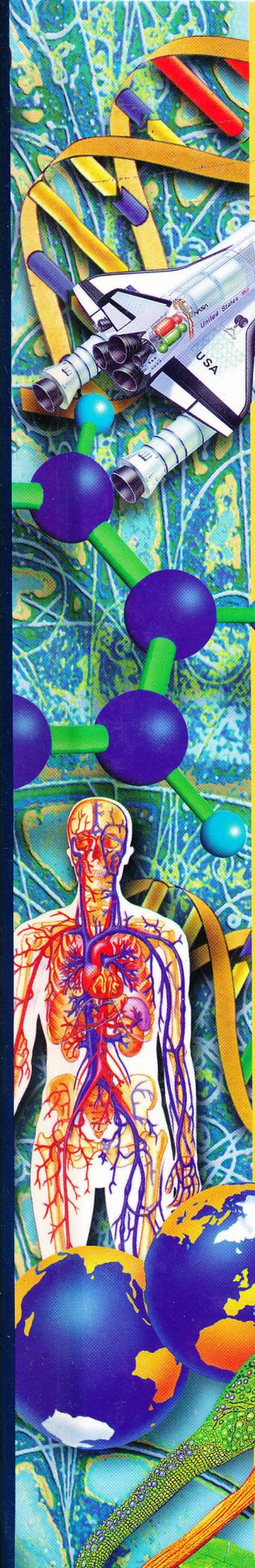


Raintree Steck-Vaughn

*Illustrated*  
**SCIENCE  
ENCYCLOPEDIA**



Volume  
19



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Volume

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**SICKLE CELL ANEMIA** (sĭk'əl sĕl ə nĕ' mĕ ə) Sickle cell anemia is a genetic (inherited) disease that affects the red blood cells (see BLOOD). A person with sickle cell anemia produces an abnormal type of hemoglobin called HbS. Hemoglobin is the oxygen-carrying chemical in the red blood cells (see HEMOGLOBIN). This abnormal hemoglobin causes the red blood cells to take on a sickle shape, like a crescent, rather than the normal round shape. That is why the disease is called sickle cell anemia.

Sickle cell anemia is caused by recessive genes. Therefore, the disease affects only people who are homozygous, or pure, for the HbS trait (see GENE; HEREDITY). This means that both parents must pass on the recessive gene to their child. In order to do this, both parents must either be carriers of the sickle cell trait or have sickle cell anemia themselves. Usually, a carrier has one gene for HbS and one gene for HbA, which is normal hemoglobin.

Sickle cell anemia mainly affects African-Americans. An affected person may show no symptoms until the onset of a sickle cell crisis. A sickle cell crisis is brought on by a deficiency, or lack, of oxygen. This deficiency may be caused by intense exercise, emotional upset, or other factors. In a crisis, the HbS forms bundles inside the red blood cells. This causes the cells to become hardened and stretched into a sickle shape. In this condition, the red blood cells get stuck in the body's capillaries (tiny blood vessels), and cause great pain. Frequently, the red blood cells even break apart. A person who has had several crises may be anemic because so many of his or her red blood cells have been destroyed (see ANEMIA). In addition, he or she may have organ damage caused by blocked circulation. A person in crisis can be treated with high-pressure oxygen and with drugs to relieve the pain. A severe crisis, however, may cause death.

Carriers of the sickle cell trait are more resistant to malaria than are people with normal hemoglobin (see MALARIA). For this reason, the number of carriers is greatest in areas of the world where malaria affects many people. One such area is in

Africa, near the equator. Most carriers never show any sign of sickle cell anemia.

Researchers are studying new drugs that may be able to prevent the red blood cells from sickling during a crisis. Some chemicals have been shown to return sickled cells to their normal shape. However, these chemicals have dangerous side effects. Therefore, researchers are still seeking a safe treatment for the disease. One possible cure for the disease is a bone marrow transplant, in which the marrow from a suitable donor is placed inside the bone marrow of the person with the disease (see BONE MARROW; TRANSPLANTATION). The new bone marrow then starts to produce normal blood cells, which reduces the number of sickle cells in the bloodstream. This transplant only works if the donor is closely related (a brother or sister) and does not have the disease.

*See also* GENETICS.

**SIDEWINDER** A sidewinder is a species of rattlesnake (see RATTLESNAKE). Sidewinders live in the deserts of North America. A sidewinder may reach 30 in. [75 cm] long. It feeds on lizards and small mammals. Most of its hunting is done at night, when the desert is cooler. The snake is able to find the animals by smell.

The sidewinder was named for the way it crawls in the sand. This snake crawls by making a series of loops with its body and twisting sideways through the sand. It leaves a trail of flat S-shaped loops.

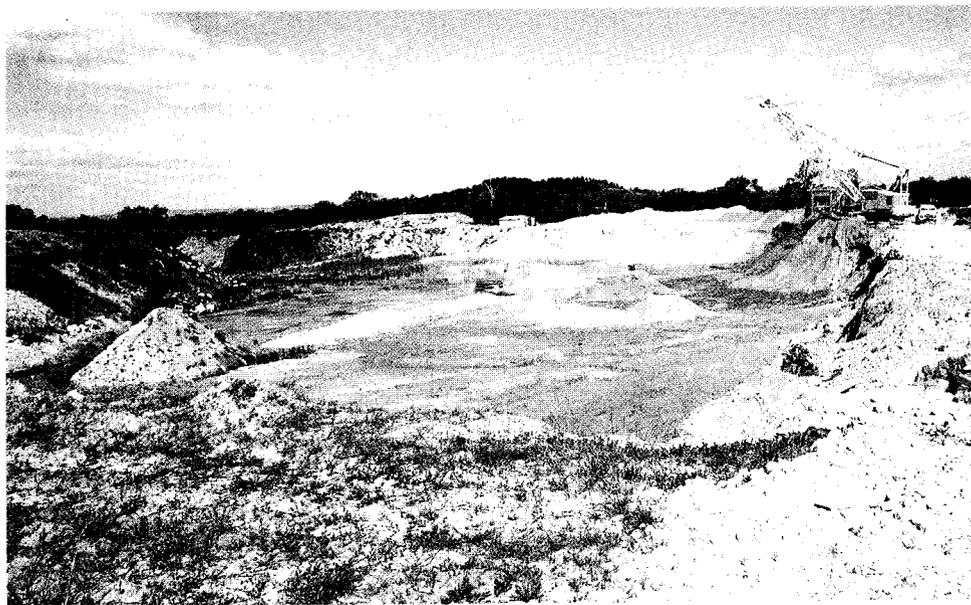
*See also* SNAKE.



#### **SIDEWINDER**

The sidewinder (above), a North American rattlesnake, was named for the way it crawls in the sand. The sidewinder feeds on lizards and small mammals.

**SILICA** (sĭl'ĭ kə) Silica is the most plentiful and widespread substance in the earth's crust. Its chemical name is silicon dioxide (SiO<sub>2</sub>). Almost



### SILICA

Sand is a common form of silica. Sand is excavated on a large scale for use in making mortar and concrete.

60 percent of the earth's crust is made of silica. It is also the main material in about 95 percent of all known rocks.

There are three main varieties of silica: quartz, tridymite, and cristobalite. Quartz is by far the most common variety of silica. Quartz forms the bulk of sands on Earth (see QUARTZ; SAND). Tridymite and cristobalite are varieties of silica found mainly in rocks of volcanic origin (see VOLCANO).

Silica is important in the formation of most crystalline rocks (see ROCK). The gemstones agate, amethyst, jasper, onyx, and opal, for example, contain silica. The shells of many microscopic organisms are made of silica. Silica also gives strength and hardness to plant stalks and bird feathers.

*See also* SILICON.

**SILICON** (sīl'ī kən) Silicon (Si) is an element that has some metallic and some nonmetallic properties. It is one of the metalloids (see ELEMENT). After oxygen, silicon is the most abundant element in the earth's crust. It is found in all ordinary rocks except limestone. It is a very reactive element and is not found in nature as a free element. It always occurs in compounds (see COMPOUND). With oxygen, silicon forms the compound silicon dioxide, more usually known as silica (see SILICA).

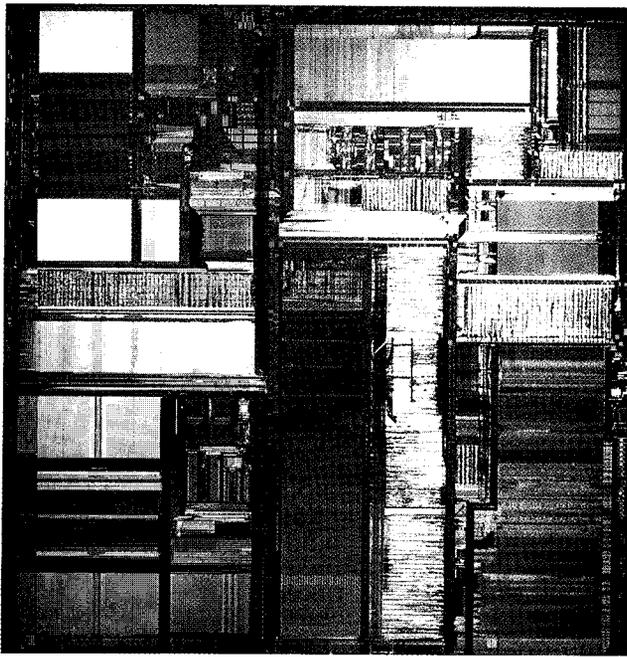
Silicon can be made by heating sand and coke in

an electric furnace (see COKE; SAND). Pure crystalline silicon is a semiconductor, which is used to make transistors, solar cells, chips, and other electronic components (see CHIP; SEMICONDUCTOR). Silicon is an important ingredient of many alloys, including some types of cast iron (see ALLOY; CAST IRON).

With carbon, silicon combines to form silicon carbide, or carborundum. It is one of the hardest materials known and is also very heat resistant. Carborundum is used as an abrasive and for the linings for high-temperature furnaces (see ABRASIVE; CARBON).

Silicon forms an important group of compounds called silicates. They are salts of silicic acid, which have the formula  $H_4SiO_4$  or  $H_2SiO_3$  (see SALTS). Sodium silicate, also called water glass, is used for preserving eggs, stopping wood from decaying, and making wood and paper nonflammable (not easily set on fire). It is also used in soaps, in the dyeing industry, and as an adhesive. The very absorbent material called silica gel is made from sodium silicate. It is used as a drying agent. Small packets of dry silica gel are often put into camera cases to take away moisture. Silicon and oxygen can be combined with carbon to form silicones (see SILICONE). Silicones have very useful properties, such as hardness and heat resistance.

Silicon has the atomic number 14. Its relative atomic mass is 28.086. It melts at  $2,570^\circ\text{F}$



### SILICON

Pure crystalline silicon is a semiconductor. It is made into silicon chips, which are used in microprocessors and other computer circuits.

[1,410°C] and boils at 4,582°F [2,548°C]. It has a valence of 4 in most of its compounds (see VALENCE). In some of its chemical properties it resembles carbon. It was discovered in 1823 by the Swedish chemist Jöns Berzelius.

See also BERZELIUS, JÖNS JAKOB.

**SILICONE** (sil'ī kōn') Silicones are synthetic (human-made) compounds containing silicon and oxygen atoms grouped together in chains. Silicones are polymers (see POLYMER). The silicon-oxygen chains are "fleshed out" with organic (carbon-containing) chemical groups attached to the chains as branches. The properties of different silicones depend upon the length of the silicon-oxygen molecules, how they are linked together, and what other chemical groups are present.

Silicones can be made into oils, resins, and rubbers (see RESIN; RUBBER). They have a high resistance to heat and moisture. The oils and resins may be painted on surfaces. They dry out to form heat- and water-resistant coatings. Kitchenware may be coated with silicones to make nonstick surfaces for cooking without oil. Silicone fluids and greases are useful as lubricants for machinery that must

withstand high temperatures. Silicones were first manufactured in the 1950s. They are now used in hundreds of branches of industry.

**SILKWORM MOTH** The silkworm moth is an insect whose larva spins a large amount of strong silk while making its cocoon (see BUTTERFLY AND MOTH; COCOON; LARVA). Silkworm moth larvae (plural of *larva*) are called caterpillars (see CATERPILLAR). The caterpillars produce silk in special glands that open near the mouth. The silk is liquid at first. However, the silk soon hardens into a fine, threadlike filament. Most commercial silk comes from caterpillars of the genus *Bombyx*. These caterpillars wrap themselves in a cocoon made of silk. It is in these cocoons that the caterpillars develop into pupae (plural of *pupa*) (see METAMORPHOSIS; PUPA).

The Chinese silk moth is the insect most frequently cultivated for its silk. Its cocoon may contain as much as 3,300 ft. [1,000 m] of continuous silk thread. The larva that produces this cocoon is cream and about 3 in. [7.5 cm] long. It has a tiny horn near its rear end. The larva usually feeds on mulberry leaves but may also eat the leaves of lettuce and other plants. The adult moth is creamy white, with a hairy body and a wingspan of about 2 in. [5 cm]. The female lives for only two or three days. During this time, she may lay as many as five hundred eggs. The adult moths cannot fly.

**SILL** A sill is a tabular (flat-surfaced) body of igneous rock formed within the earth's crust (see EARTH; IGNEOUS ROCK). A sill is created when molten (melted) rock material is forced into cracks in the existing rock. The molten rock spreads out in large sheets parallel to the layers of surrounding rock.

Sills usually are horizontal. A similar formation is a dike, which is vertical—that is, perpendicular to the existing rock (see DIKE). Sills may be up to several miles long. The thickness of sills ranges from an inch to hundreds of feet.

**SILLIMAN, BENJAMIN, JR.** (1816–1885) Benjamin Silliman was a chemist whose work helped begin the petroleum industry (see PETROLEUM). He

discovered how to separate petroleum into different grades. He also showed how different grades of petroleum could be used, some for lighting and some for lubrication.

Silliman was born in New Haven, Connecticut. He was a professor at the University of Louisville in Kentucky (1849–1854) and spent the remainder of his career as an educator in the Sheffield Scientific School of Yale University in Connecticut. Silliman's father—Benjamin Silliman, Sr. (1779–1864)—was also a chemist and a geologist. He founded the *American Journal of Science*. His son became coeditor of this journal. The mineral sillimanite was named in honor of the senior Benjamin Silliman.

**SILT** Silt is one of the three main kinds of particles found in soil (see SOIL). Silt particles are between 0.0015 and 0.0025 in. [0.038 mm and 0.064 mm] in diameter.

Silt is finer than grains of sand, but coarser than particles of clay, the other kinds of particles found

in soil (see CLAY; SAND). Silt is deposited in rivers, lakes, and oceans and also spreads over the land when rivers flood. Soils that include large amounts of silt are generally fertile.  **PROJECT 21**

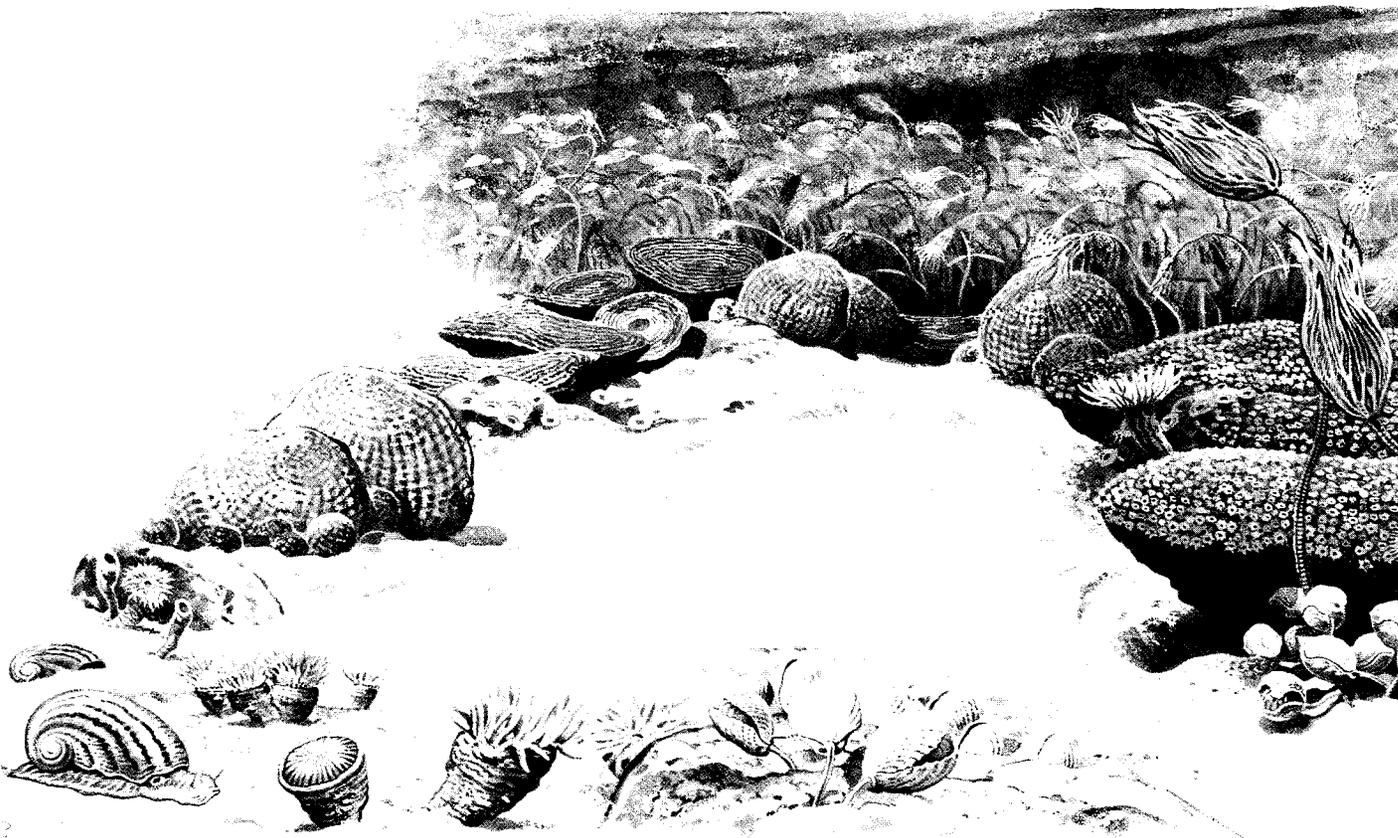
**SILURIAN PERIOD** (sī lōōr'ē ən pīr'ē əd) The Silurian period in Earth's history began about 439 million years ago and lasted for about 31 million years. It is a subdivision of the Paleozoic era (see PALEOZOIC ERA).

During the Silurian period, much of the earth was covered with shallow seas. Reefs of coral and sponges formed, and fish and nautiloids were commonplace (see CORAL; FISH). The first land plants appeared also. Deposits of salt, gypsum, and iron ore formed.

See also GEOLOGICAL TIME SCALE.

#### SILURIAN PERIOD

During the Silurian period, dating from about 439 million years ago, all forms of animal life lived in the sea. Corals, sponges, and mollusks lived in the shallow water, along with fish and nautiloids.



**SILVER**

Silver is a valuable metal that was once often used to make cutlery and other kinds of tableware. Today such items are often made of a much cheaper metal and electroplated to give them a thin coating of silver.



**SILVER** Silver is a scarce and highly valued metallic element. The chemical symbol for silver is Ag, which is from the Latin word *argentum* (see ELEMENT).

Silver has been known to humans since ancient times. Because of its bright color when polished, it has been used to make jewelry, ornaments, and tableware. It is fairly soft and can be shaped easily. Throughout the ages, silver has been used to make coins. Medals and coins for special occasions are still made of the metal, but "silver" coins in circulation today are more often made of the bright alloy cupronickel. Cupronickel contains the metals copper and nickel, but no silver (see ALLOY). However, silver is still used for international trade in the form of bars and ingots (see INGOT). For this purpose, the silver is 99.9 percent pure and is called fine silver.

Fine silver is too soft for use in jewelry and tableware. An alloy of silver with copper is much harder. Sterling silver contains 7.5 percent copper. This is usually expressed as *925 silver*, meaning that out of every 1,000 parts of the alloy, 925 parts are pure silver. Other alloys that are commonly used are 800, 830, 875, 900, and 950 qualities.

Silver tarnishes (becomes dull or discolored) when exposed to polluted air containing sulfur compounds. However, tarnishing may easily be taken off with a suitable polish.

Silver is a very good conductor of electricity (see CONDUCTION OF ELECTRICITY). Because it is so

expensive, it cannot be used in large quantities to make electric cables. However, it is used to make contacts (parts between two electrical conductors, through which electricity flows) in some kinds of electric equipment.

Other metals may be electroplated with silver. A layer of silver is deposited on another metal by electrolysis. Brass is sometimes plated first with nickel. Then the silver is electroplated onto the nickel. Nickel and silver form a very firm bond. The initials E.P.N.S. are stamped on articles that are plated this way. The initials stand for Electroplated Nickel Silver.

Silver compounds are widely used in photography (see COMPOUNDS). Silver iodide, chloride, and bromide are all sensitive to light. All are photographic chemicals (see PHOTOGRAPHY). Silver nitrate can be used to deposit metallic silver on polished glass surfaces to form mirrors.

Silver is fairly unreactive. It is sometimes found in the earth as a free (pure) metal. In 1860, a nugget of silver weighing 8 tons [7 metric tons] was found in Spain. Silver is also found in compounds. The most commonly found compounds are silver sulfide, found in the ore argentite, and silver chloride (horn silver). Silver is found in small quantities in the lead ore, galena. From the sixteenth century, Mexico has been the world's richest source of silver. Today, silver is also mined in other parts of North America and in South America, Australia, and Japan. Silver is extracted from its ores by various

methods and purified by electrolysis (see **ELECTROLYSIS**; **ORE**). The pure silver crystals that result are then melted and cast into silver bars. It can be made into various products.

Silver has the atomic number 47. Its relative atomic mass is 107.870. Silver melts at 1,762°F [961 °C] and boils at 3,956°F [2,193°C]. It has a valence of 1 or 2 in its compounds.

See also **VALENCE**.

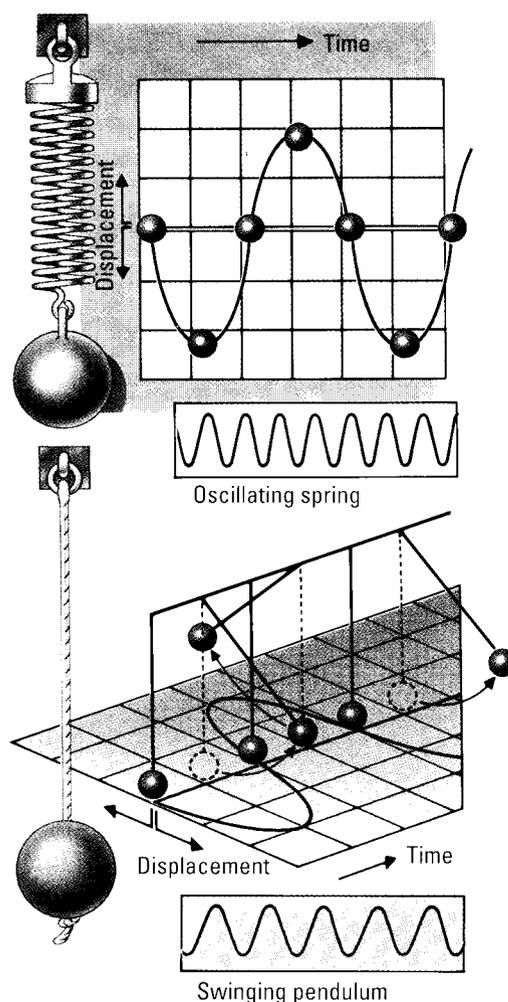
**SIMPLE HARMONIC MOTION** Simple harmonic motion is a regular back-and-forth movement that is often seen in natural systems that vibrate or swing. The movement of a pendulum, swinging backward and forward, is an example of simple harmonic motion (see **PENDULUM**). The movement of a playground swing is another example of simple harmonic motion. The vibration of a stretched cord or wire that is plucked, as in a musical instrument, is a third example.

The following example describes the forces acting on a body that is undergoing simple harmonic motion. Imagine that an object, such as a weight, hanging on a string is set swinging. The weight moves sideways for only a certain distance. The force of gravity, pulling it downward, overcomes the force that is lifting the weight from the earth (see **GRAVITY**). The speed of the weight is reduced more and more, until all movement stops at the top of the swing. Then the force of gravity pulls the weight downward to the original vertical position. As the weight swings downward, the speed of the weight increases until it is at a maximum speed when nearest the earth. As the weight's speed increases, so does its momentum (the force that a moving body has because of its weight and motion) (see **MOMENTUM**). Its momentum carries it beyond the vertical, and out to the opposite side, to an equal distance.

The time that a pendulum takes to swing from one side to the other depends on the length of the pendulum. It does not depend on the size of the object at the end of the pendulum, its mass, or how hard a push is given to the object to set it in motion (see **MASS**). The number of times that a pendulum moves from one side to the other and back again

each second is called the frequency. The maximum distance it moves in either direction from its original resting point is its amplitude (see **AMPLITUDE**; **FREQUENCY**).

The vibrations produced by musical instruments are a form of simple harmonic motion. When a guitar string is plucked, it vibrates side to side. Its movement is limited by the tension in the string. Just as gravity stops a pendulum at the end of each swing, the tension in the string stops it and starts it moving in the opposite direction. The frequency of vibration of the string depends on its length and also on the force provided by the tension of the string. The shorter the string and the greater the tension, the higher the frequency of vibration.



#### **SIMPLE HARMONIC MOTION**

Examples of simple harmonic motion include a weight oscillating (vibrating) up and down at the end of a coil spring (top) and a pendulum, which is a weight swinging at the end of a string (bottom). In each case, a graph of the weight's displacement plotted against time takes the form of a regular wavelike curve.

# SIMULATOR

A simulator (sīm'yə lā'tər) duplicates the conditions of a situation, a process, or a piece of equipment. Using a simulator, a piece of equipment or a process can be developed and tested. A simulator may be a device. For example, spacecraft simulators that look like the real craft and recreate the conditions of spaceflight are used to train astronauts. Airlines use airplane simulators to train flight personnel. The nuclear power industry uses simulators to train people in the operation of their power plants. These are only a few of the many uses of simulators.

Simulators usually duplicate the appearance and the motion of the object they simulate. For example, a spacecraft simulator has the same controls and instruments as a real craft. In addition, computer-generated color images recreate the view outside an actual spacecraft.

Not all simulators are devices. A simulator may be a computer program. A program, for example, can simulate a chemical process or a political system. As long as the characteristics of some device or system can be put into a computer, the operation of that device or system can be simulated (see COMPUTER).

Simulators may be used in research and development. Simulators make it possible to develop

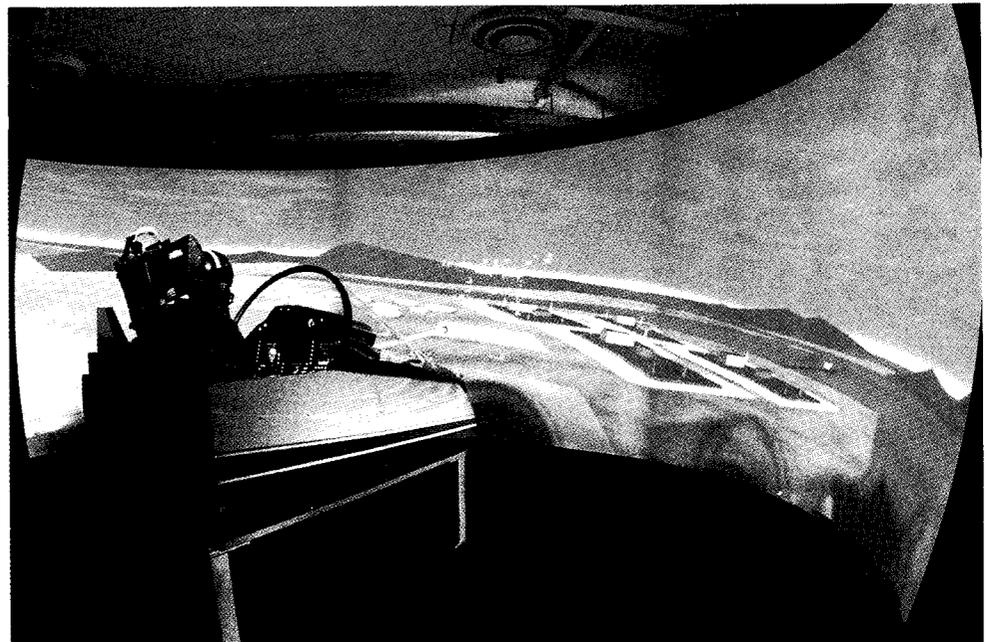
equipment that might be either too expensive or too difficult or dangerous to test without a simulator. For instance, in the development of intercontinental ballistic missiles, it would have been impossible to conduct actual tests. The use of simulators made their development possible (see MISSILE).

Perhaps the most important use of simulators is to train people to operate equipment and vehicles. Using simulators saves energy—and millions of dollars. For example, since airlines use simulators for training instead of flying the actual aircraft, they save energy. Using simulators also allows training to be more personal and thorough. For example, if a pilot has trouble with takeoffs, a simulator allows the pilot to practice taking off again and again. Simulators also allow pilots to experience emergency situations that could arise in actual flight. Experience in dangerous jobs can be gained with simulators. For example, handling liquid natural gas is a delicate and dangerous operation. A simulator can train operators safely.

There are many kinds of simulators in use today. With improved computers, it is becoming more and more possible to simulate a wide variety of processes. In time, simulators may be used to teach such diverse skills as playing tennis and performing surgical operations.

## FLIGHT SIMULATOR

A military pilot can learn to fly a high-speed jet plane on a flight simulator. The pilot can practice takeoffs, landings, and attack procedures.



**SINTERING** (sĭn'tər ĭng) Sintering is the process of heating particles of solid material until they stick together. If a mixture of powdered metals is heated to the melting point of one of the metals, the metal that melts makes the particles of the other metal stick together.

Sintering can also be carried out using pressure. When grains (particles) of a ceramic material are compressed, the parts of the grains that are in contact with one another form solid links. The powder changes into a solid mass.

By carefully sintering a powder that has grains of a known size, it is possible to make a porous solid. Gaps are left where the grains that were heated or compressed did not touch one another. Very fine filters can be made in this way, with pores (holes) of a known range of sizes (see **FILTER**).

Sintering is an important process in the making of pottery and porcelain and also in metallurgy.

*See also* CERAMICS; METAL AND METALLURGY.

**SINUS** (sĭ'nəs) A sinus is an air-filled cavity (enclosed space) in the front of the skull that connects with the nasal passages (see **NOSE**; **SKULL**). Sinuses are found in humans and also in other mammals, birds, and crocodiles.

There are four groups of sinuses in the human skull. The frontal sinuses are located in the frontal bone of the forehead, just above the eyes. The maxillary sinuses are located in the cheekbones on each side of the nose. The ethmoid sinuses lie just above the nasal passages, and the sphenoid sinuses are just behind them.

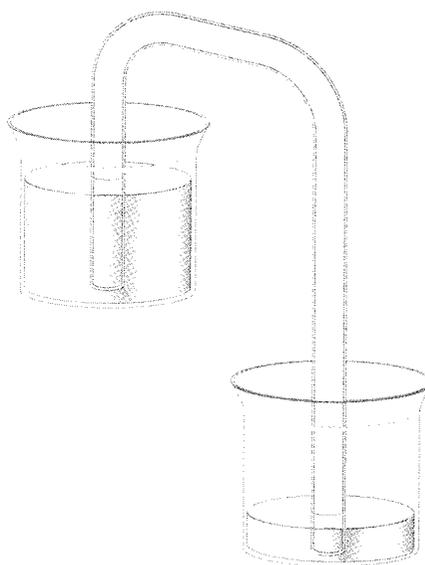
The sinuses are lined with membranes. Infections of the nose spread easily to the sinuses and inflame these membranes (see **MEMBRANE**). When this happens, painful pressure builds up in the sinuses. This condition is called sinusitis.

Allergies, colds, influenza, and many other diseases can cause sinusitis. It can be treated with drugs known as decongestants, which make the fluid in the sinus (mucus) less sticky. This helps the sinus to drain, so relieving the pressure.

*See also* INFECTION; INFLAMMATION.

**SIPHON** (sĭ'fən) A siphon is a tube, usually rubber or plastic, used to transfer liquid from a container at a higher level to a container at a lower level. The tube is bent so that one side is longer than the other. To begin siphoning, the tube is filled with the liquid to be transferred. The short side of the filled tube is placed in the higher container, and the other side is placed in the lower container. The weight of the liquid in the long side of the siphon reduces the pressure in the tube. Atmospheric pressure on the surface of the liquid in the higher container forces liquid up the short side of the tube. After the liquid reaches the top of the siphon, gravity pulls it down the long side of the tube, into the lower container. This flow continues until either all the liquid is removed from the higher container or the liquid in the lower container reaches the same level as the liquid in the higher container.

*See also* ATMOSPHERE; GRAVITY.



#### **SIPHON**

A siphon is a U-shaped tube used to transfer a liquid from one container to another container at a lower level.

**SIREN** A siren is a device used to make a warning signal. It gives off a loud, piercing sound.

One common siren is made of two cylinders that have holes in them. One cylinder is inside the other cylinder. An electric motor or hand crank makes the outer cylinder revolve. Another mechanism forces air through the cylinders. Air comes through the holes in the first cylinder and passes

through the holes in the second cylinder every time the holes are opposite one another. A low noise is created by this movement of air through the holes. As the outer cylinder is turned faster, the sound becomes louder until it grows into a long, continuous wail. The more quickly the outer cylinder is turned, the higher the volume of the sound. A newer kind of siren produces its sound electronically.

**SISAL** (sī'səl) Sisal is a monocarpic plant that is cultivated for its fiber-containing leaves. This member of the agave family thrives in warm, moist climates throughout the world (see AGAVE). It produces clusters of thick, stiff, spiky leaves that may be 6.6 ft. [2 m] long and 4 in. [10 cm] wide. Within eight years after being planted, the sisal produces a flower stalk 20 ft. [6 m] tall. Dense clusters of yellow flowers grow at the end of this stalk. The flowers produce seeds, but they also contain many small bulbs that fall to the ground and take root. The sisal plant dies shortly after flowering (see BULB AND CORM).

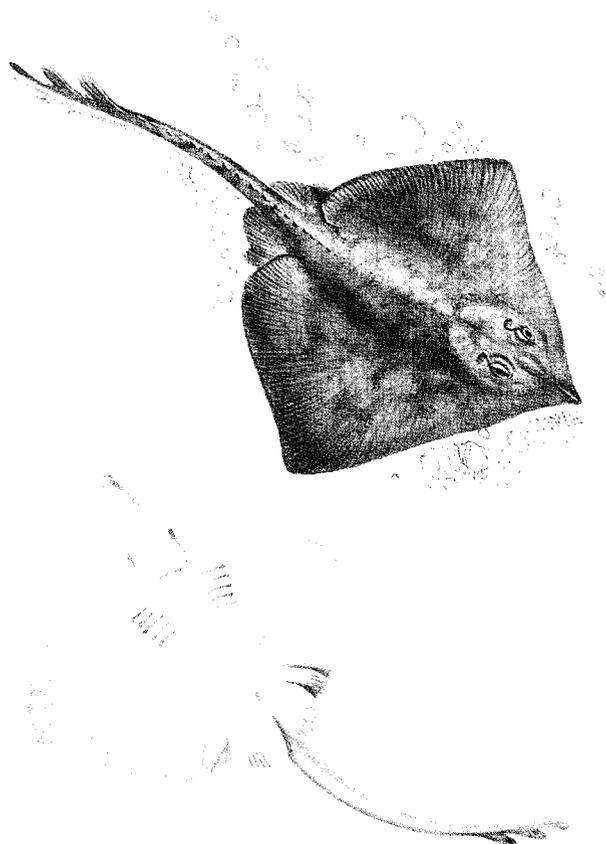
The leaves of the sisal plant yield coarse, white fibers up to 50 in. [125 cm] long (see FIBER). These fibers are very strong and flexible. Since they are



#### SISAL

Sisal is grown for its fibers in many warm parts of the world. This crop is being grown on the island of Madagascar, in the Indian Ocean.

not affected by salt water, they are often made into ropes for use on seagoing boats and ships. The fibers can also be woven into mats and rugs. More than 60 percent of the world's supply of sisal fiber comes from Tanzania and Brazil.



#### SKATE

The skate is a cartilaginous fish (its skeleton is made of cartilage) related to the sharks and rays. Shown here are the top (top) and the underside (bottom) of the common skate.

**SKATE** A skate is a saltwater fish that belongs to the family Rajidae. It is a flat, diamond-shaped fish that spends most of its time on the floor of the ocean. The skate's skeleton is made of cartilage instead of bone (see CARTILAGE). A skate is a type of ray (see RAY). Skates and other rays are related to sharks (see SHARK). Skates eat small fish, crustaceans, and mollusks (see CRUSTACEAN; MOLLUSK).

More than twenty species of skates are found in the waters off North America. Some species may reach 6 ft. [1.8 m] long. The flesh of skate fins is a popular food in Europe.

*See also* FISH.

# SKELETON

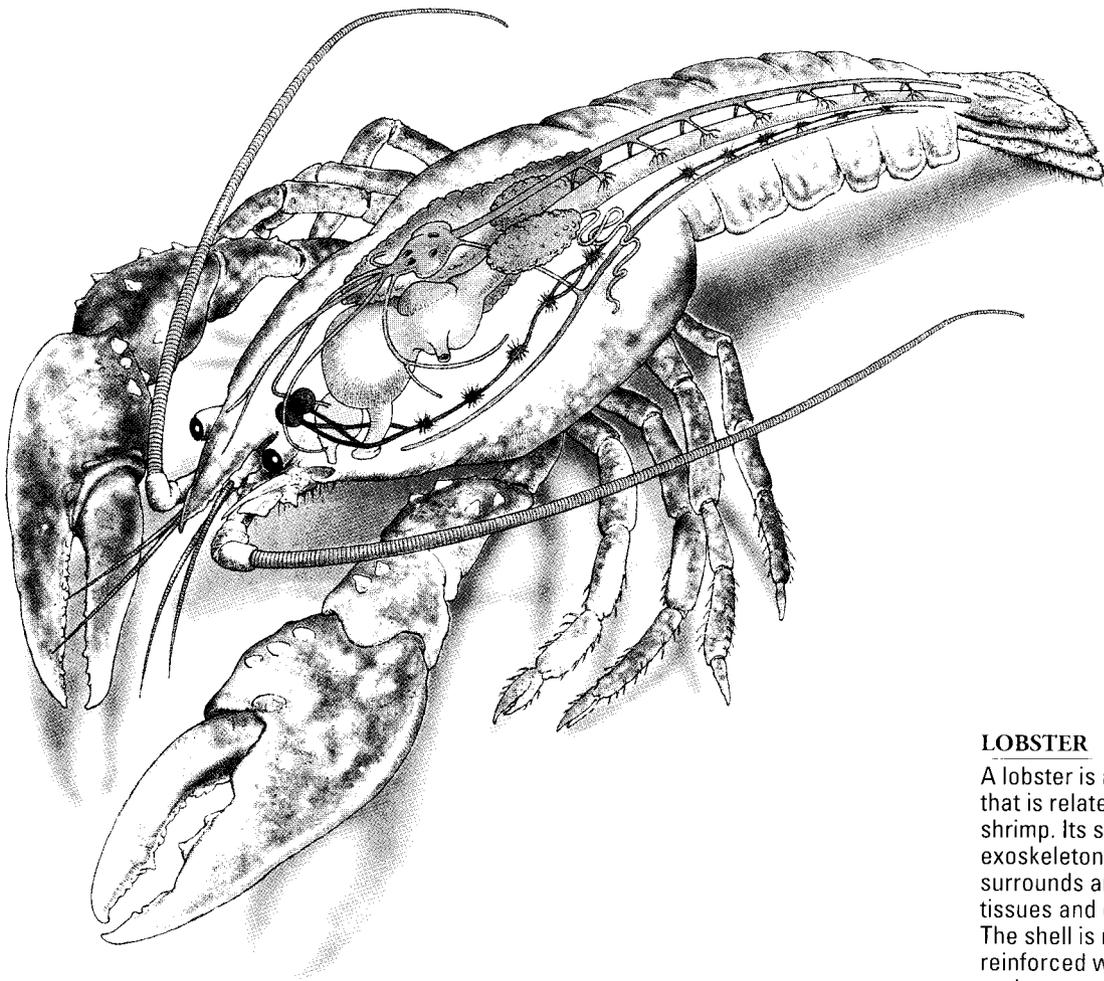
A skeleton is a structure that supports an animal's body. It may also protect the body or certain body structures. It may help the animal move about by providing a place for muscles to attach. In some cases, such as the bones in the middle ear of mammals, the skeleton even has a sensory function. There are two main types of skeletons: exoskeletons and endoskeletons.

**Exoskeleton** An exoskeleton is a hard structure on the outside of an organism's body. It is usually made of calcium carbonate, chitin, or silica (see CALCIUM CARBONATE; CHITIN; SILICA). An exoskeleton provides protection. Its major disadvantage is that it does not increase in size as the organism grows. As a result, the exoskeleton is

usually molted, or shed, several times during an organism's lifetime (see MOLTING).

Shells serve as a type of exoskeleton for many organisms (see SHELL). Some protozoans, such as foraminifers and radiolarians, produce tiny shells made of calcium carbonate or silica (see PROTOZOA). Most mollusks have shells (see MOLLUSCA). The arthropods have the most advanced exoskeletons (see ARTHROPODA). Their exoskeletons are jointed and allow for movement. They are made of chitin, often strengthened with calcium carbonate. Usually, muscles are attached to the inner surfaces of the arthropod's exoskeleton.

**Endoskeleton** An endoskeleton is a hard framework inside an animal's body. It is usually made of

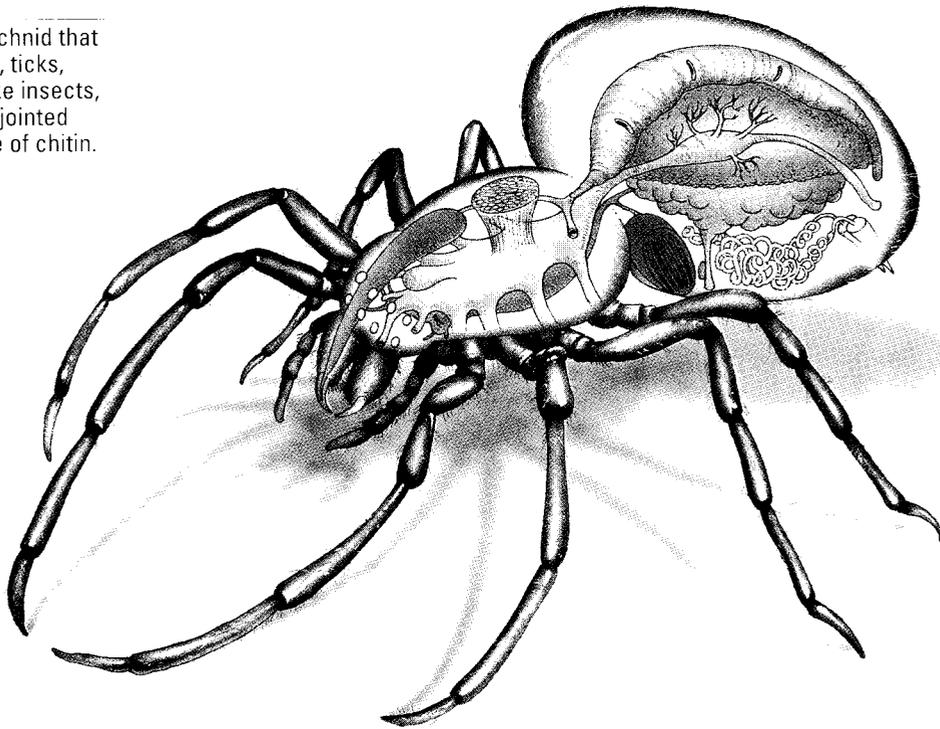


## **LOBSTER**

A lobster is a crustacean that is related to crabs and shrimp. Its shell is an exoskeleton, which surrounds and protects the tissues and organs inside it. The shell is made of chitin, reinforced with calcium carbonate to make it hard and strong.

**SPIDER**

A spider is an arachnid that is related to mites, ticks, and scorpions. Like insects, arachnids have a jointed exoskeleton made of chitin.



bone or cartilage or both (see **BONE**; **CARTILAGE**). An endoskeleton increases in size as the animal grows. It helps protect the internal organs and allows for great freedom of movement. In many animals, the endoskeleton also has other functions, such as the production of blood cells (see **BLOOD**).

Some invertebrates, such as echinoderms and sponges, have endoskeletons (see **ECHINODERMATA**; **INVERTEBRATE**; **SPONGE**). They have hard, protective structures just inside their body walls. These skeletons usually increase in size as the animal grows.

All other animals with endoskeletons are chordates

(see **CHORDATA**). Chordates include all organisms that, at some stage in their development, have a notochord (see **NOTOCHORD**).

Most of the chordates are vertebrates (see **VERTEBRATE**). The vertebrates are animals with backbones. In most vertebrates, the embryo is the only stage of development with a notochord (see **EMBRYO**). During development, the notochord is usually replaced, at least partially, by bone or cartilage. In some vertebrates, such as sharks and other cartilaginous fish, the entire skeleton is made of cartilage (see **FISH**). In most other vertebrates, the skeleton is composed mainly of bone.

The skeletons of most vertebrates share basic similarities. They all have a backbone made of bony vertebrae (see **VERTEBRA**). Most have ribs and limbs modified in various ways depending on the animal's lifestyle. The differences in skeletal structure of vertebrates give scientists insights into how the vertebrates evolved (see **EVOLUTION**).

**Human skeleton** The human skeleton is made of bones, cartilage, and tough fibrous tissue. Some bones are long and very strong. Others are flat and also very strong. Most of the long bones start out as cartilage, while most of the flat bones start out as membranes (see **MEMBRANE**). As the baby develops

**ENDOSKELETON**

A fish has an endoskeleton. This internal framework of bones or cartilage supports the animal's body and protects the organs located inside the skeleton.

before birth, calcium, phosphorus, and other substances are laid down in these cartilaginous and membranous tissues, producing bone.

Most of the bones are covered with tough fibrous tissue. The ends of bones in freely movable joints are usually covered with cartilage. This cartilage acts as a cushion in the joints (see JOINT). Bones are attached to other bones by ligaments (see LIGAMENT). Muscles are attached to bones by tendons (see TENDON). The muscles, acting across joints, are able to move the skeleton, allowing a person to make various movements.

At birth, a baby has more than 300 separate bones. As the baby grows, many of these bones fuse (join) together. The adult skeleton has 206 bones. The skeleton can be divided into two main parts: the axial skeleton (skull, backbone, sternum, and ribs) and the appendicular skeleton (shoulder, pelvis, and arm and leg bones) (see PELVIS; RIB; SKULL; STERNUM).

The skull is made up of several plates of bone, most of which fuse together after birth. The immovable joints of the skull are called sutures. The skull encloses and protects the brain. The orbits are cuplike sockets (hollow places) that hold

the eyes. In the bones of the forehead and cheeks are air-filled spaces called sinuses (see SINUS). The base of the nose is bone. The rest of the nose, however, is mostly cartilage. The maxilla is the bone of the upper jaw. The mandible is the bone of the lower jaw. Teeth, also part of the skeleton, fit into sockets in the maxilla and mandible (see TEETH). The mandible is one of the few bones in the head that can move. Some other moving bones are the tiny bones (malleus, incus, and stapes) in the middle ear (see EAR). These are the smallest bones in the body.

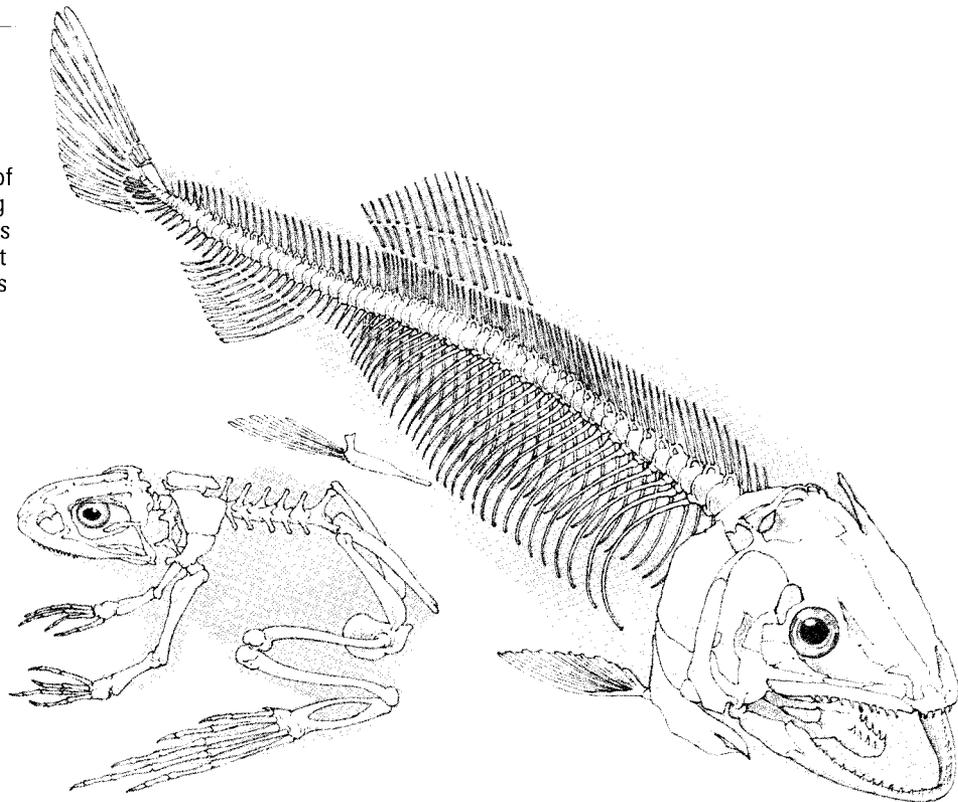
The backbone, or spine, is made up of thirty-three separate bones called vertebrae (plural of *vertebra*). The last nine vertebrae are joined together and do not move. The backbone encloses and protects the spinal cord (see SPINAL CORD).

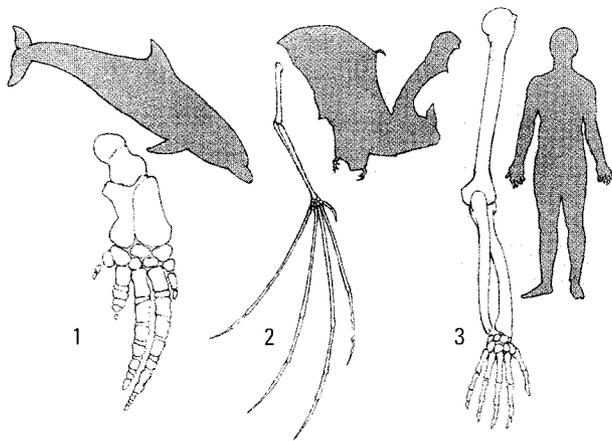
The chest is enclosed by twelve pairs of ribs. The ribs begin at the thoracic vertebrae and curve around to the front of the chest. Most of the ribs are connected to the sternum, or breastbone, in the middle of the chest.

The bones of the arms and legs are joined to the backbone by loops of bone called girdles. The pectoral, or shoulder, girdle is made up of two clavicles

## FINS AND LIMBS

A fish (right) swims by moving its long, flexible spine from side to side. It steers using fins, whose small bones may not even be connected to the rest of the skeleton. An adult frog (below) spends much of its time on land. It has a short spine and long bones in its limbs for walking and jumping.





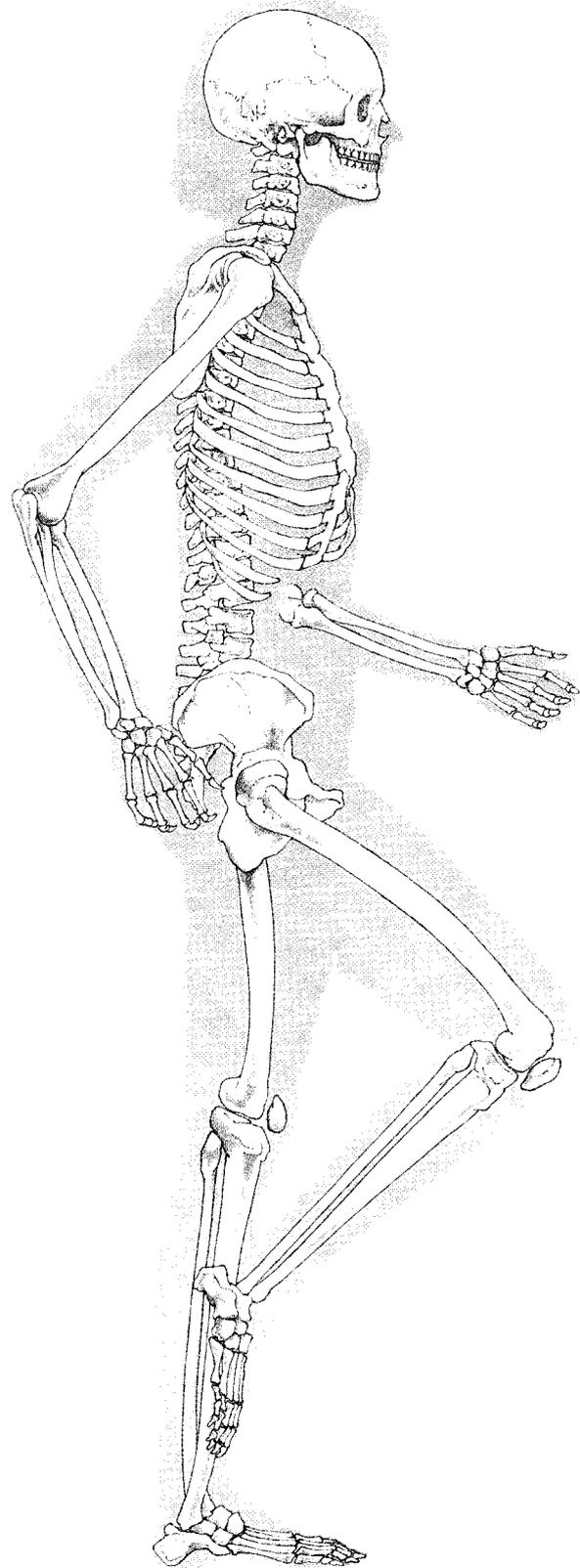
### LIMB BONES

Shown here are (1) the front flipper of a dolphin, (2) the wing of a bat, and (3) the arm of a human being. The limb bones of these mammals share a similar arrangement, but the bones have evolved very different shapes to suit the way of life of the mammal.

and two scapulas. The clavicles, also called the collarbones, do not move (see CLAVICLE). The scapulas, or shoulder blades, are able to move when the shoulders and arms move. The pelvic girdle, or pelvis, provides some protection for the lower abdomen. The pelvis is made of several bones that are fused together. It is very strong, as it must support the weight of the upper part of the body.

The bones of the arms and legs correspond closely to each other. The long, strong bone in the upper arm is the humerus (see HUMERUS). It is attached to the pectoral girdle in a ball-and-socket joint, known as the hip joint. The bones in the lower arm are the radius and ulna (see RADIUS; ULNA). The wrist and hand are made of thirteen bones: eight carpals and five metacarpals. The five fingers contain fourteen bones called phalanges (see PHALANGE).

The bones in the legs are larger and stronger than those in the arms. The femur is the bone in the upper leg (see FEMUR). It is the largest bone in the body. It is joined to the pelvic girdle in a ball-and-socket joint, known as the hip joint. The bones in the lower leg are the tibia (shinbone) and the fibula (see FIBULA; TIBIA). The patella, or kneecap, protects the knee joint (see PATELLA). The ankle and foot contain twelve bones: seven tarsals and five metatarsals (see TARSAL). The five toes contain fourteen phalanges.



### UPRIGHT POSTURE

A human being stands and walks in an upright position. The human skeleton is adapted for this posture, with the spine and legs in a straight line. During walking, the knee joint carries nearly half the body's weight.

# SKIN

Skin, also called the integument, is the outer layer or layers of cells of an animal's body. In many creatures, skin forms the outer protective coating of the body. However, the skin is really a living organ—generally the body's largest organ. Skin helps prevent infection, protects internal structures from injury, and allows information to be gathered through nerve cells, called receptors, which are scattered throughout the skin (see INFECTION; RECEPTOR). Skin also plays an important part in excretion (discharging of wastes), temperature regulation, and, in some creatures, external respiration (exchange of gases with the environment). Skin cells also make vitamin D (see VITAMIN).

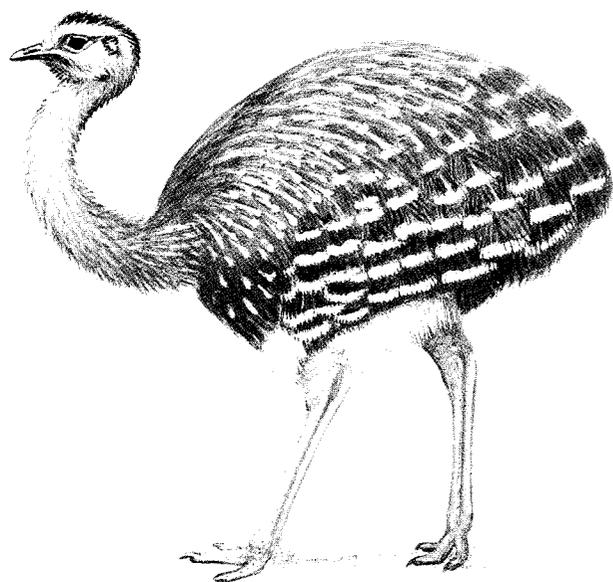
## MAMMAL SKIN

A key feature of mammals is that they grow hair on their skin. A human being is no exception, although the hair is not prominent on most parts of the body. This diagram shows a cross section of human skin, with the hairs and various receptors (nerve cells).

In most invertebrates (animals without backbones), the skin is only one cell thick, but it often secretes a hard shell or exoskeleton, which covers it (see SKELETON). Vertebrates (animals with backbones) have two basic skin layers, the inner dermis and the outer epidermis. Each of these skin layers is made up of many layers of cells. Vertebrate skin contains many glands that secrete substances such as sebum (oil), sweat, and, in mammals, milk (see GLAND; MILK; SWEAT).

All vertebrates grow some kind of hard, horny external structure on their skin. Fishes and reptiles have scales, birds have feathers, and mammals have hair. Hair grows out of pits in the skin called follicles. Hooves, nails, and claws are also outgrowths of the skin. Such external structures may provide protection or act as weapons. In addition, feathers make it possible for birds to fly and to float on water. Both feathers and hair help conserve body





### BIRD SKIN

Birds have feathers growing out of their skin. Even on a flightless bird such as a rhea (above), the feathers provide insulation and may be fluffed up when the bird is threatened or in courtship display.

heat by trapping a layer of warm air next to the skin. In many animals, coloring of the scales, feathers, or hair provides camouflage or attracts mates (see CAMOUFLAGE; FEATHER; HAIR; KERATIN; NAIL).

In human beings, the thickness of the skin varies from about 0.02 to 0.25 in. [0.05 to 0.65 cm]. Skin is thin on the eyelids and comparatively thick on the soles of the feet. The thickness or thinness of the skin is mainly due to relative thickness of the epidermis. The outer part of this layer is made up of dead, flattened, horny cells. These cells are constantly being worn away and replaced by new cells from underneath. The innermost layer of the epidermis is the fast-growing basal layer. Special cells called melanocytes are located in this layer. Melanocytes produce a pigment (coloring substance) called melanin. People with dark skin have more melanin than those with lighter skin. Freckles are also caused by melanin and may result from exposure to the sun. The epidermis is the waterproof layer of the skin. It protects the body from infection.

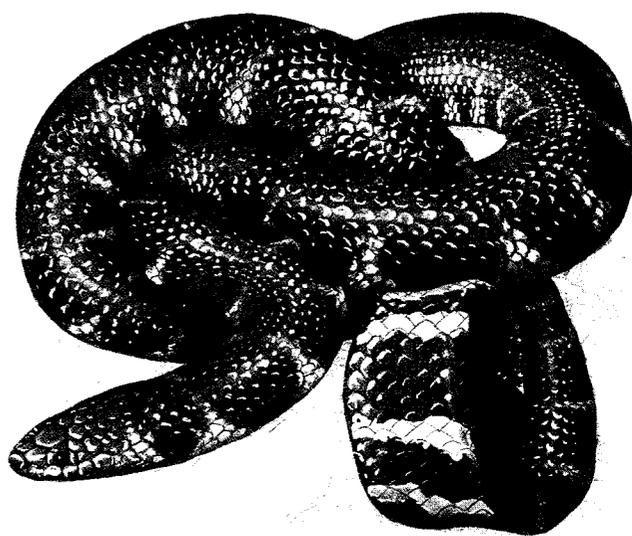
The dermis consists mostly of connective tissue, blood vessels, and receptors, or nerve endings (see CONNECTIVE TISSUE). The outer surface of the

dermis is covered in a pattern of tiny elevations called papillae. The outermost surface of the skin follows the same pattern, thereby forming a person's unique fingerprints. The amount of blood flowing through the blood vessels of the dermis is controlled automatically by the nervous system. The amount of blood flowing through the skin regulates the amount of heat lost by the blood. This helps regulate body temperature. Sweating also helps control body temperature. When sweat evaporates from the skin, the skin becomes cooler (see EVAPORATION). The skin helps conserve heat through the contraction (shortening) of tiny muscle fibers connected to the roots of the hairs. These fibers make the hairs stand on end. The action of the muscles generates heat. The raised hairs also function to trap a layer of warm air near the skin.

A third layer of skin, the subcutaneous layer, has connective tissue, blood vessels, and cells that store fat. This fat helps hold in body heat (see FAT).

It is very important for a person to keep his or her skin clean. This keeps the tiny pores (openings) in the skin from becoming clogged. It also helps prevent the spread of infection in the skin. There are many pathogens (disease-causing organisms) that can infect the skin. Any kind of inflammation or infection in the skin is called dermatitis.

See also INFLAMMATION.



### REPTILE SKIN

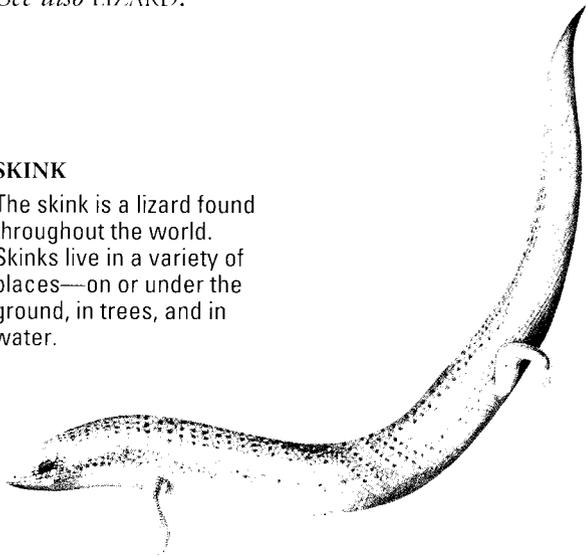
Reptiles, such as snakes, lizards, and crocodiles, have scales on their skin, as do most fish. The Malaysian pipe snake (above) spends most of its time burrowing in damp soil.

**SKINK** (skīngk) A skink is a kind of lizard found in many parts of the world. It belongs to the family Scincidae, in which there are more than nine hundred species. Skinks have short, slender legs. Most eat insects and live on the ground. Some skinks live under the ground. These skinks have permanent transparent covers over their eyes to protect them against sand and dust. Some skinks live in trees, and a few live in the water.

See also LIZARD.

#### SKINK

The skink is a lizard found throughout the world. Skinks live in a variety of places—on or under the ground, in trees, and in water.



#### SKINNER, BURRHUS FREDERIC

(1904–1990) B. F. Skinner was an American psychologist noted for theories of learning and behavior. Most of his work was in the area of animal psychology, though he also studied human psychology.

Skinner's main interest was the process of learning (see LEARNING AND MEMORY). To study this process in animals, he invented an apparatus called the Skinner box. In a Skinner box, an animal can press a special lever that automatically releases food into the animal's cage. Skinner observed how long it took a pigeon to learn that by pressing the lever, food would be released that the pigeon could eat. The Skinner box is now used in many different experiments. A Skinner box may have a number of levers for testing how the animal learns tasks of varying complexity.

Skinner was associated with the behaviorist school of psychology. Behaviorists focus on observing how animals behave in response to their

environment rather than on explaining why they behave in a particular way.

See also PSYCHOLOGY.

**SKUA** (skyōō'ə) A skua is a seabird that belongs to the family Stercorariidae. Its appearance is similar to that of a gull (see GULL). Skuas grow to a length of 23 in. [57.5 cm] with a wingspan of 16 in. [40 cm]. The skua is mostly brown with a patch of white at the ends of its wings. It spends most of its time far out at sea—in the northern parts of the Atlantic and Pacific oceans and also in the southern oceans around Antarctica. The skua comes ashore mainly to nest. It eats fish, which it often steals from other birds. It also preys on the eggs and hatchlings (babies) of other birds.



#### SKUA

The skua is a seabird that spends most of its time far out at sea. It comes on land rarely, mainly to nest.

**SKULL** The skull is the bony case that forms the shape of the head of human beings and other vertebrates (animals with backbones). The skull also encloses and protects the brain. The skull is divided into two groups of bones—those that enclose the brain and those that form the face.

The bones that enclose the brain make up the cranium. There are eight bones in the cranium. These cranial bones include the occipital bone, which is at the back of the skull. The sphenoid is at

the base of the skull. Two parietal bones are at the top and sides of the skull; a temporal bone is located above each ear; the frontal bone forms the forehead; and the ethmoid is positioned at the nose. The remaining fourteen bones of the skull form the framework of the face.

Of the twenty-two bones in the skull, the mandible, or lower jawbone, is the only one that has a movable joint. The other bones are held firmly together at immovable joints called sutures.

See also BONE; JOINT; SKELETON.

**SKUNK** The skunk is a carnivorous (meat-eating) mammal belonging to the same family as the badger and weasel (see CARNIVORE; MAMMAL). There are several species, all with black and white fur. All live in North and South America. Skunks are known for the strong odor produced by a pair of glands near the tail (see GLAND). When a skunk is frightened, it can squirt fluid from these glands as far as 13 ft. [4 m]. The smell usually keeps enemies at a safe distance. Skunks also use their scent to notify other skunks of their presence. Most skunk species send out "warning signals" before they squirt this liquid. Depending on the species, warning signals may include foot stamping or standing on the front feet to display the bold black and white patterns.

Most species are nocturnal (active at night). Skunks make their homes in hollow trees, in burrows, and sometimes under buildings. The animals feed mainly on insects, mice, gophers, squirrels, eggs, and birds.

The gestation period of a female skunk lasts between forty and seventy days (see GESTATION PERIOD). A litter may contain from two to ten young.

After having their scent glands removed, skunks are easily tamed as pets. Skunks also have commercial

value—their scent gland secretions are used in making perfume. In some geographic areas, the animal's flesh is used as food. Skunk fur has been used in the manufacture of garments.

The common skunk of North America is also called the striped skunk. This species ranges from 12 to 18 in. [31 to 46 cm] long, not including the tail. The color pattern of the common skunk varies, but the animal is frequently black with a narrow white stripe on the forehead and a white patch on the head. This patch may extend onto the back and sometimes onto the tail as a single band or two stripes.

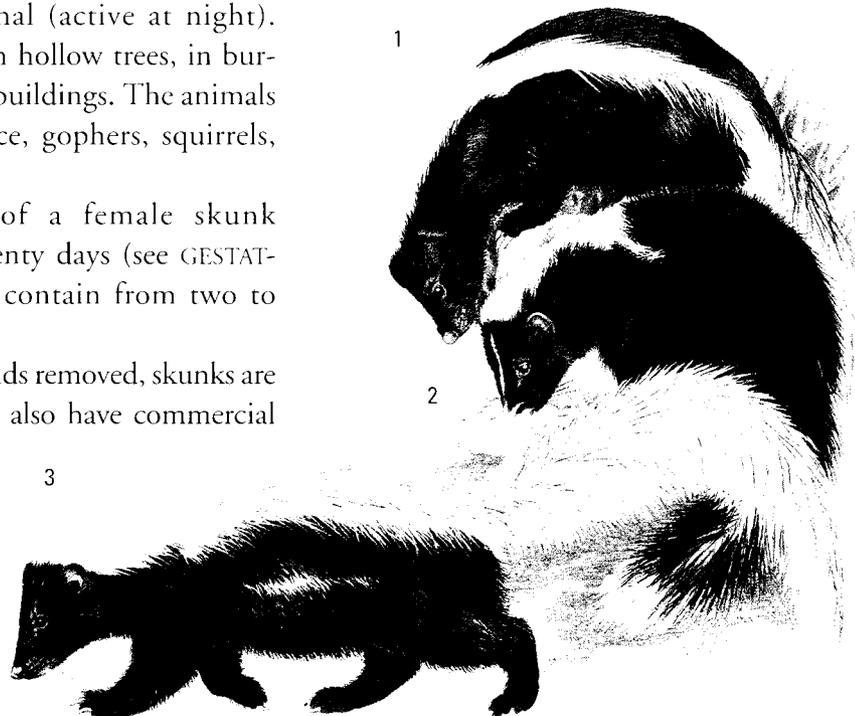
**SLATE** Slate is a fine-grained metamorphic rock (see METAMORPHIC ROCK; ROCK). Slate was formed from shale that was subjected to years of high temperature and pressure (see SHALE). Eventually, the compressed material recrystallized into slate. Slate splits easily along parallel planes into thin sheets.

The three main minerals in slate are mica, chlorite, and quartz (see MICA; QUARTZ). Most slate is black or gray. Other colors of slate include blue, red, green, and purple. These other colors occur because of impurities in the slate.

Slate is used for floors, for tabletops, and as a roofing material. In the United States, most slate is quarried in New England and Pennsylvania.

#### SKUNK

All species of skunk have black and white markings. In the common, or striped, skunk (1 and 2), there may be one or more white stripes. These can vary in thickness. The hooded skunk (3) has a white tail.



# SLEEP

Sleep is a necessary bodily activity that takes up about one-third of the lives of humans. It is also a normal part of the behavior of many other animals. Scientists do not know exactly what causes sleep, but they have learned much about what sleep is. It is a state of consciousness in which the activity of the unconscious mind takes the form of dreaming (see CONSCIOUSNESS; DREAM).

Many bodily processes change when a person is asleep. Body temperature and basal metabolic rate drop (see METABOLISM). The senses (for example, hearing) become less responsive, but they do not stop functioning. A loud noise or some other strong stimulus normally wakes a sleeping person. Sleep does not cause a person's brain to stop being active, though the brain does not carry out purposeful mental activity during sleep.

By studying the electrical activity of the brain

with an instrument called an electroencephalograph, scientists have discovered that there are at least two different kinds of sleep (see ELECTROENCEPHALOGRAPH). It is known that a normal person passes from one kind to the other kind of sleep several times in a night or sleeping period. A sleeping period for a normal adult is about eight hours.

One type of sleep, called orthodox sleep, or non-dreaming sleep, can be divided into four stages, from the lightest kind of sleep (stage 1) to the deepest sleep (stage 4). The readings from the electroencephalograph, called an electroencephalogram (EEG), show brain waves that have large, slow rhythms. These rhythms are called delta rhythms. Deep orthodox sleep generally occurs during the first two or three hours of sleep. The length of orthodox sleep may vary by individual. Some scientists believe that the repair of certain body tissues occurs during orthodox sleep. Orthodox sleep has also been shown to be involved in how the brain and the rest of the nervous system maintain their control over various parts of the body, such as the muscles (see BRAIN; NERVOUS SYSTEM).

The second type of sleep is much lighter. It is during this type of sleep that dreaming occurs (see DREAM). At this time, the muscles become very relaxed, the heartbeat and breathing are irregular, and the eyes move rapidly about. Also, the delta rhythms disappear. This dreaming sleep is called REM (rapid eye movement) or paradoxical sleep. Some scientists believe that this is the period during which brain tissue is repaired. Dreaming sleep is also important for maintaining mental abilities, such as learning and memory (see LEARNING AND MEMORY). Each period of dreaming sleep lasts from five to sixty minutes. During the night, the later periods of dreaming sleep last longer than the earlier periods. Outside events that occur during sleep—for example, noises—can affect a person's dreams. Dreams can often be remembered when the person wakes up. Dreams are most often remembered when the sleeper is awakened during dreaming sleep. However, by about ten minutes after waking, it often has become difficult for



## SLEEPING MOVEMENTS

A sleeping person does not lie in the same position all night. From time to time, during light sleep or periods of near wakefulness, the muscles become active and the sleeper turns over or moves the limbs.



#### CAT NAP

Many nonhuman mammals spend much of their time sleeping when they are not hunting. Pictured here are a lion (above), a lioness (left), and a domestic cat (below), all taking a nap.

sleepers to recall their dreams in detail.

There is some evidence that anything, such as certain drugs or stress, that greatly reduces the amount of dreaming sleep a person has may lead to mental disturbances and possibly mental illness (see MENTAL ILLNESS). Some of the effects of lack of any kind of sleep are noticeable. After staying awake for about two days, a person has a loss of energy and has difficulty concentrating and accurately performing certain tasks. The person may get angry easily and may start having hallucinations (see HALLUCINATION). After about three days, and often before, a person cannot help falling into microsleeps. These are periods of dreaming sleep that last only a few seconds. After three or four days without sleep, even the simplest mental tasks are often impossible to do.



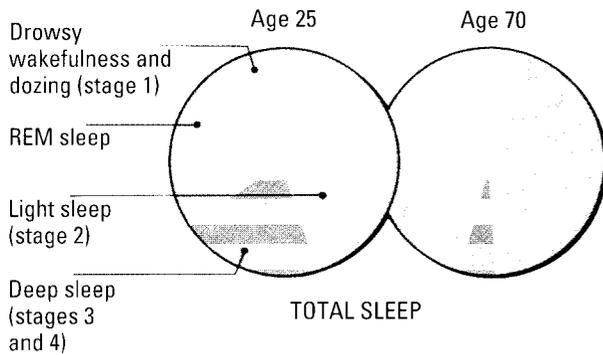
Insomnia is the inability to sleep naturally. Such sleeplessness is often associated with pain, but worry can also keep a person awake. A dark, quiet room that is well ventilated and cool helps a person relax, which is necessary for sleep to happen.

**A NIGHT'S SLEEP**

During a night's sleep, you go through cycles of changing mental activity (see charts, right). These changes can be detected by measuring a sleeper's brain waves (revealed by an electroencephalogram, or EEG) and by recording eye movements. A period of rapid eye movements, called REM sleep, is associated with dreaming.

**SLEEP AND AGE**

As a person gets older, he or she spends less time in deep sleep (stages 3 and 4) (below). A 25-year-old spends four times as long in deep sleep as does a 70-year-old. But a 25-year-old spends only one-quarter as much time dozing (stage 1). Light sleep (stage 2) stays about the same.



**TYPICAL NIGHT**

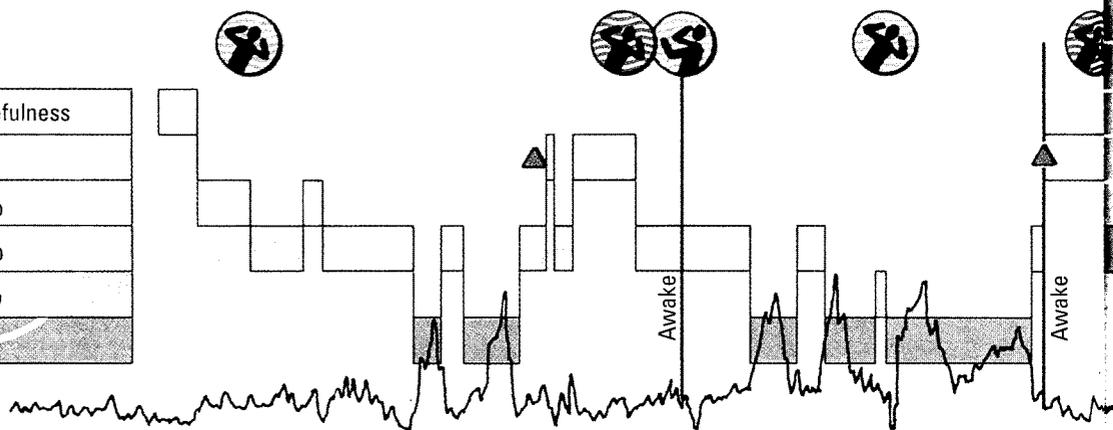
The diagram (below) shows five cycles of sleep in one night for a young adult. There is usually light sleep (stage 2) and deep sleep (stages 3 and 4) in each cycle. A change in body position often occurs after, but not during, a dream.

-  Major change in body position
-  Muscles still
-  Vivid dreams likely

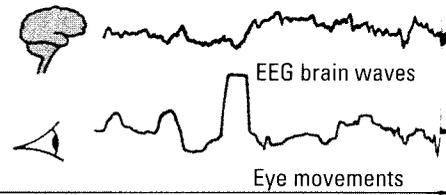
**THE STAGES OF SLEEP**

Drowsy wakefulness
REM sleep
Stage 1 sleep
Stage 2 sleep
Stage 3 sleep
Stage 4 sleep

Changes in EEG brain waves



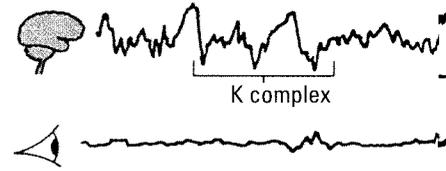
Drowsy wakefulness occurs as you fall asleep and again before you are fully awake in the morning. Also, you wake up briefly three or four times a night (at the end of each cycle of sleep), but without remembering being awake. You often turn over or move your limbs during these wakeful periods. The brain waves are regular and typical of relaxed wakefulness.



Drowsy wakefulness

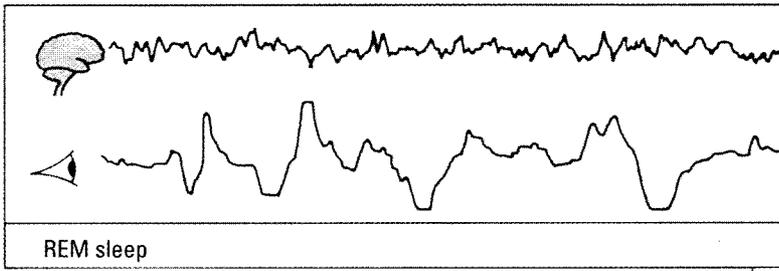
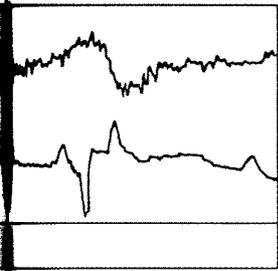
Stage 1 sleep is a very light sleep in which a person dozes, as he or she drifts in and out of sleep. As sleep takes over, the brain waves gradually lengthen, and eye movements

Stage 2 sleep is a light sleep that occupies about half of your time in bed, whether you are young or old. There may be some dreaming, but you rarely remember it. There are brain waves called K complexes immediately after REM sleep. Brain wave variations called spindles occur just before REM sleep. In both cases, eye movements and body movements are minimal.



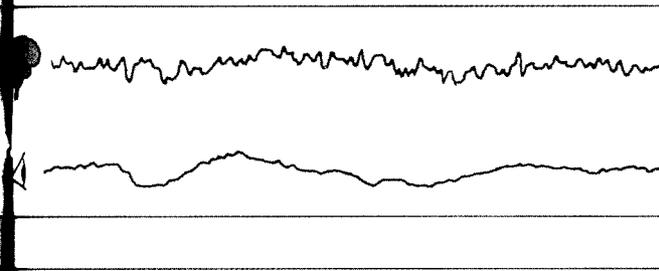
Stage 2 sleep

Stage 4 sleep is also called slow-wave sleep because the brain waves are highest and longest. The heart rate falls to its lowest values. The longest periods of stage 4 sleep occur early in the night. During later



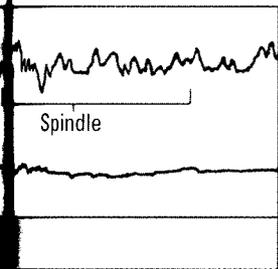
REM sleep

REM sleep, meaning rapid eye movement sleep, usually occurs when you are dreaming. The eyes move about rapidly under closed eyelids—more rapidly than when you are awake. The rate of breathing and heartbeat also become quicker. The brain waves are similar to those of stage 1 sleep. Your muscles become still, so that you do not move while dreaming.

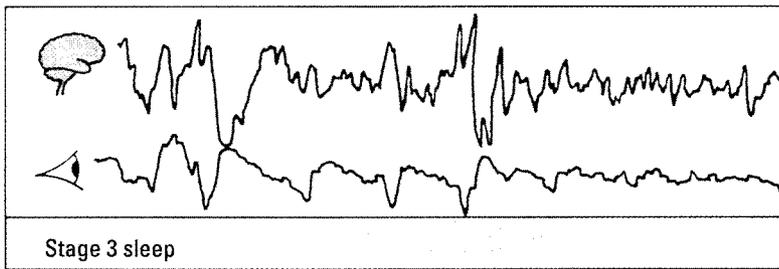


Stage 1 sleep

become slow and rolling. Breathing is more steady and even. Apart from during the first sleep cycle of the night, very little time is spent in stage 1 sleep.

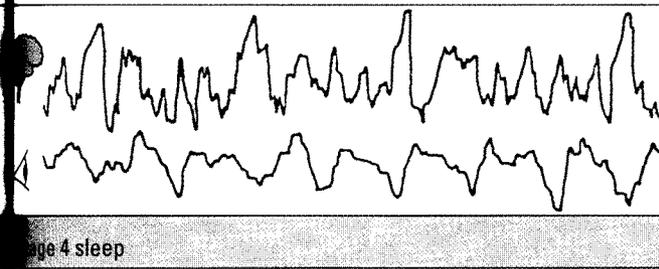


Spindle



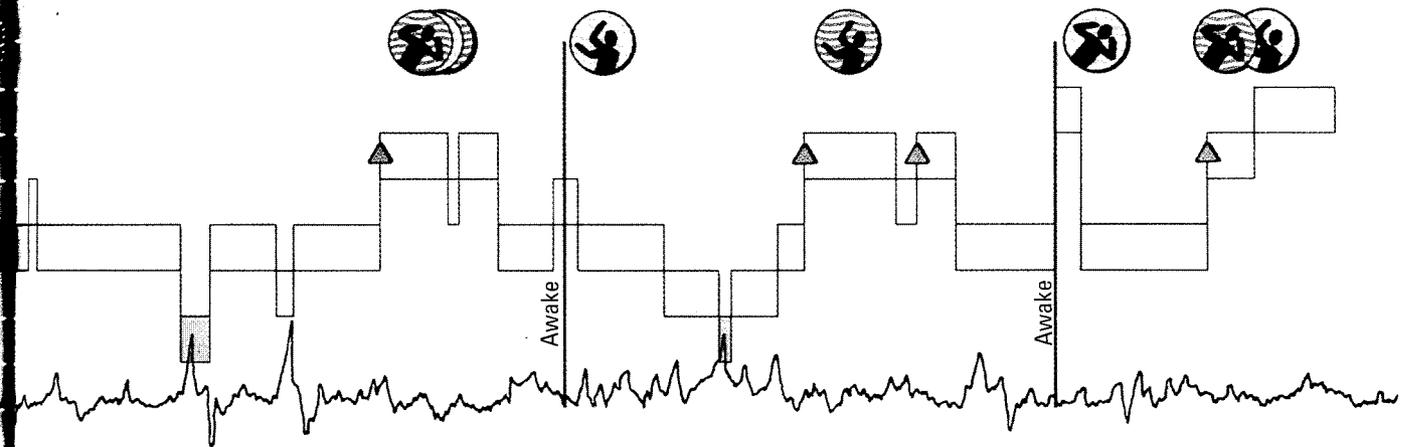
Stage 3 sleep

Stage 3 sleep is deep and restful sleep. Breathing slows down, the heart rate falls, and the muscles relax. There are no true eye movements, although the eye movement recorder responds to the brain activity. The brain waves are high and long, a pattern typical of periods of soundest sleep.

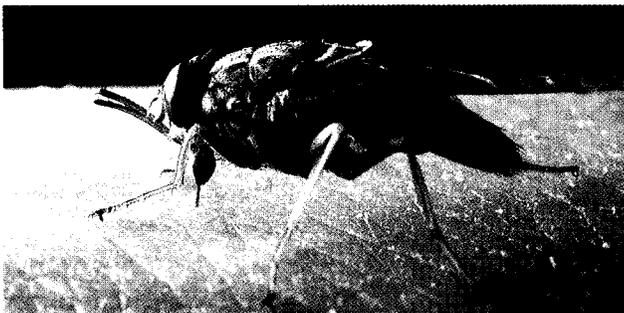


Stage 4 sleep

sleep cycles, periods of stage 4 sleep are short. There are no true eye movements and hardly any body movements. People with sleep disorders such as insomnia usually have no stage 4 sleep at all.



**SLEEPING SICKNESS** Sleeping sickness is a disease caused by infection from the protozoan (single-celled animal) *Trypanosoma* (see PROTOZOA; TRYPANOSOME). The parasite enters the body through the bite of a fly that carries it (see PARASITE). The tsetse fly in Africa and various flies in South and Central America are carriers (see TSETSE FLY). The parasite reproduces in the bloodstream and spreads to the lymph tissues and then the brain and nervous system (see BRAIN; LYMPHATIC SYSTEM; NERVOUS SYSTEM). Early symptoms of the disease are fever, a rash, and localized swelling. Once the brain is infected, signs of lethargy (lack of energy), tremors (shaking), convulsions, and coma occur, possibly leading to death (see CONVULSION). Antiprotozoal drugs are used to treat sleeping sickness. Ways to prevent infection include using insecticides to kill the fly carriers and giving antiprotozoal drugs to anyone visiting an affected area (see INSECTICIDE). Sleeping sickness can affect both human beings and other vertebrates (animals with backbones).

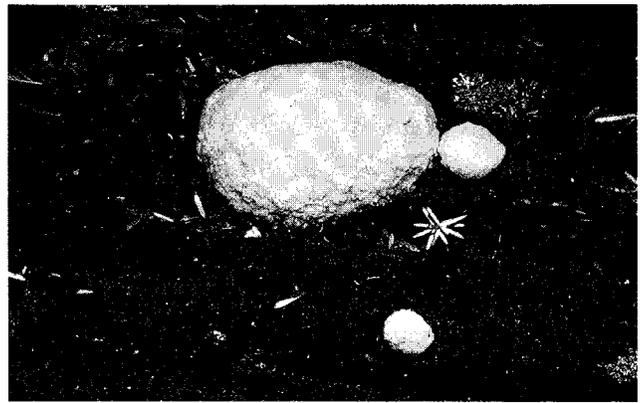


#### SLEEPING SICKNESS

In Africa, sleeping sickness is spread through the bite of the tsetse fly, which injects the disease-causing trypanosome parasite into a person's bloodstream.

**SLIME MOLD** Slime molds are a type of protist—that is, an organism belonging to kingdom Protista (see PROTISTA). Some people consider slime molds among the most interesting and unusual organisms in the world. Most have two very different stages, one in which the slime mold resembles a simple animal, the other in which it resembles a fungus.

Slime molds exist throughout the world. However, most people have never seen a slime mold. This may be because most slime molds are very small. Some varieties, though, are more than 2 ft. [60 cm] across. Most slime molds live in



#### SLIME MOLD

Most slime molds have two very different stages, one in which they resemble a simple animal and one in which they resemble a fungus.

temperate areas. They can be found in the soil, in rotting logs, or in piles of dead plant material.

There are hundreds of species of slime molds. Most slime molds have two distinctive life stages, vegetative and reproductive. The vegetative stage is characterized by a body form called a plasmodium (see PLASMIDIUM). The plasmodium is a semiliquid sheet of protoplasm, enclosed in a membrane, that oozes from one place to another under its own power (see MEMBRANE; PROTOPLASM). The reproductive stage is characterized by sporangia, or fruiting bodies (see SPORANGIUM). These sporangia are tiny, mushroom-shaped structures that usually grow on the upper surfaces of the slime mold. They produce millions of tiny, dustlike spores that are only about 0.0002 to 0.0006 in. [0.004 to 0.015 mm] in diameter. These spores may be any of several different colors and shapes, depending on the species (see SPORE).

After the spores have been released, those that land in damp places begin to grow. They swell up and grow two taillike flagella (see FLAGELLUM). The spores are now called swarm cells (see CELL). Each swarm cell swims away in search of another swarm cell. The swarm cells are gametes, or sex cells. Two swarm cells may join together to form a zygote. This zygote is the beginning of a new plasmodium (see GAMETE; ZYGOTE).

In the zygote, the flagella are permanently retracted. The cell nucleus begins to divide. It may continue dividing until the growing plasmodium has millions of nuclei (plural of *nucleus*). The plasmodium is covered with a mucuslike slime that

helps it ooze from place to place. As it moves, the plasmodium digests bacteria, molds, and other fungi (plural of *fungus*) in its path. It leaves behind a wake of dried mucus and wastes. The plasmodium may be red, yellow, orange, or cloudy white in color.

If a plasmodium is cut into several pieces, each piece can live independently. The pieces may also fuse back together into one organism. If disturbed, the plasmodium stops moving and hardens into a gel. After a while, it slowly starts moving once again. In dry weather, the plasmodium may change into a sclerotium. This is a dried, resting stage. In this form, a slime mold may live for several years. Once exposed to water, it "comes alive" and becomes a plasmodium again.

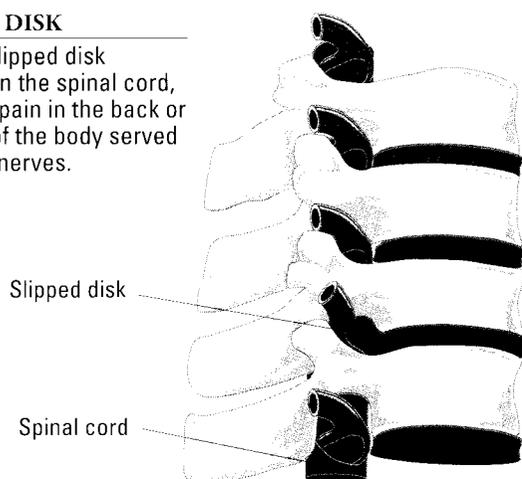
Not all slime molds follow this complex life cycle. Some slime molds are parasites that have a simpler life cycle more similar to that of a fungus.

See also FUNGUS; PARASITE.

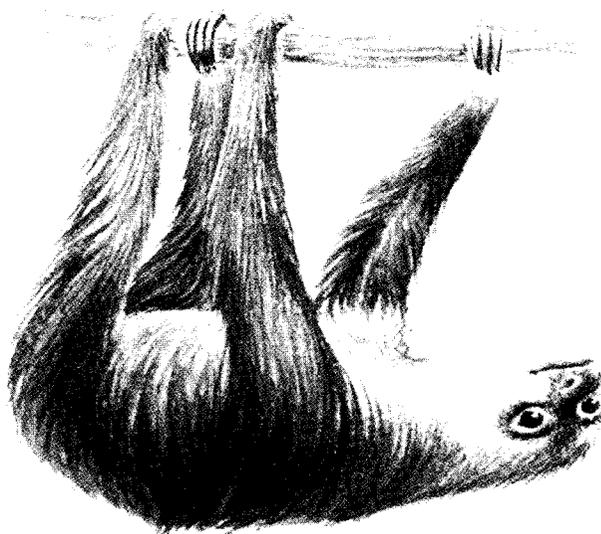
**SLIPPED DISK** A slipped disk (or prolapsed disk) is a partial collapse of an intervertebral disk. Intervertebral disks are found between the bones of the spine (vertebrae) and normally act as cushions. They contain a soft, jellylike center and a hard outer layer. Placing too much strain on the spine (such as lifting a weight incorrectly) may cause the outer layer of a disk to break, allowing the soft inner core to push through and press against the spinal cord (see SPINAL CORD). This may cause pain in the back. It may also cause pain in another part of the body, such as the arms or legs, if the pressed nerve sends signals there. The pain may be sudden,

#### SLIPPED DISK

When a slipped disk presses on the spinal cord, it causes pain in the back or in a part of the body served by spinal nerves.



or it may build up slowly. There are many possible treatments for a slipped disk, but these are complex and may be only partly effective, so it is important to avoid straining the spine.



#### SLOTH

The brown-throated three-toed sloth lives in the rain forests of South America and as far north as Panama.

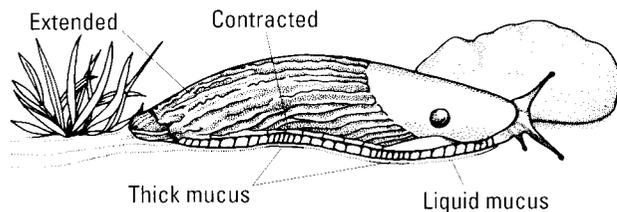
**SLOTH** *Sloth* is the name for a family of South American mammals that have a slow and unusual way of moving about. Scientists believe the sloth's sluggishness is caused, at least partly, by the animal's very low body temperature. Sloths live upside down, hanging from branches with their hooklike claws. Sloths can even fall asleep in this position. They rarely come down from the trees. They can crawl over the ground, but they cannot walk.

Sloths are often hard to see in trees because green algae covers the animal's hair, providing camouflage (see ALGAE; CAMOUFLAGE). Sloths feed on the leaves, buds, and young twigs of trees. There are two main species of sloths. The two-toed sloth has two claws on the front feet. The three-toed sloth has three claws on the front feet. Both species have three claws on the hind feet.

See also MAMMAL.

**SLUG** *Slug* is the name for any snail (class Gastropoda) that has a very small shell or no shell at all (see GASTROPOD; SNAIL). The slug has two pairs of long, slender growths called tentacles, with eyes on the outer end of the longer pair.

Most types of slugs feed on decaying matter. Many also feed on fungi (plural of *fungus*), but some feed on living plants and cause damage to crops. A few feed on earthworms. Food is usually taken in with the filelike "tongue" called the radula. Slugs are usually active only at night or after rain. They hide during the day under stones and vegetation.



### SLUG

A slug moves by extending its body over a layer of slimy mucus it produces. It then contracts part of its body, at the same time gripping mucus that has thickened. These alternate actions allow the slug to slide along.

**SMALLPOX** Smallpox, also called variola, is one of the most contagious diseases in the world. It is caused by a virus. Although this disease once caused widespread epidemics that killed thousands of people in a short time, today the disease has been wiped out through a worldwide vaccination campaign (see **DISEASE**; **EPIDEMIC**; **VIRUS**).

Like many other diseases, smallpox is probably carried by the tiny droplets shot into the air when a person coughs, sneezes, or even talks. The droplets from an infected person may find their way to the mucous membrane of the nose and throat of another person (see **MUCOUS MEMBRANE**). From such linings, the virus spreads through the rest of the body. The smallpox virus is also present in skin rashes. The disease may be spread indirectly through items such as bedclothes and utensils.

The first symptoms of smallpox appear about eight to twenty days after exposure to the virus. Symptoms often include a severe chill, headache, fever, nausea, and pains in the back, arms, and legs. Within three or four days after the disease begins, red spots appear on the skin. These spots swell, changing to blisters filled with pus. They appear first on the arms, then on the trunk, face, and legs. The location of these spots or blisters helps doctors distinguish smallpox from similar diseases. If the person with smallpox lives, the blisters dry up, and

the fever drops. Scales form and peel off, leaving reddish brown marks. These marks may stay with a person for the rest of his or her life.

In 1796, Edward Jenner, a British physician, developed a vaccine against smallpox (see **JENNER, EDWARD**; **VACCINATION**). This was the first safe and dependable form of vaccination against the disease.

In 1967, the World Health Organization (WHO) of the United Nations began a worldwide vaccination campaign against the disease. By 1979, WHO reported that smallpox had been eliminated. It recommended that vaccination be discontinued and that laboratory supplies of the virus be destroyed. By 1984, the only known samples of the smallpox virus were in special laboratories in Atlanta, Georgia, in the United States and Moscow in Russia. Destruction of these samples was planned, but late in 1993, scientists decided to allow more time to study the virus before destroying the samples.

**SMELT** A smelt is a fish that belongs to the family Osmeridae. There are several species found in North America. Most species of smelts live in the ocean and swim to freshwater rivers to spawn (see **MIGRATION**; **SPAWNING**). Some smelt have become landlocked. In other words, they are trapped in a lake or river that has no outlet to the sea. Landlocked smelt that live in large lakes usually swim up a river that flows into the lake to spawn. Fishers using hand nets in shallow water are able to catch large numbers of smelt when they are moving upstream.

One of the best-known smelts is the rainbow smelt, which is found in fresh water and in the Atlantic and Pacific oceans. It grows to a length of 8 in. [20.3 cm] and has a slender body. The mouth of the smelt is large, with many teeth. The rainbow smelt eats worms, insects, small crustaceans, and fish.

See also **CRUSTACEAN**.

**SMELTING** Smelting is the heating of minerals and ores to extract metal from them (see **METAL AND METALLURGY**; **MINERAL**; **ORE**). In ores, metal is found in combination with other materials. It is

**SMELTING**

In a smelting plant, workers use a scoop at the end of a long arm to load the furnace with an ore, a reducing agent (such as coke), and a flux (such as limestone).



found as various salts and as oxides (see OXIDE; SALT). By heating the ore, mixed with a reducing agent, the compounds can be converted to the metal (see COMPOUND; OXIDATION AND REDUCTION). A material called a flux is also added to the mixture to be smelted. A flux is material that prevents the molten (melted) metal from immediately turning into its oxide again. The flux combines with impurities and separates out to form a waste material called slag. The molten metal and the slag can be drawn off from the smelting furnace separately (see FLUX).

A good example of smelting is the extraction of iron from its ores. The lumps of iron ore, mixed with coke (a reducing agent), and limestone (a flux), are heated to a high temperature in a blast furnace (see BLAST FURNACE). The unwanted slag settles out on the surface of the molten mixture. The liquid iron can be run off from beneath the slag layer. The ores of copper, silver, and lead are smelted in a similar way to yield the metals. In the case of aluminum, the smelting is done by electrolysis of the oxide at a very high temperature.

See also ELECTROLYSIS.

**SMOG** Smog is a type of air pollution (see AIR; POLLUTION). The word *smog* originally referred to a mixture of smoke and fog that was common in southern England. The fog is natural to the climate

there. However, the smoke came from coal-burning furnaces and stoves used in factories and homes. When certain weather conditions existed, smog would remain in the air rather than blow away. Between December 5 and 9, 1952, a thick cloud of smog blanketed London and caused the death of about four thousand people. The British government then passed laws to keep industry and homes from releasing large amounts of harmful smoke into the air.

In the United States, *smog* has taken on a new meaning. The smog in the United States results from a chemical reaction that occurs when certain polluting gases mix with warm sunlight. This type of smog is called photochemical smog. It forms mainly from hydrocarbons and nitrogen oxide gases, such as nitrogen dioxide, in the air. A major source of the hydrocarbons and nitrogen oxide gases is the exhaust from automobiles. This mixture is then struck by the ultraviolet rays in sunshine and undergoes a chemical reaction to produce gases known as oxidants. Ozone is the most abundant oxidant (see HYDROCARBON; ULTRAVIOLET RAY). Photochemical smog has a brown color, caused by the nitrogen dioxide.

Smog is unhealthy. It makes the eyes water and feel irritated. Breathing smog causes coughing, painful breathing, and shortness of breath. It also reduces the amount of oxygen in a person's blood.

**SMOG**

Smog is a serious problem in many cities, including Mexico City (left). Smog forms when certain gases, such as those in automobile exhaust, react with warm sunlight.

This, in turn, makes the person's heart beat faster. Often, people with weak hearts suffer heart attacks after breathing large amounts of smog. Over three thousand cases of cancer each year are linked to smog. Doctors advise people to stay indoors and avoid physical activity during periods of heavy smog. Smog also kills many trees, flowers, and other plants.

Smog is now the worst air-pollution problem in the United States. Smog is most abundant around cities and busy highways, where many automobiles travel. Smog also is most abundant during summer, when the sun shines longer each day than it does at other times of the year. Los Angeles, California, has the worst smog problem in the United States, due to its large number of automobiles and year-round sunny climate. Forests near Los Angeles have been badly damaged by smog. California and most other states require new automobiles to have special pollution-control devices such as catalytic converters. These devices reduce the amount of pollutants in automobile exhaust. In 1989, California's South Coast Air Quality Management District established a plan to try to reduce smog levels by 70 percent by the year 2000. The plan makes it illegal to sell or use certain products that give off hydrocarbons or other pollutants in the Los Angeles area. These products include certain charcoal lighter fluids, paints, solvents, hair sprays, and deodorants. The plan also calls for a reduction in the amount of driving, a switch to electric cars or those that run on gasohol or reformulated gasoline, and controls on businesses that offer "drive-through" services.

The U.S. government also has taken major steps toward reducing smog. The Clean Air Act of 1990 requires lower levels of pollutants to be released by automobiles, factories, and power plants by the year 2000. The law requires the use of gasohol and reformulated gasoline and requires the sale of cars that use the new fuels.

*See also* GASOLINE; OZONE LAYER.

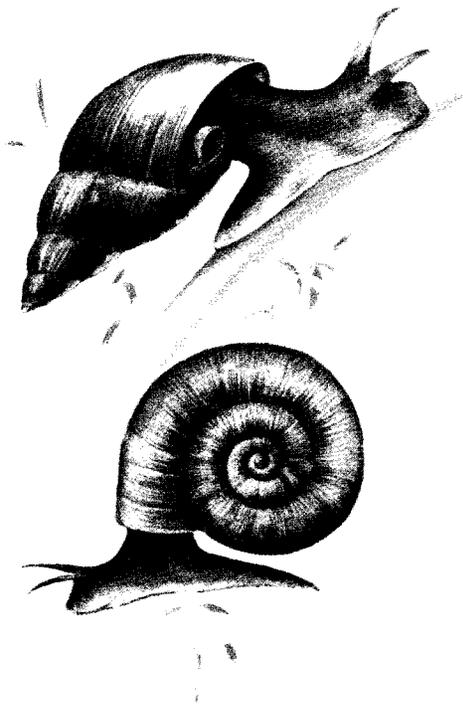
**SMOKE** Smoke is a visible cloud of airborne particles consisting of finely divided solid and liquid substances produced by combustion or a chemical reaction (see CHEMICAL REACTION; COMBUSTION). When fuel is burned, the smoke is made up mostly of particles of carbon. These blacken buildings, produce corrosion, and damage vegetation (see CORROSION). Smoke also harms lungs. Smoke particles are less than four hundred-thousandths of an inch [one millionth of a meter] in diameter.

Smoke can contribute to air pollution, especially when a layer of warm air settles over a layer of cooler air nearer the ground (see POLLUTION). This process is called thermal inversion. It traps the cool air, causing a dense, smoky fog, also known as smog (see SMOG). Smoke does have some beneficial uses. Smoke from a wood fire is used to preserve fish and meat. It is also used to protect orchards from frost. Colored smoke is used for military signals.

**SMOKING** Smoking is the breathing in (inhalation) of tobacco smoke using a pipe, cigar, or cigarette (see TOBACCO). Smoking tends to relax people who smoke and makes them feel less tense.

Tobacco smoke contains nicotine, which is addictive, so once a person starts smoking, it is difficult to stop (see ADDICTION). More importantly, smoking greatly increases the risk of getting lung cancer, as well as other lung diseases such as bronchitis and emphysema (see BRONCHITIS; CANCER; EMPHYSEMA; LUNG). It also increases the chances of developing heart disease (see HEART DISEASE). Those around the person smoking often must breathe in the smoke, thus running the same health risks as smokers. This is called passive smoking. Because of nicotine's addictive properties and the huge sums of money spent on tobacco advertising, thousands of people start smoking each year. Many thousands also die each year because of smoking. It is far better not to start smoking, or to quit, than it is to smoke.

**SNAIL** The snail is a slow-moving mollusk belonging to the group known as the gastropods (see GASTROPOD; MOLLUSCA). There are about eighty thousand kinds of snails. They are found all over the world and in all kinds of terrestrial and aquatic habitats. Snails feed on plant and animal matter, which they chew up with a rasplike tongue



**SNAIL**

There are about eighty thousand different kinds of snails, found in all locations and climates. Two common freshwater snails are pictured above—the pond snail (top) and the ram's horn snail (bottom).

called a radula. There are three main groups of snails. Prosobranchs have gills and coiled shells. Opisthobranchs are less coiled and often do not have shells. Pulmonates breathe by means of simple lungs (see GILLS; LUNG). The prosobranchs and opisthobranchs nearly all live in water, but many pulmonates live on land.

Land snails live mostly in damp places, such as in shady parks and gardens, under logs and stones, and in woodlands. A few species, however, live in the driest of deserts. Most land snails have shells and are pulmonates. The snails without noticeable shells are called slugs (see SLUG). As the land snail moves, it secretes a thin, sticky fluid called mucus. This substance lets the animal slip along easily. It also acts as a protection against injury. Land snails can even move over such materials as glass and sharp stones without getting injured. If land snails cannot find enough moisture to suit their needs, they become dormant, or inactive. They draw back into their shells and seal off the opening of the shells. When the outside air becomes moist enough, the snails come out of their shells and are active again.

Most land snails are hermaphrodite, having both male and female reproductive systems in one individual (see HERMAPHRODITE). Eggs are usually laid in damp places.

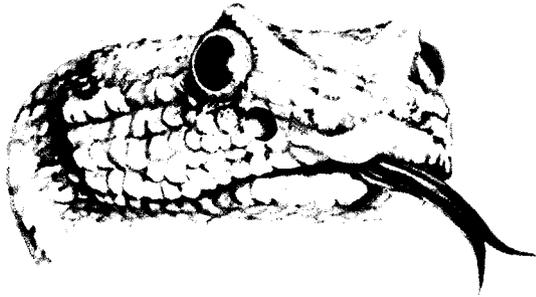
Some snails found in fresh water have lungs. These animals come to the surface for air. Other types have gills. They can breathe without coming to the surface. Many freshwater snails lay eggs. Some, however, give birth to live young.

Marine (saltwater) snails have gills. The females usually lay eggs that develop in the water. The limpet, periwinkle, and whelk are types of marine snails (see LIMPET).

Although most snails are harmless, some snails, such as the cone snails, are poisonous. Some snails spread pathogens—organisms that cause disease in humans. Others cause extensive crop damage. Some kinds of freshwater snails are used to keep aquariums clean. The marine whelks and periwinkles are widely used as human food, and some land snails are also prized as a food delicacy—frequently called *escargot*.

**SNAKE** Snakes are long-bodied reptiles that have no legs (see REPTILE). The absence of legs may be a result of passing through a burrowing stage during evolution (see EVOLUTION). Snakes are closely related to lizards (see LIZARD).

Snakes live in almost all parts of the world. However, most species of snakes live in tropical



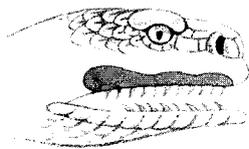
**SNAKE—Heat-sensitive pits**

The snake above is called a pit viper because of the heat-sensitive pits on the sides of its face (only one pit shows in this picture). The pits help the snake locate warm-blooded prey in the dark.

regions. Only one—the European adder—lives beyond the Arctic Circle (see ADDER). Snakes vary widely in size. A full-grown garter snake measures about 6 in. [15 cm] in length, while full-grown reticulate pythons may have a length of more than 30 ft. [9 m].

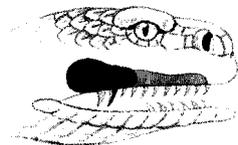
The snake's long and slender body has more ribs and vertebrae (bones of the backbone) than do other backboned animals. The snake is therefore very flexible. The internal organs are modified to fit into the narrow body. For example, the left lung is extremely small or missing altogether. In some species, the right lung runs nearly the whole length of the body.

Vestigial (poorly developed) limbs are present in the boas, pythons, and a few primitive snakes. Eyelids are absent. The eyes are covered by a transparent scale called a brille or spectacle, which keeps out dirt.

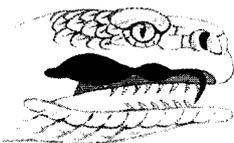


**SNAKE—Teeth**

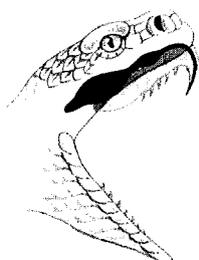
There are four types of teeth in poisonous snakes. The teeth can be all the same shape and size and have weak venom (left).



Back-fanged snakes have venom that flows along open grooves in fangs at the back of the mouth (left).



Front-fanged snakes have a pair of long, hollow fangs at the front of the mouth that inject venom into prey (left).

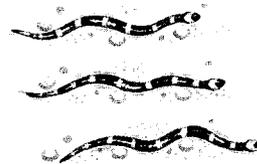


Some front-fanged snakes have hinged fangs. The fangs are very long and fold back in the mouth when the jaws are closed. When the mouth is opened, the fangs swing down and forward (left).

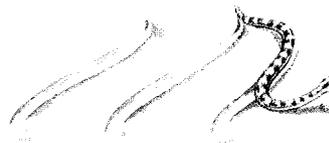


**SNAKE—Movement**

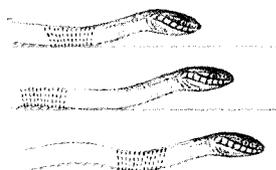
Snakes use four methods to move. Concertina (left): The snake pulls up its body while gripping the ground under its head. Then, while holding the ground with its tail, it throws its head and body forward.



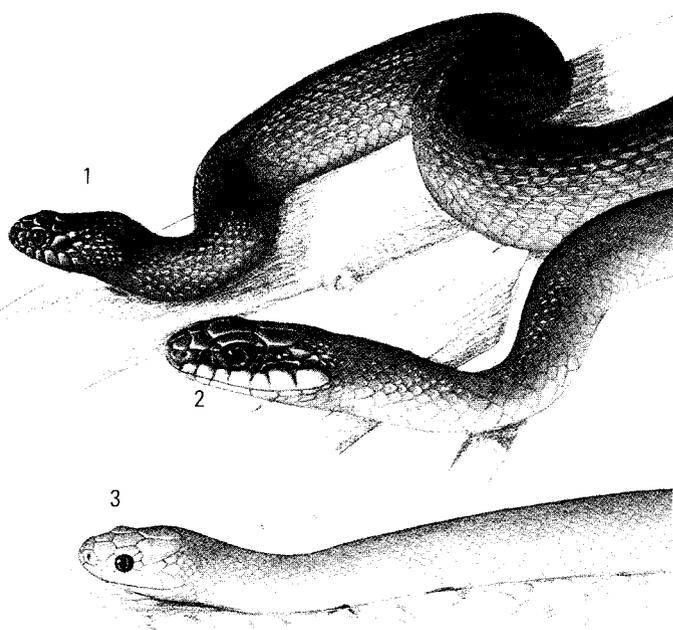
Serpentine (left): The snake creates waves in its body. These press against stones and bumps in the ground, pushing the snake forward.



Sidewinding (left): A few snakes move sideways in a series of steps. This can be a very fast form of movement.



Traction (left): Broad scales on the underside of the snake's body grip the ground. By contracting and expanding parts of the body, the snake drags itself along the ground in a straight line.



#### SNAKE—Nonpoisonous snakes

Not all snakes have poisonous bites. Pictured here are (1) the red-bellied water snake and (2) the racer, both from North America, and (3) the African house snake, which is often a harmless visitor to people's homes.

Snakes are carnivorous (meat eating), feeding mainly on small mammals. They rely mainly on scent to find prey. Snakes often flick their forked tongues in and out. The tongue aids in the sense of smell by collecting scent particles from the air and transferring them to the Jacobson's organ in the roof of the mouth. This special sense organ detects traces of scent. The pit viper also finds prey with the help of heat-sensitive pits in its face.

Some snakes are poisonous. The venom, or poison, is formed in modified salivary glands and carried down the teeth when the snake bites its victim. Some poisonous snakes have fangs (long teeth) at the back of the mouth. These snakes are generally harmless to human beings, because they cannot inject venom rapidly into large animals such as humans, although the African boomslang is a notable exception. Snakes with fangs at the front of the mouth, such as the cobra and mamba, are much more dangerous to humans. Poisonous snakes usually strike at their prey and then wait for it to collapse before they eat it.

Constrictor snakes, which are nonpoisonous, strike their prey with their teeth. If the prey is large,

these snakes wrap their bodies around it, thereby squeezing the prey until it suffocates.

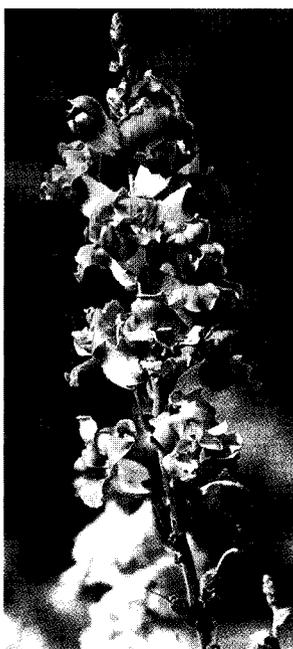
The snake can swallow large animals without chewing them. A snake's jaws are loosely attached to the skull, and the two halves of the lower jaw are connected only by stretchable tissues called ligaments (see **LIGAMENT**). The mouth can open very wide. The snake gradually works its mouth over its prey. While doing this, the snake breathes by bringing the windpipe opening forward to the front of the mouth. Swallowing and digesting a large animal may take a long time, and some larger snakes probably have only a few meals every month.

Most snakes lay eggs, but some species, especially those that live in cooler climates, give birth to live young. Adders often sun themselves for long periods to warm up the developing young inside them.

In temperate zones, snakes may hibernate in the winter (see **HIBERNATION**). When necessary, a snake may estivate, or pass the summer in inactivity. Some snakes grow a complete new skin several times a year. They slip out of the old one, turning it inside out, and leave it behind like a hollow tube. This process is called molting.

*See also* **MOLTING**.

**SNAPDRAGON** The snapdragons are flowering plants that belong to genus *Antirrhinum* of the snapdragon, or figwort, family. They are native to



#### SNAPDRAGON

The snapdragon is a popular garden plant grown for its colorful two-lipped flowers.

western North America and Europe. Snapdragons are commonly cultivated in gardens for their colorful two-lipped flowers. The flowers may be various shades of white, yellow, or purple. The two-lobed upper lip and the three-lobed lower lip are usually so tightly closed that most insects cannot get inside. Only a few species of bees are able to pollinate these flowers (see POLLINATION).

See also FLOWER.

**SNOW** Snow is tiny crystals of frozen water that falls from the sky (see CRYSTAL). Snow forms when water vapor in the air crystallizes (see VAPOR). The crystals are usually hexagonal (six-sided). However, they may form an infinite variety of shapes. No two snowflakes are exactly alike.

The air temperature between the clouds and the ground must be at or below 32°F [0°C], the freezing point of water, for snowflakes to form. If the temperature is near or at the freezing point, the

snowflakes are large and wet. At colder temperatures, the snow is fine and dry. If the ground is cold enough, the snow may collect and get very deep (see PRECIPITATION). Freshly fallen snow reflects about 95 percent of the sun's heat back into space. This is one reason why the temperature often drops so low on winter nights.

Snow has a number of benefits. Accumulated (collected) snow insulates plants and hibernating animals during the severe winter months (see HIBERNATION). Mountain snow is an important water source for rivers when the snow melts in the

#### SNOW

The air temperature between the clouds and the ground must be at or below 32°F [0°C] for snowflakes to form. If the ground is cold enough, the snow will collect (below), becoming a nuisance for people and road traffic. But a snow scene can also be beautiful, as in the picture (right) showing snow-covered boulders in Yellowstone National Park, Wyoming.



spring. Snow also provides a natural method of fertilization. When snowflakes are formed, some nitrogen from the air is contained in each flake. Later, when the snow melts, some of this nitrogen enters the soil along with the water. This nitrogen is used by plants for growth (see FERTILIZER; NITROGEN).

Permanent snow exists at the North and South poles, in Greenland, and on some mountaintops. Snow falls during the winter in most regions with moderate climates. In the United States, heavy snowfalls are usually associated with blizzards and other winter storms. A blizzard is a storm with high winds and temperatures well below freezing, as well as large amounts of snow. The snow is blown about by the fierce winds, making it difficult to see anything at a distance. The snow may be blown into huge piles called drifts. Such a storm can bring people's normal activities to a standstill.

**SNOWDROP** *Snowdrop* is the common name for several herbaceous plants belonging to genus *Galanthus* of the amaryllis family (see AMARYLLIS FAMILY; HERBACEOUS PLANT). Snowdrops grow in wooded areas in parts of Europe and Asia. They grow from bulbs and have two or three small leaves and a short stalk with a flower at the top. The white flowers have three sepals and three petals (see FLOWER).

The giant snowdrop and the common snowdrop are popular garden flowers that bloom in early spring.



#### SNOWDROP

Snowdrops bloom in early spring. They grow from bulbs and, after two or three years, form large clumps as the bulbs multiply.

**SNOW LEOPARD** The snow leopard, also known as the ounce, is a large, heavily furred cat. It lives in the Himalayas and other mountain ranges of central Asia. The animal is rarely found below an altitude of 6,000 ft. [1,800 m]. The snow leopard has a soft coat, which is pale gray with dark splotches and a dark streak along the spine. The underparts are whitish. The cat grows to be about 7 ft. [2.1 m] long, including the 3-ft. [0.9-m] tail. A snow leopard weighs from 50 to 90 lb. [23 to 41 kg]. The female has a gestation period of about ninety days (see GESTATION PERIOD). Each litter consists of two to four young. Snow leopards hunt at night, feeding on various animals, such as wild sheep and domestic livestock.

Snow leopards have been widely hunted for their fur. There are so few snow leopards left that they are now classified as an endangered species.

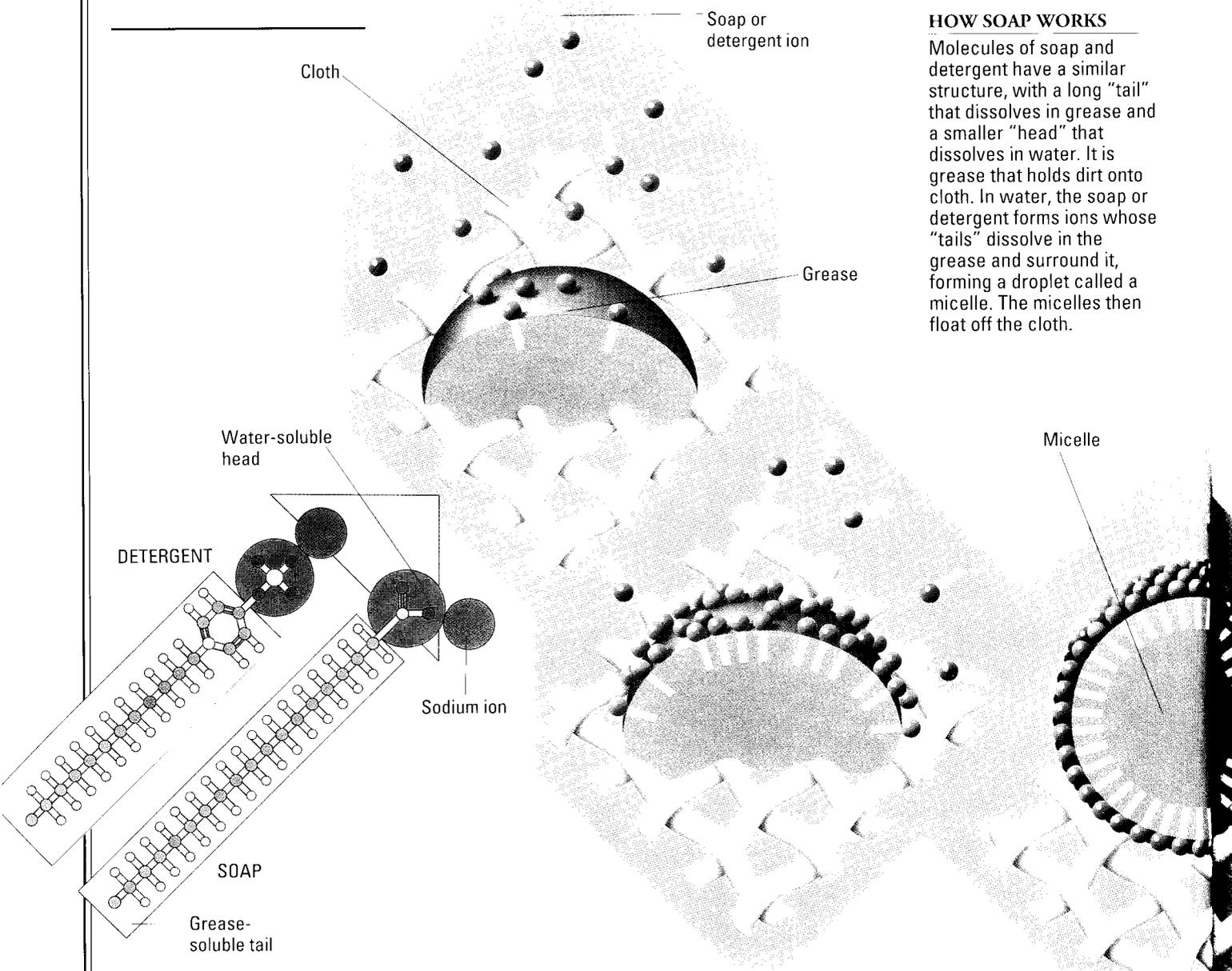
See also ENDANGERED SPECIES.



#### SNOW LEOPARD

The snow leopard lives in the high mountains of central Asia. It is an endangered species.

# SOAP



## HOW SOAP WORKS

Molecules of soap and detergent have a similar structure, with a long "tail" that dissolves in grease and a smaller "head" that dissolves in water. It is grease that holds dirt onto cloth. In water, the soap or detergent forms ions whose "tails" dissolve in the grease and surround it, forming a droplet called a micelle. The micelles then float off the cloth.

Soap is one of the most common cleansing agents used by humans. Soap has a different chemical makeup than detergent (see **DETERGENT**). People use soap to clean their skin, their clothing, and many other objects. Soap is made by boiling fats or oils together with an alkali (see **ALKALI**; **FAT**).

Washing with water and soap includes a number of complicated processes: wetting action, emulsifying action, dispersing action, and stabilization.

Water by itself does not get through a dirty or oily surface easily. Soap makes water "wetter" by lowering its surface tension (see **SURFACE TENSION**). This helps the water pass into and through the dirt and oil and remove them. Liquid molecules of soap scatter throughout (emulsify) the oil molecules so that they

float away with the wash water. Parts of the soap molecules actually surround each oil molecule to do this. Soap also disperses (separates) dirt into fine particles that are carried away by the wash water. Some soils do not dissolve easily in water. Soap works on these soils and slowly absorbs them into the suds in a process called stabilization. Other actions, such as agitating, squeezing, or rubbing, help loosen dirt and oil so that they can float off in the wash water.

**How soap is made** Soap is made by two basic methods: the kettle method and continuous processing. In the kettle method, large kettles measuring 15 to 30 ft. [4.5 to 9 m] in diameter and 45 to 60 ft. [13.5 to 18 m] in height are used. One kettle

can produce ten carloads of soap from a single batch of ingredients. Fats, oils, and sodium hydroxide are piped into the kettle. Steam pipes heat the mixture to a quick boil. After several days, the heat is turned off, and tons of salt or brine (salt solution) are added. The mixture is reheated, and it separates into two layers. The upper layer, called neat soap, contains about 70 percent soap. The lower layer, called nigre, contains 15 to 40 percent soap, glycerin (a useful by-product), and remaining fats, dirt, and coloring matter.

The kind of soap that is made depends upon the raw materials that were put into the kettle. Animal fats, such as grease and tallow, produce hard soaps that do not lather in cold water. Vegetable oils make soaps that lather in cold water but feel greasy. Most soaps are made with a mixture of animal and vegetable fats. Soft soaps, such as those used in shaving creams, are made by using potassium hydroxide instead of sodium hydroxide as an alkali.

The neat soap is drawn off from the kettle and poured into a giant mixing machine, which is called a crutcher. The crutcher blends in other ingredients, such as perfumes, water softeners, colors, and germicides (substances that kill harmful organisms such as bacteria). The soap from the crutcher is then used to make various forms of soap, including soap bars, soap flakes, and powdered soaps.

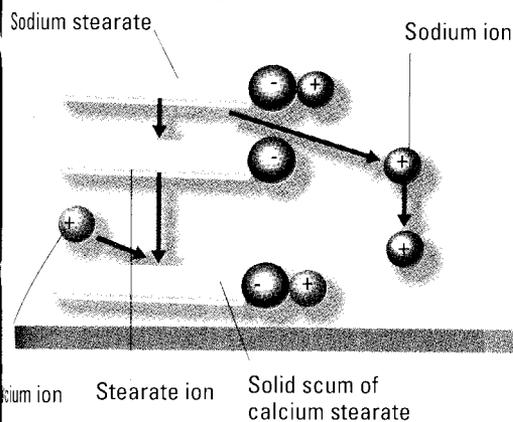
Continuous processes of making soap were developed in the 1930s. They save time and space, compared to the kettle method, and make

it easier to recover the glycerin by-product. One type of continuous processing hydrolyzes (splits) the fats in a wide, stainless steel tube that is 80 ft. [26 m] high. Fats are pumped in near the bottom, and distilled water enters near the top. The mixture is put under pressure, and the temperature is raised to 500°F [260°C]. The fats rise in the tube until they meet the water. The water separates the fatty acids and glycerin, which are drawn off through separate openings. The fatty acids pass on to mixers where sodium hydroxide is blended in to make soap. Another method, called the Sharples process, mixes hot fats and oils with a hot sodium hydroxide solution in a chamber. A centrifuge then separates the soap and other by-products (see CENTRIFUGE).

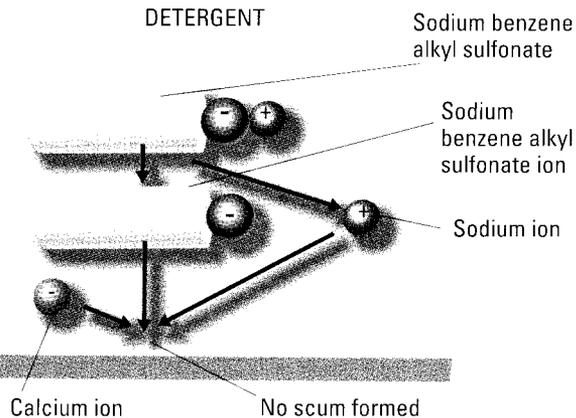
**History** The first crude soaps were made in Italy around A.D. 600. Fats or oils and potash (potassium carbonate) were the ingredients. Around A.D. 700, Spain became known for its fine castile soaps, which used olive oil instead of animal fat as a base. For the next several hundred years, France became the major soap maker in the world. The French pioneered the use of perfumes and coloring agents in soap. In colonial America and in the 1800s, people saved all household fats and greases. They boiled them together with a lye made from wood ashes to produce a strong yellow soap (see LYE).

Today, American soap companies are constantly developing new soap products to keep up with buyers' needs. The average American uses 25 lb. [11 kg] of soap a year.

### SOAP



### DETERGENT



### SOAP AND DETERGENT

Soap consists of sodium stearate. In water, it forms stearate ions, which react with calcium ions in hard water to form a scum of calcium stearate. Detergent is a salt of a sulfonic acid. It forms sulfonate ions in water. These ions do not react with calcium ions, and as a result, no scum is formed.

**SODIUM** (sō'dē əm) Sodium (Na) is a common metallic element that is silver colored, soft, and easy to cut (see ELEMENT). It is very reactive and oxidizes very quickly in air and loses its shiny appearance (see OXIDATION AND REDUCTION). When it comes into contact with water, it reacts violently. It gives off hydrogen gas, which burns. To store pieces of the metal, it is necessary to keep them away from both air and moisture. This is normally done by keeping them in containers, under kerosene or another light oil.

Sodium is so reactive that it is never found free in nature. It is always combined with other elements in compounds (see COMPOUND). The earth's crust is made up of about 2.8 percent sodium, and sodium salts are abundant. The principal salt in sea water is sodium chloride (see SALTS; SODIUM CHLORIDE).

Sodium metal is a very good conductor of electricity (see CONDUCTION OF ELECTRICITY). Because it is so reactive, it cannot be used to make wire by itself. However, cables of sodium sheathed (covered) in copper are sometimes used to carry a very heavy current. Sodium metal is prepared by the electrolysis of molten sodium chloride or sodium hydroxide (see ELECTROLYSIS).

Liquid sodium is used as a cooling fluid in some kinds of nuclear reactors. Sodium vapor is used in some street lights and automobile lights. It glows bright yellow when an electric current is passed through it.

Sodium compounds have many uses. Chile salt-peter is sodium nitrate (see SALTPETER). It is found in deposits under the ground in South America and is used as a fertilizer in agriculture (see FERTILIZER). Sodium tetraborate, also called borax, is used as a water softener (see BORAX). Various sodium compounds are also used in fire extinguishers and soft drinks, as food preservatives, and for flavoring various foods.

Sodium has the atomic number 11 and the relative atomic mass 22.9898. Sodium melts at 208°F [98°C] and boils at 1,621°F [881°C]. The chemical symbol for sodium, Na, is short for the Latin name *natrium*. Sodium has a valence of 1 in its compounds (see VALENCE). The element was

discovered by Sir Humphry Davy in 1807.

See also DAVY, SIR HUMPHRY; SODIUM BICARBONATE.

**SODIUM BICARBONATE** (sō'dē əm bī kār' bə nāt') Sodium bicarbonate is a white crystalline powder used to make baking powder. It has the chemical formula  $\text{NaHCO}_3$ . Like all carbonates and bicarbonates, it reacts with acids to form carbon dioxide gas (see ACID; CARBON DIOXIDE). Some kinds of seltzer tablets contain a dry mixture of sodium bicarbonate and a harmless acid, such as citric acid. When the mixture is dissolved in water, the compounds react to make a fizzy drink (see COMPOUND). The carbonate helps neutralize excess acid in the stomach. Baking powder makes dough rise by giving off carbon dioxide bubbles when heated.

Some kinds of fire extinguishers contain sodium bicarbonate and a glass container of acid. Striking the nozzle of the extinguisher breaks the glass, releasing large volumes of carbon dioxide gas under pressure. The carbon dioxide pushes out a jet of fireproof liquid, which can be directed at the fire to smother it (see FIRE PREVENTION).

See also SODIUM.

**SODIUM CHLORIDE** (sō'dē əm klôr'īd') Sodium chloride is best known as common salt. It has the chemical formula  $\text{NaCl}$ . Sodium chloride is a very common compound, found in many forms on Earth. It is found in sea water, which contains about 3 percent sodium chloride. The Dead Sea, an inland sea, contains about 22 percent sodium chloride. Concentrated solutions of sodium chloride and water, or brine, occur naturally underground. Lumps of sodium chloride, called rock salt, are also found in the ground (see ROCK SALT). In some parts of the world, there are huge underground deposits of salt that can be mined. These are probably the remains of inland seas that have dried up.

Sodium chloride has many uses. It may be used to prepare metallic sodium (see SODIUM). It is used in making soap and to preserve hides in leather making (see SOAP). Sodium chloride is also used in the ceramics industry, to produce a glaze finish on pottery. In winter, sodium chloride may

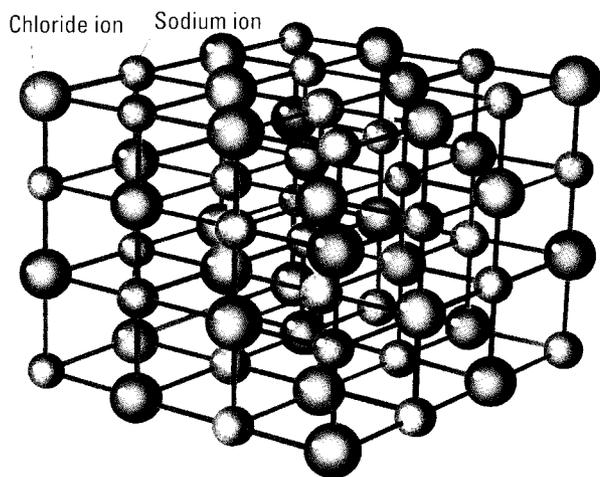
be used to help melt ice and snow on roads.

Sodium chloride, also called table salt, is used to preserve fish and other meat and to flavor food. Table salt has small quantities of additives. Magnesium carbonate is added to soak up water and to keep the salt dry and free running. Potassium iodide is added to make sure there is iodine in the diet. Iodine prevents the development of goiter, a disease of the thyroid gland (see IODINE).

Sodium chloride is present in the blood of animals in a concentration of about 0.6 percent, and it is found in tears, sweat, and other body secretions. Humans must eat small quantities of salt to stay healthy. On the other hand, too much salt can upset the body chemistry. It may be a factor in high blood pressure.

See also CHLORIDE; DIET.

## PROJECT 8



### SODIUM CHLORIDE

An ion is an atom (or group of atoms) that has lost or gained one or more electrons, leaving it with a negative or positive charge. Sodium chloride forms crystals in which sodium ions and chloride ions are bonded together in a cubic arrangement (called a crystal lattice). The ions separate when sodium chloride dissolves in water.

**SOFTWARE** *Software* refers to the programs, or sets of instructions, used by computers (see COMPUTER). Some scientists also include the data (information) that the computer manipulates in the definition of software. In contrast, *hardware* refers to the electronic and mechanical devices, such as a keyboard and disk drive, of a computer.

Some kinds of software are called systems programs or operating programs. Such programs provide the basic instructions that the computer needs

in order to perform. For example, a systems program may tell a computer to display letters, numbers, or other symbols that have been pressed on a keyboard. Systems programs are often stored in the part of the computer memory called read-only memory (ROM).

Other kinds of software are called applications programs or processing programs. Such programs provide the instructions the computer needs to perform the special tasks that the operator requests, such as word processing. Applications programs are often stored in the random-access memory (RAM).

Applications programs can be written in various "languages," depending on what the programs are used for. For example, FORTRAN is a language that is used for complex business, technical, and scientific programs for minicomputers or microcomputers. *FORTRAN* is short for "*formula translation*." BASIC is a language that is used to write simple programs for minicomputers or microcomputers. *BASIC* is short for "*beginner's all-purpose symbolic instruction code*." The person who is writing the program learns the rules and vocabulary of the language. He or she can then write a detailed program that tells the computer exactly what to do and how to do it. Once the computer receives these instructions, they are manipulated by a systems program called a language translator. A language translator changes the program into a form that the computer hardware understands.

Writing software is often a difficult job that is left to trained experts. However, the computer industry is developing ways to make writing software easier. For example, special languages called authoring languages have been developed. Authoring languages allow people who are not trained experts to write software. Authoring languages often work by asking questions of the user to lead him or her through the writing of a particular software. Some software, such as neural networks, also makes use of artificial intelligence (see ARTIFICIAL INTELLIGENCE). Artificial intelligence means that the software can "think" and "reason." This means that the software can "remember" its past mistakes and not make them again. It gets better at solving problems by learning from experience.

# SOIL

Soil is the granular (consisting of grains) material that forms the top layer of much of the land on Earth. Soil is made up of ground-up rocks, minerals, organic (carbon-containing) matter, water, and air. Soil is necessary for life on Earth. Plants need soil to grow. Animals, including humans, eat the plants (see **FOOD CHAIN**).

**Soil formation and composition** Soil formation begins with the breakdown of rocks at the surface. This breakdown is caused by weathering (see **ROCK**; **WEATHERING**). Rain, snow, ice, and running water all help reduce large rocks into smaller fragments. The initial product of weathering is a rather stony material called parent soil.

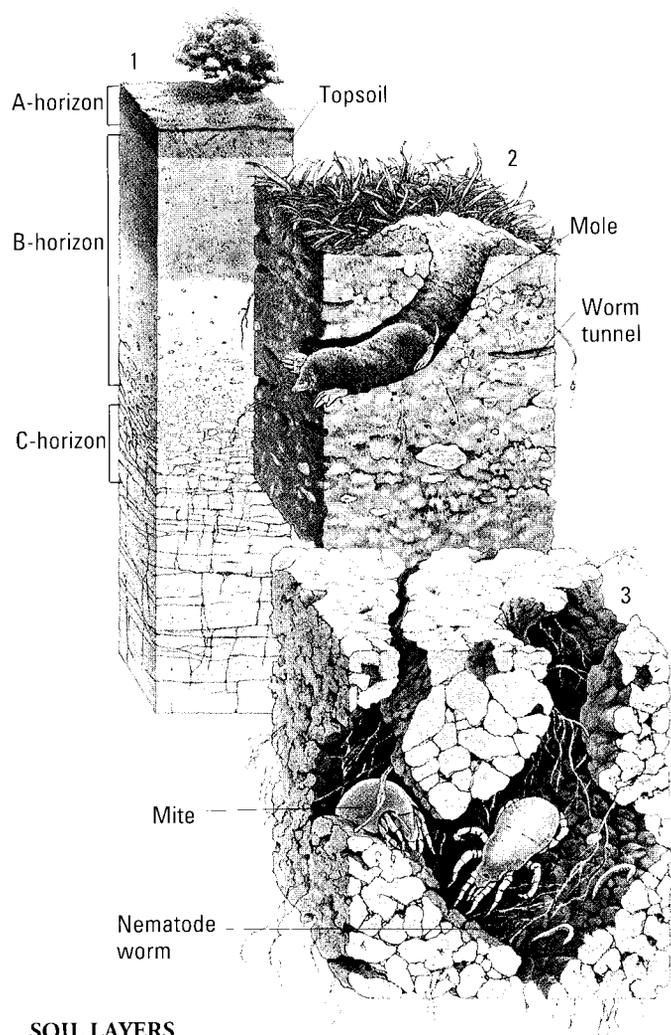
A number of forces work to break down the parent soil even further. Weathering still plays a leading role. Rain dissolves some of the minerals in the parent soil (see **MINERAL**). If rainwater—which gets into air spaces in the soil—freezes, it expands and causes rock fragments to split and break. In addition, lichens and other simple organisms live on rock fragments. They produce acids, which help break down the minerals in the rocks. This quickens the soil-forming process.

Organic matter called humus is constantly being added to the parent soil by the action of many types of bacteria, fungi, and other microscopic organisms (see **BACTERIA**; **FUNGUS**; **HUMUS**; **MICROORGANISM**). The microorganisms, which live in the soil, help decompose dead plants and animals to form humus. Humus helps loose soil grains stay together, so they resist erosion (see **EROSION**; **SOIL EROSION**). Humus also makes the soil more fertile. Fertile soil is soil that contains many nutrients (nourishing substances) and can support abundant plant life.

The process of soil formation takes long periods of time. It can take up to a thousand years to produce 1 in. [2.5 cm] of fertile soil. When fertile soil has finally formed, it consists of many tiny particles. The spaces between the soil particles contain air or water. The three main kinds of particles are sand, silt, and clay. Sand particles range in size from

0.0025 to 0.08 in. [0.064 to 2 mm]. Silt particles range in size from 0.0015 to 0.0025 in. [0.038 to 0.064 mm]. Clay particles are smaller than 0.0015 in. [0.038 mm] (see **CLAY**; **SAND**; **SILT**). Quartz and feldspar are commonly found in sandy and silty soils (see **FELDSPAR**; **QUARTZ**). Mica and vermiculite, along with minerals formed as feldspar breaks down, are among the minerals found in clayey soils (see **MICA**).

Humus makes up only about 10 percent of most soils, with rock fragments making up the remaining 90 percent. The small percentage of humus



## SOIL LAYERS

The cross section (1) illustrates the layers of soil called horizons. The A-horizon is rich in organic material. The B-horizon contains many minerals. The rocky C-horizon is a transition zone between the bedrock below and the looser horizon above. The topsoil and upper layer (2) provide homes for burrowing animals such as moles and earthworms. In close-up (3), the spaces between the soil particles are seen to be occupied by mites and nematode worms.



#### POOR SOIL

The amount of organic material in the soil varies according to the type of soil. The soil formed in the arid region pictured above is called aridisol. Aridisols contain only small amounts of organic material.

makes the soil suitable for plant life. Some of the water that enters the ground dissolves soil to form a soil solution. Plants get their water and nutrients from this solution.

**Soil layers** Deep, well-developed soil is made up of three layers called horizons. The top layer of soil, where most plants grow, is called the A-horizon. The A-horizon is also called the topsoil and is often overlain by a layer of humus. This layer is rich in organic material and contains some minerals. However, most of the minerals in the A-horizon have been washed away or have seeped down to the middle layer, called the B-horizon. Farmers often mix the A- and B-horizons when plowing their fields. The bottom layer of soil is called the C-horizon. The C-horizon is quite similar to parent soil. This layer represents a transition (passage from one place to another) zone between the earth's bedrock and the looser A- and B-horizons (see **BEDROCK**).

**Soil types** Soil is not the same every place on Earth. Differences in climate, shape of the landscape, vegetation (plant life), and the amount of time in which the soil has formed can affect the kind of soil found in an area. Different soil characteristics can be indicated by color, texture, and chemical properties.

Colors of soil range from yellow to red to black. Soil scientists can tell much about the chemical makeup of a soil by its color. For example, darker colors usually indicate a higher percentage of organic matter.

The size of the soil particles—that is—whether they are clay, sand, or silt—determines the texture of the soil. Soils are clayey, sandy, or silty, depending on how much of each of these kinds of particles the soils contain. Loam is a very fertile soil with equal amounts of sand, silt, and clay (see **LOAM**).

Soils can also be acidic, alkaline, or neutral. Extremely acidic or alkaline soil does not support plants as well as neutral soil. The most fertile farmlands have neutral soil (see **ACID**; **ALKALI**).

The system used by most soil scientists classifies soils into ten types. Alfisols occur under forests and

grasslands in moist climates. Aridisols occur in dry regions and contain only small amounts of organic matter. Entisols resemble parent soil and are found in all climates. Histosols contain a large amount of organic material and are found in water-saturated areas, such as swamps. Inceptisols are slightly more developed than entisols. They are more common in moist and semimoist climates. Mollisols develop in prairie regions. They have topsoil that is rich in organic material. Oxidols have a reddish color and occur in tropical regions. Spodosols contain iron, aluminum, and organic material in their B-horizons and are found in moist climates. Ultisols are moist, acidic soils that are found in moist climates. Vertisols have a large content of clay and are found in semimoist and dry, warm climates (see CLIMATE).

**Soil use and conservation** For humans, the most valuable use of soil is the growing of food. Fertile soil is necessary for farming. However, some unwise farming practices endanger the soil. For example, planting the same crops year after year tends to remove certain nutrients from the soil. To replace the nutrients, synthetic (human-made) fertilizers are often added. These fertilizers may contaminate the water that runs off the soil. Other chemicals added to soil, such as pesticides, may also

contaminate water runoff. The contaminated water reaches lakes and streams and filters through the soil to aquifers. This is dangerous to humans because the contaminated water may be used for drinking water (see AQUIFER; FERTILIZER; PESTICIDE). Such chemicals, if used over a long period of time, actually reduce the fertility of the soil because they destroy humus and organisms that live in the soil. In addition, clearing trees off land for farming and excessive plowing often increase soil erosion. Irrigation can be harmful if salty water is used. Crops cannot use the salt in the water. Over time, the soil may become too salty for crops to grow in it (see IRRIGATION).

Certain farming practices can conserve the richness of the soil. For example, different crops can be planted in the same field each year. This practice, called crop rotation, preserves nutrients and may even add nutrients to the soil. Certain fields can be planted with a cover crop instead of a food crop for several years. Cover crops, which are not harvested, help preserve nutrients and add nutrients to the soil as well as control soil erosion. A method called integrated pest management can be used to decrease the amount of pesticides used. In this method, natural enemies are also used to fight off pests.

See also AGRICULTURE; BIOLOGICAL CONTROL.

 PROJECT 20, 21, 73, 75



#### **RICH SOIL**

Soil is one of the earth's most important natural resources. Careful farming practices can keep soil fertile and prevent its loss due to erosion.

**SOIL EROSION** (soil ĭ rō'zhən) Erosion is the gradual wearing down and carrying away of the earth's materials (see EROSION). Soil erosion is a kind of erosion in which soil is moved from one place to another by natural means (see SOIL). Wind blows soil, and moving water washes soil away. Normally, soil erosion occurs slowly over a very long time, because vegetation—such as trees and grasses—holds the soil in place. However, such natural occurrences as forest and prairie fires can strip the land of its protective vegetation cover. People also can cause soil erosion to happen much more quickly than normal by allowing grazing by farm animals and by digging and building on steep slopes, cutting down trees, and plowing the land for crops. The rapid soil erosion that results from such activities can be very harmful.

Besides blowing and washing away, the soil can also be "worn out." Soil has nutrients (nourishing substances) in it that allow plants to grow. Each plant needs different types of nutrients. This fact helps explain why various plants grow well in some soils and not in others. When farmers plant the same crop in a field year after year, the nutrients the crop needs become used up. That crop and other similar plants will not grow well in the area until the nutrients in the soil are replenished.

**Erosion by water** Erosion often starts when rain strikes bare soil. Large amounts of rain washing down a sloping area pick up loose soil and carry it away. As soil is carried away, two types of erosion can occur. Sheet erosion carries away much of the top



#### SOIL EROSION

Without a covering of plants, soil can be washed away by rain and blown away by wind. The result of this erosion is a desolate, infertile landscape.

layer of soil, called topsoil, at a time. This leaves an entire area bare. Gully erosion causes deep ditches that grow longer and deeper with each rainstorm.

**Erosion by wind** Winds can lift the valuable topsoil from one area and bury another area with it. Strong winds can carry soil hundreds of miles. Wind erosion occurs most often in dry regions. In the 1930s, serious wind erosion occurred in the midwestern section of the United States. A long drought and destructive farming practices killed much of the prairie grasses. Then, strong winds were able to blow tons of soil away (see DROUGHT). The region affected was called the Dust Bowl.

**Effects of soil erosion** Soil erosion does more than take away valuable soil. When gullies form, they can cause sidewalks, roads, and buildings to cave in. Also, eroded soil often ends up in lakes and rivers. This causes the water to become muddy and warm. Besides making the water less attractive to swim in and drink, the soil kills fish and other organisms living in the water. Also, when rivers and lakes become clogged with soil, flooding becomes more frequent. This can change an entire ecosystem (see ECOSYSTEM).

**Prevention of soil erosion** Erosion is said to occur when the rate of soil loss is more than 1 in. [2.5 cm] per one thousand years. This is because soil is made by natural processes at the rate of about 1 inch per one thousand years. The ideal soil-loss rate is very difficult to maintain in any areas where people live. However, certain practices can bring the rate close to the goal of less than 1 inch lost per one thousand years. Many of these practices involve farming methods. For example, farmers can plant cover crops on certain fields instead of food crops. These crops, which are not harvested, help hold the soil in place and replace nutrients. No-till or conservation tilling may be used. Tilling involves plowing. No-till or conservation tilling involves leaving a certain amount of stems and roots from the previous crop in the field. The stems and roots help hold the soil in place between the time one crop is harvested and another crop is

planted. Contour plowing and strip cropping also can help reduce soil erosion. In contour plowing, the farmer plows along the curve of a slope, rather than up and down. This slows the flow of rainwater. In strip cropping, grass is planted between strips of crops to slow the flow of rainwater.

*See also* AGRICULTURE.

**SOIL MECHANICS** Soil mechanics deals with the ability of soil to support buildings, dams, and other structures. Different soil types have different abilities. Engineers must find out the type of soil at a building site before they begin to build something.

Soil is the grainy matter that forms the top layer over much of the land surface on Earth (see SOIL). Soil is made of tiny particles. These particles form the "skeleton" of the soil. Between the particles are tiny spaces called pores. These pores are partially or completely filled with water. When a heavy load is placed on the soil, water in the pores is squeezed out. This is similar to the way water is squeezed out of a sponge. How easily the water can be squeezed out of the soil determines whether an area will be easy to build on or not. Knowing the type of soil helps engineers design the best type of foundation for the site and for the structure that will be built there. The foundation is the main support for a structure. There are three main types of foundations: spread, pier, and pile.

A spread foundation evenly spreads out the weight of a structure on the soil. Spread foundations are usually made of reinforced concrete. The concrete extends outward from the edges of the structure. This type of foundation prevents uneven settling of the structure.

A pier foundation consists of heavy pillars of concrete that go down through the soil to the bedrock (see BEDROCK). If sand, gravel, or clay occurs at the base of the foundation, the piers are made larger at the bottom. This enlargement improves the foundation's ability to support the structure.

A pile foundation consists of long concrete, steel, or wood columns called piles. These piles are driven into the ground—if possible, to the bedrock. Pile foundations are used for bridges, dams, and many skyscrapers (see PILING).

Soil mechanics has various applications in the construction of walls, tunnels, highways, and other structures.

*See also* BUILDING CONSTRUCTION.

**SOLAR CELL** A solar cell is a device that converts the sun's light into electricity. Solar cells are made of thin slices of semiconductor material. Semiconductor material conducts electricity well when it is heated and when light shines upon it (see CONDUCTION OF ELECTRICITY; ELECTRICITY; SEMICONDUCTOR).

Each solar cell can produce only a fraction of a volt of electricity. To produce larger quantities of electric current, it is necessary to link together great numbers of cells. The cells are joined together in large panels, which are placed to gather the sun's rays. The electricity produced by solar panels may either be used immediately or stored in electric batteries for later use (see BATTERY; CURRENT, ELECTRIC; VOLT).

Solar cells have many different uses. For example, they are often used to power calculators (see CALCULATOR). In space, where the supply of strong sunlight is unlimited, solar cells are particularly useful. Nearly all artificial satellites receive electric power from solar cells. Special devices ensure that the solar panels are directed to get the most light from the sun.

*See also* ENERGY; PHOTOELECTRIC EFFECT; SATELLITE; SOLAR ENERGY.



**SOLAR CELL**

A solar cell can be used to power a pocket calculator. The solar cell is the small panel below the figures.

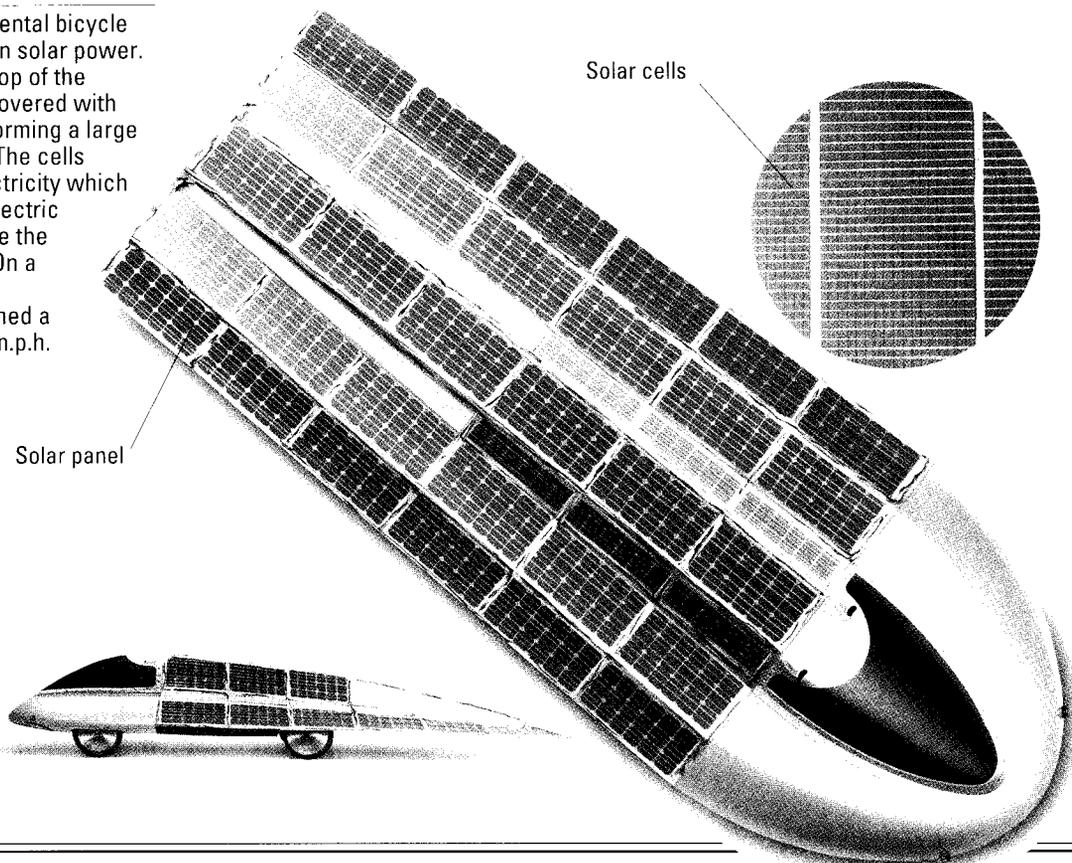
# SOLAR ENERGY

Solar energy is radiation from the sun that can produce heat directly or be converted into electricity (see **ELECTRICITY**; **RADIATION**; **SUN**). Most of the energy on Earth comes from the sun. People use much of this solar energy indirectly. For example, solar energy has given us, through certain processes, fossil fuels, such as coal and oil (see **FOSSIL FUEL**).

The sun evaporates water and produces rain and thus bodies of water, such as rivers. Such bodies of water are a source of hydroelectric power (see **HYDROELECTRIC POWER**). The sun's rays, which are strongest at the equator, warm the air there. The warm air rises, and the cooler air from the North and South poles moves in to replace it. This movement of air helps form wind currents. Wind can be used to turn turbines. The turbines drive generators, which produce electricity (see **TURBINE**; **WIND**). However, the amount of solar energy reaching the earth directly in the form of light and heat is far greater than all the indirect sources combined.

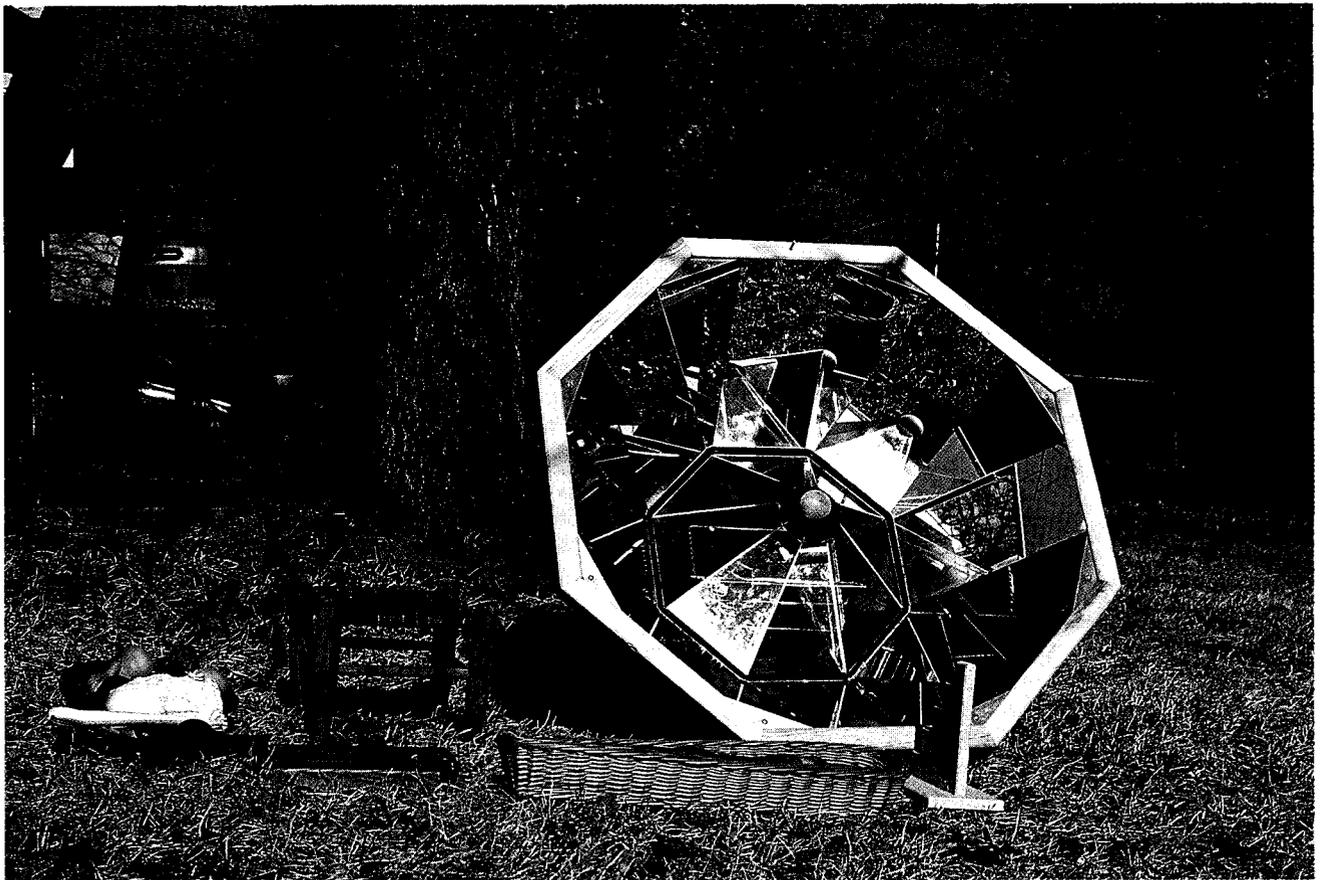
## SOLAR POWER

This experimental bicycle (right) runs on solar power. Most of the top of the machine is covered with solar cells, forming a large solar panel. The cells produce electricity which powers an electric motor to drive the rear wheel. On a long run, the bicycle reached a speed of 30 m.p.h. [48 kph].



## SOLAR HEAT COLLECTOR

This diagram of a solar heat collector shows the glazing at top, followed by the absorber plate, followed by the box that contains the glazing and the absorber plate.



### SOLAR OVEN

This solar oven has several mirrors to concentrate the heat of the sun. Here it is being used to bake bread.

Although the amount of solar energy reaching the earth as heat and light is huge, it is difficult to collect. Most of the earth's surface receives sunlight for only part of the twenty-four-hour day. Only during summertime at the poles is there constant sunshine. Particles in the earth's atmosphere absorb (soak up) or reflect heat and light from the sun. In addition, the heat and light that reach Earth are not concentrated but instead are spread out over a large area.

Scientists have developed various devices to try to collect as much of the sun's energy as possible. One of these devices is the solar cell. A solar cell converts the sun's light into electricity (see SOLAR CELL). Solar power plants use lens systems to focus the sun's light onto a particular area. This produces a high temperature, which can be used to boil water. Boiling water produces steam. The steam can be used to drive steam engines or turbines (see STEAM ENGINE).

Very high temperatures can be produced in a

device called a solar furnace. A solar furnace has a large parabolic (dish-shaped) mirror. The shape of the mirror reflects and concentrates parallel light rays to a small point. The mirror is adjusted to follow the sun's movement in the sky. Even small solar furnaces can produce temperatures up to 3,600°F [2,000°C]. Simpler devices called solar ovens are used for domestic purposes, such as cooking.

Devices used to heat homes imitate nature's greenhouse effect (see GREENHOUSE EFFECT). These devices use glass or plastic material that lets the sun's light in but prevents the sun's heat from escaping. Another device used to heat homes is called a solar heat collector. A flat-plate collector absorbs sunlight on a sheet of blackened metal (called the absorber plate) that is covered with a sheet of glass or plastic (called the glazing). The color black absorbs light better than any other color. The glass or plastic keeps the heat from escaping. Water flowing in pipes behind the metal absorbs the heat. The hot water is used to heat the home.

*See also* ENERGY; FUEL; INSULATION; SUN.

# SOLAR SYSTEM

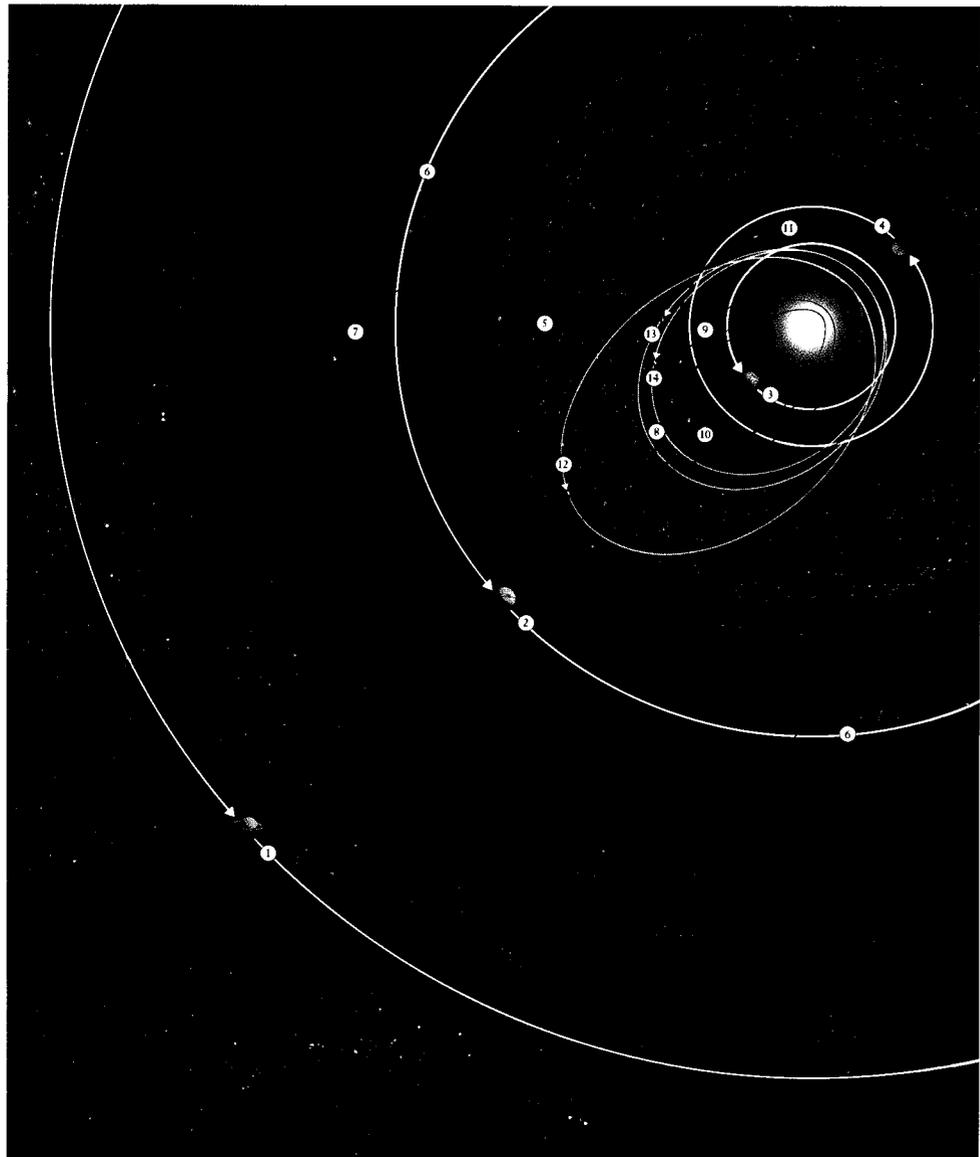
The solar system consists of the sun and all the bodies that revolve around it, including comets, meteoroids, moons, planets, and particles called interplanetary dust (see COMET; METEOR; MOON; PLANET; SUN). The solar system is a very small part of the galaxy called the Milky Way (see GALAXY; MILKY WAY).

These revolving bodies are kept in fairly stable orbits by the gravitational pull of the sun (see GRAVITY; ORBIT). The speed of the revolution of each body depends on the size of its orbit and its distance from the sun at any given time. Planets close to the sun travel at faster speeds than those farther away.

Our sun is the only star definitely known to have a planetary system (see STAR). However, scientists have begun to find evidence that other stars in our galaxy might have planets of their own.

**The sun** The sun is a medium-sized star and is 865,000 mi. [1,392,000 km] in diameter. The sun is so large that over one million planets the size of Earth could fit inside it. Scientists have also calculated that if all the parts of the solar system were weighed, the sun would make up 99 percent of the solar system's weight.

The sun and the other stars that belong to the Milky Way revolve around the center of the galaxy.



## THE SUN'S FAMILY

The solar system consists of the sun and the nine planets that orbit the sun. It also includes comets and meteors, and small rocky lumps called asteroids and meteoroids. Shown in the diagram are the orbits of the planets (1) Saturn, (2) Jupiter, (3) Earth, and (4) Mars; (5) the asteroid belt; asteroid orbits of (6) the Trojans (asteroids in Jupiter's orbit), (7) Hidalgo, (8) 1983 TB, (9) Apollo, (10) Icarus, and (11) Eros; and meteorite orbits of (12) Pribram, (13) Lost City, and (14) Innisfree.

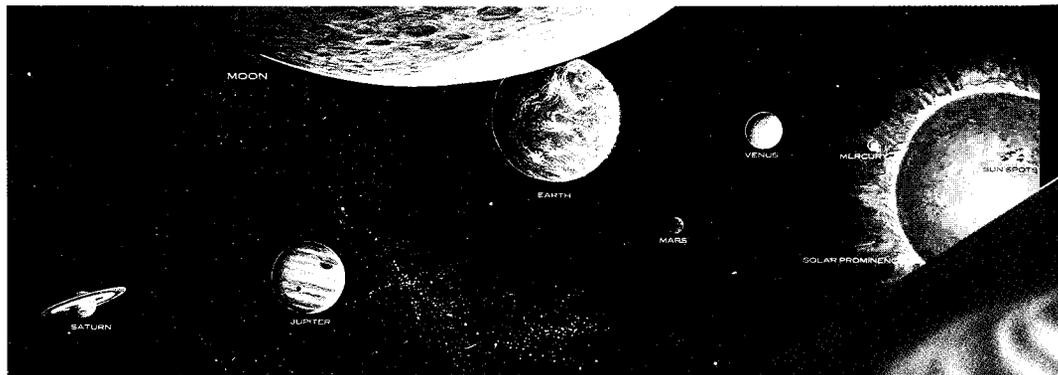
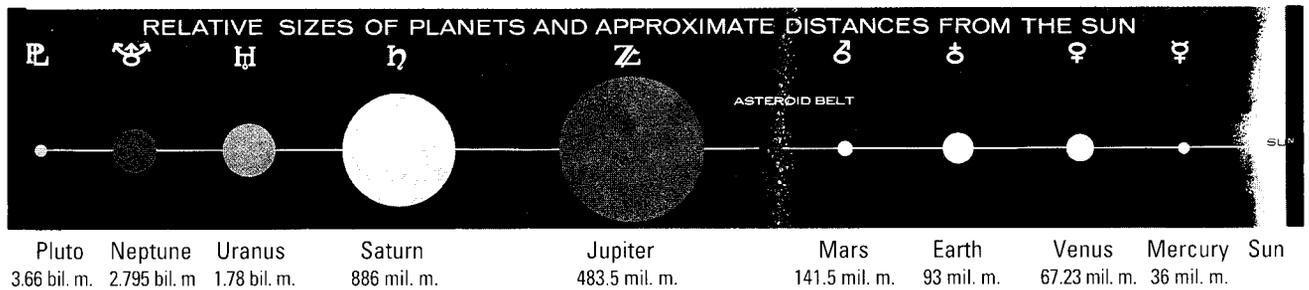
The entire solar system is moving along with the sun in its orbit. The sun revolves slowly in a counterclockwise direction.

The sun produces tremendous amounts of energy. This energy travels in the form of electromagnetic radiation—gamma rays, X rays, ultraviolet rays, visible light, infrared rays, and radio waves (see ELECTROMAGNETIC RADIATION). The sun also casts off streams of charged particles in what is called the solar wind. These particles move at high speeds through the solar system and eventually form part of the gaseous matter of space. The solar wind is partly responsible for auroras on Earth (see AURORA; SOLAR WIND).

**Major planets** A planet is a body that revolves around the sun and gives off no light of its own. There are nine known major planets. All the major

planets except for two, Mercury and Venus, have one or more natural satellites, or moons, orbiting them.

The planets are divided into two main groups. The ones closest to the sun—Earth, Mars, Mercury, and Venus—are called the inner, or terrestrial, planets. They are similar in size and are made of rocky material. *Terrestrial* means “relating to land.” The planets farther from the sun—Jupiter, Saturn, Uranus, and Neptune—are called the outer, or Jovian, planets. *Jovian* means “relating to Jupiter.” The outer planets differ greatly from the inner planets. Most of them are quite large. For example, Jupiter’s diameter is more than eleven times the diameter of Earth. Also, the outer planets consist mainly of the gases helium and hydrogen (see HELIUM; HYDROGEN). Scientists put the farthest planet from the sun, Pluto, in a category by



**VITAL STATISTICS**

The relative sizes of the planets and their distances from the sun are given in the composite diagram (above, top) produced by NASA. The diagram above is a view of part of the solar system looking toward the earth from near the moon.

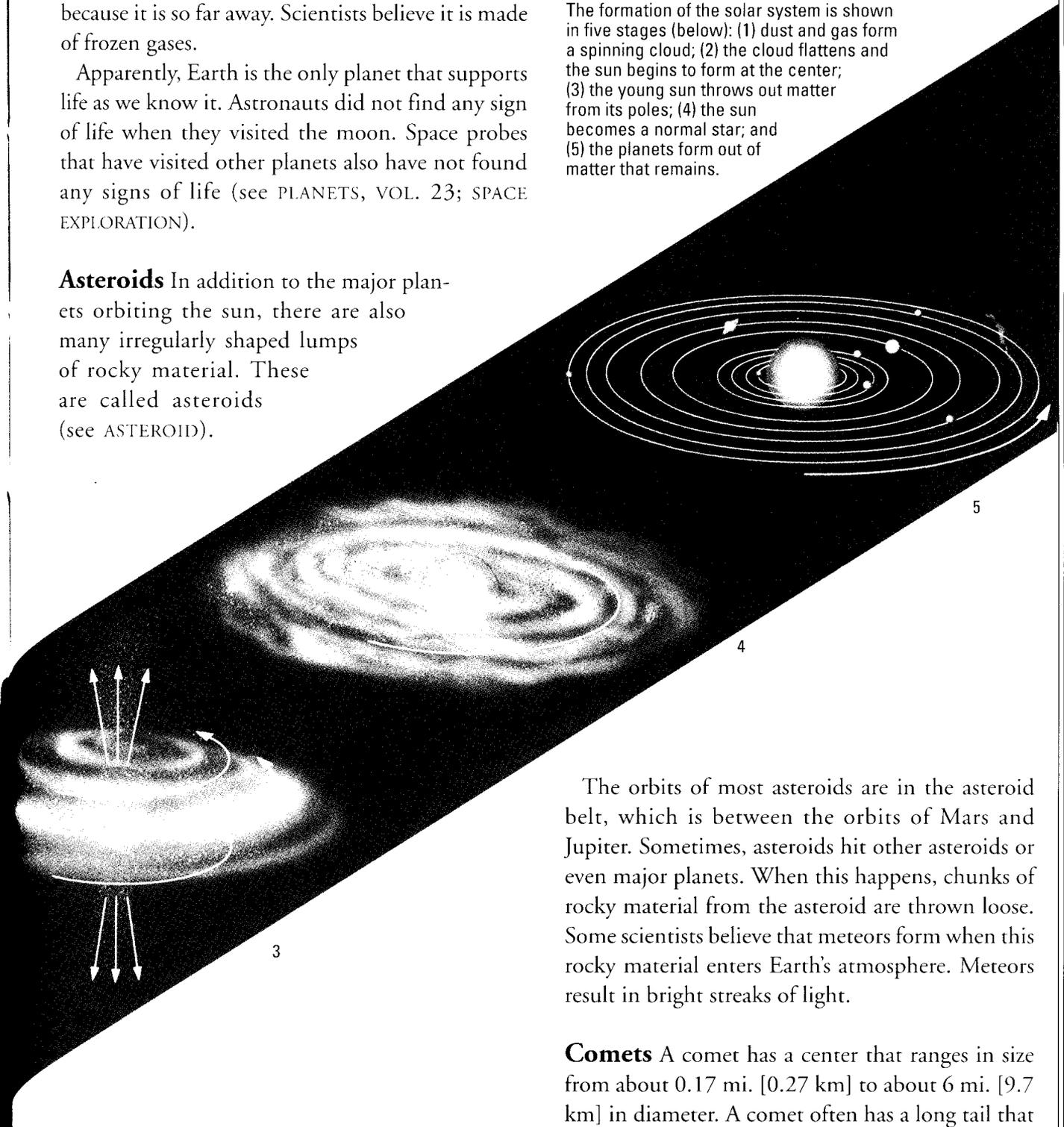
itself. Little is known about the surface of Pluto because it is so far away. Scientists believe it is made of frozen gases.

Apparently, Earth is the only planet that supports life as we know it. Astronauts did not find any sign of life when they visited the moon. Space probes that have visited other planets also have not found any signs of life (see PLANETS, VOL. 23; SPACE EXPLORATION).

**Asteroids** In addition to the major planets orbiting the sun, there are also many irregularly shaped lumps of rocky material. These are called asteroids (see ASTEROID).

#### FORMATION OF THE SOLAR SYSTEM

The formation of the solar system is shown in five stages (below): (1) dust and gas form a spinning cloud; (2) the cloud flattens and the sun begins to form at the center; (3) the young sun throws out matter from its poles; (4) the sun becomes a normal star; and (5) the planets form out of matter that remains.



The orbits of most asteroids are in the asteroid belt, which is between the orbits of Mars and Jupiter. Sometimes, asteroids hit other asteroids or even major planets. When this happens, chunks of rocky material from the asteroid are thrown loose. Some scientists believe that meteors form when this rocky material enters Earth's atmosphere. Meteors result in bright streaks of light.

**Comets** A comet has a center that ranges in size from about 0.17 mi. [0.27 km] to about 6 mi. [9.7 km] in diameter. A comet often has a long tail that can stretch many millions of miles. Most scientists think a comet is made up mainly of dust, frozen gases, and ice. When the orbit of the comet brings it close to the sun, the gases vaporize to form a cloud around the center called a coma (see VAPOR). When the comet gets even closer to the sun, these gases may be forced away from the comet, forming

Asteroids are known as minor planets. Asteroids were first discovered in 1801. Some asteroids are very small, with diameters of 700 ft. [213 m] or less. Others, however, are much larger. Ceres, the largest asteroid, has a diameter of 579 mi. [932 km]. There are thought to be about a million asteroids larger than 3,300 ft. [1 km] in diameter.

the tail. More than 700 comets have been discovered so far; about six new ones are discovered each year. Some, such as Halley's comet, are in orbits that bring them close to Earth at regular intervals.

**Meteoroid** Meteoroids are relatively small pieces of rock that orbit the sun. Meteoroids are generally smaller than asteroids. Scientists are not sure where meteoroids come from. Some believe they form from the tails of comets. Others believe they come from shattered asteroids. When meteoroids enter the earth's atmosphere, the heat caused by friction produces the bright light of meteors (see **FRIC-TION**). Some meteors become so bright that they can even be seen during the day. A very small percentage of meteoroids hit the earth's surface before they can burn up. The meteoroids are then called meteorites.

**Birth of a solar system** Scientists have been trying to explain the "birth" of our solar system for hundreds of years. Because of the flood of information from modern instruments, scientists have a general idea of how the solar system was formed.

The solar system began with the birth of the sun. The sun began to form about 4.6 billion years ago in the middle of a great cloud of gas and dust called a nebula (see **NEBULA**). The middle of this nebula began to spin and collapse in on itself, possibly triggered by the explosion of a nearby star. As the spinning part continued to collapse, gravity caused it to pull more and more material from the nebula into it. A dense region, called a protostar, was formed. This region was under great pressure, and the temperature at its core, or center, began to climb. The temperature eventually reached the millions of degrees Fahrenheit needed for fusion to start. In fusion, two or more atomic nuclei (plural of *nucleus*) combine to form a new element. In the process, a small amount of mass is converted to a huge amount of energy. The sun's fusion combines the nuclei of hydrogen atoms, forming a helium atom and releasing energy (see **ATOM**; **ELEMENT**; **FUSION**; **MASS**; **NUCLEUS**). When fusion began, the sun was born. The sun will continue to undergo fusion until it uses up all its hydrogen.

As the sun was forming in the middle of the nebula, other parts of the nebula slowly came together and cooled, forming the nine major planets. The outer planets formed in the cooler outer regions of the nebula, while the inner planets formed closer to the sun.

**Exploring the solar system** For thousands of years, humans' study of the solar system was limited by their eyes and, eventually, earthbound telescopes. That changed, however, in the 1960s, when modern rockets and other technological advancements made space exploration a reality (see **ROCKET**). Since then, artificial satellites, space probes, and space telescopes have helped scientists unlock some of the solar system's secrets (see **SATEL-LITE**; **TELESCOPE**). Some space probes have sent back very detailed and often surprising images of other planets and their moons. In 1977, the United States launched two Voyager probes. *Voyager I* flew past Jupiter and Saturn. *Voyager II* flew past Jupiter, Saturn, Uranus, and Neptune, sending many beautiful pictures of the planets back to Earth. Other probes have not been so successful. In 1993, the *Mars Observer* went silent, and was presumed lost, as it was about to enter orbit around Mars. In 1995, the U.S. probe *Galileo* reached Jupiter after a six-year journey from Earth, but it was hampered by equipment trouble. Some space probes have even landed on other planets. For example, the *Venera* space probes, which were launched by the former Soviet Union in the 1960s, 1970s, and 1980s, landed on Venus. The *Viking* space probes, which were launched by the United States in the 1970s, landed on Mars.

**Other solar systems and life** Because the universe is so huge—almost unimaginably huge—many scientists believe that there are other planetary systems. Some scientists go even further. They believe that life probably does exist in these other planetary systems, and this life may be as advanced or even more advanced than life on Earth. Many scientists have devoted their research to proving the existence of life in outer space. See also **EXOBIOLGY**; **UNIVERSE**.

**SOLAR WIND** The solar wind is the constant flow of charged particles from the sun. These particles include protons, electrons, and some nuclei (plural of *nucleus*) of heavy elements (see ATOM; ELECTRON; ELEMENT; PROTON). The solar wind streams from the sun through outer space at speeds of about 300 mi. [480 km] per second. It takes the particles about  $3\frac{1}{2}$  days to reach the earth. The solar wind is much stronger during periods of sunspot activity (see SUNSPOT).

The solar wind causes the tails of comets to point away from the sun (see COMET). It also causes magnetic storms, which may disrupt radio and television communications (see MAGNETIC STORM). The solar wind causes ionization of the gases in the upper atmosphere, resulting in the colored lights known as an aurora. The solar wind also helps form the Van Allen belts. The Van Allen belts are two zones of electrically charged particles that surround the earth.

*See also* ATMOSPHERE; AURORA; IONS AND IONIZATION; SUN; VAN ALLEN BELTS.

**SOLDERING AND BRAZING** Soldering (sŏd'ər ĭng) and brazing (brāz' ĭng) are methods of joining two pieces of metal together with a firm metal bond. The joint may be made with a pure metal or with an alloy of two or more different metals (see ALLOY). The metal or alloy is called the solder. A solder with a low melting point is called a "soft" solder. A "hard" solder has a high melting point. With very hard solders, the melting point may be very nearly the melting point of the pieces of metal that are to be joined. Therefore, the use of very hard solders requires considerable skill.

For most soldering, soft solder alloys of tin and lead are used. Such solders melt at a temperature of about 446°F [230°C]. They often contain a little of

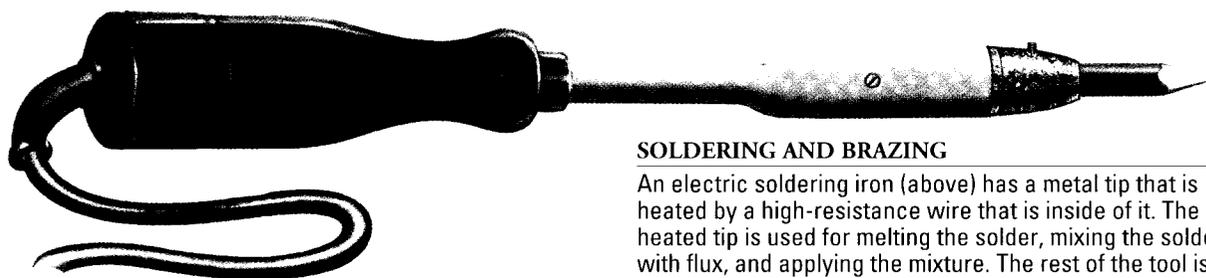
the element antimony to add strength. Soft soldering is widely practiced in plumbing, to mend and join pipes. In the electrical industry, the wires and leads of components are soldered into the circuits of radios, television sets, and other electrical equipment. The metal joint ensures that there is good electrical connection between the parts. The soldering operation is carried out with either a soldering iron or a gas blowtorch. The pieces of metal are heated, and the molten (melted) solder is allowed to flow into the joint. The solder then cools, uniting the pieces.

When a precious metal such as silver or gold is to be soldered, a hard solder is used. A typical silver solder contains about 60 percent silver, 30 percent copper, and 10 percent zinc. It melts at about 1,350°F [730°C].

Brazing is soldering using a solder that melts at temperatures above 840°F [450°C]. The work is heated with a blowtorch or may be put into a furnace. Steel is commonly brazed with copper in this way. Copper foil is put between the steel parts to be joined, and the work is passed through a furnace at a temperature that will melt the copper but not the steel. When the copper cools, the pieces are firmly united in a solid bond.

In both soldering and brazing, the pieces to be united must be absolutely clean. Otherwise, the joint will be ruined. Immediately before soldering is undertaken, the surfaces are cleaned chemically to remove grease. To remove oxides from the surfaces, and from the solder, mixtures of substances called fluxes are used. A flux prevents the formation of oxides during heating. Fluxes for soldering include resins, zinc chloride, and phosphoric acid. They may be mixed with petroleum jelly so that they are easy to apply.

*See also* FLUX; OXIDE.



#### SOLDERING AND BRAZING

An electric soldering iron (above) has a metal tip that is heated by a high-resistance wire that is inside of it. The heated tip is used for melting the solder, mixing the solder with flux, and applying the mixture. The rest of the tool is insulated from the heat.

**SOLID** Matter can exist in three states: as a solid, as a liquid, and as a gas (see GAS; LIQUID; MATTER; STATES OF MATTER). Solids normally have a definite shape. Liquids and gases mold themselves to fit whatever contains them. The state of matter of a substance depends on the temperature and the pressure applied to the substance. By reducing the temperature and increasing the pressure, every element can be turned into a solid. On the other hand, every solid element, when heated enough, will first turn into a liquid and then boil into a vapor (see VAPOR). For example, to make the gas helium into a solid, the temperature must be lowered to  $-457.96^{\circ}\text{F}$  [ $-272.2^{\circ}\text{C}$ ], and the pressure raised to 26 atmospheres (see ATMOSPHERE (UNIT)). To turn the element tungsten into a gas, it must be heated to nearly  $10,832^{\circ}\text{F}$  [ $6,000^{\circ}\text{C}$ ].

When a solid is changed from its original shape, it will tend to return to it, unless the force applied to it has been too great. The resistance of solids to a change in their form depends on their hardness and elasticity (see ELASTICITY; HARDNESS; STRESS AND STRAIN). Other properties of solids are ductility, malleability, and brittleness. The ductility of a solid is a measure of how easily it may be pulled into a new shape without breaking. The malleability is a measure of how easily it may be hammered

or rolled into a new shape. The brittleness is an indication of how much force is needed to break or shatter it. Every substance has a different combination of these characteristics.

In mathematics, a solid is a figure with three dimensions—length, width, and height. Examples of solids include a cone, prism, cube, cylinder, and a pyramid.

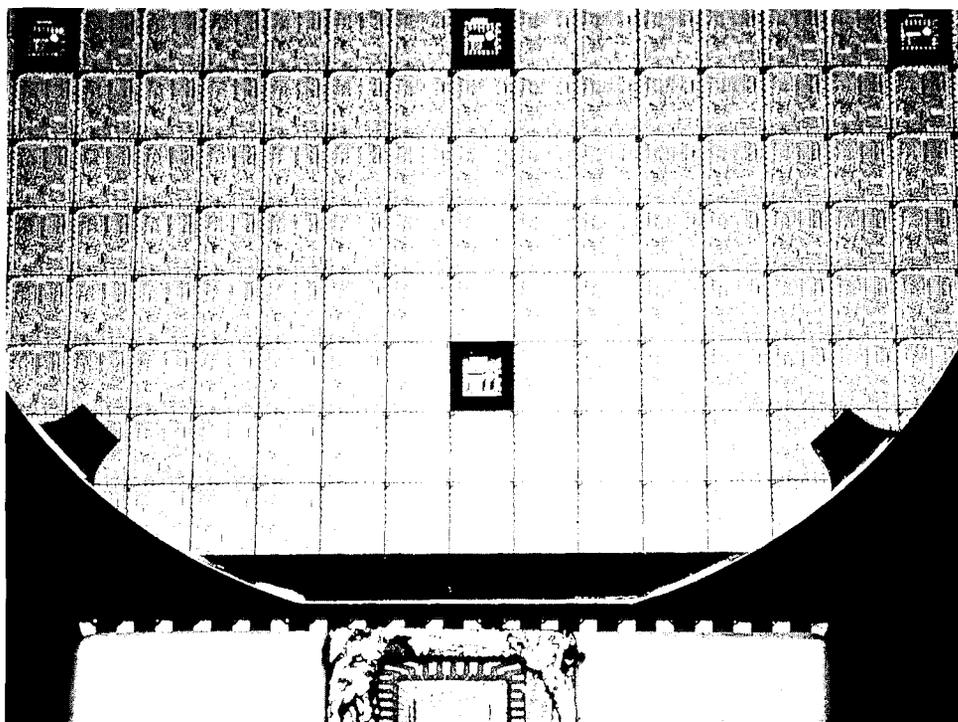
See also ELEMENT; GEOMETRY.

 PROJECT 15

**SOLID-STATE PHYSICS** Solid-state physics is the study of the physical properties of solid materials. The properties that are studied include the conduction of electricity and heat, magnetism, strength, and luminescence—the property of giving off light (see PHYSICS).

Solid-state physicists learn about solids by studying how the atoms of the solid are arranged (see ATOM). The atoms of most solid materials are arranged in regular patterns, forming crystals. A crystal of a particular material repeats itself throughout the material (see CRYSTAL). By beaming X rays, neutrons, or electrons at crystals, physicists can learn how the atoms in crystals are arranged.

One of the important achievements of solid-state physics was the development of the transistor in 1947. A transistor is a tiny device that largely



**SOLID-STATE PHYSICS**

Solid-state physics has made possible many advances in the field of electronics. One example is the production of integrated circuits on silicon wafers, as shown left.

replaced vacuum tubes in electronic equipment. During the 1960s, a method was invented for combining the work of a large number of transistors in one small integrated circuit (IC). Solid-state physics has also been responsible for other advancements in electronics—including computers—and in lasers (see CHIP; COMPUTER; INTEGRATED CIRCUIT; LASER; TRANSISTOR).

An important area of research in solid-state physics today is the study of superconductivity. Superconductivity is the ability of a substance to carry electricity without resistance. In order to become a superconductor, most metals must be cooled almost to absolute zero, which is  $-459.67^{\circ}\text{F}$  [ $-273.15^{\circ}\text{C}$ ]. In the 1980s, scientists discovered some ceramic materials became superconductive at much higher temperatures, around  $-234^{\circ}\text{F}$  [ $-148^{\circ}\text{C}$ ] or above. In the future, superconductors will allow improvements in electrical devices of all kinds.

See also ABSOLUTE ZERO; RESISTANCE, ELECTRICAL; SUPERCONDUCTIVITY.

**SOLSTICE** (sɒl'stɪs) *Solstice* refers to the days when the sun reaches its northernmost and southernmost points in the sky. Two solstices occur each

year. In the Northern Hemisphere, the summer solstice occurs on June 20 or 21, when the sun is directly over the line of latitude known as the tropic of Cancer. This day is the longest day of the year in the Northern Hemisphere. It also marks the beginning of summer in the Northern Hemisphere.

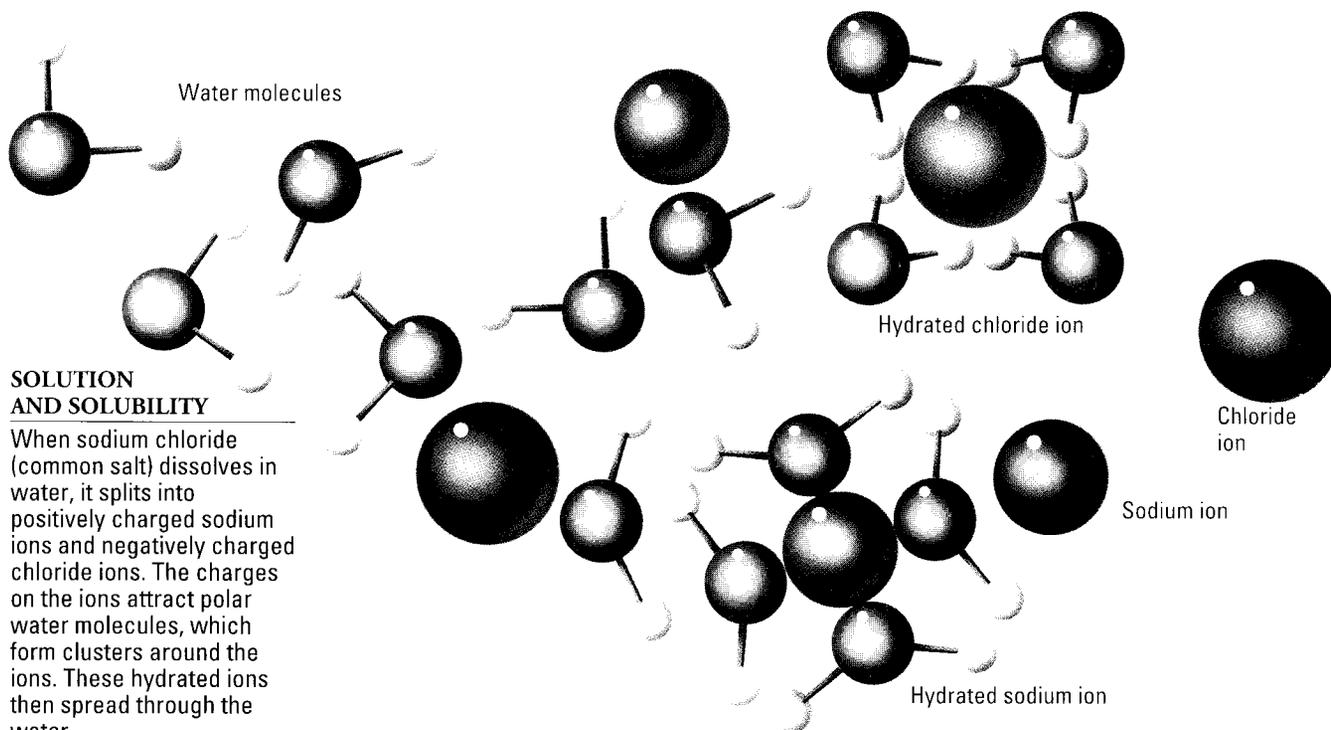
The winter solstice occurs on December 21 or 22, when the sun is directly over the line of latitude known as the tropic of Capricorn. This day is the shortest day of the year in the Northern Hemisphere. It also marks the start of winter in the Northern Hemisphere.

In the Southern Hemisphere, the seasons are reversed, with winter starting on June 20 or 21 and summer beginning on December 21 or 22.

See also EARTH; EQUINOX; LATITUDE AND LONGITUDE; SEASON; TROPIC.

## SOLUTION AND SOLUBILITY

(sɒ lōō'shən; sɒl'yə bɪl' i tē) A solution is formed when a solid dissolves in a liquid. The substance that dissolves is called the solute. The liquid in which it dissolves is called the solvent (see SOLVENT). Water is the most common solvent, but it will not dissolve all substances. Oils, fats, waxes, and many organic (carbon-containing) chemicals are insoluble



### SOLUTION AND SOLUBILITY

When sodium chloride (common salt) dissolves in water, it splits into positively charged sodium ions and negatively charged chloride ions. The charges on the ions attract polar water molecules, which form clusters around the ions. These hydrated ions then spread through the water.

(cannot be dissolved) in water. However, they will dissolve in organic solvents such as alcohol and ether (see ALCOHOL; ETHER).

A solution does not have to be a solid dissolved in a liquid. Liquids may be dissolved in each other, gases may be dissolved in liquids or solids, and solids may be dissolved in other solids. Alloys (different metals mixed together) are examples of solutions made up of solids (see ALLOY).

For a solid to dissolve in water, its molecules must be capable of forming electrostatic bonds with water molecules (see ELECTROSTATICS; MOLECULE). Molecules of water are polar. This means that one side of each water molecule has a positive charge, and the other side has a negative charge. Each water molecule forms weak electrostatic bonds with its neighboring water molecules. When molecules of another substance that has polar or ionic chemical groups are put into water, molecules of water are attracted to them (see IONS AND IONIZATION).

For example, sodium chloride (common salt) is a solid crystalline ionic compound (see SODIUM CHLORIDE). It is solid because of the strong electrical attraction between the positive sodium ions ( $\text{Na}^+$ ) and the negative chloride ions ( $\text{Cl}^-$ ). Salt dissolves in water because the polar water molecules are drawn to the charged sodium and chloride ions. Clusters of water molecules form around the ions. This lessens the attraction between the sodium and chloride ions. They separate and spread through the water in solution.

If a solvent contains a large amount of solute, it is called a concentrated solution. If it contains only a little solute, it is a weak, or dilute, solution. A given amount of solvent will dissolve only a certain amount of solute at a given temperature. When the solvent contains the maximum amount of solute, the solution is said to be saturated. If any more solute is added, the substance will not dissolve. The solubility of a substance is defined as the maximum amount of the substance, in grams, that will dissolve in 100 grams of the particular solvent at a stated temperature.

In general, the solubility of a substance increases as the temperature of the solvent is raised. This means that when the temperature of a saturated

solution is lowered, some of the solute will come out of solution. When this happens, the solute generally forms crystals (see CRYSTAL). Under certain conditions, the temperature of a saturated solution can be reduced without any crystals forming. The solution is then in a very unstable state. It is called a supersaturated solution. Sometimes adding a few crystals, or even stirring the solution, will cause crystals to suddenly form in a supersaturated solution.

 PROJECT 5, 7, 8, 14, 18

**SOLVENT** A solvent is a liquid that dissolves another substance or substances to form a solution (see SOLUTION AND SOLUBILITY). The dissolved substance is called the solute. Most solvents are liquids, but some solutions are formed by mixing gases or by mixing solids. Two liquids that mix together are said to be miscible.

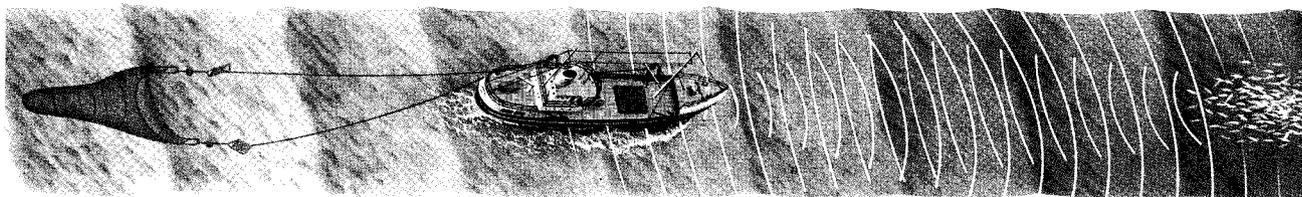
Water is one of the best-known and most effective solvents. Other useful solvents include alcohols and acetone (see ACETONE; ALCOHOL). Solvents and solutes with similar types of molecules, such as alcohol and water, will usually dissolve in each other easily.

Solvents are used in industry to make inks, paints, varnishes, and cleaning fluids (see PAINT). They are vital to the production of plastics such as nylon, polyethylene, and synthetic fibers (see NYLON; PLASTIC; SYNTHETIC FIBER). Solvents are used to extract or purify many useful materials in analytical chemistry and in petroleum refining (see CHEMISTRY; PETROLEUM). Chemists routinely crystallize pure substances, such as pharmaceuticals, from their solutions in suitable solvents.

 PROJECT 18

**SONAR** (sō'nār) Sonar is a system used to find the position and distance of objects under water. The name comes from the phrase "sound navigation and ranging." Sonar makes use of sound waves (see SOUND). Sound waves are carried very well through water. Whales are known to be able to communicate with one another over distances of many miles by means of sound signals.

Sonar is used by fishers to locate schools (groups) of fish. It is also used to detect submarines, other underwater objects, and ships.



### SONAR

Many commercial fishing vessels use sonar to locate schools of fish. A transmitter on the vessel sends out pulses of ultrasound. The sound is reflected by a fish school, and the returning echoes are picked up by an underwater microphone (receiver).

There are two types of sonar, active and passive. In active sonar, a ship or sonar unit dropped into the water sends out bursts of sound waves and “listens” for the echo from an underwater object (see ECHO). The time that passes before the echo is received gives a measurement of how far away the object is. This is possible because the speed of sound through water is known.

The burst of sound that is sent out is produced by a transmitter, which turns an electric signal into a sound signal. When the echo returns, the sound is turned back into an electric signal by a receiver.

In passive sonar, sound signals are not sent out. The noises of ships’ or submarines’ engines and propellers are simply recorded and analyzed. The

direction, but not the distance, of the sound source can be found. An advantage of passive sonar is that it gives off no sound that another sonar unit might detect.

*See also* RADAR.

**SORGHUM** (sôr'gəm) Sorghum is an important cereal grown in nearly all warm, dry parts of the world. It is also known as kaffir corn in Africa. Like other cereals, it is a member of the grass family (see GRASS). While most varieties are about 8 ft. [2.4 m] tall, some reach a height of 15 ft. [4.5 m]. Flowers grow in dense panicles (clusters) that yield 800 to 3,000 kernels, or grains. These kernels are rich in carbohydrates, proteins, and fats. They also contain calcium, iron, and vitamin B<sub>1</sub>. The kernels can be ground into a flour that is used in breads and cakes. Sorghum is also used to feed livestock, to make brooms, and to make alcohol, syrups, and cooking oils.



### SORGHUM

Sorghum is the world's fourth most important cereal crop. It is harvested by a machine similar to that used for harvesting sugar cane. The stems are loaded into trucks. They are used to make products such as alcohol that can be used as a fuel.

# SOUND

The world is full of vibrations—regular and repeated movements. When molecules in the air around us vibrate, they produce sound. We detect sound waves with one of our most important and delicate senses, the sense of hearing.

When we are first born, we hear sounds, but they probably mean nothing. Gradually, we learn to attach meaning to different patterns of sound. We learn to recognize and interpret speech. We learn to make meaningful sounds of our own. Most sounds mean something to us, whether the meaning is that the telephone is ringing, somebody is playing a violin, or an airplane is passing overhead.

Sound is of great importance to us. It is the basis of speech, which is our main means of communication (see COMMUNICATION). We have

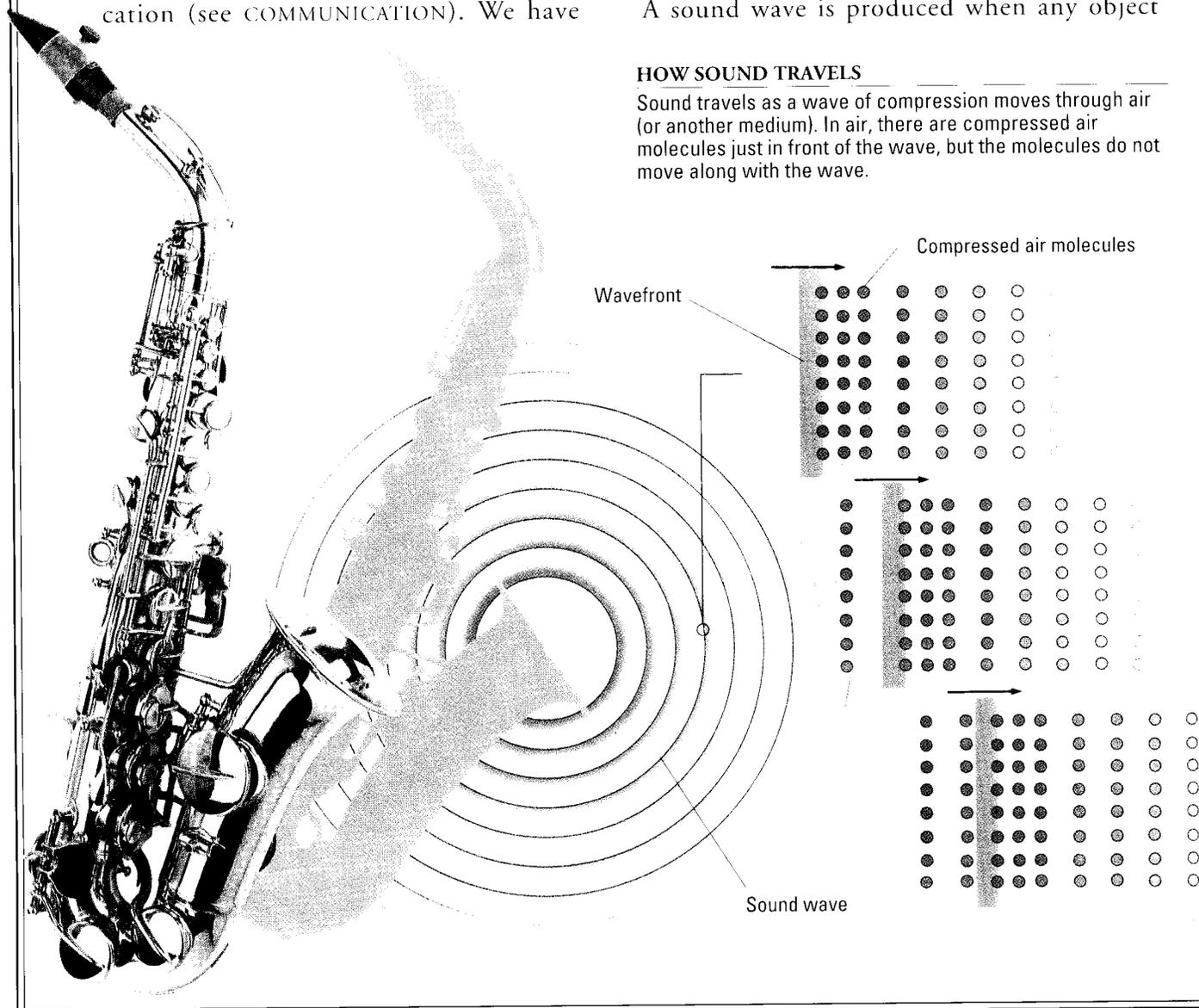
invented many devices to transmit and reproduce sound, so that we can communicate better with other people. The telephone, the radio, and the tape recorder are all examples. We use sound as a warning of danger or urgency. Foghorns, fire alarms, and police sirens are examples. We produce and listen to sound in the form of music simply for pleasure.

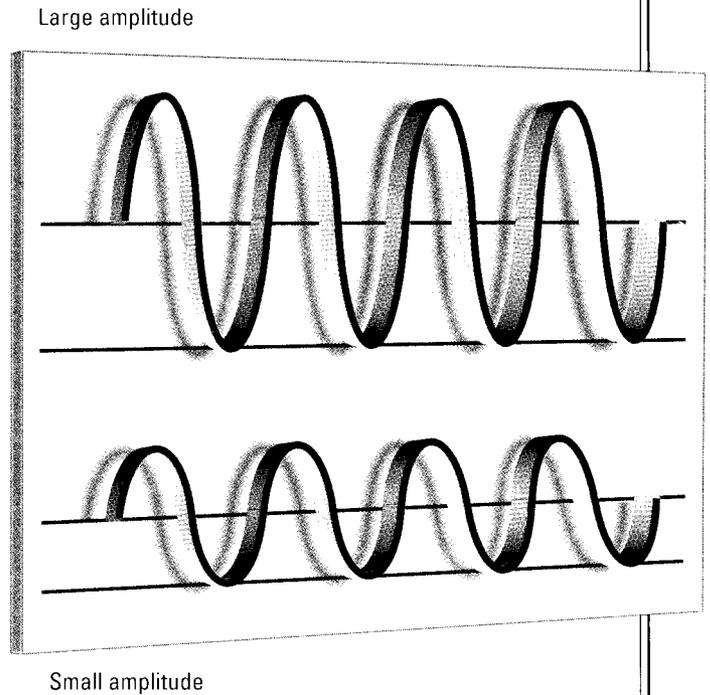
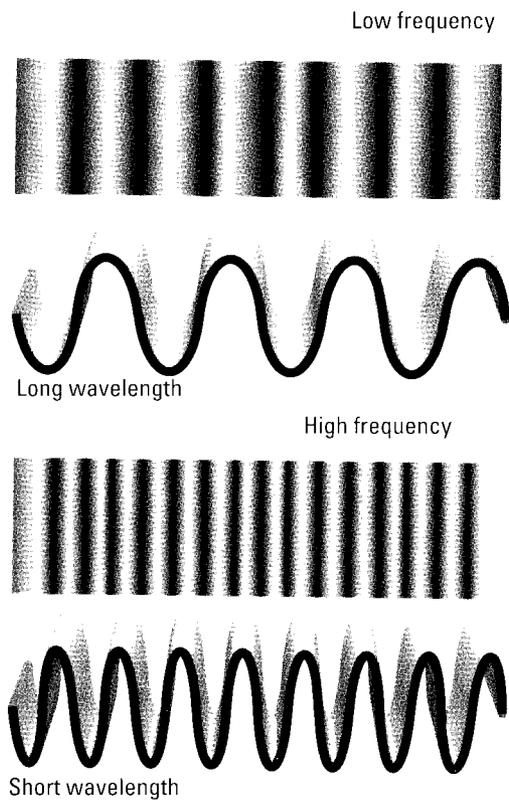
**The nature of sound** Sound travels through the air, or any other substance, in the form of sound waves (see WAVE). When the waves reach our ears, they make the eardrums vibrate. From the ear, nerve messages travel to the brain, and we hear the sound (see EAR; SENSE).

A sound wave is produced when any object

## HOW SOUND TRAVELS

Sound travels as a wave of compression moves through air (or another medium). In air, there are compressed air molecules just in front of the wave, but the molecules do not move along with the wave.





vibrates rapidly back and forth. The object may be the string of a guitar, the vocal cords in a person's throat, the piston of an engine, or the diaphragm of a loudspeaker. As one surface of the object moves forward, it pushes against the air next to it. The molecules of air are pushed together (see MOLECULE). The air is compressed. Then the air molecules spring apart again. They, in turn, push other molecules farther from the object. The region of compression moves away from the object. As this happens, the surface of the object is moving backward in its vibration. This produces a region of low pressure, or rarefaction. This region also moves outward, to be followed by the next region of compression.

The series of compressions and rarefactions make up sound waves. They travel through the air from the vibrating object in every direction, spreading out from it much like the ripples from a stone thrown into a still pond. When the vibrations strike another object, they make it vibrate too. The sound is passed onward until the waves have become so weak that they have no more energy to make air molecules vibrate.

#### PITCH AND INTENSITY

The pitch of a sound depends on its frequency (above left). A low-pitched tone has a low frequency and a long wavelength, whereas a high-pitched tone has a high frequency and a short wavelength. The intensity of a sound depends on the amplitude of the vibrations producing the sound waves (above). A wave with a large amplitude (top) produces a more intense sound than does a wave with a small amplitude (bottom).

**The speed of sound** Sound travels through air very rapidly. When you talk to someone, you see his or her lips form a word at the same time that you hear the word. You may notice, however, watching a game of baseball, that the crack of the bat against the ball is heard slightly after you see the ball being hit. You might also notice that, during a thunderstorm, you often see the lightning and then, after a moment or two, you hear the thunder.

The speed of sound in air is 760 m.p.h. [1,224 kph] at a temperature of 32°F [0°C]. This works out to about one mile in five seconds or one kilometer in three seconds. To determine how far away a thunderstorm is, count the time in seconds between when you see a lightning flash and when you hear the clap of thunder. Divide the number of



#### MUSICAL SOUNDS

All musical instruments have parts that vibrate to produce sound. In a guitar (left), the strings vibrate; in a wind instrument (right), a column of air inside the instrument vibrates.

seconds by five, and you have the distance in miles.

The speed of sound depends on the compressibility of the material through which it is traveling. The more compressible the material, the slower sound waves move through it. Air is more compressible than liquids or solids. Water transmits sound waves four times more rapidly than air does. Steel transmits sound waves about fifteen times more rapidly than air.

**Frequency and wavelength** In a sound wave, the distance between one region of compression and the next is called the wavelength. The number of compressions that occur in one second is called the frequency (see **FREQUENCY**). The greater the frequency, the shorter the wavelength. (The same applies if regions of rarefaction are considered instead.) By dividing the speed of the wave by the frequency of the vibration, the wavelength can be calculated.

Sound waves are usually referred to by their frequency rather than by their wavelength. For example, the musical note middle C has a frequency of 256 cycles (vibrations) per second. This is abbreviated as 256 cps. The unit that scientists usually use for measuring sound frequency is the hertz (Hz). One hertz is equal to one cycle per second (see **HERTZ**).

Musicians often refer to the pitch of musical notes. Notes high in the musical scale are said to be

high-pitched. They have a high frequency. A singer with a deep voice produces low-pitched notes. These notes have a low frequency. Pitch is simply another way of referring to frequency.

**Intensity and loudness** The intensity of a sound is dependent on the amplitude of the vibrations producing the sound waves. Amplitude is the distance that a vibrating object moves from its position of rest, as it vibrates. The larger the amplitude, the greater the intensity. At larger amplitudes, the sound waves are bigger, but frequency and wavelength are unchanged. The intensities of sounds are measured in units called decibels (dB) (see **DECIBEL**). Zero decibels is the least intense sound that a normal ear can hear. A jet plane taking off can produce a sound of 150 decibels.

The loudness of a sound depends partly on the intensity of the sound and partly on its frequency. The unit for measurement of loudness is called the phon. The loudness in phons of any sound is defined as the intensity (measured in decibels) of the 1,000-hertz note that is judged to be equally loud.

**Musical instruments** There are several basic kinds of musical instruments: string instruments, percussion instruments, and wind instruments. Each type of instrument produces sound in a slightly different way. String instruments have taut



strings that vibrate when they are plucked, as in the guitar and harp; struck, as in the piano; or stroked with a bow, as in the violin. In the guitar and violin, different strings are held with the fingers against a fingerboard. In the piano, different lengths of strings are arranged in a series. Each string is struck by a hammer when a person presses a key. The pitch of the note depends not only on the length of the string, but on the tension and weight of the string. High notes are produced by thin strings pulled very taut (tight). Low notes are produced by heavier and less taut strings that vibrate more slowly.

In percussion instruments, such as the drum, a tightly stretched membrane is made to vibrate by striking it. The taut skin vibrates in much the same way as a string vibrates. The smaller and tighter the skin, the higher the pitch of the note it produces.

Wind instruments rely on the vibration of columns of air enclosed in pipes of metal or wood. The length of the column of air determines the frequency—and thus the pitch—of the note. The longer the column of air, the greater the wavelength of the note, and therefore the lower the frequency. To alter the frequency of the note that is produced, different lengths of pipe can be created by opening and closing holes in the side of the pipe. Woodwind instruments, such as the flute and oboe, work in this way. Brass instruments are also wind

instruments. The notes they make are varied in a different way. The vibration of the lips at the mouthpiece makes the column of air vibrate, as in a woodwind instrument. However, by varying the pressure of the lips, the column of air can be made to vibrate in different ways. The column may vibrate as a whole. It may vibrate as two separate halves. It may vibrate as three separate thirds, and so on. In each case, the frequency of the note produced rises, because the wavelength has been reduced. The notes in the series make up what is called the harmonic series. They are harmonics, or overtones, of the fundamental note (see HARMONICS). Other notes, between those of the harmonic series, are obtained by pressing valves to add extra lengths of tubing into the system. In the case of the trombone, a length of tubing also slides in and out to add to the range of the instrument.

Almost all musical sounds contain harmonics as well as the basic note. A vibrating string moves not only as a whole, but also has smaller vibrations corresponding to half its length, and so on. The harmonics are quiet and not usually noticed. However, they add a quality to the sound of the particular instrument. They enable us to tell whether a note is being played on a piano, for instance, or on a flute.

### ACTIVITY *How to make pipes*

The pitch (highness or lowness) of the note produced by a simple pipe depends on the length of the pipe. Cut a drinking straw in half. Hold it vertically and press one end to your lower lip. With practice, you can produce a note when you blow across the end of the straw. Shorter straws produce higher notes. Try taping together straws of different lengths to make a panpipe.



**Electronic music** Instruments such as synthesizers and electronic organs produce sounds entirely by electronic means (see ELECTRONIC MUSIC). In these instruments, devices called oscillators produce electric signals that have the same frequencies as musical notes. The signals are sent through an amplifier and played back through loudspeakers or headphones, which have diaphragms that vibrate and produce musical sounds (see AMPLIFIER; LOUDSPEAKER; OSCILLATOR).

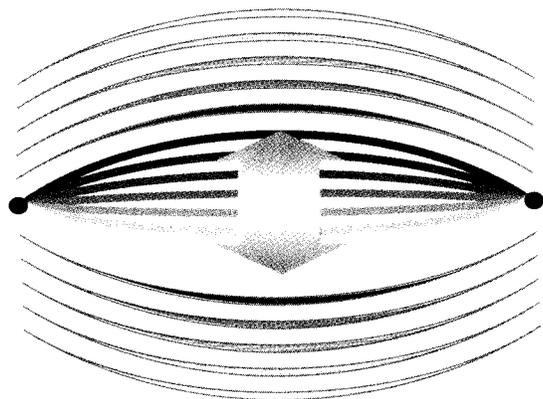
Instruments such as the electric guitar and electric piano are assisted by electronic devices. They have metal strings that vibrate in the normal way when plucked or struck. Near each string is a special magnetic pickup that responds to the vibrations and produces an alternating electric

current at the same frequency (see ALTERNATING CURRENT; ELECTROMAGNETISM). The electric current is then magnified by means of an amplifier and played through a loudspeaker. Adjustments to the tone and volume are made with a variety of electronic controls.

**Hearing and sound** The human ear can detect a wide range of sound, both in frequency and intensity. The sounds that we hear most keenly are those from sources vibrating at frequencies between 1,000 and 4,000 hertz. The entire range of frequencies audible to humans is between 20 and 20,000 hertz. The intensities detectable as sound by the average human ear cover a range of about 150 decibels. As people get older, the ear's sensitivity to very high-pitched notes declines. This explains why children sometimes can hear certain sounds that adults cannot hear.

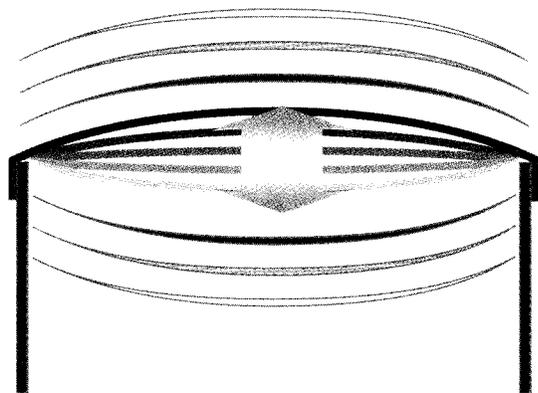
Sound waves of extremely high frequencies cannot be heard by the human ear, but they are nevertheless very useful. Sound of frequencies above 20,000 hertz is called ultrasound, and the study of it is called ultrasonics (see ULTRASOUND). Among other uses, ultrasound is used in medicine in much the same way as X rays are. The waves penetrate the body and can be used to produce pictures of internal organs.

See also ACOUSTICS; RESONANCE.



**VIBRATING STRING**

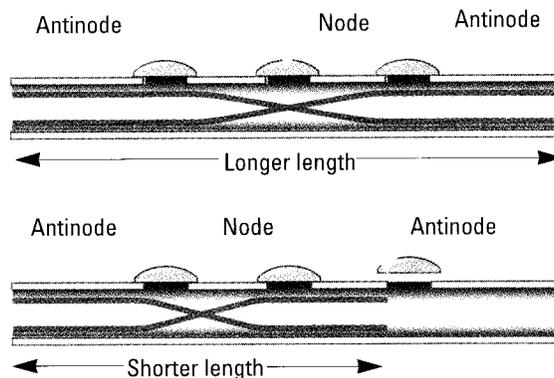
String instruments produce sound by the vibrations of the strings. The vibrations produce regions of compression and rarefaction of the air.



**VIBRATING SKIN**

Drums and other percussion instruments produce sound in a way that is similar to string instruments. However, the waves are produced from an area of membrane instead of a long string. Membranes vibrate less easily than strings, and so the sound produced dies away more quickly.

**PROJECT 47, 48, 54**



**VIBRATING AIR**

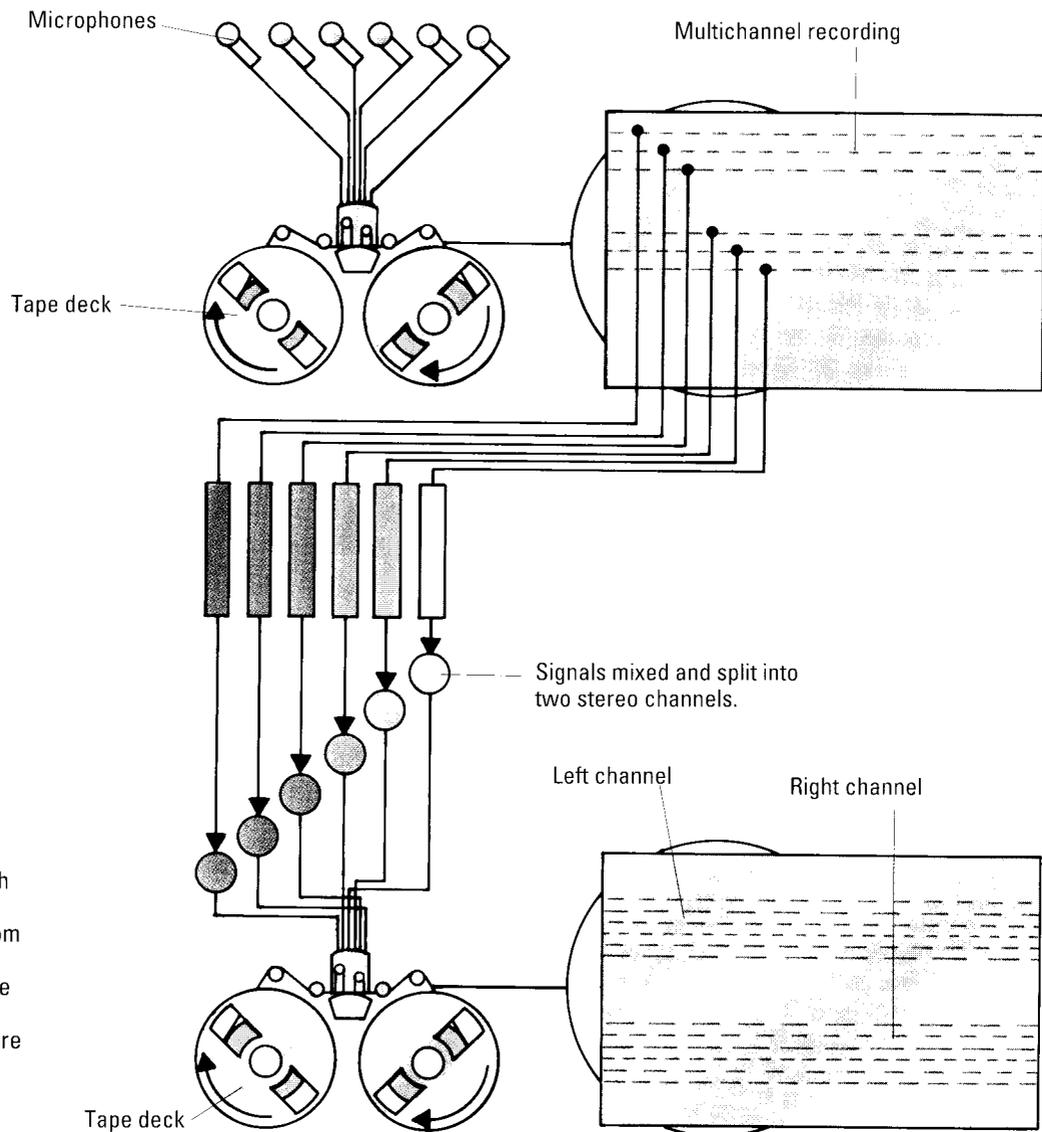
When a flute is producing sound, it contains a vibrating column of air, with minimum vibration at a node and maximum vibration at antinodes. The pitch of the note depends on the length of the column. Shortening the column will cause the instrument to produce a higher note.

# SOUND RECORDING

Sound recording is the capturing of sound in a form that can be reproduced. Sound is captured on devices such as phonograph records, compact discs, magnetic tape, videotape, and motion picture film (see MOTION PICTURE; SOUND). Sound may be recorded in different ways. For example, sound is recorded as grooves on records, digital (numerical) information on compact discs, and magnetic patterns on tape. On motion picture film, sound is recorded using patterns of light. Sound is reproduced using playback devices, such as record, disc, tape, or videotape players; amplifiers; and loudspeakers (see AMPLIFIER; LOUDSPEAKER).

There are two main methods of recording and reproducing sound (see RECORDING). Before the 1980s, almost all sound recordings were made using analog technology. In analog technology, sound is captured by converting it into a physical quantity, such as grooves or magnetic patterns. This converted form is then changed back to sound using such devices as amplifiers and loudspeakers.

In the 1970s, Thomas Stockham, an American engineer, developed digital recording. In digital recording, sound is captured by converting it into digits rather than a physical quantity. The digits form codes that are based on the binary number



## MULTICHANNEL

A commercial sound recording uses several microphones (one for each performer or part of an orchestra). The signals from the microphones are recorded on magnetic tape as a multichannel recording. The channels are then combined (mixed) to produce the two stereo channels of the final recording.

system (see **BINARY NUMBERS**; **COMPUTER**). This coding process allows recording of a wider range of sounds than does analog recording. It also means there is less of the static, hissing, and other noise distortions that occur during the analog process. As a result, sound reproduction tends to be of much higher quality than with analog recording. The compact disc, introduced in the 1980s, was the first major consumer product that used digital recording technology. Since the 1980s, the use of digital technology in sound recording and reproduction has increased. It may someday completely replace analog methods.

**Phonograph recording** The phonograph, the earliest analog recording device, was invented in 1877 by Thomas Alva Edison (see **EDISON, THOMAS ALVA**). Edison's device recorded sound on a rotating metal cylinder that was wrapped in tin foil. The vibrations of sound waves caused a needle to make a pattern of dents in the tin foil. The phonograph had another needle that played back the sound when it was placed against the tin foil on the rotating cylinder.

In 1887, the first phonograph records made of clay and shellac were invented (see **CLAY**; **SHELLAC**). Electric phonograph recording began in 1925. The records that were produced from the original recording were played on a device called a turntable at 78 revolutions per minute (rpm). In 1948, engineers at Columbia Broadcasting System (CBS) Laboratories developed a plastic, long-playing (LP) record. These plastic records were played at  $33\frac{1}{3}$  rpm and contained a total of about forty-five minutes of recorded music. The next year, Radio Corporation of America (RCA) invented a smaller plastic record that held about five minutes of music on each side. It was played at 45 rpm. Through the 1970s, most sound recordings were on phonograph records. In the 1980s, recordings on tapes and compact discs became the most widespread form. By the 1990s, most major recording companies in the United States had stopped producing records.

To make a phonograph record, the sound, such as a musical performance, is collected by microphones

that change the sound into electric signals (see **MICROPHONE**). The signals are then changed into vibrations that move a needle that has a diamond or sapphire tip, called a cutting needle. The cutting needle cuts a continuous, spiraling, V-shaped groove in the surface of a rotating disk, called the master record. This disk is made of aluminum and is coated with a heavy layer of lacquer (see **LACQUER**). As the cutting needle cuts a groove, it also vibrates from side to side. When the master record is complete, copies of it are made, packaged, and sold.

A phonograph, or record player, plays back sounds that have been recorded on records. Most record players have the same basic parts. These parts include the amplifier, loudspeaker, pickup cartridge, tone arm, and turntable. These parts may be in separate components or contained in one component.

The tone arm is attached at one end to the record player. The free end swings freely over the turntable. The turntable and the record that is placed on it rotate (spin) by means of an electric motor. The pickup cartridge is located at the free end of the tone arm. The cartridge holds the phonograph needle. The needle is lowered into the beginning of the record's groove, which is at the outer edge of the record. As the record rotates, the needle gradually moves from the outside edge toward the center. On most record players, the tone arm automatically lifts up and moves back to its original position after it reaches the end of the groove.

The main component in the pickup cartridge is a magnet or crystal. This component produces weak electrical signals when it is caused to move by the impressions in the groove. These electrical signals are fed through an amplifier. The amplifier strengthens the signals and passes them through a loudspeaker. The loudspeaker changes the signals back into sound waves.

**Tape recording** A tape recorder is a machine that can record sound on magnetic tape. The tape recorder has a microphone, which changes sound into weak electrical signals as part of the analog

recording process. An amplifier inside the microphone strengthens these signals. The signals then pass through the recording head of the tape recorder. The recording head is a coil of wire that is wound around a small piece of iron. When the signals pass through the coil, a magnetic field is produced. This field changes in strength as the signals vary. During recording, the tape moves past the recording head and the magnetic field. The tape is made of plastic coated with crystals of iron oxide. The varying magnetic field causes the iron crystals to form patterns in a single line, or "track," on the tape. As the recording takes place, fresh tape unwinds from one reel, called the feed reel, and is taken up by another reel, called the take-up reel. The turning of a device called a capstan is responsible for the tape moving from reel to reel. The tape moves at a constant speed of several centimeters a second. Devices called pressure pads hold the tape against the recording head.

Once the sound has been recorded, the tape can be stored for a long time. The tape can also be played over and over again. To play back the tape, the tape is again fed past the recording head. The head now acts as a playback head. As the tape moves past the head, the tape's magnetic pattern causes an electric current to flow through the coil in the head. This effect is called induction (see INDUCTION). As the magnetic pattern of the tape varies, the electric current flowing through the coil varies. This current is then amplified and fed into a loudspeaker. The loudspeaker changes the current into sound. Sound as well as pictures are recorded and reproduced in a similar manner on videotape (see VIDEO RECORDING).

The sound recorded on a tape can be erased, and new sounds can be recorded. Feeding the tape past a head called the erasing head produces a rapidly changing magnetic field. This removes the magnetic pattern from the tape.

Tape recorders that have a separate feed reel and take-up reel are called reel-to-reel recorders. Since the 1970s, cassette tape recorders have become widespread. A cassette is a small plastic case that contains both the feed reel and the take-up reel. To record, play back, or erase, the cassette is simply

placed in a cassette tape recorder/player, and the correct switch is pressed. The tape does not have to be threaded onto the reels by hand, as in a reel-to-reel recorder. This makes cassette tape recorders easier to operate. Videotape has also become widely available in cassette form.

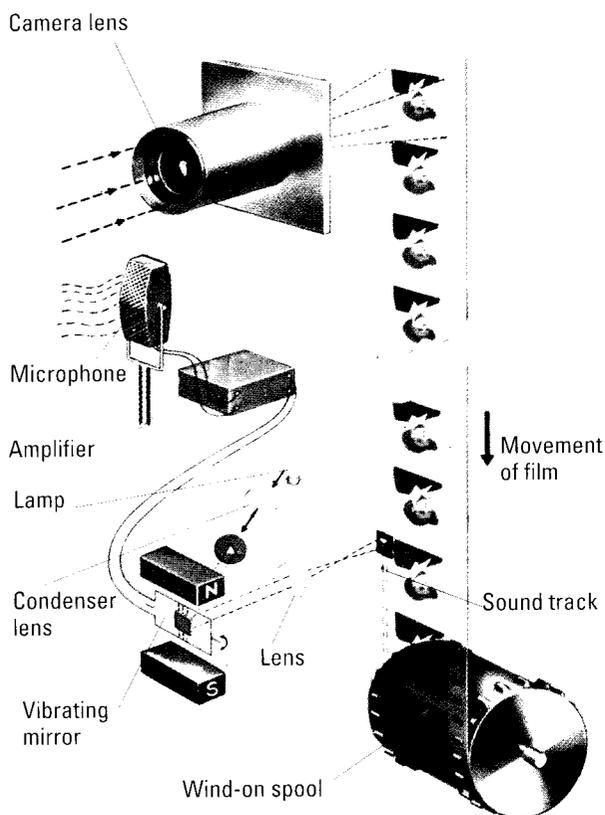
One problem with tape recording is the background noise produced by the movement of the tape across the head. Special coatings on the tape can help reduce the background noise. Many cassette tape recorders and players are now made with noise reduction features, such as Dolby B or Dolby S. Dolby B reduces background noise by 10 decibels (dB) (see DECIBEL). Dolby S, introduced in 1989, reduces background noise by over 25 dB.

Tape recorders/players are widely used in business, industry, science, and the home. In business, industry, and science, they are most often used as a way to store information. In the home, they are often used to record and listen to music. Not all tape players can record. These kind of tape players are most often found in automobiles. Some

#### RECORDING MEDIA

The chief ways of recording are with vinyl disks, audio cassettes, and compact discs (CDs). In the 1990s, vinyl disks lost popularity to the other two.





**SOUND ON FILM**

Sound for motion pictures is generally recorded as the film is being exposed in the movie camera (although other sounds, such as background music, may be added later). The sound is recorded on a strip along the edge of the film by a light beam reflected from a vibrating mirror. This creates an optical sound track.

modern tape players are small enough to fit into a pocket. Videotape, or videocassette, recorders are used with televisions to record and play back programs.

The newest tape recording equipment is digital and involves the use of digital audio tape (DAT). In the future, DAT will probably replace magnetic tape recording, just as compact discs have largely replaced phonograph records. Digital audio tapes and tape recorders/players are now available in the United States.

**Motion picture sound tracks** Motion picture sound tracks are made using light and electric signals. In this type of recording, sound vibrations are first converted into electric signals by a microphone. The signals cause a mirror to vibrate. A light passes through a lens onto the vibrating

mirror. The vibrating mirror reflects the light up and down and through a slit in another lens. The light passing through this second lens shines on the edge of the film. The edge has a special coating, similar to that on photographic film, that is sensitive to light. When light shines on the edge, it creates a pattern of light. The edge is now called the sound track. The sound track is heard by use of another beam of light. The light shines through the sound track, producing a varying signal in a photoelectric cell in the motion picture projector (see PHOTOELECTRIC EFFECT). The electrical output of the cell is then converted into sound that can be heard by the audience through the use of amplifiers and loudspeakers. Alternatively, the sound track can be contained in a magnetic strip that runs along the edge of the film. A magnetic sound track is of higher quality than the other type of sound track.

**Compact discs** Digital recording was used to produce the first compact discs in the 1980s. To make a compact disc recording, sound is broken down into 44,100 samples per second. Each of these samples is given a different binary number code. This is a series of zeroes and ones. The codes take the form of "pits" and "lands," or flat areas, etched onto a plastic disc made of polycarbonate. (This material is very durable. Motorcycle helmets and bullet-proof glass are made of polycarbonate.) Then an error correction code is added to the digitized music data, ensuring that errors during playback can be detected and corrected. When the compact disc is played back, the pits and lands are "read" by a laser beam (see LASER). The information is passed to a device called a digital-to-analog converter. This device changes the binary codes to electric signals. The signals are read, error detection/correction is applied, and the audio signals are processed and output through an amplifier and loudspeaker.

Compact discs are about 4.67 in. [11.9 cm] in diameter, which is much smaller than phonograph records that play at 45 rpm. A compact disc player has a special turntable that rotates at about 500 rpm. Because compact discs are read by a laser and

not touched by a needle, they last much longer than phonograph records.

**Other formats** Two new formats for digitally recorded sound, the digital compact cassette and the minidisc, were introduced in the early 1990s. In contrast to compact discs, both of these can be recorded and erased by home users. A minidisc (MD) is similar to a compact disc, although it is smaller, about 2.5 in. [6.4 cm] in diameter. Prerecorded MDs use the same system of pits and lands read by a laser beam as used by compact discs. MDs that are made for home recording, however, record information by means of a magnetic effect. When a home-recorded MD is played, light from the laser beam reflects differently depending on the magnetization of the surface of the disc. This produces a pattern of binary codes similar to those produced when the laser scans the series on a prerecorded MD or compact disc. Compact discs that can be affordably recorded at home are also being developed.

The other format, the digital compact cassette (DCC), is about the same size as a standard cassette tape. Because the DCC requires less space to record data, it can record much more music than an ordinary cassette. Another advantage of DCCs is that pure, exact duplicates of the sound information can be made. To protect the recordings, DCCs are

designed so that no tape is exposed until the DCC is inside the player. DCC players can display text on screen, so that the players can display information about, for example, the artist's name and recording date.

**Stereophonic sound** When sound is captured and reproduced in such a way that the result is similar to a live performance, it is called stereophonic. In other words, the sound signals reaching one ear are slightly different from those reaching the other ear. This is because of the way sound travels. If a sound is produced at one side of the head, it reaches the ear on that side more quickly. By the time sound reaches the other ear, it is reduced slightly in loudness and so "sounds" slightly different.

Stereophonic sound can be recorded and reproduced using special equipment. Two microphones must be used instead of one. One microphone picks up sound from the right, and the other microphone picks up sound from the left. In this way, the microphones pick up the differences in the timing of sounds that the ears would normally pick up. The sounds are changed into electric signals by the microphones and recorded. In phonograph recording, the cutting needle moves up and down as well as from side to side. This way, the sounds



#### RECORDING STUDIO

Multichannel recording allows sounds to be altered after the initial recording has been made. Here an engineer is mixing the channels to produce the final version of a recording.

from both microphones are recorded in one groove. In tape recording, the sound is recorded in two parallel tracks on the tape. In compact disc recording, the pits and flat areas incorporate the directions of the sounds. In each case, the recorded sound is then played back using two speakers.

There are other kinds of sound reproduction, which reproduce sound from more than two directions. For example, in quadrasonic sound, four microphones and four loudspeakers are used. Surround sound is a type of sound reproduction in which digital signals create the echoes that are characteristic of various kinds of rooms and other spaces. For example, by using a special amplifier, the listener can select whether he or she wants to hear the music as it would sound in a concert hall, cathedral, or stadium. Two main speakers carry the stereophonic sound. Other speakers, which are placed in different locations around the room, produce the echoes.

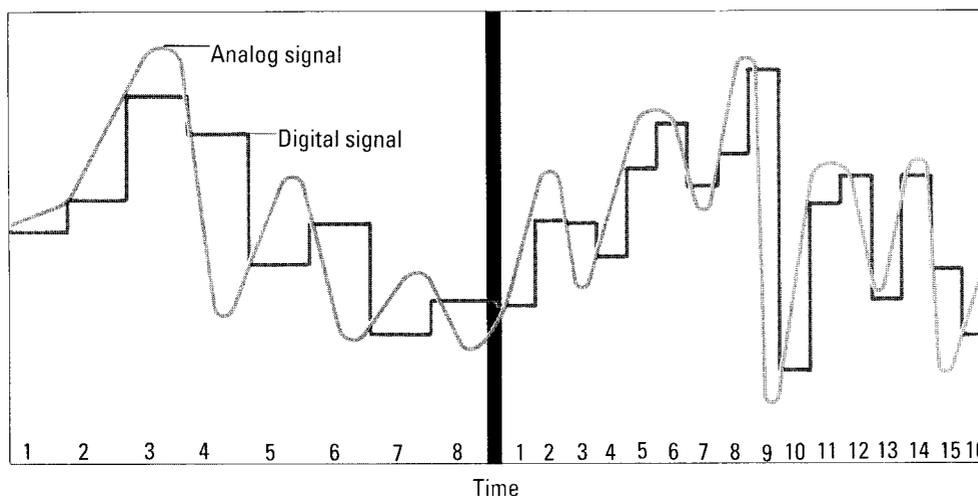
**High-fidelity sound reproduction** The aim of most sound reproduction systems is high fidelity (hi-fi), or the greatest possible faithfulness to the original sound. A sound reproduction system must meet three requirements to qualify as a high-fidelity system. It must be able to reproduce every musical tone. It must reproduce loud tones as clearly as soft tones. It must not produce any noise or other sounds of its own while in use.

The basic components, or parts, of a hi-fi system are the program source, the amplifier, and the loudspeaker. The program source can be a tape player,

compact disc player, record player, or radio. These components are often sold together as one hi-fi system. However, some people prefer to buy the components separately. Since the 1960s, hi-fi equipment has become much smaller as bulky vacuum tubes were replaced by tiny transistors (see TRANSISTOR; VACUUM TUBE).

Manufacturers began producing hi-fi equipment that was affordable to the average person around 1948, when LP records first became available. Before that time, hi-fi equipment was mainly used in radio stations and recording studios. FM radio stations began to experiment with broadcasting in stereo in the early 1950s. Today, some AM radio stations also broadcast in stereo (see RADIO). Stereophonic records were introduced in 1958, creating a tremendous demand for hi-fi home systems.

The future of sound recording and reproduction is in digital technology. Home compact disc recorders as well as compact discs that can be erased and recorded over are expected to be available in the 1990s. Scientists are also researching a type of disc that can hold a full spectrum of light in one tiny spot (see SPECTRUM). This "rainbow disc" could hold more than 1 million codes of digital information. A single disc could hold up to 100,000 albums of music. This means that if a person listened to the disc for four hours a day, it would take him or her sixty-eight years to listen to the whole disc. This type of disc would be mainly used by scientists and librarians as a way to store information.



#### DIGITAL RECORDING

Most modern sound recordings are made using digital signals. In an analog recording, the sound signal varies continuously. In a digital recording, the digits represent "steps" that correspond to the varying sound signal. If the steps are far apart (far left), the digital signal is poor. With steps closer together (left), the quality of the sound is much better.

**SOYBEAN** (soi'bēn') The soybean is an annual plant that belongs to the pea family (see ANNUAL PLANT; PEA FAMILY). It varies in height from about 1 to 6.6 ft. [0.3 to 2 m]. Its large leaves are divided into three rounded leaflets. Its deep roots help it survive even when water is scarce. Tiny, nitrogen-fixing bacteria living in the roots are able to supply the plant with nitrogen from the air (see NITROGEN FIXATION).

Soybean flowers are usually white, pink, or purple. They grow in the axils, the places between the plant stem and the leaf stems. The seeds are contained in legumes, or pods, that are about 2 in. [5 cm] long (see LEGUME). These seeds, called soybeans, are rich in fats and proteins. The seeds can be ground into a flour that is used in many foods. Oil from the seeds can be used for cooking and as a base for paints, plastics, adhesives, and many other substances.

Soybeans are native to China. They are now grown in many parts of the world. Because of their



#### SOYBEAN

Soybeans (above) are the most important crop obtained from a member of the pea family. They are a good source of vegetable protein and are used as a livestock feed and as a meat substitute for humans. The growing soybean plants are kept free from weeds by using a herbicide (weed killer) (right).



high nutritional value, soybeans are widely used as a livestock feed and a substitute for meat in the human diet. Many scientists believe that soybeans may become a major food source in the near future.

**SPACE** Space is the vast region that is usually considered to begin at the altitude above the earth where the air molecules are too far apart to produce friction with passing objects (see FRICTION). Scientists define this beginning of space as approximately 100 mi. [160 km] above the earth's surface. The atmosphere continues beyond this, but the air is very different from the air nearer the earth (see AIR; ATMOSPHERE).

Space is for the most part a vast, empty area with no known boundaries. It apparently extends in all directions and surrounds the solar system, all of the galaxies, and all of the regions between the galaxies (see GALAXY; SOLAR SYSTEM).

Interplanetary space includes the regions between the planets. The region between stars is called interstellar space (see STAR). The distance between the sun and the star nearest to it, Proxima Centauri, is about 4.3 light-years (see LIGHT-YEAR). The region between galaxies is called intergalactic space. Intergalactic space extends for unimaginable distances in all directions.

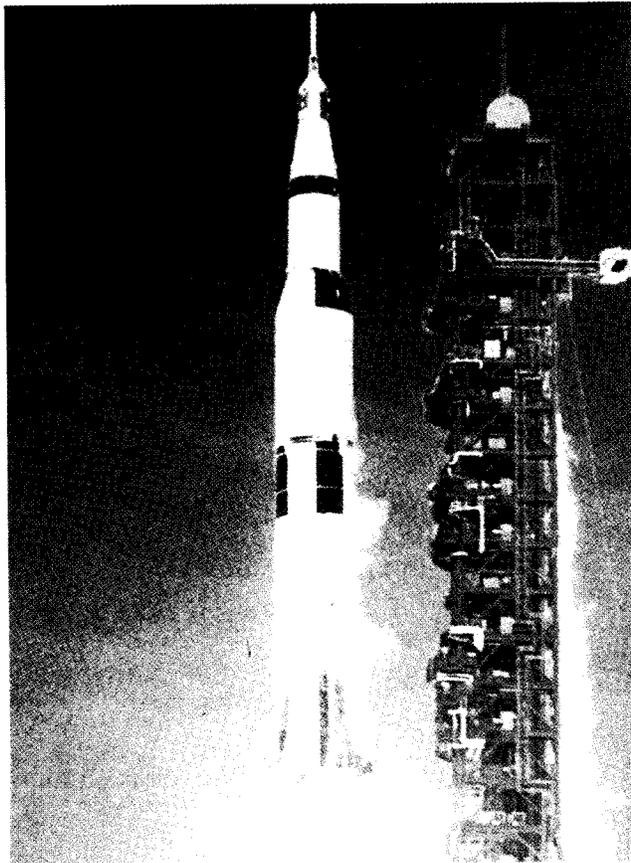
*See also* ASTRONOMY; UNIVERSE.

# SPACE EXPLORATION

Space exploration is the exploration of the region that begins at the altitude above the earth where the air molecules are too far apart to produce friction with passing objects (see SPACE). For many centuries, people have dreamed of exploring space. After World War II (1939–1945), the United States and the Soviet Union began to vigorously support space programs.

Space exploration involves many complex factors. These factors range from launching a spacecraft to keeping astronauts alive in space. An astronaut is a person who pilots a spacecraft or works in space.

**Launching a spacecraft** The greatest problem in launching a spacecraft is dealing with the earth's gravity. To go into orbit around the earth, a spacecraft must reach orbital velocity. Orbital velocity is the speed that allows a spacecraft to go into orbit



## LIFTOFF

Powerful rockets are used to launch spacecraft. Pictured is the launch of the Apollo 11 spacecraft by the rocket known as *Saturn V*.

while still remaining in the earth's gravitational field (see GRAVITY; ORBIT). To fly into the region of space called interplanetary or interstellar space, a spacecraft must reach escape velocity. Escape velocity is the speed necessary for an object to escape the gravitational pull of a larger body. In the case of space travel, the object is the spacecraft, and the larger body is the earth (see ESCAPE VELOCITY; VELOCITY).

The launching apparatus may be a single rocket or a multistage rocket (see ROCKET). A multistage rocket consists of two or more sections called stages. The first stage is called the booster. The booster lifts the entire spacecraft from the launching pad. The booster drops off when its propellant (fuel supply) is used up. At this time, the spacecraft may be moving at over 6,000 m.p.h. [10,000 kph]. When the booster drops off, the second stage takes over. The second stage drops off when its fuel supply is used up, and so on. The number of stages is determined by the weight of the spacecraft and the distance to be traveled. Most rockets have two or three stages.

**Return of a spacecraft to earth** A spacecraft must reduce speed when it reenters the earth's atmosphere. Friction between the air and the spacecraft helps the spacecraft reduce its speed (see FRICTION). Friction also produces great heat. For this reason, the spacecraft has a special heat shield (see HEAT SHIELD). In many spacecraft, the heat shield is designed to burn off when the spacecraft reenters the earth's atmosphere. This slowly disperses the buildup of heat. A kind of reusable spacecraft called a space shuttle has special permanent tiles that act as a heat shield. The tiles can withstand the high levels of heat.

Spacecraft other than the space shuttle land on Earth through the use of parachutes. When a spacecraft is about 10,000 ft. [3,000 m] above the earth's surface, several large parachutes are released. The parachutes allow the spacecraft to land slowly. Spacecraft usually land in the water, particularly in the calmer waters of the Pacific Ocean. This kind of landing is called a

splashdown. The space shuttle uses engines to land on a runway, as an airplane does.

**Living in outer space** The environment of space presents many hazards to astronauts. There is no weight and no air, there are great extremes of temperatures, and there is dangerous radiation (see RADIATION). These hazards force astronauts to live in totally artificial environments. Air pressure and content are carefully controlled inside a manned spacecraft. Dizziness and other effects of weightlessness are controlled by special drugs. Normal procedures, such as eating, drinking, sleeping, eliminating body wastes, keeping clean, and exercising are carefully planned. Astronauts eat freeze-dried food or pastelike food in tubes. Food that is freeze-dried has had its water removed while still frozen. Water is drunk directly from a nozzle. In order to sleep, astronauts must strap themselves to couches or beds to prevent them from floating around the spacecraft. The weightlessness of space makes normal use of a toilet impossible. Special collecting devices process and store wastes. Astronauts keep clean by taking showers in spe-

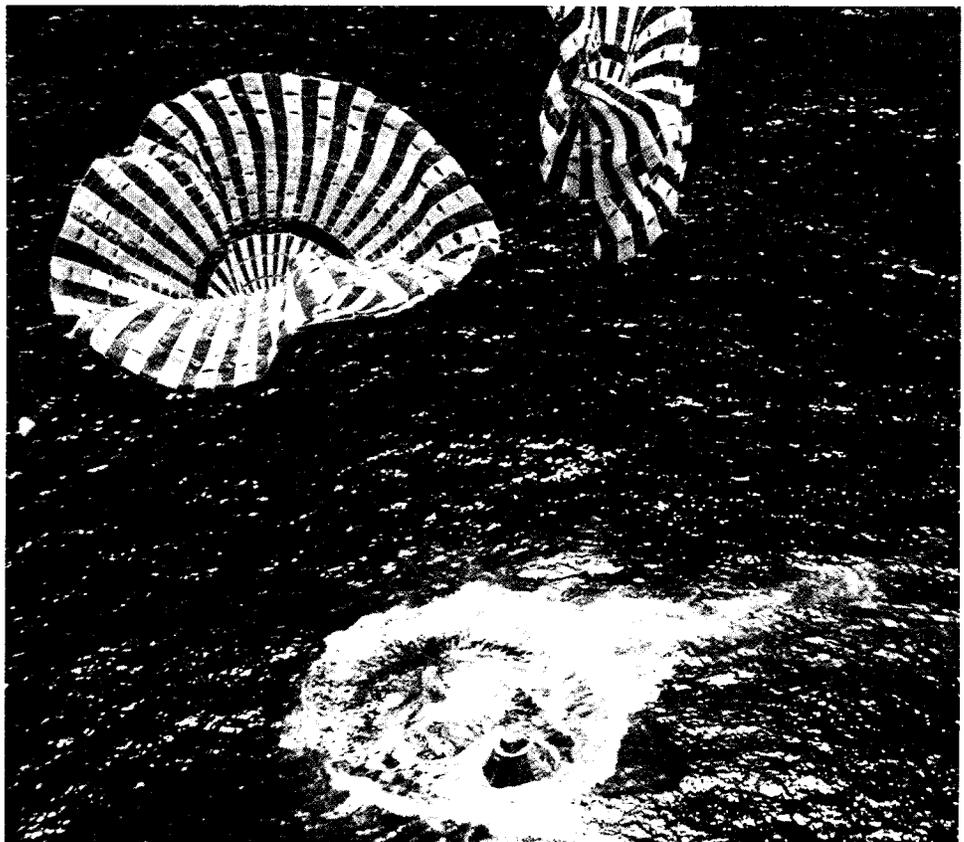
cially equipped, collapsible stalls. Astronauts maintain physical fitness by using stationary exercise devices, such as a stationary bicycle. For long periods of time in space, astronauts are provided with entertainment materials, such as books, games, and recorded music.

When moving outside the spacecraft, astronauts wear special suits. The suits protect them from radiation and major changes in air pressure. The suits include gas-propelled backpacks that help the astronauts move around. The astronauts are usually connected to the spacecraft by wires. The spacecraft itself is also protected from radiation, temperature extremes, and debris floating in space by the various materials that it is made of.

During space missions, American astronauts remain in constant radio contact with the Johnson Space Center in Houston, Texas. Scientists and technicians there monitor the workings of the spacecraft's equipment, instruct the astronauts on how to handle unforeseen problems, and plan the spacecraft's landing. The supplies and scientific equipment that a spacecraft carries are called its payload.

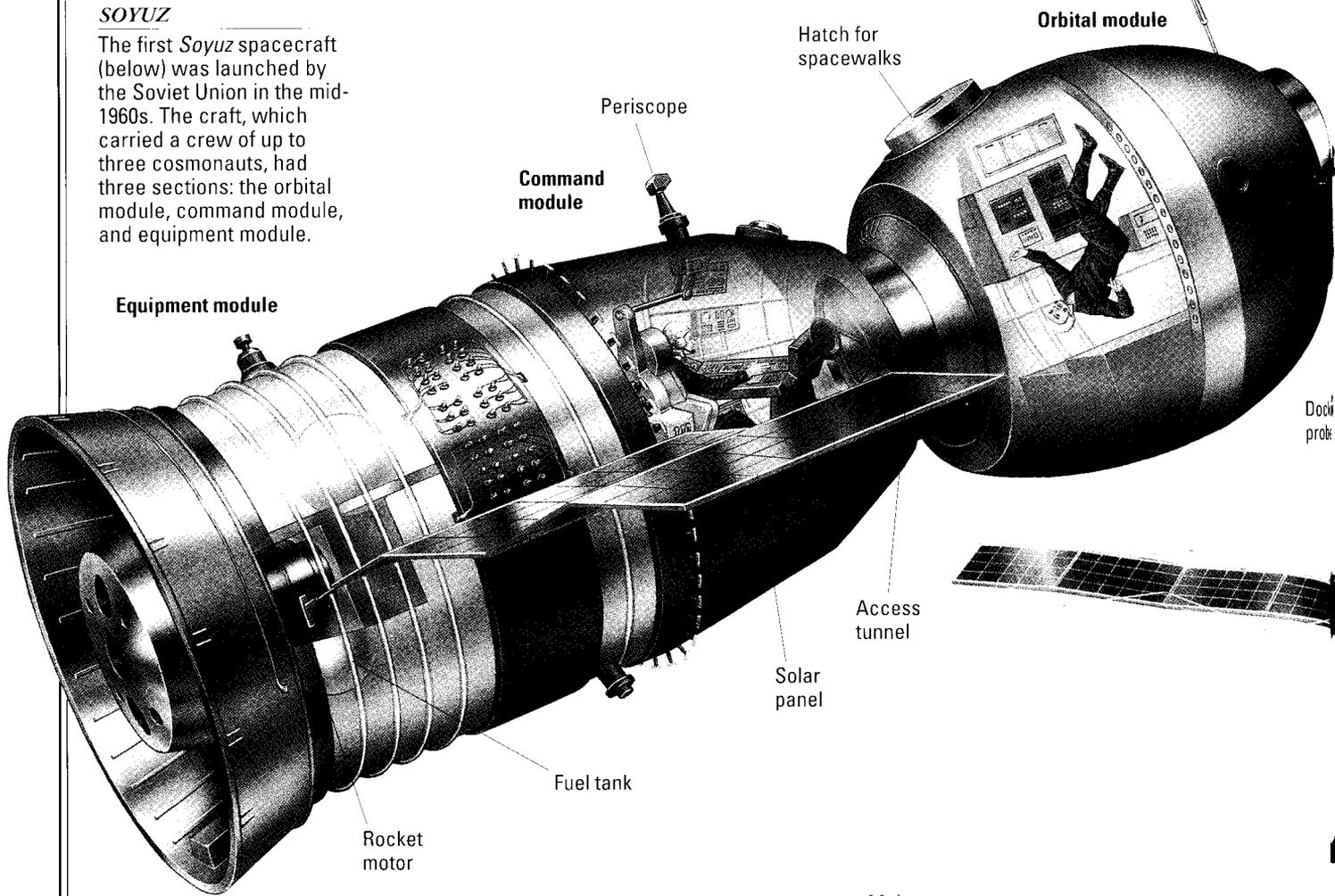
#### SPLASHDOWN

The Apollo 15 spacecraft, aided by parachutes, made a safe splashdown in the Pacific Ocean north of Hawaii in 1971.



**SOYUZ**

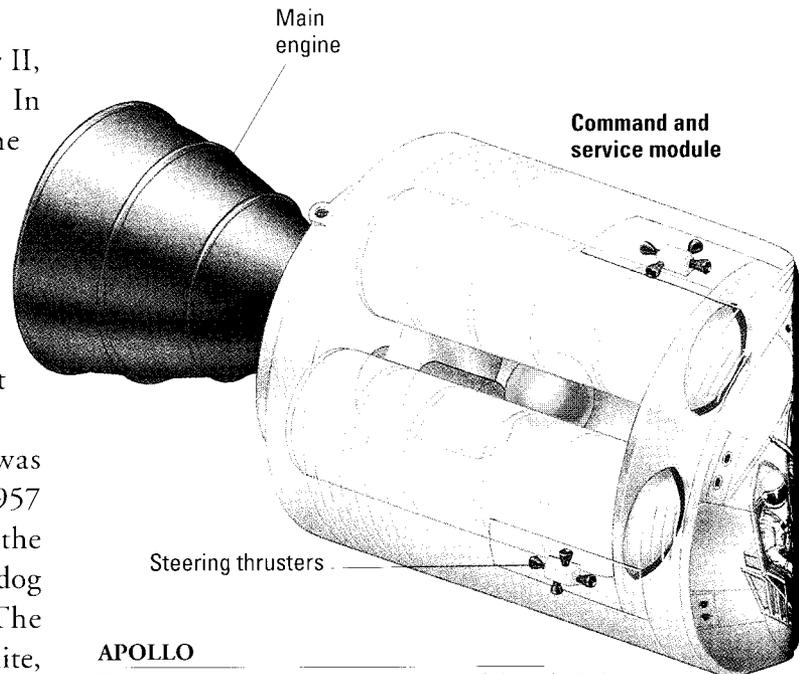
The first *Soyuz* spacecraft (below) was launched by the Soviet Union in the mid-1960s. The craft, which carried a crew of up to three cosmonauts, had three sections: the orbital module, command module, and equipment module.



**History of space travel** Before World War II, space travel and exploration were only ideas. In 1945, scientists from Germany came to the United States to develop military and space rockets. One of these scientists was Wernher von Braun. Von Braun had helped develop huge guided rockets, called V-2s, while in Germany (see BRAUN, WERNHER VON). These rockets were the forerunners of the rockets that are used to launch today's spacecraft.

*Sputnik 1*, the first artificial satellite, was launched by the Soviet Union on October 4, 1957 (see SATELLITE; SPUTNIK). One month later, the much larger *Sputnik II* was launched with a dog aboard, the first living creature in space. The United States launched its first artificial satellite, *Explorer I*, on January 31, 1958.

In 1959, the Soviet Union and the United States both succeeded in launching spacecraft that went beyond the earth's gravitational pull. The Soviet's



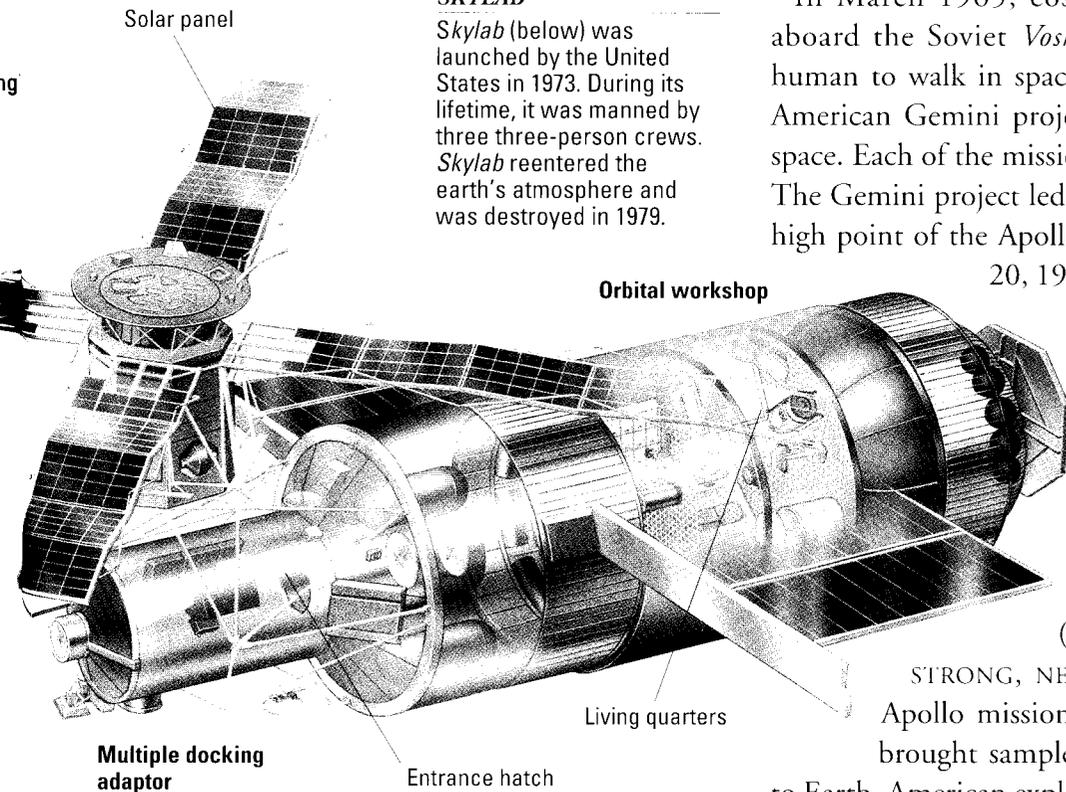
**APOLLO**

The United States' Apollo spacecraft (above), dating from 1967, consisted of two main sections: the command and service module, and the lunar excursion module. The excursion module had two parts. The descent stage remained on the moon, and the ascent stage carried two astronauts back to the command module.

*Luna I* and the United States' *Pioneer IV* were aimed at the moon. Eventually, they entered into orbit around the sun. In the 1960s, humans went into space. The first person in space was Yuri Gagarin of the Soviet Union (see GAGARIN, YURI ALEKSEYEVICH). Gagarin orbited the earth once on April 12, 1961, in *Vostok I*. On May 5, 1961, Alan Shepard in *Freedom 7* became the first American astronaut in space (see SHEPARD, ALAN B., JR).

**SKYLAB**

*Skylab* (below) was launched by the United States in 1973. During its lifetime, it was manned by three three-person crews. *Skylab* reentered the earth's atmosphere and was destroyed in 1979.

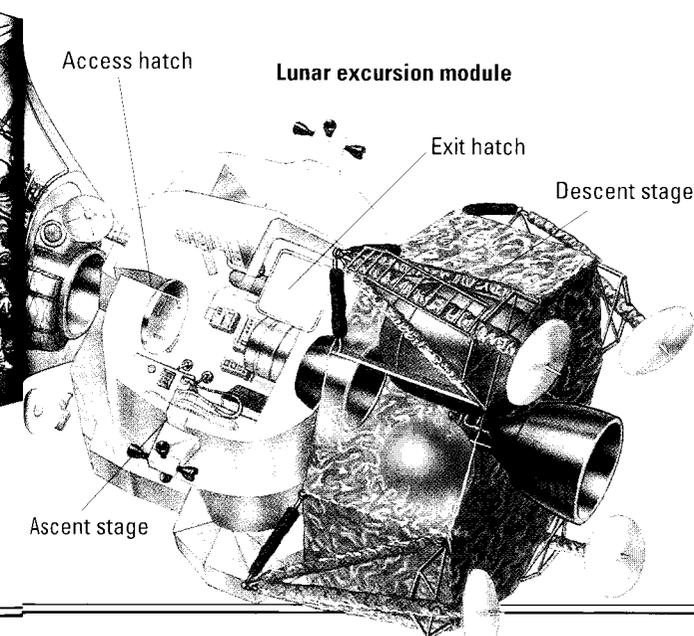


Shepard's flight took him 116.5 mi. [186.4 km] high. On February 20, 1962, astronaut John Glenn became the first American to orbit the earth (see GLENN, JOHN HERSCHEL). Glenn circled the earth three times in the spacecraft *Friendship 7*. In 1963, Valentina Tereshkova, a Soviet cosmonaut (astronaut), became the first woman in space. By the end of 1963, four Americans and six Soviets had made successful flights in space.

In March 1965, cosmonaut Alexei Leonov, aboard the Soviet *Voskhod II*, became the first human to walk in space. In 1965 and 1966, the American Gemini project sent ten missions into space. Each of the missions carried two astronauts. The Gemini project led into the Apollo project. A high point of the Apollo project occurred on July 20, 1969, when Apollo 11's lunar

landing module (unit), the *Eagle*, made a safe landing on the moon. American astronaut Neil Armstrong, who was aboard the *Eagle*, became the first person to set foot on the moon (see APOLLO PROJECT; ARMSTRONG, NEIL ALDEN). Several other

Apollo missions explored the moon and brought samples of moon materials back to Earth. American exploration of the moon ended in 1972.



In 1971, the Soviet Union launched the first space station, *Salyut I*. A space station is a spacecraft designed to remain in orbit around a planet or moon. A crew can live and work inside a space station longer than they can in other kinds of spacecraft. A space station has more room and carries supplies to last for a number of weeks. Several months after the Soviet space station was launched, three cosmonauts were transported to the station by the spacecraft *Soyuz*. They lived and performed experiments at the station there for twenty-four days. The United States launched its first space station, *Skylab*, in May 1973. Later that year, three American astronauts spent eighty-four days aboard the station. Many tests were performed on the

astronauts to determine the various effects of long-term weightlessness and other conditions encountered in space. The *Skylab* astronauts collected new information about the sun. They also took thousands of photographs of Earth. *Skylab* remained in orbit for six years, with various crews of astronauts going to and from it.

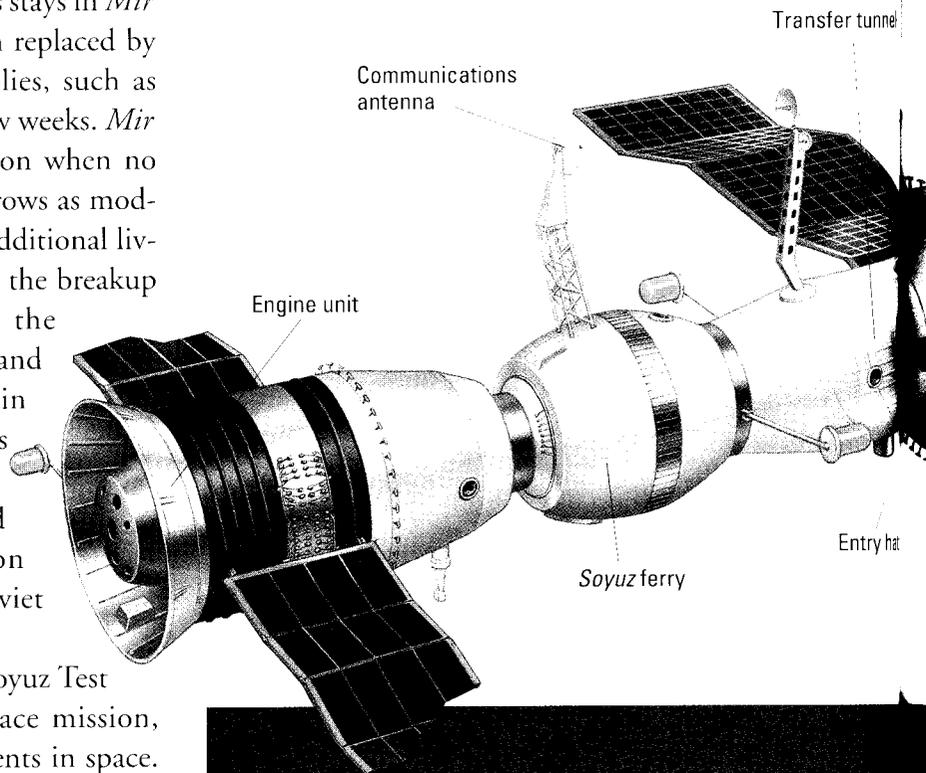
The Soviet space station *Mir* was launched in 1986. A crew of two to six cosmonauts stays in *Mir* for up to a year at a time and is then replaced by another crew. Spacecraft bring supplies, such as food, water, and mail, to *Mir* every few weeks. *Mir* has robots to operate the space station when no crew is aboard (see ROBOTICS). *Mir* grows as modules are added on. The modules are additional living quarters and laboratories. During the breakup of the Soviet Union in late 1991, the Soviet space program was disrupted, and one cosmonaut was forced to remain aboard the space station months longer than planned. The former Soviet space program is now operated primarily by Russia, in cooperation with other nations of the former Soviet Union.

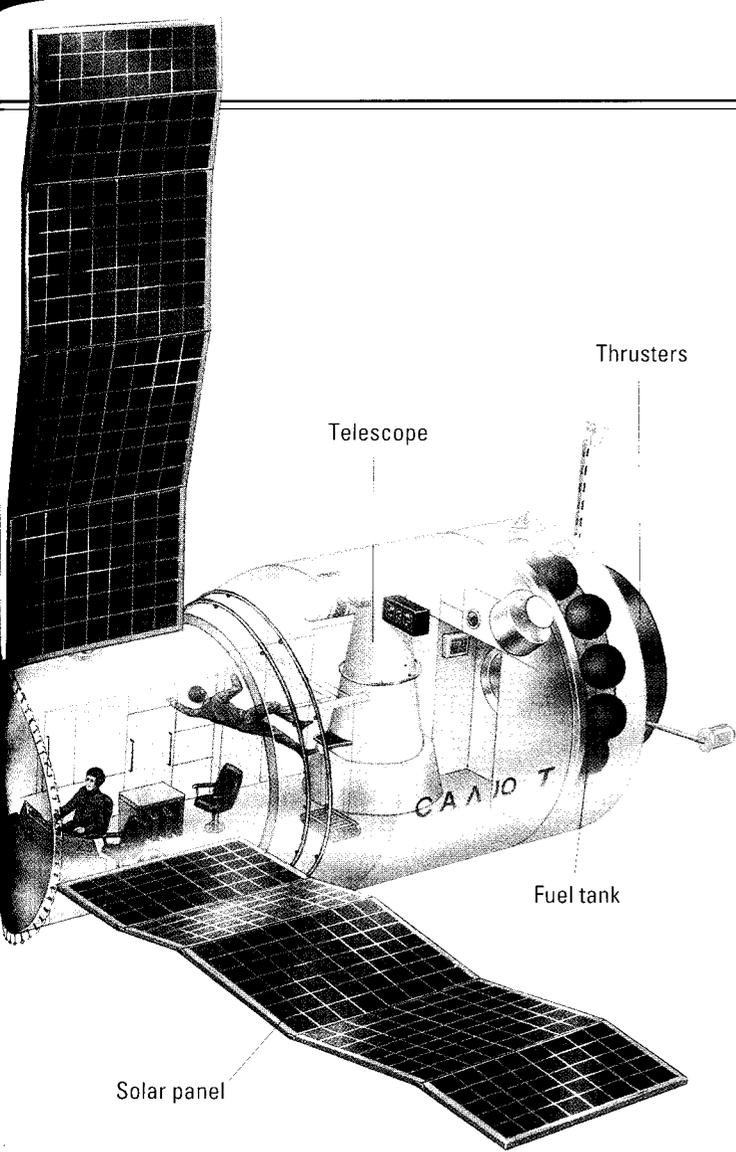
In 1975, astronauts of the Apollo-Soyuz Test Project, a joint American-Soviet space mission, performed various scientific experiments in space. This was followed by a joint unmanned mission, in which a Soviet satellite performed biological experiments that had been developed by U.S. scientists. Cooperation between the nations exploring space continues to develop. In 1995, the shuttle *Atlantis* linked up with the orbiting *Mir* space station. On board *Atlantis* were two Russians who transferred to *Mir*. Two Russians and an American who were aboard *Mir* transferred to the shuttle for the return to Earth.

**Space probes** A space probe is an unmanned vehicle that travels through the solar system and may travel beyond it (see PLANET; SOLAR SYSTEM). A space probe contains various devices that gather information about space and send the information to Earth. Between 1961 and the early 1980s, Soviet *Venera* space probes explored Venus. Other Soviet

**SALYUT**

The Soviet Union launched the first *Salyut* space station in 1971. It was designed so that a *Soyuz* spacecraft could act as a ferry to carry cosmonauts to and from the orbiting space station.



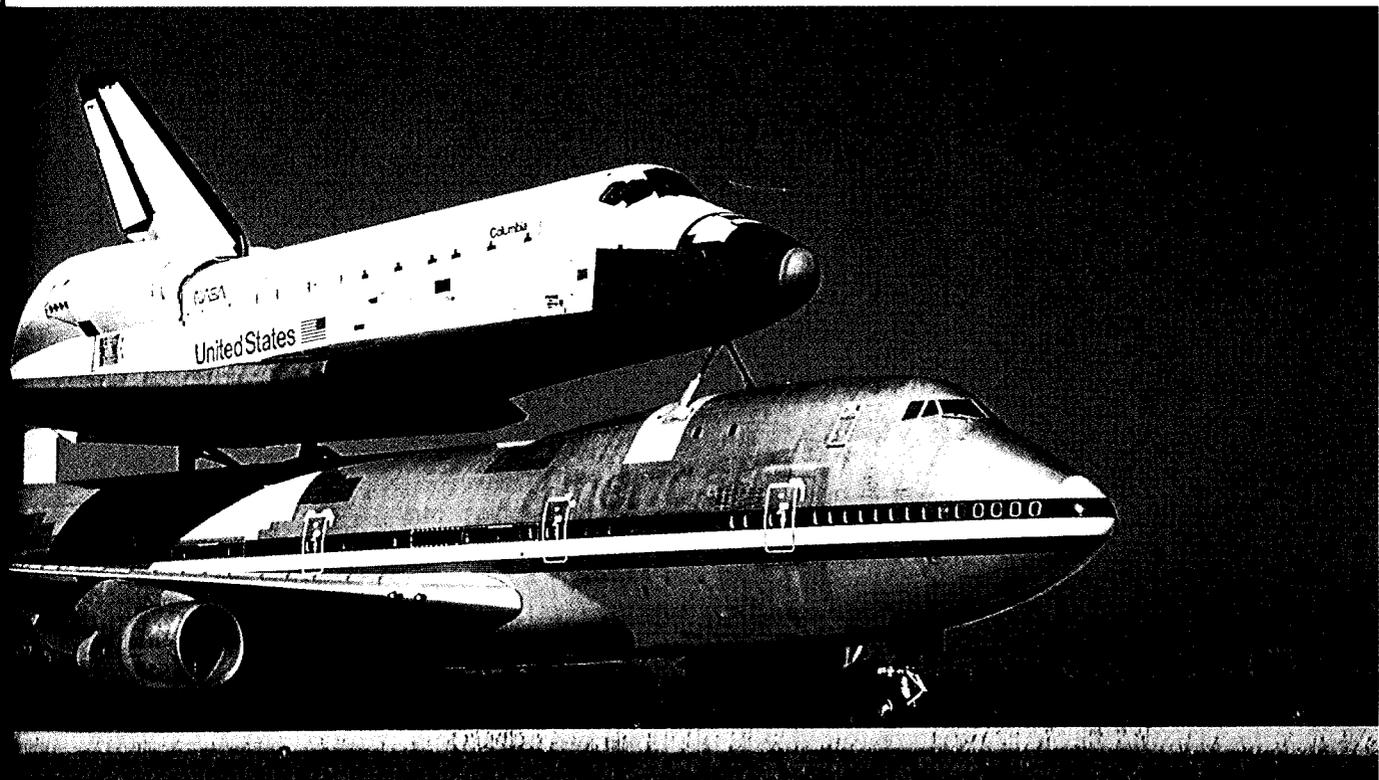


space probes explored the moon. In 1988 and 1989, Soviet *Phobos* probes explored Mars. The United States also began launching space probes in the 1960s. One important U.S. space probe is *Voyager 2*. *Voyager 2* was launched in 1977. It has sent back exciting photographs of Jupiter, Saturn, Uranus, and Neptune (see JUPITER; NEPTUNE; SATURN; URANUS). *Voyager 2* is expected to continue to send information back to Earth beyond the year 2000.

In 1989, the U.S. launched the space probe *Magellan*. *Magellan* sent back a detailed map of the surface of Venus. Another U.S. space probe, *Galileo*, also was launched in 1989. *Galileo's* final destination was Jupiter. However, along the way, *Galileo* traveled past Venus and two asteroids, Gaspra and Ida, sending pictures of them back to Earth. *Galileo* also flew past the earth twice, using the earth's gravity to help it accelerate towards Jupiter. In 1995, *Galileo* reached Jupiter and launched another smaller probe directly at

#### HITCHING A RIDE

After its first successful flight, the space shuttle *Columbia* landed at Edwards Air Force Base, California. It was then transported atop a Boeing 747 for the journey back to Cape Canaveral, Florida.



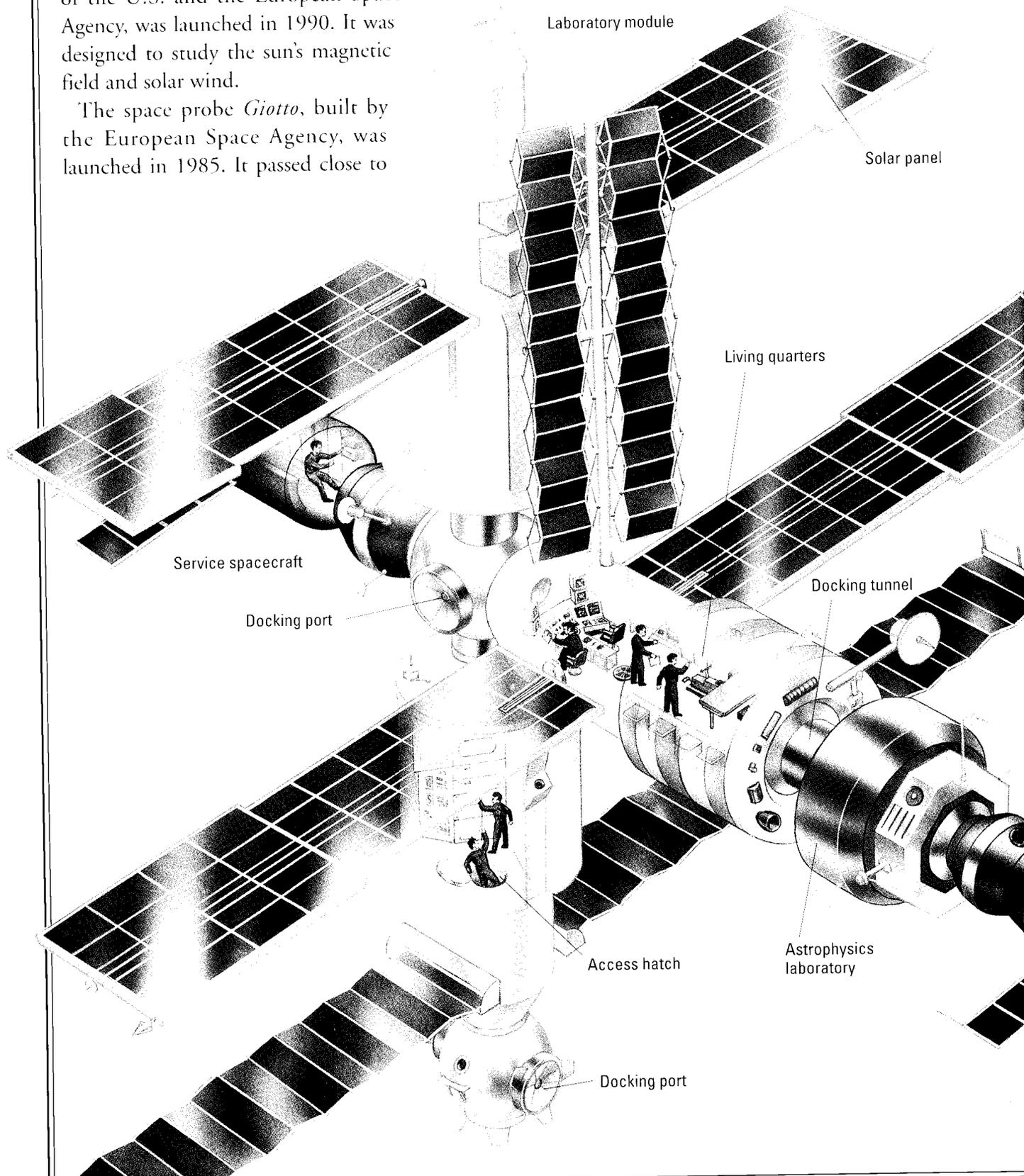
the planet to study Jupiter's atmosphere. Unfortunately, *Galileo* was hampered by equipment problems.

The space probe *Ulysses*, a joint project of the U.S. and the European Space Agency, was launched in 1990. It was designed to study the sun's magnetic field and solar wind.

The space probe *Giotto*, built by the European Space Agency, was launched in 1985. It passed close to

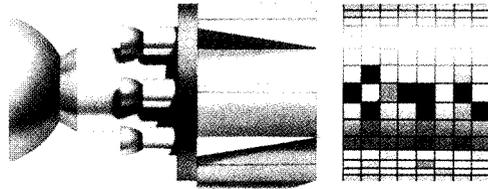
**MIR**

The Soviet Union launched the *Mir* space station in 1986. Since then, *Mir* has "grown" as more modules have been added to it. It can accommodate up to six cosmonauts for up to a year at a time.



**RAMSCOOP ROCKET**

A design for a possible future interstellar rocket, the ramscoop, has a "funnel" at the front. The funnel scoops up the hydrogen found in space, and the hydrogen is then used as fuel in a fusion rocket.



Halley's comet in 1986. In 1990, it flew by the earth, using the earth's gravity to divert its path towards another comet, called Grigg-Skjellerup, which it passed in 1992.

**Space shuttle** During the 1970s, the idea for a space shuttle was developed because of the tremendous expense of spacecraft that could be used only once. In April 1981, the United States' first space shuttle, *Columbia*, was launched from Cape Canaveral, Florida (see CAPE CANAVERAL). It later landed at Edwards Air Force Base in California. After each flight, the shuttle is carried atop a jet back to Florida.

In June 1983, Sally Ride, aboard the space shuttle *Challenger*, became the first U.S. woman in space. In January 1986, *Challenger* met with disaster shortly after being launched. The space shuttle exploded, and all seven crew members were killed instantly. Because of this tragedy, space shuttle flights were suspended for several years. The program resumed in 1989. In 1992, NASA added a new space shuttle, *Endeavor*, to its fleet to replace *Challenger*. In 1996, NASA operated four space shuttles: *Columbia*, *Discovery*, *Atlantis*, and *Endeavor*.

Because space shuttles can be reused, they allow space flights and experiments conducted in space to occur more frequently. They also are used to place satellites into orbit and repair them.

**Future space station plans** The United States, in cooperation with other countries, has plans for a second space station. The space station will be assembled in space beginning in the late 1990s.

The station will be built from separate modules. The modules will be carried into orbit by space shuttles and Russian launch vehicles. At first, astronauts will live in the station for short periods of time. Eventually, the station may be permanently occupied. A small crew will staff the station for a certain period and then will be replaced by another crew. The crews will be brought back and forth by a space shuttle.

The space station is expected to be used for studies of the long-term effects of space on astronauts and other living organisms. For example, it may be a laboratory for such experiments as those involving microgravity. (*Microgravity* refers to the zero or near-zero gravity conditions in orbit.) For example, the effects of zero gravity on bone formation in chicken embryos while they develop inside eggs may be studied. Through these experiments, scientists hope to understand the effects of zero gravity on the bone growth of humans and other animals. Scientists also may study whether semiconductor crystals of higher quality than is possible on Earth can be grown in space and whether exceptionally pure metals can be made in space.

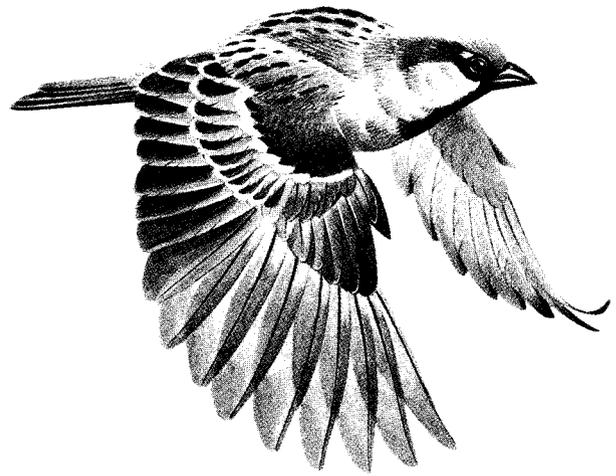
See also ASTRONAUTICS; CRYSTAL; SEMICONDUCTOR.

**SPARK PLUG** A spark plug is a device used to ignite the mixture of fuel and air in the cylinder of a gasoline engine (see **ENGINE**). It is fitted by means of a screw thread so that one end sticks into the space in the cylinder above the piston. The plug has two electrodes (see **ELECTRODE**). There is an electrode running down through its center. This electrode is surrounded by ceramic material, which is an insulator. Outside the ceramic is the metal plug casing. The casing screws into the wall of the cylinder, making electrical contact. From the lower end of the casing, the other electrode extends toward the center of the plug. A tiny gap is left between the ends of the two electrodes.

Electric wires are attached to the top end of the center electrode. A pulse of high voltage electricity is supplied from the engine's ignition coil through the distributor or through an electronic ignition system. This boosts the twelve volts from the vehicle's storage battery up to about twenty thousand volts. This is enough to make an electric spark jump across the gap between the two electrodes and ignite the explosive fuel and air mixture inside the cylinder (see **AUTOMOBILE**; **BATTERY**; **ELECTRICITY**; **VOLT**).

The plug electrodes gradually become corroded by the constant sparking. Deposits of carbon also form on them from the exhaust gases. Thus, spark plugs must be occasionally cleaned or replaced.

**SPARROW** A sparrow is a small, common bird. There are about fifty species of sparrows found in North and South America. Sparrows have streaked, brown bodies and short, stubby beaks. The sparrow's diet consists mostly of seeds. Sparrows often fly in large flocks (groups) and migrate long distances each fall and spring (see **MIGRATION**). The songs of sparrows sound like whistles. The house, or English, sparrow—perhaps the most common sparrow—is not closely related to the American sparrow. It was brought to the United States from Europe in the 1850s. Since then, it has greatly expanded its range at the expense of other types of birds. It is rarely found far from human settlements.



**SPARROW**

The house sparrow (above) has greatly expanded its range in the United States since being imported in the 1850s. Sparrows migrate long distances each fall and spring.

**SPAWNING** (spōning) *Spawning* refers to the way many water animals, especially fish, reproduce (see **REPRODUCTION**). Although different fish spawn differently, spawning usually involves external fertilization, which means that the eggs are fertilized outside of the fish's body (see **EGG**; **FERTILIZATION**). The female fish releases the eggs into the water while one or more male fish swim alongside and release sperm. The sperm fertilize the eggs, which hatch hours, days, or weeks later.

The eggs may be released in nests of stones or vegetation; on the bottom of a lake, stream, or ocean; or simply into the water. Some eggs float in the current, while other eggs stick to rocks and plants. Others get buried in sand or gravel. Fish release thousands or millions of eggs. Many of these eggs never hatch. They may die or be eaten by other fish.

Most fish spawn in the spring, when the water temperatures are rising. The fish gather in the spawning grounds in large numbers, and many of the males develop colorful patterns on their skin. These special colors, called breeding colors, show up only during the spawning season. They help attract the female fish to the male fish. Male fish also engage in special courtship behavior that helps attract female fish.

Many fish travel long distances to spawn. Some travel to one side of a lake. Some travel thousands

of miles in the oceans. Some swim upstream in rivers. Some fish that live in the ocean swim up freshwater rivers to spawn (see **MIGRATION**). These species, known as anadromous fishes, return to the same river in which they grew up as young fish before entering the sea. The best-known anadromous fish is the salmon (see **SALMON**). Large numbers of salmon are caught by fishers each year when the fish swim up the rivers during their spawning run.

The American eel does the exact opposite migration. It lives its adult life in fresh water and returns to salt water—the Sargasso Sea—to spawn.

*See also* EEL; FISH.

**SPECIES** (spē'shēz) A species, in the classification of living organisms, is a particular kind of organism, such as a gorilla or a coconut palm. Members of a species usually look alike. They can breed among themselves but usually cannot breed with members of another species. The members of a species are more closely related than are members of any other taxonomic grouping. Closely related species are placed in the same genus.

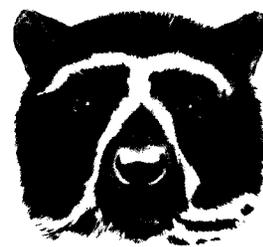
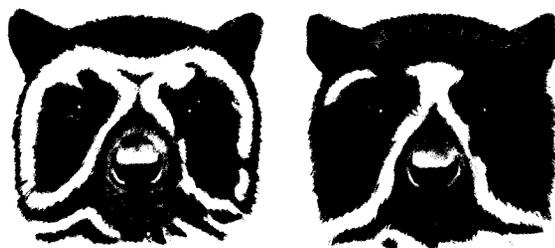
*See also* CLASSIFICATION OF LIVING ORGANISMS; GENUS; TAXONOMY.

**SPECIFIC HEAT CAPACITY** (spī sīf'īk hēt kə pās'ī tē) The specific heat capacity of a substance is the amount of heat needed to raise the temperature of one gram of the substance one degree Celsius. The specific heat of water, which is given a value of 1, is the standard for determining the specific heat capacity of all other substances.

*See also* CALORIE; HEAT; JOULE.

**SPECTACLED BEAR** The spectacled (spēk' təkəld) bear is the only South American bear. It has shaggy black or dark brown fur. The spectacled bear gets its name from the circles or semicircles of white fur around its eyes. In many of these bears, these circles of white fur look like eyeglasses. Frequently, the white fur extends down onto the neck and chest.

Spectacled bears are usually about 5 ft. [1.5 m] long and 30 in. [76 cm] high at the shoulder. They



#### **SPECTACLED BEAR**

Although there is only one species of spectacled bear, there are a variety of facial markings within the species.

weigh less than 300 lb. [135 kg]. Their diet consists mostly of fruits and leaves. Sometimes, though, they may feed on small animals. Spectacled bears usually live in cool mountain forests. They are good climbers.

*See also* BEAR.

**SPECTROMETER** (spēk trōm'ītər) A spectrometer is an instrument for taking measurements of a spectrum (see **SPECTRUM**). A spectrometer is a type of spectroscopy.

*See also* SPECTROSCOPE.

**SPECTROSCOPE** (spĕk'trə skōp') Scientists can learn many things by studying spectra (plural of *spectrum*) (see SPECTRUM). Any instrument that produces a spectrum for study can be called a spectroscope.

Scientists study various forms of electromagnetic radiation with spectroscopes (see ELECTROMAGNETIC RADIATION). Such radiation includes visible light, X rays, ultraviolet and infrared rays, microwaves, and radio waves. The radiation has waves of different frequencies in a continuous band or in a series of separate bands or lines (see FREQUENCY; WAVE). These bands or lines are made visible with a spectroscope.

To make a spectrum of visible light, the radiation may be passed through a prism (see LIGHT; PRISM). Sir Isaac Newton's prism arrangement was the first spectroscope (see NEWTON, SIR ISAAC). Another device used to separate the frequencies of visible light is a diffraction grating (see DIFFRACTION). Diffraction gratings may be used to study infrared or ultraviolet rays as well as visible light (see INFRARED RAY; ULTRAVIOLET RAY).

Different sources of radiation have different spectra. The spectra differ depending on the atoms and molecules present in the source (see ATOM; MOLECULE). By studying the spectra from a radiation

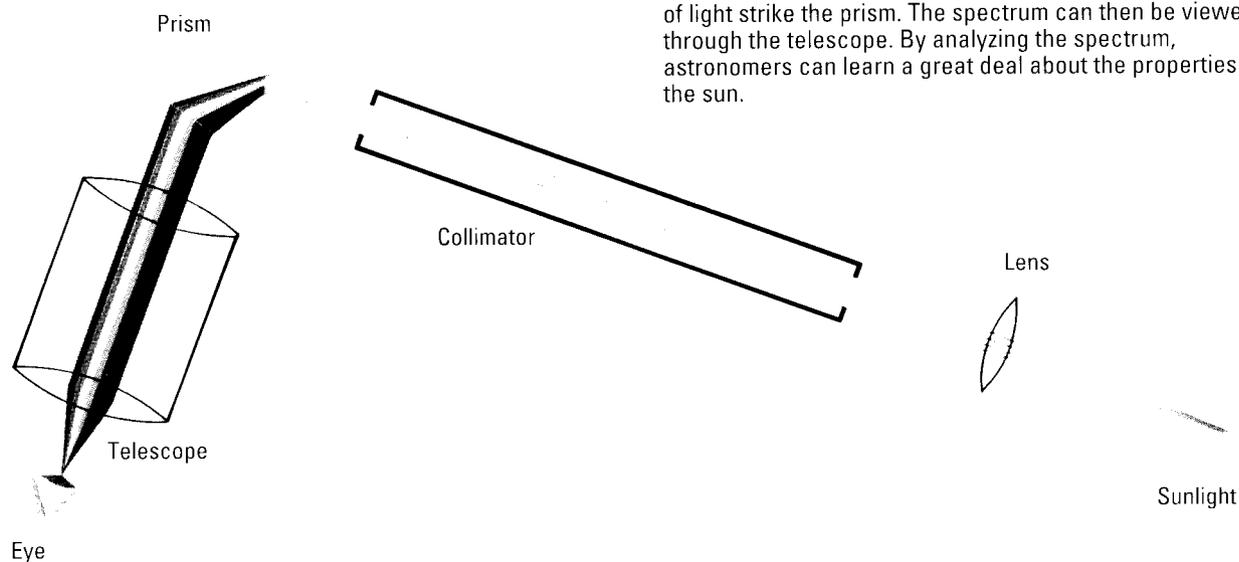
source, scientists can determine the chemical composition of the source. Astronomers use spectroscopes to analyze the spectra of radiation from the sun, stars, and distant galaxies. They are able to determine the chemical composition, temperature, and other properties of those bodies by studying the spectra (see ASTROPHYSICS).

A spectroscope equipped with a scale for measuring wavelengths or frequencies of spectra is called a spectrometer (see SPECTROMETER). Spectrophotometers are instruments that show the intensities of different frequencies in a spectrum. A spectrophotometer can be used to measure the absorption of different frequencies of light by samples of a solution. In this way, scientists can identify small quantities of substances dissolved in a liquid. A spectrograph is a device for taking pictures of different spectra so that they can be analyzed. In a mass spectrograph, charged particles given off from a source are deflected by electric and magnetic fields so that they form a kind of spectrum according to their mass. The spectrum is usually recorded on a photographic plate. The photographic plate can be analyzed to show the relative atomic masses of the elements present.

See also ELEMENT; MASS; RELATIVE ATOMIC MASS.

#### SPECTROSCOPE

A spectroscope can be used to study the spectrum of any light source. The illustration shows sunlight being focused by a lens into a device called a collimator, so that parallel rays of light strike the prism. The spectrum can then be viewed through the telescope. By analyzing the spectrum, astronomers can learn a great deal about the properties of the sun.



# SPECTRUM

A spectrum (spěk'trəm) is an arrangement of radiation in order of wavelength or frequency (see FREQUENCY; RADIATION; WAVE). The most familiar spectrum is seen in a rainbow. Raindrops split up sunlight into all the separate colors that make up white light (see LIGHT). Each color represents a small range of frequencies of light vibrations. The colors we usually see in the visible spectrum are red, orange, yellow, green, blue, indigo, and violet (see

COLOR). The light at the red end of the visible spectrum has the longest wavelengths (or lowest frequency). The light at the violet end of the visible spectrum has the shortest wavelengths (or highest frequency).

Beyond each end of the visible spectrum are other forms of radiation. We cannot see them, but they are still important. Beyond the red end are infrared rays, which are heat radiation. Beyond the violet



## EMISSION AND ABSORPTION

Glowing sodium vapor produces a yellow light that has a spectrum of two lines spaced close together (above). This kind of spectrum is called an emission spectrum.

If light passes through sodium vapor, the spectrum produced has two dark lines where the emission spectrum has two bright lines (above). This happens because the sodium vapor absorbs light at these frequencies. Such a spectrum is called an absorption spectrum.



An emission spectrum of white light is shown above. All the wavelengths are present.

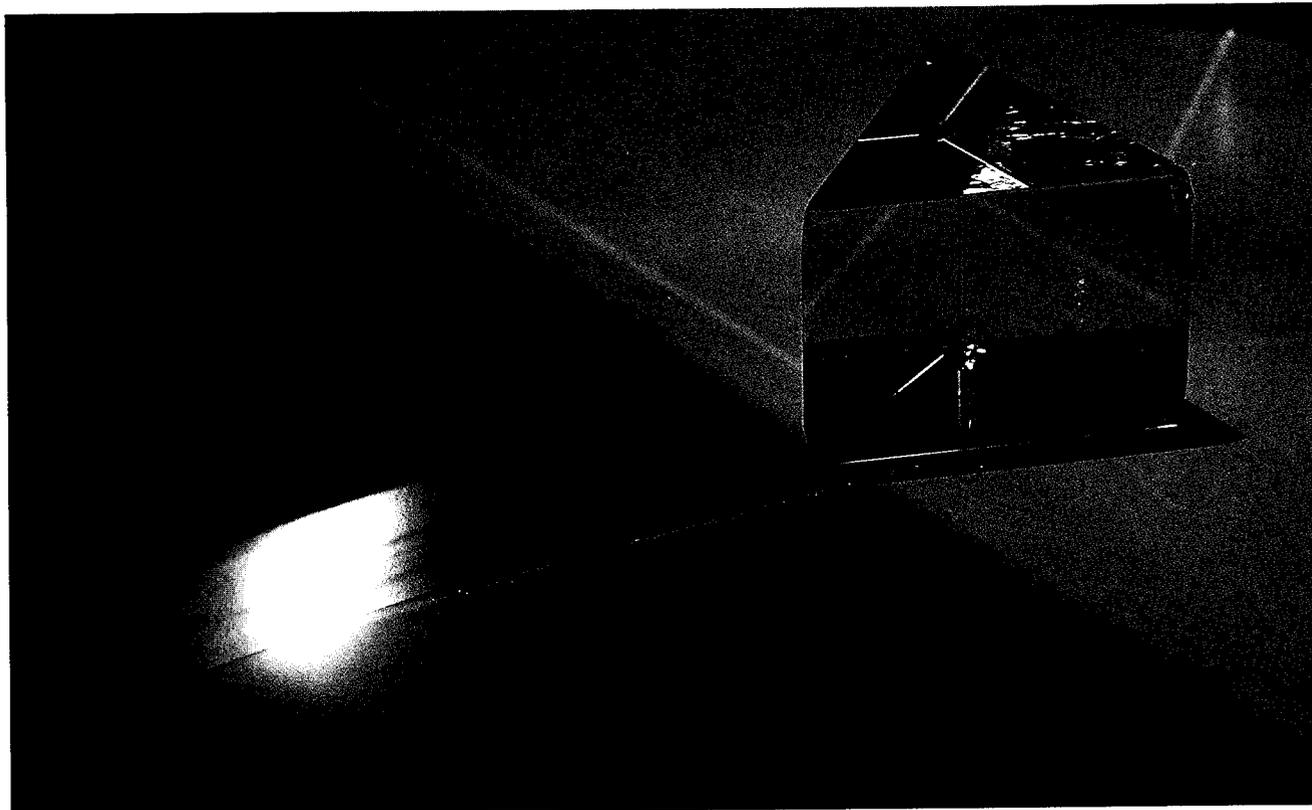
An absorption spectrum of the sun is pictured below. The dark lines represent certain wavelengths that are missing from the spectrum.



Emission spectra of various elements are shown below. Left column: hydrogen (top), mercury (middle), and sodium (bottom). Right column: barium (top), potassium (middle), and lithium (bottom). Knowledge of the spectra of individual

elements is useful in determining which elements are present in a star. The spectrum of a star can be obtained and the lines compared with those of known elements. Similarly, unknown mixtures of elements can also be analyzed.





end are ultraviolet rays. These are responsible for burning or tanning the skin. Farther beyond the infrared lie radio waves, and farther beyond the ultraviolet lie X rays and gamma rays. All these forms of radiation make up a continuous spectrum, the electromagnetic spectrum (see ELECTROMAGNETIC RADIATION).

To produce a spectrum of all the colors, white light may be passed through a prism (see PRISM). Some of the frequencies are bent more than others as they pass through the glass, and so the frequencies become separated. The spectrum can be projected on a screen or on a photographic plate. The screen may be marked with a scale of frequencies corresponding to each point in the spectrum. Such a device is a type of spectroscope (see SPECTROSCOPE).

When a spectrum of sunlight is shown on a screen in this way, it may be seen to have a number of dark lines at particular frequencies. These lines are due to elements in the outer atmosphere of the sun. The vapors of these elements absorb light of certain frequencies (see VAPOR). Dark lines are left where the light has been filtered out of the spectrum. Each element produces its own

#### SOLAR SPECTRUM

A glass prism can split a beam of white light from the sun into all the colors of the rainbow. This set of colors is known as the solar spectrum.

particular pattern of bands. The pattern for each element is known as its absorption spectrum. Absorption spectra (plural of *spectrum*) enable scientists to identify the elements in the atmosphere of the sun and other stars (see ASTROPHYSICS; ELEMENT).

Absorption spectra also help scientists understand how stars move. When stars are moving away from us, the dark lines of their absorption spectra are found to move toward the red end of the spectrum. This is called the red shift (see DOPPLER EFFECT; RED SHIFT). The faster the star is moving, the greater this shift.

If a substance is turned into a vapor by extreme heat, its elements give out a spectrum of bright lines. This is called an emission spectrum. The bright lines are in the same positions as the dark lines in the elements' absorption spectra. Often it is possible to detect the presence of an element by means of its emission spectrum when only one part in a million is present.

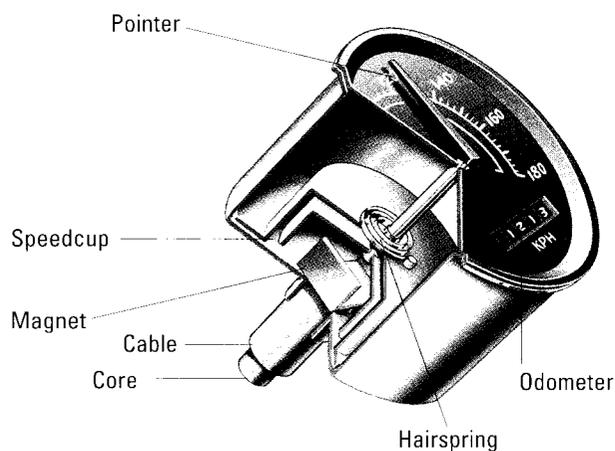
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**SPEED** Speed is a measure of the time it takes to travel a certain distance. It can be measured in miles per hour, kilometers per hour, meters per second, or any other convenient unit. For instance, if a car travels a distance of 60 miles in one hour, its speed is 60 m.p.h. (60 miles per hour). Speed is a scalar measurement, which means that it is independent of the direction of travel. Velocity, on the other hand, is a measurement of speed in a specified direction.

*See also* VELOCITY.

**SPEEDOMETER** (spĭ dŏm'ĭ tər) A speedometer is an instrument found in motor vehicles that indicates the speed of the vehicle in miles per hour, kilometers per hour, or both (see SPEED). In a mechanical speedometer, the speed is read on a dial that has numbers that usually range from 0 to 140. A moving pointer on the dial indicates the speed. Some vehicles have electronic speedometers, which display the speed as numbers on a panel.

A mechanical speedometer is driven by a flexible cable that is connected to a set of gears in the vehicle's transmission (see CABLE; GEAR). When the vehicle moves, the gears turn a core, or flexible metal shaft, inside the cable. The core turns a magnet inside a metal drum, called a speedcup, which is inside the speedometer housing (see MAGNETISM). The revolving magnet exerts a force on the speedcup that causes the speedcup to turn. The movement of the speedcup is transferred to the



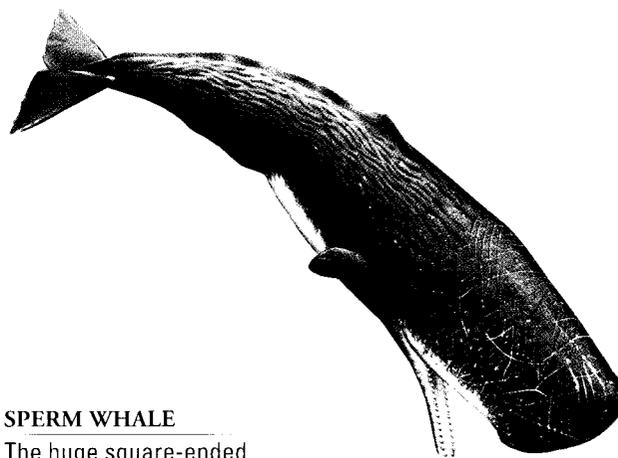
#### SPEEDOMETER

A revolving magnet at the end of the core tries to revolve the speedcup, which is held in check by the hairspring.

pointer on the dial of the speedometer. However, the motion is slowed by the action of a fine spring called a hairspring. The hairspring prevents the pointer from simply turning around and around. It also brings the pointer back to zero when the vehicle stops moving.

Most speedometers also incorporate an odometer, a device that records the distance driven. Some vehicles have trip odometers that can be reset to zero.

*See also* AUTOMOBILE.



#### SPERM WHALE

The huge square-ended head of the sperm whale is one-third of its body length.

**SPERM WHALE** The sperm whale, or cachalot, is one of the largest and best-known whales. The male sperm whale often grows to more than 60 ft. [20 m] long, but females are only about half this length. This whale is easily recognized by its square-ended head. The lower jaw is very long and narrow and swings down from the head like a trapdoor. The sperm whale has about fifty large teeth in its lower jaw that average 8 in. [20 cm] in length. The upper jaw has no teeth at all. The sperm whale lives in all oceans of the world but prefers the warmer waters of tropical regions. The sperm whale generally feeds on large squid and cuttlefish (see CUTTLEFISH; SQUID).

Sperm whales have long been sought by hunters for their oil, which is a valuable lubricant used in many industries. Sperm whales also contain a substance known as spermaceti, which is used in cosmetics and ointments.

*See also* WHALE.

**SPIDER** Spiders belong to a large class of arthropods called arachnids (see ARACHNID; ARTHROPODA). Spiders are not insects. There are about forty thousand known species of spiders and as many as another seventy thousand yet to be identified. The various species range from about 0.04 in. [1 mm] to giants measuring more than 10 in. [25 cm] across their outstretched legs.

All spiders produce silk, though not all of them make webs. Most spiders have glands that produce poison for killing or paralyzing prey (see GLAND). In North America, only six species are dangerous to human beings. These are the brown recluse, black widow, brown widow, red-legged widow, varied widow, and sac spider. Most spiders are very helpful to people because they kill large numbers of insects that people consider pests. Some spiders even eat mice and other animals such as frogs.

**Body of a spider** The body of a spider has two sections: the cephalothorax and the abdomen (see ABDOMEN; THORAX). The cephalothorax is a fused head and thorax. It is joined to the abdomen by a thin waist called a pedicel. The body has a tough skin that is covered with many hairs or tiny spines.

Like all arachnids, spiders have a pair of fanglike appendages called chelicerae. The chelicerae are located between the eyes and mouth. They each end in a hollow claw that acts as a fang, injecting poison into the spider's prey. Spiders also have a pair of leglike palps, one on each side of the mouth.

These help the spider feel its way around. Their bases are also used to slice and crush food.

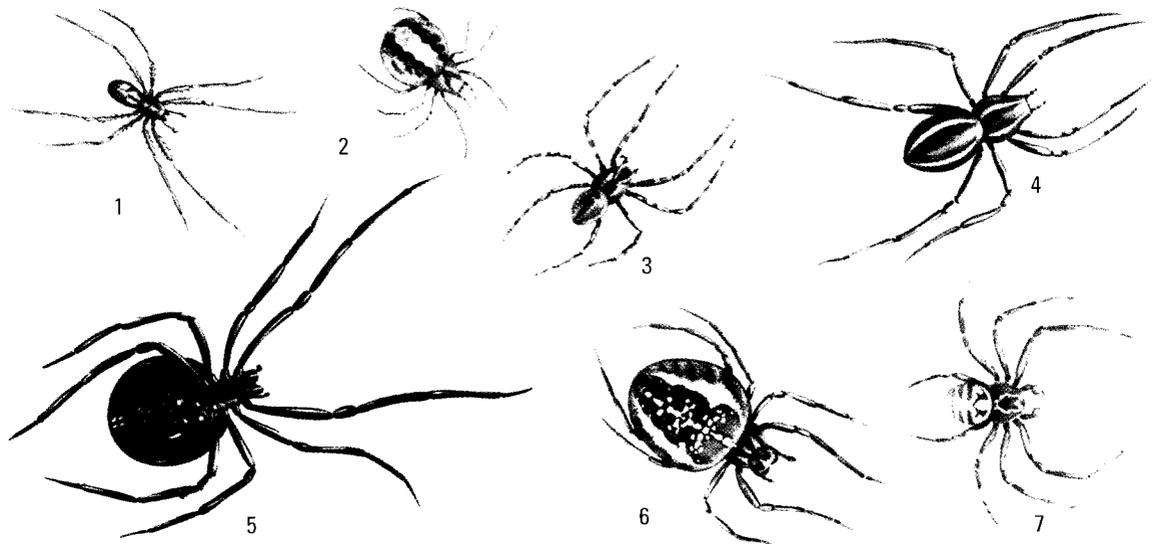
A spider cannot chew, so its food must be in liquid form. The spider has a narrow, tubelike mouth for sucking juices from its food. A spider can eat solids only after predigesting them. It does this by spitting digestive juices on the solid. This causes the solid to break down into a liquid. Most spiders have eight simple eyes, but some have less than this and some spiders have no eyes at all (see EYE AND VISION).

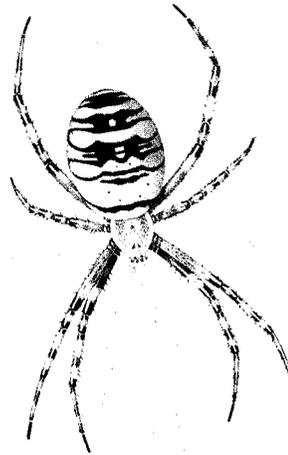
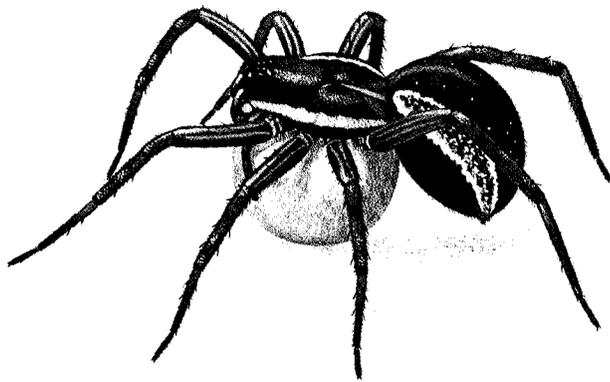
Like all arachnids, spiders have eight legs. Each leg has seven segments, the last of which ends in two or three claws. A tiny pad of hairs called a scopula may surround the claws.

Spiders produce silk in glands in the abdomen. The silk is drawn out when needed through organs called spinnerets, which are at the end of the abdomen. Most spiders have six spinnerets, but some have as few as two. A spider leaves a thin thread of silk, called a dragline, wherever it goes. As the spider moves, it attaches the dragline in various places with dots of silk called attachment disks. The dragline can be used to help a spider escape from an enemy or detect the presence of prey in a web. Many spiders weave elaborate webs of silk.

#### SPIDER—Varieties

Various kinds of spider are pictured: (1) platform spider, (2) common house spider, (3) common garden spider (male), (4) wolf spider, (5) black widow spider, (6) common garden spider (female), and (7) crab spider.



**SPIDER—Behavior**

Two types of spider behavior shown here are (1) a female raft spider carrying a sac of eggs, and (2) an orb spider displaying her warning colors as she sits at the center of her web.

Most spiders also wrap their eggs in a sack of silk. Many spiders use silk to wrap a “cocoon” around prey so that the prey cannot escape.

Spiders breathe through tiny openings called spiracles. The spiracles open into “book lungs” in the abdomen. These book lungs are made of folds of thin tissue and act much like the lungs of higher animals. The blood of spiders is colorless. There is a long, tubular heart in the abdomen. The circulatory system is open, meaning that blood flows into body spaces and does not stay in blood vessels.

**Reproduction** In most species of spiders, the females are larger than the males. As soon as a male reaches maturity, he looks for a mate. Most spiders have a complex dance that is a part of the courtship before mating. In many species, the male prepares to mate by spinning a platform of silk. He then

squirts a drop of sperm (fluid containing male sex cells) from his abdomen onto the platform. He fills the ends of his palps with this sperm and uses the palps to transfer the sperm to the female during mating. The female may store the sperm in her body for several months. When she lays her eggs, they are fertilized by the stored sperm as they leave her body. The number of eggs varies from one to several thousand, depending on the species (see EGG; FERTILIZATION; REPRODUCTION).

Most females wrap the eggs in a case of silk. In some species, the female dies soon after making the silk case. In many species, though, she carries the egg sack with her or stays with the eggs until they hatch into spiderlings.

As soon as the spiderlings have hatched, they start producing draglines. Some use these draglines to travel great distances by a process called ballooning.

**SPIDER—Trapdoor**

The trapdoor tarantula digs a burrow and then covers the entrance with a lid of silk. When an insect walks near the lid of silk, it causes the lid to vibrate. The tarantula detects the vibrations and springs out to capture the prey.



In ballooning, a spiderling spins a dragline and lets it get caught by the wind. Some spiderlings have been found floating in the air more than 200 mi. [320 km] out to sea. A spiderling looks much like a small adult spider. It molts several times before reaching full size (see *MOLTING*).

**Prey capture** As far as catching prey is concerned, there are two main groups of spiders: hunting spiders and web-spinning spiders. Most hunting spiders have good vision. They actively pursue prey by running after or pouncing on it. Tarantulas are the largest and most fearsome looking of the hunting spiders. Most of them live in burrows. The trapdoor tarantulas cover the openings of their underground homes with lids of silk. When their prey walks near the trapdoor, the tarantula detects the vibrations, opens the door, and captures the prey.

In contrast with the hunting spiders, most of the web-spinning spiders have poor vision. They rely on their webs to catch unsuspecting flying insects. Sheet-web weavers produce flat, horizontal sheets of silk. Some produce two sheets and lie in wait between them. Orb weavers produce beautiful, complex webs that are usually circular with a definite network pattern.

A third group, typified by the crab spiders, simply lie in wait for their prey without making any form of trap. They often sit in flowers and grab the insects that come to feed. Some crab spiders can change color to match different flowers.

**SPIDER MONKEY** The spider monkeys include four species of New World monkeys that belong to the genus *Ateles* in the family Cebidae. They live in tropical forests in Mexico and Central and South America. They are about 2 ft. [60 cm] long with a tail that is about 3 ft. [90 cm] long. The tail has a hairless, fingerlike tip that allows the monkeys to grasp tree branches. The monkeys can hang by their tails while they pick food with their hands. Unlike most other monkeys, the spider monkeys have no thumbs.

Most spider monkeys have brown or reddish brown fur. They live in groups of as many as one



#### **SPIDER MONKEY**

The black-handed spider monkey (above) is an agile climber and moves easily through tree branches using its grasping tail like an extra limb.

hundred monkeys. They are herbivores and usually eat fruits and nuts.

*See also* HERBIVORE; MONKEY.

**SPINA BIFIDA** Spina bifida is a congenital condition (a condition a person is born with) affecting about 1 in 700 babies. Part of the bony plate of the spine, which normally protects the spinal cord, fails to develop properly in the womb (uterus) (see *SPINAL CORD*). The nerves of the spinal cord in that area are exposed and become easily damaged, which causes paralysis. The exposed area of the spinal cord can become easily infected, which can be fatal. Spina bifida in the lower spine often causes paralysis in the legs as well as incontinence (the inability to control bowel and bladder functions). In the upper spine, it can cause paralysis in the arms. Surgery can repair the gap in the spine, but there is no way of repairing the nerves once they are damaged. Physiotherapy, or physical therapy, can help people with spina bifida to lead

independent lives. There are many therapy centers in the United States to help children with spina bifida and their parents (see *PHYSIOTHERAPY*).

**SPINACH** (spīn'īch) Spinach is an annual plant that belongs to the goosefoot family (see *ANNUAL PLANT*; *GOOSEFOOT FAMILY*). The spinach plant produces a rosette of thick, juicy leaves (see *LEAF*). These leaves are a good source of vitamins A and C. They also provide some B vitamins and they are much richer in protein than most other leaves (see *VITAMIN*). The leaves can be eaten raw in a salad, cooked as a vegetable, or used as an ingredient in many types of dishes.

**SPINAL CORD** The spinal cord is the thick bundle of nerve cells that extends from the lower part of the brain down the vertebral column (backbone) of all vertebrates, including human beings (see *NERVE CELL*; *NERVOUS SYSTEM*; *VERTEBRA*; *VERTEBRATE*). The spinal cord carries millions of nerve impulses in both directions between the brain and the trunk and limbs. Pairs of spinal nerves (cordlike bundles of nerve cell fibers) branch off from each side of the spinal cord, carrying these impulses. The whole spinal cord is encased in the vertebrae of the spine (see *SKELETON*). The spinal nerves pass through small spaces between the vertebrae. The human body has thirty-one pairs of spinal nerves.

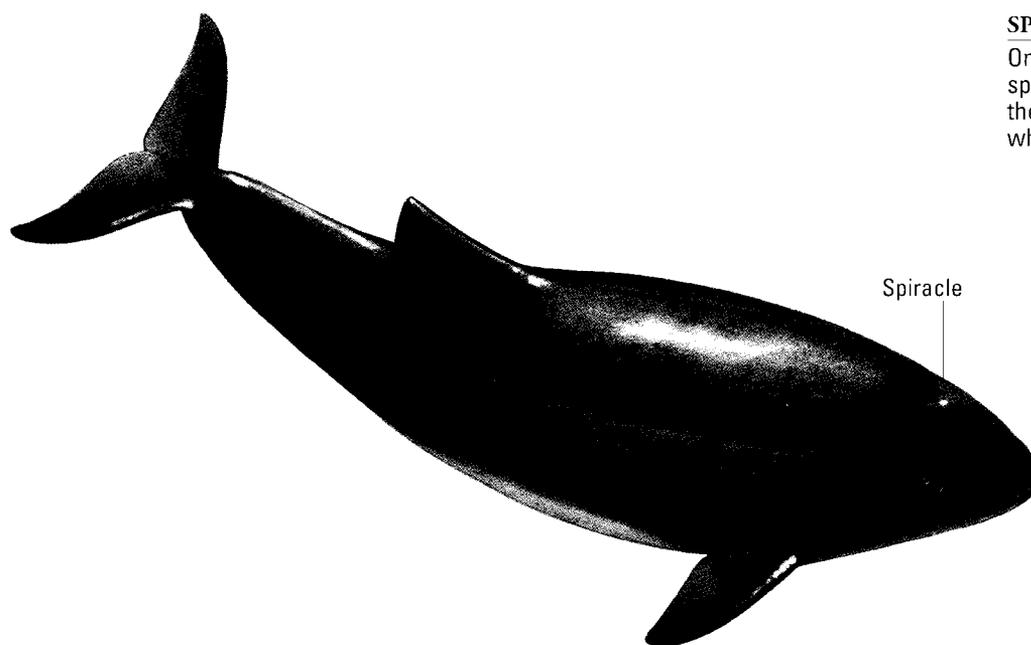
If the spinal cord is seen in cross section, the central part appears gray. The outer part looks white. The white matter is made up of nerve cells and nerves that relay nerve impulses up and down the cord. The gray matter has many synapses (junctions) between nerve cells, where messages are "switched"—that is, transferred from nerve cell to nerve cell. In particular, many reflex actions are caused by nerve impulses switched through the gray matter of the spinal cord (see *REFLEX*). This switching function is much more complex than the message carrying of ordinary nerves. Because the spinal cord forms an extension of the brain stem, and because it performs this switching function, it is considered, along with the brain, part of the central nervous system.

*See also* *BRAIN*.

**SPIRACLE** (spīr'ə kəl) A spiracle is part of the respiratory system of many animals (see *RESPIRATION*). It is an external opening through which air or water passes. In many arthropods, such as insects, the spiracles open into a series of branching tubes (see *INSECT*). Most insects have two pairs of spiracles on the thorax and eight more on the abdomen (see *ABDOMEN*; *THORAX*). In other arthropods, such as spiders and other arachnids, the spiracles open into pouches containing folded membranes (thin tissues) called book lungs (see *SPIDER*).

#### **SPIRACLE**

On this porpoise, the spiracle is the blowhole on the top of its head through which it breathes out.



In rays and some other cartilaginous fishes, spiracles are associated with the gills (see FISH; GILLS). They are small openings just behind the eyes. Water flows through the spiracles and into the gills. In whales, the spiracle is the opening of the nasal cavity. It is often called the blowhole (see WHALE). In tadpoles, the spiracle is the single opening through which water flows as it leaves the gills. When a tadpole becomes an adult frog, its left front leg emerges through the spiracle.

**SPIRAEA** (spī rē'ə) *Spiraea* is a genus of the rose family that includes about one hundred species of herbaceous plants and shrubs (see HERBACEOUS PLANT; SHRUB). Spiraeas are found throughout temperate areas of the Northern Hemisphere. They are popular garden plants because they produce clusters of beautiful white, red, or pink flowers.

See also ROSE FAMILY.



**SPIRAEA**

Shrubby types of spiraea are valued for their sprays of white, pink, or red flowers. Smaller species are known as meadowsweet in some parts of the United States.

**SPLEEN** The spleen is a large organ in the body that helps filter the blood. It is about 5 in. [12.5 cm] long and 3 to 4 in. [7.5 to 10 cm] wide in adults. The spleen weighs about 7 oz. [200 g] and consists of deep violet-red spongy tissue. It is located to the left of the stomach and a little behind it.

The spleen helps filter foreign substances from the blood. It also contains a type of white blood cell called lymphocytes. Lymphocytes fight disease-causing organisms that get into the body. The spleen also acts as an emergency blood supply. It releases some of the blood it has stored if the body loses blood through an injury (see BLOOD; IMMUNITY).

The spleen is not an essential organ. Sometimes, it becomes diseased and has to be surgically removed from the body.

See also LYMPHATIC SYSTEM.

**SPONGE** (spūnj) Sponges are simple, multicellular animals that belong to the phylum Porifera. All sponges are aquatic, and most live in tropical or subtropical oceans. Freshwater sponges often live symbiotically with various types of algae (see ALGAE; SYMBIOSIS). Sponges range in size from about 0.8 in. [2 cm] to 4 ft. [1.2 m]. They frequently live in colonies of hundreds of sponges.

The body of a sponge may be tube shaped, or it may have no particular shape. Sponges are hollow. They have many tiny openings called pores in their body walls. These pores lead to canals made of flagellated cells called collar cells (see CELL; FLAGELLUM). The flagella in these flagellated cells beat constantly. This creates a flow of water into the pores, through the body, and out a large opening called the osculum. Tiny organisms in the water are trapped and digested by the collar cells. The constant flow of water also brings in dissolved oxygen and removes wastes. There is no nervous system to control the sponge's activity, and each cell works on its own.

A sponge is supported by a framework of tiny needles or long fibers, or both. The needles are called spicules. They may be made of calcium carbonate or silica (see CALCIUM CARBONATE; SILICA). The fibers are made of a protein called spongin. When a sponge dies, it leaves its framework behind.

**SPONGE**

The bright purple vase sponge, which grows in the waters of the Caribbean, is unusual because it is fluorescent (it gives off light).

Fibrous sponge “skeletons” are collected and used for household purposes. Most of the commercially available sponges, however, are synthetic—that is, human made. They are designed to look and work like natural sponges, but they are made of plastic or other artificial materials.

Some species of sponges are hermaphrodites, and some have distinct sexes (see HERMAPHRODITE). Both kinds release sperm into the water, and some of the sperm finds its way to the eggs still nestling inside the sponges. The sperm and eggs join up, and each fertilized egg develops into a flagellated, free-swimming larva (see EGG; LARVA). This larva is swept out of the parent’s body. After swimming around for a while, the larva settles on a surface and develops into a sessile (nonmoving) adult. Sponges also reproduce by forming buds.

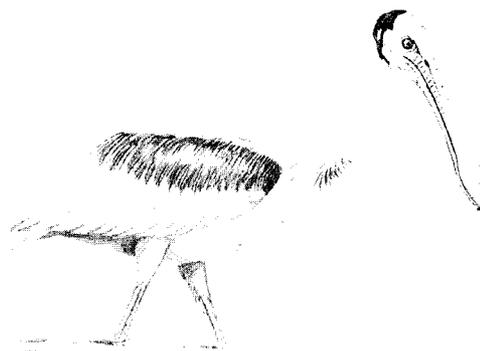
See also ASEXUAL REPRODUCTION; BUDDING.

**SPONTANEOUS GENERATION** (spōn tā'nē əs jĕn'ə rā'shən) Spontaneous generation is the theory that organisms develop from nonliving material. Early scientists had noticed that maggots (fly larvae) would suddenly appear on decaying meat. They thought these maggots appeared out of nowhere—spontaneous generation. However, in time, scientists realized that the larvae hatched from tiny eggs laid by adult flies. Such observations helped disprove the theory of spontaneous generation as an explanation for how life arises under current conditions.

It is generally accepted that all living things on Earth today come from other living things. However, many scientists are working on experiments to try to learn how living organisms first developed on Earth. Such organisms probably did arise by spontaneous generation.

See also LIFE.

**SPOONBILL** A spoonbill is a long-legged wading bird that belongs to the family Threskiornithidae. It is closely related to the ibis (see IBIS). The spoonbill was named for its long, flattened bill, which is enlarged at the tip, having a shape similar to that of a spoon. The bird moves its bill from side to side to strain small crabs, crayfish, and fish out of the water. The only species of spoonbill found in North America is the roseate spoonbill, which has a vivid pink belly, wings, and legs. It is rather rare but can be found in extreme southern Florida, Texas, and Mexico. The roseate spoonbill usually lives in shallow salt water.

**SPOONBILL**

The roseate spoonbill of North America has pink and white feathers and a long, light green bill.

**SPORANGIUM** (spə rān'jē əm) A sporangium is a caselike structure that produces, stores, and releases spores (see SPORE). In simple algae and fungi, the sporangium is one celled and produces few spores. In more advanced organisms, such as ferns and mosses, the sporangium is multicellular and produces many spores.

See also ALTERNATION OF GENERATIONS; ASEXUAL REPRODUCTION.

**SPORE** A spore is a single cell that can develop into a new organism (see CELL). Spores are produced by many organisms as part of reproduction (see ALTERNATION OF GENERATIONS; REPRODUCTION). Algae, bacteria, fungi, ferns, hornworts, liverworts, and mosses all reproduce by spores. The sporozoans, a type of parasitic protozoan, also produce spores (see ALGAE; BACTERIA; FERN; FUNGUS; MOSS, LIVERWORT, HORNWORT; PROTOZOA; SPOROZOAN).

Most spores are so light in weight that they can be carried by the wind. Some spores are called zoospores. They have one or more tiny taillike flagella and are able to swim around in water (see FLAGELLUM). Such spores are produced by some algae. Spores produced by plants that live on land, such as mosses and ferns, have thick and resistant

outer coverings (cell walls). This enables the spores to survive unfavorable conditions such as dryness and high and low temperatures. Some spores remain in an inactive, or dormant, state for years until water and the right temperature enable them to grow into new organisms.

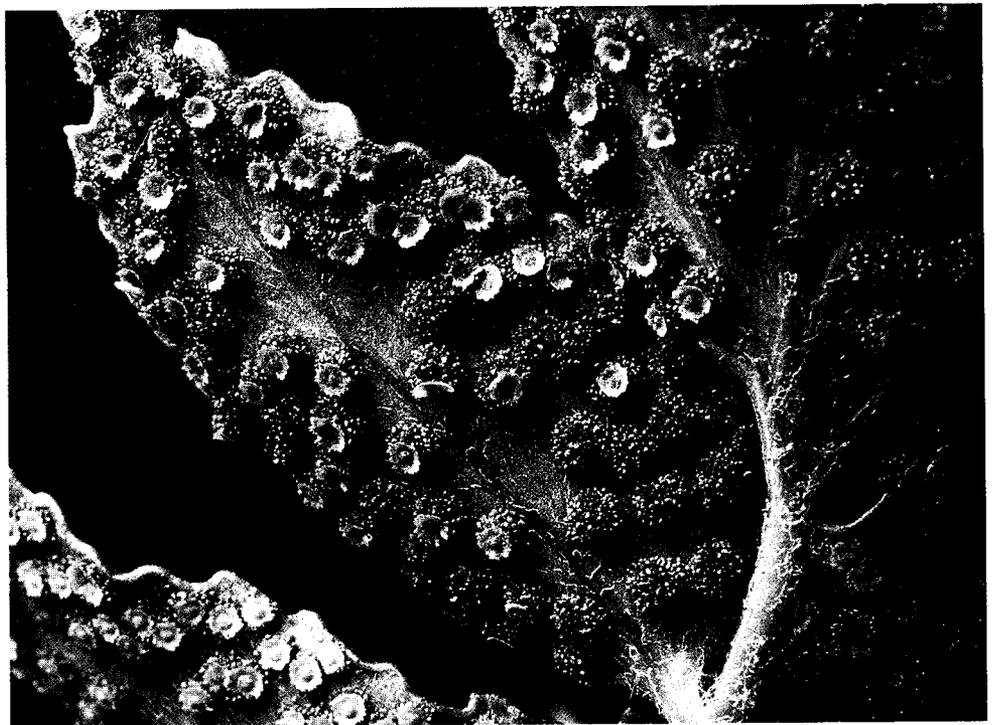
**SPOROZOAN** (spô'rə zō'ən) The sporozoans are a type of protozoan (see PROTOZOA). They are single-celled parasitic organisms that live in almost every type of animal and even in other sporozoans (see PARASITE). Many sporozoans have two different hosts at different times during their life cycles. Many sporozoans are pathogenic, or disease causing. The sporozoan *Plasmodium*, for example, causes malaria in human beings (see MALARIA; PLASMODIUM). *Plasmodium* spends part of its life in the *Anopheles* mosquito. After the mosquito bites a human or another animal, *Plasmodium* completes its life cycle in the circulatory system of that animal.

Sporozoans feed by absorbing dissolved food and body fluids from a host. All sporozoans produce spores, usually after sexual reproduction (see SPORE). Sporozoans also reproduce asexually by fission.

See also ASEXUAL REPRODUCTION; REPRODUCTION.

#### SPORE

Ferns produce spores in structures called sporangia, which form clusters on the undersides of the leaves (right).



**SPRAIN** A sprain is an injury in which ligaments are torn. Ligaments are bands of tough tissue that hold bones together (see **LIGAMENT**). Sprains are common injuries that most often occur in the ankles and wrists. They are usually caused by a sudden movement or fall. The movement stretches the ligament and causes it to tear, but not completely. When this happens, blood or other fluid may get into the joint and cause pain and swelling (see **JOINT**). Severe sprains should be treated by a doctor, who may use a plaster cast, tape, or elastic bandages to bind the injured limb to limit movement.

**SPRING AND GEYSER** Springs (sprīngz) and geysers (gī'zərs) are natural sources of water from the ground. Rain and melted snow seep into the ground and filter through the soil and rocks. Eventually, the water reaches a maximum depth in the ground. It is then called groundwater (see **GROUNDWATER**).

The groundwater may rise until it finds a way out to the surface to form a flow of water called a spring. If the spring is in an area of sandstone formations, the spring water is well filtered and clean. In areas of limestone formations, the water is not as pure. Huge amounts of water flow from the limestone springs in Missouri and Florida (see **LIMESTONE**; **SANDSTONE**).

Mineral springs are springs in which the water is

### ACTIVITY *Making a geyser*



Set a funnel mouth-downward in a can or jar of water. Place the end of a length of plastic tubing under the edge of the funnel and blow down the tubing. Watch how the water spouts out of the funnel, just like a geyser.

rich in dissolved minerals (see **MINERAL**). The areas around mineral springs are sometimes converted into health resorts or spas.

Spring water is usually cold. Some springs are warm or hot, however, and are called thermal springs. Some thermal springs originate deep in the earth where the rocks are hot. Other thermal springs form in areas of volcanic activity (see **VOLCANO**).

Geysers are springs that thrust hot water into the air. Geysers occur in areas of extremely hot rocks, often where there is volcanic activity. They consist



### SPRING AND GEYSER

Some springs originate deep within the earth, where the rocks are hot, or in areas of volcanic activity. Such springs have warm or hot water. The geyser pictured here is in Yellowstone National Park in Wyoming. The park has more hot springs, including geysers, than any other area in the world.

of a hole at the earth's surface and a tube that leads down to the rocks that are heated by the earth's interior. These rocks heat the water well above its boiling point of 212°F [100°C]. The water cannot boil, however, because of the weight of the water above it. Eventually, the water at the bottom turns to steam, causing bubbles to rise. The bubbles force some of the water out of the opening to the earth's surface. This causes the weight of the water to decrease slightly, until the water at the bottom of the spring boils over. When this happens, the water shoots out of the surface opening. Then ground-water begins to collect in the tube once more, and the eruption cycle begins again.

Geysers are found in Wyoming in the United States, Iceland, and New Zealand. In some areas, the energy of geysers is used to power electric generators and to provide heat for buildings (see ENERGY).

One of the most famous geysers is Old Faithful in Yellowstone National Park. Old Faithful erupts for four minutes every sixty-five minutes or so. These eruptions reach heights of 120 to 150 ft. [37 to 46 m]. Yellowstone has other geysers besides Old Faithful. In fact, Yellowstone contains the largest collection of geysers in the world.

*See also* WATER TABLE.

**SPRINGBOK** (sprīng'bōk') The springbok, also called springbuck, is a type of antelope resembling the gazelle (see ANTELOPE; GAZELLE). The

springbok lives on the grassy plains of southern Africa. The animal gets its name from the way it springs high into the air. When disturbed or frightened, a springbok can leap up to 10 ft. [3 m] in the air, "springing" repeatedly as it runs away at high speed. The back of the animal is sandy colored, with a white crest running from the middle of the back to the white rump patch. When the springbok senses danger, this crest is raised, and its fur stands on end.

Springboks are slender animals. They stand about 2.5 ft. [76 cm] high at the shoulder and weigh from 70 to 80 lb. [32 to 36 kg]. Both sexes of springbok have curved horns.

Millions of springboks once roamed the southern African plains, but hunters have killed many of these animals over the years. The springbok has been adopted as the national emblem of South Africa.

**SPRING (MECHANICAL)** A spring is a shaped piece of material with good elastic properties (see ELASTICITY). When a spring is distorted, it stores the energy that was used to change its shape. It changes back to its original shape when the force applied to it is removed.

There are several different kinds of springs. In automobiles, there may be leaf springs to cushion the effects of uneven roads on the vehicle's occupants. Leaf springs are several bow-shaped pieces of metal clamped together. Leaf springs distort by



**SPRINGBOK**

The springbok gets its name from its habit of "springing" into the air when frightened. These animals (left) are grazing on the sparse grass in a dried-up riverbed.

bending. In a helical spring, tough, springy metal is wound into a series of coils in a cylindrical shape. The turns of the coils may be touching, so that the spring stores energy when it is stretched, or the coils may be apart, so that energy is stored by compressing them until they touch or nearly meet.

Spiral springs, coiled in a flat plane, are used in nonelectronic watches. Winding the watch tightens the coil and stores energy. The energy is released slowly and steadily through a mechanism called an escapement (see CLOCK AND WATCH). In the kind of spring known as a torsion bar, energy is absorbed in the twisting of the bar between its ends. Torsion bars are sometimes used in vehicles.

Because springs distort in proportion to the force applied to them, they are useful in measurement of forces. The simplest spring device used to measure force is the spring balance, for weighing objects.

**SPRINGTAIL** The springtails are generally regarded as primitive, wingless insects belonging to the order Collembola, although many biologists no longer consider them to be insects (see INSECT). There are about two thousand known species, ranging in size from 0.1 to 0.4 in. [3 to 10 mm]. Springtails are characterized by a furcula, which is a forked "spring" normally held against the underside of the abdomen. A springtail can release the "spring," catapulting itself into the air. However, springtails usually move by walking.

Springtails are found throughout the world, usually in decaying vegetation or soil. They eat decaying matter and fungi as a rule, but some nibble living plants. Fossils indicate that springtails are among the oldest animals still in existence.

See also FOSSIL.

**SPRUCE** *Spruce* is the common name for evergreen, cone-bearing trees of the genus *Picea* belonging to the pine family (see CONIFER; EVERGREEN; PINE FAMILY). There are about fifty different kinds of spruce trees native to the Northern Hemisphere. Some types of spruce trees grow north of the Arctic Circle. In the United States, spruce trees grow as far south as North Carolina and Arizona.

Spruces are generally pyramid-shaped trees.



#### SPRUCE

Spruce trees have needlelike leaves and long cones that hang down. Their bark is rough and flaky. Pictured here are (1 and 2) Sitka spruce, (3) Serbian spruce, and (4) Norway spruce.

Their leaves, or needles, are dark green or blue green. The needles grow in dense spirals around the branches and point in all directions. Their cones hang down from the branches and do not fall to pieces when ripe. Spruce trees vary from 70 to 200 ft. [22 to 62 m] in height.

Large spruce trees include the Norway spruce from Europe, the Sitka spruce from western North America, and the Serbian spruce from central Europe. The Norway spruce is a quick-growing tree. The tree is logged and used for poles, interior woodwork, boxes, matches, and paper pulp (see LUMBER). Small trees of this variety are sold as Christmas trees, as are small trees of some other spruce species. The Sitka spruce is a huge tree that is used primarily for lumber. Other spruce trees include the white, red, and black spruces of eastern North America.

**SPURGE FAMILY** The spurge (spûrj) family includes 300 genera (plural of *genus*) and about 7,000 species of herbaceous plants, shrubs, and trees (see HERBACEOUS PLANT; SHRUB; TREE). They

**SPURGE FAMILY**

The aptly named firecrest spurge has bright reddish orange petallike leaves surrounding the smaller flowers, which form a cuplike cluster called a cyathia.

are all dicotyledons and grow in all but the coldest areas of the world (see DICOTYLEDON). The flowers are either staminate (male) or pistillate (female) (see FLOWER). Both sexes usually grow on one plant (see MONOECIOUS). In many cases, the flowers form a cuplike cluster called a cyathia. In a cyathia, a pistillate flower is surrounded by several staminate flowers. They are all enclosed in a whorl of colorful bracts, which are petallike leaves. The stems of plants in the spurge family contain a milky white fluid.

Some spurges belonging to the genus *Euphorbia* grow in dry parts of Africa and are very like some of the cacti of America. Other members of the spurge family include the castor bean, cassava, croton, and rubber trees.

**SPUTNIK** (spōōt'nik) *Sputnik I* was the world's first artificial satellite (see SATELLITE). It was launched by rocket from the Soviet Union on October 4, 1957. The word *sputnik* is Russian for "traveler."

*Sputnik I* was a 23-in. [58-cm] diameter sphere with four long radio antennas. A small transmitter in the satellite sent radio signals that enabled *Sputnik I*'s orbit (path around the earth) to be followed by ground stations. *Sputnik I* orbited at a height of between 141 and 588 mi. [227 and 947

km]. It went around the earth every ninety-six minutes. After 1,400 orbits, it plunged back into the earth's atmosphere and burned up on January 4, 1958.

*Sputnik II*, launched a month after *Sputnik I*, carried a dog named Laika as passenger. *Sputnik III*, launched in May 1958, weighed well over 2 tons [0.9 metric tons]. It became the first scientifically equipped laboratory in space. Seven more *Sputniks* were launched between 1958 and 1961. They carried scientific instruments and five more dogs as passengers. The Soviets used the information they gained from launching the *Sputniks* to launch the first human into space in April 1961.

See also SPACE EXPLORATION.

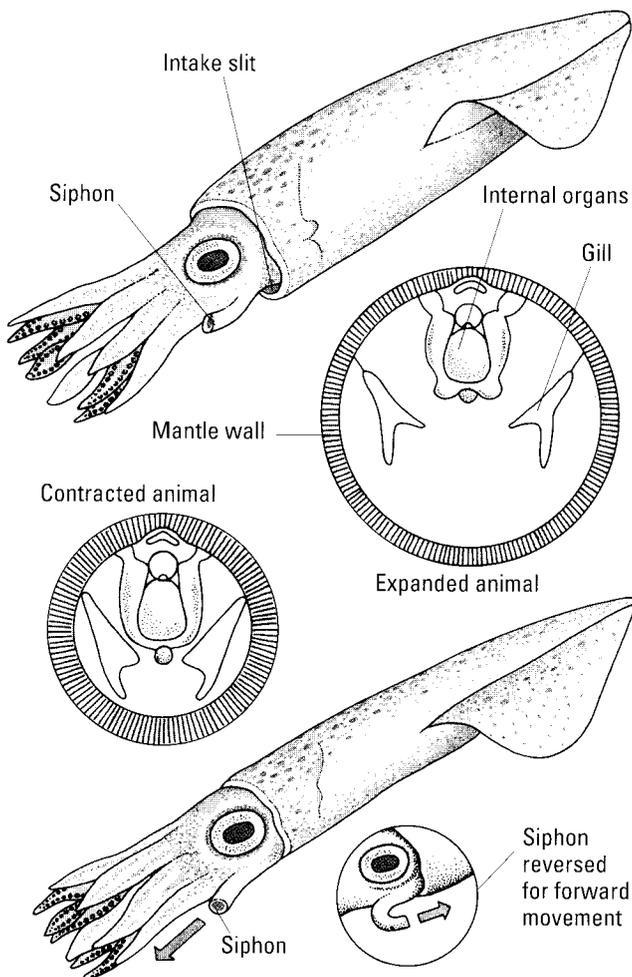
**SQUID** The squid is a marine mollusk belonging to the group known as cephalopods (see CEPHALOPOD; MOLLUSCA). It is related to the cuttlefish and octopus. There are about 350 species of squid, and they are found in oceans throughout the world, at nearly all depths. The common squid is found along the Atlantic coast of North America from Nova Scotia to Florida. Some people eat squid. Fishers also use the animal for bait.

The squid's body is shaped like a bullet, with two fins at the tail end. The front end is surrounded by ten arms, or tentacles. Two tentacles are longer than



## SQUID

The common squid (above) has a pair of large eyes and ten tentacles, with which it seizes its prey. A squid moves by sucking water into its main mantle cavity (below, top) then contracting muscles in the mantle wall to force water out of the siphon (below, bottom). This action pushes the squid backward, but it can reverse the siphon to move forward.



the others. Each tentacle has powerful suckers. These sucking disks are used to catch and hold prey. The squid's body is supported by a horny rod, called a pen, under the skin. A thick cloak of skin, called the mantle, surrounds most of the body. The mantle forms a collar just behind the head. Openings in the collar allow water to be drawn into the mantle cavity where the gills are (see GILLS). After passing over the gills, the water leaves through a muscular tube called the siphon on the underside of the body. The siphon can be pointed either backward or forward, and if the water is forced out strongly, the squid is moved either forward or backward.

Like most cephalopods, squids have an ink sac. They can squirt black clouds of inklike fluid into the water to confuse their enemies. Squids can also change color to blend with their environment (see CAMOUFLAGE). Many of the deep-sea species are bioluminescent, meaning that they glow in the dark (see BIOLUMINESCENCE).

Most squids vary in length from 0.5 ft. to 15 ft. [0.15 m to 4.6 m]. Giant squids, some of which measure 55 ft. [17 m] in length (including the tentacles), are the largest of the invertebrate animals (see INVERTEBRATE).

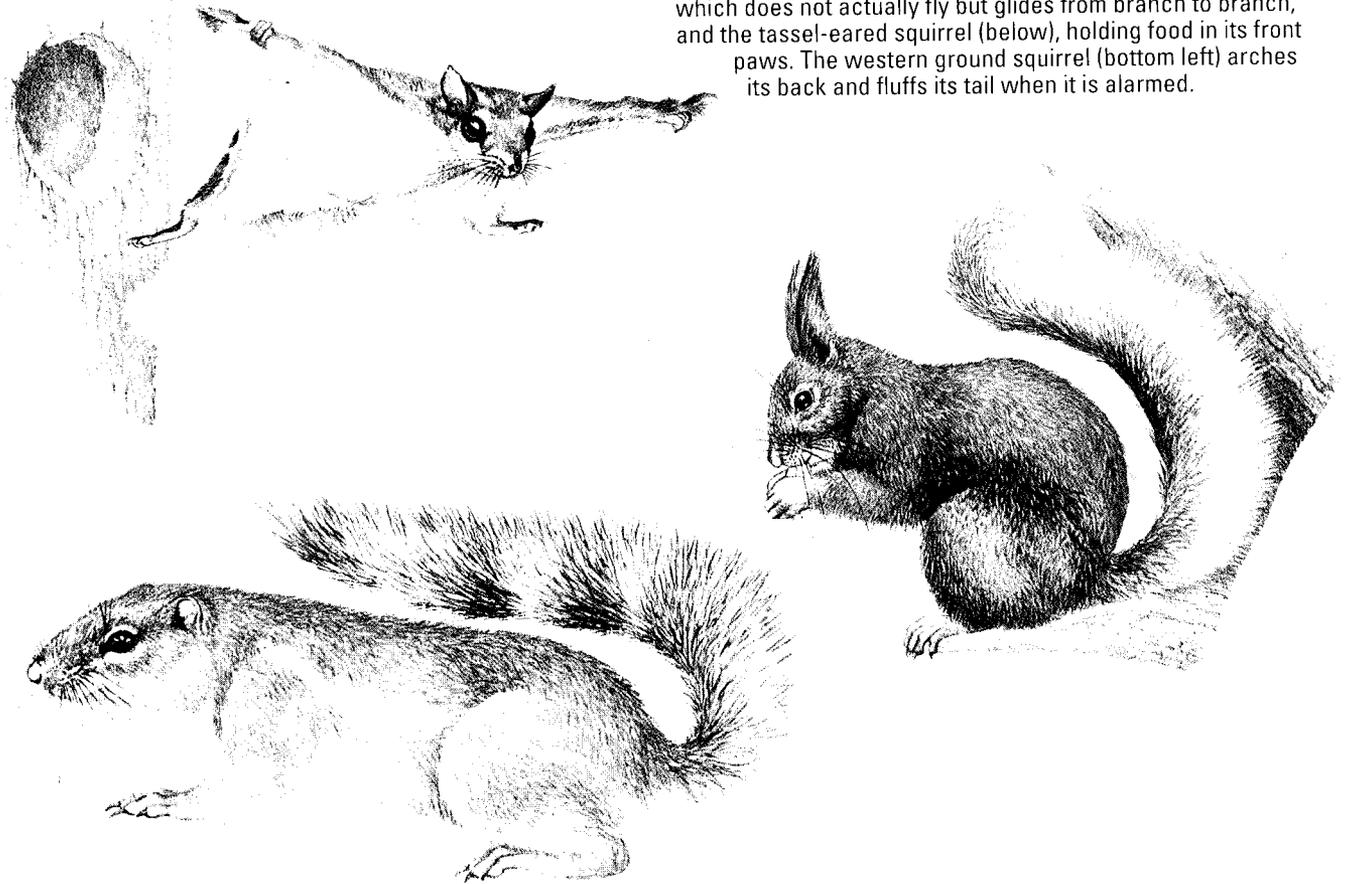
**SQUIRREL** *Squirrel* is the common name for members of the large family of rodents known as the Sciuridae (see RODENT). There are more than three hundred kinds of squirrels. The animals are found almost worldwide. Squirrels can be divided into two basic groups—tree squirrels and ground squirrels.

Tree squirrels, often seen in forests, are usually lively animals with long, bushy tails. These animals scamper on the ground and in trees. They can often be seen leaping from branch to branch. Tree squirrels often have two homes, a permanent one and a temporary one. The permanent home may be a nest built on a branch or a den made in a hollow tree trunk. During winter, several squirrels may share one den. Nests used for temporary purposes are merely loose piles of twigs and leaves. Such nests are used during the hot summer months.

Squirrels spend much of their time searching for

## SQUIRREL

Tree squirrels include the southern flying squirrel (left, top), which does not actually fly but glides from branch to branch, and the tassel-eared squirrel (below), holding food in its front paws. The western ground squirrel (bottom left) arches its back and fluffs its tail when it is alarmed.



food. They eat fruit, nuts, corn, berries, and seeds. A female squirrel has a gestation period of thirty to forty-five days (see *GESTATION PERIOD*). She may give birth twice a year. Litters normally consist of two to six young.

Gray squirrels, fox squirrels, red squirrels, and flying squirrels are the main kinds of tree squirrels. Gray squirrels usually are gray on their backs and white on their underparts. In the United States, eastern gray squirrels live east of the Rocky Mountains. Western gray squirrels live along the Pacific coast. The fox squirrel is the largest type of tree squirrel in North America. Some fox squirrels grow to 28 in. [71 cm] in length, including the 12-in. [30-cm] tail. Their fur is gray, reddish brown, or black. Found in the east-central United States, fox squirrels are more aggressive than most other kinds of tree squirrels.

Red squirrels are the most active and noisiest of all the squirrels. They are famous for the many pine

cones they collect and store for food. A red squirrel may gather more than a hundred pine cones in an hour. When winter comes, the squirrel may have stored three to ten bushels of pine cones. Few red squirrels are more than 1 ft. [30 cm] in length. Red squirrels are found in most parts of the United States and Canada. Flying squirrels are the smallest kind of tree squirrels. Few grow more than 10 in. [25 cm] in length. The flying squirrel has a fold of skin that stretches from the front leg to the rear leg on each side of the body. This skin allows the flying squirrel to glide. Some flying squirrels can glide more than 150 ft. [46 m]. Unlike other kinds of tree squirrels, flying squirrels are usually active only at night. They are found throughout the United States and Canada.

The other main group of squirrels, the ground squirrels, have short tails and seldom climb trees. These squirrels live on the ground and make burrows. They feed on a variety of plant material and

on insects and other small animals. Ground squirrels include chipmunks, marmots, prairie dogs, and woodchucks. Many of them go into hibernation for the winter.

*See also* HIBERNATION.

**STAINLESS STEEL** Stainless steel is an iron alloy that resists corrosion and stains (see ALLOY; CORROSION; IRON). Such metals as chromium and nickel are alloyed with iron to make stainless steel.

Stainless steel has a wide range of uses. It is used for cutlery, kitchenware, tools and automobile parts, and mixing equipment in the dairy, brewing, food-processing, and chemical industries. Stainless steel was invented because of a chance observation. In 1913, a British gunsmith called Harry Brearley made various iron alloys for his work. The ones that did not work well for his guns, he generally threw away. One day, he found some scraps that had been sitting around for several months. All of the scraps had rusted except for the alloy containing 12 percent chromium. He used this formula to develop stainless steel.

*See also* STEEL.

## STALACTITE AND STALAGMITE

Stalactites (stə lăk'tītz') and stalagmites (stə lăg'mītz') are rock formations that occur in caves. Stalactites hang from cave roofs like icicles, while stalagmites rise from cave floors.

Stalactites and stalagmites are usually found in limestone caves. Groundwater seeping through the limestone dissolves calcium carbonate (see CALCIUM CARBONATE; GROUNDWATER; LIMESTONE). When the water reaches the cave roof, it forms a droplet. Carbon dioxide is given off by this droplet, which makes the water unable to hold as much calcium carbonate, and so a tiny particle of calcium carbonate is deposited on the cave roof. Eventually, the deposits accumulate to form a stalactite.

Stalagmites form in a similar manner, except that the water drips from the roof or wall of the cave to the floor. The impact of the fall shocks the calcium carbonate out of solution and forms a deposit. The deposits eventually accumulate to form a stalagmite.

Sometimes, stalactites and stalagmites meet and form a continuous pillar from the cave floor to the roof. Carlsbad Caverns in New Mexico and other



### STALACTITE AND STALAGMITE

Stalactites (which hang down) and stalagmites (which grow upward) form spectacular rocky structures in limestone caves. They are made of calcium carbonate, which comes from groundwater seeping through the cave roof.

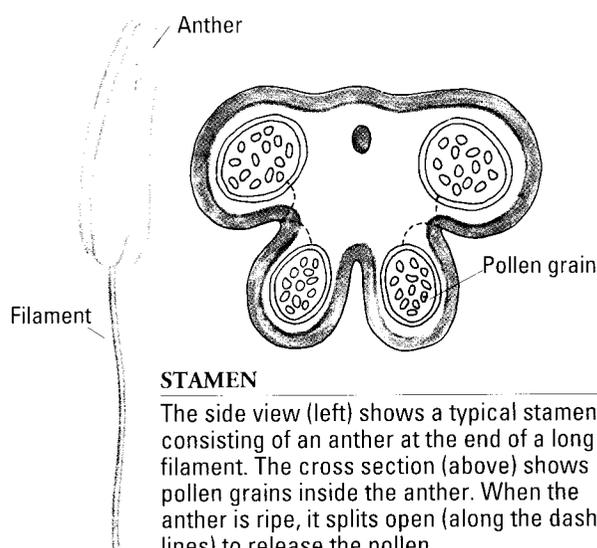
caves in Virginia, Kentucky, and Indiana contain stalactites and stalagmites.

*See also* CAVE.

**STAMEN** (stā'mən) The stamen is the male reproductive organ of a flower. It produces pollen and is usually located within the corolla, a group of colorful petals. The bright colors of the petals attract birds and insects that pollinate the flower (see POLLEN; POLLINATION).

The stamen usually consists of a slender stalk called a filament, topped by a four-chambered pouch called the anther (see ANTHOR). Pollen grains are produced in the anther and are released when the anther splits open. Flowers that are pollinated by wind instead of by insects or birds often have longer filaments. Also, the anthers are loosely attached to the tops of these filaments. This allows the filament and anther to swing in the breeze and scatter the pollen when the anther splits open.

*See also* FLOWER.



#### STAMEN

The side view (left) shows a typical stamen, consisting of an anther at the end of a long filament. The cross section (above) shows pollen grains inside the anther. When the anther is ripe, it splits open (along the dashed lines) to release the pollen.

### STANDARD TEMPERATURE AND PRESSURE

Standard temperature and pressure, abbreviated STP, are conditions often used in calculations in physics and chemistry. Standard temperature is a temperature of 32°F [0°C], and standard pressure is 760 mm of mercury, also called one atmosphere or 14.7 lb. per sq. in. [1.03 kg per sq. cm] (see ATMOSPHERE (UNIT)). Another term for these conditions is *normal temperature and pressure* (NTP). Using the standard temperature and

pressure allows scientists to compare the results of different physical processes.

*See also* PRESSURE; TEMPERATURE.

**STANDARD TIME** Standard time is the system in which the world is divided into twenty-four specific time zones. Each zone occupies about 15° out of 360° of longitude (see LATITUDE AND LONGITUDE). Since the earth rotates once on its axis every twenty-four hours, each time zone has a difference of one hour (see TIME ZONE).

In the forty-eight adjacent states of the United States, there are four time zones: Eastern, Central, Mountain, and Pacific. Thus, when it is 8 A.M. in New York City, it is 7 A.M. in Chicago, 6 A.M. in Denver, and 5 A.M. in San Francisco. During the summer, most states advance their clocks one hour. This is called daylight saving time.

**STANDING WAVE** A standing wave is a form of vibration in which there is no visible movement of a wave along the object that is vibrating (see WAVE). When a stone is thrown into a still pool of water, it causes waves that spread out. The waves move away from the place where the stone entered the water. If they meet the surface of a solid, such as the side of the pool, they are reflected. Reflected waves travel back from the solid object, in the opposite direction. They meet new oncoming waves and have an effect on them. If the timing is absolutely right, the crests and troughs of the reflected and oncoming waves will coincide. The result is a pattern of waves that is going neither forward nor backward. The waves become stationary, or standing, waves.

When the string of a violin, guitar, or other musical instrument vibrates, the same thing happens. Standing waves are set up in the string. There is no visible wave movement from one end of the string to the other. The center of the string vibrates most. The outer ends do not vibrate at all. Standing waves like this are set up in the columns of air in wind instruments. They are also set up by radio waves in the antennas and electric circuits of radio and television receivers.

*See also* RESONANCE; SOUND.