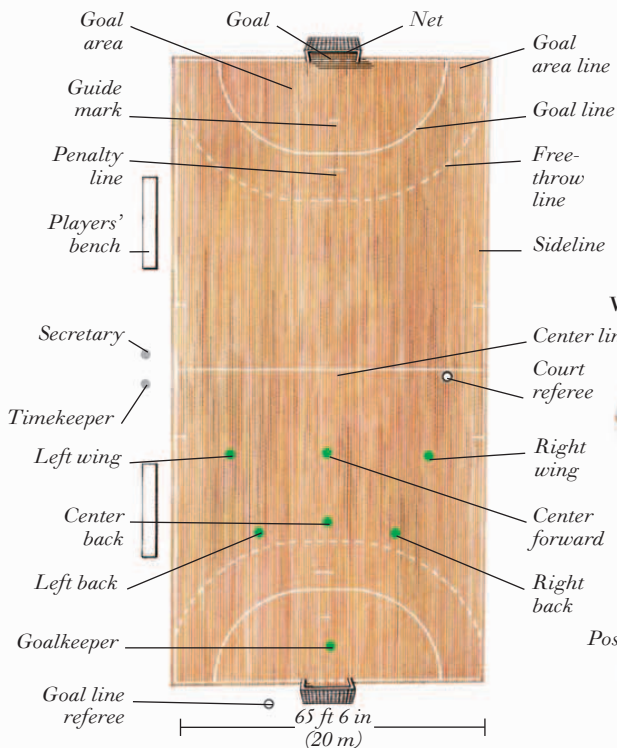


NETBALL GOALPOST AND NET

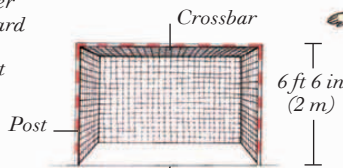
NETBALL PASSES



HANDBALL COURT



HANDBALL
MEN'S: 7 1/2 IN (18.8 CM)
WOMEN'S: 7 IN (17.5 CM)



HANDBALL NET

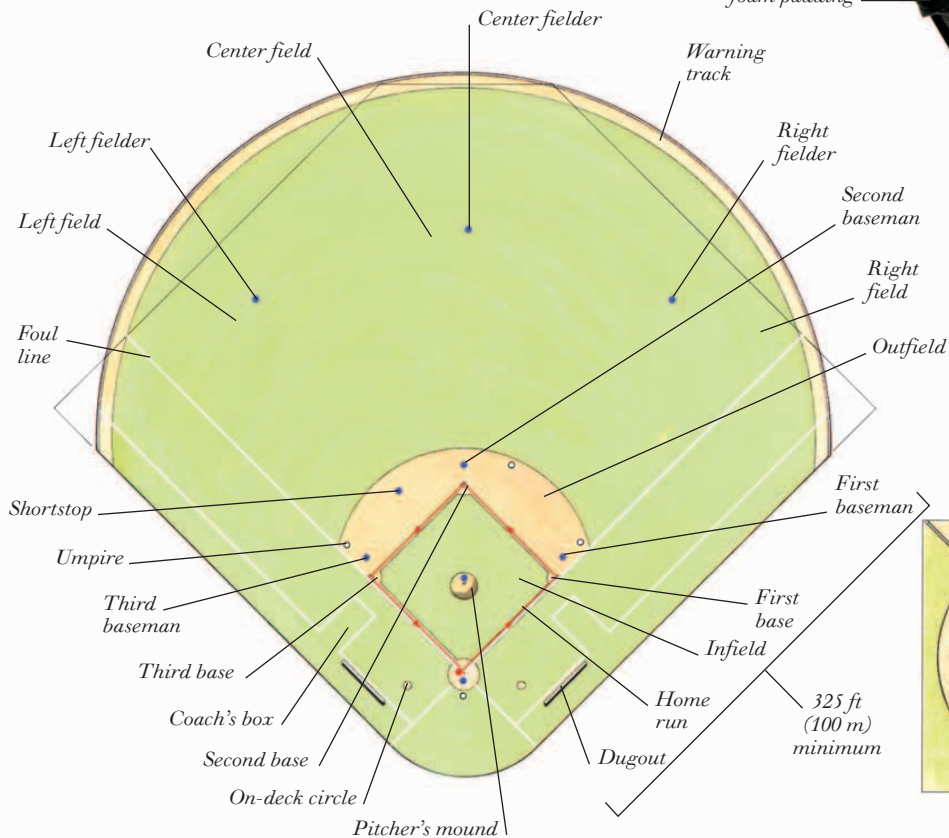
HANDBALL SKILLS



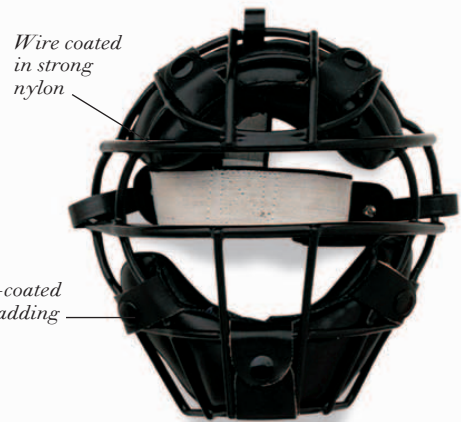
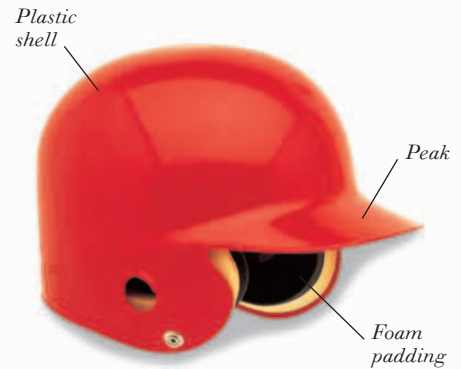
Baseball

BASEBALL IS A BALL GAME for two teams of nine players. The batter hits the ball thrown by the opposing team's pitcher, into the area between the foul lines. He then runs around all four fixed bases in order to score a run, touching or "tagging" each base in turn. The pitcher must throw the ball at a height between the batter's armpits and knees, a height which is called the "strike zone." A ball pitched in this area that crosses over the "home plate" is called a "strike" and the batter has three strikes in which to try and hit the ball (otherwise he is "struck out"). The fielding team tries to get the batting team out by catching the ball before it bounces, tagging a player of the batting team with the ball who is running between bases, or by tagging a base before the player has reached it. Members of the batting team may stop safely at a base as long as it is not occupied by another member of their team. When the batter runs to first base, his teammate at first base must run on to second—this is called "force play." A game consists of nine innings and each team will bat once during an inning. When three members of the batting team are out, the teams swap roles. The team with the greatest number of runs wins the game.

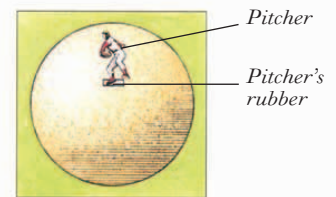
BASEBALL FIELD



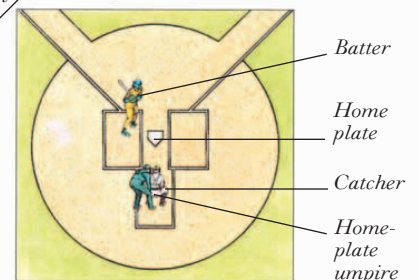
BATTER'S HELMET



CATCHER'S MASK



PITCHER'S MOUND

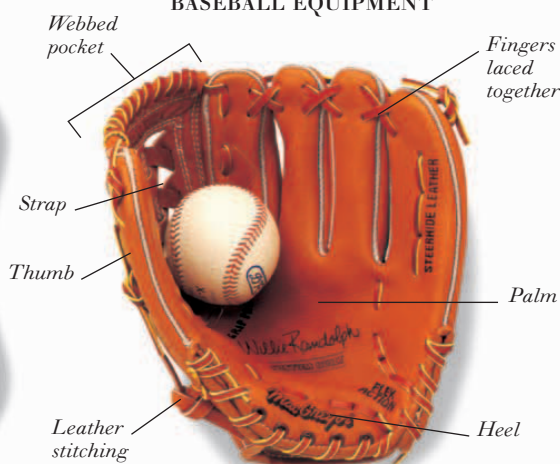


HOME PLATE

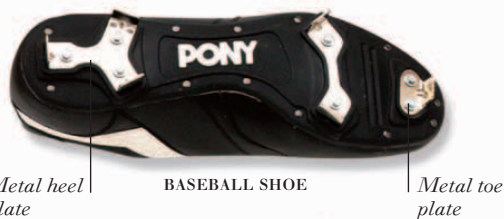
MAKING A BASEBALL



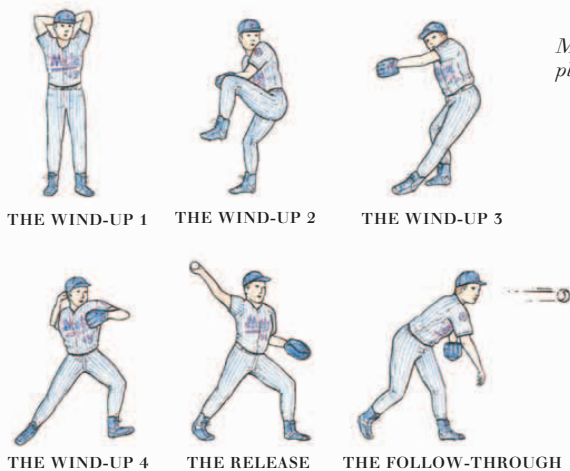
BASEBALL EQUIPMENT



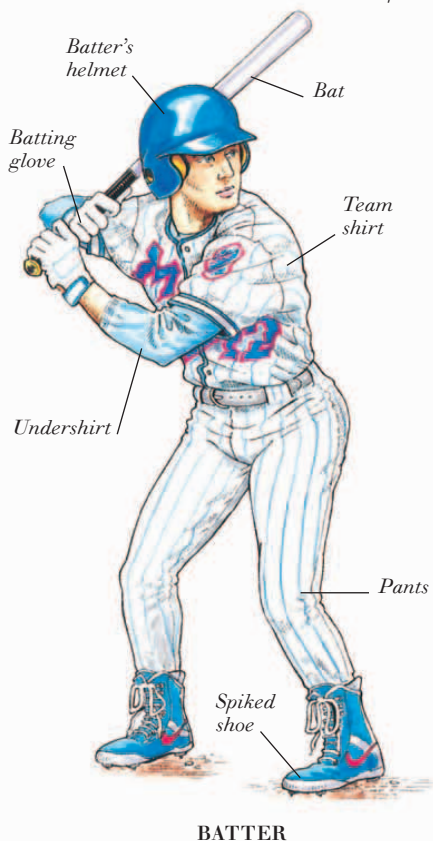
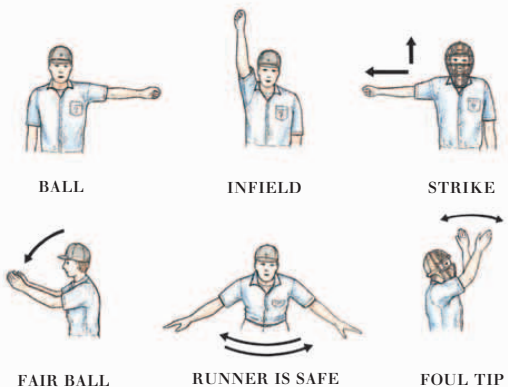
FIELDER'S GLOVE AND BALL



THE PITCHING SEQUENCE



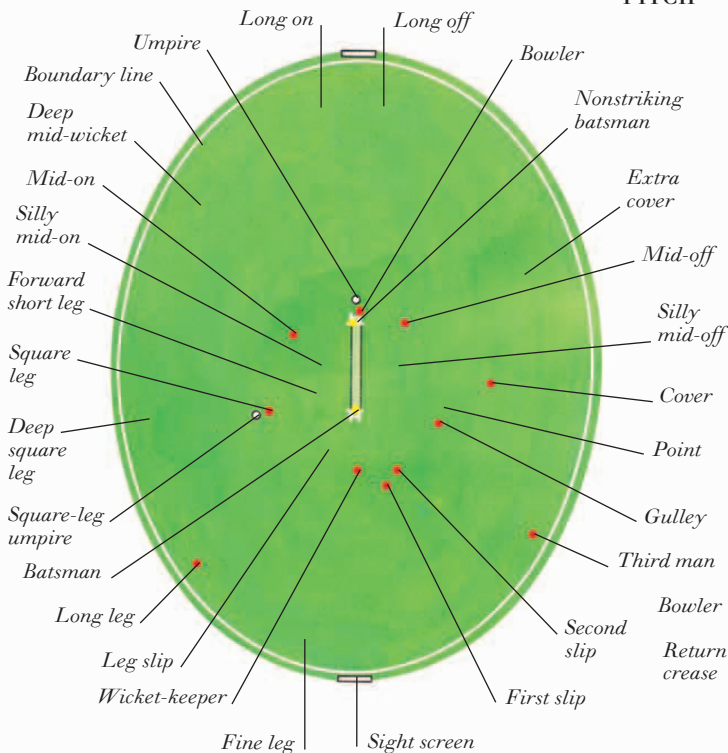
UMPIRING SIGNALS



Cricket

CRICKET IS A BALL GAME PLAYED by two teams of eleven players on a pitch with two sets of three stumps (wickets). The bowler bowls the ball down the pitch to the batsman of the opposing team, who must defend the wicket in front of which he stands. The object of the game is to score as many runs as possible. Runs can be scored individually by running the length of the playing strip, or by hitting a ball that lands outside the boundary ("six"), or that lands inside the boundary but bounces or rolls outside ("four"); the opposing team will bowl and field, attempting to dismiss the batsmen. A batsman can be dismissed in one of several ways: by the bowler hitting the wicket with the ball ("bowled"); by a fielder catching the ball hit by the batsman before it touches the ground ("caught"); by the wicket-keeper or another fielder breaking the wicket while the batsman is attempting a run and is therefore out of his ground ("stumped" or "run out"); by the batsman breaking the wicket with his own bat or body ("hit wicket"); by a part of the batsman's body being hit by a ball that would otherwise have hit the wicket ("leg before wicket" ["lbw"]). A match consists of one or two innings and each inning ends when the tenth batsman of the batting team is out, when a certain number of overs (a series of six balls bowled) have been played, or when the captain of the batting team "declares" ending the innings voluntarily.

POSSIBLE FIELD POSITIONS FOR AN AWAY SWING BOWLER TO A RIGHT-HANDED BATSMAN (IN RED) AND OTHER FIELD POSITIONS



CRICKET STROKES



FORWARD DEFENSIVE STROKE



BACKWARD DEFENSIVE STROKE



ON-DRIVE



OFF-DRIVE



PULL



HOOK

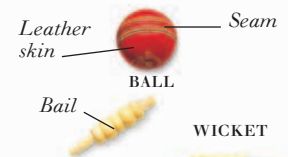


SQUARE CUT



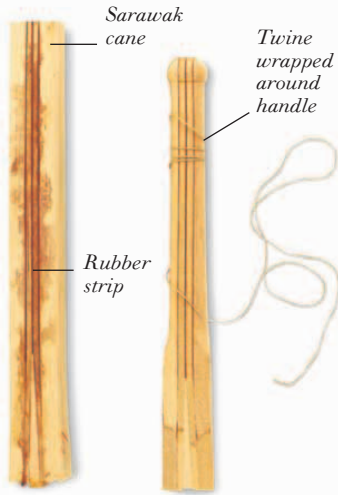
LEG GLANCE

CRICKET BALL AND WICKET



Stump

MAKING A BAT HANDLE

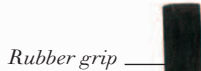


PROTECTIVE CLOTHING



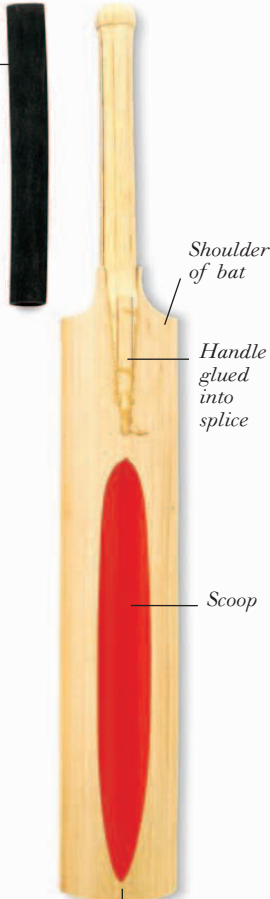
LAMINATING THE WOOD

BINDING THE HANDLE

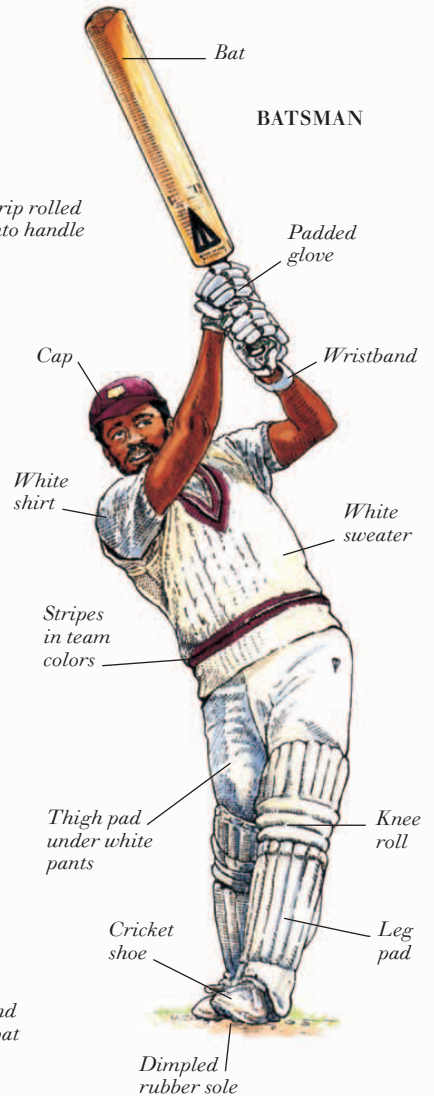


ADDING THE HANDLE TO THE BAT

MAKING A BAT BLADE



BATSMAN



SEASONING THE TIMBER

CUTTING THE SPLICE

FITTING THE HANDLE

FINISHING TOUCHES

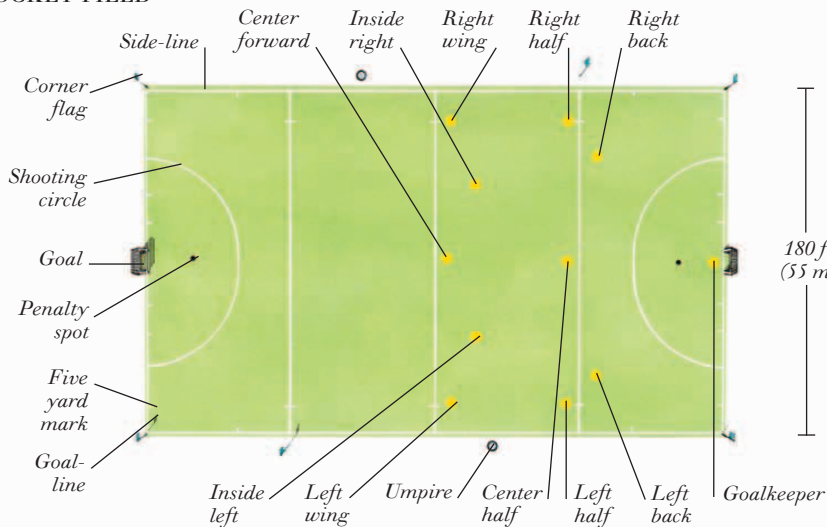
Field hockey, lacrosse, and hurling

ALL OVER THE WORLD, TEAM GAMES have evolved that require that a ball be struck or carried, and tossed at the end of a stick. Early forms of these games include hurling, shinty, bandy, and pelota. Field hockey is played by men and women: two teams of 11 players try to gain and keep possession of the ball and score goals by using the hockey stick to propel the ball into their opponents' goal net. Skills such as passing, pushing, or hitting the ball by slapping or lifting it in a flicking movement, and shooting at goal are crucial. Hockey is played indoors and outdoors on grass or synthetic fields. Lacrosse is played internationally as a 12-a-side game for women and as 10-a-side game for men. The women's field has no absolute boundaries but the men's field has clearly defined side-lines and end-lines. The ball is kept in play by being carried, thrown, or batted with the crosse, and rolled or kicked in any direction. In men's and women's lacrosse, play can continue behind the marked goal areas. Similar skills are required in hurling—a Gaelic field game played on the same field as Gaelic football (see pp. 528–529), using the same goalposts and net. In hurling, the ball may be struck with or carried on the hurley and, when off the ground, may be struck with the hand or kicked. Goals (three points) are scored when the ball passes between the posts and under the crossbar; one point is scored when it passes between the posts and over the crossbar.

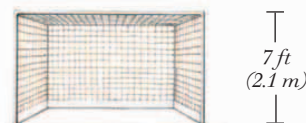
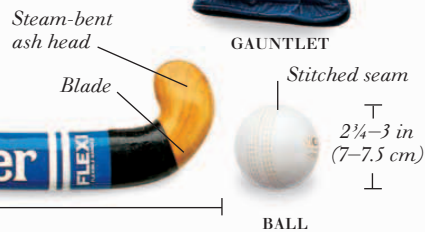
HOCKEY STICK AND BALL



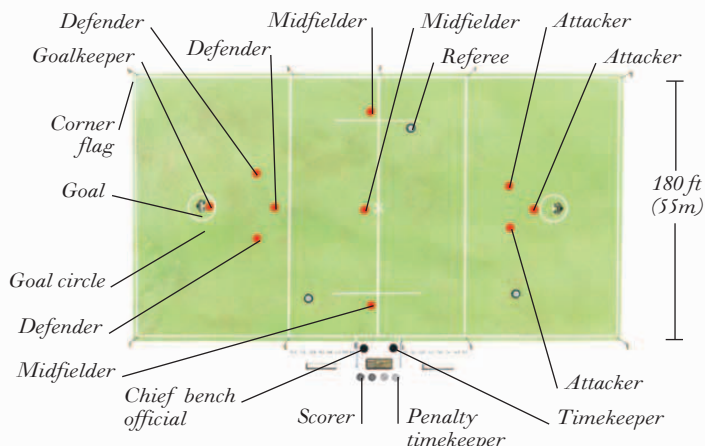
HOCKEY FIELD



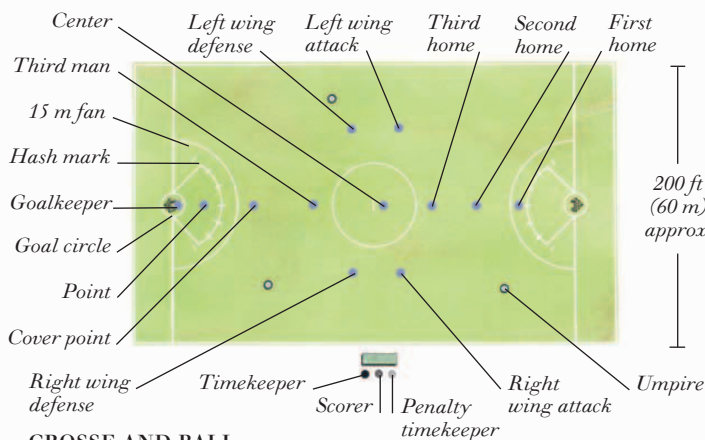
GOALKEEPER'S EQUIPMENT



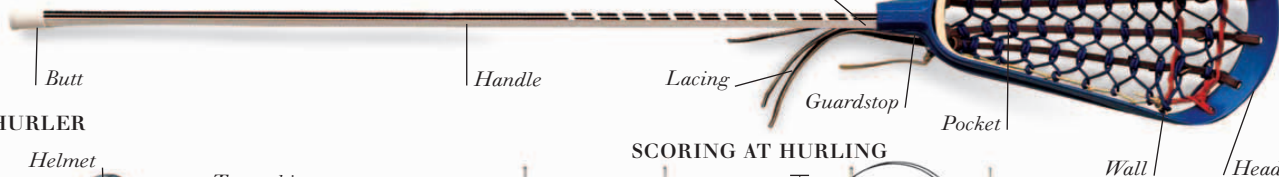
MEN'S LACROSSE FIELD



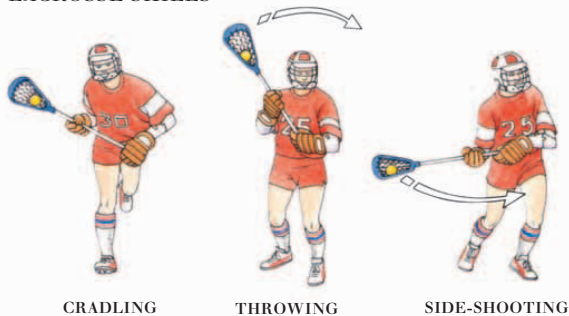
WOMEN'S LACROSSE FIELD



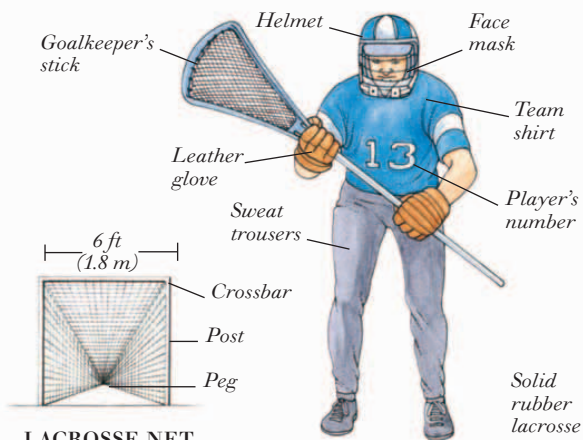
CROSSE AND BALL



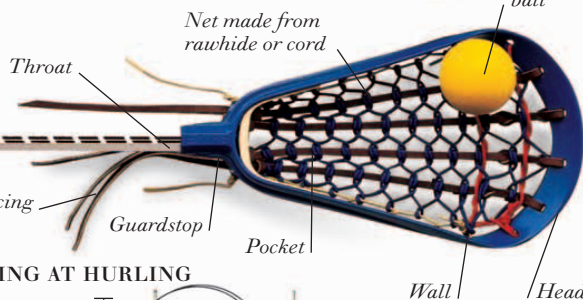
LACROSSE SKILLS



LACROSSE GOALKEEPER



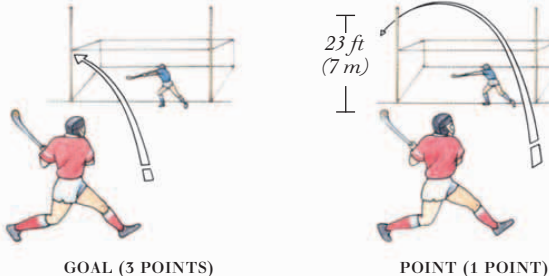
LACROSSE NET



HURLER



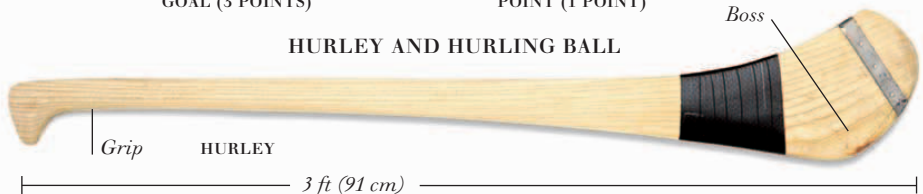
SCORING AT HURLING



Leather cover around a cork center



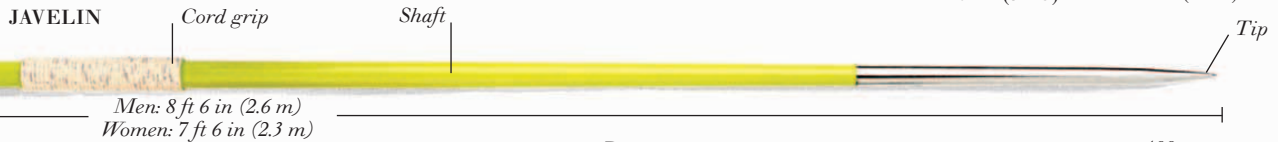
HURLEY AND HURLING BALL



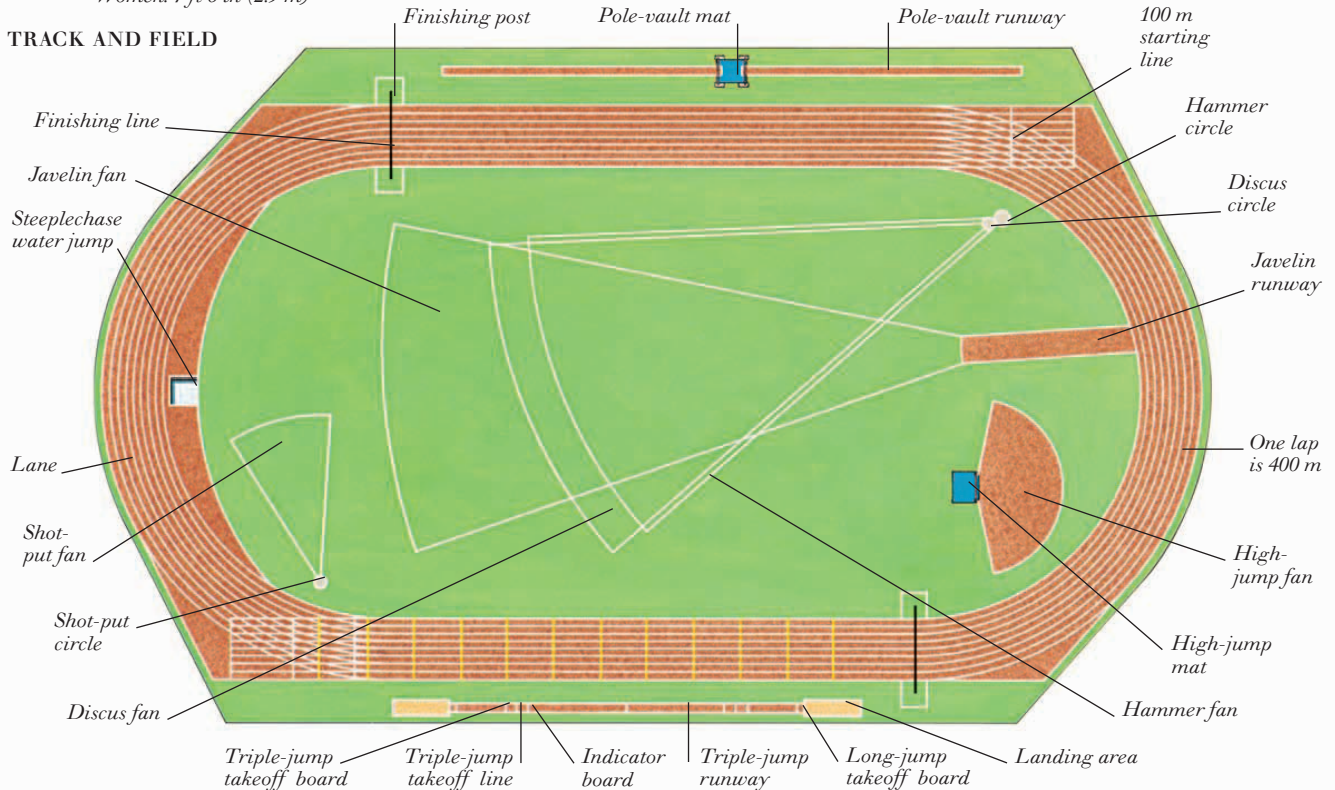
Track and field

THE SPORTS that make up track and field are divided into two main groups: track events—which include sprinting, middle- and long-distance running, relay running, hurdling, and walking—and field events that require jumping and throwing skills. Contests designed to test the speed, strength, agility, and stamina of athletes were held by the ancient Greeks over 4,000 years ago. However, the abolition of the Olympic Games in 393 AD meant that track and field events were neglected until the revival of large-scale competitions in the mid-nineteenth century. Modern stadia offer areas reserved for the long jump, triple jump, and pole vault usually situated outside the running track. The javelin, shot, hammer, and discus are thrown within the track area. Most athletes specialize in one or two events but, in the heptathlon, women compete in seven events, held over two days: 200 m and 800 m races, 100 m hurdles, javelin, shot put, high jump, and long jump. In the decathlon, men compete in 10 events over two days: 100 m, 400 m, and 1,500 m races, 110 m hurdles, javelin, discus, shot put, pole vault, high jump, and long jump.

FIELD EVENT EQUIPMENT



TRACK AND FIELD





RELAY BATONS

Hollow plastic tube

TYPES OF SHOE



Spiked sole

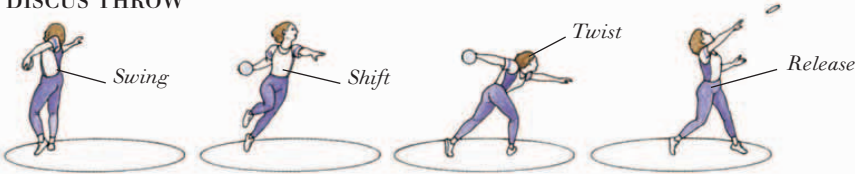
TRACK SHOE



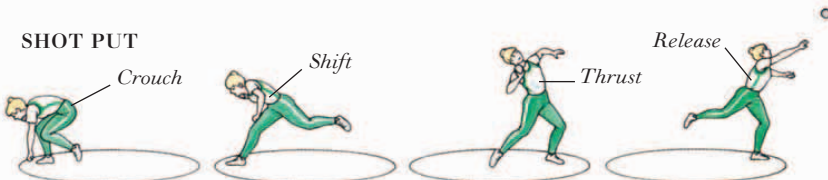
Air-cushioned sole

RUNNING SHOE

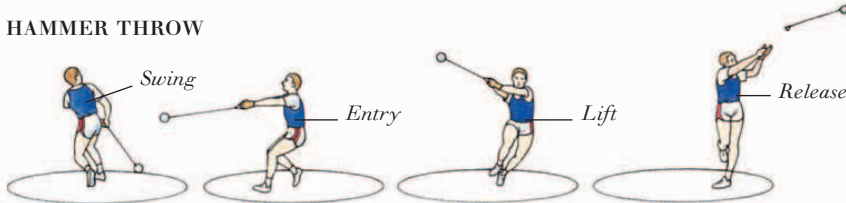
DISCUS THROW



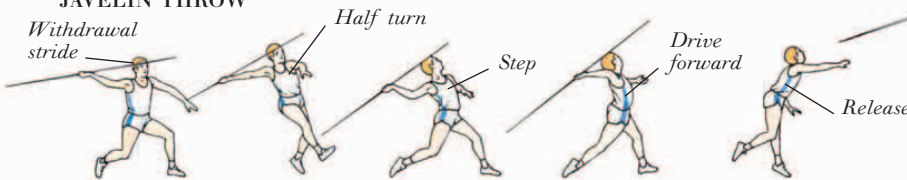
SHOT PUT



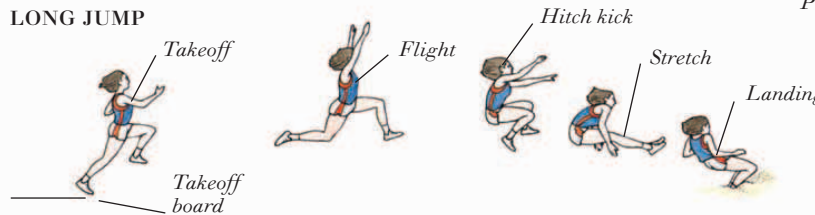
HAMMER THROW



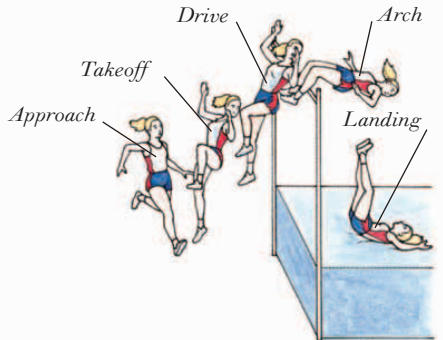
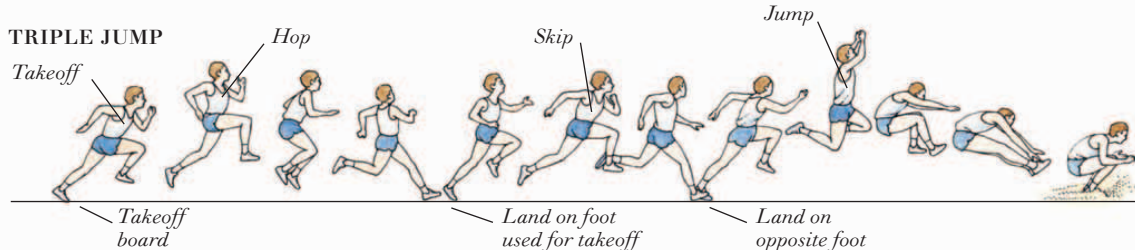
JAVELIN THROW



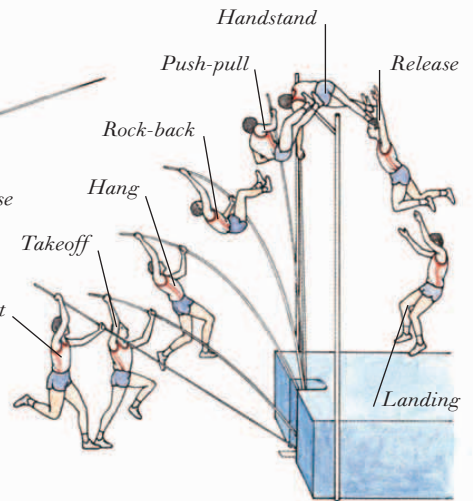
LONG JUMP



TRIPLE JUMP



HIGH JUMP



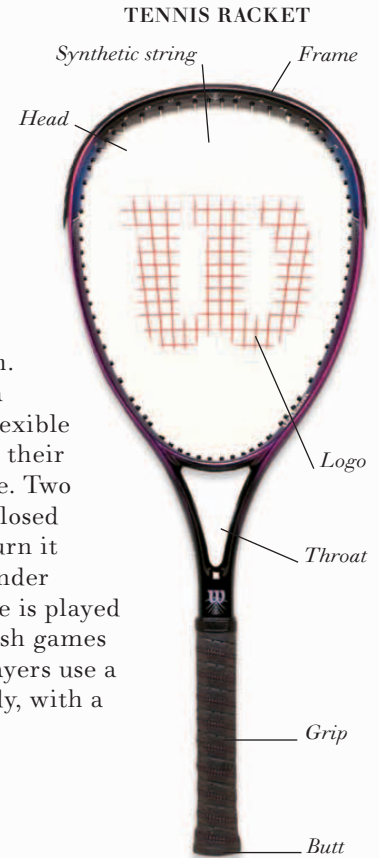
POLE VAULT

Racket sports

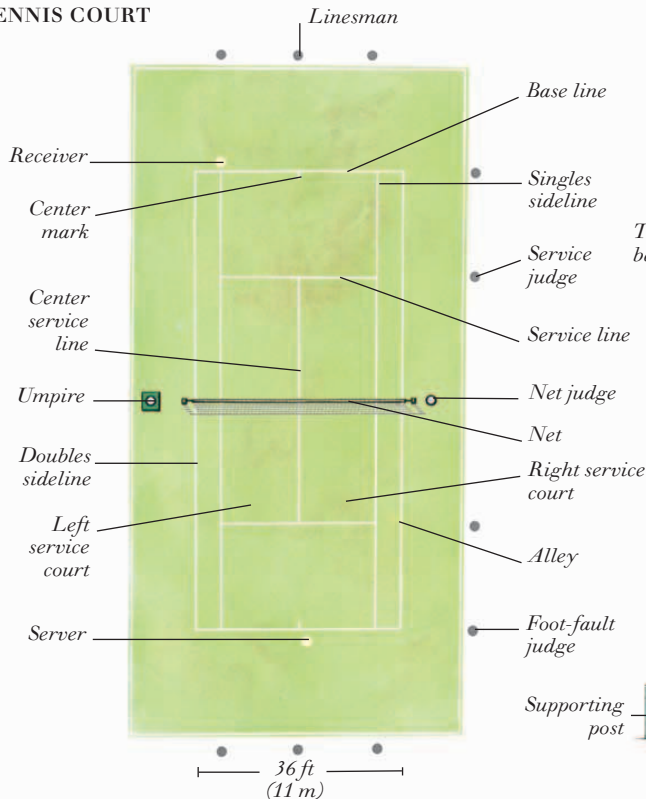


PROTECTIVE
EYEWEAR

THE OBJECT OF ALL RACKET SPORTS is to make shots the opponent cannot return. Games are played by two players (singles) or four players (doubles). Racket shape and size is tailored to each sport, but all rackets are constructed of wood, plastic, aluminum, or high-performance materials such as fiberglass and carbon graphite. Racket strings are usually synthetic, although natural gut is still used. Tennis is played on a court divided by a low net. Opposing players serve alternate games. At least six games must be won to gain a set, and two or sometimes three sets are needed to win a match. Tennis courts may be concrete, grass, clay, or synthetic, each surface requiring a different style of play. Badminton is an indoor sport that is played with light, flexible rackets and a birdie on a court with a high net. Players can score points only on their serve. The first to reach 15 points (11 points for women's singles) wins the game. Two games are needed to win a match. Squash and racketball are both played in enclosed courts. One player hits the ball against the front wall, and the other tries to return it before it bounces on the floor more than once. Squash rackets have smaller, rounder heads and stiffer frames than badminton rackets. In the United States, the game is played on a narrower court than an international court using a much harder ball. Squash games are played to 15 points (American) or 9 points (international). In racketball, players use a ball that is larger and bouncier than a squash ball. The racket is thick and sturdy, with a large head, short handle, and a thong that loops around the wrist. Points can be won only when serving, and the first player to reach 21 points wins.



TENNIS COURT



TENNIS PLAYER

MAKING A TENNIS BALL

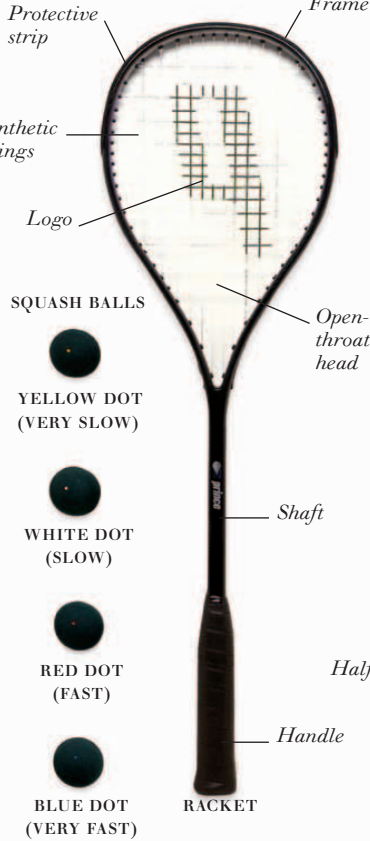


TENNIS NET

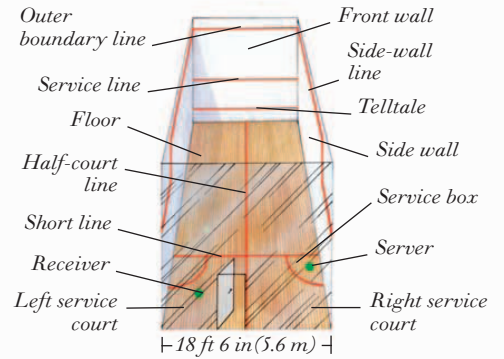
BADMINTON RACKET AND BIRDIE



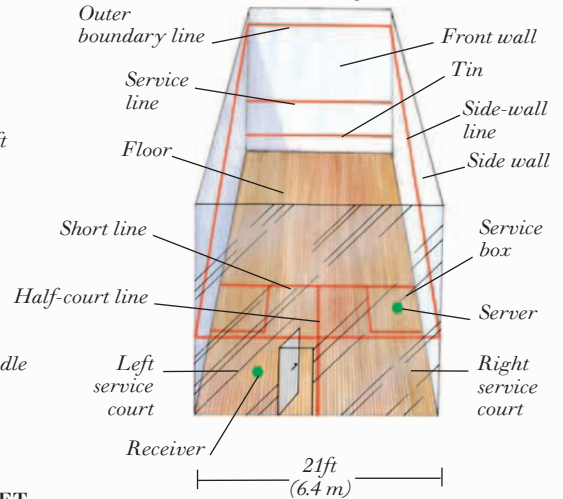
SQUASH RACKET AND SQUASH BALLS



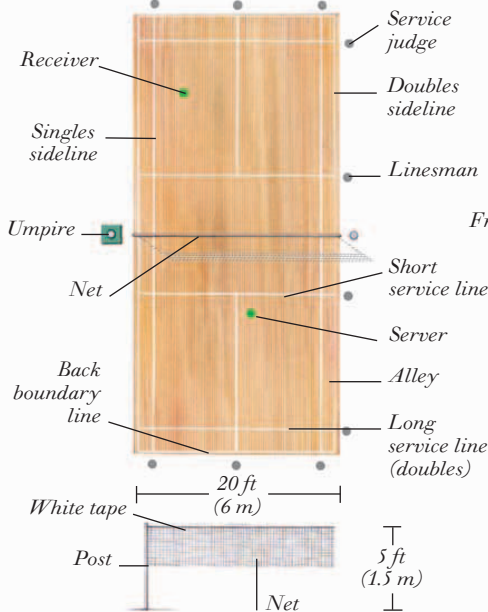
AMERICAN SQUASH COURT



INTERNATIONAL SQUASH COURT



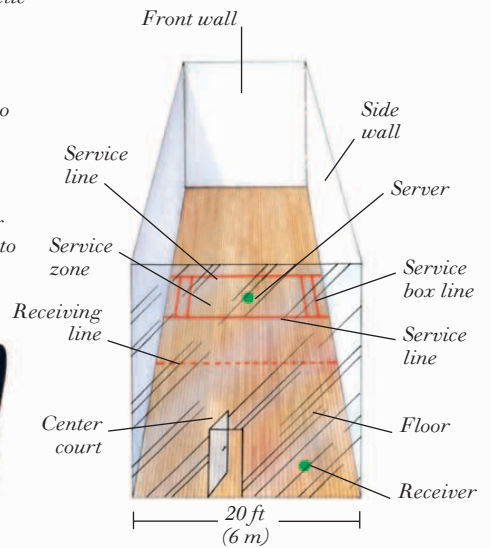
BADMINTON COURT



RACKETBALL RACKET, BALL, AND GLOVE



RACKETBALL COURT



BADMINTON NET

Golf

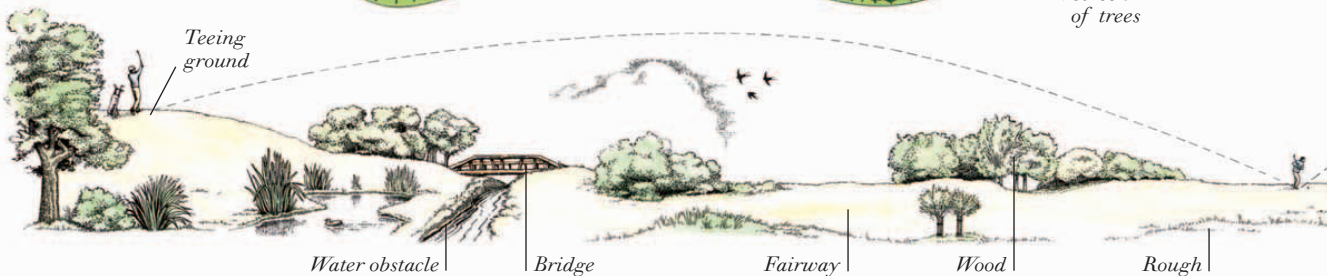


GOLF BALL AND TEE

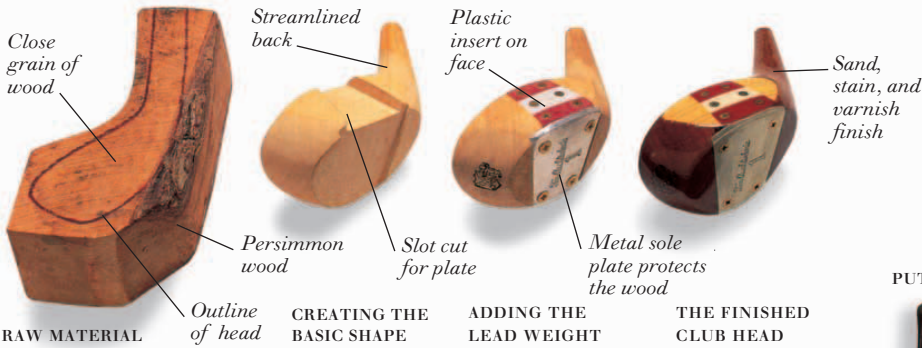
THE GAME OF GOLF was first played in Scotland some 400 years ago. Players are required to hit a ball, using a wooden or iron club, from a smooth level point or “teeing ground,” down the “fairway,” and on to a putting green where the target hole is located. The fairway is a strip of clear land along which there are natural hazards—such as ponds and streams, man-made hazards—such as bunkers (sand pits), and rough (areas of uncut grass). Championship golf courses have 18 holes. The object of the game is to hit the ball into each hole in turn, and to complete the “round” using as few strokes as possible. Players compete individually or in teams, playing the course together in groups of two, three, or four. The two basic forms of competition are match play and stroke play. In match play, the side winning the majority of holes over a certain number of rounds wins the match. In stroke play, the winner is the player who finishes a certain number of rounds having made the fewest strokes.



A TYPICAL HOLE



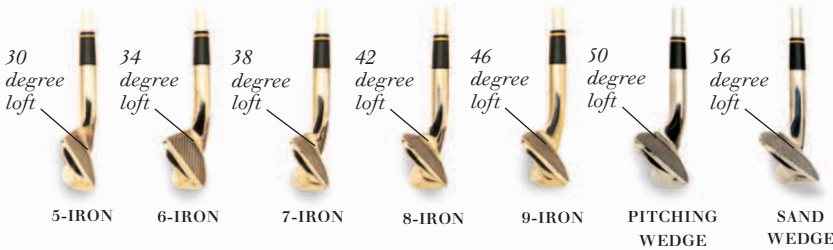
MAKING A WOODEN CLUB



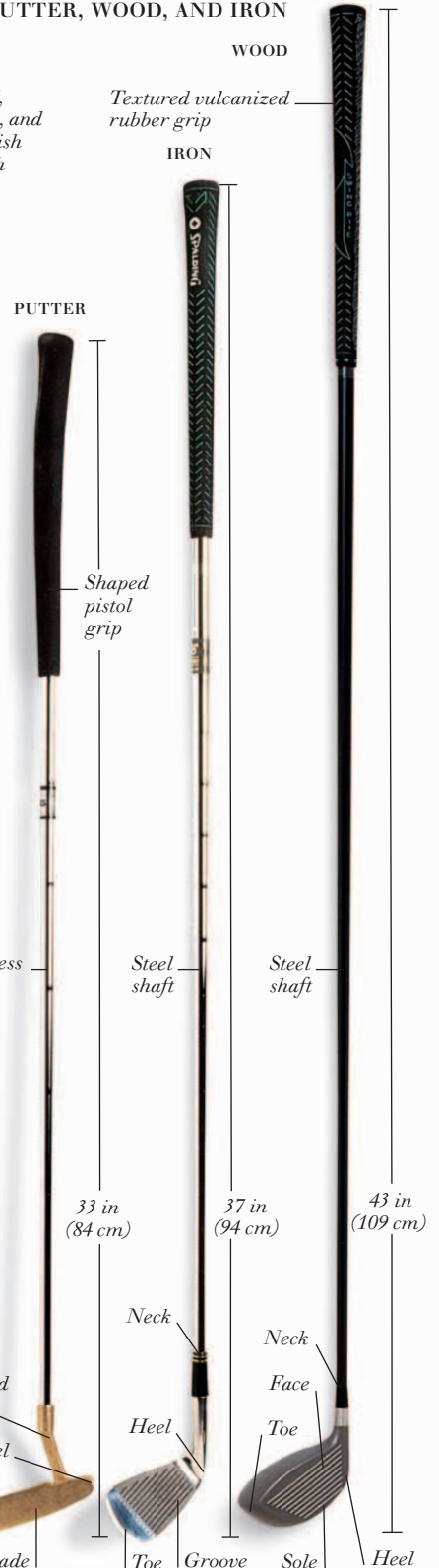
RANGE OF WOODEN CLUBS



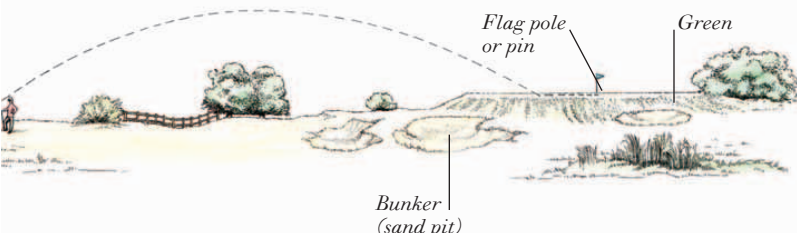
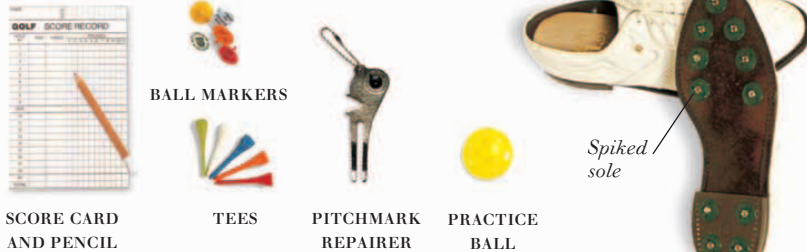
RANGE OF IRON CLUBS



PUTTER, WOOD, AND IRON

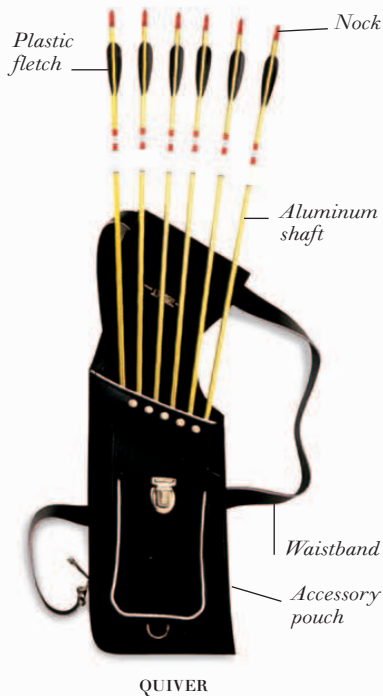


GOLF ACCESSORIES

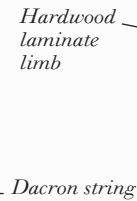
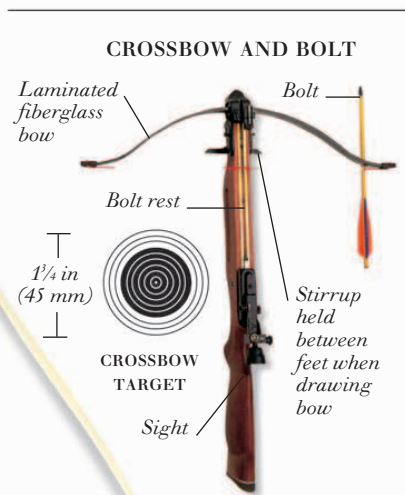
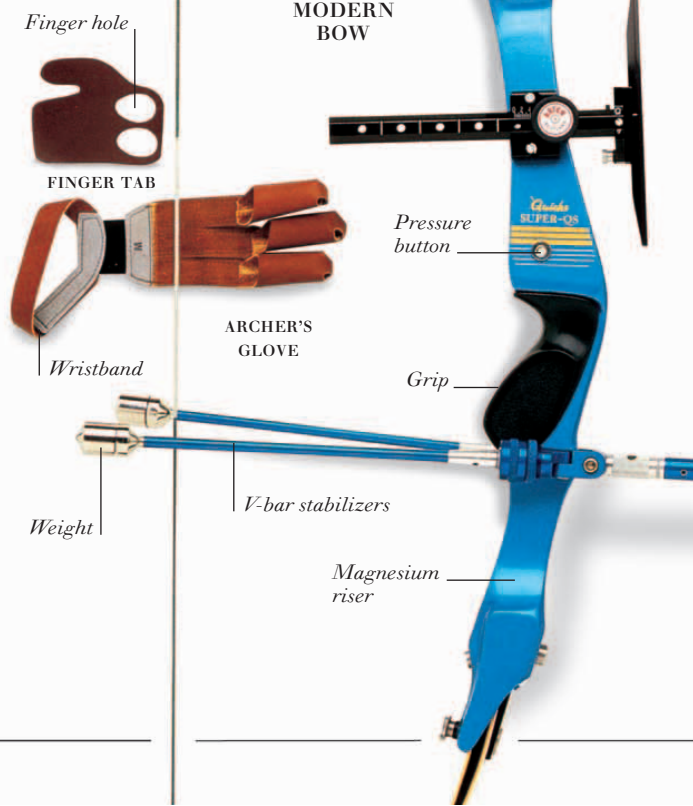


Archery and shooting

TARGET SHOOTING AND ARCHERY EVOLVED as practice for hunting and battle skills. Modern bows, although designed according to the principles of early hunting bows, use laminates, fiberglass, dacron, and carbon, and are equipped with sights and stabilizers. Competitors in target archery shoot over distances of 100 ft (30 m), 165 ft (50 m), 230 ft (70 m), and 300 ft (90 m) for men, and 100 ft (30 m), 165 ft (50 m), 200 ft (60 m), and 250 ft (70 m) for women. The closer the shot is to the center of the target, the higher the score. The individual scores are added up, and the archer with the highest total wins the competition. Crossbows are used in match competitions over 33 ft (10 m), and 100 ft (30 m). Rifle shooting is divided into three categories: smallbore, bigbore, and air rifle. Contests take place over a variety of distances and further subdivisions are based on the type of shooting position used: prone, kneeling, or standing. The Olympic biathlon combines cross-country skiing and rifle shooting over a course of approximately 12½ miles (20 km). Additional magazines of ammunition are carried in the butt of the rifles. Bigbore rifles fitted with a telescopic sight can be used for hunting and running game target shooting. Pistol shooting events, using rapid-fire pistols, target pistols, and air pistols, take place over 33 ft (10 m), 82 ft (25 m), and 165 ft (50 m) distances. In rapid-fire pistol shooting, a total of 60 shots are fired from a distance of 83 ft (25 m).



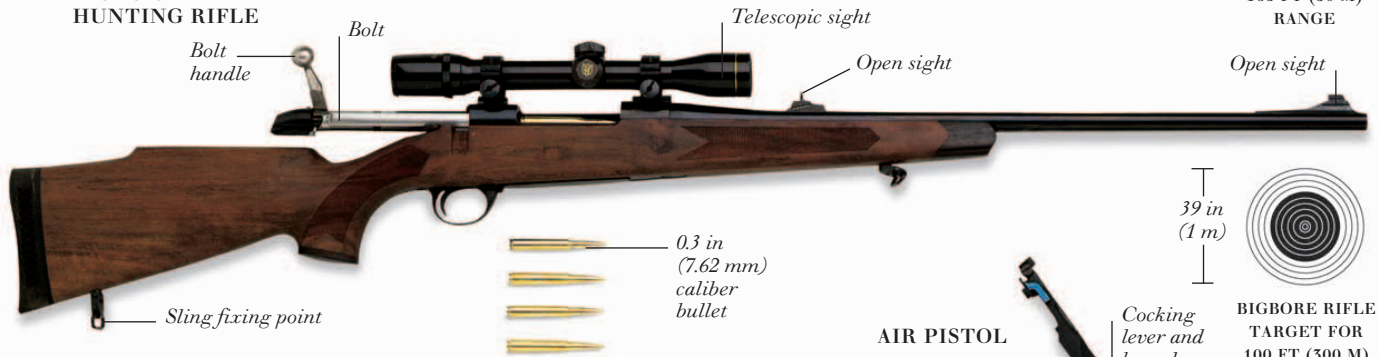
ARCHERY EQUIPMENT



SMALLBORE BIATHLON RIFLE



BIGBORE HUNTING RIFLE



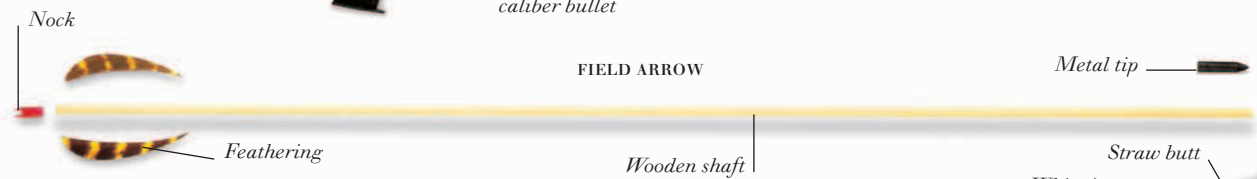
TARGET PISTOL



AIR PISTOL

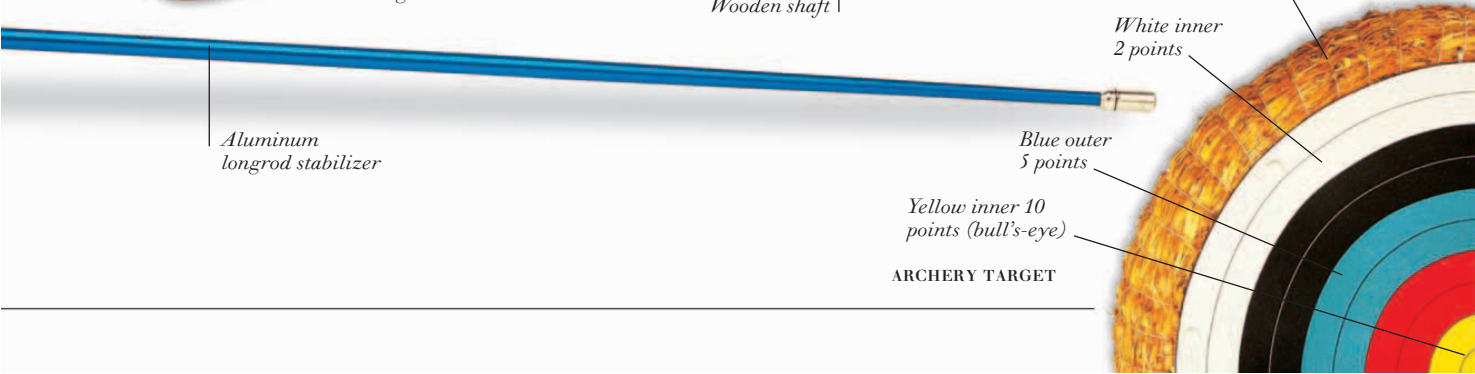


FIELD ARROW



WOODEN SHAFT

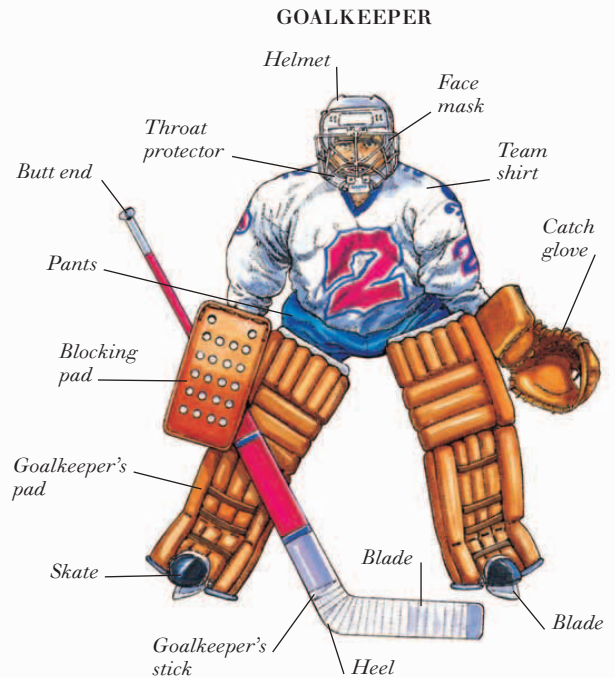
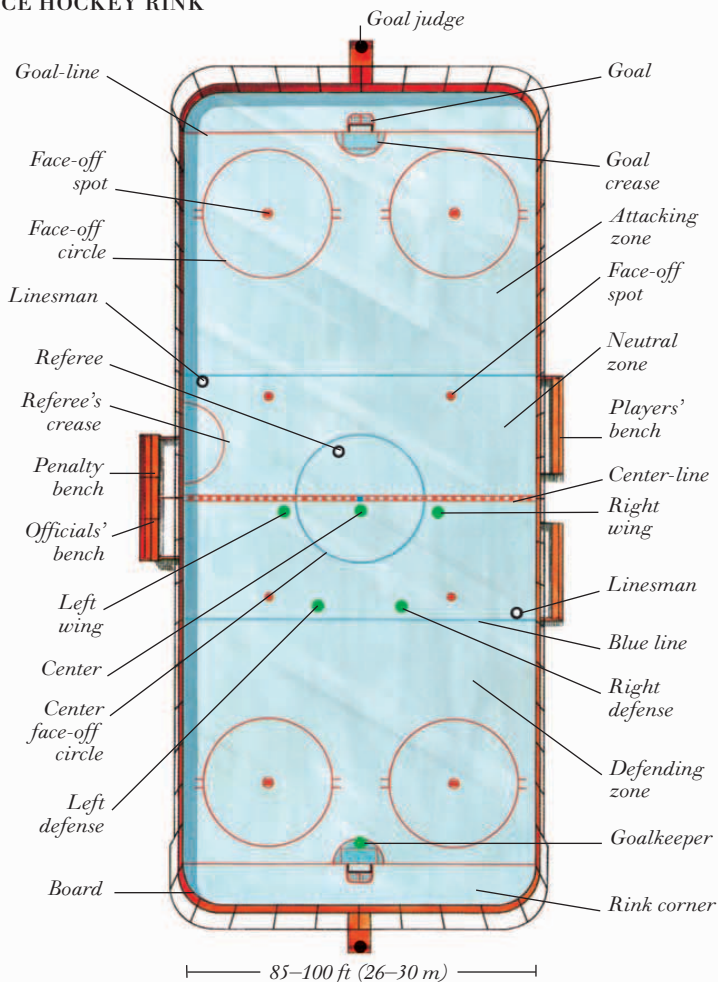
STRAW BUTT



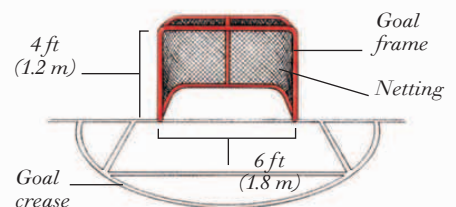
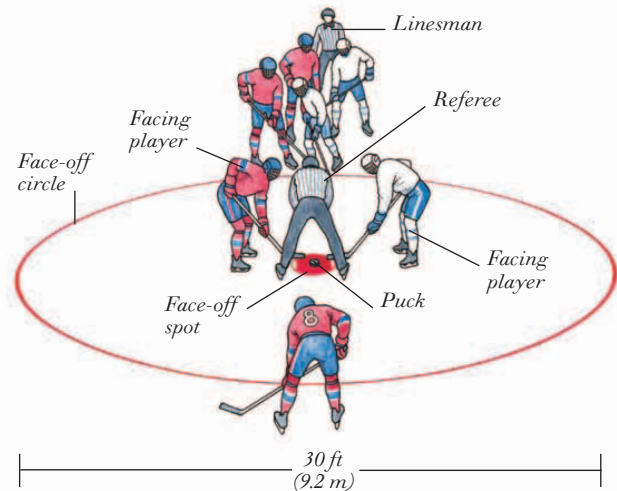
Ice hockey

ICE HOCKEY IS PLAYED by two teams of six players on an ice rink, with a goal net at each end. The object of this fast, and often dangerous, game is to hit a frozen rubber puck into the opposing team's net with a ice hockey stick. The game begins when the referee drops the puck between the sticks of two players from opposing teams, who "face off." The rink is divided into three areas: defending, neutral, and attacking zones. Players may move with the puck and pass the puck to one another along the ice, but may not pass it more than two zones across the rink markings. A goal is scored when the puck entirely crosses the goal-line between the posts and under the crossbar of the goal. A team may field up to 20 players although only six players are allowed on the ice at one time; substitutions occur frequently. Each game consists of three periods of 20 minutes, divided by breaks of 15 minutes.

ICE HOCKEY RINK



THE FACE OFF



ICE HOCKEY GOAL

GOALKEEPER'S HELMET



PLAYER'S BODY ARMOR



ICE HOCKEY STICKS

GOALKEEPER'S STICK

OUTFIELD PLAYER'S STICK

SHOULDER AND CHEST PADDING

Shoulder padding

ELBOW PADS



Strap

Chest padding

Wrist protection

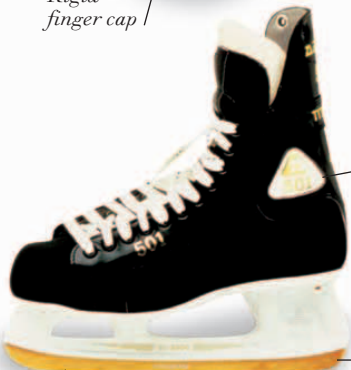


GLOVE

Heavy padding

Flexible gusset

Rigid finger cap



Ankle support

Safety heel tip

Blade

SKATE

Rigid plastic casing

Thick foam backing



LEG PROTECTOR

Knee protection

Leg pad

Puck stopper

Wide lower shaft

Vulcanized rubber

3 in (7.6 cm)

FROZEN PUCK

15 in (39 cm)

Thick blade

12 1/2 in (32 cm)

Heel



4 ft 9 in (147 cm)

Thin shaft

Alpine skiing

COMPETITIVE ALPINE SKIING is divided into four disciplines: downhill, slalom, giant slalom, and super-giant slalom (Super-G). Each one tests different skills. In downhill skiing, competitors race down a slope marked out by control flags, known as “gates,” and are timed on a single run only. Competitors wear crash helmets, one-piece Lycra suits, and long skis with flattened tips to minimize air resistance. Slalom and giant slalom skiers negotiate a twisting course requiring balance, agility, and quick reactions. Courses are defined by pairs of gates. Racers must pass through each pair of gates to complete the course successfully. Competitors are timed on two runs over different courses, and the skier who completes the courses in the shortest time wins. The equipment and protective guards used by slalom skiers are shown opposite. In Super-G races, competitors ski a single run that combines the technical challenge of slalom with the speed of downhill. The course requires skiers to complete medium-to-long radius turns at high speed, and contain up to two jumps. Clothing is the same as for downhill, but slightly shorter skis are used.

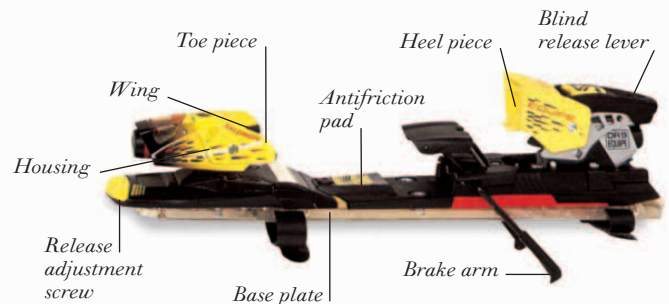
DOWNHILL SKIER



ALPINE SKI SLOPE COURSES

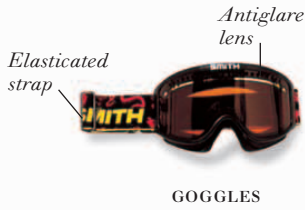


SKI BOOT



SAFETY BINDING

SLALOM CLOTHING AND EQUIPMENT



GOGGLES



SLALOM HELMET



SKI GLOVE

Adjustable shoulder strap

High collar

Double-knit wool and polyester fabric



PADDED SWEATER



Shock-absorbing platform under boot

Molded polypropylene

HAND GUARD

Edge

Waterproof fabric

74-80 in (188-203 cm)

Cuff fits over ski boot

Tough polypropylene shell deflects the shaft of the slalom gate



LEG GUARD

Shaft

Basket

SLALOM SKI POLE

SLALOM SKI

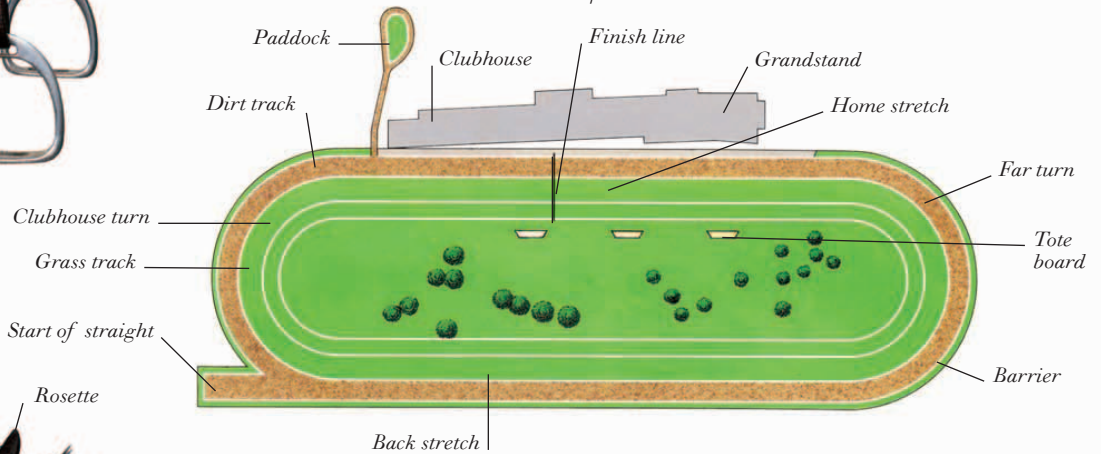


PADDED SKI PANTS

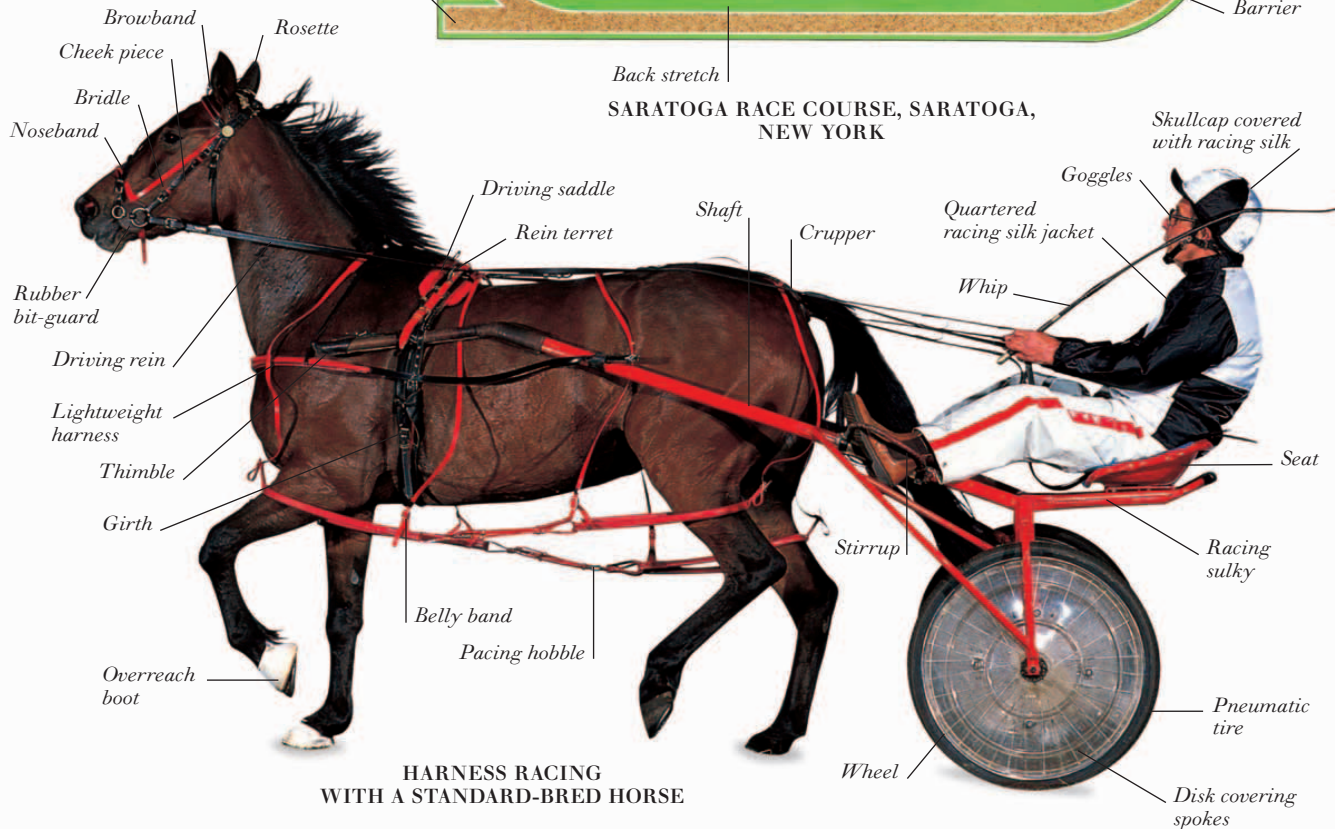
RACING SADDLE



RACING SILKS



SARATOGA RACE COURSE, SARATOGA, NEW YORK



HARNESS RACING WITH A STANDARD-BRED HORSE

Judo and fencing

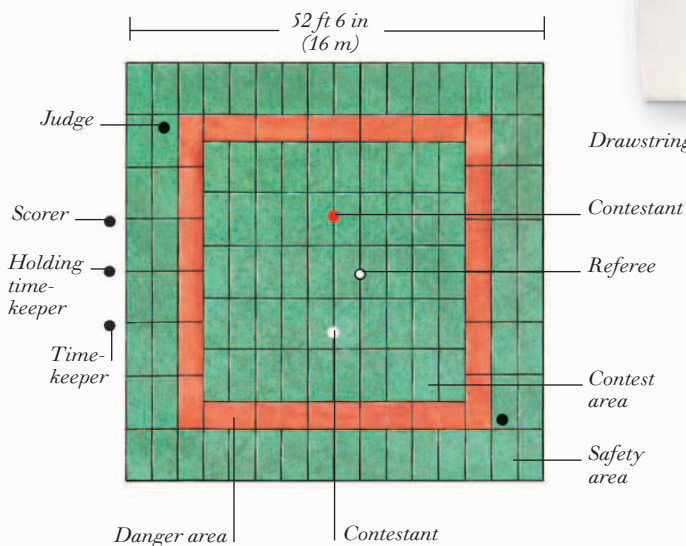
COMBAT SPORTS ARE BASED ON THE SKILLS used in fighting. In these sports, the competitors may be unarmed—as in judo and boxing—or armed—as in fencing and kendo. Judo is a system of unarmed combat developed in the East. Translated from the Japanese, the name means “the gentle way.” Students learn how to turn an opponent’s force to their own advantage. The usual costume is loose white pants and a jacket, fastened with a cloth belt. The color of belt indicates the student’s level of expertise, from white-belted novices to the expert “black belts.” Competitions take place on a mat or “shiai-jo,” 30 or 33 ft (9 or 10 m) square in size, bounded by “danger” and “safety” areas to prevent injury. Competitors try to throw, pin, or master their opponent by applying pressure to the arm joints or neck. Judo bouts are strictly monitored, and competitors receive points for superior technique, not for injuring their opponent. Fencing is a combat sport using swords, which takes place on a narrow “piste” 46 ft (14 m) long. Competitors try to touch specific target areas on their opponent with their sword or “foil” while avoiding being touched themselves. The winner is the one who scores the greatest number of hits. Fencers wear clothing made from strong white material that affords maximum protection while allowing freedom of movement, steel mesh masks with padded bibs to protect the fencer’s neck, and a long white glove on their sword hand. Fencing foils do not have sharpened blades, and their tips end in a blunt button to prevent injuries. Three types of swords are used—foils, épées, and sabers. Official foil and épée competitions always use an electric scoring system. The sword tips are connected to lights by a long wire that passes underneath each fencer’s jacket. A bulb flashes when a hit is made.

JUDO HOLDS AND THROWS



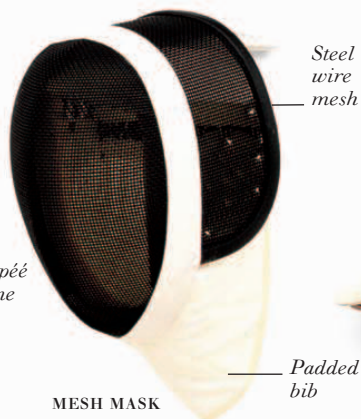
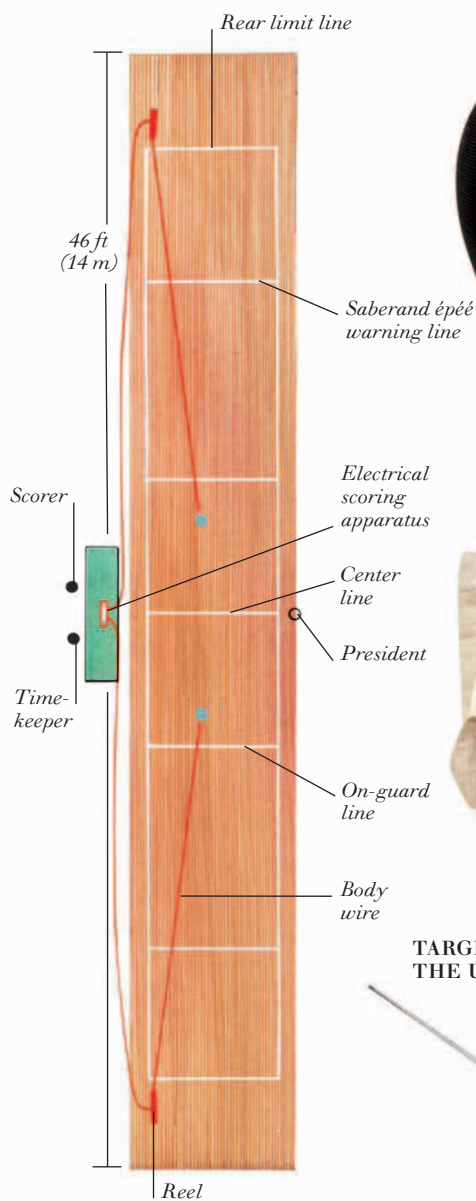
UNIFORM

JUDO MAT

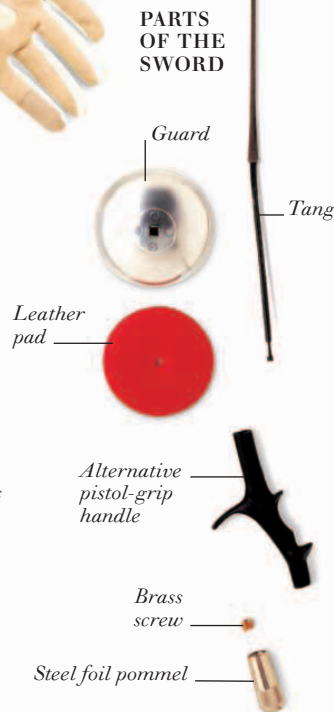
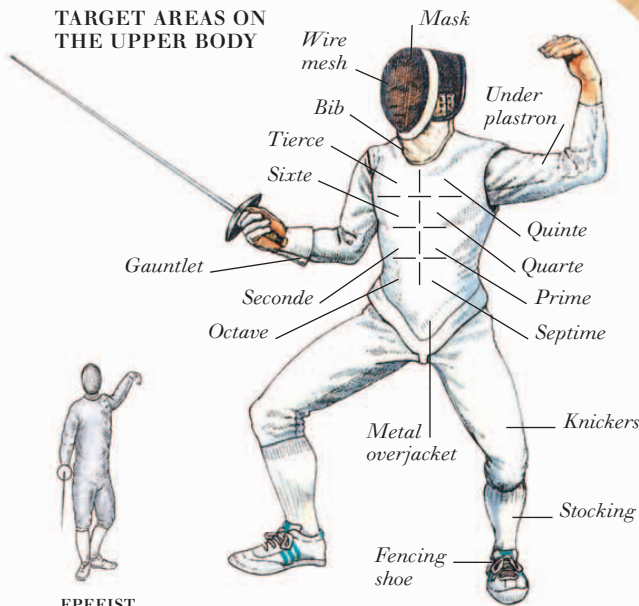


FENCING PISTE

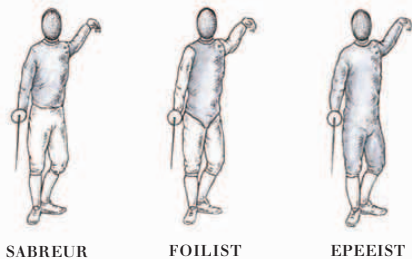
FENCING EQUIPMENT



TARGET AREAS ON THE UPPER BODY



FENCING TARGET AREAS



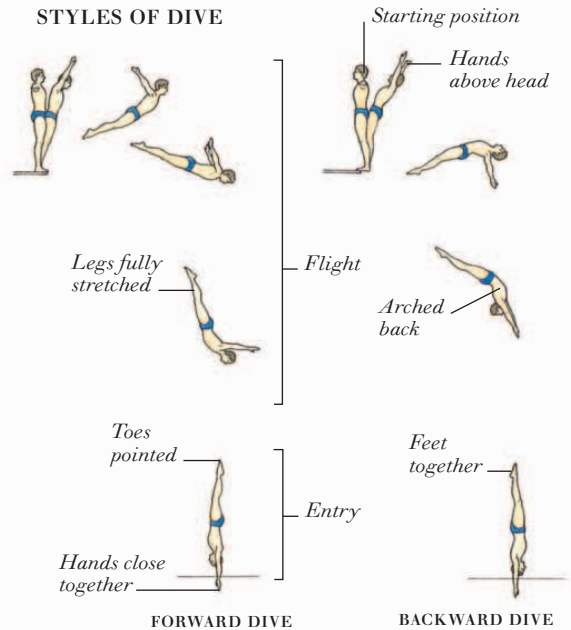
Swimming and diving



SWIMMING
GOGGLES

SWIMMING WAS INCLUDED in the first modern Olympic Games in 1896 and diving events were added in 1904. Swimming is both an individual and a team sport and races take place over a predetermined distance in one of the four major categories of stroke—freestyle (usually front crawl), butterfly, breaststroke, and backstroke. Competition pools are clearly marked for racing and antiturbulence lane lines are used to separate the swimmers and help keep the water calm. The first team or individual to finish the race is the winner. Competitive diving is divided into men's and women's springboard and platform (highboard) events. There are six official groups of dives: forward dives, backward dives, armstand dives, twist dives, reverse dives, and inward dives. Competitors perform a set number of dives and after each one a panel of judges award marks according to the quality of execution and the degree of difficulty.

STYLES OF DIVE



Latex rubber molds to shape of head

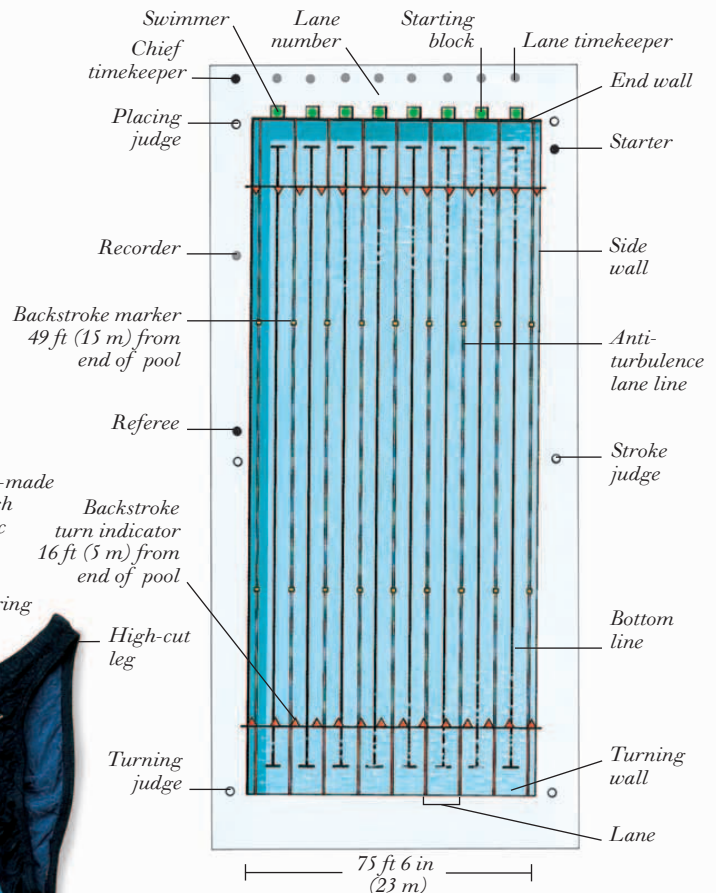
SWIMWEAR

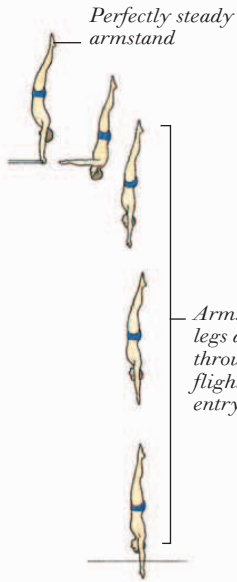


SWIMSUIT

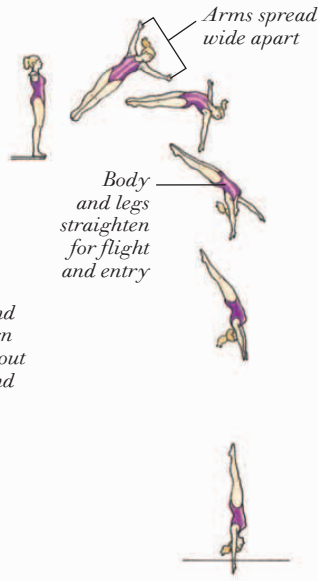
TRUNKS

SWIMMING POOL

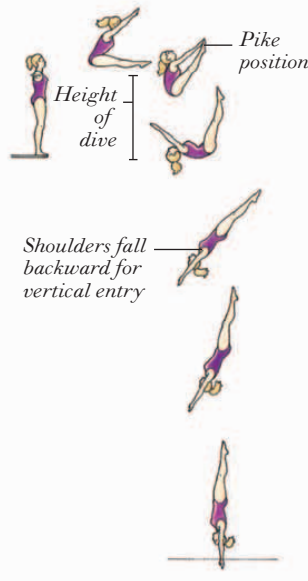




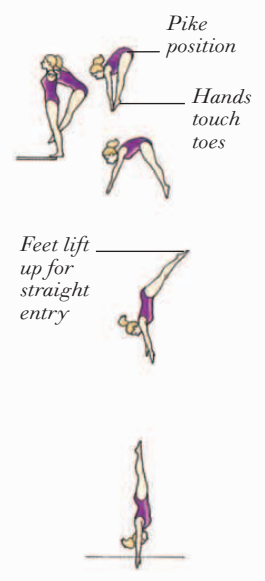
ARMSTAND DIVE



TWIST DIVE



REVERSE DIVE PIKED



INWARD DIVE PIKED

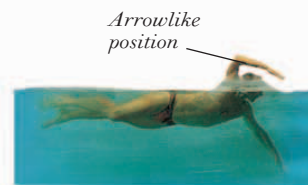
FRONT CRAWL



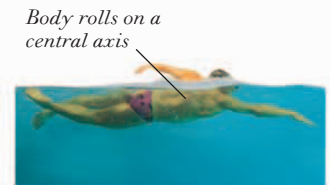
FULL BODY STRETCH



LOWER ARM PULL



STREAMLINED ARM ENTRY



SIDE-TO-SIDE BODY ROLL

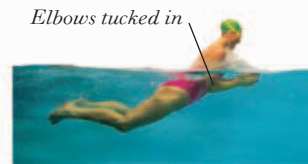
BREASTSTROKE



BODY GLIDE



DOUBLE ARM PULL



SQUEEZING THE WATER



FROG KICK

BACKSTROKE



BODY ROLL



PULLING THROUGH



STRAIGHTENING OUT



SHOULDER LIFT

BUTTERFLY



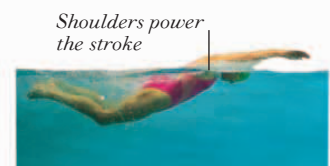
CATCHING THE WATER



DOUBLE ARM PULL



KICKING DOWN

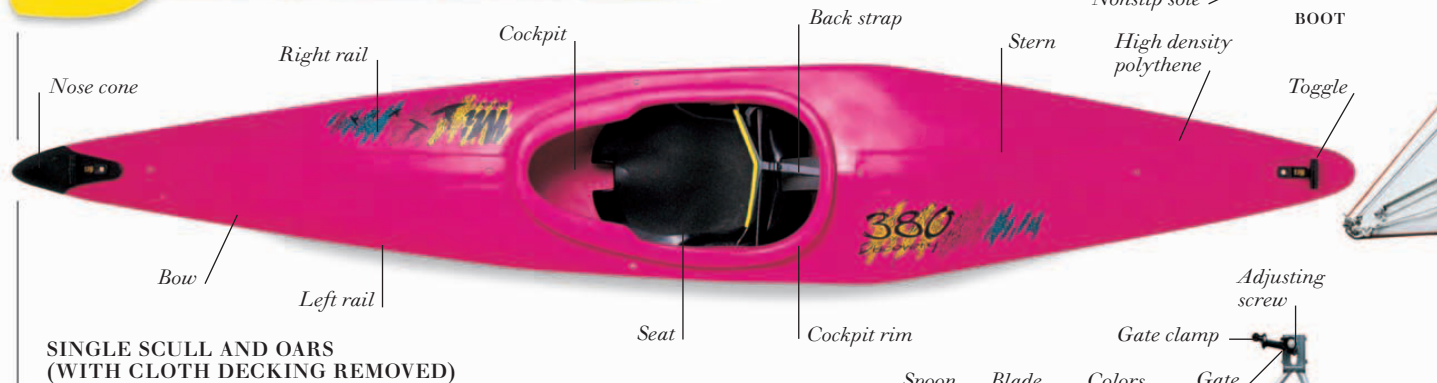
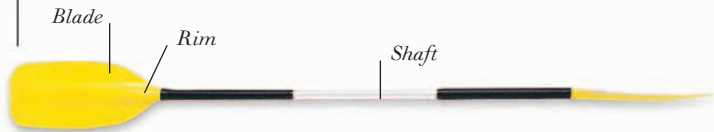


WHOLE BODY UNDULATION

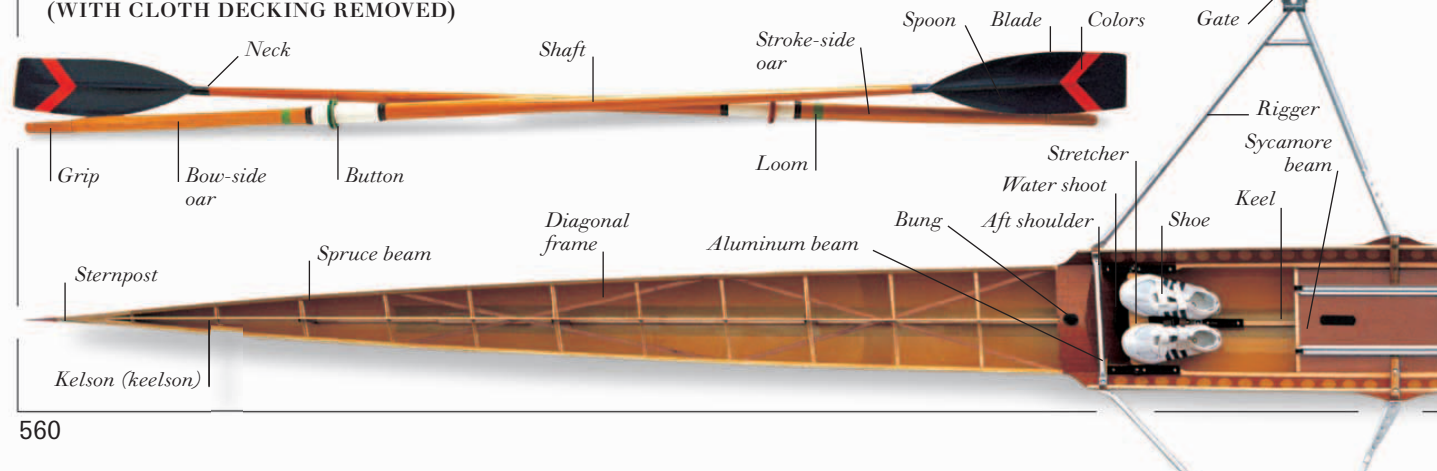
Canoeing, rowing, and sailing

WATERBORNE SPORTS are as varied as the crafts used. There are two disciplines in rowing; sweep rowing, in which each rower has one oar, and sculling, in which rowers use two oars. There are a number of different Olympic and competitive rowing events for both men and women. The number of rowers and weight classes vary. Some rowing events use a coxswain; a steersman who does not row but directs the crew. Kayaks and canoes are used in straight sprint and slalom races. Slalom races take place over a course consisting of 20 to 25 gates, including at least six upstream gates. In yacht racing, competitors must complete prescribed courses, organized by the race committees, in the shortest possible time, using sail power only. Olympic events include classes for keel boats, dinghies, and catamarans.

ONE-PERSON KAYAK AND PADDLE



SINGLE SCULL AND OARS (WITH CLOTH DECKING REMOVED)



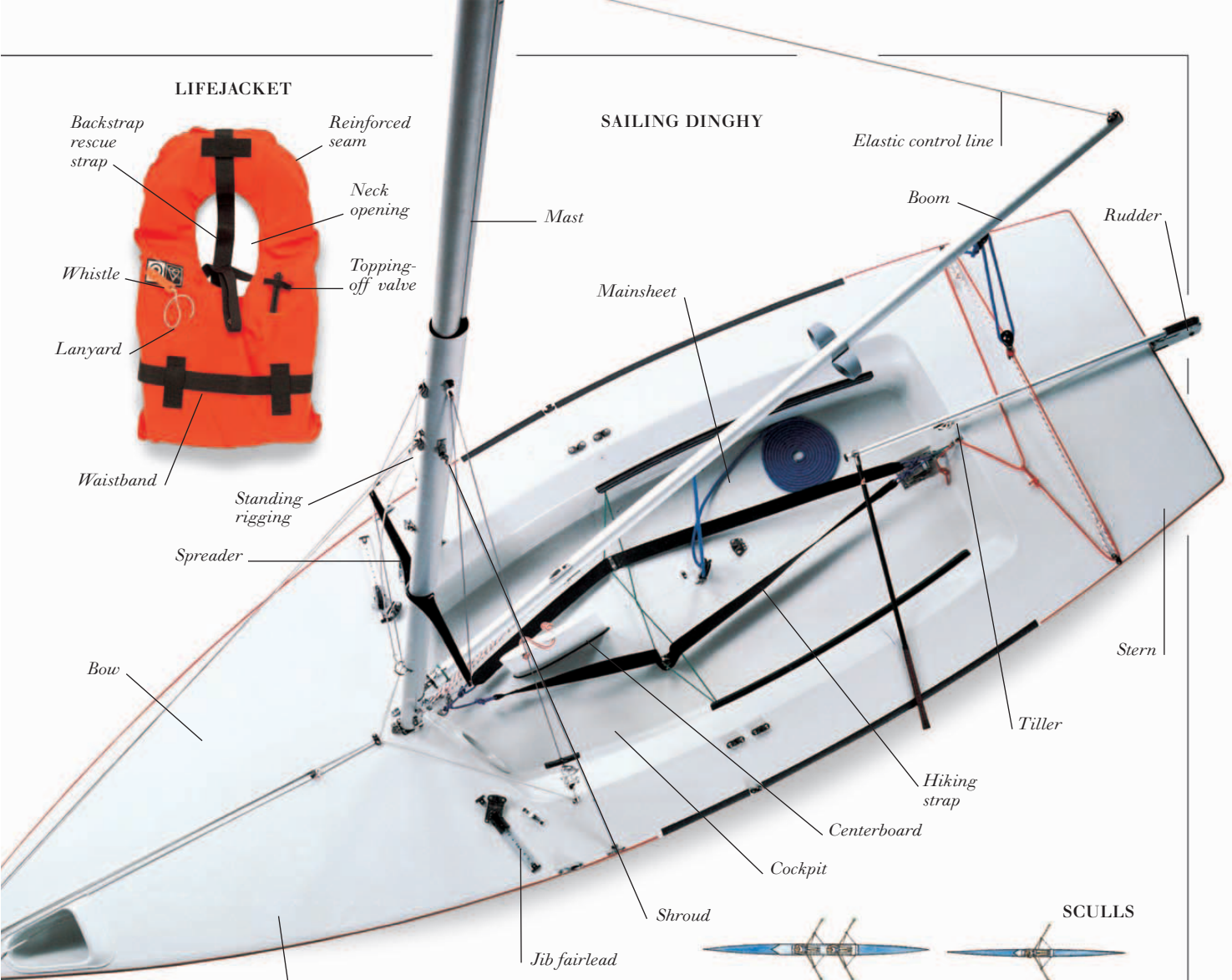
SAILING GEAR



LIFEJACKET



SAILING DINGHY

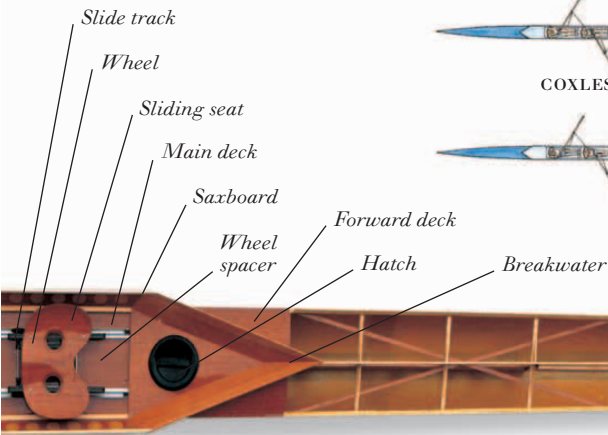
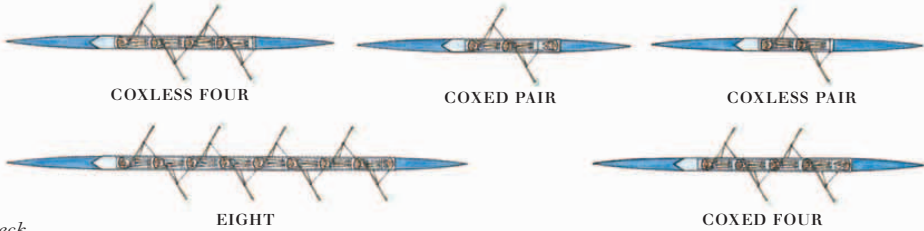


Nonslip deck surface

SCULLS



SWEEP-ROWING BOATS



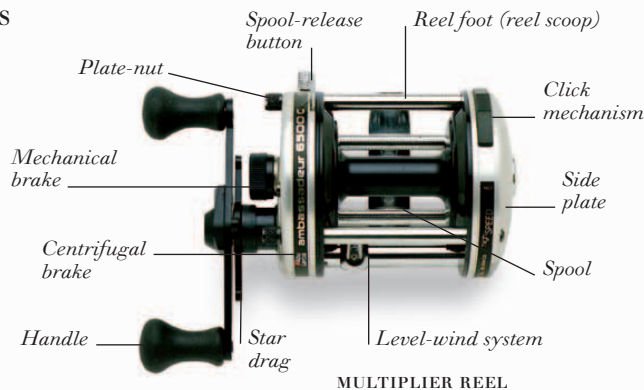
Angling

ANGLING MEANS FISHING WITH A ROD, reel, line, and lure. There are several different types of angling: freshwater coarse angling, for members of the carp family and pike; freshwater game angling, for salmon and trout; and sea angling, for sea fish such as flatfish, bass, and mackerel. Anglers use a variety of methods for catching fish. These include bait fishing, in which bait (food to allure the fish) is placed on a hook and cast into the water; fly fishing, in which a natural or artificial fly is used to lure the fish; and spinning, in which a lure that looks like a small fish revolves as it is pulled through the water. The angler uses the rod, reel, and line to cast the lure over the water. The reel controls the line as it spills off the spool and as it is wound back. Weights may be fixed to the line so that it will sink. Swivels are attached to prevent the line from twisting. When a fish bites, the hook must become embedded in its mouth and remain there while the catch is reeled in.

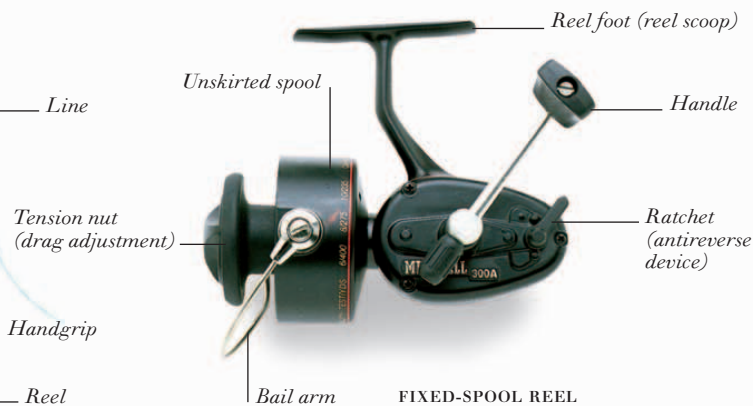


Weights may be fixed to the line so that it will sink. Swivels are attached to prevent the line from twisting. When a fish bites, the hook must become embedded in its mouth and remain there while the catch is reeled in.

REELS



MULTIPLIER REEL

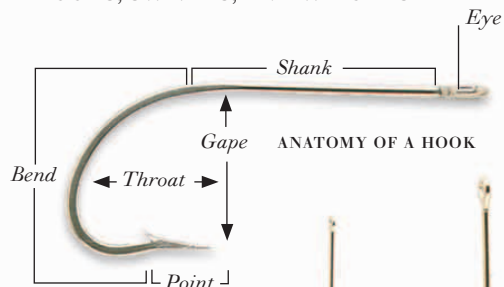


FIXED-SPOOL REEL

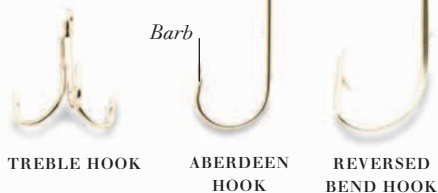
BUTT SECTION



HOOKS, SWIVELS, AND WEIGHTS



ANATOMY OF A HOOK



FLY ROD AND REEL



Disk drag housing



Reel foot (reel scoop)

Line

Drag knob screw



Clicker plate



Drag knob



Butt extension

Release lever

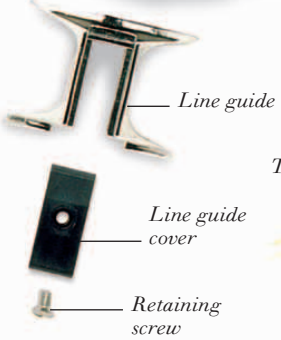
Spool screw

Spool cover

Release spring

Spool-release button

ARTIFICIAL FLIES



Line guide

Line guide cover

Retaining screw

DUNKELD WET FLY



Body

Cheek

Head

Hackle

Ribbing

Tail

DEER HOPPER DRY FLY



Front hackle

Eye

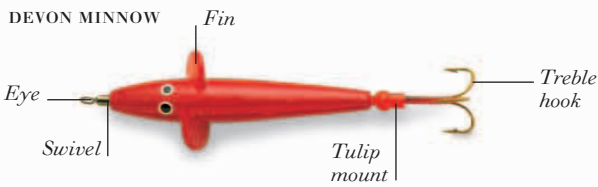
Head

Wing

Hook

Tail

ARTIFICIAL LURES



DEVON MINNOW

Fin

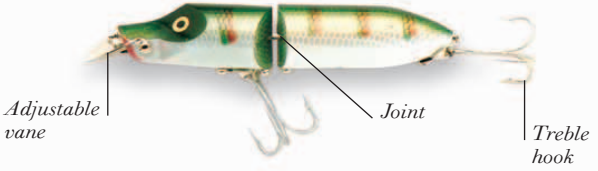
Eye

Swivel

Tulip mount

Treble hook

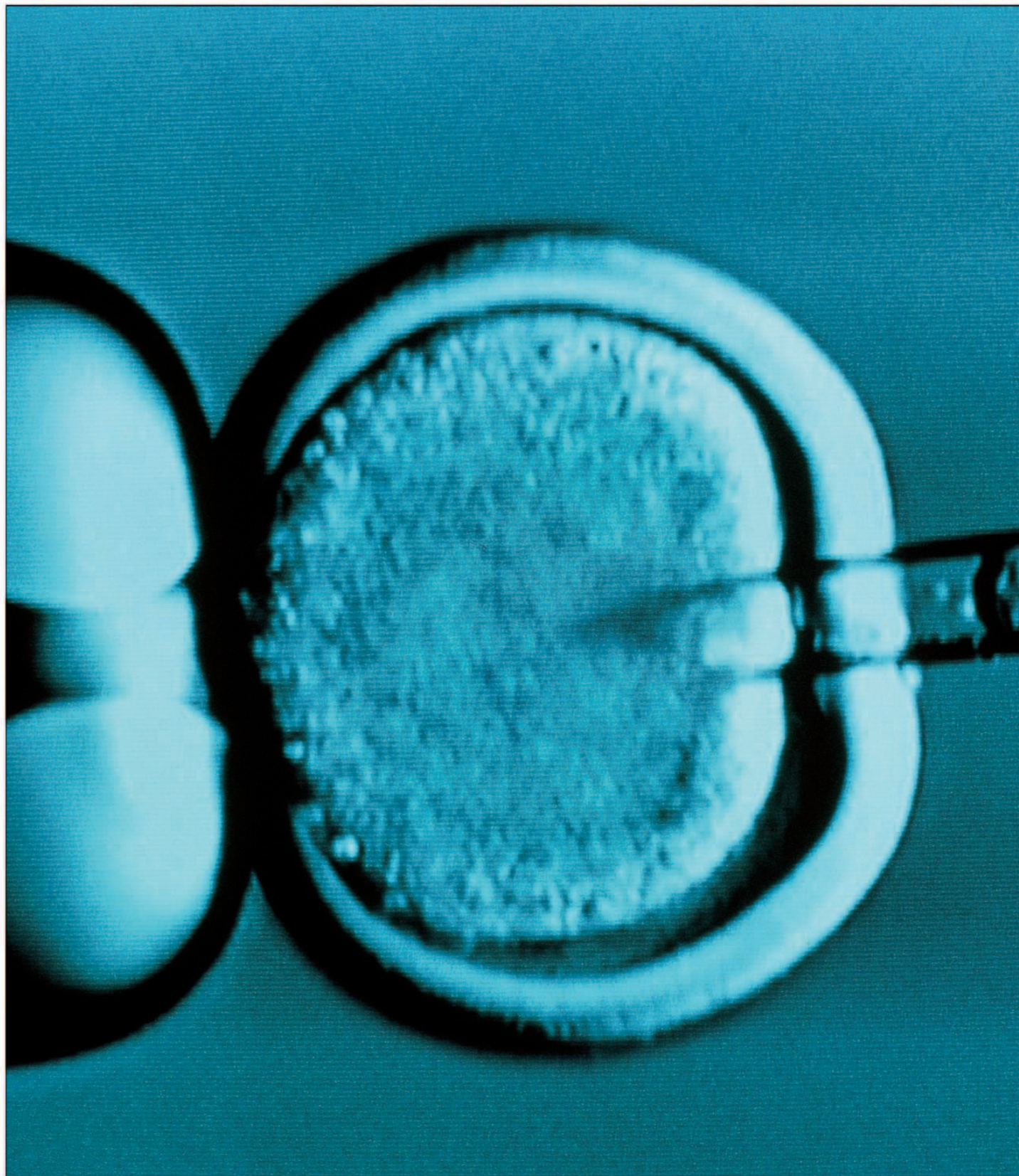
JOINTED PLUG



Adjustable vane

Joint

Treble hook



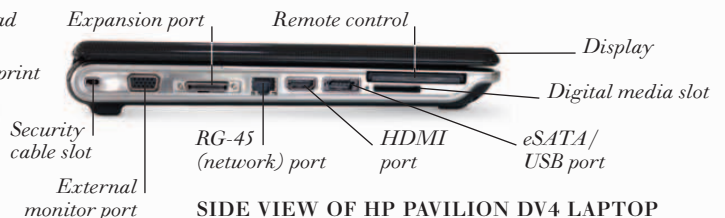
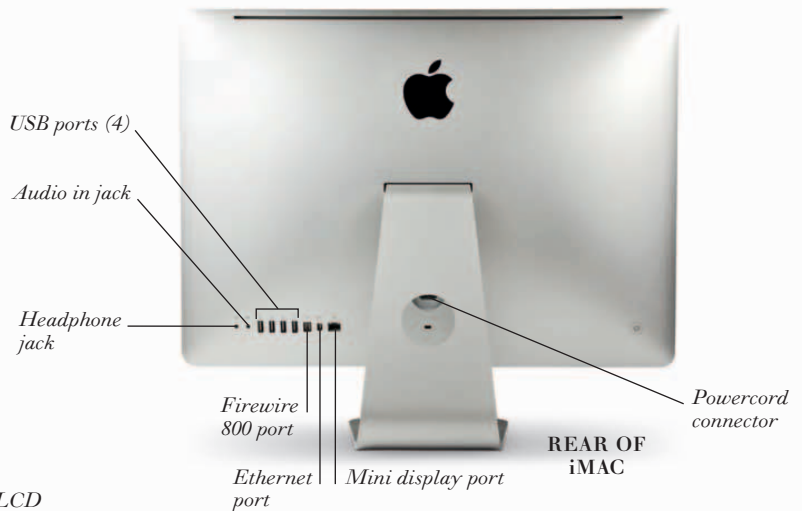


THE MODERN WORLD

PERSONAL COMPUTER.....	566
HANDHELD COMPUTER.....	568
FLATBED SCANNER.....	570
AIRBUS 380.....	572
INKJET PRINTER.....	574
THE INTERNET.....	576
ELECTRONIC GAMES.....	578
DIGITAL CAMERA.....	580
DIGITAL VIDEO CAMERA.....	582
HOME CINEMA.....	584
PERSONAL MUSIC AND VIDEO.....	586
CELLPHONES.....	588
GLOBAL POSITIONING SYSTEM.....	590
VACUUM CLEANER.....	592
IRON AND WASHER-DRYER.....	594
MICROWAVE COMBINATION OVEN.....	596
TOASTER.....	598
DRILL.....	600
HOUSE OF THE FUTURE.....	602
RENEWABLE ENERGY.....	604
CLONING TECHNOLOGY.....	606
ROBOTS.....	608
HIGH-PERFORMANCE MICROSCOPES.....	610
SPACE TELESCOPE.....	612
PROBING THE SOLAR SYSTEM.....	614

Personal computer

PERSONAL COMPUTERS (PCs) fall into two main types: IBM-compatible PCs, known simply as PCs, and Apple Macintosh PCs, known as “Macs.” They differ in the way files and programs, and the user’s access to them, are organized, and programs must be tailored for each type. However, in most other respects PCs and Macs have much in common. Both contain microchips, or integrated circuits, that store and process data. The “brain” of any PC is a chip known as the central processing unit (CPU), which performs mathematical operations in order to run program instructions and receive, store, and output data. The most powerful personal computer CPUs today can perform more than a billion calculations a second. Data can be input via CDs, USB memory sticks, and other storage media. Highly portable laptop and network PCs are also in widespread use. Most PCs are able to communicate with many other devices, including digital cameras (see pp. 580-81) and smartphones (see pp. 588-89).

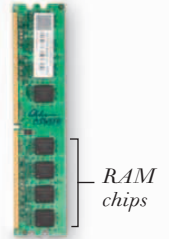


COMPONENTS OF A SYSTEM UNIT



CD drive

DVD drive



RAM chips

COOLING FAN

RAM BOARD

Floppy drive

Power button

Reset button

Chassis

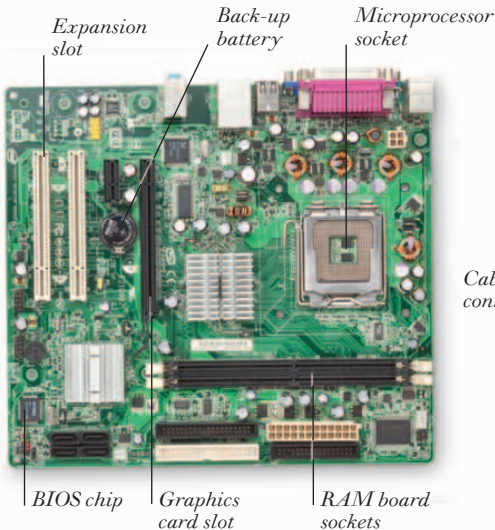


CD DRIVE

SYSTEM UNIT OF A PC



SIDE CABLE



Expansion slot

Back-up battery

Microprocessor socket

BIOS chip

Graphics card slot

RAM board sockets

MOTHERBOARD

Video out connectors

Circuit board



Cooling fan

Graphics processor

GRAPHICS CARD

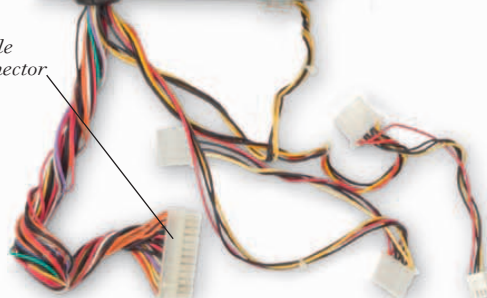
Edge connector



MICROPROCESSOR



Cable connector



POWER SUPPLY



HARD DISC DRIVE



DATA CABLE

Handheld computer

BY THE EARLY 1990s electronic circuitry had been miniaturized to such an extent that it was possible to make small handheld computing devices. The first of these was the Personal Digital Assistant (PDA), which offered features including an address book, calendar, and notepad. In recent years, PDAs have been overtaken by smartphones with internet and email access (see pp. 588–589). A related product is the e-book reader, which stores books in digital form and uses “electronic paper” to mimic the appearance of ink on real paper. An e-book reader no bigger than a thin paperback can store several thousand digital books in its memory. The most recent small computing device is the handheld computer. This looks like a thin flat display, but it is actually a complete computer. Handheld computers are typically controlled by a touch-sensitive screen and have a wireless link to other computers and the internet. They run software applications, or apps, downloaded from the internet. The most popular handheld computer currently is the Apple iPad. It has a multitouch interface that enables its screen to detect the movements of fingertips. In addition to selecting options and apps by touching the screen, images can be enlarged or shrunk by moving fingertips apart or together on the screen.



APPLE IPAD

Home button

App icon

Touch data is sent as a list of finger positions to the controller where the information is used to zoom in and out of a web page

LCD with buttons displayed

Fingers alter the electric field around nearby sections of the grid

User touches clear protective screen

Touchscreen electronics interpret the outputs from the grid to work out exactly where the fingers are

6-in (15-cm) screen

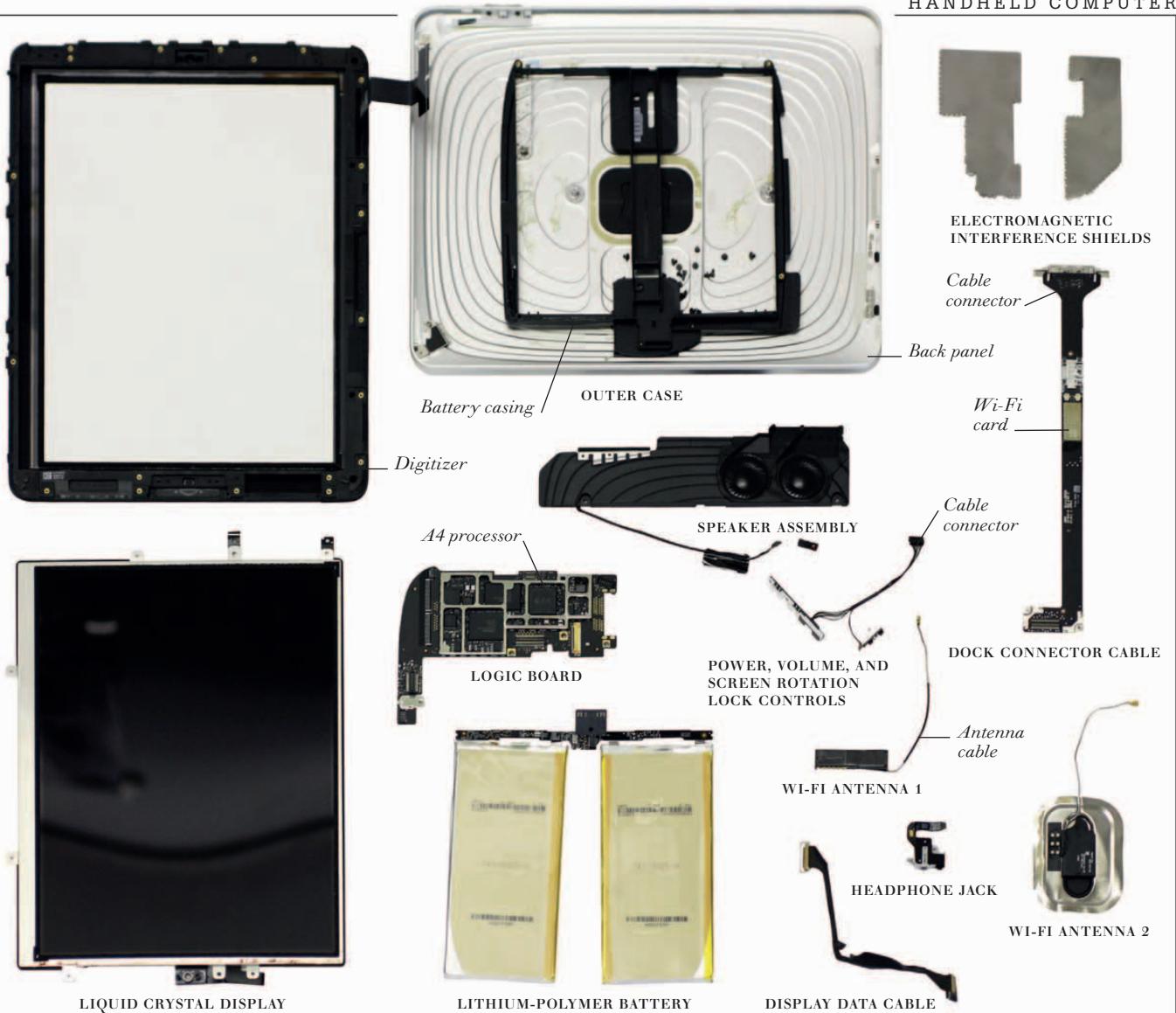
Next page button

Previous page button

Joystick controller

MULTITOUCH INTERFACE

ACER LUMIREAD E-READER



COMPONENTS OF AN APPLE IPAD

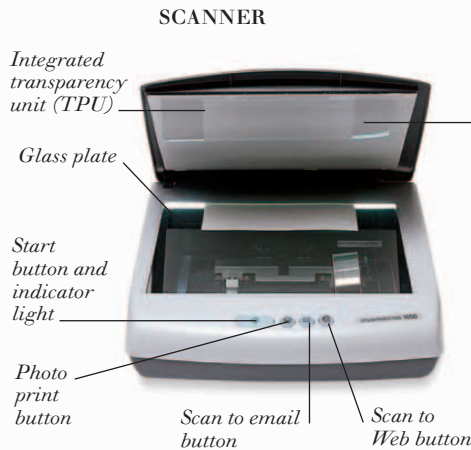
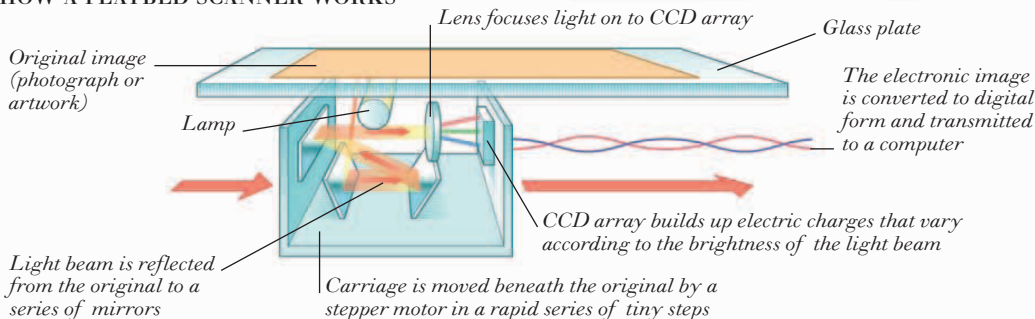


OTHER TABLET COMPUTERS

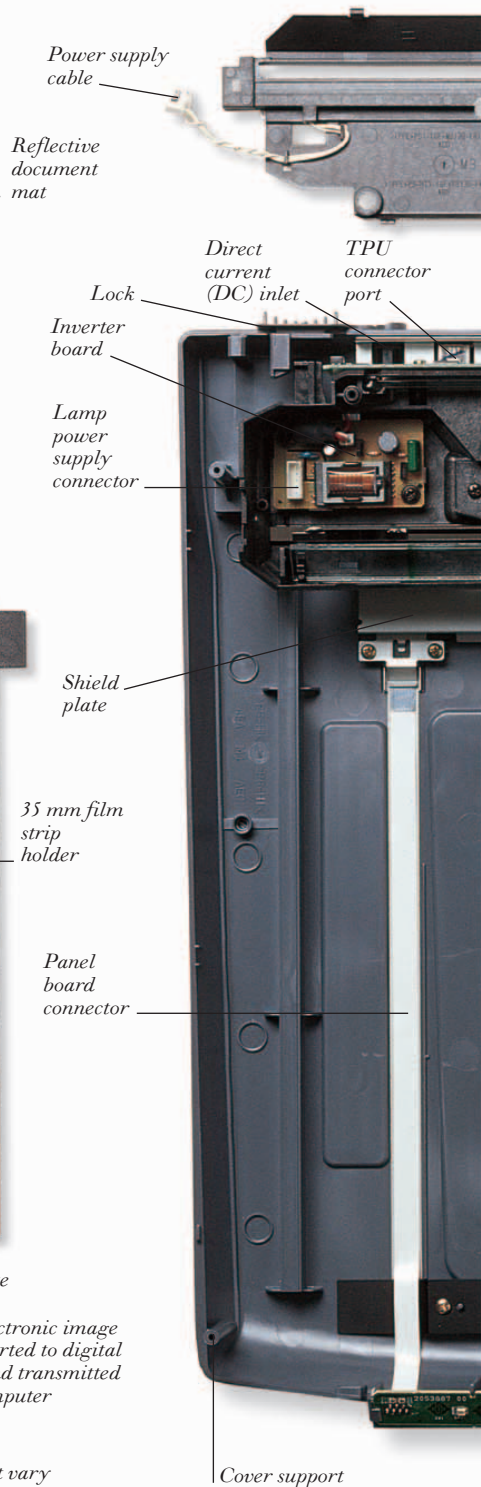
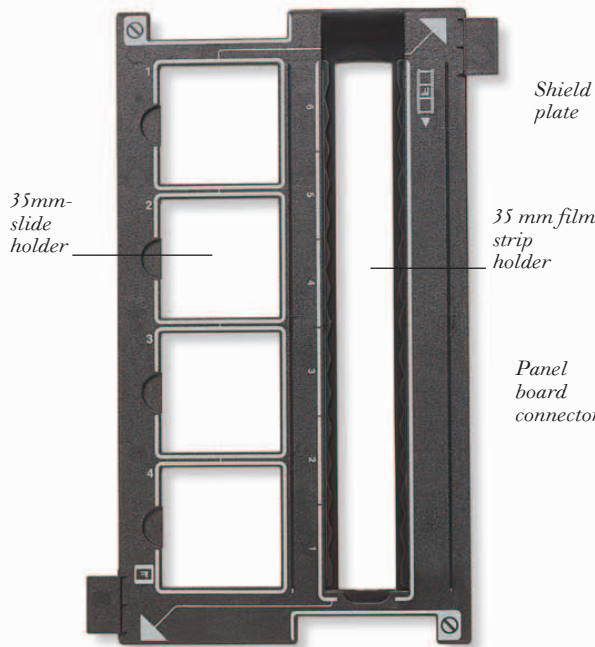
Flatbed scanner

SCANNERS CONVERT physical images into electronic form, allowing them to be sent over the internet, displayed on a website, stored on a computer, and manipulated using specialized software. Scanners work by detecting and analyzing light reflected from an opaque image, such as a photographic print. Some can also scan photographic transparencies by analyzing light that has passed through the image. Flatbed scanners contain a unit, called the scan head, that contains a lamp, mirrors, a lens, and an array of CCDs (Charge-Coupled Devices). The carriage passes beneath the image; the lamp shines light on to or through the original; the mirrors reflect the light on to the lens, which focuses it on to the CCD array. Each CCD detects the brightness of light from a particular pixel (picture element) along a horizontal strip and converts this data into an electric signal. For color images, the light is usually passed through red, green, and blue filters and then directed to the CCD array so that it can be broken down into its component colors. This information is then converted to digital form. The quality of the image depends on its resolution, measured in dpi (Dots Per Inch).

HOW A FLATBED SCANNER WORKS

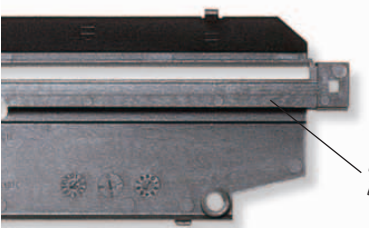


FILM AND SLIDE HOLDER



UNDERSIDE OF SCAN HEAD COVER

COMPONENTS OF A SCANNER



Underside of lamp housing

Lens assembly

Universal serial bus (USB) port

Ferrite core

Integrated transparency unit (TPU)

Scan head

Reflective document mat

Mirror

FCC cable

Carriage shaft

FCC cable slot

Idler pulley

Control panel circuit board

OVERHEAD VIEW



TPU connector

LID ASSEMBLY

Hinge

Glass plate



Finger recess

UNDERSIDE OF COVER

Underside of control panel

THE EFFECT OF SCANNING AT DIFFERENT RESOLUTIONS

Pixel



15 DPI
Lowest resolution at which you may scan.

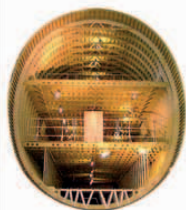


72 DPI
Used for websites and screen images.



300 DPI
Used for printing books and magazines.

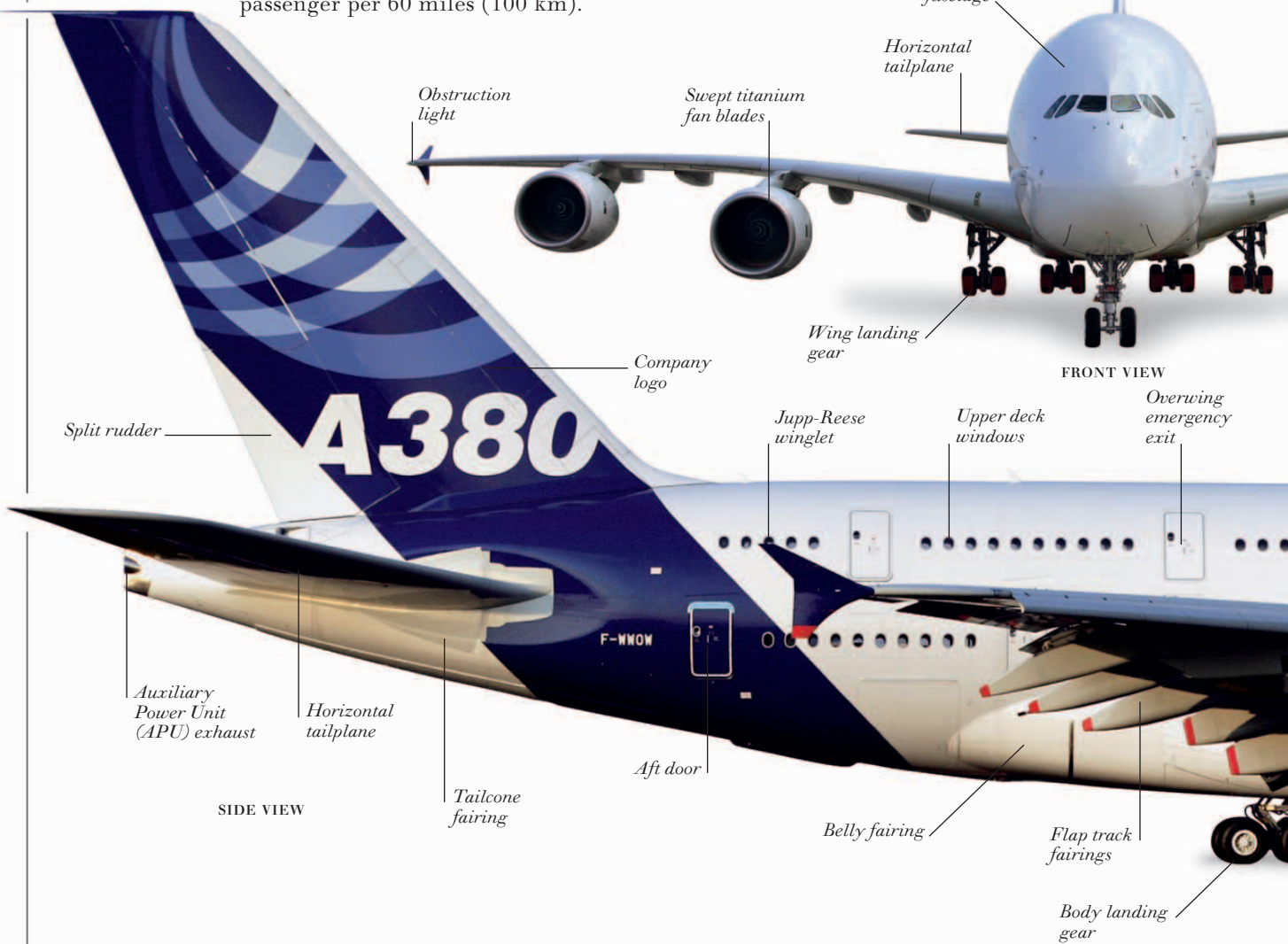
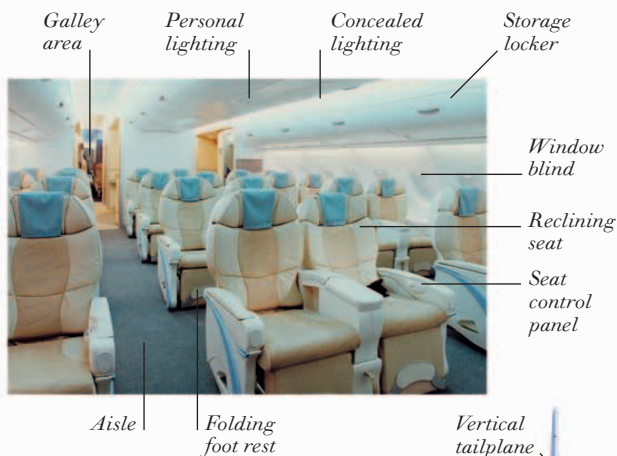
Airbus 380



CROSS-SECTION OF FUSELAGE

THE AIRBUS A380 WAS CONCEIVED in the early 1990s to compete with, and if possible replace, the Boeing 747. Work began in earnest on what was then called the A3XX in 1994. Its maiden flight was in April 2005. The A380's shape is subtly molded to minimize drag from its ovoid fuselage. The structure makes extensive use of composite materials, such as thermoplastics and GLARE (aluminum and glass fiber). Its engines are very powerful, but also very efficient. It is claimed that when carrying 550 passengers, the A380 uses only $\frac{3}{4}$ gallon (2.9 liters) of fuel per passenger per 60 miles (100 km).

INTERIOR VIEW OF BUSINESS CLASS CABIN

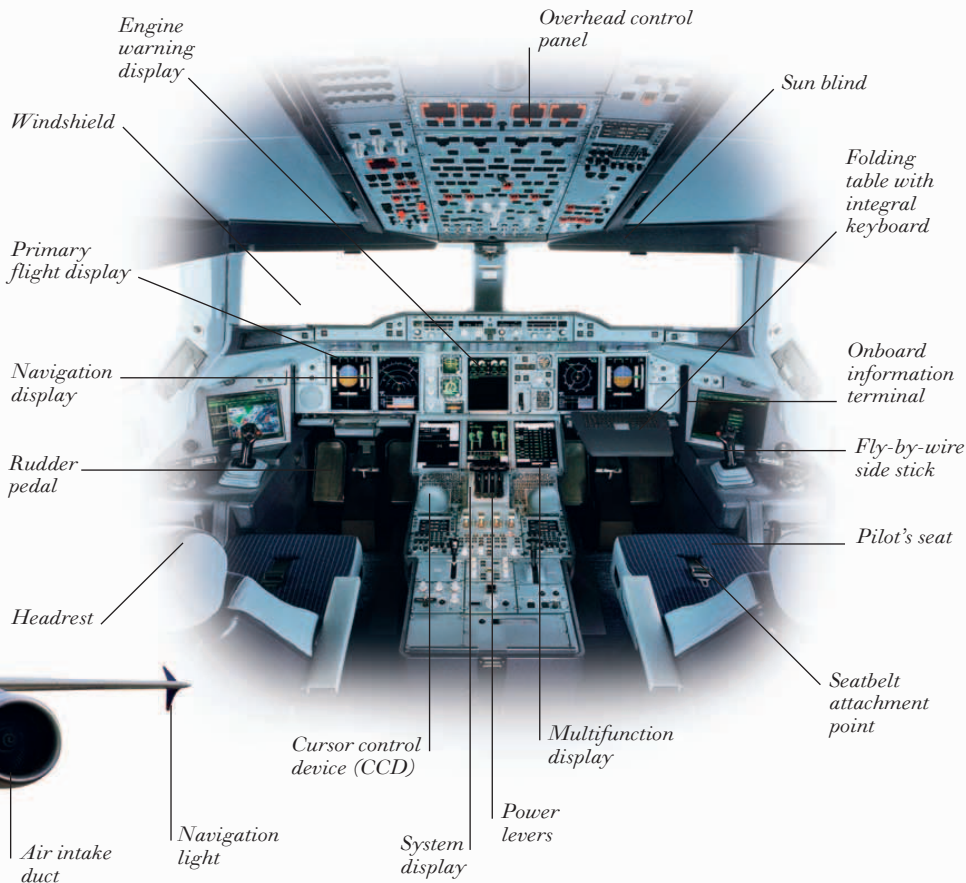


INTERIOR VIEW OF GALLEY



Counter
Bar area
Storage unit
Nonslip flooring

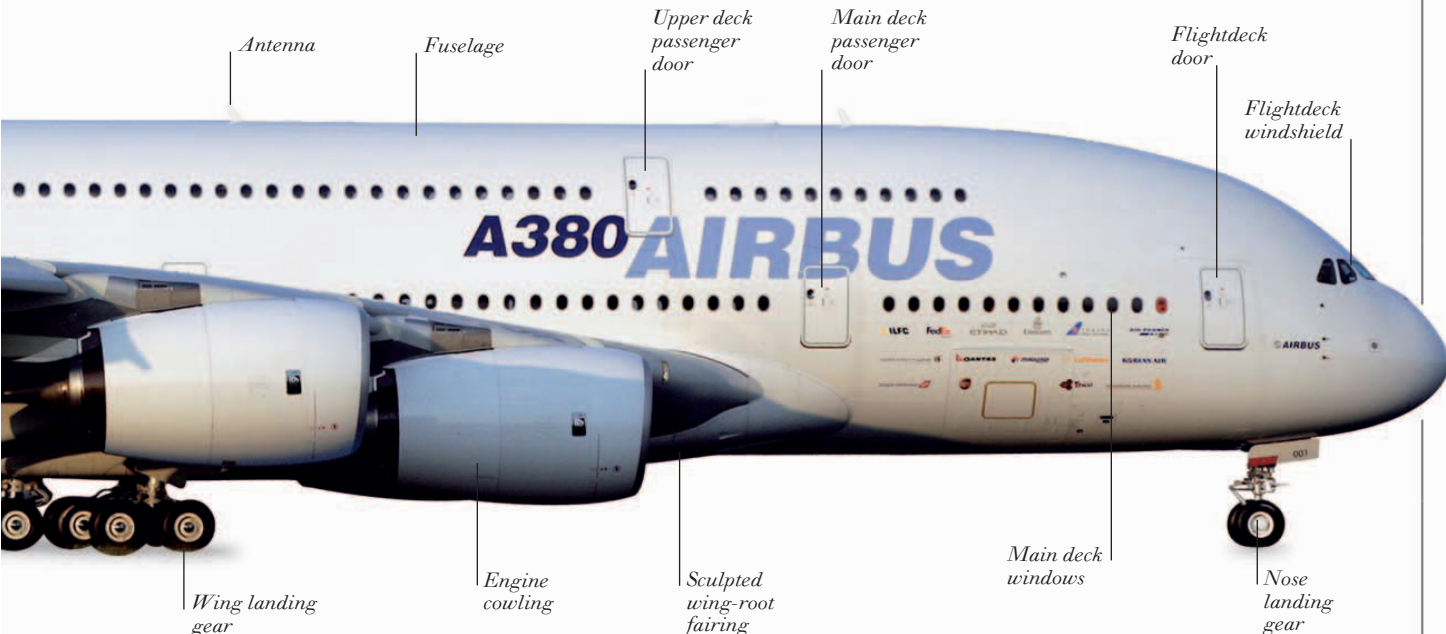
COCKPIT



Engine warning display
Overhead control panel
Sun blind
Folding table with integral keyboard
Onboard information terminal
Fly-by-wire side stick
Pilot's seat
Seatbelt attachment point
Multifunction display
Power levers
System display
Cursor control device (CCD)
Rudder pedal
Navigation display
Primary flight display
Windshield
Navigation light
Headrest



Pylon forward fairing
Wing leading edge
Flap track fairings
Air intake duct

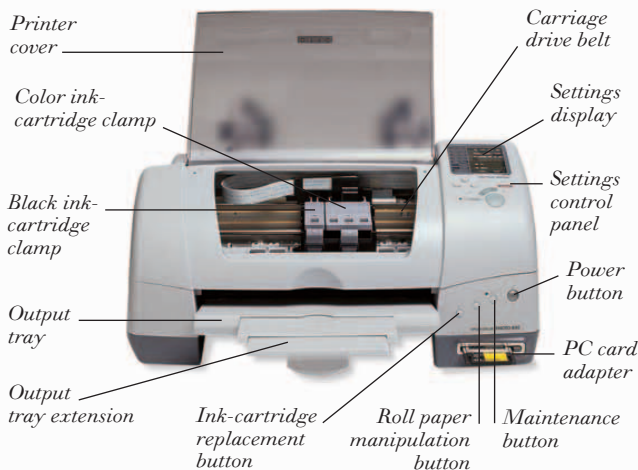


Antenna
Fuselage
Upper deck passenger door
Main deck passenger door
Flightdeck door
Flightdeck windshield
Main deck windows
Nose landing gear
Sculpted wing-root fairing
Engine cowling
Wing landing gear

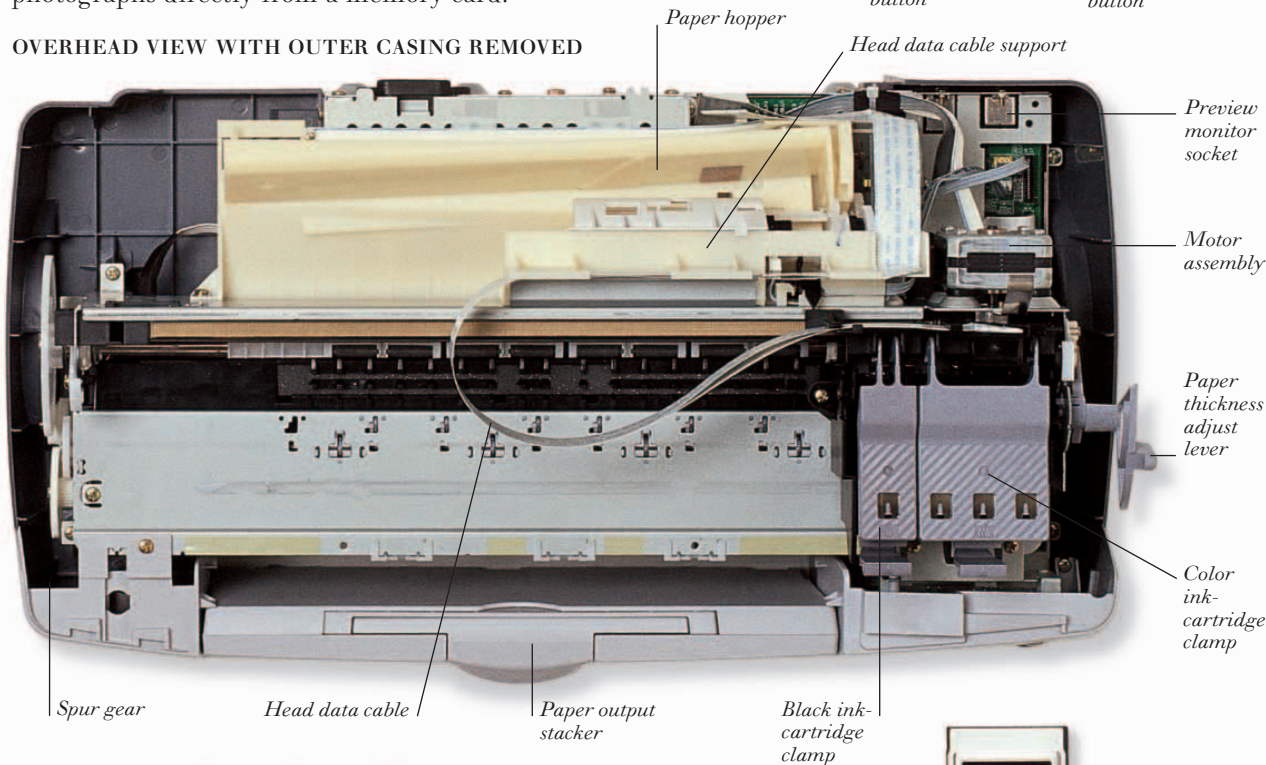
Inkjet printer

INKJET PRINTERS EXPEL ink droplets from hundreds of tiny jets, or nozzles, on to a medium, such as paper, to print an image. Each droplet corresponds to a single pixel (picture element). Black-and-white printers use only black ink, while color printers overprint combinations of the printing colors (cyan, yellow, magenta, and black) to create a full color range. The printhead containing the nozzles moves sideways across the paper, creating a line of pixels, before the paper moves slightly forward so the next line can be printed. Two basic methods are used to eject ink: thermal, in which ink is heated to form an expanding bubble that expels a droplet from the nozzle, and piezoelectric, in which an electric current expands a crystal causing it to push out the ink droplet. The printer shown here can print digital photographs directly from a memory card.

EPSON STYLUS PHOTO 895 COLOR INKJET PRINTER



OVERHEAD VIEW WITH OUTER CASING REMOVED

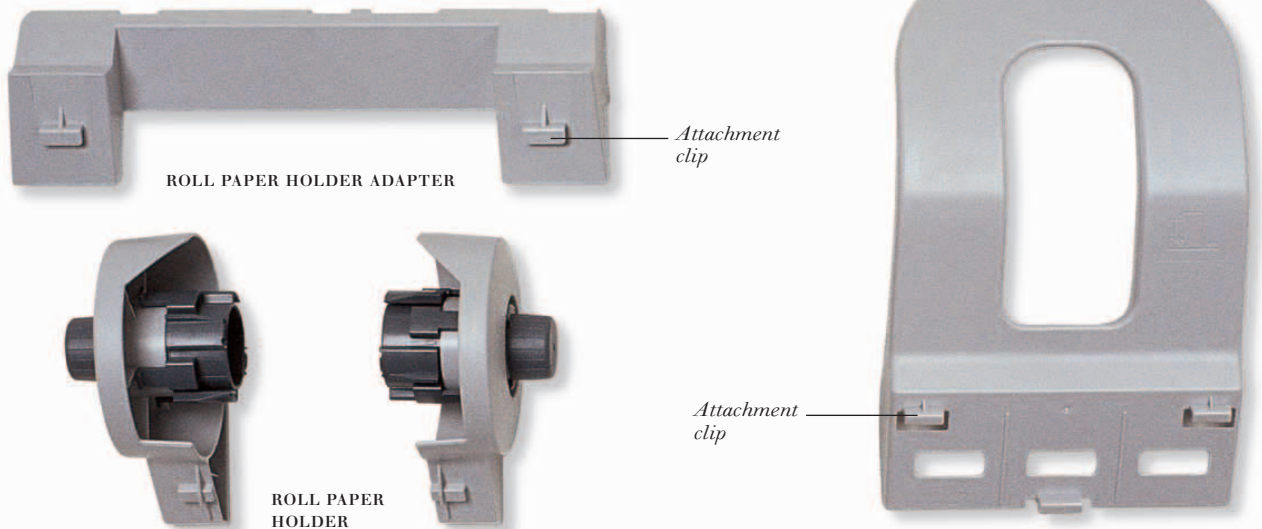


INK CARTRIDGES

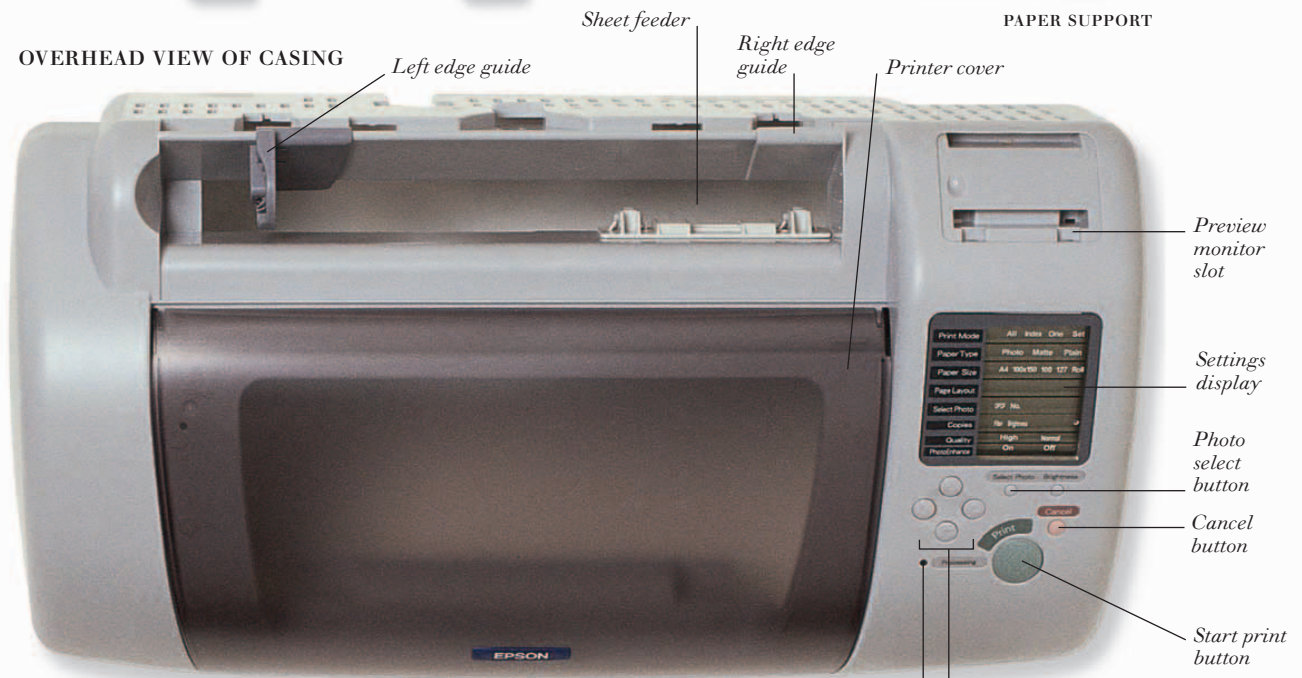


PC CARD ADAPTER

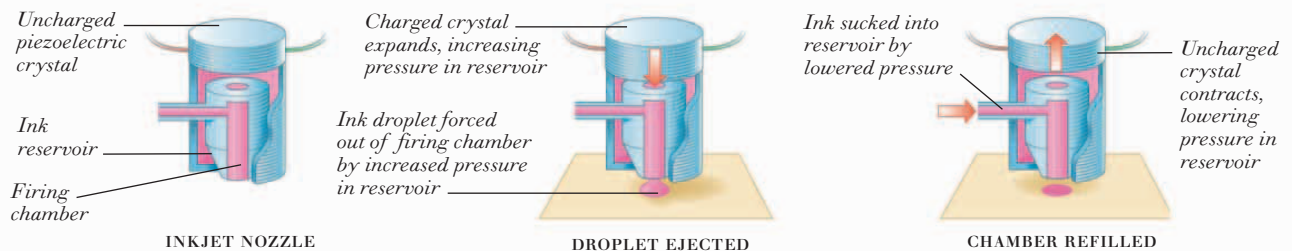
PAPER FEED COMPONENTS



OVERHEAD VIEW OF CASING



HOW A PIEZOELECTRIC INKJET PRINTHEAD WORKS



The internet

THE INTERNET CONSISTS OF TENS of thousands of computer networks linked together to form one huge global network, allowing any computer on one network to communicate with any computer on another. The two main services used on the internet are email and the World Wide Web.

Email allows text messages to be sent—along with attached computer files, images, or video clips, for example—to other computers on the internet. The web consists of billions of pages made up of digital files that are stored on computers across the world and can be viewed using a web browser. The web also provides interactive access to various services, for example, banking and shopping.



Recipient's ISP receives message and stores it until retrieved by the recipient

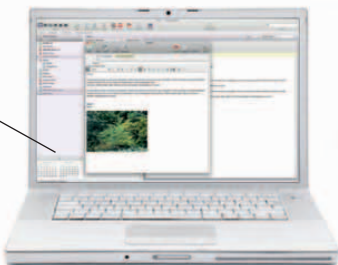
Sender's internet service provider (ISP) directs message into the internet

Telephone line

Modem encodes and sends message via the telephone line

HOW EMAIL WORKS

Screen displays email program



EMAIL SENDER

EMAIL ADDRESS

User name

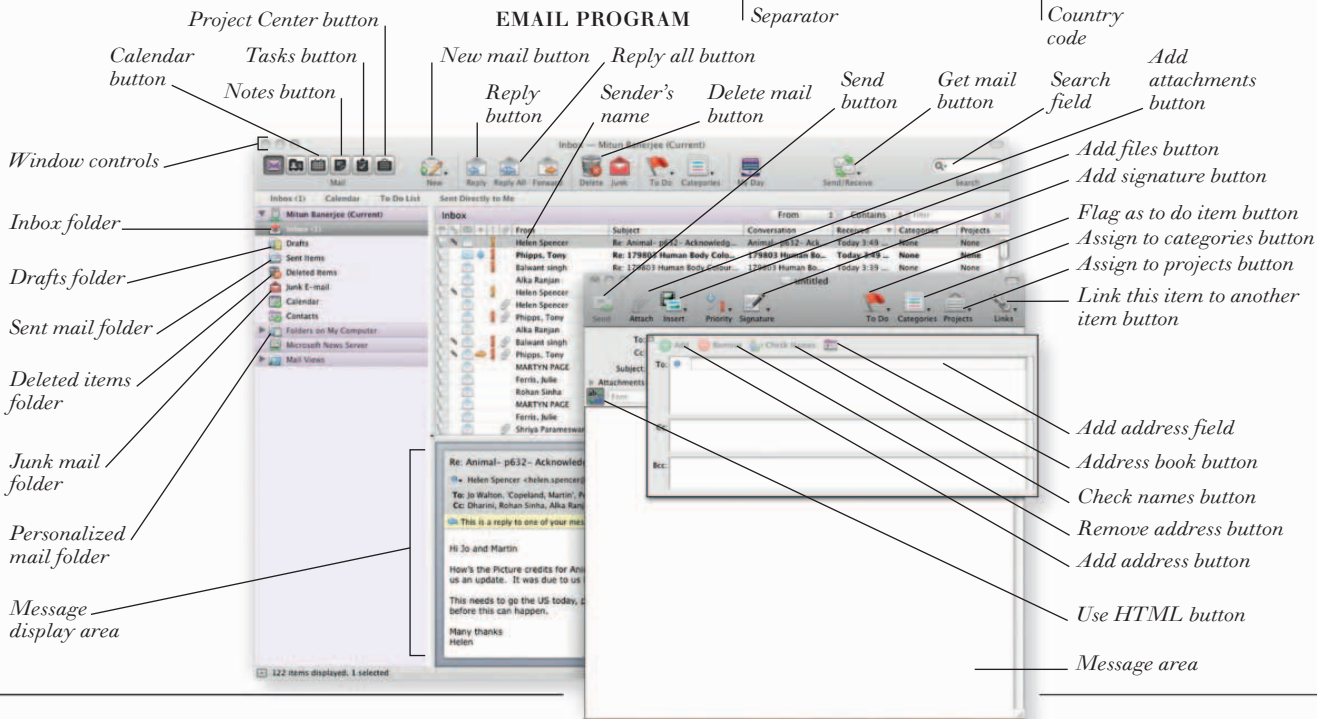
Domain name

anna@merlin.provider.co.uk

Separator

Country code

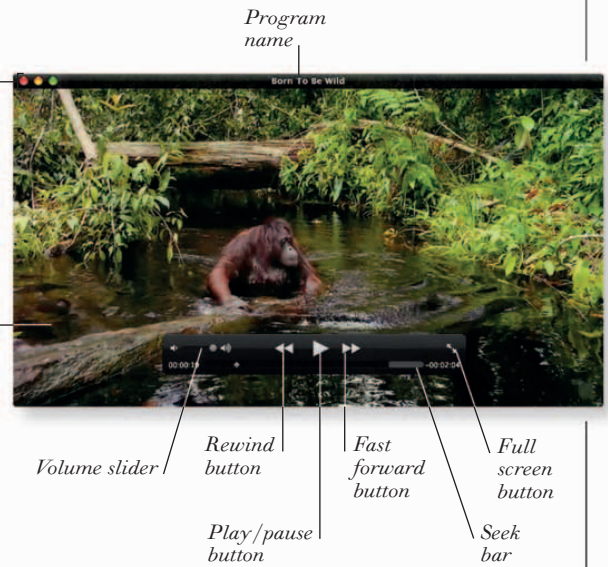
EMAIL PROGRAM



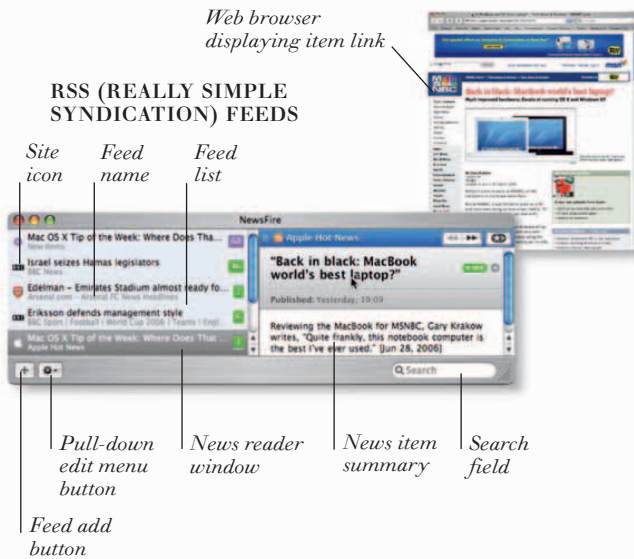
EMAIL RECIPIENT



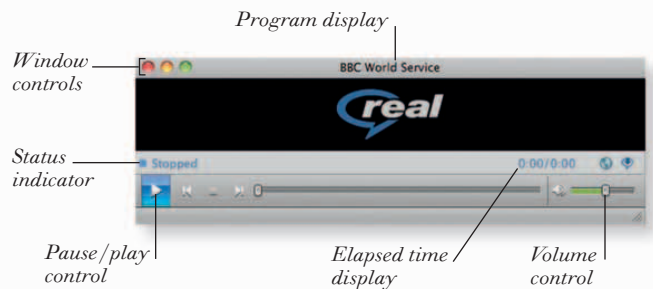
STREAMED INTERNET VIDEO ON-SCREEN DISPLAY



RSS (REALLY SIMPLE SYNDICATION) FEEDS



STREAMED INTERNET RADIO ON-SCREEN DISPLAY



WEB PAGES



UNIVERSAL RESOURCE LOCATOR (URL) ADDRESS



Electronic games

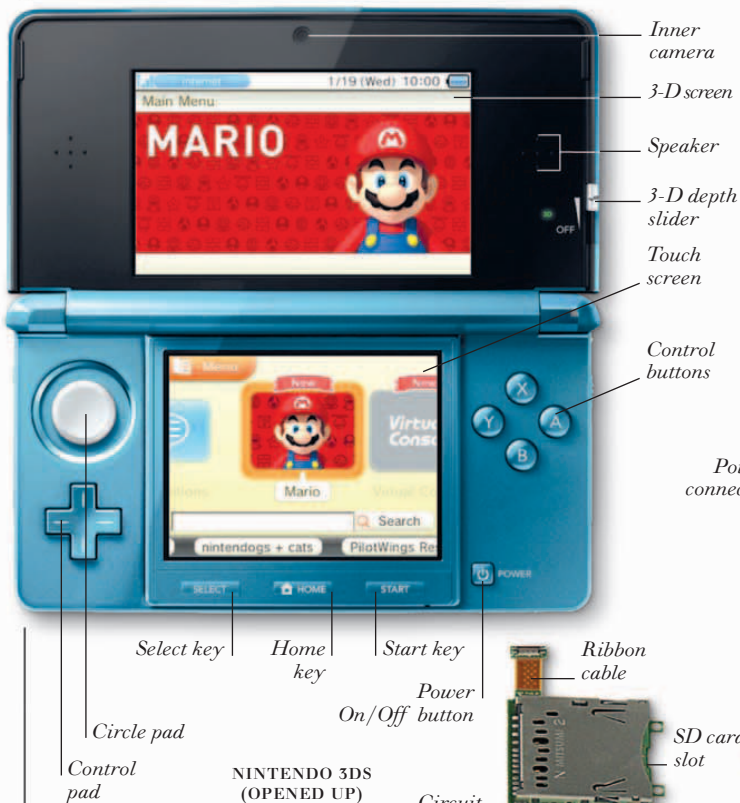


MARIO SPORTS MIX WII

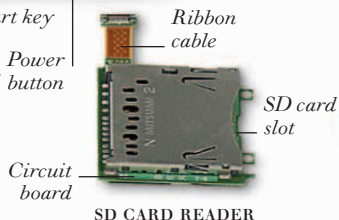
VIDEO GAMES HAVE BEEN around since the early 1970s. They are played on PCs, arcade machines, on a TV using a home console, and on portable handheld consoles. Players use devices such as joysticks and control pads with buttons to control movement and action on screen.

The latest generation of consoles uses motion sensor technology to allow players to manipulate objects on screen by simply moving the controller. The most advanced game systems respond to gestures and commands spoken by a player, without any need to use a hand controller. The game itself is stored in the form of digital information on CD, DVD, or microchip—which may be integral or stored in a removable cartridge—or on an internal hard disk. A central processing unit (CPU) (see pp. 566–567) is needed to process commands from the players, while specialized graphics chips are used to process the complex mapping and texturing functions that make modern games appear so realistic.

NINTENDO 3DS

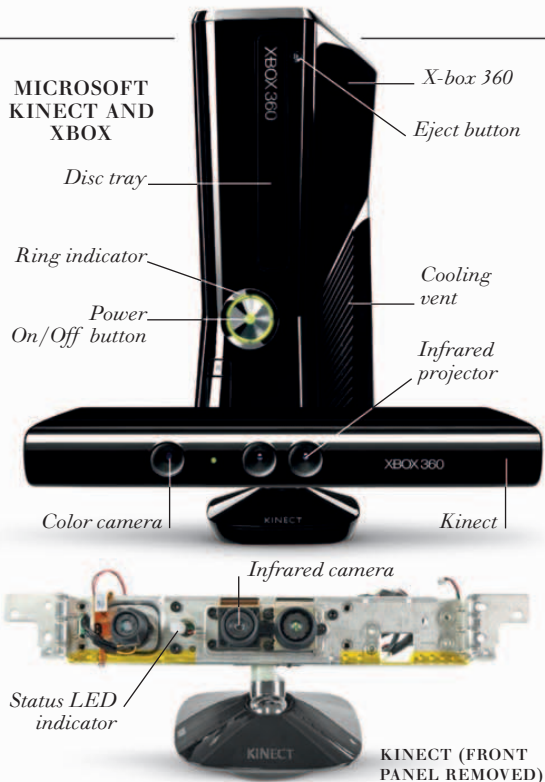
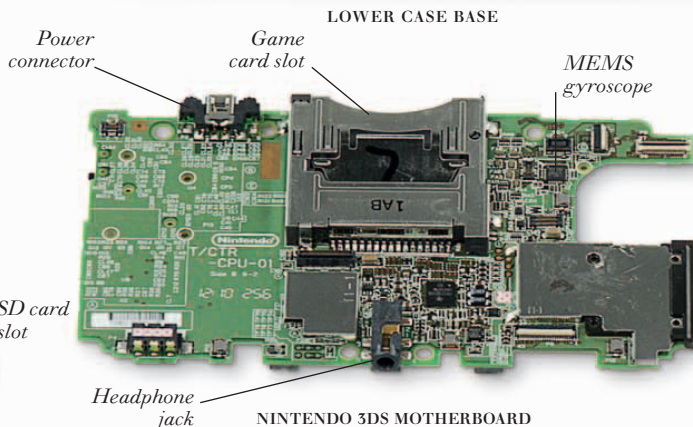
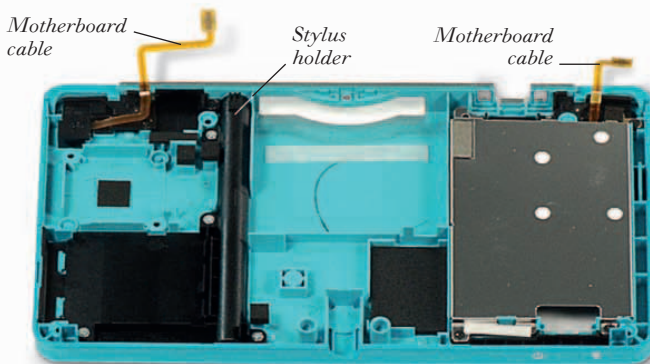


NINTENDO 3DS (OPENED UP)



SD CARD READER

COMPONENTS OF NINTENDO 3DS



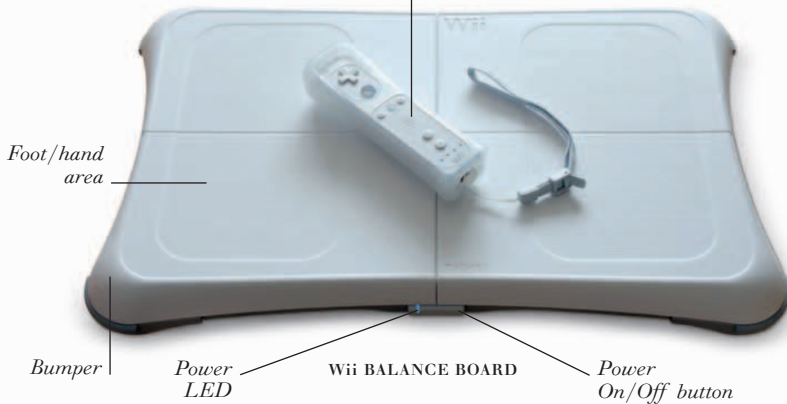
NINTENDO Wii FIT PLUS



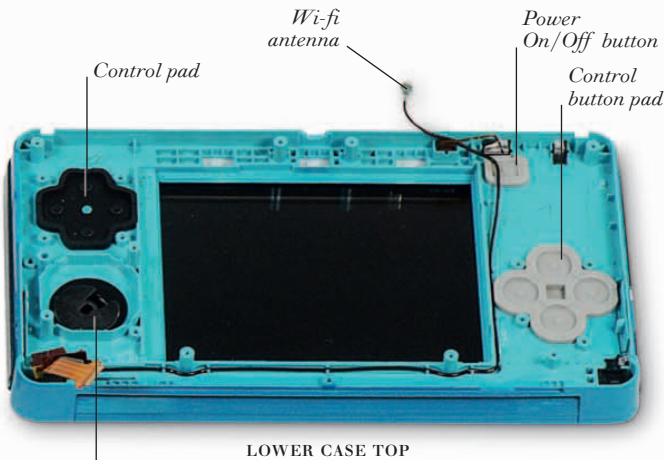
Wii FIT PLUS BALANCE GAME



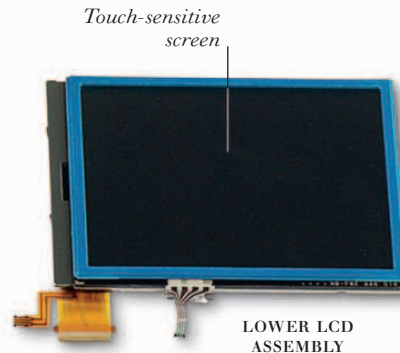
ACTIVITIES ON A BALANCE BOARD



Wii HAND CONTROLLER



LOWER CASE TOP



LOWER LCD ASSEMBLY



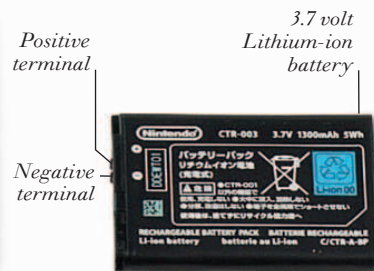
WI-FI BOARD



INFRARED BOARD



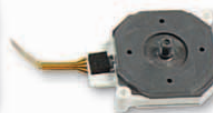
BATTERY COVER



RECHARGEABLE BATTERY



VOLUME CONTROL

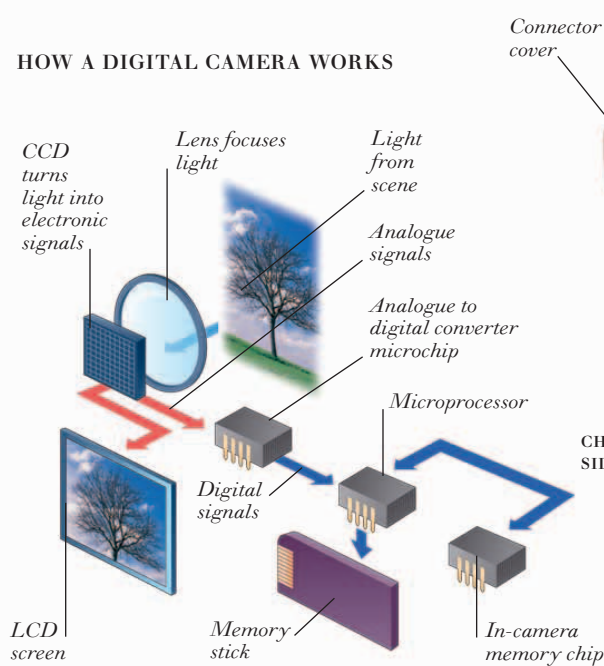


CIRCLE PAD

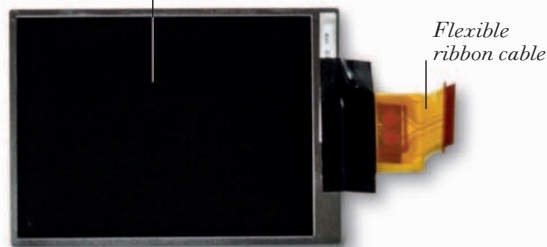
Digital camera

FOR MORE THAN 200 YEARS, CAMERAS recorded pictures as chemical changes in silver-containing substances, on a strip of flexible, celluloid film. The digital camera records pictures in electronic form. At its heart is a specialized integrated circuit known as a charge-coupled device (CCD). This has millions of microunits known as pixels. It works in the opposite way from a miniature computer or TV screen. Instead of electric signals making pixels shine, when light hits a pixel it generates a tiny electrical signal, according to the light's color and brightness. The signals from the CCD's millions of pixels are analogue: they vary continuously in a wavelike fashion. They are converted by a microchip to digital codes of numbers, represented as on-off electronic pulses. The digital signals are processed and fed to the camera's internal memory or a removable memory device such as a data card or memory stick. Photographs can be downloaded from a digital camera to a computer via a cable or in some cases a wireless link. Some digital cameras automatically reduce blurring caused by camera shake or fast movement, some can record video clips as well as still pictures.

HOW A DIGITAL CAMERA WORKS

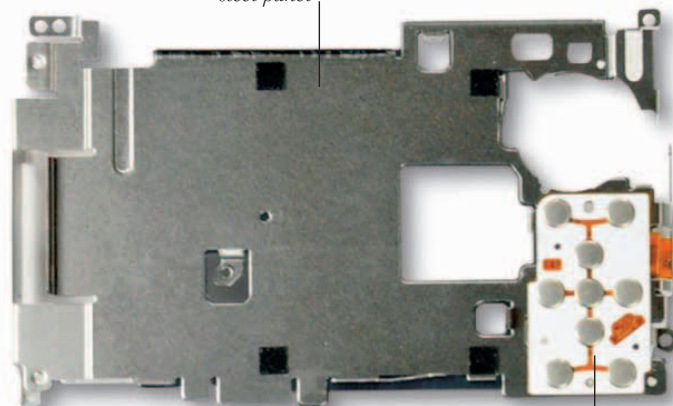


2½ in (6.8cm) liquid crystal display



MONITOR

Protective steel panel



CHASSIS

Keypad

Connector cover

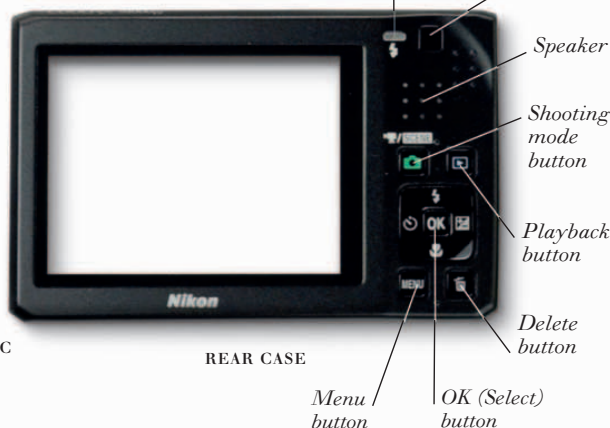
Eyelet for camera strap



CHROMED PLASTIC SIDE COVER

Flash lamp

Infrared receiver (rear)



REAR CASE

Speaker

Shooting mode button

Playback button

Delete button

Menu button

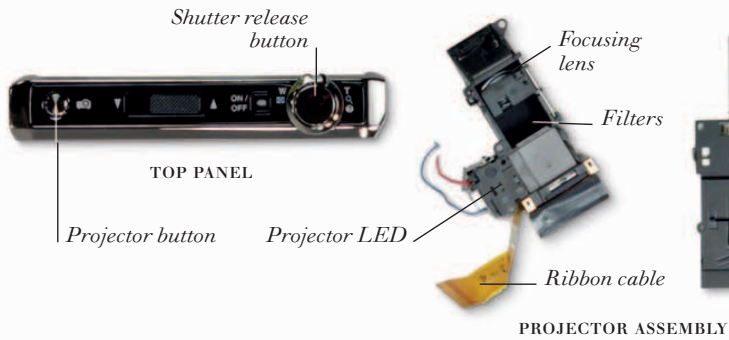
OK (Select) button



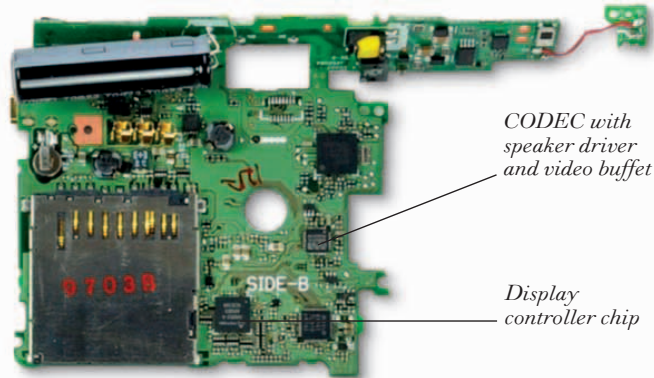
SPEAKER ASSEMBLY

Speaker mounting bracket

COMPONENTS OF NIKON COOLPIX S1000PJ



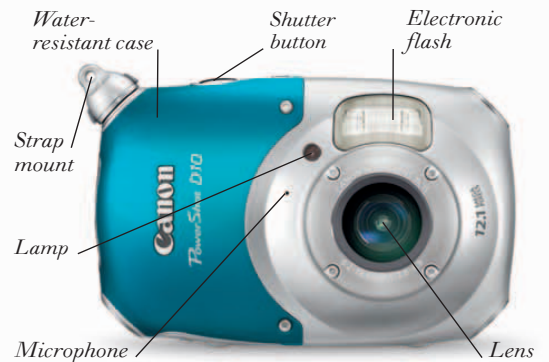
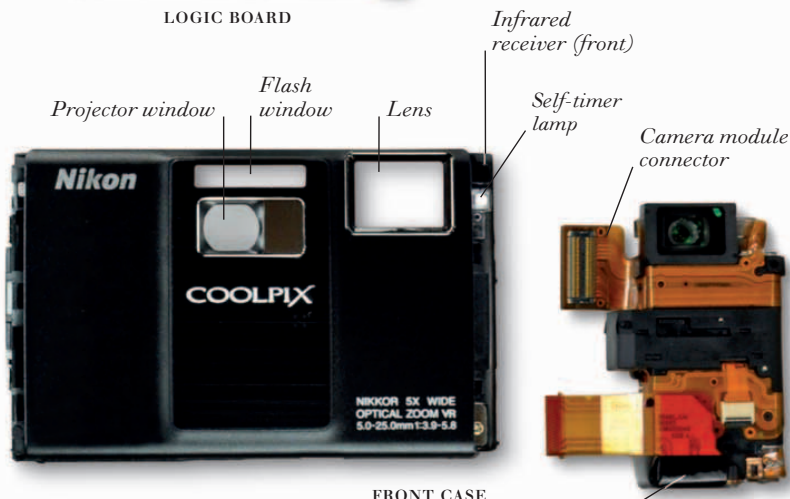
TYPES OF DIGITAL CAMERA



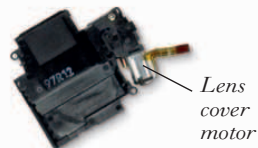
LOGIC BOARD



DIGITAL CAMERA WITH INTERCHANGEABLE LENS



EN-EL12 RECHARGEABLE BATTERY



LENS COVER



Digital video camera

A VIDEO CAMERA, OR CAMCORDER, records a scene as a sequence of 25 or 30 still images per second, along with sound. It comprises a video camera to capture light from the scene, a viewfinder through which the scene may be viewed, a screen on which the recorded scene may be viewed, a charge-coupled device (CCD) to convert the visual data into an electric signal, and a means of storing the signal. Digital video cameras convert the signal into digital form—a series of separate measurements of the initial analogue (continuously varying) signal. They record the digital signal, usually on a chip or hard disk. Video cameras often have a slot where a memory card can be inserted to expand the memory and store longer recordings or more still pictures.

COMPONENTS OF A JVC EVERIO VIDEO CAMERA



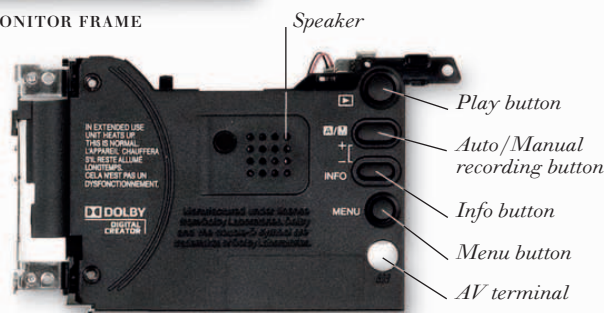
MONITOR SHELL



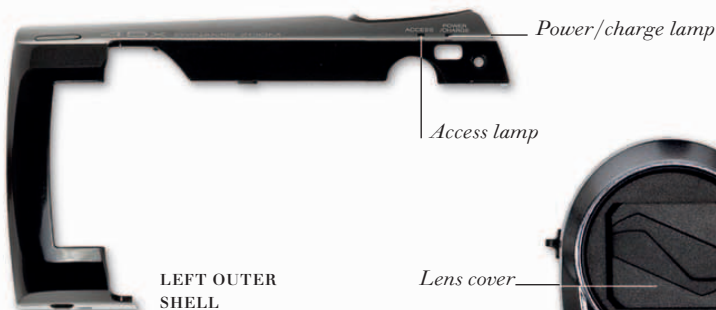
MONITOR MOUNT



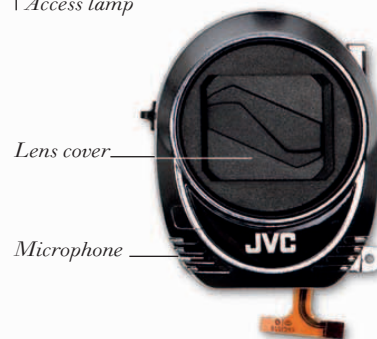
MONITOR FRAME



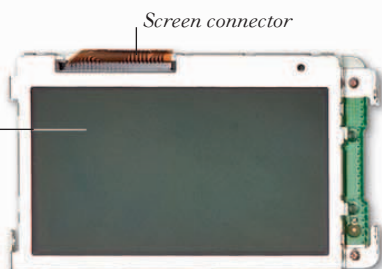
LEFT SIDE



LEFT OUTER SHELL



LENS COVER ASSEMBLY



MONITOR SCREEN



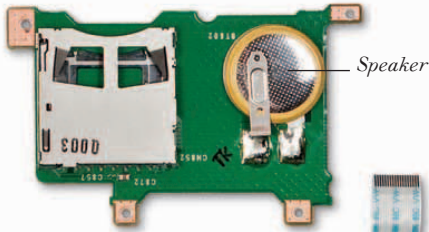
TOP VIEW

Screen connector
2 1/4-in (6.8-cm) LCD screen

Speaker
Play button
Auto/Manual recording button
Info button
Menu button
AV terminal

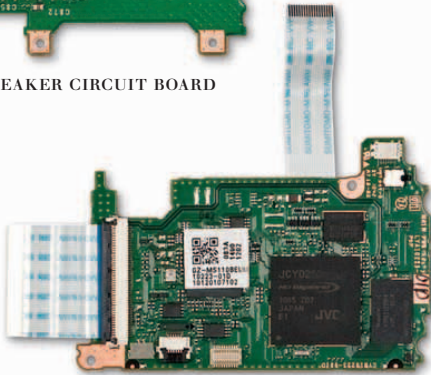
OK button
Grip belt
Battery
Power/Charge lamp
Access lamp
Zoom select lever

Power/charge lamp
Access lamp
Lens cover
Microphone

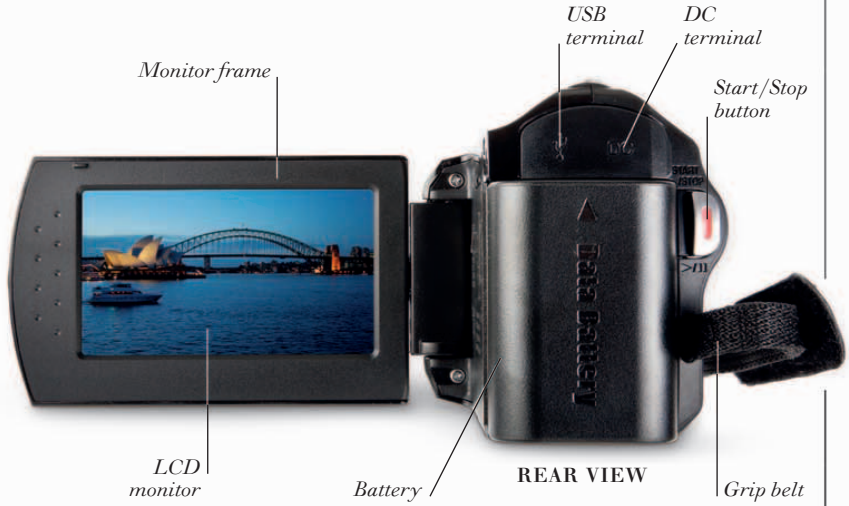


Speaker

SPEAKER CIRCUIT BOARD



MOTHERBOARD



Monitor frame

LCD monitor

USB terminal

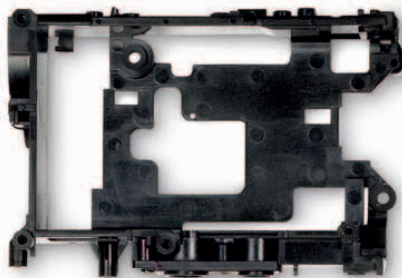
DC terminal

Start/Stop button

BATTERY

Battery

Grip belt



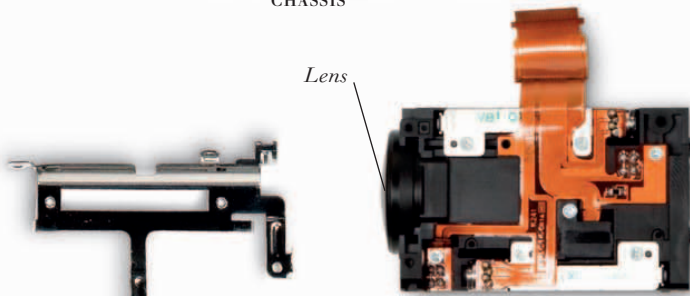
CHASSIS



RIGHT OUTER SHELL

Lens cover switch

Grip belt release lever



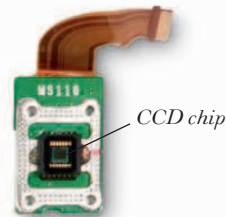
Lens

CCD mounting peg

LENS UNIT

LENS UNIT MOUNT

GRIP BELT FASTENER



SENSOR BOARD

CCD chip



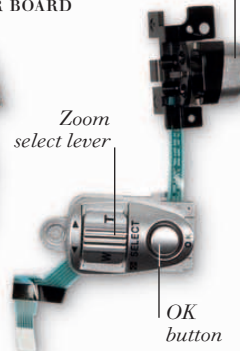
SDHC CARD



GRIP BELT



REAR PANEL



Zoom select lever

OK button

CONTROL UNIT

Start/Stop button

3.6-volt lithium-ion battery

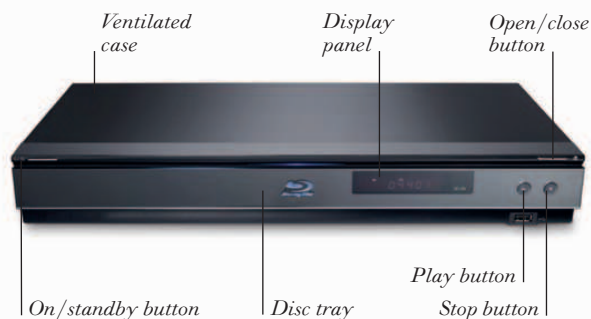


RECHARGEABLE BATTERY

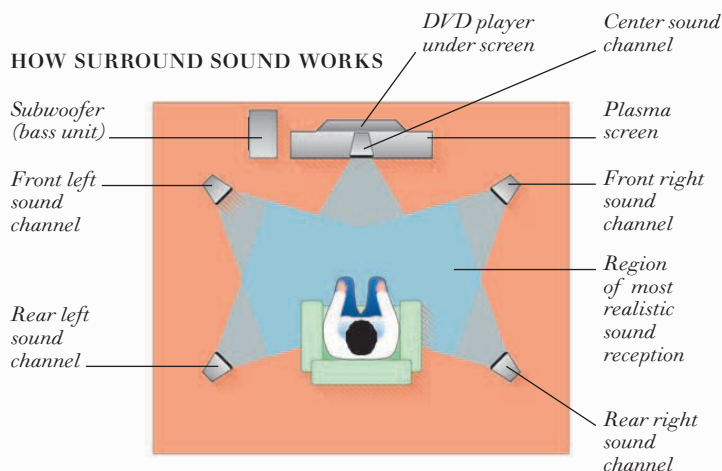
Home cinema

HOME CINEMA REPLICATES a real “movie theater” using pictures displayed on a high-quality widescreen television set, such as a plasma TV, and surround sound from strategically sited loudspeakers. The source for sound and vision is a DVD (Digital Versatile Disc). Its player uses standard CD (Compact Disc) digital technology, but with a higher density of laser-read microscopic pits—more than 20 billion such pits in multilevel spiral tracks that, stretched out, would extend nearly 25 miles (40km). Blu-ray is a high-quality DVD system that fits much more data on its disc than standard DVDs, allowing High Definition video files to be stored. It is hard for the human ear to discern the direction of low-pitched sounds, so these emanate from a central bass speaker, often built into or below the screen unit. High-pitched sounds, the direction of which is easier to detect, emanate from mid- and high-frequency speakers positioned around the viewer. Plasma screens use fluorescent tube (“strip-light”) technology. Tiny three-cell pixels, each about one millimeter across, contain red, green, and blue phosphor chemicals and a gas mix. Where electric pulses coincide for a split second in the crisscross matrix of wire electrodes, the gas energizes and emits ultraviolet light, which in turn makes the phosphor glow.

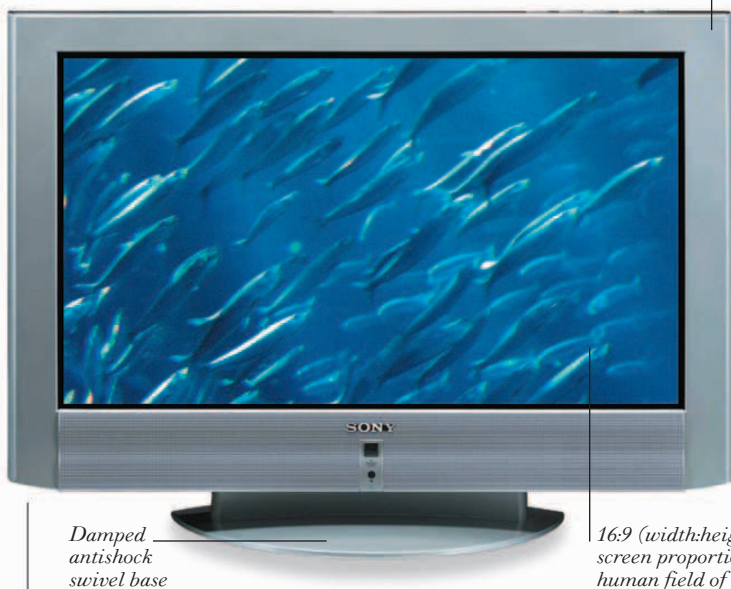
BLU-RAY PLAYER



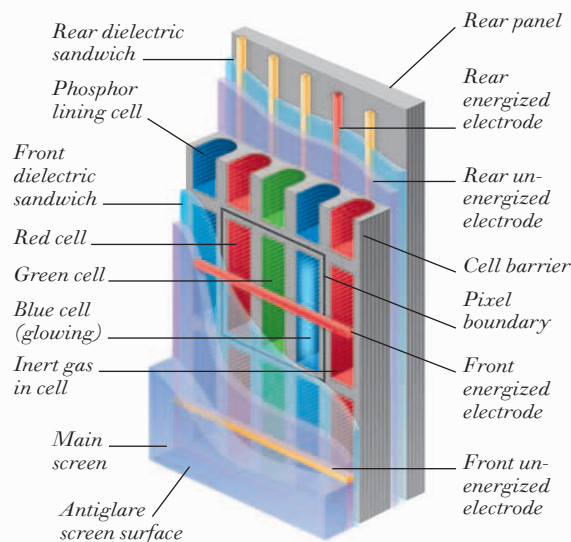
HOW SURROUND SOUND WORKS

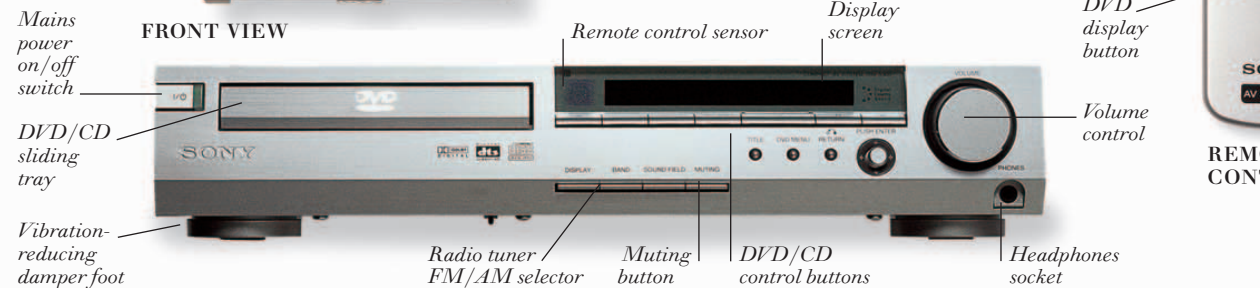
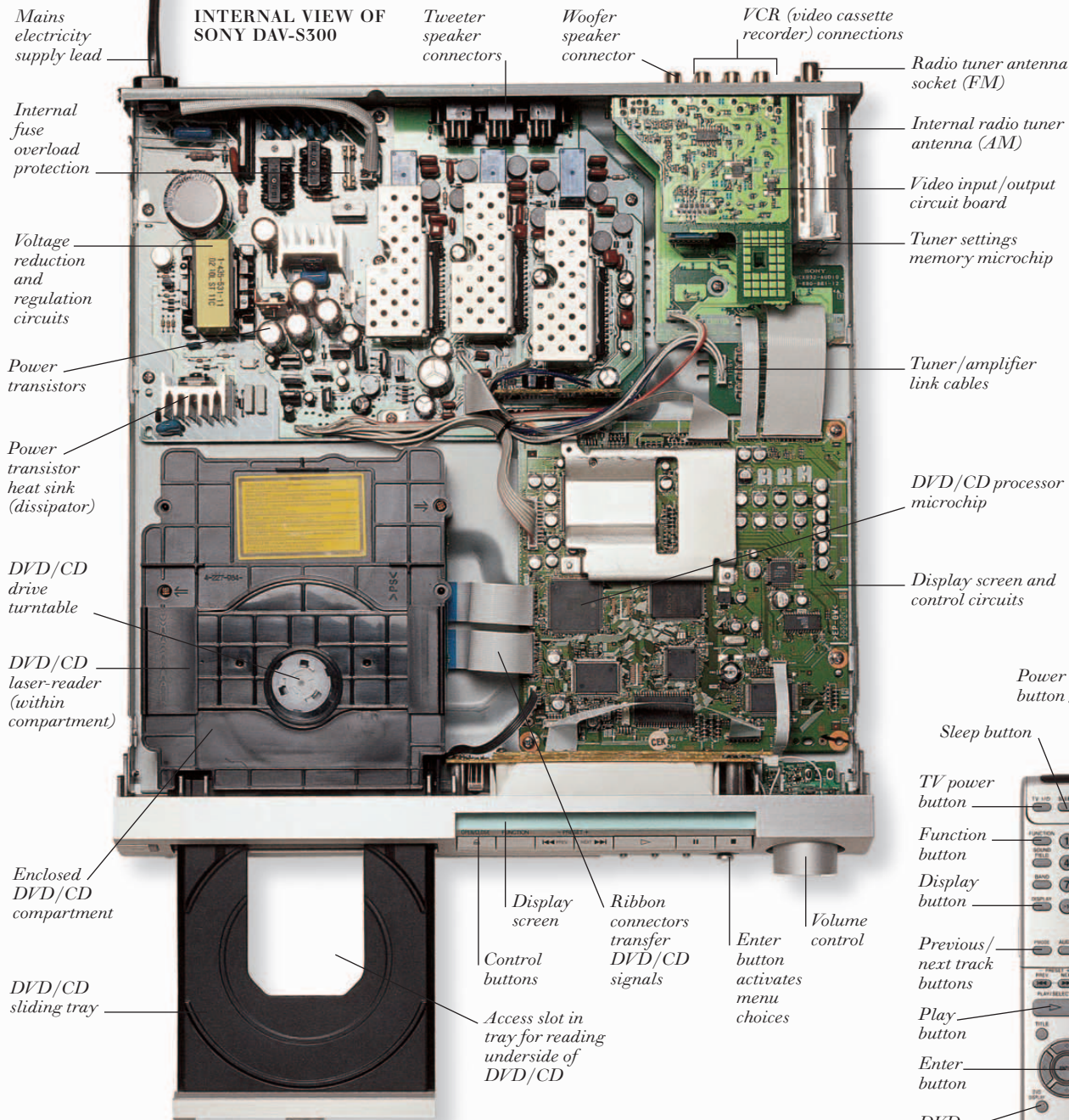


WIDE-SCREEN PLASMA DISPLAY



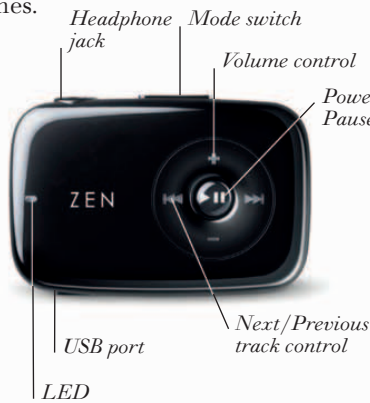
HOW A PLASMA SCREEN WORKS





Personal music and video

THE FIRST BATTERY-DRIVEN PORTABLE source of sound and music was the transistor radio of the 1950s. In the 1970s, the magnetic audio cassette tape allowed recordings to be played on portable tape players. Also, new metal alloys permitted the tiny but high-power magnets needed for lightweight earphones. In the 1980s, compact discs brought music into the digital era. Sony's MD, or minidisc, introduced re-recordable CDs that used magnetic and optical technology. From the mid 1990s, music could be stored in all-electronic digital form in a microchip, usually in the MP3 file format. These files can be transferred between devices and via the Internet. Today, a variety of portable media gadgets can record, play, and store video, photographs, and music in electronic form.



CREATIVE ZEN STONE

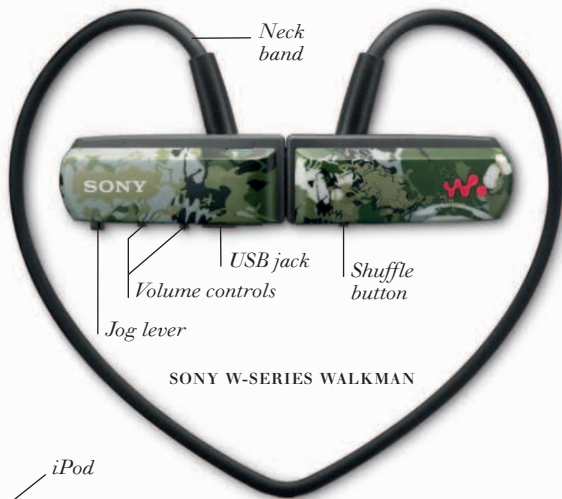
MP3 PLAYERS



SONY B-SERIES MP3 PLAYER



JBL SPYRO SPEAKERS

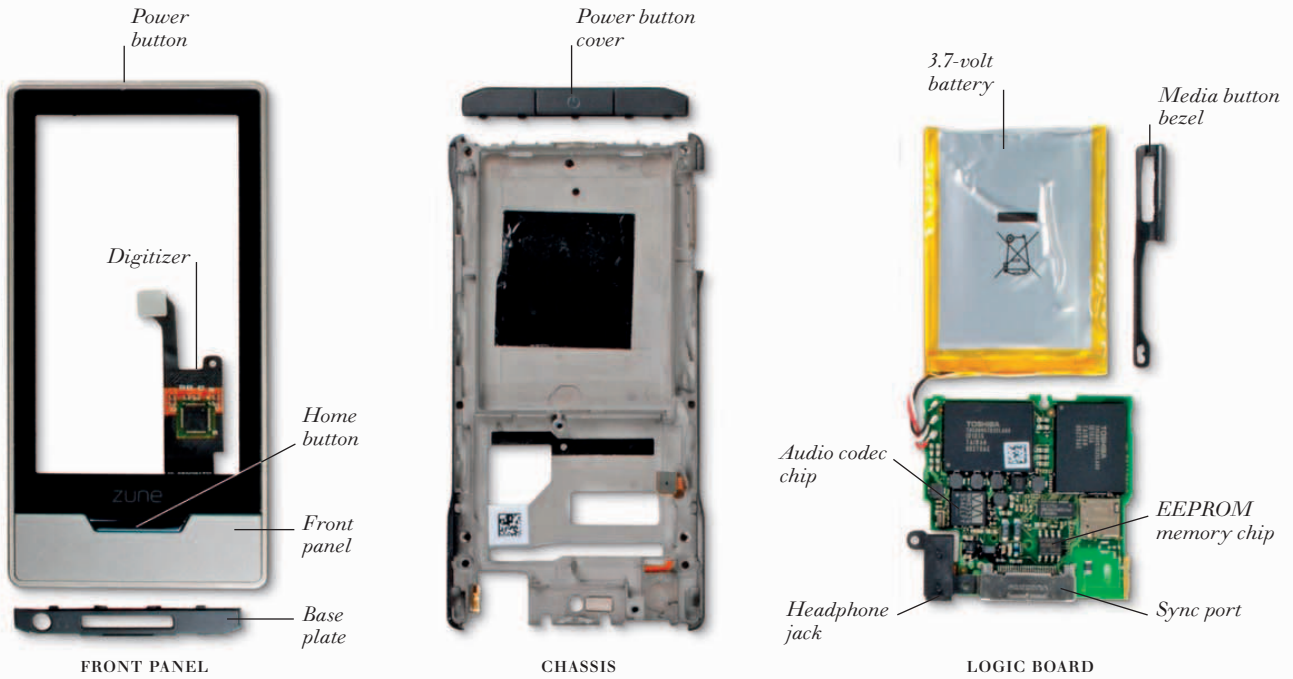


SONY W-SERIES WALKMAN



ZEPPELIN IPOD SPEAKER DOCK

COMPONENTS OF MICROSOFT ZUNE HD



MICROSOFT ZUNE HD

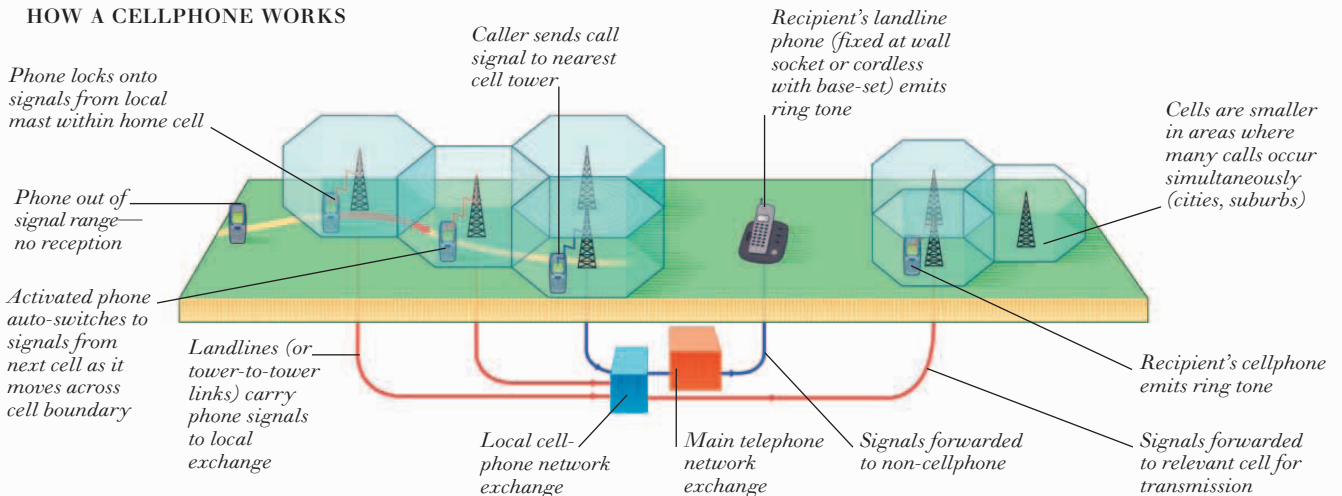


Cellphones

IN THE EARLY 1990s, THE CELLPHONE (or mobile phone) was a rare luxury, but in recent years it has outsold almost every other electrical gadget—as a professional tool, domestic convenience, and even a fashion accessory. Cellphones have also generally shrunk in size, due to improvements in rechargeable batteries, which now store more electricity for longer in a smaller package, and to smaller, more efficient electronics that use less electricity. A “cellphone” is basically a low-power radio receiver-transmitter, plus a tiny microphone to convert sounds into electrical signals, and a small speaker that does the reverse. When the cellphone is activated, it sends out a radio signal that is answered by nearby mast transmitter-receivers. The phone locks onto the clearest signal and uses this while within range (the range of each transmitter is known as a cell). The phone continuously monitors signal strength and switches to an alternative transmitter when necessary. The phone’s liquid crystal display (LCD) shows numbers, letters, symbols, and color pictures. Newer models have a larger screen for more complex color images, and commonly incorporate a camera, radio, and MP3 functionality. Smartphones, which are increasingly widespread, contain additional software and more may be downloaded. Smartphones typically offer internet and email access, PDA-like functions (see pp. 568–569), and may even contain GPS navigation software.



HOW A CELLPHONE WORKS



COMPONENTS OF BLACKBERRY CURVE 8520

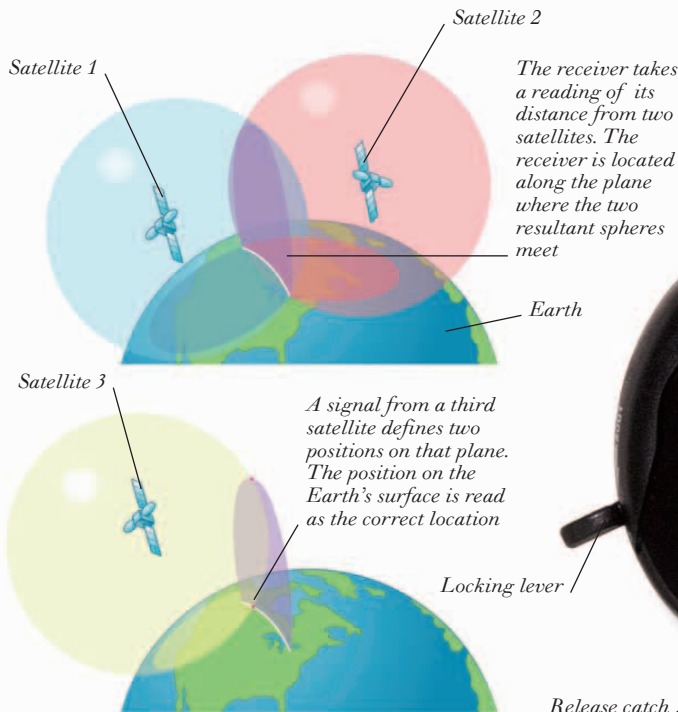
BLACKBERRY CURVE 8520



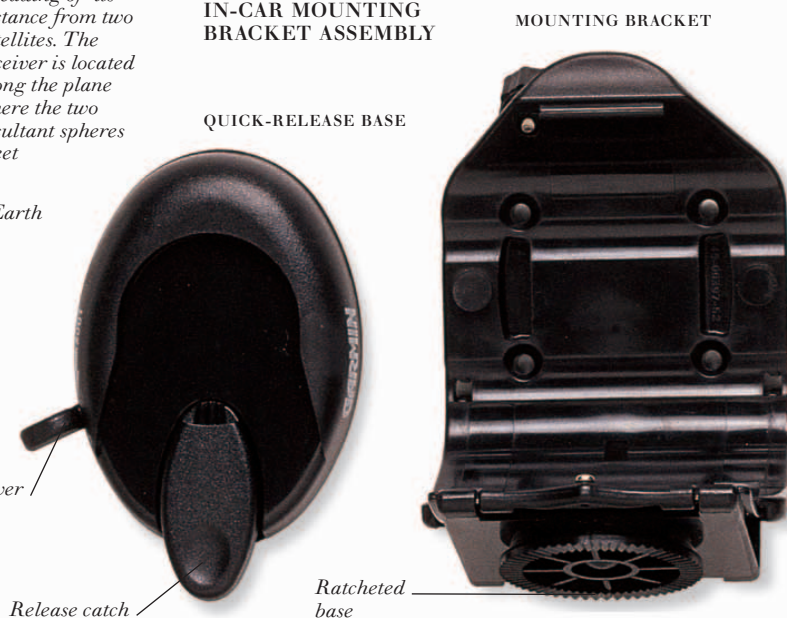
Global positioning system

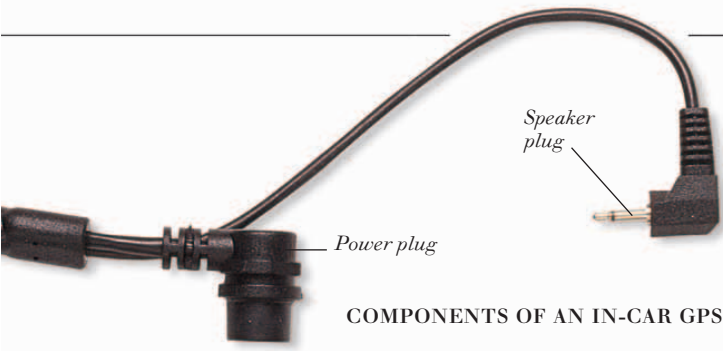
THE GLOBAL POSITIONING SYSTEM (GPS) is a network of 24 navigation satellites orbiting the Earth that people can use to pinpoint their position. The satellites orbit at a height of 12,500 miles (20,000 km). A GPS receiver picks up signals from any of these satellites that are above the horizon. It uses information in each signal to work out how far away it is from the satellite. It can calculate its position on the Earth's surface when it has information from at least three satellites. A basic GPS receiver shows the latitude and longitude of its position on its screen. More advanced receivers, especially those designed for use in vehicles, show their position on a digital map. These receivers often show extra information, such as the vehicle's speed and the length of the journey. Some receivers warn drivers if they exceed the speed limit for a road and even tell drivers which traffic lane to use at the next junction. Directions are shown on the screen and also spoken by a synthesized voice.

HOW GPS WORKS

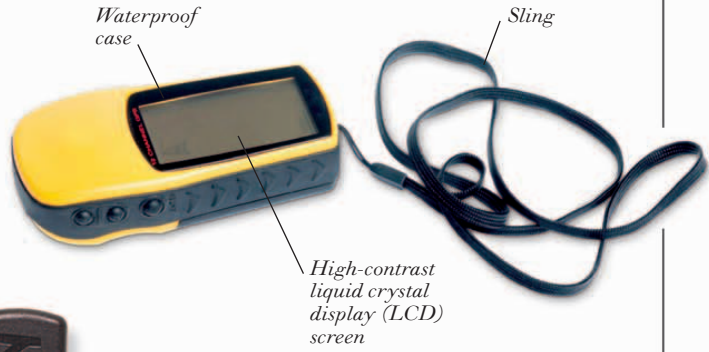


IN-CAR MOUNTING BRACKET ASSEMBLY

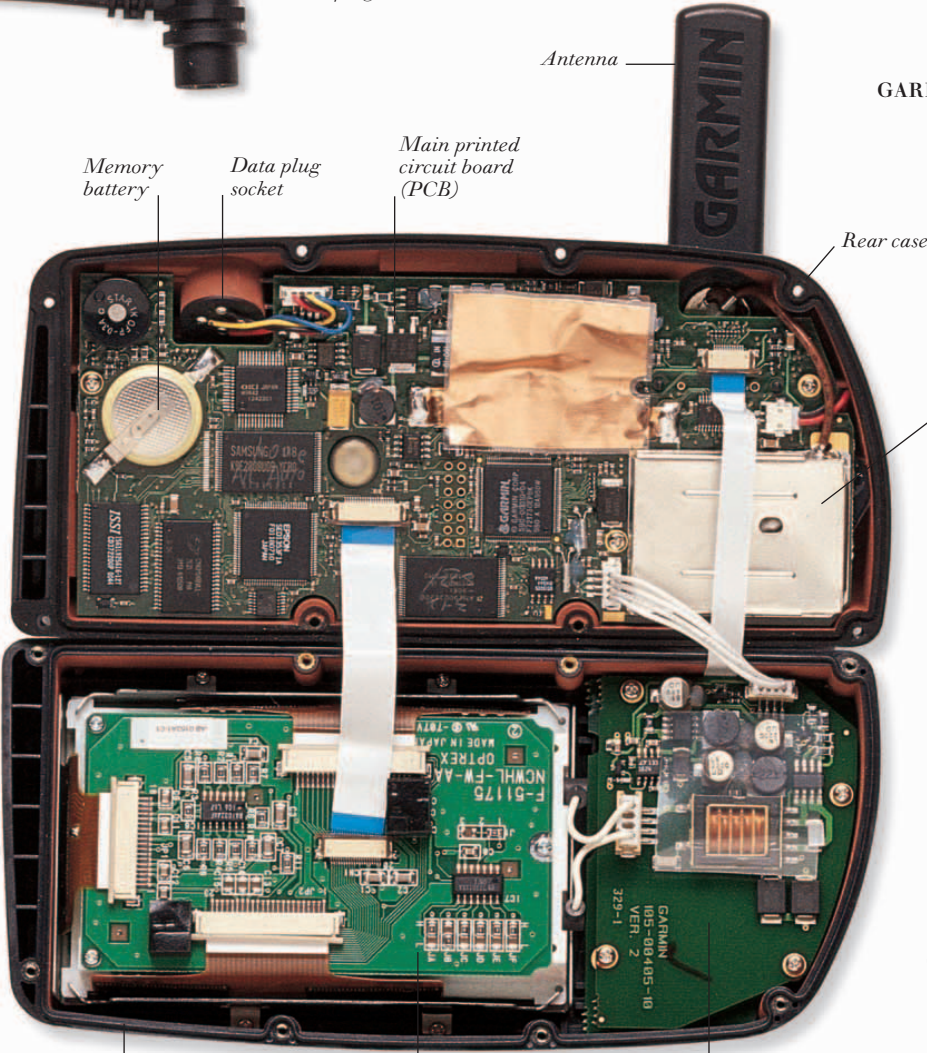




COMPONENTS OF AN IN-CAR GPS



GARMIN ETREX HANDHELD GPS



USB PROGRAMMER ASSEMBLY

Shielded receiver

Data cartridge

Universal serial bus (USB) programmer



SPARE FUSES



Front case

Liquid crystal display (LCD) assembly

Underside of control pad

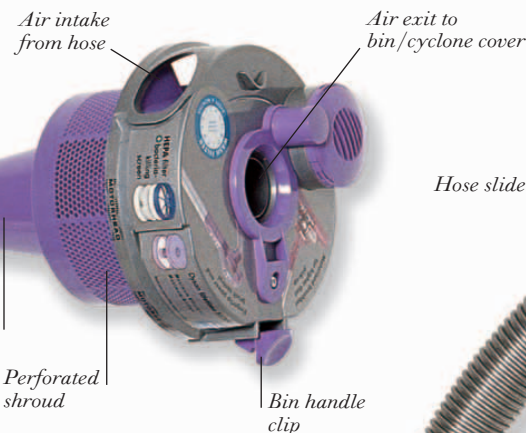
Vacuum cleaner

IN A CONVENTIONAL VACUUM CLEANER, an electric motor spins a fan that sucks in air carrying dust and debris. The air is forced through tiny pores in a dust bag, trapping most particles. In the 1990s, James Dyson's dual cyclone "bagless" design did away with the dust bag—and the reduced airflow caused by clogging of its pores. An electrically driven fan creates a partial vacuum within the machine. This sucks air into the machine past a rotating brush that loosens dirt. The air flows into a cylinder-shaped bin. As the air whirls around the bin like a miniature storm, or cyclone, larger particles are flung outward and fall to the bottom of the bin. The air then passes through perforations into a cone-shaped inner bin and then into a series of smaller cones, spinning faster all the time and flinging smaller and smaller particles out. The nearly clean air exits the machine through microfilters that trap the tiniest particles. Some Dyson vacuum cleaners run on a large ball instead of wheels. The ball makes it easier to steer the cleaner.



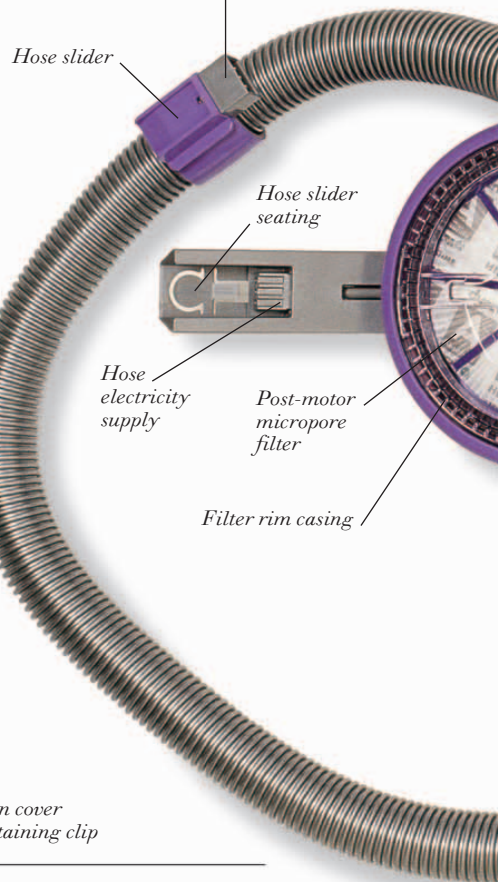
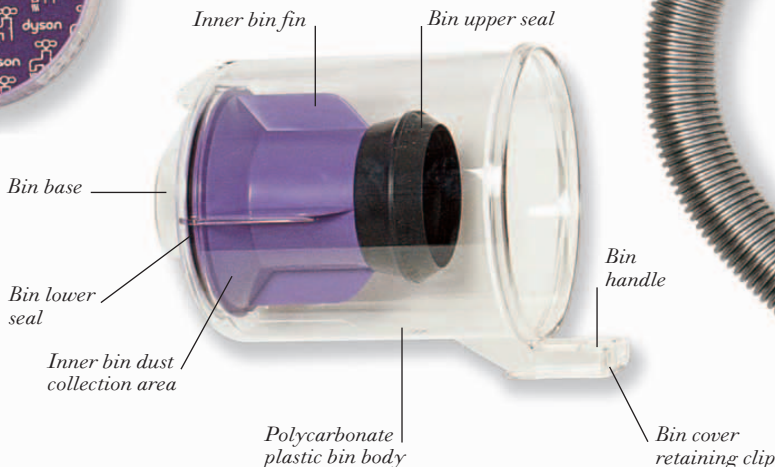
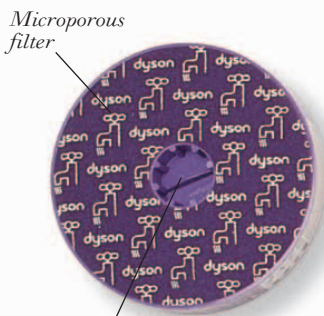
DYSON DC05 MOTORHEAD

CYCLONE ASSEMBLY

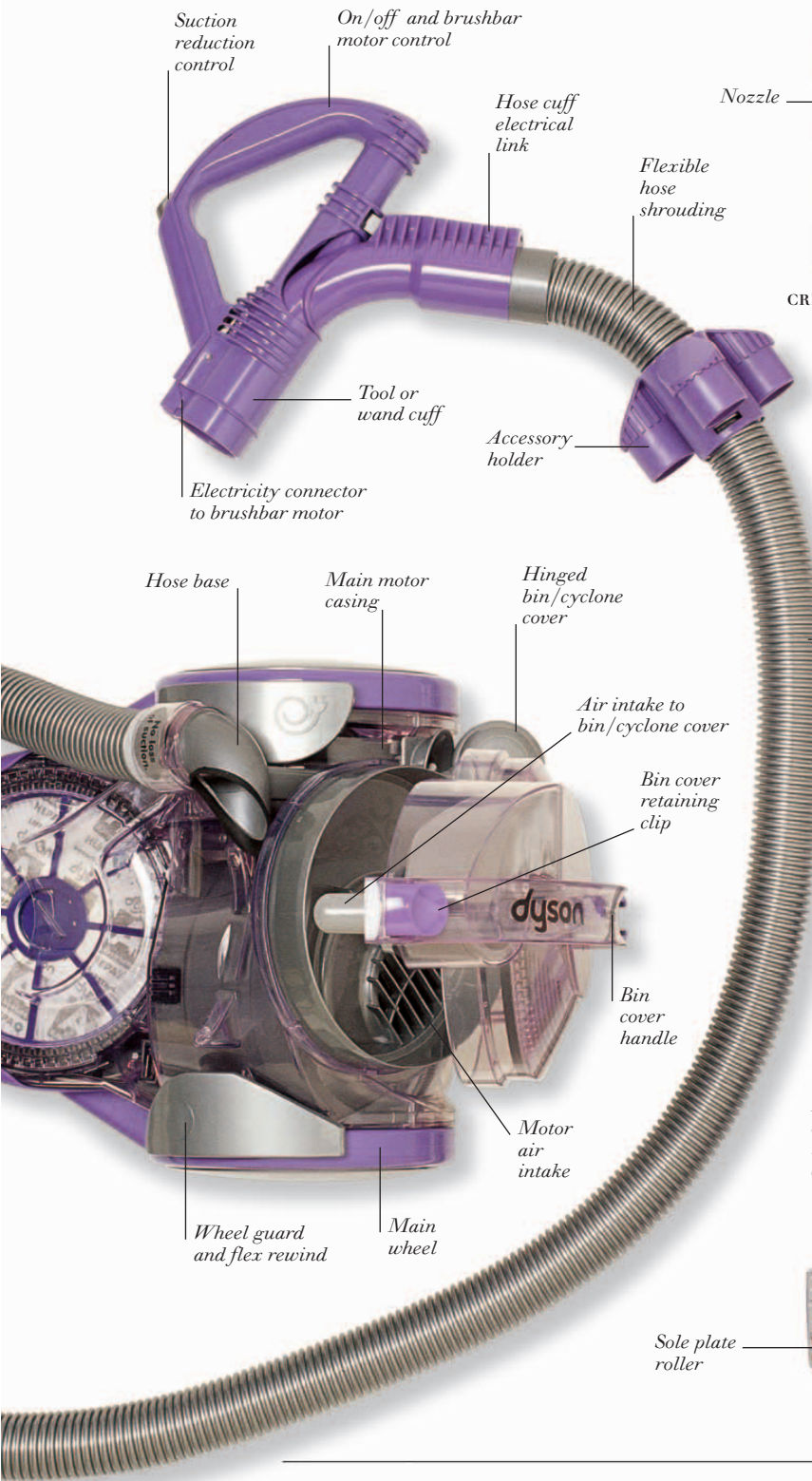


DUST COLLECTION BIN

WASHABLE PRE-MOTOR FILTER



**OVERHEAD VIEW OF
DYSON DC05 MOTORHEAD**



ACCESSORIES



*Tool/
brushbar
connector*

*Textured
scraper*

STAIR TOOL

CREVICE TOOL

*Brush tool
articulation*

UPHOLSTERY BRUSH

WAND

*Flexible
hose
shrouding*

**MOTORIZED
BRUSHBAR
FLOOR TOOL**

*Wand/handle
connector*

*Handle
connector*

*Brushbar
drive
motor
cover*

Roller

*Sole plate
roller*

*Brushbar drive
belt cover*

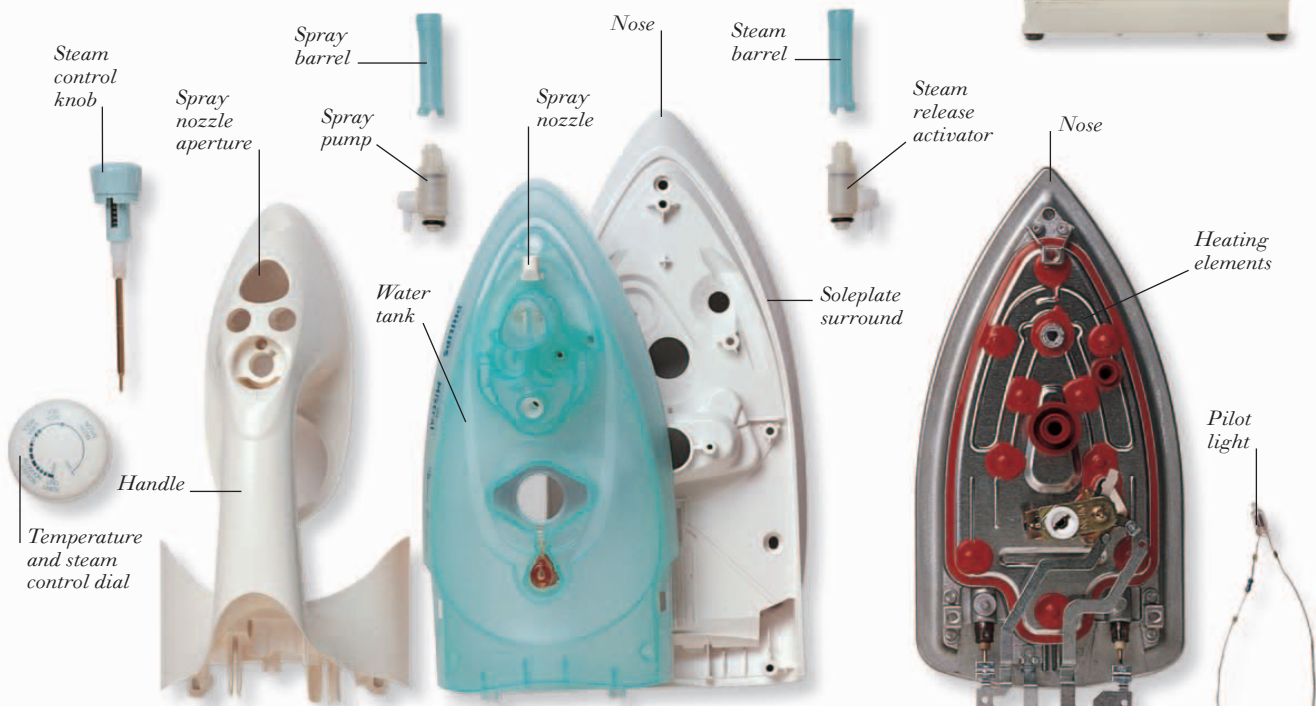
*Rotating
brushbar*

Sole plate

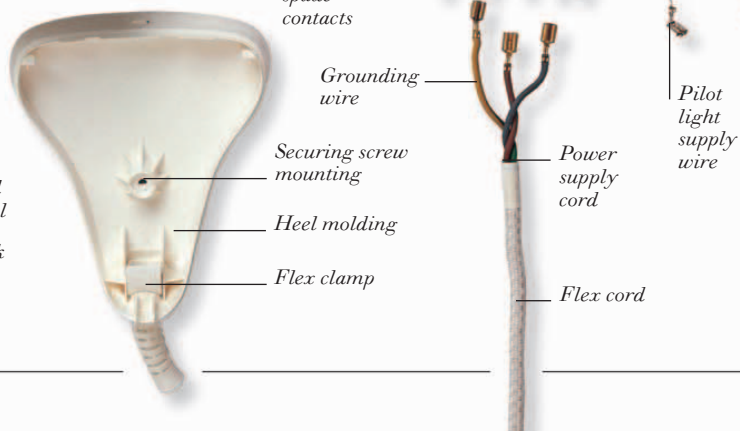
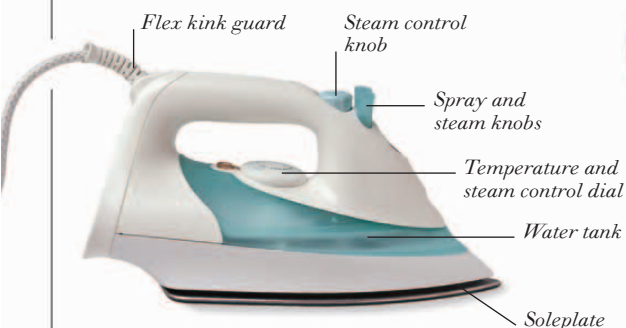
Iron and washer-dryer

IN THE DAYS BEFORE WASHING MACHINES, laundry was done by hand—washed in a barrel, squeezed in a roller-mangle, hung on a line, and smoothed with an iron heated on the stove. In the 1880s, electrically heated irons were one of the first home electrical appliances. Today's iron still applies heat, sometimes moistened with steam, to dampen and flatten garment fibers. Machines with electric heaters and motors took the strain out of washing from the 1910s. Up to the 1960s, three machines were needed to wash, spin, and dry. Now clothes are swirled in a rotating ribbed tub of hot water, then spun fast to throw off most of the water, before slowly tumbling in electrically heated air to dry—all in one appliance.

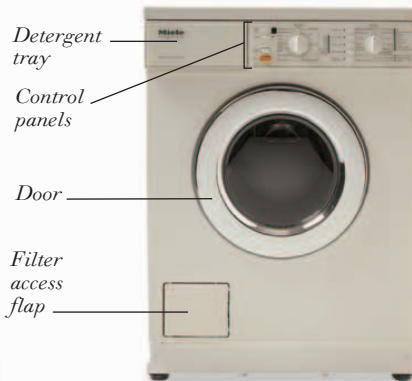
COMPONENTS OF A STEAM IRON



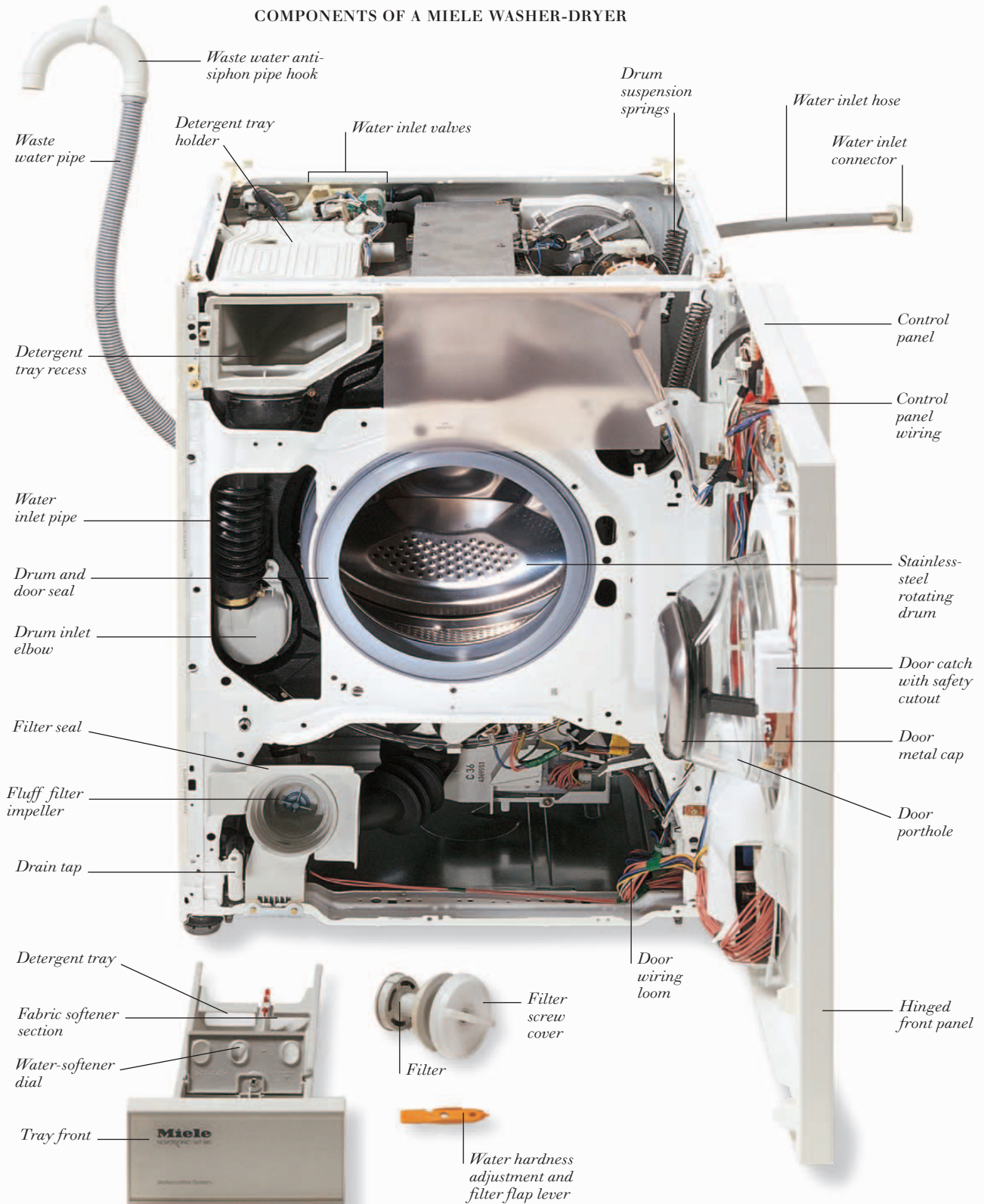
SIDE VIEW OF STEAM IRON



FRONT VIEW OF A MIELE WASHER-DRYER



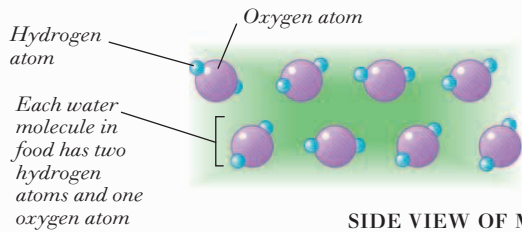
COMPONENTS OF A MIELE WASHER-DRYER



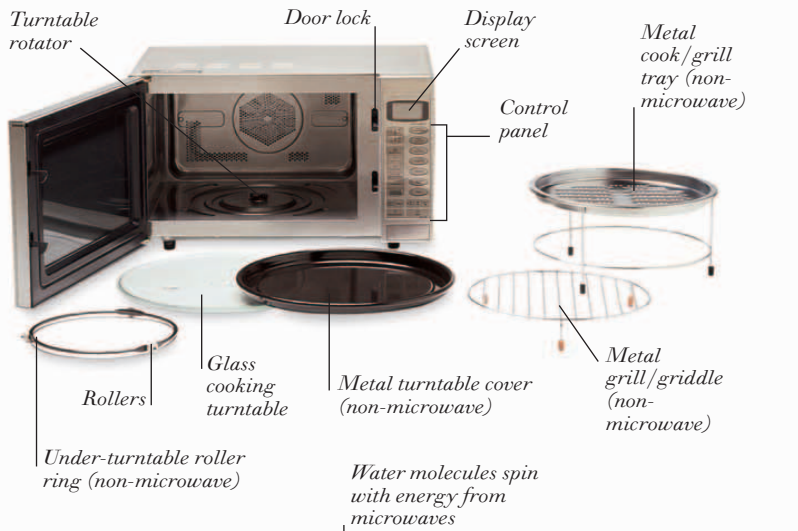
Microwave combination oven

CONVENTIONAL OVENS use electrically warmed elements or a flame to heat food. In a microwave oven heat energy is created by electromagnetic waves produced by a magnetron and led by waveguides into the oven compartment. These microwaves cannot pass through the compartment's metal casing, being reflected within and spread evenly by a fan. But they do pass through most types of plastic, ceramics, and glass. Therefore platters or containers made from these materials are suitable for use in microwave ovens. A combination oven also has conventional heating elements, to grill and "brown" in the traditional fashion, either alone or in conjunction with microwaves.

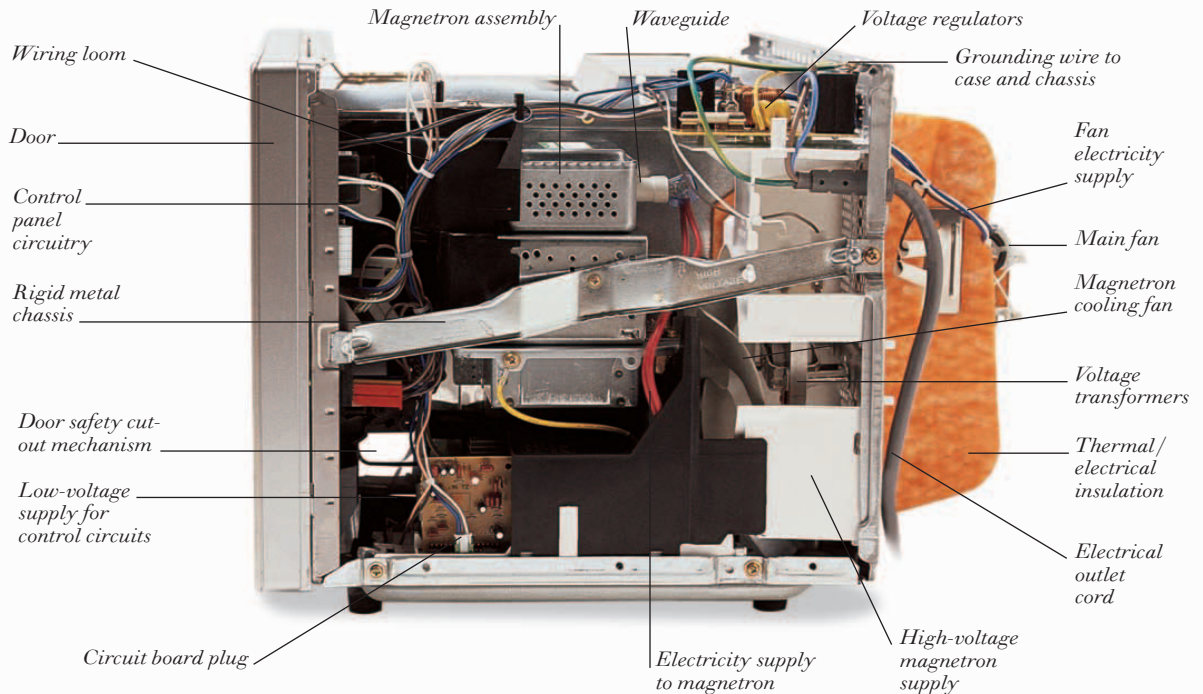
HOW MICROWAVES HEAT FOOD



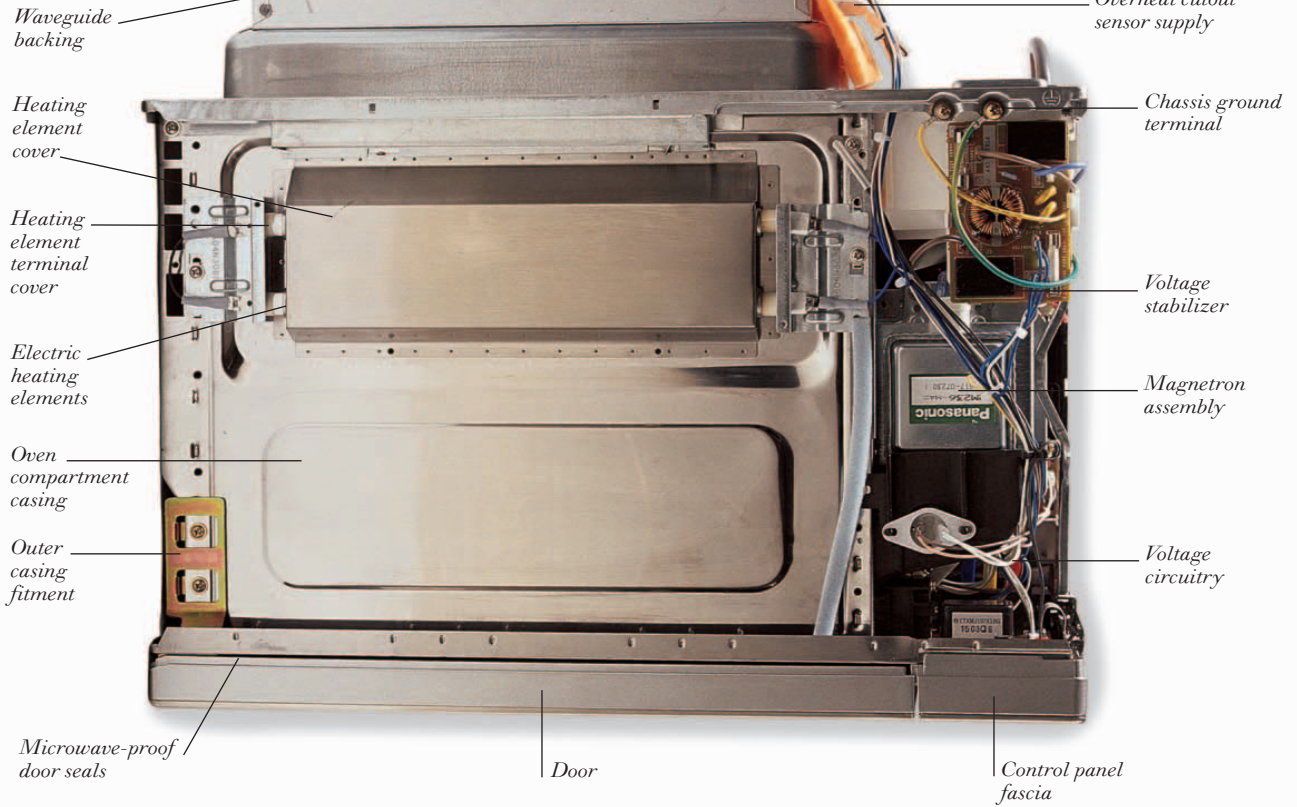
MICROWAVE COMBINATION OVEN



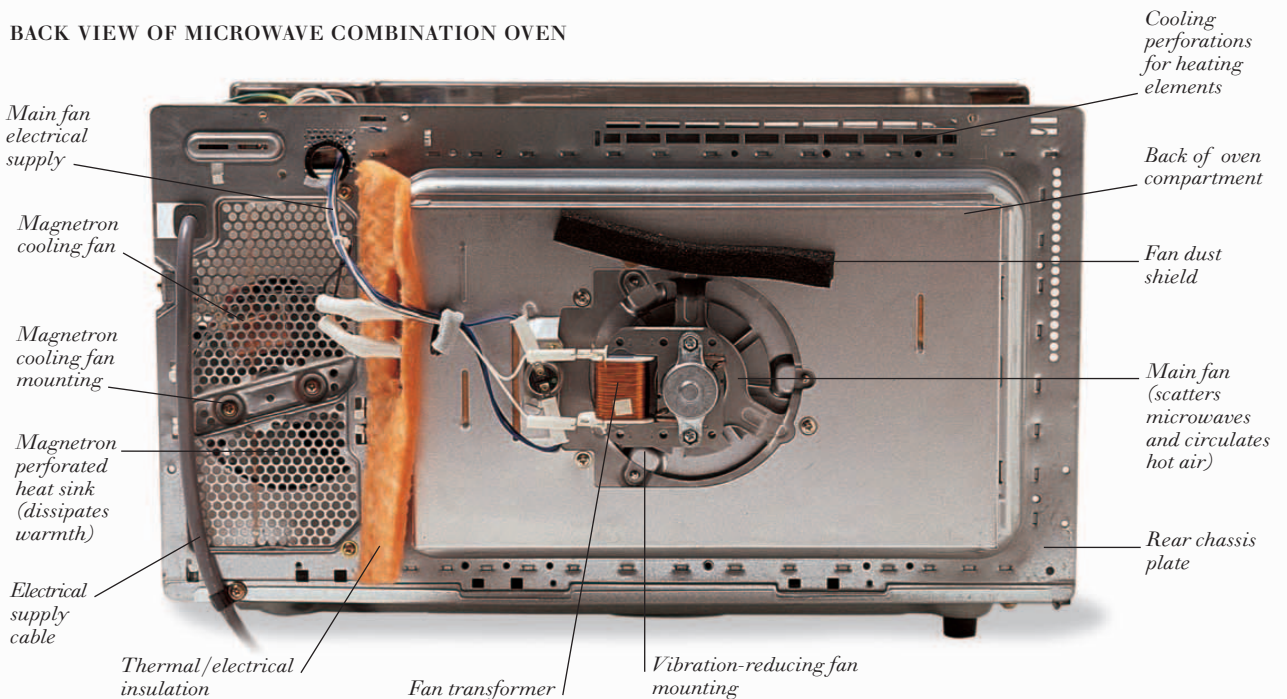
SIDE VIEW OF MICROWAVE COMBINATION OVEN



TOP VIEW OF MICROWAVE COMBINATION OVEN

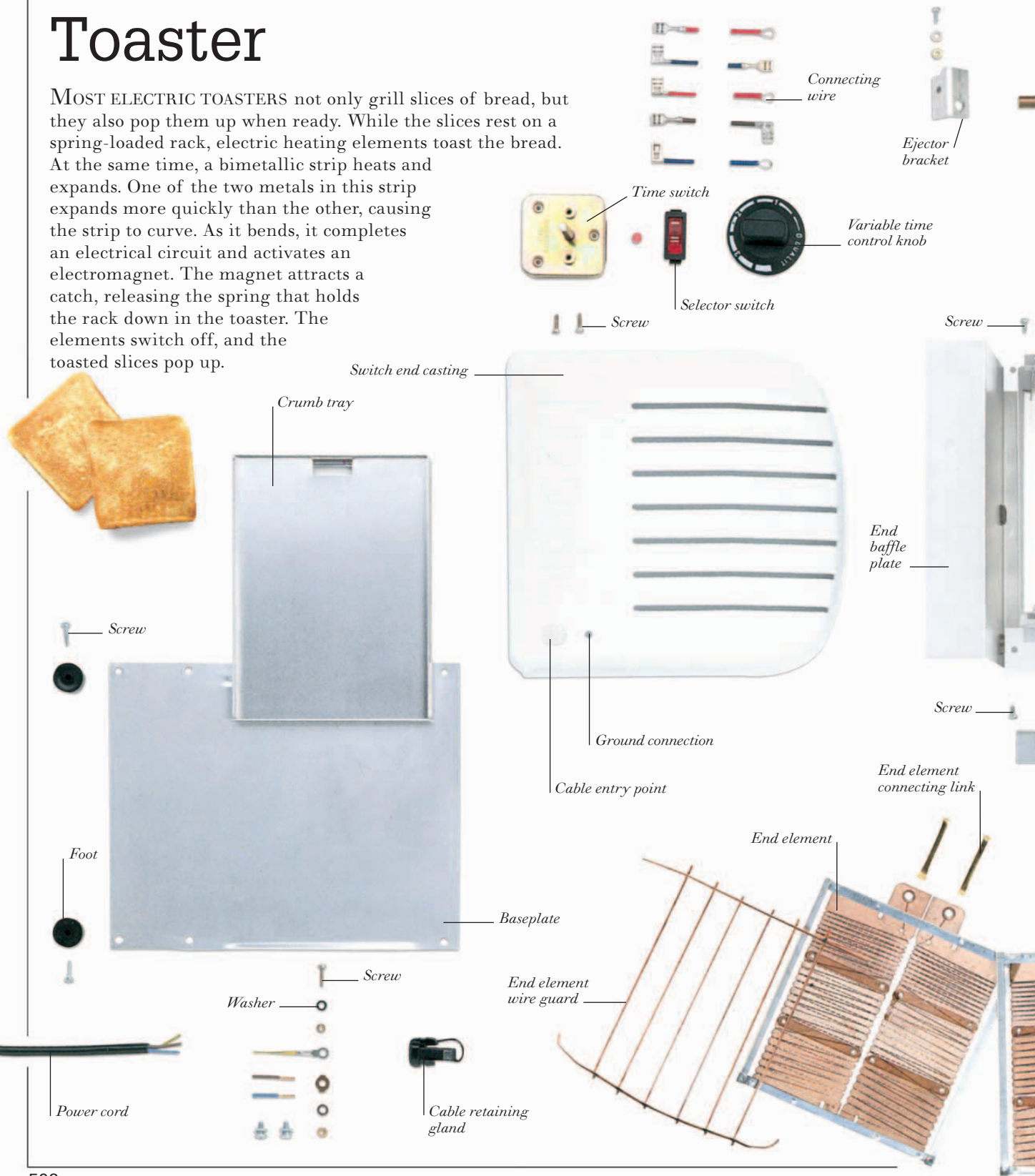


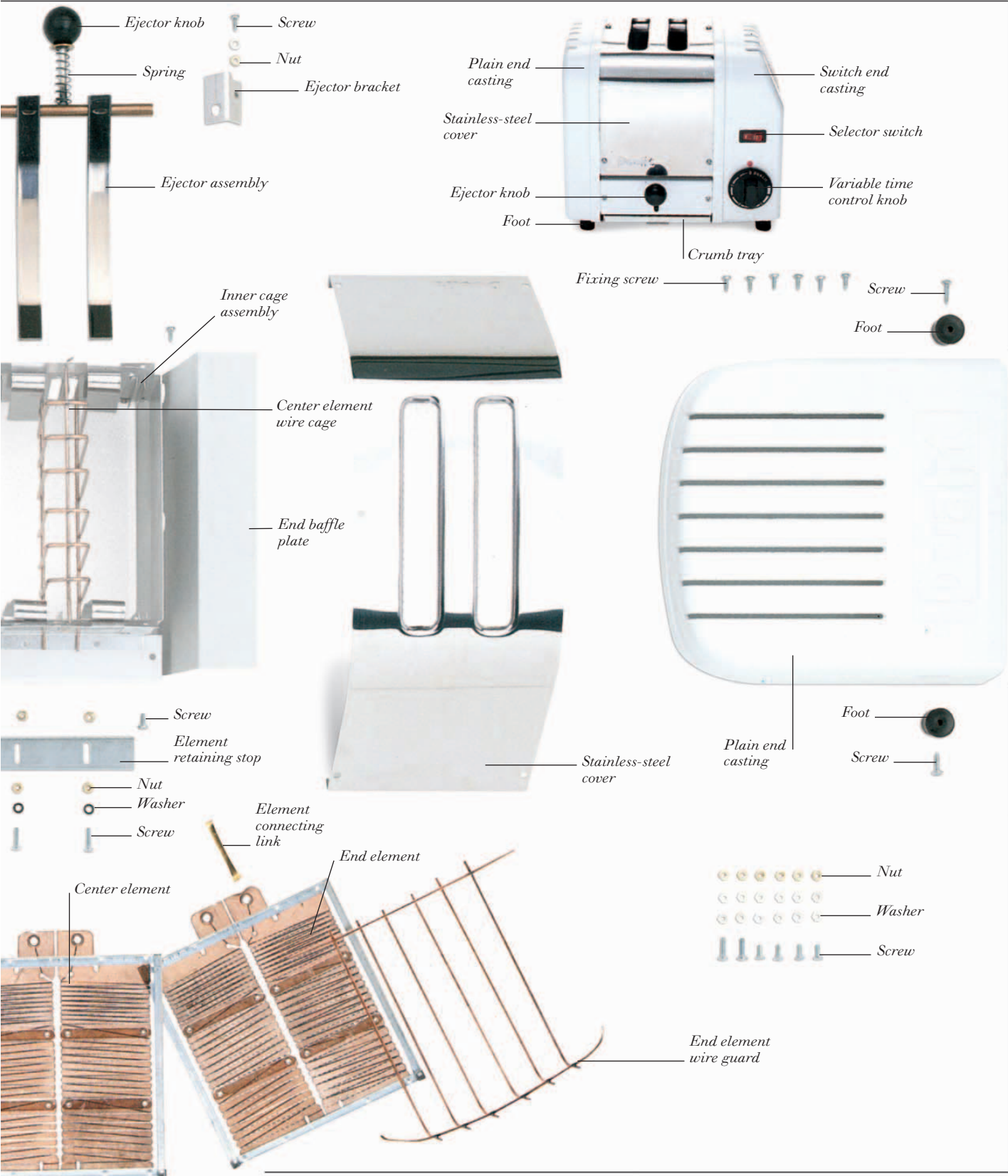
BACK VIEW OF MICROWAVE COMBINATION OVEN



Toaster

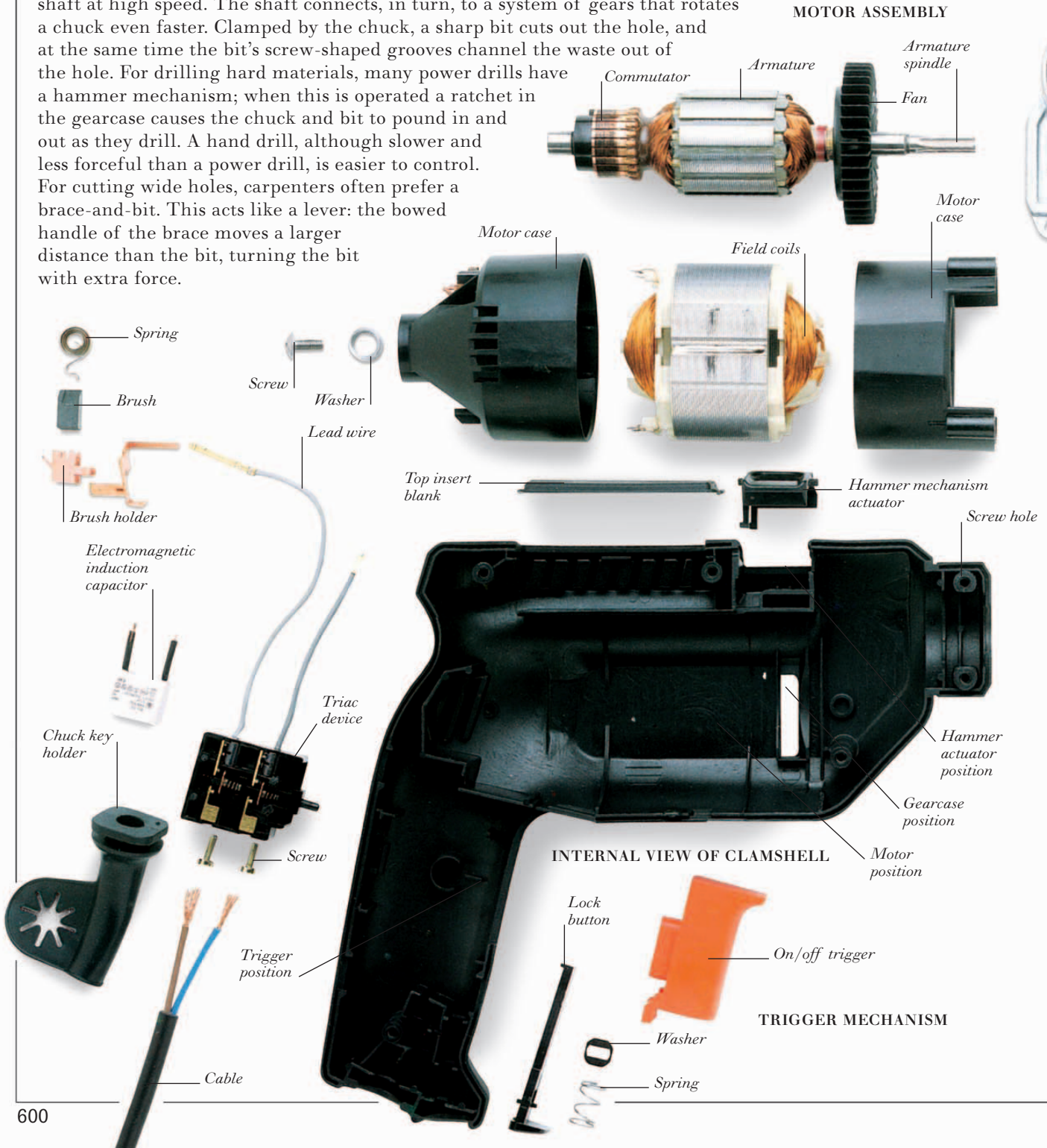
MOST ELECTRIC TOASTERS not only grill slices of bread, but they also pop them up when ready. While the slices rest on a spring-loaded rack, electric heating elements toast the bread. At the same time, a bimetallic strip heats and expands. One of the two metals in this strip expands more quickly than the other, causing the strip to curve. As it bends, it completes an electrical circuit and activates an electromagnet. The magnet attracts a catch, releasing the spring that holds the rack down in the toaster. The elements switch off, and the toasted slices pop up.



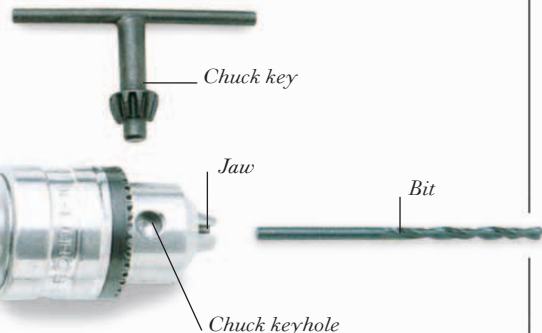
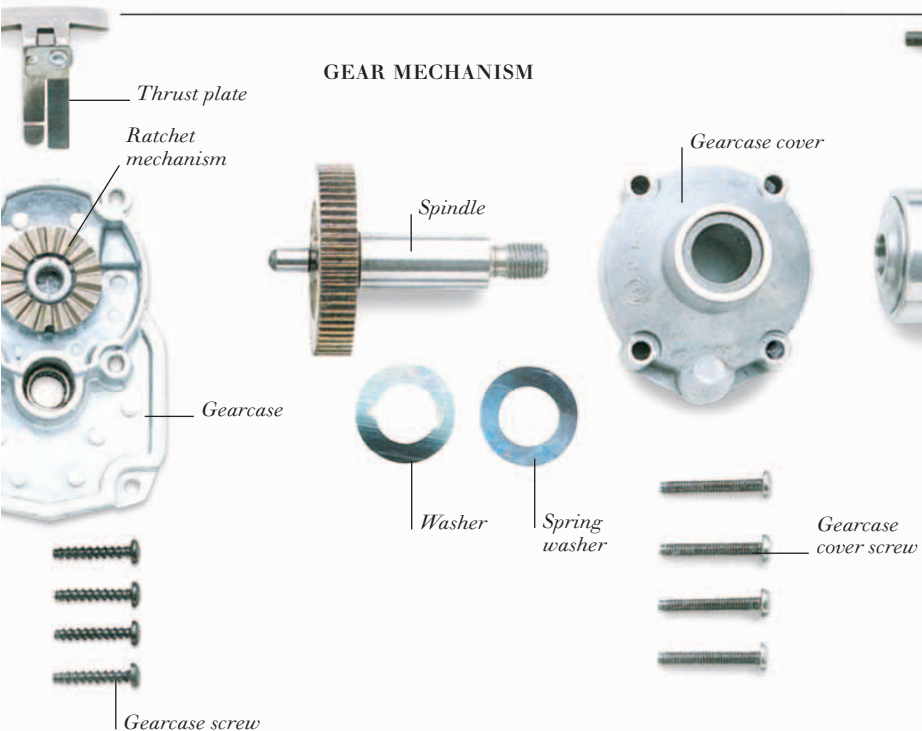


Drills

THE ELECTRICALLY POWERED MOTOR OF A POWER DRILL, cooled by a fan, turns a shaft at high speed. The shaft connects, in turn, to a system of gears that rotates a chuck even faster. Clamped by the chuck, a sharp bit cuts out the hole, and at the same time the bit's screw-shaped grooves channel the waste out of the hole. For drilling hard materials, many power drills have a hammer mechanism; when this is operated a ratchet in the gearcase causes the chuck and bit to pound in and out as they drill. A hand drill, although slower and less forceful than a power drill, is easier to control. For cutting wide holes, carpenters often prefer a brace-and-bit. This acts like a lever: the bowed handle of the brace moves a larger distance than the bit, turning the bit with extra force.



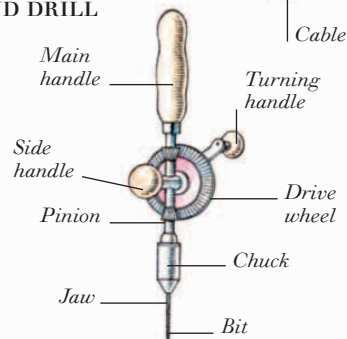
GEAR MECHANISM



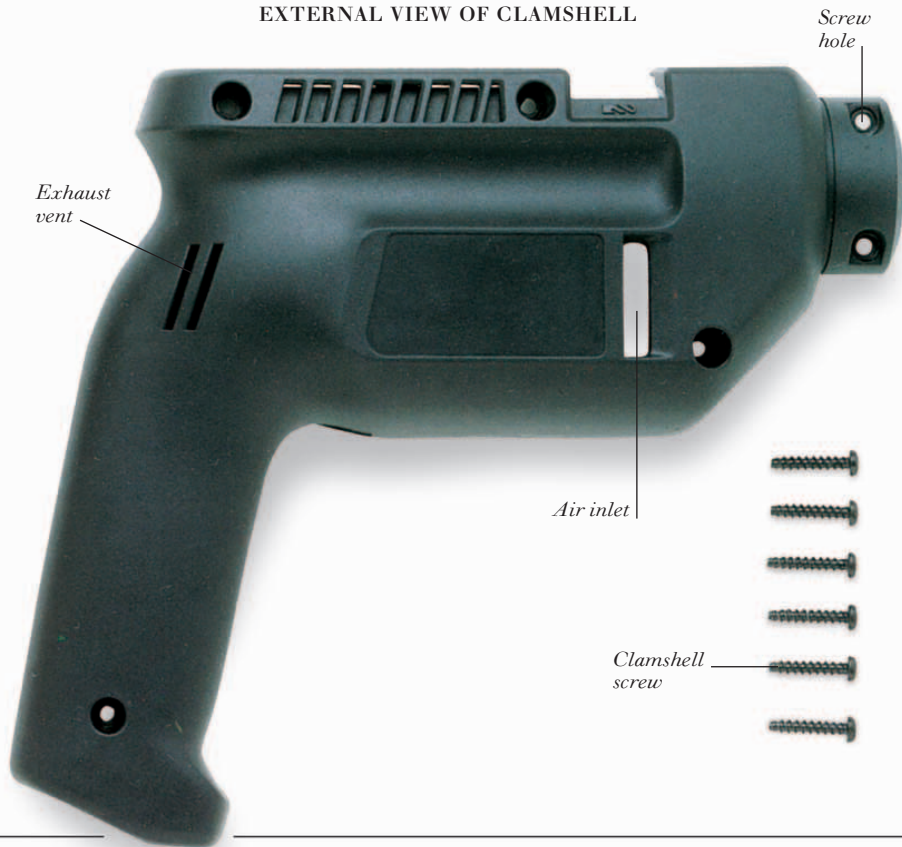
POWER DRILL



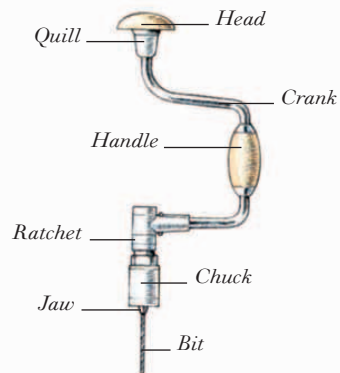
HAND DRILL



EXTERNAL VIEW OF CLAMSHELL



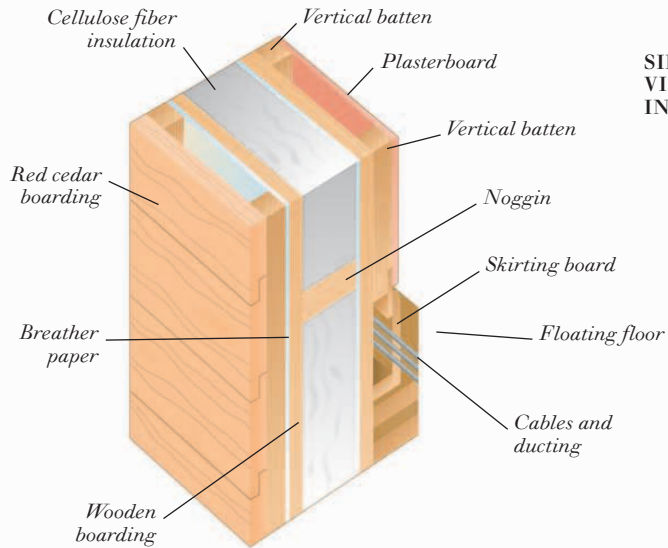
BRACE-AND-BIT



House of the future

HOUSES IN THE FUTURE are likely to be more environmentally friendly and energy-efficient than older dwellings, by making better use of materials and intelligent control systems. The Integer house was designed by Cole Thompson Associates, Bree Day Partnership, and Paul Hodgkins Associates, and built in conjunction with the Building Research Establishment in the UK. One of its key features is a large sun room that warms one side of the house. Extensive use is made of recycled, natural, and renewable materials and energy. The walls are made from timber and insulated with fiber from recycled newspaper; waste water from the bathrooms is saved and used to flush the toilets; and a wind turbine and solar panels contribute some of the electricity requirements. Many elements were prefabricated off-site for ease of construction. The Integer house uses only half the energy and a third less water than a traditionally built house.

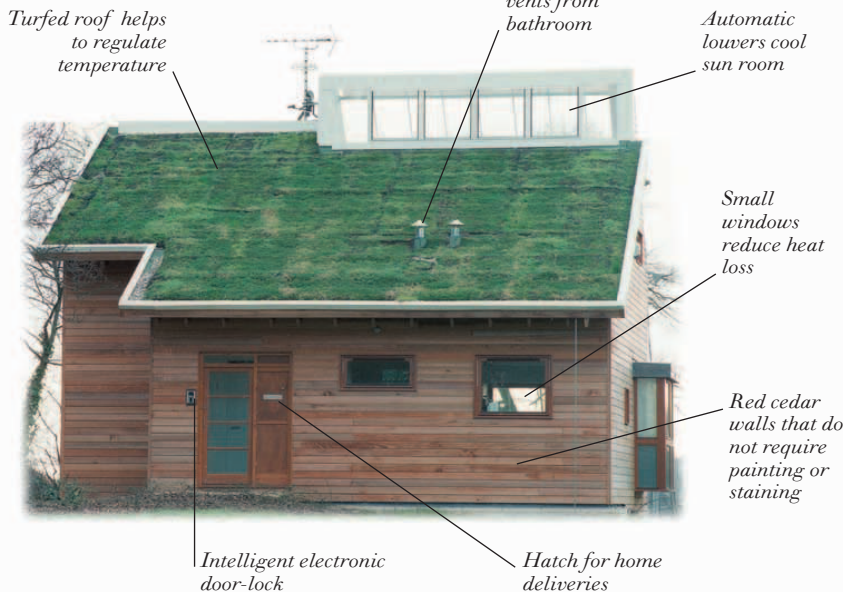
WALL CONSTRUCTION



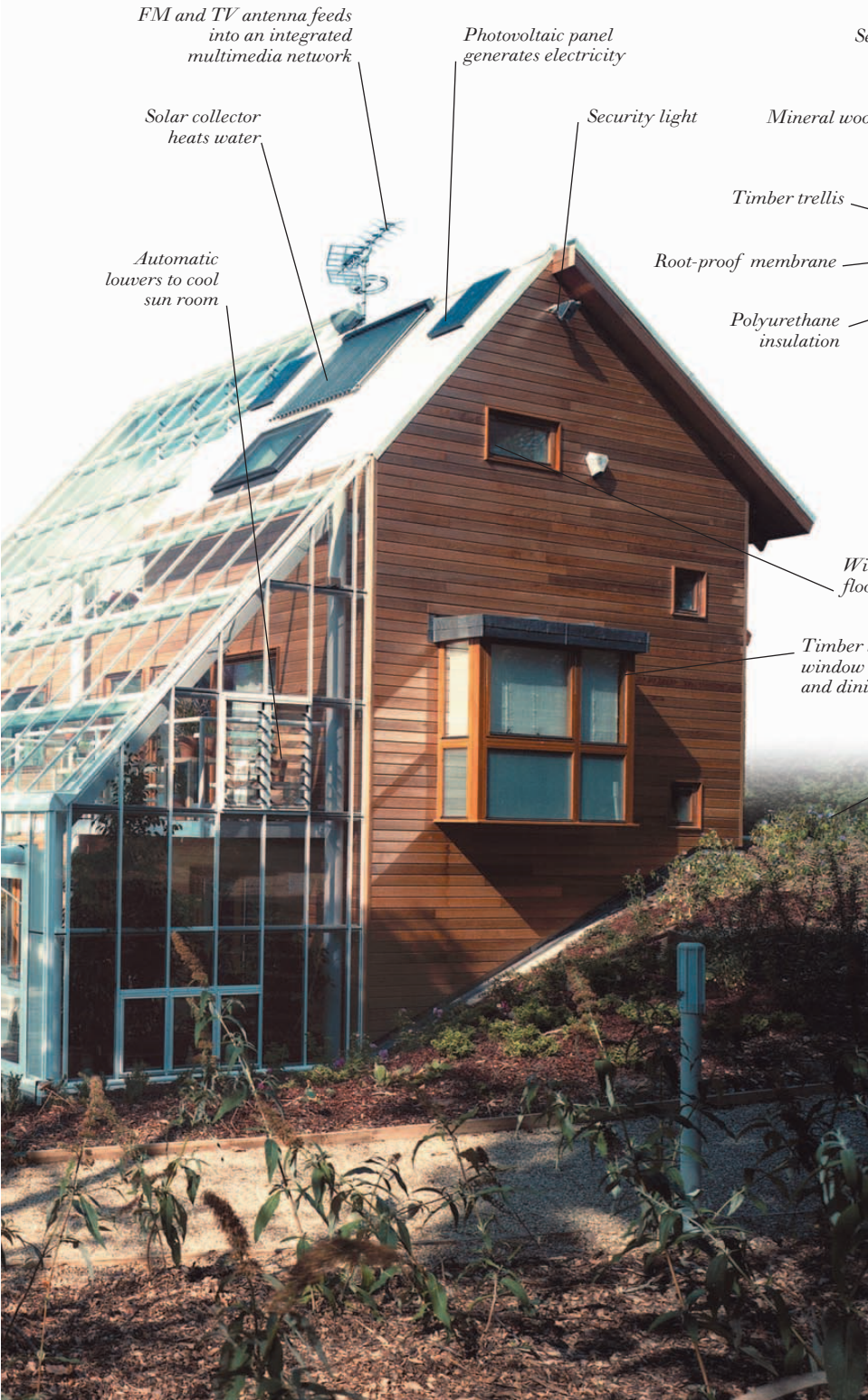
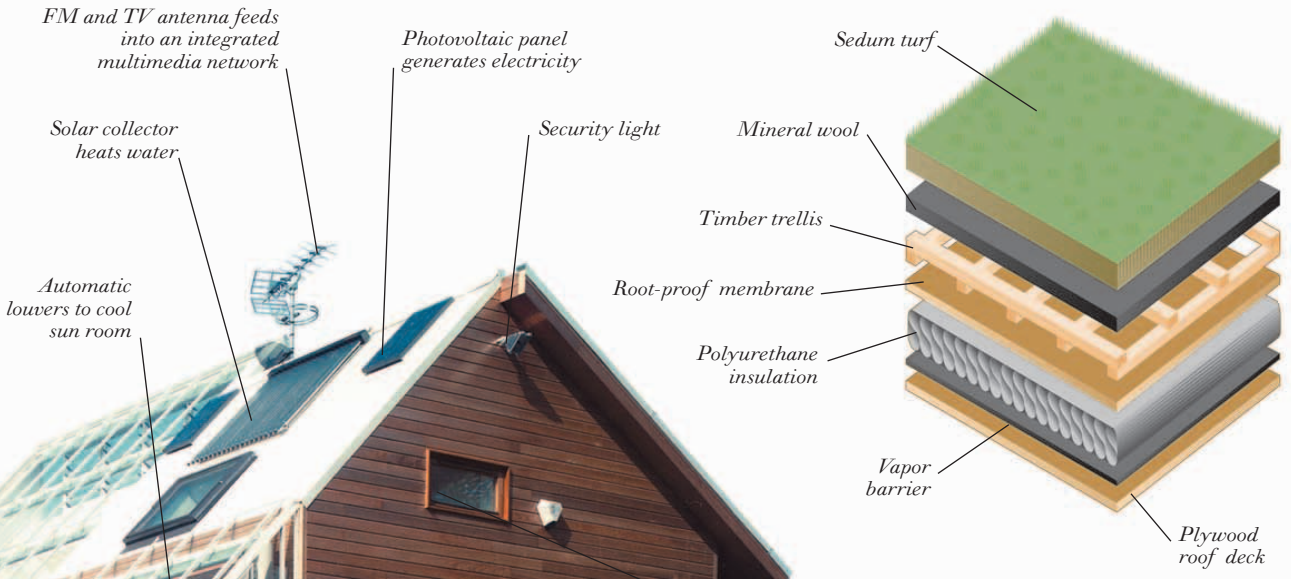
SIDE AND REAR VIEW OF THE INTEGER HOUSE



FRONT VIEW OF THE INTEGER HOUSE



ROOF CONSTRUCTION



FM and TV antenna feeds into an integrated multimedia network

Photovoltaic panel generates electricity

Solar collector heats water

Security light

Sedum turf

Mineral wool

Timber trellis

Root-proof membrane

Polyurethane insulation

Vapor barrier

Plywood roof deck

Automatic lowers to cool sun room

Window to upper floor home office

Timber bay window to living and dining area

Earth bank insulates lower floor

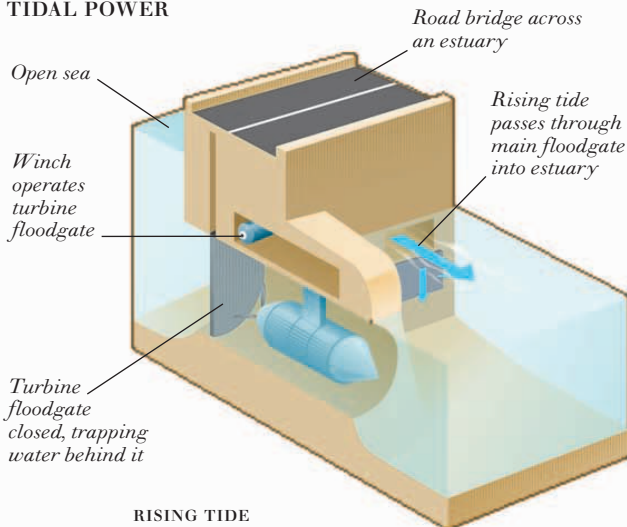
Blinds that open and close automatically in response to sunshine

SUN ROOM INTERIOR

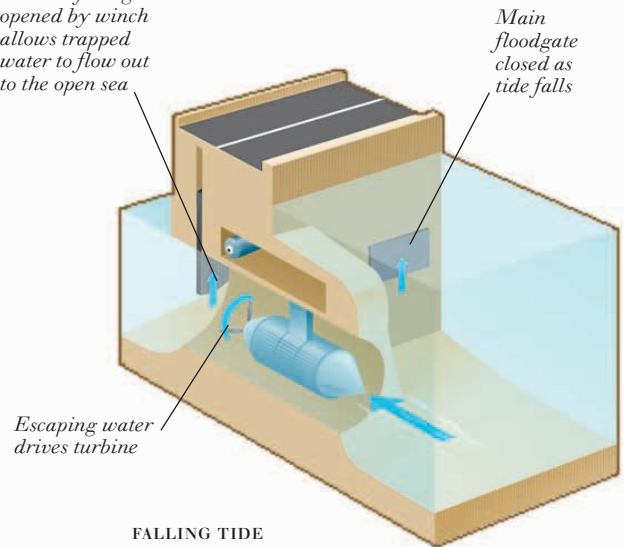
Renewable energy

RENEWABLE ENERGY COMES from sources that do not become depleted as we use the energy. When a fossil fuel such as coal is burned, it is gone forever, but a renewable source remains available no matter how much is used. The tides, waves, flowing water, sunlight, and the wind are all renewable sources of energy. Wind and water energy are captured by a device called a turbine. The turbine spins and drives an electricity generator. Energy from sunlight, or solar energy, is changed into electricity in two main ways. One uses mirrors to concentrate solar energy and magnify its heating effect which is used to change water into steam to drive turbines. Photovoltaic cells change sunlight directly into electricity. A cell is made from two layers of silicon. One gives out electrons (negative particles) and the other receives them. Sunlight knocks electrons out of atoms where the two layers meet, separating them from the positive particles. The electrons are attracted to one layer of the cell, the positive particles to the other layer. Electrons are naturally attracted to the positive particles, but to come together again, the electrons must flow out of the cell, through an external electric circuit, or load, and back to the other side of the cell, creating a charge. The cell supplies electric current for as long as light keeps falling on it.

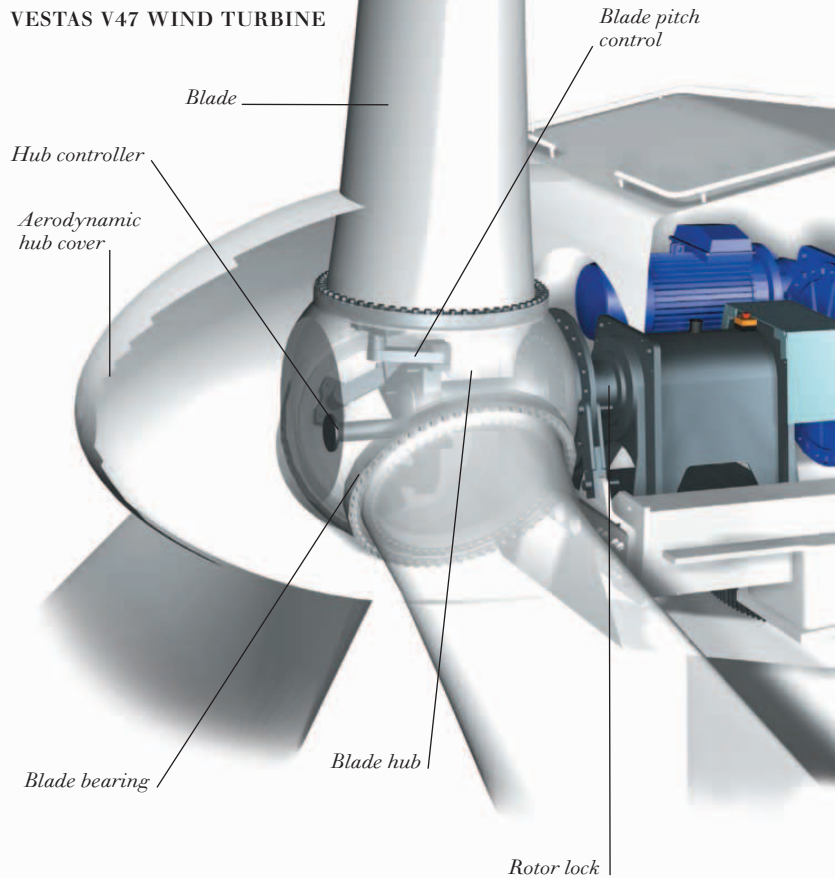
TIDAL POWER

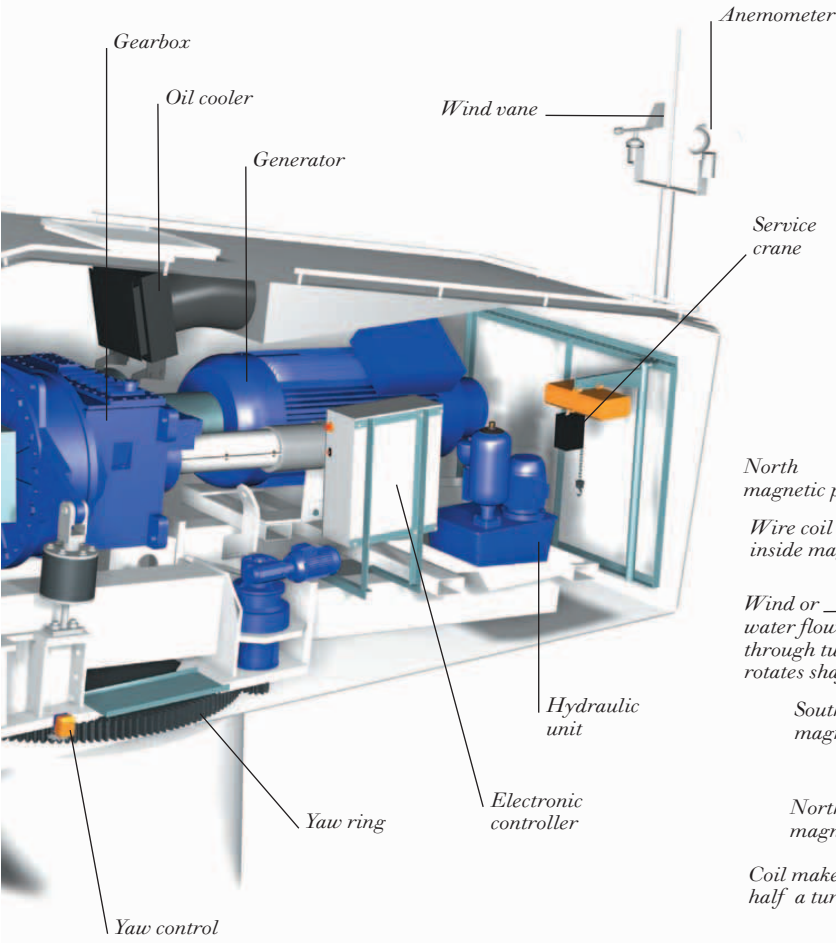


Turbine floodgate opened by winch allows trapped water to flow out to the open sea



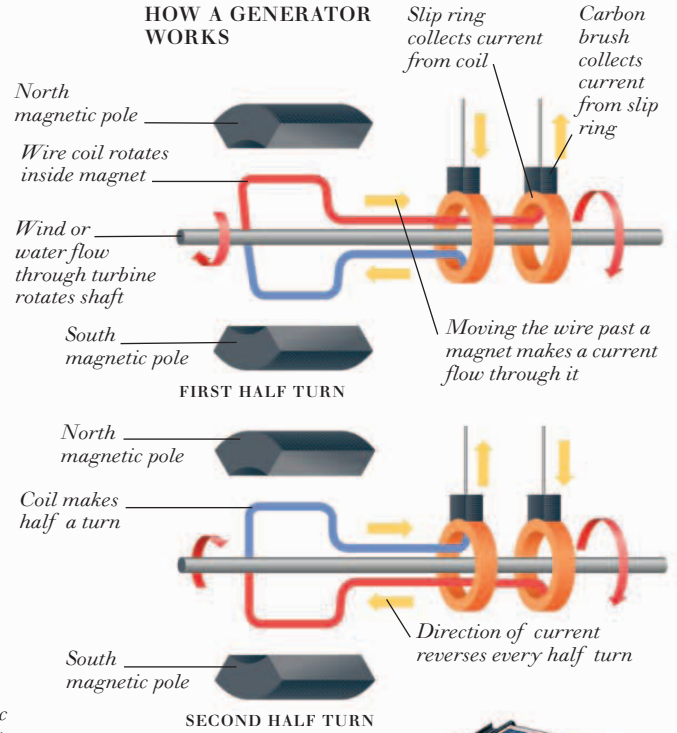
VESTAS V47 WIND TURBINE



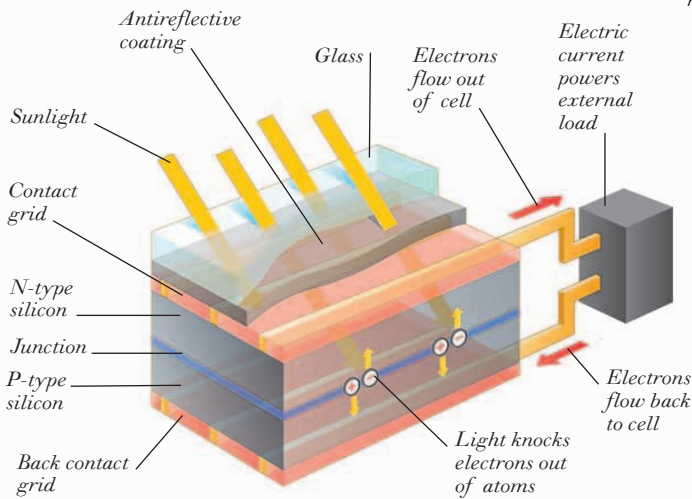


WIND TURBINES IN A WIND FARM

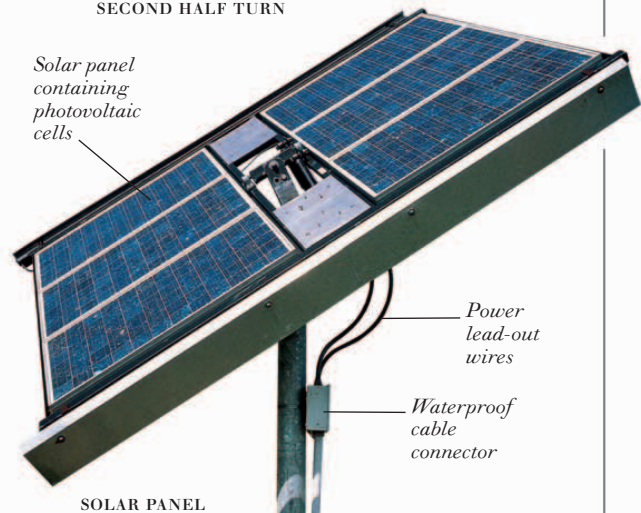
HOW A GENERATOR WORKS



SOLAR POWER



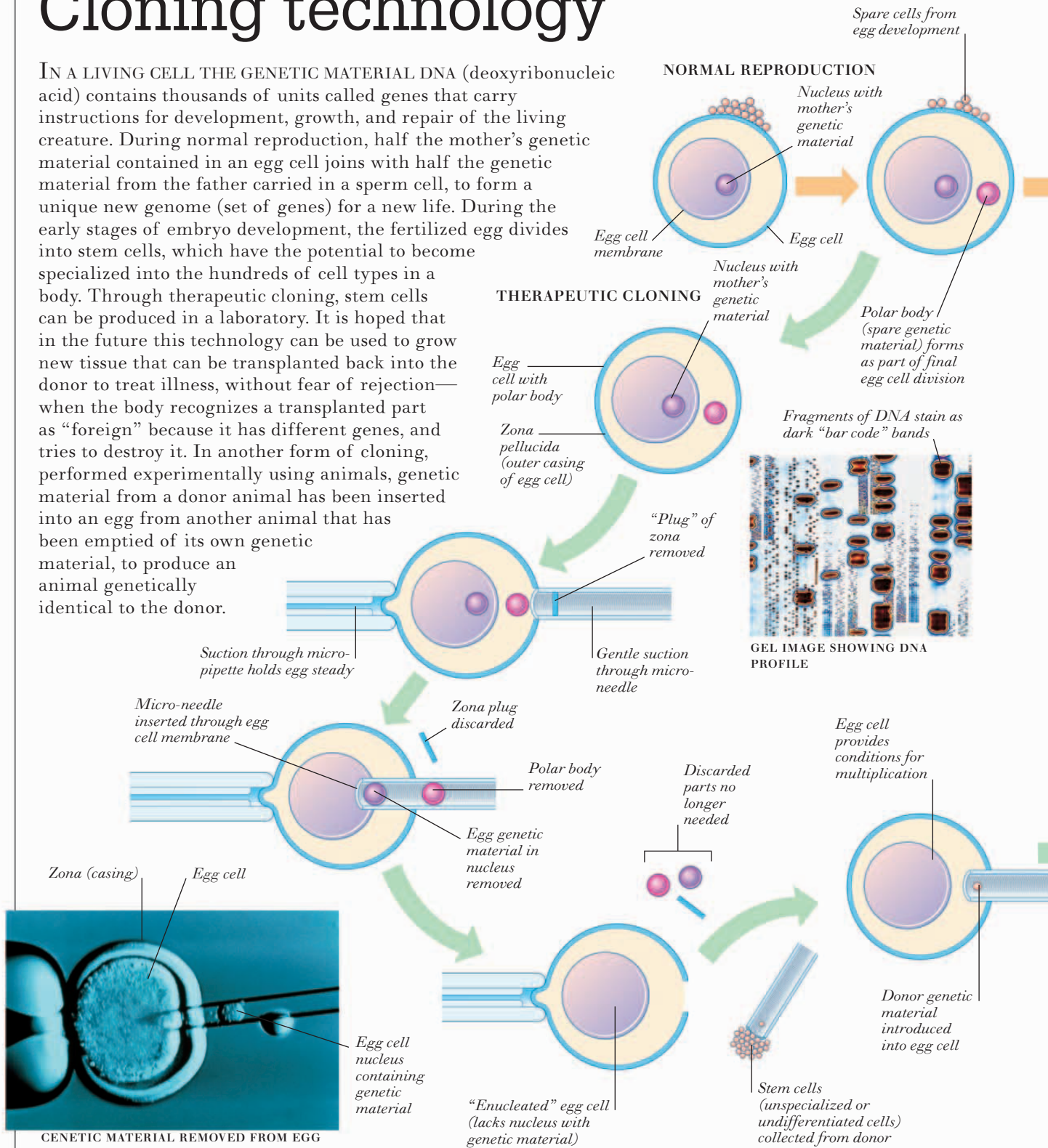
HOW A PHOTOVOLTAIC CELL WORKS



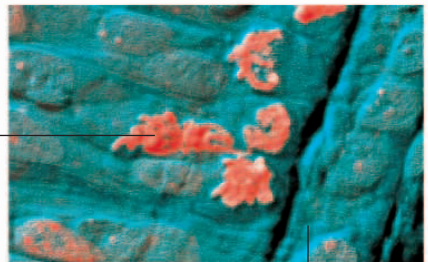
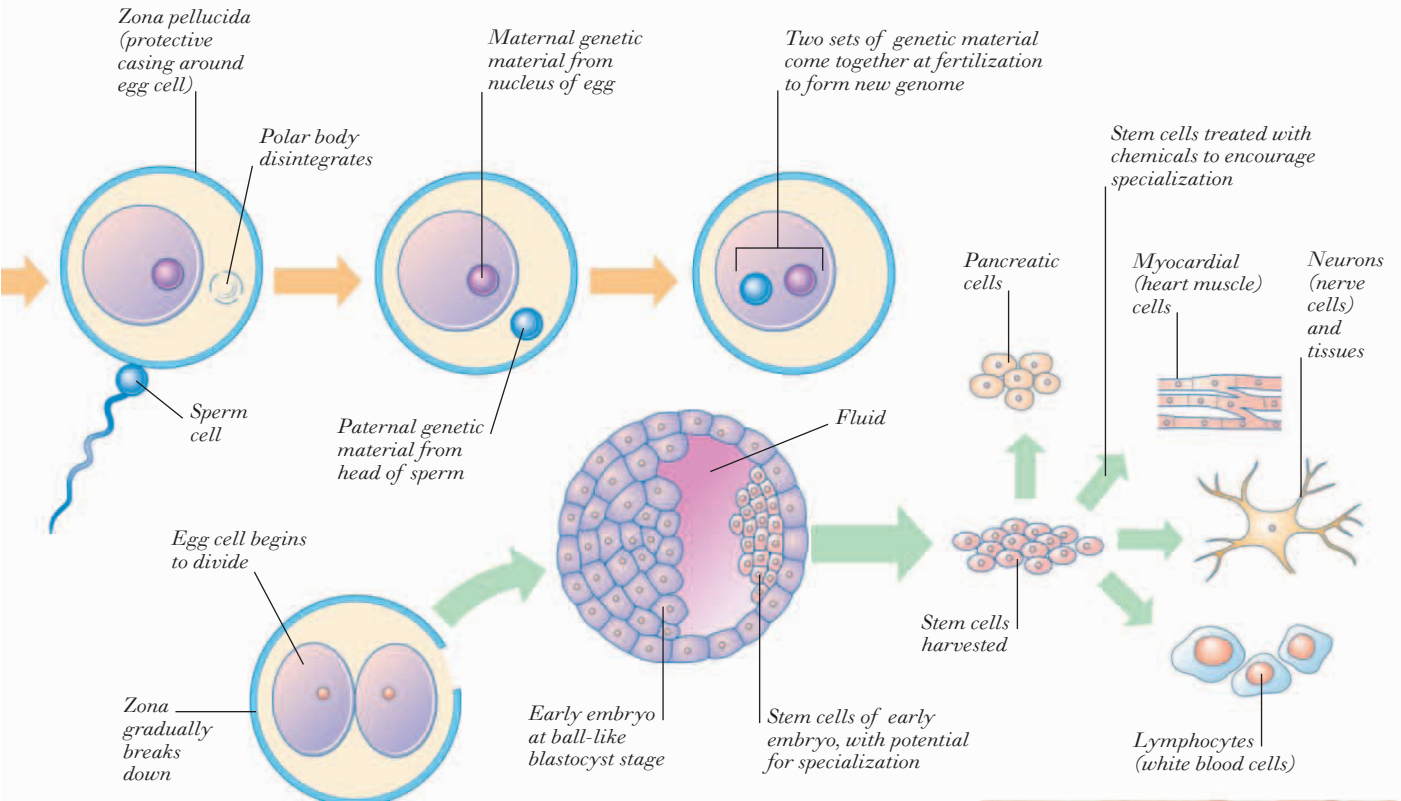
SOLAR PANEL

Cloning technology

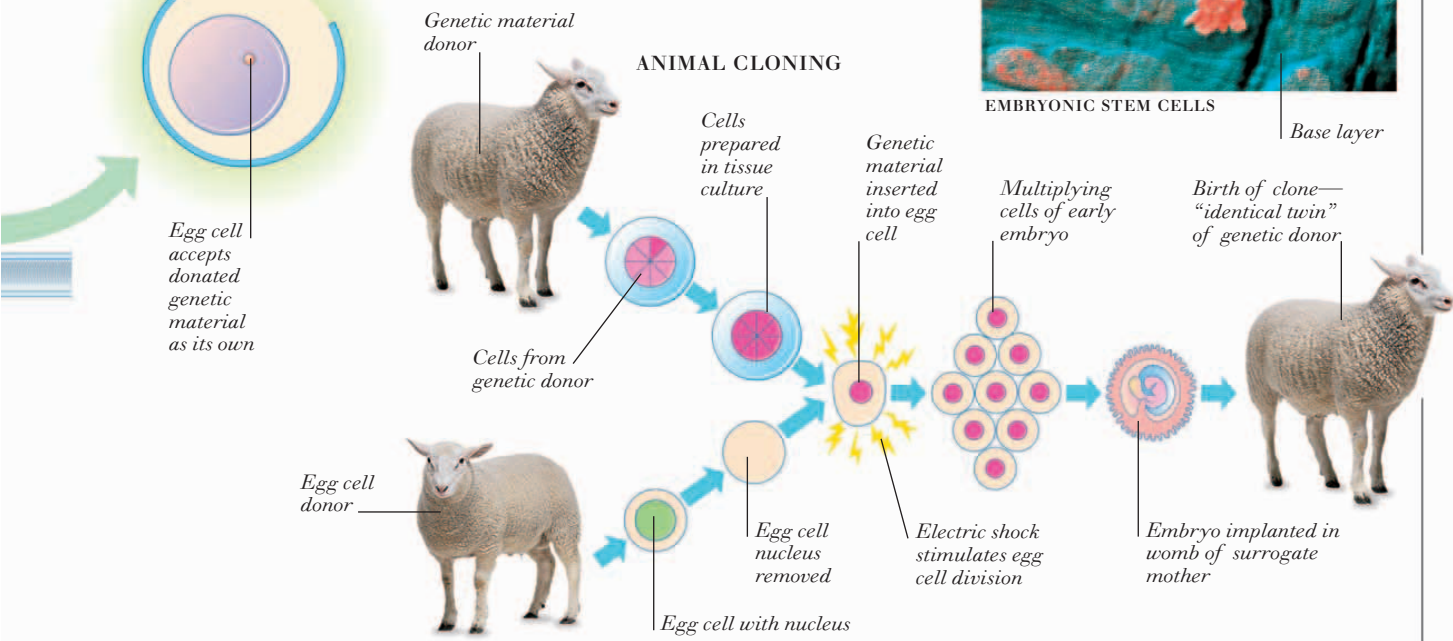
IN A LIVING CELL THE GENETIC MATERIAL DNA (deoxyribonucleic acid) contains thousands of units called genes that carry instructions for development, growth, and repair of the living creature. During normal reproduction, half the mother's genetic material contained in an egg cell joins with half the genetic material from the father carried in a sperm cell, to form a unique new genome (set of genes) for a new life. During the early stages of embryo development, the fertilized egg divides into stem cells, which have the potential to become specialized into the hundreds of cell types in a body. Through therapeutic cloning, stem cells can be produced in a laboratory. It is hoped that in the future this technology can be used to grow new tissue that can be transplanted back into the donor to treat illness, without fear of rejection—when the body recognizes a transplanted part as “foreign” because it has different genes, and tries to destroy it. In another form of cloning, performed experimentally using animals, genetic material from a donor animal has been inserted into an egg from another animal that has been emptied of its own genetic material, to produce an animal genetically identical to the donor.



GENETIC MATERIAL REMOVED FROM EGG

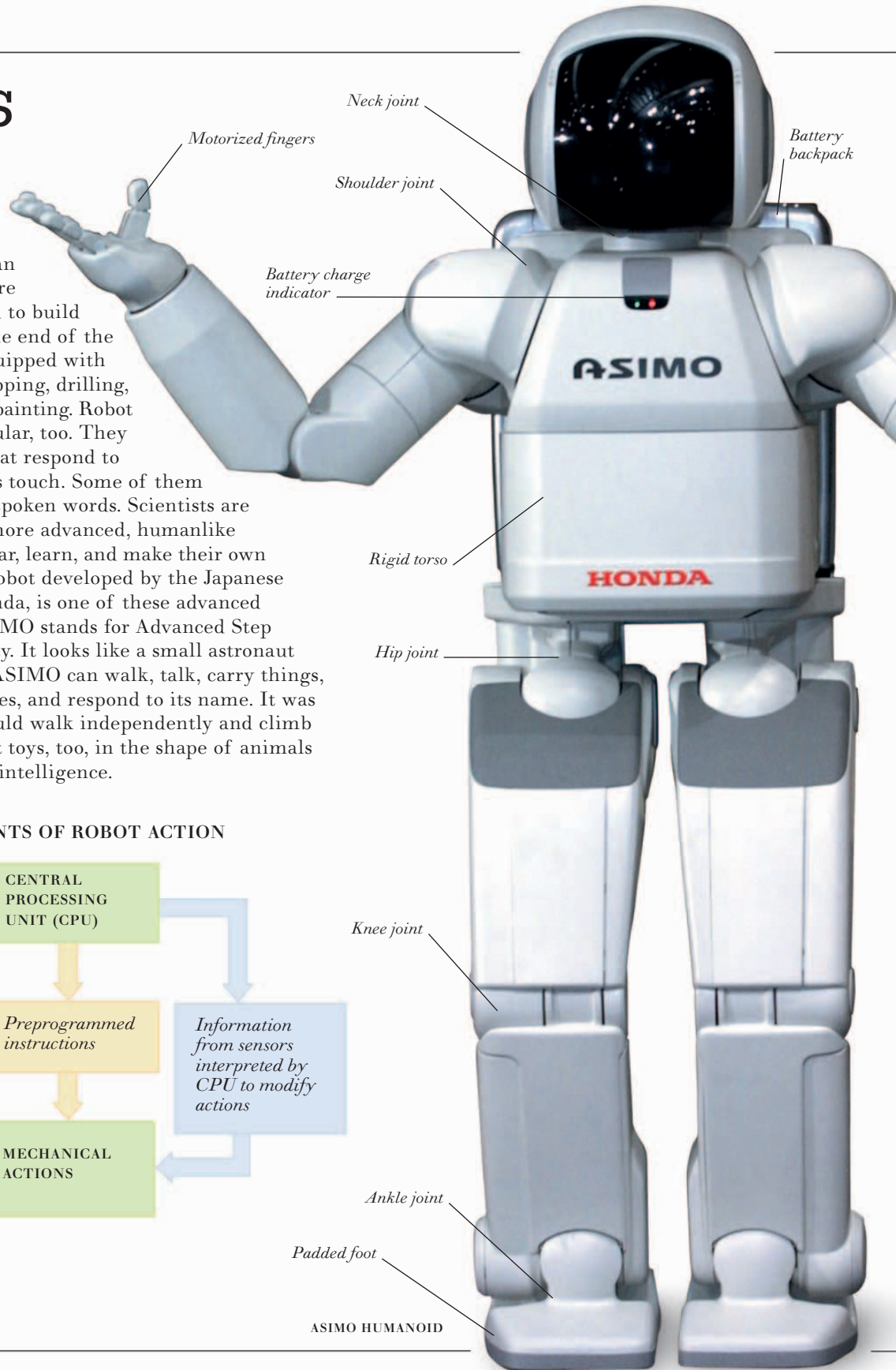


ANIMAL CLONING

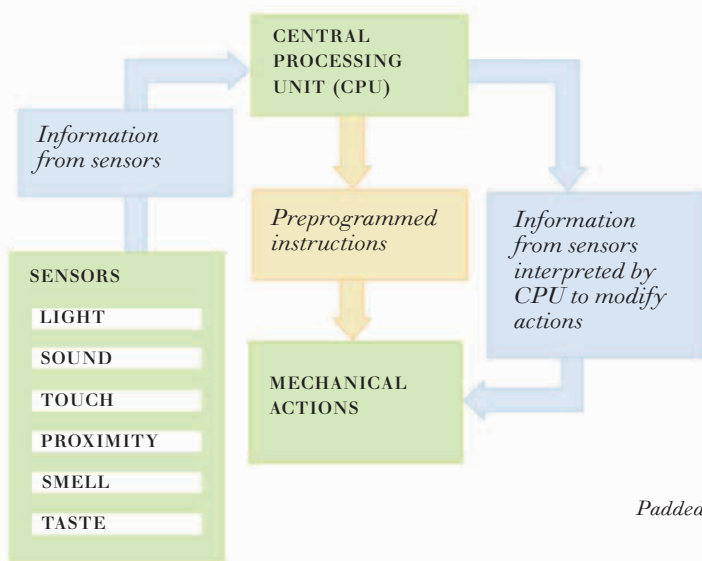


Robots

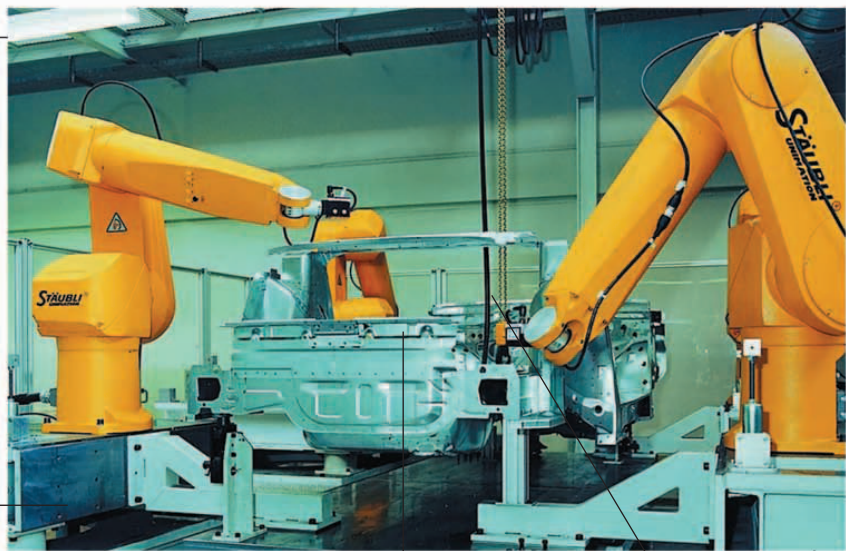
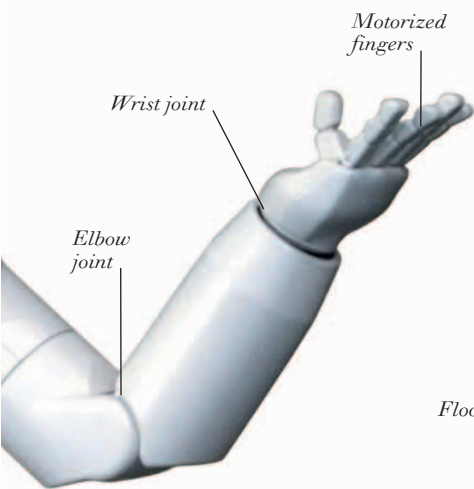
ROBOTS ARE MACHINES THAT CAN carry out a variety of tasks on their own, with little or no human control. Most robots are mechanical arms used to build things in factories. The end of the robot's arm can be equipped with different tools for gripping, drilling, cutting, welding, and painting. Robot toys have become popular, too. They incorporate sensors that respond to sounds and sometimes touch. Some of them can even understand spoken words. Scientists are also trying to create more advanced, humanlike robots that can see, hear, learn, and make their own decisions. ASIMO, a robot developed by the Japanese car manufacturer Honda, is one of these advanced humanoid robots. ASIMO stands for Advanced Step in Innovative MObility. It looks like a small astronaut wearing a backpack. ASIMO can walk, talk, carry things, recognize familiar faces, and respond to its name. It was the first robot that could walk independently and climb stairs. There are robot toys, too, in the shape of animals with simple artificial intelligence.



ELEMENTS OF ROBOT ACTION



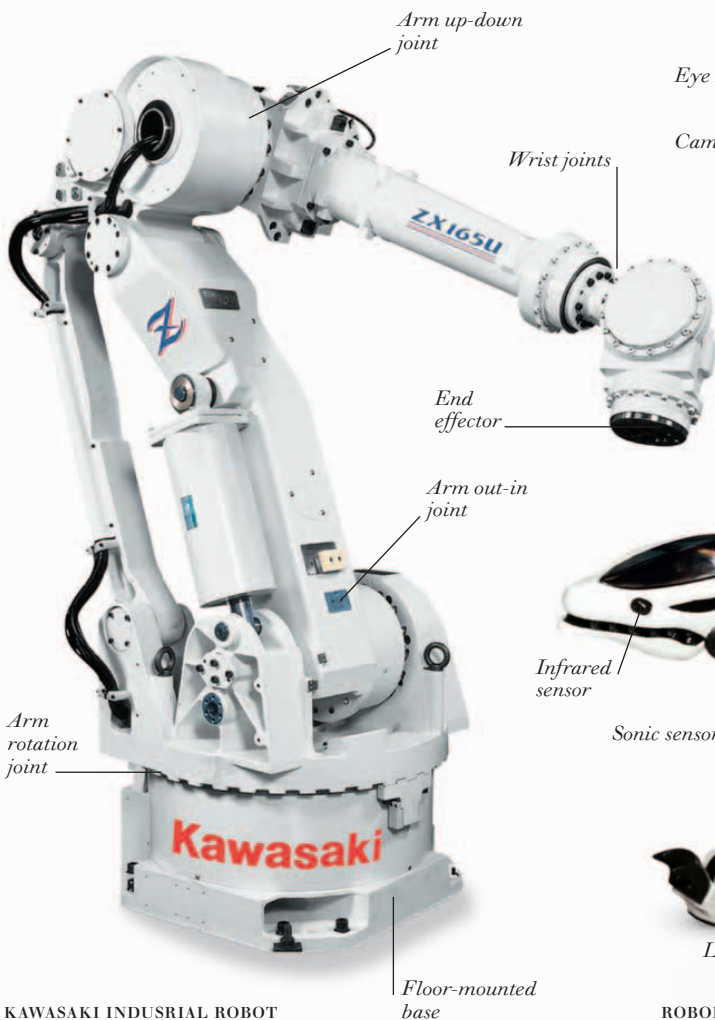
ASIMO HUMANOID



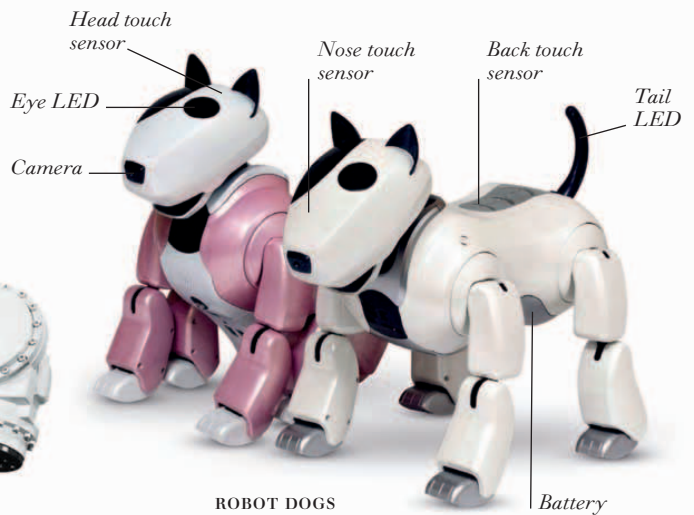
CAR-BUILDING ROBOTS

Vehicle body

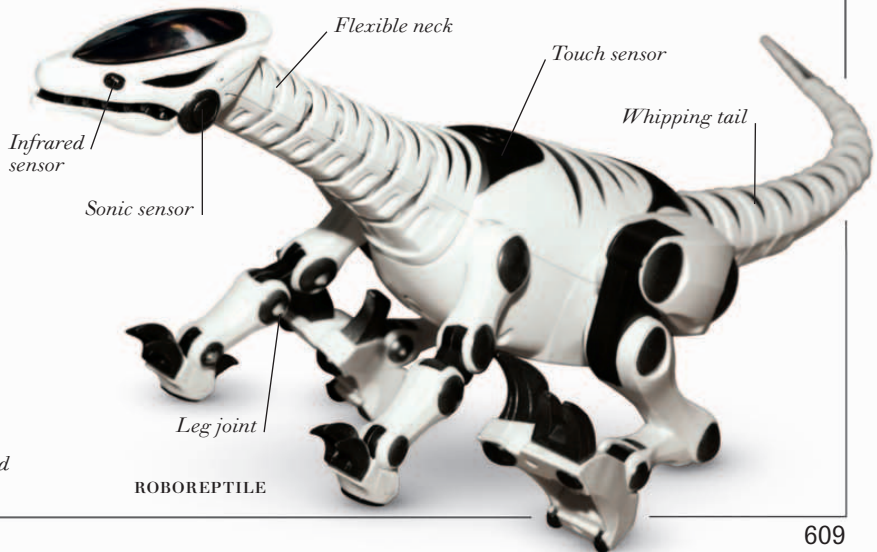
Welding tool



KAWASAKI INDUSTRIAL ROBOT



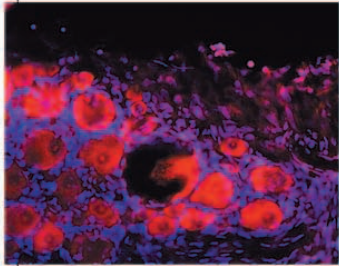
ROBOT DOGS



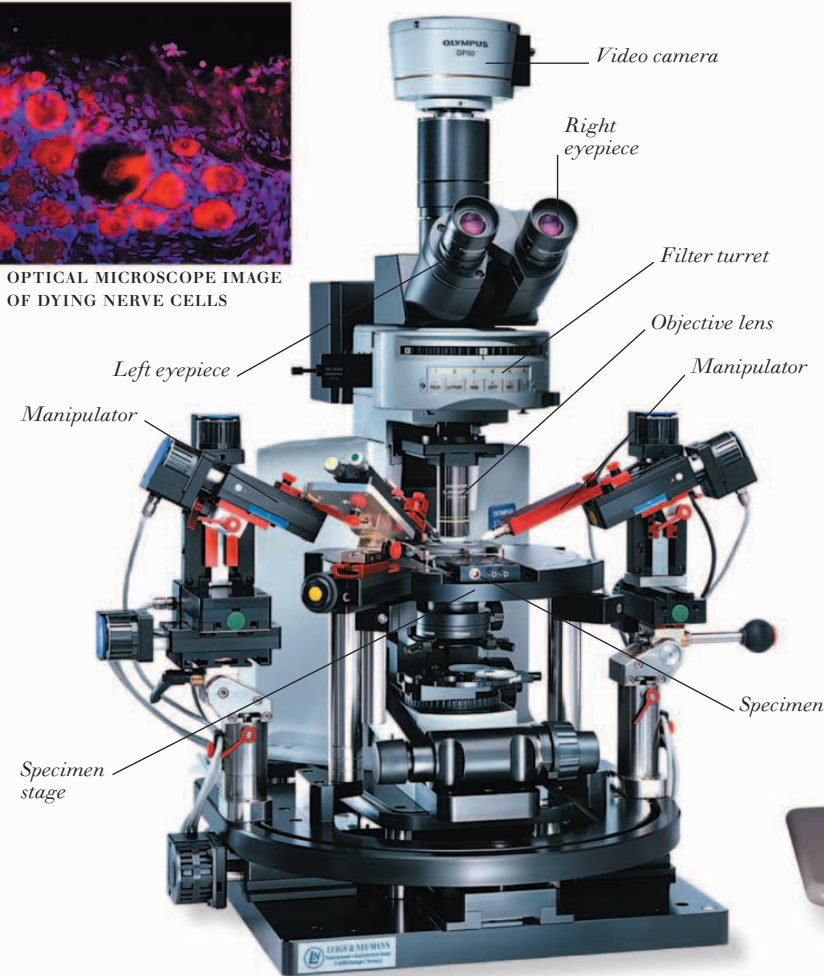
ROBOREPTILE

High-performance microscopes

OPTICAL MICROSCOPES FORM A MAGNIFIED image by using lenses to bend light. Some special-purpose optical microscopes used in industry and research are designed for observing particular materials, such as living cells. They produce magnifications of up to about 2,000. Electron microscopes produce magnifications of as much as 50 million, although 2 million is more typical. Their images are formed by means of electrons focused by magnetic lenses. There are two main types: scanning electron microscopes (SEMs) scan electrons back and forth across the surface of a specimen; transmission electron microscopes (TEMs) transmit electrons through a thin slice of the specimen.

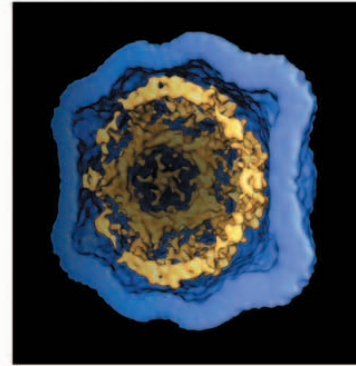


OPTICAL MICROSCOPE IMAGE OF DYING NERVE CELLS

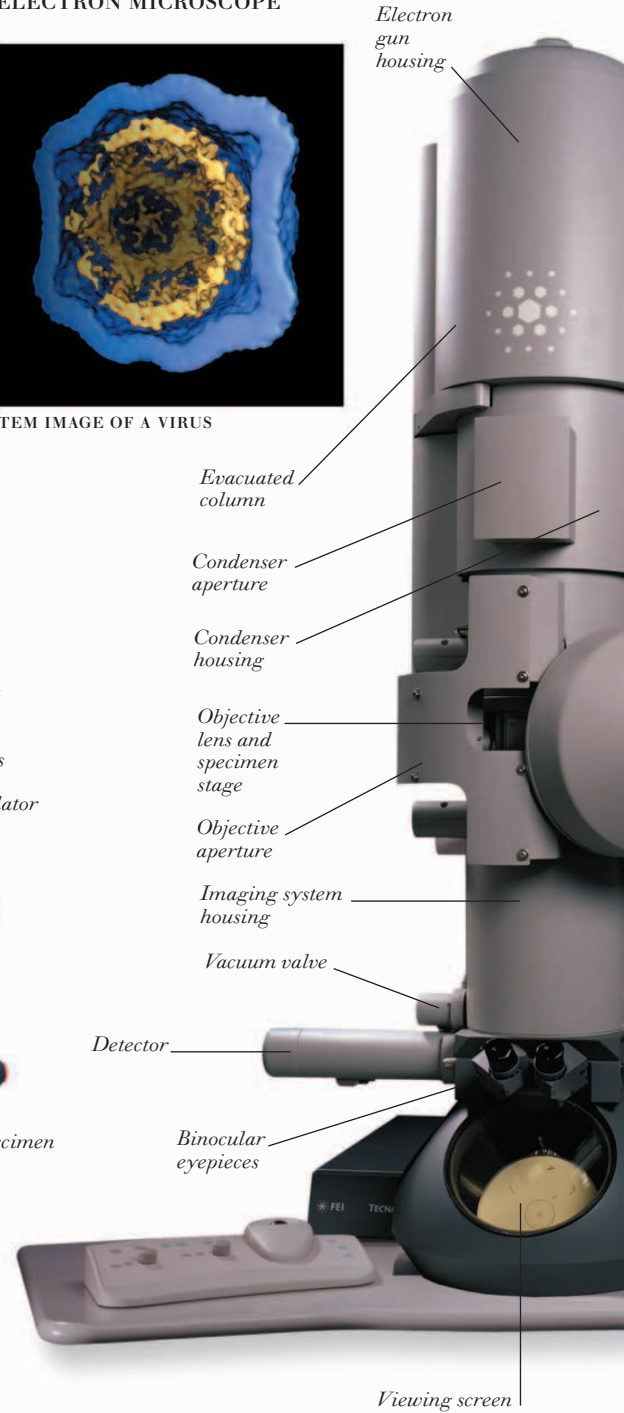


OLYMPUS BX51W1 OPTICAL MICROSCOPE

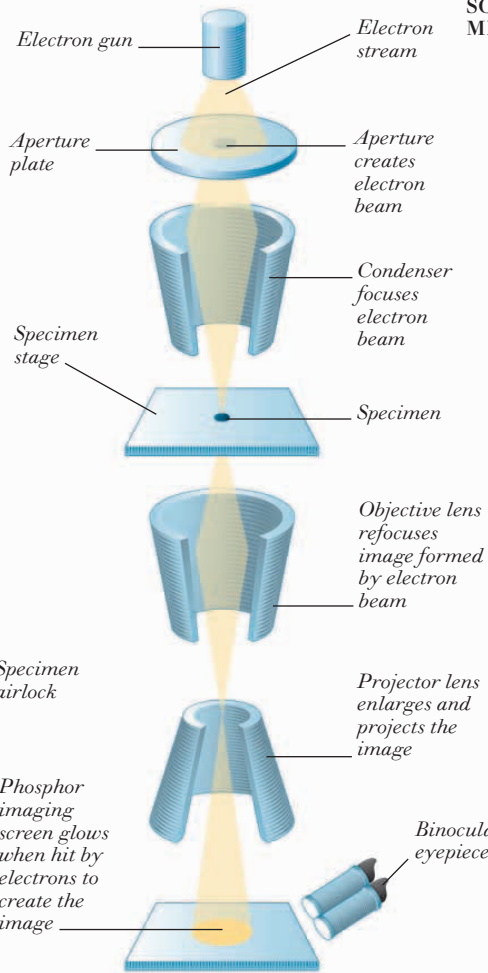
FEI TECNAI G² TRANSMISSION ELECTRON MICROSCOPE



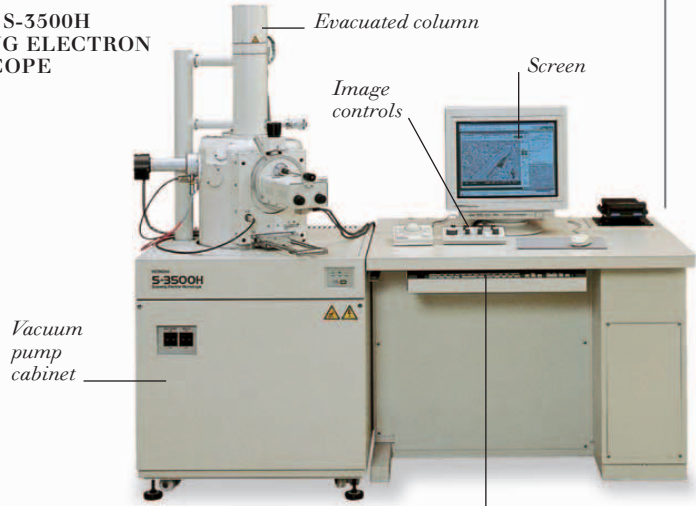
TEM IMAGE OF A VIRUS



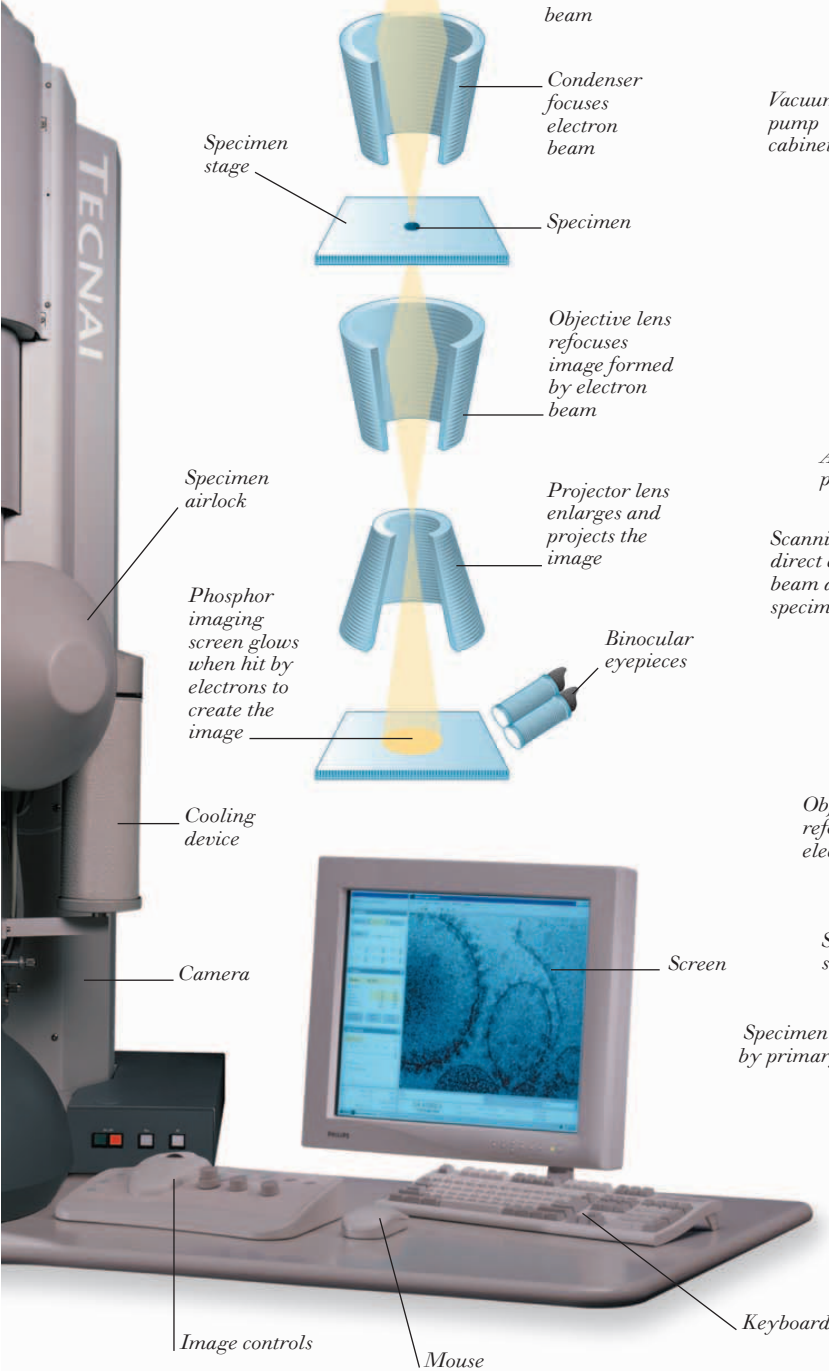
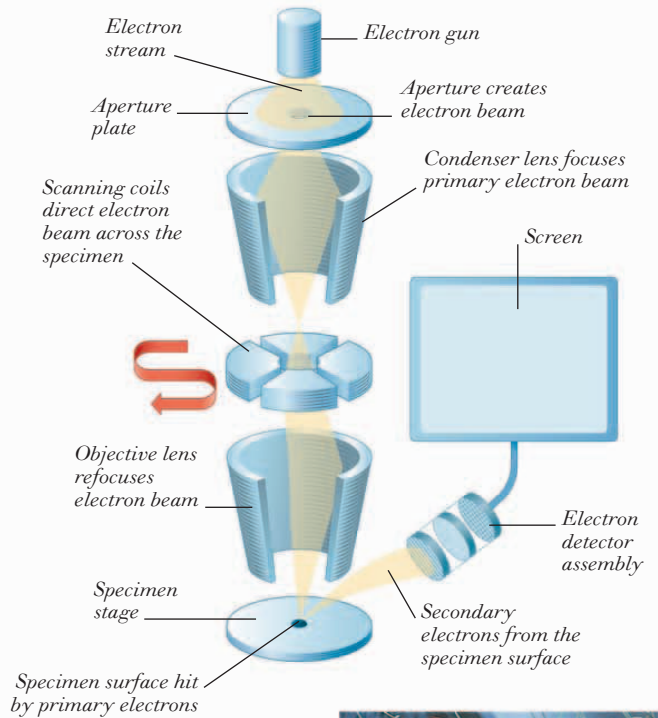
HOW A TEM WORKS



HITACHI S-3500H SCANNING ELECTRON MICROSCOPE

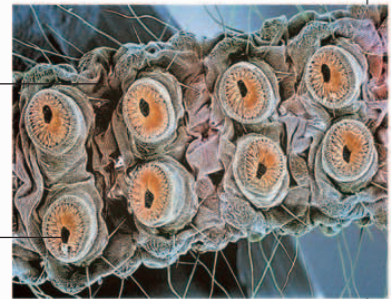


HOW A SEM WORKS



Underside of caterpillar body

Caterpillar foot



SEM IMAGE OF A CATERPILLAR

Space telescope

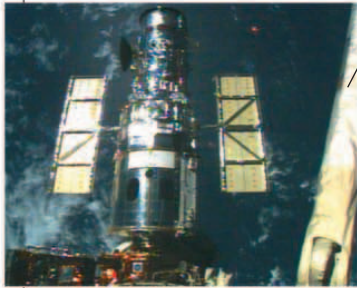
SPACE TELESCOPES ORBIT THE EARTH hundreds of miles above the ground, their instruments collecting light from stars and galaxies. Telescopes in space have a clearer view than those on Earth, because they are unaffected by the Earth's atmosphere, which absorbs or distorts much of this radiation. There are a variety of types of space telescope designed to observe different types of light. The Hubble Space Telescope observes infrared, ultraviolet, and visible light. It can detect objects that are 100 times fainter than those any telescopes on Earth can see. When this 12-ton (11,000-kilogram), 43-foot (13-meter) long telescope was launched by the Space Shuttle in 1990, it was found that its primary mirror was faulty and its images were blurred. Astronauts fitted extra optics to correct the problem in 1993.

IMAGES TAKEN BY HUBBLE

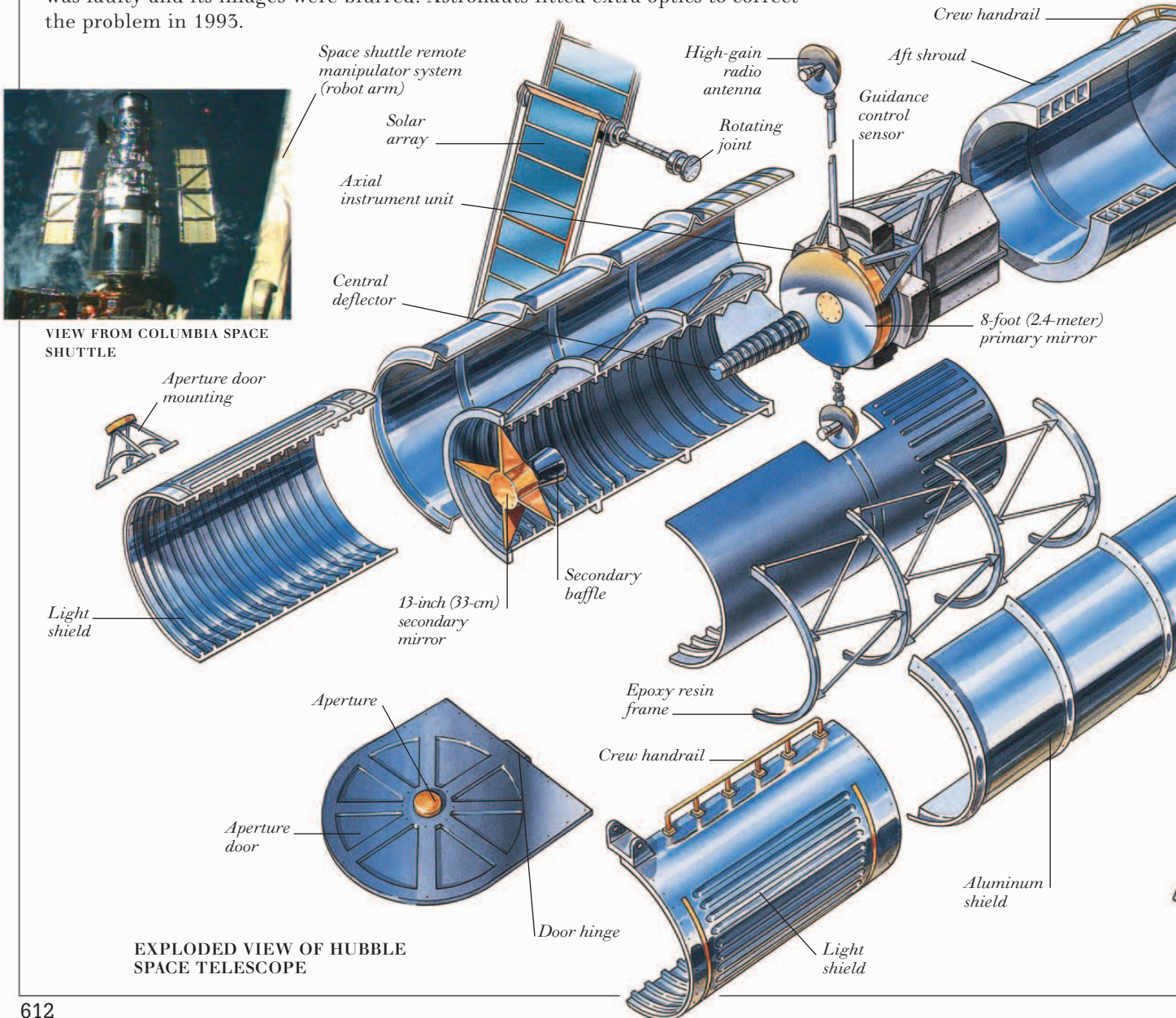
Pillar of gas



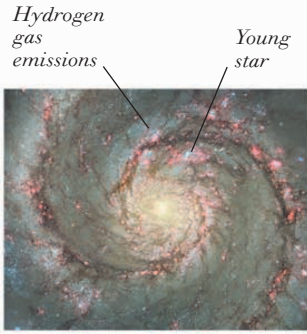
CONE NEBULA



VIEW FROM COLUMBIA SPACE SHUTTLE



EXPLODED VIEW OF HUBBLE SPACE TELESCOPE



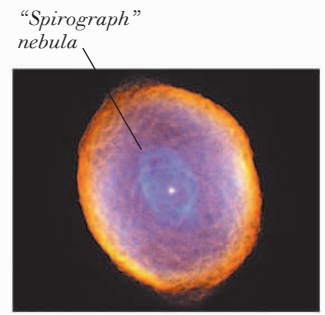
"WHIRLPOOL" GALAXY



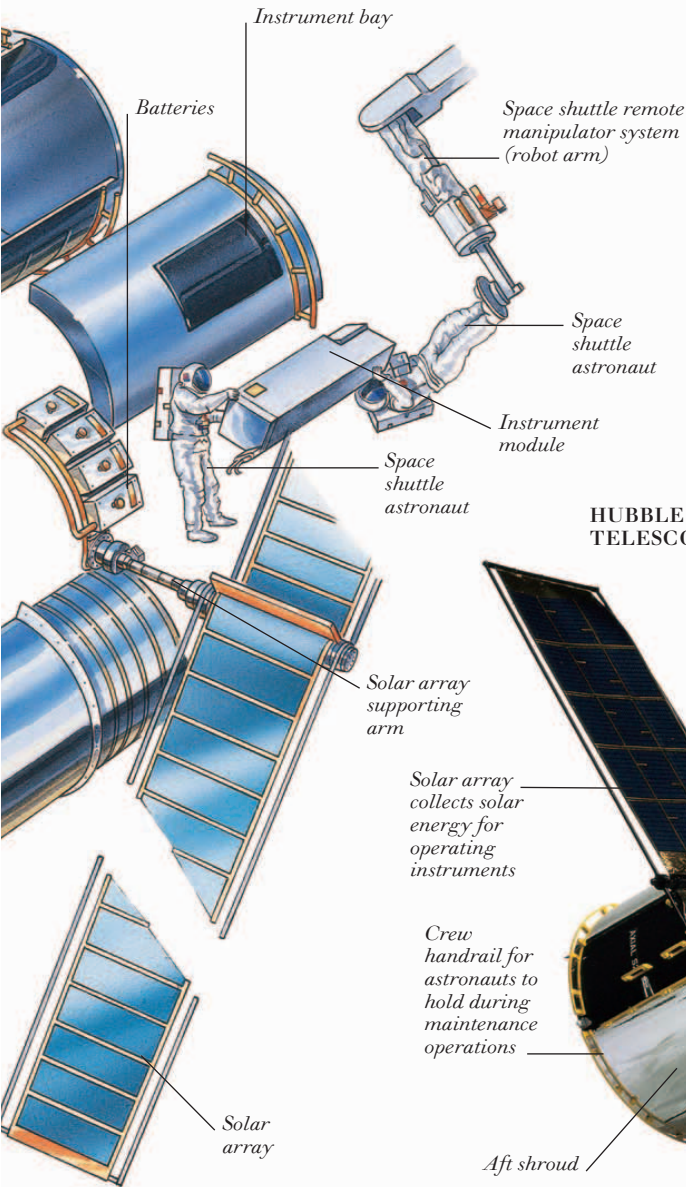
DRACO CONSTELLATION



OMEGA NEBULA



LEPUS CONSTELLATION



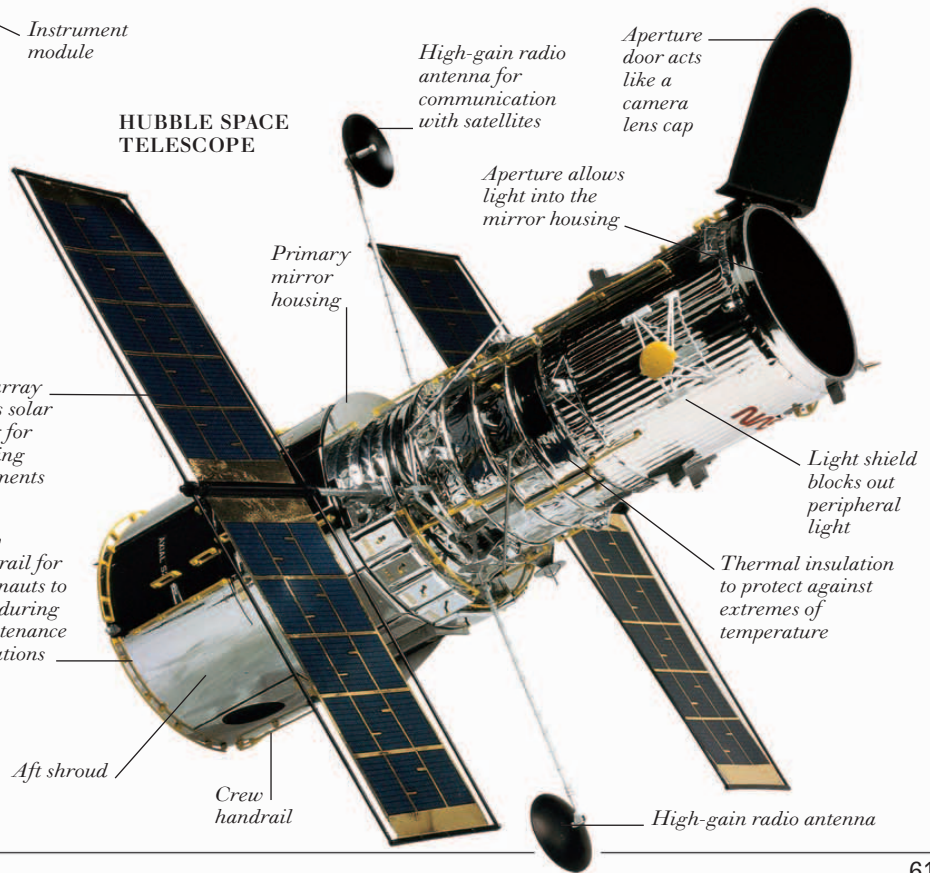
HUBBLE SPACE TELESCOPE



PLEIADES STAR CLUSTER

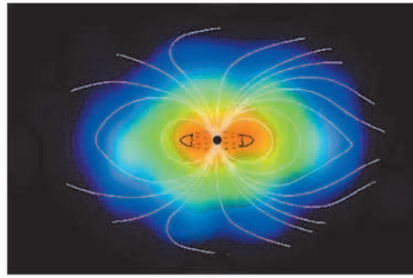


GREAT NEBULA, ORION

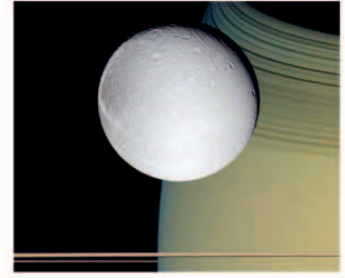


Probing the solar system

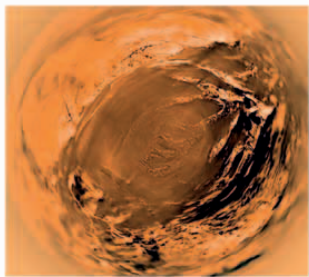
SPACE PROBES HAVE VISITED every planet in the solar system. They take photographs and gather data that cannot be collected using Earth-based equipment. Some probes fly past or orbit around planets or moons, while others land. Two Voyager space probes flew past the outer planets in the 1970s and 1980s. Two Viking spacecraft landed on Mars in 1976. The Magellan spacecraft orbited Venus from 1989 and mapped its surface. The Pathfinder spacecraft landed on Mars in 1997 and released a rover vehicle to explore the surface. The Mars Exploration Rover (MER) Mission landed two rovers in 2003. The Cassini space probe reached Saturn in 2004, and in 2005 its mini-probe, Huygens, landed on one of its moons, Titan, and became the first probe to land on a moon of another planet.



A MAP OF JUPITER'S VAST MAGNETIC FIELD PRODUCED BY CASSINI'S INSTRUMENTS



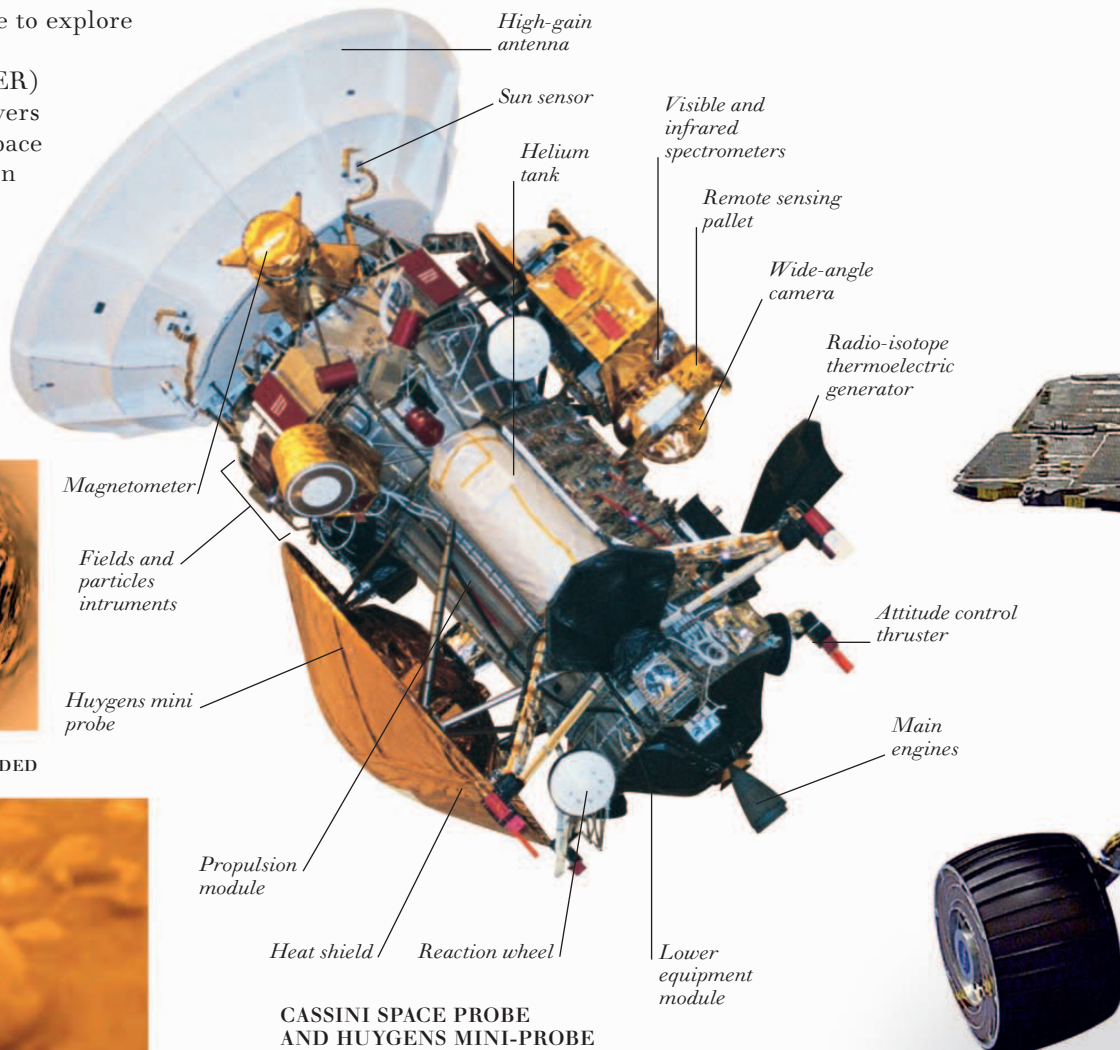
DIONE, ONE OF SATURN'S MOONS, ORBITING ABOVE THE "A" RING



PANORAMIC VIEW OF TITAN TAKEN AS HUYGENS DESCENDED



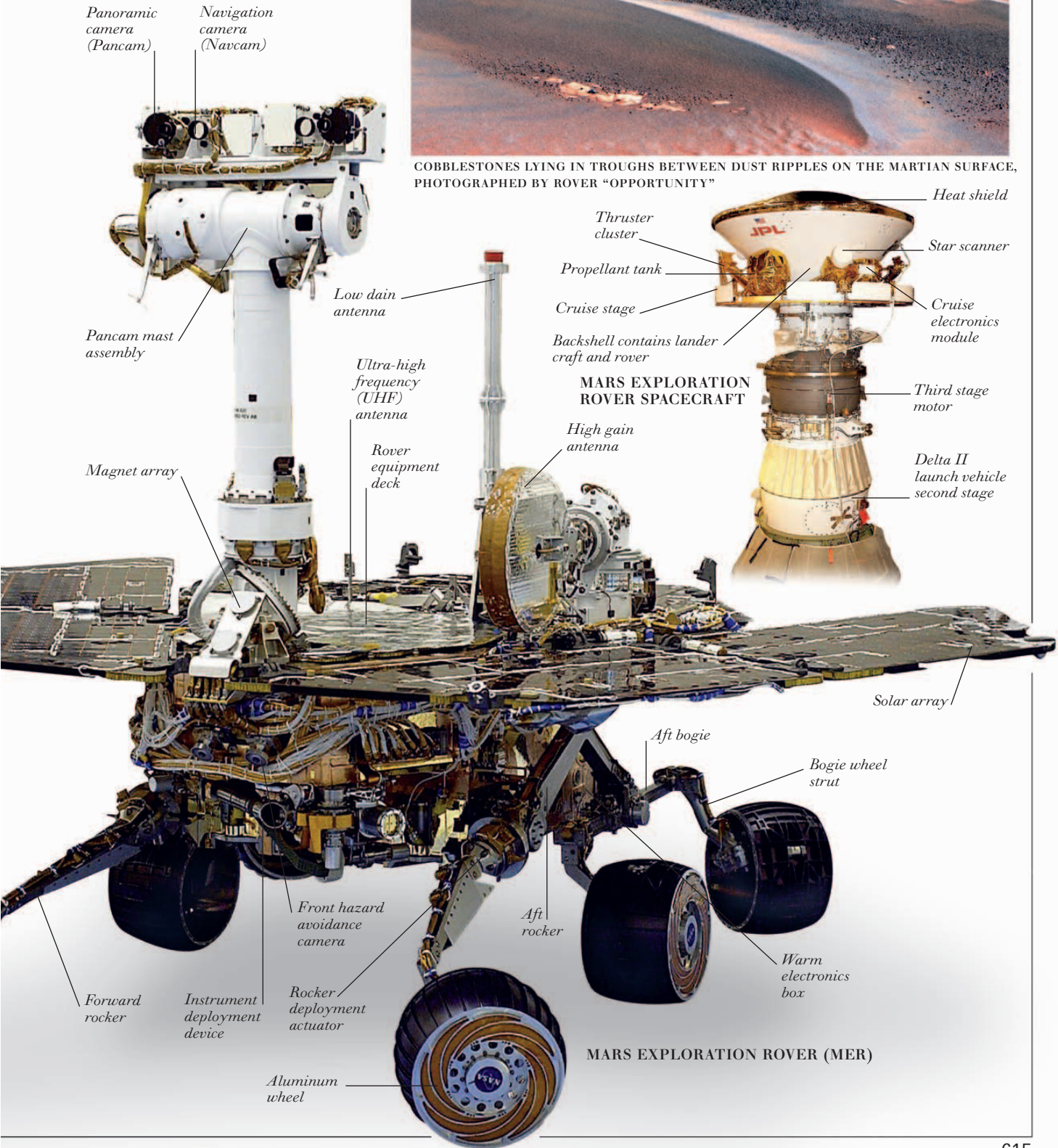
THE ROCK-STREWN SURFACE OF TITAN, PHOTOGRAPHED BY HUYGENS



CASSINI SPACE PROBE AND HUYGENS MINI-PROBE



COBBLESTONES LYING IN TROUGHS BETWEEN DUST RIPPLES ON THE MARTIAN SURFACE, PHOTOGRAPHED BY ROVER "OPPORTUNITY"



Panoramic camera (Pancam)
Navigation camera (Navcam)

Pancam mast assembly

Magnet array

Forward rocker

Instrument deployment device

Aluminum wheel

Low gain antenna
Ultra-high frequency (UHF) antenna

Rover equipment deck

Front hazard avoidance camera

Rocker deployment actuator

Aft rocker

Thruster cluster
Propellant tank
Cruise stage
Backshell contains lander craft and rover

High gain antenna

MARS EXPLORATION ROVER SPACECRAFT

Aft bogie

Bogie wheel strut

Warm electronics box

MARS EXPLORATION ROVER (MER)

Heat shield
Star scanner
Cruise electronics module
Third stage motor
Delta II launch vehicle second stage

Solar array

Political map of the world

This map depicts the political boundaries of the world's nations. There are currently 196 independent countries in the world—a marked increase from the 82 that existed in 1950. With the trend toward greater fragmentation, most recently with the creation of Southern Sudan in July 2011, this figure is likely to increase. The largest country in the world is the Russian Federation, which covers 6,592,800 square miles (17,075,400 sq km), while the smallest is the Vatican City, covering 0.17 square miles (0.44 sq km). Under the Antarctic Treaty of 1959, no countries are permitted territorial claims in Antarctica.



ABBREVIATIONS

AFGH.	Afghanistan
ALB.	Albania
AUT.	Austria
AZ. OR AZERB.	Azerbaijan
B. & H.	Bosnia & Herzegovina
BELG.	Belgium
BELO.	Belorussia
BOTS.	Botswana
BULG.	Bulgaria
CAMB.	Cambodia
C.A.R.	Central African Republic
CRO.	Croatia
CZ. REP.	Czech Republic
DOM. REP.	Dominican Republic
EST.	Estonia
HUNG.	Hungary
KYRG.	Kyrgyzstan
LAT.	Latvia
LIECH.	Liechtenstein
LITH.	Lithuania
LUX.	Luxemburg
MACED.	Macedonia
MOLD.	Moldavia
MON.	Montenegro
NETH.	Netherlands
PORT.	Portugal
ROM.	Romania
RUSS. FED.	Russian Federation
SLVK.	Slovakia
SLVN.	Slovenia
S.M.	San Marino
SWITZ.	Switzerland
TAJ.	Tajikistan
THAI.	Thailand
TURKMEN.	Turkmenistan
U.A.E.	United Arab Emirates
UZBEK.	Uzbekistan
VAT. CITY	Vatican City
ZIMB.	Zimbabwe

Time zones

The world is divided into 24 time zones, measured in relation to 12 noon Coordinated Universal Time (UTC), on the Greenwich Meridian (0°). Time advances by one hour for every 15° longitude east of Greenwich (and goes back one hour for every 15° west), but the system is adjusted in line with administrative boundaries. Numbers on the map indicate the number of hours that must be added to, or subtracted from UTC to calculate the time in each zone. Thus, the eastern United States (−5) is 5 hours behind UTC.

TYPES OF CALENDAR

GREGORIAN

The 365-day Gregorian calendar was introduced by Pope Gregory XIII in 1582 and is now in use throughout most of the Western world. Every four years (leap year) an extra day is added. Below are the names of the months (and number of days).

January (31)	July (31)
February (28, 29 in leap years)	August (31)
March (31)	September (30)
April (30)	October (31)
May (31)	November
June (30)	December (31)

JEWISH

The Jewish calendar is a lunar calendar adapted to the solar year. It normally has 12 months but in leap years, which occur seven times in every cycle of 19 years, there are 13 months. The years are calculated from the Creation (which is placed at 3761 BC); the months are Nisan, Iyyar, Sivan, Thammuz, Ab, Elul, Tishri, Hesvan, Kislev, Tebet, Sebat, and Adar, with an intercalary month (First Adar) being added in leap years.

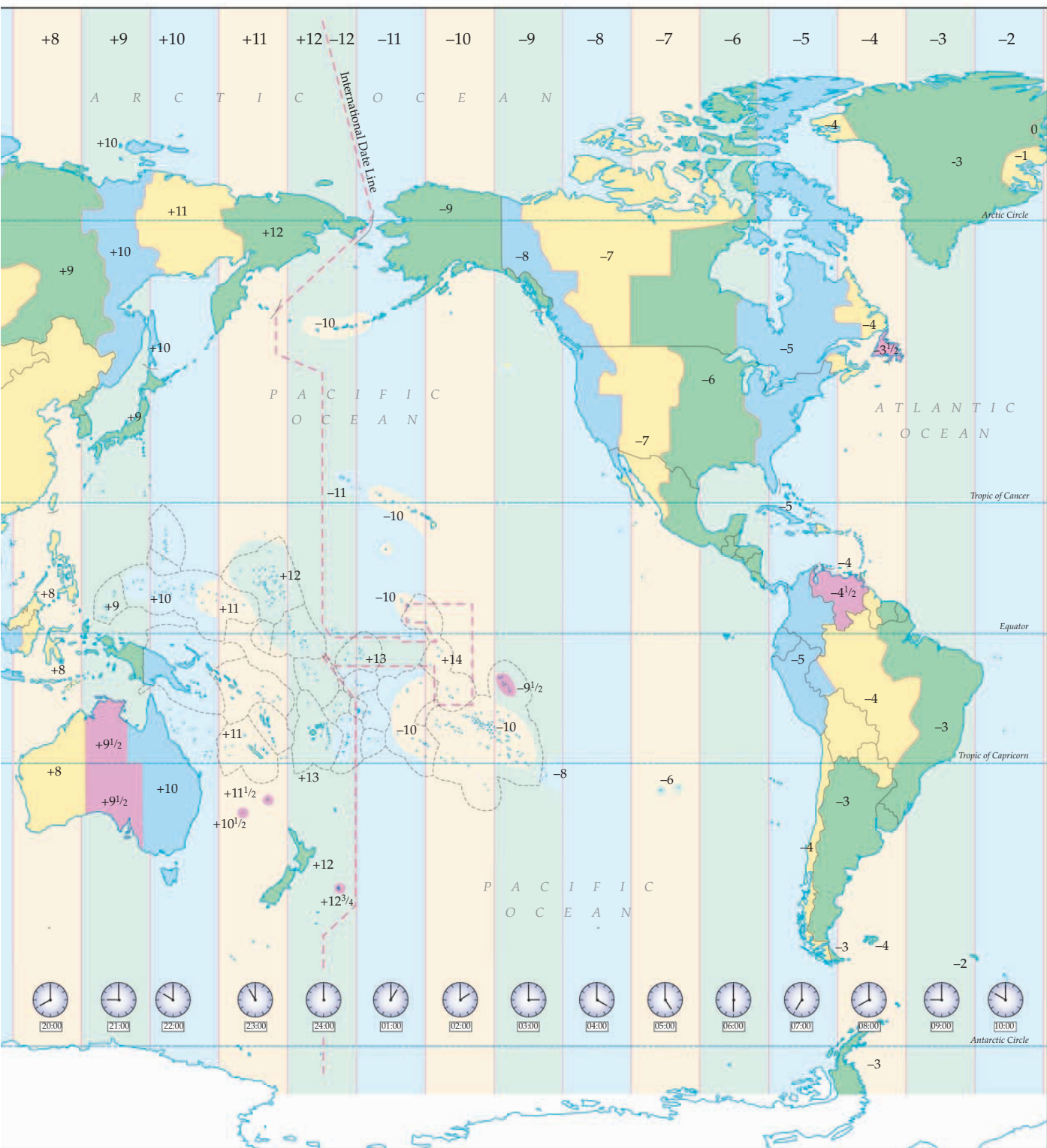
MUSLIM

The Muslim calendar is based on a year of 12 months, each month beginning roughly at the time of the New Moon. The months are Muharram, Safar, Rabi'i, Rabi'II, Jumada I, Jumada II, Rajab, Sha'ban, Ramadan, Shawwal, Dhu l-Qa'dah, and Dhu l-Hijja.

CHINESE

The Chinese calendar is a lunar calendar, with a year consisting of 12 months. Intercalary months are added to keep the calendar in step with the solar year of 365 days. Months are referred to by a number within a year, but also by animal names that, from ancient times, have been attached to years and hours of the day.





Useful data

UNITS OF MEASUREMENT

METRIC UNIT	EQUIVALENT
Length	
1 centimeter (cm)	10 millimeters (mm)
1 meter (m)	100 centimeters
1 kilometer (km)	1,000 meters
Mass	
1 kilogram (kg)	1,000 grams (g)
1 metric ton (t)	1,000 kilograms
Area	
1 square centimeter (cm ²)	100 square millimeters (mm ²)
1 square meter (m ²)	10,000 square centimeters
1 hectare	10,000 square meters
1 square kilometer (km ²)	1,000,000 square meters
Volume	
1 cubic centimeter (cc)	1 milliliter (ml)
1 liter (l)	1,000 milliliters
1 cubic meter (m ³)	1,000 liters
Capacity (liquid and dry measures)	
1 centiliter (cl)	10 milliliters (ml)
1 deciliter (dl)	10 centiliters
1 liter (l)	10 deciliters
1 decaliter (dal)	10 liters
1 hectoliter (hl)	10 decaliters
1 kiloliter (kl)	10 hectoliters

IMPERIAL UNIT	EQUIVALENT
Length	
1 foot (ft)	12 inches (in)
1 yard (yd)	3 feet
1 rod (rd)	5½ yards
1 mile (mi)	1,760 yards
Mass	
1 dram (dr)	27.344 grains (gr)
1 ounce (oz)	16 drams
1 pound (lb)	16 ounces
1 hundredweight (cwt) (long)	112 pounds
1 hundredweight (cwt) (short)	100 pounds
1 ton (long)	2,240 pounds
1 ton (short)	2,000 pounds
Area	
1 square foot (ft ²) (in ²)	144 square inches
1 square yard (yd ²)	1 square foot (ft ²)
9 square feet	
1 acre	4,840 square yards
1 square mile	640 acres
Volume	
1 cubic foot	1,728 cubic inches
1 cubic yard	27 cubic feet
Capacity (liquid and dry measures)	
1 fluidram (fl dr)	60 minims (min)
1 fluid ounce (fl oz)	8 fluidrams
1 gill (gi)	5 fluid ounces
1 pint (pt)	4 gills
1 quart (qt)	2 pints
1 gallon (gal)	4 quarts
1 peck (pk)	2 gallons
1 bushel (bu)	4 pecks

NUMBER SYSTEMS

ROMAN	ARABIC
I	1
II	2
III	3
IV	4
V	5
VI	6
VII	7
VIII	8
IX	9
X	10
XI	11
XII	12
XIII	13
XIV	14
XV	15
XX	20
XXI	21
XXX	30
XL	40
L	50
LX	60
LXX	70
LXXX	80
XC	90
C	100
CI	101
CC	200
CCC	300
CD	400
D	500
DC	600
DCC	700
DCCC	800
CM	900
M	1,000
MM	2,000

METRIC TO IMPERIAL CONVERSIONS

TO CONVERT	INTO	MULTIPLY BY
Length		
Centimeters	inches	0.3937
Meters	feet	3.2810
Kilometers	miles	0.6214
Meters	yards	1.0940
Mass		
Grams	ounces	0.0552
Kilograms	pounds	2.2050
Metric tons	long tons	0.9843
Metric tons	short tons	1.1025
Area		
Square centimeters	square inches	0.1550
Square meters	square feet	10.7600
Hectares	acres	2.4710
Square kilometers	square miles	0.3861
Square meters	square yards	1.1960
Volume		
Cubic centimeters	cubic inches	0.0610
Cubic meters	cubic feet	35.3100
Capacity		
Liters	pints	1.7600
Liters	gallons	0.2200

IMPERIAL TO METRIC CONVERSIONS

TO CONVERT	INTO	MULTIPLY BY
Length		
Inches	centimeters	2.5400
Feet	meters	0.3048
Miles	kilometers	1.6090
Yards	meters	0.9144
Mass		
Ounces	grams	28.3500
Pounds	kilograms	0.4536
Long tons	metric tons	1.0160
Short tons	metric tons	0.9070
Area		
Square inches	square centimeters	6.4520
Square feet	square meters	0.0929
Acres	hectares	0.4047
Square miles	square kilometers	2.5900
Square yards	square meters	0.8361
Volume		
Cubic inches	cubic centimeters	16.3900
Cubic feet	cubic meters	0.0283
Capacity		
Pints	liters	0.5683
Gallons	liters	4.5460

RULES OF ALGEBRA

EXPRESSION	COMMENTS	EXPRESSION BECOMES
$a + a$	Simple addition	$2a$
$a + b = c + d$	Subtract b from either side	$a = c + d - b$
$ab = cd$	Divide both sides by b	$a = cd \div b$
$(a + b)(c + d)$	Multiplication of bracketed terms	$ac + ad + bc + bd$
$a^2 + ab$	Use parentheses	$a(a + b)$
$(a + b)^2$	Expand terms in parentheses	$a^2 + 2ab + b^2$
$a^2 - b^2$	Difference of two squares	$(a + b)(a - b)$
$1/a + 1/b$	Find common denominator	$(a + b)/ab$
$a/b \div c/d$	Dividing by a fraction is the same as multiplying by its reciprocal	$a/b \times d/c$

POWERS OF TEN USED WITH SCIENTIFIC UNITS

FACTOR	NAME	PREFIX	SYMBOL
10^{18}	quintillion	exa-	E
10^{15}	quadrillion	peta-	P
10^{12}	trillion	tera-	T
10^9	billion	giga-	G
10^6	million	mega-	M
10^5	thousand	kilo-	k
10^2	hundred	hecto-	h
10^1	ten	deca-	da
10^{-1}	one-tenth	deci-	d
10^{-2}	one-hundredth	centi-	c
10^{-3}	one-thousandth	milli-	m
10^{-6}	one-millionth	micro-	μ
10^{-9}	one-billionth	nano-	n
10^{-12}	one-trillionth	pico-	p
10^{-15}	one-quadrillionth	femto-	f
10^{-18}	one-quintillionth	atto-	a

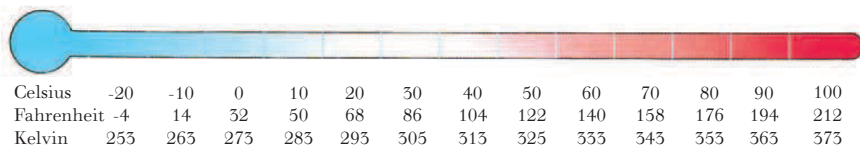
Note: The American system of numeration for denominations above one million is used in this book. In this system, each of the denominations above one billion (1,000 millions) is 1,000 times the preceding one.

BIOLOGY SYMBOLS

SYMBOL	MEANING
O	female individual (used in inheritance charts)
□	male individual (used in inheritance charts)
♀	female
♂	male
×	crossed with; hybrid
+	wild type
F ₁	offspring of the first generation
F ₂	offspring of the second generation

TEMPERATURE SCALES

To convert from Fahrenheit (F) to Celsius (C): $C = (F - 32) \div 5 \div 9$
 To convert from Celsius to Fahrenheit: $F = (C \times 9 \div 5) + 32$
 To convert from Celsius to Kelvin (K): $K = C + 273$
 To convert from Kelvin to Celsius: $C = K - 273$



MATHEMATICAL SYMBOLS

SYMBOL	EXPLANATION
+	addition
-	subtraction
×	multiplication
÷	division
=	equals
≠	does not equal
>	greater than
<	less than
≥	greater than or equal to
≤	less than or equal to
∞	infinity
%	percent
π	pi (3.1416)
°	degree
≈	is approximately equal to
∠	angle
∥	parallel to
∑	summation
u, v	vectors
f(x)	function
!	factorial
√	square root
ξ	universal set
A ∩ B	intersection
A ∪ B	unison
A ⊂ B	subset
∅	null set

CHEMISTRY SYMBOLS

SYMBOL	MEANING
+	plus; together with
-	single bond
•	single bond; single unpaired electron; two separate parts or compounds regarded as loosely joined
=	double bond
≡	triple bond
R	group
X	halogen atom
Z	atomic number

PHYSICS SYMBOLS

SYMBOL	MEANING
α	alpha particle
β	beta ray
γ	gamma ray; photon
ε	electromotive force
η	efficiency; viscosity
λ	wavelength
μ	micro-; permeability
ν	frequency; neutrino
ρ	density; resistivity
σ	conductivity
c	velocity of light
e	electronic charge

SCIENTIFIC NOTATION

NUMBER	NUMBER BETWEEN 1 AND 10	POWER OF TEN	SCIENTIFIC NOTATION
10	1	10^1	$1 \ 3 \ 10^1$
150	1.5	$10^2 (= 100)$	$1.5 \ 3 \ 10^2$
274,000,000	2.74	$10^8 (= 100,000,000)$	$2.74 \ 3 \ 10^8$
0.0023	2.3	$10^{-5} (= 0.001)$	$2.3 \ 3 \ 10^{-5}$

TRIGONOMETRY

Angle A (degrees)	sin A	cos A	tan A
0	0	1	0
30	1/2	√3/2	1/√3
45	1/√2	1/√2	1
60	√3/2	1/2	√3
90	1	0	∞

Shapes: Plane

Two-dimensional shapes are termed plane (or flat) shapes. Plane shapes constructed with straight sides, as illustrated here, are called polygons. They are categorized according to the number of sides they have—for example, three-sided polygons are known as triangles. A polygon that has sides of equal length and internal angles of equal size, such as a square, is said to be regular.



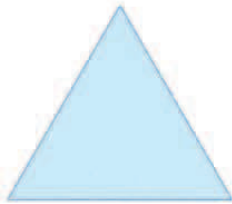
SCALENE TRIANGLE
A triangle (three-sided polygon) with no equal sides or angles.



ISOSCELES TRIANGLE
A triangle with only two sides and two angles equal.



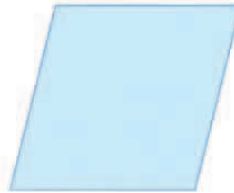
RIGHT-ANGLED TRIANGLE
A triangle with one angle as a right angle (90°).



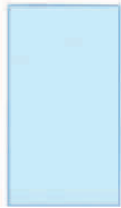
EQUILATERAL TRIANGLE
A regular triangle. All angles are 60° .



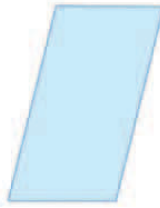
SQUARE
A regular quadrilateral. All angles are 90° .



RHOMBUS
A quadrilateral with all sides equal and two pairs of equal angles.



RECTANGLE
A quadrilateral with four right angles and opposite sides of equal length.



PARALLELOGRAM
A quadrilateral with two pairs of parallel sides.



TRAPEZIUM
A quadrilateral with one pair of parallel sides.



PENTAGON
A five-sided polygon. A regular pentagon is shown above.



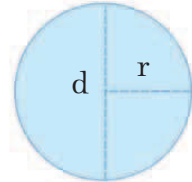
HEXAGON
A six-sided polygon. A regular hexagon is shown above.



OCTAGON
An eight-sided polygon. A regular octagon is shown above.

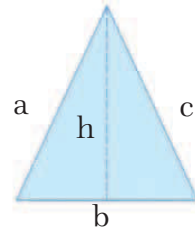
AREAS AND PERIMETERS

The formulae for calculating the areas and perimeters of simple plane shapes were devised by Classical Greek mathematicians.



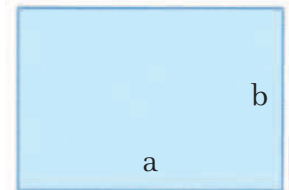
CIRCLE
 r = radius
 d = diameter = $2 \times r$

Circumference = $2 \times \pi \times r$
Area = $\pi \times r^2$
($\pi = 3.1416$)



TRIANGLE
Height = h
Sides = a, b, c

Perimeter = $a + b + c$
Area = $\frac{1}{2} \times b \times h$

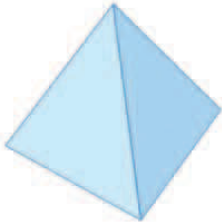


RECTANGLE
Sides = a, b

Perimeter = $2 \times (a + b)$
Area = $a \times b$

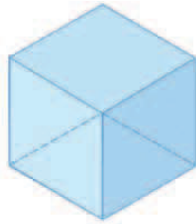
Shapes: Solid

Three-dimensional shapes are known as solid shapes and include spheres, cubes, and pyramids. A solid shape with a polygon at each face is called a polyhedron.



TETRAHEDRON

A four-sided polyhedron. A regular tetrahedron is shown.



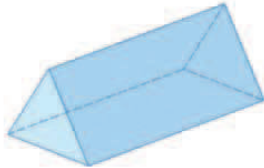
CUBE

A regular hexahedron. All sides are equal and all angles are 90° .



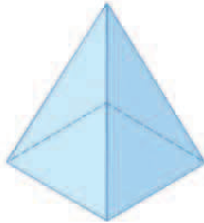
OCTAHEDRON

A polyhedron with eight sides.



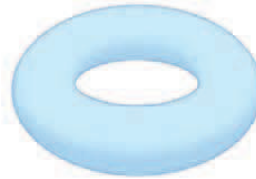
PRISM

A polyhedron of constant cross-sections in planes perpendicular to its longitudinal axis.



PYRAMID

A polygonal base and triangular sides that meet at a point.



TORUS

A doughnutlike, ring shape.



SPHERE

A round shape, as in a ball or an orange.



HEMISPHERE

Formed when a sphere is cut exactly in half.



SPHEROID

An egg-shaped solid object whose cross-section is a circle or an ellipse.



CONE

An elliptical or circular base with sides tapering to a single point.



RIGHT CYLINDER

A tube-shaped, solid figure. A right cylinder has parallel faces.



HELIX

A twisted curve. The distance moved in one revolution is its pitch.

SURFACE AREAS AND VOLUMES

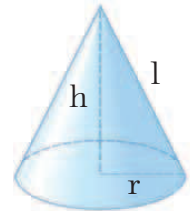
Volume refers to the amount of space that a solid object occupies. Its surface area is the sum of the area of each of its faces.



CYLINDER

Surface area = $2 \times \pi \times r \times h + 2\pi r^2$
Volume = $\pi \times r^2 \times h$

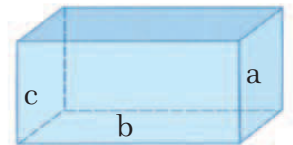
Height = h
Radius = r



CONE

Surface area = $\pi \times r \times l + \pi r^2$
Volume = $\frac{1}{3} \times \pi \times r^2 \times h$

Height = h
Radius = r
Side = l



RECTANGULAR BLOCK

Surface area = $2(a \times b + b \times c + a \times c)$
Volume = $a \times b \times c$

Sides = a, b, c

Index

- A**
Aa lava 275
Abacus
Ancient Egyptian temple 459
Ancient Greek building 460
Medieval church 469
Neoclassical building 485
Abalone 176
Abaxial epidermis 139
Abaxial surface
Butterwort leaf 161
Fern pinnule 121
Mulberry leaf 150
Water hyacinth leaf 158
Water lily leaf 159
Welwitschia leaf 125
Abbey of St. Foi 468
Abdomen
Crab 172
Crayfish 172
Human 211
Insect 168-169
Rattlesnake 185
Scorpion 170
Shrimp 172
Spider 171
Abdominal aorta 215, 255
Abdominal artery 175
Abdominal cavity 215
Abdominal segment
Butterfly 169
Crayfish 172
Eurypterid fossil 79
Extinct shrimp 79
Abductor digiti minimi muscle 251, 255
Abductor pollicis brevis muscle 251
Aberdeen hook 562
Abies Concolor 66
Abomasum 198
Aboral surface
Sea urchin 175
Starfish 174
Abortive ovule 151
Abortive seed 146
Abrasion
Glacier 286
Weathering and erosion 282
Absolute magnitude
Hertzsprung-Russell diagram 25
Stars 22
Absorption lines 22-25
Absorptive hyphae 114
Abutment 484-485
Abyssal plain 298
Acacia tree sap 458
Acadagnotus 64
Acamar 19
Acanthostachys strobilacea 112-115
Acanthostega 80
Acanthus leaf 460
Accelerated electron 319
Acceleration 520-521
Electric train 528
Motorcycle 364
Access door 535
Accessory drive pad 419
Accessory pouch 548
Access panel 529, 353
Access slot 585
Accidentals 502-505
Accretion disc 27-29
AC electric train 528
Acer Lumiread e-reader 568
Acer pseudoplatanus 151, 151
Acer sp. 127
Acetabularia sp. 116
Acetabularium 225
Acetabulum
Eryops 81
Ormithischian 82
Saurischian 82
Acetylene headlight 356-357
Achenes 150
Achernar 20
Achilles tendon 252-255
Acid
Intaglio printing 446
Reversible reaction 512
Salt formation 512
Acidalia Planitia 45
Acidic solution 446, 448
Acid-resistant ground 446-447
Acid-secreting stomach cell 217
Acipenser sturio 180
Acorn 151
Acoustic guitar 512-515
Acropolis 460
Acrosomal cap 259
Acroterion 460-461
Acroteuthis 278
Acruz
Centaurus and Crux 21
Southern stars 21
Acrylic ink 448
Acrylic paint techniques 445
Acrylic-primed board 442
Acrylics 442-445
Actinia equina 166
Actinides 510
Actinium 510
Actinotroche sphyrodeta 166
Action level 514
Active galaxy 12
Active volcano 272
Igneous and metamorphic rocks 275
Mountain building 62
Actuating lever system 530
Acuminate leaf apex 156-157
Acute leaf apex 157
Adam's apple 212, 244-245
Adam's ring
Neptune's rings 50
Structure of Neptune 51
Adaptation 112
Dryland plants 156-157
Wetland plants 158-159
Adaxial epidermis 139
Adaxial surface
Butterwort leaf 161
Mulberry leaf 150
Tree mallow leaf 151
Water hyacinth leaf 158
Water lily leaf 159
Welwitschia leaf 125
Add address button 576
Add attachments button 576
Address options button 576
Adductor longus muscle 225, 226
Adductor magnus muscle 227
Adductor muscle 175
Adductor pollicis muscle 251
Adductor tubercle 225
Adenine 216
Adhara 18, 21
Adipose tissue 215, 255
Adjustable antenna 591
Adjustable damper 518
Adjustable link 562
Adjustable vane 563
Adjusting screw 560
Admiralty anchor Type ACII 586
Admiralty pattern anchor 386
Adrenal gland 215, 257
Adventitious buds 154
Adventitious roots
Aechmea miniata 162
Canadian pond weed 158
Couch grass 115
Fern 121
Horsetail 120
Ivy 131
Monocotyledon 126
Potato 128
Rock stonecrop 128
Tree fern 112
Vegetative reproduction 154-155
Water fern 158
Water hyacinth 158
Water lily 159
Advertising 368
Advertising panel 355
Aechmea miniata 162
Aedicule
Ancient Roman building 465
Renaissance building 474, 476
AEG Turbine Hall 495
Aegyptopithecus 75
Aeration zone 295
Aerial
Frigate 597
Honda Insight 354
Renault Clio 349
Aerial mammals 104
Aerial rig 597
Aerial root 162
Aerial shoot 155
Aerial stem 119, 155
Aerodynamic balance 414-415
Aerodynamic hub cover 604
Aerodynamic roof 354
Aerodynamic tubing 360
Aerodynamic underside components 554
Aerodynamic windshield 346
Aerofoil guard 529
"Aero" handlebars 360-361
Aerosol spray fixative 450, 440
"Aerotuck" position 360
Aesculus hippocastanum 150
Aesculus parviflora 157
Afferent arteriole 257
A-frame
Concorde 416
Gliders, hang-gliders, and ultralights 426
Africa
Cretaceous period 72-75
Earth's physical features 264-265
Great Rift Valley 60
Jurassic period 70
Late Carboniferous period 66
Middle Ordovician period 64
Quaternary period 76-77
Tertiary period 74-75
Triassic period 68
African elephant 200-201
African plate 59
Aft anchor 595
Aft bogie 615
Aft door 416, 572
Afterbay 514
After brake rope 387
After bridge 595
Afterburner
Jet engine 418
Supersonic jetliner 416
Afterburner nozzle 421
Aftercastle
Sailing warship 377
Square-rigged ship 375
Aftercastle castle-deck gunport 377
After compass platform 395
After fashion piece 581
After funnel
Battleship 595
Iron paddlesteamer 592
Afterpeak 392
After muffler 427
After spring rope 387
Aft fairing 415
Aft galley unit 417
Aft hydroplane 596
Aft main door 414-415
Aft rocker 615
Aft shoulder 560
Aft shroud 612, 613
Aft spar 415
Agate burnisher tip 452
Aggregate fruits 148-149
Bramble 130
Development 146-147
Aghulas current 297
Agnatha 178
Agropyron repens 115
Ahead/astern controls 590
Aileron
ARV light aircraft 424
BAe-146 components 414
Curtiss biplane 398-399
Hawker Tempest components 409
Lockheed Electra airliner 406
LVG CVI fighter 405
Schleicher glider 426
Aileron control wire 405
Aileron hinge strut 405
Aileron mass balance 424
Aileron operating arm 398
Aino Planitia 36-37
Air
Atmosphere 300
Oceans and seas 296
Weather 302-305
Air ambulance 422
Airbag suspension 351
Air bladder 117
Air-brake
BAe-146 components 415
Schleicher glider 426
Tornado 421
Air-brake coupling hose 326
Air-brake jack 421
Air brushes 442
Airbus 580 572-575
Air chamber 118
Air cleaner
Jaguar V12 engine 345
Renault Clio 551
Air compression 326
Air-conditioning 496-497
Air-conditioning compressor 344, 354
Air-conditioning duct 417
Air-conditioning pump 344
Air-conditioning refrigerant pipe 344
Air-cooled engine
Motorcycle engine 366
V8 engine 404
Air cooling baffle 402
Air cooling fan 427
Air cooling scoop 365
Air-cushioned sole 545
Air data probe 420
Air exit 592
Air filter
Bell-47 helicopter 422
Harley Davidson FLHS Electra Glide 365
Pegasus Quasar
Volkswagen Beetle 340
ultralight 427
Air hose 442
Air impingement starter 418
Air inlet
Jaguar V12 engine 345
Power drill 601
Air intake
Concorde, the 416
Double-decker tour bus 335
Formula One race car 356, 357
Lockheed Electra airliner 406
MCW Metrobus 552-555
Modern military aircraft 420-421
Single-decker bus 335
Turbojet engine 418
Turboprop engine 419
Vacuum cleaner 592, 595
Air intake box 425
Air-intake duct 354, 575
Air intake vent 541
Air mass 296
Air outlet 556, 427
Air passage
Lambeosaurus 99
Parasaurolophus 99
Air pistol 548-549
Air plants 162
Air pressure 305
Air pump
Oscillating steam engine 391
Steamboat 391
Air reservoir valve 527
Air resistance 552
Air rifle shooting 548
Air sac
Chicken's egg 192
Scots pine 122
Air scoop
ARV Super 2 424
Volkswagen Beetle 340
Air spaces
Clubmoss stem 120
Mare's tail stem 135
Moss 119
Root 152
Stem 155
Wetland plants 158-159
Airspeed-indicator tube
ARV light aircraft 425
BE 2B wings 404
Airspeed pitot tube 404
Air taxi 422
Air temperature 500
Air temperature probe
BAe-146 components 412
Bell Jetranger helicopter 425
Air vent
Bicycle helmet 360
Hockey helmet 540
Suzuki RGV500 368-369
Air ventilator inlet 405
Aisle
Airbus 380 572
Ancient Egyptian temple 458
Cathedral dome 484
Gothic church 470, 472-475
Medieval church 468-469
Akna Montes 37
Ala 213, 225
Alar groove 215
Alarm vibrator motor 558
Alba Fossae 43
Alba Patena 45
Albatagnius 40
Albertosaurus 84
Albireo 20
Albumen 192
Albumen gland 177
Alcohol fermentation 315
Alcor 19
Alcyone 20
Aldebaran 18, 21
Alderamin 19
Aethopteris 67, 278
Algae 56, 112, 116-117
Desmid 112
Earth's evolution 56
Fossil record 279
Lichen symbiote 114
Algal cell 114
Algal layer 114
Algebra 621
Algei 20
Algenib 19, 20
Algebra 18
Algol 19, 20
Alhambra 488
Alhena 18, 21
Alicante 450
Alidade 377
Alimentary canal 248-249
Alhoth 18
The Big Dipper 19
Alkaid 18
The Big Dipper 19
Alkali metals 510
Allantoic fluid 192
Allantois 192-195
All-around bicycle 360
"All clear" position 330
All-enclosing fairing 369
Alley 544-545
Alligator 186
Allison 250-C20J
turbohaft engine 425
Allium sp. 145
Allosaurus 71, 85
Allotropes 511
Alloy disc 517
Alloy frame 368
Alloy wheel
Formula One race car 356, 357
Honda VF750 364-365
Renault Clio 550-551
Suzuki RGV500 368-369
All-terrain bicycle 358
Alluvial cone 282
Alluvial fan 282
Alluvium-filled basin 282
Almah 19, 20
Pegasus and Andromeda 19
Al Nair 19, 20
Alnilam 18
Alnitak
Horsehead Nebula 16
Orion 18
Alouatta seniculus 205
Alpha Centauri 21
Alpha Hydri 20
Alpha Mensae 20
Alphard 18, 21
Alpha Regio 36-37
Alpha ring 48
Alphecca 18, 21
Alpheratz 19, 20
Pegasus and Andromeda 19
Alphonsus 40
Alpine skiing 552-555
Alps 60, 265

- Alrami 21
 Alsatian dog 195
Alstroemeria aurea 129
 Altair 19, 20
 Altar 470
 Alternating current 328
 Alternative engines 346-347
 Alternator
 Diesel train 326
 Ford V6 12-valve engine 344
 Jaguar V12 engine 345
 NPT 301 turbojet 418
 Renault Clío 351
 Alternator belt 351
 Altitude scale 377
 Alto clef 502
 Altcumulus cloud 302
 Alto mute 507
 Altostratus cloud 502
 Alto voice 502
 Aludra 21
 Alula 191
 Aluminum 311
 Earth's composition 39
 Earth's crust 58
 Aluminum alloy backing 346
 Aluminum arrow shaft 548
 Aluminum beam 560
 Aluminum bonnet 354
 Aluminum cowl 401
 Aluminum flush-riveted skin 407
 Aluminum gearbox casing 366
 Aluminum racket 544
 Aluminum shield 612
 Aluminum wheel 406, 615
 Aluminum wire figure 455
 Alveolar artery and vein 247
 Alveolar bone 247
 Alveoli 254-255
 Amaryllis 155
 Amateur rules 552
 Amazon Basin 39
 Amazon Kindle e-reader 569
 Amazon River 264
 Amazonis Planitia 43
 Ambiens muscle
 Albertosaurus 84
 Iguanodon 97
 Ambulacral groove 79, 175
 Ambulatory corridor 465
 Amelodontal junction 247
 American alligator 186
 American beaver 197
 American black bear 195
 American squash court 545
 American squash game 544
 Americium 311
 Ammonia
 Jupiter's atmosphere 45
 Saturn's atmosphere 47
 Structure of Neptune 51
 Structure of Uranus 49
 Ammonite 278-279
 Ammonite shell 267
 Ammonium dichromate 312
 Ammonium
 hydrosulfide
 Jupiter's atmosphere 45
 Saturn's atmosphere 47
Ammophila arenaria 115
 Ammunition 548-549
 Ammunition box 408
 Amnion 192-193, 260
 Amniotic egg 80
 Amniotic fluid 192, 260
 Amniotic sac 260
 Amoebocyte 166
 Amphibia 182
 Amphibian 80-81, 182-183
 Earth's evolution 56
 Fossil 278-279
 Primitive 68-69, 78
 Amphibole 275
 Amphitheater 464-465
 Amplification
 Drums 518
 Electronic instruments 520
 Guitar 512
 Stringed instruments 510
 Vibraphone 516
 Xylophone 516
 Amplifier 520
 Amps 516
 Ampulla
 Ear 242-245
 Fallopian tube 258-259
 Sea urchin 175
 Starfish 174
 Ampullar nerve 242
 Anal canal 249
 Anal clasper 169
 Anal fin
 Bony fish 180-181
 Lamprey 178
 Anal fin ray 180
 Anal flap 200
 Analog signals 580
 Anal sphincter muscle 249
Anchisaurus 88-89
 Anchor
 74-gun ship 580
 BAE-146 components 412, 414
 Battleship 394-395
 Frigate 397
 Junk 376
 Roman corbita 372
 Square-rigged ship 375
 Tea clipper 392
 Types 386
 Wooden sailing ship 379
 Anchor bearing 415
 Anchor buoy 379
 Anchor cable
 74-gun ship 380
 Sailing warship 376
 Anchor chain 386, 395
 Anchoring 386-387
 Anchor-joint 492
 Anchor rode 372
 Ancient Egyptian building 458-459
 Ancient Greek building 460-461, 462
 Ancient Greeks 542
 Ancient Roman building 462-465, 474
 Ancillary drive belt 347
 Ancillary drive pulley 345
 Ancore 372
 Andamenti 451
 Andes
 Cretaceous period 73
 Earth's external features 39
 Jurassic period 70
 Late Carboniferous period 66
 Quaternary period 76-77
 Tertiary period 74-75
 Triassic period 68
 Androecium 140-141, 145
 Andromeda 19, 20
 Andromeda Galaxy 14, 19
 Anemometer 605
Anemonia viridis 166
 Anemophilous pollination 144
 Angiospermophyta 112, 126
 Angiosperms 279
 Angle bar 595
 Angle buttress 471, 472
 Angle-of-attack probe 420
 Anglerfish 180
 Angling 562-563
 Angoulême Cathedral 468-469
 Angular mountain ridge 295
 Angular notch 249
 Angular process 194
 Angular unconformity 276
 Anhydrous copper sulfate 313
 Animal cloning 607
 Animal life
 Electromagnetic radiation 314
 Primitive 78
 Animal remains
 Fossils 278
 Sedimentary rocks 276
 Animal stances 82
 Animals 56, 67, 78
 Anions 308
 Ankle
 Anchisaurus 89
 Corythosaurus 98
 Edmontonia 95
 Herrerasaurus 86
 Human 211
 Iguanodon 96
 Pachycephalosaurus 100
 Psittacosaurus 105
 Stegoceras 101
 Stegosaurus 92
 Triceratops 102
 Tyrannosaurus 84
 Ankle joint
 Brachiosaurus 90
 Diplodocus 90
 Euoplocephalus 94
 Human 219
 Parasaurolophus 98
 Plateosaurus 88
 Stegoceras 101
 Struthiomimus 87
 Triceratops 102
 Tyrannosaurus 84
 Ankylosaurs 85, 92, 94-95
 Anne's Spot 47
 Annual growth ring 125
 Annuals 128
 Annular river drainage 288
 Annular tendon 241
 Annulet 460
 Annulus
 Fern 121
 Mushroom 115
 Annulus of trunk 201
 Ant 168
 Anta 461
 Antarala 490-491
 Antarctica
 Cretaceous period 72-75
 Earth's physical features 264-265
 Jurassic period 70
 Late Carboniferous period 66
 Quaternary period 76-77
 Tertiary period 74-75
 Triassic period 68
 Antarctic Circle
 Satellite map 265
 Surface currents 297
 Antarctic circumpolar current 296
 Antares 18, 21
 Antefixa 461
 Antelope 198
 Antenna
 Airbus 580 575
 Battleship 395
 Crab 172
 Crayfish 173
 Frigate 397
 Global positioning system 590, 591
 Insects 168-169
 Malacostraca 172
 Roman corbita 372-373
 Shrimp 172
 Volleyball net 554
 Antennule 173
 Anterior antebrachial muscle 86
 Anterior aorta 170
 Anterior arch 222
 Anterior brachial muscle
 Brachiosaurus 91
 Gallimimus 86
 Anterior branch of spinal nerve 225
 Anterior chamber 241
 Anterior chamber of cloaca 185
 Anterior crural muscle
 Brachiosaurus 90
 Gallimimus 86
 Anterior dorsal fin
 Bony fish 181
 Dogfish 179
 Lamprey 178
 Anterior fontanelle 220
 Anterior horn 225
 Anterior median fissure 225, 238
 Anterior median vein 253
 Anterior nasal spine 220-221
 Anterior petal 141
 Anterior root 258
 Anterior semicircular canal 243
 Anterior sepal 141
 Anterior tentacle 177
 Anterior tibial artery 253
 Anterior tibial muscle
 Albertosaurus 84
 Iguanodon 97
 Anterior tubercle 222
 Anterior wing of shell 176
 Antheridium 117
 Fern 121
 Moss 119
 Antherozooids 116-117
 Fern 121
 Moss 119
 Anthers 140-143, 145
 Dicotyledons 126-127
 Fertilization 146-147
 Pollination process 144-145
 Anthozoa 166
 Anthracite coal 280
Anthriscus sp. 135
 Anthroids 202
Anthurium andreanum 145
 Antibodies 255
 Anticlinal fold 60
 Anticline 60-61, 62
 Anticline trap 280-281
 Anticlinorium 61
 Anti-collision beacon 422-423
 Anti-corrosion paint 413
 Anticyclonic storm system
 Cloud features of Neptune 50
 Jupiter 44-45
 Structure of Saturn 47
 Anti-friction pad 552
 Anti-glare lens 553
 Anti-glare screen surface 584
 Antihelix 242
 Anti-lift bracing wire
 Avro triplane 405
 Blackburn monoplane 401
 Blériot XI monoplane 401
 LVG CVI fighter 405
 Anti-lift wire 399
 Antimacassar 329
 Antimony 311
 Antipodal cell 147
 Anti-reflective coating 605
 Anti-reverse drive 562
 Anti-roll bar
 Renault Clío 350-351
 Volkswagen Beetle 340
 Anti-submarine torpedo tube 397
 Anti-surge baffle 544
 Anti-torque tail rotor 425
 Antitragus 242
 Anti-vibration engine mount 411
 Antler hammer 109
 Antler harpoon 109
 Antlia 18, 21
 Antonia di 41
 Antorbital fenestra
 Baryonyx 83
 Camarasaurus 91
 Diplodocus 90
 Plateosaurus 88
 Anura 182
 Anus
 Barnacle 173
 Bony fish 181
 Butterfly 169
 Cow 198
 Crayfish 173
 Dolphin 205
 Domestic cat 195
 Elephant 200
 Human 249, 258, 261
 Octopus 176
 Rabbit 196
 Sea urchin 175
 Snail 177
 Spider 170
 Starfish 174
 Tortoise 187
 Anvil 242
 Aorta
 Anterior 170
 Bony fish 181
 Dogfish 179
 Dolphin 205
 Dorsal 179, 181, 182
 Human 215, 250-251, 252, 255, 256-257
 Posterior 170
 Spider 170
 Ventral 179
 Apatite 271
 Ape 108, 202-205
 Aperture 610, 612, 613
 Aperture door 612, 613
 Aperture door mounting 612
 Aperture plate 611
 Apex
 Beetle wing 168
 Butterfly wing 169
 Calligraphy characters 445
 Clubmoss shoot 120
 Fern frond 121
 Fern pinnule 121
 Horsetail shoot 120
 Leaf 136-137, 154-155
 Lung 255
 Moss 119
 Pegasus XL SE
 Pine shoot 125
 Snail shell 177
 Tongue 244-245
 ultralight 426
 Apex wire 426
 Aphelion 30-31
 Aphrodite Terra 36-37
 Apical bud
 Bulb 155
 Pine shoot 125
 Apical foramen 247
 Apical meristem 134
 Apical notch
 Seaweed 116
 Thalloid liverwort 118
 Apollo 41
 Apomixis 146
 Apophysis 119
 Apothecium 114
 Appalachian mountains
 Late Cretaceous period 67
 Mountain building 62
 Quaternary period 72
 Satellite map 264
 Tertiary period 75
 Triassic period 69
 Apparent magnitude 22
 Appendix
 Chimpanzee 202
 Human 249
 Rabbit 196
 Appendix orifice 249
 Apple 148-149
 Apple iMac 567
 Apple iPad 568-569
 Apple Macintosh PCs 566
 Approach 543
 Apse 465, 469, 481
 Aquarius 19, 20
 Aquatic mammals 104
 Aqueuduct 256
 Aqueous humor 241
 Aquiclude 292
 Aquifer 292
 Aquiferous system 166
 Aquila 19, 20
 Ara 20
Ara ararauna 190
 Arabesque
 Islamic building 488-489
 Neoclassical molding 480
 Arabia
 Cretaceous period 72
 Jurassic period 70
 Arabian Desert 265
 Arabic number system 591
 Arachnids 170-171
 Arachnoid granulation 257
 Arachnoid mater 237, 240
 Aral Sea 265
 Araneae 170
Araucaria araucana 68
 Arcade
 Ancient Roman building 464-465
 Baroque church 479-481
 Gothic building 470-471
 Medieval church 468-469
 Twentieth-century building 495
 Arcadia Planitia 43
 Arch 484-485
 Ancient Roman building 462, 464-465
 Asian building 490-491
 Baroque church 479, 480
 Calligraphy characters 445
 Cathedral dome 487
 Features of a coastline 295
 French temple 484-485
 Gothic church 470-475
 High jump 543
 Islamic building 488-489
 Medieval building 466-469
 Nineteenth-century building 492-493
 Renaissance building 474-475
Archaeopteryx 57, 84, 85
 Arched brace 473

- Arched doorway 474, 475
 Arched facade 495
 Archegoniophore 118
 Archeonium
 Fern 121
 Liverwort 118
 Moss 119
 Scots pine 122
 Archery 548-549
 Archery screen 377
 Archimedes 40
 Architrave
 Ancient Egyptian temple 458-459
 Ancient Greek temple 461
 Ancient Roman building 463, 465
 Baroque church 479-481
 French temple 485
 Gothic building 475
 Neoclassical building 478, 482-485
 Renaissance building 476-477
 Archivolt
 Baroque church 479, 481
 French temple 485
 Gothic church 471
 Medieval building 467-468
 Renaissance building 477
 Arch of aorta 253
 Arch of Titus 465
 Arch-plate 495
 Archway 495
 Medieval church 469
 Molding 485
 Arctic Circle
 Satellite map 265
 Surface currents 297
 Arctic Ocean 265
 Arcturus 18, 21
 Hertzsprung-Russell diagram 25
 Area measurements 590
 Areas 622, 623
 Areola 160
 Areole 156
 Arête 286-287
 Argentina 351
 Argon
 Atmospheric composition 301
 Mars' atmosphere 43
 Mercury's atmosphere 155
 Periodic table 311
 Venus' atmosphere 37
 Argyre Planitia 43
 Ariel 48
 Aries 19, 20
 Aril
 Lychee fruit 148
 Yew seed 123
 A ring 46-47
 Aristarchus 40
 Aristillus 40
 Aristoteles 40
 Arkab Prior 21
 Arkansas hone-stone 452
 Arm
 74-gun ship 580
 Calligraphy characters 445
 Gorilla 203
 Human 210
 Lion 194
 Roman anchor 372
 Starfish 174
 Volkswagen Beetle 341
 Armature
 Power drill motor 600
 Sculpture 452, 454-455
 Armature spindle 600
 Arm bud 260
 Armed sports 556-557
 Armor
 Battleship 394
 Gun turret 396
 Ironclad 593
 Armored dinosaurs 92
 Armored seat back 409
 Arm out-in joint 608
 Armpit 211, 254
 Armpit bight 388
 Armrest 329, 407
 Arm rotation joint 608
 Arms of Brazil 394
 Armstand dive 558-559
 Arm up-down joint 608
 Arrector pili muscle 255
 Arriccio 454
 Arrow head 109
 Arse 582
 Arsenic 311
 Arsia Mons 45
Arsinoitherium 57, 75, 104-105
 Art deco style 495
 Twentieth-century building 494, 495
 Artemon 372
 Arterial system
 Brain 252
 Kidney 256
 Arteriole 252
 Artery
 Abdominal 173
 Alveolar 247
 Anterior tibial 253
 Axillary 255
 Basilar 252
 Brachial 253
 Central retinal 240
 Common carotid 215, 251, 255
 Common iliac 215, 253, 257
 Coronary 250-251, 253
 Digital 251, 255
 Dorsal metatarsal 253
 Epibranchial 179
 External iliac 215, 225, 253
 Femoral 225, 255
 Gastric 255
 Hepatic 248, 252-255
 Interlobular 256
 Internal carotid 243, 252
 Internal iliac 215, 253
 Lateral plantar 253
 Orbital 179
 Peroneal 253
 Popliteal 253
 Posterior cerebral 252
 Posterior tibial 255
 Pulmonary 182, 251, 253, 254-255
 Pulp 247
 Radial 251, 253
 Renal 256-257
 Splenic 253
 Sternal 173
 Subclavian 215, 251, 253
 Superior mesenteric 253, 256
 Superior thyroid 244
 Testicular 257
 Ulnar 251, 253
 Umbilical 260
 Vertebral 223, 252
 Artesian water 292
 Arthropoda 168, 170, 172, 278
 Articular capsule 232
 Articular cavity
 Hip joint 225
 Metatarsophalangeal joint 232
 Artificial elements 310
 Artificial fly 562-563
 Artificial light 519
 Artificial lure 563
 Artillery loop 589
 Artillery wheel 354
 Artiodactyla 104, 198-199
 Artist's easel 437
 Artist's signature 437, 445
 Artist's stamp 445
 Art nouveau style 495
Arundinaria nitida 151
 ARV Super 2 light aircraft 424-425
 Arzachel 40
 Ascender 445
 Ascending aorta 251
 Ascending colon 249
 Asclerius Mons 43
 Asexual reproduction 154
 Ash
 Mountain building 62
 Rock cycle 266
 Volcano 272-273
 Ash chute 395
 Ash-cinder volcano 272
 Ash eruptions 272
 Ash head 540
 Ashlar 464, 486
 ASIMO humanoid 608-609
 Asia
 Cretaceous period 72-75
 Earth's physical features 264-265
 Himalaya formation 62-63
 Hominids 108
 Jurassic period 70
 Middle Ordovician period 64
 Quaternary period 76-77
 Tertiary period 74-75
 Triassic period 68
 Asian buildings 490-491
 Asian elephant 200-201
Asparagus setaceus 64
 Ass 198
 Association football 524-525
 Astatine 311
Asterias rubens 175
Asterina gibbosa 175
 Asteroids 52-53
 Solar system 30
Asteroxylon 78-79
 Asthenosphere 58-59
 Astragal
 Church of the Sorbonne 486
 Ship's shield 395
 Astragalus 185
 Astrolabe 376, 377
 Astronavigation dome 408
 Asymmetric ridge 285
 Atacama Desert 264
 Atalanta Planitia 36
 Athletics 542-543
 Atlantic Ocean 264-265
 Quaternary period 77
 Tertiary period 75
 Atlas
 Baroque building 482
 Horse 199
 Human 222
 Moon 40
 Atlas mountains
 Earth's external features 39
 Quaternary period 77
 Satellite map 265
 Atmosphere
 Earth 38-39, 64, 300-301
 Jupiter 45
 Mars 43
 Mercury 34-35
 Neptune 51
 Pluto 51
 Saturn 47
 Uranus 49
 Venus 37
 Water cycle 288
 Atoll 298-299
 Atoll development 299
 Atomic mass 309, 310
 Atomic number 310
 Atomic weight 310
 Atoms 306, 308-309, 596
 Chemical properties 310
 Chemical reactions 312
 Periodic table 310
 Atrial diastole 250
 Atrial systole 251
 Atrium
 Hong Kong and Shanghai Bank 498
 Human 215, 250-251
 Sponge 166
 Attached column
 Ancient Roman building 465
 Baroque church 480
 Gothic building 473
 Medieval building 468-469
 Neoclassical building 479
 Attachment-bracket 424
 Attachment clip 575
 Attachment lug 404
 Attachment plate 424
 Attack line 534
 Attack radar 420
 Attic
 Baroque church 480-481
 Cathedral dome 487
 Neoclassical building 478, 485
 Attic vase 372
 Attitude control thruster 614
 Attraction 316-317
 "A" turret 394
 Auda 491
 Audio clock settings 521
 Audio codec chip 587
 Audio software sequencer 521
 Auditorium 479
 Auditory canal 242
 Auditory meatus
 Chimpanzee 202
 Seal 204
 Auger 374
 Augusta National Golf course 546
 Aureole 471
 Auricle 242
 Auricular surface 225
 Auriga 18, 21
 Aurora 38, 301
 Australasia 264-265
 Australia
 Cretaceous period 72-75
 Jurassic period 70
 Late Carboniferous period 66
 Middle Ordovician period 64
 Quaternary period 76-77
 Railroad track gauge 351
 Satellite map 265
 Tertiary period 74-75
 Triassic period 68
 Australian Desert 265
 Australian rules football 524, 528-529
Australopithecus 77, 108
 Lower jaw 107
 Tertiary period 74
 Autofeather unit 419
 Autogiro 422
 Automatic cylinder lubricator 342
 Automatic direction-finding aerial 425
 Automatic door 328-329
 Automatic louvers 602, 603
 Automatic pen 444
 Automatic Train
 Protection (ATP) 330
 Automobile freight car 327
 Autopilot 412
 Autumn wood xylem 134
 Auxiliary air intake 420-421
 Auxiliary generator 327
 Auxiliary power unit 417
 Auxiliary Power Unit (APU) exhaust 572
 Auxiliary power unit inlet 415
 Aves 188
Avimimus 87
 Avogadro 41
 Avro triplane IV 402-403
 Avro Tutor biplane 402-403
 Away swing bowler 338
 Awning 499
 Ax 109, 374
 Axial gland 175
 Axial instrument unit 612
 Axial tilt
 Earth 38
 Jupiter 44
 Mars 42
 Mercury 34
 Moon 40
 Neptune 50
 Pluto 51
 Saturn 46
 Uranus 48
 Venus 36
 Axilla 211
 Axillary artery 235
 Axillary bud 134
 Dicotyledon stem 127
 Durmast oak 131
 Leaf scars 154
 Axillary vein 253
 Axinite 270
 Axis
 Azolla sp. 158
 Horse 199
 Human 222
 Seed 152-153
 Pine cone 122
 Axis of rotation
 Jupiter 44
 Mars 42
 Mercury 34
 Moon 40
 Neptune 50
 Pluto 51
 Pulsar 28
 Saturn 46
 Uranus 48
 Venus 36
 Axle
 Avro triplane 402-403
 Blackburn monoplane 400
 Bus 333
 Curtiss biplane 399
 Honda VF750 365
 Lockheed Electra airliner 407
 LVG CVI fighter 405
 Steam locomotive 324
 Axle bolt 425
 Axon 239
Aythya fuligula 188
 Azimuthal map projection 265
 Azo yellow 442
 Azurite 506

B

- B-17G Flying Fortress bomber 408
 Baboon 202
 Bach 35
 Back
 Block and tackle 383
 Elephant 200
 Horse 198
 Human 210
 Lion 195
 Backboard 532
 Back bone 222
 Back check 514
 Back contact grid 605
 Background radiation 10
 Back/Home button 586
 Back judge 526
 Back line 535
 Back pocket 528
 Backrest
 ARV light aircraft 425
 Lockheed Electra passenger seat 407
 Backs
 Handball 535
 Hockey 540
 Soccer 524
 Volleyball 534
 Backshell 615
 Back sight 549
 Backstay 378, 379, 580
 Backstay stool 381
 Back strap 560, 561
 Backstroke 558-559
 Backup battery 567
 Backward defensive stroke 538
 Backward dive 558
 Backwash 294
 Back zones 534
 Bacteria 56
 Bactrian camel 199
 Baculum 144
 Badger 194
 Badminton 544-545
 BAe-146 jetliner components 412-415
 Baffin Island 264
 Baffle 341
 Baffle plate 347
 Bage, C. 492
 Baggage compartment door 423
 Bagneux Church 468-469
 Bahada 282
 Bail 538
 Bail arm 562
 Bailey 466
 Bail handle 336
 Bailly 40
 Baird's beaked whale 205
 Bait fishing 562
Balaenoptera musculus 205
 Balance 232
 Balance and muscle coordination 257
 Balance weight
 Jaguar V12 engine 345
 Mid West rotary engine 411
 Balancing drilling
 Mid West rotary engine 411
 Wankel rotary engine 347
Balanophyllia regia 167
 Balata surface 546
 Balcony 493
 Islamic tomb 489
 Nineteenth-century building 493
 Renaissance theater 477
 Rococo style 478, 482
 Sailing ship 378, 379, 381
 Baleen whale 204

- Ball
 Australian rules football 528
 Baseball 557
 Basketball 553
 Cricket 538
 Football 526
 Gaelic football 528-529
 Golf 546
 Handball 555
 Hockey 540
 Hurling 541
 Lacrosse 541
 Netball 555
 Racketball 545
 Rugby 524, 530-531
 Soccer 524
 Squash 545
 Tennis 544
 Volleyball 554
 Ballast 524
 Ball bearings 558-559
 Ballflowers 470-471
 Ball marker 547
 Ball size number 525
 Baltica 65
 Baltimore oriole 193
 Baluster
 Asian building 490
 Gothic building 475
 Neoclassical building 485
 Balustrade
 Asian building 490
 Baroque church 479-480
 Cathedral dome 487
 Gothic church 472-475
 Neoclassical building 478, 485
 Nineteenth-century building 495
 Renaissance theater 477
 Twentieth-century building 495
 Balzac 55
 Bamboo 131
 Banana 146
 Banded ironstone 277
 Banded milk snake 184
 Bandy 540
 Bank of England 482
 Banner 375
 Bar
 Musical notation 502
 Relief-printing press 449
 Bar area 573
 Barb
 Angling 562
 Cnidocyte 167
 Barbary 150-151
 Barbette
 Battleship 394
 Gun turret 396
 Bar code 606
 Bare end
 Reef knot 588
 Single sheet bend 387
 Barium 310
 Bark
 Bishop pine stem 125
 Epiphyte 162
 Lichen 114
 Perennials 150-151
 Stem 154
 Woody plants 150-151
 Bar keel 392
 Barkhan dune 285
 Bar line 502
 Barnacle 172-173
 Barnard's Star 23
 Baroque style 478-485
Barosaurus 82
 Barred spiral galaxy
 Galaxies 12-15
 Milky Way 14-15
 Objects in universe 11
- Origin and expansion of universe 10-11
 Barrel
 Gun turret 597
 Wood capstan 587
 Barrel joint 508
 Barrel vault 484-485
 Ancient Roman building 465-464
 Baroque church 479
 Medieval church 468
 Nineteenth-century building 495
 Barrier beach 294
 Barrier reef 299
 Barry, C. 495
 Bars 516-517
 Bar swivel 562
Baryonyx 85, 84-85
 Baryte 270
 Basal disk 167
 Basal scale 114
 Basalt 274-275
 Basaltic lava 272
 Bascule 495
 Base
 Ancient Greek temple 461
 Ancient Roman building 465, 465
 Asian building 491
 Baroque church 479, 481
 Dome 484, 486, 487
 French temple 485
 Gothic church 470, 472
 Medieval church 469
 Neoclassical building 478, 485
 Renaissance theater 477
 Sheet lead 385
 Twentieth-century building 494
 Twin bollards 386
 Baseball 536-557
 Base line
 Calligraphy lettering 445
 Tennis 544
 Basement 485
 Basement membrane of Bowman's capsule 257
 Base of phalanx 250
 Base plate 552
 Bases 556
 Basic movements 257
 Basic shield volcano 272
 Basidium 115
 Basilar artery 252
 Basilar membrane 245
 Basilican system 468
 Basilica of St. Madeleine 468
 Basilic vein 255
 Basket
 Basketball 552
 Ski pole 552-555
 Basket arch 472, 484
 Basketball 552-553
 Basket star 174
 Basking shark 179
 Bas-relief carving 491
 Bass angling 562
 Bass bridge
 Concert grand piano 515
 Upright piano 514
 Bass clarinet 504
 Bass clef 502
 Bass drum 504-505, 518-519
 Bass formation 277
 Bass joint 508
 Bass notes 512
 Bassoon 505, 504-505, 508
 Bass/Play mode 586
 Bass voice 502
 Bastille 466
- Bat
 Baseball 557
 Cricket 559
 Bat (animal) 105
 Batholiths 274-275
 Batsman 558-559
 Batten
 74-gun ship 581
 Junk 376
 Wall construction 602
 Batter 536-537
 Battery
 Bell-47 helicopter 422
 Bersey electric cab 542
 Digital video camera 582
 Hubble Space Telescope 613
 Inverter 555
 Kirby BSA racing sidecar 369
 Battery assembly 555
 Battery box 527, 424
 Battery carrier 558
 Battery compartment 407
 Battery cover 579
 Battery cooling fan 555
 Battery electronic control module (ECM) 555
 Battery overspill 422
 Battery strap 539
 Batting gloves
 Baseball 557
 Cricket 559
 Battlemented cornice 471
 Battlements 466-467
 Battleship 594-595
 Bauxite 268
 Bay
 Building 468, 469, 494
 Coastline features 295
 River features 291
 Bay-head beach 294
 Bay-leaf garland 480
 Bayonet fixing 552
 Bay window 477
 BE 2B bomber 404-405
 Beach
 Coastline 294-295
 River development 289
 Beacon 407, 422-425
 Beaded edge tire 556
 Beadlet anemone 166
 Bead molding 459
 Beak
 Ankylosaurus 94
 Attic vase 372
 Bird 188-190
 Ceratopsian 100
 Chelonian 186
 Dolphin 204
 Euoplocephalus 94
 Hatching chick 192-195
 Iguanodon 97
 Moss 119
 Octopus 176
 Ornithopod 96
 Panoplosaurus 94
 Protoceratops 102
 Psittacosaurus 105
 Stegosaurus 92
 Beaked whale 204
 Beaker 312
 Beam
 BAe-146 jetliner 414
 Gothic church 473
 High-tension 496
 Iron paddlesteamer 595
 Modern building 497-499
 Nineteenth-century building 492
 Single skull 560
 Bean
 Black 153
 Broad 152
 Bear 104, 106, 194-195
 Bearing
 Electric generator 517
- Jaguar V12 engine 345
 Motorcycle gearbox 666
 Rotary engine output shaft 411
 Bearing assembly 425
 Bearing housing 344
 Bearing mount 411
 Bearing seal 559
 Bearing sleeve 558
 "Beast feet" 84
 Beaten gold 432
 Beaters 516, 518-519
 Beets 502
 Beaver 196-197
 Becket 585
 Becket Chapel 467
 Bed
 Relief printing press 449
 Sedimentary rocks 276
 Bedding plane
 Cave system 285
 Coastline 294-295
 Bedford cord upholstery 356
 Bedplate 590
 Bedrock 298
 Bedrock formation 291
 Bee 168, 379
 Bee hummingbird 195
 Bee pollination 144-145
 Beeswax 584
 Beethoven 35
 Beetle 168
 Begonia 129, 155
Begonia x tuberhybrida 129, 155
 Behavior 108, 257
 Belaying pin 582
 Belenmites 71, 278-279
 Belfry
 74-gun ship 380
 Church of St. George in the East 481
 Bell 508
 Bell 206 Jetranger 423
 Bell 47G-3B1 422-423
 Bellatrix 18
 Bell chamber 495
 Bell crank 391
 Bell housing 347
 Bell joint 508
 Bello 55
 Bell Regio
 Radar map of Venus 36
 Structure of Venus 37
 Belly
 Bird 188
 Caiman 186
 Dolphin 204
 Elephant 201
 Horse 198
 Lion 195
 Lizard 184
 Sail 584
 Viola 511
 Violin 510
 Belly-band 555
 Belly-fairing 572
 Belt
 Jupiter 44-45
 Structure of Saturn 47
 Belt armor 594
 Belt color 556
 Belt drive 366
 Belt pulley 345
 Belt tensioner 544, 364
 Belvedere 476
 Bench officials
 Ice hockey 550
 Lacrosse 541
 Bending 318
 Bends 387
 Benguela current 297
 Satellite map 264
 Benz, Karl 354
 Benz Motorwagen 555
 Benz six-cylinder engine 405
- Berardius bairdi* 205
Berberis sp. 150-151
 Berkelium 311
 Berries 148-149
 Bersey electric cab 342
 Berthing ropes 387
 Beryl 270
 Beryllium 310
 Beta Hydri 20
 Beta Mensae 20
 Beta Pictoris 21
 Beta ring 48
 Betelgeuse 18, 21
 Hertzprung-Russell diagram 25
 Orion 18
 Universe 10-11
Betula grossa 74
Betula lenta 76
Betulites 74
 Bevel gear 555
 Bevel pinion 558
 Beverley Minster 484
 Bezel 584
 Bhagirathi Parbat 62
 Bianco di San Giovanni 454-455
 Biathlon rifle 549
 Bib 557
 Bi-block engine 557
 Biceps brachii muscle 226
 Biceps femoris muscle 227
 Bicycle 360-361
 Bicycle anatomy 558-559
 Bicycle riding 515
 Biennials 128
 Biflagellate cell 116
 Bifurcate ligament 252
 "Big Ben" 495
 Bigbore rifle shooting 548-549
 Big end
 Flat-four cylinder arrangement 340
 Four-stroke cycle 343
 Jaguar straight six engine 344
 Mid West engine 410
 Trojan engine 542
 Big-end bearing 355
 Bight 588
 Big toe 252-253
 Bile duct 189, 249
 Bilge keel 595, 597
 Bilge keelson 395
 Bill
 Danforth anchor 586
 Running block 385
 Sail hook 584
 Bilobed leaves 125
 Bin base 592
 Bin cover handle 595
 Bin cover retaining clip 592, 595
 Binder 464
 Binder bolt 361
 Binding 585
 Acoustic guitar 512
 Iron paddlesteamer 592
 Binding medium 440
 Bin handle 592
 Bin handle clip 592
 Bin lower seal 592
 Binnacle box 378
 Binocular eyepieces 610, 611
 Bin upper seal 592
 Bin upper seal seating 592
 Biology symbols 591, 621
 Bipedal dinosaur 84, 96, 100
 Bipinnate leaf 157
 Biplane elevator 398-399
 Biplanes 402-403, 408
 Bipolar neuron 239
 Birch 74, 76
 Bird 84, 188-191
- Beak 190
 Earth's evolution 57
 Feathers 191
 Feet 190
 Fossil record 279
 Wing 191
 "Bird feet" 96
 Bird-hipped dinosaur 82, 92, 96
 Bird of prey 188
 Bird pollination 144
 Bishop pine 124-125
 Bismuth 281, 511
 Bit 601
 Biternate leaves 157
 Bit-guard 555
 Bitt
 74-gun ship 380-381
 Roman corbita 375
 Bitter end, Hawser 587
 Bituminous coal 280
 Bivalves 79, 176, 278-279
 Blackbacked gull 193
 Black bean 155
 Black belt 556
 Blackberry 150, 146-147
 Blackberry Curve 8520 589
 Blackburn monoplane 400-401
 Blackburn, Robert 400
 Black dwarf 24-25
 Blackheaded gull 189
 Black ink cartridge 574
 Black ink-cartridge clamp 574
 Black holes 28-29
 Galaxies 12
 Massive stars 26-27
 Black Mesa 277
 Black rhinoceros 199
 Black Sea 265
Blackstonia perfoliata 144
 Black walnut 157
 Black widow spider 171
 Bladder
 Bony fish 181
 Chimpanzee 202
 Dolphin 205
 Domestic cat 195
 Elephant 200
 Human 215, 257, 258-259, 261
 Lizard 185
 Rabbit 196
 Soccer ball 525
 Swim 178, 180-181
 Tortoise 187
 Urinary 181
 Bladder wrack 117
 Blade
 Butterwort 161
 Calligraphy drawing board 445
 Danforth anchor 386
 Dicotyledon leaf 127
 Fencing foil 557
 Golf clubs 547
 Hockey stick 540
 Kayak paddle 560
 Leaf surfaces 156, 158
 Monocotyledon leaf 127
 Propeller 390
 Roman rudder 373
 Sculling or 560
 Seaweed 116-117
 Vegetative reproduction 154
 Wendy fly trap 160
 Volkswagen Beetle 341
 Wetland plants 158-159
 Wind turbine 604
 Blade bearing 604
 Blade counterweight 406, 422
 Blade hub 604
 Blade pitch control 604
 Blade-root attachment 422-423

- Blade tip sealing shroud 419
- Blanking plate 411
- Blast bag 396
- Blastocyst 607
- Blast-pipe 325
- Blending 440
- Blériot XI monoplane 401
- Blériot, Louis
Early monoplane 400
Pioneers of flight 398
- Blindage 377
- Blind arch
Asian building 491
Cathedral dome 487
Gothic church 470
- Blind door 478
- Blind pull 336-337
- Blind release bar 552
- Blinds 605
- Blind-side prop 550
- Blind spot 241
- Blind tracery 495
- Blind trefoil 475
- Blind window 478
- Block and tackle 382-385
- Block carving 470
- Block cube 270
- Block disintegration 282
- Block-fault lake 295
- Block-fault mountain 62
- Blocking pad 550
- Blocks 310
- Blood cells 255
- Blood clotting 255
- Blower control 325
- Blower isolator valve 325
- Blow hole 508
- Blowhole 205
- Blubber 204
- Blue-and-yellow macaw 190
- Blue cell 584
- Blue-green alga 56, 78
- Blue light 518
- Blue line 550
- Blue supergiant star
Hertzsprung-Russell diagram 25
Stellar black hole 29
- Blue whale 204-205
- Bluff 289
- Blunt button 556-557
- Blu-ray player 584
- BMW R/60 motorcycle 362
- Board
Ice hockey rink 550
Modeling 445
Pastels 441
- Boarding 464
- Board mounting 450-451
- Boat boom 395
- Boatbuilder's tools 374
- Boat handling derrick 395
- Boat slide 378
- Boat winch 394
- Bobstay 379
- Body
Anchisaurus 89
Discus 542
Dunkeld wet fly 565
Motorcycle 364-365
Sauropodomorpha 88
Stringed instruments 510
- Body bag 426
- Body cells 216-217
- Body cradle 398
- Body drop 556
- Body joint
Flute 508
Piccolo 508
- Body landing gear 572
- Body mount 358
- Body organs 214-215
- Body padding 526
- Body sections
Insect 168
Scorpion 170
Spider 170-171
Body shell 518-519
- Bodyshell
Renault Clio 548-549
Volkswagen Beetle 341
- Body tackles 528
- Body temperature regulation
Dinosaurs 92
Mammals 104
- Body wire 557
- Bodywork 348-349
- Race cars 356
Volkswagen Beetle 341
- Bodywork mounting point 364
- Boeing 747-400 412
- Bogie axle 326
- Bogie frame 325
- Bogie main landing gear 416
- Bogie wheel strut 615
- Boiler
Box boiler 392
Donkey boiler 392
Steamboat with paddle wheels 391
Steam locomotives 324-325
Boiler pressure gauge 325
Boiler water level 325
- Bolt base 432-435
- Bollard
Battleship 395
Frigate 397
Mooring and anchoring 386-387
- Bolton 282
- Bolster 378
- Bolt
Church of St. Pierre 499
Lower deadeye 585
Shackle 386
Toaster 598
- Bolted anchor 425
- Bolt hole
Drum brake 365
Mid West rotary engine 411
Twin bollards 387
- Bolt rest 548
- Bolt rope 372, 584
- Bolts 548-549
- Bomb 404, 408
- Bomb aimer's viewing panel 408
- Bomb door 408
- Bomber
Modern military aircraft 420
World War I aircraft 404-405
World War II aircraft 408-409
- Bomb rack 404
- Bonaventure mast 377
- Bonaventure topcastle 377
- Bonaventure topmast 377
- Bonaventure top yard 377
- Bonaventure yard 377
- Bonded brick wall 492
- Bonding
Chemical reactions 312
Covalent 309
English bond 485
Gases 307
Ionic 308
Liquids 307
- Bone cell 217, 225
- Bone marrow smear 225
- Bones
Fossil 278
Human 224-225, 250, 252
- Bone structure 108
- Bone surface 807
- Bony crest
Baryonyx 83
Corythosaurus 98
Lambeosaurus 99
- Parasauroplophus* 99
- Bony dorsal shield 78
- Bony fish 180-181
- Bony frill 100
- Bony nodule
Pachycephalosaurus 100
Prenocephale 100
- Bony ridge 100
- Bony shelf 100, 101
- Bony spike 100
- Bony strut 85
- Bony studs 92
- Bony tendons 96
- Boom
Battleship 394-395
Curtiss Model-D pusher 399
Double topsail schooner 385
Guest boat boom 394
Hong Kong and Shanghai Bank 498
Longboat 580
Rigging 382
Sailing dinghy 561
- Boom guy block 382
- Boomkin 380
- Bootes 18, 21
- Bordino Steam Carriage 354-355
- Borealis Planitia 55
- Borneo 265
- Boron 311
- Boss
Church roof 468-469
Hurley 541
Viking karv 374
- Bothriolepididae* 65
- Botryoidal habit 270-271
- Bottom ballast 377
- Bottom bracket 358
- Bottom hose 351
- Bottom plate 390, 392-395
- Bottom race 359
- Bottomset strata 285
- Boudin 60-61
- Boulder beach 295
- Boulder clay 286
- Bounce pass 555
- Boundary
Cricket 558
Mantle crust 39
Outer core-mantle 59
- Boundary line
Australian rules football 528
Badminton 545
Cricket 558
Squash 545
- Bow
74-gun ship 381
Kayak 560
Sailing dinghy 561
Stringed instruments 510
Wooden sailing ship 378
- Bowball 561
- Bow drill 109
- Bower anchor
Battleship 395
Sailing warship 377
Wooden sailing ship 379
- Bow front 483
- Bowl 445
- Bowler 538
- Bowline 588, 589
- Bowling crease 538
- Bowman's capsule 256
- Bowman's space 257
- Bow ornament 375
- Bowpost 561
- Bows 548
- Bow section 392
- Bow-side oar 560
- Bowsprit
Iron paddlesteamer 595
- Longboat 580
- Rigging 582
- Sailing warship 376
- Tea clipper 392
- Wooden sailing ship 378-379
- Bowspit cap 382
- Bowtell molding 475
- Box 477
- Box boiler 392
- Box fold 61
- Box freight car 327
- Boxing 556
- Box-leaved milkwort 144
- Box-section tubular cradle frame 364
- Box sister keelson 393
- Boxwood staff 377
- Brace
Asian building 490
Barrel vault 485
Dome 486
Double topsail schooner 385
"Ellerman Lines" steam locomotive 324
Gothic building 475
Neoclassical building 479
Nineteenth-century building 493
Roman corbita 372
Sailing warship 377
Trombone 306
Wooden sailing ship 378
- Brace-and-bit 600-601
- Brace block 375
- Bracer 548
- Brachial artery 255
- Brachialis muscle 226
- Brachial plexus 258
- Brachial valve 278
- Brachiocephalic trunk 251
- Brachiocephalic vein 255
- Brachiopods 278-279
- Brachioradialis muscle 226
- Brachiosaurus* 88, 90-91
- Brachylophosaurus* 98
- Bracing 515
- Bracing cable 427
- Bracing strut 401-402, 425
- Bracing tube 364
- Bracing wire
Blériot XI monoplane 401
LVG CVI fighter 405
Wright Flyer 399
- Bracken 121
- Bracket
Baroque church 479
Cathedral dome 484
Gothic building 475
Islamic tomb 489
Medieval building 466
Neoclassical building 478
Renaissance building 475
- Bracket shell 58
- Bracteoles
Dehiscent fruit 151
Ice-plant 129
Live-forever 129
- Bracts 141-145
Bromeliad 115
Dicotyledon flower 127
Durmast oak 151
Florists' *chrysanthemum* 129
Guzmania lingulata 165
Ice-plant 129
Indehiscent fruit 150
Live-forever 129
Peruvian lily 129
Rose 151
Slender thistle 129
Wind-pollinated plant 144
- Bract scales 122
- Braided polyester 588
- Braided stream 286
- Braiding
Dragon prowhead 374
River features 290
- Brailing rope 372
- Brail line 372
- Brain
Bird 189
Bony fish 181
Butterfly 169
Chimpanzee 202
Crayfish 173
Dogfish 179
Dolphin 205
Domestic cat 195
Elephant 200
Hominid 108
Human 236-237
Lizard 185
Octopus 176
Rabbit 196
Spider 170
- Braincase 108
- Brain cavity 100
- Brainstem 236
- Brake 332, 350
- Brake actuating chain 327
- Brake arm 552
- Brake back plate 340, 350
- Brake block 360
- Brake bridge 361
- Brake cable 365
- Brake calliper
ARV light aircraft 424
Disc brake 365
Harley-Davidson FLHS Electra Glide 363
Honda VF750 364-365
Husqvarna Motocross TC610 368
Renault Clio 351
Suzuki RGV500 368-369
Wagon bogie 351
- Brake cylinder 327, 350-351
- Brake disc
ARV light aircraft 424
Renault Clio 351
Wagon bogie 351
- Brake drum 539-540, 542
- Brake duct 357
- Brake fluid 565
- Brake hose 351
- Brakeless wheel hub 369
- Brake lever
ARV light aircraft 425
Benz Motorwagen 355
Bicycle 359
Eddy Merckx racing bicycle 361
Harley-Davidson FLHS Electra Glide 363
Kirby BSA 369
Suzuki RGV500 369
White Steam Car 342
"Windcheetah" racing HPV bicycle 361
- Brake master cylinder
Harley-Davidson FLHS Electra Glide 363
Honda VF750 364
Suzuki RGV500 368
- Brake mount 424
- Brake pad
Disc brake 365
Eddy Merckx racing bicycle 361
Renault Clio 351
Wagon bogie 351
- Brake pedal
Harley-Davidson FLHS Electra Glide 363
Honda VF750 364
Oldsmobile bodywork 357
Renault Clio 350
Steam-powered Cugnot 354
- Suzuki RGV500 368
- Brake pipe
ARV light aircraft 424
BAe-146 components 414
Lockheed Electra airliner 406-407
- Brake pivot bolt 361
- Brake plate 365
- Brake quadrant 355
- Brake rigging
British Rail Class 20 diesel engine 327
"Ellerman Lines" steam locomotive 324-325
- Brake rod 337, 339
- Brake servo 351
- Brake shield 351
- Brake shoe 350
"Deltic" diesel-electric locomotive 327
Drum brake 365
"Ellerman Lines" steam locomotive 325
Renault Clio 350
- Brake slip 395
- Brake torque arm 364
- Brake vacuum pump 324
- Braking
Motorcycle 364
Train 350
- Braking control system 330
- Braking distance 331
- Bramante 35
- Bramble 130, 146-147
- Branched leaf venation 127
- Branches
Bishop pine 124
Clubmoss 120
Crab cactus 129
Dicotyledons 127
Horsetail 120
Perennials 130-131
Seaweed 117
Sporophore 114
Woody plants 130-131
- Branchial heart 176
- Branching bracteole 151
- Branchiostegal ray 181
- Branchlet 114
- Branch trace 125
- Brassavola nodosa* 162
- Brass valve 336-337
- Brass housing for ignition cable 343
- Brassica* sp. 132
- Brass instruments 504-505, 506-507
- Brazil 351
- Brazilian battleship 394-395
- Brazilian current 296
- Brazilian Highlands 264
- Break 598
- Breakfast room 483
- Breakwater
Battleship 395
Frigate 397
Single scull 561
- Breast
Bird 188
Horse 199
Human 211
Breast auger 374
Breast bone 218
Breast stroke 558-559
Breastwork 380
Breather paper 602
Breather pipe 422
Breccia 276-277
Breech 396
Breech block 396
Breeches 557
Breech wheel 396
Breve rest 502
Brick arch 324
Brick pier 495
Brick vault 492

- Brick wall 492
 Bridge
 Acoustic guitar 512-513
 Battleship 594-595
 Cello 511
 Double bass 511
 Electric guitar 513
 Frigate 597
 Golf course 546
 London Bridge 466-467
 Medieval castle 467
 Modern building 498
 Viola 511
 Violin 510
 Bridge pin 512
 Bridges 530
 Bridle 555
 Bright Angel shale 277
 B ring 46-47
 Britain 551
 Brittle stars 174-175
 Broad ax 574
 Broadcom Persona tablet 569
 Broad disk 79
 Broad lace trim 356-357
 Broadside 378
 Broken pediment 481
 Bromeliads 112-115
 Epiphytic 162-165
 Bromine 511
 Bronchi 254
 Bronchial nerve 254
 Bronchial tree 254
 Bronchial vein 254
 Bronchiole and alveoli 254
 Bronchus
 Frog 182
 Human 215, 255
 Bronze casting 452
 Bronze finishing tools 454
 Bronze mast truck 372
 Bronze statue 455
 Broomrape 163
 Browband 554-555
 Brow horn 102
 Brow horn core 103
 Brown alga 116
 Brown scales 121
 Brown seaweed 116-117
 Brow ridge
Australopithecus 108
 Gorilla 205
Homo sapiens 108
 Browser menu 577
 Brush 452, 444, 600
 Brushbar 592, 593
 Brushbar drive belt cover 595
 Brushbar motor control 595
 Brush holder 600
 Brushing boot 554
 Brush lettering equipment 444
 Brush rest 444
 Brush tool articulation 595
 Bryce Canyon 276
 Bryophyta 118
 Bryophytes 112, 118-119
 Bryozoans 279
Bryum sp. 112
 Buccal cavity
 Bird 189
 Chimpanzee 202
 Dolphin 205
 Domestic cat 195
 Elephant 200
Pachycephalosaurus 100
 Rabbit 196
 Tortoise 187
 Buccal mass 176
 Buccinator muscle 229
 Bucket seat 561
 Bucket tappet 344
 Bud
 Adventitious 154
Aechmea miniata 162
 Apical meristem 154
 Begonia 129
 Bishop pine 124
 Broomrape 163
 Clematis flower 151
 Dicotyledons 127
 Durmast oak 151
 Florists'
 chrysanthemum 129
 Mohs scale 150
 Larkspur 141
 Lily 140
 Lime 145
 London plane 154
 Moss 119
Oxalis sp. 121
 Pine needle 125
 Rhizome 155
 Root tuber 154-155
 Rose 131
 Rowan twig 151
 Stolon 154
 Water lily 159
 Buddhist style 490
 Budh Planitia 55
 Bud scale
 Bishop pine 124
 Dicotyledon stem 127
 London plane 154
 Pine shoot apex 125
 Buffer
 "Deltic" diesel-electric locomotive 527
 "Ellerman Lines" steam locomotive 524-525
 Italian State Railroads Class 402 528
 "Rocket" steam locomotive 524
 Buffering pad 328
 Bugle 506
 Bulb
 Renault Clio 552
 Vegetative reproduction 154-155
 Bulb horn
 1906 Renault 557
 Ford Model T 558
 Bulbil 154-155
 Bulbourethral gland 259
 Bulkhead
 ARV Super 2 425
 Flat freight car 527
 Bulkhead stiffener 593
 Bulkhead trim 407
 Bulldog clip 450
 Bullet 597, 549
 Bullet block 375
 Bullet-shaped guard 278
 Bull-head rail 531
 Bullnose chisel 452
 Bull's-eye 549
 Bulwark
 74-gun ship 580
 Ironclad 595
 Bumblebee 168
 Bumper
 Bus 552-553
 Honda Insight 554
 Renault Clio 548-549
 Volkswagen Beetle 341
 Bung 313, 560
 Bunkers 546-547
 Bunk space 597
 Bun lamp burner 539
 Buntline 572
 Buon fresco 454-455
 Buoy 379
 Buoyant wetland plants 158
 Burmese pagoda 490
 Burning reaction 312, 313, 315
 Burnisher 452, 446
 Bursting charge 597
 Buses 552-555
 Business class cabin 572
 Bush 605
 Bushes 150-151
 Bushing 514
 Butt
 Bassoon 508
 Lacrosserosse 541
 Tennis racket 544
 Butt cap 563
 Butte
 Igneous rock structures 274
 Weathering and erosion 285
 Buttercup 127, 152-153
 Butterfly 168
 Butterfly knot 589
 Butterfly plate 582
 Butterfly swimming stroke 558-559
 Butterwort 160-161
 Butt extension 563
 Buttock
 Horse 198
 Human 210
 Button head rivet 592
 Button-quilted upholstery 536
 Buttruss 484
 Baroque church 478-481
 Dome 486
 Gothic church 470-475
 Medieval building 466, 468-469
 Nineteenth-century building 493
 Butt section 562
C
 3C275 (quasar) 11
Caardius tenuiflorus 129
 Cab 324, 327
 Cabane strut 404
 Cabbage 152
 Cab-end bogie 527
 Cabin
 74-gun ship 580-581
 Iron paddlesteamer 592-595
 Wooden sailing ship 579
 Cabin air-discharge aperture 414
 Cabin air duct 417
 Cabin air-pressure discharge valve 415
 Cabinet rasp 452
 Cabin trim 406-407
 Cable 600-601
 Cable entry point 598
 Cable guide 358-359, 560
 Cable holder 595
 Cable retaining gland 598
 Cables and ducting 602
 Cable stop 565
 Cacti
 Desert survivors 112
 Dryland adaptation 156
 Herbaceous flowering plants 129
 Cadmium 511
 Cadmium red 456
 Cadmium yellow 458
 Caecum
 Bird 189
Brachiosaurus 90
 Chimpanzee 202
 Cow 198
 Digestive 176, 175
 Gut 170
 Human 249
 Octopus 176
 Pyloric 181-174
 Rabbit 196
 Rectal 174
 Caelum 18
 Caernarvon Castle 466
 Caiman 186-187
 Calamus 191
 Calcanean tendon 252-255
 Calcaneum 185, 199
 Calcareous ooze 299
 Calcareous plates 172
 Calcareous tufa 284
 Calcite (calcium carbonate)
 Blue chalk 450
 Carbonates 269
 Cave 284-285
 Fossils 278
 Mohs scale 271
 Sedimentary rocks 277
 Testing candle wax 513
 Calcite curtain 285
 Calcite ossicle 174
 Calcite ridge 284-285
 Calcium 310
 Earth's composition 59
 Earth's crust 58
 Seawater salt content 296
 Calcium line 25
 Caldera
 Igneous rock structures 275
 Lake formation 293
 Volcano 272
 Caledonian mountains
 Late Carboniferous period 67
 Triassic period 69
 Calendars 618
 Calf 210
 Californian purple sea urchin 175
 Californium 311
Calliactis parasitica 166
 Calligraphy 444-445
 Calliper assembly 365
 Callipers 452
 Callisto 44
 Caloris Basin 54-55
 Caloris Montes 55
Calypse helenae 195
 Calyptra 119
 Calyx 140
Allium sp. 145
 Centaury 144
 Human 256
 Simple succulent berry 149
 Cam 544
Camarasaurus 91
 Cambium 126
 Cambrian period
 Fossil record 279
 Geological timescale 56
 Camcorder 582
 Cam cover
 Jaguar straight six engine 544
 Jaguar V12 engine 345
 72° VTO engine 356
 Camera module 581
 Camellia 157
 Camels 198-199
 Camera 608, 611
 Digital 580-581
 Digital video 582-585
 Camera pouch 426
 Cam follower
 Ford diesel engine 547
 Jaguar straight six engine 544
 Jaguar V12 engine 345
 Velocette OHV engine 367
 Cam lobe 544
 Camouflage 409
 Camouflage coloration 192
 Campaniform capital 458
 Campanile 477
Camptosaurus 70, 97
 Camshaft 345-345
 Camshaft gear 367
 Camshaft sprocket 345
 Camshaft timing gear 344
 Canada 531
 Canadian football 524, 526-527
 Canadian pond weed 158-159
 Canal
 Sea urchin 175
 Starfish 174
 Canals 42
 Canaries current 296
 Cancel button 575
 Cancellous bone 224
 Cancer 18, 21
 Candelabrum 476
 Candle lamp 355
 Candle wax 312-315
 Canes Venatici 18, 21
 Canine tooth
 Bear 106, 194
 Chimpanzee 202
 Human 246
Hyaenodon 107
 Lion 194
 Opossum 106
Smilodon 107
Toxodon 106
Canis familiaris 195
 Canis Major 18, 21
 Canis Minor 18, 21
 Canister 594
 Cannon 576, 594
 Cannon bone 198-199
 Cannonade bicycle 361
 Cannoeing 560-561
 Canopus 15
 Canopy
 1906 Renault 356-357
 ARV light aircraft 424-425
 Bell-47 helicopter 422
 Daimler engine 345
 Ford Model T 559
 Hawker Tempest components 409
 Oldsmobile engine 356
 Schleicher glider 426
 Schweizer helicopter 425
 Canopy latch 425
 Canopy rail 409
 Canson paper 441
 Cant frame 581
 Cantilever beam 494
 Cantilever brake 558, 561
 Cantilever brake boss 559
 Cantilevered shade 495
 Cantle
 Racing saddle 555
 Showjumping saddle 554
 Canvas
 Acrylic paint 442
 Oil paint 456
 Preparation 457
 Canvas shroud 562
 Canvas support 457
 Canyon
 Sedimentary rocks 276-277
 Weathering and erosion 282-285
 Cap
 Alga 116
 Fungus 114-115
 Radicle tip 153
 Wood capstan 587
 Wooden sailing ship 378-379
 Capacity measurements 590
 Cape gooseberry 149
 Capella 18, 21
 Cape Royal 277
 Capillary fringe 293
 Capillary network 254
 Capital
 Ancient Egyptian building 458-459
 Ancient Greek building 458, 460-461
 Ancient Roman building 458, 465, 465
 Asian building 490, 491
 Baroque church 479, 481
 Cathedral dome 487
 Domed roof 486
 French temple 485
 Islamic mosque 488
 Medieval building 467-469
 Neoclassical building 478, 485
 Ptolemaic-Roman period 459
 Renaissance building 476-477
 Romanesque style 468
 Capitate bone 250
 Capitulum 129, 142
 Cap line 445
 Capricornus 19, 20
 Capstan 587
 74-gun ship 380
 Iron paddlesteamer 595
 Wooden sailing ship 379
 Capstan screw 514
 Capsule
 Dry fruit 150-151
 Moss 112, 119
 Captain's cabin 379, 581
 Captain's seat 416
 Captain's shelter 394
 Capybara 196-197
 Carapace 172-173, 187
 Carbon
 Atomic mass 310
 Bows 548
 Candle wax 512-515
 Coal formation 280
 Minerals 268
 Periodic table 511
 Small stars 24-25
 Structure of red supergiant 26
 Carbonates 269
 Carbon atom 158
 Carbon burn 605
 Carbon dioxide
 Earth's atmosphere 300
 Gas 512-515
 Mars' atmosphere 45
 Photosynthesis 158
 Respiratory system 255
 Scrubber compartment 397
 Structure of comet 55
 Venus' atmosphere 57
 Carbon graphite racket 544
 Carbonic acid 284
 Carboniferous period 56-57, 66-67
 Reptiles 80
 Carbon ink stick 444
 Carbonized wood 450
 Carbon monoxide
 Mars' atmosphere 45
 Venus' atmosphere 57
 Carbon powder 311
 Carbon-rich earth layers 66
 Car-building robots 609
 Carburetor
 ARV light aircraft 425
 Mid West twin-rotor engine 411
 Pegasus Quasar ultralight 427
 Two-stroke engine 366
 Carburetor cover 369
 Carburetor hot-air intake pipe 422
 Carburetor hot air lever 425
 Cardiac notch 248

- Cardiac region of stomach 179
 Cardiac stomach 174
 Cardiac vein 250
Carduus tenuiflorus 129
 Cargo-carrying boat
 Dhow 376
 Junk 376
 Liberty ship 392
 Roman corbita 372-373
 Tea clipper 392
 Cargo derrick 392
 Cargo hatch 376
 Cargo hold 372, 392
 Car, hybrid 354
 Caribbean plate 59
 Caribbean Sea 264
 Carina 21
 Carinal canal 120
 Carina plate 173
 Carling 580
 Carmel formation 276
 Carnallite 271
 Carnassial teeth 194
 Carnivores 104, 194-195
 Jurassic period 70
 Theropod 84
 Triassic period 68
 Carnivorous plants
 160-161
 Pitcher plant 115
 Carotid canal 220
 Carp 180
 Carpals
 Bird 189
 Bird's wing 191
 Domestic cat 195
 Elephant 201
 Frog 185
 Hare 197
 Horse 199
 Kangaroo 206
 Lizard 184
 Platypus 206
 Rhesus monkey 202
 Seal 204
 Carp angling 562
 Carpathian mountains 77, 265
 Carpels 140-141
 Dehiscent fruit 151
 Fertilization 146-147
 Fruit development 148-149
 Insect-pollinated plant 144
 Lemon fruit 148
 Ovary 140
 Stigma 140
 Style 140
 Carpel wall 148, 151
 Carphophore 151
 Carpus
 Crab 172
 Crayfish 173
 Human 218
 Carrara white marble 453
 Carriage 413, 570
 Carriage drivebelt 574
 Carriage shaft 571
 Carrick bend 587, 589
 Carrion crow 195
 Carrot 128, 152
 Carrying fork 334
 Carrying wheel 324
 Cartilage
 Auricle 242
 Bony fish 180
 Meatus 242
 Wrist 250
 Cartilaginous fish 178-179, 180
 Cartouche 458
 Cartridge starter 408
 Caruncle 215
 Carved sculpture 452, 453
 Carved stone 488
 Carvel-built hull 376, 391
 Carvel planking 376, 377
 Carving
 Asian building 490-491
 Gothic building 470
 Sculpture 452
 Carving mallet 452
 Caryopses 113, 150
 Casa de las Conchas 476
 Casa del Fascio 495
 Caspian Sea 265
 Cassette compartment lid 582
 Cassini Division 46, 47
 Cassini space probe 614
 Cassiopeia 19
 Cassowaries 188
 Cast alloy wheel 346
 Cast aluminum wheel spider 356
Castanea sativa 156, 150
 Castanets 504, 517
 Casting 452, 454
 Cast-iron 492-493
 Cast-iron chair 351
 Cast iron cylinder barrel 365
 Castle-deck gunport 376-377
 Castles, 374, 466-467
 Castor 18, 21
Castor canadensis 197
 Cat 104, 194-195
 Catalyst 355
 Catalytic converter 344, 350, 356
 Catamaran 560
 Cataphoresis coating 348
 Cataphyll 152
 Cat block 381
 Catcher's mask 356
 Catch glove 550
 Catena 372
 Canary 328, 330
 Caterpillar 168, 169, 611
 Eggs 192
 Catharina 40
 Cathedra
 74-gun ship 380
 Battleship 395
 Cathedral of St. Lazare 468
 Cations 308
 Catkin 144
 Catted anchor 381
 Cattle 104, 198
 Caucasus 265
 Caudal fin 178, 179, 180-181
 Caudal musculature 90, 95
 Caudal plate 92-93
 Caudal spike 92-93
 Caudal vertebrae
 Ankylosaurus 95
 Archaeopteryx 85
 Crocodile 186
 Diplodocus 90
 Domestic cat 195
 Elephant 201
 Eryops 81
 Euoplocephalus 95
 Gallimimus 86
 Hare 197
 Horse 199
 Iguanodon 96, 97
 Kangaroo 206
 Kentrosaurus 95
 Lizard 184-185
 Parasauroplophus 98
 Plateosaurus 89
 Platypus 206
 Rhesus monkey 202
 Seal 204
 Stegoceras 101
 Stegosaurus 95
 Struthiomimus 87
 Triceratops 102
 Tuojiangosaurus 93
 Tyrannosaurus 84-85
 Westlothiana 81
 Caudate nucleus 257
 Caudex 115
 Caudo-femoral muscle 97
 Cauliculus 460
Caulophryne jordani 180
 Cave bear skull 77
 Caves 284-285
 Coastline 294-295
 Glacier 286
 Cavetto molding
 Ancient Egyptian building 458-459
 Baroque church 479
 French temple 485
 Gothic building 472
 Renaissance building 477
 Cavies 196
 Cayley, Sir George 398
 CCD (Charge-Coupled Devices) 570
 C clef 502
 CD/DVD drive 567
 Cedar-tree laccolith 274
 Ceilings 463, 484
 Celestial equator
 Stars of northern skies 18-19
 Stars of southern skies 20-21
 Celestial poles 18
 Celestial sphere 18
 Cell
 Alga 116-117
 Body 217
 Building 469, 485
 Chusan palm leaf 150
 Clubmoss stem 120
 Collar 166
 Dicotyledon 126-127
 Epidermal 166
 Epiphytic orchid 162
 Fern rachis 121
 Horsetail stem 120
 Leaf 126, 139
 Marram grass 115
 Monocotyledon 126-127
 Moss 119
 Mushroom 115
 Photosynthesis 158-159
 Pine 124-125
 Pore 166
 Root 132-135
 Root tip 152
 Sinus 112
 Spirogyra sp. 117
 Stem 134-135
 Wetland plants 158-159
 Cella 461, 463, 485
 Cell body 259
 Cell membrane 217
 Cell nuclear membrane 216
 Cell nucleus 217
 Cell nucleus residue 254
 Cello 503-505, 510
 Cellphones 588-589
 Cells 607
 Cellulose fiber insulation 602
 Cell wall
 Alga 112, 116
 Leaf 139
 Palisade mesophyll 139
 Root 132
 Spirogyra sp. 117
 Stem surface 156
 Celsius temperature scale 590
 Cement-based adhesive 450
 Cement gland 175
 Cement-rendered wall 494
 Cenozoic era 57, 74, 76
 Fossil record 279
 Censer 488
Centaurium erythraea 144
 Centaurus 18, 21
 Centaurus A (radio galaxy) 13
 Centaurus and Crux 21
 Central Asia 64
 Central bulge 12, 14
 Central canal 258
 Central computer control 328
 Central deflector 612
 Central electrode 306
 Central nervous system 258
 Central peak
 Degas and Brönte 54
 Venus' craters 36
 Central retinal artery 240
 Central retinal vein 240
 Central shield 187
 Central sulcus 236-237
 Center
 Australian football 528
 Basketball 522
 Canadian football 526
 Football 526
 Lacrosse 541
 Netball 535
 Rugby 530
 Centerboard 561
 Center buckeye coupler 326
 Center circle
 Australian rules football 528
 Basketball 532
 Ice hockey 550
 Netball 535
 Soccer 524
 Center console 355
 Center court 545
 Centered rudder 375
 Center element 599
 Center field 536
 Center flag 529
 Center forward 540
 Center gangway 329
 Center Georges Pompidou 496-497
 Center girder 393
 Center half 540
 Center halfback 528, 529
 Center half-forward 528, 529
 Center line 413, 415
 Fencing piste 557
 Ice hockey 550
 Soccer 524
 Center-line beam 426-427
 Center line keelson 393
 Centrifugal brake 562
 Centrifugal compressor 418
 Centrifugal effect 297
 Centriole 217
 Centripetal river drainage 288
 Centrum 187
Cephalopsis 65
 Cephalic groove 173
 Cephalic vein
 Human 255
 Octopus 176
 Cephalopods 176, 279
 Cephalothorax
 Crayfish 173
 Malacostraca 172
 Scorpion 170
 Shrimp 172
 Spider 170-171
 Cepheus 19
 Ceramic end-piece 319
 Ceratopsia 85, 103
 Ceratosauria 85
 Ceramium Tholus 43
Cercidiphyllum sp. 72
 Cerebellum 212, 236-237, 238
 Cerebral areas 237
 Cerebral ganglion 169, 177
 Cerebral vessel 257
 Cerebrum 212, 236-237, 238
 Cereoid cactus 129
 Cerium 510
Ceropegia woodii 157
 Ceruchi 372
 Cerussite 269
 Cervical musculature
 Euoplocephalus 94
 Gallimimus 86
 Cervical nerves 258
 Cervical plate 92-93
 Cervical rib 84, 96, 100-101, 105
 Cervical vertebrae
 Archaeopteryx 85
 Arsinoitherium 104
 Bird 189
 Brachiosaurus 91
 Crocodile 186
 Domestic cat 195
 Elephant 201
 Eryops 80
 Hare 197
 Horse 199
 Human 212, 222, 245
 Iguanodon 96
 Kangaroo 206
 Kentrosaurus 95
 Lizard 184
 Parasauroplophus 99
 Plateosaurus 88
 Platypus 206
 Rhesus monkey 202
 Seal 204
 Stegoceras 101
 Stegosaurus 95
 Struthiomimus 87
 Toxodon 106
 Tuojiangosaurus 93
 Tyrannosaurus 84
 Cervix 258-259
Cervus elephas 199
 Cesium 510
 Ceteaceans 204-205
Cetiosaurus 91
Cetorhinus maximus 179
 Cetus 19, 20
 Chaffinch 193
 Chain
 Bicycle 358-359, 360-361
 Drum kit 518
 Wheel and axle 320
 Wooden sailing ship 378
 Chain bobstay 382
 Chain drive
 Motorcycle clutch 362
 Werner motorcycle 366
 Wright Flyer 398-399
 Chain locker 393
 Chain motif 491
 Chain plate 382
 Chain swivel 386
 Chain wale 376-377
 Chajya 489
 Chalcedony 271
 Chalk 430
 Tempera 452
 Gesso 434
 Pastel making 440
 Fresco 434
 Sedimentary rocks 277
 Chamber
 Building 465, 491
 Gun turret 396
 Chambers
 Seaweed 116
 Stomach 138
 Substomatal 199
 Chamfered corner 485, 488, 494
 Championship golf courses 546
 Change 321
 Chang Jiang 265
 Channel
 74-gun ship 381
 Sailing warship 376-377
 Temple of Neptune 460
 Wooden sailing ship 378
 Channelled wreck 116
 Chapel
 Baroque church 479
 Gothic church 470
 Medieval church 469
 Chapel pier 467
 Chaplet 454
 Chapter-house 472
 Charcoal drawing 430-431
 Charentais molen 149
 Charge
 Four-stroke cycle 345
 Modern engines 344
 Charged atom 306, 308
 Charged particle 316
 Charging with ball 533
 Charon 50
 Chart house 394
 Chase 393
 Chassis
 Digital camera 580
 First cars 354-355
 Ford Model T 358
 Kirby BSA sidecar 369
 Microwave combination oven 596
 Monocoque 365
 Motorcycle 362, 364-365
 Microsoft Zune HD 587
 Oldsmobile chassis 357
 Panhard-system Volkswagen Beetle 340
 White Steam Car 342
 Chassis earth terminal 597
 Chassis electrical plug 357
 Chassis frame 358
 Chassis number 327
 Chataya arch 491
 Châteaux 474, 476-477
 Chat selector button 576
 Chattrra 491
 Chattravali 490-491
 Chauffeur's seat 334
 Checkerbloom 136
 Check pawl 562
 Cheek
 74-gun ship 381
 Dunkled wet fly 563
 Horse 199
 Human 212
 Running block 585
 Sailmaker's mallet 584
 Stegosaurus 92
 Cheek horn 103
 Cheek-piece
 Harness racer 555
 Showjumper 554
 Cheek pouch 98, 196
 Cheek teeth
 Ankylosaurus 92
 Carnivores 194
 Ornithopods 96
 Tetralophodon 104
 Theropods 84
 Cheese 382, 388-389
Cheiracanthus 65
Cheirolepis 65
 Chelkhov 35
 Chela 170, 172, 173
 Chelicera 79
 Chelicerae 170-171
 Chelicerates 279
 Cheliped
 Crab 172
 Crayfish 173
 Chelonia 186
 Chemical bond 507
 Chemical change 280-281
 Chemical energy 314-315
 Chemical equations 312

- Chemical properties
Electrons 308, 310
Substances 306
- Chemical reactions
312-313
- Chemical sedimentary
rocks 276
- Chemical symbols 312,
591
Periodic table 310-311
- Chemical weathering 282
- Chemise 466-467
- Chemistry symbols 621
- Cherry 148
- Cherry wood 512
- Chert 277
- Cherub 472
- Chervil 135
- Chest
Gorilla 205
Human 211, 214
Lion 194
Chestnut 198
Chest padding 551
Chest pass 532, 535
Chest protector 527
Chevet 469
Chevron 81, 85, 87, 89, 93,
95-96, 98, 101-102
Chevron fold 61
Chevron-tread tire 336
Chi1 Orionis 18
Chi2 Orionis 18
Chiaiolite hornfels 275
Chihuahuan Desert 264
Chile 331
Chimney
Bordino Steam Carriage
354
"Ellerman Lines" steam
locomotive 325
Iron paddlesteamer 395
"Rocket" steam
locomotive 324
Chimney-shaft 467
Chimney-stack 476, 485
Chimpanzee 202-203
Chin
Bird 188
Human 211, 212
China
Ball games 524
Late Carboniferous
period 66-67
Middle Ordovician
period 64-65
Ornithopod 96
Railroad track gauge 551
Thyreophorans 92
Chinese calendar 618
Chinese characters 445
Chinese junk 376
Chinese white 438
Chin groove 199
Chin guard 553
Chin gun turret 408
Chinle formation 276
Chin rest 510-511
Chin spoiler 546
Chipmunk 196
Chirosnotes 87
Chisel 452-453
Chlamydomonas sp. 116
Chlorenchyma 120
Chloride 296
Chlorine 311
Chlorophyll 138
Chloroplast 139
Photosynthesis pigment
116, 138, 162
Chlorophyta 116
Chloroplast 158-159
Alga 112
Chlamydomonas sp.
116
Envelope 139
Epiphytic orchid 162
Internal view 139
Spirogyra sp. 117
- Choanocyte 166
Choir 468-469, 470, 472
Choir manual 514
Choir-screen 470
Choir-stall 470
Choir stop 514
Chondrichthyes 178
Chondrosteian fish 69
Chong Ch'ol 35
Chordae tendineae 251
Choriollaontoic
membrane 192
Chorion 260
Choroid 240
Christian architecture 468
Christmas rose 139
Chromate ion 312
Chrome passivation 348
Chrome plating 347
Chrome trim strip 341
Chromium
Mineralization zones
281
Oxide 312
Periodic table 310
Chromosphere 32-33
Chrysalis 168
Chrysanthemum
morifolium 129
Chryse Planitia 43
Chrysler Building 495
Chrysocyon brachyurus
195
Chuck 601
Chuck key 601
Chung-ta-wei 376
Church
Santa Sophia 487
Sorbonne 486
St. Botolph 473
St. Eustache 477
St. George in the East
478, 481
St. Maclou 470, 472
St. Maria della Salute
478
St. Maria della Vittoria
478
St. Paul-St. Louis
478-479
St. Pierre de Libreville
496, 499
St. Serge 469
Church-roof boss 468
Chusan palm 127, 130
Ciconia ciconia 188
Cigarette lighter adapter
and speaker cable 590
Ciliary body 241
Cincture 477
Cinder cone
Igneous rock structures
274
Volcanic structure 273
Cinema, home 584-585
Cinnabar 271
Cinquefoil molding 471
Circle 479, 622
Circle area measurement
590
Circle pad 579
Circuit 516
Circuit board 579, 582,
585, 589
Circuit board plug 596
Circuit breaker 314
Circular mountain lake
295
Circulatory system
252-255
Circumference 622
Cirque 286-287
Cirque formation 287
Cirque Napoleon 478-479
Cirri 172
Cirrocumulus cloud 302
Cirrostratus cloud 302
Cirrus 173
- Cirrus cloud
Neptune 50
Structure of Mars 43
Weather 302-303
Cirrus limon 148
City bus 332
Civet 194
Cladding 494, 496,
498-499
Cladode 129
Cladonia floerkeana 114
Cladonia portentosia 114
Clam 176
Clamp
Cross-stave 377
Intaglio printing 313
U-tube 446
Clarinet 503-504, 508
Classical-style
architecture 474, 478,
482
Clastic sedimentary rocks
276
Claves 517
Clavicle
Bird 189
Bony fish 181
Eryops 80
Human 211, 218
Kangaroo 206
Rhesus monkey 202
Clavius 40
Clavus 373
Claw
Albertosaurus 84
Anchisaurus 89
Archaeopteryx 85
Beetle 168
Bird 188
Bumblebee 168
Caiman 187
Chick 195
Crab 172
Crayfish 173
Dinosaur 85
Herresaurus 86
Kangaroo 207
Lizard 184
Marble sculpture 452
Pachycephalosaurus
100
Psittacosaurus 105
Scorpion 170
Spider 171
Stegoceras 101
Terrapin 187
Tyrannosaurus 84
Clawed feet 190, 206
Clay 298
Clay daub 465
Clay modeling 452, 455
Clay mounds 286
Clear space 534
Cleavage 270
Clef 502
Cleithrolepis granulatus
69
Cleithrum 80
Clematis 150-151, 157
Clench nail 375
Cleomedes 40
Cleopatra Patera 57
Clerestory 459, 472, 479
Clew 375
Clewline 379, 385
Cliffs
Coastlines 294-295
River's stages 289
Sedimentary rocks
276-277
Climate
Carboniferous period
66
Geological time 56
Oceans and seas 296
Weather 302
Climatic change
Coastline 294
Geological time 56
- Clincher wheel 339
Clinker-built hull 375
Clinker-built oak planking
375
Clints 284-285
Clitoris 243
Cloaca
Bird 189
Brachiosaurus 90
Dogfish 179
Eupocephalus 95
Frog 182
87
Lizard 185
Spider 170
Tortoise 187
Cloacal opening 185
Clock operator 532
Clock tower 493
Cloister 472
Cloning technology
606-607
Close-stowing anchor 386
Cloud deck 50-51
Cloud features
Neptune 50
Saturn 46
Venus 36
Clouds
Earth's atmosphere 301
Jupiter 44-45
Mars 42-43
Neptune 50-51
Saturn 46-47
Uranus 48-49
Venus 36-37
Water cycle 288
Weather 302-303
Cloud shadow 50
Clouds of dust and gas
Life of massive star 24
Milky Way 14-15
Nebulae and star
clusters 16-17
Origin and expansion of
universe 11
Small stars 24
Cloudtop temperature
Structure of Jupiter 45
Structure of Neptune 51
Structure of Saturn 47
Structure of Uranus 49
Clove hitch 588
Cloven hoof 198
Clubmosses 64, 66,
120-121
Clump cathead 395
Clustered column 469
Clutch 564, 566
Clutch and flywheel 540
Clutch cable 350, 363, 365
Clutch center plate 351
Clutch cover 363
Clutch lever 363, 369
Clutch pedal 350
Clutch pressure plate 351
Clutch release bearing
351
Clypeaster 279
Cnidocytes 166-167
CNS 238
Coal
Earth's evolution 57
Mineral resources
280-281
Power stations 314
Sedimentary rocks 276
Steam locomotive 324
Coal-forming forests 57
Coal measures 61
Coaming 381
Coastal spring 292
Coaster 374-375
Coastlines 294-295
Cave 284
Cobalt
Mineralization zones
281
Periodic table 311
- Cobra lily 160-161
Coccoseus 65
Coccygeal cornu 225
Coccygeal vertebrae 222
Coccyx 218, 222
Cochlea 242-243
Cocking lever 549
Cockpit
Airbus 380 573
Avro biplane 405
Kayak 560
LVG CVI fighter 405
Modern military
aircraft 420-421
Sailing dinghy 561
Schleicher glider 426
Cockpit canopy 409
Cockpit coaming 425
Cocoa 148
Cocoonin sandstone 276
Cocos nucifera 135
Cocos plate 59
Cod 180
Codiaeum variegatum 136
Coelenterata 166
Coeliac trunk 236-237
Coelodonta 76-77, 104
Coelophysidae 69
Coelurus 87
Coenobium 116
Coffer 465, 485
Coffered vault 485
Coffering 475
Cogged drive belt 344
Coil spring
"Ellerman Lines" steam
locomotive 324
Motorcycle 364
Coil suspension spring
"Deltic" diesel-electric
locomotive 327
"Eurostar" multi-
voltage electric train
329
Wagon bogie 331
Coke hopper 334
Cold air intake 420
Cold-air unit 417
Cold front 302-303
Cold occlusion 302
Cold-water pipe 405
Cold-water upwelling 296
Coleoptera 168
Coleus sp. 134
Collagen and elastic fibers
252
Collapsed crater 293
Collar
Cathedral of Notre
Dame de Paris 473
Sea anemone 167
Snail 177
Collar-beam 473
Collar bone 211, 218
Collar cell 166
Collar of horsetail 120
Collecting duct 236
Collecting tubule 236
Collective lever 422
Collenchyma 126, 134-135
Colliding plates 272
Colloids 306
Colon
Butterfly 169
Cow 198
Human 215, 249, 259
Rabbit 196
Colonette
Gothic church 473
Islamic building 488
Medieval building
467-469
Neoclassical building
479
Renaissance building
474
Colonnade
Ancient Greek building
460-461
- Ancient Roman
building 462-463
Cathedral dome 484,
487
Neoclassical building
483
Colonnaded story 494
Color 270
Color changes 312-313
Color ink cartridge 574
Color ink-cartridge
clamp 574
Color light signals 330
Color wheel 439
Colorado River
Earth's evolution 57
Grand Canyon 277
Valley 277
Colosseum 462, 464-465
Colpus 144
Columba 18, 21
Columella 119, 145
Column
Ancient Egyptian
building 458-459
Ancient Greek building
458, 460
Ancient Roman
building 458, 462-463,
465
Baroque church
480-481
Cathedral dome 487
Cave system 285
French temple 485
Gothic church 475
Islamic mosque 488
Medieval church
468-469
Modern building
496-498
Concyclicodonous
flower 126
Neoclassical building
478-479, 485
Nineteenth-century
building 492-493
Renaissance building
477
Coma 52-53
Coma Berenices 18, 21
Combat sports 556-557
Combination lever 325
Combustion 326
Combustion chamber
Capacity 366-367
Iron paddlesteamer
393
Jaguar straight six
engine 344
Jet engines 418-419
Combustion cycle 410
Comets 30, 52-53
Common bile duct 252
Common blackheaded
gull 189
Common brittle star 175
Common carotid artery
215, 251, 255
Common centaury 144
Common crus 243
Common digital extensor
muscle 84, 97
Common elder 143
Common English ivy 131
Common horse chestnut 130
Common horsetail 120
Common Iguana 82
Common iliac artery 215,
253, 257
Common iliac vein 215,
253, 257
Common ivy 137
Common lime 143
Common link 386
Common mulberry 130
Common peroneal nerve
238
Common rafter 473, 486

- Common starfish 175
Common tern 195
Common time 502
Communication 108
Communications aerial 424
Commutator 600
Commuters 365
Compact bone 224-225
Compact disc 584, 586
Companion cells 132-134
Companion ladder 381
Companion way 380
Company logo 572
Compass
 Battleship 394
 Vault decoration 485
Compass and rangefinder platform 394
Competent bed rock 61
Competition motorcycles 368-369
Competitions
 Archery 548
 Diving 558
 Judo 556
 Rowing 560
 Skiing 552-555
Complete mesentery 167
Composite capital 478
Composite column 478
Composite pilaster 478
Composite volcano 272
Composter 602
Compound eye
 Beetle 168
 Bumblebee 168
 Butterfly 169
 Crab 172
 Crayfish 175
 Damsel fly 168
 Malacostraca 172
 Shrimp 172
Compound inflorescence 151, 142
Compound leaf 150-151, 156
Compound pier 468-469
Compound pulleys 320
Compounds 268, 506, 508
Compound succulent fruit 148-149
Compound umbel 145
Compressible gas 365
Compression
 Faults and folds 60
 Glacier 286
 Igneous and metamorphic rocks 274
 Mineral resources 280
 Mountain building 62
 Rock cycle 266
Compression ring
 Ford diesel engine 347
 Jaguar straight six engine 344
Compression stroke 345
Compressor 418
Compressor piston 344
Compsognathus 70
Computer
 and Email program 677
 Electronic instruments 520
 Laptop 567
 Modern bodywork 548
 Tablet 568-569
Computerized ignition system 344
Concave brace 477
Concave molding 482
Concave wall 478, 481
Concealed lighting 572
Conceptacles 116-117
Concert grand piano 515
Concha
 Ear 242
 Nasal 221, 241
Conchoidal fracture
- Extrusive igneous rocks 275
 Fracture 270
 Sedimentary rocks 277
Concorde 416-417
Concrete 492, 494, 496-499
Concrete shielding 314
Concrete shoe 499
Concrete track 328
Concrete wall 463, 465, 496
Condensation 307
 Nuclear power station 514
 Testing candle wax 315
Condensation level 302
Condenser 342
Condenser aperture 610
Condenser housing 611
Condenser lens 611
Conducting tissue 119
Conductor
 Electrical circuit 316
 Generating magnetism 514
 Orchestra 504
Conductor's stand 505
Condylactis sp. 166
Condyle
 Carnivore 194
 Human 220
Cone 625
Cones
 Bishop pine 124
 Gymnosperms 122
 Igneous and metamorphic rocks 274
 Pine 122
 Scots pine 122
 Smooth cypress 125
 Volcanoes 272-275
 Welwitschia 125
 Yew 125
Cone sheet 274
Cone stalk 124
Cone surface area measurement 590
Cone volume measurement 590
Congas 519
Congo Basin 39
Congo River 265
Conical bore 507
Conical dome 476
Conical map projection 265
Conical spire 466, 476
Conical volcano 272
Conifer
 Cretaceous period 72
 Earth's evolution 57
 Fossil record 279
 Gymnosperm 122-125
 Jurassic period 70
 Triassic period 68
Coniferophyta 122
Conjugation 117
Conjunctiva 241
Connecting rod
 Bordino Steam Carriage 354
 Flat-four cylinder arrangement 540
 Four-stroke cycle 345
 Iron paddlesteamer 592
 Jaguar straight six engine 344
 Jaguar V12 engine 345
 Mid West two-stroke engine 410
 Steamboat with paddle wheels 391
Connecting wire 598
Connective tissue cells
Connectors 569
Conning tower 394, 397
Conocephalum conicum 118
Con-rod 340, 343-345
- Conservation of Energy Law 314
Conservatory 602, 605
Console 579
Constellations 18-21, 615
Constratum 575
Constrictor snakes 184
Construction sculpture 452
Contact 552
Contact grid 605
Contact metamorphism 274
Contant d'l'vry 478
Contest area 556
Contests
 Head-butting 100
 Shooting 548
Continental crust 58-59
Mineralization zones 281
Mountain building 62-65
Ocean floor 298
Continental drift 58
Continental margin sediments 299
Continental rise 298
Continental Sea 73, 75
Continental shelf
 Ocean floor 298
 Prehistoric Earth 69, 71
 Rock cycle 267
Continental slope
 Ocean floor 298
 Offshore currents 296
 Rock cycle stages 267
Continents
 Formation of the Earth 38, 56
 Earth's physical features 264-265
 Geological time 56
Contrabassoon 504-505
Contractile vacuole 117
Control cabinet 396
Control circuit 328
Control buttons 585
Control column
 ARV light aircraft 425
 BE 2B bomber 404
 Curtiss biplane 398-399
Control-column aperture 425
Control flag 552
Controller 332
Control line 561
Control panel 571, 595, 596
Control panel and disc tray cover 584
Control panel boards 597
Control panel fascia 597
Control panel microchips 596
Control panels 594
Control panel wiring 595
Control platform 590
Control reservoir drain 326
Control rod 314, 424
Control room 397
Control stalk 353
Convection cell 35
Convection current 38
Convective zone 24, 35
Converging plates 65
Conversion 550
Convex portico 485
Cook/grill tray 596
Cooking 108
Cooksonia 56
Cooksonia hemispherica 64
Coolant 314
Coolant inlet 424
Coolant jacket 410-411
Coolant outlet
 ARV light aircraft 424
- Jaguar V12 engine 345
Mid West two-stroke engine 410
Coolant passage 346
Coolant pipe 354
Coolant pump 410
Coolant rail 345
Cooling device 611
Cooling fan 345, 567
Cooling fin
 Drum brake 365
 Mid West rotary engine 411
 Two-stroke engine 366
 Velocette OHV engine 367
Cooling intake 534
Cooling perforations 597
Cooling tank 335
Cooling tower
 Center Georges Pompidou 496-497
 Nuclear power station 314
Cooling water tank 335
Co-orbital moons 46
Coping-stone 495
Copper
 Mineral resources 280-281
 Minerals 268
 Periodic table 311-312
 Copper body-shell 519
 Copper face 384
 Copper nitrate solution 512
 Copper ore 506
 Copper plate nib 444
 Copper sheathing 392
 Copper sulfate 315
 Coprates Chasma 45
Copulatory bursa
 Butterfly 169
 Snail 177
Coracoid
 Bird 189
 Diplodocus 90
 Eiroplocephalus 94
 Gallinimus 86
 Triceratops 102
 Turtle 187
 Tyrannosaurus 84
Coral 78, 166-167
 Atoll development 299
 Fossil record 279
Corallina officinalis 117
Coral reef
 Earth's evolution 56
 Ocean floor 298
Cor Anglais 504-505, 508
Corbel
 Cathedral dome 487
 Medieval building 467, 469
 Neoclassical building 482
 Nineteenth-century building 495
 Renaissance building 477
 Rococo style 478
Corbita 372-373
Cor Caroli 18, 21
Cordaites 67
Cordate leaf bases 156-157
Cordite case 396
Cordite handling room 396
Cordite supply shuttle 396
Core
 Earth 58-59
 Helix Nebula 17
 Massive stars 26-27
 Moon 40
 Neutron stars and black holes 28-29
 Small stars 24-25
 Structure of comet 55
 Structure of Earth 63
- Structure of Jupiter 45
Structure of Mars 45
Structure of Mercury 55
Structure of Neptune 31
Structure of Pluto 51
Structure of Saturn 47
Structure of Uranus 49
Structure of Venus 37
Core-engine jet pipe 412, 415
Core jet pipe 419
Core temperature
 Structure of Earth 39
 Structure of Jupiter 45
 Structure of main sequence star 24
 Structure of red giant 25
 Structure of red supergiant 26
 Structure of Saturn 47
 Structure of Sun 35
 Structure of Uranus 49
Corinthian capital 460, 463, 479, 481
Corinthian column 463-464, 479-480
Corinthian entablature 463
Corinthian order 460, 462
Corinthian pilaster 463-464, 480-481
Coriolis force 296-297, 300
Cork
 Obes 508
 Stems 134-135
 Woody dicotyledons 127
Corns 154-155
Corn 112
Cornea 241
Corner arc 524
Corner seal 347
Cornet 506
Cornice
 Ancient Egyptian temple 458-459
 Ancient Greek building 460-461
 Ancient Roman building 462-465
 Asian building 491
 Baroque church 479-481
 Dome 484, 486
 French temple 485
 Gothic church 470-475
 Islamic tomb 489
 Medieval building 466-467, 469
 Neoclassical building 478-479, 482-485
 Nineteenth-century building 495
 Renaissance building 474-477
 Twentieth-century building 494
Cornucopia 480
Corolla 140, 142-145
Corona
 Earth's atmosphere 300
 Palazzo Strozzi 475
 Sun's atmosphere 32-53
Corona Australis 19
Corona Borealis 18, 21
Coronal section through brain 236-237
Coronal suture 220
Coronary artery 250-251, 255
Coronary sinus 250
Corona temperature 35
Coronet 198, 554
Coronoid process 194, 220
Corpus albicans 258
Corpus callosum 256-257
Corpus cavernosum 259
Corpus luteum 258
- Corpus spongiosum 259
Corridor 465
Corries 286-287
Corrugator supercilii muscle 228-229
Cortex
 Apical meristem 134
 Canadian pond weed 158-159
 Clubmoss stem 120
 Dicotyledon 127
 Epiphytic orchid 162
 Hair 254
 Horsetail stem 120
 Kidney 256
 Lichen 114
 Monocotyledon 127
 Moss 119
 Pine 125
 Rhizome 155
 Root 132-135
 Stems 134-135
 Water hyacinth 158
 Water lily 159
Corundum 271
Corvus 18, 21
Corvus corone 195
Corynactis viridis 166
Corythosaurus 96, 98
Cosmic background radiation 10
Cosmic ray 301
Costal cartilage 218
Costal facet 225
Costal margin 168, 169
Costal shield 187
Cotter pin 385
Cotton duck canvas 437, 445
Cotyledon 126, 152-155
 Development 152
 Dicotyledon 126
 Dry fruit seed 150-151
 Embryo development 147
 Epigeal germination 155
 Hypogeal germination 152
 Monocotyledon 126
 Pine 122
 Root development 132
 Seed 152-155
 Succulent fruit seed 148-149
Couch grass 115
Coucey-le-Chateau 466-467
Coulomb 316
Counter
 Calligraphy lettering 445
Counterbalancing weight 506
Counter, galley 575
Counter rail 581
Counter timber 581
Counterweight
 Flat-four cylinder arrangement 340
 Four-stroke cycle 345
 Hong Kong and Shanghai Bank 498
 Jaguar V12 engine 345
 Output shaft 547
 Relief printing press 449
 Rotary engine output shaft 410
 Trojan engine 342
 V12 cylinder arrangement 345
Country code 576
Coupling
 Conventional hookscrew 328
 "Ellerman Lines" steam locomotive 324
Coupling rod 325

- Couronnement 472
Course
Asian building 491
Medieval building 466-467
Neoclassical building 485
Nineteenth-century building 492-493
Court referee 555
Court
Basketball 532
Handball 535
Netball 535
Volleyball 534
Court seal 575
Courtship display 188
Courtyard 465, 466
Cousinnet 460
Covalent bonding 508-509
Cove 381
Coved dome 478, 485
Cover point 541
Cover support 570
Coverts 188, 191
Cow 198
Cowhide face 384
Cowling fastener 408
Cowling panel 407, 412
Coxa
Beetle 168
Crayfish 175
Scorpion 170
Coxswain 560
CQR anchor 586
Crab 172
Crab apple 126
Crab cactus 129
Crab Nebula 28
Cracks 284-285
Cradle frame
Honda VF750 364
Weslake Speedway motorcycle 369
Cradling 541
Crane 498
Cranial nerves 238
Cranium
Ankylosaurus 94
Archaeopteryx 85
Australopithecus 108
Bat 105
Camarasaurus 91
Diplodocus 90
Elephant 201
Eryops 80
Euoplocephalus 94
Homo sapiens 108
Hyaenodon 107
Iguanodon 96
Kentrosaurus 95
Lambeosaurus 99
Moeritherium 105
Opossum 106
Pachycephalosaurus 100
Panoplosaurus 94
Parasaurolophus 99
Platosaurs 88
Prenocephale 100
Protoceratops 102
Stegoceras 100
Stegosaurus 93
Struthiomimus 87
Syracosaurus 102
Toxodon 106
Triceratops 105
Tuojiangosaurus 95
Tyrannosaurus 84
Crank 320
Brace-and-bit 601
Eddy Merckx racing bicycle 360
"Ellerman Lines" steam locomotive 325
Crank bolt 538, 360
Crankcase
BE 2B bomber 404
British Rail Class 20
diesel engine 327
Humber engine 343
Jaguar straight six engine 344
Jaguar V12 engine 345
Mid West two-stroke engine 410
Oldsmobile engine 336
Trojan engine 342
Velocette OHV engine 367
Werner motorcycle 362
Crankcase breather pipe 402
Crank handle 539
Crankpin 343
Crankshaft
Benz Motorwagen 335
Flat-four cylinder arrangement 340
Four-stroke cycle 343
Iron paddlesteamer 392
Mid West two-stroke engine 410
Oklsmobile engine 336
Oscillating steam engine 391
Straight four cylinder arrangement 345
Two-stroke engine 366
Velocette OHV engine 367
Crankshaft counterweight 344
Crankshaft pulley 544, 355
Crash bar 362-365
Crash cymbal 518
Crash helmet 552
Crater
Mercury's North Pole 35
Northern stars 18
Oceanus Procellarum 40
Southern stars 21
Surface features of Mars 42
Crayfish 172-173
Crayon 448
Creative Zen Stone 586
Creeping stems 154
Clubmoss 120
Strawberry 128
Cremasteric fascia 259
Cremocarp 150-151
Crenellation 466
Crepidoma 461, 481
Crescent-shaped dune 285
Crest
Building 479, 488, 495
Fold formation 60
Horse 199
Lizard 184
Ship's shield 395
Crested porcupine 197
Cretaceous period 72-73
Fossil record 279
Geological time 56-57
Crevasse 287
Crevice 284
Crevice tool 593
Crew handrail 612, 613
Crew's seat 416
Cricket (animal) 168
Cricket (game) 538-539
Cricoid cartilage 255
Cricothyroid ligament 244
Cricothyroid muscle 229, 244-245
C ring 46-47
Cringle 384
Crista 242
Crocket 471-472
Crocodile clip connector 316
Crocodiles 68, 73, 186-187
Crocodylus niloticus 186
Crocodile 271
Cronaca 474
Crook 508
Crop
Bird 189
Butterfly 169
Octopus 176
Snail 177
Crop-duster 410
Crops 315
Crop-sprayer 410, 422
Cross
Baroque church 480
Dome 486-487
Motif 472
Crossandra nilotica 145
Crossbar
Calligraphy characters 445
Eddy Merckx racing bicycle 360
Gaelic football 529
Handball 535
Hurling 540
Rugby 530
Cross-bed set 283
Crossbow 548
Cross-bracing 497-499
Cross-country skiing 548
Crosse 540-541
Crossing 469-470, 477
Crossing tower 468
Cross-member 358-359
Cross-piece 376-377, 387
Cross-pollination 144
Cross-staff 377
Cross-stave 376-377
Cross tube 423
Cross wall of hypha 115
Crosswise strut 512
Crochet rest 502-503
Croton 136
Crouch 543
Croup 198
Crow 195
Crown
Bird 188
Building 484, 490
Danforth anchor 586
Harp 511
Head 212
Relief-printing press 449
Rigger 582-585
Roman anchor 372
Sail hook 384
Shackle 386
Teeth 247
Timpanum 519
Crowning cornice
Ancient Roman building 464, 465
Baroque church 479
Renaissance building 474-475
Crown wheel
Benz Motorwagen 335
Ford Model T 358
Cruciform column 492
Cruciform pedestal 481, 487
Cruck frame 466
Cruise electronics module 615
Cruise stage 615
Crumb tray 598-599
Crupper 555
Crusafontia 56
Crus cerebri of midbrain 257
Crus of diaphragm 255
Crust
Moon 41
Ocean floor 298
Pulsar 28
Regional metamorphism 274
Structure of comet 53
Structure of Earth 58-59
Structure of Mars 43
Structure of Mercury 35
Structure of Venus 57
Crustaceans 172-173
Arthropoda 170
Cretaceous period 72-73
Fossil 279
Crustal movement
Coastline 294
Faults and folds 60
Mineralization zones 280
Mountain building 62
Rock cycle 266
Volcano 272
Crustal plate boundary 39
Crustal plates 58-59, 60
Crustose lichen 114
Crutch
Viking karv 375
Crux-Centaurus Arm 14
Crypt 467
Crypt-window 481
Crystalline external crust 28
Crystalline stalagmitic floor 284
Crystallization 507
Crystal Palace Exhibition Hall 492-493
Crystals
Faults 60
Intrusive igneous rocks 275
Mineral features 270-271
Minerals 268-269
Solids 307
Crystal systems 270
Ctenidium 176
CT scan 214
Cube 623
Cubic crystal 270
Cubic system 270
Cubital fossa 211
Cuboid bone 232
Cucumis melo 149
Cud 198
Cuesta 285
Culm 151
Cumulonimbus cloud 302
Cumulus cloud 302
Cuneate leaf base 136-137
Cuneus 465
Cup 509
Cup mute 507
Cupola 466, 479, 493
Cupressus glabra 125
Cup-shaped mouthpiece 506-507
Cup surrounding stomata 157
Cupula 242
Cupule 150
Curium 311
Current 296-297
Current electricity 316
Cursor control device (CCD) 573
Curtain 477, 497
Curtain wall 466, 496, 498
Curtiss, Glenn 398
Curtiss Model-D Pusher 398-399
Curved buttress 478-481
Curved cornice 462
Curvilinear tracery 470, 472
Cuscuta europaea 163
Cushion
Doric capital 460
Rowing positions 575
Cushion star 175
Cusp
Asian building 488
Gothic building 472-473
Structure of a tooth 247
Cusped fold 61
Cusped foreland 294
Cusped arch 489
Cuspidate leaf apex 137
Cutaneous nerve 238
Cuticle
Bishop pine needle 124
Dryland plants 156
Golden barrel cactus 156
Hair 234
Haworthia truncata 157
Leaf 159
Lithops brom fieldii 157
Marram grass 115
Monocotyledon leaf 126
Nail 251
Rose stem 155
Rush stem 135
Wetland plants 158
Cuttlefish 176
Cutty Sark 392
Cyanotrichite 269
Cycadophyta 122
Cycads 68, 122-123, 279
Cycas revoluta 68, 123
Cycas sp. 68
Cyclic-pitch lever 422-423
Cyclone assembly 592
Cyclonic storm
Structure of Earth 59
Structure of Mars 43
Structure of Neptune 50
Cyclostomata 178
Cygnus 19, 20
Cylinder
Diesel train 526
Early engines 342-343
"Ellerman Lines" steam locomotive 325
Iron paddlesteamer 392
Modern piston aero-engines 410
Motorcycle 362, 366
Oldsmobile engine 336
"Rocket" steam locomotive 324
Cylinder barrel
Mid West two-stroke engine 410
Werner motorcycle 362
Cylinder block 339
Cylinder-cooling gills 407
Cylinder drain cock lever 325
Cylinder head
72° V10 engine 356
ARV light aircraft 425
British Rail Class 20 diesel engine 327
Daimler engine 343
Jaguar straight six engine 344
Jaguar V12 engine 345
Mid West two-stroke engine 410
Oldsmobile engine 336
Two-stroke engine 366
Velocette OHV engine 367
Cylinder liner
Jaguar Straight six engine 344
Mid West two-stroke engine 410
cylinder shape 623
Cylinder surface area measurement 590
Cylinder volume measurement 590
Cylinder wall 343
Cylindrical map projection 264
Cyma recta 475
Cyma reversa 460, 472
Cymatium 475
Cymbals 504-505, 516-517
Drum kit 518
Cyme 129, 143
Cypress 125
Cypselas 150
Cyrillus 40
Cystic duct 248
Cytoplasm
Chlamydomonas sp. 116
Diatom 116
Human 217
Palisade mesophyll 139
Root cell 132
Thalassiosira sp. 116
Cytosine 216
D
Dacron 548
Dacron sailcloth 384
Dacron skin 426
Dactylus 172-173
Dado
Baroque church 481
French temple 485
Neoclassical building 479
Renaissance building 476
Dagger 472
Dagoba stupa 490-491
Daimler double-sleeve valve engine 345
Daimler, Gottlieb 354
Daisy gypsum 269
Dakota sandstone 276
D'Alembert 41
Dalmanian coastline 295
Da Maiano, B. 474
Damped anti-shock swivel base 584
Damper
Piano 514
TGV electric high-speed train 529
Wagon bogie 331
Damper bar 516
Damper body 365
Damper pedal
Concert grand piano 515
Tubular bells 516
Upright piano 514
Vibraphone 517
Damper unit 425
Damp lime-plaster 454
Damselfly 168
Dancette-pattern mosaic 489
Dandelion 150
Danforth anchor 386
Dangler area 556
Danilova 36
Dark mica 274
Dark nebulae 16
Darlingtonia californica 160-161
Dart sac 177
Darwin 43
Da Sangallo, G. 474
Dash 355
Dashboard
1906 Renault 337
Bordino Steam Carriage 335
Ford Model T 358
Dashboard radiator 356-357
Dash panel 355
Dash radio speaker 353
Data cartridge 591
Data plug 591
Data plug socket 591
Daucus carota 128, 132
Daughter bulbs 154
Daughter plants 154
David 395
D-block 310-311
DC converter 355
DC converter connection 355
E

- DC current 328
DC socket 586
Dead-ball line 550
Deadeye
 74-gun ship 580
 Longboat 580
 Rigging 582-585
 Roman corbita 373
 Sailing warship 377
Deadnettle 135
Dead organisms 278
Dead plant encrustations 284
Dead Sea 292-295
Deadwood 581
Debris
 Glacier 286-287
 Mountain building 62
 Ray crater 34
Decathlon 542
Decidial plate 260
Deciduous plants 130-151
Deciduous teeth 246
Deciduous trees 72
Deck
 Greek trireme 373
 Roman corbita 373
Deck beam
 74-gun ship 580
 Ironclad 595
 Paddle steamer 590, 595
 Roman corbita 372
Deck house 373, 376
Deck lantern 392
Deck planking 593
Deck rail 373
Decorative letter 445
Deep cracks 284-285
Deep current systems 296-297
Deepened valley 295
Deep floor 595
Deep mid wicket 538
Deep-ocean floor 298
Deep-ocean floor sediments 299
Deep peroneal nerve 258
Deep relief carving 453
Deep square leg 558
Deer 104, 198-199
Deer hopper dry fly 563
Defenders
 Ice hockey 550
 Lacrosse 541
 Soccer 524
Defending zones 550
Defense 526, 535
Defensive back 526
Defensive end 526
Defensive tackle 526
Deflation hollow 285
Degreased bare metal 348
Dehiscence 150-151
 Fern spore 121
 Pollen sac 144
Dehiscent fruits 150-151
Dehydration 152
De-icing leading edge 414, 415
Deimos 42
Deinonychus 73
Deinotherium 77
Dekla Tessera 57
de la Cierva, Juan 422
Deleted items folder 576
Delete mail button 576
Delphinium 150
Delphinium orientalis 141
Delphinium sp. 151
Delphinus 19, 20
Delta
 Coastline 294
 River features 290
 River 288-289
 Rock cycle 266-267
Delta Andromedae 19
Delta Crucis 21
Delta formation 291
Delta Hydris 20
Delta II launch vehicle second stage 615
Delta ring 48
Deltavalia vjatkensis 81
“Deltic” diesel-electric locomotive 526-527
Deltoid leaf 137
Deltoid ligament 232
Deltoid muscle 226-227
Demountable wheel 358-359
Dendrite 239
Dendritic copper 268
Dendritic gold 268
Dendritic river drainage 288
Deneb 19, 20
 Hertzsprung-Russell diagram 25
Deneb Algedi 19, 20
Deneb Kaitos 19, 20
Denebola 18, 21
Dens 222
Density
 Formation of black hole 29
 Massive stars 26-27
 Small stars 24-25
 Stellar black hole 29
Dentary 181
 Dentary bone 96, 102, 107
Dentate leaf margin
 Hogweed 129
 Ice-plant 129
 Live-forever 129
 Mulberry 130
 Rock stonecrop 128
Dentil
 Ancient Roman building 462
 Baroque church 479, 481
 Cathedral dome 487
 French temple 485
 Neoclassical building 478
 Renaissance building 475
Dentite 247
Deoxyribonucleic acid strand 139
Deperdussin, Armand 400
Depressed arch
 Ancient Roman building 462
 Islamic building 488-489
Depressions 302
Depressor anguli oris muscle 228-229
Depressor labii inferioris muscle 229
Depth charge 394
Derailleur cage plate 358
Deranged river drainage 288
Dermal armor 95
Dermal papilla 255
Dermis 254-255
Derrick 392, 395
Descender 445
Descending colon 249
Desert 59, 57
 Carboniferous to Permian period 66
 Earth’s physical features 264-265
 Rock cycle 266
 Weathering and erosion 282-283
Desertification 57, 76
Desiccated clay 285
Design
 Fresco 454-455
 Modeled sculpture 452
 Mosaic 449
Deslandres 40
Desmid 112
Destination screen 552
Detachable bud 154
Detachable ink reservoir 444
Detachable rim 359
Detector 610
Detergent tray 594, 595
Detergent tray holder 595
Detergent tray recess 595
Deuterium nucleus 22
Deutscher Werkbund style 495
Devonian fish 65
Devonian period 64-65, 80
Devonil record 279
 Geological time 56
 Primitive life 78
Devon minnow 565
Dewlap 184
Dextral strike-slip fault 61
Dhow 376
Diabase sill 277
Diagonal bracing 401
Diagonal reinforcement 374
Diagonal strut 599
Diagonal turn 588
Dial
 Clocktower 495
 Sundial 377
Diameter 622
 Atoms 308
 Earth 30
 Fluorine-19 atom 309
 Fluorine-19 nucleus 309
 Jupiter 26, 44
 Jupiter’s moons 44
 Life of massive star 26-27
 Life of small star 21-26
 Mars 30
 Mars’ moons 42
 Mercury 30
 Moon 40
 Neptune 31
 Neptune’s moons 50
 Planets 30-31
 Pluto 31
 Saturn 27, 46
 Saturn’s moons 46
 Stars 22
 Sun 32
 Uranus 27, 48
 Uranus’ moons 48
 Venus 30
Diamond 311
 Mineral features 270-271
 Native elements 268
Diamond-shaped painting knife 436
Diamond whetstone 452
Diaphragm
 ARV Super 2 424
 Chimpanzee 202
 Domestic cat 195
 Elephant 200
 Human 215, 254-255
 Rabbit 196
Diastema 106
Diatom 116
Diceros bicornis 199
Dichasial cyme 145
Dicksonia antarctica 70, 112-115
Dicloelasia bilobata 65
Dicotyledon 126-127, 141-145
Dicyothyris 278
Didelphis 106
Didelphis virginiana 207
Dielectric sandwich 584
Diesel-electric train 326
Diesel fuel injection 326
Diesel motor compartment 397
Diesel, Rudolph 326
Diesel train 324, 326-327
Differential 356
Differential housing 358
Diffuser 556
Digestive caecum 173, 176
Digestive enzymes 161
Digestive gland
 Snail 177
 Spider 170
Digestive glands/zones
 Butterwort 161
 Monkey cup 161
 Venus fly trap 160
Digestive system
 Cow 198
 Human 248-249
Digit 105
Digital artery 231, 235
Digital camcorder 582-583
Digital camera
 3-D digital camera 581
 Digital camera with interchangeable lens 581
 Digital SLR 581
 Underwater digital camera 581
Digital extensor muscle 94
Digital flexor muscle 84
Digital media slot 567
Digital nerve 231
Digital sampler 520-521
Digital vein 253
Digital video camera 582-583
Digitate leaf 137
Digits
 Bird 189
 Bird’s wing 191
 Frog 182
 Kangaroo 207
 Rabbit 196-197
 Rat 196
 Salamander 182
 Seal 204
Dike 274
Dike swarm 274
Dilator muscle 241
Dilsea carnosa 117
Dimetrodon loomisii 67
Dinghy 560
Dinosaur cladogram 83
Dinosaur 56-57, 80, 82-83
 Fossil record 279
Dionaea muscipula 160
Dione 46, 614
Dip 60
Diplodocus 70, 88, 90-91
Dip pen 450
Dipping bed rock 60-61
Dipping lug foresail 585
Diprotodon 76
Dip-slip fault 61
Dipstick 554
Dipstick tube 346, 356
Dipterus valeciennesi 81
Direct current 328
Direct current (DC) inlet 571
Direction bar 414
Direction-finding-aerial fairing 408
Direct method mosaic creation 450
Direct-vision panel
 ARV light aircraft 425
 Bell-47 helicopter 422
Dirt track motorcycle racing 568
Disc brake
 Harley-Davidson FLHS Electra Glide 362-363
 Honda CB750 363
 Honda VF750 364
 Husqvarna Motocross TC610 368
 Lockheed Electra airliner 407
Motorcycle 364-365
 Suzuki RGV500 368-369
Disc brake calliper 364, 368-369
Disconformity 276
Discovery Rupes 55
Discus 542-543
Disk
 Basal 167
 Crab 166-167
 Liverwort 118
 Pedal 167
 Sea anemone 166-167
 Starfish 174
 Starfish fossil 79
 Disk drag 562-563
 Disk florets 129, 142, 145
Displacement reactions 512
Display button 585
Display controller chip 571
Display panel
 Blu-ray recorder 584
 Display screen 585, 596
Display screen and control circuits 585
Distal convoluted tubule 256-257
Distal end of radius 251
Distal interphalangeal joint 251
Distal phalanx 219, 230, 232
Distal tarsal 183
Distance lines
 Gaelic football 529
 Rugby 530
Distance running 542
Distance signaling 530
Distilled water 444
Distiller 397
Distributary
 River features 290-291
 Rivers 288-289
Distributor
 Hawker Tempest Mark V 408
 Jaguar straight six engine 544
 Jaguar V12 engine 545
 Renault Clio 351
Distributor drive shaft 345
Distributor fixing point 346
Diving 558-559
DNA 139, 216, 606
Dobro resonator 513
Dock 554
Document panel 407
Document table 571
Dodder 163
Dog 104, 194-195
Dogfish 178-179, 192
Dog-leg hole 546
Dog-leg staircase 481
Doline 284-285
Dolomedes fimbriatus 171
Dolphins 204-205
Dolphin striker 382
Domain name 576
Dome 484, 486-487
 Ancient Roman building 462
 Asian building 490-491
 Baroque church 480-481
 French temple 485
 Islamic building 488
 Medieval building 467, 469
 Neoclassical building 478
 Renaissance building 475-477
 Domed receptacle 142
 Domed roof 489
 Domed topdeck 401
 Domed turret 493
 Dome metalling 486
Dome of the Rock 487
Dome timbering 486
Dome volcano 62, 272
Donjon 466-467
Donkey boiler 392
Donor genetic material 606, 607
Door
 Ancient Egyptian tomb 458-459
 Ancient Roman building 463
 Baroque church 479
 Bell 206 jetliner 423
 Double-decker touring bus 353
 Gatwick Express “People Mover” 328
 MCW Metrobus 352-353
 Microwave combination oven 596
 Neoclassical building 478
 Renaissance theater 477
 Renault Clio 549
 Single-decker bus 353
 TGV electric high-speed train 529
 Washer-dryer 594
Door catch 541
Door catch with safety cut-out 595
Door frame 412
Door glass 348
Door handle 341, 548
Door hinge 612
Door jamb 478
Door key and lock 348
Door lock 596, 602
Door metal cap 595
Door molding 353
Door porthole 595
Door safety cut-out mechanism 596
Door trim panel 353
Doorway 474-475, 479, 481, 495
Door wiring loom 595
Doppler 41
Dorado 21
Doric capital 460
Doric column 460, 464
Doric half-column 464
Doric order 460
Dormancy
 Horse chestnut bud 130
 Seed 152
Dormant volcano 272
Dormer head 495
Dormer window 476, 493, 495
Dorsal abdominal artery 173
Dorsal aorta
 Bony fish 181
 Dogfish 179
 Frog 182
Dorsal blood vessel 169
Dorsal fin
 ARV light aircraft 424
 Bony fish 181
 Concorde, the 416
 Dogfish 179
 Dolphin 205
 Lamprey 178
 World War II aircraft 408-409
Dorsal fin ray 181
Dorsal interosseous muscle 235
Dorsal lobe 158
Dorsal mantle cavity 176
Dorsal margin of shell 176
Dorsal metatarsal artery 253
Dorsal plate 78, 92-93
Dorsal scale 184, 186
Dorsal scute 95

- Dorsal spine base 78
Dorsal venous arch 255
Dorsal vertebrae
 Archaeopteryx 85
 Brachiosaurus 90
 Diplodocus 90
 Eryops 80
 Euoplocephalus 94
 Gallimimus 86
 Iguanodon 96
 Kentrosaurus 95
 Parasaurolophus 99
 Pareiasaur 81
 Plateosaurus 88
 Stegoceras 101
 Stegosaurus 95
 Struthiomimus 87
 Tuojiangosaurus 95
 Tyrannosaurus 84
Dorsum 215
Double-arm pantograph
 328
Double bass 505-505, 510,
 511
Double bassoon 504-505
Double-decker bus 352-353
Double decomposition
 reaction 312-315
Double-dipper palette
 attachment 436
Double-ended hull 375
Double flat 502
Double hallway 373
Double helix 216
Double-planet system
 Earth 38
 Pluto 50
Double-pyramid crystal
 270
Double reed 508
Double rope becket 385
Doubles 544
Double samaras
 Dry fruit 150-151
 Sycamore 131
Double scull 561
Double sharp 502
Double topsail schooner
 385
Dowel
 Mid West single rotor
 engine 410
 Mortise-and-tenon
 fastening 375
Dowel hole 410-411
Downfolds 60
Downhaul 585
Downhill skiing 552
"Downs" 526
Downthrow 60
Down tube 360
Dox formation 277
Dpi (Dots Per Inch) 570
Draco 19, 20
Draft mark
 Frigate 397
 Wooden sailing ship
 379
Drafts folder 576
Draft tube 314
Drag
 Biplanes and triplanes
 402
 Cycling 360
 Early monoplane 400
 Early passenger aircraft
 406
Drag knob 565
Drag link
 19th century
 paddlesteamer 391
 Ford Model T 359
 White Steam Car 342
Dragon prowhead 374
Drag spindle 562
Drag washer 562
Drainage systems divide
 289
Drain mast 412, 415
Drain-pipe 492
Drain plug 359
Drakensberg 265
Dravidian finial 491
Dravidian style 490
Drawbridge 495
Drawbridge windlass 467
Drawing 450-451
Drawing board 430,
 444-445
Drawing instruments 450
Drawing materials 430
Dreadnought-type
 battleship 394
Dressing-room 477
Dribbling
 Basketball 532
 Gaelic football 528
 Handball 554-555
 Soccer 524
Drill 600-601
D ring 46-47
Drip-cap 482
Drive 545
Drive belt 354, 355, 344,
 362
Drive bracket 405
Drive chain 366, 368
Drive end 317
Drive gear 411
Driven gear 410
Driven pulley 355
Drive pillar 424
Drive plate 545
Drive point 346
Driver 547
Driver protection 357
Driverless train 328
Driver's platform 324
Driver's radio aerial 357
Driver's seat
 Bordino Steam Carriage
 335
 "Deltic" diesel-electric
 locomotive 527
 "Mallard" express
 steam locomotive 325
 Paris Metro 328
Drive shaft
 Jet engine 419
 Renault Clio 351
 Volkswagen Beetle 340
Drive sprocket mounting
 spline 366
Drive-wheel 601
Driving band 397
Driving chain 355
Driving pulley 355
Driving rein 555
Driving saddle 555
Driving sprocket 355
Driving wheel 324-325
Drizzle 302
Dromiceiomimus 86
Droop nose 416
Droop stop 422-423
Drop 381
Drop arm
 Ford Model T 359
 White Steam Car 342
Drop-down window 334
Drop glass 341
Drop goal 550
Drop handlebar 361
Dropkick 530
Drop tank 408
Drop window 352
Drowned coastline
 294-295
Drowned valley 295
Drum 486
 Ancient Greek building
 460
 Baroque church 481
 Cathedral dome 487
 Relief printing press
 449
 Washer-dryer 595
Drum and door seal 595
Drum brake
 BMW R/60 362
 Motorcycle 364-365
 Vespa Grand Sport 160
 Mark 1 365
 "Windcheetah" racing
 HPV bicycle 361
Drumhead 387
Drum inlet elbow 595
Drumlins 286
Drum pad 520
Drums 518-519, 520
Drum suspension springs
 595
Drupelets 146-149
Drupes 131, 148-149
Dry air 303
Dry brush 438-439
Dry capacity
 measurements 590
Dry fresco 434-435
Dry fruits 150-151
 Couch grass 113
 Durmast oak 131
 Sycamore 131
Dry gallery 284-285
Drying agent 315
Dry lake bed 285
Dryland plants 156-157
Dryopteris filix-mas
 120-121
Dryosaurus 70
Dry pericarps 150
Dry season 295
Dry wash 285
Dual click gear 562
Dual ignition plug 427
Dual seat 364
Dubhe 18
 The Plough 19
Dubika 490
Duck 188
Duck-billed platypus
 206-207
"Duckbills" 96
Duct 496, 497
Duct of Bellini 256
Ductus deferens 259
Dugout 536
Dumb iron 356, 342
Dummy front door 559
Dunkled wet fly 563
Duodenum
 Bird 189
 Cow 198
 Elephant 200
 Frog 182
 Human 215, 248-249
 Rabbit 196
 Tortoise 187
Duplex tubular cradle
 frame 363
Duradon 384
Dura mater 223, 237, 240
Durmast oak 131
Dust
 Asteroids, comets, and
 meteoroids 52-53
 Mars 42-43
 Moon 41
 Nebulae and star
 clusters 16-17
 NGC 2997 (spiral
 galaxy) 12
 Overhead view of our
 galaxy 14
 Solar system 30
 Venus' atmosphere 37
Dust cap 359
Dust cloud
 Geological time 56
 Large Magellanic Cloud
 12
 Mars 42-43
 Milky Way 14-15
 Nebulae and star
 clusters 16-17
 Origin and expansion of
 universe 11
 Volcano 272
Dust collection bin 592
Dust lane
 Centaurus A 13
 Horsehead Nebula 16
 NGC 2997 (spiral
 galaxy) 12
 Optical image of
 Rings and dust lanes 48
 Trifid Nebula 16
Dust particles 53
Dust shroud 340
Dust storm 45
Dust tail 52-55
Dutch cubist style 495
Dutch shoe 377
Dutch triple fiddle block
 385
DVD/CD control buttons
 585
DVD/CD drive turntable
 585
DVD/CD laser-reader 585
DVD/CD on-screen menu
 display button 585
DVD/CD processor
 microchip 585
DVD/CD sliding tray 585
DVD/CD stop button 585
DVD display button 585
DVD player 584-585
Dwarf crocodile 82
Dwarf shoot 124-125
Dynastes hercules 12
Dyson DC05 vacuum
 cleaner 592-595
Dysprosium 311
E
Ear
 Calligraphy characters
 445
 Elephant 200
 Gorilla 205
 Hare 196
 Horse 198
 Human 210, 212,
 242-245
 Kangaroo 207
 Rabbit 196
 Rat 196
Eardrum
 Chick 195
 Frog 182
 Human 243
 Lizard 184
Earles fork 362
Early desertification 57
Early engines 342-345
Early English
 Perpendicular-style
 tracery 472
Early English-style
 window 472
Early monoplanes
 400-401
Early passenger aircraft
 406-407
Early tram 352
Early voyagers 374-375
Earphone 586
Earpiece 588
Earplug 558
Earth 38-39
 Cretaceous period 75
 Energy emission from
 Sun 22
 Jurassic period 71
 Objects in universe 11
 Phases of the Moon 41
 Primitive life 78-79
 Quaternary period 77
 Solar eclipse 32
 Solar system 30
 Tertiary period 75
 Tides 297
 Triassic period 69
Earth-ball fungus 115
Earth bank 603
Earth connection 598
Earth formation 56-57
Earth pigments 454
Earthquake anatomy 63
Earthquake region 59
Earthquakes
 Crustal movement 58
 Faults and folds 60
 Mountain building
 62-63
Earth's atmosphere 38-39,
 78, 300-301
Earth's composition 39
Earth's core 38-39, 63
Earth's crust 38-39, 58-59
 Igneous and
 metamorphic rocks 274
 Lake formation 292
 Volcano 272
Earth's crustal plates 62,
 64
Earth's energy 314
Earth's evolution 56-57
Earth's external features
 39
Earth's formation 38, 56, 64
Earth's interior
 Ocean floor 298
 Rock cycle 266
 Structure 39
Earth's layers 38
Earth's magnetic field 38
Earth's mantle 38-39,
 58-59
Earth's orbit 297
Earth's physical features
 264-265
Earth's rotation 38
 Atmospheric circulation
 and winds 300
 Oceans and seas 296
 Satellite mapping 264
Earth's satellite 38
Earth's surface
 Atmosphere 300-301
 Earth's physical
 features 264
 Formation of the Earth
 38-39
 Geological time 56
 Mineral resources 280
 Mountain building 62
 Oceans and seas 296
 Precambrian to
 Devonian period 64
 Rock cycle 266
Earth's tilt 38
Earth wire 594
Earwig 168
East Africa 351
East Asian buildings
 490-491
East Australian current
 297
East Greenland current
 296
Eaves
 Ancient Greek building
 461
 Ancient Roman
 building 462, 464
 Islamic tomb 489
 Modern building 499
 Neoclassical building
 482
 Renaissance building
 477
Eaves board 490
Eccentric 392
Eccentric rod 391
Eccentric rotor journal
 347
Eccentric shaft 347, 411
Eccentric-shaft bearing
 410
Echidna nebulosa 180
Echidnas 206
Echinocactus grusonii 156
Echinoderms 174, 279
Echinus 460
Echinus escleutus 175
Echo-sounding 298
Ecliptic
 Inclination of planetary
 orbits 31
 Stars of northern skies
 18-19
 Stars of southern skies
 20-21
ECM 355
Echpora 75
Ectoderm 167
Eddy Merckx racing
 bicycle 360-361
Edible sea urchin 175
Edmontonia 95
Eel 180
EEPROM memory chip
 587
Efferent arteriole 252-257
Effervescence 316
Effort 320-321
Egg cells 606-607
Eggs 192-195
 Amphibian 78, 80
 Baltimore oriole 195
 Bee hummingbird 195
 Bird 188
 Butterfly 168
 Capsule 192
 Carrion crow 195
 Case 192
 Chaffinch 195
 Chicken 192
 Common tern 195
 Dinosaur 82
 Dogfish 192
 Frog 182-185, 192
 Giant stick insect 192
 Greater blackbacked
 gull 195
 Hatching 192-195
 Human 258, 260
 Indian stick insect 192
 Leaf insect 192
 Maiaasaura 98
 Membrane 195
 Ostrich 195
 Quail 192-195
 Reptile 66, 184
 Titanosaurid 91
 Willow gourd 195
Egg tempera 452
Egg-tooth 192-195
Egg white 192
Egg yolk binding medium
 452
Egypt 351
Egyptian building 458-459
Eichhornia crassipes 158
Eighteenth-century
 building 492
 Baroque 481
 Neoclassical 478,
 482-485
Eighteenth-century building
 490-491
Einsteinium 311
Eisila Regio 36-37
Ejectatory duct 259
Ejecta
 Degas and Bronte 34
 Features of supernova 27
 Ray crater 34
 Venusian craters 32
Ejector assembly 599
Ejector exhaust 408
Ejector-seat roof hatches
 421
Ekeing 381
Ekman spiral 296-297
El-Ayni Mosque 488
Elapsed time display 577
Elasmobranchs 178
Elastic fiber 252, 254
Elastic rocks 60

- Elbow
Anchisaurus 89
Corythosaurus 98
Edmontonia 95
Gorilla 205
Horse 199
Human 210
Iguanodon 97
Lion 194
Psittacosaurus 105
Stegoceras 101
Stegosaurus 92
Triceratops 103
Elbow guard 553
Elbow joint
Brachiosaurus 91
Diplodocus 90
Eryops 80
Euoplocephalus 94
Human 218
Parasaurolophus 99
Plateosaurus 88
Stegoceras 101
Triceratops 102
Tyrannosaurus 84
Elbow pad 527, 551
Elder 150-151, 140-145
Electrical braking 530
Electrical cells 516-517
Electrical charge
imbalance 516
Electrical circuit 516
Toaster 598
Electrical contact 519
Electrical effects 516
Electrical energy 514-515
Electrical harness 414
Electrical inverter 422
Electrical plant 496
Electrical relay 596
Electrical relay box 530
Electrical service
compartment 407
Electrical supply 516
Electrical wiring harness
418
Electric bass guitars 512
Electric cable 517
Electric car 542
Electric charge 508
Electric coil 517
Electric current 516-517,
328, 603
Electric equipment
compartment 329
Electric fuel pump 422
Electric generator 517
Electric guitar 512-513
Electric heating elements
597
Electric ignition control
362
Electricity 516-517
Electricity connector to
brushbar motor 593
Electricity generation
Diesel train 526
Electric train 526
Magnetism 517
Electricity supply 590
Electric locomotive 524,
328-329
Electric motor
Diesel train 526
Electric train 528
Tram 532
Electric motor/generator
557
Electric motor housing
554
Electric power line 528,
402
Electric power socket 422
Electric scoring system
556-557
Electric street tramway
552
Electric toaster 598
Electric train 528-529
- Electric transmission 526
Electric trolley 532
Electric window motor
549
Electrode 506
Electromagnet 517, 598
Electromagnetic
induction capacitor 600
Electromagnetic radiation
514-515, 518
Electromagnetic
spectrum 518-519
Electron 508, 516
Atomic number 510
Fluorine-19 509
Electron beam 611
Electron detector
assembly 611
Electron gun 611
Electron gun housing
610
Electron microscope 610
Electronic controller 605
Electronic control signals
530
Electronic control-unit
connector 556
Electronic drums 520
Electronic engine control
(EEC) unit 418-419
Electronic games 578-579
Electronic ignition unit
551
Electronic impulses 584
Electronic instruments
520-521
Electronic signals 512
Electronic warfare mast
597
Electrons 605
Electron shell 508-509,
510
Electron stream 611
Electron transfer 508
Electrostatic forces 508,
516
Electrostatic generator
516
Electrothermal de-icing
panel 416
Element retaining stop
599
Elements 506, 508
Atomic mass 510
Minerals 268
Periodic table 510-511
Elephant 90, 104, 200-201
Elephas maximus 200
Elevated green 546
Elevating wheel 596
Elevation 498
Elevator
ARV light aircraft 424
BAe-146 components
415
Bell-47 helicopter 423
Biplanes and triplanes
402-403
Curtiss biplane 599
Early monoplanes
400-401
Hawker Tempest
components 409
Schleicher glider 426
World War I aircraft 405
Wright Flyer 599
Elevator arm 425
Elevator chassis box 415
Elevator control cable
599, 403
Elevator control rod 409
Elevator control wire
Bell-47 helicopter 47
Bleriot XI monoplane
401
Curtiss biplane 599
LVG CVI fighter 405
Elevator drive wheel 599
Elevator hinge
- BAe-146 components
415
BE 2B tail 405
Blackburn monoplane
400
Hawker Tempest
components 409
Elevator operating arm
599
Elevator-operating
bracket 401
Elevator push-rod
424-425
Elevator rocking arm 404
Elevator trimtab 424, 409
Elevator wire 398
Eleventh-century building
466, 468
Elevon 416-417, 421
Elevon-jack fairing 416
Elevon power control unit
417
"Ellerman Lines" steam
locomotive 324-325
Elliott steering knuckle
536
Ellipsoid orb 486
Elliptical galaxy 11-12
Elliptical orbit 50
Elliptical leaf 157
Elm 144, 150
El Nath 18, 21
Elodea canadensis
158-159
Elodea sp. 159
Elongating root 153, 155
Elythia 64
Eltanin 19
Elytron 168
Email 576, 577
Email address 576
Email program 576, 577
Email sender 576
Emarginate apex 156
Embellisher 553
Embols 372
Embrasure 466-467, 469
Embryo 607
Cotyledon 152-153
Dry fruit seed 150-151
Fertilization 146-147
Germination 152-153
Human 260
Reptile 80
Seed leaf 152
Succulent fruit seed
148-149
Embryonic root 150,
152-153
Embryonic shoot 147
Epigeal germination
153
Hypogeal germination
152
Pea seed 150
Pine 122
Seed axis 152-153
Embryo sac 146-147
Emergency canopy
release handle 420
Emergency door control
332-333
Emergency escape hatch
406
Emergency exit 416-417
Emergency oxygen
cylinder 417
Emergent coastlines
294-295
Emission nebula 11-12,
14, 16-17
Empire State Building 494
Enamel
Islamic buildings 488-489
Teeth 247
Enceladus 46
Encke 40
Encke Division 46-47
Enclosed bridge 597
- Enclosed DVD/CD
compartment 585
Encroachment 527
End 588-589
End baffle plate 598-599
End block 512
End effector 608
E.N.-EL12 rechargeable
battery 581
End element 598-599
End-grain wood block 449
End-line
Basketball 552
Football 526
Men's Lacrosse 540
Volleyball 534
End link 586
Endocardium 250
Endocarp 146-147,
148-149
Endoderm 167
Endodermis
Bishop pine needle 124
Canadian pond weed
stem 158-159
Dicotyledon 127
Epiphytic orchid 162
Fern rachis 121
Horsetail stem 120
Mare's tail stem 155
Monocotyledon 127
Pine root 125
Root 152-153
Water hyacinth root 158
Endomysium 228
Endoperidium 115
Endoplasmic reticulum
239
Endopod 172
Endoscopic view
Alimentary canal 248
Vocal cords 245
Endoskeleton 174
Endosperm 147
Endosteum 225
Endothecium 144
Endothelium 252
End-pin 510
End-plate
Formula One race car
356-357
Modern piston aero-
engine 410-411
End-plate aerodynamic
skirt 557
End zone 526
En echelon fractures
60-61
Energized electrode 584
Energy 514-515
Chemical reactions 512
Electron shells 310
Light 518
Renewable 604-605
Energy conversion 158
Energy emission from
Sun 22
Engaged column 469
Engaged pediment
462-465
Energy 542-547, 410-411,
418-419
1906 Renault 537
1-liter VTEC 534
72° V10 556
ARV light aircraft 425
BAe-146 jetliner 415
BMW R/60 562
Bordino Steam Carriage
534
Diesel 526
Early monoplane
400-401
Hawker Tempest
components 408
Helicopter 422-423
Honda CB750 563
Honda VF750 564
Kirby BSA 569
- Lockheed Electra
airliner 406-407
Motorcycles 562, 564,
366-367
Oldsmobile engine
356
Pegasus Quasar
ultralight 427
Pioneers of flight
398-399
Renault Clio 550-551
Velocette overhead
valve (OHV) 367
Volkswagen Beetle
340
Engine aft bulkhead 421
Engine air intake
BE 2B bomber 404
Concorde 416
Formula One race car
356, 357
Hawker Tempest
fighter 409
Schweizer helicopter
423
Tornado 420
Engine and propeller
thrust frame 598
Engine bearer 545
Engine block 547
Engine cover
Formula One race car
356, 357
Honda VF750 574
Oldsmobile bodywork
337
Two-stroke engine 566
Vespa Grand Sport 160
Mark 1 565
Volkswagen Beetle 541
Engine cowling
Airbus 380 573
ARV light aircraft
424-425
Avro biplane 403
Concorde 416
Hawker Tempest
components 408
Lockheed Electra
airliner 407
Pegasus Quasar
ultralight 427
Engine crankcase 327
Engine drive belt 354
Engineering 496
Engine front mount
418-419
Engine front support link
417
Engine fuel pump 417
Engine instruments 425
Engine lid 541
Engine lifting eye 347
Engine mounting
ARV light aircraft 425
Blackburn monoplane
401
Honda VF750 564
Modern piston aero-
engine 411
Pegasus Quasar
ultralight 427
Velocette OHV engine
367
Engine pylon 412
Engine rear mount
Pegasus Quasar
ultralight 427
Turboprop engine 419
Engine room 526
Engine timing gear 556
Engine warning display
573
Englacial moraine 287
Englacial stream 286
England 92
English baroque style
480-481
- English bond brickwork
485
English Decorated style
470
English ivy 151
English Perpendicular
style 470, 472
Engraving 446
Enif 19, 20
Pegasus and
Andromeda 19
Ensign staff 596
Entablature
Ancient Greek building
460
Ancient Roman
building 462-465
Baroque church
480-481
Cathedral dome 487
French temple 485
Neoclassical building
478-479, 482-483
Entasis 461
Enter button 585
Enter key 590
Enteromorpha linza 117
Entomophilous
pollination 144
Entrance
Islamic tomb 489
Medieval building
466-467
Modern building
496-499
Neoclassical building
483
Nineteenth-century
building 495
Twentieth-century
building 494
Entrenched meander 290
Entresol 467
Enucleated egg cell 606
Enzyme 160
Eocene epoch
Fossil record 279
Geological timescale 57
- Eon
Fossil record 279
Geological time 56-57
Epee 556-557
Epibranchial artery 179
Epicardium 250
Epicenter 63
Epicytol 152-155
Epicranial aponeurosis 237
Epidermal cell 166
Epidermis
Apical meristem 154
Canadian pond weed
stem 159
Clubmoss stem 120
Dicotyledon 126-127
Epiphytic orchid 162
Fern rachis 121
Flower 142
Horsetail stem 120
Human 234-235
Leaf 159
Marram grass 115
Monocotyledon 126-127
Moss 119
Multilayered 162
Pine needle 124
Pine stem 125
Prickle 135
Radicke 152
Rhizome 155
Root 132-135
Stem 134-135
Water hyacinth 158
Water lily 159
Epididymis 259
Epidote 269
Epigeal germination
152-153
Epiglottis
Elephant 200

- Human 212, 244-245, 248, 255
Epiphysis 250
Epiphytes 112, 162-163
Epithelial cell 217
Epithelium 254
Epoccipital bone 102
Epoch
 Fossil record 279
 Geological time 56-57
Epoxy resin frame 612
Epsilon Centauri 21
Epsilon Crucis 21
Epsilon Hydri 20
Epsilon ring 48-49
Epson Stylus Photo 895
 color inkjet printer 574
Equal-shock intensity lines 63
Equator
 Atmosphere 500
 Quaternary period 76
 Saturn 47
 Satellite map 265
 Surface currents 297
Equatorial air 500
Equatorial current 296-297
Equatorial furrow 144
Equatorial Zone 45
Equestrian sports 554-555
Equisetites sp. 66
Equilateral triangle 622
Equisetum arvense 70, 120
Equuleus 19, 20
Era
 Fossil record 279
 Geological time 56-57
Eraser 430
Erasing stick 448
Erbium 511
Erect limb stance 82
Erh-wei 576
Eridanus 19, 20
E ring 46
Erosion 282-283
 Coastline 294-295
 Lake formation 295
 Ocean floor 298
 River features 290-291
 Rock cycle 267
 Sedimentary rocks 276
Eryops 80-81
Escalator 497-498
Escape/back button 589
Esker 286
Esophagus
 Barnacle 175
 Bird 189
 Brachiosaurus 91
 Butterfly 169
 Chimpanzee 202
 Cow 198
 Dogfish 179
 Dolphin 205
 Domestic cat 195
 Elephant 200
 Human 212, 215, 245, 248
 Lizard 185
 Rabbit 196
 Snail 177
 Spider 170
 Starfish 174
 Tortoise 187
Estomoceras perforatum 65
Estuarine mud-flat 295
Estuary 288, 290-294
Eta Centauri 21
Eta Mensae 20
Eta Orionis 18
Eta ring 48
Eta Sagittarii 21
Etching 446
Ethernet port 566
Euaethlus emilia 170
Euoplocephalus 94-95
Eurasia 76
Eurasian plate 59
Europe 44
Europa
 Cretaceous period 72-75
 Earth's physical features 264-265
 Electric train 528
 Electric tram 552
 Jurassic period 70
 Loading gauge 351
 Middle Ordovician period 64
 Quaternary period 76
 Railroad track gauge 351
 Tertiary period 74-75
 Triassic period 68
 European field elm 144
 European half-screw coupling 402
 Europium 511
 "Eurolstar" multivoltage electric train 528-529
 Eurypterid fossil 79
 Eustachian tube 243
 Eustreptospondylus 85
 Euthyneria 460
 Evacuated column 610, 611
 Evaporation 507
 Event horizon 28-29
 Evergreens 150-151
 Everlasting pea 129
 Evolvute shell 278
Evolution
 Earth 56-57
 Living things 278
Excretory pore 177
Excurrent pore 166
Exfoliation 282
Exhaust
 Catalytic converter 355
 Ford diesel engine 347
 Modern mechanics 350-351
 Paddlesteamer 391
 Exhaust clamp 562
 Exhaust collector ring 405, 406
 Exhaust cone 419
 Exhaust connection 427
 Exhaust diffuser 418
 Exhaust downpipe 350
 Exhaust fairing 419
 Exhaust gas recirculation valve 544
 Exhaust heat shield 345
 Exhaust manifold 1906 Renault 357
 ARV light aircraft 425
 Jaguar V12 engine 345
 Mid West two-stroke engine 410
 Renault Clio 351
 Exhaust nozzle 418
 Exhaust pipe
 Avro biplane 405
 Bell-47 helicopter 422
 BMW R/60 562
 Brazilian battleship 395
 Harley-Davidson FLHS 562
 Electra Glide 563
 Formula One race car 356
 Hawker Tempest fighter 409
 Honda CB750 365
 Honda VF750 364
 Kirby BSA 369
 Lockheed Electra airliner 406-407
 Oldsmobile engine 356
 Pegasus Quasar ultralight 427
 Suzuki RGV500 368
 White Steam Car 342
 World War I aircraft 404-405
 Exhaust pipe flange 411
 Exhaust port
 "Deltic" diesel-electric locomotive 326
 Four-stroke cycle 345
 Mid West 75-HP engine 410
 Two-stroke engine 367
 Velocette OHV engine 367
 Wankel engine 347
 Wankel rotary cycle 346
 Exhaust silencer 425, 427
 Exhaust stack 405
 Exhaust steam water injector control 325
 Exhaust stroke 343
 Exhaust system 368
 Exhaust tract 410
 Exhaust valve 343-345
 Exhaust valve push-rod 400
Exhaust vent
 British Rail Class 20 diesel engine 327
 Drill 601
 "Union Pacific" locomotive 326
Exine 144-145
Exit door 353
Exocarp 146-149
Exoccipital bone 185
Exocet missile launcher 397
Exodermis 162
Exoperidium 115
Exopod 172
Exoskeleton
 Insect 168
 Malacostraca 172
 Spider 171
 Exosphere 500
 Exothermic reactions 512
 Expander bolt 359
 Expandible sponge 448
 Expansile jaw 85
 Expansion lever 325
 Expansion of sail 378-379
 Expansion slot 567
 Expelling plate 397
 Expiration 255
 Exploding shell 396, 397
 Expressionist style 495
 Extended cave system 285
 Extended port air-brake 421
Extensor digitorum brevis muscle 255
Extensor digitorum longus tendon 255
Extensor digitorum tendon 251
Extensor hallucis brevis muscle 235
Extensor hallucis longus tendon 253
Extensors of hand 227
External anatomy
 Body 210-211
 Brain 257
 Ear 242-243
 Foot 253
 Hand 251
 Sperm 259
 External auditory meatus
 Homo erectus 108
 Homo sapiens 108, 220, 242
 External cranium 28
 External elastic lamina 252
 External iliac artery 215, 225, 253
 External iliac vein 215, 253
 External monitor port 567
 External nostril 184
 External oblique muscle 226
External occipital crest 220
External pubo-ischio-femoral muscle 97
External skeleton
 Insect 168
 Malacostraca 172
 Spider 171
External spermatic fascia 259
External urinary meatus 258
Extinct geyser 275
Extinction
 Dinosaur 56, 74, 82, 104
 Life 66
 Pleistocene mammals 76
 Extinct volcano 62, 272
 Igneous rock structures 275
 Mountain building 62
 Ocean floor 298
Extradors 484-485
Extra period 532
Extrusive rocks 274, 275
Eye
 Allosaurus 85
 Amphibian 182
 Anchisaurus 89
 Angling hook 562
 Beetle 168
 Bird 188
 Bony fish 181
 Brachiosaurus 91
 Bumblebee 168
 Butterfly 169
 Caiman 186
 Carnivore 194
 Chick 192-193
 Corythosaurus 98
 Crab 172
 Crayfish 175
 Crocodilian 186
 Deer hopper dry fly 565
 Devon minnow 563
 Dhow 576
 Dogfish 178
 Dolphin 204
 Elephant 201
 Figurehead 374
 Forward-facing 194
 Frog 182
 Gallinimus 86
 Gorilla 203
 Greek and Roman ships 372
 Herrerasaurus 86
 Horse 188
 Human 211, 212, 240-241
 Iguanodon 97
 Kangaroo 207
 Knot 388
 Lamprey 178
 Lion 194
 Lizard 184
 Median 170
 Octopus 177
 Pachycephalosaurius 100
 Psittacosaurus 105
 Rabbit 196
 Rat 196
 Rattlesnake 185
 Rigging 382-385
 Salamander 182
 Scallop 176
 Scorpion 170
 Seal 204
 Shrimp 172
 Simple 170-171
 Snail 177
 Snake 185
 Spider 170
 Stegoceras 101
 Stegosaurus 92
 Terrapin 187
 Triceratops 102
 Trilobite fossil 78
 Tyrannosaurus 84
 Westlothiana 87
Eyeball 241
Eye bolt 581
Eyebrow
 74-gun ship 581
 Human 212
Eyelash 212
Eyelid
 Caiman 186
 Human 213
 Snake 184
 Terrapin 187
Eyepieces 610, 611
Eye plate lug 382
Eyespot 116
F
F-14 Tomcat fighter 420
Fabric 584
Fabric covering
 Aluminum and steel wing 405
 BE 2B tail 405
 Blériot XI monoplane 401
 Steel-tube fuselage 405
Fabric lacing 405
Fabric skin 401
Fabric softener section 595
Fabry 41
Facade
 Ancient Greek building 461
 Ancient Roman building 465
 Baroque church 480-481
 Gothic church 470-472
 Modern building 496-499
 Neoclassical building 478, 485
 Nineteenth-century building 495
 Renaissance building 474
Facade pediment 481
Facade wall 470
Face
 Deadeye 385
 Human 211
 Sailmaker's mallet 384
Face mask
 Fencing 557
 Football 526
 Hockey goalkeeper 540
 Ice hockey goalkeeper 550
 Lacrosse goalkeeper 541
 Slalom skiing 555
 Facet 222-225
 Faering 374-375
 Fag end 587, 588
 Fahrenheit temperature scale 590
 Fairing 364, 369
 Fairing of landing gear 415
 Fairing panel 415
 Fairlead
 Battleship 395
 Frigate 397
 Rigging 585
 Roman corbita 373
 Fairway 546
 Falciform ligament 248
 Falco tinnunculus 189
 Falkland current 296
 Fall 382
 Fallopian tube 258-259, 261
 False acacia 136
 False anthers 141
 False door 458-459
False fruit 148-149
False ram bow 394
"False ribs" 218
False septum 151
Falx cerebri 257
Fan
 Jaguar straight six engine 344
 Jet engines 418-419
 Microwave combination oven 596-597
 Power drill 600
Fan blade
 Renault Clio 355
 Turbofan 419
Fancase 418
Fan drive shaft 345
Fan dust nozzle 412
Fan dust shield 597
Fan fold 61
Fang 170
Fan transformer 597
Fan motor 351
Fan vault 484-485
Farming ax 109
Fascia
 Ancient Roman building 465-466
 Baroque church 479, 481
 Cellphones 589
 Dome 486
 French temple 485
 Gothic building 472
 Medieval building 467, 469
 Modern building 498
 Neoclassical building 482
 Renaissance building 476-477
 Renault Clio 355
Fast forward button 577
Fat
 Cells 217
 Tissue 215, 235
Faultline
 Lake formation 292
 Mountain building 62-65
 Weathering and erosion 285
Fault plane 60
Faults 60-61, 292
 Mineral resources 280
 Mountain building 62
 Oil and gas traps 281
 Showjumping competitions 554
 Fault spring 292
 Fault structure 60
 Fault trap 281
 Fava bean 135, 152
 F-block 311
 FCC cable 571
 F clef 502
 Feather 188, 191
 Feathered loat 391
 Feathering 440-441
 Feather shuttlecock 544-545
 Feather star 174
 Feed add button 577
 Feed bilge pump 391
 Feeder station 528
 Feed list 577
 Feed name 577
 Feet
 Human 252-253
 Theropods 84
 Fei Tecnai G2
 transmission electron microscope 610
 Feldspar 267, 269, 275
 Felloe 390
 Felt blanket 447

- Felt-covered beater 516
518-519
- Felt-tip pen 444
- Female
Body 210, 211
Pelvis 218, 258
Reproductive organs 259
- Female apex 119
- Female cones
Bishop pine 124
Gymnosperm 122
Pine 122, 124
Smooth cypress 123
Yew 123
- Female flower organs 140-143
- Female flower remains 148
- Female flowers 143, 144, 148
- Female gametes
Fertilization 146-147
Gymnosperm 122
Seeds pine 122
Seaweed 116-117
Yew 123
- Female receptacles 117
- Female reproductive organs
Fern 121
Fruit 148
Moss 119
Plants 144
- Femoral artery 225, 253
- Femoral musculature 86
- Femoral nerve 238
- Femoral vein 253
- Femoro-tibial muscle 84
- Femur
Albertosaurus 84
Archaeopteryx 85
Beetle 168
Bird 189
Brachiosaurus 90
Butterfly 169
Crocodile 186
Dinosaur 82
Domestic cat 195
Elephant 201
Eryops 81
Euoplocephalus 94
Frog 185
Galimimus 86
Hare 197
Horse 199
Human 218-219, 224-225
Iguanodon 96-97
Kangaroo 206
Kentrosaurus 95
Lizard 184
Parasaurolophus 98
Pareiasaur 81
Plateosaurus 88
Platypus 206
Rhesus monkey 202
Scorpion 170
Seal 204
Spider 171
Stegoceras 101
Stegosaurus 93
Struthiomimus 87
Toxodon 107
Triceratops 102
Tuojiangosaurus 95
Turtle 187
Tyrannosaurus 84
- Fencing 556-557
- Fender
1906 Renault 536-537
BMW R/60 with Steib chair 562
Cannondale ST 1000 touring bicycle 361
Ford Model T 358-359
Harley-Davidson FLHS
Electra Glide 363
Honda VF750 364
- Husqvarna Motocross TC610 368
- Kirby BSA 569
- Lockheed Electra 406
- Motorcycle 564
- Suzuki RG500 369
- Volkswagen Beetle 341
- Weslake Speedway motorcycle 369
- Fender eye bolt 539
- Fender jazz bass guitar 513
- Fender stay 337, 362, 363
- Fender stratocaster guitar 513
- Fenestration 474, 494
- Fermentation 513
- Ferrium 311
- Fern 120-121
Fossil 66, 279
Life-cycle 121
Prehistoric Earth 68, 70, 72
Tree fern 112-113
Ferral cell 300
- Ferrite core 571
- Fertile horsetail stem 120
- Fertile oasis 285
- Fertilization 146-147
Fern 121
Gymnosperm 122
Scots pine 122
Seaweed 117
- Festoon
Ancient Roman building 462-463
Cathedral dome 487
Neoclassical building 478-479
- Fetal skull 220
- Fetlock 199, 554
- Fetus 260-261
- Fiber 154-155
- Fiberglass 548
Bow 548
Bucket seat 361
Canopy frame 425
Fuel tank 425
Racket 544
Reinforced plastic cover 329
Wheel guard 369
- Fiber insulation 602
- Fiber plate 566
- Fibrils 52
- Fibrin 253
- Fibrous capsule 256
- Fibrous habit 271
- Fibrous pericardium 250
- Fibrous septum 245
- Fibula
Albertosaurus 84
Brachiosaurus 90
Crocodile 186
Diplodocus 90
Domestic cat 195
Elephant 201
Eryops 81
Euoplocephalus 94
Hare 197
Horse 199
Human 219, 232-233
Iguanodon 96-97
Kangaroo 206
Lizard 184
Parasaurolophus 99
Plateosaurus 88
Platypus 206
Rhesus monkey 202
Seal 204
Stegoceras 101
Stegosaurus 95
Struthiomimus 87
Toxodon 107
Triceratops 102
Turtle 187
- Tyrannosaurus* 84
Fibulare 185
Ficus carica 148
Ficus sp. 137
Fid 583, 584
Fiddle block 378, 383
Held arrow 549
Field coil 600
Fielder's glove 537
Field events 542
Field goal 526-527
Fielding 558
Fielding team 536
Field judge 526
Field positions 538
Fields and particles instruments 614
Field umpire 528
Fifteenth century
Mihrab 488
Renaissance building 474-475
Style 462, 470
Terrace 490
Tracery 472
Fig 137, 148
Fighters 404-405, 408-409, 420
Fighting 556
Fighting platform 574
Figurehead
74-gun ship 580-581
Wooden sailing ship 379
Figure-eight turns 587
- Filament
Alga 116
Dicotyledon flower 126-127
Fern 121
Fertilization 146-147
Flowers 140-141, 143
Fungal 114-115
Jellyfish 167
Light bulb 319
Nebulae and star clusters 16-17
Sun 32-33
Moss 119
Pollination 144
- Filbert hog hair brush 456
- File status indicator 577
- Filicinophyta 120
- Filiform papilla 244
- Filing 455
- Filled shell 310-311
- Fillet
Ancient Greek temple 461
Dome 486
French temple 485
Gothic building 470
Neoclassical molding 480
Renaissance building 475, 477
Riling transom 381
- Film and transparency holder 570
- Filter 576
Filter access flap 594
Filter rim casing 592
Filter seal 595
Filter screw cover 595
Filter turret 610
Fimbria 258-259
- Fin
Anal 178, 181
ARV light aircraft 424
Avro biplane 402
BAe-146 components 415
Blackburn monoplane 401
Caudal 178-181
Concorde 416
Devon minnow 563
Dorsal 178-179, 181, 205
- Helicopter 425
Lockheed Electra
airliner 407
Lungfish 81
LVG CVI fighter 405
Pectoral 178, 180-181
Pelvic 179-181
Schleicher glider 426
Tornado 421
Ventral 179
World War II aircraft 408-409
- Final drive and gearbox 340
- Final-drive sprocket 335
- Fin-attachment skin 415
- Find key 590
- Fine leg 538
- Fine linen canvas 437
- Fine-toothed marble claw 453
- Finger
Anchisaurus 89
Gorilla 205
Human 211
Iguanodon 97
Pachycephalosaurus 100
Psittacosaurus 103
Stegoceras 101
Theropod 84
Fingerboard 510-511, 513
Finger-claw 85, 85
Finger hole 508
Finger key 507
Fingerless glove 527
Fingernail 231
Finger recess 571
Finger tab 548
Fimial
Asian building 490-491
Baroque church 479, 481
Gothic church 470-471
Islamic building 488-489
Medieval building 468
Neoclassical building 478
Nineteenth-century building 493
Renaissance building 476
- Finish line 542, 554-555
- Fin leading-edge attachment 415
- Finned tail 80
- Fin-root aerial fairing 421
- Fin tip 415
- Fin tip fairing 421, 424
- Fin trailing edge 415
- Fir 66
Fire 108
Fireball 10
Firebox 324-325
Fire-escape 497-498
Fire extinguisher 328
Fire-extinguisher discharge indicator 412
Fire-hole 325
Fire-making tools 109
Fireman's seat 325
Fire opal 270
Fireplace 466-467
Fire-resistant clay 454
Fire-resistant curtain 497
Fire-resistant panel 496
Fire-tube boiler 534
Fire tubes 324-325
Firewall 406, 425
Firewire ports 560
Firewire socket 587
Firing 452
Firing chamber 575
Firing pin 549
Firn 287
First century 462-464
"First down" 526-527
First pilot's seat 408
- First quarter 41
First rate ship 578
First slip 538
First transition metals 310
First violin 503, 504-505
First wheel set 329
- Fish
Bony 180-181
Breathing 180
Cartilaginous 178
Fossil 279
Holostean 75
Jawless 178-179
Fish davit 379
Fisherman's schooner 385
Fishing tackle 109
Fish-scale tile 476-477, 486
Fishtail nectaries 160
Fissure 247
Fissures 157
Fissure volcano 272
Five-line stave 502
Five yard mark 540
Fixative 430, 440
Fixed float 390
Fixed gear 346-347, 411
Fixed lug 583
Fixed-spool reel 562
Fixing screw 599
Fjord 294-295
Flagella 166
Flagellum
Beetle 168
Chlamydomonas sp. 116
Moss 119
Seaweed gametes 117
Snail 177
Sperm 259
Flag halyard 580
Flagmast 395
Flag pin 547
Flagpole 495
Flaking rock 282
Flamboyant tracery 472
Flame 312-313
Flamingo 188, 190
Flamsteed 40
Flange 492, 498
Flanged plate 425
Flank
Bird 188
Cow 198
Flanker
Canadian football 526
Rugby 530
Flank spike 95
Flap
ARV light aircraft 425
Formula One race car 356, 357
Hawker Tempest components 409
Lockheed Electra
airliner 406
Tornado 421
Flap drive screw 413
Flap lever 425
Flap seal 413, 414
Flap tip 414
Flap torque tube 424
Flap track 413
Flap-track fairing 413, 415, 572, 573
Flared bell
Brass instruments 506-507
Woodwind instruments 508-509
Flash lamp 580
Flash steam generator 342
Flash tube 397
Flask 312-313
Flat
Musical notation 502
Twin bollards 386
Flatbed scanner 570-571
Flatboard 584
- Flat bottom 391
Flat-bottomed rail 531
Flat chisel 452
Flat cone 272
Flatfish angling 562
Flat-four engine 340
Flat freight car 527
Flat horse-races 554
Flat laminae 138
Flat roof
Ancient Egyptian building 458
Neoclassical building 483
Twentieth-century building 494-495
Flat seam 384
Flat seizing 383, 389
Flat soffit 464
Flattened pericarp 151
Flattened petiole 160
Flattened stem 129
Flat-topped plateau 275, 282
Flat-topped seamant 298
Flat wire seizing 383
Flavian amphitheater 464
Flax-spinning mill 492
Fleet number 333
Flesh-eaters 194
Flesh-eating dinosaur 70
Flesh tones 433
Fleshy aril 148
Fleshy axis 143
Fleshy fruit 146-147
Fleshy hair 140
Fleshy infolded receptacle 148
Fleshy scale leaf 155
Fletch 548
Flexible hose shrouding 593
Flexible ribbon cable 580
Flex kink guard 594
Flexor digitorum longus muscle 233
Flexor digitorum tendon 251
Flexor hallucis longus muscle 233
Flexor pollicis brevis muscle 231
Flexor retinaculum muscle 231
Flexors of forearm 226
Flexors of hand 227
Flexor tubercle 85
Flex rewind 593
Flight 543
Flight-control hydraulic jack 416
Flight-control mixing unit 417
Flight-control rod 423
Flight controls 412
Flightdeck door 573
Flightdeck windshield 573
Flight feathers 188, 191
Flight instruments 425
Flight refueling receptacle 421
Flint 277
Flint tools 108-109
Flipper
Dolphin 204
Seal 204
Flicth-plated wooden chassis 342
Float 390-391
Floating disc brake 364-365
Floating floor 602
"Floating" rib 218
Flocked pastel board 441
Floodgate 604
Flood-plain 289-291
Floods 290
Floor
Gun turret 596

- Ironclad 395
 Longboat 380
 Modern building 496-498
 Nineteenth-century building 492
 Twentieth-century building 494-495
 Floor anchor 407
 Floorboard 464, 486
 Floor-joist 464
 Floor-mounted base 608
 Floor pan 340
 Floor torn 518-519
 Florence Cathedral 475, 487
 Florets 142
 Florists'
 chrysanthemum 129
 Ultraviolet light 145
 Florida current 296
 Florists' chrysanthemum 129
 Flower bud
Aechmea miniata 162
 Broomrape 165
 Bulb 155
 Clematis 151
 Florists'
 chrysanthemum 129
 Hibiscus 127
 Ice-plant 129
 Live-forever 129
Oxalis sp. 157
 Peruvian lily 129
 Rose 151
 Water lily 159
 Wind pollination 144
 Flowering plant 57, 70, 72
 Flowering shoot 155
 Flowers 140-145
Brassavola nodosa 162
 Bromeliad 113
 Broomrape 163
 Buds 140-141, 145
 Clematis 151
 Color 140, 144-145
 Dicotyledons 126-127, 141-145
 Dodder 165
 Epiphytes 162-165
 Everlasting pea 129
 Florists'
 chrysanthemum 129
Guzmania lingulata 163
 Ice-plant 129
 Involucre 129
 Monocotyledons 126, 140-141, 145
 Peruvian lily 129
 Pollination 144-145
 Rose 151
 Russian vine 151
 Scented 144
 Stem arrangements 145
 Ultraviolet light 145
 Vegetative reproduction 154
 Water lily 159
 Yew 125
 Flower scars 154
 Flower spike 143, 155
 Flower stalk
Brassavola nodosa 162
 Bulbil 154
 Clematis 151
 Dry fruit 150-151
 Fertilization 146-147
 Florists'
 chrysanthemum 129
 Fruit development 146-147
 Monocotyledons 140-141, 145
Oxalis sp. 157
 Rose 151
 Rowan 151
 Russian vine 151
 Succulent fruit 148-149
 Sycamore 151
 Water lily 159
 Flow splitter 418
 Fluid filter impeller 595
 Fluff 306
 Fluke
 74-gun ship 380
 Danforth anchor 386
 Fluorescent light 518-519
 Fluorine 508-509, 511
 Fluorite 271
 Halides 269
 Flush-riveted aluminum fuselage 425
 Flush-riveted metal-skinned wing 406
 Flush window 494
 Flute 505, 504-505, 508
 Fontanelle 220
 Fluted pilaster 462
 Fluted pinnacle 481
 Fluted shaft 478
 Flute tube 325
 Fluting 461, 463
 Flutter kick 559
 Fly 168
 Fly-by-wire side stick 573
 Fly fishing 362
 Fly-half 530
 Flying boat 406
 Flying buttress
 Gothic building 470-473
 Medieval building 466, 468-469
 Nineteenth-century building 493
 Flying Fortress bomber 408
 Flying helmet 404
 Flying jib 585
 Flying reptile 70
 Flying tackle 531
 Fly rod 562-563
 Flywheel
 Benz Motorwagen 355
 Early engines 342-343
 Etching press 447
 Mid West rotary engine 411
 Oldsmobile engine 356
 Renault Clio 351
 Steamboat 391
 Flywheel retaining thread 411
 Flywheel with balance weight 347
 FM and TV aerial 603
 Focker, Anthony 404
 Fo'c'sle 580
 Focus 65
 Focusing lens 581
 Fog 42-45
 Fog-lamp 349, 353
 Fog light 532, 363
 Foil 556-557
 Foilist 557
 Foil pommel 557
 Folded rock 60, 266
 Impermeable rock 281
 Mineral resources 280
 Strata 60-61
 Folded schist 274
 Folding foot rest 572
 Folding mountain range 274
 Folding step 326
 Folding table with integral keyboard 573
 Fold mountains 62
 Fold of mucous membrane 249
 Folds 60-61
 Foliage leaf
 Bishop pine 124
 Bud 124
 Bulb 155
 Germination 152-155
 Monocotyledon 126
 Parasitic plant 162
 Pine 124-125
 Rhizome 155
 Seedling 152-153
 Stem bulbil 155
 Yew 125
 Foliated capital 469
 Foliated frieze 469, 479
 Foliated panel 479
 Foliated scrollwork 472
 Foliated volute 476
 Foliolate papilla 244
 Foliose lichen 114
 Foliose thallus 114
 Follicle
 Dehiscent dry fruit 150-151
 Hair 235
 Ovary 258
 Fomalhaul 19, 20
 Fontanelle 220
 Font color button 576
 Foot menus button 576
 Food storage
 Bulb 155
 Corm 155
 Embryo 147
 Rhizome 155
 Root tuber 155
 Scale leaf 155
 Seed 152
 Succulent 156-157
 Swollen stem 113, 155
 Foot
Anchisaurus 89
 Bird 190
 Caiman 186-187
Corythosaurus 98
 Cow 198
Diplodocus 90
 Duck 188
 Elephant 90
 Gorilla 205
 Harp 511
Herrerasaurus 86
 Horse 198
 Human 210
Iguanodon 96
 Kangaroo 207
Pachycephalosaurus 100
 Relief-printing press 449
 Sails 374, 585
 Slug 176
 Snail 177
Stegoceras 101
Stegosaurus 92
 Toaster 598-599
Tyrannosaurus 84
 Tube 174
 Webbed 188
Westlothiana 81
 Football 524, 526-527
 Footboard 335
 Foot brake 363
 Footbridge 493
 Foot-fault judge 544
 Foot mat 363
 Foot pedal 366, 514
 Footplate 324
 Footrest
 Curtiss biplane 398-399
 Suzuki RGV500 368
 Weslake Speedway motorcycle 369
 Footrest hanger 364
 Foot rope 378-379, 382, 385
 Foot throttle 427
 Foramen cecum 244
 Foramen magnum 220
 Foraminiferans 279
 Force 320-321
 "Force play" 536
 Ford Cosworth V6
 12-valve engine 344
 Ford Cosworth V6
 24-valve engine 344
 Ford, Henry 358
 Ford Model T 538-539
 Ford turbocharged diesel engine 547
 Fore-and-aft rigged lateen sails 376
 Fore-and-aft sails 384
 Fore-and-aft schooner 385
 Forearm
 Gorilla 203
 Horse 199
 Human 210
 Movement 227
 Forearm guard 548
 Forearm pass 534
 Fore bitt 580
 Fore breast rope 387
 Forecarriage 535
 Forecastle
 74-gun ship 380
 Sailing warship 376
 Square-rigged ship 375
 Forecastle castle-deck gunport 376
 Forefoot
 Caiman 186
Diplodocus 90
Edmontonia 95
 Elephant 90
 Iron paddlesteamer 395
Stegosaurus 92
 Fore hatch tackle 579
 Forehead
 Bird 188
 Dolphin 204
 Elephant 200-201
 Horse 199
 Human 211, 212
 Foreleg
 Caiman 186
 Elephant 201
 Lizard 184
 Terrapin 187
 Forelimb
Anchisaurus 89
 Bird 188
Corythosaurus 98
Edmontonia 95
 Frog 182
 Hare 196
Herrerasaurus 86
Iguanodon 97
 Kangaroo 207
Pachycephalosaurus 100
Pittacosaurus 105
 Rabbit 196
 Rat 196
 Salamander 182
Stegoceras 101
Stegosaurus 92
 Thyreophorans 92
Triceratops 102
Tyrannosaurus 84
 Forelock 199
 Fore lower topsail 585
 Fore mast
 Iron paddlesteamer 392
 Roman corbita 372
 Sailing warship 376
 Square-rigged ship 375
 Wooden sailing ship 379
 Fore mast course 379
 Foremast hole 380
 Fore mast topgallant sail 379
 Fore mast topsail 379
 Forepeak 395
 Fore royal stay 385
 Fore sail 372, 385
 Fore sail halyard 380
 Foreset strata 285
 Fore shroud 379
 Foresight
 Rifle 549
 Target pistol 549
 Foreskin 259
 Fore spring rope 387
 Fore stay
 Rigging 382
 Roman corbita 372
 Sailing warship 376
 Wooden sailing ship 379
 Fore staysail 379, 385
 Forest-dwelling mammals 74
 Fore throat halyard 385
 Fore top 379
 Fore topcastle 376
 Fore topgallant mast 379
 Fore topmast 376, 379
 Fore topmast stay 376, 379
 Fore topmast staysail 385
 Fore topmast staysail tack 382
 Fore topsail 379
 Fore upper topsail 385
 Forewing 169
 Fore yard 376, 379
 Fore yard lift 585
 Foreged iron anchor 392
 Fork
 ARV Super 2 425
 Eddy Merckx racing bicycle 361
 Harley-Davidson FLHS Electra Glide 363
 Honda CB750 363
 Motorcycle 364
 Vespa Grand Sport 160
 Mark 1 363
 Fork blade 359
 Forked beam 380
 Forked connecting-rod 342
 Fork end 385
 Fork slide 365
 Formeret 469, 479
 Furnace 19, 20
 Fornix 236-237
 Fortifications 466
 Forum of Trajan 463
 Forward bulkhead panel 406
 Forward deck 561
 Forward defensive stroke 538
 Forward dive 558
 Forward door 415, 417
 Forward-facing eyes 194
 Forward fairing 415
 Forward-firing machine-gun 405
 Forward funnel 393, 395
 Forward fuselage structure 401
 Forward galley 416
 Forward hydroplane 397
 Forward main door 412
 Forward ramp drive 417
 Forward rocker 615
 Forward rollover structure 357
 Forwards 532, 534-535
 Forward short leg 538
 Forward spar 415
 Fossa ovalis 251
 Fossil fuel 280-281, 314-315
 Fossilization 278
 Fossil record 279
 Fossils 278-279
Acanthostega skull 80
Ankylosaurus tail club 95
 Birch leaf 74, 76
 Blue-green algae 78
 Brachiopod 65
 Clubmoss 66
 Eurypterid 79
 Fern 66
 Graptolite 65
 Horsetail 66
Hyaenodon skull 107
 Jawless fish 78
 Land plant 64
 Lungfish 81
 Nautiloid 65
 Palm bark 74
 Shark teeth 67
 Starfish 79
 Swamp plant 64
 Sweetgum leaf 76
 Titanosaurid egg 91
 Trilobite 78
 Fossil skeleton
Archaeopteryx 85
 Bat 105
Parasaurolophus 98
 Pareiasaur 81
Struthiomimus 87
Westlothiana 81
 Foster, N. 496, 498
 Foul lines 536
 Fouls 532
 Foul tackle 524
 Foul tip 537
 Foundation
 Ancient Roman building 464
 Iron paddlesteamer 392
 Modern building 496
 Nineteenth-century building 492
 Foundry plug 387
 Fountain pen 444
 Four-aspect color light signal 350
 Four-chambered heart 104
 Four-cylinder 12-HP engine 399
 Four-cylinder motorcycle 363
 Four-footed dinosaur 88, 92, 96, 100
 Four-pulley system 320
 Four-stroke combustion engine 366
 Four-stroke cycle 343
 Fourteenth century 474
 Arch 488
 Gothic building 471-473
 Medieval building 466-467
 Roof 490
 Style 470
 Fourth mast 376
 Four-wheel bogie 417
 Fovea 224
 Fowler flap 413, 414
 Foxes 194
 Fracastorius 40
 Fracture 270
 Fractured rock 34
Fragaria x ananassa 128, 150
 Fra Mauro 40
 Frame
 74-gun ship 381
 ARV light aircraft 424
 Bicycle 358-359
 Cannondale SH600
 Digital video camera 582
 Hybrid bicycle 361
 Concert grand piano 515
 Concorde, the 416
 Harley-Davidson FLHS Electra Glide 363
 Honda VF750 364
 Ironclad 395
 Longboat 380
 Medieval house 466
 Modeled sculpture 452
 Modern building 496
 Motorcycle 364
 Oscillating steam engine 390
 Racing bicycle 360
 Racket 544-545
 Relief-printing press 449
 Single scull 560
 Steam-powered Cugnot 355

- Steel 494
Upright piano 514
Weslake Speedway motorcycle 369
Frame angle 360
Frame drum 518
Frame head 540
Frame-mounted fairing 364
Fram Rupes 55
Francis turbine 314
Francium 510
Frapped turn 389
Free nerve ending 255, 259
Freestyle swimming stroke 558
Free-throw line 552-553, 555
Freewheel 361
Freewheel lock nut 358
Freewheel sprocket 360
Freezing 307
Freezing level 302
Freight car 327
Freight service 326
French baroque style 479, 482
French bowline 388
French Flamboyant style 470
French trotter 554
Fresco 454-455
Freshwater bay 291
Freshwater angling 562
Freshwater lake
Lakes and groundwater 292
Weathering and erosion 285
Freshwater turtle 186
Fret 512-515
Fret-pattern mosaic 488-489
Fretwork 461, 491
Frieze
Ancient Egyptian building 459
Ancient Greek building 461
Ancient Roman building 465, 465
Baroque church 479, 481
Cathedral dome 487
French temple 485
Medieval church 469
Neoclassical building 478-479, 482
Renaissance building 476
Twentieth-century building 495
Frigate 396-397
Fring 46-47
Fringed crumple cap 115
Fringilla coelebs 193
Fringing reef 299
Frog 182-185
Double bass bow 511
Eggs 185, 192
Fossil 278
Violin bow 510
Frog kick 559
Frond
Fern 120-121
Seaweed 116-117
Tree fern 112-113
Front air dam 354
Frontal bone
Bony fish 181
Chimpanzee 202
Human 212-213, 220-221
Frontalis muscle 226, 228-229
Frontal lobe 256-257
Frontal notch 215
Frontal process 221
Frontal rib 161
Frontal sinus 212, 245
Front axle
1906 Renault 356-357
Ford Model T 358
Honda VF750 365
Husqvarna Motocross TC610 368
Kirby BSA 369
Front brake cable
Bicycle 359
Eddy Merckx racing bicycle 361
Front brake lever 365
Front bumper 352
Front cantilever brake 359
Front crawl 558-559
Front cylinder exhaust pipe 368
Front derailleur 358-360
Front hazard avoidance camera 615
Front leg 168-169
Front light
Bicycle 360
Paris Metro 328
Italian State Railroads Class 402 328
Frontoparietal bone 183
Frontozygomatic suture 220
Front spring 357
Front wheel
Bicycle 359
Front wing 168
Front wedging 282, 286-287
Froude's early test propeller 391
Frozen rubber puck 550-551
Fruit
Bramble 130
Couch grass 113
Development 146-147
Dry 150-151
Durmast oak 151
Peach 131
Pitcher plant 113
Rowan 131
Succulent 148-149
Sycamore 151
Fruit wall 148-149, 150-151
Fruticose lichen 114
Fruticose thallus 114
"F" turret 394
Fucoxanthin 116
Fucus spiralis 116
Fucus vesiculosus 116, 117
Fuel/air intake pipe 357
Fuel and oil heat exchanger 418
Fuel and oil tank 398-399
Fuel cap 348, 369
Fuel contents indicator 413
Fuel-cooled oil cooler 419
Fuel drip tray 411
Fuel filler and vent 405
Fuel filler cap
Curtiss biplane 398
Volkswagen Beetle 340
Fuel filler neck 340
Fuel filter 419
Fuel heater 419
Fuel hose 425
Fuel injection 344, 356
Fuel inlet 419
Fuel-jetison pipe 417
Fuel-jetison valve 406
Fuel manifold 418-419
Fuel nozzle 418-419
Fuel pipe
Concorde 417
Curtiss biplane 398
Jaguar V12 345
Fuel reservoir 368
Fuel sediment bowl 359
Fuel shut-off valve cable 419
Fuel sprayer 418
Fuel supply pump 327
Fuel tank
Avro triplane 402
Benz Motorwagen 355
BMW R/60 362
Concorde, the 417
"Deltic" diesel-electric locomotive 326
Harley-Davidson FLHS Electra Glide 365
Helicopter 422-425
Honda VF750 364
Lockheed Electra airliner 407
LVG CVI fighter 405
Pegasus XL SE ultralight 426
Renault Clio 350
Suzuki RGV500 369
Volkswagen Beetle 340
Werner motorcycle 362
Weslake Speedway motorcycle 369
White Steam Car 342
Wright Flyer 398
Fuel tank breather 369
Fuel tank cradle 422
Fuel tank filler cap 369
Fuel tank filler neck 350
Fuel tank filler nozzle 427
Fuel tank sender unit 340
Fuel tank top skin 425
Fuel tap 366
Fuel vent pipe 422
Fulcrum 320-321
Full back
Australian rules football 527
Canadian football 526
Football 526
Gaelic football 529
Rugby 530
Full back line 529
Full-elliptic leaf spring 354-355
Full-elliptic steering spring 357
Full forward 528-529
Fumaroles 272-275
Funaria hygrometrica 119
Funaria sp. 119
Functionalism 496
Function button 585
Function display 520-521
Fundus 258
Fungal filament 114-115
Fungi 112, 114-115, 135
Fungia fungites 167
Fungiform papilla 244
Fungoid-structure encrustations 284
Funicle 150
Funnel
Battleship 395
Frigate 397
Iron paddlesteamer 392-395
Lizard 185
Octopus 176-177
Steamboat with paddle wheels 391
Funnel guide 126
Funnel stay 395
Furcula 189
Furled forecourse sail 375
Furled lateen main sail 376
Furled lateen mizzen sail 375, 376
Furnerius 40
Furrow 282
Furud 21
Fused carrels 140, 144, 151
Fused petals 142, 145
Fused receptacles 149
Fuselage 401, 409, 424, 572, 573
Fuselage bottom skin 424
Fuselage bracing wire 405, 426
Fuselage mid-section 412
Fuselage nose-section 412
Fuselage skin 402
Fuselage spine fairing 414
Fuselage tail-section 415
Fuselage top skin 424
Fuses 591
Fusion crust 52
Futtock shroud 378
G
Gabbro 267, 274
Gable
Gothic building 470-473
Medieval building 467, 469
Nineteenth-century building 492-493
Renaissance building 476
Gabled arch 471
Gacruy 21
Gadolinium 311
Gaelic football 528-529
Gaff 580, 385
Gagarin 41
Gait 554
Galactic center 14, 18, 20
Galactic nucleus 12-13
Galactic plane 14-15
Galaxy 10-15, 613
Galena 268
Galeocerdo cuvier 179
Galilean moons 44
Galium aparine 150
Gallbladder
Domestic cat 195
Human 248, 252
Rabbit 196
Tortoise 187
Galle ring 50-51
Gallery
74-gun ship 381
Ancient Roman building 465
Baroque church 479-480
Cathedral dome 487
Frigate 397
Medieval building 466-468
Modern building 496-497
Renaissance theater 477
Wooden sailing ship 378-379
Galley 372-397
Galley area, business class cabin 572, 573
Gallimimus 82, 84, 86-87
Gallium 311
Galois 41
Galvanized "D" shackle 386
Gambrel roof 490
Game target shooting 548
Gamete 154
Brown seaweed 116-117
Bryophyte 118-119
Fern 120-121
Fertilization 146-147
Gymnosperm 122
Moss 112
Pine 122
Vegetative reproduction 154
Yew 123
Gametophyte
Bryophyte 118-119
Fern 120-121
Liverwort 118
Moss 112, 119
Gamma 18, 21
Gamma Centauri 21
Gamma Hydri 20
Gamma Mensae 20
Gamma radiation 10
Gamma ray 22, 318-319
Gamma ring 48
Ganges River 288
Joule 514, 316
Ganges plain 65
Ganges River delta 288
Ganglion 173, 177
Gangway
74-gun ship 380
Colosseum 464
Sailing warship 377
Ganymede 44
Gape
Angling hook 562
Dolphin 204
Garboard strake 395
Gargoyle 473
Garmin Etrex handheld GPS 591
Garnet 267
Garnet-mica schist 267
Garnierite 270
Garudimimus 86
Gas 306-307
Asteroids, comets, and meteoroids 52-53
Chemical reactions 315
Massive stars 26-27
Mineral resources 280-281
NGC 2997 (spiral galaxy) 12
Small stars 24-25
Stellar black hole 29
Gas blanket 300
Gas cloud
Earth's formation 56
Milky Way 14
Nebulae and star clusters 16-17
Origin and expansion of universe 10-11
Gas current 29
Gas deposit 57, 281
Gaseous exchange in alveolus 255
Gaseous water 49
Gas exchange 134
Leaf 138-139
Photosynthesis process 138
Root 132
Sunken stoma 156-157
Wetland plants 158
Gas formation 280-281
Gas giants
Jupiter 44-45
Neptune 50-51
Saturn 46-47
Solar system 30-31
Uranus 48-49
Gaskin 198, 554
Gas loop 32-35
Gas molecule 55
Gassendi 40
Gas shell 16-17, 25
Gas tail 52-55
Gastralia 85, 87
Gas traps 281
Gastric artery 255
Gastrocnemius muscle
Albertosaurus 84
Euoplocephalus 94
Human 226-227
Iguanodon 97
Gastroepiploic vein 253
Gastropod mollusk 75
Gastropods 176, 279
Gastrovascular cavity 167
Gas turbine 418
Gate
Building 467, 490-491
Canoeing 560
Downhill skiing 552
Hydroelectric power station 314
Gate clamp 560
Gate-house 467
Gateway 460
Gatwick Express "People Mover" 328
Gauge 350-351
Gauge class 325
Gauged arch 492
Gauntlet 540, 557
Gavia gangeticus 186
G clef 502
Gear band 356
Gearbox
ARV light aircraft 425
Ford Model T 359
Harley-Davidson FLHS Electra Glide 365
Motorcycle 364, 366
Renault Clio 351
Volkswagen Beetle 340
Wind turbine 605
Gearbox bevel drive 418
Gearbox case 410
Gearbox drive spline 410
Gearbox fixing stud 556
Gearbox mount 415
Gearbox oil scavenging line 419
Gearbox unit 413
Gear cable 359
Gearcase 601
Gearcase position 600
Gear change 365
Gear-change rod 351
Gear lever
1906 Renault 357
Husqvarna Motocross TC610 368
Renault Clio 350
Two-stroke engine 366
Gear lever knob 340
Gear lever surround 352
Gear ratios 361
Gear retainer 562
Gear shift 359
Gear system 358, 366
Gears
Drills 600
Motorcycle 366
Gelatine roller 447
Gemini 18
Gemma 118
Generative nucleus 147
Generator 317
British Rail class 20 diesel engine 327
Diesel train 326
Electric train 326
Nuclear power station 314
Van de Graaff 316
Wind turbine 605
Generator cooling fan 327
Generator housing 411
Generator rotor
Hydroelectric power station 314
Mid West engine 410
Generator unit 314
Genetic material 606, 607
Genioglossus muscle 245
Geniohyoid muscle 245
Genome 607
Genital plate 175
Gentlemen's room 477
Geographic pole 38
Geological time 56-57, 279
Geranium pratense 144
Gerberette 497
Gerbil 196
Germanium 311
German-style baroque 482
Germany 326
Germinal epithelium 258

- Germination 152-155
 Cabbage seed 132
 Epigeal 152-153
 Fern spore 121
 Hypogeal 152-155
 Mushroom spore 115
 Pine 122
 Pollen grain 146-147
 Gesso 432, 435
 Get mail button 576
 Geyser 272-273, 275
 Gharial 186
 Ghost anemone 166
 Giant redwood 112
 Giant slalom 552
 Giant stars 22-23, 26
 Gibbon 202
 Gibson Les Paul guitar 513
 Gig 395
 Gilded band 490
 Gilded cross 487
 Gilded orb 487
 Gilded rib 487
 Gilded truck 378-379
 Gilding materials 431, 432
 Gill
 Bivalves 176
 Bony fish 180-181
 Dogfish 178-179
 Fungi 114-115
 Lamprey 178
 Newt 182
 Salamander 182
 Tadpole 185
 Gill filament 180
 Gill opening 178
 Gill raker 180
 Gill slit 178-180
 Gilt ironwork 482, 490
 Ginger 155
 Gingiva 247
 Ginkgo 68, 70, 72, 122-125, 279
Ginkgo biloba 68, 123
Ginkgo phylla 122
Ginkgo pluripartita 72
 Giornate 434-435
Giraffa camelopardalis 199
 Giraffe 198-199
 Girder 495
 Girdle 116
 Girdle scar 125
 Girth
 Harness racer 555
 Showjumper 554
 Gizzard
 Bird 189
Brachiosaurus 91
Euoplocephalus 94
Gallinimus 86
 Glabella
 Human skull 213, 221
 Trilobite fossil 78
 Glacial deposits 286-287, 292-293
 Glacial periods 56-57, 76
 Glacial sediments 299
 Glacial streams 286
 Glacier Bay 286
 Glacier features 286-287
 Glaciers 286-287
 Prehistoric Earth 66, 76
 River's stages 289
 Rock cycle 266-267
 Weathering and erosion 282
 Glaciers 286-287
 Gladiolus 154-155
 Gland
 19th century
 paddlesteamer 591
 Axial 175
 Butterwort 161
 Cement 173
 Green 175
 Monkey cup 161
 Mucous 177
 Pedal 177
 Poison 170, 176
 Rectal 179
 Salivary 177
 Silk 170
 Venus fly trap 160
 Glass penis 259
 GLARE upper fuselage 572
 Glass 307
 Buildings 492, 494
 Photovoltaic cell 605
 Tesserac 450
 Glass bulb 319
 Glass cooking turntable 596
 Glass curtain 497
 Glass deflector 325
 Glass enamel 450
 Glass flask 512
 Glass mosaic 489
 Glass muller 436, 440
 Glass pane 494
 Glass paper 441
 Glass plate 570, 571
 Glass prism 518
 Glass slab 436, 440
 Glass tube 519
 Glass wall 496, 499
 Glazing
 Acrylic paints 442
 Modern building 496-499
 Twentieth-century building 494
 Glazing bar 499
 Gleba 114-115
Glechoma hederacea 154
Gleditsia triacanthos 157
 Glenoid cavity 80
 Gliders 426-427
 Global positioning system (GPS) 590-591
 Global warming 301
 Globe 264
 Globe Theater 477
 Globular cluster 12, 16, 21
 Globule 24, 26
 Glomerulus 256-257
Gloriosa superba 145
 Glory lily 145
 Gloss finish
 Acrylics 442
 Oil painting 436
Glossoptera 67
 Gloster Meteor fighter 408
 Glove box 425
 Gloves
 Baseball fielder 557
 Cricket batsman 559
 Cricket wicket-keeper 539
 Fencing 556-557
 Football 527
 Ice hockey 551
 Lacrosse goalkeeper 541
 Racketball 545
 Sailing 560
 Skiing 552-553
 Soccer goalkeeper 525
 Glucose 158
 Glulam wall-plate 499
 Gluon 309
 Gluteal fold 210
 Gluteus maximus muscle 227
 Gluteus medius muscle 225
 Gluteus minimus muscle 225
 Glyph 460
 Gnathostomata 178, 180
 Gneiss 274
 Gnetophytes 122
 Gnome seven-cylinder rotary engine 400
 Gnomon 377
 Goal
 Australian rules football 528
 Gaelic football 529
 Hockey 540
 Hurling 541
 Ice hockey 550
 Lacrosse 541
 Rugby 550-551
 Soccer 524
 Goal area
 Gaelic football 529
 Handball 535
 Soccer 524
 Goal attack 535
 Goal circle 535, 541
 Goal crease 541, 550
 Goal defense 535
 Goal judge 550
 Goalkeeper
 Australian rules football 528
 Gaelic football 529
 Handball 534-535
 Hockey 540
 Ice hockey 550
 Lacrosse 541
 Netball 535
 Soccer 524-525
 Goalkeeper's equipment 540
 Goalkeeper's gloves 525
 Goalkeeper's helmet 550-551
 Goalkeeper's kicker 540
 Goalkeeper's pad 550
 Goalkeeper's shirt 525, 550
 Goalkeeper's stick 550
 Goal line
 Australian rules football 528
 Football 526
 Handball 535
 Hockey 540
 Ice hockey 550
 Rugby 530
 Soccer 524
 Goal line referee 535
 Goal net 524, 534, 550
 Goalposts
 Australian rules football 528
 Football 526
 Gaelic football 529
 Netball 535
 Rugby 530
 Goal shooter 535
 Goal square 528
 Goal third 535
 Goal umpire 528-529
 Goat 198
 Goat hair brush 458, 442
 Calligraphy 444
 Goat hake wash brush 458
 Gobi Desert 265
 Goggles
 Harness racing 555
 Skiing 552-553
 Swimming 558
 Gold 31, 268, 280-281, 458
 Gold chalcocyanide 271
 Golden barrel cactus 156
 Golden lion tamarin 205
 Gold leaf 432
 Fresco 435
 Illumination 444-445
 Smalti 450
 Vitreous glass 451
 Wood sculpture highlighting 453
 Golf 546-547
 Golgi complex 217
 Gomphoi 573
 Gonad
 Jellyfish 167
 Octopus 176
 Sea anemone 167
 Sea urchin 175
 Starfish 174
 Gondwana
 Cretaceous period 72
 Jurassic period 70-71
 Late Carboniferous period 66-67
 Middle Ordovician period 64-65
 Gong 504, 516
Goniastrea aspera 167
 Gonopore
 Barnacle 173
 Sea urchin 175
 Snail 177
 Starfish 174
 Goose-feather quill 444
 Goosegrass 150
 Goose neck 388
 Gopher 196
 Gopuram finial 491
 Gorge
 Cave 284-285
 River features 290
 Gorilla 202-203
 Gothic architecture 468, 470-475
 Gothic book script lettering 445
 Gothic stone arch 467
 Gothic torus 470
 Gouge
 Relief printing 446, 449
 Woodcarving 454-455
 Gour 284-285
 Goya 35
 GPS 590-591
 Grab handle 362
 Graben 61
 Graben lake 293
 Gracilis muscle 226-227
 Graded wash 439
 Graffian follicle 258
 Graffias 21
 Gran Chaco 264
 Grand Canyon 57, 226-227
 Grand piano 514-515
 "Grand Prix" world championships 368
 Grandstand 535
 Granite-aggregate slab 499
 Granite cladding 494
 Granular stalk 114
 Granum 139
 Grape hyacinth 155
 Graphics card 567
 Graphite 268, 311
 Graphite pencil 450
 Graphite stick 430
 Graphite-type anchor 376
 Grasping tail 202
 Grass 115
 Grate 324
 Grating 380-381
 Graver 449
 Gravitation (gravity)
 Atmosphere 300
 Force and motion 320
 Neutron stars and black holes 28
 Oceans and seas 296-297
 Universe 10
 Gravitational pull 296-297
 Gravity-feed fuel tank 405
 Gray Cliffs 276
 Gray matter 256-257, 258
 Gray squirrel 197
 Gray whale 204
 Grease 446
 Greaser 359
 Great Bear Lake 264
 Great cabin 379, 381
 Great Dark Spot 50-51
 Greater blackbacked gull 193
 Greater flamingo 190
 Greater ornament 214
 Greater palatine foramen 220
 Greater trochanter of femur 224-225
 Greater wing coverts 188
 Greater wing of sphenoid bone 220-221
 Great Lakes 264
 Great manual 514
 Great Mosque 484
 Great Red Spot 44-45
 Great Rift Valley 60
 Great saphenous vein 255
 Great stop 514
 Greek ship 372-373
 Greek-style fret ornament 483
 Green (golf) 547
 Green alga 112, 116-117
 Green calc-silicate mineral 275
 Green cell 584
 Green chlorophyll pigment 116, 138
 Green earth 434-435
 Green fluorite 269
 Green gland 173
 Greenhouse effect 36, 300-301
 "Greenhouse gas" 301
 Greenland
 Cretaceous period 73
 Late Carboniferous period 66
 Middle Ordovician period 64
 Satellite map 264
 Green light 318, 330-331
 Green seaweed 117
 Green snailcock anemone 166
 Green starboard navigation light 406
 Greenwich Meridian
 Satellite map 264-265
 Surface currents 296
 Gregorian calendar 681
 Grid lines 445
 Griffin 461
 Grikes 284
 Grille
 "Eurostar" warning horn 329
 Roman Mill 464
 Grill/griddle 596
 Grimaldi 40
 Grip
 Sailmaker's fid 384
 Sailmaker's mallet 584
 Gripe 379
 Groin
 Arches and vaults 485
 Human body 211
 Groin pad 527
 Groin vault 479, 484-485
 Grommet 373, 375, 384, 426
 Groove
 Rope starter 335
 Serving mallet 384
 Grooved racing tire 356, 357
 Groove for FCC cable 571
 Grooving 385
 Grotesque figure 476
 Ground handling wheel 422
 Ground ivy 154
 Ground-mapping radar 420
 Groundmass 268-269
 Ground roller 447
 Groundwater 292-293
 Volcanic structure 273
 Groat 450-451
 Growing point 153
 Growing tip 79
 Growth line
 Fossilized jawless fish 78
 Snail 177
 Groynes 294
 Grundtvig Church 495
 Gruppo Seven Cubist 495
 Grus 19, 20
 Gryphon 461
Gryposaurus 96, 99
 Guanine 216
 Guard
 Basketball 532
 Fencing foil 557
 Football 526
 Guard cell 158-159
 Guardrail 391-392, 395
 Guardstop 541
 Gubernator 373
 Gudgeon 375
 Gudgeon pin 345
 Gudgeon strap 574
 Guest boat boom 398
 Guiana Highlands 264
 Guidance control sensor 612
 Guide hair 126
 Guide mark 535
 Guide wheel 328
 Guinevere Planitia 36, 57
 Guitars 510, 512-515
 Gula Mons 57
 Gulf of Mexico 264
 Gulf Stream 296
 Gull 189, 193
 Gully 538
 Gully 289
 Gum 247
 Gum arabic 438
 Lithographic printing 446, 448
 Pastel making 440
 Gun
 1.3 kg gun 395
 5 pound gun 395
 4½ in gun 397
 4½ in gun 394
 11 cm gun 397
 12 cm gun 394
 12 in gun 394
 30 cm gun 394
 Battleship 394
 Frigate 397
 Measurements 394
 Sailing warship 376
 Wooden sailing ship 378, 379
 Gun battery 395
 Gun carriage 377
 Gun deck 380
 Gun loading cage 396
 Gunnery control radar dish 397
 Gunnery spotting top 394
 Gunport 581
 Sailing warship 376-377
 Wooden sailing ship 379
 Gun position 397
 Gun section 392
 Gunship 422
 Gun turret 396-397
 Battleship 394
 Frigate 397
 World War II aircraft 408
 Gut
 Cecum 170
 Gutenberg discontinuity 39
 Gutter 486, 492, 602
 Guyot 298
Guzmania lingulata 162-163
 Gymnosperm 122-125
 Gynoecium 140
 Gypsum 271
 Gyroscopic gunsight 409

- H**
- Habit 270-271
Habitat 112
 Dryland plants 156-157
 Wetland plants 158-159
Hackle 563
Hackly fracture 270
Hadar 21
Hadley cell 500
Hadrosaur 96, 98-99
Hadrosaurus 96, 99
Hafnium 510
Hagfish 178
Hail 502
Hair 254-255
 Cobra lily 160
 Golden barrel cactus 156
 Inflorescence 140, 142
 Insulating 104, 107
 Mammal 104
 Marram grass 115
 Monocotyledon 126
 Pitcher plant 113
 Root 152
 Venus fly trap 160
 Water fern leaf 158
Hair bulb 255
Hair cell 242-245
Hairdryer 515
Hair follicle 254-255
Hair gel 506
Hair-like sepal 142
Hair shaft 235
Hakatai shale 277
Hale-Bopp Comet 53
Halfback 526, 529
Halfback flank 528
Half-column 464, 468-469
Half-court line 545
Half-forward 529
Half-forward flank 528
Half-fruit 151
Half hitch 588
Half-shaft
 Ford Model T 538
 Formula One race car 556
 Half turn 545
Halide 269
Halite crystal 277
Hall
 Asian building 491
 Hypostyle 458
 Medieval building 466-467
 Modern building 496, 499
 Neoclassical building 485
Halleflinta 275
Halley's Comet 52
"Hall-keeps" 466
Hallux
 Anchisaurus 89
 Archaeopteryx 85
 Herreirasaurus 86
 Human 252
 Tyrannosaurus 84
Halo 14
Halogen headlight bulb 352
Halogens 511
Halo ring 44
Halvard
 Double topsail schooner 585
 Junk 576
 Longboat 580
 Rigging 582
 Roman corbita 372, 373
 Viking karv 574
Hamada 282-285
Hamal 19, 20
Hamate bone 250
Hammer 242, 285
 Antler 109
 Athletics 542
 Concert grand piano 515
 Mosaic 450
 Target pistol 549
 Upright piano 514
Hammer actuator 600-601
Hammer-beam roof 470, 475
Hammerhead shark 179
Hammer throw 545
Hand
 Anchisaurus 89
 Human 210
 Iguanodon 97
 Pachycephalosaurus 100
 Primate 205
 Stegoceras 101
 Tyrannosaurus 84
Handball 534-535
Handbrake 537, 539-540, 550
Handbrake control shaft 358
Handbrake quadrant 359
Hand brake wheel 351
Hand drill 600-601
Handheld gun 408
Handle
 Belaying pin 582
 Brace-and-bit 601
 Steam iron 594
Handlebars
 Bicycle 358-359
 BMW R /60 562
 Cannondale SH600 hybrid bicycle 361
 Cannondale ST 1000 touring bicycle 361
 Eddy Merckx racing bicycle 361
 Suzuki RGV500 568
Handle connector 595
Handling
 Motorcycle 560
 Touring bicycle 564
Hand protector 568
Hand rail
 "Ellerman Lines" steam locomotive 524
 Modern building 498
 Renaissance building 477
 Sailmaker's mallet 384
 Serving mallet 584, 588
 Ship's wheel 390
 TGV electric high-speed train 529
 Twentieth-century building 194
Hands 250-251
Handstand 545
Hand throttle 427
Handy Billy 382-385
"Handy man" 108
Hanger 498
Hang-giders 426-427
Hanging valley 286-287
Hapteron 116-117
Hard disk drive 567
Hard endocarp 146-147, 149
Hard granite 285
Hard hat 554
Hard-headed beater 516, 518-519
Hard metals 510
Hardness 270-271
Hard palate 212, 245
Hard rock 60
 Faults and folds 60
 Glacier 286
 River features 290-291
 Weathering and erosion 282
Hard trim 352
Hardwood implements 452
Hardwood laminate limb 548
Hardwood panels 432
Hardwood sticks 517
Hardy 450
Hare 196-197
Harley-Davidson FLHS
 Electra Glide 362-363
Harmika 491
Harmon, A.L. 494
Harmonically-tuned exhaust system 356
Harmony
 Drums 518
 Percussion instruments 516
Harness
 Avro triplane IV 402
 Equestrian sports 555
Harness racing 554
Harness strap 409
Harp 504, 510-511
Harpoon point 109
Hash mark 541
Hastate leaf 128
Hatch
 Cargo 376
 For home deliveries 602
 Iron paddlesteamer 595
 Single scull 561
Hatch board 372
Hatch coaming 381
Hatching egg 192-193
Hatchling 98
Hathor Mons 37
Haunch 484
Haustoria 163
Haustriation of colon 249
Haversian system 225
Hawker Tempest 408-409
Hawksmoor, N. 478, 481
Haworthia truncata 157
Hawse hole
 74-gun ship 581
 Sailing warship 576
 Wooden sailing ship 378
Hawse piece 581
Hawse pipe 395, 395
Hawser 586-587
Hawser fairlead 395
Hawthorne 35
Haystack boiler 354
Haze 57, 47
 74-gun ship 580
 Allosaurus 85
 Beetle 168
 Brace-and-bit 601
 Bumblebee 168
 Butterfly 169
 Caterpillar 169
 Ceratopsian 100
 Deer hopper dry fly 563
 Double bass bow 511
 Double topsail schooner 585
 Dunkeld wet fly 565
 Femur 224-225
 Frog 182
 Hammer 542
 Human 211, 212-213
 Insect 168
 Lacrosse crosse 541
 Lamprey 178
 Pachycephalosaurus 100
 Phalanx 250
 Prosauropod 88
 Racing bicycle 360
 Racing saddle 554
 Rattlesnake 185
 Sail 375, 384
 Sauropodomorph 88
 Serving mallet 388
 Snail 177
 Sperm 259
 Stegoceras 101
 Stegosaurus 92
 Tennis racket 544
 Thyreophoran 92
 Ulna 251
 Violin bow 510
Headband 544
Head beam 580
Headboard 581
Head-butting contest 100
Head crest 96
Head cringle 584
Head data cable 574
Head data cable support 574
Head earing 375
Headers
 Brickwork 485
 Nineteenth-century building 492
Head horn 94
Head joint 508
Headlight
 Bordino Steam Carriage 335
 Bulbs 552
 Ford Model T 358-359
 Renault Clio 549, 553
 Volkswagen Beetle 541
Headland 294
Headlight
 BMW R/60 562
 "Eurostar" multi-voltage electric train 329
 Harley-Davidson FLHS Electra Glide 563
 Italian State Railroads Class 402 328
 MCW Metrobus 352
 Single-decker bus 553
 "Union Pacific" locomotive 526
 Vespa Grand Sport 160 Mark 1 363
Head linesman 526
Headphone jack 578, 586, 587
Head rail 380-381
Headrest
 Airbus 580 275
 ARV light aircraft 425
 Formula One race car 356
 Hawker Tempest fighter 409
 Mazda RX-7 546
 Renault Clio 549, 552
 TGV electric high-speed train 329
 "Windcheetah" racing HPV bicycle 361
Head rope 587
Headset 361
Headstock
 Acoustic guitar 512-513
 Electric guitar 515
 Honda VF750 564
Head tube 359-361
Headward erosion 290
Headwaters 288
Hearing 257, 242
Heart
 Bird 189
 Bony fish 181
 Branchial 176
 Butterfly 169
 Chimpanzee 202
 Crayfish 175
 Dogfish 179
 Dolphin 205
 Domestic cat 195
 Elephant 200
 Euioplocephalus 94
 Frog 182
 Gallimimus 86
 Human 214-215, 250-251
 Lizard 185
 Mammal 104
 Octopus 176
 Rabbit 196
 Snail 177
 Spider 170
 Systemic 176
 Tortoise 187
Heartbeat sequence 250-251
Heart bulge 260
Heartwood 125
Heat 514-515
 Chemical reactions 312
 Global warming 300-301
 Igneous and metamorphic rocks 274
 Heat absorption 92
 Heated filament 519
 Heater element contacts 548
 Heater unit 555
 Heat exchanger
 Concorde 417
 Nuclear power station 314
 Volkswagen Beetle 540
Heat exchanger air intake 421
Heat exchanger exhaust duct 420
Heat exchanger hot-air exhaust 421
Heating element cover 597
Heating elements 594
Heating element terminal cover 597
Heat radiation 92
Heat shield
 Jet engine 419
 Motorcycle 365
 Space probes 614
Heat trapping 500
Heaver for wire serving 385
Heaving line 589
Heavy chemical elements 27
Hedera colchica 157
Hedera helix 151, 157
Heel
 Horse 198
 Human 210
 Rudder post 392
Heel molding 594
Heine 35
Heka 18
Helen Planilia 56
Helianthus annulus 145
Heliconia peruviana 145
Helicoprion besonowii 67
Helicopter landing-pad 498
Helicopters 396, 410, 422-425
Helium
 Jupiter 44-45
 Massive stars 26
 Mercury's atmosphere 35
 Neptune's atmosphere 51
 Pluto's atmosphere 51
 Periodic table 511
 Saturn 46-47
 Small stars 24-25
 Sun 52
 Uranus' atmosphere 49
Helium-3 nucleus 22
Helium-4 nucleus 22
Helium line 25
Helium tank 614
Helix 242, 623
Helix Nebula 17
Helleborus niger 159
Hellenic plate 59
Helmet
 Baseball batter 556
 Bicycle 560
 Cricket 539
 Football 526-527
 Hockey goal keeper 540
 Hurling 541
 Ice hockey 550-551
 Lacrosse goalkeeper 541
 Skiing 542
 Helmsman 372-373
 Hemal spine 180
 Hematite 268
 Hemiclypsis 56
 Hemisphere 623
 Hemispherical dome 477, 486-487, 490-491
 Hen coop 395
 Hepaticae 118
 Hepatic artery 248, 252-253
 Hepatic portal vein 255
 Heptathlon 542
 Heracleum sp. 151
 Heracleum sphondylium 129
 Heraldic device 372
 Herbaceous plants 126, 128-129
 Structure 112-115
 Woody 150-151
 Herbaceous stems 154
 Herbivores
 Carnivora 194
 Jurassic period 70
 Margocephalian 100
 Ornithopodan 96
 Prosauropods 88-89
 Sauropodomorphian 88
 Triassic period 68
 Hercules 19, 20, 40
 Herds 88
 Hermaphrodite duct 177
 Hermit shale 276
 Herodotus 40
 Herrerasaurids 68, 86
 Herring-bone pattern 488
 Hertzprung 41
 Hertzprung-Russell diagram 22-25
 Hesperidium 148
 Hestia Rupes 57
 Heterocentrotus mammillatus 175
 Heterodontosaurus 85
 Heteropoda venatoria 171
 Hexagon 622
 Hexagonal system 270
 HF radio aerial 408
 HF radio aerials fairing 417
 Hibiscus 126-127
 Hide 105
 Hide grip 384
 Hieroglyphs 458-459
 High altar 470
 High-altitude cloud 45, 50
 Highboard diving 558
 High-density minerals 280
 High-energy particle 501
 High-energy radiation 22
 High-explosive projectile 396
 High-gain antenna 615
 High-gain radio antenna 612, 613
 High-jump 542
 Highland coastline 295
 High-level jet streams 500
 High nose 357
 High-performance microscopes 610-611
 High-pressure areas 502-505
 High-pressure bleed venturi connector 419
 High-pressure compressor 418
 High-pressure cylinder 542
 High-pressure turbine 418

- High-pressure zone 300
 High-speed trains 328-329
 High Spring tide 296-297
 High temperature gas 306
 High-tension beam 496
 High-tension ignition lead 344
 High tension wire 315
 High tide 296-297
 High-velocity air duct 420
 High voltage cable 314, 355
 High-voltage connector 355
 High-voltage magnetron supply 596
 Hi-hat cymbal 518
 Hilbert 41
 Hillman anti-kink weight 562
 Hilum
 Dehiscent fruit seed 151
 Epigeal germination 153
 Hypogaeal germination 152
 Succulent fruit seed 148-149
 Himalayas
 Earth's physical features 264-265
 Geological time 56-57
 Formation 60, 62-62
 Mountain building 62-63
 Quaternary period 77
 Tertiary period 74
 Himeji Castle 490
 Hind foot
 Caiman 187
Stegosaurus 92
 Hindgut 173
 Hind leg
 Amphibian 182
 Beetle 168
 Bumblebee 168
 Butterfly 169
 Caiman 187
 Elephant 200
 Frog 182
 Hare 196
Iguanodon 97
 Lizard 185
 Rabbit 196
 Terrapin 187
 Hind limb
Anchisaurus 89
Corythosaurus 98
Edmontonia 95
 Frog 182
Iguanodon 96
 Kangaroo 207
Pachycephalosaurus 100
 Prosauropod 88
Sittacosaurus 103
 Rabbit 197
 Rat 196
 Salamander 182
Stegoceras 101
Stegosaurus 92
 Theropods 84
 Thyreophoran 92
Triceratops 102
Tyrannosaurus 84
 Hindlimb bone 105
 Hind wing 168-169
 ARV light aircraft 425
 BAe-146 components 412-415
 Hinge 571
 Hinge bracket 414
 Hinge cell 113, 160
 Hinged bin/cyclone cover 593
 Hingeless bivalve shell 79
 Hingeline 60
 Hip
Anchisaurus 89
 Human 211
 Kangaroo 207
 Lion 195
 Midway Gardens 495
Stegosaurus 92
 Hip girdle 80
 Hip joint 218, 224-225
Brachiosaurus 90
Diplodocus 90
Gallimimus 86
Parasaurolophus 98
Platesaurus 88
Stegoceras 101
Struthioimimus 87
 Hip pad 527
Hippeastrum sp. 155
 Hipped roof 476-477
Hippocampus kuda 180
Hippophae rhamnoides 156
 Hippopotamus 198
Hippopotamus amphibius 77
Hippuris vulgaris 135
 Hip-rafter 490
 Hispano Mark V 20-mm cannon 409
 Historiated boss 469
 Historiated keystone 469
 Hitachi S-3500H scanning electron microscope 611
 Hitched hauling end 383
 Hitch-kick 543
 Hitch pin
 Concert grand piano 515
 Upright piano 514
 Hittorff, J.I. 479
 Hobbles 554
 Hock 195, 198
 Hockey 540-541
 Hock joint 554
 Hog hair brush 432, 434
 Hog's-back 283
 Hog's-back jump 554
 Hoopweed 129, 130-131
Hohenbuehelia petaloides 115
 Hoisting cage 396
 Holden 43
 Holdfast 116-117
 Holding 527
 Holding timekeeper 556
 Hold pillar 393
 Hole and peg joint 373
 Hollow disk wheel 361
 Hollow pith cavity 120
 Holmium 511
 Holocene epoch
 Fossil record 279
 Geological timescale 37
 Holostean fish 73
Homarus sp. 73
 Home cinema 584-585
 Home key 578
Homesaurus pulchellus 71
 Home page 577
 Home plate 536
 Home run 536
 "Home" signal 530
 Hominid 74-75, 108-109, 202
Homocephale 101
Homo erectus 108
Homo habilis 108
Homo sapiens 57, 76, 108-109
 Honda CB750 362-363
 Honda Insight 354
 Honda VF750 364-365
 Honda-stone 452
 Honesty 150-151
 Honeycomb coral 167
 Honey guides 140-141, 145
 Honey locust 137
 Hong Kong and Shanghai Bank 496, 498
 Honshu 265
 Hood
 1906 Renault 337
 Battleship 394
 Ford Model T 339
 Gun turret 396
 Jellyfish 167
 Pitcher plant 160
 Renault Clio 349
 Volkswagen Beetle 340-341
 Hood bag 346
 Hood catch 336, 349
 Hood end 374
 Hood frame 339
 Hood iron 334
 Hood-mold 479, 481, 486
 Hood-release cable 349
 Hood-release handle 341
 Hoof 198, 554
 Hoofbone 105, 198
 Hooflike nail 36-37
 Hook
 Angling 562
 Cricket 538
 Deer hopper dry fly 563
 Devon minnow 563
 Rigging 583
 Sail 384
 Hooked beak 190
 Hooked pericarps 150
 Hooked riffer 454
 Hooker 530
 Hoop 380, 425
 Hoover Factory 495
 Hop 543
 Hopper freight car 327
 Horizon 576
 Horizontal bed rock 61
 Horizontal cleavage 270
 Horizontal muffler 529
 Horizontal fissure 255
 Horizontally opposed engine 362
 Horizontal movement 60
 Horizontal, stabilizer 425
 Horizontal tailplane 572
 Horn
 Ford Model T 339
 Glacier 286-287
 Mooring 387
 Musical instrument 503, 504
 "Union Pacific" locomotive 326
 Vespa Grand Sport 160
 Mark 1 363
 Horn balance 414, 415
 Horn bulb 339
 "Horned faces" 100
 Horny beak 96
 Horse 104-105, 198-199
 Horse chestnut 150, 137
 Horse-drawn vehicle 532
 Horsehair bow 510-511
 Horsehead Nebula 16
 Horse riding 534-555
 Horseshoe arch 484
 Horsetail 120-121
 Horsley Church 473
 Horst 61
 Horu Geyser 272
 Hose base 593
 Hose cuff electrical link 593
 Hose electricity supply connector 592
 Hose slider 592
 Hose slider seating 592
 Host plants 162-163
 Hot-air de-icing duct 414
 Hot mineral springs 272
 Hot spot
 Black holes 29
 Earth's crust 58
 Ocean floor 298
 Hot water jet 275
 Hound 378
 Hour line 377
 Household appliances 315
 House of the future 602-603
 Housing
 Alpine skiing 552
 Electric motor 342
 House spider 171
 Howe 36
Howea forsteriana 126
 Howler monkey 202
 HP Pavilion DV4 laptop 566
 Hti 490
 Huang He 265
Huayangosaurus 93
 Hub
 1906 Renault 336
 ARV light aircraft 424
 Benz Motorwagen 355
 Bicycle wheels 358-359
 Blackburn monoplane 400-401
 Bordino Steam Carriage 334
 Eddy Merckx racing bicycle 361
 Paddle wheel 390-391
 Pegasus Quasar ultralight 427
 Propellers 390
 Renault Clio 351
 Wright Flyer 399
 Hub and brake drum 350
 Hub bearing 351
 Hubble Space Telescope 612-613
 Hub bolt 338
 Hub brake shoe 338
 Hub cap
 1906 Renault 336
 Ford Model T 339
 Renault Clio 350
 Hub carrier 351
 Hub controller 604
 Hub nut 350
 Hub quick release lever 361
 Hub seal 350
 Hudson Bay 264
 Hull
 Carvel-built 376, 391
 Clinker-built 375
 Cross-section 378
 Double-ended 375
 Greek and Roman ships 372-373
 Iron and wood 392
 Hull plank 373
 Human body 210-211
 Human classification 108
 Human Powered Vehicles (HPV) 558, 360
 Humans 37, 76, 108, 202, 315
 Humber engine 345
 Humboldt current 296
 Humerus
Archaeopteryx 85
Arsinoitherium 104
 Bird 189, 191
Brachiosaurus 91
 Crocodile 186
Diplodocus 90
 Domestic cat 195
 Elephant 201
 Eryops 80
Euoplocephalus 94
 Frog 185
Gallimimus 86
 Hare 197
 Horse 199
 Human 218
Iguanodon 96
 Kangaroo 206
Kentrosaurus 93
 Pareiasaur 81
Platesaurus 88
Stegoceras 100
Struthioimimus 87
Toxodon 106
Triceratops 102
Tyrannosaurus 84
 Humic acid 284
 Hunter-killer submarine 396-397
 Hunter's bend 588
 Hunting 108, 548
 Huntsman spider 171
 Hurdle races 554
 Hurdling 542
 Hurling 540-541
 Hurricane 302-303
 Husk 150
 Husqvarna Motocross TC610 368
 Huygens mini-probe 614
Hyaeonodon 74, 107
 Hyaline cartilage 225
 Blackburn bicycle 360-361
 Hybrid car 354
 Hybrid power 355
 Hydra 18, 21
 Hydrated copper sulfate 313
 Hydraulic actuator attachment 413, 414
 Hydraulic brake calliper 424
 Hydraulic brake hose 369
 Hydraulic brake pipe 414
 Hydraulic fluid
 Disc brake 365
 Spring/muffler unit 365
 Hydraulic grab 396
 Hydraulic hand-pump 421
 Hydraulic hose 369
 Hydraulic unit 605
 Hydrocarbon 313
 Hydrochloric acid 312
Hydrochoerus hydrochaeris 197
 Hydroelectric power-station 314
 Hydrogen 308, 310
 Candle wax 312-313
 Covalent bonding 309
 Jupiter's atmosphere 45
 Massive stars 26
 Mercury's atmosphere 35
 Nebulae and star clusters 16-17
 Neptune's atmosphere 51
 Nuclear fusion in Sun 22
 Salt formation 312
 Saturn's atmosphere 47
 Small stars 24-25
 Sun 32
 Uranus' atmosphere 49
 Hydrogen alpha line 23
 Hydrogen atom 138, 596
 Hydrogen beta line 25
 Hydrogen fluoride 308
 Hydrogen gamma line 25
 Hydrogen gas 312
 Hydrogen nucleus 22
 Hydrogen requirement 158
 Hydrogen sulfide 51
 Hydroplane 396-397
 Hydroxide 268
 Hydrus 20
 Hyena 194
 Hymenoptera 168
 Hyoglossus muscle 244
 Hyoid bone 244-245, 255
Hyacrosaurus 99
 Hypaethral temple 460-461
 Hypereston 373
 Hyperlink 577
 Hyphae
 Fungus 114-115
 Mycorrhizal association 135
 Hypocotyl 152-153
 Hypodermis
 GynospERM 125
 Human 235
 Hypogaeal germination 152-153
 Hypoglossal nerve 244
Hypogymnia physodes 114
 Hypostyle hall 458-459
 Hypothalamus 236
Hypsilophodon 72, 82
 Hypural 180
Hystrix africae australis 197
 I
 I bar 393
 IBM-compatible PCs 566
 Ice 66, 307
 Glacier 286-287
 Weathering and erosion 282
 Ice age 56
 Ice-age mammals 76
 Ice block
 Ice-fall 287
 Lake formation 293
 Ice cap 287
 Ice crystal 302
 Ice cube 307
 Ice erosion 287
 Ice-fall 287
 Ice hockey 550-551
 Ice margin lake 286
 Ice plant 128-129
 Ice sheet 76
 Ichthyosaur 70-71
Ichthyostega 56, 80
 Icons 376
Icterus galbula 193
 Idle control valve 344
 Idocare 270
 Igneous intrusion 274
 Igneous rock 266-267, 274-275
 Igniter 418
 Igniter plug 419
 Ignition amplifier 345
 Ignition coils 354
 Ignition control 362
 Ignition lever 338
 Ignition lock 362
 Ignition switch 357
 Ignition trigger housing 410
Iguana iguana 82
Iguanodon 73, 96-97
 Ileocaecal fold 249
 Ileum
 Bird 189
 Frog 182
 Human 226, 249
 Rabbit 196
 Iliac crest 224-225
 Iliac fossa 224
 Iliac spine 224
 Iliac muscle 225
 Ilio-femoral muscle 84, 97
 Ilio-fibular muscle 84, 97
 Ilio-ischial joint 82
 Iliopsoas muscle 226
 Ilio-pubic joint 82
 Ilio-tibial muscle
Albertosaurus 84
Euoplocephalus 94
Iguanodon 97
 Ilium
Archaeopteryx 85
 Bird 189
Diplodocus 90
Eryops 81
Euoplocephalus 94

- Frog 185
Gallimimus 86
 Human 218
Iguanodon 96-97
Kentrosaurus 95
 Ornithischian 82
Parasaurolophus 98
Plateosaurus 88
 Saurischian 82
Stegoceras 100-101
Stegosaurus 95
Struthiomimus 87
Toxodon 107
Tuojiangosaurus 95
Tyrannosaurus 84
 Illuminated manuscript 452
 Illumination 444-445
 iMac 566
 Image controls 611
 Imaging system housing 610
 Imaging the body 214
 Imago 168
 Immature pitcher 161
 Immature spur 141
 Impasto 456-457, 442
 Impeller 547
 Imperial-Metric conversions 591, 620
 Imperial unit measurements 590
 Impermeable clay 292
 Impermeable mudstone 292
 Impermeable rock
 Cave 284-285
 Lake 292
 Mineral resources 280-281
 River's stages 289
 Impermeable salt dome 281
 Impermeable shale 292
 Impost
 Ancient Roman building 465
 Cathedral dome 484
 Gothic building 475
 Islamic building 488
 Medieval building 466, 469
 In-board 561
 Inboard elevon 417, 421
 Inboard elevon-jack fairing 416
 Inboard end 587
 Inboard engine 415
 Inboard lift spoilers 415
 Inboard trimtab 415
 Inbound line 526
 Inbox folder 576
 Incandescent light 318-319
 In-car GPS 590-591
 In-car mounting bracket assembly 590
 In-camera memory chip 580
 Incident laser light 519
 Incisive canal 245
 Incisor teeth
 Bear 194
 Chimpanzee 202
 Elephant 201
 Human 245, 246
 Lion 194
 Rabbit 196
 Rodent 196
 Toxodon 106
 Incline 468
 Incompetent bed rock 61
 Incomplete mesentery 167
 Incurrent pore 166
 Incus 242
 Indehiscent fruit 150
 Index finger 250-251
 India
 Cretaceous period 72-75
 Jurassic period 70
 Himalaya formation 62-65
 Late Carboniferous period 66
 Middle Ordovician period 64
 Mountain building 62-65
 Quaternary period 76-77
 Railroad track gauge 551
 Energy emission from Sun 22
 Tertiary period 74-75
 Threophorans 92
 Triassic period 68
 Indian ocean 75, 75, 77, 265
 Indian stick insect 192
 Indicator
 "Deltic" diesel-electric locomotive 527
 Bus 555
 Harley-Davidson FLHS Electra Glide 565
 Honda CB750 565
 MCW Metrobus 552
 Volkswagen Beetle 540
 Indicator assembly 552
 Indicator board 542
 Indicator lamp 555
 Indicator lens 541
 Indirect method mosaic creation 450-451
 Indium 311
 Indo-Australian plate 59
 Inducer 418
 Induction stroke 545
 Indus 20
 Indusium 121
 Industrial Revolution 492
 Inert gas 511, 584
 Inferior articular process 225
 Inferior concha 212, 241
 Inferior extensor retinaculum 255
 Inferior meatus 245
 Inferior mesenteric vein 255
 Inferior nasal concha 221, 241, 245
 Inferior oblique muscle 241
 Inferior orbital fissure 221
 Inferior rectus muscle 241
 Inferior vena cava 215, 252-255, 257
 Infertile swamp 288
 Infield 556-557
 Infilled swamp 291
 Inflated petiole 158
 Inflation valve 405
 Inflorescences 140
 Aechmea miniata 162
 Bromeliad 115
 Catkin 144
 Compound 142-145
 Couch grass 115
 Dodder 165
 Stem arrangements 145
 Inflorescence stalk 140-145
 Aechmea miniata 162
 Brassavola nodosa 162
 Everlasting pea 129
 Indehiscent fruit 150
 Peach 151
 Peruvian lily 129
 Rowan 151
 Russian vine 151
 Succulent fruit 148
 Vegetative reproduction 154-155
 Wind-pollinated plant 144
 Inflorescence types
 Capitulum 129, 142
 Compound umbel 145
 Dichasial cyme 145
 Raceme 129
 Single flower 145
 Spadix 145
 Spherical umbel 145
 Spike 145, 155, 162
 Infraorbital foramen 221
 Infraorbital margin 213, 221
 Infrared radiation 318-319
 Energy emission from Sun 22
 Infrared map of our galaxy 15
 Infrared board 579
 Infrared camera 578
 Infrared receiver 580
 Infrared projector 578
 Infrared sensor 609
 Infrapinnate muscle 227
 Infratemporal fenestra
 Baryonyx 85
 Camarasaurus 91
 Diplodocus 90
 Heterodontosaurus 85
 Lambeosaurus 99
 Panoplosaurus 94
 Parasaurolophus 99
 Plateosaurus 88
 Protoceratops 102
 Triceratops 105
 Infratemporal foramen 106-107
 Ingres paper 441
 Initial cave 285
 Ink 450, 444
 Ink-cartridge replacement button 574
 Ink cartridges 574
 Ink dabber 446
 Inkjet nozzle 575
 Inkjet printer 574-575
 Ink outlet hole 574
 Ink pad 445
 Ink reservoir 444, 575
 Ink roller 448, 449
 Ink sac 176
 Ink stick 444
 Ink stone 444
 Inlay 488-489
 Inlet 295
 Inlet cone 418
 Inlet manifold
 Daimler engine 545
 Jaguar V12 engine 545
 Mid West single-rotor engine 411
 Inlet manifold tract 545
 Inlet-over-exhaust (IOE) engine 562
 Inlet port 545, 567
 Inlet rotor 547
 Inlet tract 410
 Inlet valve 545, 545, 562
 Inner bin fin 592
 Inner bud scales 154
 Inner cage assembly 599
 Inner clutch drum 566
 Inner core 58-59, 41
 Inner counter 445
 Inner cyclone cone 592
 Inner dome 484
 Inner floret 129, 142
 Inner jib downhaul 585
 Inner jib halyard 585
 Inner jib stay 582
 Inner jib tack 582
 Inner layer of cortex
 Dicotyledon 127
 Epiphytic orchid 162
 Monocotyledon 127
 Wetland plants 158-159
 Inner mantle 44-47
 Inner martingale stay 585
 Inner membrane 159
 Inner planetary orbits 51
 Inner posts 528
 Inner tepal 126, 140, 145
 Inner tube 559, 424, 507
 Inner vane 191
 Innings 556, 558
 Inorganic substances 280
 Inscription 488
 Insectivorous plants 115, 160-161
 Insects 168-169, 279
 Cretaceous 72-75
 Plant food 160-161
 Pollinators 144-145
 Inselberg 285
 Insoluble solids 512
 Inspection cover
 Avro biplane 405
 Lockheed Electra airliner 407
 Inspection door 407
 Inspection panel 417
 Inspiration 255
 Instep 211
 Instrument bay 615
 Instructor's cockpit 405
 Instrument console 420
 Instrument deployment device 615
 Instrument landing system aerial 420-421
 Instrument module 615
 Instrument panel
 ARV light aircraft 425
 Bell-47 helicopter 422
 Renault Clio 555
 Schweizer helicopter 426
 Insulating column 516
 Insulating hair 104, 107
 Insulation 500
 Insulator
 Electric circuit 516
 Generating magnetism 517
 Hydroelectric power station 514
 Intaglio printing 446-447, 448
 Intake manifold 351, 354
 Intake pipe 535
 Intake port 546
 Integral ink reservoir 444
 Integrated transparency unit (TPU) 570, 571
 Integrated transport system 552
 Integument
 Ovule 147
 Scots pine 122
 Intelligent electronic door-lock 602
 Intentional foul 555
 Intercolleular septum 254
 Intercolleular leaf space 159
 Interception 526
 Inter-City travel 352
 Intercolleularia 461, 485
 Intercompressor bleed valve 419
 Intercompressor diffuser pipe 419
 Intercostal muscle 91, 255
 Interdental papilla 247
 Interdental septum 247
 Interglacial period 76
 Integer house 602, 605
 Interior light 553
 Interlobular artery 256
 Interlobular vein 256
 Interlocking spur 289
 Intermediate housing 546
 Intermediate lamella 225
 Intermediate ring 565
 Internal capsule 257
 Internal carotid artery 243, 252
 Internal combustion engine
 First cars 554
 Motorcycle engine 666
 Pioneers of flight 598
 Internal crust 28
 Internal elastic lamina 252
 Internal fuse overload protection 585
 Internal iliac artery 215, 255
 Internal iliac vein 255
 Internal jugular vein 255
 Internal skeleton 174
 Internal spermatic fascia 259
 Internal urethral orifice 257
 Internal urethral sphincter muscle 257
 International referees signals 555
 International rules 552
 International squash 544-545
 International track gauge 351
 Internet 576-577
 Internet service provider (ISP) 576
 Internode
 Canadian pond weed 158-159
 Horsetail 120
 Ice-plant 129
 Live-forever 129
 London plant 154
 Rhizome 155
 Rock stoncrop 128
 Rose stem 150
 Stem 154
 Stolon 154
 Interopercular bone 181
 Interosseous ligament 252
 Interphalangeal joint
 Baryonyx 85
 Human 231, 255
 Interplane strut 599, 404-405
 Interradicular septum 247
 Interrupter gear 404
 Intertellar cloud remains 615
 Intertragic notch 242
 Intertrochanteric line 225
 Intertropical convergence zone 500
 Interventricular septum 251
 Intervertebral disc 212, 218, 223, 245, 261
 Intestinal muscle 226
 Intestine
 Bony fish 181
 Butterfly 169
 Chimpanzee 202
 Cow 198
 Crayfish 175
 Dogfish 179
 Dolphin 205
 Elephant 200
 Frog 182
 Gallimimus 86
 Human 214
 Large 195, 202
 Lizard 185
 Sea urchin 175
 Small 182, 185, 187, 195, 198, 200, 202
 Spider 170
 Tortoise 187
 Intrados 469, 484
 Introitus 258
 Intrusive rocks 26, 275
 Invasion stripes 409
 Invertebrates
 Earth's evolution 56
 Fossil record 279
 Insects 168-169
 Marine 65
 Inverted ovolo 486
 Inverter 555
 Inverter board 570
 Inverter cooling fan 555
 Inverter cooling fan connector 555
 Inverter housing 555
 Inward dive 558, 559
 Io 44
 Iodine 511
 Ion 508
 Ionic bonding 508
 Ionic capital 460
 Baroque church 481
 French temple 485
 Renaissance building 476
 Ionic column
 Baroque church 481
 French temple 485
 Neoclassical building 485
 Ionic half-column 464
 Ionic order 460
 Iota Centauri 21
 Iota Pegasi 19
 Iota Sagittarii 21
 iPhone 4 588
 Ipomeoa batatas 154
 Iran 551
 Ireland 551
 Iridium 511
 Iridocorneal angle 241
 Iris
 Human 215, 226, 241
 Linear leaf 157
 Octopus 177
 Iris laziica 137
 Iron 511
 Earth's composition 59
 Earth's crust 58
 Golf club 547
 Magnetic domains 517
 Meteorite 52
 Nineteenth-century buildings 492
 Structure of Mercury 55
 Structure of Venus 57
 Iron armature support 455
 Ironclad 592-595
 Iron club 546-547
 Iron filings 517
 Iron hull 592-595
 Iron oxide
 Earth pigments 454
 Flesh-colored pigments 455
 Sanguine crayon 450
 Sedimentary rocks 267, 277
 Iron oxide dust 42
 Iron paddlesteamer 392-395
 Iron pyrite 79, 270
 Iron railing 495
 Iron roof 479
 Iron ship 392-395
 Iron, steam 594
 Iron tracery 495
 Iron tire 554
 Ironwork 478, 482
 Irregular galaxy 10-12, 15
 Irreversible reactions 512
 Ischial tuberosity 224
 Ischium
 Archaeopteryx 85
 Bird 189
 Parasaurolophus 98
 Plateosaurus 88
 Saurischian 82
 Stegoceras 100-101
 Stegosaurus 95
 Struthiomimus 87

- Triceratops* 102
Tyrannosaurus 84
 Ishtar Terra 56-57
 Islamic buildings 488-489,
 Islamic mosaic 489
 Islands 291, 294
 Isocline 61
 Isolated single boulders 286
 Isolated steep-sided hill
 285
 Isolator valve 525, 527
 Isoseles triangle 622
 Isoseimal lines 65
 Isotopes 510
 ISP 576
 Israel 295
 Isthmus
 Reproductive system
 258-259
 Water hyacinth 158
 Italian State Railroads
 Class 402 328
 Italic Roman lettering 445
 Item link 577
 Itonaco 434
 Ivy 150-151, 157
- J**
 Jack 514
 Jacket-wall 466
 Jack-rafter 473
 Jack staff
 Battleship 594
 Frigate 397
 Square-rigged ship 575
 Wooden sailing ship 579
 Jacob's ladder 578
 Jagged fracture 270
 Jaguar straight six engine
 344
 Jaguar V12 engine 345
 Jali 488-489
 Jamb
 Ancient Roman temple
 465
 Baroque church 479
 Medieval church 468
 Neoclassical building
 478, 482-485
 Nineteenth-century
 building 492
 Jami Masjid 488
 Javelin 542-545
 Jaw
 Brace-and-bit 601
 Hand drill 601
 Human 212, 220-221
 Power drill 601
 Rope 589
 Jawbone
Allosaurus 85
Australopithecus
 107-108
 Ceratopsian 100
 Dolphin 204
 Horse 105
 Human 220, 247
 Ornithopod 96
 Shark 178
 Snake 184
 Theropods 84
 Jawless fish 78, 178-179,
 180
 JBL Spyro speakers 586
 Jeer 577
 Jejunum 249
 Jelly 192
 Jellyfish 78, 166-167
 Earth's evolution 56
 Fossil record 279
 Jet engine 412, 418-419
 Jetliners 412-415
 Jet pipe 418-419, 425
 Jet pipe connection 419
 Jetstream 300, 418
 Jewel anemone 166
 Jewel Box 11
- Jewish calendar 618
 Jib boom 579, 582
 Jib fairhead 561
 Jib halyard 580
 Jibsail 578, 579, 585
 Jib sheet 585
 Jib stay 582
 Jib tack 582, 585
 Jockey 554-555
 Jockey wheel 358
 Jodhpurs 554
 Joint
 Cave 284-285
 Coastline 295
 Faults and folds 61
 Jointed plug 19
 Weathering and erosion
 282
 Jointed leg 79, 168
 Jointed pincer 79
 Jointed solidified lava 292
 Jointed stem 151
 Joints 224-225, 608
 Joist 464, 486
 Jones, H. 495
 Jordan 295
 Jordan River 295
 Journal 547
 Joystick 361, 520
 Judo 556-557
 Jugal bar 201
 Jugal bone 96, 102-105
 Jugal plate 94
Juglans nigra 157
 Jugular vein 215
 Juice sac 148
 "Jumbo jet" 412
 Jumps 552, 554
 Jump seat 557
 Jump shot 552, 555
 Junction
 Electrical circuit 316
 Giornata 434-435
 Photovoltaic cell 605
 Junction board 355
Juncus sp. 135
 Junior ratings' mess 397
 Junk 576
 Junk mail folder 576
 Junk ring 545
 Jupiter 50-51, 44-45, 614
 Jupp-Reese winglet 572
 Jurassic period 70-71
 Fossil record 279
 Geological time 57
 Jury mast knot 389
Justicia aurea 144
 Juvenile volcano 275
 JVC Everio camcorder 582
- K**
 Kabe 375
 Kaibab limestone 276
 Kaibab Plateau 277
 Kaiparowits formation
 276
 Kaiparowits Plateau 277
 Kalahari Desert 265
Kalanchoe
daigremontiana 154
 Kalasa finial 489
 Kalos 372
 Kame delta 286
 Kame terrace 286
 Kangaroo 206-207
 Kappa Pegasi 19
 Kara Kum 265
 Karv 374
 Kasugado Shrine of Enjoji
 490
 Kasuga-style roof 490
 Katastroma 573
 Kaus Australis 19, 20
 Sagittarius 21
 Kaus Borealis 21
 Kaus Meridionalis 21
 Kawana House 496
- Kawasaki industrial robot
 609
 Kayak 560
 Kayenta formation 276
 Kazakstania 65
Kedrostis africana 115
 Keel
 Battleship 395
 Bird 189
 Frigate 397
 Ironclad 395
 Iron paddlesteamer 392
 Longboat 280
 Sailing warship 377
 Viking ship 374-375
 Wooden sailing ship
 378
 Keel boat 560
 Keeled lesene 486
 Keeler 41
 Keelson (Kelson) 560
 19th century paddle
 steamer 391
 Ironclad 395
 Keep 466
 Keeper ring 562
 Kelvin temperature scale
 590
 Kendo 556
Kentrosaurus 92-95
 Kepler 40
 Keraia 372
 Keratin 94
 Kestrel 189
 Ketch 584, 585
 Kettle 286
 Kettle drum 519
 Kettle lake 293
 Post-glacial valley 286
 Kevlar 584, 588
 Key
 Concert grand piano
 515
 Home keyboard 520
 Motorcycle clutch 366
 Musical notation 502
 Steel lock 360
 Synthesizer 520
 Upright piano 514
 Woodwind instruments
 508-509
 Keyboard 521, 566, 611
 Keyboard instruments
 514-515, 520
 Key guard 509
 Keypad 589
 Key rod 509
 Key signature 502
 Keystone 484
 Ancient Roman
 building 465, 465
 Baroque church 479,
 481
 French temple 485
 Medieval church 469
 Neoclassical building
 478, 482
 Renaissance building
 476-477
 Keyway 390
 Kick-stand 365
 Kick-starter 365, 366
 Kidney
 Bird 189
 Bony fish 181
Brachiosaurus 90
 Dogfish 179
 Dolphin 205
 Domestic cat 195
 Elephant 200
 Frog 182
Gallimimus 86
 Human 215, 256-257
 Lizard 185
 Octopus 176
 Rabbit 196
 Snail 177
 Tortoise 187
 Kidney ore hematite 268
- Kidney-shaped palette 456
 Killer whale 205
 Killick 586
 Kiln 452
 Kimberlite 268, 275
 Kinetic energy 314-315
 Kinetic sculpture 452
 King pin 558
 King-post 473, 479
 Early monoplane
 400-401
 Pegasus Quasar
 ultralight 427
 Pegasus XL SE
 ultralight 426
 King-post strut 401
 King spoke handle 390
 Ring strut 464
 King vulture 190
 Kirby BSA racing sidecar
 369
 Kittiwake 190
 Kivis 188
 Knee
Anchisaurus 89
Corythosaurus 98
 Faering 375
 Gorilla 205
 Horse 199
 Human 211
Iguanodon 96
 Kangaroo 207
 Lion 195
Pachycephalosaurius
 100
Psittacosaurus 105
 Rabbit 197
Stegoceras 101
Stegosaurus 92
Tyrannosaurus 84
 Wooden ships 581
 Knee joint
Brachiosaurus 90
Diplodocus 90
Euoplocephalus 94
 Human 219
Parasauroplophus 98
Plateosaurus 88
Stegoceras 101
Struthiomimus 87
Toxodon 107
Triceratops 102
Tyrannosaurus 84
 Knee of the head 378
 Knee pad 527, 554
 Knee roll 559, 554
 Knife
 Palette 436
 Relief printing 446,
 449
 Knighthead 380
 Knots 388-389
 Knuckle 210
 Koala 207
 Kochab 18
 Kope 372-375
 Korolev 41
 Krypton 311
 Kuan Han-ch'ing 35
 Kubernetes 572
 Kuiper belt 50, 50
 Kunzite 271
 Kuroshio current 297
- L**
 Labellum 126, 145
 Label mold 481
 Labia 258
 Labial palp 168
 Labrum 168
Laburnum x watereri 157
 Lacolith 273-275
 Lacerta 19, 20
 Lacertilia 184
 Lacrimal apparatus 241
 Lacrimal bone
 Bony fish 181
- Human 221
Protoceratops 102
 Lacrimal canaliculus 241
 Lacrimal gland 241
 Lacrimal punctum 241
 Lacrimal sac 241
 Lacrosse 540-541
 Lacuna
 Bones and joints 225
 Clubmoss 120
 Mare's tail 135
 Wetland plants 158-159
 Lacustrine terrace 286
 Lada Terra 36, 37
 Ladder
 74-gun ship 581
 Battleship 394
 Frigate 396
 Iron paddlesteamer
 392, 395
 Roman corbita 372-375
 Train equipment 350
 Wooden sailing ship
 378
 Ladder way 395-396
 Lady Chapel, Salisbury
 Cathedral 470
 Lagomorpha 196
 Lagoon
 Atoll development 299
 Coastline 294-295
 River features 290-291
 Lagoon Nebula 21
Lagopus lagopus 195
Lagostomus maximus 197
 Lake Baikal 265
 Lake Erie 264
 Lake Huron 264
 Lake Michigan 264
 Lake Nyasa 265
 Lake Ontario 264
 Lakes 292-295
 Glacier 286-287
 Groundwater system 295
 Igneous rock structures
 275
 River features 290
 River's stages 289
 Rock cycle 266-267
 Weathering and erosion
 285
 Lake Superior 264
 Lake Tanganyika 265
 Lake Victoria 265
 Lakshmi Planum 37
 Lambda Andromedae 19
 Lambda Pegasi 19
 Lambdoid suture 220
Lambeosaurus 96, 98-99
 449
 Lamb, T. 494
 Lamella 139
 Lamina 156
 Butterwort 161
 Couch grass 113
 Dicotyledon leaf 127
 Human 222-223
 Leaf 158
 Monocotyledon leaf 127
 Seaweed 116-117
 Succulent 115
 Vegetative reproduction
 154
 Water hyacinth leaf 158
 Water lily leaf 159
Laminaria digitata
 116-117
 Laminates 548
Lamium sp. 135
 Lamp 570, 571
 Lamp bracket 356, 342
 Lamp cluster 341
 Lampland 45
 Lamprey 178
Lampropeltis ruthveni 184
Lampropeltis triangulum
annulata 184
 Lamp shield 550
 Lanceolate leaf 120, 151,
 156
- Lancet 471
 Lancet arch 475, 484
 Lancet window 470-472
 Land 39
 Amphibians 80
 Animals 64
 Atmosphere 301
 Plants 56, 64
 Rivers 288
 Vertebrates 82
 Landau body 554
 Landau iron 554
 Landing 477
 Landing and taxiing light
 414
 Landing gear 406-407,
 424-425, 573
 Landing-gear muffler 423
 Landing gear door
 BAe-146 components 414
 Concorde 416
 Hawker Tempest
 components 409
 Lockheed Electra
 airliner 406-407
 Landing gear drag strut
 401
 Landing gear fork 407
 Landing gear front strut
 400, 404
 Landing gear hydraulics
 417
 Landing gear leg 424
 Landing gear rear cross-
 member 400
 Landing gear rear strut
 400-401
 Landing gear strut 405
 Landing light
 BAe-146 jetliner
 components 414-415
 Bell-47 helicopter 422
 Lockheed Electra
 airliner 407
 Schweizer helicopter
 423
 Landing skid
 Avro triplane 405
 Blackburn monoplane
 400-401
 Helicopter 422-425
 Wright Flyer 599
 Land movement 59
 Land plants 56, 78
 Landscape features
 290-291, 294
 Land surface removal 282
 Land turtle 186
 Lane
 Athletic track 542
 Swimming pool 558
 Lane time-keeper 558
 Langrenus 40
 Language 108
 Langur 202
 Lantern 486
 Baroque church
 480-481
 French temple 485
 Neoclassical building
 478-479
 Twentieth-century
 building 494
 Wooden sailing ship
 379
 Lanthanides 310
 Lanthanum 310
 Lanyard
 Lifejacket 561
 Oar 575
 Rigging 582-585
 Roman corbita 375
 Lap 542
 Lapilli 272
 Lap strap
 ARV light aircraft 425
 Curtiss biplane 398
 Lockheed Electra
 passenger seat 407

- Pegasus Quasar ultralight 427
- Laptop computer 566, 567
- Laptops 567
- Large intestine
Brachiosaurus 90
 Chimpanzee 202
 Domestic cat 195
Eupocephalus 94
 Human 214
- Large Magellanic Cloud
 Hydrus and Mensa 20
 Our galaxy and nearby galaxies 15
 Stars of southern skies 20-21
- Large mammals 57
- Larkspur 141, 151
- Larus marinus* 195
- Larus ridibundus* 195
- Larva 168
- Laryngeal prominence 212, 244-245
- Larynx
 Amphibian 182
 Human 214-215, 244
- Laser ranger 420
- Lateen sail 375, 376, 384
- Lateral angle 215
- Lateral bracing strut 402-405, 416
- Lateral branch
 Adventitious roots 158-159
 Horsetail 120
 Vegetative reproduction 154
- Lateral bud 134
 Begonia 129
 Dicotyledon 127
 Horse chestnut 150
 Leaf scars 154
 London plane tree 134
 Rhizome 155
 Rowan twig 151
 Stem bulbil 155
 Stolon 154
- Lateral canal
 Human 247
 Starfish 174
- Lateral caudal musculature 87
- Lateral column 225
- Lateral control wheel 401
- Lateral control wire 404
- Lateral dorsal aorta 179
- Lateral epicondyle 225
- Lateral fault 61
- Lateral fault lake 293
- Lateral lacuna 257
- Lateral line 181
- Lateral malleolus 235
- Lateral mass 222
- Lateral moraine 286-287
- Lateral plantar artery 253
- Lateral plate 78
- Lateral rectus muscle 240-241
- Lateral root 135
 Broomrape host 165
 Carrot 128
 Dicotyledon 127
 Germination 152-155
 Horse chestnut 150
 Seedling 152-155
 Strawberry 128
 Sweet pea 128
- Lateral root scar 128
- Lateral sepal 141
- Lateral shield 187
- Lateral shoot 156
- Lateral strike-slip fault 61
- Lateral sulcus 237
- Lateral tepal 126
- Lateral vein 136, 159
- Lateral ventricle 257
- Lath 464
- Lathyrus latifolius* 129
- Lathyrus odoratus* 128
- Latissimus dorsi muscle 227
- Latrodectus mactans* 171
- Lattice-beam 496-497
- Latticed screen 488-489
- Latticed shade 495
- Lattice-truss 499
- Lattice window 492
- Lattice-work 493
- Laurasia
 Cretaceous period 62
 Jurassic period 70-71
 Late Carboniferous period 66-67
- Laurentia 65
- Laurentian Library 474-475
- Lava 62
 Igneous and metamorphic rocks 274-275
 Mountain building 62
 Rock cycle 266
 Volcano 272-273
- Lava eruptions 272
- Lava flow 273
 Contact metamorphism 274-275
 Mars 42
 Rock cycle 266
- Lava fragments 272
- Lavatera arborea* 151
- Lava types 275
- Lavinia Planitia 36-37
- Lawrencium 311
- Layering
 Fresco 434-435
 Pastel colors 440
- Lay-up shot 552
- LCD see Liquid crystal display (LCD)
- LCD monitor 585
- Leach 374, 384
- Lead
 Mineralization zones 281
 Minerals 268
 Periodic table 311
- Lead covering 487
- Leading block 594
- Leading edge
 Avro biplane 405
 Avro triplane 405
 BAe-146 components 413, 414-415
 BE 2B tail 405
 BE 2B wings 404
 Blackburn monoplane 401
 Concorde, the 416-417
 Hawker Tempest components 409
 Lockheed Electra airliner 406
 Northrop B-2 bomber 421
 Pegasus Quasar ultralight 427
 Wright Flyer 599
- Leading-edge aerial 421
- Leading-edge fairing 425
- Lead-in wire 319
- Lead iodide 315
- Lead nitrate 315
- Lead shot 517
- Lead wire 600
- Leaf axis 157
- Leaf bases 128, 156-157
Aechmea miniata 162
 Couch grass 115
 Dicotyledon 127
 Florists' chrysanthemum 129
Kedrostis africana 115
 Maidenhair tree 125
 Monocotyledon 126-127
 Mulberry 130
Oxalis sp. 157
 Passion flower 150
 Peach 151
 Seedling 153
 Strawberry 128
 String of hearts 157
 Tree fern 112
 Tree mallow 151
 Vegetative reproduction 154-155
 Venus fly trap 160
 Water lily 159
 Wind pollination 144
- Leaf succulents
Haworthia truncata 157
Lithops bromfieldii 157
Lithops sp. 156
- Leaf trace 127
- Leaf venation 129
- Leafy liverwort 118
- Leafy thallus 114
- Lean-to roof 468-470, 472
- Water hyacinth 158
- Leaf blade
 Butterwort 161
 Dicotyledon 127
 Leaf surface 136, 158
 Monocotyledon 127
 Vegetative reproduction 154
 Venus fly trap 160
 Wetland plants 158-159
- Leaf insect 192
- Leafless branch 120
- Leaflets 136-137
 Everlasting pea 129
 Fern 120-121
 Horse chestnut leaf 150
 Mahonia 130-151
 Monocotyledon 126
 Pinna 121, 156-157
 Rose 151
 Rowan 150
 Sago palm 125
 Tree fern 112-115
- Leaflet stalk 137
- Leaf-like structures 141-145
 Dehiscent fruit 151
 Dicotyledon flower 127
Guzmania lingulata 163
 Ice-plant 129
 Live-forever 129
 Peruvian lily 129
 Slender thistle 129
 Wind pollination 144
- Leaf margin 129
Aechmea miniata 162
 Slender thistle 129
 Vegetative reproduction 154
- Leaf notch 154
- Leaf primordium 154
- Leaf scar
 Begonia 129
 Elder 150
 Horse chestnut 150
 Ice-plant 128-129
 London plane 134
 Rock stonecrop 128
- Leaf shape 136-137
- Leaf sheath 129
- Leaf spring 538
- Leaf spring suspension 327
- Leaf stalk 128, 136-137
 Chusan palm 130
 Clematis 131
 Cobra lily 160
 Common horse chestnut 150
 Dicotyledon 127
 Everlasting pea 129
 Florists' chrysanthemum 129
Kedrostis africana 115
 Maidenhair tree 125
 Monocotyledon 126-127
 Mulberry 130
Oxalis sp. 157
 Passion flower 150
 Peach 151
 Photosynthesis 134, 158-159
 Pine 122, 124-125
 Pitcher development 161
 Pitcher plant 113, 160-161
 Primordia 134
 Stomata 139
 Strawberry 128
 Tendrils 161
 Toadflax 129
 Tree fern 112-115
 Tree mallow 151
- Leather ball making 525
- Leather grommet 373
- Leather hood 334
- Leather ink dabber 446
- Leather pad 557
- Leather upholstery 337
- Leather valance 337
- Leathery exocarps 148
- Leaves 136-137
 Abaxial surface 123, 130
 Adaxial surface 123, 130
Aechmea miniata 162
 Apex 136-137
 Apical meristem 134
 Barberry 130-151
 Bishop pine 124
Brassavola nodosa 162
 Bromeliad 112-115
 Broomrape 165
 Butterwort 161
 Canadian pond weed 158-159
 Carnivorous plants 160-161
 Cheekerbloom 136
 Chusan palm 130
 Classification 136-137
 Clematis 130-131
 Clubmoss 120
 Cobra lily 160
 Couch grass 115
 Dicotyledon 126-127
 Dryland plants 156-157
 Durmast oak 131
 Epiphyte 162-165
 Fern 120-121
 Florists' chrysanthemum 129
 Germination 152-155
Guzmania lingulata 162-165
Haworthia truncata 157
 Hinge cell 115
 Hogweed 129
 Horsetail 120
 Intercellular space 139
 Ivy 131
Kedrostis africana 115
 Lamina 136
Lithops bromfieldii 157
 Liverwort 118
 London plane tree 134
 Maidenhair tree 125
 Margin 136
 Marram grass 115
 Midrib 136
 Monkey cup 161
 Monocotyledon 126-127
 Moss 112, 119
 Mulberry 130
 Orange lily 154
Oxalis sp. 157
 Parasite host 163
 Passion flower 130
 Peach 151
 Photosynthesis 134, 158-159
 Pine 122, 124-125
 Pitcher development 161
 Pitcher plant 113, 160-161
 Primordia 134
 Stomata 139
 Strawberry 128
 Tendrils 161
 Toadflax 129
 Tree fern 112-115
 Tree mallow 151
- Vegetative reproduction 154-155
- Le Corbusier 494
- LEDs 608
- Leda Planitia 36, 37
- Ledge 381
- Leech 374, 384
- Leechline 375
- Left edge guide 575
- Leg
 Amphibian 182
 Caiman 186-187
 Crab 172
 Crayfish 172-175
 Crocodilian 186
 Elephant 200
 Frog 182
 Gorilla 205
 Human 210
 Kangaroo 207
 Lizard 184-185
 Relief-printing press 449
 Salamander 182
 Scorpion 170
 Shrimp 172
 Spider 170-171
 Tadpole 183
 Terrapin 187
 Tripod congas stand 519
 "Leg before wicket" 558
- Leg bud 260
- Leg pad 539, 551
- Leg protector 551
- Leg slip 538
- Legumes 150
- Leibnitz 41
- Lemercier, J. 486
- Lemming 196
- Lemon 148
- Lemur 202-205
- Lemur catta* 205
- Lena River 265
- Lenoir, Etienne
 Early engines 542
 First cars 534
- Lens
 Flatbed scanner 570
 Human body 241
 Microscope 610, 611
 Lens cover 581
 Lens cover assembly 582
 Lenticels 150-151, 154
 Lentiform nucleus 237
 Leo 18, 21
 Leo Minor 18, 21
Leonaspis 279
 Leonid meteor shower 52
Leontopithecus rosalia 205
Lepidodendron 66-67
 Lepidoptera 168
Lepidotes maximus 75
Leptoceratops 103
 Lepus 21
 Lesbian leaf pattern 460
 Lesene
 Ancient Roman building 462, 465
 Baroque church 480-481
 Dome 486
 French temple 485
 Gothic church 473
 Renaissance building 476-477
 Lesser trochanter of femur 225
 Lesser wing covert 188
 Lesser wing of sphenoid bone 221
- Letronne 40
- Lettering 444-445
- Levator anguli oris muscle 229
- Levator labii superioris muscle 229
- Levator palpebrae superioris muscle 241
- Levee 289-291
- Level-wind system 562
- Lever 320-321
- Le Verrier ring 50-51
- L.G. Optimus 2X 588
- Liang K'ai 35
- Libellulum longialatum* 73
- Liberty ship 392
- Libra 18, 21
- Library 485, 496
- Licence holder 332
- Lichens 114-115
- Lid
 Moss 119
 Pitchers 161
 Ships for war and trade 377
- Lid assembly 571
- Lierne 469
- Life 56, 78-79, 300
- Lifeboat 594
- Lifeboat davit 395
- Life buoy 395
- Life-cycle
 Brown seaweed 117
 Fern 121
 Insect 168
 Moss 119
 Mushroom 115
 Plants 112
 Scots pine 122
- Lifeguard 332
- Lifejacket 561
- Life of massive star 26-27
- Life of small star 24-25
- Life-raft 416
- Liferaft cylinder 397
- Lift
 Athletics 543
 Center Georges Pompidou 497
 Double topsail schooner 385
 Roman corbita 572
 Sailing warship 376-377
 Wooden sailing ship 378
- Lift bracing wire
 Biplanes and triplanes 405
 Early monoplane 400-401
 Pegasus Quasar ultralight 427
 World War I aircraft 404-405
- Lifting handle 336
- Lifting lug 530
- Lift spoiler 413, 414
- Lift wire 399
- Ligament
 Bifurcate 232
 Cricothyroid 244
 Deltoid 232
 Falciiform 248
 Foot 232
 Hip joint 224
 Iliofemoral 224
 Interosseus 232
 Ovarian 258
 Periodontal 247
 Plantar calcaneonavicular 232
 Posterior cuneonavicular 232
 Posterior tarsometatarsal 232
 Pubofemoral 224
 Talonavicular 232

- Zonular 241
 Ligature 508, 509
 Light 514-515, 518-519
 Chemical reactions
 312
 Renaissance building
 474
 Seed germination 152
 Translucent "window"
 157
 Twentieth-century
 building 495
 Ultraviolet 145
 Light aircraft 410, 424-425
 Light Emitting Diode 585
 Lighterman's hitch 589
 Light hour 14
 Lighting hole 395
 Light level sensor 581
 Lightning 45, 516
 Lights
 Bicycle 360
 MCW Metrobus 352
 Light screen 594
 Light shield 612, 613
 Light switch 539
 Lightweight plastic intake
 manifold 354
 Light-well 487
 Light year 14
 Lignite 280
 Lignum vitae bearing
 387
 Ligulate ray floret 129
 Lillenthal, Otto 398
Lilium bulbiferum 154
Lilium sp. 135, 138,
 140-141, 155
 Lily
 Bulbil 154-155
 Flower 140-141
 Leaf surface 138
 Limb
 Mammal 104
 Paddlesteamer 390
 Reptile 80
 Structure of a fold 60
 Limber hole 593
 Lime 145
 Lime-resistant pigment
 434
 Limestone
 Cave 284
 Contact metamorphism
 274
 Faults and folds 60
 Fossilized blue-green
 alga 78
 Lower Carboniferous 60
 Limestone block 470
 Limestone cladding 494
 Limestone false door 459
 Limestone spring 292
 Limestone strata 284
 Lime water 313
 Limonite groundmass
 268-269
 Limpet 176
Linaria sp. 129
 Line 562
 Linea alba 226
 Linear dune 285
 Linear leaf 129, 137
 Linebacker 526
 Line guide 563
 Line judge 526
 Line of sight 41
 Linesman
 Badminton 545
 Gaelic football 529
 Ice hockey 550
 Soccer 524
 Tennis 544
 Volleyball 554
 Lingual nerve 244
 Lingual tonsil 245
 Link 586
 Linocut 446
 Linoleum block 446, 449
 Linseed oil 456
 Lintel
 Building 459, 494
 Coastline 295
 Lintel course 485
 Lion 194-195
 Lion crest 395
 Lionfish 180
 Lip
 Flower 126, 145
 Human 212-215
 Lamprey 178
 Pollination 145
 Lip of trunk 200-201
 Lip plate 508, 508
 Lip tension 506
Liquidambar styraciflua
 76
 Liquid capacity
 measurements 590
 Liquid crystal display
 (LCD)
 Apple iPad 568
 Garmin Etrex handheld
 GPS 591
 HP Pavilion DV4 laptop
 567
 JVC Everio camcorder
 582-585
 Nikon Coolpix S1000PJ
 580
 Liquid helium 45
 Liquid hydrogen 44-47
 Liquid ink 444
 Liquids 306-307
Litchi chinensis 148
 Lithification 266
 Lithium 308, 310
 Lithium fluoride molecule
 308
 Lithium-ion battery 589
 Lithium-ion rechargeable
 battery 579
 Lithium-polymer battery
 569
 Lithographic printing 446
 Lithographic printing
 equipment 448
Lithops bromfieldii 157
Lithops sp. 156
 Lithosphere 58-59
 Little finger 250-251
 Little grebe 190
 Little toe 252-253
 Live-forever 128-129
 Liver
 Bird 189
 Bony fish 181
 Chimpanzee 202
 Dogfish 179
 Dolphin 205
 Domestic cat 195
Euoplocephalus 94
 Frog 182
Gallinimus 86
 Human 214, 248, 252
 Lizard 185
 Rabbit 196
 Tortoise 187
 Liverworts 112, 118-119
 Livestock freight car 327
 Living organisms 306
 Lizard 184-185, 582
 "Lizard-feet forms" 88
 Lizard-hipped dinosaurs
 82, 88-89
 Llama 198
 Load 520-521
 Loading arm 396
 Loading gauge 330-331
 Load space 334
 Lobby 498
 Lobe
 Liverwort 118
 Venus fly trap 160
 Lobed leaf 129, 151
 Lobsters 172
 Lobule 242
 Local Arm 14
 Local control cabinet 396
 Lock button 600
 Lock forward 550
 Lockheed Electra airliner
 406-407
 Locking lever 590
 Lock nut 351, 359
 Locks 360
 Lock washer 558-559
 Locomotion 104
 Locomotives 324-329
 Lodging knee 381
 Loft 477
 Log basket 334
 Logic board 581
 Loin
 Horse 198
 Human 210
 London Bridge 466-467
 London plane tree 134
 Longboat 380
 Long bridge 515
 Long-distance cycling 560
 Long-distance running
 542
 Longeron 405, 424
 Longitudinal channels
 120
 Longitudinal fissure
 256-257
 Long jump 542-545
 Long leading-link fork 362
 Long leg 558
 Long off 558
 Long on 558
 Long pass 552
 Long radius turns 552
 Longrod stabilizer 549
 Longship 374-375
 Longshore drift 294-295
 Long-travel suspension
 368
 Long-wave radio 318
 Look out periscope 596
 Loom 560
 Loop 388-389
 Looped prominence 32-33
 Loophole
 Medieval building
 466-469
 Renaissance building
 477
 Loop of Henlé 256
 Loose forward 530
 Loose-head prop 530
 Lopoliith 274
 Lora 127, 130
 Lorises 202
 Lost-wax casting method
 454
 Lotus flower 488
 Lotus petal 489
 Loudspeaker 520
 Lounge 392
 Louvre 493, 498
 Love-in-a-mist 150-151
 Lowell 45
 Lower Carboniferous
 Limestone 60
 Lower crankcase 410
 Lower curb of antihelix
 242
 Lower deadeye 582-583
 Lower deck 395
 Lower-energy radiation
 22
 Lower epidermis 159, 159
 Lower equipment module
 614
 Lower eyelid 215
 Lower fin 425
 Lower haze 37
 Lower LCD assembly 579
 Lower lobe of lung 215,
 254-255
 Lower seed axis 152-153
 Lower topsail 585
 Lower-wing attachment
 404
 Lower yard 595
 Low gain antenna 615
 Lowland coastline 295
 Low Neap tide 297
 Low pressure areas 300,
 302-305
 Low pressure gases 306
 Low tides 296-297
 Low-voltage supply 596
Loxodonta africana 200
 Lozenge 471, 485
 Lubricant 366
 Lucarne window 480-481,
 486
Lufengosaurus 89
 Luff 384-385
 Lug 382, 586
 Lugger 384
 Lug sail
 Junk 376
 Sail types 384
 Lumbar nerves 258
 Lumbar vertebrae
 Crocodile 186
 Domestic cat 195
 Hare 197
 Horse 199
 Human 222-223
 Kangaroo 206
 Platypus 206
 Rhesus monkey 202
 Seal 204
 Lumbrical muscle 231
 Lump hammer 452-455
 Lunae Planum 43
Lunaria annua 151
 Lunate bone 230
 Lunette 480
 Lung
 Amphibian 182
 Bird 189
Brachiosaurus 91
 Chimpanzee 202
 Dolphin 205
 Domestic cat 195
 Elephant 200
Euoplocephalus 94
 Frog 182
Gallinimus 86
 Human 214-215, 252,
 254-255
 Lizard 184-185
 Rabbit 196
 Snail 177
 Snake 184
 Spider 170
 Tortoise 187
 Lungfish 80, 81
 Lunule 231
 Lures 562-563
 Lutetium 311
 LVG CVI fighter 405
 Lychee 148
 Lycoming four-cylinder
 engine 423
 Lycoming six-cylinder
 engine 422
 Lycopodophyta 64, 120
 Lymphocytes 253
 Lynx 18, 21
 Lynx helicopter 396
 Lyra 19, 20
 Lysosome 217
 Macroscopule 55
 Macs 566
 Macula 240-241
 Madagascar 265
 Madreporite 174, 175
Madrillus sphinx 205
 Maenianum summum 465
 Magazine 548-549
 Magellanic Cloud 15, 20
 Maginus 40
 Maglev train 528-529
 Magma
 Igneous and
 metamorphic rocks 26
 Mountain building 63
 Ocean floor 298-299
 Rock cycle 266
 Volcanoes 272
 Magma reservoir
 Igneous rock structures
 275
 Volcanic structure 273
 Magnesium 310
 Earth's composition 39
 Earth's crust 58
 Seawater salt content
 296
 Magnesium alloy oil sump
 pan 354
 Magnesium housing for
 air intake 355
 Magnesium riser 548
 Magnet 598, 605
 Magnet array 615
 Magnetic axis 28
 Magnetic compass 423
 Magnetic field 58
 Magnetism 316-317
 Magneto
 Avro triplane 402
 Hawker Tempest
 components 408
 Wright Flyer 399
 Magneto driver 567
 Magnetometer 614
 Magnetosphere 38
 Magnetron assembly 596,
 597
 Magnetron cooling fan
 596, 597
 Magnetron cooling fan
 mounting 597
 Magnetron perforated
 heat sink 597
 Magnitude 22
 Magnolia 57, 72
 Mahonia 130-131
 Maidenhair tree 122-123
 Maillot 386
 Main deck passenger door
 375
 Main deck windows 573
 Main engines 614
 Main fan 596, 597
 Main fan electrical supply
 597
 Main-line signaling
 system 350-351
 Main motor casing 595
 Main printed circuit board
 (PCB) 591
 Mainrail head 379
 Main sail
 Dhow 376
 Roman corbita 373
 Sailing rigs 385
 Square-rigged ship 375
 Main screen 584
 Mains earthing wire 596
 Mains electricity supply
 lead 585
 Main sequence star
 Massive stars 26
 Objects in universe 11
 Small stars 24
 Stars 22-23
 Mains flex 594
 Mains flex clamp 594
 Main sheer strake 393
 Main sheet
 Longboat 380
 Roman corbita 373
 Sailing dinghy 561
 Viking karv 375
 Main shroud 573
 Mains lead 597-598
 Main spar bridge 413
 Mains power on/off
 switch 585
 Mains spade contacts
 594
 Main stay 377, 379
 Mains supply lead 594
 Maintenance button 574
 Main topcastle 377
 Main topgallant mast 377,
 378
 Main topgallant sail 379
 Main topgallant stay 379
 Main topmast 377, 379
 Main topmast topcastle
 377
 Main topsail 379
 Main topsail halyard 385
 Main topsail yard 379
 Main top yard 377
 Main turbine 597
 Main wale 381
 Main wheel 426, 595
 Main wing bracing-strut
 401
 Main wing-strut 427
 Main yard
 Dhow 376
 Sailing warship 377
 Wooden sailing ship
 379
 Maize 127
 Major calyx 256
 Major coverts 188, 191
 Malachite 433
 Malacostraca 172
 Malaysia 331
 Male
 Bladder 257
 Body 210, 211
 Pelvis 259
 Reproductive organs
 259
 Urinary tract 257
 Male apex 119
 Male catkin 144
 Male cone 122-123, 24
 Male fern 120-121
 Male flower organs
 140-143
 Male flowers
 Fertilization 146-147
 Gymnosperms 122
 Painter's palette 145
 Seaweed 116-117
 Succulent fruit 148
 Wind-pollinated plant
 144
 "Mallard" express steam
 locomotive 324-325
 Mallet
 Marble carving 452
 Ships and sailing 385,
 384, 388
 Tubular bells 516
 Malleus 242
 Malpighian tubule
 Butterfly 169
 Spider 170
 Malus 373
Malus sp. 126
Malus sylvestris 149
 Mammals 104-107
 Carnivora 194
 Cetacea 204
 Cretaceous period 72
 Earth's evolution 56-57
 Fossil record 279
 Jurassic period 70
 Lagomorpha 196
 Large 57
 Marsupalia 206

- Monotremata 206
 Pinnipedia 204
 Primates 202
 Proboscidea 200
 Rodentia 196
 Shrewlike 70
 Small 56
 Tertiary period 74-75
 Ungulates 198
 Mammoth 107
Mammut 75
Mammuthus 76, 77, 104
 Mandapa 491
 Mandarinfish 180
 Mandible
 Acanthostega 80
 Ankylosaurus 94
 Arsinoitherium 104
 Baryonyx 85
 Bat 105
 Bear 194
 Beetle 168
 Bird 188-189
 Bony fish 181
 Camarasaurus 91
 Chimpanzee 202
 Crayfish 173
 Crocodile 186
 Diplodocus 90
 Elephant 201
 Eryops 80
 Euoplocephalus 94
 Hare 197
 Heterodontosaurus 85
 Horse 199
 Human 220-221, 244-245
 Hyaenodon 107
 Iguanodon 96
 Kangaroo 206
 Lambeosaurus 99
 Lion 194
 Moeritherium 105
 Panoplosaurus 94
 Parasauroplophus 99
 Phiomia 105
 Plateosaurus 88
 Protoceratops 102
 Rattlesnake 185
 Rhesus monkey 202
 Seal 204
 Stegoceras 100-101
 Styracosaurus 102
 Toxodon 106
 Triceratops 105
 Turtle 187
 Tyrannosaurus 84
 Mandrills 202-203
 Mane 194, 199
 Manganese 281, 510
 Manharness knot 589
 Manifold connector 555
 Manilla rope 589
 Manipulator 610
 Man-of-war 578
 Mansard roof 490
 Mantellisaurus 96-97
 Mantle
 Earth 58-59, 58-59, 65
 Mars 45
 Mercury 55
 Moon 41
 Mollusks 176-177
 Neptune 51
 Pluto 51
 Saturn 51
 Regional
 metamorphism 274
 Uranus 49
 Venus 57
 Maple 127
 Map projections 264-265
 Maracas 504, 516-517
 Marble 274
 Marble block 453
 Marble breaking
 equipment 450
 Marble mosaic 489
 Marble sculpture 452
 Marble tessera 450
 Marble veneer 462
Marchantia polymorpha
 118
 Mare Crisium 40
 Mare Fecunditatis 40
 Mare Frigoris 40
 Mare Humorum 40
 Mare Imbrium 40
 Mare Ingenii 41
 Mare Moscovense 41
 Mare Nectaris 40
 Mare Nubium 40
 Mare Orientale 41
 Mareotitis Fossae 43
 Mare Serenitatis 40
 Mare Smithii 41
 Mare's tail 155
 Mare Tranquillitatis 40
 Mare Vaporum 40
 Margaritifer Sinus 43
 Margin
 Lamina 116-117, 161
 Leaf 129, 156-157
 Needle 124
 Water lily leaf 159
 Marginal shield 187
 "Margined heads" 100
 Marginocephalians 85, 100-105
 Maria 40
 Marine invertebrates
 65
 Marine plants 56
 Marine reptiles 57, 70
 Marine sediments 280
 Marine turtles 186
Mariopsis 66
 Markab 19, 20
 Markeb 21
 Marlin 588
 Marlinspike 585, 589
 Marsopets 202
 Marram grass 113
 Mars 50, 42-45, 615
 Mars Exploration Rover
 (MER) 615
 Mars Exploration Rover
 spacecraft 615
 Marsh 295
 Marsupials 104, 206-207
 Martellange, E. 479
 Martingale 582, 557
 Martingale stay 585
 Mary Rose 576
 Mascaron 487
 Mask 460, 487, 556
 Ancient Roman
 building 465
 Cathedral dome 484
 Neoclassical building
 482
 Masonry apron 487
 Mason's mark 470
 Mason's tools 485
 Mass
 Atoms and molecules
 509, 520
 Earth 50
 Jupiter 26, 44
 Mars 50
 Mercury 50
 Neptune 51
 Planets 50-51
 Pluto 51
 Saturn 51
 Stars 22
 Uranus 51
 Venus 50
 Massive habit 270-271
 Massive stars 26-27
 Mass measurements 590
 Massospondylidae 89
 Mass-production 358-359, 492
 Mass transportation 532
 Mast
 Battleship 394
 Frigate 397
 Greek galaxy 572
 Iron paddlesteamer 592
 Junk 576
 Longboat 580
 Roman corbita 573
 Sailing 561
 Sailing warship 576-577
 Submarine 397
 Tea clipper 392
 Three-masted square-
 rigged ship 575
 Viking karv 575
 Wooden sailing ship
 578-579
 Mast band 582
 Master cylinder
 Disc brake 365
 Harley-Davidson FLHS
 Electra Glide 365
 Honda VF750 364
 Master shipwright 574
 Master's sea cabin 581
 Masthead
 Roman corbita 573
 Viking karv 575
 Wooden sailing ship
 578
 Mast head bend 589
 Masthead pulley for tye
 halyard 575
 Mast hoop 585
 Mastoid fontanelle 220
 Mastoid process 220, 242
 Mast partner 581
 Mast step 592
 Mast truck 572
 Matar 19
 Match play 546
 Maternal blood pool 260
 Maternal blood vessel 260
 Mathematical symbols
 621
 Mato Grosso 264
 Matter 506-507
 Electrical charge 516
 Identification 512
 Mature ruptured follicle
 258
Mausonites spriggi 65
 Maxilla
 Ankylosaurus 94
 Baryonyx 85
 Bear 194
 Bony fish 181
 Camarasaurus 91
 Chimpanzee 202
 Diplodocus 90
 Elephant 201
 Eryops 80
 Euoplocephalus 94
 Frog 185
 Horse 105
 Human 212, 220-221, 244-245, 246, 248
 Iguanodon 96
 Lion 194
 Pachycephalosaurus 100
 Prenocephale 100
 Stegoceras 100
 Toxodon 106
 Maxillary fenestra 90
 Maxilliped 173
 Maxwellian diagram 518
 Maxwell Montes 56, 57
 Mazda RX-7 546
 McLaren Mercedes MP4-
 13 556-557
 MCW Metrobus 552-553
 ME 262 fighter 408
 Meadow cranesbill 144
 Meadow rue 157
 Meadow sage 145
 Meander 461
 Meanders 288-289, 290
 Measurement units 620
 Meatus 242-245
 Mechanical semaphore
 signal 530
 Mechanical weathering
 282
 Mechanics 550-551
 Mechanism of respiration
 255
 Medallion 476
 Media guide button 577
 Medial epicondyle 225
 Medial malleolus 253
 Medial moraine
 Glaciers 286-287
 River's stages 289
 Medial rectus muscle
 240-241
 Median canal 243
 Median cubital vein 253
 Median eye 170
 Median glossoepiglottic
 fold 244
 Median nerve 258
 Median sulcus 244
 Median wing coverts 188
 Medieval castles 466-467
 Medieval churches
 468-469
 Medieval houses 466-467
 Medinet Habu, Egypt 459
 Mediterranean Sea 74, 265
 Mediterranean sea
 anemone 166
 Medium-wave radio 518
 Medulla 114, 254, 256
 Medulla oblongata 212, 256-257
 Medullary cavity 224
 Medullary pyramid 256
 Medullary ray 125
Medullosa 66
 Megaspores 122
Megazostrodon 104
 Megrez 19
Meiolania 77
 Meissner's corpuscle
 254-255, 259
 Mekong River 265
 Melanin 254
Melanosaurus 68, 88-89
 Melon 149, 205
 Melting glacier 286, 289
 Meltwater 287, 289
 Meltwater pool 286
 Membrane
 Chloroplasts 159
 Chorioallantoic 192
 Egg 193
 Shell 192
 Thylakoid 159
 Memory stick 581
 Mendel 41
 Mendeleev 41
 Mendeleevium 511
 Meninges 257
 Menkalinan 21
 Menkar 19, 20
 Menkent 21
 Mensa 20, 21
 Mental foramen 213, 220-221
 Mentalis muscle 229
 Mental protuberance 221
 Mental symphysis 220
 Mentolabial sulcus 215
 Menu key 590
 Merak 19
 Merchants' Exchange 495
 Mercury 50, 54-55
 Mercury (metal) 281, 311, 519
 Mericarp 151
 Meristematic cells 154
 Merlon 466
 Mermaid's purses 192
 Mersenius 40
 Merus 172, 175
Merycoiodon 75
 Mesa 275, 277, 282
 Mesentery 167, 182
 Mesocarp 146-147, 148, 148-149
 Mesoglea 167
 Mesohyal 166
 Mesophyll 155
 Bishop pine needle 124
 Dicotyledon leaf 126
 Marram grass 113
 Monocotyledon leaf
 126
 Palisade layer 159
 Spongy layer 159
 Mesosphere 500
 Mesothorax 168
 Mesozoic era
 Cretaceous period 72
 Dinosaurs 82
 Fossil record 279
 Geological timescale 57
 Jurassic period 70
 Reptiles 80
 Triassic period 68
 Mess 597
 Message area 576
 Message display area 576
 Metacarpals
 Archaeopteryx 85
 Arsinoitherium 104
 Baryonyx 85
 Bird 189, 91
 Brachiosaurus 91
 Cow 198
 Diplodocus 90
 Domestic cat 195
 Elephant 90, 201
 Eryops 80
 Euoplocephalus 94
 Frog 185
 Gallimimus 86
 Hare 197
 Horse 198-199
 Human 218-219, 250
 Kangaroo 206
 Lizard 184
 Parasauroplophus 99
 Plateosaurus 88
 Platypus 206
 Rhesus monkey 202
 Seal 204
 Stegoceras 100
 Toxodon 106
 Triceratops 105
 Tyrannosaurus 84
 Metacarpophalangeal
 joint 85
 Metal cook/grill tray 596
 Metal grill/griddle 596
 Metalliferous muds 299
 Metallizing 486
 Metal modeling
 implements 452
 Metal needle pad 584
 Metal nib 444
 Metal riser 455
 Metal runner 455
 Metals 510
 Metal tire 324
 Metal wire conductor
 516-517
 Metamorphic aureole 26
 Metamorphic rocks 26, 274-275, 266-267
 Metamorphosis
 Amphibian 182
 Frog 185
 Insect 168
 Metasoma 170
 Metatarsals
 Albertosaurus 84
 Archaeopteryx 85
 Brachiosaurus 90
 Crocodile 186
 Domestic cat 195
 Elephant 201
 Eizyops 81
 Euoplocephalus 94
 Frog 185
 Hare 197
 Horse 199
 Human 218-219, 252
 Iguanodon 96-97
 Kangaroo 206
 Lizard 184
Parasauroplophus 98
Plateosaurus 88
 Platypus 206
 Rhesus monkey 202
 Scorpion 170
 Seal 204
 Spider 171
Stegoceras 100-101
Struthiomimus 87
Toxodon 107
Triceratops 102
 Metathorax 168
 Metaxylem 127, 152-153
 Meteor 52, 501
 Meteorite
 Asteroids, comets, and
 meteoroids 52
 Earth's atmosphere 58
 Moon 41
 Ray crater 54
 Meteorite impact 54, 40
 Meteoroids 52-53
 Solar system 50
 Methane
 Jupiter 45
 Neptune and Pluto
 50-51
 Saturn 47
 Uranus 48-49
 Methane cirrus clouds
 50-51
 Metis Regio 36
 Metope 460
 Metric-Imperial
 conversions 620
 Metric unit
 measurements 590
Metricium senile 166
 Metrobus 552-553
 Metrolink tram 532
 Mexican hat plant 154
 Mexican mountain king
 snake 184
 Mexican true red-legged
 tarantula 170
 Mexico 351
 Mezzanine 467, 496
 Miaplacidus 21
 Mica 26, 270
 Mice 104, 196
 Michelangelo 55
Microasterias sp. 112
 Microfilament 217
 Microneedle 606
 Microorganisms 58, 78
 Microphone 581
 Micropipette 606
 Microporous filter 592
 Microprocessor
 Personal computer 567
 Digital camera 580
 Microscopes 610-611
 Microsoft Kinect 578
 Microsoft Zune HD 587
 Microsporangium 122
 Microspores 122
 Microsporophyll 122
 Microtubule 217, 259
 Micro-USB (Universal
 Serial Bus) socket 589
 Microwave oven 515
 Microwave radiation 10
 Microwave combination
 oven 596-597
 Microwaves 518, 596
 Midbrain 256
 Middle ear ossicles 242
 Middle finger 250-251
 Middle leg
 Beetle 168
 Bumblebee 168
 Butterfly 169
 Middle lobe of lung 215,
 254-255
 Middle meatus 241,
 245
 Middle nasal concha 212,
 221, 241, 245

- Middle phalanx 219, 250, 252
Middle rail 381
Midfielders
 Gaelic football 529
 Lacrosse 541
 Soccer 524
Midgut 173
Mid-latitude band 36
Mid-latitude cyclones 502
Mid-ocean ridge 281, 298-299
Mid-off 558
Mid-on 558
Midrib
 Dicotyledon leaf 126-127
 Durmast oak leaf 151
 Fern fronds 121
 Hogweed leaf 129
 Ice-plant leaf 129
 Live-forever leaf 129
 Liverwort 118
 Monkey cup 161
 Moss leaf 119
 Spiral wrack 116
 Sweet chestnut leaf 156
 Tree fern 115
 Venus fly trap 160
 Water lily leaf 159
Midships fence 373
Midships section 392
Midwater current 297
Midway Gardens 495
Mid West single-rotor engine 411
Mid West twin-rotor engine 411
Mid West two-stroke engine 410
Miele washer-dryer 594, 595
Mihrab 488
Milan Cathedral 475
Milankovic 45
Milk snake 184
Milk teeth 246
Milky quartz 268, 271
Milky Way 14-15
 Northern stars 18
 Solar system 50
 Stars of southern skies 20
Mill 462, 464, 492
Millstone grit 60-61
Milne 41
Milton 55
Mimas 46
Mimosa 21
Mimulopsis solmsii 145
Minaret 488-489
Mineral-filled fault 60-61
Mineral-rich deposits 298
Minerals 268-269
 Carnivorous plants 160
 Epiphytes 162
 Fossils 278
 Mineral features 270-271
 Mineral resources 280-281
 Photosynthesis 158-159
 Wetland plants 158
 Xylem vessel 154
Mineral spicules 166
Mineral spring 273
Mineral wool 605
Minim 502
Minmi 95
Minor calyx 256
Minor coverts 188, 191
Mint 109
Mintaka 18
Miocene epoch
 Fossil record 279
 Geological timescale 57
Mira 19, 20
Mirach 19, 20
Miranda 48
Mirfak 19, 20
Mirzam 18, 21
Missile launcher 397
Mississippian period 56
Mississippi Delta 290-291
Mississippi-Missouri River 264
Mississippi River 291
Mist 306
Mistle thrush 190
Mistletoe 162
Mitochondrial crista 217
Mitochondrial sheath 259
Mitochondrion 217, 239
Mitral valve 251
Mixosaurus 57
Mizar 19
Mizzen backstay 378
Mizzen bitt 581
Mizzen course 379
Mizzen mast
 Dhow 376
 Iron paddlesteamer 392
 Junk 376
 Sailing warship 377
 Square-rigged ship 375
 Wooden sailing ship 378
Mizzen sail 375, 585
Mizzen shroud 378
Mizzen stay 378
Mizzen top 378
Mizzen topcastle 377
Mizzen topgallant sail 379
Mizzen topmast 377, 378
Mizzen topsail 379
Mizzen yard 376-377, 378
Moat 466-467
Mobile sculpture 452
Modeling 452
Modeling tools 454
Modem 576, 577
Moderator 314
Modern buildings 496-499
Modern engines 344-345
Modern humans 57
Modern jetliners 412-415
Modern military aircraft 420-421
Modern piston aero-engines 410-411
Mode switch 586
Modified cuticle 157
Modified lateral shoots 156
Modified leaflets 129
Modified leaves
 Barberry 150-151
 Cobra lily 160
 Dryland plants 156-157
 Everlasting pea 129
 Golden barrel cactus 156
 Pitcher development 161
 Spines 156
 Strawberry 128
Modified shoots 156
Modified stipules 128-129
Modillion
 Baroque church 479
 Neoclassical building 478
 Renaissance building 475
Moenaave formation 276
Moenkopi formation 276
Moeritherium 104
Mohorovic discontinuity 39
Mohs scale 270-271
Molar tooth
 Arsinoitherium 104
 Australopithecus 107
 Bear 106, 194
 Chimpanzee 202
 Elephant 201
 Horse 105
 Human 246
 Hyaenodon 107
Moeritherium 105
Opossum 106
Phomia 105
Toxodon 106
Mold 278
Molded bracket 484
Molded corbel 493
Molding 485
 Ancient Egyptian temple 458-459
 Asian building 490
 Baroque church 480-481
 Dome 486-487
 Gothic church 471-472
 Medieval building 466, 469
 Neoclassical building 479-480, 482
 Renaissance building 475-477
 Ship's shield 395
Molding tool 454
Molds 114
Molecular orbitals 308
Molecules 306, 308-309
Mollusks 176-177
 Belemnite 71
 Nautiloid 69
Molten bronze 454
Molten core 59
Molten rock
 Igneous and metamorphic rocks 274
 Matter 306
 Ocean floor 298
 Plate movements 58
 Rock cycle 266
 Volcanoes 272
Molting 171
Molybdate 269
Molybdenum 310
Mongoses 194
Monkey cup 161
Monkeys 202-205
Monitor
 Digital camera 580
Monoceros 18, 21
Monoclinical fold 60
Monocline 61
Monoclinic system 270
Monocoque chassis 365
Monocoque shell 548
Monocotyledonous petals 140, 145
Monocotyledonous sepals 126, 140, 145
Monocotyledons 126-127, 140-141, 145
Monodon monoceros 205
Monograptus convolutus 65
Monolithic shaft 465
Monoplanes 400-401, 402, 406
Monotremes 206-207
Montes Apeninus 40
Montes Cordillera 41
Montes Jura 40
Montes Rook 41
Monteverdi 35
Montgolfier brothers 398
Monument 470
Moon 40-41
 Objects in universe 11
 Solar eclipse 32
 Tides 296-297
Moonquake region 41
Moons
 Jupiter 44
 Mars 42
 Neptune 50
 Saturn 46
 Solar system 50
 Uranus 48
 Mooring 386-387
 Moorish arch 484
 Moraine 286-287, 292-295
 Moray eel 180
Mortar 452
Mortice 373
Mortise 486, 492
Morus nigra 150
Mosaic 450-451
Islamic building 488-489
Tools 450
Mosque 484, 488
Mosses 112, 114, 118-119
 Epiphytic 162
 Life-cycle 119
 Structure 119
Moth 168
Motherboard
 Digital camcorder 585
 Personal computer 567
Motherboard cable 578
Mother's milk 104
Motion 520-521
Motion sensor 579
Motorcross motorcycle racing 568
Motor air intake 595
Motor assembly 574
Motorcycle chassis 362, 364-365
Motorcycle engines 366-367
Motorcycle racing 568
Motorcycles 362-365
Motorcycle sidcar 362, 369
Motor-driven bogie axle 326
Motor electronic control module (ECM) 355
Motor end plate 228, 239
Motorhead 592, 593
Motorized buses 332
Motor neuron 228, 239
Motor operating signal 330
Motor whaler 397
Motte 466
Mouchette 472
Mounds 286
Mountain bikes 558, 560
Mountain building 56, 58, 62-65
Mountain hollows 286
Mountain lake 288
Mountain range 288
Mountain physical features 264
Earth's physical features 264
Faults and folds 60
Geological time 56
Igneous and metamorphic rocks 274
Mountain building 62
Ocean floor 298
Plate movements 59
Mountain ridge 295
Mountain ring 34
Mountains 62-65, 267
Mountain spring 288
Mounting bracket 390
Mounting bush 365
Mounting splines 366
Mose 521, 566, 611
Mouse and collar 379
Mouth
 Barnacle 173
 Bony fish 180-181
 Cobra lily 160
 Cow 198
 Crayfish 175
 Dogfish 179
 Dolphin 204
 Elephant 200
 Frog 182
 Gorilla 205
 Horse 199
 Human 211, 212, 244-245, 248
 Jellyfish 167
 Kangaroo 204
 Lamprey 178
Lizard 184
Pitcher plant 161
Rabbit 196
Rat 196
Sea anemone 166-167
Seal 204
Sea urchin 175
Snail 177
Spider 170
Starfish 174-175
Mouth diffuser 430, 440
Mouthpiece
 Brass instruments 506
 Clarinet 508
 Tenor saxophone 509
 Trumpet 506
 Wind synthesizer 521
Movement
 Gas particles 307
 Objects 520
MP5 players 586
MRI scan
 Head 214
 Brain 236
Mt. Everest 264
Mu Andromedae 19
Muav limestone 277
Muccini brush 434
Mucosa 248
Mucosal gland 254
Mucous gland 177
Mucronate leaf apex 137
Mucus-secreting duodenal cells 217
Mud 267, 275
Mud crab 279
Mud flat 295
Mud pools 272-273
Mud river 298
Mulberry 130
Muliphen 21
Mullion
 Gothic church 470, 472-473
 Modern building 497-499
 Renaissance building 476
 Small-scale rock formation 60-61
 Twentieth-century building 494
Multicellular animals 56
Multicellular organisms 78
Multicellular soft-bodied animals 56
Multifoil 472
Multifunction display 573
Multigabled roof 492
Multiplait nylon 588
Multiplate clutch 364, 366
Multiple fruits 148-149
Multiplier reel 562
Multi-ply tire 416
Multipolar neuron 239
Multitouch interface 368
Mu Orionis 18
Mu Pegasi 19
Musa lacatan' 146
Muscari sp. 155
Musci 118
Muscle 226-229
 Abductor digiti minimus 231, 235
 Adductor longus 225
 Adductor magnus 227
 Adductor pollicis 231
 Abductor pollicis brevis 231
 Anal sphincter 249
 Arrector pili 235
 Cricothyroid 244-245
 Dilator 241
 Dorsal interosseous 235
 Energy system 315
 Extensor digitorum brevis 235
 Extensor hallucis brevis 235
 Flexor digitorum longus 235
 Flexor hallucis longus 235
 Flexor pollicis brevis 231
 Flexor retinaculum 231
 Genioglossus 245
 Geniohyoid 245
 Gluteus medius 225
 Gluteus minimus 225
 Hyoglossus 244
 Iliacus 225
 Inferior oblique 241
 Inferior rectus 241
 Intercostal 255
 Internal urethral sphincter 257
 Lateral rectus 240-241
 Levator palpebrae superioris 241
 Lumbrical 231
 Medial rectus 240-241
 Myohyoid 245
 Opponens digiti minimi 231
 Opponens pollicis 231
 Orbicularis oris 245
 Papillary 251
 Pectineus 225
 Peroneus brevis 235
 Peroneus longus 235
 Psoas major 225, 257
 Pyloric sphincter 249
 Soleus 235
 Sphincter 241
 Styloglossus 244
 Superior longitudinal 245
 Superior oblique 241
 Superior rectus 241
 Tensor tympani 243
 Thyrohyoid 244
 Tibialis anterior 235
 Tibialis posterior 235
 Urethral sphincter 257
 Vastus lateralis 225
 Vastus medialis 225
Muscovite 269
Muscular septum 176
Mushroom anchor 586
Mushroom coral 167
Mushrooms 114, 115
Music 514, 586
Musical Instrument
 Digital Interface (MIDI) system 520-521
Musical manuscript 502-503
Musical notation 502-503
Musical score 502-503, 505
Music gallery 477
Musicians 504
Music software 520
Muslim calendar 618
Mussels 176
Mussosaurus 68
Mutes 506-507
Muttaborrasaurus 97
Muzzle 199, 397
Mycelium 114-115
Mycorrhizal association 135
Myelin sheath 239
Mylar 384
Myocardium 250-251
Myofibril 228
Myohyoid muscle 245
Myometrium 260
N
Nail
 Corythosaurus 98
 Edmontonia 95

- Elephant 90
Human 231
Iguanodon 96-97
Stegosaurus 92
Triceratops 102
Nair Al Zaurak 19, 20
Naismath, James 532
Namib Desert 265
Naos 461, 463, 485
Nape 188, 210
Napier Saber 24-cylinder engine 408
Naris
Anchisaurus 89
Ankylosaurus 94
Arsinoitherium 104
Australopithecus 108
Baryonyx 85
Brachiosaurus 91
Camarasaurus 91
Corythosaurus 98
Edmontonia 95
Eryops 80
Euoplocephalus 94
Homo erectus 108
Homo habilis 108
Homo sapiens 108
Hyaenodon 107
Iguanodon 96
Lambeosaurus 99
Moeritherium 105
Opussum 106
Panoplosaurus 94
Parasaurolophus 99
Plateosaurus 88
Protoceratops 102
Smilodon 107
Stegoceras 100-101
Stegosaurus 92
Styracosaurus 102
Triceratops 102-105
Tyrannosaurus 84
Narrow gauge track 351
Narwhal 205
Nasal bone
Ankylosaurus 94
Bear 194
Frog 185
Human 220-221
Lion 194
Panoplosaurus 94
Protoceratops 102
Toxodon 106
Nasal cavity
Chimpanzee 202
Domestic cat 195
Elephant 200
Human 245, 248
Rabbit 196
Nasal horn 104
Nasalis 229
Nasal passage 200
Nasal plug 205
Nasal septum 215, 221, 241
Nash 21
Nasion 221
Nasolacrimal duct 241
Nasopharynx 245
Natal cleft 210
Natal cocoon 24, 26
Native elements 268
Natural bridge 290
Natural elements 310
Natural fly 562
Natural forces 314
Natural glass 306
Natural gut strings 544
Natural lakes 292
Natural satellites 40
Natural sponge 438
Nautiloid mollusk 69
Fossil 65
Navajo Mountain 277
Navajo sandstone 276
Nave
Ancient Egyptian temple 458-459
Baroque church 479
Cathedral dome 484
Gothic church 470-473
Medieval church 468-469
Ship's wheel 390
Navel 211, 260
Nave plate 390
Navicular bone 252
Navigating bridge 594
Navigational aerial 425-424
Navigation area 577
Navigation buttons 577
Navigation camera (Navcam) 615
Navigation display 575
Navigation light 575
Navigator's cockpit 420
Navigator's seat 408
Navka 37
Nazca plate 59
Neanderthals 108
Neap tides 296-297
Nebulae 16-17
Cone 612
Galaxies 12-15
Great, Orion 615
Life of massive star 26
Milky Way 14-15
NGC 1566 (Seyfert galaxy) 15
Omega 615
Small stars 24
Structure of nebula 24
Neck
Acoustic guitar 512-513
Anchisaurus 89
Calligraphy character 445
Arsinoitherium 104
Corythosaurus 98
Electric guitar 515
Golf club 547
Harp 511
Horse 199
Human 211, 224-225, 247, 258-259
Iguanodon 97
Pachycephalosaur 100
Rat 196
Saurodomorpha 88
Sculling oar 560
Stegoceras 101
Stegosaurus 92
Stringed instruments 510
Tenor saxophone 509
Theropod 84
Violin 510
Necking 581
Nectar 142, 160-161
Nectaries 141, 144-145
160-161
Needles
Bishop pine 124
Pine 124-125
Scots pine 122
Yew 125
Nefertiti Corona 57
Negative electric charge 316
Negative ions 508, 510
Neo-Baroque style 492-493
Neo-Byzantine style 492-493
Neoclassical style 478-483, 496
Neodymium 310
Neo-Gothic style 492-493
Neo-Greek style 492-493
Neon 35, 511
Nepenthes mirabilis 161
Nephron 256
Neptune 51, 50-51
Neptunides polychromus 12
Neptunium 311
Nerve
Ampullar 242
Bronchial 254
Cervical 258
Cochlear 245
Common peroneal 258
Cranial 258
Cutaneous 258
Deep peroneal 258
Digital 251
Femoral 258
Hypoglossal 244
Lingual 244
Lumbar 258
Median 258
Optic 240
Posterior tibial 258
Pudendal 258
Pulp 247
Radial 258
Sacral 258
Sciatic 258
Spinal 223, 258
Superficial peroneal 258
Superior laryngeal 244
Thoracic 258
Ulnar 251, 258
Vestibular 245
Vestibulocochlear 245
Nerve cell 217, 257, 259
Nerve cord 173
Nerve fiber 255
Nerve ring 175
Nervous system 176, 258-259
Nervous tissue 166
Netball 554-555
Network port 566
Neural spine
Arsinoitherium 104
Bony fish 180
Brachiosaurus 90
Eryops 81
Euoplocephalus 95
87
Iguanodon 96
Parasaurolophus 98
Plateosaurus 89
Stegoceras 100-101
Stegosaurus 95
Toxodon 106
Triceratops 102
Tuojiangosaurus 95
Tyrannosaurus 85
Neurofilament 259
Neuron 259
Neurotransmitter 259
Neutralization 512
Neutrino 22
Neutron 22, 28
Neutrons 508, 509, 510
Neutron stars 28-29, 26-27
New Guinea 265
New mail button 576
New Moon 41
News item summary 577
News reader window 577
New State Paper Office 482
Newton (N) 520
Newton, Isaac 320
Newton meter 320-321
Newton's Motion laws 320-321
Newts 182
New World monkeys 202-205
New Zealand 265, 272
Next/Previous track control 587
Next file button 577
Next key 568
NGC 1566 (Seyfert galaxy) 15
NGC 2997 (spiral galaxy) 12
NGC 4406 (elliptical galaxy) 11
NGC 4486 (elliptical galaxy) 12
NGC 5256 (spiral galaxy) 11
NGC 5754 (colliding galaxies) 9
NGC 6656 (globular cluster) 21
NGC 6822 (irregular galaxy) 11
Nib types 444
Niche
Ancient Roman building 462
Asian temple 491
Baroque church 480
Cathedral dome 487
Gothic church 471-472
Islamic building 488
Medieval building 467
Neoclassical building 482
Renaissance building 476
Nickel 57, 49, 281, 311
Nickel-iron 270
Nigella damascena 151
Nikon Coolpix S1000PJ 580-581
Nile crocodile 186
Nile River 264-265
Nimbostratus cloud 502
Nimbus cloud 502
Nineteenth-century buildings 479, 482, 492-495, 494
Ninth-century building 490
Nintendo 3DS 578
Nintendo Wii Fit Plus 579
Niobe Planitia 56, 57
Niobium 310
Nippers 450
Nipple
Human 211
Marsupials 206
Nissl body 259
Nitrate ions 512
Nitrates 160
Nitrogen
Atmospheric composition 501
Helix Nebula 17
Mars' atmosphere 45
Periodic table 311
Pluto's atmosphere 51
Venus' atmosphere 37
Nitrogen dioxide gas 312
Nobelium 311
Noble gases 310-311
Nock 548
Noctis Labryrinthus 42, 45
Nocturnal mammals 104
Node
Bamboo 151
Brassavola nodosa 162
Canadian pond weed 158-159
Couch grass 115
Dicotyledons 127
Horsetail 120
Ice-plant 129
Live-forever 129
Modern buildings 497
Rhizome 155
Rock stoncrop 128
Rose stem 130
Stems 154
Stolon 154
Strawberry 128
Node of Ranvier 228, 259
Nodule fields 299
Nodules 128
Noggin 602
Nonconformity 276
Non-drive end 317
Nonesuch House 467
Nonexplosive eruptions 272
Nonflowering plants 68
Nonmetals 310
Nonreturn valve 367
Nonskid tire 357
Nonslip flooring 575
North America
Appalachian Mountains 62
Cretaceous period 72-73
Earth's physical features 264
Jurassic period 70
Late Carboniferous period 66
Middle Ordovician period 64
Quaternary period 76-77
Tertiary period 74-75
Triassic period 68
North American
Cordillera 71
North American period 56
North American plate 59
North Atlantic current 296
North Atlantic Gyre 296
North Atlantic Ocean 39, 71, 73
North East Africa 64
Northeasterly wind 303
Northeast monsoon 297
Northeast trade winds 300
North Equatorial Belt 45
North Equatorial current 296-297
Northern Hemisphere 296-297
North Galactic Pole 15
North magnetic polar region 28
North Pacific current 296
North Pacific Gyre 296
North polar aurora 45
North polar ice cap 43
North Pole
Atmospheric circulation and winds 300
Coriolis force 297
Jupiter 44
Mars 42
Mercury 34
The Moon 40
Neptune 50
Pluto 51
Pulsar 28
Saturn 46
Uranus 48
Venus 36
North rim 277
North Temperate Zone 45
North Tropical Zone 45
Northwesterly wind 303
Nose
B-17 bomber 408
Concorde, the 416-417
Iron 594
Horse 198
Human 211-212, 244-245
Lion 194
Lockheed Electra airliner 406
Rabbit 196
Rat 196
Noseband 554, 555
Nose clip 558
Nose cone 418, 560
Nose cover 357
Nose-owl 412
Nose-end bogie 527
Nose-gear
ARV light aircraft 424-425
Concorde, the 417
Tornado 420
Nose horn 102, 103
Nose landing gear 573
Nose ring
Avro biplane 405
Blackburn monoplane 400
Nose wheel
ARV light aircraft 425
Curtiss biplane 598
Pegasus XL SE
Tornado 420
ultralight 426
Nostril
Bird 188
Chick 193
Crocodilians 186
Dolphin 205
Domestic cat 195
Elephant 200
Frog 182
Gorilla 205
Horse 198
Human 215
Kangaroo 207
Lion 194
Lizard 184
Monkey 202
Rat 196
Rattlesnake 185
Seal 204
Nostril pocket 80
Notes 502, 506
Notosaurus reptile 69
Notre Dame de Paris 470, 473
Nozzle
Concorde, the 416-417
Jet engines 418-419
Tornado 421
Vacuum cleaner 595
NPT 301 turbojet 418
N-type silicon 605
Nu Andromedae 19
Nucleus 147
Nuchal plate 187
Nuchal ring 95
Nuchal shield 187
Nuclear energy 314
Nuclear fusion
Massive stars 26
Small stars 24
Stars 22
Sun 32
Nuclear "hunter-killer" submarine 596-597
Nuclear power station 514
Nuclear reactions 315
Nucleolus 216, 239
Nucleoplasm 216
Nucleus
Asteroids, comets, and meteoroids 52-53
Atoms and molecules 308, 309
Chlamydomonas sp. 116
Cnidocytes 167
Egg cell 606, 607
Endosperm 147
Fungal cell 115
Galaxies 12-15
Generalized human cell 216
Muscle cell 228
Neuron 259
Overhead view of our galaxy 14
Palisade mesophyll cell 139
Pollen 122
Pollen tube 147
Roots 132
Scots pine pollen 122
Side view of our galaxy 14
Synergid 147
Thalassiosira sp. 116
Nuctenea umbratica 171
Number systems 620
Nunki 19, 20-21
Nu Orionis 18
Nut
Deadeye 585
Dry fruit 150

- Durmast oak 151
Toaster 598
Nutterackers 321
Nutlets 150
Nutrients
 Carnivorous plants 160
 Epiphyte supply 162
 Phloem sieve tube 154
 Plant transport 159
Nylon and silicon cloth 584
Nymphaea sp. 159
Nyssa sylvatica 137
- O**
O₂ sensor 555
Oak 74
Oar
 Greek and Roman ships 372-375
 Junk 376
 Longboat 580
 Viking ships 374-375
Oarweed 116-117
Oasis 283
Oberon 48
Ob-Irtysh River 265
Objective aperture 610
Objective lens 610, 611
Object mass 320
Oblique-slip fault 61
Oboe 504-505, 508
Obovate leaves 137
Observer's cockpit 405
Observer's windshield 404
Obsidian 275, 306
Obstruction light 572
Obturator canal 224
Obturator membrane 224
Occipital bone 202, 220
Occipital condyle 107, 194, 220
Occipital lobe 236-237
Occipital region 106
Occluded fronts 302-305
Ocean currents 296-297
Ocean floor 298-299, 266-267
Oceanic crust
 Earth's crust 58-59
 Mineralization zones 281
 Mountain building 62-65
 Ocean floor 298
Oceanic seahorse 180
Ocean ridges 58-59
Oceans 59, 296-297, 301
Ocean trenches
 Ocean floor features 299
 Offshore currents 296
 Plate movements 58
Oceanus Procellarum 40
Ocellus 176
Octafoil 471
Octagon 622
Octahedron 623
Octastyle portico 462
Octave 557
Octopus 176-177
Ocular end 377
Oculus
 Ancient Roman building 462-463
 Gothic church 472-475
 Medieval building 466, 469
 Neoclassical building 483
 Roman corbita 372
Odd-toed ungulates 198-199
Odontoblast 247
Oeil-de-boeuf window
- Baroque church 479, 481
 Cathedral dome 487
Oerlikon gun position 397
Off-road motorcycle racing 568
Offshore deposits 294
Ogee 595
Ogee arch 488
Ogee-arched motif 490
Ogee curve 472
Ogee-curved dome 486
Ogee-curved roof 489
Ogee molding 475-477, 481
Ogee tracery 495
Ohms 316
Oil
 Clutches 366
 Diesel trains 326
 Energy storage 315
 Mineral resources 280-281
Oil bottle dripped 336
Oil cooler 347, 364, 605
Oil-cooler duct 415
Oil cooler matrix 347
Oil deposit formation 57
Oil deposits 281
Oil dipstick 544
Oil duct 151
Oil feed 411
Oil feed pipe 345, 366, 367
Oil filter
 1-liter VTEC engine 354
 Ford diesel engine 347
 Jaguar V12 engine 345
 Turbofan engine 418
 Turboprop engine 419
Oil-fired power station 315
Oil formation 280-281
Oil muffler 364
Oil paints 436-437
Oil pipe banjo 345
Oil-pressure regulating valve 419
Oil pump
 Humber engine 343
 Mid West single-rotor engine 411
 Velocette OHV engine 367
 Weslake speedway bike 369
Oil rig 315
Oil side lamp 356-337
Oil sump
 Honda VF750 364
 Humber engine 343
 Modern engines 344-345
 Velocette OHV engine 367
Oil tank
 Bell-47 helicopter components 422
 Harley-Davidson FLHS Electra Glide 363
 Lockheed Electra airliner 406
 Turbofan engine 418
 Turbofan engine 419
Oil traps 281
Oldsmobile 336-337
Old World monkeys 202-203
Olecranon 85
Olecellus 64
Oleo lock-jack 414
Olfactory bulb 181
Oligocene epoch
 Fossil record 279
 Geological timescale 57
Olivine
 Igneous rock 267
 Meteorites 52
 Silicates 269
Olivine gabbro 275
- Olympus BX51W1 optical microscope 610
Olympus Mons 42-43
Omasum 198
Omega Centauri 21
Omicron Andromedae 19
Omicron Canis Majoris 21
Omicron2 Canis Majoris 21
Omicron Orionis 18
Omicron Sagittarii 21
Omnivores 84
Omohyoid muscle 229
Onboard information panel 573
One-toed ungulates 198
Onion dome 467, 486-488
Onion-skin weathering 282
On/off/pause button 586
On-screen display 577
Onyx 268
Oocyte 258
Ogonium 117
Oort Cloud 30, 52
Oospheres 116-117
 Fern 121
 Moss 119
Ooze 298
Open cluster 16
Open gun mounting 394
Opera House, Paris 493
Opera House, Sydney 496, 499
Opercula 180
Opercular bone 181
Operculum
 Bony fish 180-181
 Cnidocyte 167
 Giant stick insect eggs 192
 Indian stick insect eggs 192
 Leaf insect eggs 192
 Moss 119
Ophidia 184
Ophiothrix fragilis 175
Ophiuchus 19, 20
Ophthalmos 572
Opisthodomos 461
Opisthosoma 170-171
Opossoms 206, 207
Opponens digiti minimi muscle 231
Opponens pollicis muscle 231
Opportunity 615
Optical drive 567
Optical map of our galaxy 14-15
Optical microscope 610
Optic chiasma 236
Optic disk 240-241
Optic nerve 240
Option connector 571
Opus incertum 463, 465
Opus quadratum 465
Opus sectile mosaic 488-489
Oral arm 167
Oral cavity 248
Oral disk 166-167
Oral surface 175
Orange citrine 271
Orange halite 269, 277
Orange light 318
Orangutans 202
Ora serrata 241
Orb 486
 Baroque church 480
 Cathedral dome 487
 Gothic church 471
 Neoclassical building 479
 Nineteenth-century building 493
 Renaissance building 477
- Orbicularis oculi muscle 226, 229
Orbicularis oris muscle 228-229, 245
Orbicular lamina 158
Orbicular leaves 157
Orbit
 Acanthostega 80
 Ankylosaurus 94
 Archaeopteryx 85
 Arsinoitherium 104
 Australopithecus 108
 Baryonyx 85
 Bear 194
 Bird 189
 Bony fish 181
 Camarasaurus 91
 Chimpanzee 202
 Diplodocus 90
 Elephant 201
 Eryops 80
 Euoplocephalus 94
 Heterodontosaurus 85
 Homo erectus 108
 Homo habilis 108
 Homo sapiens 108
 Horse 199
 Hyenodon 107
 Iguanodon 96
 Inner planetary 50
 Lambeosaurus 99
 Lion 194
 Lizard 184
 Opossum 106
 Outer planetary 31
 Pachycephalosaurus 100
 Panoplosaurus 94
 Parasaurolophus 99
 Plateosaurus 88
 Platypus 206
 Preoncephale 100
 Protoceratops 102
 Rattlesnake 185
 Rhinos monkey 202
 Smilodon 107
 Stars of northern skies 18
 Stars of southern skies 20
 Stegoceras 100-101
 Styracosaurus 102
 Toxodon 106
 Triceratops 105
 Tyrannosaurus 84
Orbital artery 179
Orbital cavity 220
Orbital motion 31, 52
Orbital plane
 Earth 58
 Jupiter 44
 Mars 42
 Mercury 34
 Neptune 50
 Pluto 51
 Saturn 46
 The Moon 40
 Uranus 38
 Venus 36
Orbitals 308-309, 310
Orbital speed (velocity)
 Mercury 34
 Solar system 30-31
Orb spider 171
Orchestra layout 504-505
Orchestral instruments 504-505
 Musical notation 502-503
 Orchestras 504-505
 Orchestra shell 495
 Orchids 126, 133, 162
 Orcinus orca 205
Ordovician period 64-65
 Fossil record 279
 Geological time 56
 Primitive life 78
Organ 514, 502-505
Organic compound 315
- Organic material deposition 281
Organic remains 276-277, 280
Organ of Corti 245
Oriel window 467
"O Ring" drive chain 366
Orion 18, 21, 24
Orion Arm 14
Orion Nebula 15, 17, 18
Orion's belt 15-16
Ornament
 Asian building 491
 Baroque church 479, 481
 Cathedral dome 487
 Islamic building 488
 Neoclassical building 485
Ornithischia 68-69, 82-85
 Marginocephalians 100
 Ornithopods 96
 Stegosaurs 92-93
 Thyreophorans 92
Ornithomimosaur 86-87
Ornithopoda 85
Ornithopods 96-97, 98-99
Ornithorhynchus anatinus 207
Orobanche sp. 163
Orogenesis 62-63
Oropharynx 245
Orpiment 270-271
Orthoclase 269, 271
Orthorhombic system 270
Os 258-259
Oscillating cylinder 390
Oscillating electric field 318
Oscillating magnetic field 318
Oscillating steam engine 390-391
Osculum 166
Osmium 311
Ossicles 79, 174
Ossicles of middle ear 242
Osteichthyes 180
Osteocyte 225
Osteolaemus tetraspis 82
Osteon 225
Ostiole 117
Ostium
 Crayfish 173
 Sea anemone 167
 Spider 170
 Sponge 166
Ostrich 188, 195
Ostrich 194
Otto cycle 342
Otto, Nikolaus 342
Ouranosaurus 97
Outboard ammunition-feed blister 409
Outboard elevon 421
Outer bud scale 134
Outer casing fitment 597
Outer core 58-59, 41
Outer ear
 Brachiosaurus 91
 Stegoceras 101
 Stegosaurus 92
Outer electrons 310-311
Outer envelope 25-26
Outer fertilized floret 142
Outer jib downhaul 385
Outer jib halyard 385
Outer jib sheet 385
Outer jib stay 382
Outer lamella 225
Outer mantle
 Jupiter 44-45
 Saturn 46-47
Outer tepals
 Glory lily 143
 Lily 140
 Monocotyledons 126
Outfield 536
- Outlet manifold 411
Output tray 574
Outrigger 373, 377
Outwash fan 286
Outwash plain 287
Outwash terrace 286
Ovary
 Barnacle 173
 Bony fish 181
 Brachiosaurus 90
 Butterfly 169
 Chimpanzee 202
 Crayfish 173
 Dogfish 179
 Epigeal germination 153
 Fertilization 146-147
 Flower 140-143
 Gallinimus 86
 Human 258-259
 Hypogeal germination 152
 Insect pollination 144
 Lizard 185
 Rose 131
 Spider 170
 Succulent fruit 148-149
 Tortoise 188
Ovate leaf
 Ice-plant 129
 Live-forever 129
 Strawberry 128
Ovda Regio 36, 37
Oven compartment 597
Overarm pass 535
Overhand knot 388
Overhand serve 534
Overhead camshaft engine 368
Overhead control panel 573
Overhead pass 532
Overhead valve engine (OHV) 367, 369
Over-reach boot 555
Overs 538
Oversailing fascia 477, 482, 486
Overthrust fold 61
Overturned fold 61
Overwing emergency exit 572
Oviduct
 Barnacle 173
 Brachiosaurus 90
 Butterfly 169
 Crayfish 173
 Dogfish 179
 Lizard 185
 Spider 170
 Tortoise 187
Ovolo 486
Ovolo molding
 Cathedral dome 487
 Gothic church 472
 Neoclassical building 480
Ovotestis 177
Ovules 140-145
 Bishop pine 124
 Dehiscent fruit 151
 Fertilization 146
 Pine 122
 Scots pine 122
 Smooth cypress 123
 Yew 123
Ovuliferous scales
 Bishop pine 124
 Pine 122
 Scots pine 122
 Smooth cypress 123
 Yew 123
Ovum
 Ancient Roman building 462
 Fertilization 146-147
 Scots pine 122
Oxalis sp. 157
Oxbow lake 293

- River features 290
 River's stages 289
 "Ox-eye" window
 Baroque church 479, 481
 Cathedral dome 487
 Oxides 268
 Oxygen
 Atmospheric
 Atom 596
 Composition 301
 Early microorganisms 78
 Earth's composition 39
 Earth's crust 58
 Earth's formation 38, 64
 Helix Nebula 17
 Mars' atmosphere 43
 Mercury's atmosphere 35
 Periodic table 311
 Photosynthesis 158
 Seed germination 152
 Structure of red supergiant 26
 Respiration 255
 Oxygenated blood 255
 Oxygen bottle 408
 Oxygen group 311
 Oyashio current 297
 Oyster fungus 114
 Oysters 176
 Ozone 64
 Ozone layer 300
- P**
Pachycephalosaurus 69, 85, 100
Pachypteris sp. 68
Pachyrhinosaurus 105
 Pacific coastline 295
 Pacific Ocean 264-265, 272
 Pacific plate 59
 Pacing races 554
 Pacing sulky 554-555
 Pacinian corpuscle 254-255
 Pack-ice 296
 Packing tissue
 Dicotyledon leaf 126
 Fern rachis 121
 Golden barrel cactus 156
Haworthia truncata 157
 Horsetail stem 120
 Leaf succulents 157
Lithops bromfieldii 157
 Monocotyledon leaf 126
 Roots 152-155
 Stem 154-155
 Stem succulents 156
 String of hearts 157
 Water lily leaf 159
 Padded coaming
 Avro biplane 405
 BE 2B bomber 404
 Paddle
 Eurypterid fossil 79
 Kayak 560
 Paddlesteamer
 19th century 390-391
 Iron 392-395
 Paddle wheels 390-391, 392
 Padmakosa 489
 Page key 590
 Page locator 577
 Pagoda 490
 Pahoehoe 272
 Painted Desert 277
 Painting knives 436, 442
 Painting tools 442
 Pair-cast cylinder 345
 Paired cylinder 342
- Palace of Westminster 492-495
 Palais de Fontainebleau 476
 Palais de Versailles 482
 Palatine Chapel
 Aix-le-Chapelle 484
 Palatine tonsil 212, 244-245
 Palatoglossal arch 244
 Palazzo Stanga 482
 Palazzo Strozzi 474-475
 Pale calcite 26
 Pale feldspar 26
 Paleocene epoch
 Fossil record 279
 Geological timescale 57
 Paleontology 278
 Paleozoic era
 Fossil record 279
 Geological time 56
 Palette 145, 456
 Palette knife 456
 Paling 466, 477
 Palisade mesophyll 126, 159
 Palladium 311
 Palm
 Danforth anchor 586
 Hand 211
 Roman anchor 572
 Sailmaker's 384
 Tertiary plant 74
 Palmar arch 255
 Palmaris longus tendon 251
 Palmar vein 255
 Palmate leaves 150, 156
 Palmate venation 129
 Palmette 460-461, 479-480
Palmoxylon 74
 Pampirs 265
 Pampas 264
 Panama Tornado GR1A 420-421
 Pancam mast assembly 615
 Pancreas
 Bird 189
 Bony fish 181
 Chimpanzee 202
 Dogfish 179
 Domestic cat 195
 Frog 182
 Human 215, 249
 Rabbit 196
 Tortoise 187
 Pandas 194
 Panduriform leaves 156
 Pane 494
 Panel 485
 Asian building 491
 Baroque church 479-481
 Cathedral dome 487
 Gothic building 475
 Islamic building 488
 Medieval building 466, 469
 Modern building 496-498
 Neoclassical building 478-479
 Nineteenth-century building 493
 Renaissance building 475
 Twentieth-century building 494
 Panel board connector 570
 Pangaea 66, 68-69, 70
 Panniers 560, 561, 562
Panoplosaurus 94
 Panic 151
 Panoramic camera (Pancam) 615
 Pantheon 462-465
- Pantile 464, 482
 Pantograph 328, 350
Pan troglodytes 202
 Paper
 Acrylic paint 442
 Calligraphy 444, 445
 Pastels 440
 Printing processes 446, 447
 Watercolors 458
 Paper feed components 575
 Paper hopper 574
 Paper output stacker 574
 Paper stumps 440
 Paper support 575
 Papilla
 Flower 140
 Hair 235
 Renal 256
 Tongue 244
 Papillary muscle 251
 Pappus 142
 Papyrifrom column 459
 Parabellum machine-gun 405
 Parabolic dune 285
 Paraboloid roof 496, 499
 Parachute seed dispersal 150
 Paradise palm 126
 Paragaster 166
 Parallel dunes 285
 Parallelogram 622
 Parallel river drainage 288
 Parallel shaft 382
 Parallel venation 126
 Parana River 264
 Parapet
 Ancient Roman building 465
 Asian building 491
 Baroque church 481
 Dome 486
 Gothic church 470-472
 Islamic tomb 489
 Medieval building 467
 Neoclassical building 478, 485
 Nineteenth-century building 493
 Twentieth-century building 494
 Parapet rail 485
 Paraphysis 117, 119
Parasauroplophus 98-99
 Parasitic anemone 166
 Parasitic cone 272-275
 Parasitic plants 162-165
 Parasitic volcano 275
 Paraxeresia 373
 Parceling 588
 Parchment
 Gilding 452
 Imitation 445
 Pareiasaur 81
 Parenchyma
 Dicotyledon leaf 126
 Dryland plants 156-157
 Fern rachis 121
 Golden barrel cactus 156
 Horsetail stem 120
 Monocotyledon leaf 126
 Pine stem 125
 Roots 152
 Stems 154-155
 Water lily leaf 159
 Parent plant 154
 Parietal bone
 Bony fish 181
 Chimpanzee 202
 Human 220-221
 Parietal fenestra 102
 Parietal lobe 236-237
 Parieto-occipital sulcus 236-237
- Parietosquamosal frill 102-105
Paripteris 66
 Paris Metro 328
 Parroccipital process
Paruanodon 96
Platesaurus 88
 Parrel
 Dhow 376
 Longboat 380
 Sailing warship 377
 Viking karv 375
 Parrel beads 384
 Parrel tackle 376
 Parthenon 461
 Partial solar eclipse 32
 Partial veil 115
 Particle attraction 307
 Particle properties 318
Passiflora caerulea 150
 Passing brace 475
 Passion flower 150
 Passive stack vents 602
 Pastels 440-441
 Pastern 198-199, 554
 Pasteur 41
 Patagonia 264
 Patella
 Domestic cat 195
 Elephant 201
 Hare 197
 Horse 199
 Human 219
 Platypus 206
 Rhesus monkey 202
 Scorpion 170
 Spider 171
 Patellar surface 225
 Patera
 Neoclassical building 480
 Renaissance building 476
 Pause/play control 577
 Paved floor 492
 Pavilion 489, 495
 Paving slab 499
 Pavlova 37
Pavlova 278
 Pavo 20
 Pavonis Mons 45
 Paw 195
 Pawl 380
 Pawl slot 587
 Paxton, J. 492-495
 Pazzi Chapel 475
 PCB see printed circuit board (PCB)
 PC card adapter 574
 PCs 566
 PDAs 568, 588
 Pea
 Dry fruit 150
 Danforth anchor 386
 Peach 151, 148
 Peacock 20
 Peak halyard 380
 Peat 280
 Peccaries 198
Pecopteris 66
 Pectineus muscle 225-226
 Pectoral fin
 Bony fish 180-181
 Lamprey 178
 Pectoral fin ray 181
 Pectoralis major muscle 226
 Pedal board 514
 Pedal cluster 340
 Pedal disc 167
 Pedal-driven bicycle 358
 Pedal gland 177
 Pedalia 372
 Pedals
 Bass drum 518
 Bicycle 320, 358-359
 Eddy Merckx racing bicycle 360
 Harp 511
- Hi-hat cymbal 518
 Piano 514
 Rossini Italian time-trial bicycle 361
 Pedal-muffler bar mechanism 516
 Pedal stop 514
 Pedestal
 Ancient Roman building 462
 Baroque church 480-481
 Dome 484, 486-487
 French temple 485
 Harp 511
 Neoclassical building 479
 Renaissance building 476
 Pedice 168
 Pedicel
Brassavola nodosa 162
 Clematis 151
 Dicotyledon flower 127
 Dry fruit 150-151
 Fertilization 146-147
 Florists' chrysanthemum 129
 Flowers 140-141, 145
 Fruit development 146-147
Oxalis sp. 157
 Pitcher plant 115
 Rose 151
 Rowan 151
 Russian vine 151
 Succulent fruit 148-149
 Sycamore 151
 Vegetative reproduction 154
 Water lily 159
 Pedicle of vertebra 225
 Pedicle valve 278
 Pediment
 Ancient Greek building 460
 Ancient Roman building 462-465
 Baroque church 480-481
 Neo-Baroque building 495
 Neoclassical building 478
 Renaissance building 476
 Pedipalp 170-171
 Peduncle 140, 142-143
Aechmea miniata 162
Brassavola nodosa 162
 Everlasting pea 129
 Florists' chrysanthemum 129
 Indehiscent fruit 150
 Peach 151
 Peruvian lily 129
 Rowan 151
 Russian vine 151
 Succulent fruit 148-149
 Toadflax 129
 Vegetative reproduction 154
 Wind-pollinated plant 144
 Peephole 412, 414
 Pegasus 19, 20
 Pegasus Quasar ultralight 426-427
 Pegasus XL SE ultralight 427
 Peg-box 510-511
 Pegmatite 26
 Peg of vertebra 222
 Pelagic clay 299
 Pelagicypoda 176
Peloneustes philarcus 71
 Pelota 540
Pelvetia canaliculata 116
 Pelvic fin
 Bony fish 180-181
- Dogfish 179
 Pelvis
 Bird 189
 Bony fish 181
 Dinosaur 81
 Domestic cat 195
 Elephant 201
 Hare 197
 Horse 199
 Human 256, 258, 259
 Kangaroo 206
 Lizard 184
 Platypus 206
 Rhesus monkey 202
 Seal 204
 Turtle 187
 Penalty area 524
 Penalty box 524
 Penalty kick 550
 Penalty spot 529, 540
 Pencils 430
 Pencil sharpener 450
 Pencil slate sea urchin 175
 Pendentive 479, 484, 488
 Penguins 188
 Penis
 Barnacle 175
 Dolphin 205
 Human 211, 259
 Snail 177
 Pennant number 397
 Pennsylvanian period 56
 Penny washer 385
 Pens 430
 Penstock 514
 Pentagon 622
 Pentaradiate symmetry 174
 Pentroof 490
 Penumbra 52
 Pepo 149
 Pepper-pot lantern 481
 Perch 180
 Percolation 280
 Percussion instruments 516-517
 Drums 518-519
 Electronic 520
 Orchestral arrangement 504-505
 Perennials 128, 150-151
 Peropod 172-175
 Perforated shroud 592
 Perianth 140
 Pericardial cavity 250
 Pericarp 148
 Dry fruit 150-151
 Embryo development 147
 Fruit development 146-147
 Succulent fruit 148-149
 Sycamore 151
 Pericranium 237
 Pericycle 127, 152
 Periderm 125
 Peridium 115
 Perihelion 30-31
 Perimeters 622
 Perineum 258
 Periodic table 510-511
 Periodontal ligament 247
 Periodontium 247
 Periosteum 225
 Peripheral nervous system 238
 Peripetal temple 460-461
 Periscope 396, 397
 Perissodactyla 104, 198-199
 Peristome tooth 119
 Peristyle 461
 Peritoneum 249, 257
 Permeable limestone
 Caves 284-285
 Lake formation 292
 Permeable rock 292
 Permeable sandstone 292

- Permian period 66-67
 Fossil record 279
 Geological time 57
 Peroneal artery 253
 Peroneus brevis muscle 227, 253
 Peroneus brevis tendon 235
 Peroneus longus muscle 235
 Peroxisome 217
 Perseus 19, 20
 Perseus Arm 14-15
 Persian ivy 137
 Personal computer 566-567
 Personal digital assistants (PDAs) 568
 Personalized mail folder 576
 Personal lighting 572
 Personal music and video 586-587
 Perspective drawing 451
 Peru current 296
 Peruvian lily 129
 Petal molding 480
 Petals 140-145
 Clematis 151
 Color 140, 144-145
 Dicotyledons 126-127
 Everlasting pea 129
 Fertilization 146
 Insect pollination 145
 Monocotyledons 126
 Peruvian lily 129
 Rose 131
 Water lily 159
 Petavious 40
 Petiole 128, 156-157
 Chusan palm 150
 Clematis 151
 Cobra lily 160
 Dicotyledons 127
 Everlasting pea 129
 Florists' chrysanthemum 129
 Horse chestnut 150
 Kedrostis africana 115
 Maidenhair tree 125
 Monocotyledons 126-127
 Mulberry 150
 Oxalis sp. 157
 Passion flower 150
 Peach 151
 Rock slonecrop 128
 Seedling 155
 Strawberry 128
 String of hearts 157
 Tree fern 112
 Tree mallow 151
 Vegetative reproduction 154
 Venus fly trap 160
 Water lily 159
 Wind-pollinated plant 144
 Petiolule 157
 Petrol 515
 Peugeot, Armand 354
Phacops 64
 Phaeophyta 16
 Phaet 21
Phalaenopsis sp. 126
 Phalanges
 Cow 198
 Crocodile 186
 Diplodocus 90
 Domestic cat 195
 Elephant 90
 Eryops 80-81
 Frog 185
 Hare 197
 Horse 198-199
 Kangaroo 206
 Lizard 184
 Parasaurolophus 99
 Plateosaurus 88
 Platyopus 206
 Rhesus monkey 202
 Seal 204
 Stegoceras 100-101
 Triceratops 102-105
 Turtle 187
 Tyrannosaurus 84
 Phalanx
 African elephant 201
 Archaeopteryx 85
 Arsinoitherium 104
 Baryonyx 85, 87
 Horse 105
 Human 219, 250
 Plateosaurus 88
 Stegoceras 100
 Struthiomimus 87
 Toxodon 107
 Phallus impudicus 114
 Phanerozoic eon 279
 Pharyngeal tubercle 220
 Pharynx
 Bony fish 180-181
 Dogfish 179
 Human 212, 244
 Sea anemone 167
 Sea urchin 175
 Phasciarctos cinereus 207
 Phaseolus sp. 155
 Phases of the Moon 41
 Phekda 19
 Phellem
 Pine root 125
 Stem 154-155
 Woody dicotyledon 127
 Phi Andromedae 19
 Phidias 55
 Philippine plate 59
 Phillips, Horatio 402
 Philoxenus 55
 Philtr ridge 215
 Philtrum 215
 Phiomia 104
 Phloem 158
 Bishop pine 124-125
 Clubmoss stem 120
 Dicotyledons 126-127
 Dodder host 165
 Epiphytic orchid 162
 Fern rachis 121
 Horsetail stem 120
 Marram grass 115
 Monocotyledons 126-127
 Parasite host 165
 Photosynthesis 158
 Pine root/stem 125
 Radicule 152
 Root 152-155
 Sieve tube 154
 Stem 154-155
 Water hyacinth root 158
 Water lily leaf 159
 Phloem fibers 134-155
 Phloem sieve tube 134
 Phobos 42
 Phoebe Regio 56
 Phoenicoperla ruber 190
 Phoenix 19, 20
 Phorusrhacos 74
 Phosphates 269
 Phosphate/sugar band 216
 Phosphor imaging screen 611
 Phosphor lining cell 584
 Phosphorus 511
 Photomicrographs of skin and hair 255
 Photons 518
 Photo print button 570
 Photo select button 575
 Photosphere 32-35
 Photosynthesis 112, 116, 134, 156, 158-159
 Carnivorous plants 160-161
 Organelle 116, 159
 Photosynthetic cells 159
 Bishop pine 124
 Coconut palm stem 155
 Water lily leaf 159
 Photosynthetic region 157
 Photosynthetic tissue
 Cacti 156
 Dicotyledon leaf 126
 Horsetail stem 120
 Marram grass 115
 Monocotyledon leaf 126
 Rush stem 155
 Photovoltaic cell 605
 Photovoltaic panel 605
 Phyla 116
 Phyllode 160
 Phylum 116
 Physalis peruviana 149
 Physeter catodon 205
 Physical weathering 282
 Physics symbols 621
 Pi2 Orionis 18
 Pi5 Orionis 18
 Pi4 Orionis 18
 Pi5 Orionis 18
 Pi6 Orionis 18
 Pia mater 257, 240
 Piano 503, 514
 Piano nobile 474, 494
 Piano, R. 496
 Piazza 474
 Pi Canis Majoris 21
 Piccolo 504, 508
 Pictor 21
 Pier 484
 Ancient Egyptian temple 459
 Ancient Roman building 465
 Baroque church 480
 Gothic church 470
 Medieval building 467-469
 Renaissance building 476-477
 Twentieth-century building 494-495
 Pier buttress 469-471, 486
 Pietra dura inlay 489
 Piezoelectric inkjet printhead 575
 Pigments 455, 454, 456
 Pigs 104, 198
 Pilaster
 74-gun ship 581
 Ancient Greek building 461
 Ancient Roman building 465-465
 Asian temple 490-491
 Baroque church 479-481
 Cathedral dome 484, 487
 Gothic church 471
 Neoclassical building 478, 485
 Renaissance building 476
 Pileus 114-115
 Pillar
 Asian buildings 490-491
 Domed roof 486
 Gothic church 472
 Ironclad 395
 Renaissance building 477
 Twin bollards 587
 Pillow lava 298
 Pilotis 494
 Pilot light 594
 Pilot's cockpit
 LVG CVI fighter 405
 Tornado 420
 Pilot's cradle 398-399
 Pilot's seat
 Airbus 380 575
 Avro biplane 402
 Curtiss biplane 598
 Pegasus Quasar ultralight 427
 Pin
 Capstan 387
 Dome timbering 486
 Pinacocyte 166
 Pineal body 212, 256
 Pine hull 375
 Pines 122, 124-125
 Pinguicula caudata 161
 Pinion
 Benz Motorwagen 355
 Ford Model T 558
 Hand drill 601
 Pinna
 Elephant 201
 Everlasting pea 129
 Fern 121
 Gorilla 205
 Human 242-245
 Kangaroo 207
 Leaves 156-157
 Rabbit 196
 Rat 196
 Sago palm 125
 Tree fern 112-115
 Pinnacle
 Baroque church 479, 481
 Gothic church 470, 472-475
 Medieval church 469
 Nineteenth-century building 495
 Renaissance building 476
 Pinnate leaves 156-157
 Mahonia 150-151
 Rowan 150
 Sago palm 125
 Pinned sheepskin 589
 Pinnipedia 204
 Pinnule 121, 157
 Pinnocytotic vesicle 217
 Pintle strap 578
 Pinus muricata 72, 124-125
 Pinus sp. 122, 124-125
 Pinus sylvestris 122
 Pi Pegasi 19
 Pipette 512
 Pips 148-149
 Pi Sagittarii 21
 Pisanosaurus 68
 Pisces Austrinus 19, 20
 Piscis 19, 20
 Pisiform bone 250
 Piste 556, 557
 Pistol shooting 548
 Piston
 Disc brake 565
 Early engines 542-545
 "Ellerman Lines" steam locomotive 525
 Ford diesel engine 547
 Mid West two-stroke engine 410
 Modern engines 544-545
 Relief-printing press 449
 Steam locomotive 524
 Two-stroke engine 566
 Velocette OHV engine 567
 Volkswagen Beetle 340
 Piston engines 410-411, 424
 Piston rod 524, 554, 390
 Piston valves
 Brass instruments 506
 Cornet 507
 "Ellerman Lines" steam locomotive 525
 Flugelhorn 507
 Stringed instruments 510
 Trumpet 506
 Tuba 507
 Pisum sativum 150
 Pitavus 40
 Pitch
 Brass instruments 506
 Drums 518
 Musical notation 502
 Percussion instruments 516
 Propeller action 390
 Screw thread angle 520
 Woodwind instruments 508
 Pitched roof
 Ancient Roman building 462, 464
 Gothic church 471-472
 Medieval building 466-468
 Nineteenth-century building 492
 Renaissance building 476-477
 Twentieth-century building 495
 Pitcher 556
 Pitcher plants 115, 160-161
 Pitches
 Australian rules football 528
 Baseball 556
 Cricket 558
 Gaelic football 529
 Lacrosse 540
 Pitching wedge
 Baseball 557
 Golf 547
 Pitfall traps 160
 Pith
 Apical meristem 154
 Bishop pine stem 125
 Dicotyledon stem 127
 Epiphytic orchid 162
 Horsetail stem 120
 Monocotyledon root 127
 Pine stem 125
 Stems 154-155
 Pith cavity 155
 Pitot head
 ARV light aircraft 425
 BAe-146 jetliner components 412
 Bell-47 helicopter 422
 Concorde 416-417
 Hawker Tempest fighter 409
 LVG CVI fighter 405
 Schweizer helicopter 425
 Tornado 420
 Pitot mast 407
 Pituitary gland 212, 256
 Pivot
 Astrolabe 377
 BAe-146 jetliner components 414
 Drum brake 565
 Sundial 377
 Viking ships 374-375
 Pixel 570, 571
 Place kick 550
 Placenta
 Dry fruit 150-151
 Fern pinnule 121
 Human 260
 Succulent fruit 148-149
 Placental mammals 74, 104
 Placer deposits 280
 Plagioclase feldspar 275
 Plains viscacha 197
 Planck 41
 Plane shapes 622
 Planetary nebula
 Nebulae and star clusters 17
 Small stars 24-25
 Planetary rotation 50
 Planets
 Jupiter 44-45
 Mars 42-45
 Mercury 54-55
 Neptune 50-51
 Pluto 50-51
 Saturn 46-47
 Solar system 50-51
 Uranus 48-49
 Venus 56-57
 Planking
 Ironclad 595
 Longboat 580
 Roman corbita 575
 Sailing warship 577
 Tea clipper 592
 Plantar calcaneonavicular ligament 252
 Plant bodies 116
 Plant capital 459
 Plant-eating dinosaurs 68, 70
 Plant matter 280
 Plant remains
 Fossils 278-279
 Mineral resources 280
 Sedimentary rocks 276
 Plants 56, 66
 Electromagnetic radiation 514
 Flowering 57, 70, 72
 Fossil record 279
 Non-flowering 68
 Plant variety 112-115
 Plasma 506
 Plasma display 584
 Plasma screen 584
 Plaster 452, 464-465
 Plasterboard 602
 Plastic bumper 354
 Plastic fletch 548
 Plastic front wings 554
 Plastic insulator 516, 517
 Plastic rackets 544
 Plastid 116
 Platanus x acerifolia 154
 Platband 481
 Plate
 Etching press 477
 Motorcycle clutch 566
 "O Ring" drive chain 566
 Plateau
 Neptune's rings 50
 Structure of Neptune 51
 Plateaus 276-277
 Plate boundaries 62, 275
 Plate clip 587
 Platelets 255
 Plate movements 58-59
 Faults and folds 60
 Mountain building 62-65
 Platen 449
Plateosaurus 69, 88-89
 Plate tectonics 58-59
 Platform
 Cathedral dome 487
 Early tram 552
 Medieval building 467-468
 Modern building 498
 Platform diving 558
 Platform stage 477
 Platform 511
 Plat lesene 480
 Plat 40
 Platypus 206-207
 Platysma 229
 Playa 285
 Play button 585
 Player's bench
 Basketball 552
 Football 526
 Handball 555
 Ice hockey 550
 Volleyball 534
 Play/pause control 577
 Plaza 498
 Pleistocene 14, 16, 19, 20
 Pleistocene epoch

- Fossil record 279
 Geological timescale 57
 Pleistocene period 76
 Plenum chamber 544-545
 Plenum ring 418
 Pileopod 172
Plesiochelys laticutata 75
 Plesiosaurs 70-71
Pleurotus pulmonarius 114
 Plica circulare 249
 Plicate lamina 127
 Pliers 321
 Plinth
 Baroque church 480
 French temple 485
 Islamic tomb 489
 Modern building 499
 Neoclassical building 479, 485
 Renaissance building 476
 Twentieth-century building 494-495
 Pliocene epoch
 Fossil record 279
 Geological timescale 57
 Plough anchor 586
 Plug-ins 521
 Plug lead conduit 357
 Plugs 272-275
 Igneous rock structures 274
 Plumage 188
 Plume 45
 Plumose anemone 166
 Plumule 147, 152-155
 Plunge 60
 Plunge pool 289, 291
 Pluto 51, 50-51
 Plutonium 510-511
 Plywood roof deck 605
 Plywood skin 404
 Pneumatic tires 358, 555
 Podetium 114
 Podium 463, 499
 Point
 Angling hook 562
 Crickets 538
 Double bass bow 511
 Sailmaker's fid 584
 Sculpting tool 452-455
 Violin bow 510
 Point bar
 Mississippi Delta 291
 River's stages 289
 Pointed arch 466, 467, 469, 472
 Pointed hog hair brush 454
 Pointed riffler 454
 Pointed sable brush 444
 Pointing 385
 Poison duct 170
 Poison gland
 Octopus 176
 Spider 170
Polacanthus 95
 Polar band 36
 Polar body 606, 607
 Polar bottom water 296
 Polar easterlies 500
 Polar fronts 302
 Polar hood 36
 Polaris 14, 18-19
 Polar jet stream 300
 Polar nuclei 146
 Poles 297, 500
 Pole star 14, 18
 Pole vault 542
 Polian vesicle 175
 Political map of the world 616-617
 Poll 199
 Pollen 140, 142, 144-145
 Dicotyledon flower 126
 Fertilization 146-147
 Pollen-forming structures 122
 Pollen grains 144-145
 Fertilization 146-147
 Pine 122
 Scots pine 122
 Pollen sac wall 144
 Pollen tubes
 Fertilization 146-147
 Scots pine 122
 Pollination 144-145, 122
 Pollux 18, 21
 Polonium 511
 Polycarbonate plastic bin 592
 Polyester 588
Polygala chamaebuxus 144
 Polygotus 55
Polygonum
 baldschuanicum 131
 Polyhedral dome 486-487
 Polypropylene rope 588
 Polythene 306
Polytrichum commune 119
 Polyurethane insulation 605
 Pome 151, 149
 Pommel 554
 Pond weeds 158
 Pons 212, 236-237
 Poop break 575
 Poop deck
 74-gun ship 581
 Iron paddlesteamer 592
 Roman corbita 575
 Poop rail
 74-gun ship 581
 Wooden sailing ship 378
 Poor metals 310-311
 Popchu-Sa Temple 490
 Popliteal artery 253
 Popliteal fossa 210
 Porch 470-471
 Porcupines 196-197
 Pore
 Bishop pine needle 124
 Blackberry 147
 Dryland plants 156-157
 Elder stem 150
 Epigeal germination 157
 Crickets 538
 False fruit 148
 Gas exchange 158, 158
 Golden barrel cactus 156
 Haworthia truncata 157
 Leaf 158-159
 Liverwort 118
 Monocotyledon leaf 126
 Nuclear membrane 217
 Perennial bark 150-151
 Pollen grain 144-145
 Seed 153
 Sponge 166
 Water absorption 150, 153
 Wetland plants 158
 Woody plants 130-131
 Woody stems 134
 Porifera 166
 Porocyte 166
 Porous limestone 284
 Porous stipe 114
 Porphyritic andesite 275
 Porpoises 204
 Porrima 21
 Porsche, Ferdinand 340
 Port
 Trojan two-stroke engine 342
 Wooden sailing ship 379
 Portal 476, 480
 Portal vein 252
 Porta Nigra 462, 465
 Port bower anchor 377, 395
 Port foremast 376
 Porthole
 Battleship 594
 Dome 487
 Frigate 597
 Portico
 Ancient Greek building 460-461
 Ancient Roman building 462-465
 Neoclassical building 482-485
 Renaissance building 475
 Portugal 351
 Portuguese bowline 588
 Position guide 447
 Positive electric charge 316
 Positive ions 308, 310
 Positive metal comb 516
 Positive terminal 516, 517
 Positron 22
 Post 481, 486
 Postabdominal spine 169
 Postacetabular process 82
 Postcentral gyrus 257
 Post-crural musculature 90
 Posterior antebrachial musculature 86, 91
 Posterior aorta 170
 Posterior arch 222
 Posterior border of vomer 220
 Posterior brachial muscle 86, 91
 Posterior branch of spinal nerve 225
 Posterior cerebral artery 252
 Posterior chamber 241
 Posterior chamber of cloaca 185
 Posterior column 225
 Posterior crural muscle 87
 Posterior cuneonavicular ligament 252
 Posterior dorsal fin
 Bony fish 181
 Dogfish 179
 Lamprey 178
 Posterior horn 225
 Posterior nasal aperture 220
 Posterior nasal spine 220
 Posterior part of tongue 245
 Posterior petal 141
 Posterior root 225, 238
 Posterior semicircular canal 245
 Posterior sepal 141
 Posterior tarsometatarsal ligament 252
 Posterior tentacle 177
 Posterior tibial artery 253
 Posterior tibial nerve 238
 Posterior tubercle 222
 Posterior vena cava 182
 Posterior wing of shell 176
 Posterolateral horn 94
 Post-glacial stream 286
 Post-glacial valley 286
 Post-modernism 296, 496
 Post-motor micropore filter 592
 Potassium 55, 58, 286, 310
 Potassium chromate solution 512
 Potassium dichromate ions 512
 Potassium iodide 512-513
 Potassium nitrate 315
 Potassium permanganate 306
 Potato 128
 Potential energy 314, 315
 Potholes 284
 Pouch 206
 Power bar 552
 Power drill 600-601
 Power button
 Home cinema 585
 Inkjet printer 574
 Personal computer 566-567
 Power levers 575
 Power output 360, 366
 Power/play/pause button 586
 Power plug 591
 Power stations 514, 315
 Power steering belt 551
 Power steering pump 344, 351
 Power stroke 345
 Power-to-weight ratio 528
 Power transistor heat sink (dissipator) 585
 Power transistors 585
 Practice projectile 596
 Pradakshina 491
 Praesepe 18
 Prairie style 495
 Praseodymium 310
 Pratt & Whitney Canada turbofan engine 418-419
 Pratt & Whitney Canada turboprop engine 419
 Pratt & Whitney radial engine 406-407
 Praxiteles 35
 Preactabular process 82
 Precambrian period 56, 64-65, 279
 Precambrian seas 78
 Precentral gyrus 257
 Precious metals 511
 Precipitate 512
 Precipitation 288, 302-305
 Predatory dinosaurs 84
 Predatory theropods 88
 Predatory bone
 Arsinoitherium 104
 Iguanodon 96
 Lambeosaurus 99
 Protoceratops 102
 Triceratops 105
 Prefix 577
 Prehensile tail 202
 Prehistoric foods 109
 Pre-load adjuster 365
 Premaxilla
 Baryonyx 85
 Arsinoitherium 104-105
 Bony fish 181
 Chimpanzee 202
 Elephant 201
 Frog 185
 Iguanodon 96
 Lambeosaurus 99
 Premolars
 Australopithecus 107
 Bear 106, 194
 Chimpanzee 202
 Horse 105
 Human 246
 Lion 194
Prenocephale 100-101
 Prepercular bone 181
 Preparatory drawing 450-451
 Prepubic process
 Iguanodon 96
 Parasaurolophus 98
 Stegosaurus 95
 Prepubis
 Ornithischian 82
 Stegoceras 100-101
 Prepuce 259
 Preserved remains 278
 Press
 Etching 447
 Lithographic printing 446
 Relief-printing 449
 Pressed steel wheel 340
 Pressure
 Formation of black hole 29
 Igneous and metamorphic rocks 274
 Mineral resources 280
 Stellar black hole 29
 Volcanic features 275
 Pressure line 418
 Pressure plate 366
 Pressurized cabin 406
 Pressurized keel box 417
 Pressurized strut 425
 Pressurized water reactor 314
 Presta valve 561
 Presynaptic axon 239
 Presynaptic membrane 239
 Preview monitor slot 575
 Preview monitor socket 574
 Previous file button 577
 Previous key 568
 Previous/next track buttons 585
 Previous track control 587
 Prickers 385
 Prickle
 Blackberry 147
 Bramble stem 150
 Rose stem 130
 Slender thistle 129
 Primary bronchus 215
 Primary colors 439
 Primary-drive gear 366
 Primary flight display 575
 Primary flight feathers 188, 191
 Primary follicle 258
 Primary leaf 121
 Primary mirror 612
 Primary mirror housing 615
 Primary mycelium 115
 Primary remiges 188, 191
 Primary root 132-135
 Germination 152-155
 Seedling 152-155
 Primary teeth 246
 Primary thallus 114
 Primary xylem 125, 135
 Primates 108, 202-205, 279
 Primer 548, 436
 Primitive crocodylians 68
 Primitive life-forms 64
 Primitive mammals 206
 Principal arteries and veins 253
 Principal rafter
 Ancient Roman mill 464
 Dome 486
 Gothic building 475
 Printer 574-575
 Printer cover 574, 575
 Printing block 449
 Printing papers 447
 Print making 446-447, 448-449
 Prism 518, 625
 Prismatic habit 271
 Privy 580
Probactosaurus 97
 Probes, space 614-615
 Proboscidea 104
 Proboscis 169, 201
 ProCambial strand 134
 Procerus muscle 229
 Processing cooling fan 567
 Processing light 575
 Processional path 470
Procompsognathus 87
Procoptodon 76
 Procyon 8, 21
Procyon lotor 195
 Production line
 Mass-production 358
 Modern bodywork 348
 Modern trim 552
 Programme display 577
 Program name 577
 Projectile 396
 Projector assembly 581
 Projector lens 611
 Prokaryotes 78
 Prolegs 169
 Promethium 311
 Prominence 32-35
 Pronaas 461
 Pro-otic bone 185
 Propagative structures 154-155
 Propellant 396
 Propellant tank 615
 Propeller 390-391
 ARV light aircraft 425
 Battleship 395
 Biplanes and triplanes 402-405
 Early monoplanes 400-401
 Ford diesel engine 347
 Frigate 396
 Hawker Tempest components 408
 Lockheed Electra airliner 406-407
 Pegasus Quasar ultralight 427
 Pioneers of flight 398-399
 Submarine 396
 World War I aircraft 404-405
 Propeller-bolt collar 411
 Propeller brake pad 419
 Propeller drive flange
 ARV light aircraft 425
 Modern piston aero-engines 410-411
 Propeller drive gearbox 427
 Propeller drive shaft 408
 Propeller-hub spinner 407
 Propeller shaft
 Brazilian battleship 395
 Wright Flyer 599
 Propeller shaft boss 595
 Propeller-shaft bracing strut 398-399
 Propeller shaft rear bearing 410
 Propeller speed probe 419
 Propeller spinner 408, 409
 Propodus 172, 175
 Propylaea 460
 Prosauropoda 85
 Prosauropods 88
 Proscapular process 187
 Prosimians 205
 Prosimii 202
 Prosoma 170, 171
 Prostate gland 257, 259
 Prostyle colonnade 485
 Protractinium 510
 Protective clothing
 Crickets 539
 Football 528
 Ice hockey 550-551
 Protective eyewear 544
 Protective gaiter 422
 Protective outer layer 125
 Protective root covering 153
 Protective scale 134
 Protective scale leaf 155
 Protein body 112
 Protein fibers 166
 Protein matrix 166
 Protein synthesis site 139
 Proterozoic era 279
 Proteus 50
 Prothallus 121
 Prothorax 168
 Protista 112, 116
Protoceratops 102-105

- Protoplanets 10-11
Proton 508, 516
Atomic mass 510
Atomic number 510
Fluorine-19 509
Nuclear fusion 22
Protonema 119
Protostar 24, 26
Protoxylem
Dicotyledon root 127
Monocotyledon root 127
Root 152-153
Proventriculus
Bird 189
Crayfish 175
Prow 372, 375
Prowhead 374
Proxima Centauri 18
Proximal convoluted tubule 256-257
Proximal interphalangeal joint 251
Proximal phalanx 250, 252
Prunus persica 151
Psathyrella candolleana 115
Pseudocarps 148-149
Pseudo-Corinthian capital 476
Psi Sagittarii 21
Psittacosaurus 100, 105
Psoas major muscle 225, 257
Pterapsis 65
Pterichthyodes 65
Pteridium aquilinum 121
Pterois voltans 180
Pteron 460-461, 463
Pterosaurs 70-71
Pterygoid bone 185
Pterygoid hamulus 220
Pterygoid plate 220
Ptolemaeus 40
Ptolemaic-Roman period 459
"P" turret 395
P-type silicon 605
Pubic bone 261
Pubic ramus 257
Pubic symphysis 258
Pubis
Archaeopteryx 85
Bird 189
Diplodocus 90
Eryops 81
Gallimimus 86
Human 218, 224, 259
Iguanodon 96
Ornithischian 82
Plateosaurus 88
Saurischian 82
Stegosaurus 95
Struthiomimus 87
Tyrannosaurus 84
Pubofemoral ligament 224
Pudenda 211
Pudendal nerve 258
Puffballs 114
Pugin, A.W.N. 495
Pull-down edit menu button 577
Pulley bolt 360
Pulley rim rear brake 562
Pulley wheel
Simple pulleys 520
Van de Graaff generator 316
Pulmonary artery
Frog 182
Human 251, 255, 254-255
Pulmonary semilunar valve 251
Pulmonary trunk 251, 255
Pulmonary vein 251, 253, 254
Pulp artery and vein 247
Pulp chamber 247
Pulp horn 247
Pulp nerve 247
Pulsar 28
Pumice 275
Marble carving 453
Pump
Nuclear power station 314
Testing candle wax 313
Pump drive belt 410
Pump drive shaft 411
Pump piston 391
Pupa 168
Pupil
Caiman 186
Human 213, 226, 241
Pupil's cockpit 405
Puppies 18, 21
Purchase 582-585
Purchase wire 594
Pure substances 506
Purfling 510, 511
Purkinje's cells 237
Purlin 475
Pusher propeller
Pegasus Quasar
ultraflight 426
Pioneers of flight 398-399
Push moraine 286
Push-rod 565, 567
Putter 547
Putting green 546
Putto 476
Putty eraser 450, 440
"P" wave 63
Pygal shield 187
Pygostyle 189
Pylon 514
Pylon fairing 427
Pylon forward fairing 573
Pylon strut 427
Pyloric cecum
Bony fish 181
Starfish 174
Pyloric duct 174
Pyloric region of stomach 179
Pyloric sphincter muscle 249
Pyloric stomach 174
Pyramid 458, 623
Pyrenees 77, 265
Pyrenoid 112, 116
Pyrites 268
Intrusive igneous rocks 275
Pyroclasts 272
Pyromorphite 269
Pyroxene 52, 267
Pyxis 18
- Q**
Quadrant arch 468
Quadrate bone 181
Quadratojugal bone
Frog 185
Heterodontosaurus 85
Quadrilateral 489
Quadrupartite vault 469
Quadrupedal dinosaurs 88, 92, 96, 100
Quadruplanes 402
Quark 509
Quarter back 526
Quarterdeck 580-581
Quarterdeck house 376
Quarter gallery 381
Quarter glass 348
Quarter light 540-541
Quarter panel molding 352
Quarter trim panel 352
Quartz
Color 271
Metamorphic rock 267
Oxides/hydroxides 268
Quasar (quasi-stellar object)
Galaxies 12
Objects in universe 11
Origin and expansion of universe 10-11
Quasar nucleus 13
Quaternary period 57, 76-77
Fossil record 279
Quatrefoil 471-475
Quaver 502
Quayside 587
Queen-post 473
Quercus palustris 74
Quercus petraea 151
Quick-release base 590
Quick-release mechanism 425
Quick-release strap 560
Quill
Drill 601
Feather 191
Writing tool 444
Quinacridone red 442
Quit key 590
Quiver 548
Quoin
Baroque church 481
Medieval building 466
Nineteenth-century building 492
Renaissance building 476
- R**
Rabbit line 380
Rabbits 196-197
Raccoons 194-195
Race car 556-557
Raceme 129
Rachilla 157
Rachis 156-157
Bipinnate leaf 157
Couch grass 113
Everlasting pea 129
Feather 191
Fern 121
Hogweed 129
Pinnate leaf 156-157
Rowan leaf 150
Tree fern 112
Trippinate leaf 157
Racing bicycle 560
Racing chain 561
Racing colors 554-555
Racing saddle 554
Racing sidecar 568-569
Racing "silks" 554-555
Racing tire 565
Formula One race car 556-557
Suzuki RGV500 568-569
Racketball 544-545
Racket sports 544-545
Radar
Modern jetliners 412
Modern military aircraft 420-421
World War II aircraft 408
RADAR antenna 597
RADAR for gunnery and missile control 597
Radial artery 251, 255
Radial canal
Jellyfish 167
Sea urchin 175
Starfish 174
Radial cartilage 180
Radial diffuser 418
Radial engine
Curtiss biplane 398-399
Lockheed Electra
airliner 406-407
Radial groove 565
Radial nerve
Human 258
Sea urchin 175
Radial river drainage 288
Radial spoke 47
Radial studio easel 457
Radial wall 465
Radiation 38
Electromagnetic 314
Energy emission from Sun 22
Galaxies 12-15
Nebulae and star clusters 16
Ozone formation 64
Universe 10
Radiative zone
Structure of main sequence star 24
Structure of Sun 33
Radiator
1906 Renault 536-537
ARV light aircraft 424
Ford Model T 538-539
Hawker Tempest fighter 409
Honda VF750 364
Kirby BSA 569
Renault Clio 551
Wright Flyer 399
Radiator-access cowling 408
Radiator air vent 568
Radiator apron 539
Radiator fan 526
Radiator fan 526
Radiator filler neck 539
Radiator header tank 408
Radiator hose 539
Radiator outlet 409
Radiator pipe 564
Radiator shell 539
Radicl
Dry fruit 150
Embryo development 483
Epigeal germination 153
Hypogeal germination 152
Radio
Bell-47 helicopter 422
Renault Clio 555
Streamed internet 577
Radio aerial 426
Radio antenna 395
Radio galaxies 12-15
Radio image 13
Radio-isotope thermo-electric generator 614
Radio lobe 15
Radio mast 494
Radio operator's seat 408
Radio plugs 425
Radio speaker 553
Radio tuner aerial socket (FM) 585
Radio tuner FM/AM selector 585
Radio-ulna 185
Radio wave beam 28
Radio-wave emission 15
Radio waves
Electromagnetic spectrum 518
Pulsar 28
Radio image of Centaurus A 13
Radium 510
Radium
Archaeopteryx 85
Arsinoitherium 104
Baryonyx 85
Bird 189, 191
Circle 622
Circledile 186
Diplodocus 90
Domestic cat 195
Elephant 90, 201
Eryops 80
Euoplocephalus 94
Hare 197
Horse 199
Human 218, 230-231
Iguanodon 96
Kangaroo 206
Lizard 184
Parasaurolophus 99
Pareiasaur 81
Plateosaurus 88
Platyopus 206
Rhesus monkey 202
Seal 204
Stegoceras 100-101
Struthiomimus 87
Toxodon 106
Triceratops 102
Turtle 187
Radius arm 357
Radius rod
Avro Tutor biplane 405
Ford Model T 538-539
Radome
BAe-146 jetliner 415
Concorde, the 416-417
Tornado 420
Radon 511
Radula 176-177
RAF Central Flying School badge 402
RAF roundels 405, 409
Raft 496
Rafter
Ancient Roman mill 464
Dome 486
Gothic building 475
Modern building 499
Nineteenth-century building 492
Raft spider 171
Rail
Electric tram 532
Kayak 560
Neoclassical building 483
Relief-printing press 449
Train 530-531
Wooden sailing ship 579
Rail chair 524
Railing
Asian building 490-491
Cathedral dome 487
Medieval building 467
Nineteenth-century building 493
Renaissance theater 477
Railroad crest 326
Railroad system 524
Rain 502
Rain erosion 294
Rain gutter 412, 415
Rainwater
Caves 284
Weathering and erosion 282
Raised beach 295
Raja clavata 179
Raked windshield 555
Raking cornice
Ancient Greek building 460-461
Ancient Roman building 462-463
Baroque church 480-481
Neoclassical building 478
Raking stempost 576
Ram 572
Ramaria formosa 114
Ramentum 112, 121
Rammer 396
Ramp 467, 494
Ram scoop
BE 2B bomber 404
Tornado 420-421
Rangefinder
Battleship 594
Gun turret 396
Ranks 514
Ranunculus sp. 127, 152-153
Raphé 155
Rapid-fire pistols 548
Rapids
River features 290
River's stages 289
Rare earths 310
Rare gases 511
Ras Algethi 20
Ras Alhague 19, 20
Rasp 452
Raspberry 149
Rat 104, 196
Ratchet
Brace-and-bit 601
Fixed-spool reel 562
Ratched base 590
Ratchet mechanism 601
Ratchet wheel 554
Rating 378
Ratings' mess 597
Ratline 376, 379
Rat's tail 584
Rat tail 389
Rattlesnake 185
Raw sienna 434
Raw umber 434
Ray
Branchiostegal 181
Caudal fin 180
Dorsal fin 181
Jawless fish 178
Liverwort 118
Mercury 34
Near side of the Moon 40
Parenchyma cells 154
Pectoral fin 181
Ray crater 54
Ray florets
Florists' chrysanthemum 129
Sunflower 142, 145
Reactants 512
Reaction wheel 614
Reactive metals 510-511
Reactor core 514
Reactor space 597
Rear axle 558
Rear axle adjuster 564, 568
Rear bearing 411
Rear brake 562
Rear brake cable 559, 560
Rear brake calliper 568
Rear brake pedal 568
Rear bulkhead 417
Rear cantilever brake 558
Rear case 591
Rear chassis plate 597
Rear cylinder exhaust pipe 568
Rear derailleur 558, 560
Rear door 559
Rear dropouts 558
Rear hatch 549
Rear hub quick-release spindle 558
Rear indicator 562
Rear lamp
Oldsmobile trim 337
Volkswagen Beetle 540
Rear leaf spring 558
Rear light
Bicycle 560
Italian State Railroads Class 402 528
Paris Metro 328
Rear limit line 557
Rear-mounted propeller
Pegasus Quasar
ultraflight 426
Pioneers of flight 398-399
Rear oil lamp 556

- Rear shelf 552
Rear shock absorber 340
Rear subframe 364
Rear tail light 529
Rearview mirror
 1906 Renault 356
 Formula One race car 357
 Renault Clio 355
Receiver
 American squash 545
 Badminton 545
 International squash 545
 Racketball 545
 Tennis 544
Receiving line 545
Receptacles
 Algae 116
 Dicotyledon flower 127
 Dry fruit 150-151
 Fertilization 147
 Flower 140-36
 Rose 151
 Seaweed 116-117
 Succulent fruit 148-149
Recessed arch 488
Recessed hinge 414, 415
Rechargeable battery
 Digital camera 581
 Nintendo Wii Fit Plus 579
Recharge area 292
Reclining seat 572
Recoil cylinder 396
Reconnaissance camera 420
Recorded information 521
Recording light 585
Record/Stop button 586
Rectal cecum 174
Rectal gland 179
Rectangle 622
Rectangular block 625
Rectangular cross-band 374
Rectangular pier 465, 467, 480
Rectangular river drainage 288
Rectangular window
 Ancient Roman building 465
 Asian building 490
 Baroque church 481
 Medieval building 466
 Renaissance building 474, 476
Rectum
 Bird 189
 Butterfly 169
 Chimpanzee 202
 Cow 198
 Dogfish 179
 Dolphin 205
 Elephant 200
 Frog 182
 Human 215, 248-249, 258-259, 261
 Lizard 185
 Rabbit 196
 Starfish 174
 Tortoise 187
Rectus abdominis muscle 226
Rectus femoris muscle 226
Recumbent fold 61
Red algae 116
Red blood cells 217, 255
Red-brown crocoite 271
Red card 524
Red cedar boarding 602
Red cell 584
Red deer 199
Red dwarf 25
Red earth 453, 454-455
Red filter signal light 407
Red giant
 Small stars 24-25
 Stars 22-25
Red howler monkey 205
Red light 518
 Main-line signaling system 350, 351
Red light photon 518
Red marble 450
Red port navigation light 406
Red sandstone 277
Red seaweeds 117
Red spot 44-45
Red supergiant
 Massive stars 26-27
 Stars 22-25
Reduction gearbox
 Early piston aero-engines 410-411
 Jet engines 419
 Turbo-prop engine 419
Redwall limestone 277
Red warning light
 Italian State Railroads Class 402 328
 Paris Metro 328
Redwood trees 70
Reed pen 444
Reef knot 588
Reef point 585
Reel
 Angling equipment 562-565
 Fencing piste 557
 Frigate 397
Reel foot 562-565
Reel scoop 562-565
Reel seat 563
Reentrant angle 485
Reentrant corner 479
Referee
 Basketball 552
 Football 526
 Gaelic football 529
 Ice hockey 550
 Judo 556
 Lacrosse 541
 Rugby 530
 Soccer 524
 Swimming 558
 Volleyball 554
Referee's crease 550
Referee's equipment 524
Referee's signals
 Basketball 555
 Football 527
Reflection 318
Reflection nebula 16
Reflector
 Ford Model T 559
 Oldsmobile trim 557
Refraction 318-319
Refractory (heat-resistant) skin 421
Refrigerator freight car 527
Régie Autonome des Transports Parisien 528
Regional metamorphism 274
Regional weather 502
Registers 514
Regolith (soil) 41
Regula 461
Regulator
 "Mallard" express steam locomotive 325
 "Rocket" steam locomotive 324
Regulator valve 325
Regulus 18, 21
Rein 554
Reinforce 395
Reinforced concrete 494, 497
 Ties 530
Reinforced plinth 499
Rein terret 555
Relative atomic mass 510
Relay baton 545
Relay running 542
Release 557, 545
Release adjustment screw 552
Release button 425
Release catch 590
Release lever 565
Release spring 565
Relief 458
Relief printing 446
Relief printing equipment 449
Relieving arch
 Ancient Roman building 462, 465
 Medieval building 466-467
Remiges 188, 191
Remote control 584, 585
Remote control sensor 585
Remote sensing palette 614
Removable archery screen 377
Renaissance buildings 474-477
Renal artery 256-257
Renal column 256
Renal papilla 256
Renal pelvis 256
Renal sinus 256
Renal vein 256-257
Renalt (1906) 356-357
Renault Clio 348-355
Renault logo 348
Renewable energy 604-605
Renoir 35
Repeater indicator 555
Repeating pattern 507
Replum 151
Reply all button 576
Reply button 576
Reproduction
 Algae 116-117
 Cloning 606-607
 Fertilization 146-147
 Flowering plants 140
 Liverwort 118
 Moss 118-119
 Vegetative 154-155
Reproductive canal 94
Reproductive chamber 116
Reproductive organs 259
Reproductive structures
 Flower 140-145
 Pollination 144
Reproductive system 258-259
Reptiles 80-81, 184-187
 Carboniferous period 66
 Dinosaurs 82-83
 Fossil record 279
 Jurassic period 70
 Present-day 82
 Rhynchosaurian 71
 Synapsid skull 67
 Triassic period 68
Reptilia 184, 186
Repulsion 316-317
"Request identification" aerial 421
Reradiated heat 300-301
Reredos 470
Rescue truck 561
Reservoir 514
Reset button 560
Resin canal
 Bishop pine needle 124
 Pine root/stem 125
Resistance 316
Resonator 515
Respiration 255
Respiratory system 254-255
Rest
 Musical notation 502
 Newton's first motion law 521
Resurgence 284-285
Retaining bolt hole 366
Retaining screw 562, 565
Reticulum
 Digestive system of a cow 198
 Southern stars 20
Retina 240-241
Retraction jack 417
Retractor muscle 167
Retreating glacier 286
Retrices 188
Retroarticular process 85
Return 486-487
Rev counter 369
Reversed bend hook 562
Reversed dive piked 559
Reverse dip-slip fault 61
Reverse dive 558
Reverse-flow combustion chamber 418
Reverse lever 342
Reverser handle 325
Reverse shock wave 27
Reversible reactions 512
Reversing shaft lock control 525
Reversing wheel 392
Revivalist style 495-494
Rewind button 577
Rhamphodopsis 65
Rhamphorhynchus sp. 71
Rheas 188
Rhenium 510
Rhesus monkey 202
Rhinosceroses 198-199
Rhizine 114
Rhizoids 118-119
 Alga 116
 Fern 121
 Liverwort 118
 Moss 119
Rhizomes 154-155
 Fern 121
 Herbaceous flowering plants 128
 Horsetail 120
 Water hyacinth 158
 Water lily 159
Rhizophore 120
Rho1 Sagittarii 21
Rhodium 511
Rhodophyta 116
Rhomboides major muscle 227
Rhomboid leaves 157
Rhombus 622
Rhopalium 167
Rhynchosaurian reptile 71
Rhynchosaurus 68-69, 71
Rhyolite 274-275
Rhyolitic lava 272
Rhythm
 Drums 518
 Percussion instruments 516
Rhythm pattern selector 520
Rib
 Acoustic guitar 512
 Archaeopteryx 85
 Avro triplane 403
 Baroque church 479
 BE, 2B tail 405
 BE, 2B wings 404
 Bird 189
 Blackburn monoplane 401
 Bony fish 181
 Brachiosaurus 90
 Concorde, the 417
 Crocodile 186
 Diplodocus 90
 Dome 486-487
 Domestic cat 195
 Double bass 511
 Elephant 201
 Eryops 80
 Euoplocephalus 94
 Gallimimus 86
 Hare 197
 Herbaceous (lowering) plant 128
 Horse 199
 Kangaroo 206
 Lizard 184
 Medieval church 469
 Modern building 499
 Pareiasaur 81
 Pegasus Quasar ultralight 426-427
 Pegasus XL, SE ultralight 426
 Plateosaurus 88
 Platypus 206
 Rhesus monkey 202
 Seal 204
 Snake 185
 Stegoceras 101
 Struthiomimus 87
 Toxodon 107
 Triceratops 102
 Tyrannosaurus 84
 Violin 510
 Westlothiana 81
Riband 581
Ribbon connectors 585
Ribbon Lake 287
Ribbon window 499
Rib cage
 Carnivores 195
 Human 218
Ribosome
 Chloroplast 159
 Human cell 217
Rib vault 469, 484-485
Ribic building 470
Medieval building 467
Renaissance building 477
Rice paper 445
Ride cymbal 519
Ridge
 Epigeal germination 155
 False septum 151
 Gothic building 475
 Modern building 499
 Nineteenth-century building 492
 Seed 155
 Twentieth-century building 495
Ridge and furrow roof 492
Ridge-board 475
Ridge-rib 469, 485
Ridges 286-287
Ridge tile 464, 476
Riding bit 372
Riding jacket 554
Riffler 452, 453, 454
Rifle 548, 549
Rift valley 58
 Lake formation 292-295
Rig 584-585
Riga brush 454
Rigel
 Northern stars 18
 Orion 18
 Southern stars 21
 Star magnitudes 22
Rigger 560
Rigger's gauge 382
Rigging 582-585
 Iron 392
 Sailing dinghy 561
 Wooden sailing ship 378-379
Rigging rail 376
Rigging tools 382-385
Right-angled triangle 622
Right cylinder 623
Right edge guide 575
Right whales 204
Rigid rod 60
Rigol 581
Rim
 Bicycle wheel 358-359
 Kayak paddle 560
 Paddle wheel 391
 Tam-tam 516
 Twin bollards 386
Rim brake 530
Rim clamp 357
Rim of pitcher 161
Rim plate 390
Rim section 390
Rind 149
Ring
 74-gun ship 380
 Mushroom 115
 Roman corbita 372
Ring 1986 U1R 48
Ring 1986 U2R 48
Ring 6 48
Ring bolt 375
Ring canal
 Sea urchin 175
 Starfish 174
Ring dyke 26
Ring finger 250-251
"Ring of Fire" 272
Ring of trunk 201
Rings
 Jupiter 44-45
 Neptune 50-51
 Saturn 46-47
 Uranus 48-49
Rings 4 and 5 48
Ring scar 130, 151
Ring-tailed lemur 205
Rink corner 550
Riojasaurus 89
Ripple finish 451
Risper
 Bronze casting 454, 455
 Staircase 477
Rising air
 Atmospheric circulation and winds 500
 Precipitation 502
Rising land 294
Risorum muscle 229
Rissa tridactyla 190
Ritchey 45
River Amur 265
River banks 289, 290
Riverbed 289
River capture 288
River cliff 289, 290
River course 288
River development 289
River drainage patterns 288
River features 290-291
River flow 290
River mouth 290
Rivers 288-289
 Earth's physical features 264
 River features 290-291
 Rock cycle 266-267
 Weathering and erosion 282
River source
 River features 290
 Rivers 288
River's stages 288-289
River terrace 290-291
River valley 288, 289, 290
Riveted plates 392
Road spring 540
Roband 372, 374
Robie House 495
Robinia pseudoacacia 156
Roboreptile 609
Robots 608-609
Robot dogs 609
Roche 41
Roches moutonnées 286
Rock compression 60
Rock crystal 271
Rock cycle 266-267
Rock debris 295

- Rock deformations 60, 61
 Rocker 446
 Rocker arm 366
 Rocker-beam 496-497
 Rocker cover 547, 554
 Rocker deployment actuator 615
 Rock erosion 282
 Rocker keypad 591
 Rocker pad 590
 "Rocket" steam locomotive 324
 Rocket launcher 397
 Rock fracture 60
 Rock ground mass 269
 Rocking beam 334
 Rocking elevator arm 424
 Rocking lever 342
 Rock layer
 Caves 284
 Faults and folds 60
 Rock lip
 Cirque formation 287
 Tarn lake 295
 Rock mounds 286
 Rock particles 266-267
 Rock pavement 282-285
 Rock pedestal 282-285
 Rock prisms 61
 Rocks
 Faults and folds 60-61
 Fossils 278-279
 Igneous and metamorphic rocks 274-275
 Mineral resources 280
 Minerals 268
 Rock cycle 266-267
 Sedimentary rocks 276
 Weathering and erosion 282
 Rock salt
 Halides 269
 Sedimentary rocks 276-277
 Rock scar 284
 Rock stoncrop 128
 Rock strata 60, 61
 Fossils 278
 Rock stress 60, 61
 Rock tension 60, 61
 Rocky Mountains 73, 75, 77, 264
 Rocky planets
 Mars 42-43
 Mercury 34-35
 Solar system 30-31
 Venus 36-37
 Rococo style 478
 Rod 562-565
 Rodentia 104, 196
 Rodents 196-197
 Rod-shaped structure 144
 Rogers, R. 496
 Roll 400
 Roller
 Mid West single-rotor engine 410
 Motorized brushbar floor tool 593
 "O Ring" drive chain 366
 Painting tool 442
 Printing equipment 447, 449
 Tenor saxophone 509
 Roller-bearing axle box 327
 Roller-blind 497
 Roller path 396
 Rollers 596
 Rolling hitch 388
 Rollover button 577
 Roll paper holder 575
 Roll paper holder adapter 575
 Roll paper manipulation button 574
- Roll spoiler 414
 Roll-spoiler hydraulic actuator attachment 414
 Rolls-Royce Olympus Mark 610 turbojet 417
 Roman anchor 372
 Roman architecture 462-465
 Roman corbita 372-373
 Romanesque style 468, 470
 Roman mill 464
 Roman number system 591
 Roman ships 372-373
 Roof boss 468
 Roof construction 603
 Roof dome 552, 553
 Roofed space 479
 Roofing tile 482
 Roofless temple 460
 Roof molding 352
 Roofs 484
 Ancient Egyptian temple 458-459
 Ancient Roman building 462
 Asian building 490
 Baroque church 481
 Dome 486
 Gothic building 470-473
 Hammer-beam 470, 473
 Islamic building 488-489
 Medieval building 467, 468
 Modern building 496-499
 Neoclassical building 479, 483
 Nineteenth-century building 492
 Renaissance building 476-477
 Twentieth-century building 494-495
- Root
 BAe-146 jetliner components 415, 415
 BE 2B wings 404
 Tooth 247
 Root canal 247
 Root cap
 Broad bean 133
 Radicle 153
 Root growth 282
 Root hairs 132
 Root nodule 128
 Root of tail 198
 Root parasite 165
 Root-proof membrane 603
 Root rib 415
 Roots 132-133
 Adventitious 112-113
 Amaryllis 155
 Begonia 155
Brassavola nodosa 162
 Bromrape host 163
 Carrot 128
 Cell division 133
 Clubmoss 120
 Couch grass 113
 Dehiscent fruit 150
 Dicotyledons 127
 Elongation region 133
 Embryo 147
 Epigeal germination 155
 Epiphytes 162-163
 Fern 121
 Germination 152-153
 Ginger 155
 Gladiolus 155
 Golden barrel cactus 156
 Grape hyacinth 155
 Horse chestnut 150
 Horsetail 120
- Hypogeal germination 152
 Ivy 131
Kedrostis africana 113
 Lily 155
 Monocotyledons 126-127
 Mycorrhizal association 133
Oxalis sp. 157
 Pine seedling 122
 Potato 128
 Rock stoncrop 128
 Seedling 152-153
 String of hearts 157
 Sweet pea 128
 Sweet potato 155
 Vegetative reproduction 154-155
 Water hyacinth 158
 Water transport 158
 Root scar 128
 Root succulents 157
 Root tip 132-133
 Radicle 152-153
 Root tubers 154-155, 157
 Rope and paterae decoration 459
 Rope band 372
 Rope hole 586
 Rope molding 395
 Rope parrel 373
 Rope preventer 378
 Ropes 388-389
 Rope serving mallet 385
 Rope strand 584
 Rope wooding 379
 Rope work 588
 Rorquals 204
Rosa sp. 150-151, 155
 Rose 150-151
 Rose quartz 271
 Rosette
 Epiphytic plants 162-163
 Neoclassical building 480
 Rosette Nebula 11
 Rossby waves 300
 Rossini Italian time-trial bicycle 361
 Rostellum 16
 Rostral bone 102, 103
 Rostrum
 Crayfish 173
 Dolphin 204
 Rotary engine 346-347
 Blackburn monoplane 400
 Modern piston aero-engines 410-411
 Rotary valves 507
 Rotating beacon 407
 Rotating drum 595
 Rotating joint 612
 Rotational period 36
 Rotor
 Mid West rotary engine 411
 Rotor and seals 347
 Rotor blade 423
 Rotor chamber
 Mid West single-rotor engine 410
 Wankel rotary engine 346
 Rotor gear 346-347
 Rotor gear teeth 411
 Rotor house 314
 Rotor hub
 Bell-47 helicopter 422
 Schweizer helicopter 423
 Rotor journal 347
 Rotor lock 604
 Rotor mast 422-423
 Rotunda 462-463, 482
 Rough 546
 Rough endoplasmic
- reticulum 217
 Rough terrain motorcycle racing 568
 Rough-textured paper 439, 441
 Roulette 446
 Rounce 449
 Round arch
 Ancient Roman building 464-465
 Baroque church 479-480
 Dome 484, 486-487
 French temple 485
 Gothic church 473
 Medieval building 467-469
 Nineteenth-century building 495
 Renaissance building 474-475
 Round-arched window
 Ancient Roman building 465
 Baroque church 481
 Dome 486
 Medieval building 466, 468-469
 Neoclassical building 478
 Round ball 524
 Round-corner single limousine coachwork 336
 Roundel
 Avro biplane 405
 Hawker Tempest fighter 409
 Roundhead nib 444
 Roundhouse 380
 Round pin 335
 Round shot 378
 Round thimble 384
 Route information 332
 Route key 590
 Rover 528
 Rover equipment deck 615
 Rowan 150-151
 Rowing 560-561
 Rowing boat 375
 Rowing positions on a Greek trireme 373
 RSS (really simple syndication) feeds 577
 Rubber bungee shock absorber 425
 Rubber cord suspension 402-405
 Rubber guide wheel 528
 Rubber mounting bush 365
 Rubber puck 550-551
 Rubber roller 449
 Rubber sealing strip 413
 Rubber-sprung wheel 400-401
 Rubber tire 402
 Rubber-tired running wheel 328
 Rubber wheel-guard 328
 Rubber wheels
 Paris Metro 328
 "People Mover" 328
 Rubbing
 Charcoal drawing 451
 Relief printing 446
 Rubbing ink 448
 Rubbing strake
 Mazda RX-7 346
 Roman corbita 372
 Rubbing strip 353
 Rubens 35
 Rubidium 510
Rubus fruticosus 130, 146-147
Rubus idaeus 149
 Ruckman 528
 Rucknover 528
- Ruckstell axle 359
 Rudder
 ARV light aircraft 424
 Avro biplane 402
 Avro triplane 405
 BAe-146 jetliner 415
 Battleship 395
 BE 2B bomber 405
 Blackburn monoplane 401
 Blériot XI 401
 Concorde 416-417
 Curtiss biplane 399
 Dhov 376
 Frigate 396
 Greek and Roman ships 372-373
 Iron paddlesteamer 392
 Junk 376
 Lockheed Electra airliner 407
 Longboat 380
 LVG CVI fighter 405
 Northrop B-2 bomber 421
 Sailing dinghy 561
 Sailing warship 377
 Schleicher glider 426
 Submarine 396
 Tornado 421
 Viking boats 374-375
 Wooden sailing ship 378
 World War II aircraft 408-409
 Wright Flyer 399
 Rudder cable
 ARV light aircraft 424
 Avro biplane 402
 Rudder chain 378
 Rudder head 376
 Rudder hinge
 Avro biplane 402
 Blériot XI monoplane 401
 Rudder mass balance 424
 Rudder pedal 425, 575
 Rudder post
 BE 2B bomber 405
 Blackburn monoplane 401
 Iron paddlesteamer 392
 Rudder power control unit 417
 Rudder strut 399
 Rudder tip fairing 424
 Rudder trintab 409
 Ruden 372
 Rudimentary ear 260
 Rudimentary eye 260
 Rudimentary liver 260
 Rudimentary mouth 260
 Rudimentary vertebra 260
Ruellia grandiflora 145
 Ruffini corpuscle 235, 239
 Ruga 248
 Rugby 524, 550-551
 Rugby League 550-551
 Rugby Union 550
 Rules of algebra 621
 Rumen 198
 Ruminants 198
 Rumpler monoplane 400
 Run 536
 Runners
 Bronze casting 454-455
 Rock stoncrop 128
 Strawberry 128
 Vegetative reproduction 154
 Running 542
 Running back 526
 Running block 383
 Running board
 Ford Model T 339
 1906 Renault 337
 Volkswagen Beetle 341
 Running martingale 554
- Running part 382
 Running rail 328
 Running rigging 382-383, 385
 Running shoe 543
 Running track 542
 Running wheel 328
 Runs 538
 Rupes 34
 Rupes Altai 40
 Rush 135
 Russian vine 131
 Rustication
 Neoclassical building 479, 482-483
 Renaissance building 474-475
 Rusts 114
 Ruthenium 311
- S**
 62 Sagittarii 21
 Sabik 20
 Sable brush
 Acrylics 442
 Calligraphy 444
 Oil paints 436
 Tempera 432
 Watercolors 458
 Sabers 556-557
 Saberur 557
 Saber warning line 557
 Sacajawea 37
 Saccule 243
 Sacral foramen 223
 Sacral nerves 258
 Sacral plexus 238
 Sacral promontory 223
 Sacral vertebra 185
 Sacral vertebrae
Diplodocus 90
Eryops 81
 Human 223
Iguanodon 96
Parasaurolophus 98
Plateosaurus 88
Stegoceras 101
 Sacristy 470
 Sacrum
 Crocodile 186
 Domestic cat 195
 Elephant 201
 Hare 197
 Horse 199
 Human 218, 223, 259
 Kangaroo 206
 Lizard 184
 Rhesus monkey 202
 Seal 204
 Saddle
 Acoustic guitar 512
 Bicycle 358-359
 Cannondale SH600 hybrid bicycle 361
 Eddy Merckx racing bicycle 360
 Horse racing 555
 Show jumping 554
 Werner motorcycle 362
 Saddle clamp 360
 Safety area 556
 Safety barrier 552
 Safety belt 356
 Safety binding 552
 Safety harness 357
 Safety valve
 Bordino steam carriage 334
 Steamboat 391
 Safe working load mark 383
Sagittaria elegans 166
 Sagitta 20
 Sagittal crest 107, 194
 Sagittal section through brain 236
 Sagittarius 19-21

- Sagittarius Arm 14
Sago palm 125
Sahara 59, 264-265
Sail
 Roman corbita 372-373
 Square-rigged ship 375
 Types 384-385
 Viking karv 374
Sail batten 376
Sailcloths 384
Sail foot control line 375
Sail hook 384
Sailing 560-561
Sailing rigs 384-385
Sailing warship 376-377
Sailmaker's whipping 382
Sailmaking tools 384
Sail patterns 379, 384
Saiph 18
Salamanders 182
Salient 466
Salisbury Cathedral 470-471
Saliva 244
Salivary gland
 Butterfly 169
 Snail 177
Salmon 109, 180
Salmon angling 562
Salmon bend gouge 452
Salmon radial engine 398-399
Salt
 Dead Sea 295
 Seawater sail content 296
Saltasaurus 72, 91
Salt-dome trap 281
Salt formation 312
Salt groundmass 277
Salt lakes 292
Samaras
 Dry fruit 150
 Sycamore 151, 150
Samarium 311
Sambucus nigra 150-151, 145
Samotherium 74
Samsung Galaxy Tab 569
San Andreas fault 58, 62-65
Sand-bars 290
Sand box 326, 327
Sand dunes
 Rock cycle 267
 Weathering and erosion 282-285
Sand groundmass 277
Sanding pipe 329
Sand-pits 546
Sandstone
 Marble tomb of Itimad-Ud-Daula 489
 Sedimentary rocks 276
Sand wedge 299
Sand wedge 547
Sandy deposits 298
Sandy spit 295
Sanguine crayon 450
Sankey diagram 314
Sappho Patara 37
Sapwood 125
Saratoga Race Course 553
Sarcolemma 24
Sarcomere 24
Sarcophilus harrisii 207
Sarcoplasmic reticulum 24
Sarcophamphus papa 190
Sarracenia purpurea 115
Sartorius muscle 226
Satellite 264
Satellite cable 586
Satellite map 264-265
Satellite speaker 586
Saturated zone 292-293
Saturn 46-47, 614
 Solar system 31
Saucer dome 486-487
 Ancient Roman building 462
 Saurischia 82-83, 84, 88
 Sauropoda 85
 Sauropodomorpha 83, 88
 Sauropodomorphs 88-91
 Sauropods 70, 88
 Savannah 74
 Save as draft button 576
 Saxboard 561
 Saxophone 504, 508-509
 Scala 372-373
 Scale (musical) 502
 Scale leaf scar 124, 155
 Scale leaves
 Bishop pine 124
 Bulb 155
 Corm 155
 Epiphytic orchid 162
 Hypogeal germination 152
 Pine 122, 125
 Plumule 152
 Rhizome 155
 Sago palm 125
 Stem bulbil 155
 Scalene triangle 622
 Scalenus medius muscle 229
 Scale of degrees 377
 Scales
 Asteroxyton 79
 Bishop pine 124
 Bony fish 180
 Bract 122
 Brassavola nodosa 162
 Caiman 186
 Cartilaginous fish 178
 Crocodilians 186
 Dicotyledons 127
 Fern fruit 148
 Falsen fronds 121
 Insects 168
 Lepidoptera wings 168
 Lizard 184
 Mushroom 115
 Ovuliferous 122-124
 Pine cone 122
 Pine shoot apex 125
 Rattlesnake 185
 Sago palm 122
 Tree fern 112
 Yew 125
 Scallop 176
 Fossil 278
 Scalloped hammerhead shark 179
 Scalp 254, 256-257
 Scaly lichens 114
 Scintigram 214
 Scaly skin
 Anchisaurus 89
 Corythosaurus 98
 Dinosaurs 82
 Edmontonia 95
 Echthyostega 80
 Iguanodon 97
 Pachycephalosaur 100
 Psittacosaurus 105
 Reptile 80
 Snake 184
 Stegosaurus 92
 Triceratops 102
 Tyrannosaurus 84
 Westlothiana 81
 Scandinavia 64, 69
 Scandium 310
 Scan head 571
 Scanner 570-571
 Scanning coils 611
 Scanning electron microscope (SEM) 610, 611
 Scan to email button 570
 Scan to web button 570
 Scapania undulata 118
 Scape 168
 Scaphoid bone 250
 Scaphoid fossa 242
Scaphonyx fischeri 69
Scapula
 Archaeopteryx 85
 Arsinoitherium 104
 Bird 189
 Bony fish 181
 Brachiosaurus 91
 Crocodile 186
 Diplodocus 90
 Domestic cat 195
 Elephant 201
 Eiryops 80
 Euoplocephalus 94
 Gallimimus 86
 Hare 197
 Horse 199
 Human 210, 218
 Iguanodon 96
 Kangaroo 206
 Lizard 184
 Parasaurolophus 99
 Pareiasaur 81
 Plateosaurus 88
 Platypus 206
 Rhesus monkey 202
 Seal 204
 Stegoceras 101
 Struthiomimus 87
 Toxodon 106
 Triceratops 102
 Tuojiangosaurus 95
 Turtle 187
 Tyrannosaurus 84
 Scapular muscle 91
 Scarlet star 162-165
 Scarp 395
 Scars
 Horse chestnut 130
 Leaf 128-30, 154
 Rowan twig 131
 Scavenge oil line 419
 Scelidosaurus 71
 Scent 144
 Scheat 19, 20
 Schedar 19
 Schickard 40
 Schist 26
 Schizoearpic dry fruits 150-151
 Schleicher K25 glider 426
 Schlumbergera truncata 129
 Schooner 384-385
 Schrodinger 41
 Schubert 35
 Schwann cell 228, 239
 Schweizer 300c 425
 Sciatic nerve 258
 Scientific notation 621
 Scintigram 214
 Scissor brace 475
 Sciurus carolinensis 197
 Sclera 213, 240
 Scleroid 159
 Sclerenchyma
 Fern rachis 121
 Horsetail stem 120
 Marram grass 113
 Monocotyledon leaf 126
 Stems 134-135
 Sclerenchyma fibers 135
 Scleroderma citrinum 115
 Sclerotic ring 90, 99
 Scooter 50-51
 Score 588
 Scorecard 547
 Scorer
 Basketball 552
 Fencing contest 557
 Judo contest 556
 Lacrosse 541
 Netball 535
 Volleyball 534
 Scoria 275
 Scoring
 Australian rules football 528
 Badminton 544
 Baseball 556
 Basketball 552
 Cricket 558
 Gaelic football 529
 Hockey 540
 Hurling 540-541
 Netball 534
 Rugby 530-531
 Tennis 544
 Volleyball 534
 Scorper 449
 Scorpion 170, 278
 Scorpioides 170
 Scorpius 19, 20
 Scotia 465, 485
 Scots pine 122
 Scraper 46
 Scraper ring 344
 Scratchplate 515
 Screed 282-285
 Screen
 Computer 576, 577, 611
 French baroque building 482
 Hydroelectric power station 314
 Islamic building 488-489
 Screen printing 448
 Streamed internet video 577
 Twentieth-century building 494
 Screen bulkhead 381
 Screen lens 589
 Screen printing 446, 448
 Screw 320
 Acoustic guitar 513
 Double bass bow 511
 Power drill 600
 Toaster 598
 Violin bow 510
 Screw coupling 525
 Screw down greaser 556
 Screw fitting 519
 Screw hole 600
 Screw joint 413
 Screw link 386
 Screw locking nut 563
 Screw pressure adjuster 447
 Scriber 446
 Scroll
 Cello 511
 Double bass 511
 Viola 511
 Violin 510
 Scrolled buttress 478
 Scroll motif 470, 491
 Scroll molding 466
 Scroll ornament 476, 479, 485
 Scroll-shaped corbel 482, 487
 Scrollwork 472
 Scrotum 211, 259
 Scrum-half 530
 Scrummages 530
 Scul 561
 Scullying 560
 Scul oar 560
 Sculpted wing-root fairing 575
 Sculptor 19, 20
 Sculptural decoration 467
 Sculpture 452-455, 495, 495
 Sculptured testa 151
 Scumbling 440-441
 Scupper 595
 Scute 186
 Scutellum 168
 Scutum 19
 Scutum plate 175
 Scyphozoa 166
 Sea
 Anticline trap 281
 Fossils 278
 Hurricane structure 305
 River features 290-291
 Sea anemone 166-167
 Sea angling 562
 Seabed
 Fossils 278
 Ocean floor 298
 River features 290
 Rivers 288
 Seabed profile 299
 Sea buckthorn 136
 Seacat missile launcher 397
 Sea-cave 295
 Sea-cliff 294-295
 River features 291
 Sea creature remains 298
 Sea cucumber 174
 Sea daisies 174
 Sea-dwelling organic structures 78
 Seafloor spread 58
 Seahorse 180
 Sea level 66
 Sea-level variations 294
 Sea lilies 174
 Sea lion 204
 Seals 204-205
 Seam
 Riveted plates 392
 Sail 584
 Seaming twine 384
 Seamounts 298
 Sea of Japan 265
 Search field 576, 577
 Searchlight 394-395
 Seas 296-297
 Igneous and metamorphic rocks 275
 Rivers 288
 Satellite map 265
 Seasons 72
 Seat
 1906 Renault 337
 Driver's 325, 328
 Faering 375
 Fireman's 325
 First cars 334-335
 Ford Model T 339
 Greek trireme 573
 Harley-Davidson FLH5 Electra Glide 363
 Honda CB750 565
 Honda VF750 564
 Husqvarna Motocross TC10 568
 Kayak 560
 Longboat 580
 Motorcycle 364
 Racing sulky 355
 Renault Clio 352-355
 Showjumping saddle 554
 Suzuki RGV500 568
 TGV electric high-speed train 329
 Vespa Grand Sport 160
 Mark 1 363
 Weslake Speedway motorcycle 369
 Seat angle 360
 Seat assembly 425, 555
 Seat attachment rail 416
 Seat back rest frame 337, 352-353
 Seat beam 399
 Seatbelt attachment point 573
 Seat belt catch 352
 Seat control panel 572
 Seat cushion 407, 425
 Sea temperature 503
 Seat frame 353
 Seating 465
 Seat mount 340
 Seat pan 409
 Seat post 358, 360
 Seat post quick-release boll 358
 Seat spring 355
 Seat squab 355, 357
 Seat stay 358, 360
 Seat support strut 398
 Seat tube 358, 360, 361
 Sea urchins 174-175
 Seawater
 River features 290
 Salt content 296
 Seaweeds 116-117
 Seaworm 78
 Sebaceous gland 234-235
 Secondary baffle 612
 Secondary bronchus 215
 Secondary colors 439
 Secondary conduit 272-275
 Rock cycle 266
 Secondary crater 34
 Secondary flight feathers 188, 191
 Secondary follicle 258
 Secondary mirror 612
 Secondary mycelium 115
 Secondary phloem 134-135
 Secondary remiges 188, 191
 Secondary rotor 317
 Secondary suspension 327
 Secondary thallus 114
 Secondary vascular tissue 134
 Secondary xylem 125, 134-135
 Second-century building 462
 Second electron shell 509
 Second mast 376
 Second-row forward 530
 Second slip 538
 Second toe 252
 Second violins 503, 504-505
 Second wheel set 529
 Secretory gland 161
 Secretory thyroid gland cells 217
 Secretory vesicle 216
 Secure anchor 386
 Security light 605
 Sediment
 Coastlines 294-295
 Fossils 278
 Glaciers 286-287
 Lakes 292
 Mineral resources 280
 Mountain building 62-65
 Ocean floor 298-299
 River features 290-291
 Rivers 288
 Rock cycle 266-267
 Sedimentary rocks 276-277
 Igneous and metamorphic rocks 274
 Rock cycle 266-267
 Sedna Planitia 36-37
 Sedum rupestre 128
 Sedum spectabile 128-129
 Seed
 Apomixis 146
 Apple 149
 Cape gooseberry 149
 Dehydration 152
 Dispersal 148-151
 Dormancy 152
 Dry fruit 150-151
 Embryo development 147
 Fig 148
 Germination 132, 152-153
 Goosegrass 150
 Gymnosperms 122
 Hilum 148-149, 151-153
 Hogweed 151
 Honesty 151
 Larkspur 151
 Lemon 148

- Love-in-a-mist 151
 Lychee 148
 Melon 149
 Parts 152-155
 Pea 150
 Pine 122
 Raspberry 149
 Root development 132
 Scots pine 122
 Smooth cypress 125
 Strawberry 150
 Succulent fruit 148-149
 Sweet chestnut 150
 Sycamore 151, 151
 Wind dispersal 150
 Wings 150-151
 Yew 125
- Seed axis 152-155
 Seed coat 152, 152-155
 Dry fruit 150-151
 Embryo development 147
 Epigeal germination 153
 Hypogeal germination 152
 Succulent fruit 148-149
 Seed fern 278
 Seed leaves 126, 152-155
 Dry fruit 150-151
 Embryo development 147
 Epigeal germination 153
 Hypogeal germination 152
 Pine 122
 Succulent fruit 148-149
- Seedlings
 Epigeal germination 153
 Hypogeal germination 152
 Pine 122
- Seed-producing organs 148-149
 Seed scar 122
 Seed stalks 150
 Seed wings 151
 Seek bar 577
 Segmental arch 492
 Segmental pediment 462, 478
 Segnosauria 85
 Seif dune 285
 Seismic activity 58
 Seizing 383, 384, 387, 388-389
- Selaginella sp. 120
 Select key 578
 Selector fork 566
 Selector switch 598-599
 Selenite 270
 Selenium 511
 Self-pollination 144
 SEM 601, 611
 Semaphore signal 350
 Semen 217
 Semiarch 470-471
 Semibreve 502-503
 Semibulbhead 425
 Semicircle 532
 Semicircular canals 243
 Semicircular tower 465
 Semiconductor 306
 Semidome 484, 482, 488
 Semielliptical arch 484
 Semielliptic leaf spring 342
 Semilunar fold 249
 Semi-metals 510-511
 Seminal receptacle 169
 Spider 170
 Seminal vesicle 259
 Semiquaver 502
 Semisolid core 37
 Semisolid outer core 41
 Semisprawling stance 82
Westlothiana 81
- Semitendinosus muscle 227
 Send button 576
 Sender's name 576
 Senior ratings' mess 597
 Sensory antenna 168
 Sensory hinge 160
 Sensory tentacle 176
 Sent mail folder 576
 Sepal 140-145
 Clematis 151
 Dicotyledons 126-127
 Dry fruit 150-151
 Everlasting pea 129
 Fertilization 146-147
 Monocotyledons 126
 Peruvian lily 129
 Pitcher plant 113
 Pollination 145
 Rose 151
 Succulent fruit 149
 Sepal remains 146-147
 Sepal sheath 141
 Separated carpels 151
 Separator 576
 Septime 557
 Septum 115
 False 151
 Interventricular 251
 Nasal 213, 241
 Placenta 260
 Sequencer 521
 Sequoiadendron sp. 70
 Series electrical circuit 316
 Serif 445
 Serous pericardium 250
 Serpens Caput 18, 21
 Serpens Cauda 19, 20
 Serpentes 184
 Serpentine neck 374
 Serrated tooth 84, 85, 88
 Serrate leaf margins 129
 Serratus anterior muscle 226
 Server 554, 544, 545, 576
 Server Service 544
 Service area 534
 Service box line 545
 Service court 544, 545
 Service crane 605
 Service door 415
 Service guide 544, 545
 Service line 544, 545
 Service shaft 498
 Service zone 545
 Serving 388
 Serving mallet 385, 384, 388
 Servo control-unit fairing 417
 Servo-tab 414, 415
 Sesamoid bone 198
 Seta 112, 119
 Set-back buttress 481
 Set square 445
 Settings control panel 574
 Settings display 574, 575
 Setting select buttons 575
 Seven Sisters 14
 Seventeenth century 474
 Building 479-481, 488
 Capital 490
 Dome 486-487
 Roof 490
 Style 478
 Tomb 489
 Seventh century
 Building 491
 Sevier fault 276
 Sex cells 154
 Fertilization 146-147
 Gametophyte plants 120
 Gymnosperms 122
 Liverwort 118
 Moss 118-119
 Sextans 21
 Sexual reproduction
- Algae 116-117
 Bryophytes 119
 Flowering plants 140-147
 Mosses 118-119
 Seaweed 116-117
Spirogyra sp. 117
 Seyfert 41
 Seyfert galaxies 12-13
 Shackle 582, 586
 Shackle pin 582
 Shaft
 Ancient Egyptian column 459
 Ancient Greek temple 461
 Ancient Roman building 465, 465
 Arrow 548
 Asian building 490-491
 Badminton racket 545
 Electric generator 517
 Feather 191
 Femur 225
 French temple 485
 Golf club 547
 Harness racer 555
 Hydroelectric power station 514
 Javelin 542
 Kayak paddle 560
 Medieval church 468-469
 Modern building 498
 Neoclassical building 478, 485
 Nineteenth-century building 495
 Phalanx 250
 Power drill 600
 Roman Corbita 573
 Sculling oar 560
 Ski pole 553
 Squash racket 545
 Shaft drive 366
 Shale
 Contact metamorphism 274
 Grand Canyon 277
 Shallow carved-built hull 391
 Shallow Hats 295
 Shank
 Anatomy of a hook 562
 Danforth anchor 386
 Hook 385
 Roman anchor 372
 Sail hook 584
 Shackle pin 582
 Shannon bone 198
 Shape
 Chemical reactants 512
 Matter 306-307
 Periodic table 510
 Shapes (plane; solid) 622
 Sharks 178-179, 180
 Sharp 502
 Sharpey's fiber 225
 Shaula 19, 20
 Shave 374
 Shaving foam 306
 Shearing 61
 Sheave 385
 Sheave for cat tackle 380
 Sheep 198
 Sheepskin numnah 554
 Sheer 374
 Sheerplank 380
 Sheer pole 375
 Sheer strake 375, 395
 Sheet 372, 375, 382
 Sheet anchor 395
 Sheet bend 389
 Sheet feeder 575
 Sheet-iron louvre 495
 Sheet lead 385
 Shelf formation 282
 Shell
 579 cm shell 597
- 6 in shell 597
 Building 464, 476
 Chelonians 186
 Crab 172
 Dorsal margin 176
 Egg 192-195
 Exploding 394, 596-597
 Fossil 278
 Massive stars 26
 Mollusk 176-177
 Octopus 176
 Rib 176
 Rudiment 176
 Scallop 176
 Small stars 24-25
 Snail 177
 Standing block 582
 Terrapin 187
 Ventral margin 176
 Shell bogie 596
 Shell case 397
 Shelled invertebrates 56
 Shelley 55
 Shell-like fracture 270
 Shell room 396
 Shelly limestone 267
 "Shiaijo" 556
 Shield 394-395
 "Shield bearers" 92
 Shielded receiver 591
 Shield plate 570
 Shield volcano 42
 Shin
Herrerasaurus 86
 Human 211
 Shinarump member 276
 Shin guard
 Slalom skiing 553
 Soccer 525
 Shinty 540
 Shinuom quartzite 277
 Ship 587
 74-gun ship 379,
 380-381
 Ship of the line 580-581
 Ship's cannon 376, 394
 Ships of Greece and Rome 372-375
 Ship's shield 394-395
 Ship's wheel 378, 390, 394
 Shipwright 374
 Shiv 585
 Shiver 585
 Shock absorber
 1906 Renault 356
 ARV light aircraft 425
 Football helmet 527
 Honda CB750 365
 Honda VF750 364
 Renault Clio 550
 Suzuki RG V500 368
 Vespa Grand Sport 160
 Mark 1 365
 Volkswagen Beetle 340
 Shock-absorbing platform 555
 Shock-absorbing spring 401, 405
 Shock-strut 401
 Shock waves 27
 Path 63
 Athletics 543
 Basketball 535
 Golf 547
 Handball 555
 Rowing 560
 Shoes
 Baseball 557
 Football 527
 Hurling 541
 Riding 554
 Rugby 531
 Sailing 560
 Ski 552
 Soccer 525
 Shoot
 Broomrape 163
 Embryo 147
 Horsetail 120
- Hypogeal germination 152
 Pine 125
 Vegetative reproduction 155
 Shoot apex 125
 Shooting 548-549
 Shooting circle 540
 Shooting positions 548
 Shoreline
 Coastlines 294
 Continental-shelf floor 298
 Short line 545
 Shorts
 Australian rules football 529
 Soccer 525
 Hurling 541
 Volleyball 534
 Short saphenous vein 255
 Shortstop 536
 Short-wave radio 518
 Shot
 Field events equipment 542
 Gun 378
 Shot garland 381
 Shot put 543
 Shot-put circle 542
 Shot-put fan 542
 Shoulder
Anchisaurus 89
 Cello 511
Corythosaurus 98
 Double bass 511
 Gorilla 205
 Harp 511
 Horse 199
 Human 210
Iguanodon 97
 Rabbit 196
 Rigging 582-583
Stegoceras 101
Stegosaurus 92
 Viola 511
 Violin 510
 Shoulderblade 210, 218
 Shoulder cowling 412
 Shoulder girdle 80
 Shoulder joint
Brachiosaurus 96
Gallimimus 81
 Human 218
Parasaurolophus 99
Plateosaurus 88
Triceratops 102
Tyrannosaurus 84
 Shoulder pad 426
 Shoulder padding 551
 Shoulder pass 535
 Shoulder spikes
Edmontonia 95
Euoplocephalus 94
 Shoulder wheel throw 556
 Showjumping 554
 Shreve, R.H. 494
 Shrewlike mammals 70
 Shrimp 172
 Fossil 79
 Shrine 490-491
 Shroud
 Dhow 376
 Longboat 580
 Rigging 383
 Roman corbita 373
 Sailing dinghy 561
 Sailing warship 376
 Shrubs 150-151
 Shuffle button 586
 Shutter button 581
 Shutter for gun 394
 Shuttlock 544-545
 Shuttle switch 586
 Sickle motif 491
Sidalcea maliflora 156
 Side aisle
 Cathedral dome 484
 Gothic church 472-473
- Medieval church 469
 Side bench 580
 Side brace and retraction jack trunnions 414
 Sidecar
 BMW R/60 362
 Motorcycle racing 368-369
 Side chapel 469-470, 479
 Side counter timber 581
 Side-cowling 408
 Side drum 504-505
 Side fairing 415
 Side forequarter hold 556
 Side gear 347
 Side housing 346-347
 Side lamp 358-359
 Sidelight 332, 335, 362
 Sideline
 Badminton 545
 Basketball 552
 Football 526
 Handball 535
 Hockey 540
 Men's lacrosse 540
 Netball 535
 Tennis 541
 Volleyball 534
 Side marker lamp 346, 349
 Side-mounted engine 398
 Side plate 562
 Side pod 556, 357
 Side reflector 562, 363
 Siderite band 277
 Side rudder 374-375
 Side-shooting 541
 Side vent 329
 Side wall 545, 558
 Side-wall line 545
 Sideways erosion
 River features 290
 Rivers 288
 Sierra Madre 264
 Sierra Nevada 57, 75
 Sieve tubes 154
 Sieving beak 188
 Sif Mons 37
 Sight 394
 Sight pin 549
 Sight screen 558
 Sighting hood
 Battleship 394
 Gun turret 396
 Sighting rule 376-377
 Sights 548-549
 Sigma Canis Majoris 21
 Sigmoid colon 249
 Signal flag compartment 397
 Signal gear 395
 Signaling systems 330-331
 Sikorsky, Igor 422
 Silence 502
 Silencer
 Harley-Davidson FLHS
 Electra Glide 362
 Renault Clio 550
 Suzuki RG V500 368
 Vespa Grand Sport 160
 Mark 1 365
 Weslake Speedway motorcycle 369
 Silencing heat exchanger 404
 Silicate core 51
 Silicate dust 55
 Silicate material 39
 Silicate rock 39
 Silicates 269
 Siliceous ooze 299
 Silicon 26
 Earth's composition 59
 Earth's crust 58
 Periodic table 511
 Variety of matter 306
 Siliquas 150-151
 Silk gland 170

- Sill 26
Ancient Roman mill 464
Renaissance building 475
Twentieth-century building 494
Sill trim 535
Silly mid-off 538
Silly mid-on 538
Silurian period
Fossil record 279
Geological time 56
Silver
Mineral resources 280-281
Minerals 268
Periodic table 311-312
Streak 271
Silver lines 450-451
Silver molybdenite 271
Silver nitrate solution 512
Silverpoint 450, 451
Silver wire 450
Silvery metals 510
SIM (Subscriber Identity Module) card slot 589
Simple electrical circuit 516
Simple eye 170-171
Simple leaves 156-157
Entire 150
Hastate 128
Herbaceous flowering plants 128-129
Lanceolate 151
Lobed 151
Simple machines 520
Simple Machines Law 520
Simple succulent fruits 148-149
Single bass note siring 515
Single-celled micro-organisms 78
Single clump block 375
Single cylinder 535
Single-decker bus 352, 353
Single flowers 140-141, 145
Single front driving wheel 354
Single-glazed conservatory 602
Single-leg main landing gear 407
Single overhead cam engine 365
Single-piece skin 415
Single-pulley system 520
Single reed 508, 509
Singles 544
Single scull 560, 561
Single sheet bend 387
Single-sided trailing-link fork 365
Single wing hold 556
Singularity
Formation of black hole 29
Stellar black hole 29
Sinistral strike-slip fault 61
Sink-holes 284-285
Sinking land 294
Sinopia 454, 455
Sinuous venous sclerae 241
Sinuous cell wall 156
Sinus
Frontal, 212, 245
Green alga 112
Renal 256
Superior sagittal 212
Sinus Borealis 69
Sinus Irid um 40
Siphon
Octopus 176-177
Sea urchin 175
Siphonoglyph 167
Sirius
Canis Major 21
Northern stars 18
Our galaxy and nearby galaxies 15
Southern stars 21
Spectral absorption lines 25
Star magnitudes 22
Sirius A 25
Sirius B 25
Site icon 577
Sixteenth century
Building 476-477
Staircase 472
Style 462, 470
Size (glue) 451, 452, 456
Skarn 26
Skate
Chondrichthyes 178
Ice hockey 550, 551
Skeletal muscle 228
Skeletal muscle fiber 228
Skeleton
Archaeopteryx 85
Arsinoitherium 104-105
Baryonyx hand 85
Bat 105
Bird 189
Bony fish 180-181
Cow's foot 198
Crocodile 186
Diplodocus 90
Domestic cal 195
Klephant 201
Eryops 80-81
Frog 185
Hare 197
Horse 199
Human 218-219
Iguanodon 96
Kangaroo 206
Kentrosaurus 95
Lizard 184
Parasurolophus 98-99
Pareiasaur 81
Platosaurs 88-89
Platypus 206
Rhesus monkey 202
Seal 204
Snake 185
Spider 171
Sponge 166
Stegoceras 100-101
Stegosaurus 95
Struthiomimus 87
Toxodon 106
Triceratops 102-105
Tuofigatisaurus 95
Turtle 187
Tyrannosaurus 84-85
Westlothiana 81
Sketch book 450
Skid 402, 404
Skid beam 380
Skid goggles 552, 555
Skiing 552, 555
Skilled movements 257
Skin
Amphibian 80, 182
Drumhead 518
Lizard 184
Reptile 80
Snake 184
Succulent fruits 148-149
Waterproof 81
Skin and hair 254-255
"Skin-grip" pin 424-425
Skin lap-joint 413, 414, 415
Skin tones 441
Ski pole 552
Skirting board 602
Skis 552
Skull
Acanthostega 80
Alligator 186
Ankylosaurus 94
Australopithecus 108
Baryonyx 85
Bear 194
Bird 189
Camarasaurus 91
Chimpanzee 202
Crocodilians 186
Diplodocus 90
Domestic cat 195
Elephant 201
Euoplocephalus 94
Fetal 220
Gharial 186
Hadrosaurs 96
Hare 197
Heterodontosaurus 85
Homo erectus 108
Homo habilis 108
Horse 199
Human 108, 212, 218, 220-221, 222, 256-257
Hyaenodon 107
Iguanodon 96
Kangaroo 206
Lambeosaurus 99
Lion 194
Lizard 184
Marginocephalian 100
Moeritherium 105
Octopus 176
Opossum 106
Pachycephalosaurs 100
Pachycephalosaurus 100
Phiomia 105
Platosaurs 88
Platypus 206
Prenocephale 100
Protoceratops 102
Rattlesnake 185
Rhesus monkey 202
Seal 204
Smilodon 107
Stegoceras 100
Styracosaurus 102
Synapsid reptile 67
Tortoise 77
Turtle 187
Skull bones 81
Skullcap 555
Skunks 194
Skylight
BattleShip 394
Building 495, 494
Iron paddlesteamer 392-395
Skyscraper 494
Slab
Ancient Egyptian building 458-459
Modern building 499
Twentieth-century building 494
Slaked lime 454
Slalom
Skiing 552
Canoeing 560
Slalom clothing 553
Slalom equipment 555
Slalom gate 552
Slat 421
Slate 274, 275
Sleep button 585
Sleeper 524, 531
Sleeve port 345
Sleeve valve 545
Slender thistle 129
Slick racing tire 365
Kirby BSA 369
Suzuki RCV500 369
Slide 596
Slide bar 325
Slide brace 507
Slide locking lever 596
Slide track 561
Slide valve 590
Sliding bed 447
Sliding curtain 529
Sliding seat 561
Sliding window 535
Sling fixing point 549
Slip face 285
Slip faults 61
Slipher 45
Slope structure 60
Sloping roof 486
Slug 176
Slumped cliff 295
Slur 505
Smallbore rifle shooting 548
Smallbore rifle target 549
Small intestine
Brachiosaurus 90
Chimpanzee 202
Cow 198
Domestic cat 195
Elephant 200
Euoplocephalus 94
Frog 182
Human 214, 249
Lizard 185
Tortoise 187
Small Magellanic Cloud
Hydrus and Mensa 20
Our galaxy and nearby galaxies 15
Stars of southern skies 20
Small stars 24-25
Small theropods 87
Small-scale rock deformities 61
Smalti 450
Smalti mosaic 450
Smartphones 588-589
Smash 554
Smell 244
Smilodon 107
Smokebox 524, 525
Smoky quartz 268
Smooth cypress 125
Smooth endoplasmic reticulum 216
Smudging 450, 451
Smuts 114
Snail 176-177
Snake-head ornament 575
Snakes 184-185
Snap head 392
Snare 518
Snare drum 518
Snort mast 597
Snout
Anchisaurus 89
Caiman 186
Crocodilians 186
Dogfish 178
Edmontonia 95
Herrerasaurus 86
Iguanodonts 96
Jawless fish fossil 78
Pachycephalosaurus 100
Rat 196
Snow
Glaciers 286-287
Weather 502
Snowflake moray eel 180
Snowflakes 502
Soane, J. 478, 482-485
Sobokou Planitia 35
Soccer 524-525
Soccer uniform 525
Socle
Ancient Egyptian temple 458
Baroque church 479
Cathedral dome 487
Gothic church 472
Medieval church 469
Neoclassical building 478-479
Renaissance building 474
Soda lite 269
Sodium 55, 58
Periodic table 310
Seawater salt content 296
Sodium hydroxide 312
Sodium lines 25
Soffit 464, 484, 498
Soft eye 582
Soft hair brush 456, 538, 440
Soft-headed beater 516, 517, 519
Soft metals 510
Soft palate 212, 245
Soft pastels 440
Soft pedal 514, 515
Soft rock
River features 290
Weathering and erosion 282
Software effect plug-in 521
Solanum tuberosum 128
Solar array 612, 613, 615
Solar array supporting arm 615
Solar cell 605
Solar collector 605
Solar day 34
Solar eclipse 52
Solar flare 52-55
Solar panel 496, 605
Solar power 605
Solar radiation 500-501
Solar system 58, 50-51, 614-615
Solar wind
Earth's magnetosphere 38
Structure of comet 55
Sun 52
Solarium 494
Solar Wings Pegasus
Quasar ultralight 427
Sole of foot 254
Soleplate 595
Soleplate roller 595
Soleplate surround 594
Soleus muscle 227, 253
Solfataras 272-275
Solid body 512, 515
Solid crystals 506
Solid heart thimble 385
Solidified lava
Lake formation 292
Volcanoes 272-275
Solid ink stick 444
Solid rubber tire 355
Solids 506-507
Chemical reactions 312
Solid shapes 622
Solutions 506, 512-515
Sonic sensor 609
Sombrero 12
Somites 79
SONAR bulge 597
SONAR torpedo decoy 596
SONAR transducer array 597
Sonic boom 416
Sonoran Desert 264
Sony B-series MP3 player 586
Sony DAV-S500 585
Sony W-series walkman 586
Soot particles 515
Sophocles 35
Soralium 114
Sorbus aucuparia 130-131
Soredia 114
Sori 120-121
Sostenuto pedal 514, 515
Sound 314-315
Coastline 295
Musical notation 502
Soundboard
Acoustic guitar 515
Concert grand piano 515
Harp 511
Upright piano 514
Viola 511
Violin 510
Sound channels 584
Sound hole
Acoustic guitar 512-513
Cello 511
Double bass 511
Viola 511
Violin 510
Sound module 521
South Africa 64
South America 264
Cretaceous period 72-75
Jurassic period 70
Late Carboniferous period 66
Middle Ordovician period 64
Quaternary period 76-77
Tertiary period 74-75
Triassic period 68
South American plate 59
South Asian buildings 490-491
South Atlantic Gyre 296
Satellite map 265
South Atlantic Ocean 59, 75
Southeast trade winds 500
Southeasterly wind 505
South Equatorial Belt 45
South equatorial current 296-297
Southerly wind 505
Southern Hemisphere 296-297
Southern polar region 64
South Galactic Pole 15
South Indian Gyre 297
South magnetic polar region 28
South Pacific Gyre 296
South Pacific Ocean 59
South polar ice cap
Structure of Mars 45
Surface of Mars 42
South Pole
Atmospheric circulation and winds 500
Coriolis force 297
Earth 58
Jupiter 44
Mars 42
Mercury 54
The Moon 40
Neptune 50
Pluto 51
Pulsar 28
Saturn 46
Uranus 48-49
Venus 56
South rim 277
South seeking pole 517
South Temperate Belt 45
South Temperate Zone 45
South Tropical Zone 45
Space 300-301
Space probes 614-615
Space shuttle astronaut 613
Space shuttle remote manipulator system (robot arm) 612, 613
Space telescope 612-613
Spadix 145
Span 484
Spandrel
Gothic church 471
Islamic building 488-489
Neoclassical building 482
Nineteenth-century

- building 495
 Renaissance building 474
 Spanish bowline 389
 Spar
 BAe-146 jetliner components 415
 BE 2B tail 405
 Concorde, the 417
 Pegasus Quasar ultralight 427
 Spare tire 357, 359
 Spare wheel well 541
 Spark plug 342-343, 410
 Spark plug cap 366
 Spark plug head 346
 Spark plug lead 344
 Spar trunnion 409
 Spat 426-427
 Spathe 145
 Horsetails 120
 Spawn 182-185, 192
 Speaker
 Digital video 583
 Electronic music system 521
 Headphones 586
 System unit 567
 Speaker assembly 580
 Speaker plug 591
 Speak key 590
 Spear 582
 Spear head 109
 Specimen 610, 611
 Specimen airtlock 611
 Specimen stage 610, 611
 Spectral absorption lines 22-23
 Spectral type 22-23
 Spectral hematite 268
 Speech 237
 Speed
 Forces 320
 Gearbox 366
 Speedball nib 444
 Speedometer 362
 Speedometer drive 565
 Sperm 258-259
 Spermatheca
 Snail 177
 Spider 170
 Sperm cell 217, 607
 Sperm duct 195
 Spermoviduct 177
 Sperm whale 204-205
 Sperry-ball gun turret 408
 Sphenethmoid bone 185
 Sphenoidal fontanelle 220
 Sphenoidal sinus 212, 245
 Sphenoid bone 220
 Sphenopids 279
Sphenopteris latiloba 72
 Sphere 625
 Spherical umbel 145
 Spheroid 625
 Sphincter muscle
 Anal 249
 Iris 241
 Pyloric 249
 Sea anemone 167
 Urethral 257
Sphyrna lewini 179
 Spica 18, 21
 Spicule 32, 35
 Spicules 166
 Spider
 Arachnid 170-171
 Bicycle 358, 360
 Spider seat 334
 Spigot 387
 Spike
 Aechmea miniata 162
 Dodder 165
 Double bass 511
 Flower 143
 Grape hyacinth 155
 Thyreophorans 92-95
 Volleyball 534
 Spiky cupule 150
 Spinal column 258
 Spinal cord
 Bird 189
 Bony fish 181
 Chimpanzee 202
 Dogfish 179
 Dolphin 205
 Domestic cat 195
 Elephant 200
 Human 212, 217, 225, 256, 258, 261
 Lizard 185
 Rabbit 196
 Spinal ganglion 225, 258, 243
 Spinal nerve 225, 238
 Spindle 601
 Spine
 Aechmea miniata 162
 Barberry 150-151
 Bromeliad 115
 Calligraphy character 445
 Cnidocyte 167
 Diatom 116
 Drivland plants 156
 Golden barrel cactus 156
 Hemal 180
 Herbaceous flowering plants 128-129
 Human 218, 222-223
 Mahonia 150-151
 Modern jetliners 413, 415
 Neural 180
 Sea urchin 174
 Starfish 174
 Spine end fairing 421
 Spinner
 ARV light aircraft 424-425
 Hawker Tempest components 408
 Hawker Tempest fighter 409
 Lockheed Electra airliner 407
 Turbofan engine 418
 Spinneret 170-171
 Spinner mounting disc 406
 Spinning lure 562
 Spinose-dentate margin 129
 Spinous process 222-223
 Spiny anteaters 206
 Spiny leaflets 150-151
 Spiracle
 Acanthostega 80
 Caterpillar 169
 Spider 170
 Spiral arm
 Galaxies 12-15
 Milky Way 14
 Spiral ganglion 243
 Spiraling clouds 302
 Spiraling low-pressure cells 302
 Spiraling rain 305
 Spiraling winds 502-505
 Spiral scroll 460
 Spiral spring 449
 Spiral staircase 472, 476
 Spiral tubes 342
 Spiral valve 179
 Spiral wrack 116
 Spire
 Asian building 490-491
 Gothic church 470-471, 475
 Medieval building 466, 468
 Nineteenth-century building 493
 Renaissance building 476-477
 Spirit lamp 454
 Spiricketing 381
Spirogyra sp. 117
 Spit 291
 Splayed window-sill 475, 482
 Spleen
 Bony fish 181
 Chimpanzee 202
 Domestic cat 195
 Elephant 200
 Frog 182
 Human 215, 249
 Splenic artery 255
 Splinging fid 383
 Splint bone 198
 Splinter bar 355
 Splintery fracture 270
 Split flap 406
 Split line 151
 Split-open pollen sac 144
 Split rudder 421, 572
 Spoiler 546, 349
 Spoiler anchorage 413
 Spoiler arm 414
 Spoke
 Bicycle wheel 358-359
 Bordino Steam Carriage 335
 Eddy Merckx racing bicycle 361
 Etching press 447
 Paddle wheel 391
 Ship's wheel 390
 Spoked wheel
 Bicycle 358-359
 Pacing sulky 555
 Spoke guard 558
 Spoke nipple 361
 Sponge roller 442
 Sponges 166-167
 Fossils 279
 Spongocoel 166
 Spongy bone 224
 Spongy mesophyll 126, 159
 Spongy tissues 156
 Spool 362
 Spoon 560
 Spoon-shaped tooth 91
 Sporangia 120-121
 Sporangiphore 120
 Sporangium 79
 Spore-case 79
 Spore-producing structures
 Fern 121
 Fungi 114-115
 Lichen 114
 Moss 112
 Spores
 Clubmoss 120
 Fern 120-121
 Fungi 114-115
 Horsetail 120
 Lichen 114
 Liverworts 118
 Mosses 118-119
 Mushroom 115
 Sporophores 114-115
 Sporophyles
 Clubmoss 120
 Fern 120-121
 Horsetail 120
 Liverworts 118
 Moss 112, 118-119
 Sports tire 365
 Sports wheel 340
 Sprag clutch 410
 Spray and steam knobs 594
 Spray barrel 594
 Spray nozzle 594
 Spray pump 594
 Spreader 561
 Spring
 Lakes and Groundwater 292
 Motorcycle 366
 Power drill 600
 Toaster 599
 Spring and chassis unit 337
 Spring balance 320
 Springboard diving 558
 Spring/muffler unit 565
 Springing point 467, 484-485
 Spring line 292
 Spring perch 358
 Spring petiole 160
 Spring shock absorber 358-359
 Spring tides 296-297
 Spring-trap mechanism 160
 Spring washer 601
 Spring wood xylem 134
 Sprint races 560
 Springing 542
 Sprilsail 378
 Sprit yard 376
 Sprocket 358, 366
 Spruce 513
 Spruce beam 560
 Sprung chassis 334
 Spun yarn 588
 Spun yarn serving 583
 Spur 169
 Spur gear 574
 Spurious wing 191
 Squadron code 409
 Squamala 184
 Squamous bone 183
 Squamous suture 220
 Squamulose lichens 114
 Squamulose thallus 114
 Square 622
 Square cut 538
 Square knot 388
 Square leg 538
 Square-leg umpire 558
 Square masonry 465
 Square rib 486
 Square-rigged ship 375
 Square sail 374, 378, 384
 Square-section steel tubing 364
 Square-section tire 362, 369
 Squash 544, 545
 Squeegee 448
 Squid 176
 Squinch 466
 Squirrel 196-197
 Squirrel hair brush 458
 Squirrel mop wash brush 458
 SST 416-417
 St. John's wort 145
 St. Basil's Cathedral 487
 St. Paul's Cathedral
 Arch 484
 Baroque style 478, 480-481
 Dome 480, 486-487
 Old 470, 472
 Stabilizer 397, 548
 Stabilizer-bar weight 422
 Stabilizer fin 396
 Stable elements 310, 311
 Stack 295
 Staff 377, 396
 Stage 477, 495
 Stage-door 477
 Stained glass 470
 Stainless steel cover 599
 Staircase
 Ancient Roman building 465
 Baroque church 481
 Gothic church 470, 472
 Medieval building 466
 Modern building 496-497, 499
 Neoclassical building 485
 Renaissance building 474-477
 Staircase turret 468
 Stairs 477
 Stair tool 593
 Stairway 489
 Stalactites 284-285
 Stalagmites 284-285
 Stalagmitic boss 284
 Stalagmitic floor 284
 Stalk
 Algae 116
 Barnacle 173
 Dicotyledons 127
 Flower 140
 Fungi 114-115
 Liverwort 118
 Monocotyledons 128
 Moss 112, 119
 Pitcher plant 113
 Seaweed 117
 Stem succulent 115
 Water lily 159
 Stalked barnacle 173
 Stalked secretory glands 161
 Stalk scar 125
 Stall warning vane 412
 Stamen remains 146-147, 150
 Stamens 140-143
 Anther 140-145
 Dicotyledon flower 126-127
 Fertilization 146-147
 Filament 140-145
 Insect-pollination 144
 Monocotyledon flower 126
 Rose 131
 Stamp 445
 Stance
 Dinosaurs 82
 Hominids 108
 Westlothiana 81
 Stanchion 373, 393
 Standard 554
 Standardized horse 554, 555
 Standard European paper 445
 Standard knee 581
 Standby pitot head 416-417
 Standing block 382
 Standing lug mizzen 385
 Standing part
 Hawser bend 387
 Rigging 382-385
 Single sheet bend 387
 Standing position 348
 Standing rigging 382-385
 Standoff half 530
 Stapes 242
 Staple 449
 Starbirth region 16
 Starboard side 374
 Starch grains 139
 Chlamydomonas sp. 116
 Orchid root 135
 Star clusters 16-17, 615
 Objects in universe 11
 Our galaxy and nearby galaxies 14
 Star coral 167
 Star drag 562
 Star dune 285
 Starfish 174-175
 Fossil 79
 Star formation in Orion 24
 Starling 467
 Star magnitudes 22
 Stars 22-25, 613
 Massive stars 26-27
 Milky Way 14-15
 Neutron stars and black holes 28-29
 Small stars 24-25
 Star clusters 16, 613
 Sun 32-35
 Star scanner 615
 Star-shaped parenchyma 135
 Star-shaped sclereids 159
 Stars of northern skies 18-19
 Stars of southern skies 20-21
 Starter 359, 558
 Starter cog 356
 Starter motor
 Hawker Tempest components 408
 Mid West twin-rotor engine 411
 Renault Clio 551
 Volkswagen Beetle 340
 Starter ring 545
 Starling block 558
 Starting handle 356-357, 358, 345
 Starling line (100m) 542
 Start print button 575
 Stale room 392
 Static air-pressure plate 412
 Static discharge wick 406
 Static electricity 316
 Stationary gear 346-347, 411
 Slalor 410
 Statue 472, 478
 Statue creation 455
 Statuette 476, 481
 Status indicator 577
 Staurikosaurus 69
 Stay 325, 392
 Staysail 378, 385
 "Stealth" bomber 420-421
 Steam 275, 507
 Locomotives 324, 325
 Nuclear power station 314
 Oil-fired power station 315
 Steam barrel 594
 Steamboat with paddle wheels 391
 Steam car 354, 342
 Steam chest 354
 Steam chest pressure gauge 325
 Steam condenser 397
 Steam control knob 394
 Steam dome 325
 Steam engine 390-391
 Steam generator 314
 Steam grating 380
 Steam iron 594
 Steam launch 394
 Steam locomotive 324, 325
 Steam pipe 334-335
 Steam pipework 397
 Steam-powered Cugnot "Fardier" 334
 Steam release activator 594
 Steam whistle 392
 Steel 492
 Steel and concrete floor 498
 Steel and titanium skin 416
 Steel beater 517
 Steel brace 493
 Steel column 497-498
 Steel floor-plate 497
 Steel frame 360, 364
 Steel girder framework 314
 Steel lattice-beam 497
 Steel lock 360
 Steel mullion 494
 Steel point 432
 Steel rails 330
 Steel-reinforced concrete 494

- Steel sleeper 530
Steel wheel 540, 550-551
Steeple 471, 481
Steeplechase 554
Steep ridge 285
Steerboard side 374
Steerer tube 359
Steering 550, 564
Steering actuator 416
Steering arm 558-559
Steering box assembly 340
Steering column
Benz Motorwagen 555
Ford Model T 559
Renault Clio 550
Volkswagen Beetle 541
Steering gear 392
Steering gearbox 359
Steering head 355
Steering idler 540
Steering knuckle 558
Steering link 355
Steering oar 374
Steering pump pulley 344
Steering rack 355, 350
Steering spindle 356
Steering stop 425
Steering tie-rod 340
Steering tiller 354-355, 557
Steering track-rod 357
Steering wheel
1906 Renault 557
Ford Model T 558-559
Renault Clio 550, 355
White Steam Car 342
Steering wiffletree 357
Stegoceras 100-101
Stegosauria 85
Stegosaurus 71, 92
Steib chair 362
Stela 459
Stele
Dicotyledons 127
Monocotyledons 127
Root 132-135
Stellar core 17
Stellar spectral absorption lines 22-25
Stellate parenchyma 155
Stem 154-155
Aechmea miniata 162
Asteroxylon 79
Bamboo 151
Barberry 150-151
Battleship 394
Begonia 129
Bishop pine 124-125
Brassavola nodosa 162
Bromeliad 115
Broomrape 163
Calligraphy character 445
Canadian pond weed 158-159
Chusan palm 150
Clubmoss 120
Corallina officinalis 117
Couch grass 115
Crab cactus 129
Dicotyledons 126-127
Dodder 163
Eddy Merckx racing bicycle 361
Epiphytes 162-163
Everlasting pea 129
Florists' chrysanthemum 129
Flower arrangements 145
Golden barrel cactus 156
Guzmania lingulata 162-163
Hogweed 129
Horsetail 120
Ice-plant 128-129
Iron paddlesteamer 595
Ivy 131
Kedrostis africana 115
Live-forever 128-129
Liverwort 118
Maidenhair tree 125
Maple 127
Monocotyledons 126-127
Moss 119
Parasitic plants 163
Passion flower 130
Peach 151
Perennials 150-151
Sago palm 125
Strawberry 128
String of hearts 157
Vegetative reproduction 154-155
Water fern 158
Welwitschia 123
Woody plants 130-131
Woody stem 154
Yew 125
Stem bases
Bulbil 155
Guzmania lingulata 162-163
Stem branch 129
Stem bulbils 155
Stem cambium 126
Stem cells 606, 607
Stem head 376
Stempost
74-gun ship 581
Dhow 376
Longboat 380
Sailing warship 376
Viking ships 374-375
Stem projections 156
Stem segments 129
Stem succulents 115, 156-157
Stem tubers 128, 154
Stencil 446
Step
74-gun ship 381
ARV light aircraft 424
BE 2B bomber 404
Blériot XI monoplane 401
Medieval building 467
Modern building 499
Neoclassical building 485
Steam-powered Cugnot 354
Twentieth-century building 495
Wooden sailing ship 378
Stephenson, Robert 324
Steppled roof 481
Stepped stempost 375
Stepped sternpost 375
Sterile hairs 117, 119
Sterile ray 119
Sterile ray floret 142
Sterile shoot 120
Sterile whorl 116
Stern
74-gun ship 581
Iron paddlesteamer 592
Kayak 560,
Sailing dinghy 561
Wooden sailing ship 378-379
Sterna hirsundo 195
Sternal artery 175
Sternal bone 96, 102
Stern balustrade 375
Stern carving 581
Stern framing 392
Stern gallery 397
Stern lantern 379
Sternocleidomastoid muscle 226-227, 229
Sternohyoid muscle 229
Sternpost
Greek galley 372
Roman corbita 375
Sailing warship 377
Single scull 560
Viking ships 374-375
Wooden sailing ship 378
Stern quarter gallery 579
Stern rope 587
Stern section 392
Sternum
Bird 189
Domestic cat 195
Elephant 201
Hare 197
Horse 199
Human 218
Kangaroo 206
Seal 204
Stern walk 395
Stibnite 268
Stick insect 192
Stiff brush 456
Stifle 198
Stigma
Damsel fly 168
Dicotyledon flower 126-127
Fertilization 146-147
Flower 140-145
Pollination 144-145
Stigma remains 146-147, 150-151
Stilt 494
Stilted arch 468
Sting 170
Stinging cells 166
Stinkhorn 114
Stipe 114-115, 116-117
Stippled effect 442
Stipule
Begonia 129
Everlasting pea 129
Passion flower 150
Rose 151
Seedling leaf 152
St. John's wort 145
Strawberry 128
Stirrup
Crossbow 548
Ossicles of middle ear 242
Saddle 555
Stoa 460
Ancient Roman building 463, 465
Islamic building 488
Stock
74-gun ship 580
Danforth anchor 386
Roman anchor 372
Stockless anchor 586
Stöfler 40
Stoker's seat 534
Stolons 154
Stomach
Barnacle 175
Bird 189
Bony fish 181
Chimpanzee 202
Cow 198
Crayfish 175
Dogfish 179
Dolphin 205
Domestic cat 195
Elephant 200
Frog 182
Human 214, 248
Jellyfish 167
Lizard 185
Octopus 176
Babbit 196
Ruminants 198
Snail 177
Starfish 174
Tortoise 187
Stomach throw 556
Stomata
Dryland plants 156-157
Golden barrel cactus 156
Haworthia truncata 157
Monocotyledon leaf 126
Photosynthesis role 138-139
Pine needle 124
Wetland plants 158
Stone
Succulent fruits 148
Lithographic printing 446, 448
Sculpture 452
Stone canal 174, 175
Stone plate 446, 448
Stony-iron meteorite 52
Stony meteorite 52
Stop lamp assembly 352
Stop signal 530
Stopwatch 524
Storage locker 572
Storage organs
Bulb 155
Corm 155
Rhizome 155
Scale leaf 155
Seed 152
Succulent tissue 156-157
Swollen stem 115, 155
Tubers 128, 155
Underground 154-155
Storage unit 575
Store button 521
Stores pylon 420-421
Stork 188
Storm 505
Straddle wire 358, 359
Straight 555
Straight four cylinder arrangement 545
Straight gouge 452
Straight handlebar 361
Strake
Concorde 416-417
Ironclad 395
Roman corbita 572
Viking ships 374-375
Strapontin 357
Strap-shaped leaf 162
Strata 276
Faults and folds 60-61
Sedimentary rocks 276
Stratocumulus cloud 302
Stratosphere
Earth's atmosphere 300-301
Jupiter's atmosphere 45
Mars' atmosphere 43
Saturn's atmosphere 47
Stratum basale 255
Stratum corneum 255
Stratum granulosum 255
Stratum spinosum 255
Stratus cloud 302
Strawberry 128, 150
Straw butt 549
Streak 270-271
Stream
Glaciers 286-287
Groundwater system 295
Spring examples 292
Streamed internet radio on-screen display 577
Streamed internet video on-screen display 577
Streamlined spinner 407
Strengthening tissue
Fern rachis 121
Horsetail stem 120
Marram grass 115
Monocotyledon leaf 126
Stems 134-135
Water lily leaf 159
Stress 61
Stretcher
Brickwork 485
Nineteenth-century building 492
Single scull 560
Stretches 555
Striated effect 442
Striation 46
Strike
Baseball 556
Baseball umpire signal 557
Slope structure 60
Striker 524
Strike-slip fault 61
Strike-slip fault lake 295
Strike zone 556
Strindberg 35
String
Acoustic guitar 512-515
Cello 511
Concert grand piano 515
Double bass 511
Electric guitar 515
Harp 511
Upright piano 514
Viola 511
String arm 511
String course
Ancient Roman building 465
Cathedral dome 487
Medieval building 466-467
Nineteenth-century building 495
Stringed instruments 510, 511
Guitar 512, 515
Orchestral arrangement 504, 505
Strings
Guitar 512-515
Racket 544
Violin 510
Strix aluco 190
Strobili 120
Stroke judge 558
Stroke play 546
Strokes 546
Stroke-side oar 560
Stroma 159
Stroma thylakoid 139
Strongylocentrotus purpuratus 175
Strontium 510
Strop 585
Strut
Dome 484, 486
Gothic building 475
Marble sculpture support 455
Neoclassical building 479
Paddlesteamer 590
Timpanum 519
Strut insert 340
Struthio camelus 188
Egg 195
Struthiolaria 279
Struthiomimus 84, 87
Stub axle 424
Stud
Ancient Roman mill 464
Gothic building 475
Mid West single rotor engine 410
Studding sail boom 378
Studding sail yard 378
Studio Elvira 495
Study 477
Stuffing box 590
Stump
Coastline 295
Wicket 558
Stupa 490-491
Stupica 491
Sturgeon 180
Style 140-145
Fertilization 146-147
Monocotyledon flower 126
Pitcher plant 115
Pollination 144-145
Rowan fruit 131
Style of the gnomon 377
Style remains
Dry fruit 150-151
Fruit development 146-147
Succulent fruit 148-149
Stylect 167
Stylobate 460
Styloglossus muscle 244
Styloid process 220, 245
Styracosaurus 102, 105
Subacute leaf apex 136-137
Subarachnoid space 257
Subclavian artery 215, 251, 255
Subclavian vein 255
Subduction 58
Subduction zone 281
Subframe 351
Subgenital pit 167
Subglacial stream 287
Sublimation 307
Sublingual fold 245
Sublingual gland 244-245
Submandibular gland 244
Submarine 396-397
Submarine canyon 298
Submerged atoll 299
Submerged glacial valleys 294-295
Submerged river valleys 294
Subopercular bone 181
Substitutions 532, 550
Substomal chamber 139
Substrate 112
Substratum 115
Subsurface current 297
Subtropical jet stream 500
Subwoofer 586
Succulent fruits 148-149, 150
Bramble 150
Development 146-147
Peach 151
Rowan 151
Succulent leaves 128, 157
Succulent plants 156-157
Succulents 112
Leaf 157
Stem 156-157
Stem and root 157
Trailing stem 157
Succulent stem 129
Sucker
Lamprey 178
Octopus 176
Sucking stomach 170
Suction reduction control 595
Sugar
Fermentation 312
Formation 158
Photosynthesis 315
Transport 159
Sulcus terminalis 244
Sulfates 269, 296
Sulfides 268
Sulfur 39, 268
Periodic table 311
Sulfur dioxide 37
Sulfuric acid 56-57
Sulfurous gases 275
Sulky 554-555
Sumatra 265
Sumigi 490
Summer petiole 160
Summit caldera 42
Sump 343, 344-345
Sump pan 354
Sun 32-35, 58
Atmosphere 301
Comet tails 48
Earth's energy 314
Electromagnetic radiation 314-315

- Energy emission from Sun 22
Light 518
Milky Way 14
Objects in universe 11
Oceans and seas 296-297
Ozone formation 64
Solar eclipse 52
Solar system 50-51
Stars 22-25
Sun blind 575
Sundew 160
Sundial 576, 577
Sunflower 140, 142, 145
Sunken stoma 157
Sunlight and photosynthesis 158
solar power 605
Sun roof 541
Sun scoop 498
Sun sensor 614
Sunspots 52-55
Sun visor 350, 355
Supai group 277
Superclusters 10
Supercooling 507
Supercool liquid 506-507
Superficial peroneal nerve 258
Superficial skeletal muscles 226-227
Superfluid neutrons 28
Super-giant slalom (Super-G) skiing 552
Supergiant stars
Massive stars 26
Stars 22-25
Stellar black hole 29
Supergranule 55
Superheater 525
Superior articular facet 222
Superior articular process 222-225
Superior concha 212
Superior laryngeal nerve 244
Superior longitudinal muscle 245
Superior meatus 245
Superior mesenteric artery 255, 256
Superior mesenteric trunk 257
Superior mesenteric vein 255
Superior nasal concha 245
Superior oblique muscle 241
Superior orbital fissure 221
Superior ramus of pubis 224, 257
Superior rectus muscle 241
Superior sagittal sinus 212, 257
Superior thyroid artery 244
Superior vena cava 215, 251, 252-255, 255
Supernova
Massive stars 26-27
Nebulae and star clusters 16
Neutron stars and black holes 29
Supernova remnant
Nebulae and star clusters 16-17
X-ray image of Crab Nebula 28
Supersonic flight 416
Supersonic jetliners 416-417
Supersonic transport 416-417
- Supporter 581
Supporting tissue
Bishop pine stem 125
Dicotyledon leaf 126
Stems 134-135
Supraesophageal ganglion 173
Supraoccipital bone 181
Supraoccipital crest 84
Supraorbital fissure 221
Supraorbital foramen 221
Supraorbital margin 215, 220, 221
Supraorbital notch 215
Supraorbital ridge
Chimpanzee 202
Stegoceras 100
Styracosaurus 102
Suprarenal gland 257
Suprarenal vein 257
Suprascapula 185
Suprasternal notch 211
Surangular bone 102
Surcingle loop 555
Surface areas 625
Surface currents 296-297
Surface deposits 275
Surface layer 295
Surface ocean current 296
Surface streams 284
Surface temperature 59
Stars 22
Structure of main sequence star 24
Structure of Mars 45
Structure of Mercury 35
Structure of Neptune 51
Structure of red giant 25
Structure of red supergiant 26
Structure of Venus 37
Sun 55
Surface terrain 284
Surface vegetation 282
Surface winds 500
Surrogate mother 607
Surround sound 584
Surround sound special effect plug-in 521
Surveillance RADAR 397
Suspended erratic 286
Suspension
"Deltic" diesel-electric locomotive 527
Motocross racing 368
Motorcycle 564
Ultralight 426
Suspension arm 550-551
Suspension linkage 362
Suspension spring 550
Suspension strut 340, 351
Suspension top mount 340
Sustaining pedal 514, 515
Suture 202
Su-wei 576
Suzuki RGV500 568, 569
Swab hitch 587, 589
Swallow 585
Swallow-hole 284
Swamp 290-291
Swan neck ornament 375
Swash plate 344
Swash zone 294
S waves 65
Sweat duct 255
Sweat gland 254-255
Sweat pore 254-255
Sweep rowing 560
Sweep-rowing boat 561
Sweeping low throw 556
Sweet chestnut 156, 144, 150
Sweetgum 76
Sweet pea 128
Sweet potato 154
Swell manual 514
Swell of muzzle 395
- Swell pedal 514
Swell stop 514
Swept titanium fan blades 572
Swift tackle 377
Swim bladder 178, 180-181
Swimmeret 172
Swimming 558, 559
Swimming pool 558
Swimwear 558
Swingarm 564, 568
"Swing-wings" 420
Switch 316
Switchboard room 397
Switch end casting 598-599
Switch gear 314
Swivel becket 582
Swivels
Mooring and anchoring 586
Angling 562, 565
Swivel suspension ring 377
Swollen leaf base 154-155
Swollen stem base
Guzmania lingulata 165
Kedrostis africana 115
Oxalis sp. 157
Swollen stem 154-155
Sword 556-557
Sycamore 131, 150-151
Sycamore beam 560
Syconium 148
Syenite 275
Symbiosis
Lichens 114
Mycorrhizal association 135
Symbols
Biology 591
Chemistry 591
Communication 108
Mathematics 591
Music 502, 505
Physics 591
Symphony orchestra 504, 505
Synapsid reptile skull 67
Synaptic knob 228, 259
Synaptic vesicle 239
Sync port 587
Synsarcopus gynoecium 140
Synchirpus splendidus "180
Synchronized elevator 425
Syncline 60, 61, 62
Synclinorium 61
Synnergid nucleus 147
Synsacrum 189
Synthesizer 520
Synthetic brush 436, 438
Synthetic flax 584
Synthetic hog hair brush 442
Synthetic materials 506
Synthetic polymer 506
Synthetic resin 442
Synthetic ropes 588
Synthetic sable brush 442
Synthetic strings 544, 545
Synthetic wash brush 458, 442
Syria Planum 42, 45
System display 575
Systems connector 415
System unit 567
- T
Tabernacle 463, 474, 476
Tab hinge 415
Tablet computer 568-569
Tablet flower 488, 491
Tabletting 572, 584
- Tabular habit 271
Tacan aerial 420
Tachybaptus ruficollis 190
Tack 375
Tackling
Australian rules football 528, 529
Football 526
Rugby 531
Soccer 524
Tactical air navigation (Tacan) aerial 420
Tadpoles 182-183, 192
Taenia 460
Taenia colica 249
Taffrail 378, 381
Tail
Amphibian 182
Anchisaurus 89
BE 2B bomber 404
Caiman 187
Calligraphic character 445
Corythosaurus 98
Crocodilians 186
Deer hopper dry fly 565
Dolphin 205
Dunkeld wet fly 565 87
Hare 196
Hawker Tempest components 409
Herrerasaurus 86
Horse 198
Ichthyostega 80
Iguanodon 96
Iguanodonts 96
Kangaroo 206
Lion 195
Lizard 184-185
Lungfish 81
Monkey 202
Ornithopods 96
Pachycephalosaurus 100
Prehensile 202
Rabbit 196-197
Rat 196
Rattlesnake 185
Rigging 582-585
Salamander 182
Sauropodomorpha 88
Schweizer helicopter 425
Scorpion 170
Ski 552-555
Stegoceras 101
Stegosaurus 95
Tadpole 185
Triceratops 102
Tyrannosaurus 84
Westlothiana 81
Tail area 78
Tail boom 425
Tail bud 260
Tail bumper 417
Tail club 95
Tail cone 416-417, 418
Tailcone fairing 572
Tail crest 128
Taileron 420-421
Tail fairing 409
Tail feathers 188
Tail fluke 205
Tailgate 348
Tail gunner's compartment 408
Tail-gun turret 408
Taillight
BMW R/60 362
Harley-Davidson FLHS
Electra Glide 362
Honda CB750 363
Vespa Grand Sport 160
Mark 1 365
Tailpiece 510, 511
Tail-pin 510
Tail pipe 540
- Tailplane
Airbus 580 572
ARV light aircraft 424
BAe-146 jetliner 415
BK 2B tail 405
Biplanes and triplanes 402-405
Blackburn monoplane 401
Blériot XI monoplane 401
Curtiss biplane 599
Hawker Tempest 409
Lockheed Electra airliner 407
Schleicher glider 426
Tailplane fairing 415
Tailplane root 409
Tailplane tip 407, 415
Tailrace 514
Tail rod 590
Tail rotor 422-425
Tail-rotor drive shaft 422, 425
Tail rotor gearbox 425
Tau shield 78
Tailskid
ARV light aircraft 424
Avro triplane 405
BE 2B bomber 405
Blackburn monoplane 400-401
LVG CVI fighter 405
Tail spike 92
Tail spine 79
Tail unit 568
Tailwheel
Avro biplane 402
B-17 bomber 408
Hawker Tempest fighter 409
Lockheed Electra airliner 407
Schleicher glider 426
Tailwheel leg 401
Takeoff and landing skid 398
Takla Makan Desert 265
Talc 270-271
Tallow coating 579
Talonaviular ligament 252
Talons 188
Talus 282-285
Talus bone 252
Tamarins 202, 205
Tambourine 504, 518
Tam-tam 504, 516
Tandem wings 402
Tank 592
Tank drain tap 407
Tank inspection access 417
Tank support 359
Tantalum 510
Tantalus Fossae 45
Tapeats sandstone 277
Tapir 198
Tappet 545
Tappet adjustor 567
Tap root 128
Tarantula Nebula 26-27
Large Magellanic Cloud 12
Tarantulas 170-171
Target areas 556, 557
Target hole 546
Target pistol 548, 549
Target shooting 548, 549
Tarn 295
U-shaped valley formation 287
Tarsal bone
Albertyosaurus 84
87
Iguanodon 97
Tarsals
Crocodile 186
Domestic cat 195
- Elephant 201
Frog 185
Hare 197
Horse 199
Kangaroo 206
Lizard 184
Platypus 206
Rhesus monkey 202
Seal 204
Tarsiers 202
Tarsomere 15
Tarsometatarsus 189
Tarsus
Beetle 168
Bird 188
Human 219
Scorpion 170
Spider 171
Tas-de-charge 469
Tasmanian devil 207
Taste 244
Taste bud 244
Tau Orionis 18
Taurus 19, 20
Taurus mountains 77
Tau Sagittarii 21
Tawny owl 190
Taxiing light 414, 420
Taxus baccata 70, 125
Tea clipper 592
Team crest 551
Team jersey 529
Team name 555
Tear fault 61
Technetium 310
Technosaurus 69
Tee 546
Teeing ground 546
Tee peg 547
Teeth
Ankylosaurus 92
Bear 106
Caiman 186
Canine 194, 202
Carnassial 194
Carnivores 194
Ceratopsian 100
Cheek 194
Chimpanzee 202
Crocodilians 186
Extinct shark 67
Hadrosaur 96
Hominid 108
Horse 105
Human 246-247
Iguanodont 96
Incisor 194, 196, 201, 202
Lamprey 178
Leaf-shaped 88-89
Molar 194, 201, 202
Ornithopod 96
Premolar 194, 202
Rabbit 196
Rodents 196
Theropod 84
Thyreophoran 92
Venus fly trap 160
Teeth development 246
Tegenaria gigantea 171
Telephone line 576
Telescope, space 612-613
Telescopic fork
Harley-Davidson FLHS
Electra Glide 363
Honda CB750 363
Honda VF750 364
Honda Varnia Motocross TC610 368
Motorcycle 364
Suzuki RGV500 368
Weslake Speedway motorcycle 369
Telescopic muffler 326, 529
Telescopic sight 548, 549
Telescopic strut 416
Television 315
Telltale 545

- Tellurium 511
Tellus Regio 36, 37
Tellus Tessera 37
Telson 172
 Fossil 79
TEM 610, 611
Tempe Fossae 45
Tempera 432, 435
Temperate latitudes 302
Temperature
 Atmosphere 500-501
 Chemical reactions 512-515
 Formation of black hole 29
 Germination 152
 Matter 306-307
 Mineral resources 280
 Oceans and seas 296
 Stellar black hole 29
 Weather 302-305
Temperature and pressure sensor 418
Temperature and steam control dial 594
Temperature changes
 Atmosphere 501
 Oceans and seas 296
 Weathering and erosion 282
Temperature scales 621
Tempered pigment 432
Temple 484-485
 Ancient Egyptian 458
 Ancient Greek 460-461
 Ancient Roman 462-465
 Asian 490
Temple blocks 516
Temple Butte limestone 277
Temple Cap sandstone 276
Temple of Amon-Re 458-459
Temple of Aphaia 461
Temple of Athena Polias 460
Temple of Heaven 490
Temple of Isis 459
Temple of Mallikarjuna 491
Temple of Neptune 460-461
Temple of Vesta 462-465
Temple of Virupaksha 490-491
Tempo 504
Temporal bone
 Chimpanzee 202
 Human 220-221, 242
Temporal lobe 257
Temporalis muscle 226-227, 229
Tendon
 Achilles 252-253
 Annular 241
 Calcaneal 252-253
 Extensor digitorum longus 253
 Extensor digitorum 251
 Extensor hallucis longus 253
 Flexor digitorum 251, 87
 Palmaris longus 251
 Peroneus brevis 253
Tendril
 Arabesque 480
 Clematis 150
 Dogfish egg 192
 Everlasting pea 129
 Monkey cup 161
 Passion flower 150
Tennis 544
Tennis racket 544
Tenon
 Flax spinning mill 492
 Hull plank fastening 375
Tenor drum 518-519
Tenor joint 508
Tenor mule 507
Tenor sax strings 515
Tenor saxophone 509
Tenor voice 502
Tension
 Drums 518
 Faults and folds 60-61
 Mountain building 62
Tension column 497
Tension control 552
Tension key 518, 519
Tension member 499
Tension pulley 360
Tension rod 518, 519
Tension screw 518
Tensor fasciae latae muscle 226
Tensor tympani muscle 245
Tentacle
 Coelentrates 166
 Jellyfish 167
 Mollusks 176-177
 Scallop 176
 Sea anemone 166-167
 Snail 177
Tenth century
 Building 490
 Style 468
Tepal scar 140
Tepal
 Flower parts 140, 145
 Monocotyledons 126
 Peruvian lily 129
Terbium 511
Teres major muscle 227
Teres minor muscle 227
Tergum plate 175
 Egg 193
Terminal box 517
Terminal bronchiole 254
Terminal bud
 Bishop pine 124
 Horse chestnut 150
 London plane 154
 Rhizome 155
 Root tuber 154-155
 Stems 154
 Stolon 154
Terminal ileum 249
Terminal lake 286
Terminal moraine
 Glaciers 286
 Rivers 289
Terminal pinna 156
Terminal ring 259
Terminus 286
Terrace
 Asian building 490-491
 Modern building 497-499
 Twentieth-century building 494-495
Terracotta clay 455
Terrain-following radar 420
Terrapin 186-187
 Bird 188
 Terrestrial animal 74
Terrestrial mammal 104
Terrestrial sediment 299
Tertiary bronchus 215
Tertiary period 57, 74, 75
 Fossil record 279
Tessellation 489
Tessera 450, 489
Test 174-175
Testa 152
 Dry fruit 150-151
 Embryo development 147
 Epigeal germination 153
 Hypogeal germination 152
 Succulent fruit seed 148-149
Testicle 259
Testicular artery 257
Testicular vein 257
Test is
 Barnacle 175
 Dolphin 205
 Domestic cat 195
 Human 259
 Rabbit 196
Test tube 313
Tetanurae 85
Tethus Regio 36
Tethys 46
Tethys Sea
 Cretaceous period 73
 Jurassic period 71
Tertiary period 74, 75
 Triassic period 69
Tetragonal system 270
Tetrahedron 623
Tetralophodon 75, 104
Text 444
Textured papers 441
Textured scraper 595
TGV electric high-speed train 529
Thalamian 375
Thalamus 256-257
Thalassiosira sp. 116
Thalicttrum delawayi 137
Thallium 511
Thaloid liverwort 118
Thallus
 Algae 116-117
 Lichen 114
 Liverwort 118
 Seaweed 116-117
T-handle auger 374
Thar Desert 265
Tharsis Tholus 43
Thatched roof 477
Thaumasia Fossae 45
The Big Dipper 19
Themis Regio 36
Therapeutic cloning 606
Theobroma cacao 148
Therapsids 104
Thermal/electrical insulation 596, 597
Thermal insulation 613
Thermals 426
Thermocouple bus-bar 419
Thermogram 214
Thermosphere
 Earth's atmosphere 300
 Mars' atmosphere 43
 Venus' atmosphere 37
Thermostat 411
Theropoda 85
Theropods 84-87
Thesium alpinum 145
Theta Sagittarii 21
Theta Andromedae 19
Theta Pegasi 19
Thetis Regio 36
Thick skull 46
Thigh
 Anchisaurus 89
 Bird 188
 Corythosaurus 98
 Gorilla 205
 Horse 198
 Human 211
 Iguanodon 96
 Kangaroo 207
 Lion 195
 Psittacosaurus 105
 Stegoceras 101
 Stegosaurus 92
 Triceratops 102
 Tyrannosaurus 84
Thigh musculature 90
Thigh pad 527
Thimble
 Harness racing 555
 Rigging 385, 384
Third-century building 465
Third home 541
Third man 558, 541
Third rail 328
Third stage motor 615
Thirteenth century
 Building 467, 469-471
 Style 470
Thirty-five mm film strip holder 570
Thistle funnel 513
Thole pin 580
Thoracic cavity 255
Thoracic leg 169
Thoracic nerve 258
Thoracic pleurae 78
Thoracic segment 79
Thoracic vertebrae
 Crocodile 186
 Domestic cat 195
 Hare 197
 Horse 199
 Human 222
 Kangaroo 206
 Platypus 206
 Rhesus monkey 202
 Seal 204
Thoracolumbar vertebrae
 Elephant 201
 Lizard 184
Thorax
 Cirripedia 172
 Human 211
 Insects 168-169
 Thorium 510
 Thornback ray 179
 Thoroughbred horse 554
 Thranite 375
 Thread 167
 Three-blade main rotor 425
 Three-cylinder Anzani engine 401
 Three-cylinder engine 425
 Three-lobed stigma 145
 Three-masted square-rigged ship 375
 Three-point line 532
 Three pounder 395
 Three-toed ungulates 198
 Threshold 465
Throat
 Angling hook 562
 Bird 188
 Danforth anchor 386
 Human 212, 244-245
 Lacrosse crosse 541
 Racketball racket 545
 Squash racket 545
 Tennis racket 544
Throatlatch 199
Throttle
 Avro triplane 402
 Curtiss biplane 598
 "Rocket" steam locomotive 524
 Suzuki RGV500 363
 Vespa Grand Sport 160
 Mark 1 563
 Weslake Speedway motorcycle 569
Throttle butterfly 545
Throttle cable 350
 Harley-Davidson FLHS Electra Glide 365
 Husqvarna Motocross TC610 368
 Kirby BSA racing sidecar 369
 Suzuki RGV500 369
 Weslake Speedway motorcycle 569
Throttle lever 419, 425
Throttle linkage
 Ford Model T 358
 Jaguar V12 engine 345
 Oldsmobile trim 357
 Renault Clio 550
Throttle wheel 342
Throat
- Judo 556
 Structure of a fault 60
Thrower 394
Throw-in 532
Thrushes 188
Thrust 545
Thruster cluster 615
Thrust fault 61
Thrust plate 601
Thrust-reverser 421
Thulium 511
Thumb 211, 250-251
Thumb-claw
 Anchisaurus 89
 Apatosaurus 85
 Baryonyx 83, 85
 Massospondylus 85, 89
 Plateosaurus 88
Thumbhole 384
Thumb knot 589
Thumb piston 514
Thumb-spike 96-97
Thwart 375, 375, 580
Thylakoid 139
Thymine 216
Thyreophora 85
Thyreophorans 92-95, 94-95
Thyristor converter 328
Thyroid membrane 244
Thyroid muscle 229, 244
Thyroid cartilage 245, 255
Thyroid gland 214-215, 217, 244-245, 255
Tibetan plateau 63
Tibia
 Archaeopteryx 85
 Beetle 168
 Butterfly 169
 Crocodile 186
 Diplodocus 90
 Domestic cat 195
 Elephant 201
 Eryops 81
 Gallimimus 86
 Hare 197
 Horse 199
 Human 219, 252-253
 Iguanodon 96-97
 Kangaroo 206
 Lizard 184
 Parasaurolophus 99
 Plateosaurus 88
 Platypus 206
 Rhesus monkey 202
 Scorpion 170
 Seal 204
 Spider 171
 Stegoceras 101
 Stegosaurus 95
 Struthiomimus 87
 Toxodon 107
 Triceratops 102
 Turtle 187
 Tyrannosaurus 84
Tibiale 185
Tibial flexor muscle 97
Tibialis anterior muscle 226, 253
Tibialis posterior muscle 253
Tibiofibula 185
Tibiotarsus 189
Tidal bulge 297
Tidal currents 296-297, 298
Tidal flow 296
Tidal levels 295
Tidal power 604
Tidal river-mouth 295
Tidal scour 298
Tidal waves 58
Tides 294, 297
Tie
 Basketball match 552
Tie plate 395
Tierceron 485
Tie rod 354, 340
Tiger seat 354
Tiger shark 178-179
Tight end 526
Tight-head prop 550
Tile
 Dome 486
 Islamic mosque 488
 Modern building 499
 Neoclassical building 482
 Renaissance building 476-477
Tiled roof 495
Tilia sp. 134
Tilia x europaea 145
Tiller
 Dhow 376
 First cars 354-355
 Longboat 380
 Oldsmobile trim 357
 Roman corbita 375
 Sailing dinghy 561
 Steamboat with paddle wheels 391
 Viking ships 374-375
Till and rotation
 Jupiter 44
 Mars 42
 Mercury 34
 The Moon 40
 Neptune 50
 Pluto 51
 Saturn 46
 Uranus 48
 Venus 36
Timber 516
Timber frame
 Ancient Roman building 462, 464-465
 Dome 486
 Medieval building 466-467
 Renaissance building 477
Timber head 380
Timber rafter 492
Timber trellis 605
Time interval signal 350
Timekeeper
 Basketball 552
 Fencing contest 557
 Handball 555
 Judo contest 556
 Lacrosse 541
 Netball 555
 Swimming 558
Time signature 502
Time switch 598
Time-trial bicycle 360
Time zones 618-619
Timing chain 345, 345
Timing chest 343
Timing gear 367
Timpani 505, 504, 505, 518
Timpanum 519
Tin 511
 Mineralization zones 281
 Squash 545
Tinatin Planitia 37
Tinted paper 441
Tip of dodder stem 163
Tip ring 565
Tip section 565

- Tire
1906 Renault 356-357
ARV light aircraft 424
Avro triplane 402
BAe-146 jetliner 414
Bicycle 358-359
Blériot XI monoplane 401
BMW R/60 362
Cannondale SH600 hybrid bicycle 361
Curtiss biplane 398
Double-decker tour bus 355
Eddy Merckx racing bicycle 360
First cars 334-335
General use 365
Lockheed Electra airliner 407
MCW Metrobus 355
Metal 324
Motocross racing 368
Motorcycle 365
Pacing sulky 355
Pneumatic 358, 355
Race car 356-357
Renault Clio 332-335
"Rocket" steam locomotive 324
Rossin Italian time-trial bicycle 361
Single-decker bus 335
Slick racing 365
Suzuki RGV500 368-369
Trials 365
Tubeless sports 365
Volkswagen Beetle 340
World War I aircraft 404-405
- Tire carrier 357
Tire tread 360, 365, 368
Tire wall 360
Tissue culture 607
Titan 614
Titania 48
Titanium 310
Titanohydrax 74
Toad 182
Toadflax 129
Toaster 598-599
Toe
Albertosaurus 84
Anchisaurus 89
Archapteryx 85
Bird 188
Caiman 186-187
Corythosaurus 98
Golf club 547
Gorilla 205
Herrerasaurus 86
Human 211, 232-233
Iguanodon 96-97
Lion 194
Lizard 184
Pachycephalosaurus 100
Psittacosaurus 105
Stegoceras 101
Tyrannosaurus 84
Toe clip 360
Toenail
Elephant 200
Gorilla 205
Human 233
Toe piston 314
Toe strap 358-359
Toggle switch 513
Toilet 416, 485
Tolstoj 35
Tomb 458-459, 489
Tomb of Itimad-ud-daula 489
Tomb of King Tjetji 459
Tombolo 294
Tom-toms 518-519
Tondo brush 434
Tone editor control 520
Tonehole 509
- Tone pattern selector 520
Tongs 321
Tongue
Allosaurus 85
Caiman 186
Chimpanzee 202
Corythosaurus 98
Cow 198
Dolphin 205
Domestic cat 195
Elephant 200
Human 212, 226, 244, 248
Iguanodon 97
Lamprey 178
Lion 194
Rabbit 196
Rattlesnake 185
Ski boot 552
Ton-wei 576
Tool and battery box 335
Tool/brush-head connector 595
Tool or wand cuff 595
Tools
Rigging 382-385
Sailmaking 384
Viking boatbuilding 374
Tooth
Acanthostega 80
Anchisaurus 89
Ankylosaurus 94
Arsinoitherium 104
Australopithecus 108
Baryonyx 85
Camarasaurus 91
Diplodocus 90
Dragon prowhead 374
Eryops 80
Euoplocephalus 94
Heterodontosaurus 85
Homo habilis 108
Human 108, 246-247, 248
Iguanodon 96
Lambeosaurus 99
Moeritherium 105
Pastels application 440
Phiomia 105
Platesaurus 88
Protoceratops 102
Smilodon 107
Triceratops 105
Tyrannosaurus 84
Toothless beak
Ankylosaurus 92
Corythosaurus 98
Euoplocephalus 94
Gallimimus 86
Theropods 84
Triceratops 102
Topaz 271
Topcastle 373, 377
Topgallant mast
Battleship 395
Sailing warship 377
Wooden sailing ship 378-379
Top hose 351
Topmast 377, 378
Topping lift 580
Topping-up valve 561
Top-plate 464
Top race 359
Topsail
74-gun ship 379
Double topsail schooner 585
Junk 376
Topset strata 285
Topside strake 395
Top sliding block 437
Tornado GR1A 420-421
Torosaurus 75
Toroweap formation 276
Torpedo 394-397
Torque arm 364, 365
Torquemeter mount 419
Torque tube 358-359
- Torque tube assembly 425
Torrential rain 302
Torsional vibration muffler 410-411
Torsion bar 350
Tortillon 440, 441
Tortoise 186
Tortoise skull 77
Torus
Ancient Roman building 465
Asian building 490
Dome 486
Gothic building 470
Medieval building 467-469
Renaissance building 475, 477
Shapes: solid 625
Total solar eclipse 52
Tote board 555
Touch-down 526
Touch-in goal line 530
Touch judge 530
Touch line
Rugby 530
Soccer 524
Touchpad 566
Touchpiece 509
Touchscreen 568-569, 578-579, 587
Touch sensor 609
Tour buses 332
Tour do César 466
Touring bicycle 360, 361
Tourmaline 269
Tower
Ancient Roman building 465
Asian building 490-491
Clock 493
Gothic church 472
Islamic building 488
Medieval building 466-467, 468-469
Modern building 496-497
Nineteenth-century building 492-495
Renaissance building 476
Twentieth-century building 495
Tower Bridge 492-495
Tower vault 469
Towing fairlead 395
Towing hook 335, 426
Town Hall 495
Toxodon 76, 106, 107
TPU connector 571
Trabecula 250-251
Trace fossils 278
Tracery
Gothic building 470-473
Nineteenth-century building 495
Trachea
Bird 189
Brachiosaurus 91
Chimpanzee 202
Dolphin 205
Domestic cat 195
Elephant 200
Gallimimus 86
Human 212, 215, 244-245, 248, 255
Lizard 185
Rabbit 196
Spider 170
Tortoise 187
Trachelion 460
Trachycarpus fortunei 127, 130
Track 413
Track control arm 340
Track events 542, 543
Track gauge 350, 351
Track rod
- Elegance and utility 356-357
Ford Model T 358-359
Renault Clio 351
Track shoe 545
Traction motor 328
Trade winds 300
Traffic congestion 352
Traffic surveillance 422
Tragus 242
Trailboard 379
Trailing arm 340
Trailing edge
BAe-146 jetliner components 413, 414, 415
BE 2B tail 405
BE 2B wings 404
Hawker Tempest components 409
Pegasus Quasar ultralight 426-427
Trailing-link arm 414
Trailing wheel 324
Train equipment 330-331
Training gear 396
Trains
Diesel 326-327
Electric 328-329
High-speed 328-329
Steam 324-325
Trams 332-335
Tran axle 340
Transept
Gothic church 470, 473
Medieval church 468-469
Transfer port 342
Transformation 168
Transformer 314, 328
Transform fault 59
Transistor 584
Transitional cell mucosa 257
Transition metals 310, 311
Transit plug 397
Translucent crystal 271
Translucent impasto glaze 445
Translucent white marble 455
Translucent "window" 157
Transmission 350-351
Transmission adaptor plate 344
Transmission electron microscope (TEM) 610, 611
Transmission system 326, 366
Transom
74-gun ship 381
Junk 376
Longboat 380
North wing, Chateau de Monlal 476
Sailing warship 377
Transparency holder 570
Transparent glassy crystal 271
Transparent lower drumhead 518
Transverse tissue 160
Transverse wash 439
Transpiration 156
Transponder aerial 425
Transportation lock 571
Transportation system 332
Transport tissue
Golden barrel cactus 156
Monocotyledons 126
Photosynthesis 138-139
Transversary 377
Transverse arch 485
Baroque church 479
Medieval church 468-469
- Transverse colon 249
Transverse dune 285
Transverse foramen 222
Transverse leaf spring 358
Transverse line 555
Transverse process
Human 222-223
Platesaurus 89
Tyrannosaurus 85
Transverse rib 485
Transverse strut 512
Trapezium 17, 622
Trapezium bone 230
Trapezius muscle 226-227, 229
Trapezoid bone 230
Traps
Butterwort 161
Cobra lily 160
Monkey cup 161
Pitcher plant 115, 160-161
Sundew 160
Venus fly trap 160
Traveler 380
Traveling 555
Travertine shell 464
Tray fascia 595
Tread 477
Tread pattern 365
Treasury of Atreus 461
Trebble bridge 514
Trebble clef 502
Trebble hook 562-565
Trebble note strings 515
Trebble voice 502
Tree 66-67, 130-131
Energy storage 315
Epiphytes 162-163
Gymnosperms 122-125
Tree fern 112-113
Tree mallow 131
Tree root action 282
Treenail 387
Trefoil
Gothic church 470-473
Nineteenth-century building 493
Trefoil arch 473, 484
Trellis window 459
Trellised river drainage 288
Trembler coil box 335
Trenail 387
Trestle trees 378
Trevithick, Richard 324
Triac device 600
Trials tire 365
Triangle
Shapes: plane 622
Musical instrument 504, 517
Steamboat with paddle wheels 391
Triangle mosaic 489
Triangular buttress 484
Triangular fossa 242
Triangular horn 85
Triangular lesene 481
Triangular pediment 462
Triangular-section fuselage
Avro triplane 405
Bell-47 helicopter 425
Blackburn monoplane 401
Triangulum 19, 20
Triangulum Australe 21
Triassic period 68-69
Fossil record 279
Geological time 57
Triatic stay 385
Tribune 467-468
Tributary
Coastlines 295
Rivers 288
Tributary moraine 287
Tributary stream 289
- Triceps brachii muscle 227
Triceratops 100, 102-105
Trichome 156
Marram grass 115
Trichinic system 270
Tricolpate pollen grain 145
Tricuspid valve 251
Triere 375
Trifid Nebula 16
Trifoliate leaves 128, 130
Laburnum 137
Oxalis sp. 157
Triforium 469
Trigger
Air pistol 549
Biathlon smallbore rifle 549
Cnidocyte structure 167
Trigger hair 160
Trigger mechanism 600
Trigger position 600
Triglyph 460
Trigon 488
Trigonal system 270
Trigone 257
Trigonometry 621
Trike nacelle 426-427
Trilette mark 145
Trilobate rotor 346
Tri-lobed tail 81
Trilobites 64, 78
Earth's evolution 56
Fossil record 279
Trim 352-355
1906 Renault 356-357
Oldsmobile trim 357
Renault Clio 350-351
Volkswagen Beetle 341
Trimala 491
Trimtab 407, 414, 415
Trim tank 416-417
Trinity Chapel, Salisbury Cathedral 470
Tripinnate leaves 137
Triplanes 402-403
Triple bar jump 554
Triple jump 542
Triple spine 130-131
Tripod mast 394
Tripod stand
Congas 519
Drum kit 518
Electronic drums 520
Modeling stand 455
Radial studio easel 437
Tripping palm 386
Tripping ring 372
Triquetral bone 230
Trirame 372-373
Tri-spoke wheel 361, 368, 369
Triton 50
Tri-wing screw 587
Trochanter
Beetle 168
Scorpion 170
Spider 171
Trochlea
Baryonyx 85
Human 241
Trochoid housing 410
Trojan two-stroke engine 342
Trolley 352
Trombone 504, 505, 506, 507
Tropeter 375
Trophoblast 260
Tropic formation 276
Tropic of Cancer
Satellite map 265
Surface currents 297
Tropic of Capricorn
Satellite map 265
Surface currents 297
Tropical cyclone 302
Tropical orchids 162

- Tropical rainforest 39, 66
Troposphere
 Earth's atmosphere 500
 Jupiter's atmosphere 45
 Mars' atmosphere 43
 Saturn's atmosphere 47
 Venus' atmosphere 37
Trout 180
Trout angling 562
Truck
 Early tram 532
 Greek galley 372
 Longboat 580
 Wooden sailing ship 378-379
Trumpet 504, 506, 505
Truncate leaf base 137
Trunk
 Elephant 200-201
 Mammoth 107
 Phiomia 105
 Tree fern 112
 Woody flowering plant 150-151
Trunnion 595
Truss
 Gothic church 473
 Modern building 497-499
 Steam boat with paddle wheels 391
Truss rod 513
Try 530, 531
T-section beam 492
Tsiolkovsky 41
T-type cantilevered fin 426
Tu-144 416
Tuba 504, 505
Tube fret 174, 175
Tubeless sports tire 565
Tuber
 Broomrape 145
 Dryland plants 157
 Horsetail 120
 Potato 128
 Vegetative reproduction 155
Tubercle
 Corythosaurus 98
 Golden barrel cactus 156
 Sea urchins 174
 Starfish 174
 Stem projections 156
Tubular bells 504, 516
Tubular chassis 335
Tubular drums 518
Tubular open cradle frame 369
Tubular petioles 160
Tuck 581
Tudor arch 484
Tufted duck 188
Tug propeller 391
Tulip mount 563
Tuner/amplifier link cables 585
Tuner sellings memory microchip 585
Tungsten
 Mineralization zones 281
 Periodic table 310
 Tungsten carbide lip 450
 Tungsten filament 519
 Tunica adventitia 252
 Tunica intima 252
 Tunica media 252
 Tuning adjuster 510-511
 Tuning pedal 519
 Tuning peg 510, 511
 Tuning pin 514, 515
 Tuning slide 506
Tunnel
 Cave 285
 Trains 350
Tunnel vault 485
Tuojiangosaurus 92
Tupelo 137
Turbine
 Energy 314-315
 Floodgate 604
 Jet engines 418-419
Nuclear "Hunter-Killer" submarine 397
Turbo-charged diesel engine 327
Turbocharger 556
Turbofan engine 418-419
 Landing gear 412
Turbo impeller 347
Turbojet engine 418-419
 Landing gear 412
 Supersonic jetliner 416
Turbo propeller 347
Turboprop engine 418-419
Turdus viscivorus 190
Turfed foot 602, 605
Turgei strait 71
Turkish crescent finial 488
Turk's head 583
Turnbuckle
 Avro triplane 402
 Blackburn monoplane 401
 Curtiss biplane 398
 LVG CVI fighter 405
 Rigging screw 583
Turn indicator 558
Turning force 320
Turning indicator 352, 353
Turning judge 558
Turning vane 557
Turns 555
Turntable 596
Turntable rotator 596
Turpentine 436
Turret 486
 Baroque church 481
 Battleship 394-395
 Gothic church 470-471
 Gun turret 396
 Medieval building 466, 468
 Nineteenth-century building 495
 Renaissance building 476-477
Turtle 72-73, 186-187
Tuscan capital 465
Tuscan pilaster 465, 485
Tusche 446
Tusche pen 448
Tusche stick 448
Tusk
 Elephant 200-201
 Mammoth 107
 Phiomia 105
TV mini-camera 356
TV power button 585
Tweeter loudspeaker connectors 585
Twelfth century
 Building 466-467
 Church 469, 473
 Roof 490
 Style 468, 470
Twentieth-century buildings 494-495
Twin-blade main rotor 423
Twin carbon-fiber disc brake 369
Twin carburetors 427
Twin-cylinder engine
 Harley-Davidson 362
 Pegasus Quasar ultralight 427
 Steam-powered Cugnot 334
Twin-domed forehead 200
Twine 584
Twin-lobed leaf blade 160
Twin nose-wheel 420
Twin rate spring 365
Twin rear axle 353
Twin rudder 372
Twin-wheel main landing gear 414
Twin-wheel nose-gear 417, 420
Twist 588
Twist dive 558, 559
Twisted wire habit 271
Two-lobed stigma 142
Two-pulley system 320
Two-seater cockpit 421
Two-stroke combustion engine 366
Two-toed ungulates 198
Two-towered gate 467
Tyagaraja 35
Tycho 40
Tye 377
Tye halyard 374
Tympan 449
Tympanic bullet 194
Tympanic canal 243
Tympanic membrane 243
Tympanum
 Frog 182
 Quail chick 193
Typhoon 302
Tyrannosaurus 73, 84-85
Tyringham House 483
U
UHF aerial 420
UK loading gauges 351
Ulmus minor 144
Ulna
 Archaeopteryx 85
 Arsinoitherium 104
 Baryonyx 85
 Bird 189, 191
 Brachiosaurus 91
 Crocodile 186
 Diplodocus 90
 Domestic cat 195
 Elephant 90, 201
 Eryops 80
 Euoplocephalus 94
 Gallimimus 86
 Hare 197
 Horse 199
 Human 218, 230
 Iguanodon 96
 Kangaroo 206
 Kentrosaurus 93
 Lizard 184
 Parasauroplopus 99
 Pareiasaur 81
 Plateosaurus 88
 Platypus 206
 Rhesus monkey 202
 Seal 204
 Stegoceras 100, 101
 Stegosaurus 93
 Struthiomimus 87
 Toxodon 106
 Triceratops 102
 Tuojiangosaurus 95
 Turtle 187
 Tyrannosaurus 84
Ulnar artery 231, 255
Ulnar nerve 231, 238
Ultra-high frequency (UHF) antenna 615
Ultralights 410, 426-427
Ultramarine lapis lazuli 433
Ultrasound scan 214
Ultraviolet light 145, 319
Ultraviolet radiation 22, 319
Ultraviolet solar radiation 300
Umbels 143
Umbilical artery and vein 260
Umbilical cord 260-261
Umbilicus 211, 260
Umbo 176
Umbra 32
Umbrella 491
Umbriel 48
UMD drive ribbon cable 379
Umpire
 Badminton 545
 Baseball 536
 Cricket 538
 Football 526
 Hockey 540
 Lacrosse 541
 Netball 535
 Tennis 544
 Volleyball 534
Umpire signals 537
Una corda pedal 514, 515
Unarmed combat 556
Underarm pass 535
Underframe 332
Underground mycelium 115
Underground stem 154
Underground storage organs 154-155
Underground stream 284-285
Underground water
 Lake formation 292
 Rivers 288
Underhand serve 354
Under plastron 557
Under-turnstile roller ring 596
Underwater digital camera 581
Underwater mountains 298
Underwing fairing 425
Unenergized electrode 584
Ungulates 198-199
Unicellular organisms 56
Unified leaf pair 157
Uniform motion 321
"Union Pacific" diesel train 326
Unipolar neuron 239
Unison 503
Unit number 328
Units of measurement 620
Universal resource locator (URL) address 577
Universal serial bus (USB) ports 566, 567, 570
Universal serial bus (USB) programmer 591
Universal veil 114-115
Universe 10-11
Unmapped region
 Degas and Brönte 34
 Structure of Mercury 35
Unmillennium 311
Unmillhexium 310
Unmilloctium 311
Unmillpentium 310
Unmillquandium 310
Unmillseptium 310
Unreactive gas mixture 319
Unreactive metals 311
Unstable elements 310
Unukalhai 21
Upcurved edge 191
Upfold 60
Uppol trap 280
Uppolstery 336-337
Uppolstery brush 593
Uplifted block fault mountain 62
Upper arm 210
Upper Belvedere 482
Upper Carboniferous Coal Measures 61
Upper Carboniferous Millstone Grit 60-61
Upper crankcase 410
Upper crux of antihelix 242
Upper deadeye 382-383
Upper deck 580
Upper deck passenger door 575
Upper deck windows 572
Upper epidermis 159
Upper eyelid 213
Upper fin 423
Upper finishing 381
Upper Frater 473
Upper gallery 379
Upper head 587
Upper jaw 212, 220-221, 244-245, 246, 248
Upper jaw tusk 105
Upper joint
 Clarinet 508
 Cor Anglais 508
 Oboe 508
Upper lobe of lung 215, 254-255
Upper octave key 509
Upper rudder 416-417
Upper seed axle 152-153
Upper sheer strake 393
Upper topsail 385
Upper wireless and telegraphy yard 395
Upright man 108
Upright piano 514
Upright planks jump 554
Upright poles jump 554
Upsilon Sagittarii 21
Upstream gates 560
Uphrow 267
Urachus 57
Ural mountains
 Cretaceous period 73
 Earth's physical features 265
 Jurassic period 71
 Late Carboniferous period 67
 Triassic period 69
Uranium 310
Uranium fuel 514
Uranus/Tholus 43
Uranus 48-49
 Solar system 31
Ureter
 Bird 189
 Bony fish 181
 Domestic cat 195
 Elephant 200
 Frog 182
 Human 215, 256-259
 Lizard 185
 Rabbit 196
 Snail 177
Ureteric orifice 257
Urethra
 Chimpanzee 202
 Domestic cat 195
 Human 256-257, 259, 261
 Rabbit 196
 Urethral opening 259
Urethral sphincter muscle 257
Urinary bladder 181
Urinary system 256-257
Urinogenital opening
 Bony fish 181
 Dolphin 205
URL 577
Urn 478, 481, 487
Urodela 182
Uropod 172
Urostyle 183
Ursa Major 18, 19
Ursa Minor 18, 21
Ursus americanus 195
Ursus spelaeus 77, 106
U-shaped gouge 449
USB *see* Universal serial bus (USB)
USB ports 566
USB port 366, 586
USB programmer assembly 591
User name 576
U-shaped valley 286-287
Uterine wall 260-261
Uterus
 Chimpanzee 202
 Elephant 200
 Human 258-259
Utricle 243
U-tube 313
Utzon, J. 499
Uvula 212, 245, 248
V
V1 "flying bomb" 408
V12 cylinder arrangement 545
V4 engine unit
 British Rail Class 20 diesel 327
 Honda VF750 364
Vacuole
 Chlamydomonas sp. 116
 Diatom 116
 Human cell 216
 Palisade mesophyll 159
 Vacuum brake lever 325
 Vacuum circuit breaker 328
 Vacuum cleaner 592-593
 Vacuum operated inlet valve 362
 Vacuum pump cabinet 611
 Vacuum reservoir 324
 Vacuum valve 610
Vagina
 Chimpanzee 202
 Elephant 200
 Human 258-259, 261
 Snail 177
 Spider 170
Valance
 1906 Renault 337
 Ford Model T 339
 Volkswagen Beetle 341
Valency electrons 310
Vallate papillae 244
Vallular canal 120
Valles Marineris 43
Valley
 Coastline 294
 Glacier 286-287
 Grand Canyon 277
 Mountain 620
 River features 290
 River 288-289
 Rock cycle stages 267
 Valley floor erosion 267
 Valley head 289
 Valley rafter 473
 Valley spring 292
 Välmiki 35
Valve 359
 Valve chest 324
 Valve cusp 252
 Valve lifter 367
 Valve return spring 347
 Valve rocker 344, 402
 Valves
 Bivalves 176
 Dehiscent fruit 151
 Indehiscent fruit 150
 Scallop 176
 Valve slide 506, 507
 Valve spring 343, 344
 Valve system 506
 Vanadium 310
 Van Allen radiation belt 58
 Van de Graaff 41
 Van de Graaff generator 316
 Vane 191
 Van Eyck 35
 Vang 378
 Vanishing point 431

- Vapor barrier 605
Variable incidence air intake 420
Variable incidence gust-alleviator 421
Variable nozzle 416-417
Variable pitch aluminum-alloy blade 408
Variable pitch propeller 396
Variable time control knob 598-599
Variegated lamina 151, 137
Varnish 548, 456
Vasa recta 256
Vascular cambium 134-135
Vascular plants 279
Vascular plexus 255
Vascular strand 149
Vascular system 162-165
Vascular tissue 150
Aerial shoot 155
Apical meristem 134
Bishop pine 124
Canadian pond weed 159
Clubmoss stem 120
Corm 155
Dicotyledon 127
Dodder 163
Epiphytic orchid 162
Fern rachis 121
Higher plants 118-119
Horsetail stem 120
Marram grass 113
Monocotyledon 126-127
Parasite host 163
Perennials 130-131
Pine needle 124
Pine root/stem 125
Radicle 152
Rhizome 155
Root 132-135
Stem 134-135
Water hyacinth root 158
Water lily leaf 159
Woody plants 130-131
Vas deferens
Domestic cat 195
Human 259
Rabbit 196
Vastitas Borealis 43
Vastus lateralis muscle 225-226
Vastus medialis muscle 225-226
Vault 484-485, 496
Ancient Roman building 462-464
Baroque church 479
Gothic building 470
Medieval building 467-469
Modern building 496, 499
Nineteenth-century building 492-493
Renaissance building 477
Vaulting shaft 468-469
V-belt pulley 347
VCR connections 585
Vedette boat 395
Vega 19, 20
Our galaxy and nearby galaxies 15
Vegetable oil 436
Vegetative reproduction 154-155
Veil 114-115
Vein
Alveolar 247
Anterior median 253
Axillary 253
Basilic 253
Brachiocephalic 253
Bronchial 254
Cardiac 250
Central retinal 240
Cephalic 176, 253
Common iliac 215, 253, 257
Dicotyledon leaf 126-127
Digital 253
External iliac 215, 253
Femoral 253
Gastroepiploic 253
Great saphenous 253
Hepatic portal 253
Hogweed leaf 129
Inferior mesenteric 253
Inferior vena cava 215, 252-253, 257
Insect 168, 169
Interlobular 256
Internal iliac 255
Internal jugular 253
Jugular 215
Leaf 136, 158-159
Median cubital 255
Monocotyledon leaf 126
Palmar 255
Portal 252
Pulmonary 251, 255, 254
Pulp 247
Renal 256-257
Short saphenous 253
Subclavian 255
Superior mesenteric 255
Superior vena cava 215, 251, 252-253, 255
Suprarenal 257
Testicular 257
Tree mallow leaf 131
Umbilical 260
Water hyacinth leaf 158
Water lily leaf 159
Vela 18, 21
Velamen 162
Velarium 464
Velar scale 115
Vela Supernova Remnant 17
Vellum 432
Velocette overhead valve (OHV) engine 367
Velum 375
Vena cava
Frog 182
Inferior 215, 252-253, 257
Superior 215, 251, 252-253, 255
Vendelinus 40
Veneer 462
Venomous snake 184
Vent
Frigate 397
Igneous rock structures 275
Mountain building 62
Rock cycle 266
Suzuki RGV500 368
Volcano 272-273
Ventilation 462
Ventilator 422, 425
Ventilator exit 406-407
Ventral abdominal artery 175
Ventral antebrachial muscle 94
Ventral aorta 179
Ventral fin 179
Ventral margin of shell 176
Ventral nerve cord 169, 175
Ventral scale 184, 186
Ventricle
Brain 256-257
Heart 215, 250-251, 252
Ventricular diastole 251
Ventricular systole 251
Venturi 424
Venus 36-37
Solar system 50
Venus fly trap 160
Verdaccio 435
Verge 464, 492
Vermiculated rustication 482
Vermilion 453
Vermilion border of lip 215
Vermilion Cliffs 277
Versal lettering 445
Vertebra 261
Bony fish 180
Cervical 212, 222
Frog 183
Lumbar 222-223
Rattlesnake 185
Rudimentary 260
Thoracic 222-223
Turtle 187
Westlothiana 81
Vertebral artery 223, 252
Vertebral body 223
Vertebral column 218, 222, 257
Vertebral foramen 222-223
Vertebral shield 187
Vertebrates 56, 64, 104
Fossil record 279
Vertex
Building 495
Human body 212
Vertical air current 502
Vertical batten 602
Vertical cleavage 270
Vertical frame ladder 592
Vertical movement
Faults and folds 60
Lake formation 292
Vertical muffler 329
Vertical pupil 186
Vertical ridge 129
Vertical spindle 387
Vertical stroke 445
Vertical tailplane 572
Very high frequency (VHF) radio 318
Vesicle 148
Vespa Grand Sport 160
Mark 1 363
Vespa scooter 362, 363
Vessel
Baroque church 479
Gothic church 470
Medieval church 468-469
Vesta Rupes 37
Vestas A-47 wind turbine 604
Vestibular canal 243
Vestibular membrane 243
Vestibular nerve 243
Vestibule
Ancient Greek temple 461
Baroque church 481
Human body 212, 245
Medieval church 469
Neoclassical building 483
Vestibulocochlear nerve 243
VHF aerial
B-17 bomber 408-409
BAe-146 jetliner 415
Bell Jetranger helicopter 423
Concorde 416-417
VHF radio 318
VHF omni-range aerial
Bell-47 helicopter 422
Concorde, the 417
VHF omni-range and instrument-landing-system aerial 412
Vibraphone 504, 516, 517
Vibration-reducing fan mounting 597
Vibration-reducing muffler foot 58
Vibrations
Brass instruments 506
Stringed instruments 510
Vibrato arm 513
Vibrato effect 516, 517
Vibrissa
Lion 194
Rabbit 196
Rat 196
Seal 204
Vicia faba 133, 152
Video
Digital 582-583
Streamed internet 577
Video camera 610
Video input/output circuit board 585
Viewfinder 582
Viewing screen 610
Viewing window 581
Viewing window objective lens aperture 580
Viking ships 374-375
Villa Rotunda 475
Villa Savoye 494
Villi of mucosa 548
Viola 503, 504, 505, 510, 511
Violent eruptions 272
Violet light 518
Violin 503, 504, 505, 510
Violoncello 510-511
Virginia opossum 207
Virgo 18, 21
Virtual mixing board 521
Visceral cartilage 254
Visceral hump 177
Visceral pericardium 250
Viscous coupling 344-345
Visible and infrared spectrometers 614
Visible light 318-319
Vision 257
Visor 416-417
Visual recognition 237
Vitreous glass mosaic 451
Vitreous glass tessera 450, 451
Vitreous humor 240
Vitta 151
Vivaldi 35
Vocal cords 245
Voices 505
Volans 21
Volcanic activity
Mineralization zones 280
Rock cycle 266
Volcanic eruption 26
Volcanic gases 64
Volcanic island 58, 299
Volcanic lake 295
Volcanic lava
Jupiter 44
Mars 42
The Moon 40
Venus 36
Volcanic mountain 62
Volcanic rock 298, 306
Volcano 58, 63, 272-273
Jupiter 44
Locations 275
Mars 42
Mineralization zones 281
Mountain building 62-65
Ocean floor 298
Vent 62
Venus 36
Volkmann's canal 247
Volkman's vessel 225
Volkswagen Beetle 340-341
Volleyball 534-535
Voltage 306, 516
Voltage circuitry 597
Voltage reduction and regulation circuits 585
Voltage regulators 596
Voltage stabilizer 597
Voltage transformers 596
Volume 306, 507
Volume control
Electronic instruments 520, 521
Streamed internet radio 577
Home cinema 585
Nintendo Wii Fit Plus 579
Personal music 586-587
Volumes 625
Volume slider 577
Volute
Ancient Greek building 460-461
Baroque church 479, 481
Dome 486
Islamic building 488
Neoclassical building 478, 480
Renaissance building 476-477
Volva 114-115
Volvox sp. 116
Vomer 221
Von Kármán 41
Voussoir 484-485
Ancient Roman building 465
Neoclassical building 482
Renaissance building 474
V-shaped gouge 449
V-shaped valley
River features 290
Rivers 288-289
V-strut 404-405
VTEC engine 354
V-twin engine 362, 365
Vulpecula 19
Vulture 190
Vulva 200
Vyasa 35
Vyne 482
W
Wadi 283
Wagner 35
Wagon 324
Wagon bogie 330
Wagon vault 485
Wahweap sandstone 276
Waist
74-gun ship 580-581
Human 210
Stringed instruments 510-511
Waistband 548
Waist gun 508
Wale
74-gun ship 581
Roman corbita 373
Sailing warship 376-377
Walkway 497
Wall
Ancient Greek temple 461
Ancient Roman building 462, 465
Baroque church 478-479, 481
Carpel 148, 151
Cell 112, 117, 132, 139
Concrete 496
Fruit 148-151
Fungal tissue 115
Glass 496
Gothic church 470
Islamic building 488
Medieval building 466-467, 469
Modern building 498-499
Neoclassical building 479, 482
Nineteenth-century mill 492
Ovary 140, 150
Renaissance building 476-477
Twentieth-century building 494
Wall anchor 407
Wall construction 602
Wall panel 406-407
Wall painting 434
Walrus 204
Walter 40
Wand 592, 593
Wand handle and brushbar controls 592
Wand/handle connector 593
Wand telescopic link 593
Wankel, Felix 346
Wankel rotary engine 346-347
Wannanosaurus 101
Wardrobe 416
Wardroom 581
Warhead 594
Warm air 300, 302-303
Warm blood
Mammals 104
Theropods 84
Warm electronics box 615
Warm front 302-303
Warm occlusion 302
Warm periods 56
Warning horn 327, 329
Warning light 328, 356
Warship
74-gun ship 379, 380-381
Battleship 394-395
Frigate 396-397
Ironclad 392-393
Man-of-war 378-379, 379
Sailing warship 376-377
Submarine 396-397
Wasatch formation 276
Washable pre-motor filter 592
Wash cant 378
Washer-dryer 594-595
Wash over dry brush 439
Washburn 12-string guitar 153
Washer
Bicycle 358
Power drill 600-601
Toaster 598-599
Washer jet 355
Washes 438, 439
Washing machine 315
Wasp 168
Waste heat 314-315
Waste water anti-siphon pipe hook 595
Waste water pipe 595
Water 38, 66
Absorption 150
Amphibian 80
Changing states 307
"Deltic" diesel-electric locomotive 326
Energy generation 314-315
Epiphyte supply 162
Fermentation 313
Lithographic printing 446
Mars 42

- Molecule 138
Oceans and seas 296
Photosynthesis 138
Pollination 144
Reversible reactions 312
Seed germination 152-155
Solutions 306
Storage organs 156-157
Transport 134, 139
- Water and oil pump assembly 356
Waterborne sports 560-561
Water-closet 483
Watercolor 438-439
Watercolor paint pan 458
Watercolor paper 439, 441
Watercolor-style acrylic painting 442, 443
Water connection 342
Water-cooled engine 366
Water cycle 288
Water density 296
Water distribution 264
Water droplets 45
Waterfall 291
 Glacier 286
 River 289-290
 Rock cycle 267
Water fern 158
Water float 324
Water hardness
 adjustment and filter flap lever 595
Water hyacinth 158
Water ice
 Jupiter's atmosphere 45
 Mercury's atmosphere 47
 Structure of comet 53
 Structure of Mars 43
 Structure of Neptune 51
Water-ice fog 42
Water-ice permafrost 43
Water inlet connector 595
Water inlet hose 595
Water inlet pipe 595
Water inlet valves 595
Water jacket
 Daimler engine 343
 Ford diesel engine 347
 Humber engine 343
 Jaguar straight six engine 344
Water key 506, 507
Water lily 158-159
Waterline 580
Water obstacle 546
Water outlet 425
Water passage 346
Water pipe
 1906 Renault 337
 Humber engine 343
 Wright Flyer 399
Water pressurizer 314
Waterproof acrylic paint 442
Waterproof cable connector 605
Waterproof covering
 Bishop pine needles 124
 Golden barrel cactus 156
 Haworthia truncata 157
 Lithops bromfieldii 157
 Monocotyledon leaf 126
 Rush stem 135
 Wetland plants 158
Waterproof shell 80
Waterproof ski clothing 533
Waterproof skin 81
Waterproof storage box 427
- Water pump
 Hybrid car 354
 Jaguar V12 engine 345
 Renault Clio 351
 White Steam Car 342
Water pump pulley 347
Water rail 345
Water reactor 314
Water-retaining cuticle 78
Water salinity 296
Water-saturated permeable rock
 Lakes and groundwater 292
 Mineral resources 280-281
Watershed 289
Water shoot 560
Water softener dial 595
Water-soluble glue 450
Water storage tank 497
Water-storing parenchyma 156-157
Water supply
 Gun turret 396
 Steam locomotive 324
Water table
 Cave system 284
 Lake formation 292
Water tank
 Bordino Steam Carriage 334
 "Ellerman Lines" steam locomotive 324
 Steam iron 594
 White Steam Car 342
Water vapor
 Chemical reactions 312-313
 Hurricane structure 303
 Jupiter's atmosphere 45
 Mars' atmosphere 43
 Saturn's atmosphere 47
 Venus' atmosphere 37
 Water cycle 288
Water vascular system 174
Waterway 380, 393
Wattle-and-daub
 Ancient Roman building 462, 464-465
 Medieval house 466
Wave 294, 298
 Erosion 294
 Features 294
 Properties 318
Wave-cut platform 295
Waveguide 596, 597
Wavelength 318
Wavellite 269
Wavering pitch 516, 517
Wavy foliation 267
Wax modeling 452
Wax riser 454
Wax runner 454
Waxy cuticle 156, 157
Waxy fruit skin 149
Waxy laminae 159
Waxy zone 161
Weapon-bay bulkhead 421
Weaponry 375
Weasel 194
Weather 302-305
Weathercock 486
Weathering 282-283
 Gothic church 471-472
 Medieval church 469
 Mineral deposits 280
 Renaissance building 477
 Rock cycle 266
 Sedimentary rocks 276
Weather radar 416
Weather shutter for gun 394
Weather-vane 471, 477
Web
 Frog 182
 Internet 576
- Webbed feet 188, 190
Web browser 577
Web pages 577
Webcam 566
Website address 577
Weight
 Arch 484
 All-round bicycle 360
 Bolts 548
 Measurement 520, 590
 Motorcycle engine 366
 Newton meters 320
Weights 562
Wei-wei 376
Welding tool 608
Weld line 592
Welt 122-123
Welwitschia mirabilis 122-123
Werner motorcycle 362
Weslake Speedway motorcycle 369
West Africa 73
West Australian current 297
Westerlies 300
Westlothiana 67, 80-81
Westminster Abbey 484
Westminster Cathedral 495
Wet-in-wet wash 438, 439
Wetland plants 158-159
Wet season 295
Wet wash 438
Wezen 18
 Canis Major 21
Whaler 595
Whales 204-205
Wheat 109, 150
Wheel
 1906 Renault 337
 Alloy 356, 357
 Bicycle 358-359
 Diesel motor output 326
 First cars 354-355
 Force/motion 320
 Ford Model T 338-339
 Harley-Davidson FLHS Electra Glide 363
 Mars exploration rover (MER) 615
 Mazda RX-7 346
 Motorcycle 364
 Pacing sulky 555
 Paddle 390-391
 Renault Clio 350-351
 Rossini Italian time-trial bicycle 361
 Ship 378, 590, 594
 Single scull 561
 Volkswagen Beetle 340
 Weslake Speedway motorcycle 369
Wheel axle
 BAe-146 jetliner 414
 Touring bicycle 360
Wheelbase 360
Wheelchair access 533
Wheel fairs
 Blackburn monoplane 400
 Pegasus Quasar ultralight 427
 Pegasus XL SE ultralight 426
Wheel fork 335
Wheel guard 324, 369, 593
Wheel hub 414
Wheel nut 356, 357
Wheel sets 327, 329
Wheel sparer 561
Whelp 387
Whetstone 452
Whip 555
Whipping 384, 388
Whisker
 Lion 194
 Rabbit 196
 Rat 196
- Seal 204
Whisker boom 382
"Whispering Gallery" 484
Whistle
 Iron paddlesteamer 592
 Life jacket 561
 Referee 524
Whistle lever 525
White belt 556
White blood cells 217, 255
White Cliffs 276
White diamond 268
White dwarfs
 Small stars 24-25
 Stars 22-25
White fieldspar 275
White-gray crystal 271
White light 518
White matter
 Cerebrum 236-237
 Spinal cord 238
White of eye 215
White oval
 Jupiter 44-45
 Saturn 46
White spirit 436
White Steam Car 342
White stork 188
White warning light 528
White whale 204
Whorls
 Flower 140
 Green alga cell 116
 Sepals 144, 149
Wicket 538
Wicket-keeper 538
Wide-angle camera 614
Widened joint 282
Wide receiver 526
Wide-screen plasma display 584
Wiener 41
Wi-fi antenna 569, 579
Wi-fi board 579
Wii balance board 579
Wii hand controller 579
Willow grouse 193
Wind
 Atmosphere 300
 Ekman spiral 297
 Energy generation 514
 Oceans and seas 296-297
 Rock cycle 266-267
 Water cycle 288
 Weather 302
 Weathering and erosion 282-283
 Windspeed 303
Windcheetah SL Mark VI "Speedy" racing HPPV bicycle 561
Wind chest 514
Wind controller 521
Wind deflector 341
Wind-dispersed seeds 150-151
Wind erosion 282-283
 Coastline 294
Winding cornice 472
Wind instruments 508, 509
 Brass 506, 507
 Electronic 520
 Woodwind 508, 509
Windlass
 Buildings 467, 477
 Roman corbita 372
Windlass bar 380
Window
 Ancient Egyptian building 459
 Ancient Roman building 463, 465
 Asian building 490-491
 Baroque church 479-481
 Dome 486-487
 Dormer 495
- Double-decker tour bus 333
"Eurostar" multi-voltage electric train 329
Gothic building 470-475
MCW Metrobus 333
Medieval building 466-469
Modern building 498, 499
Neoclassical building 478, 482-483
Nineteenth-century building 492-493
Renaissance building 474, 476
Rococo style 482
Single-decker bus 333
TGV electric high-speed train 329
Twentieth-century building 494-495
Window blind 336, 572
Window controls 376, 577
Window frame 486
Window glass 348
Window jamb 479, 482, 485
Windowsill
 Baroque church 479
 Neoclassical building 482-485
 Twentieth-century building 494
Window shade button 577
Window stage 477
Wind-pollinated plants 144
Windshield
 Airbus 380 573
 BAe-146 jetliner components 412
 BE 2B bomber 404
 BMW R/60 sidecar 362
 Concorde, the 416-417
 "Deltic" diesel-electric locomotive 327
 Double-decker tour bus 333
 Ford Model T 339
 Harley-Davidson FLHS Honda Insight 354
 Electra Glide 363
 Hawker Tempest components 409
 Kirby BSA racing sidecar 362
 Lockheed Electra airliner 406-407
 Tornado 420
Windshield wiper
 "Deltic" diesel-electric locomotive 327
 "Eurostar" multi-voltage electric train 329
 Italian State Railroads Class 402 328
 MCW Metrobus 332
 Paris Metro 328
 TGV electric high-speed train 329
 "Union Pacific" locomotive 326
 Volkswagen Beetle 341
Windsor green 438
Windspeed 303
Wind synthesizer 521
Wind turbine 604, 605
Wind-up 337
Windvane 375, 605
Windward face 283
Wing
 1906 Renault 336
 Alula 191
 ARV light aircraft 424-425
 Australian rules football 528
 Avro biplane 403
- BAe-146 jetliner components 413, 414
BE 2B wings 404
Beetle 168
Biplanes and triplanes 402
Bird 188, 191
Blackburn monoplane 401
Bones 191
Bumblebee 168
Butterfly 169
Cobra lily 160
Coverts 188
Curtiss biplane 398
Deer hopper dry fly 563
Developing 192
Dry fruit 150-151
Early monoplanes 400
Feather 188, 191
Ford Model T 338
Formula One race car 357
Gliders, hang-gliders, and ultralights 426
Handball 535
Hawker Tempest components 409
Hockey 540
Ice hockey 550
Lockheed Electra airliner 406
Pine seed 122
Pitcher plant 113
Rugby 530
Scots pine seed 122
Showjumping fence 554
Ski boot safety binding 552
Spurious 191
Sycamore 131
Wing assembly 415
Wing attack 535, 541
Wing case 168
Wing defense
 Lacrosse 541
 Nethall 535
Winged seeds
 Scots pine 122
 Sycamore 131, 151
Winged stem 129
Wing end-plate 357
Wing-feather impression 85
Wing fillet panel 409
Wingframe 427
Wing landing gear 572, 573
Wing leading edge 573
Winglet 356
Wing mirror 554
Wing piping 341
Wing-protecting skid 398-399
Wing-root glove fairing 420-421
Wing-root mount 415
Wing scar 122
Wing stay 339
Wing strut
 ARV light aircraft 424-425
 Avro triplane 402-403
 Curtiss biplane 398
Wing supports 357
Wingtip
 ARV light aircraft 424
 BE 2B wings 404
 Hawker Tempest components 409
 Schleicher glider 426
Wingtip aerial fairing 421
Wing vein 168, 169
Wing warping 400
Wire armature 454, 455
Wire bristle brush 519
Wire coil 605

- Wire-ended cutting tool 454
- Wire-end tools 452
- Wire gauze pad 342
- Wireless and telegraphy yard 395
- Wireless office 397
- Wires 518
- Wire wheel 402
- Wiring loom 596
- Wishbone
- Bird 189
 - Formula One race car 357
- Withdrawal stride 543
- Withdrawing-room 483
- Withers 199
- Wolf 195
- Wolffian duct 179
- Wolf hair brush 444
- Wollastonite 271
- Womb 258-259
- Women's lacrosse field 540, 541
- Women's shot 542
- Wood
- Golf club 547
 - Sculpture 454
- Wood block 446, 449
- Wood capstan 387
- Woodcarving 452, 453
- Woodcut 446
- Wooden arrow 109
- Wooden artillery wheel 337
- Wooden bar 516
- Wooden boarding 602
- Wooden body 510
- Wooden body-shell 519
- Wooden buffer 324
- Wooden case 514, 515
- Wooden-domed deck 405
- Wooden driving wheel 324
- Wooden frame
- Harp 511
 - Printing mesh 446, 448
 - Sculpture 452
 - Steam-powered Cugnot "Fardier" 534
- Wooden golf clubs 546, 547
- Wood engraving 446, 447
- Wood engraving print 449
- Wooden grip 549
- Wooden hearth 109
- Wooden "key" 351
- Wooden packing 397
- Wooden panel 473
- Wooden sailing ship 378-379
- Wooden sleeper 324, 331
- Wooden spoke 334
- Wooden-spoked wheel 339
- Wooden stands 554
- Wooden wheel 334
- Woodwind instruments 504, 505, 508, 509
- Woodwork 467
- Woody flowering plants 126, 130-131
- Woody pericarps 150
- Woody plants 126
- Woody scales
- Bishop pine cone 124
 - Smooth cypress 123
- Woody stem 134-135
- Woofer loudspeaker connector 585
- Wooding 376
- Work 314
- Working chamber 396
- World War I aircraft 404-405
- World War II aircraft 408-409
- World Wide Web 576
- Worming 588
- Worms
- Earth's evolution 56
 - Fossil record 279
- Woven dacron 384
- Wrack 116-117
- Wren, C. 478
- Baroque church 480
 - Cathedral dome 484, 487
- Wrest plank
- Concert grand piano 515
- Upright piano 514
- Wright brothers
- Modern piston aero-engines 410
- Pioneers of flight 398-399
- Wright, F. L. 495
- Wright Flyer 398-399
- Wrist
- Corythosaurus* 98
 - Elephant 90
 - Human 211, 230-231
 - Iguanodon* 97
 - Stegosaurus* 92
 - Triceratops* 102
- Wrist joint
- Baryonyx* 85
 - Brachiosaurus* 91
 - Diplodocus* 90
 - Euoplocephalus* 94
 - Human 218
 - Parasaurolophus* 99
 - Plateosaurus* 88
 - Robot 608
 - Stegoceras* 100, 101
 - Tyrannosaurus* 84
- Wrist pin 390
- Wrist position 444
- Writing tools 444
- Wrought iron boiler 324
- Wrought iron rail 324
- Wuerhosaurus* 93
- Wulfenite 269
- X**
- Xerophytes 156-157
- Xi2 Sagittarii 21
- Xi Orionis 18
- Xi Pegasi 19
- X line 445
- X-ray 318-319
- Colon 214
 - Gallbladder 214
 - Hand 230
- X-ray emission 28
- X-ray image of Crab Nebula 28
- "X" turret 395
- Xylem
- Bishop pine 124
 - Clubmoss stem 120
 - Dicotyledons 126-127
 - Dodder host 165
 - Epiphytic orchid 162
 - Fern rachis 121
 - Higher plants 118-119
 - Horsetail stem 120
 - Marram grass 115
 - Monocotyledons 126-127
 - Pine needle 124
 - Pine root/stem 125
 - Radicle 152
 - Root 132
 - Stem 154-155
 - Water hyacinth root 158
 - Water lily leaf 159
- Xylem fibers 134-135
- Y**
- Yacht racing 560
- Yangchuanosaurus 85
- Yangtze River 265
- Yard 382
- Battleship 395
 - Double topsail schooner 585
 - Greek and Roman ships 372, 373
 - Steel 392
 - Tea clipper 392
 - Viking karv 375
- Yardang 282
- Yardarm 379
- Yardsman 526
- Yasti 490, 491
- Yaw control 605
- Yaw ring 605
- Year
- Earth 50
 - Jupiter 30
 - Mars 50
 - Mercury 26, 34
 - Neptune 31
 - Planets 50-51
 - Pluto 31
 - Saturn 31
 - Uranus 31
 - Venus 30
- Yeast
- Fermentation 313
 - Fungi 114
- Yellow card 524
- Yellow light 518, 531
- Yellow ochre 442
- Yellow orpiment 271
- Yellow River 265
- Yellow warning arm 350
- Yellow-wort 144
- Yew 125
- Y.M.C.A. 532
- Yolk 192
- Yolk sac 192
- Ytterbium 311
- Yttrium 310
- "Y" turret 395
- Yucca 126
- Yucca sp.* 126
- Z**
- Zagros Mountains 75
- Zaire 265
- Zap button 586
- Zea mays* 127
- Zeami 35
- Zebra 198
- Zeeman 41
- Zeilleria frenzlii* 66
- Zeppelin ipod speaker dock 586
- Zeta Centauri 21
- Zeta Sagittarii 21
- Zeugen 282
- Ziggurat-style step-back 494
- Zinc 281, 312
- Zinc phosphating 548
- Zinc plating 477
- Zingiber officinale* 155
- Zion Canyon 276
- Zirconium 310
- Zona pellucida 606, 607
- Zone
- Jupiter 44-45
 - Structure of Saturn 47
- Zone defenses 533
- Zonular ligament 241
- Zoom keys 590
- Zoomorphic head 574
- Zosteres 372
- Zosterophyllum ilanoveranum* 64
- Zubenelegubi 18, 21
- Zubeneschamali 18, 21
- Zugon 373
- Zybian 373
- Zygomatich arch
- Bear 194
 - Chimpanzee 202
 - Human 215, 220
 - Lion 194
 - Smilodon* 106
 - Toxodon* 107
- Zygomatich bone 220-221
- Zygomatichus major muscle 228-229
- Zygote
- Bryophyte 118-119
 - Fertilization 146-147
 - Plant formation 146
 - Primitive land plants 120
 - Seaweed 116-117

Acknowledgments

**Dorling Kindersley would like to thank
(in order of sections):**

**The Universe
(consultant editors—Sue Becklake,
Gevorkyan Tatyana Alekseyevna):**

John Becklake; the Memorial Museum of Cosmonautics, Moscow; The Cosmos Pavilion, Moscow; The United States Space and Rocket Centre, Alabama; Broadhurst, Clarkson and Fuller Ltd.; Susannah Massey

**Prehistoric Earth
(consultant editors—William Lindsay, Martyn Bramwell, Dr. Ralph E. Molnar, David Lambert):**

Dr. Monty Reid, Andrew Neuman, and the staff of the Royal Tyrrell Museum of Palaeontology, Drumheller, Alberta; Dr. Angela Milner and the staff of the Department of Palaeontology, the Natural History Museum, London; Professor W. Ziegler and the staff, in particular Michael Loderstaedt, of the Naturmuseum Senckenburg, Frankfurt; Dr. Alexander Liebau, Axel Hünghreßbüller, Reiner Schoch, and the staff of the Institut und Museum für Geologie und Paläontologie der Universität, Tübingen; Rupert Wild of the Institut für Paläontologie, Staatliches Museum für Naturkunde, Stuttgart; Dr. Scheiber of the Stadtmuseum, Nördlingen; Professor Dr. Dietrich Herm of Staatssammlung für Paläontologie und Historische Geologie, München; Dr. Michael Keith-Lucas of the Department of Botany, University of Reading; Richard Walker; American Museum of Natural History, New York

**Plants
(consultant editor—Richard Walker):**

Diana Miller; Lawrie Springate; Karen Sidwell; Chris Thody; Michelle End; Susan Barnes and Chris Jones of the EMU Unit of the Natural History Museum, London; Jenny Evans of Kew Gardens, London; Kate Biggs of the Royal Horticultural Society Gardens, Wisley, Surrey; Spike Walker of Microworld Services; Neil Fletcher; John Bryant of Bedgebury Pinetum, Kent; Dean Franklin

**Animals
(consultant editor—Richard Walker):**

David Manning's Animal Ark; Intellectual Animals; Howletts Zoo, Canterbury; John Dunlop; Alexander O'Donnell; Sue Evans of the Royal Veterinary College, London; Dr. Geoff Potts and Fred Frettsome of the Marine Biological Association of the United Kingdom, Plymouth; Jeremy Adams of the Booth Museum of Natural History, Brighton; Derek Telling of the Department of Anatomy, University of Bristol; the Natural History Museum, London; Andy Highfield of the Tortoise Trust; Brian Harris of the Aquarium, London Zoo; the Invertebrate Department, London Zoo; Dr. Harold McClure of the Yerkes Regional Primate Research Center, Emory University, Atlanta, Georgia; Nielson Lausen of the Harvard Medical School, New England Regional Primates Research

Centre, Southborough, Massachusetts; Dr. Paul Hopwood of the Department of Veterinary Anatomy, University of Sydney; Dean Franklin

**The Human Body
(consultant editors—Dr. Frances Williams,
Dr. Fiona Payne, Richard Cummins FRCS):**
Derek Edwards and Dr. Martin Collins, British School of Osteopathy; Dr. M.C.E. Hutchinson of the Department of Anatomy, United Medical and Dental Schools of Guy's and St. Thomas' Hospitals, London. Models—Barry O'Rorke (Bodyline Agency) and Pauline Swaine (MOT Model Agency)

**Geology, Geography, and Meteorology
(consultant editor—Martyn Bramwell):**
Dr. John Nudds of the Manchester Museum, Manchester; Dr. Alan Wooley and Dr. Andrew Clark of the Natural History Museum, London; Graham Bartlett of the National Meteorological Library and Archive, Bracknell; Tony Drake of BP Exploration, Uxbridge; Jane Davies of the Royal Society of Chemistry, Cambridge; Dr. Tony Waltham of Nottingham Trent University, Nottingham; staff of the Smithsonian Institute, Washington; staff of the United States Geological Survey, Washington; staff of the National Geographic Society, Washington; staff of Edward Lawrence Associates (Export Ltd.), Midhurst; John Farndon; David Lambert

**Rail and Road
Rail (consultant editor—John Coiley)**
Michael Ashworth of the London Transport Museum

**Road (consultant editors—David Burgess-Wise,
Hugo Wilson)**
The National Motor Museum, Beaulieu; Alf Newell of Renault UK Ltd.; David Suter of Cheltenham Cutaway Exhibits Ltd.; Francesca Riccini of the Science Museum, London. Signore Amadelli of the Museo dell'Automobile Carlo Biscaretti di Ruffia; Paul Bolton of the Mazda MCL Group; Duncan Bradford of Reg Mills Wire Wheels; John and Leslie Brewster of Autocavan; David Burgess-Wise; Trevor Cass of Garrett Turbo Service; John Corbett of The Patrick Collection; Gary Crumpler of Williams Grand Prix Engineering Ltd.; Mollie Easterbrooke and Duncan Gough of Overland Ltd.; Arthur Fairley of the Vauxhall Motor Company; Paul Foulkes-Halbard of Filching Manor Motor Museum; Frank Gilbert of I. Wilkinson and Son Ltd.; Paolo Gratton of Gratton Museum; Colvin Gunn of Gunn and Son; Judy Hogg of Ecurie Bertelli; Milton Holman of Dream Cars; Ian Matthews of IMAT Electronics; Eric Neal of Jaguar Cars Ltd.; Paul Niblett, Keith Davidson, Mark Reumel, and David Woolf of Michelin Tyre plc; Doug Nye; Kevin O'Keefe of O'Keefe Cars; Seat UK; Ian Whitley, Raj Johal and Andy Faiers of the Honda Institute; Roger Smith; Jim Stirling of Ironbridge Gorge Museum, Staffordshire; Jon Taylor; Doug Thompson; Martyn Watkins of Ford Motor Company Ltd.; John Cattermole, Customer Services Manager at London Northern Buses; F. W. Evans Cycles Ltd.; Trek UK Ltd. (Bicycle); Sam Grimmer; Colin Uttley

**Physics and Chemistry
(consultant editor—Jack Challoner)**

**Sea and Air
Sea (consultant editors—Geoff Hales and
Harvey B. Loomis):**
David Spence, Gillian Hutchinson, David Topliss, Simon Stephens, Robert Baldwin, Jonathan Betts, all of the National Maritime Museum, London; Ian Friel; Simon Turnage of Captain O.M. Watts of London Ltd.; Davey and Company Ltd., Great Dunmow; Avon Inflatables Ltd., Llanelli; Musto Ltd., Benfleet; Peter Martin of Spencer Rigging Ltd., Southampton; Peter Rowson of Ratseys Sailmakers, Southampton; Swiftech Ltd., Wallingford; Colin Scattergood of the Barrow Boat Company Ltd., Colchester; Professor J.S. Morrison of the Trireme Trust, Cambridge; The Cutty Sark Maritime Trust; Adrian Daniels of Kelvin Hughes Marine Instruments, London; Arthur Credland of Hull City Council Museums and Art Galleries; The Hull Maritime Society; Gerald Clark; Peter Fitzgerald of the Science Museum, London; Alec Michael of HMB Subwork Ltd., Great Yarmouth, and Ray Ward of the OSEL Group, Great Yarmouth; Richard Bird of UWI, Weybridge; Walker Marine Instruments, Birmingham; The International Sailing Craft Association; The Exeter Maritime Museum; Jane Wilson of the Trinity Lighthouse Company, London; The Imperial War Museum Collections; Thorn Security Ltd.; Michael Bach

Air (consultant editor—Bill Gunston):
Aeromega Helicopters, Stapleford; Aero Shopping, London; Avionics Mobile Services Ltd., Watford; Roy Barber and John Chapman of the RAF Museum, Hendon; Mitch Barnes Aviation, London; Mike Beach; British Caledonian Flight Training Ltd.; Fred Coates of Helitech (Luton) Ltd.; Michael Cuttall and CSE Aviation Ltd., Oxford; Dowty Aerospace Landing Gear, Gloucester; Guy Hartcup of the Airship Association; Anthony Hooley, Chris Walsh, and David Cord of British Aerospace Regional Aircraft Ltd.; Ken Huntley of Mid-West Aero Engines Ltd.; Imperial War Museum, Duxford; The London Gliding Club, Dunstable; Musée des Ballons, Calvados; Noel Penny Turbines Ltd.; Andy Pavey of Aviation Scotland Ltd.; Tony Pavey of Thermal Aircraft Developments, London; the Commanding Officer and personnel of RAF St Athan; the Commanding Officer and personnel of RAF Wittering; The Science Museum, London; Ross Sharp of the Science Museum, Wroughton; The Shuttleworth Collection; Skysport Engineering; Mike Smith; Solar Wings Ltd., Marlborough; Julian Temple of Brooklands Museum Trust Ltd.; Kelvin Wilson of Flying Start

**Architecture
(consultant editor—Alexandra Kennedy):**
Stephen Cutler for advice and text; Gavin Morgan of the Museum of London, London; Chris Zeumer of the Weald and Downland Museum, Singleton, Sussex; Alan Hills and James Putnam of the British Museum, London; Dr. Simon Penn and Michael Thomas of the Avoncroft Museum of Buildings, Bromsgrove,

Worcestershire; Christina Scull of Sir John Soane's Museum, London; Paul Kennedy and John Williamson of the London Door Company, London; Lou Davis of The Original Box Sash Window Company, Windsor; Goddard and Gibbs Studios Ltd., London, for access to stained glass windows; The Royal Courts of Justice, Strand, London; Charles Brooking and Peter Dalton for access to the doors and windows in the Charles Brooking Collection, University of Greenwich, Dartford, Kent; Clare O'Brien of the Shakespeare Globe Trust, Shakespeare's Globe Museum, Bear Gardens, Southwark, London; Ken Teague of the Horniman Museum, London; Canon Haliburton, Mike Payton, Ken Stones, and Anthony Webb of St Paul's Cathedral, London; Roy Spring of Salisbury Cathedral; Reverend Gillean Craig of the Church of St George in the East, London; the Science Museum, London; Dr. Neil Bingham; Lin Kennedy of Historic Royal Palaces; Katy Harris of Sir Norman Foster and Partners; Production Design, Thames Television plc, London; Dominique Reynier of Le Centre Georges Pompidou, Paris; Denis Roche of Le Musée National des Monuments Français, Paris; Franck Gioria and students of Les Compagnons du Devoir, Paris, for access to construction models; Frank Folliot of Le Musée Carnavalet, Paris; Dr. Martina Harms of Hessische Landesmuseums, Darmstadt; Jefferson Chapman of the University of Tennessee, Knoxville, for access to the model of the Hypostyle Hall, Temple of Amon-Re; staff of the Palazzo Strozzi, Florence; staff of the Sydney Opera House, Sydney; staff of the Empire State Building, New York; Nick Jackson; Ann Terrell

The Visual Arts

(consultant editor—Pip Seymour):

Rosemary Simmons; Michael Taylor of Paupers Press, London; Tessa Hunkin and Emma Biggs of Mosaic Workshop, London; John Tiranti, Jonathan Lyons of Alec Tiranti Ltd., London; Chris Hough; Dr. Ashok Roy; Satwinder Sehmi of Alphabet Soup, London; Phillip Poole of Cornelissens, London; George Weil and Sons Ltd., London; The National Gallery, London; Chris Webster of the Tate Gallery, London; China Art Cultural Centre, London; London Graphic Centre, London; A.P. Fitzpatrick, London; Flowers Graphics, London; Intaglio Printmaker, London; Falkiner Papers, London; Edgar Udny and Co., London; John Green

Music

(consultant editor—Susan Sturrock):

Boosey and Hawkes Music Publishers Ltd., London, for permission to reproduce extract from The Prodigal Son by Arthur Sullivan; The Bass and Drum Cellar, London; Empire Drums and Percussion, London; Argents (part of World of Music), London; Bill Lewington Ltd., London; Frobenius organ at Kingston Parish Church, Surrey; Yamaha-Kemble Music (UK) Ltd., Tilbrook, Milton Keynes; Yamaha Atelier, London; Akai (UK) Ltd., Hounslow, Middlesex; Casio Electronics Co. Ltd., London; Roland (UK) Ltd., Fleet, Hampshire; Richard Schulman; Andy Brown of Musictrack

Sports

The Sports Council Information Centre, London; The British Olympic Games Committee; Brian Crennell of Black's Leisure Group (First Sport); Lillywhites of Piccadilly, London; Mitre Sports International Ltd., Huddersfield; David Bloomfield of the Football Association; Denver Athletics Ltd., Norfolk; Greg Everest and Keith Birley of the British League of Australian Rules Football; Peter McNally of the Gaelic Athletic Association; Jeremy Garman of James Gilbert Ltd.; Rex King of the Rugby Football Union, Twickenham; Neil Tunnicliffe and John Huxley of the Rugby Football League, Leeds; Wayne Patterson of the Basketball Hall of Fame, Springfield, Connecticut; Brian Coleman of the English Basketball Association; All American Imports, Northampton; George Bulman of the English Volleyball Association; Julie Longdon of Mizuno Mallory (UK) Ltd.; Juliet Stanford of the All-England Netball Association; Jeff Rowland of the British Handball Association; Cally Melin of Adidas UK Ltd.; Patrick Donnely of the Baseball Hall of Fame, Cooperstown, New York; Ian Lepage and Stephen Barlow of the Hockey Association, Milton Keynes; Alison Taylor and Anita Mason of the All England Women's Lacrosse Association, Birmingham; David Shuttleworth of the English Lacrosse Union; Les Barnett and Jock Bentley of the British Athletic Federation Ltd., Birmingham; Mike Gilks of the Badminton Association of England; Gurinder Purewall for advice on archery; Chris McCartney of the US Archery Association; Geoff Doe of the National Smallbore Rifle Association, Bisley, Surrey, for information and reference material on shooting; Fagan Sports Goods Distributors, Surrey; Konrad Bartelski for advice on skiing; The British Ski Federation, Edinburgh; Mike Barnett of Snow and Rock of London; Sally Spurway of Mast-Co. Ltd., Reading; Sarah Morgan for advice on equestrian sports; Steve Brown and the New York Racing Association Inc, New York; Danrho of London; Alan Skipp and James Chambers of the Amateur Fencing Association, London; Carla Richards of the US Fencing Association; Hamilton Bland and John Dryer of the Amateur Swimming Association, Loughborough; Cotswold Camping Ltd., London; Tim Spalton of Glyn Locke (Racing Shells) Ltd., Chalgrove; Terry Friel of the US Rowing Association; House of Hardy; Leeda Fishing Tackle

The Modern World

John Lewis, Brent Cross, for the loan of products for photography; Apple Computers UK; Palm Inc.; Epson UK; Naynesh Mistry of Brother UK; Nintendo; Sony UK; Nokia Mobile Phones Ltd.; Sony Ericsson; Tony Broad of Garmin Europe; Dualit Ltd.; Black and Decker Ltd.; James Honour of the Buildings Research Establishment; Craig Anders of Cole Thompson Associates; Vestas Wind Systems; Bryan Adams of MIT; Dr. Julian Heath of *Microscopy and Analysis*; Fei UK Ltd.; Steve Parker; Ian Graham

PHOTOGRAPHY:

M. Alexander; Peter Anderson; Colin Bowling; Charles Brooks; Jane Burton; Peter Chadwick; Simon Clay; Gordon Clayton; John Cooley; Andy Crawford; Geoff Dann; Philip Dowell; John Downs; Mike Dunning; Torla Evans; David Exton; Paul Forrester; Robert and Anthony Fretwell of Fretwell Photography Ltd.; Philip Gatward; Steve Gorton; Anna Hodgson; Gary Kevin; J. Heseltine; Cyril Laubscher; John Lepine; Lynton Gardiner (American Museum of Natural History, New York); Steve Gorton; Michelangelo Gratton; Judith Harrington; Peter Hayman; Anna Hodgson; Colin Keates; Gary Kevin; Dave King; Bob Langrish; Brian D.Morgan; Nick Nicholls; Nick Parfitt; Tim Parmenter and Colin Keates (Natural History Museum, London); Tim Ridley; Dave Rudkin; Philippe Sebert; James Stevenson; Clive Streeter; Harry Taylor; Matthew Ward; Jerry Young

PHOTOGRAPHIC ASSISTANCE:

Kevin Zak; Gary Ombler; Govind Mittal

ILLUSTRATORS:

Julian Baum; Rick Blakeley; Kuo Rang Chen; Karen Cochrane; Simone End; Ian Fleming; Roy Flooks; Mark Franklin; David Gardner; Will Giles; Mick Gillah; David Hopkins; Selwyn Hutchinson; Mei Lim; Linden Artists; Nick Loates; Chris Lyon; Kathleen McDougall; Coral Mula; Sandra Pond; Dave Pugh; Colin Rose; Graham Rosewarne; John Temperton; Halli Verrinder; John Woodcock; Chris Woolmer

MODEL MAKERS:

Roby Braun; David Donkin; Morrison Frederick; Gordon Models; John Holmes; Graham High and Jeremy Hunt of Centaur Studios; Richard Kemp; Kelvin Thatcher; Paul Wilkinson

ADDITIONAL DESIGN ASSISTANCE:

Stefan Morris; Ulysses Santos; Suchada Smith; Niyati Gosain; Jomin Johnny; Ridhi Khanna; Amit Malhotra; Payal Rosalind Malik; Anamica Roy; Ira Sharma; Balwant Singh

ADDITIONAL EDITORIAL ASSISTANCE:

Helen Castle; Colette Connolly; Camela Decaire; Nick Harris; Andrea Horth; Stewart McEwen; Damien Moore; Melanie Tham; Pragati Nagpal; Suparna Sengupta; Anita Kakar; Divya Chandhok

INDEX: Kay Wright; Lynn Bresler

Picture credits:

The publisher would like to thank the following for their kind permission to reproduce their photographs:

2011 Research In Motion Limited 589tr; Action Plus 550tc; Alamy images David Kilpatrick 581tr, 581cra; Nikreates 586ca; NordicImages 591tr; Oleksiy Maksymenko Photography 568cra; Arthur Turner 579cla; Martin Williams 569bl; Anglo Australian Telescope Board 11cl, 11cra, 11cbl, 12tr, 12bc, 13tl, 13bl, 14tl, 16b, 17tc, 17bl, 22tl/D.Malin 16tl, 26tr, 27tl; Austin Brown and the Aviation Picture Library 426tl; Baptistery, Florence/Alison Harris 453r; Biophoto Associates 217ca, 217cra, 228cbc, 228cbc 250tr; BRE Imaging 602bl, 602r, 603tr, 603br; Paul Brierley 311bra; Bowers & Wilkins: B&W Group Ltd 586b; British Aerospace/Anthony Hooley 412tl, 415tl; British Aerospace (Commercial Aircraft) Ltd 416tl; By permission of the British Library 432tl, 445bl; British Museum 459tl, 459tr, 460tr, 460tc, 460tb, 489b; BP Exploration 299; Duncan Brown 25tl; Frank Lloyd Wright, American, 1867-1959, Model of Midway Gardens, 1914, executed by Richard Tickner, mixed media, 1987, 41.9 x 81.3 x 76.2, 1989.48 view 1. Photography courtesy of the Art Institute of Chicago 495t; J.A. Cooley 331cr; Bruce Coleman Ltd/Andy Price 272tl; Canon Europe 581cbr; Corbis Jon Stokes/Science Photo Library 576cl; Wu Ching-teng/Xinhua Press 568br; Haruyoshi Yamaguchi/Sygmna 608r; Courtesy of the Board of Trustees of the Victoria and Albert Museum, London 454-455b; Creative Labs, Inc. 586tc; Dorling Kindersley Owen Peyton Jones 566cr, 582-583, 589; Dyson 592tr; European Passenger Services 329tl; ESA /PLV 11bl; European Southern Observatory (ESO) 53tl; Fei Co. 610tc, 610r; French Railways 329c; FUJIFILM UK 581br; Garmin Europe 590c; Geoscience Features 311cla; Robert Harding Picture Library 62tl; Getty Images Bloomberg 569bc, 569br; Tony Cordoza 584tr; Hannah Johnston 588ca; Photodisc/Ryan McVay 577tl; Harman International Industries, Incorporated JBL 586cl; Hitachi High-Technologies Co. Ltd 611tr; Michael Holford/British Museum 372bl, Michael Holford 374tr; Honda 354tr, 355b; Hutchison Picture Library 60cl; iFixit Miroslav Djuric 580-581 (Nikon Coolpix S1000PJ), 587 (Components of Microsoft Zune HD); Brett Hartt 578cra; The Image Bank/Edward Bower

306tr; Jet Propulsion Laboratory 11cbr; 30bc; 31bc; 31cbr; 38tl; 42cbr; 44cb; 44cbr; 44bc; 46tl; 46cr; 46cb; 46bc; 46br; 50tl; 50cra; 50cl; 50c; 50cr; 50br; Kawasaki (UK) 609bl; KeyMed Ltd 248bl, 249bl, 249bcl; Department of Prints and Drawings, Uffizi, Florence/Philip Gatward 431tc/Uffizi, Florence/Philip Gatward 433tl; Robin Kerrod/Spacecharts 615br; Dr. D.N. Landon (Institute of Neurology) 228bl,br; LG Electronics 588cr; Life Science Images/Ron Boardman 244bl, 244br; The Lund Observatory 15bc; Brian Morrison 329tl, 329tr; © The Henry Moore Foundation 455tr; Used with permission from Microsoft 578tr, 587br; Musée d'Orsay, Paris/Philippe Sebert 437tc, 441tc; Musée du Louvre, Paris/Philippe Sebert 453tl, 453l, 453br; Musictrack/MOTU Digital performer 521bcl; NASA/AUI 13tr; NASA and The Hubble Heritage Team (AURA/STScI) 44tl; NASA Dr. R. Albrecht, ESA/ESO Space Telescope European Coordinating Facility 31fbr; CXC/ASU/J. Hester et al 28cra; JPL/DLR 44br; JPL JHUAPL 42br; JPL-Caltech/University of Arizona 42fbr; NASA/JPL 11 cbr, 11br, 30tl, 30bl, 30br, 30bc, 31bc, 31br, 31bl, 34cr, 38tl, 40tl, 40cr, 42cr, 44cb, 44cbr, 44bc, 44cr, 46cbr, 46tl, 46cr, 46cb, 46bc, 46br, 48tl, 48cra, 48bca, 48bc, 48br, 50tl, 50bc, 50bc, 50cbr, 50br, 50cr, 52cr, 612cr, 612tr; 613tl, 613cl, 613tr, 613cr, 613c, 614tl, 614tr 614cl, 614bl, 614c, 615tr, 615cr, 615c; National Maritime Museum 373br, 392-393b; National Medical Slide Bank 217cr; Nature Photographers/Paul Sterry 286tl; Newage International 317bl; Nintendo 578tl, 578clb, 579tl, 579tr, 579cra; Olympus 610cl, 61 obi; Oxford Scientific Films/Breck P. Kent 166tl; Planet Earth 274tr; Press Association Images AP 609cr; Quadrant 326tr; Margaret Robinson 352tl; Giotto The Expulsion of the Merchants from the Temple Scala 435tc, 435bl, 435br; RapidRepair.com Ben Levy 569ca (iPad Components); Rex Features Jonathan Hordle 609br; Roland UK 521tl; Science Photo Library 10bl, 13tr, 214cbr, 214bl, 256tr/Michael Abbey 225tc/Agema Infrared Systems 318tl/AGFA 220tl/Alex Barte 605tr/David Becker 607cr/Biophoto Associates: 217cbr/Dr. Jeremy Burgess/ Science Photo Library 132tr; Dr. Jeremy Burgess 255bcl/CNRI 214tl, 214cl, 214c, 214cr, 214bl, 214clb, 214cbr, 214bcl, 214br, 217cb, 235bcr, 238tl, 249cbr, 253tr, 253cra, 256tl; Science Photo Library /Earth Satellite Corporation 288cl, 293br/Dr. Brian Eyden 228cbr/Professor C. Ferlaud 245bl/Vaughan Fleming 311tl/Simon Fraser/U.S. Dept.of Energy 214bcl,

266tl/Eric Grave 217br/Hale Observatories 32br/Max Planck Institute for Radio Astronomy 15tl/Jan Hinsch 225tc/Jodrell Bank 11tr, 15c /Manfred Kage 217c, 235br, 237br/Dr. William C. Keel 13br/Keith Kent 564c/James King-Holmes 316tl, 606bl/Russ Lappa 310bra/John Mead 605br/Astrid & Hans-Freider Michler 217tr /Dennis Milon 52bl/NASA 11cla, 12tl, 15r, 30c, 32tl, 35tl, 36tl, 36cl, 36cr, 36bc, 42tr, 52tl, 291tr, 300tl/National Optical Astro Observatory 52tr/NIBSC 253cbr/Omikron 244bc/David Parker 63bl, 304-305, 308br/Alfred Pasiaka 606cr/Philippe Plailly 308tl/Quest 611br/Roussel-UCLAF/CNRI 217tc/Rev Ronald Royer 52cr/Royal Observatory, Edinburgh/D Malin 11tl, 11cr,12c, 16cl, 16cr, 17br/David Scharf 235bl/Dr. Kaus Schiller 248cl, 248cbr, 248br/Secchi-Lecaque/Koussel-UCLAF/CNRI 253br/H. Sochurek 214cb/Stammers/Thompson 230tl/Sheila Terry 234tl/US Department of Energy 310bc/US Geological Survey/Science Photo Library 8-9, 30br, 42tl, 42bl/Tom Van Sant/Geosphere Project, Santa Monica/Science Photo Library 273tr, 281tr, 296tr, 297tl/Dr. Christopher B. Williams/(Saint Marks Hospital) 249br; Oxford Scientific Films/Animals/ Breck P. Kent 167tl; Pratt & Whitney Canada 418-419b, 419t; Science Museum 306bl, 306bcl; 306 bcr, 324t, 326-327b), 330tr, 331ct, 331 cb; Sony Corporation 586tr, 586cr; Sporting Pictures 524tl, 544cr; TechRepublic Bill Detwiler 578-579b; Tony Stone Worldwide 280tl; David Bomberg St Pauls and River 1945/Dinora Davies-Rees/Tate Gallery 431bc; David Hockney A Bigger Splash 1967/ © David Hockney/Tate Gallery 443tc; J.M.W. Turner The Burning of the Houses of Parliament Tate Gallery 439tc; Vision 26tr, 27c; Jerry Young 306tl; Dr. Robert Youngson 241cr; courtesy of Vestas Wind Systems 604t; Zefa 217bc/Janicek 276tl/H. Sochurek 210tl, 250tl, 254tl/G. Steenmans 292tl

(t=top, b=below/bottom, a=above, l-left, r=right, c=center, f=far)

All other images © Dorling Kindersley
For further information see: www.dkimages.com

Every effort has been made to trace the copyright holders. Dorling Kindersley apologizes for any unintentional omissions and would be pleased, in any such cases, to add an acknowledgment in future editions.

Some pages in this book previously appeared in the Visual Dictionary series published by Dorling Kindersley. Contributors to this series include:

Project Art Editors: Duncan Brown, Ross George, Nicola Liddiard, Andrew Nash, Clare Shedden, Bryn Walls

Designers: Lesley Betts, Paul Calver, Simone End, Ellen Woodward

Additional design assistance: Sandra Archer, Christina Betts, Alexandra Brown, Nick Jackson, Susan Knight

Project Editors: Fiona Courtney-Thompson, Paul Docherty, Tim Fraser, Stephanie Jackson, Mary Lindsay

Editorial Assistant: Emily Hill

Additional editorial assistance: Susan Bosanko, Edward Bunting, Candace Burch, Deirdre Clark, Jeanette Cossar, Danièle Guitton, Jacqui Hand, David Harding, Nicholas Jackson, Edwina Johnson, David Lambert, Gail Lawther, David Learmount, Paul Jackson, Christine Murdock, Bob Ogden, Cathy Rubinstein, Louise Tucker, Dr. Robert Youngson

Picture Researchers: Vere Dodds, Danièle Guitton, Anna Lord, Catherine O'Rourke, Christine Rista, Sandra Schneider, Vanessa Smith, Clive Webster

Series Editor: Martyn Page

Series Art Editor: Paul Wilkinson

Managing Art Editors: Philip Gilderdale, Steve Knowlden

Art Director: Chez Pichthal

Managing Editor: Ruth Midgley

Production: Jayne Simpson