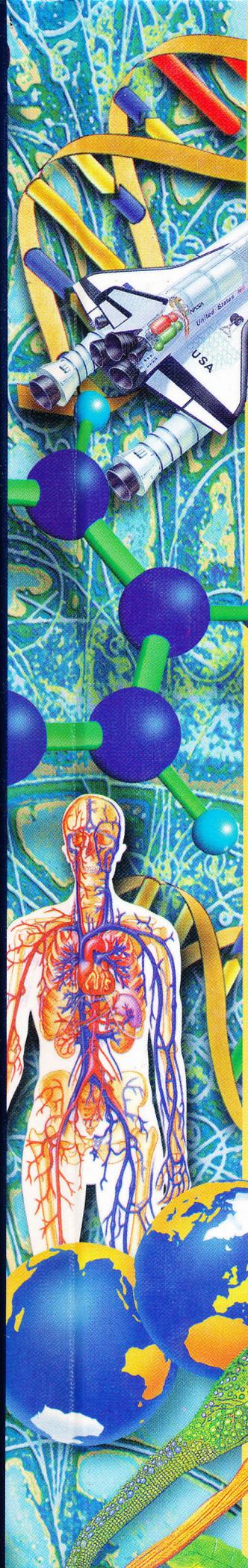


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BEE – CAM

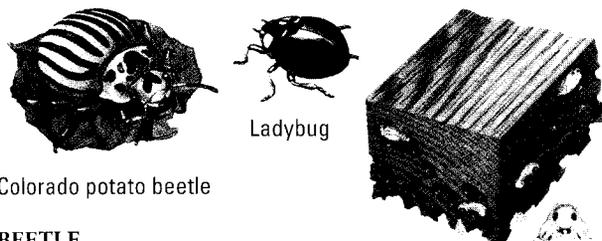


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BEETLE Beetles are insects belonging to the order Coleoptera. There are at least 278,000 kinds of beetles. Four of every ten insects are beetles.

Beetles are most easily identified by their elytra, a pair of hard shields that often cover the wings and most of the body. Beetles, which have strong jaws for biting, feed on plants and animals.



Colorado potato beetle

Ladybug

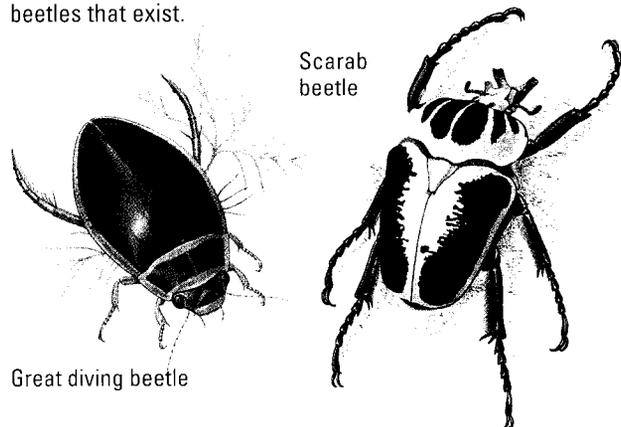
Larva of furniture beetle

BEETLE

There are more types of insects than any other type of invertebrate (animal without a backbone). There are more types of beetles than any other type of insect. Pictured are just a few of the various kinds of beetles that exist.



Weevils



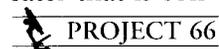
Scarab beetle

Great diving beetle

All insects have three-part bodies, made up of the head, the thorax, and the abdomen (see ABDOMEN; THORAX). However, unlike the bodies of other insects, the sections of the bodies of beetles are closely and strongly joined. Beetles are many different colors. Some are brightly colored. Others are dull. Beetles develop from eggs to larvae to pupae to adults (see METAMORPHOSIS). Most live for about one year. A few live for up to five years. Some may live for only a few weeks. Beetles may live in water, or above or under the ground. Some beetles eat meat, while others eat plants. Beetles such as the ladybug are helpful to plant life. They eat smaller insects, such as aphids, that are harmful to plants.

Some beetles are too small to be seen with the naked eye. The largest beetle is the African Goliath beetle, which is the largest insect. Goliath beetles can grow to be 4 in. [10 cm] long and 8 in. [20 cm] wide.

The June beetle, or June bug, is common in the United States. It is a large, brown insect that can be seen on plants in the spring. The Japanese beetle is also common in the United States. It was brought from Asia to North America in 1916. Like the June beetle, it is a plant eater that is considered a pest.



BEGONIA (bĭ gōn'yə) The begonia is a plant with waxy leaves and brightly colored flowers. It grows mainly in tropical climates as a vine and shrub. The species cultivated in the United States is usually small. The blossoms may grow as single or double flowers, and their colors may be red, orange, yellow, white, or pink. Begonia leaves are smooth and shiny with a waxy covering.

The root of the begonia can be tuberous or fibrous. Begonias with tuberous roots have large flowers and bloom in the summer. The fibrous types are used as houseplants and bloom in the winter. Many types, such as the rex begonia, have few flowers but are grown for their colorful leaves. *See also* ROOT; TUBER.



BEGONIA

This beautiful begonia has a double red flower, consisting of an outer ring of petals as well as an inner ring.

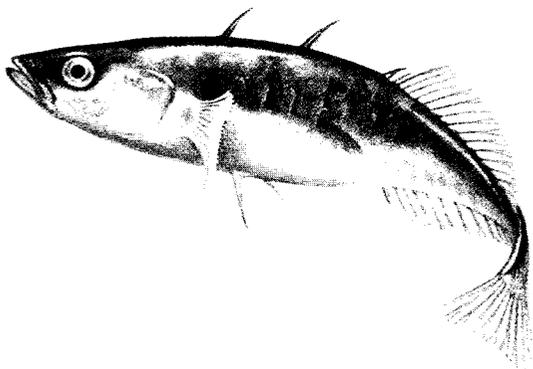
BEHAVIOR OF ANIMALS

Every species of animal acts differently. Each eats a certain food. Each lives in a certain place. Each reproduces in a certain way. The ways an animal acts are the behavior of the animal. Scientists who study animal behavior are called ethologists.

There are two main types of animal behavior: instinctive and learned. Instinctive behavior is behavior that the animal inherits from its parents (see HEREDITY; INSTINCT). A young fish does not have to learn how to swim. It knows how to swim right after it is born. Learned behavior is behavior that has to be taught to the animal. For example, a human child does not know how to tie a shoe until he or she is taught to do so.

Instinctive behavior An ethologist can find out which behavior is learned by taking a very young animal away from all other members of its species. The animal's subsequent behavior will be instinctive because there is no other animal to teach it. If a bird that is hatched away from all other birds can fly, then flying is instinctive behavior. Most of the courtship and mating behavior by which an animal reproduces is instinctive. Instinctive behavior is caused, or triggered, by a signal called a releaser. Releasers may be things that are seen, heard, smelled, felt, or tasted. The sight of a hawk overhead is a releaser for a mouse to run and hide. The releaser for an animal to eat is hunger.

An interesting example of instinctive behavior is found among a kind of fish known as a stickleback. A male stickleback instinctively chases other



males out of his territory. If a male is chased into his own territory, he will turn, attack, and drive off the first stickleback. The releaser in this case seems to be the red belly of the male. A stickleback in his territory will attack even a dummy of the correct size and color. However, he will pay no attention to a male stickleback that has been painted to conceal his red belly.

Many animals that live in groups have developed instinctive behavior that controls the group. Examples of such social animals are insect colonies, schools of fish, herds of deer, and flocks of birds. Aggressive or unfriendly behavior does occur among animals. However, there is rarely an actual fight among members of the same species. It is even more rare for the animals to hurt or kill each other. For example, wolves may growl at each other. However, before a fight actually begins, the younger or smaller wolf cowers and backs away. This instinctive behavior prevents animals from killing or harming members of their own group.

Learned behavior This kind of behavior is learned from experience. A dog learns to avoid a busy highway. If a cat learns that mice live in a woodpile, the cat will visit the area often. Many

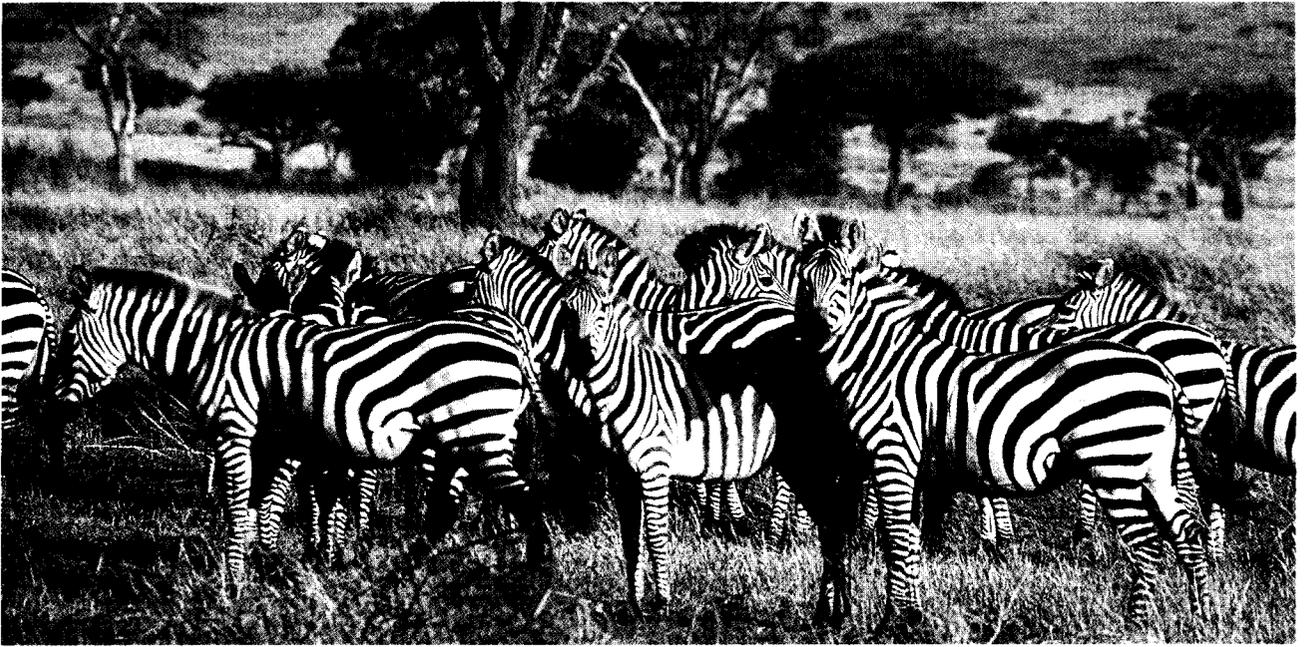
KILLER WHALES

A social group, or pod, of killer whales (orcas) swims off the coast of British Columbia. Killer whales often hunt in groups and will cooperate with each other to force a school of fish to the surface, where the whales can more easily catch and eat them.

STICKLEBACK

The red belly of a male stickleback will make another male stickleback instinctively attack it if the first fish swims into his territory.





ZEBRA

Zebra herd together because their stripes make it very difficult for predators to pick out individual animals to attack. This is an example of instinctive behavior.

animals are trained by humans. Seeing Eye dogs that help blind people get around are displaying learned behavior. There are many different kinds of learned behavior. One of the most interesting kinds was discovered by Konrad Lorenz, an Austrian ethologist. He learned that when a baby bird hatches from the egg, it identifies the first

object it sees as its mother. He called this imprinting. When Lorenz artificially hatched goose eggs and stood next to the hatching eggs, the baby geese thought he was their mother. They followed him wherever he went.

Vertebrates have better-developed brains than invertebrates, so they are better able to learn behavior. Mammals generally learn faster than other kinds of vertebrates, and humans learn behavior faster than any other species.

See also ANIMAL KINGDOM.



BELL, ALEXANDER GRAHAM (1847–1922) Alexander Graham Bell was a Scottish-American scientist who invented the telephone. Born in Scotland, Bell and his family moved to Ontario, Canada, for health reasons. Bell's two brothers had died of tuberculosis, and Bell himself was showing signs of the disease. Bell recovered within a year. At 23 years of age, Bell devoted himself to improving communication among the deaf.

While experimenting with the possibility of sending several telegraph signals over one wire at the same time, Bell became interested in sending voice sounds over a wire. In 1874, Bell secured the help of Thomas Augustus Watson, an expert in the field of telegraphy (see TELEGRAPH). Watson was of great help in Bell's early experiments. Bell was issued a patent for the telephone in 1876. A year later, he founded the Bell Telephone Company.

In his later years, Bell continued working on new inventions. Some of his ideas led to the development of the iron lung, the radio, phonograph



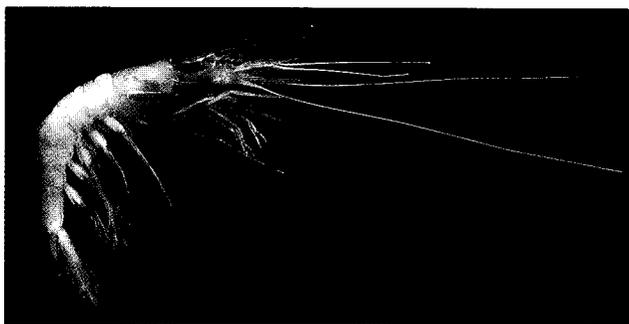
ALEXANDER GRAHAM BELL

This Scottish-born scientist invented the telephone.

records, the hydrofoil, and the metal detector. His chief interest, though, remained the education of the deaf. He used much of his money and influence to establish research and care institutions in Europe and the United States.

See also TELEPHONE.

BENTHOS Benthos is the name for all organisms that live on or in the bottom of a body of water. Benthic organisms live on top of the sand beneath the ocean, under the mud beneath a lake, or among the rocks of a streambed. They can be plants, insects, worms, crustaceans, fishes, or other kinds of organisms. Many of the benthic animals eat dead matter that falls to the bottom from the water above. Benthic organisms are also a valuable source of food for other aquatic animals.



BENTHOS

Benthos means "living at the bottom of the sea." This shrimp is classified as a benthic animal because it lives up to 14,000 ft. [4,500 m] below the surface of the water.

BENZ, KARL (1844–1929) Born in Karlsruhe, Germany, Karl Benz was one of the first engineers to build motor-driven vehicles. He founded Benz and Company to manufacture gasoline engines. Benz started to build his first gas engine in 1879, building a practical automobile by 1885. He installed the gas engine on the back of a tricycle. The vehicle had an electric ignition, a water-cooled engine, shaped "poppet" valves, and a differential gear, features still common in automobiles today. A few months after Benz had finished his automobile, a fellow German, Gottlieb Daimler, completed a motorcycle powered by a gasoline engine. Karl Benz later designed a float-type carburetor and a transmission system.

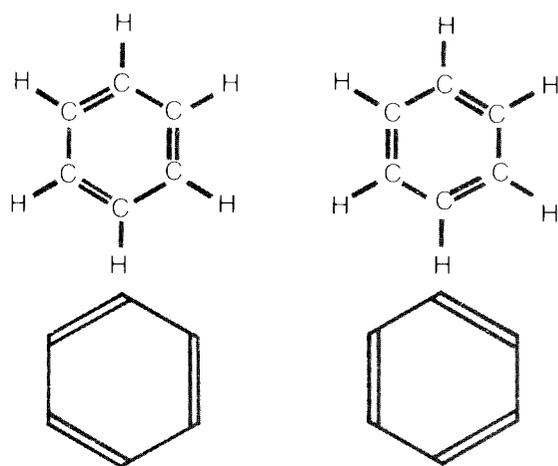
See also AUTOMOBILE.

BENZENE Benzene is a colorless liquid with a strong odor. Benzene was discovered by Michael Faraday in 1825 (see FARADAY, MICHAEL). Benzene is used in the manufacture of many chemical products, such as synthetic detergent, aniline dye, nylon, synthetic rubber, and Styrofoam (see ANILINE; NYLON; RUBBER).

Benzene has the chemical formula C_6H_6 . The benzene molecule has its carbon atoms arranged in a ring called a benzene ring. Benzene belongs to a group of compounds called aromatic hydrocarbons (see HYDROCARBON). Benzene melts at $42^\circ F$ [$5.5^\circ C$] and boils at $176.2^\circ F$ [$80.1^\circ C$]. Benzene is sometimes called benzol.

One method of producing benzene is by heating coal tar and condensing (changing to a liquid) the vapors from the tar. Coal tar is a thick, black, sticky liquid that is a by-product in the manufacture of coke (coal that has been heated to a high temperature without air). Today, large amounts of benzene are obtained from petroleum rather than coal tar.

Benzene is a dangerous chemical. It is known to affect the blood and can cause severe anemia and leukemia (a form of cancer) (see ANEMIA; CANCER). Those who come in constant contact with it, such as those who work in rubber factories,



BENZENE

The molecule of benzene has six carbon atoms and six hydrogen atoms joined in a ring by alternate single and double bonds. These bonds may be drawn in either of the two arrangements (left and right, top), but usually are drawn without the C and H symbols (left and right, above).

may be at a severe health risk. Benzene and its derivatives are no longer used in high-school chemistry laboratories.



BENZENE

Synthetic rubber, used mainly for making vehicle tires, is produced from chemicals made from benzene. Formerly derived from coal, benzene is now made from crude oil (petroleum).

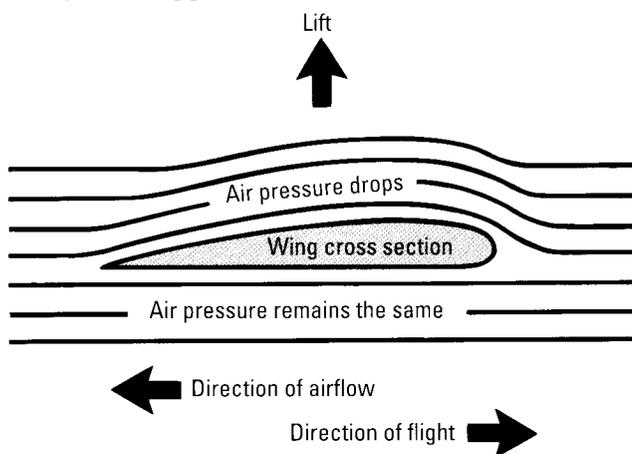
BERIBERI (běr'ē běr'ē) Beriberi is a disease that affects the nervous and circulatory systems. It is caused by a lack of thiamine (vitamin B_1) in the diet. Beriberi causes severe pain and weakness in the arms and legs. It may cause difficulties with balance and coordination; memory problems; and swelling of the body tissues, called edema. In advanced cases, coma, heart failure, and death can occur.

Beriberi was very common in China, Japan, and the Philippines through the nineteenth century. The people in these countries had a diet consisting largely of polished white rice. Polishing the rice removes the outer layer, which contains thiamine (see RICE).

In modern times, people who drink large amounts of alcohol usually have unbalanced diets, which may lead to beriberi. The disease can be treated with a diet of thiamine-rich foods such as unpolished cereal grains, peas, and liver. Injections of synthetic (human-made) thiamine are also effective.

See also DIET; NUTRITION; VITAMIN.

BERNOULLI EFFECT As the speed of a fluid or gas increases, its pressure decreases. This is known as Bernoulli effect. It was first described by Daniel Bernoulli in the 1700s (see **BERNOULLI FAMILY**). Although Bernoulli was referring to liquids flowing steadily at one level, the effect has many other applications.



BERNOULLI EFFECT

Bernoulli effect in aerodynamics: Air moving over an airplane's wing goes a longer distance, so it must travel faster. Therefore, there is less air pressure on the top of the wing than on the bottom, which causes the wing to be pushed upward.

Bernoulli effect allows airplanes to fly. An airplane wing, seen from the tip, is flat on the bottom and curved on the top. As the wing travels through the air, the air must travel either over or under the wing. Air moving over the wing goes a longer distance, so it must travel faster. Because air moving over the wing is moving faster, there is less air pressure on the top of the wing. This means that there is more pressure on the bottom of the wing, which pushes the wing upward, causing the plane to stay in the air (see **AIRFOIL**).

The same effect can be seen in a bathroom shower. Water from the shower moves the air inside the shower faster than the air outside the shower. This means there is more air pressure on the outside of the shower curtain than on the inside, so the shower curtain blows inward.

BERNOULLI FAMILY Bernoulli was the family name of three Swiss mathematicians and physicists. There were two brothers, Jacques and Jean, and Jean's son, Daniel. Each served as professor at the University of Basel in Switzerland.

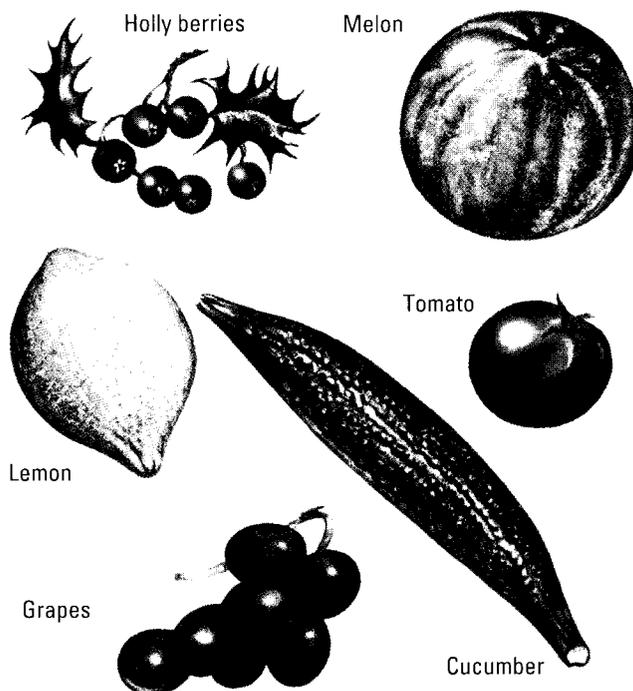
Jacques Bernoulli (1654–1705) made important discoveries in mathematics. He worked on finite series and their sums, on calculus, and on trigonometry. He developed new material in the theory of probability. The Bernoulli numbers used in this branch of mathematics are named after him.

Jean Bernoulli (1667–1748) was also a mathematician, working on calculus and complex numbers. He also worked in applied mathematics, with subjects such as astronomy, the tides, optics, and ships' sails.

Daniel Bernoulli (1700–1782) was the best known member of the family. He developed the science of hydrodynamics, which is the branch of physics dealing with the forces that fluids in motion exert. One of his discoveries is known as Bernoulli effect (see **BERNOULLI EFFECT**). He also worked on differential equations, trigonometry, calculus, and probability theory.

See also **AIRFOIL**.

BERRY In botany, the word *berry* refers to a simple fruit having a skin or rind surrounding the seeds in a fleshy substance called pulp. Common



BERRY

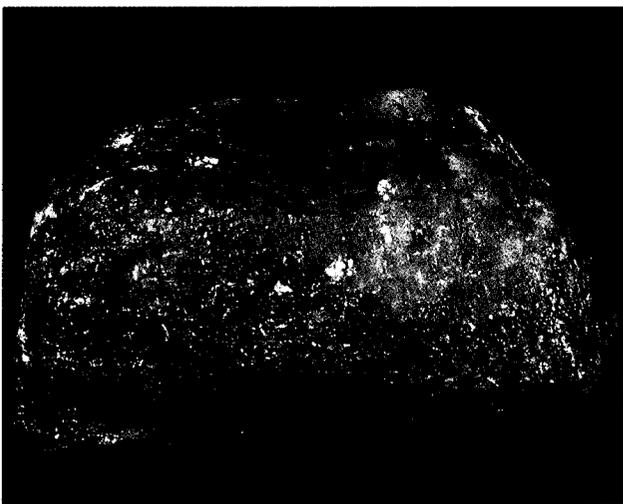
Berries have supplied food for people for many centuries. Animals in the wild also rely on a wide variety of berries for food.

kinds of berries are blueberries, grapes, tomatoes, citrus fruits, and melons. In spite of their names, strawberries, blackberries, and raspberries are not true berries. However, most people call any small, juicy fruit that has many seeds a berry.

See also FRUIT.

BERYL (bĕr'əl) Beryl is a hard mineral found mainly in granite rocks and used as a gemstone. In the rocks in which it is found, beryl usually appears in the form of six-sided crystals, ranging in diameter from 0.25 in. [0.64 cm] to 12 in. [30 cm]. Some beryl crystals have been found in Maine measuring about 18 ft. [5 m] in length. Beryl is one of the most important sources of the rare element beryllium. Most deposits are located in Brazil, India, South Africa, and parts of the United States.

Most often yellowish green in color, beryls may also be red, green, blue, or yellow. Types of beryl include the dark green emerald, the blue green aquamarine, the rose morganite, the yellow green hiddenite, and yellow golden beryl.



BERYL

Gems can be made by cutting and polishing beryl crystals like the one shown above.

BERZELIUS, JÖNS JAKOB (1779–1848) Jöns Berzelius was a Swedish chemist who was the first person to make a fairly accurate list of the relative atomic masses (see RELATIVE ATOMIC MASS). He also developed the chemical symbols and formulas in use today. He studied the effects of

electricity on solutions, introducing the idea of radicals (see RADICAL).

Berzelius discovered the elements selenium, thorium, and silicon. Many of the terms used in chemistry, such as *catalyst*, *isomer*, and *protein*, were first used by Berzelius. Because of his many accomplishments, Jöns Berzelius was the most famous chemist of his time.

See also CHEMISTRY.

BESSEMER, SIR HENRY (1813–1898) Sir Henry Bessemer was an English inventor who developed an inexpensive process for making steel. The Bessemer process, introduced in 1856, blasts air through molten pig iron (crude iron) to burn out the impurities. This method greatly reduced the cost of producing steel. It has since been modified by using pure oxygen instead of air (see STEEL).

Bessemer was a self-educated engineer. In addition to his work with steel, he developed a solar furnace, a large telescope, and a type of “gold” powder made from brass used to tint paint.

BETA-BLOCKER A beta-blocker is a type of drug given by a doctor to slow down the heart rate. Beta-blockers are used to treat some heart conditions, high blood pressure, and the symptoms of anxiety.

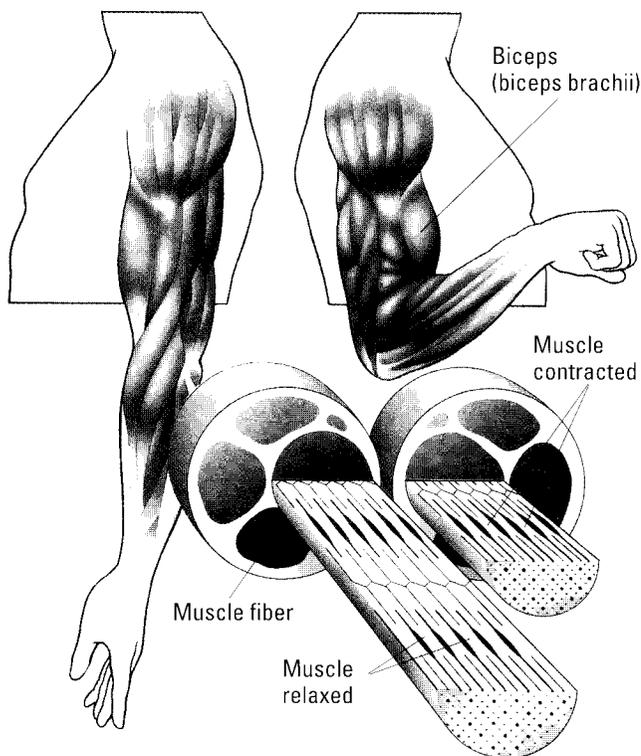
In 1948 the American pharmacologist Raymond Ahlquist suggested that special regions of the heart, called beta-receptors, are sensitive to adrenaline (see PHARMACOLOGY). Adrenaline is the hormone released in stressful situations to prepare the body for “fight or flight” by making the heart beat faster (see ADRENAL GLANDS). Later, in 1964, the Scottish pharmacologist James Black found a compound, called propranolol, that would block the beta-receptors and so prevent adrenaline from having its effect on the heart.

Since that time scientists have discovered several more beta-blockers. Today atenolol is the most popular drug prescribed for the treatment of hypertension (high blood pressure) and coronary heart disease (disease of the arteries supplying blood to the heart).

BETA PARTICLE Beta particles are electrons sent out in streams by the nuclei of certain radioactive atoms. Most beta particles are negatively charged, but some are positively charged and are called positrons. The streams of beta particles are often called beta rays. These rays travel at a speed almost equal to that of light. Having such high energy, beta rays can pass through solid matter several millimeters thick. They ionize the substances through which they pass, knocking electrons from some of the atoms. Beta particles can be detected by Geiger counters and by photographic film. The other kinds of radiation produced by radioactive substances are alpha particles and gamma rays.

See also ALPHA PARTICLE; GAMMA RAY; GEIGER COUNTER; IONS AND IONIZATION; RADIOACTIVITY.

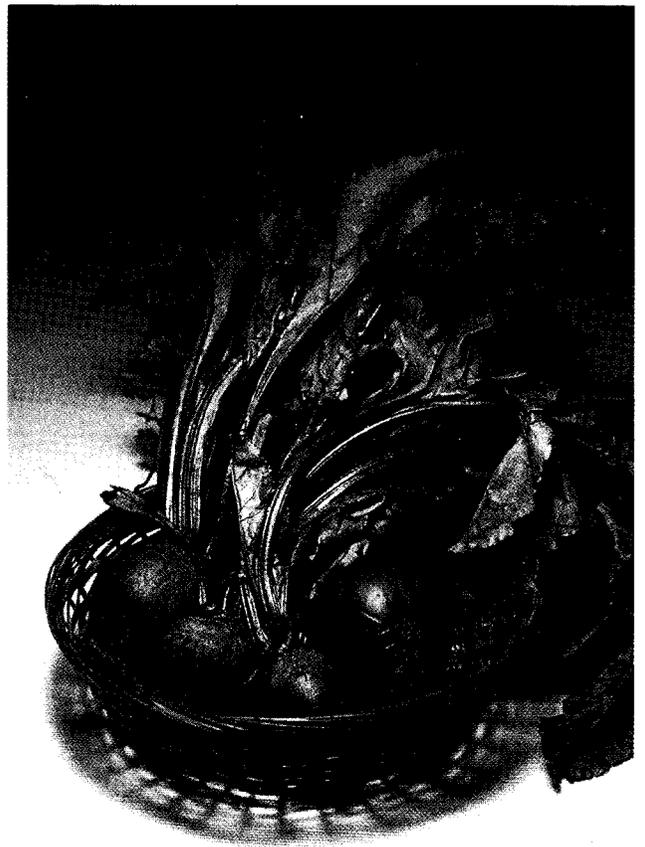
BICEPS The biceps are muscles found in the human body. One is attached to the front side of the upper arm. Its action has the effect of bending the arm and helping in the rotation of the hand.



BICEPS

When the biceps muscle contracts, it does so by special filaments in the muscle fiber sliding past one another. This movement makes the muscle become shorter. Energy obtained from food is used up in the process.

It is called the biceps brachii. A person can feel the contraction of his or her biceps brachii when he or she turns a screwdriver. Another muscle, the biceps femoris, is found at the back of the upper leg. It allows the leg to bend at the knee and helps the lower leg rotate to the side when the knee is bent. The biceps femoris also helps the other leg muscles straighten the thigh at the hip joint.



BIENNIAL PLANT

Like many root vegetables, beets are biennial plants harvested in their first year.

BIENNIAL PLANT Biennial plants live for only two years. In the first year, they grow strong roots and leaves. Food is stored in the roots for use during the second year. As winter approaches, biennial plants enter a time of dormancy, during which very little growth takes place.

In the second year, biennial plants use the stored food to produce flowers and seeds. Some biennial plants are carrots, beets, and cabbage. These vegetables are eaten after the first season, before the plant can flower.

BIG BANG THEORY The big bang theory is an explanation for the formation of the universe. The theory suggests that, about 15 to 20 billion years ago, all the matter in the universe occupied a tiny volume, smaller than an atom. It was fantastically hot and dense, and instantly exploded. Scientists refer to this explosion as the "big bang." The exploding universe was a mixture of particles and radiation, referred to as the primordial fireball. (*Primordial* means "in the beginning.") Many of the particles were short-lived ones that do not exist in today's universe. But there were also particles that still exist today. Electrons were created from radiation. Protons and neutrons were constantly built up from other particles, but they could not survive at these high temperatures.

The fireball cooled as it expanded. Within one second the universe had cooled down so much that protons and neutrons could survive. In three minutes the nuclei of hydrogen and helium had

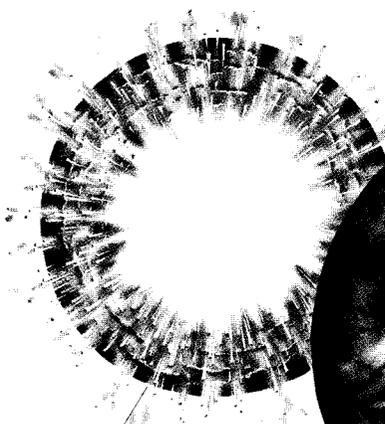
appeared. After about 100,000 years, these nuclei combined with electrons to form atoms of hydrogen and helium, with tiny amounts of other elements. This matter eventually formed the stars, gas, and dust that make up the galaxies today. The galaxies are still flying apart from the force of the big bang. See also ATOM; COSMOLOGY; ELEMENTARY PARTICLES; UNIVERSE.

BIG DIPPER AND LITTLE DIPPER

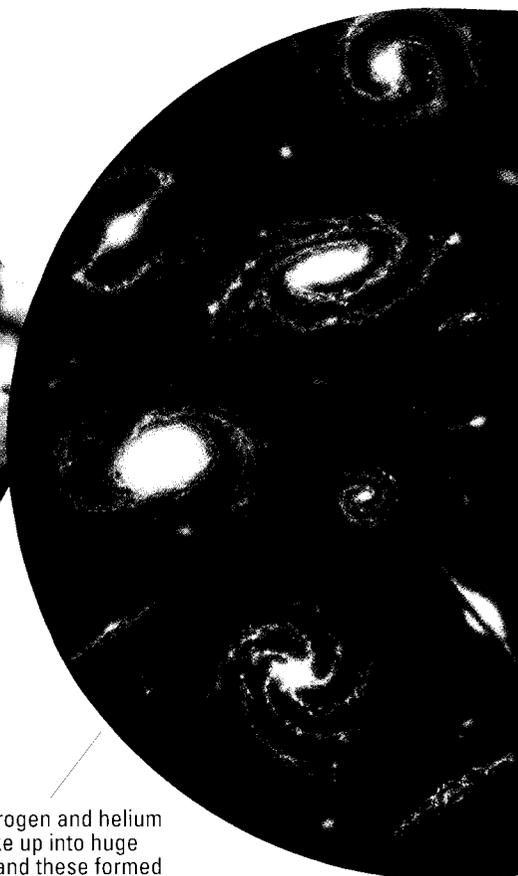
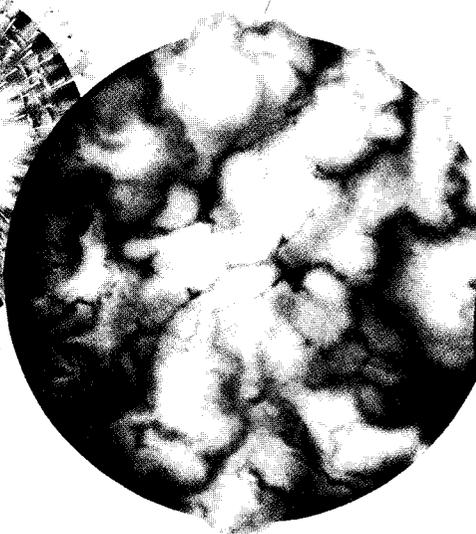
The most familiar groups of stars in the northern hemisphere are the Big Dipper and the Little Dipper. Each group has seven stars. Four stars make up the corners of the cup shapes. Three stars make up the handles.

Both of these groups of stars seem to revolve around the North Star (also called the Pole Star, or Polaris). The North Star is almost directly over the earth's North Pole and forms the tip of the handle of the Little Dipper (see NORTH STAR).

In the first three minutes, the particles that were created in the big bang became nuclei of hydrogen and helium.



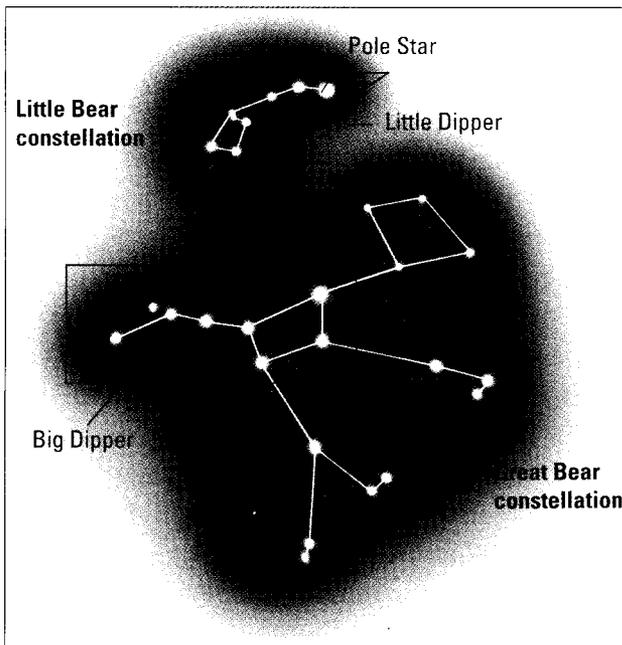
Over 15 billion years ago, the universe was created in a gigantic explosion.



BIG BANG THEORY

Most astronomers believe that the universe began in a colossal explosion, 15–20 billion years ago. It consisted at first of a hot gas of fast-moving particles. The gas cooled and formed clouds of hydrogen and helium gas, which broke up into galaxies and then into stars.

The hydrogen and helium gas broke up into huge clouds, and these formed the stars and galaxies.



BIG AND LITTLE DIPPER

The Big Dipper and Little Dipper are the most obvious groups of stars in the two constellations of the Great Bear and Little Bear. During the night, as the earth turns on its axis, they seem to revolve around Polaris (the North Star or Pole Star), at the tip of the "handle" of the Little Dipper.

The Big Dipper is part of the constellation called Ursa Major, or the Great Bear. The Little Dipper is part of Ursa Minor, the Little Bear.

See also CONSTELLATION.

BILE Bile is a greenish yellow digestive fluid made in the liver and stored in the gallbladder. Bile helps the body neutralize acid and absorb fat. During digestion, bile travels to the small intestine. Once there, it breaks down fatty foods.

See also DIGESTIVE SYSTEM.

BIMETALLIC STRIP A bimetallic strip is made by fastening together two strips of different metals. The metals are often brass and iron. When different metals are heated, they expand by different amounts. This happens when a bimetallic strip is heated, and this causes the strip to bend. When it is cooled, the strip returns to its original shape. Bimetallic strips are used in some thermostats for controlling heating systems. When the temperature rises, the strip starts to bend. Eventually it bends so much that it stops the supply of gas or electricity to the heater. When the temperature drops to a certain point, the strip

bends back again, and the supply is reconnected. Bimetallic strips are also used in circuit breakers, which are switches that stop or start the flow of an electric current.

See also CIRCUIT BREAKER; EXPANSION.

BINARY NUMBERS Binary numbers are numbers written in a number system that has 2 as its base. Every number system has a base, or quantity, used as a starting point for calculation. The base of a number system can be any number at all. Throughout history, different number systems have been used by different cultures. The ancient Babylonians based their system on 60, the Romans on 12. The decimal system, based on 10, is used throughout the world now. With the coming of computers, the binary system, based on the number 2, has come into widespread use.

The numerals, or number symbols, used in a number system depend on the base of the system. Ten symbols (0, 1, 2, 3, 4, 5, 6, 7, 8, 9) must be used for the decimal system. In the binary system, only two symbols (0 and 1) are used.

It is because of this that binary numbers are more helpful for use in computers than decimal numbers. The numeral 1 can be coded by the computer as a single electrical pulse. The numeral 0 can be coded as the lack of an electrical pulse.

The computer term *bit* is taken from the words *binary digit*. Each zero or one is called a bit. Computers of a simple design use eight bits to code letters, numbers, and symbols. An eight-bit series of zeroes and ones is called a byte. The following are examples of bytes and the characters they represent:

01000001 = A

01000010 = B

00110001 = 1

00110010 = 2

Newer and faster computers can read more than one byte at a time. A sixteen-bit computer reads two bytes at a time, while a thirty-two bit computer reads four bytes at once.

See also COMPUTER.

BINARY STAR A star that consists, or appears to consist, of two close stars is called a binary star. An example of a binary star is the middle star in the handle of the northern-sky star group called the Big Dipper. If you look at it carefully, you may see that it seems to consist of two stars. (It helps to look not directly at the star but with the star just off the center of your field of vision.) But these two stars are not associated. Although they appear to lie in almost the same line of sight as seen by us, they are actually trillions of miles apart.

Many more stars that look single to the naked eye appear as double through telescopes. Many of these are really associated, going around each other under the influence of their mutual gravitational attraction. When studied over a period, they can be seen to revolve around each other.

Some stars that are really doubles are so close to each other, or so far from us, that they look like single stars even through telescopes. But analysis of their light often shows that they are binary stars. At any moment one of them will be approaching the earth while the other will be moving away. The light waves from the approaching star will be shortened and will show a blue shift, while the light waves from the receding star will be lengthened and will show a red shift (see BLUE SHIFT; DOPPLER EFFECT; RED SHIFT). The shifts will reverse as the stars continue around their orbits.

BINARY STAR

Two stars that revolve around each other make up a binary star, or binary system (right). They revolve around a point called the center of gravity, G, which moves steadily through space. To the naked eye, they nearly always look like a single star.

In some binary systems, each star passes in front of and behind the other one as seen from the earth (right). When the brighter star passes behind the fainter one, we see a large drop in their combined brightness (graph below). When the fainter star passes behind, we see a smaller drop. These variations in brightness repeat at regular intervals.

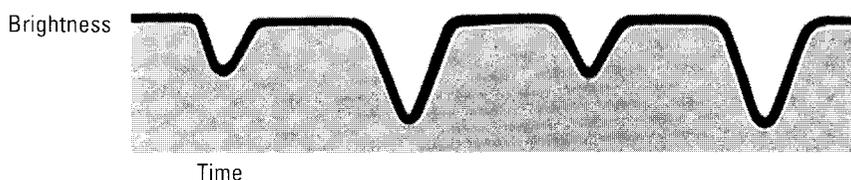
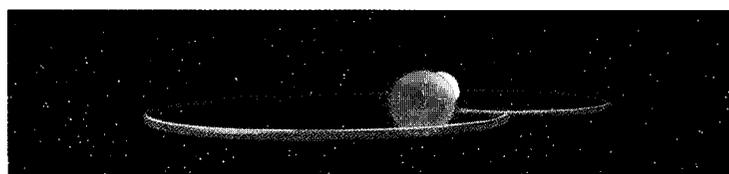
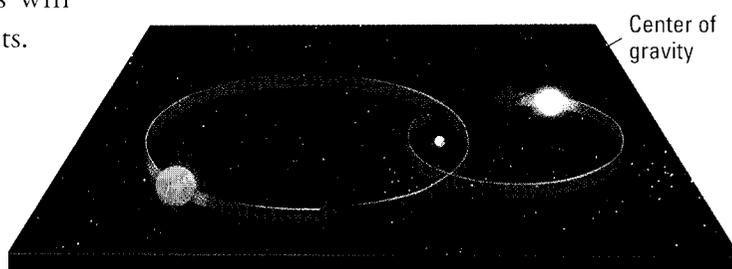
Observing the movements of binary stars can tell astronomers how strong the gravity of each star is, and hence its mass. The mass of a star is the most crucial factor that determines how bright it is, how long it will shine, and how it will die.

Many star systems have more than two members. For example, Epsilon Lyrae in the constellation of the Lyre appears as a double star to the naked eye. Through a small telescope each of these can be seen to be a double star. And the blue and red shifts in the light show that the brightest of these four is itself a double.

Single stars like our sun are less common than stars that belong to pairs or larger groups. But they are more likely to have planets that can support life. Planets orbiting multiple stars are likely to be flung off into space, or to be periodically roasted by going too close to one of the stars.

See also GRAVITY; SPECTROSCOPE; SPECTRUM; STAR.

BINDWEED (bīnd'wēd') Bindweed is the name of a group of perennial plants belonging to the morning glory family (see MORNING-GLORY; PERENNIAL PLANT). Bindweeds are found throughout the United States and southern Canada, as well as in Europe and parts of Asia. They grow along roads, beaches, and fields. The hedge bindweed and field bindweed often grow among



cultivated crops, causing extensive damage. Bindweeds have arrow- or heart-shaped leaves and white, pink, or blue funnel-shaped flowers.



BINDWEED

The plant pictured can be identified as bindweed by its typical arrow-shaped leaves and funnel-shaped white flowers. Since it is fast-growing, it can quickly take over an area of soil and make the growth of other plants impossible.

BINET, ALFRED (1857–1911) Alfred Binet was a French psychologist who developed the first intelligence test for children. The French government asked Binet to design a test that could identify children who seemed to be less intelligent than the average. The learning ability of these children is usually much less than that of other children the same age. The purpose of the tests was to allow educators to decide which children needed special schooling.

In 1905, working with Theodore Simon, Binet developed the Binet-Simon intelligence tests. These were the first scales for measuring intelligence, or discovering “mental age.” They helped teachers find out the relative intelligence of their students. Later, the tests were adapted by other psychologists to find a child’s intelligence quotient (IQ). The IQ is a number equal to the mental age, as determined by testing, divided by the chronological, or actual, age of the person tested, and then multiplied by 100. If a person’s

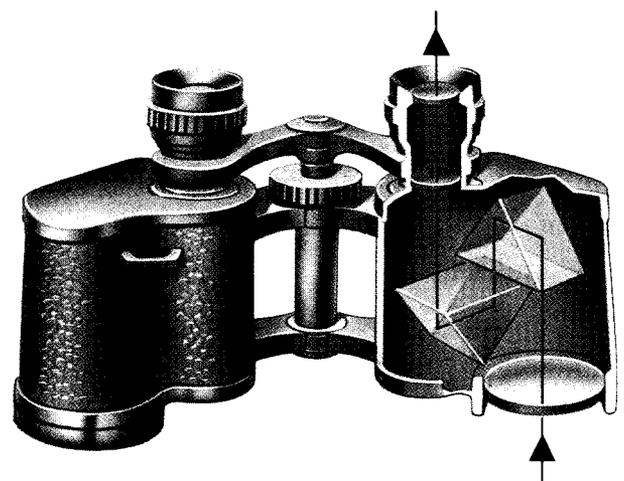
intelligence is average, then his or her mental age and his or her chronological age are the same. Thus, the person’s mental age divided by his or her chronological age is 1. When that is multiplied by 100, the answer is 100. Therefore, the IQ of an average person is 100. Many people have questioned the accuracy and purpose of IQ measurement, but intelligence tests are still used.

See also INTELLIGENCE.

BINOCULARS Binoculars are a pair of small telescopes built into a casing, or frame (see TELESCOPE). The telescopes allow stereoscopic vision, which is the ability to judge depth by using both eyes at the same time. Binoculars make distant objects seem closer by means of magnification (see MAGNIFICATION).

The two telescopes in binoculars are exactly alike. Each telescope is built into a funnel-shaped tube, or cylinder. An objective lens is at the wider end of each tube. An eyepiece, consisting of one or more lenses, is at the narrower end of each tube. Each tube contains two prisms located between the objective and eyepiece lenses (see LENS; PRISM).

The objective lenses gather light from the object being viewed. They form images that are upside down and reversed right-to-left. By bending the



BINOCULARS

Binoculars are optical instruments designed for use with both eyes to achieve a close-up view of things from a distance. Each tube of the instrument contains two prisms. They bend the light rays four times as they pass through the instrument.

light beams, the prisms correct the image to proper orientation before it reaches the eyepiece lenses. The eyepiece lenses further magnify the image.

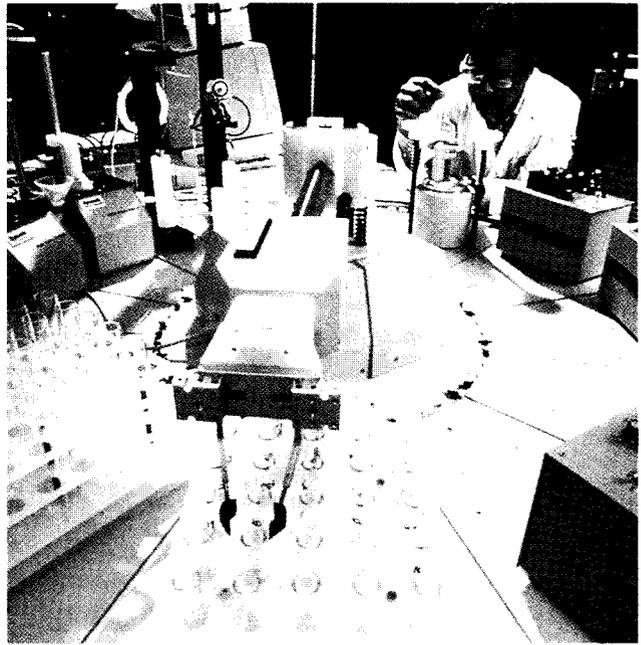
Most binoculars have adjusting wheels, or knobs, that change the distances between the objective lenses and the eyepiece lenses. This movement of the lenses closer or farther apart brings the object into focus. Some binoculars have one focus wheel for both telescope tubes. Higher-quality binoculars have controls for independent focus of each telescope.

Binoculars usually have two numbers printed or engraved somewhere on the outer covering. The first number is the power or magnification. The second number is the diameter of the objective lens in millimeters. Binoculars that are marked 6 x 35, for example, will magnify an object six times through an objective lens that is 1.4 in. [35 mm] in diameter.

Many modern microscopes are arranged in binocular fashion. This gives the viewer a three-dimensional image.

BIOCHEMISTRY (bīō kēm'ī strē) Biochemistry is the science that studies the chemical makeup and processes of all living things. The whole structure of living things is built up from chemical substances. These substances are constantly changing. Complex molecules, such as proteins and carbohydrates, are being broken down into simpler parts. Simple parts are being built up again.

The study of biochemistry began in the late eighteenth century. Chemicals were taken from living things and studied. Since the late nineteenth century, biochemists have made many discoveries. Some important discoveries are connected with food and energy. Biochemists have discovered how plants use energy from the sun to build simple substances into more complex ones by photosynthesis (see PHOTOSYNTHESIS). They have found how animals break down foods by digestion into simpler parts, and then build these up again. Biochemists have also traced the complex series of reactions linked with the Krebs cycle. The reactions in this cycle release the energy



BIOCHEMISTRY

Biochemists have made important contributions to pharmacology (the study of drugs). Here, a scientist monitors a robot's testing of drugs for purity.

in food molecules (see KREBS CYCLE). Biochemists have studied special molecules in living cells called nucleic acids. Scientists believe these acids may be the controllers of all growth and reproduction. One form of nucleic acid, RNA, is found throughout the cell, where it controls the making of protein. DNA is another form of nucleic acid. DNA carries and passes a kind of "blueprint," or plan of a living thing, from one generation to the next (see GENE; NUCLEIC ACID). Biochemistry is also concerned with the workings of membranes and with the chemical changes that take place in muscles as they contract and in nerve cells as they conduct messages.

Through its discoveries of how the body functions in health and sickness, biochemistry has contributed to medicine. It has led to the understanding and treatment of diseases in which the body's chemistry goes wrong. Pharmacology, the study of drugs and their actions, is closely related to biochemistry (see PHARMACOLOGY). Techniques of biochemistry, such as chemical analysis, chromatography, and the use of radioisotopes as "tracers," are valuable in the study of many diseases (see CHROMATOGRAPHY; TRACER). Biochemists are helping learn some of the causes of mental illness,

the origins of birth defects, and how poor diet affects intelligence, growth, and development.

BIODEGRADABILITY Biodegradability refers to the ability of a substance to decompose, or be broken down, by microorganisms (see *DECOMPOSITION*; *MICROORGANISM*). Examples of substances in nature that are biodegradable are leaves, bodies of animals, and oil. Many human-made products, such as Styrofoam and plastics, are not biodegradable. Many areas in the United States are running out of places to store these wastes. These substances will build up and pollute the environment. To help control this pollution, scientists are researching ways to make some human-made substances, such as plastics, biodegradable.

BIOFEEDBACK Biofeedback is a method of becoming aware of involuntary body processes, such as blood pressure and body temperature. Once aware of these processes, a person may learn to exercise some voluntary control over them.

The way a person becomes aware of these body processes is by being connected to different biofeedback machines by electrodes. An electrode is an electrical conductor by which an electric current enters or leaves an object. The machine measures body processes and conveys information about them to the person through a tone or display on a computer screen. For example, if a person's blood pressure falls below a certain level, a tone might sound. The person can learn to lower his or her blood pressure by first recalling how he or she felt when the tone sounded. The person then concentrates on achieving the feeling again.

Many biofeedback machines measure the electrical signals given off by muscle contractions. Muscle contractions can indicate tension. By learning to control tension, other problems may be cured. For example, bed-wetting problems are linked to tense pelvic muscles. Children who can learn how to keep their pelvic muscles relaxed through biofeedback may be able to stop wetting their beds. Similarly, migraine headaches may be

the result of tense neck muscles. Headaches may be prevented by learning how to keep the neck muscles relaxed. Other biofeedback devices may detect tiny amounts of perspiration on the skin, which is also linked to tension. Biofeedback recordings of very slight muscle activity have helped some patients gain slight control over areas thought to be paralyzed. Biofeedback has also been found to help other conditions, such as stuttering, stomach ulcers, epilepsy, and asthma (see *ASTHMA*). Biofeedback is gaining wide acceptance. Physicians may also advise patients with certain difficulties to try biofeedback.

BIOGAS *Biogas* is the name given to methane gas produced by organic matter. In marshland, the action of bacteria feeding on dead vegetation produces methane. Because of this, methane is also called marsh gas. The digestive processes inside the intestines of cows and other ruminants (animals that chew a cud) also generate methane. This important biogas is produced commercially by growing bacteria in tanks full of farm manure. Biogas and other substances made from it, such as methanol, may one day replace fuels such as gasoline that are made from crude oil. Oil is a nonrenewable resource. When the earth's natural reserves of oil have been extracted, there will be no more to replace them. Natural oil reserves could be exhausted by the middle of the twenty-first century. Biogas is a renewable source of energy. The only major drawback to its widespread production and use is that it could have damaging environmental effects.

See also *BIOMASS*; *GREENHOUSE EFFECT*; *METHANE*.

BIOLOGICAL CLOCK Biologists believe that living things—in fact, possibly all cells—have a “built-in clock” that helps them control their regular activities (see *BIORHYTHMS*). For instance, certain species of mice are active only at night. When these mice are kept in a cage that is dark all day, they still sleep during the day and are active at night. Their “built-in clock” apparently tells them when night has come, even though their eyes cannot tell.

Vertebrate animals have a special organ attached to the base of the brain, known as the pineal gland, which responds to daily changes in light (see PINEAL GLAND). Our eyes detect the light and pass messages to the pineal gland, which sends the information to a collection of nerve cells—a “master clock”—in another part of the brain. This “master clock” uses the information it receives from the pineal gland and other organs to control our activity during the day and to give us our sense of time. We sometimes disturb the “master clock” by traveling quickly across time zones. Although we can easily reset our watches, our body clock may take many days to adjust (see JET LAG).

Scientists have also found that plants have a biological clock, which helps them to respond to the length of daylight and darkness. This is important in regulating when they flower, and when the flowers open and close (see PHOTOPERIODISM).

BIOLOGICAL CONTROL Biological control is a method of fighting pests by using their natural enemies against them. Natural enemies are used instead of artificial means, such as chemical pesticides (see PESTICIDE). For example, cats naturally feed on mice, so cats are often used by humans to kill mice around the home. Biological control is used on a much larger scale on farms. Farmers bring natural enemies, such as certain disease-causing organisms, into their fields to reduce the amount of harmful pests. For example, a virus causes the disease myxomatosis among rabbits. It has been used in Australia to reduce the number of rabbits, which once caused widespread crop damage (see DISEASE). A bacterium which produces a substance poisonous to certain caterpillars is often sprayed on trees to control gypsy moths and other insects.

Plants are another method of biological control. For example, mint, garlic, and marigolds produce chemicals that repel certain insects. Gardeners often plant these among their other flowers or vegetables to keep away plant-damaging insects. The release of sterile (infertile) male insects into an area where plants are being raised is another



BIOLOGICAL CONTROL

Biological control fights pests by means of their natural enemies. Insects that are harmless to people are put in a position to eat the eggs, larvae, or adults of another insect that is a serious pest to people.

method of biological control. Many female insects mate only once. Thus, if they mate with one of the sterilized males, they will not be fertilized, and no young will be produced.

Scientists are researching new methods of biological control. For example, they are researching ways to produce a type of bacteria that would be added to the soil in which plants are being raised. This bacteria would kill certain disease-causing organisms among plants. Scientists are also researching a fungus that is fatal to locusts. In the late 1980s, \$400 million was spent on pesticides to kill locusts in Africa. Plagues of locusts swarm across Africa eating everything in their way. The fungus may be able to control them where pesticides have failed. Scientists have even succeeded in using genetic engineering to produce vegetables that make their own insecticides (see GENETICS).

No method of biological control has been found to be completely effective. Thus, chemical pesticides are still used. Unfortunately, chemical pesticides sometimes kill desirable pests as well as the pests they are meant to control. Scientists hope that improved methods of biological control will gain an increasing role in controlling pests. They believe that this may someday mean the end of the release of polluting chemicals into the environment.

See also INSECT.

BIOLOGY

Biology is the science that studies all living things. Because the cell is considered to be the basic unit of life, all organisms that are made up of one or more cells are clearly in the domain of biology (see CELL; CLASSIFICATION OF LIVING ORGANISMS; LIFE).

There are some organisms, however, that are acellular, or not made up of cells. A virus, for example, has no characteristics of life when it is studied in the isolated state (see VIRUS). When present in a living cell, however, a virus can cause the reproduction of other viruses like itself. Because reproduction is a characteristic of living organisms, many scientists consider the virus to be alive.

History of biology People have been interested in biology since prehistoric times. They realized that some things were living or had been living while other things had never been alive. It was not until the time of the ancient Greek and Roman civilizations, however, that biological observations were written down and recorded for future generations. The Greek philosopher

Aristotle is often considered to have been the first biologist (see ARISTOTLE). With the fall of these cultures in the first few centuries A.D., interest in the sciences declined. For almost a thousand years, superstition and magic obscured scientific progress.

In the sixteenth century, Sir Francis Bacon played a large role in reawakening scientific curiosity (see BACON, FRANCIS). In the years that followed, many other scientists began studying living things. With the invention of the microscope in the seventeenth century, a whole new world was opened to the scientist—the previously unseen world of the cell (see MICROSCOPE). Biology, once a purely descriptive science, now became an experimental science. It was not enough for biologists to see something happen. They wanted to know how and why it was

BOTANY

One of the major areas of biology is botany. Botanists study plant life. The scientist pictured is carrying out an experiment to find out how well young corn plants will grow in chemical solutions instead of soil. This method of growing plants is called hydroponics. Botanists believe that hydroponics could help produce food in parts of the world where the soil is poor.



happening, and they devised experiments to discover the answers. By the nineteenth century, biology had been established as a major field of scientific research. In the following decades, the understanding of life and related biological knowledge increased at a rapid rate.

Fields of biology Biology is usually divided into two major fields: botany and zoology (see BOTANY; ZOOLOGY). Botany is the study of the plant kingdom, and zoology is the study of the animal kingdom. Since many organisms do not fit into either of these fields, some biologists consider a third major field to be microbiology, which is the study of all microscopic forms of life (see MICROBIOLOGY).

These major fields are subdivided into ten broad areas of study. Anatomy deals with the structure of living things. Biochemistry deals with chemicals and chemical reactions that affect life. Biological earth science uses the earth sciences in the study of living things. Biomathematics uses mathematics to study life. Biophysics studies the physical properties that affect life. Ecology studies the relationships between living organisms and between organisms and their environment. Pathology studies diseases that affect living

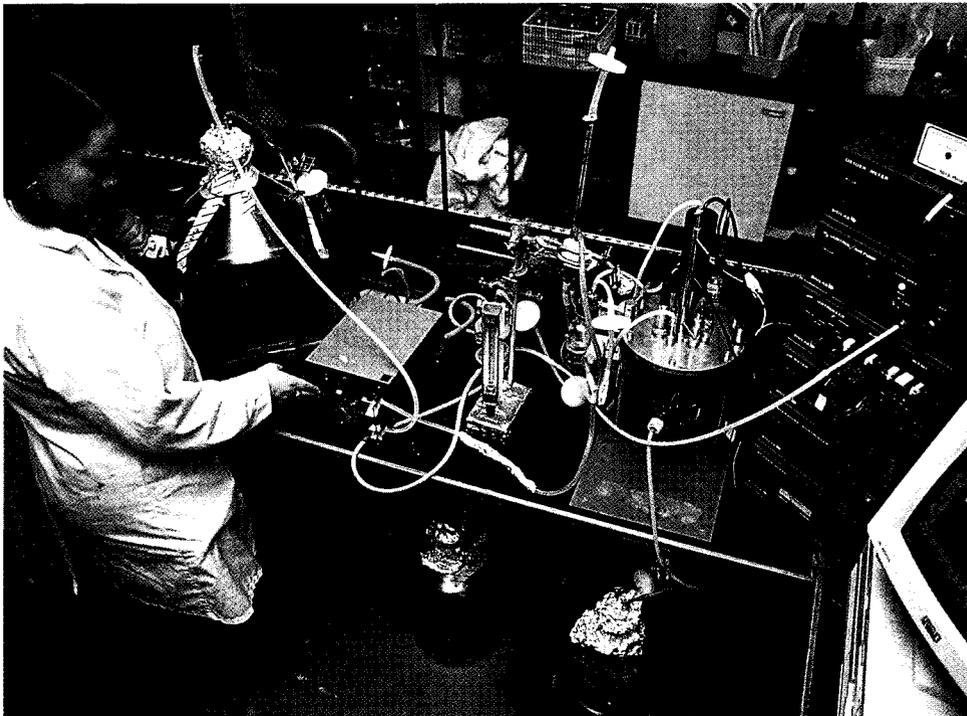
organisms. Physiology studies the functions of living things. Biological psychology studies the psychology of living things. Taxonomy names and classifies living organisms.

See also ANATOMY; BIOCHEMISTRY; BIOPHYSICS; ECOLOGY; PATHOLOGY; PHYSIOLOGY; PSYCHOLOGY; SCIENCE; TAXONOMY.



ECOLOGY

One field of biology is called ecology. Ecologists study the ways in which living things interact with their environment. A polar bear is being weighed as part of a study of the wildlife of the Canadian Arctic (above).



LABORATORY WORK

Much of the work of the biologist takes place in the laboratory. Living cell growth is being studied to find out more about food poisoning (left).

BIOLUMINESCENCE (bī'ō lōō'mā nēs'əns)

Bioluminescence is the production of light by living things. This biochemical reaction results in very little heat. Many bioluminescent creatures live so deep in the oceans that light from the sun never reaches them. These creatures use their bioluminescence to attract mates, to confuse attackers, and, in some cases, to attract prey. They do not use this light to see where they are going.

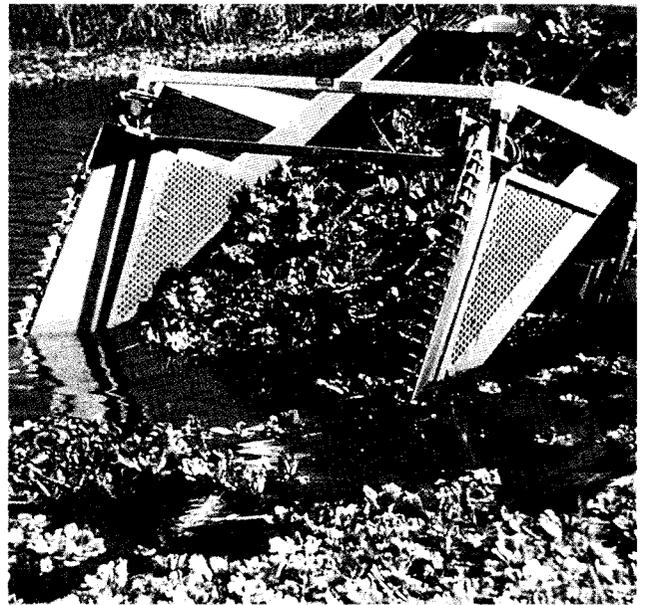
The regular blinking of fireflies as they signal their mates on summer evenings is an example of bioluminescence. Some bacteria and fungi also show bioluminescence.

See also FIREFLY; LUMINESCENCE.

**BIOLUMINESCENCE**

In the mating season, fireflies use bioluminescence to flash light signals to attract other fireflies.

BIOMASS Biologists and other scientists use *biomass* to describe populations of living things in terms of their total weight or volume within a given area, or habitat. Biomass can be a measure of all the living things in a habitat, a given species in a habitat, or a group of species in a habitat. For example, the biomass of a rain forest could include the weight or volume of all the plants and animals that live in it. The biomass of a particular body of

**BIOMASS**

Scientists are experimenting with the use of aquatic plants, such as these being removed from a Florida canal, as a source of energy. Such renewable energy sources are called biomass.

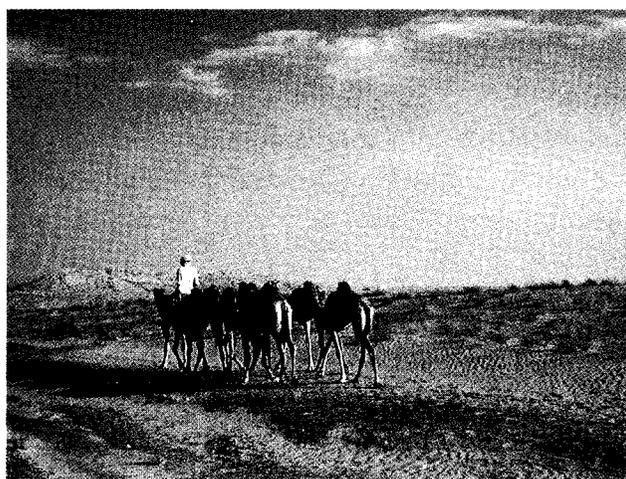
water could refer to one particular species, such as the shrimp, that lives there.

Biomass can also refer to renewable energy sources, such as trees. Examples of nonrenewable energy sources are coal and oil. Biomass materials, such as wood, sawdust, grain, and aquatic plants, can be used to produce energy. For example, the materials can be burned to produce heat. Also, certain processes can convert biomass into a synthetic, or human-made, form of oil. This oil is called biocrude. Many scientists believe biomass will be an increasingly important energy source as nonrenewable energy sources are depleted.

See also AQUATIC PLANT; ENERGY.

BIOME A biome is a large natural area that has a particular climate, plants, animals, and other characteristics that make it different from other areas. Rain forests, tundras (cold, treeless plains), savannas (tropical grasslands), and deserts are examples of different land biomes. An ocean is an example of an aquatic biome. The plants and animals that live in a biome are adapted to its particular conditions, such as temperature, rainfall, and soil type.

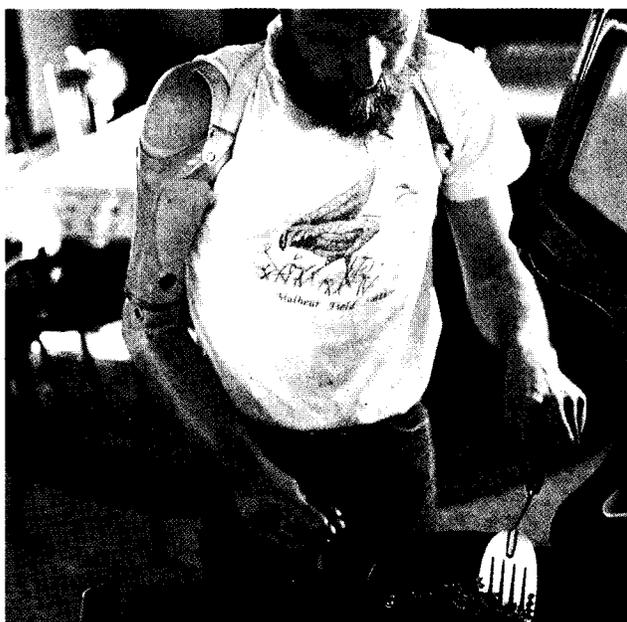
See also ECOLOGY; ECOSYSTEM.



BIOME

Desert biomes contain plants and animals adapted to life in extreme climates. Not only must they survive with very little water, but they must also withstand an enormous range of temperatures, from freezing cold at night to baking hot by day.

BIONICS Bionics is the study of machines that behave in the same way as living organisms, or parts of organisms. Robots that move using jointed limbs are examples of bionic machines. Computers programmed to use artificial intelligence are also bionic machines. In medicine, bionics refers to the development of artificial organs such as kidneys and hearts. Most artificial arms and legs are made to look like real limbs, but they cannot function in quite the same way. New



BIONICS

This man has a bionic arm moved by motors controlled by nerve impulses from his own muscles.

types of bionic arms and legs are being developed to use motors controlled by nerve impulses from their wearer's own muscles. Some bionic systems are designed to make paralyzed limbs function by using electricity to stimulate the limb muscles. This makes the muscles contract, which makes the limb move in the same way that it moves in a healthy person. New types of bionic arms and legs have been developed that use motors controlled by the detection of electrical field patterns in muscle tissues usually picked up at many sites on the surface of the skin.

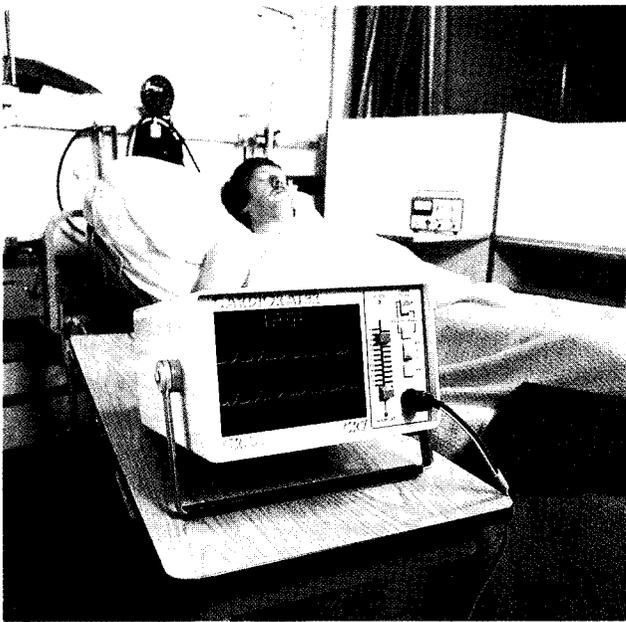
See also ANDROID; CYBERNETICS; ROBOTICS.

BIOPHYSICS Biophysics is a relatively recent scientific discipline that combines the special interests of physics and chemistry with those of biology. Most of the research in biophysics has been done by physicists with a strong interest in biology. The methods of physics and chemistry are used to study and to explain the structures of living organisms, the mechanics of life processes, and the cooperative biological interactions that are essential to life.

The biophysicist describes biological processes in physical terms. His or her research is subject to laboratory experiments and testing, mathematical measurements, biochemical analysis, and other means of precise physical interpretation.

The recent growth of biophysics is largely the result of the development of biophysical tools and instruments that measure, describe, and analyze biological processes and functions. Some of these instruments include electron microscopes, X-ray equipment, radioisotope scanners, ultracentrifuges, oscilloscopes, spectrometers, electronic amplifiers, computers, lasers, and electronic monitoring devices. The term *medical physics* is often used to refer to work done using radiological instruments (see RADIOLOGY).

In the nineteenth century, physicists and anatomists conducted many experiments on living tissues. Using a galvanometer, the scientists discovered that minute electrical currents were generated in muscles and across nerve membranes (see GALVANOMETER). Further research led to the study



BIOPHYSICS

This hospital patient is connected to an electronic machine that monitors his heartbeat. The electrical activity of the heart muscle is displayed as a pulsating trace on a television-type screen.

of neurophysiology and the electrical nature of nerve impulses. Such investigations provided early research for the field of biophysics.

From 1895 to 1900, experiments by Henri Becquerel, Pierre and Marie Curie, and Ernest Rutherford (with radioactivity) and Wilhelm Roentgen (with X rays) provided unique tools for the growth of biophysics (see BECQUEREL, ANTOINE HENRI; CURIE FAMILY; ROENTGEN, WILHELM CONRAD; RUTHERFORD, ERNEST). In the 1920s, George de Heresy discovered that radioactive tracers follow the course of bodily substances (see RADIOACTIVITY; TRACER; X RAYS).

Electronic and atomic instruments developed during World War II (1939–1945) were significant for biophysics. Radar and sonar devices, which were used to detect aircraft, ships, and submarines, gave rise to the development of improved electronic equipment. The atomic bomb was developed with the aid of nuclear reactors. Following the war, these reactors provided an abundant supply of radioactive isotopes, which have been of great value in biophysical research and related fields (see NUCLEAR ENERGY).

With the development of the electron microscope,

cells and tissues could be scanned and magnified more than 400,000 times (see ELECTRON MICROSCOPE). This made it possible to observe the physical activity of molecules and enzymes (proteins that cause or speed up chemical reactions) and to describe the structural activity of muscular contraction.

Biophysicists also study and explain the interchange of gases between the lungs and the blood and between the blood and the cells. They examine the effects of light, heat, cold, noise, pressure, and other forces on the physiology of living things. They study sensory communication and the mechanics of seeing, hearing, tasting, smelling, and feeling. They examine the complex relationship between stimulus and action.

Some of the most important applications of biophysics relate to surgical procedures, hospital patient care, nuclear medicine, and medical engineering. Biophysical instruments are used to diagnose and treat cancers and viral, circulatory, and kidney diseases. Diagnostic radiological instruments are used to image various body areas in order to locate tumors. Radiation therapy machines can give exact doses of radiation to control certain tumors (see NUCLEAR MEDICINE; RADIATION THERAPY). In research laboratories, biophysicists examine the physical activities that cause the death of cells, tissues, and whole organisms, and try to discover the causes of cell mutations (changes) and uncontrolled cancerous growths.

Patient-monitoring systems and intensive care units use biophysical instruments before, during, and after surgery. Pulse, body temperature, and blood pressure are monitored. The electrical activity of the brain, heart, and other vital organs is tracked on monitoring devices.

Biophysicists and biomedical engineers have developed electronic aids for the deaf and the blind, artificial arms and legs, and orthopedic implants to replace worn hip and knee joints. Kidney dialysis machines enable people with damaged kidneys to go on living relatively normal lives. Bionics, a recent branch of biophysics, uses electronic devices to do the work of impaired organs. The electronic pacemaker is an example of

one of these devices. The potential for biophysical research instruments valuable to the diagnosis and treatment of diseases is virtually unlimited.

See also BIOCHEMISTRY; BIOLOGY; BIONICS; CHEMISTRY; MOLECULAR BIOLOGY; PHYSICS; PHYSIOLOGY.

BIORHYTHMS No one knows exactly how biological rhythms work. Scientists believe that living things have a “built-in clock” that “tells” the animal or plant what time of day it is (see BIOLOGICAL CLOCK). Cycles that occur regularly in living things are called biological rhythms, or biorhythms. Sleeping is a biological rhythm in humans, for example, because adult humans sleep every 24 hours. Some rhythms, such as going to sleep, involve conscious behavior. Other rhythms, such as heartbeat, are under the control of the autonomic nervous system.

Biological rhythms occur without the organism completely controlling them. For example, a person’s heart beats constantly, he or she sleeps regularly, and his or her blood pressure changes in response to various situations. A person can exercise some control over some of these rhythms—for example, by delaying sleep for a certain amount of time. However, a person cannot totally control the rhythms. For the most part, they happen by themselves.

There are several kinds of biological rhythms. Some occur twice a day. For example, crabs come out of their holes at every low tide. Some kinds of biological rhythms occur once a day, such as adult humans sleeping. These daily rhythms are called diurnal or circadian, both words coming from Latin words referring to day (see CIRCADIAN RHYTHM). Other rhythms occur once a month, such as the menstrual cycle in women. These cycles are called lunar, which refers to the moon, which also has a monthly cycle. Annual rhythms occur once a year, such as flowers blossoming on a plant.

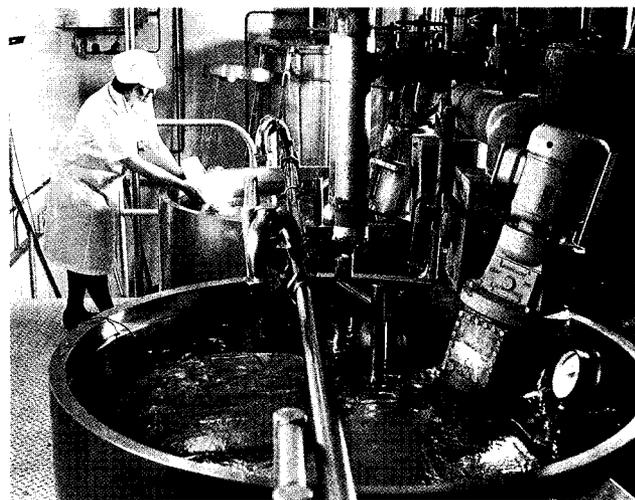
BIOSPHERE *Biosphere* is a term used to describe the parts of the earth and the thin layer of air above its surface that support life. The

biosphere includes the soil, rivers, lakes, oceans, and the lower atmosphere.

See also ATMOSPHERE; EARTH.

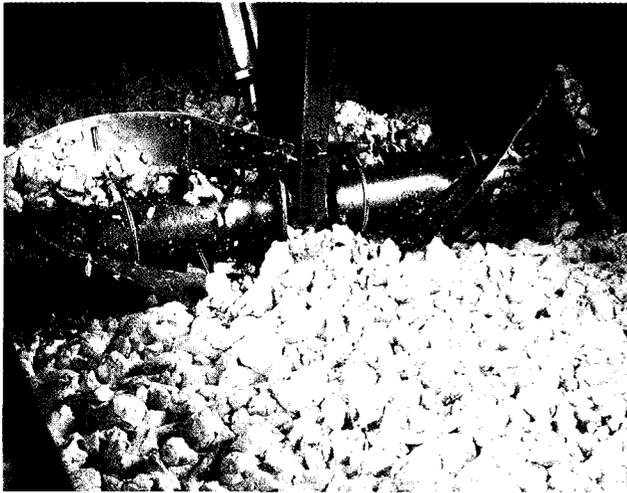
BIOTECHNOLOGY Biotechnology is technology based on biological processes. It makes use of plant and animal cells, microorganisms, and their products to create useful substances. There are many forms of biotechnology, from cheesemaking to manufacturing antibiotics to genetic engineering. Bread, yogurt, wine, and biological detergents are all products of biotechnology. Biotechnology is the category of all the studies and techniques that combine the ideas and needs of biology and medicine with engineering. One goal of biotechnology is to increase the available food for the increasing world population.

Fermentation Fermentation involves the use of microorganisms to break down organic compounds. Yeast breads are made by using yeast, a single-celled organism, to change chemicals in the dough into carbon dioxide gas, which causes the dough to rise. Bacteria and molds can also be used for fermentation. In Brazil, alcohol made by fermenting sugar-cane juice, is used instead of gasoline to fuel vehicles. Some antibiotics are made by fermentation, too. Penicillin, the first modern antibiotic, was made by the action of a mold on molasses. During World War I, acetone, needed



BIOTECHNOLOGY—Making curds

Vats called fermenters hold milk products at a steady temperature in the early stages of cheesemaking.



BIOTECHNOLOGY—Cheese

When the solid curds have been separated from the watery whey, the curds are shredded and compressed to make cheese.

for making explosives, was produced by using bacteria to ferment grain (see FERMENTATION).

Waste treatment One major drawback of industrial development is the amount of waste and pollution that it produces. Sewage is treated by letting microbes break it down into simpler, less harmful compounds. The bacterium *stearothermophilus* is particularly good at converting straw, a waste material in farming, into ethanol, which can be used as a fuel. Other bacteria can deal with more toxic materials. *Pseudomonas* can break

down hydrocarbons such as crude oil (see BACTERIA).

Genetic engineering Genetic engineering describes the ways in which scientists manipulate the genetic code of living organisms (see GENETIC ENGINEERING). The manipulation is actually carried out by enzymes. These natural proteins can snip sections out of a string of DNA, the cell's genetic code. The sections can be put together again in a different order. DNA from different cells can be combined in this way, too. With these methods, it is possible to make bacteria that produce useful materials such as insulin, which helps to control diabetes. Some children do not grow normally because they lack a vital growth hormone. They can be given extra growth hormone which used to be taken from human donors after death but is now produced using genetically engineered bacteria. By altering the genetic make-up of plants, new strains of crops can be produced that have higher yields or greater resistance to disease or drought conditions.

Vaccines to combat diseases used to be made from the blood of people suffering from the disease. Vaccines contain antibodies that attack the disease-causing organism. But vaccines made in this way are not pure. In 1975 George Köhler and César Milstein developed a way of making purer



BIOTECHNOLOGY— Making drugs

A technician tests the quality of chemicals used for making drugs. Such quality control is vital to check the purity of medicines.

antibodies, called monoclonal antibodies, which are used to make purer vaccines. They are also used for identifying blood groups and testing blood for harmful organisms before it is used for blood transfusions.

In the future it may be possible to eliminate inherited illnesses by altering the genetic make-up of sufferers (see GENETICS). Treating diseases by genetic engineering is called gene therapy.

Safety It is important that genetically altered material is not released from the laboratory where it was made until it is proved to be harmless. Regulations for the safe handling and release of genetically altered organisms are still being developed. In the 1970s fears that genetic engineering could lead to deadly new organisms escaping into the environment led to the introduction of guidelines to control research. In the future numerous genetically altered organisms, from viruses to trees, could be released intentionally to improve the environment. In 1980 a patent was granted in the United States for an "oil-eating" bacterium. In 1992, 157 countries agreed to consider the need for international agreements on the safe handling and use of these organisms.

See also DNA; FLEMING, SIR ALEXANDER; GENETIC FINGERPRINTING; PASTEUR, LOUIS; PASTEURIZATION; PENICILLIN; YEAST.

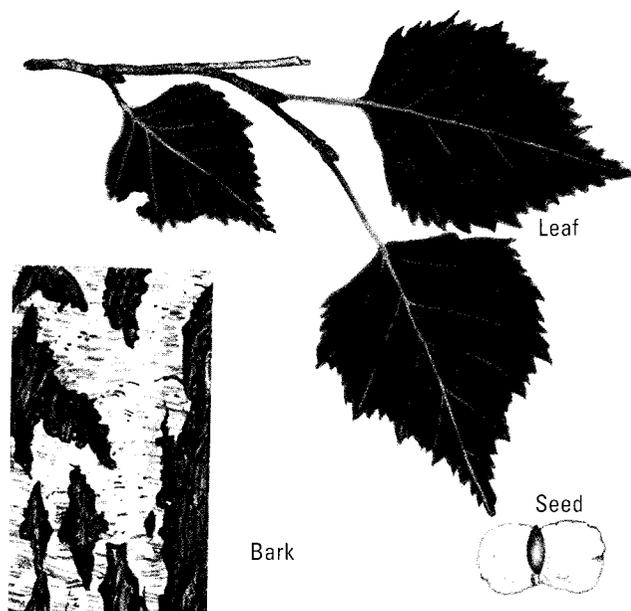
BIRCH The birches are a family of about forty trees and shrubs that grow in the cold and moderate-climate areas of North America, Europe, and Asia. Most birches have thin, easily peeled bark and tall, slender trunks growing in pairs or larger groups. Flowers are produced either on a male catkin in the fall, or on a female catkin in the spring (see CATKIN).

Birches grow well in poor soil and are often used for ornamental purposes. The sap produces an oil that can be used to make birch beer.

There are several common species of birches in the United States. The yellow birch is one of the most common. It grows to 50 to 82.5 ft. [15 to 25 m] high. It may be silver, yellow, or gray when mature. The bark is loose and peels off naturally.

Its hard wood is good for furniture. The paper birch grows to 60 to 82.5 ft. [18 to 25 m] high. It has thin, white bark. The bark was used by Native Americans to build birchbark canoes.

See also ALDER.



BIRCH

The trees in the birch family produce their flowers on either male or female parts called catkins (above). The seeds on the female catkins have papery wings to help them catch the wind and be blown away to colonize new ground.

BIRD

Birds are warm-blooded animals of the class Aves. Like mammals, they are vertebrates. They are different from most mammals in that they do not bear live young but lay eggs from which the young are hatched. Birds have feathers, wings, and beaks that make them different from all other animals and easy to identify (see EGG; FEATHER; MAMMAL; VERTEBRATE).

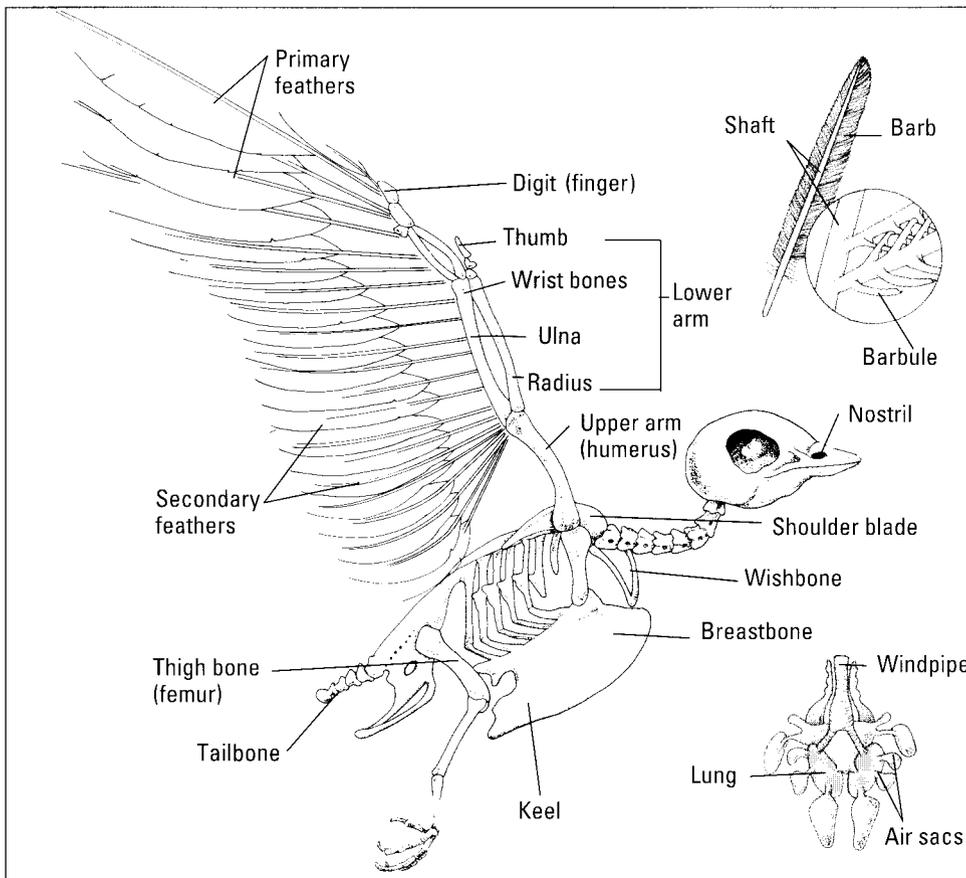
Birds evolved from reptiles during the age of dinosaurs. Evolution of feathers from reptilian scales helped make flight possible (see ARCHAEOPTERYX; FLIGHT). The adaptation to flight is probably responsible for the large number and wide distribution of birds. There are more birds than all other terrestrial (land-dwelling) vertebrates combined.

Most birds are good fliers, but there are a few so-called flightless kinds, such as the ostriches and the penguins. The penguins' wings have changed into swimming flippers in the millions of years since they first appeared on earth. The ostriches

move about on their long, strong legs. Their wings are too small and weak to enable them to fly.

Birds use aerodynamic principles of lift and thrust in flying (see AERODYNAMICS). Their light, feathered wings and hollow bones help keep them as light as possible. By flapping their wings, they are able to produce thrust. Some birds, once they are aloft, glide and soar on air currents with almost no effort. Vultures and albatrosses are birds that can soar for hours, barely flapping their wings.

There are about nine thousand species of birds. They range in size from the tiny hummingbird, about 2 in. [5 cm] in length, to the ostrich, which can grow to 8 ft. [2.5 m] in height and can weigh as much as 300 lb. [136 kg].



PLUMAGE

Bird feathers, such as the ones on this purple macaw, are used for flight and display. Some birds also use feathers for camouflage.

BIRD FEATURES

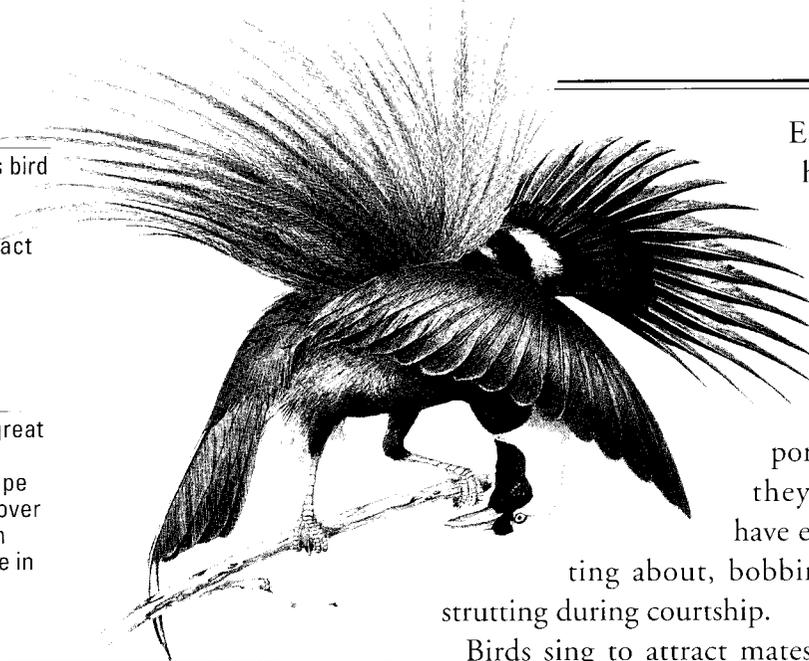
A bird is covered with feathers. The streamlined shape of a bird allows it to move easily through the air. The bones are light—many are hollow—yet strong. Powerful muscles attached to the breastbone make the wings beat for flight. The lungs have air sacs to increase the oxygen supply when flying.

DISPLAY

The male Count Raggi's bird of paradise (right) is displaying his brightly colored feathers to attract a female.

FLIGHT

As a bird, such as the great egret (below), flaps its wings, their curved shape makes air move faster over the top of the wing than below it. This difference in air speed produces an upward force or lift.



Each species of bird has its own form of courtship behavior before nesting. For example, the grebes do a courtship dance on the ponds and lakes where they nest. Other birds have elaborate ways of flitting about, bobbing their heads, and strutting during courtship.

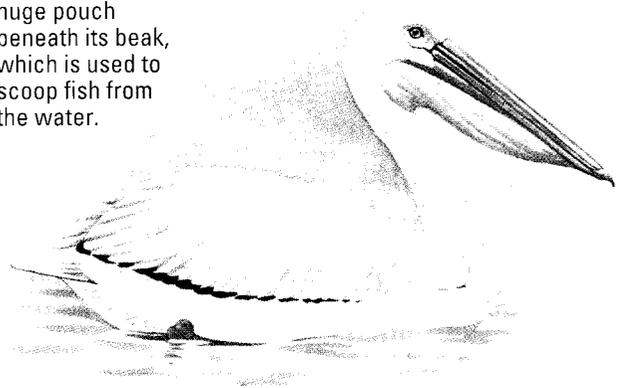
Birds sing to attract mates and to warn other birds away from their nesting area. In all species of songbirds, the male is usually the singer. Not all bird songs are beautiful. For example, the mockingbird has its own harsh call, but can imitate the songs of other birds. The crow has a very unmusical "caw." Birds have various calls other than songs, such as alarm signals, calls of aggressiveness, calls to parents, and calls begging for food.

After courtship, most birds make nests in which to lay their eggs. The nests may be simple hollowed-out places in the ground, or they may be complicated, woven from grass and other soft materials. In some species, the male constructs the nest. In others, the female does so. Both sexes cooperate in certain species.

The newly laid eggs in the nest must be kept warm until they hatch. This is usually done by the birds sitting on the eggs. When the young birds hatch, they vary in their ability to move around. Ground-nesting and water-nesting species are

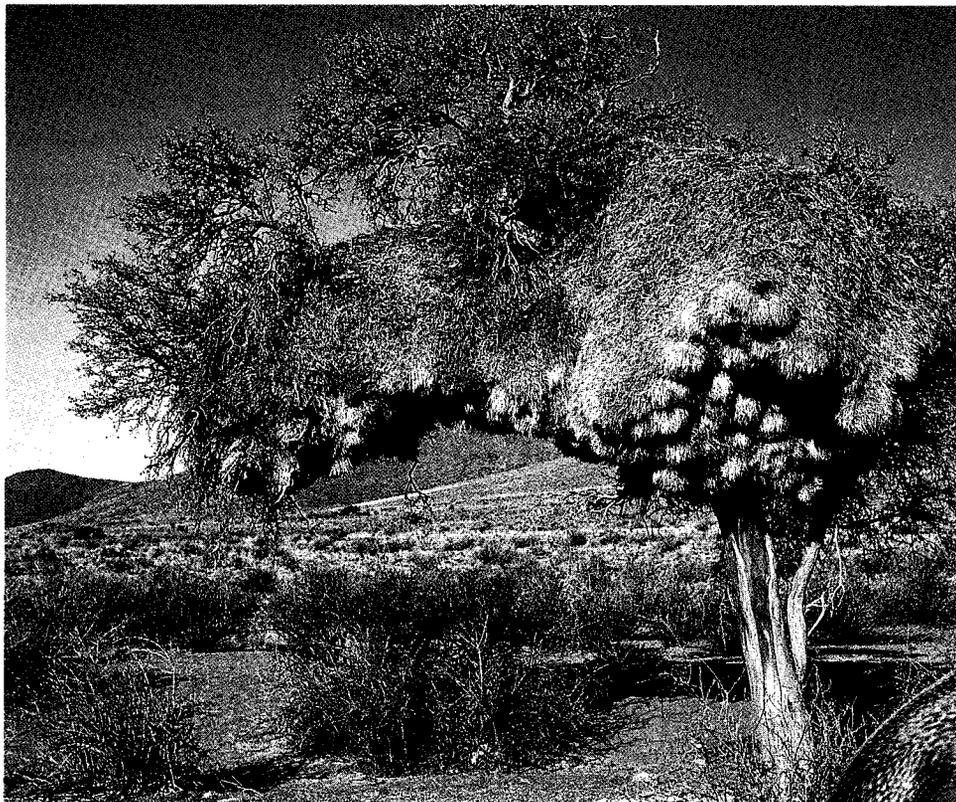
BIRD BEAK

The pelican has a huge pouch beneath its beak, which is used to scoop fish from the water.



Birds live in most regions of the world, from the arctic to the tropics. They have adapted their behavior to the different climates and geographic regions.

Birds have no teeth. Instead, they have light, horny beaks with which they gather food (see **BEAK**), and a toughened part of the alimentary canal, called the gizzard, in which the food is ground down into small fragments (see **ALIMENTARY CANAL**). This means that food is chewed near the bird's center of gravity, which helps it in flying. Birds eat mainly insects, seeds, and animal flesh. Their beaks vary in shape and size depending on what they eat (see **ADAPTATION**). The insect-eating birds, such as the starlings, have thin beaks with which they can probe into cracks and crevices. Seed-eating birds, such as sparrows, have strong beaks to crack the shells of seeds. Flesh-eating birds, such as the hawk and the owl, have beaks that are hooked.



NEST BUILDING

Most birds build nests in which to lay their eggs and raise their young. Groups of male African sociable weaver birds have built these curious upside-down grass nests in a tree.

feathered and alert when they are hatched and can look after themselves as soon as they leave the eggs. Most nestlings, however, are helpless in the nest and must be fed by the parents until they grow feathers and are able to fly. When they first fly from the nest, they are called fledglings.

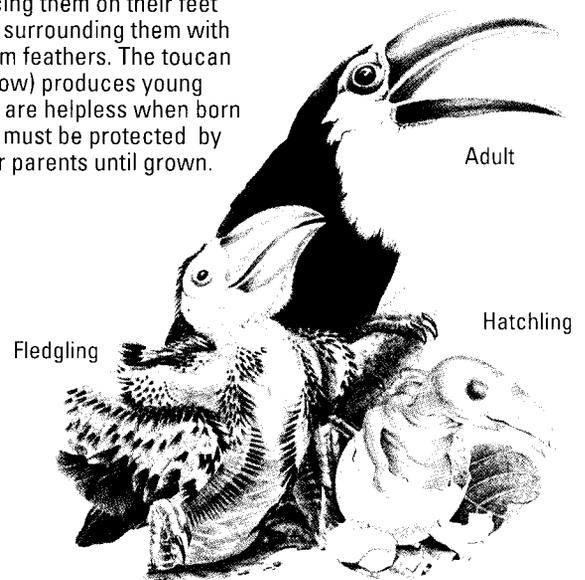
Many birds migrate during certain seasons (see MIGRATION). They may fly long distances over land and water to warmer climates during winter. They return the next spring, usually to the same area, to mate and raise their young. The arctic terns are unusual in that they may travel 11,000 mi. [17,700 km] each way during their migrations from their breeding grounds in the Arctic to their wintering grounds in the Antarctic. No one knows exactly how birds like these are able to navigate long distances over land and water. The subject has been studied by scientists for many years. It is possible that they use several methods, including knowing the direction in which the sun sets and knowing the positions of certain stars.

Birds are usually helpful to humans. They may eat harmful insects or rodents. Some birds can be destructive, though, such as those that eat seeds of farmers' crops.



HATCHING

Emperor penguins (above) keep their eggs warm by placing them on their feet and surrounding them with warm feathers. The toucan (below) produces young that are helpless when born and must be protected by their parents until grown.



BISMUTH (bīz'məth) Bismuth (Bi) is a brittle metallic element that is white with a reddish tint. Bismuth is sometimes found in nature as a free metal—that is, uncombined with other substances. It also occurs in minerals such as bismuth glance and bismite (see ELEMENT; MINERAL).

Bismuth is used mainly in making alloys that melt at low temperatures (see ALLOY). These alloys are used to make safety plugs in automatic sprinkler systems that put out fires. Heat melts the plugs, turning on the system when needed. Bismuth is also used for cooling in nuclear reactors. It is used for this because it does not easily absorb neutrons. Bismuth compounds are used in medicines and in making cosmetics (see COMPOUND).

Bismuth's atomic number is 83. Its relative atomic mass is 208.98. The melting point of bismuth is 520°F [271°C], and its boiling point is 2,840°F [1,560°C]. Its relative density is 9.8 (see RELATIVE DENSITY).

BISON Bison is the scientifically correct name for the North American wild animal often—but wrongly—called the buffalo. The bison is a large member of the cattle family with shaggy brown hair and a large hump at the shoulder. The male may be 12.5 ft. [3.8 m] long and 6 ft. [1.8 m] tall, weighing as much as 3,080 lb. [1,400 kg] when fully grown. The female is much smaller, rarely weighing more than 900 lb. [408 kg].

Bison live and travel in herds. Although not fully mature until they are between six and eight years old, bison start mating in their third year. A single calf is born in May or June. Although bison may live and breed as long as 40 years, most die before they are 25 years old.

In 1850, there were more than 20 million wild bison in the United States. By 1900, hunters had reduced this number to about 300. Strict laws were passed to stop this killing. The number of bison has since increased to about 40,000 in North America.

The beefalo is an animal produced by mating bison and cattle. Its meat is similar to beef but is less expensive. The beefalo, like the bison, does

not need special grains for feed but instead grazes on grass and small plants.

A European bison called the wisent has become almost extinct due to uncontrolled hunting. The 1,500 remaining wisents are in zoos and game preserves to help conserve their numbers.



BISON

The American bison once roamed the plains of North America in vast herds.

BIT *Bit* is short for *binary digit*. A binary digit can have one of two values, zero or one (see BINARY NUMBERS). A bit is the smallest unit of information in the binary system. The way that computers work is based on the binary system because the two values of each bit can be represented by switching a simple electronic circuit on and off. "Off" represents zero; "on" represents one. Information is processed and stored inside computers in groups of eight bits called bytes. Each byte represents one character or symbol. All the information that is fed into a computer, whether it is in the form of sounds, numbers, text, or pictures, is converted into binary numbers for the computer to process. A standard code, the American Standard Code for Information Interchange (ASCII), is used to convert information into binary numbers.

See also COMPUTER.

BIVALVE A bivalve is an invertebrate animal that lives in water and belongs to the class Pelecypoda of the phylum Mollusca (see INVERTEBRATE; MOLLUSCA). *Bivalve* means "two valves,"

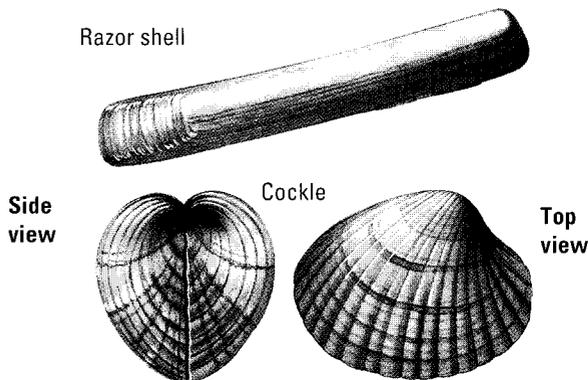
and the animal has a hard shell with two similar sides (valves) attached by a hinge at the back. This hinge allows the shell to open like a book. Types of bivalves include the clam, oyster, mussel, and scallop. Inside the shell is the soft, fleshy animal, which has a muscular foot but no head or legs. The animal feeds by extending a siphon, which acts as a straw to suck water into the shell and past the bivalve's mouth. Small organisms are filtered out of the water and eaten. The bivalve breathes by using its gills, which remove oxygen from the water sucked up by the siphon.

Bivalves are found in both fresh and salt water. Most live on the bottom of an ocean, lake, or river, but others attach themselves with tough, sticky threads to rocks at the edge of the water. Many bivalves are popular as a food.

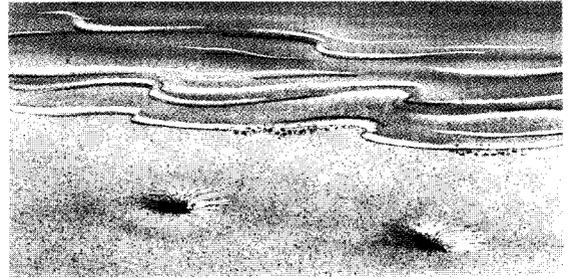


BIVALVE

Giant clams, such as the one pictured at top, are the largest bivalves. The two valve halves of the shell are held open by muscles, like a pair of lips. Bivalve shells (below) range in shape from circular and oval cockles and clams, to the long, narrow razor shells.



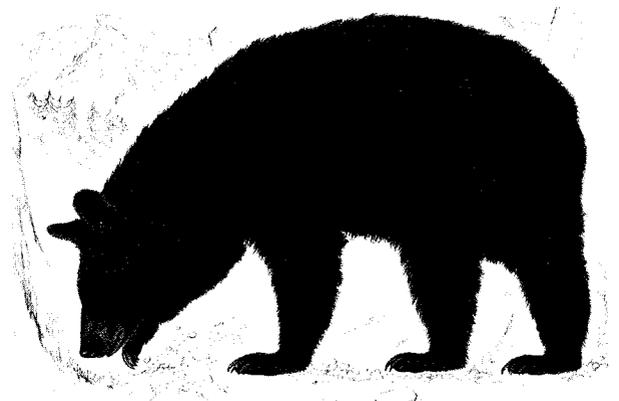
ACTIVITY *Finding bivalves*



You can find bivalve mollusks on rocky and sandy shores, between the high- and low-tide marks. Blue mussels have two thin, oval-shaped valves. You will often see them attached to objects by dark threads called byssus. You may find the shells of various types of clams. Living bivalves make small depressions that you can see in the sand as they draw in food and water.

BLACK BEAR The American black bear lives in large forests throughout North America. Its coat is usually black, but other colors are not uncommon. The blue bear, actually black and gray, is a kind of black bear considered sacred by the Native Americans of southeast Alaska. The black bear grows to 5 ft. [1.5 m] in height and weighs between 200 and 500 lb. [91 and 227 kg]. The female usually gives birth to between one and four cubs every other year.

There are about 75,000 black bears living in national forests in the United States. Black bears are good runners and may reach speeds of



BLACK BEAR

Black bears are found in forests throughout North America and in parts of Asia. Some are gray or even white.

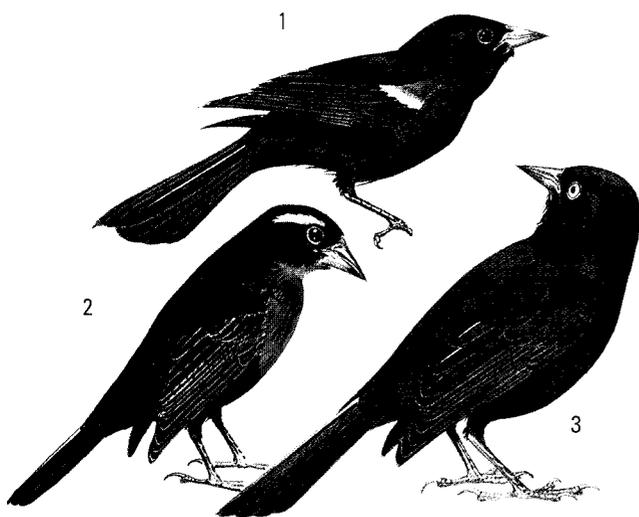
25 m.p.h. [40 kph]. They are also good climbers and may rest in trees for hours at a time. Many bears living in national parks have lost their fear of human beings and may seem playful when begging for food. At times, though, these bears have attacked and killed the people who were feeding them.

Another variety of black bear is the Asiatic black bear. It is smaller than its American cousin, usually weighing less than 255 lb. [116 kg]. Also called the Himalayan black bear, it is found in the mountains and forests of south and east Asia. It has a V-shaped white marking on its chest and tufts of white hair on its chin.

Many Chinese believe that the bones and meat of the Asiatic black bear have special healing powers.

See also BEAR.

BLACKBIRD The blackbird is a member of the American blackbird family, Icteridae, that includes red-winged blackbirds, bobolinks, grackles, meadowlarks, and orioles. The common European blackbird is actually a thrush, very much like the American robin. The red-winged blackbird found throughout North America is about 8 in. [20 cm] long. Males are black with a



BLACKBIRD

Pictured are three of the many varieties of blackbirds: (1) the red-winged blackbird, (2) the red-breasted blackbird, and (3) the rusty blackbird.

red wing patch, and females are streaked gray and brown. The bird nests in marshes and bushes near water. The bird uses its long, pointed bill to pick insects from plants or from the ground. Blackbirds also eat seeds.

See also BIRD.

BLACK HOLE A black hole is an extremely dense body in space whose gravity is so strong that nothing, not even light, can escape from it. A black hole can be left after a very large star dies in a gigantic explosion. Black holes cannot be seen, but their existence can be inferred by observations.

When a star dies, it runs out of nuclear fuel. This causes the star to cool and shrink. If the mass of the star is less than 1.4 times that of our sun, a very dense star is left that astronomers call a white dwarf. A white dwarf is very hot, but small and faint. Our sun will collapse billions of years from now and become a white dwarf.

If the mass of the collapsing star's core is between 1.4 and 2.5 times that of our sun, the outer layers are blown off in a giant explosion, while the core collapses to become a remnant even more dense than a white dwarf. Astronomers call it a neutron star. We can observe some neutron stars as pulsating radio sources called pulsars.

If, however, the mass of the core exceeds that of the sun's by 2.5 times or more, the collapse will continue until not even light can escape, and a black hole forms.

Black holes can probably form in other ways, too, wherever large amounts of matter fall together and are squeezed into a tiny volume by their own gravitation. Some may have been formed in the explosion that created the universe (see BIG BANG THEORY). Others are apparently formed in young galaxies when gas, dust, and stars fall in toward the center.

The size of the hole that forms will depend on the mass of the star. Gravitational collapse will compress (squeeze) a star so much that a body whose diameter was originally measured in millions of miles will form a black hole only a few miles across. Because the density that results from such compression is so great and the gravitational

force is so strong, even the hole's own light and radio waves cannot escape from its surface. Astronomers can only visualize it as a completely dark, powerful, invisible mass.

But, surprisingly, black holes can be responsible for the brightest objects in the universe. Gas, dust, and even stars can fall into a black hole, and when they do so, they can never return to the outside universe again. Most black holes are probably surrounded by a rotating disk of matter, spiraling into destruction. This matter rubs against itself as it falls in and heats up to millions of degrees. Floods of light, radio waves and X rays flood out into space as the doomed matter vanishes. The massive black holes in the centers of young, far-away galaxies show up as quasars. Though quasars are so far away that they look fainter than the faintest naked-eye star, a single quasar can actually be brighter than the whole galaxy that surrounds it. Yet all this energy pours out from a volume possibly smaller than our solar system.

Investigation of the possibility of black holes dates from 1917, when a German astronomer, Karl Schwarzschild, predicted that they would one day be found. The idea of black holes was revived in the 1960s to explain the fantastic energy output of the newly discovered quasars.

Studies of X rays from outer space, using instruments mounted on space satellites, have detected what seem to be black holes in orbit around other kinds of objects. However, only one star gave out visible light. The other, invisible, star was the source of the X rays and could be a black hole.

The next step toward verifying the existence of black holes is to find a way to improve visual observation of the sky. In 1994 the Hubble Space Telescope, which was launched in 1990, photographed a bright disk of gas at the center of the spiral galaxy M87, which lies 50 million light-years away. The gas is rotating fast, apparently under the gravitational attraction of an unseen object with a mass three billion times that of the sun. Astronomers believe this must be a black hole.

See also NEUTRON STAR; PULSAR; QUASAR; SUPERNOVA.

BLACK LIGHT Black light is ultraviolet, or invisible, light. It cannot be seen by the human eye because its rays lie beyond the violet end of the spectrum. However, black light can be "seen" in other ways. For instance, black light shows up on photographic film. It also causes certain oils, minerals, and chemicals to give off visible light. Black light is sometimes used to create special effects, such as dancing skeletons, on the stage. The skeletons are painted on black costumes with fluorescent paint (see FLUORESCENCE). Under black lights, only the paint shows. The rest of the costume cannot be seen.

See also ULTRAVIOLET RAY.

BLACKWELL, ELIZABETH (1821–1910) Elizabeth Blackwell was the first woman medical doctor in the United States. She is best known for her efforts to help women be accepted into medical colleges in the United States and Europe.

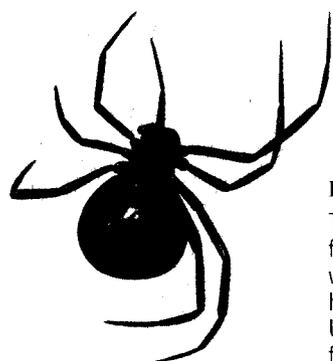
Blackwell was born in Bristol, England. She moved to the United States with her family when she was a child. Blackwell became a teacher in 1842 and studied medicine in her spare time. She applied to many medical colleges, but her application was rejected because she was a woman. Finally, in 1847, Blackwell was accepted by the Geneva Medical College in New York.

After she completed her medical degree, Blackwell applied for several positions in New York City. However, again, she was not hired because she was a woman. Blackwell then set up her own medical practice with her sister, Emily Blackwell. Emily had become a medical doctor shortly after Elizabeth. The practice later became the New York Infirmary for Women and Children. Later, Blackwell organized a college as part of the infirmary. The college was run entirely by and for women.

During the Civil War (1861–1865), Blackwell led a group of nurses who helped wounded soldiers. In 1869, Blackwell opened another medical practice in London and helped found the London School of Medicine for Women. She taught gynecology at the school. Gynecology is a branch of medicine that deals with the health of women.

BLACK WIDOW The black widow spider is a poisonous species belonging to the family Theridiidae. It bears the name *widow* because the female often eats the male after mating. The female is shiny and black, and its body is about 0.5 in. [12.5 mm] long. It has a red or yellowish pattern in the shape of an hourglass on the underside of the abdomen. The male is much smaller, reaching only 0.14 in. [4 mm] in length.

Black widow spiders usually live in warm regions. They often live in buildings. They eat insects that have become trapped in their webs. The black widow's bite does not usually kill a person, but a person may become sick for several days after being bitten. The poison of the North American black widow is stronger than that of the European variety.



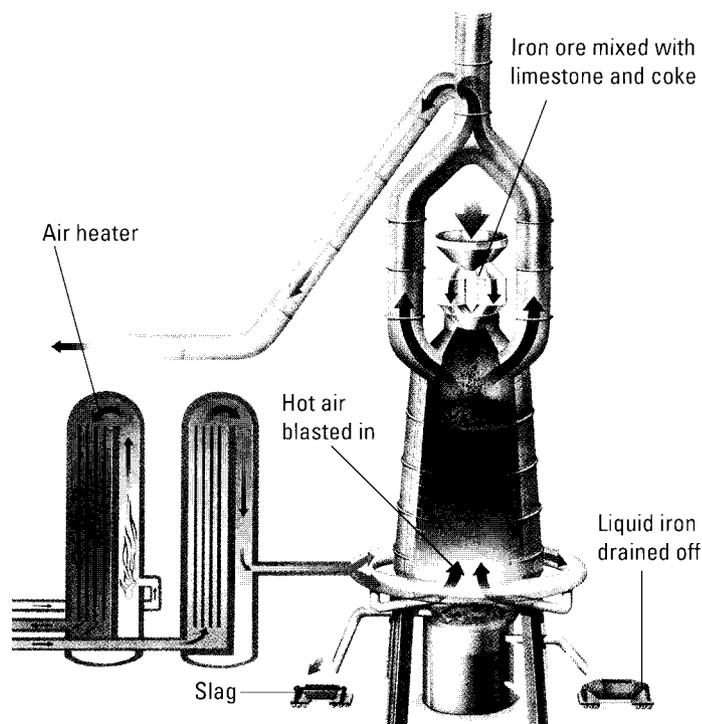
BLACK WIDOW

The black widow spider, found in many of the warmer parts of the world, has a dangerous bite. Usually, people do not die from its bite, but they suffer pain and possibly paralysis.

BLAST FURNACE A blast furnace is a large (often several stories high), usually cone-shaped structure, made of a heat-resistant material such as brick or steel. Blast furnaces are used to make much of the world's iron supply through a process called smelting.

In smelting, iron is made by first "charging," or loading iron ore, coke (coal that has been heated to a high temperature without air), and crushed limestone into the top of a blast furnace through a large hole. A stream of very hot air is then blown into the furnace from the bottom. The hot air causes the coke to burn at very high temperatures. The air also combines with the carbon in the coke. The gas carbon monoxide is produced. This leaves the iron ore free of oxygen.

The burning coke produces the 3,000°F



BLAST FURNACE

Iron is extracted from iron ore by a blast furnace. The furnace is loaded with iron ore, limestone, and coke. Hot air is blasted in to raise the temperature to 3,000 °F [1,600 °C] and melt the iron out of the ore.

[1,600°C] or higher temperatures needed to melt the iron out of the ore. Every four or five hours, workers remove a clay plug from a hole at the bottom of the furnace. This lets the melted iron flow out of the furnace. At the same time, the limestone, which has combined with impurities in the iron, flows out of the furnace on top of the iron. This limestone waste is called slag. It is disposed of. The iron is cast into large ingots, or slabs.

The iron made by blast furnaces is called crude or pig iron. Most of it is used later to make steel. Steel is made by melting the iron again and then blowing oxygen through it. Some iron, however, is remelted and cast into ornamental ironware and other items. It is then known as cast iron.

Blast furnaces are expensive and time consuming to build and operate. Also, they produce a great deal of pollution. This is also true of the ovens used to make the coke that the furnaces use as fuel. These problems have caused many iron producers to turn to other, cheaper and less polluting, methods of iron making.

See also COKE; FURNACE; IRON; SMELTING; STEEL.

BLIGHT A blight is a sudden, serious plant disease caused by a bacterium, fungus, or virus (see BACTERIA; FUNGUS; VIRUS). Blights are characterized by a rapid withering of parts of the diseased plants. Blights often reduce yields of crops such as corn, soybeans, and wheat. Blights also attack flowering plants, such as the rose.

The most damaging type of blight is caused by fungi. However, blights caused by fungi can be controlled by fungicides, chemicals that kill fungi (see FUNGICIDE). The second most damaging kind of blight is produced by a virus. The virus is passed from plant to plant by insects. Although the virus cannot easily be killed, the blight can be controlled by insecticides, chemicals that kill insects (see INSECTICIDE). A less harmful type of blight is caused by bacteria. However, blight caused by bacteria is difficult to control.

Plant biologists are currently searching for blight-resistant varieties of the most common commercially important crop plants.



BLIGHT

Ergot is a poisonous fungus that causes plant blight on grasses and cereal crops. It is dangerous to cattle which feed on infected grass.

BLINDNESS Blindness is a temporary or continuing loss of sight. Temporary blindness, or blackout, can happen to jet pilots and astronauts when they are accelerating at five to six times the force of gravity. Blackout is also a symptom of a certain kind of kidney disease.

Continuing blindness can be caused by either an injury to, or a disease in, the parts of the eye through which light passes to the retina, the light-sensitive layer at the back of the eye (see EYE AND

VISION). Blindness can also be caused by damage to the retina itself; to the optic nerve, which carries messages from the eyes to the brain; or to the parts of the brain that process signals from the eyes.

Many diseases are known to cause blindness if untreated. One of the most common is trachoma, in which the transparent coverings of the eyes become infected with bacteria called *Chlamydia trachomatis*. Trachoma is most common in hot, dry areas and can be carried by flies. It affects an estimated 400 million people. Other diseases that can result in blindness include leprosy, tuberculosis, meningitis, measles, diphtheria, and scarlet fever.

Some people who suffer from a form of the disease diabetes become blind (see DIABETES). This is because the disease causes chemical changes in the blood that make the clear lens in the eye cloudy. The cloudiness in a lens is called a cataract. The most successful way of treating cataracts is to remove the lens and then to use eyeglasses, contact lenses, or an artificial lens.

In the condition called glaucoma, fluid constantly made at the front of the eye cannot drain away as it usually does (see GLAUCOMA). Increased pressure from the fluid may damage the sensitive nerves and blood vessels in the eye, eventually leading to blurred vision and blindness.



BLINDNESS

A Seeing Eye dog can give tremendous help to a blind person, as well as companionship. Dogs with a quiet temperament are trained to recognize dangerous situations and to keep their owners safe.

Although "blindness" is a common term, few people are totally blind and unable even to tell the difference between light and dark. Much more common is "visual impairment," in which sight is blurred or restricted in some way. For some people with visual impairment a Seeing Eye dog takes the place of the owner's eyes and allows greater independence.

Recently, "ultrasonic eyeglasses" have become available. These send out a beam of ultrasonic sound waves, too high in pitch for humans to hear. The waves bounce off objects, and their echoes are detected by a receiver in the frame of the eyeglasses, which turns them into sounds. With training, people who are blind can interpret these sounds and build up a picture of the world around them.

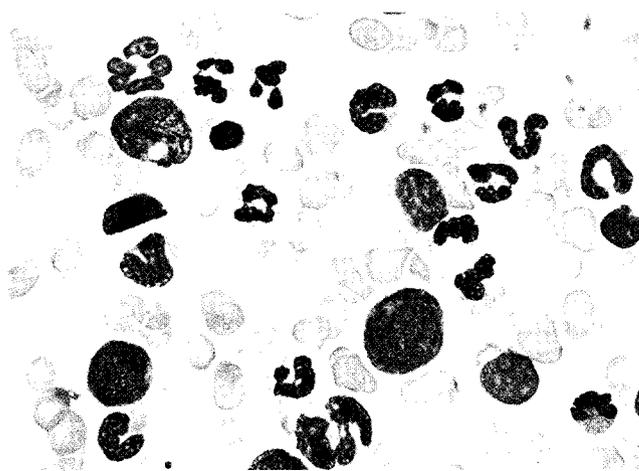
Similarly, people who are visually impaired can use print-to-voice machines to scan printed words and convert them into speech, using an electronic voice synthesizer. This device can be connected to a special printer that translates the words on the page into a print-out in Braille. Braille is the traditional system of touch-reading, which uses patterns of six raised dots to represent letters, numbers, simple sounds, and words.

BLOOD Blood is the fluid that supplies the cells of the human body with the food and oxygen they need for work and growth. On its way from the heart, blood also carries heat to all parts of the body. On its way back to the heart, it helps remove carbon dioxide and other waste products. It contains special cells that help fight infection. It also forms solid clots to temporarily close wounds in the skin. Human blood is red because it contains hemoglobin, which is a red pigment (see HEMOGLOBIN).

The amount of blood in a human body depends on the size of the person. The total volume of blood is about 8 percent of body weight. A 160 lb. [73 kg] man has about 6 qt. [5.6 liters] of blood. An 80 lb. [36 kg] child has about 2.5 qt. [2.8 liters]. A 9 lb. [4 kg] infant has about 5.4 oz. [0.3 liters]. People who live at high altitudes have about 2 qt. [1.9 liters] more blood than people who live in low regions. The extra blood carries

the extra oxygen needed by the body at high altitudes.

Human blood, called whole blood, consists of solid particles floating in a straw-colored liquid called plasma. Plasma is made up of water, proteins, sugars, salts, and other substances (see PLASMA). The particles consist of red and white blood cells, or corpuscles, and smaller particles, called platelets. The plasma contains many proteins, including albumin, globulin, and fibrinogen. Albumin helps the blood retain water by drawing it from body tissue by osmosis (see OSMOSIS). Globulin contains antibodies that fight disease (see ANTIBODY). Fibrinogen combines with chemicals released by platelets to form blood clots.



BLOOD

Blood cells, magnified ten thousand times, are pictured. The pale red blood cells, called erythrocytes, have no nuclei. The white blood cells, or leucocytes, have an obvious nucleus, and have here been stained purple.

Red blood cells, or erythrocytes, are formed in the bone marrow (see BONE MARROW). They are tiny disks, about 0.00028 in. [0.007 mm] in diameter, and resemble doughnuts when seen through a microscope. The human body is constantly forming red blood cells. Red blood cells live for 120 days. Old red cells are destroyed in the bone marrow, spleen, and elsewhere at the rate of 2 million cells per second (see SPLEEN).

White blood cells, or leucocytes, are mostly formed in the bone marrow. White cells are larger than red cells. They average 0.00028 to 0.00048 in. [0.007 to 0.012 mm] in diameter. White cells have a nucleus, or center, unlike red cells. White

cells protect the body against, and fight, infection. Neutrophils are white cells that fight bacterial infection. They are the most numerous type of white cells. Lymphocytes are white cells that control immunity, a process that helps protect the body against infection by bacteria, viruses, and other foreign substances. A third type of white blood cell, called a monocyte, consumes bacteria and works with lymphocytes during immune reactions (see IMMUNITY).

Sometimes, a particularly massive infection may spread from the injured part of the body into the blood itself. This condition is referred to as sepsis, or blood poisoning. Sepsis includes such symptoms as fever, shock, skin rash, and hypothermia. Hypothermia is a condition in which body temperature drops dangerously low. Sepsis is treated with large doses of antibiotics (see ANTIBIOTIC).

Platelets are tiny disks 0.00008 to 0.00016 in. [0.002 to 0.004 mm] in diameter. They help prevent loss of blood. If a small blood vessel is cut or broken, platelets stick to the damaged edges and to each other. As they pile up, they form a temporary seal over the injury. At the same time, platelets release a substance that starts the process of blood clotting. Blood clots are larger "plugs" that prevent additional loss of blood.

People with too few platelets in their blood bleed a great deal before their blood clots. A small cut could cause a person to bleed to death if blood did not clot. Some people have blood that does not clot properly. This is a serious condition called hemophilia (see HEMOPHILIA).

Blood pressure is the pressure that blood exerts on the walls of the arteries (see ARTERY). The amount of pressure depends upon the strength of the heart muscle, the amount of blood in the circulatory system, and the condition of the arteries. Measurements of blood pressure are given with two numbers, such as 120/80. This is expressed verbally as 120 over 80. The first number represents the pressure when the heart is contracting. It is called the systolic pressure. The second number represents the pressure when the heart is relaxing. It is called the diastolic pressure. Normal pressure for adults is 120/80 (see HEART).

Systolic blood pressure usually rises with age because the arteries become less flexible. As the arteries become less flexible, the same volume of blood passes through them, but pressure is higher because the arteries do not expand as much with each heartbeat. High blood pressure, also called hypertension, can contribute to heart disease, kidney disease, or stroke (see STROKE). Excessive weight and lack of exercise can contribute to hypertension. Low blood pressure is called hypotension. It rarely indicates serious disease, unless a person is bleeding a great deal.

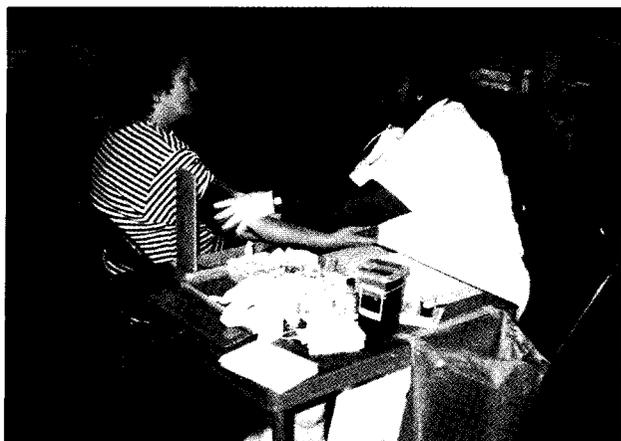
Most animals, including fish, birds, and insects, have blood in their bodies. The blood is usually red. However, some invertebrates (animals without backbones) have blood that contains a protein called hemocyanin. It causes their blood to be blue in color. Other invertebrates have green, yellow, or colorless blood.

See also BLOOD TRANSFUSION; BLOOD TYPES; CIRCULATORY SYSTEM.

BLOOD TRANSFUSION Blood transfusion is the process of putting whole blood or blood plasma into a person's body to replace blood lost through sickness or injury (see BLOOD). This process has saved millions of lives. It is especially helpful in counteracting shock, a common cause of death in accident victims.

The discovery of blood types by the Austrian-American scientist, Karl Landsteiner, in 1900 made blood transfusions practical on a large scale (see BLOOD TYPES). At first, donors came to the patient's bedside, and blood was transferred directly. Then, in 1914, it was discovered that blood could be stored for a short period of time. It had to be refrigerated, and a chemical that prevented clotting had to be added. Today, blood and blood components for transfusion are collected from donors and stored in blood banks.

Most blood banks are operated by the American Red Cross. The blood is stored in plastic bags and classified by type. Whole blood is stored for up to three weeks. Certain components of blood that have been separated from whole blood can be frozen and stored for several years. Blood banks in



BLOOD TRANSFUSION

People called donors give blood to blood banks. Blood banks supply blood to people who need a transfusion due to accident or illness.

the United States collect more than 9 million pints [4.5 million liters] of blood a year. Blood donors are normal, healthy volunteers who are screened carefully by the blood bank to make sure that they do not have any disease, such as AIDS, that may be transmitted in their blood (see AIDS). They donate about a pint of blood each session and rarely notice any side effects. Although the bone marrow quickly replenishes the amount of blood that has been donated, blood donors are not allowed to give blood more often than every two months.

Before a transfusion is given, the patient's blood is tested to determine its ABO and Rh groups. Donor blood with the same types is selected. Another test, called a cross match, makes sure that the blood of both patient and donor can be mixed together without causing a harmful reaction. The plastic bag containing the blood is hung on a stand above the patient's bed. The blood flows down through a plastic tube, through a hollow needle that has been inserted into the patient's arm, and into a vein. The rate of flow is carefully controlled.

BLOOD TYPES Human blood is classified into blood types based on the presence or absence of certain antigens on red blood cells (see BLOOD). Antigens are special large molecules on the surfaces of cells. If certain antibodies (a kind of protein) are mixed with blood, they react with these

antigens and cause the red blood cells to clump together (see ANTIBODY). Clumping can block small blood vessels and result in serious illness or death. Blood types, or blood groups, are important in blood transfusions. When one person's blood is being given to another, the recipient's blood plasma could contain antibodies that react with the antigens on the donor's red blood cells, causing clumping (see BLOOD TRANSFUSION).

Blood types are inherited. There are two major grouping systems, the ABO system and the Rh system. The ABO system was developed in 1900 by the Austrian-American scientist Karl Landsteiner. He determined that blood can be one of four types: A, B, AB, or O. As the chart shows, type A contains only the antigen called A. Type B contains only the antigen called B. Types A and B contain antibodies in the plasma against the antigens that are not present on the red blood cells. Type AB contains both A and B antigens. Type O contains no antibodies in the plasma. Type O contains no antigens, but it does contain both anti-A and anti-B antibodies.

Doctors prefer to use identical ABO blood types during transfusions to avoid any possibility of clumping. In emergencies, type O blood can be given to anyone—it is the universal donor. Type AB can receive blood from anyone in an emergency when the specific type is not available. Type AB is called the universal recipient. About 45

BLOOD TYPES

This table describes the ABO blood grouping system. The blood group an individual belongs to depends on what antigens are present on his or her red cells.

CLASSIFYING BLOOD INTO TYPES		
Blood Type	Antigens on Red Blood Cells	Antibodies in Plasma
A	A	B
B	B	A
AB	A & B	NONE
O	NONE	A & B

percent of Americans have type O blood, 41 percent have type A, 10 percent have type B, and 4 percent have type AB. Recent studies have shown that there may be a relationship between blood types and certain diseases. For instance, people with type A blood are more likely to get cancer of the stomach than are people with other blood types.

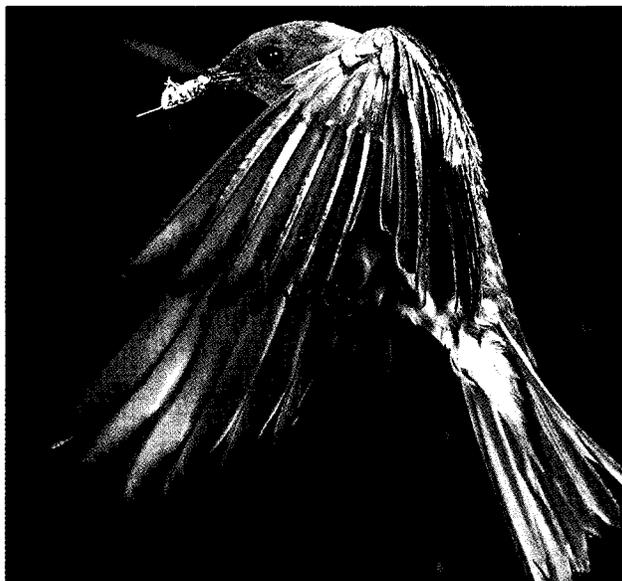
In 1940, Landsteiner and Alexander S. Wiener, an American scientist, discovered another important factor, the rhesus, or Rh, factor. About 85 percent of Americans have the Rh factor on the surface of their red blood cells. Their blood is called Rh-positive. People who lack this factor have Rh-negative blood. Those with Rh-negative blood may produce anti-Rh antibodies in their plasma.

An Rh-positive patient can receive a transfusion from an Rh negative donor. If an Rh-negative patient receives Rh-positive blood, however, antibodies will be produced. These antibodies will not usually have an effect unless a second Rh-positive transfusion is given. Then, the anti-Rh antibodies will attack the antigens on the Rh-positive blood cells and cause clumping.

A similar situation may occur if an Rh-negative mother and an Rh-positive father have a child. Since blood types are inherited, the child may be Rh-positive. Before being born, the baby's blood may cause production of anti-Rh antibodies by the mother. This will not have an effect on the first child. If the mother becomes pregnant with another Rh-positive baby, her antibodies may react with the baby's red blood cell Rh antigens. This can result in clumping and in destruction of the red blood cells in the baby, causing anemia or brain damage (see ANEMIA). If the second child (or any others) is born suffering from this disease, which is called hemolytic disease of the newborn, the baby's blood can be replaced with fresh blood. This will prevent most serious damage. In recent years, physicians have developed a serum to prevent an Rh-negative mother from producing anti-Rh antibodies during her pregnancy (see SERUM).

BLUEBIRD The bluebird is a small bird that is a kind of thrush (see THRUSH). It is related to the robin. There are three species of bluebirds. The

eastern bluebird is found in central and eastern North America. The western bluebird and mountain bluebird are found west of the Rocky Mountains in the United States and Canada and in western Mexico.



BLUEBIRD

A male mountain bluebird has caught an insect, which it is carrying back to its nest to feed its chicks.

Bluebirds gather in small flocks when not nesting. They grow to be 6 in. [15 cm] long. The male eastern bluebird has a dark blue back. The male western bluebird has a rusty back. Both have blue wings, orange breasts, and white bellies. The male mountain bluebird has a light blue back and breast and a white belly. Female bluebirds are brownish but show blue in the wings. The song of the bluebird is a pretty whistle. The eastern bluebird has become very rare in recent years. Scientists think that the use of pesticides and the introduction of the starling from Europe caused the decline in the number of bluebirds.

See also STARLING.

BLUE JAY The blue jay is a bird that belongs to the crow family, Corvidae. It is found in central and eastern North America. The blue jay grows to a length of 10 in. [25 cm]. It has a grayish white belly and blue back. The call of the blue jay is a loud "jay, jay." Although its song is not very musical, the blue jay has many calls and can imitate

the songs of many other birds, especially hawks. Blue jays flock together and can be very noisy.

See also BIRD.



BLUE JAY

The blue jay pictured has fluffed out its downy feathers to keep warm on a winter's day.

BLUE SHIFT A blue shift is an effect that appears in the spectrum of an object. A spectrum is the band of color produced when light is spread out into its separate wavelengths (see **SPECTRUM**). When a heavenly object such as a star moves toward the earth, the wavelengths of light it emits are shortened. If the object is moving very fast, the light in the red part of the spectrum may be turned into orange, for example, and yellow into green. This effect is called a blue shift, because the colors in the visible part of the spectrum move closer to blue, which is the color with the shortest wavelength. A blue shift cannot be seen with the naked eye, but can be detected with sensitive instruments.

A spectrum of light from a star, galaxy, or other object is generally crossed by dark lines at wavelengths where the object gives out extra light or less light. These lines are closer to the blue end of the spectrum than they would be if the distant object were not moving toward us. Lines that would otherwise be in the blue part of the spectrum can be shifted into the invisible ultraviolet part of the spectrum.

See also RED SHIFT.

BLUE WHALE The blue whale is the largest animal now living on earth. This sea mammal may reach a length of 100 ft. [30 m] and a weight of 150 tons [136 metric tons] (see **MAMMAL**). A type of baleen, or toothless, whale, the blue whale has a mouth containing bony plates to strain small organisms from the water (see **KRILL**).

The blue whale is a dull blue color. Blue whales live mostly in the colder oceans, near the arctic and antarctic regions. During the winter months, the blue whale herds swim to warmer waters near the equator to give birth to their calves. Because blue whales have been hunted for years, they are close to becoming extinct. In an attempt to prevent this, international agreements have been made to limit whaling.

See also EXTINCTION; WHALE.

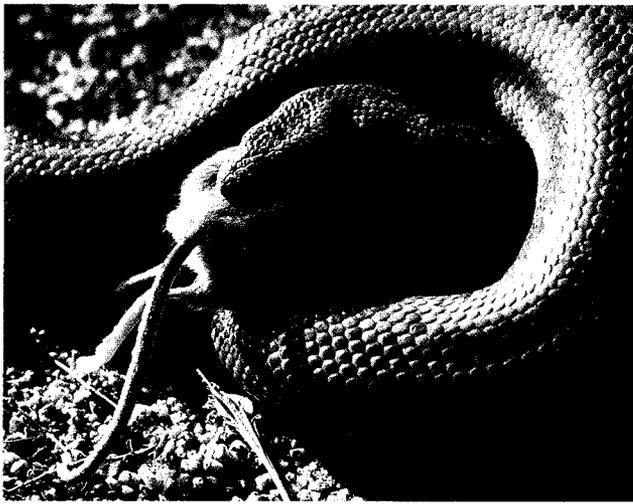


BLUE WHALE

This blue whale, swimming off the California coast, is forcing water out of its blow hole after coming up from a deep dive.

BOA The boas are among the most primitive living snakes. They are nonpoisonous. Most boas live in tropical Central and South America. The largest may be 18 ft. [5.5 m] long. The two species that live in the southwestern United States are smaller, about 3.3 ft. [1 m] long. The boa does not lay eggs. It is ovoviviparous and gives birth to live baby snakes (see **REPRODUCTION**). A boa may produce as many as sixty young in each yearly brood (group).

The most famous of the boas is the boa constrictor. Like all boas, it attacks its prey with its

**BOA**

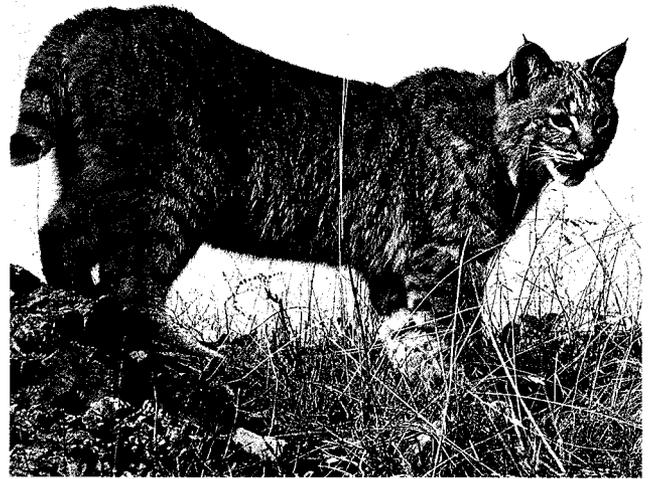
Boas, like the rosy boa above, are large, nonpoisonous snakes. Boas kill their prey by coiling around their victim and squeezing.

long, curved, fanglike teeth. It then coils its body around the prey. As the coils tighten, the prey is unable to breathe, and it finally suffocates. The tips of a boa's jawbones can stretch so far apart that the boa can swallow rodents, birds, and other small animals whole. Its throat and body are also able to stretch. Once the prey has been swallowed, the snake may lie quietly for as long as a week to digest its meal. If upset during this time, the boa may spit out its food. If threatened, the boa becomes active and defends itself. Like all snakes, the boa can go without food for several months at a time.

See also SNAKE.

BOBCAT The bobcat is a member of the cat family, Felidae. It is a type of lynx (see LYNX). It reaches a length of 3.3 ft. [1 m] and a height of 23 in. [57.5 cm] at the shoulder. The bobcat has reddish brown fur with black spots. The bobcat gets its name because it has a short or "bob" tail. It has 28 pointed teeth, and sharp claws on each paw. The teeth and claws of the bobcat are used to kill and eat its food, which is made up mainly of rodents, rabbits, and sometimes deer. Although the bobcat is found all over the United States and Canada, it is now much less common in the mid-western corn belt.

See also CAT.

**BOBCAT**

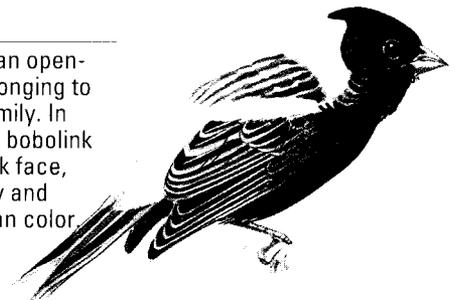
The bobcat is found widely in North America, but is becoming less common where its forest habitats are threatened.

BOBOLINK A bobolink is a bird that makes its home on farmland and in meadows. It belongs to the blackbird family, Icteridae, and can be found in many open parts of the United States. Bobolinks grow to 7 in. [18 cm] in length. The male has a black face, breast, and belly. His back and wings are light yellow, tan, and white. Females are a dull tan color. Males resemble females in winter, at which time the birds live in central South America. The bobolink's song is loud and long and sounds like the bird's name.

See also BIRD; BLACKBIRD.

BOBOLINK

The bobolink is an open-country bird belonging to the blackbird family. In winter, the male bobolink will lose its black face, breast, and belly and become a dull tan color.



BOHR, NIELS (1885-1962) Niels Bohr was a Danish physicist who developed an important theory about the structure of the atom. He based it on an earlier theory by the British physicist Ernest Rutherford (see RUTHERFORD, ERNEST). Rutherford had shown that the atom contains a positively charged central nucleus. We now know that this nucleus is made up of positively charged

protons and neutral neutrons. Negatively charged electrons orbit around it. An atom has equal numbers of protons and electrons.

Bohr suggested that when an electron absorbs energy it jumps into a wider orbit farther away from the nucleus. He stated that when an electron moves back into a lower orbit, which is closer to the nucleus, it gives off energy in the form of radiation. This energy exists in "packets" called quanta (see QUANTUM THEORY). Bohr also said that the outermost electrons determine the chemical properties of the atom.

Bohr developed his theory for the hydrogen atom, which is the simplest atom and has just one electron. He was able to determine exactly how much energy was taken in or given out with each jump of the electron. Bohr was awarded the Nobel Prize for physics in 1922.

During World War II (1939–1945), Bohr served as an adviser on the first atomic bomb project at Los Alamos, New Mexico. He devoted much of his time after 1945 to promoting the peaceful uses of atomic energy.

See also ATOM; RADIATION.

BOILING AND BOILING POINT

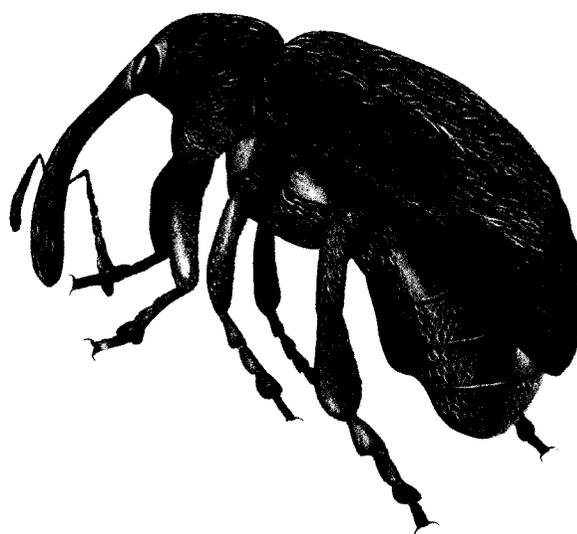
Boiling occurs when a liquid is heated so much that it bubbles and changes into a vapor. The boiling point is the temperature at which the liquid boils. At this temperature, the vapor pressure of a liquid is equal to the pressure of the atmosphere on the liquid. At sea level, the atmospheric pressure is 14.7 lb. per sq. in. [1.03 kg per sq. cm], and water boils at 212°F [100°C]. This standard pressure is called one atmosphere. Above sea level, where the atmospheric pressure is lower, water boils at lower temperatures. At the top of a mountain that is 1.8 mi. [3 km] high, water boils at 194°F [90°C] (see ATMOSPHERE (UNIT); PRESSURE; VAPOR PRESSURE).

The boiling point of a liquid stays the same under the same atmospheric pressure. Water always boils at 212°F [100°C] at sea level, alcohol at 173.3°F [78.5°C], and mercury at 673.8°F [356.6°C]. The boiling point of a liquid is usually found by holding a thermometer in the vapor just

above the liquid, but not in the liquid. If the atmospheric pressure is increased, the boiling point of the liquid is raised. A pressure of ten atmospheres raises the boiling point of water to 356°F [180°C].

BOLL WEEVIL The boll weevil is a brownish black beetle that feeds inside the seed pods, called bolls, of cotton plants. The beetle is about 0.25 in. [6 mm] long. A native of Mexico and Central America, the boll weevil spread into Texas about 1890. Since then, it has spread through most of the cotton fields of the United States. The boll weevil destroys three million to five million bales of cotton each year. In the spring, the female lays eggs in the cotton boll. Within a few days, the eggs develop into wormlike larvae, or grubs, that eat and destroy the boll. These grubs become adults within two to three weeks. Then the process begins again. Several generations of weevils are produced every summer. Pesticides have had little lasting effect on the boll weevil. Plant breeders are now developing early maturing and fast-flowering cotton varieties to resist infestation by the boll weevil.

See also METAMORPHOSIS; WEEVIL.



BOLL WEEVIL

The boll weevil is a native of Central America and Mexico, but it is now found in many cotton-growing areas. It is one of the most serious cotton pests. Like all weevils, its jaws are at the end of its long snout. The female uses her jaws to nibble holes in the cotton flowers and bolls, and then lays her eggs in them.

BOLLWORM The bollworm is a caterpillar that bores into and destroys cotton plants. It also ruins more than 100 million dollars' worth of corn annually. The adult is a grayish brown moth that lays eggs on the cotton boll, on corn silk, or on other crops. Within a week, these eggs develop into the destructive caterpillars. Bollworms produce two to five broods (groups of young) each year. Tiny wasps are among their greatest enemies and these have been used as a means of biological control (see BIOLOGICAL CONTROL).

See also BUTTERFLY AND MOTIL.

BONDING Bonding describes the way that atoms link together to form molecules. An atom is surrounded by up to seven shells of electrons orbiting the nucleus. Each shell can hold up to a certain number of electrons. The first shell can hold up to two electrons. The second shell can hold up to 8, the third up to 18, the fourth up to 32, and so on. When atoms come together to make molecules, they gain, lose, or share electrons so that each atom has the most stable number of electrons in its outermost shell. Atoms bond mainly in two ways, called ionic (or electrovalent) bonding and covalent bonding.

Two atoms form an ionic bond when one atom gives one or more electrons to the other atom. They are called ionic bonds because atoms that have lost or gained electrons are called ions. Ionic compounds have high melting points and boiling points because ionic bonds are very strong. When they melt or dissolve in water and an electric current is passed through them, the ions travel through the solution to the electrodes. Positive ions (cations) travel to the cathode, and negative ions (anions) travel to the anode. This is called electrolysis.

Atoms form covalent bonds by sharing pairs of electrons. Normally, each atom provides one electron of each pair. Most covalent bonds are strong. They are the bonds that hold together the atoms in the molecules that make up living things.

The combining power of an atom is called its valence. Valence equals the number of electrons it can share with, or give to, other atoms. For

example, a hydrogen atom has one electron to share (valence = 1). An oxygen atom can share two electrons (valence = 2). So when hydrogen and oxygen combine to form water (H_2O), each oxygen atom combines with two hydrogen atoms. The electrons lost, gained, or shared in bonding are called valence electrons.

See also ATOM; COMPOUND; IONS AND IONIZATION; MOLECULE.

BONE Bone is a type of hard tissue found in most vertebrate animals. It is one kind of connective tissue. Connective tissue has very few cells and a large amount of a "filler substance," called intercellular matrix. The matrix contains inorganic salts such as compounds of calcium and phosphorus. The matrix also contains collagen, a strong protein produced by the bone cells. Collagen and the inorganic salts are present in a child's bone in roughly equal amounts, but the percentage of inorganic material in the bone rises to about 65 percent in the skeletons of adults. The calcium and phosphorous make the bone hard, and the collagen gives it resistance and prevents it from being brittle (see COLLAGEN; CONNECTIVE TISSUE; VERTEBRATE).

Bone tissue forms individual structures within the body. These structures are called bones. The human body has 206 bones. These bones are connected to form a skeleton (see ANATOMY). Bones support the body and protect some of its parts, like the brain. Muscles are attached to the bones. Most bones have a hollow center filled with marrow. Blood cells are produced in the marrow and are sent into the circulatory system (see BONE MARROW).

Bones are formed in a baby before it is born, but they are soft to begin with. After birth, while the baby matures, the bones slowly harden through the process called ossification. The ends of bones remain soft for many years, however, so that the bones can grow longer as the person becomes older. Sometimes growth continues after the bones have hardened. This results in a disease called acromegaly (see ENDOCRINE).

There are other diseases that can affect bones.

Rickets causes children's bones to become soft and deformed. It is caused by a lack of vitamin D and calcium in the diet. Osteoporosis causes bones of elderly people to become porous and brittle. The breaking of a bone is called a fracture.

See also ARTHRITIS; CARTILAGE; JOINT; LIGAMENT; TENDON.

BONE MARROW Marrow is the soft substance that fills the cavities of bones. It contains several different kinds of cells, including red and white blood cells and fat cells, as well as connective tissue (see CONNECTIVE TISSUE). Marrow may be red or yellow in color. Its function is to produce new blood cells for the body.

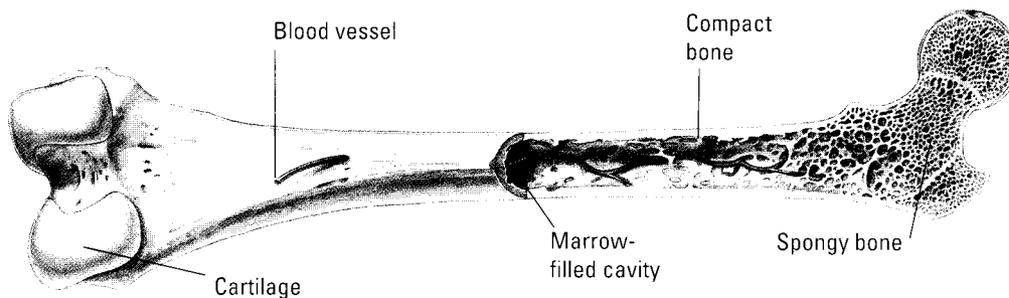
After birth, red blood cells, most white blood cells, and fragments of cells, called platelets, are formed in the bone marrow. Platelets aid in the clotting of blood (see BLOOD). In infants, all the bones are filled with red marrow making new blood cells. In adults, most of the bones contain yellow marrow, which does not make blood cells. Red marrow remains in the sternum (breast bone), ribs, bones of the spine, pelvis, and some skull bones of adults. However, when the body needs extra blood cells, the yellow marrow in the other bones can become red marrow again. Then it can manufacture extra blood cells.

When a person has a blood disease, examining a sample of bone marrow under the microscope may show what is wrong. A small quantity of marrow is withdrawn from the center of a bone, through a needle. Changes in the marrow occur in some kinds of anemia and in leukemia.

See also ANEMIA; BONE; LEUKEMIA.

BONE MARROW

Most bones, such as this femur (thigh bone), have a hollow center filled with marrow, surrounded by a thin layer of tough, compact bone. The ends of the bones are coated with smooth cartilage, which prevents damage to the bones that move against one another in a joint.



BORAGE FAMILY The borage family includes about 1,500 species of dicotyledonous plants that have hairy, rough leaves and stems. This family includes annual and perennial herbaceous plants (see ANNUAL PLANT; DICOTYLEDON; HERBACEOUS PLANT; PERENNIAL PLANT). The flowers are blue or purple in color, with five petals joined at the base. These plants grow in temperate climates.

The most familiar member of the borage family is the forget-me-not, a blue and yellow flower that grows in most areas of the United States. The subject of many legends and romantic stories, the forget-me-not has come to be a symbol of friendship and love.



BORAGE

The borage family includes about 1,500 plant species and is found in temperate regions. The family includes the forget-me-not, which is pictured.

BORAX Borax ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$) is the common name for a soft, white, many-sided crystal that dissolves easily in water. Borax is an important compound of the element boron (see BORON; COMPOUND; CRYSTAL). The chemical name for borax is sodium borate or sodium tetraborate. The compound is obtained from the minerals kernite and tincal. Most of the world's supply of borax comes from southern California. Workers use dynamite to blast loose the solid borax. Large chunks of it are then crushed and dissolved. The solution goes through many steps until borax crystals are obtained.

Borax is used in making glass, soaps, welding flux, food preservatives, enamels, and glazes. The compound is also used as an antiseptic in ointments and eye washes. Chemists use the borax bead test to find out whether substances contain certain metals. A borax bead is made by dipping a small loop of platinum wire into a borax solution. The loop is then heated until a clear, glassy bead forms. Then the loop is touched with the substance to be tested, usually in solution, and heated again. The bead turns a certain color, depending on which metal is in the substance. For example, if cobalt is present, a dark blue bead appears. A light blue bead appears for copper, a brown one for nickel, and an amethyst one for manganese.

BORON Boron (B) is a nonmetallic element that appears as a yellowish brown crystal. Boron is found in combination with other elements in minerals such as kernite, tincal, colemanite, and boracite (see CRYSTAL; ELEMENT; MINERAL).

The United States has large supplies of minerals containing boron compounds (see COMPOUND). Boron is taken out of these minerals by chemical methods and by electrolysis (see ELECTROLYSIS). Boron was first isolated in 1808 by Sir Humphry Davy of England (see DAVY, SIR HUMPHRY). Joseph Louis Gay-Lussac and Louis Thenard obtained pure boron in France in the same year.

Boron is able to absorb neutrons (one kind of atomic particle) without being changed by them. It is used to make control rods for nuclear reactors (see NUCLEAR ENERGY). These rods control the

neutrons that cause atomic nuclei to split. Boron alloys are used to harden steel (see ALLOY). Compounds such as titanium boride and tungsten boride are heat resistant. They are used in various rocket parts. Useful boron compounds also include boric acid, used in medicine, and borax (see BORAX). Scientists believe that small amounts of boron aid plant growth. Large amounts, however, are poisonous to plants and animals. Boron has an atomic number of 5. Its relative atomic mass is 10.8. It melts at $3,774^\circ\text{F}$ [$2,079^\circ\text{C}$] and has a boiling point of $4,622^\circ\text{F}$ [$2,550^\circ\text{C}$]. The relative density of boron is 2.35 (see RELATIVE DENSITY).



BOTANY

This botanist is gaining knowledge about the number of plant species in a field by using a quadrant (a type of grid).

BOTANY (*bŏt'n ē*) Botany is the study of plants. Plants have interested people for thousands of years. The ancient Babylonians and Egyptians observed and named plants. Theophrastus, a pupil of the Greek philosopher Aristotle, wrote *An Inquiry Into Plants* in 300 B.C. This was a series of books dealing with the structure of plants. Because of his pioneering work, Theophrastus is often considered the father of botany. The Roman naturalist Pliny included plants in his writings in 50 B.C. At about the same time, the Greek physician Dioscorides listed and described six hundred plants with medical uses.

There was little further progress in botany until the seventeenth century. It was at this time that interest in all fields of science was reawakened. In 1665, the English physicist Robert Hooke

observed and named cells in cork. In the 1670s, both the English botanist Nehemiah Grew and the Italian biologist Marcell Mapighi wrote books on plant structure. In 1735, the Swedish biologist Linnaeus developed a standard way to name and classify plants (see CLASSIFICATION OF LIVING ORGANISMS; LINNAEUS, CAROLUS). Later, in 1753, he published a massive work, containing descriptions of 6,000 plants found in different parts of the world known at that time. In 1774, the English chemist Joseph Priestly noted that plants give off oxygen in sunlight (see PHOTOSYNTHESIS). In 1839, the German botanists Matthias Schleiden and Theodor Schwann announced the cell theory. The cell theory states that all living things are made up of cells (see SCHLEIDEN, MATTHIAS JAKOB; SCHWANN, THEODOR). In the 1830s, the English botanist Robert Brown published a book dealing with the reproduction of plants. In 1865, Gregor Mendel, an Austrian monk, formulated genetic laws on the basis of his experiments in growing peas (see GENETICS; MENDEL, GREGOR).

All food comes from plants, either directly or indirectly. Therefore, all life depends on plants. In order to understand any living creature, one must first understand plants. The importance of plants has been known since the first crops were sown and the first fields cultivated. Plants have managed to survive and adapt, even to severe climates and to climate changes. In daylight, plants produce oxygen and use carbon dioxide, which allows animal life to survive (see CARBON CYCLE; RESPIRATION). Some plants, such as poison ivy, can be toxic to humans. Still other plants have medical value and can be used to treat various diseases.

Plants are becoming more important in today's world. Scientists believe many uses of plants have yet to be discovered. With increased knowledge of botany, there will not only be greater control over plants, but also greater understanding of how humankind fits into the natural world.

See also AGRICULTURE; ECOLOGY; FOOD CHAIN; HORTICULTURE; PLANT KINGDOM.

BOTULISM (bōch'ə līz'əm) Botulism is a disease of the nervous system caused by a toxin, or

poison. The toxin is produced by *Clostridium botulinum*, a type of bacterium. *Clostridium botulinum* produces spores, which can survive the temperature of boiling water, 212°F [100°C], for hours. The spores can live in improperly canned foods. If the canned foods contain no oxygen, the spores can germinate to produce a new generation of bacteria. These may give off botulinum toxin, one of the most dangerous poisons known. The human intestine absorbs this toxin and carries it to neuromuscular junctions, the sites where nerves transmit messages to muscles. There, the toxin interferes with the ability of the nerves to tell the muscles to contract. This causes paralysis, a condition where the muscles stop working. People who ingest botulinum toxin may die of suffocation, as the muscles used in breathing are paralyzed. Surgeons may cut an emergency air passage into the windpipe and use a respirator to aid the victim in breathing. Usually, if a person survives the paralysis, he or she recovers completely. If discovered at an early stage, the chances of surviving are much better. The person may take antitoxin to neutralize the toxin in the body.

Home-canned goods are usually the chief source of botulism. Modern commercial canning methods have made botulism rare in the United States. See also POISON; TOXIN.

BOUGAINVILLEA (bōōg'ən vīl'yə) *Bougainvillea* is a genus of about fourteen flowering shrubs and climbing plants. They grow in warm



BOUGAINVILLEA

Bougainvillea is a type of shrub, highly prized for its red or purple flowers. Gardeners usually grow it from stem cuttings.

and tropical climates. The flowers, in groups of three, are enclosed by three large, bright purple or red leaves called bracts. The leaves are on alternate sides of the stem. Bougainvilleas are showy plants that can be raised from stem cuttings.

BOWERBIRD The bowerbird belongs to the family Ptilonorhynchidae. It is found in Australia, New Guinea, and neighboring islands. The bowerbird is usually blue-black. It feeds chiefly on fruit. It is named for the fancy bower, or shelter, that the male builds to attract females. The male attracts the female to his bower by placing brightly colored feathers and shells inside it and just outside the entrance. Then he dances and bows before her. Each species builds a different type of bower and uses different decorations and displays. If mating occurs, the female flies off to build her own nest, a much simpler structure than the males' bower. There, she rears her young alone.

See also BIRD.

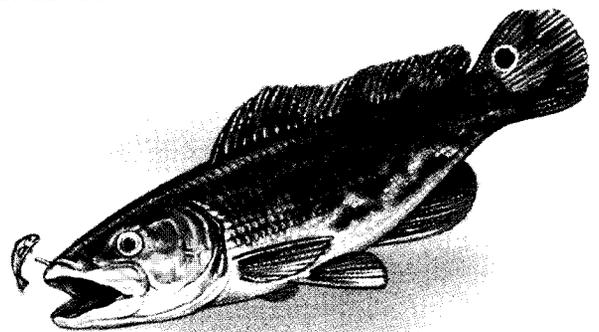


BOWERBIRD

Bowerbirds, found in Australia and New Guinea, are named for the elaborate bowers, or shelters, built by the males to court the females. The bowers are generally made of twigs and decorated with colorful objects to attract the females.

BOWFIN The bowfin is a very primitive freshwater fish belonging to the family Amiidae. Fossils of this fish have been found embedded in rocks of the Jurassic period, dating back 180 million years. The bowfin is found in more than one-third of the eastern United States and in portions of eastern Canada. It has a long, deep body that can reach a length of 34 in. [87 cm] and a weight of 15 lb. [6.8 kg]. Bowfins live in swampy, weedy lakes and rivers. The bowfin is one of the few fishes able to breathe air. When the water in which the bowfin is living becomes polluted and there is little oxygen left, the bowfin rises to the surface and gulps air. This air enters the swim bladder, where oxygen is absorbed into the blood. Because of this ability, the bowfin is able to live in water where other fishes cannot. Bowfins eat popular sport fishes and are therefore considered pests by some people.

See also FISH.



BOWFIN

The bowfin is a primitive fish found in rivers and lakes in eastern North America. It is one of the few fishes able to breathe air.

BOX ELDER The box elder is a tree that belongs to the maple family. It is found in many parts of North America. Box elders do not live very long. They grow to heights of 70 ft. [21 m]. The trunk can be up to 10 ft. [3 m] across. The bark has large, vertical cracks. The leaves of the box elder are different from those of the sugar maple. They have a simpler form, with leaf stalks containing three, five, or seven leaflets (see LEAF). Although branches of box elder break easily and the tree is often poorly formed, the box elder is a popular shade tree. The wood of the box elder is

**BOX ELDER**

The box elder bears clusters of winged fruit, as do all trees in the maple family.

soft. It is used for making furniture, boxes, and wooden utensils.

See also MAPLE FAMILY.

BOYLE, ROBERT (1627–1691) Robert Boyle was an Irish chemist and physicist who studied the compression and expansion of air and

**ROBERT BOYLE**

Boyle's law was named after this seventeenth-century Irish scientist.

gases. He is best known for the law he formulated called Boyle's law (see **BOYLE'S LAW**). Boyle was the first scientist to believe that all chemical substances exist as either elements or compounds (combinations of elements). He also supported experimentation and the rapid publication of results. Boyle improved the air pump. He also studied the boiling and freezing of liquids at reduced pressures.

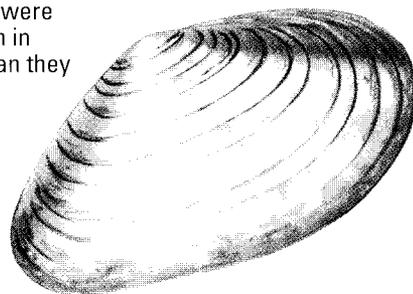
BOYLE'S LAW Boyle's law shows how the pressure and volume of a gas are related. It was discovered in 1662 by Robert Boyle, an Irish scientist. The law says that if the volume of a given mass of gas is doubled, the pressure is halved. The reverse is also true. If the pressure on a given mass of gas is halved, the gas will occupy twice the volume. The temperature of the gas has to remain the same for this to be true. The volume of the gas is said to be inversely proportional to the pressure.

See also BOYLE, ROBERT; CHARLES'S LAW; GAS.

BRACHIOPOD The brachiopods are a phylum of about 300 kinds of tongue-shaped, marine invertebrates (see **INVERTEBRATE**). Also called lamp shells because of their resemblance to old Roman oil lamps, brachiopods are animals with two shells, like bivalve mollusks (see **BIVALVE**). One shell covers the top side. The other shell covers the bottom side. Two coiled arms, called brachia, help these animals guide food into their mouths. Brachiopods anchor themselves to the bottom of the ocean by means of stalks, called pedicles, at the rear ends of their bodies. Shells

BRACHIOPOD

Brachiopods are two-shelled marine invertebrates. They were much more common in prehistoric times than they are today.



range from 0.2 to 4 in. [5 to 100 mm] in length. Brachiopods are found in all the oceans.

Brachiopods first appeared millions of years ago. They were very abundant during the Paleozoic era (570 million to 245 million years ago) but have greatly declined since then. Geologists have discovered more than 35,000 species of fossil brachiopods.

BRAGG FAMILY One of the most remarkable father-and-son science teams of the twentieth century was that of Sir William Henry Bragg (1862–1942) and his son, Sir William Lawrence Bragg (1890–1971). Working together as research physicists, they studied the structure of crystals by means of X rays. They are considered the founders of solid-state physics, a field that pioneered the development of transistors (see SOLID-STATE PHYSICS). In 1915, they won the Nobel Prize for physics.

The Braggs developed the X-ray spectrometer. Using this instrument, they discovered much about the atom and how atoms are arranged in crystals. In the same year, the younger Bragg established Bragg's law of X-ray diffraction, a basic rule for learning the structure of a crystal (see CRYSTAL; X-RAY DIFFRACTION). Sir William Henry Bragg established a school of crystallographic research at University College in London, England. William's son founded a school for research in physics of metals, alloys (mixtures of metals), and silicates (minerals that contain silicon, oxygen, and metallic elements) at Manchester, England.

BRAHE, TYCHO (1546–1601) Tycho Brahe was a Danish astronomer. He made the most accurate observations that any astronomer recorded before the invention of the telescope. Unlike most astronomers before his time, Brahe observed the planets night after night, not just at certain times of the year. In 1572, Brahe observed a star in the constellation Cassiopeia that had not been visible before. Chinese astronomers had previously observed such "new" stars, but Brahe was the first European to record such a discovery. It

challenged the ancient idea that the heavens could not change. Brahe was also the first astronomer to understand the effect of refraction by the atmosphere on astronomical observations (see REFRACTION OF LIGHT).

A major part of Brahe's work was the correction of the observations of earlier astronomers. During his more than twenty years of observations in Denmark, Brahe recorded valuable information on many stars, the planets, the moon, and the comet of 1577. He made his astronomical instruments as accurate as possible. His careful records became the basis of later advances in astronomy. Johannes Kepler, who was his assistant, used Brahe's calculations after his death to work out the shape of the planets' orbits around the sun. Brahe never accepted the idea that the earth was a planet and moved around the sun. He agreed that the planets revolved around the sun, but thought that the sun revolved around the earth (see KEPLER, JOHANNES).

Brahe's interest in astronomy began when, as a boy, he witnessed a total eclipse of the sun. Although his family wanted him to become a lawyer, Brahe was drawn to the study of the sky. In 1563, a year after he completed study of the law, Brahe made his first recorded observation. He watched as Jupiter passed between the earth and Saturn. This was the beginning of his scientific career.

In 1571, Brahe built an observatory at a castle owned by his wealthy uncle. He became so famous for his astronomical work that the king of Denmark, Frederick II, ordered him to give lectures on astronomy. Because Brahe also pleased the king with his astrology, the king gave Brahe the island of Hven. Brahe built two observatories on this island, calling them the Castle of the Sky and the Castle of the Stars. These observatories became the models for construction of later observatories throughout Europe.

Brahe left Denmark for Bohemia in 1597. He spent the remaining few years of his life in Prague, where Johannes Kepler continued to work with him.

See also ASTROLOGY; ASTRONOMY.

BRAIN

The brain is the most important part of the nervous system in humans and other animals (see NERVOUS SYSTEM). The brain is responsible for memory, learning, thought, sensation, and control of the muscles. The human nervous system has about thirteen billion nerve cells. About ten billion of these are in the brain (see NERVE CELL). These nerve cells receive information from the outside environment through sense organs, such as the eyes and ears, as well as information regarding the body's inside environment, such as the contracting of muscles and blood pressure. The brain uses this information in very complex processes to decide what actions to take. Then it sends out signals to muscles and other organs of the body.

The human brain can be divided into three main parts: the cerebrum, cerebellum, and brain stem. Although many brain activities require the contributions of all three parts, certain tasks are handled by each part. The cerebrum is the center of higher thought, such as learning and memory. The cerebellum is responsible for coordination of various muscular activities, such as running and walking. The brain stem is in charge of the body's involuntary processes, such as heart rate and breathing.

The cerebrum is the largest part and is divided into two halves called the cerebral hemispheres. The outer surface of the cerebral hemispheres is called the cortex. It contains the cell bodies of the nerve cells.

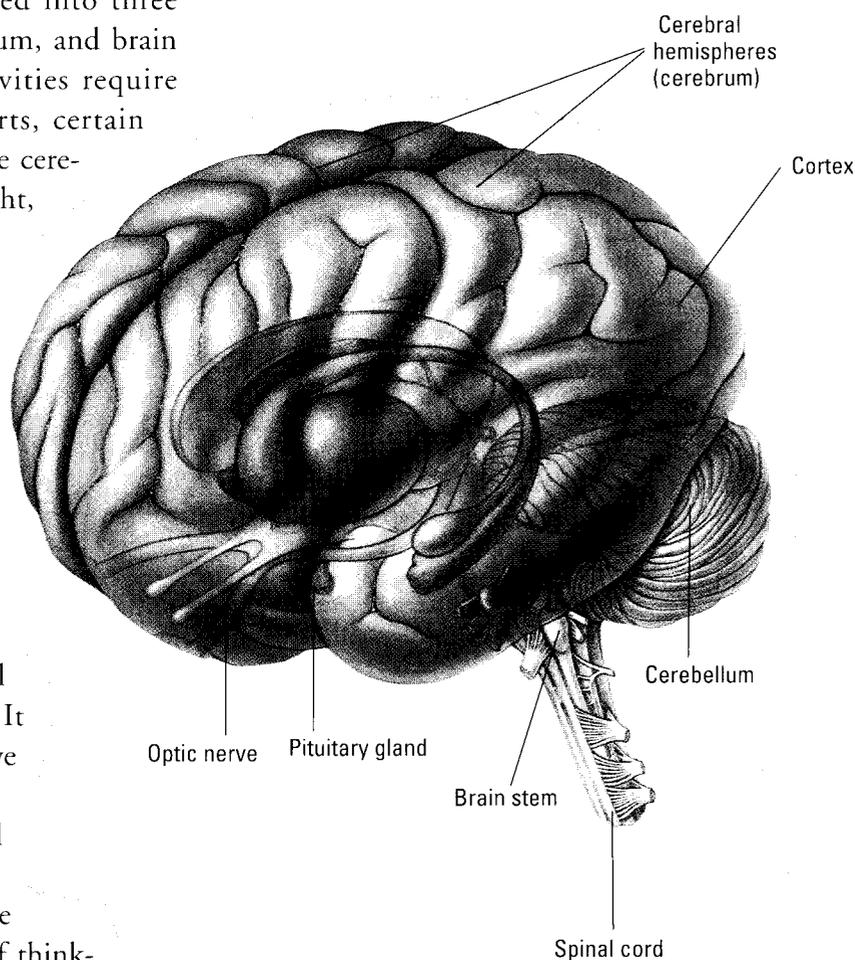
Different regions of the cerebral hemispheres are called lobes. The frontal lobes are just behind the forehead, and there the processes of thinking, judgment, and reasoning take place. Behind the frontal lobes are cells that control movement of the whole body. The parietal lobes are on each side of the brain. Cells in these lobes

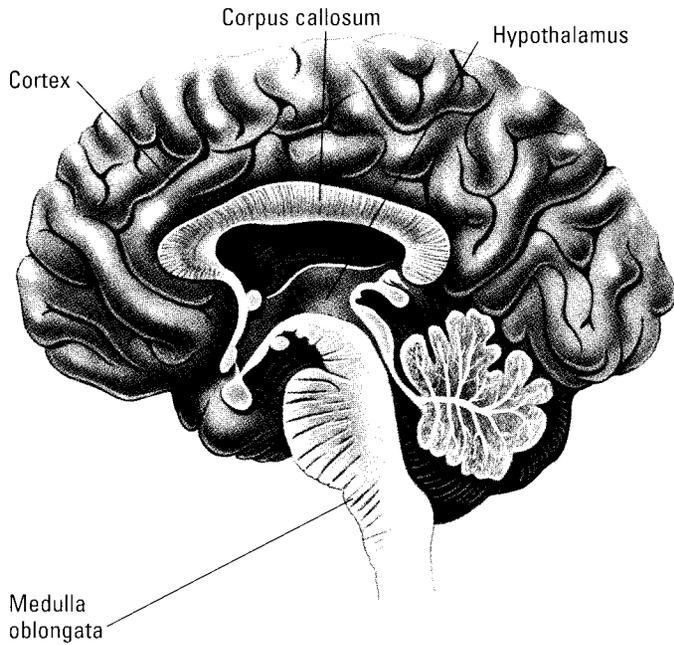
receive messages having to do with touch, body position, pain, and temperature. The temporal lobes are near the ears and serve as centers for hearing. Near these lobes are small areas for smell and taste. The occipital lobes at the back of the brain are centers for the sense of sight.

Other parts of the hemispheres, called associative centers, are connected with all of these lobes. The associative areas process information from many different parts of the brain. These associative areas

PARTS OF THE BRAIN

The brain is the most important part of the central nervous system, which also includes the spinal cord. There are three main regions in the brain: the cerebrum, the cerebellum, and the brain stem.





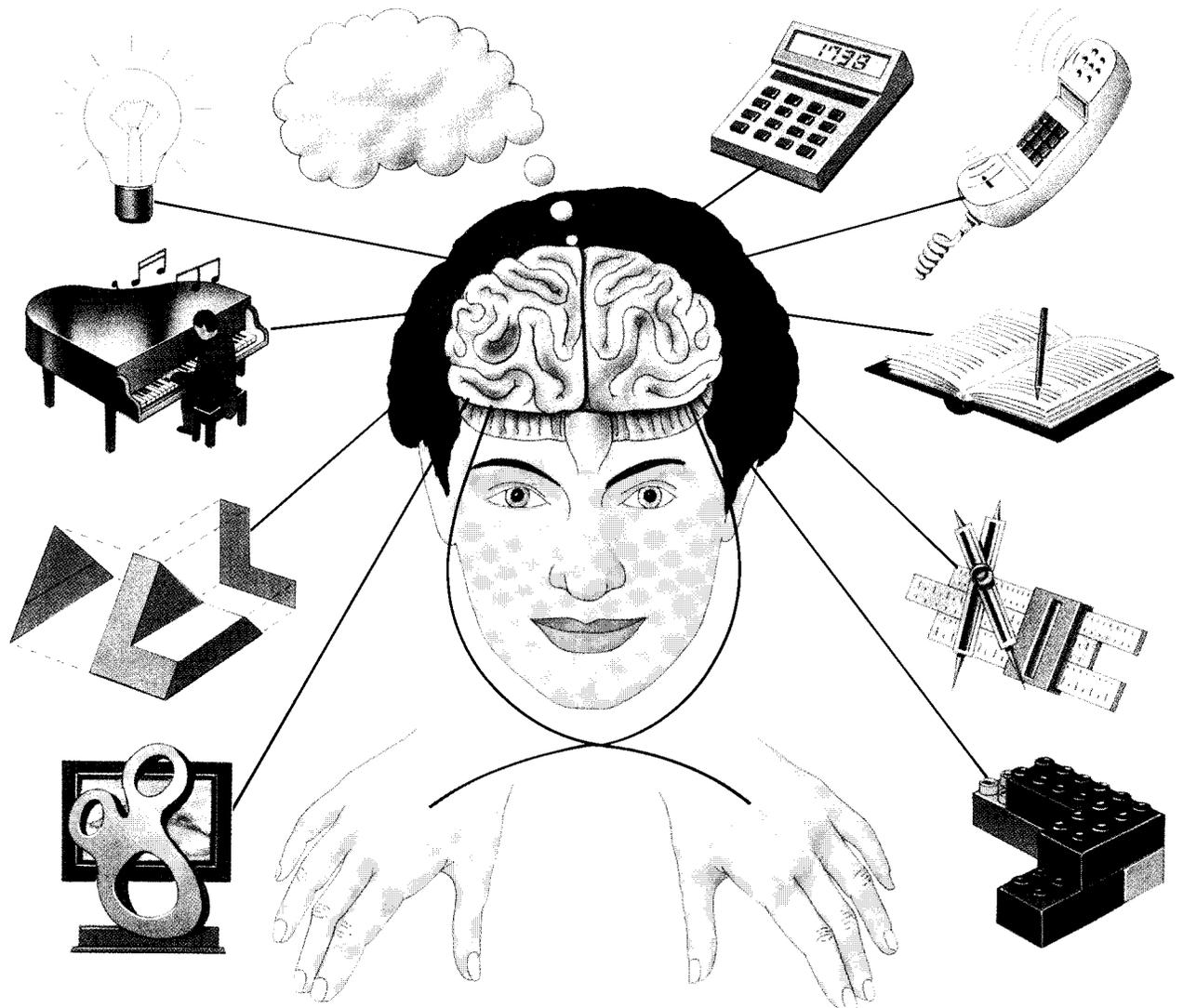
are important for learning and memory and for the development of intelligence.

In all parts of the cerebrum, signals from the nerves on one side of the body arrive at the brain and cross over to the opposite side. A special part of the brain, the corpus callosum, serves as the crossover center linking the left and right hemispheres.

The functions of the two hemispheres are not

BRAIN SECTION AND WORKINGS

A cross section of the brain shows the highly folded cortex (left). The billions of cells that make up the cortex provide us with the ability to learn and remember. Investigations into how the brain works suggest that the left and right sides of the brain do different things (below). The left side of the cerebrum seems to control our understanding of language and numbers. The right side appears to give us our creativity and appreciation of visual art and music.





CORTEX

When viewed through a microscope, the cortex is made up of millions of nerve cells with many branching "arms." These arms allow countless connections to be made between nerve cells in different parts of the brain. This is important in controlling and coordinating our thoughts and actions.

exactly the same. For example, one hemisphere is usually the dominant, or stronger, of the two. The dominant hemisphere is usually responsible for various special functions. If an individual has a dominant right eye and is right-handed, that person is likely to have a dominant left hemisphere. In most people, the areas that control speech are located in the left hemisphere, while areas that govern how we perceive the shapes and movements of objects are found in the right hemisphere.

The cerebellum is the second largest part of the brain and lies toward the rear of the cerebrum. It is concerned with balance, position of the body, and coordination of movements.

The brain stem contains the hypothalamus. The hypothalamus regulates such functions as movement of the intestines, reactions to emotions, and sleep. The brain stem also contains the medulla oblongata, which regulates breathing, heartbeat, and the contraction of blood vessels.

The brain is protected by the thick bone of the skull. However, the brain can be injured by hard blows to the skull or by cutting off the oxygen supply to the nerve cells. Physical damage may not always be fatal. Lack of oxygen for only a few minutes, however, can cause death.

The functions of the brain can be changed by

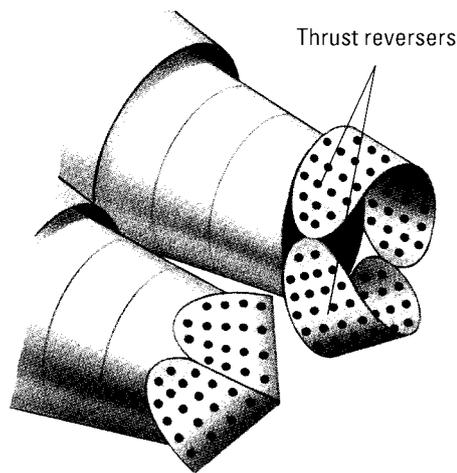
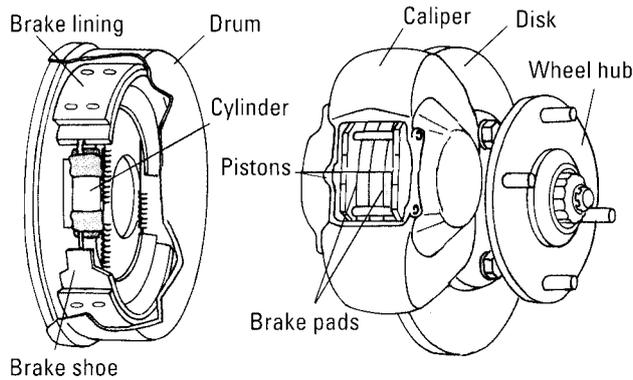
diseases and certain drugs, resulting in marked changes in behavior. Other changes in brain function and behavior do not seem to have any physical cause. Both kinds of brain disorders are often called mental illnesses (see MENTAL ILLNESS). People suffering from mental illnesses may show extreme changes in mood and in thinking processes.

The study of brain functions and behavior in other animals has given us knowledge about the importance of certain parts of the human brain. For example, animals that need good balance and muscular coordination, such as birds and mammals, have a larger cerebellum than fish and reptiles. The development of the cerebral hemispheres in humans is the greatest difference between humans and other animals. Recently, scientists have begun experimenting with ways to grow new brain tissue that could be used in implants.

The human brain weighs about 50 oz. [1,450 g]. Weight and size of the brain are not related to intelligence. The brain of the elephant weighs about three times more than the average human brain. The brain of a mentally retarded person may weigh just as much as that of a person with high intelligence.

See also PSYCHIATRY; PSYCHOLOGY.

BRAKE A brake is a device used to slow down and stop a moving object, such as a wheel or a shaft. Mechanical brakes work by friction, which is produced by pressing a piece of hard material against the turning part (see FRICTION). The emergency brake in automobiles is a mechanical brake. Bicycle brakes can be calipers that produce friction against the rim of the wheel by a pincer device. These brakes are operated by cables and levers.



BRAKE

A drum brake (top left) works by pressing brake linings against a drum attached to the wheel. A disk brake (top right) works by pressing brake pads against a disk spinning with the wheel. Friction between the linings, or pads, and drum, or disk, slows the wheels. Airplanes brake after landing by using thrust reversers (above) to direct exhaust from their jet engines forwards.

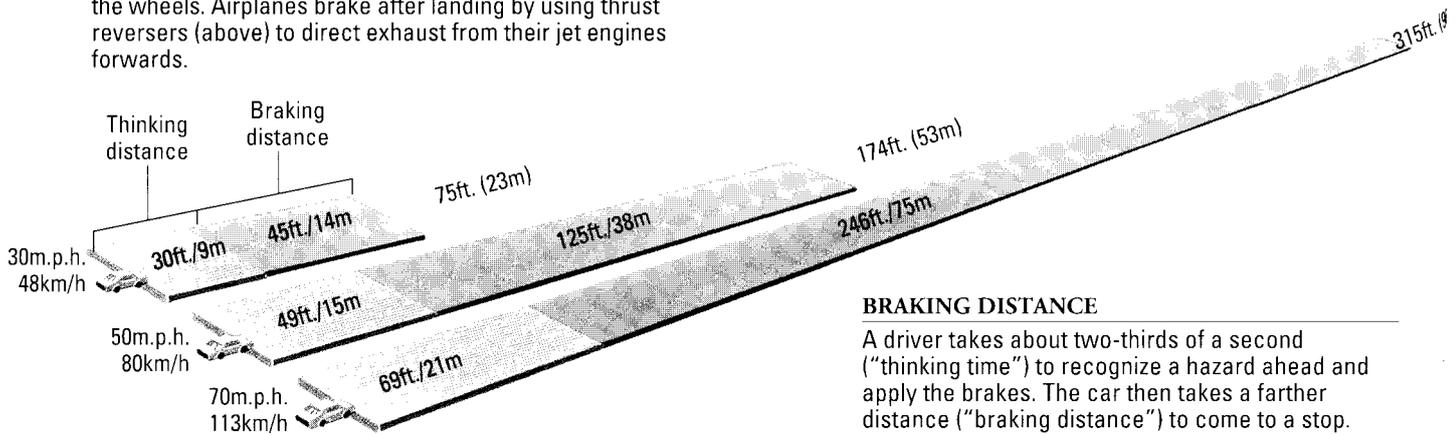
The main brakes on automobiles are not mechanical brakes. Instead, they operate by a hydraulic system in which the force applied to the brake is transmitted by a fluid (see HYDRAULICS). Two kinds of hydraulic brakes are used in automobiles. In drum brakes, two curved brake shoes are located inside a drum that is attached to a wheel. When the shoes are forced against the inner surfaces of the drum, the braking action takes place. In disk brakes, flat brake pads are pressed against a disk attached to the wheel.

Heavy trucks, buses, and trains use air brakes. When such brakes are applied, compressed air is released from a storage unit. The air pushes on pistons, which force brake shoes against the wheels. The quick-action automatic air brake was invented in the United States by George Westinghouse in 1868. An improved version of Westinghouse's brake system is still in use on trains.

Airplanes use various types of brakes similar to those on automobiles. A jet airplane can also be slowed down by reversing the thrust of its engines. On spacecraft, this braking action is done by small rockets whose nozzles are aimed in the direction of flight.

BRAKING DISTANCE Braking distance is the distance in which a vehicle can come to a halt from the point where the driver applies the brakes. The length of the braking distance depends on the force with which the brakes can slow the turning of the wheels, and the strength of the grip between the tires and the road surface. Each of these in turn depends on many factors.

In car brakes either a hollow drum or a disk is



BRAKING DISTANCE

A driver takes about two-thirds of a second ("thinking time") to recognize a hazard ahead and apply the brakes. The car then takes a farther distance ("braking distance") to come to a stop.

attached to the axle, depending on the type of braking system. To slow the wheel, a brake shoe is pressed against the inside of the drum, or the disk is squeezed by friction pads. If brake pads or shoes are worn, the slowing power of the brakes is reduced. If the brakes get too hot from friction, their grip weakens, and they are said to fade.

The grip of tires on the road surface is lessened if there is water or oil on the road. The tread of a tire consists of channels molded into the surface to allow water to flow away. No tire can provide an effective grip on an icy, greasy, or oily road surface.

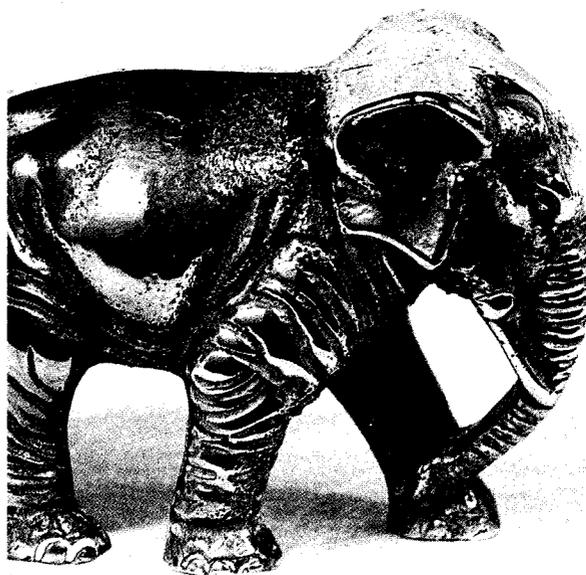
The tires' grip on the road is improved, and the braking distance reduced, by antilock braking systems (ABS). During braking on a slippery road surface, sensors detect when a wheel has started to slip. The brake is automatically released briefly, the wheel turns freely, and its grip is restored.

Any increase in speed causes a much greater increase, proportionally, in braking distance. On a dry road, with tires in good condition, a medium-sized car traveling at 20 m.p.h. [32 kph] has a braking distance of about 20 ft. [6 m]. But a car traveling at 40 m.p.h. [64 kph] has a braking distance of four times this, not twice as much. And a car moving at 60 m.p.h. [96 kph] brakes to a halt in about 180 ft. [54 m]—nine times as far as the first car.

The total stopping distance of a car is greater than the braking distance, however. A driver takes about two-thirds of a second from seeing a danger to recognizing it as such and actually applying the brake. In a car traveling at 60 m.p.h. [96 kph], that adds another 59 ft. [18 m] of distance.

See also AUTOMOBILE; BRAKE.

BRASS Brass is an alloy of copper and zinc. (An alloy is a mixture of two or more metals.) Brass was made on the Greek island of Rhodes as early as 500 B.C. The ancient Romans were the first to make wide use of brass. They made the alloy by melting zinc ores with copper ores. Since late in the 1700s, brass has been made by first taking the pure metals out of their ores. Pure zinc is then added to pure copper.



BRASS

Brass is an attractive gold-colored metal that is easily formed into complex shapes like this elephant.

The amount of copper used in brass may be anywhere from 55 percent to more than 95 percent. The color and hardness of brass vary with the mixture. Yellow brass, also known as high brass or cartridge brass, contains about 70 percent copper. Red brass, also called low brass, contains at least 80 percent copper. Muntz metal, also called alpha-beta brass, is an alloy of about 60 percent copper and about 40 percent zinc. Alloys with a high copper percentage are nearly as soft as pure copper. Adding zinc makes the alloy stronger and tougher. An alloy of 55 percent copper and 45 percent zinc is hard and brittle.

Sometimes amounts of other elements are added to brass for special uses. Lead is added to brass to make it easier to work by machine. Tin and nickel are added to increase the alloy's resistance to corrosion and wear. Manganese, iron, and aluminum are other elements added to brass, depending on how the alloy is to be used (see ALLOY).

Brass is used for such things as hardware, electrical fixtures, ornaments, and jewelry. It is also used for military decorations, shafts, pipes, and fittings for marine use.

BRAUN, WERNHER VON (1912–1977) Wernher von Braun was one of the world's foremost rocket engineers. He was a leading authority on space travel and directed the building of the rocket that put the first American into space. Von Braun was born in Germany. During World War II (1939–1945), he was in charge of Germany's rocket program. He played a major role in the development of the huge V-2 rockets with which Germany bombed cities in England. The V-2 was the world's first ballistic missile (see **MISSILE**).

In 1945, von Braun led a group of 116 German scientists that surrendered to the U.S. Army. Von Braun and his group were sent to the Redstone Arsenal in Huntsville, Alabama, to develop guided missile systems. They designed and built the first U.S. ballistic missile. Von Braun became a U.S. citizen in 1955.

In 1961, von Braun's team built the rocket that launched Alan B. Shepard, Jr., into the earth's orbit. Later, von Braun worked on the Saturn rockets that eventually carried people to the moon. He resigned his post of deputy associate administrator of NASA (National Aeronautics and Space Administration) in 1972 and became an executive with a major aerospace manufacturing firm. From 1975 until his death in 1977, he was director of the National Space Institute, an organization that promotes public understanding of the U.S. space program.

See also **ROCKET**; **SPACE EXPLORATION**.



WERNHER VON BRAUN

This German-born engineer directed America's rocket development.

BRAZIL NUT The Brazil nut is the seed of a tree that grows along the Amazon River in Brazil. This evergreen tree has a long, straight trunk that grows as tall as 150 ft. [45 m]. The branches grow at the top of the tree. The leaves are green and leathery. They are oblong in shape, measuring up to 15 in. [38 cm] in length and 6 in. [15 cm] in width.

As many as 24 Brazil nuts grow in each pear-shaped fruit. This fruit has a tough, woody covering and may reach 8 in. [20 cm] or more in diameter. When harvested in June, the fruit is opened and the nuts removed. The nuts have an extremely tough outer shell shaped like a section of an orange. Inside the shell is a butter-colored nutmeat that is rich in oil. The nut is very tasty and is sometimes used in candies. The oil can be used in salad dressings and for making soap.

See also **NUT**.



BRAZIL NUT

Brazil nuts have a tough outer shell and a creamy colored nutmeat, from which an oil can be extracted for use in salad dressings.

BREAD Bread is one of the world's oldest and most important foods. Bread has been eaten for thousands of years and is the key part of many people's diets around the world. Bread is usually made of flour, which is ground grain, and water. Salt or a sweetener, such as sugar or honey, may be added to the mixture for flavor.

Yeast breads are one type of bread. Yeast is a leaven, a substance that causes breads to rise.



BREAD

There are many different kinds of bread, which differ according to the type of flour used and the method of baking.

Common white bread and French bread are examples of yeast bread. One step in the manufacture of yeast breads involves letting the mixture of ingredients, called dough, ferment. During fermentation, yeast reacts with other chemicals in the dough to produce bubbles of carbon dioxide gas. These bubbles cause the dough to rise, giving the bread a light, airy texture.

When the dough has completed rising, which often takes many hours, it can be formed into loaves or rolls and baked in an oven. The heat in the baking process causes the dough to rise slightly more and form a crust, or outer coating, around the bread.

Another group of breads, called unleavened breads or flat breads, are made without yeast. Examples of flat breads are tortillas and matzohs. Because no carbon dioxide is produced, the dough of unleavened bread does not rise. Unleavened breads have a heavier and thicker consistency than yeast bread.

The final group of breads is called quick breads. Examples of quick breads are muffins and biscuits. Quick breads rise like yeast breads, but do not contain yeast. They are raised by another substance, such as baking powder.

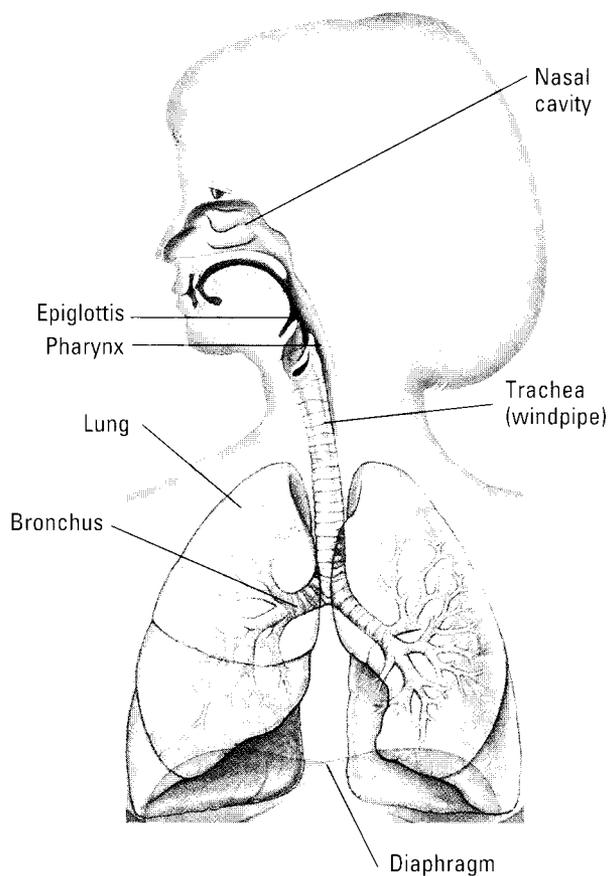
Many different grains are used to make bread. People in different parts of the world make bread from grain that is indigenous to their area. Indigenous means to naturally occur in a region or environment. Those areas that have a mild climate, such as parts of the United States and Europe, make their bread mostly from wheat (see

CLIMATE). In colder parts of the world, such as northern Europe, bread is often made from barley, oats, or rye. In very warm parts of the world, such as Central and South America, bread is usually made from corn, rice, or millet.

Bread made from whole wheat is the most nourishing kind of wheat bread because the nutrient-rich husks have not been removed from the grain. White bread, on the other hand, is made from grain from which the husks have been removed.

BREATHING Breathing is the movement of gases between an animal and its environment. Breathing is part of respiration, in which oxygen is used to break down food for energy (see RESPIRATION).

Humans and many other animals, such as dogs and horses, use lungs to breathe. Lungs are moist, spongy organs rich in blood vessels. Lungs are located in the chest. The lungs expand and fill with air when a human or other animal inhales, or



BREATHING

We breathe in when our diaphragm muscle contracts and flattens. Air is sucked down our windpipe and into our lungs.

ACTIVITY Breathing

You can show that your breath contains water by doing this simple test. Take a mirror or stand close to a cold window. If you breathe out gently but steadily against the glass, you will be able to see tiny droplets of water appear on the glass. This water comes from deep inside your lungs, where it helps to dissolve oxygen and carbon dioxide gases as they pass into and out of your bloodstream.

breathes in. Oxygen in the air passes through the thin, moist walls of the many blood vessels in the lungs and into the bloodstream. At the same time, the waste product, carbon dioxide gas, passes out of the bloodstream into the lungs. Waste-filled air is forced out of the body by exhaling.

Insects and fish do not have lungs, but they have other ways to breathe. Insects breathe through tiny holes, called spiracles, along the sides of their bodies. Fish use gills to breathe. Gills are specialized organs that take in oxygen from the water in which the fish live. Amphibians, such as

frogs, breathe through their skin and their lungs.

See also CARBON DIOXIDE; LUNG; OXYGEN.

 **PROJECT 64**

BREEDER REACTOR A breeder reactor is a type of nuclear reactor. It is called a breeder reactor because it produces, or breeds, fuel as a by-product of its nuclear reactions. In fact, while producing steam to generate electricity, a breeder reactor produces more fuel than it uses. Almost all of the uranium mined from the earth is uranium-238, which cannot be used as a fuel in nuclear reactors. Only a very small part (less than one percent) of the uranium mined is composed of the lighter isotope, uranium-235 (see ISOTOPE). Uranium-235 can be used as a fuel in nuclear reactors because its atoms split and release energy more easily than uranium-238 (see FISSION). Breeder reactors convert uranium-238 into a usable nuclear fuel. In the reactor, particles called neutrons fly out of a core filled with uranium-235 and strike a blanket of uranium-238 that surrounds the core. Nuclear reactions between the neutrons from the uranium-235 and the uranium-238 change the uranium-238 into uranium-239, which changes into other elements by a process called radioactive decay. It finally becomes plutonium-239, which can be used as a fuel in a nuclear reactor or for making nuclear weapons.

See also NUCLEAR ENERGY; NUCLEAR WEAPONS; PLUTONIUM; RADIOACTIVITY; REACTOR, NUCLEAR; URANIUM.

**BREEDER REACTOR**

Breeder reactors produce more nuclear fuel as a by-product of their nuclear reactions. The final product in most breeder reactors is plutonium, which can be used as a nuclear fuel.

BREEDING

Breeding is a way to either change or keep a type of animal or plant by selecting the best samples, or offspring, for reproduction.

There are two main techniques for changing or keeping an animal or plant through sexual reproduction—inbreeding and outbreeding (see REPRODUCTION). Inbreeding is the mating of closely related males and females of the same breed. Inbreeding helps bring out, or “fix,” a set of desirable traits. The problem with inbreeding is that any inherited weaknesses also become fixed. Inbred plants and animals tend to be smaller and

grow more slowly. They also may produce fewer offspring than outbred animals or may even produce no offspring at all.

Outbreeding, the second technique of breeding by sexual reproduction, keeps a population healthy because it brings new genes into the population. A gene is a unit of heredity that determines characteristics that an organism inherits from its parents (see GENE). There are two types of outbreeding. One type, called hybridization, involves mating two different breeds that have each been inbred. The offspring is called a hybrid (see HYBRID). The second type of outbreeding, called crossbreeding, involves mating two different breeds that have not been inbred.



Plant breeding As soon as people began growing crops, they became plant breeders. For example, by choosing the largest seeds for sowing each year, people were able to improve the yields from their crops.

In the 1700s, growers began to try various ways to improve crops. They started to remove pollen from one plant and place it on another (see POLLEN). This was done to combine features of different plants into one plant. Sometimes, these methods were successful. It was not until the

TISSUE CULTURE

In modern plant breeding, plants often begin life in the laboratory. There scientists can control their growing conditions with great precision. A small piece of tissue from one plant, grown in the right medium, can produce several new, identical plants for research.

TRIAL BEDS

When new plants are bred, large numbers are grown in trial beds to study their characteristics. Growers look for plants that combine a good yield of flowers, fruit, or seed, with strong, healthy growth and no undesirable side effects.



**SELECTIVE BREEDING**

Selective breeding enables scientists to produce new varieties of fruit and other crops that are more resistant to diseases and pests. Here plant breeders have produced "dwarf" apple trees that bear fruit close to the ground. Fruit from this type of tree can be gathered using machines.

1900s that genetics became a science (see GENETICS). Today, breeders produce crops with better flavors, higher yields, and more resistance to disease. Much effort also goes into making prettier flowers.

Suppose a modern plant breeder wants to produce a new kind of apple with a red skin, hard flesh, and the ability to stay "good," or go rotten very slowly. First, the breeder examines many apples and chooses possible parents that have qualities the breeder wants for the new apple. The breeder transfers the pollen from the flower of one kind to the flower of another kind, just as the early growers did. The modern plant breeder has a much better chance to succeed, however, because of his or her knowledge of genetics. The breeder collects the seeds produced and sows them. He or she tends the trees that grow from the seeds until they produce fruit. It may take 15 years or more before fruit will be produced and the breeder can see his or her results.

Desirable traits can also be reproduced in plants through asexual reproduction. For example, breeders use a method called cloning to increase their supply of plants with certain characteristics (see ASEXUAL REPRODUCTION). In grafting, parts of two different plants are joined to form a single plant. The scion (bud, branch, or piece of stem) of one plant is joined to the root stock of another plant. The root stock may include the lower part

of the stem. In fruit trees, the scion often has desirable fruit in terms of color, flavor, size, and number and size of seeds. The root stock may be from a tree that grows well in poor soil or low temperatures. When the two pieces are joined, the new tree will have the characteristics of both trees. Many fruit-bearing trees, such as the avocado, lemon, and orange, are grown by grafting.

Plant breeders try to produce new varieties by treating seeds with radiation or chemicals. This often changes the genes and chromosomes that control the nature of the plant. These methods produce mutations that may result in bigger or better plants. Several kinds of wheat have been produced in this way (see CHROMOSOME; MUTATION).

Plant breeders are also researching how to transfer specific traits to plants by combining DNA from a desirable plant with DNA from another plant of the same species, at the seed stage (see DNA). The breeders use bacteria to insert the DNA. The new plant will then have the best characteristics of both plants.

Animal breeding Animals are chosen for breeding by mass selection or family selection. Mass selection involves choosing animals individually because of certain traits. Family selection involves choosing a particular animal because its ancestors have desirable traits. A pedigree is a

record of an animal's ancestors. Various animals were bred from wild species using mass selection or family selection. For example, all the modern kinds of dogs came from dogs that began to be trained by people more than ten thousand years ago. Since 1700, great strides have been made in breeding farm animals. For example, pigs once had most of their weight in the front. Because the best meat is found in the hind parts, breeders have slowly shifted the weight from the front to the back. This was done by breeding those pigs with large hind regions.

Cattle breeding has also made great progress in recent years. Some breeds now produce more milk or better meat. Artificial insemination is one method used in cattle breeding. In artificial insemination, sperm is taken from a bull with very desirable traits and placed into the reproductive organs of several females. In this way, the percentage of eggs being fertilized, and thus, calves being born, is much higher than if the bull were to fertilize one or more cows naturally (see FERTILIZATION). A good herd of cattle can be built up very quickly. Other ways of breeding cattle involve superovulation and embryo transfer. Superovulation is the production of extra eggs by a very valuable female. The female receives extra hormones (chemicals normally released by the body) that cause her to produce many more eggs than just one. The eggs are fertilized through artificial insemination. After one week, the embryos (fertilized eggs) are removed from the original cow and transferred into other, less valuable cows. These less valuable cows then carry the calves until they are ready to be born.

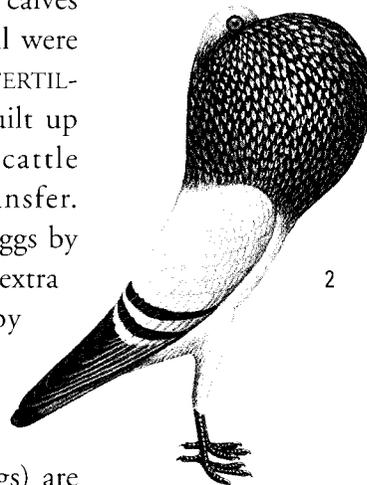
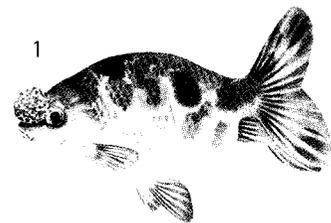
Another method of increasing the number of cattle born is through artificial twinning. In artificial twinning, an embryo that is a week old is removed from the cow and sliced in half. Each half is placed in two other cows, where the embryos grow normally. Triplets can also be produced this way.

The latest research in livestock breeding involves genetic engineering.

DNA from a desirable breed, such as one that grows quickly, can be added to a newly fertilized egg in the laboratory. Breeders use bacteria to actually insert the DNA. The egg is then inserted back into the animal. This process is called implantation. The animal that grows from the egg will then have the best characteristics from the parents as well as from a third breed.

The goal of all breeding research is to produce those traits in plants and animals that humans find most useful. Scientists often test new breeding methods on bacteria and viruses. These organisms reproduce quickly. This allows scientists a chance to see very soon what changes occur.

See also REPRODUCTION.



ANIMAL BREEDING

By breeding together animals that show unusual features, many varieties have been produced. These include: (1) pompoon goldfish, (2) pouter pigeon, and (3) lop-eared rabbit.



BRIDGE

Bridges are structures that carry roads or railways across obstructions. A bridge may be built for cars, trucks, trains, or people. The obstructions may be valleys, bodies of water, or other roads and railways.

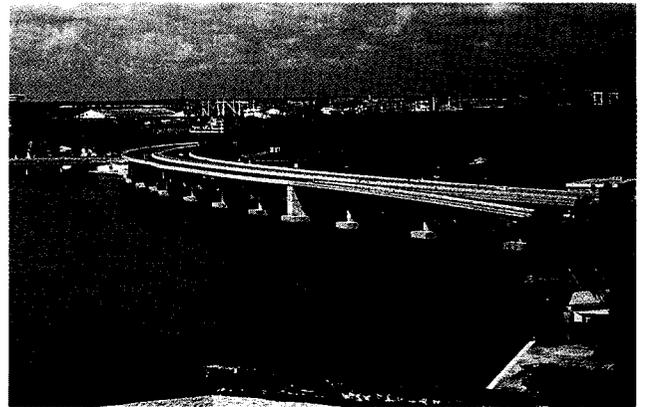
Early people probably found that a fallen log across a stream provided them with a useful footbridge. In jungle areas, they could make a simple footbridge out of ropes of vines twisted together. When people began to find that their log and vine bridges could not carry carts and wagons or large numbers of people across wider spans, they began to improve their bridges to meet their needs.

One kind of bridge is a beam bridge. The log across the stream is a form of beam bridge. Modern bridges use beams of steel or reinforced concrete. However, the gap that a beam bridge can span is limited in width. If too much weight is put on it, it will sag and even collapse. To overcome this weakness, two or more beams can be placed end-to-end across the gap, with their ends resting on a support in the middle. This support is called a pier. The pier is usually a very strong structure made of concrete and steel. By use of a number of beams and piers, a bridge can be built across almost any body of shallow water, no matter how wide it is. A bridge using multiple beams and piers carries a highway across Lake Pontchartrain in Louisiana. It is 24 mi. [38.6 km] in length and has 2,235 concrete beams, each 56 ft. [17.1 m] long.

Special kinds of beam bridges have been built over rivers used by large ships. Some of these bridges are movable. The swinging drawbridge turns on a pier in the middle of the river channel

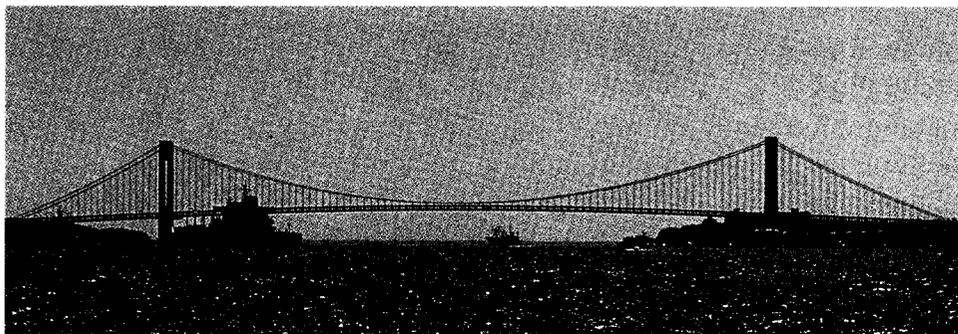
to let ships pass by. A lift bridge can be raised like an elevator to let ships go underneath. A bascule bridge swings up and down like the gates at a railroad crossing.

The ancient Romans built bridges supported by large wedge-shaped stones put together in the shape of an arch. These stones were held in place by a keystone that was placed at the top of the arch. The arch supported the weight of the bridge on top of it. To cross wide spans, several arches were used. The Roman arch had a span of about 100 ft. [30 m]. Today, arches are rarely made with stones. Instead, concrete and steel are used (see ARCH). If the distance across the gap is too great for the use of arches, bridge builders can use cantilevers. The cantilever is a beam that is fixed at one end to a wall or other structure. It is unsupported at the other end. The cantilever bridge is made by cantilevering beams outward from each side of a river. Using cantilevers, wider spans can be crossed. However, the longer the beam, the heavier and stronger the structures at the shore have to be. It is not always practical or possible to build the huge bases that may be needed. Sometimes, it is not worthwhile to spend the



GIRDER BRIDGE

Eko Bridge (above), in Lagos, Nigeria, is an example of a modern girder bridge.

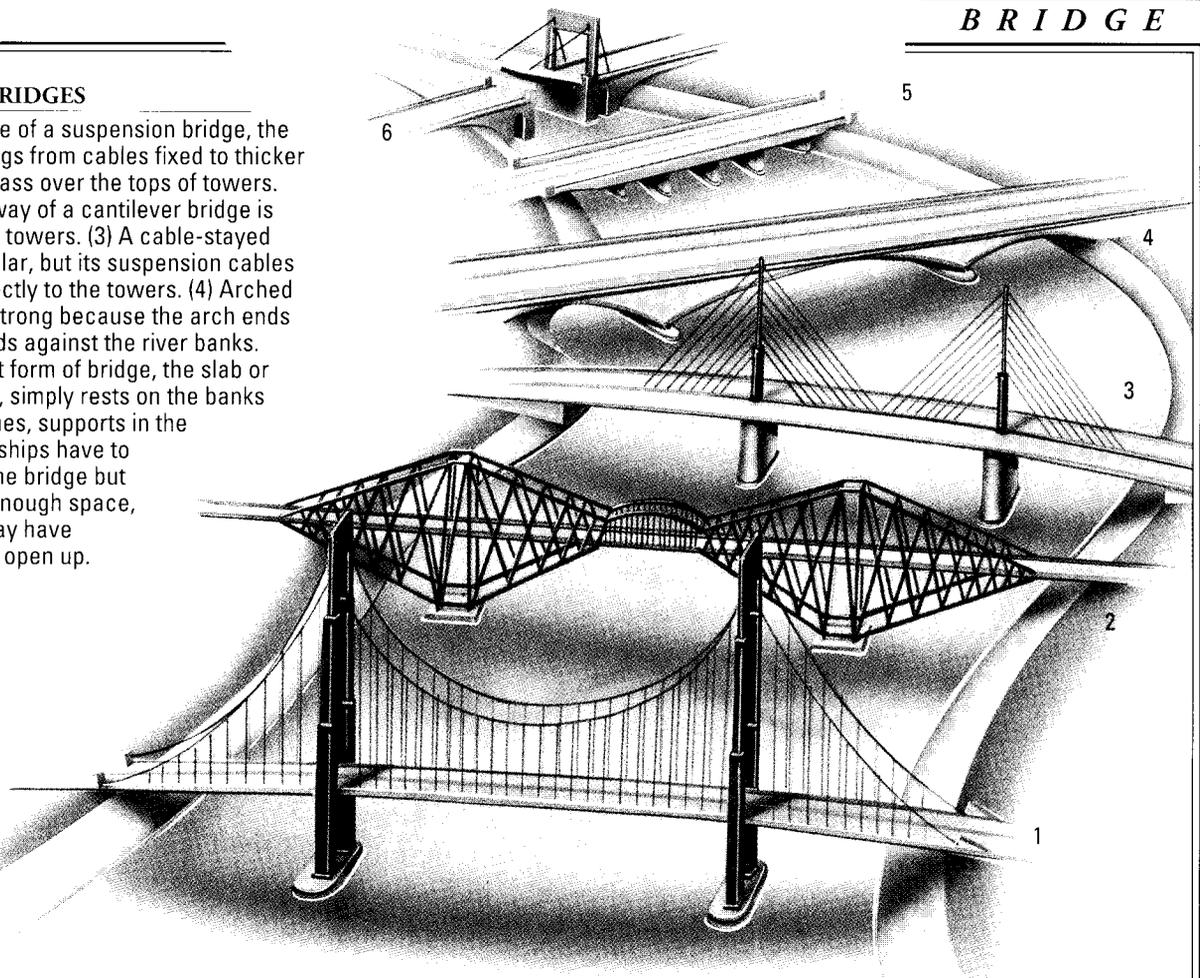


SUSPENSION BRIDGE

The Verrazano-Narrows Bridge in New York (left) is, at nearly 2 mi. [3.2 km] long, one of the world's longest suspension bridges.

TYPES OF BRIDGES

(1) In the case of a suspension bridge, the roadway hangs from cables fixed to thicker cables that pass over the tops of towers. (2) The roadway of a cantilever bridge is supported by towers. (3) A cable-stayed bridge is similar, but its suspension cables are fixed directly to the towers. (4) Arched bridges are strong because the arch ends push outwards against the river banks. (5) The oldest form of bridge, the slab or girder bridge, simply rests on the banks and, sometimes, supports in the middle. (6) If ships have to pass under the bridge but there is not enough space, the bridge may have sections that open up.



money. Other times, the ground at the shore may be muddy and not strong enough (see *CANTILEVER*).

The suspension bridge usually has two tall towers, one at each end. Strong cables are anchored firmly at each end (see *CABLE*). The cables are spun from steel wire and may be several feet thick. The cables run from one shore to the other, over the tops of the towers. Hanging down from these cables are strong steel cables spaced several yards apart. The bridge deck hangs from the suspended cables. The towers over which the cables are strung serve as piers for the bridge. The suspension bridge, like the arch bridge, can be designed for beauty as well as usefulness. Two good examples of suspension bridges are the Golden Gate Bridge, which crosses San Francisco Bay in California, and the Verrazano-Narrows Bridge, which spans the entrance to the harbor in New York City.

The design and building of any but the simplest bridge is a complex task. However, the development

of modern computers and testing procedures has helped simplify it.

Engineers take into account the intended load and the width and height of the span when designing a bridge. The geology of the surroundings is another important consideration. For example, bridges in areas where earthquakes are likely to occur must be built to withstand shifts in the earth. Engineers also must take into account the aerodynamic qualities of a bridge. Aerodynamics is the study of how air flows around an object (see *AERODYNAMICS*). The larger any bridge is, the greater surface area it presents to the wind.

Engineers perform many tests to ensure that the bridges they build will be aerodynamically sound—that is, that they can withstand the force of strong winds from different directions. One of these tests involves the use of a scale model of the bridge they intend to build and a wind tunnel similar to the one used in the design of aircraft and automobiles.

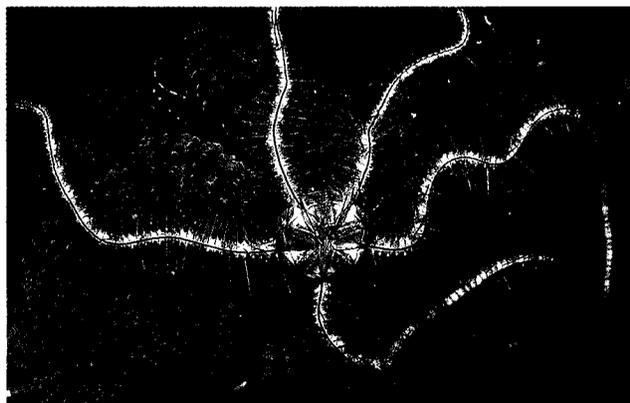
BRITISH THERMAL UNIT The British thermal unit, or BTU, is a measure of heat energy. It is the amount of heat needed to raise the temperature of one pound of water by one degree Fahrenheit. The BTU is used less now than in the past. It is more common today to use the SI unit of energy called the joule. *SI* stands for the French words *Système International*, which is the international system of units used by scientists. One BTU is equal to 1,055 joules (see **JOULE**).

Because the joule is a small unit, the kilojoule is often used. One kilojoule is 1,000 joules. The BTU is, therefore, nearly equal to a kilojoule (1 BTU = 1.055 kilojoules). Another heat unit is the calorie (see **CALORIE**). One BTU is equal to 252 calories.

BRITTLE STAR The brittle star is an ocean invertebrate that belongs to the phylum Echinodermata. It is closely related to the serpent star and the basket star (see **ECHINODERMATA**; **INVERTEBRATE**).

The brittle star has a disk-shaped body and five long, spiny arms. The distance from the tip of one arm to the tip of the opposite arm may be from 2 to 8 in. [5 to 20 cm]. The arms break off easily, but new ones grow back quickly. The brittle star uses its long arms to move along the sea floor. Its mouth is on the underside of its body. It feeds on dead matter that has settled to the ocean bottom.

See also **BASKET STAR**.



BRITTLE STAR

The brittle star is an animal that lives on the ocean bed. It has five spiny arms, which means it is related to the basket star and starfish.

BROMINE (brō'mēn') Bromine (Br) is a non-metallic element and a member of the halogen group of elements (see **ELEMENT**; **HALOGEN**). It is a heavy, reddish brown liquid with a strong, irritating odor.

Bromine usually occurs in nature in the form of bromides. Seawater contains bromides, and bromine is obtained by treating seawater with chlorine. Among its other uses, bromine is used to make silver bromide. Silver bromide is sensitive to light and is used in photographic films and paper.

Bromine has an atomic number of 35 and a relative atomic mass of 79.9. Its freezing point is 19°F [-7°C], and its boiling point is 138°F [59°C]. Its relative density is 3.1 (see **RELATIVE DENSITY**). It was discovered by a French chemist, Antoine-Jérôme Balard, in 1826.

BRONCHITIS (brōn kī'tīs) Bronchitis is a condition in which the bronchial tubes of the lungs are inflamed. The inflamed bronchial tubes overproduce mucus, leading to coughing and breathing difficulties. Other symptoms include chest pains and fever. Severe cases can be fatal (see **MUCOUS MEMBRANE**; **RESPIRATORY SYSTEM**). Bronchitis is caused by a bacterium or a virus infection or by inhaling irritating fumes, such as tobacco smoke.

Bronchitis may be either acute or chronic. Acute bronchitis is usually caused by a bacteria or virus (see **BACTERIA**; **VIRUS**). Acute bronchitis may last for several weeks and is accompanied by a cough and fever. Acute bronchitis can turn into a more serious condition called chronic bronchitis. Chronic bronchitis can also be caused by smoking cigarettes. The smoke irritates the lungs, causing an overproduction of mucus. Chronic bronchitis lasts longer than acute and, in fact, may never go away.

BRONZE Bronze is a hard, durable alloy made mostly of copper and tin. Sometimes, people refer to certain alloys of copper with little or no tin as bronze. Some brasses, which are made of copper and zinc, are called bronze. However, the term usually means that the copper alloy in question



BRONZE

Bronze was one of the first metals used because it melted in the heat of a wood fire. In time, chemicals in the air make the surface turn a green color.

contains considerable tin. People have used bronze for about five thousand years (see ALLOY; BRASS).

There are many types of bronze. They all have different uses. An alloy made from four parts of copper and one of tin is called bell metal. It is used for molding bells. Adding lead to copper and

tin results in a bronze that is used for ornamental objects, such as statues, and for objects that need to be lubricated, such as bearings. Most bronzes resist corrosion and may last for hundreds of years.

BROWN BEAR The brown bears are several species of bears living in the forests and mountains of North America, Europe, and Asia. In North America, the bears live mostly in Alaska and northern Canada. The brown bears are larger than any other type of bear. The largest brown bears are the Alaskan brown bears, which may grow as tall as 9 ft. [2.7 m] and weigh as much as 1,650 lb. [750 kg]. One type of Alaskan brown bear is the Kodiak bear. The European brown bear is smaller. It may be 6.6 ft. [2 m] tall and may weigh 770 lb. [350 kg]. Other types of brown bear include the grizzly bear.

The fur of a brown bear may be brown, black, reddish, yellow, or grayish-white. Although usually a plant eater, the brown bear may attack animals for food. The brown bear also fishes, scooping fish out of the water with its paws. Although brown bears can be very dangerous, they rarely attack unless they are threatened.

See also BEAR.



BROWN BEAR

This Alaskan brown bear has caught a salmon, one of its favorite foods, by using its paws to scoop the fish out of the river.

BROWNIAN MOVEMENT Brownian movement is the random motion of tiny particles suspended in a liquid or gas. It is named after Robert Brown, a British chemist. In 1827, Brown noted this movement by observing pollen grains suspended in water.

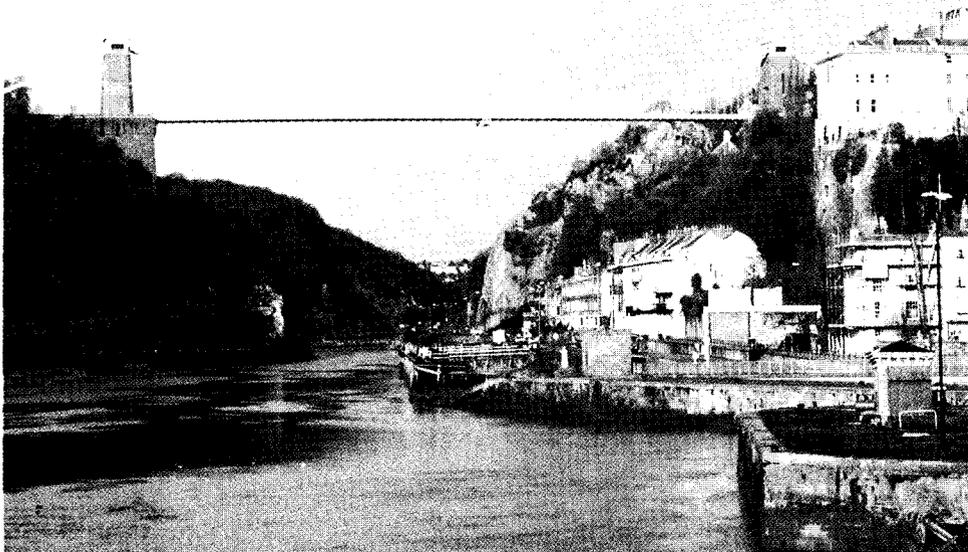
If particles of smoke are watched through a microscope, they are seen moving about in a random manner. This motion is caused by the molecules in the air striking the smoke particles. The air molecules are so small they cannot be seen. Their movement, however, is so rapid that they cause the smoke particles to move. Brownian movement provides direct evidence that matter is made up of very small particles.

BRUNEL, ISAMBARD KINGDOM (1806–1859) Isambard Kingdom Brunel was born in Portsmouth, England. He became the most famous engineer of his day for the new ways in which he used iron. He built bridges, railway lines, tunnels, buildings, and ships. His first bridge was the Clifton suspension bridge over the Avon Gorge, although it was not completed until 1864, after his death. He is most famous for his achievements in marine engineering. He built the

steamship *Great Western*, which, in 1838, made one of the first transatlantic crossings by a steamship. His next ship, the *Great Britain* (1843), was the first large steamship to be built from iron and powered by propellers instead of paddle wheels. He went on to build the *Great Eastern* (1858), which was designed to carry 4,000 passengers. It was more than five times the size of any other ship afloat. When it failed to attract the numbers of passengers it was designed for, it was used for laying transatlantic telegraph cables. It ended its days as a summer attraction for visitors to Liverpool.

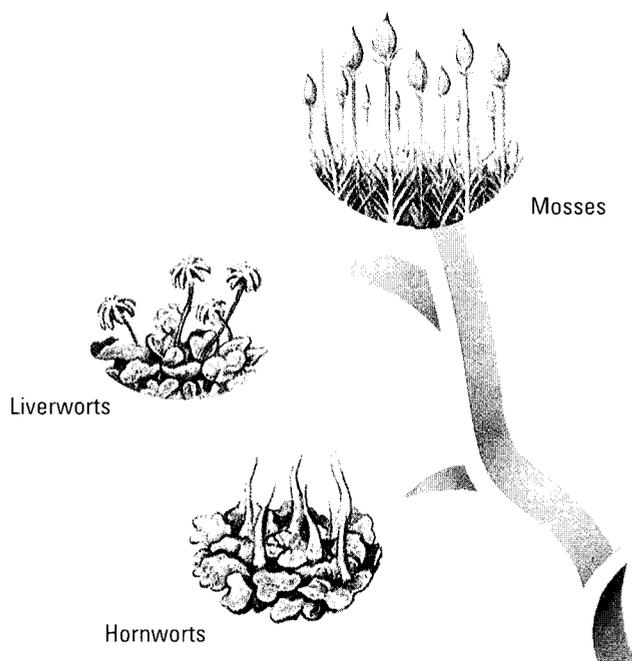
See also BRIDGE; SHIPS AND SHIPBUILDING.

BRYOPHYTE (brī'ə fīt') Bryophyte is the name for the small, low-growing plants in the division Bryophyta. These plants lack true flowers, leaves, roots, seeds, or stems. Bryophytes are found in many parts of the world, but mostly in wet and shady locations. In some environments, such as bogs, bryophytes are the most common plants. Most botanists recognize three kinds of bryophytes. They are mosses, liverworts, and hornworts. Some botanists believe that hornworts should be placed in the same class as liverworts.



BRUNEL

The Clifton suspension bridge spanning the gorge of the Avon River, in England, was one of the most important works of the British civil engineer Isambard Kingdom Brunel.



BRYOPHYTE

The bryophytes are a group of flowerless plants that grow in wet places. Unlike other plants, bryophytes do not have stems, leaves, or roots. The group is divided into three types: the mosses, the liverworts, and the hornworts.

Bryophytes reproduce by means of alternation of generations. That means a generation that reproduces sexually is followed by one that reproduces asexually by means of spores, which in turn is followed by a sexual generation, and so on.

See also ALTERNATION OF GENERATIONS; MOSS, LIVERWORT, AND HORNWORT.

BUCKTHORN FAMILY The buckthorn family includes more than five hundred species of perennial dicotyledons (see DICOTYLEDON; PERENNIAL PLANT). They are mostly climbing shrubs related to the vine family. Although native to Europe, many varieties are common in the United States. The buckthorn plant is a thorny shrub that may grow as tall as 11.5 ft. [3.5 m]. It produces clusters of small greenish flowers in May. Later, it produces small berries, each of which contains four seeds. The leaves are oval in shape with rounded bases. The bark can be used to produce a yellow dye.

The California lilac also belongs to the buckthorn family. This tree may grow to be 33 ft. [10 m] tall. The California lilac has bright blue



BUCKTHORN FAMILY

The common buckthorn is a tall shrub with shiny leaves, greenish-yellow flowers, and spine-tipped branches.

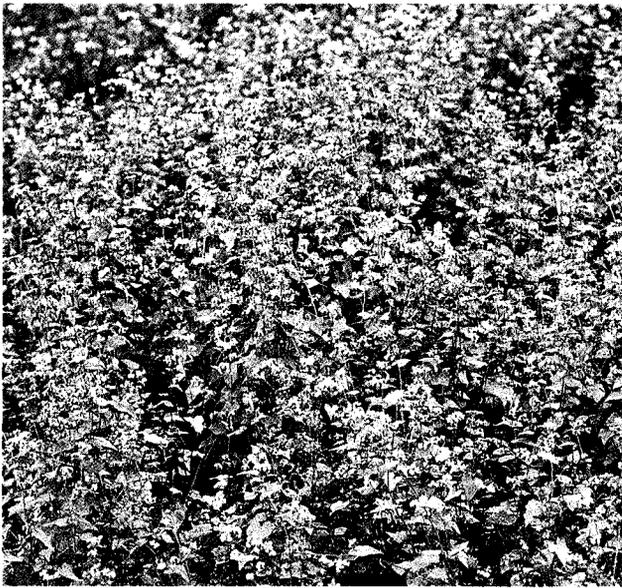
flowers and is found growing only in warm climates.

Another member of the buckthorn family is the California bearberry. The bark of this plant can be used to produce a powerful laxative called cascara.

BUCKWHEAT FAMILY The buckwheat family contains more than seven hundred species, most of which live in temperate regions of the northern hemisphere. Most are herbaceous dicotyledons that spread by underground rhizomes (see DICOTYLEDON; HERBACEOUS PLANT; RHIZOME). Some grow as tall as 10 ft. [3 m]. The most familiar species are rhubarb and the buckwheat plant.

Buckwheat is an annual plant grown in Europe, central Asia, and the eastern United States. Buckwheat may grow to be about 3.3 ft. [1 m] tall. It has arrow-shaped leaves and nectar-filled flowers. Bees are attracted to this nectar and make a rich, dark honey known as buckwheat honey from it.

Buckwheat is a strong, easily grown plant that is raised for its seed. These seeds can be used as bird feed. They can also be ground up to make a



BUCKWHEAT FAMILY

Buckwheat is grown for its nectar-rich flowers, which are favorites of bees, and for its seeds.

flourlike powder for cooking. Buckwheat, though not a grass, is often considered a grain.

BUD A bud is an undeveloped part of a growing plant. It may develop into a flower, a leaf, or a shoot. The bud is protected by bud scales that surround the delicate, developing structures in the bud. Some buds have extra layers of protection against low temperatures and water loss. These layers are usually located under the bud scales.

A terminal bud grows at the end of a stem. The



BUD

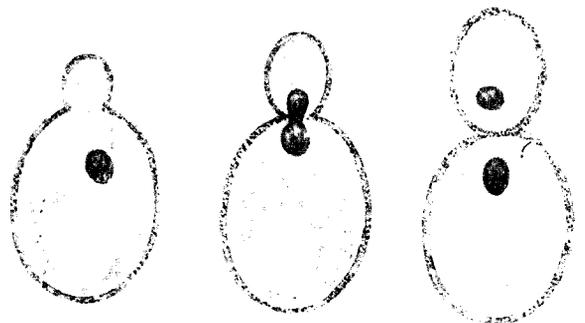
Plants that bear several flower buds usually open in turn. This lengthens the time available for pollination.

terminal bud is the growing region that causes an increase in height. The terminal bud produces a hormone called auxin that controls the growth of lateral buds. Lateral buds grow along the sides of stems and shoots. These buds usually produce flowers or leaves. Some produce leafy shoots that grow into branches. If the lateral bud is located in the axil, it is called an axillary bud (see AXIL). All other lateral buds are called adventitious buds. Adventitious buds sometimes form where a plant has been injured.

After losing its leaves in the fall, a deciduous tree produces winter buds that will not start growing until the spring (see DORMANCY). These buds must be exposed to a long period of cold during the winter before they can grow into new leaves or leafy shoots. If there is an unusual period of warm weather during the winter, these buds may begin to grow. When the weather becomes cold again, however, many of these buds will die.

See also PLANT KINGDOM.

BUDDING Budding is a type of asexual reproduction (see ASEXUAL REPRODUCTION). It occurs in some lower organisms. During budding, a swelling develops on the body of the parent. This swelling, or bud, develops into another organism that is exactly like the parent. Some animals, such as coral, produce buds that stay permanently attached to the parent. Most sponges and some jellyfish, however, produce buds that become separate organisms. The term *budding* also describes a special, artificial way of growing plants.



BUDDING

When a cell buds, as is happening to the yeast fungus cell above, a swelling first appears. Copies of all the important parts of the parent cell, particularly the nucleus, pass into the swelling. After a short time, the bud breaks off to begin an independent life.

BUFFALO The buffalo is a member of the cattle family. It has very short, black hair, and long, heavy horns. Asiatic water buffalo are natives of India and other parts of southern Asia, but have been taken to many other countries to work. They can survive in hot, dry places, but are best suited to hot, wet climates. They like water and spend a lot of time in marshes and muddy pools. They cake themselves with mud for protection from insects, and when the dried mud falls off, it removes ticks from the buffalos' bodies (see TICK). Water buffalo also seem to have an immunity (resistance) to many diseases spread by insects. In tropical climates, therefore, it is a much more effective load-pulling farm animal than the horse. The water buffalo produces as much milk as a cow, but its milk is twice as rich in cream. Buffalo milk and cream are used for expensive dairy products throughout Europe and Asia.

The African buffalo lives throughout Africa south of the Sahara. Since it is exposed to many different climates and diets, it looks different in different parts of the continent. The name *buffalo* is often incorrectly given to the North American bison (see BISON).

BUFFALO

The Asiatic water buffalo is suited to life in hot, humid climates. The buffalo pictured is pulling logs felled in a tropical forest plantation.



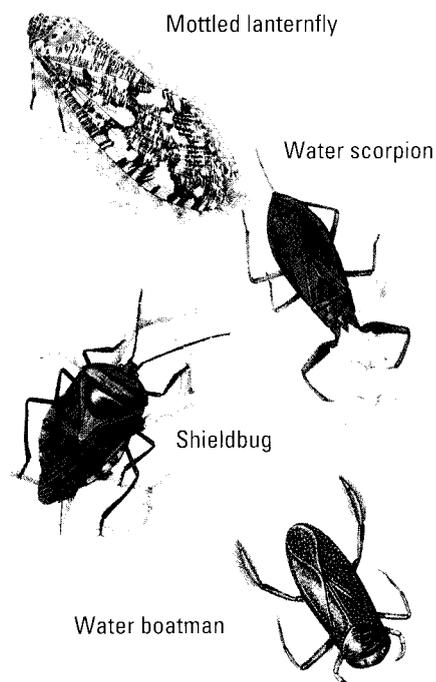
BUG (COMPUTER) A bug is an error in a computer program that makes the program do something unplanned. A program that stops working altogether because of a bug is said to have crashed. Computer programs are so complicated that they are always checked for bugs. Checking and removing errors in software programs is called debugging.

See also COMPUTER; SOFTWARE.

BUG (INSECT) Bugs are insects belonging to the order Hemiptera; most are in the suborder Heteroptera. There are about 80,000 known species of bugs. Bugs have sharp, piercing beaks attached to their heads. They use their beaks to suck juices from plants and animals. Most bugs have two pairs of wings, though a few have no wings. The front wings are often tough and leathery, but always have flimsy tips.

Most bugs are harmless. Some, such as aphids, are a threat to plant life. Bedbugs feed on the blood of animals, especially humans. The word *bug* is commonly but incorrectly used to describe all insects.

See also INSECT.



BUG (INSECT)

The mottled lanternfly is a bug with uniform front wings. The other bugs shown here are heteropteran bugs, with membranous tips on their front wings.

BUILDING CONSTRUCTION

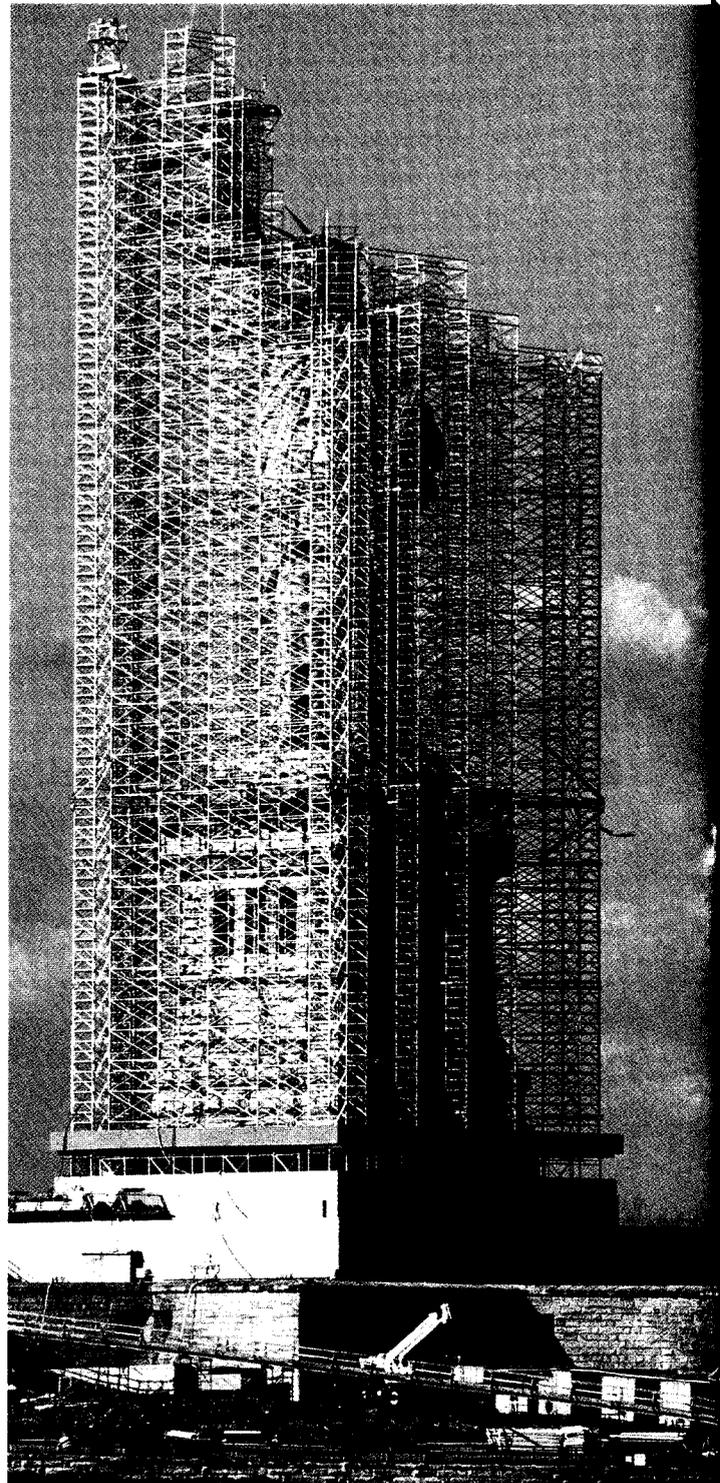
Among the world's largest buildings are the Pentagon, in Washington, D.C., with 5 stories (floors) enclosing almost 4 million sq. ft. [over 340,000 sq. m] of area, and Chicago's Sears Tower, with 110 stories reaching 1,454 ft. [443 m] in height. Both of these differently shaped structures were built using similar methods of modern building construction.

Two types of construction are commonly used: load-bearing wall construction and curtain wall construction. Load-bearing walls are heavy walls on which beams are rested to carry the load of the floor above. The taller the building, the heavier and thicker the walls have to be. Most of the buildings put up before the 1900s were of this type. If you visit an old castle or an old church, you can see that the base of the walls, which rest on the foundation, are sometimes 30 ft. [9 m] thick.

Curtain walls are used with a steel skeleton construction principle. A strong framework is made of steel girders and beams welded and riveted together. The floors and outside walls are hung on this framework. This method of construction is used in modern skyscrapers. It would be almost impossible to build a skyscraper using load-bearing walls. If the building were 30 stories tall, the load-bearing walls would have to be about 100 ft. [30 m] thick at the base. Until curtain wall construction was developed, buildings of more than 6 or 7 stories were rare.

The first step in construction is to test the soil to find out what type of foundation can be built. A foundation is then designed for the type of building and the weight the ground can bear. The structure of the building above the foundation is designed to carry the building loads and be safe. Several types of loads must be taken into account. The dead load is the weight of the building itself. The live load is the weight of furniture, equipment, stored materials, and the people who will occupy the building. Other types of loads also have to be considered, such as wind load, snow load, and possibly the force of earthquakes.

The structure of the building includes the beams,



RESTORATION WORK

The Statue of Liberty (above), one of the world's most famous statues, stands in the entrance to New York Harbor. The whole structure, including its base, rises to 306 ft. 8 in. [93.5 m]. The figure itself is 152 ft. 2 in. [46.4 m] tall. It was originally made from copper sheets fixed to an iron frame. The statue is seen here during restoration work undertaken between 1983 and 1986 when the rusted iron frame was replaced by one made from stainless steel.

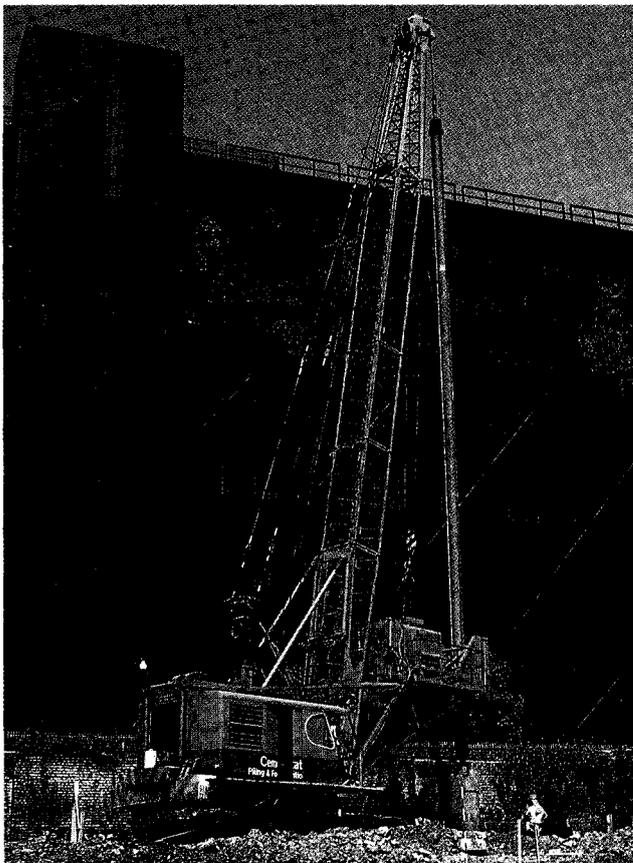
MODERN BUILDINGS

A modern building is built around a steel skeleton, which bears the weight of the building. A wide variety of materials, from traditional stone and brick to aluminum or plastic, is used for covering the skeleton.



FOUNDATIONS

The construction of a modern building begins with its foundations. Long piles are driven deep into the ground to provide a firm base for the building.



girders, and columns. They can be made of wood, steel, or reinforced concrete. Beams and girders run horizontally in the framework of the skeleton. Columns are heavy vertical parts that carry the load of the beams and girders. Triangular supports between beams or girders are called trusses. Some parts of the structure carry no loads, such as the roof, the inside walls, windows, doors, stairs, elevators, and other equipment.

A method of construction called prefabrication is commonly used in modern buildings. Prefabricated parts are made in factories and then shipped to the place where the building is being put up. Many types of building sections can be prefabricated, such as walls for houses and arches for churches and gymnasiums. Concrete beams, walls, floors, and roofs can be precast (see CASTING). Modular construction is a process used in prefabrication. In modular construction, a standard measurement is used as the basis of all building materials. This unit size, or module, is 4 in. [10 cm].

BULB AND CORM Bulbs and corms are underground plant parts that are filled with stored food. They are characteristic of many monocotyledons (see MONOCOTYLEDON). Although similar in appearance and function, bulbs differ from corms.

A bulb is a dense cluster of scaly, food-filled leaves surrounding a bud. This bud develops into a shoot, flower, and leaves. Roots grow down from the bulb to absorb water.

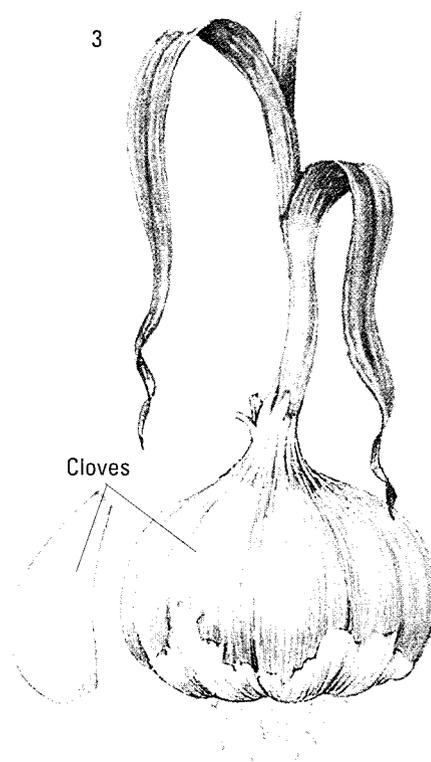
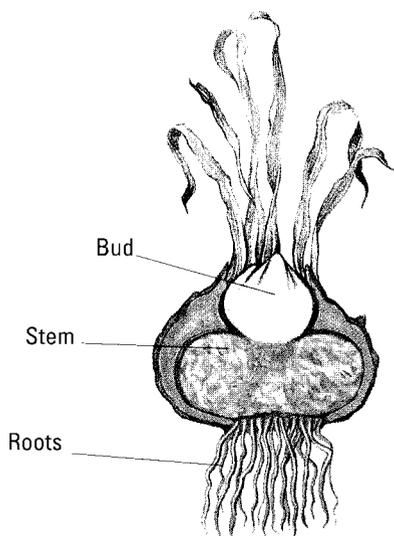
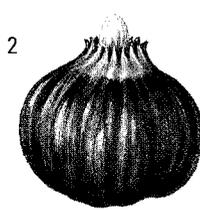
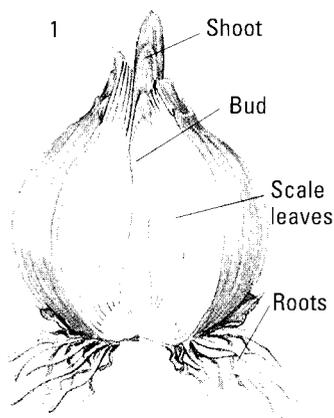
Most bulbs begin to grow in the spring. At that time, the stored food is used rapidly as the shoot grows, producing leaves and flowers. These new leaves produce food, which goes back down to the bulb. New scaly leaves then form around a new bud. This process is repeated every year. Some common bulb-forming plants are the tulip, onion, and lily.

A corm stores food in a ball-shaped, underground stem instead of in scaly leaves. There is a bud on top of it. When the bud begins to grow, it uses the stored food to produce the new shoot, flower, and leaves. Food produced in the leaves goes down to

the base and forms a new corm on top of the old shriveled one. At the same time, special roots pull the corm deeper into the soil. This process brings the new corm down to the right depth. Gladiolus and crocus are the best-known corm-producing plants.

BULIMIA (byōō līm'ē ə) Bulimia is an eating disorder in which overeating in secret after a period of self-deprivation is followed by self-induced vomiting. This cycle is referred to as binge and purge. Bulimia most often occurs in females who are adolescents or young adults and have a very low opinion of themselves (low self-esteem). Bulimia is less common in males but often more severe in them.

The bulimic knows that the way she eats is not normal but cannot control it. Bulimics like to binge on food that is sweet and high in calories, such as candies, cookies, and ice cream. Bulimics are usually more socially withdrawn than those suffering from anorexia nervosa. Anorexia nervosa is



BULB AND CORM

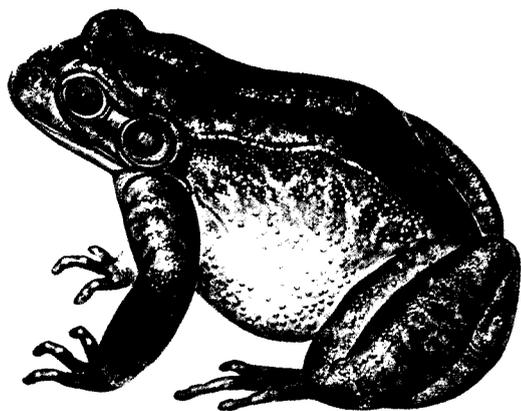
(1) The scales of a bulb in early spring are packed with food. By the time the flowers open, the scales are thin and empty. (2) Corms store food in swollen stems instead of in swollen scale leaves. (3) Garlic bulbs consist of several small sections, called cloves, each of which can grow into a new bulb.

another eating disorder that involves self-starvation (see ANOREXIA NERVOSA). However, bulimia can occur along with anorexia nervosa.

Unlike those who suffer from anorexia nervosa, the bulimic's weight remains about normal because she does eat regular meals, but binges and purges at other times. However, the bulimic is still undernourished because, as she vomits, she gets rid of nutrients derived from previous meals as well as food just eaten. Repeated vomiting can also cause dehydration, inflammation of the esophagus and larynx, and changes in body chemistry. The changes in body chemistry can cause muscle spasms and weakness.

Treatment, which centers on breaking the binge-purge cycle, involves psychological therapy to improve self-esteem. During therapy, the bulimic learns how to change her behavior and develops a healthy body image. Treatment may include antidepressant drugs. Symptoms of bulimia may recur over the years.

BULLFROG The bullfrog is the largest frog of North America. It grows to a length of 8 in. [20 cm]. The bullfrog is found throughout the eastern and central United States. It is usually green with dark spots. The skin of a bullfrog is "slimy" because it is covered with mucus to prevent it from drying out. The bullfrog usually eats insects, which it catches with its long tongue. However, it also eats fish, snakes, and other frogs. The croak of the

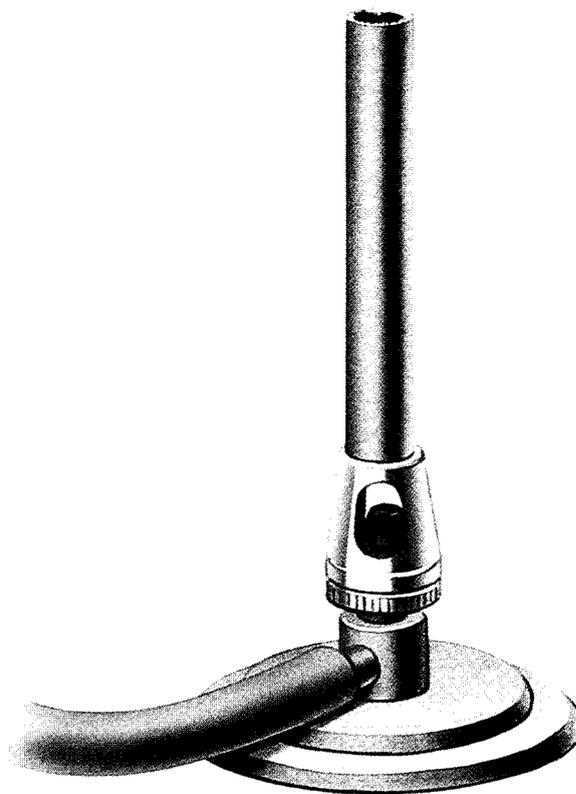


BULLFROG

The frog's long, muscle-packed back legs are very powerful and well-designed for both jumping and swimming.

bullfrog is deep and loud. It is often heard at night. The bullfrog is an amphibian and lives in or near water (see AMPHIBIAN). It belongs to the family Ranidae.

BUNSEN BURNER The Bunsen burner is a gas burner used in science laboratories to heat substances. The burner is named after Robert Bunsen, a German chemist. The Bunsen burner consists of a metal tube on a stand. A rubber hose connects the metal tube to a gas jet. An adjustable opening at the bottom of the tube controls how much air mixes with the gas. Gas mixes with air before burning, allowing the Bunsen burner to produce a flame without smoke. This type of flame is hot and clear, with a blue cone in the middle. The hottest point is just above this cone. Reducing the amount of air makes the flame orange and smoky, producing less heat. The Bunsen burner has been in wide use since its invention because it gives a very hot flame and is simple and inexpensive.



BUNSEN BURNER

The Bunsen burner produces a steady, smokeless gas flame for scientific experiments. It was named for the German chemist Robert Bunsen, who invented the burner in 1855.

BUOYANCY

Buoyancy (boi'ən sē) is the tendency of an object that is immersed in a fluid (a liquid or a gas) to rise. All liquids and gases exert an upward force, which partly opposes the force of gravity (see GRAVITY).

When an object is placed in a fluid, it displaces (pushes aside) a certain amount of fluid. The upward force from that displaced fluid is equal to the weight of the displaced fluid. The Greek mathematician Archimedes discovered this principle as it relates to water (see ARCHIMEDES). The principle can also be applied

to gases. Whether this upward force is strong enough to make an immersed object rise depends on the density (mass per volume) of the object (see DENSITY).

In order for an object to rise, the object must have enough volume to displace an amount of liquid or gas that is equal to the object's own weight (see VOLUME). That is, the object must be less dense than the liquid or gas in which it is immersed. For example, a solid steel block that weighs 20,000 lb. [9,072 kg] would sink in water. The volume of the block would not be large enough to displace an amount of water equal to its weight. However, suppose that same 20,000 lb. [9,072 kg] of steel was made into a ship that was large enough to displace an amount of water equal to its weight. The ship would float. Objects, such as ships, float better in salt water, which is the water found in oceans. Salt water is more dense than fresh water, so salt water exerts more of an upward force.

On average, the human body has a density slightly less than that of water, which explains why swimmers can float in water. Some objects, such as submarines, can adjust their density. A submarine becomes more or less dense—allowing it to submerge or rise—by taking water into its tanks or forcing water from its tanks, using compressed gas.

Helium has a density that is less than air, so balloons filled with helium are buoyant.

See also GAS; LIQUID; MASS; WEIGHT.

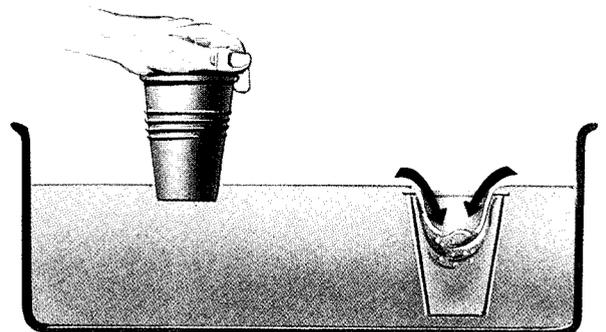
 PROJECT 3, 4, 10



FLOATING

An ocean liner floats because its weight is exactly balanced by the upward force of the water that it displaces.

ACTIVITY *How to test buoyancy*



Test the buoyancy of a plastic cup in a bowl of water. Hold the cup in its normal position, with its mouth upwards. Notice that you have to press down quite hard to push the cup into the water. The water pushes up with a force equal to the weight of the water that the cup is pushing out of the way. When the rim goes under the surface, the cup fills with water. You can feel the upward buoyancy force decreasing and becoming almost nothing. When the cup is completely under water, only a small volume of water is displaced, which is equal to the volume of the thin material of the cup.

BURBANK, LUTHER (1849–1926) Luther Burbank was an American scientist who became famous for his work in plant breeding. During his more than fifty years of work in horticulture, Burbank developed hundreds of varieties of trees, fruits, vegetables, flowers, grains, and grasses. Many of these plants were new creations formed by cross-breeding or hybridization. Others were greatly improved forms of already existing plant life. Burbank's first important product was the Burbank potato. He later developed a spineless cactus for feeding cattle, an almost transparent blackberry, and a daisy that is a combination of American, European, and Japanese varieties.

Burbank produced new and improved plant forms by means of breeding (see BREEDING). For example, Burbank created a new fruit called a plumcot by cross-breeding an apricot and a plum. Burbank grew thousands of the same kind of plant to obtain one or a few plants to breed.

As a boy in Lancaster, Massachusetts, Burbank worked at gardening. At the age of nineteen, he read a book by Charles Darwin called *Variation of Animals and Plants Under Domestication*. This book sparked his interest in experimenting with plant life. He bought a small farm two years later near Lunenburg, Massachusetts, where his scientific career began. In 1875, Burbank moved to Santa Rosa, California, where he set up another experimental farm and lived out the rest of his life. His experiments with plums and prunes led to important improvements in the way farmers grow these fruits today.

See also HORTICULTURE.

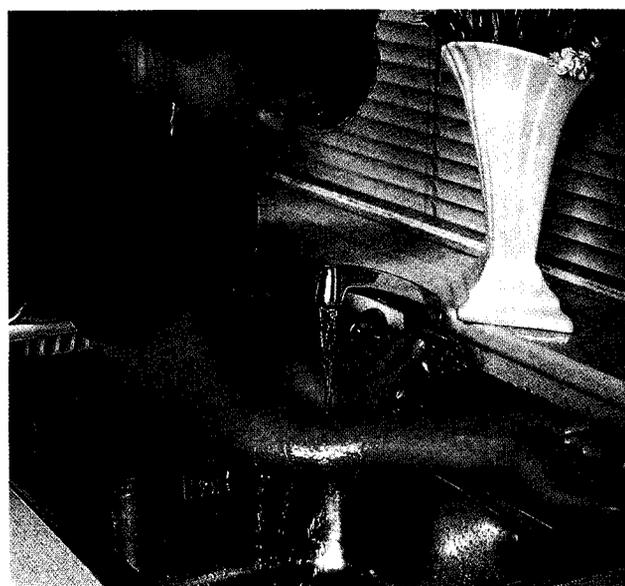
BURN A burn is an injury to the skin or mucous membrane that results from being exposed to fire, heat, caustic substances, radiation, or electricity (see CAUSTIC; ELECTRICITY; FIRE; RADIATION). Inhaling hot air or smoke may produce burns to the respiratory system (see RESPIRATORY SYSTEM). A burn caused by a hot liquid or steam is called a scald.

Burns are grouped according to the level of injury to the skin (see SKIN). A burn that affects only the top layer of the skin, the epidermis, is called a

first-degree burn. The skin reddens, but there are no blisters, and the skin remains unbroken. A first-degree burn is painful but heals without scarring. Common causes of first-degree burns are moderate overexposure to the sun and physical contact with hot objects, such as a hot pan. First-degree burns do not usually need medical treatment. Cold water or ice may be applied to ease the pain. If necessary, dry, sterile gauze can be applied to act as a cushion between the burn and clothing that might irritate it.

A second-degree burn causes damage to deeper layers of the skin. Deep reddening of the skin occurs, and blisters develop. A blister occurs because capillaries in the skin are damaged, allowing body fluid to escape from them (see CAPILLARY). This fluid pushes the epidermis upward, causing a blister. Swelling occurs over several days. Second-degree burns can result from extreme overexposure to the sun, physical contact with hot liquids, or from exposure to radioactive particles.

Second-degree burns without open blisters should be treated by dipping the burned area in cold water until the pain lessens. Clean cloths should be used to blot the burned area dry. Blisters should not be broken, and skin tissue should not be removed. Dry, sterile gauze should be applied to all second-degree burns. All but the most minor second-degree burns need medical attention.



BURN

Good first-aid treatment for a burn is to hold it under cold running water.

Third-degree burns are the most severe type of burn. Third-degree burns look white, but charred. A third-degree burn reaches the deepest layer of the skin or even the underlying muscle tissue. Such a burn can result from exposure to fire or electricity. However, the victim may have no feeling in the burned area because the nerve endings in the skin have been destroyed. The victim may also experience shock. Shock is a serious state of collapse that happens when the body overreacts to an injury (see SHOCK). Third-degree burns should not be rinsed in cold water or be touched. Clothing that has come in contact with the burn should be removed only by a medical doctor. Third-degree burns require immediate medical attention, and need new skin to be surgically placed over them (grafting) to heal.

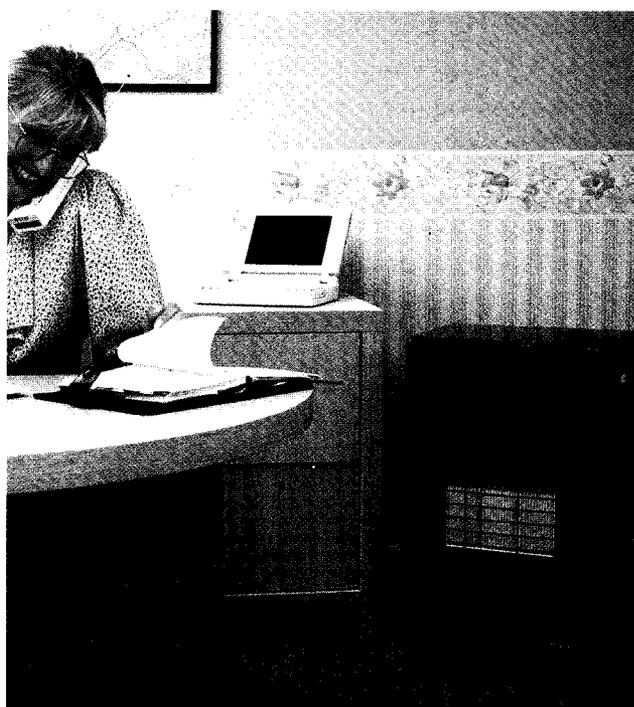
BUS A bus is a set of electrical connections that link different parts of a computer. There are three kinds or types of buses. The data bus carries data. The address bus carries information about where data is stored in the computer's memory. The control bus carries timing and control signals. These interconnections are called buses because, in early computers, they were solid metal bars called bus-bars. In modern computers they are thin strips of copper on a circuit board.

See also COMPUTER.

BUTANE Butane (C_4H_{10}) is a colorless, flammable gas. Butane is found in natural gas and petroleum. Under pressure, butane may easily turn into a liquid. A mixture of liquefied butane is called liquefied petroleum gas, or LPG, and is a fuel used in industry, trucks, and some homes. Butane is sometimes added to increase the evaporation rate of gasoline in cold climates. Isobutane, a form of butane, is used to make high-octane gasolines (see GASOLINE). Butane is also used to make synthetic rubber.

In its normal state, butane has a boiling point of $31.1^\circ F$ [$-0.5^\circ C$]. Butane is one of the hydrocarbons. The carbon atoms in a butane molecule may be arranged in two different forms, or isomers.

See also HYDROCARBON; ISOMER.



BUTANE

Butane is supplied in pressurized cylinders for use as a fuel in indoor appliances such as heaters and stoves. It is also a raw material used in the manufacture of synthetic rubber.

BUTTER Butter is the fat obtained from milk. Butter is often used as a spread on bread, muffins, and other baked goods. Butter is also used widely in frying and baking.

In some parts of the world, people also use butter for skin cream, hair dressing, and medicine. High in the Himalaya mountains, where the weather is always cold and the butter does not melt, it is even used to make statues.

In North America, almost all butter is made from cows' milk. In other parts of the world, however, butter is often made from the milk of such animals as the camel, llama, reindeer, sheep, water buffalo, yak, and zebu.

Butter usually contains between 80 and 85 percent fat. The rest is mostly water. Because its fat content is so high, butter is a source of energy. It is also a rich source of vitamin A. In addition, butter contains phosphorus, calcium, and vitamins D and E. However, butter also contains cholesterol, a fatty substance that contributes to some kinds of heart disease.

See also CHOLESTEROL; DIET; HEART DISEASE; MILK; NUTRITION.

BUTTERCUP The buttercup is a bright yellow wildflower that grows throughout the United States and in other countries with temperate climates. Its name comes from the way its five shiny, yellow petals form a cup-shaped flower. There are several species and, like other members of the crowfoot family, most of them have leaves divided into three parts that look like a bird's foot (see CROWFOOT FAMILY).

Buttercups are found in woods and fields during the spring and summer. They may grow as tall as 4 ft. [1.2 m]. Animals do not eat the buttercup plant because of its bitter, burning juice. For this reason, farmers consider the buttercup a weed. The various buttercup species include the creeping buttercup, swamp buttercup, meadow crowfoot, bulbous buttercup, and grassy buttercup.



BUTTERCUP

The buttercup's shiny petals enclose a large number of yellow stamens that produce pollen.

BUTTERFLY AND MOTH Butterflies and moths are insects belonging to the order Lepidoptera, meaning "scale wings." Their wings are covered with thousands of tiny, colored scales. These scales are very fragile and rub off like dust if touched. Butterflies and moths live throughout the world, wherever there are plants. These insects vary greatly in size and coloration. A few species travel in groups and may migrate thousands of miles to avoid the winter cold. There are nearly ninety

families of Lepidoptera. Butterflies make up twelve families; moths make up the rest. Skippers are a type of butterfly with mothlike features, such as short fuzzy bodies.

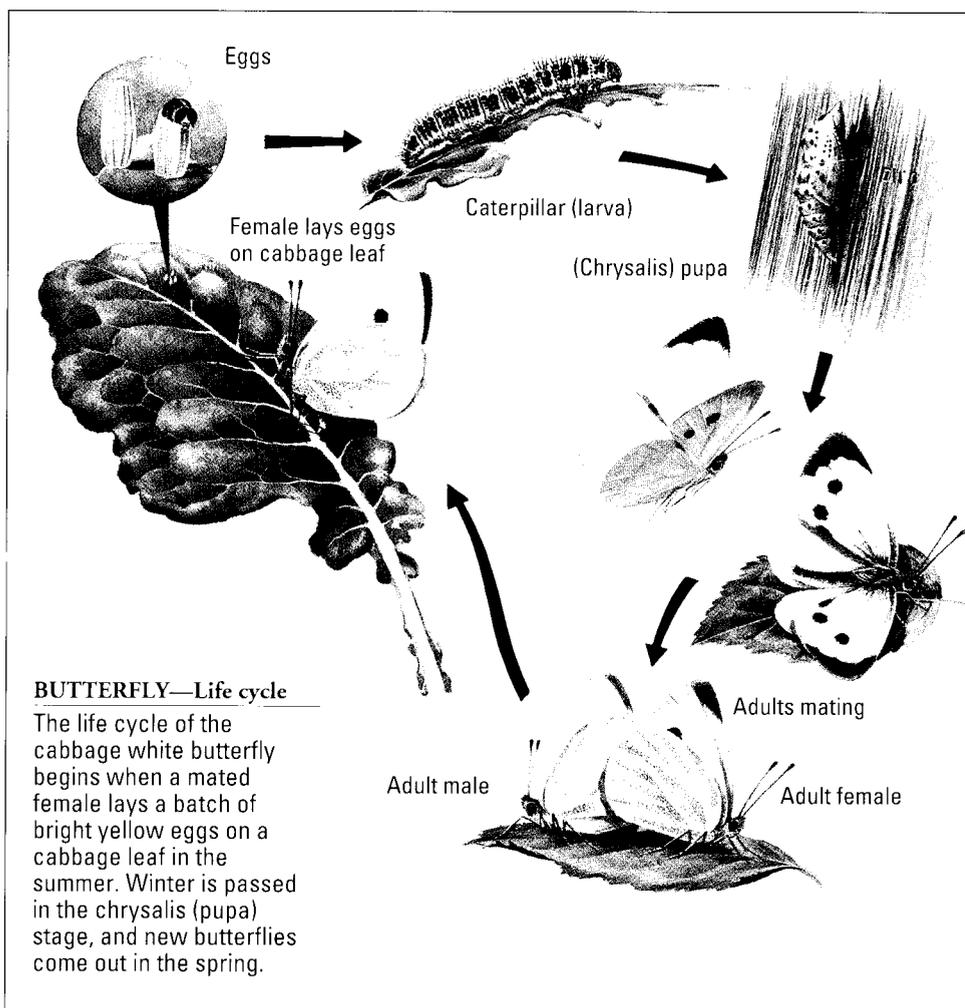
Body structure Both butterflies and moths have three body sections: the head, thorax, and abdomen (see ABDOMEN; THORAX). The head has two compound eyes and a pair of antennae (see ANTENNAE). The antennae are used as "feelers" to "smell" flowers and to "hear" sounds. Butterflies and moths "taste" plants with their legs, however. Then the female can choose the right plant on which to lay her eggs. The mouth has no jaws and cannot be used for chewing. Instead, there is a proboscis, or coiled tubelike tongue, which can be thrust into a flower to suck out the nectar. While feeding, butterflies and moths transfer pollen from flower to flower (see POLLINATION).

The thorax has three segments, each of which has a pair of legs. The front legs are sometimes small and useless. The other legs are weak and are rarely used for walking. The front wings are attached to the middle segment. The rear wings are attached to the third segment. The wings are fragile, yet strong enough to stand the pressures of flight. The veins in the wing are not only for support, but often have blood, nerves, and air tubes within them.

The abdomen usually has ten segments, the last few of which are modified for reproduction. Most segments have a pair of spiracles (openings) for breathing. The abdomen frequently puts out scents to attract mates.

Life cycle Butterflies and moths undergo complete metamorphosis. Their four stages of development are egg, larva, pupa, and adult (see LARVA; METAMORPHOSIS; PUPA). The female may lay more than a thousand eggs on the undersides of leaves or on other substances that can serve as a food source for the larvae. These eggs usually hatch in a few days but may take as long as eight months. An egg produces a larva, or caterpillar (see CATERPILLAR).

The larva has twelve segments. It eats, grows, and sheds its skin by molting. Then it eats and grows some more. This process is repeated several times



BUTTERFLY AND MOTH
 A swallowtail butterfly is shown at the top and an atlas silk moth below it. Notice the knobbed feelers of the butterfly and the feathery feelers of the moth. Many moths also have very hairy bodies. They are often much plumper than butterflies.

before the caterpillar enters the pupal stage. In this way, caterpillars can cause extensive damage to crops and other plants. The larvae of some moths eat wool and other fabrics, causing damage to clothes and rugs.

The pupa forms within the skin of the caterpillar. It splits the skin and grabs onto a silk “button,” which the caterpillar had deposited earlier. A shell forms around the pupa, which is called a chrysalis (see **CHRYSA LIS**). The caterpillar begins to change into an adult. The pupa moves very little, if at all, during this time. Many moths, and a few butterflies, spin a silklike cocoon around themselves in the pupal stage (see **COCOON**). The pupa takes from ten days to eight months to become an adult.

Once the adult has been formed, a fluid is given off to dissolve the chrysalis or cocoon. About ten minutes later, the adult emerges and

ACTIVITY *Watch butterflies feeding*

Watch butterflies on flowers to see how they uncoil their slender, hairlike tongues and push them into the flowers to suck out the nectar. Look also for the little knobs on the ends of their antennae. Most moths have feathery antennae.

starts to flex its wings and legs. Within thirty minutes, the adult is ready to fly. The adult does not grow any larger.

Enemies Butterflies and moths have many natural enemies. Flies and wasps lay their eggs on the caterpillars. When the eggs hatch, the fly or wasp larvae feed on the caterpillars. Some insects, spiders, birds, frogs, and lizards also feed on caterpillars and adults. Since butterflies and moths are unable to defend themselves, they seek protection by hiding or moving away from trouble. Many have protective coloration for camouflage. Others have bitter or poisonous body fluids and are equipped with warning coloration (see MIMICRY; PROTECTIVE COLORATION; WARNING COLORATION).

Differences between butterflies and moths Although there are several general differences between butterflies and moths, these differences do not apply to all species. Butterflies have antennae that end in a knob or club. Moths have featherlike or hairlike antennae tapering to points. Most butterflies fly only during the day; most moths fly at night (see NOCTURNAL BEHAVIOR). Most butterflies rest with their wings folded up over their bodies; many moths rest with their wings flat at their sides.

See also INSECT.

BUZZARD Although there is no bird in North America with the name *buzzard*, the name is often used for any large bird of prey. North American vultures are often nicknamed buzzards. Some of the birds that Americans call hawks are called buzzards in Europe and Africa.

See also HAWK; VULTURE.

BYRD, RICHARD E. (1888–1957) Rear Admiral Richard E. Byrd, U.S. Navy, was an Arctic and Antarctic explorer and aviator. He did more than any other person to open the frozen continent of Antarctica for exploration.

In 1925, Byrd commanded the airplane flights of the MacMillan Arctic Expedition over Greenland

and Ellesmere Island. On May 9, 1926, Byrd and Floyd Bennett became the first people to fly over the North Pole.

In 1928, Byrd led an expedition to Antarctica. A base camp called “Little America” was established on the Ross Ice Shelf. On November 28 and 29, 1929, Byrd and his chief assistant, Bernt Balchen, became the first people to fly over the South Pole. Byrd took another expedition to Antarctica in 1933. A new base camp was built. For two years, scientists on the expedition studied weather, meteors, cosmic rays, and geography. Byrd manned an advance camp by himself most of one winter. He wrote about his experiences in a book titled *Alone* (1938).

In 1939, Byrd led the U.S. Antarctic Service Expedition. A huge new base camp, “Little America III,” was built. Five major explorations were started. World War II (1939–1945) forced the expedition to cease operations in 1941. After service in World War II, Byrd led another expedition from 1946 through 1947. It was called “Operation High Jump,” and it involved 13 ships and 4,700 people. Extensive mapping of unexplored areas was done. Byrd flew over the South Pole again on February 16, 1947.

Byrd visited Antarctica again in 1956 through 1957. He watched the building of “Little America V,” the newest base camp, and flew over the pole for a third time.

In 1957, when Byrd was almost seventy years old, he directed the Antarctica activities during the International Geophysical Year.

BYTE (bīt) A byte is a group of eight binary digits, or bits, used by computers to process data (see BIT). Each bit may be a zero or a one. 10011101 is an example of a byte. Each eight-digit number that makes up a byte represents a letter, number, or symbol. A universal code is used to convert each letter, number, or symbol into a byte. The code is called the American Standard Code for Information Interchange, or ASCII (ăś'kē). The size of a computer's memory is usually measured in kilobytes (1,024 bytes) or megabytes (one million bytes).

See also COMPUTER.

C

CABBAGE Cabbage is a member of the brassica family. Its leaves are tightly packed to form a head. This vegetable is grown throughout the United States, Europe, and Asia. It is a biennial plant that can be harvested in the first year for its large, edible head or in the second year for its seeds (see BIENNIAL PLANT).

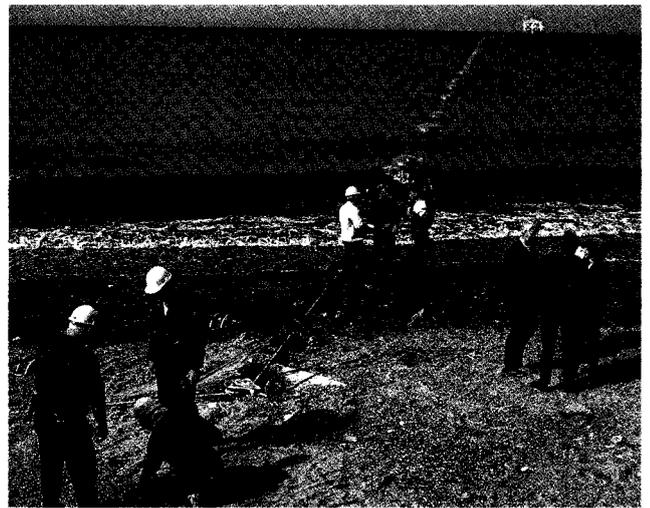
There are three kinds of cabbage. White cabbage has pale green leaves. It is a popular food in the United States. It can be eaten raw in salads or cooked. Red cabbage is similar in taste to white cabbage. Its leaves are reddish purple in color. Both white cabbage and red cabbage can be used to make sauerkraut. Savoy cabbage, which has dark, wrinkled leaves, has a more distinctive flavor than the others. It can also be eaten raw in salads or cooked.

**CABBAGE**

Cabbages store food in their tightly packed leaves. They also provide us with useful vitamins and minerals.

CABLE Cables are strands of fiber or wire bundled together, usually into long lengths. The two basic kinds of cable are structural cable and conductive cable. Structural cables are used to move heavy objects and hold things in place. Conductive cables are used for the transmission of electricity and pulses of light.

Elevators and cranes use structural cables. These cables are usually made of steel. Structural cables

**CABLE**

Electrical power and telecommunications are carried across stretches of water by cables laid on the seabed by cable-laying ships.

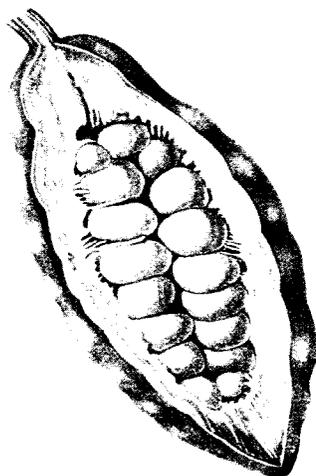
also hold tall radio towers and sailboat masts in place. The large wire or rope cables on tugboats are strong enough to pull the largest ships. Huge suspension bridges hang over rivers from hundreds of cables that are each several inches thick. The famous cable cars of San Francisco, California, are trolleys pulled up steep hills by underground cables.

Unlike structural cable, conductive cable is not used or built solely for strength. Conductive cables are one or more conductors, or carriers, of electricity or light (see CONDUCTION OF ELECTRICITY; FIBER OPTICS). For example, power transmission cables distribute electrical energy from generating stations to homes, businesses, and industries. Also called high-tension lines, power transmission cables conduct thousands of volts of electricity.

Communication cables are used to carry telegraph, telephone, television, and radio signals. These cables provide rapid communication across long distances. Cables that carry electrical power and communication signals are often strung between overland poles or towers. Some are buried beneath the ground in trenches or tunnels or are laid across the bottoms of bodies of water. Today, there are several communication cables along the bottom of the Atlantic Ocean, between Europe and North America. Cables also link North America with Asia, Australia, and South America.

CACAO (kə kă' ō) The cacao is an evergreen tree that produces seeds, called cacao or cocoa beans, that are used to make cocoa and chocolate (see EVERGREEN). The cacao tree is a native of tropical America, but is now grown mainly in West Africa. It may grow as tall as 26 ft. [8 m]. The cacao tree has large, oblong leaves, and pink or yellow flowers that grow directly on the trunk. When the flower dies, it leaves a yellow, cucumber-shaped fruit, or cocoa pod, which contains about thirty seeds. These flattened seeds vary in color from light brown to purple. They are usually about 1 in. [2.5 cm] in diameter.

Cocoa beans are also the source of cocoa butter that is used in candies, medicines, and tanning lotions. At one time, the beans were used as money in Central America.



CACAO

The ripe cocoa beans, seen here in the pod, are dried and roasted before they can be used to make cocoa and chocolate. Cocoa is made from beans that have been crushed to remove most of the oily cocoa butter. Chocolate has extra cocoa butter added to give it a smooth texture.

CACTUS FAMILY The cactus family, Cactaceae, includes more than two thousand species of plants. Most of them are xerophytes. These are plants that can live and grow with a limited water supply. In North America, cacti are found in desert areas of the southwestern United States and in Mexico. The leaves are modified into sharp spines for protection. The leaves do not produce any food for the plant. Photosynthesis, the process by which green plants make food, takes place in the thick, fleshy, green stems (see PHOTOSYNTHESIS; XEROPHYTE). These stems also store water. They have tough, leathery skins to prevent evaporation. The roots extend for great distances

around the cactus plant. Because the roots grow near the surface, they can absorb water from even the smallest rainfall. New branches and flowers grow from the same cushionlike structures that produce the spines. These structures are called areoles. Large, colorful flowers bloom after a rainfall. Many cacti produce edible fruits, some of which are made into jellies and jams.

A familiar type of cactus is the saguaro, or giant cactus, which grows in deserts from Arizona through southern California. The smaller cereus cactus produces fragrant flowers that open only at night. The peyote cactus grows in Texas and New Mexico. It produces a powerful hallucinogenic drug used by certain Indians in religious ceremonies (see HALLUCINOGEN). The famous plant breeder, Luther Burbank, developed a spineless cactus, which is used as a food source for animals (see BURBANK, LUTHER).

Some small varieties of cactus are popular as houseplants. They thrive in the dry, artificial heat that harms most other houseplants. They require little care and regularly produce colorful flowers.

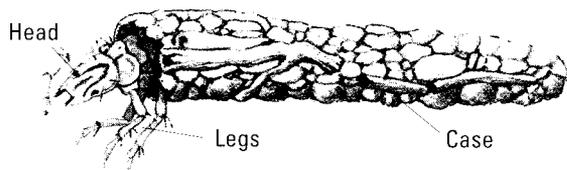


CACTUS FAMILY

Each colorful cactus flower rarely lasts for more than a few hours. Many open in the evening and are dead by morning.

CADDIS FLY A caddis fly is an insect that belongs to the order Trichoptera. There are nearly six thousand species of caddis flies found all over the world. The larvae of caddis flies live in fresh water, and many of them build protective cases to live in. The cases are made of sand, sticks, pebbles, or litter.

Some larvae feed on other small animals, some eat algae, but most eat whatever they can find on the bottom of the stream bed. The larva changes into an adult, flying insect (see **METAMORPHOSIS**). The adult reaches lengths of 0.25 to 1.6 in. [6 to 40 mm]. Caddis flies are covered with fine hairs. Both the larval and adult caddis flies are food for fish such as trout. Fishers often use the insect as bait.



CADDIS FLY

Many caddis fly larvae build silk-lined portable cases. Each kind of caddis larva builds its case in a different design. As the larva grows, it adds more material to the front end of its case.

CAFFEINE (kă fēn') Caffeine is a naturally occurring drug. It is found in such plant products as coffee beans, cacao beans, cola nuts, and tea leaves.

Caffeine is a stimulant—that is, a substance that increases the activity of an organism. Taken in small amounts, caffeine reduces drowsiness, increases the heart rate, and increases urination. In large amounts, caffeine can cause such symptoms as restlessness and sleeplessness, and, in some cases, delirium and heart irregularities. Caffeine is a type of alkaloid, and it is mildly habit-forming. Long-term use of caffeine is not believed to affect a person's mental health. However, a person who stops taking caffeine after long-term use may experience such physical effects as headache and irritability.

See also ADDICTION; ALKALOID; COFFEE; TEA.

CAISSON (kă' sŏn') A caisson is a boxlike or cylindrical structure that provides a dry work area in a body of water. It is lowered through the water

and serves as a station from which workers can build a foundation for a bridge or a building. The caisson is usually built of metal but may be made of concrete and wood.

A box caisson has an open top and a closed bottom. It is floated into position and sunk by filling it with sand or water. An open caisson is open at both ends. Its bottom edges are sharp so they can cut into the earth beneath the water. Both box and open caissons are used in fairly shallow water.

A pneumatic caisson is used in deeper, more difficult waters. It has a lower and an upper section. The lower section is like an open caisson in that it has sharp edges. As a foundation is built in the upper section, the weight forces the lower section into the earth. Compressed air is then forced into the lower section. This forces the water out. The mud and dirt are also removed. In order to keep the water out and to keep the caisson from being crushed by the water pressure, the caisson is filled with air under high pressure.

Workers entering the caisson must do so through a series of chambers called air locks. The air pressure is gradually increased in the air locks until it is the same as in the work area below. Workers leaving the caisson must undergo the reverse process, called decompression, in these air locks. A sudden drop in the air pressure could cause a worker to suffer from caisson disease, or what is known as the bends.

See also CAISSON DISEASE.

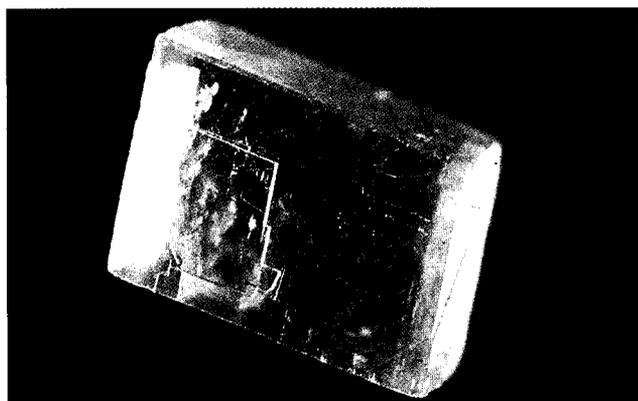
CAISSON DISEASE Caisson disease, or the bends, is a dangerous and painful condition. It can be experienced by deep-sea divers, fliers, and people who work in caissons (see **CAISSON**). As a diver swims down below the water surface, the pressure of the water around him or her increases. A diver breathes air containing nitrogen as well as oxygen (see **DIVING**). Increased water pressure can force the nitrogen to dissolve in the blood. If the diver returns to the surface slowly, the pressure decreases slowly. Then nitrogen can return to the air harmlessly. If the diver surfaces too quickly, however, the rapid decrease in pressure causes some of the dissolved nitrogen to form bubbles in the blood.

These bubbles can block small blood vessels. This causes tingling, followed by pain and loss of muscular control. If it is untreated, caisson disease can cause death.

Caisson disease in divers can be prevented by returning to normal pressure slowly. This is called decompression. In addition, the diver may breathe a combination of oxygen and helium before and during decompression. In severe cases, the diver is put into a sealed pressure unit, or decompression chamber. Here the pressure is increased until the nitrogen bubbles dissolve in the blood again. Then, air pressure in the chamber is decreased slowly until it is equal to the air pressure at sea level. This process takes several hours. In the case of fliers, nitrogen bubbles are formed by ascending too quickly in an unpressurized aircraft. They dissolve on returning to ground level.

CALCITE Calcite (CaCO_3) is a mineral that is the main ingredient of rocks such as chalk, marble, and limestone. Iceland spar, Mexican onyx, and the stalactites and stalagmites in caves are some of the different kinds of calcite. Calcite crystals form shapes with six flat faces. Opposite faces are parallel. Calcite is the most stable form of calcium carbonate at normal temperature and pressure (see CALCIUM CARBONATE).

Iceland spar is a very pure form of calcite. Crystals of Iceland spar are almost clear. They exhibit the property of double refraction. That is, if



CALCITE

Iceland spar is a clear form of calcite. Its crystals have six faces, with opposite faces being parallel. A light ray is split into two when it enters Iceland spar, so objects seen through the crystal appear to be doubled.

a crystal of Iceland spar is placed over a sheet of paper on which a single line has been drawn, the crystal will refract, or bend, the light passing through it—but there will appear to be two parallel lines, instead of one, on the paper. This ability to double refract makes Iceland spar crystals useful in certain optical instruments.

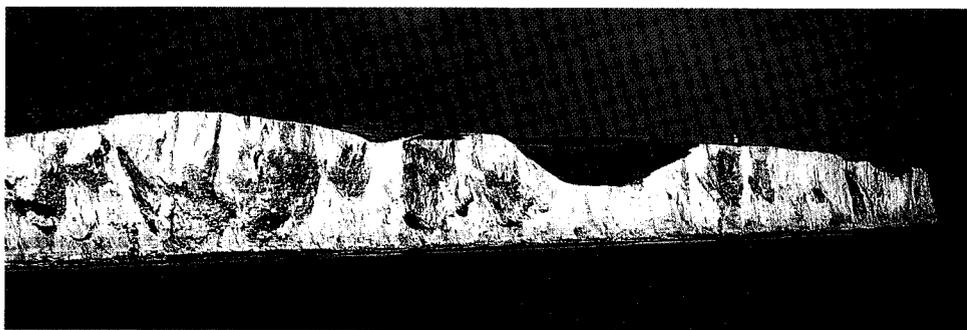
See also CHALK; CRYSTAL; LIMESTONE; MARBLE; REFRACTION OF LIGHT; STALACTITE AND STALAGMITE.

CALCIUM (*kāl'sē əm*) Calcium (Ca) is a silvery white metallic element. It was first discovered in 1808 by Sir Humphry Davy (see DAVY, SIR HUMPHRY; ELEMENT). Three percent of the earth's crust is calcium. Although very common, calcium is always found in nature in the form of compounds, never as a pure metal. Calcium's compounds are found in chalk, limestone, marble, and gypsum. Calcium is also found in the skeletons and shells of living and dead organisms. The metal is obtained by the electrolysis of one of calcium's compounds, calcium chloride (see CHALK; ELECTROLYSIS; GYPSUM; LIMESTONE; MARBLE).

Calcium is necessary to all living things. It is vital for the growth and health of bones and teeth. Calcium also helps the blood to clot and the muscles to contract. The human body gets its calcium from milk, milk products, and green vegetables.

Calcium compounds have many uses. Calcium fluoride is used in steel making. Bleaching powder is a calcium compound. Calcium oxide, or quicklime, is used in making glass and mortar. It is also used in agriculture to enrich the soil. Calcium sulfate is better known as plaster of Paris (see PLASTER OF PARIS). Acetylene is made by adding water to calcium carbide (see ACETYLENE). Calcium phosphate is used to make fertilizers. The main use of calcium metal is in alloys (see ALLOY). Calcium melts at 1,542°F [839°C]. It boils at 2,703°F [1,484°C]. Its relative density is 1.5 (see RELATIVE DENSITY). Calcium belongs to the group of elements called the alkaline earth metals. Its atomic number is 20. Its relative atomic mass is 40.08.

See also ALKALINE EARTH METAL; CALCIUM CARBONATE; CALCIUM CHLORIDE.

**CALCIUM CARBONATE**

The famous White Cliffs of Dover, on the south coast of England, are made mostly of chalk, a common mineral form of calcium carbonate.

CALCIUM CARBONATE Calcium carbonate (CaCO_3) is a white mineral found in many forms. Calcite is the most stable form of calcium carbonate at normal temperature and pressure (see **CALCITE**). Calcium carbonate dissolves slightly in water containing carbon dioxide. In this solution, the mineral forms calcium bicarbonate (see **SOLUTION AND SOLUBILITY**). When calcium carbonate is heated, it loses carbon dioxide and forms quicklime.

Calcium carbonate is used in making tooth powders and toothpastes. It is also used in white paint and in cleaning powders. In industry, it is a source of calcium and carbon dioxide.

See also **CALCIUM**; **MINERAL**.

CALCIUM CHLORIDE Calcium chloride (CaCl_2) is a salt found in many bodies of water. It is also a by-product of several industrial processes. Calcium chloride is used as a drying agent, bleaching powder, and antifreeze. It is also used in refrigerating solutions and to melt ice on roads.

See also **CALCIUM**.

CALCULATOR Calculators are machines that perform mathematical calculations, such as addition, subtraction, multiplication, and division. Simple calculators, such as the abacus, have been used for thousands of years (see **ABACUS**). A revolution in electronics that occurred in the 1970s led to the development of pocket-sized electronic calculators. Today's calculators allow their users to perform even complex mathematical calculations easily.

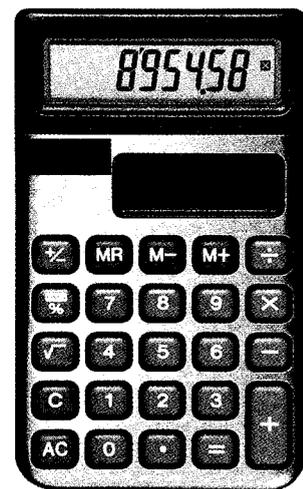
Most calculators include the following parts: a power source, number pad, display, and microprocessor. The power source may be batteries or tiny solar cells (see **BATTERY**; **SOLAR CELL**). The

number pad allows the user to enter information. Each time a key on the number pad is pressed, electrical contacts inside the calculator are closed. This allows electrical signals to be sent to the microprocessor. The display may be made of liquid crystals or light-emitting diodes (see **LCD**; **LED**). Some calculators can also print their results on paper. A microprocessor contains many electronic components on a silicon chip. Microprocessors can be thought of as small computers on a chip (see **CHIP**; **INTEGRATED CIRCUIT**).

The microprocessor performs many functions in a calculator. Its main function is to process information in order to come up with a solution to a mathematical problem. For example, a user may press the following keys on the number pad: $100 \times 500 =$. The microprocessor receives this information, then calculates and displays the answer as 50,000. The microprocessor can also store information while it is still calculating. For example, by pressing a certain key, the user can tell the microprocessor to store one answer as he or she asks it to perform another calculation. Advanced calculators allow the user to plug additional memory units into

CALCULATOR

This solar-powered calculator is driven by electricity produced when light falls on the solar panel below the display.



the calculator. These memory units can store instructions as well as solutions.

See also COMPUTER; ELECTRONICS.

CALCULUS Calculus is a branch of advanced mathematics. It was invented during the 1600s by Sir Isaac Newton and Gottfried Wilhelm von Leibniz. Calculus deals with changing quantities. It is most often associated with graphs of equations that involve curved rather than straight lines. Used in most sciences, calculus is especially important in physics and engineering. Learning calculus requires a knowledge of algebra, geometry, and trigonometry (see ALGEBRA; GEOMETRY; TRIGONOMETRY). There are two kinds of calculus: differential calculus and integral calculus.

Suppose you wanted to know the shape and size to make a pot so that it would hold a quart of water. With knowledge of calculus, you would be able to calculate the dimensions. A bullet fired from a rifle travels with decreasing speed on its route to a target. How much its speed decreases and the effect of other factors on its speed (such as wind, air friction, and the shape of the bullet) are problems that can be solved with calculus.

People's first ideas of mathematical concepts related to those of calculus came from Archimedes, a scientist of ancient Greece (see ARCHIMEDES). His work in geometry and physics led to the invention of calculus almost two thousand years after his death in 212 B.C.

The word *calculus* comes from a Latin word

meaning "pebbles." People once used pebbles to solve mathematical problems.

See also NEWTON, SIR ISAAC.

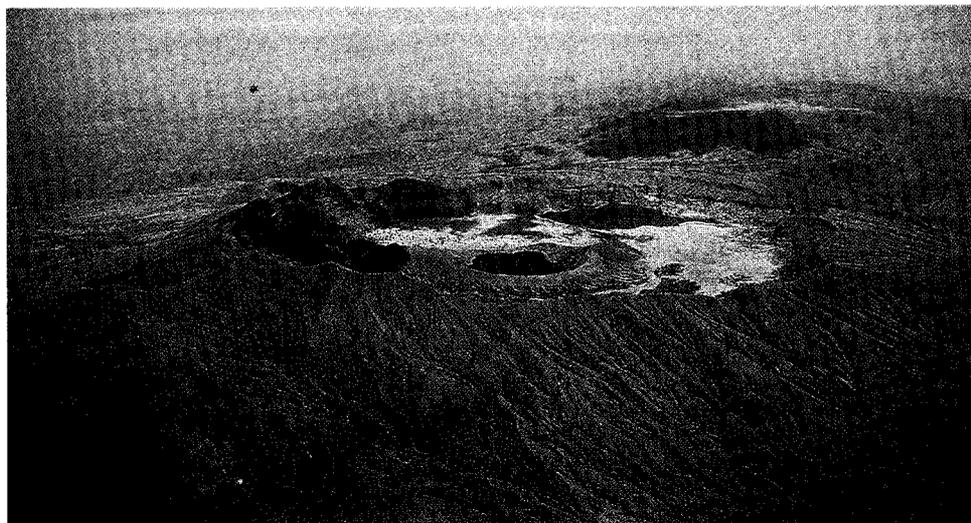
CALDERA A caldera is a bowl-shaped depression in the earth's surface, more than about 3,300 ft. [1 km] in diameter, that is associated with volcanism.

A volcano develops when hot, liquid rock, or magma, from deep underground erupts onto the surface. Often the magma is trapped under the surface and fills a large hollow called a magma chamber. Magma may force its way to the surface by pushing aside rocks that lie in its way. Or magma may reach the surface very quietly by simply flowing out through cracks in the earth or by melting the rocks in its path to the surface. A volcanic eruption may be a very violent explosion or merely a very quiet river of molten rock. When a great deal of magma escapes a chamber, either by eruption or movement to another chamber, the crust overlying the magma chamber may subside, leaving a large hole called a collapse caldera. The volcano may continue to be active, and ordinary craters may form within the caldera (see CRATER). Approximately eighty calderas around the world belong to volcanoes that are still active. Calderas often fill with water to form lakes.

It is also possible for the top of a volcano to be blown off in a single violent explosion to form an explosion caldera, but most calderas are formed by collapse.

CALDERA

The crater of the Jebel Marra volcano in Sudan, Africa, forms a huge caldera. It is the fourth largest volcanic crater in the world.



CALENDAR

The calendar is a system of dividing a year into days, weeks, and months. A calendar was first needed to help early people predict seasonal weather changes that affected their farming and commerce. When it was observed that seasons occur at regular times each year, a simple calendar was developed. When people noticed the relationship between the positions of the stars and the seasons of the year, the accuracy of these calendars improved.

Some ideas are basic to any calendar. *Solar* refers to the sun, and *lunar* refers to the moon. The solar

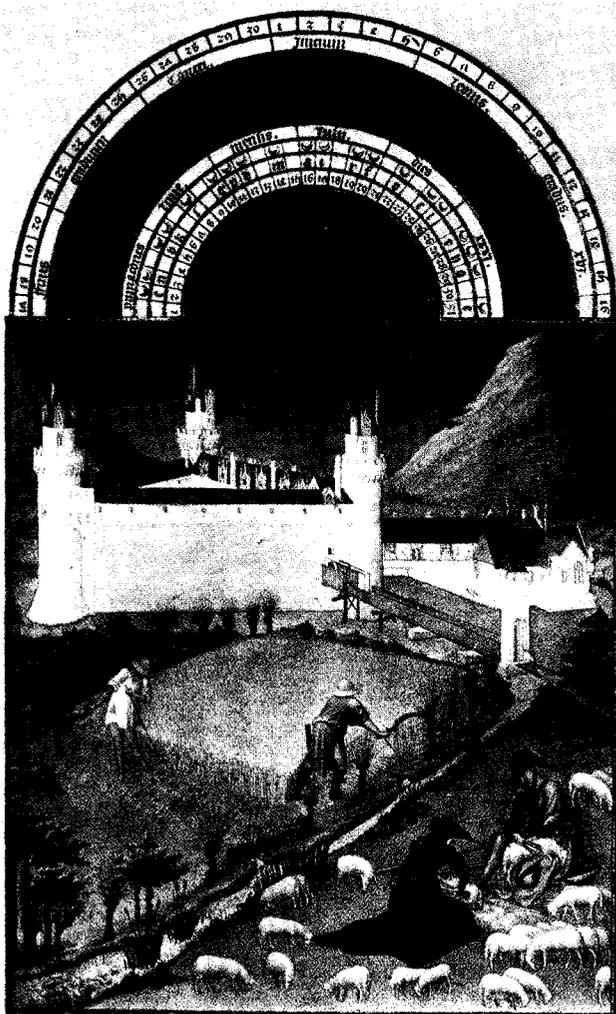
day is the unit of 1 day and 1 night (about 24 hours). The solar year is based on the positions of the stars and a cycle of 4 seasons. It is 365 days, 5 hours, 48 minutes, and 46 seconds long. A lunar month is the time between one full moon and the next, or one new moon and the next, or $29\frac{1}{2}$ days. Since 12 lunar months have 354 days, and 13 lunar months have $383\frac{1}{2}$ days, neither is suitable for a solar year. The 7-day week is a completely artificial arrangement. It was probably based on the superstition that 7 is a number with special powers.

Babylonian calendar This calendar of ancient Babylonia had 12 lunar months of 29 and 30 days alternately. Since this calendar was 11 days shorter than the solar year, an extra month was added 3 times every 8 years. After several years, this calendar became quite inaccurate.

Egyptian calendar This calendar of ancient Egypt was based on a 365-day solar year divided into 12 months of 30 days each. The extra 5 days were added at the end of the year. Because this did not account for the extra $\frac{1}{4}$ day each year, it became inaccurate after several years.

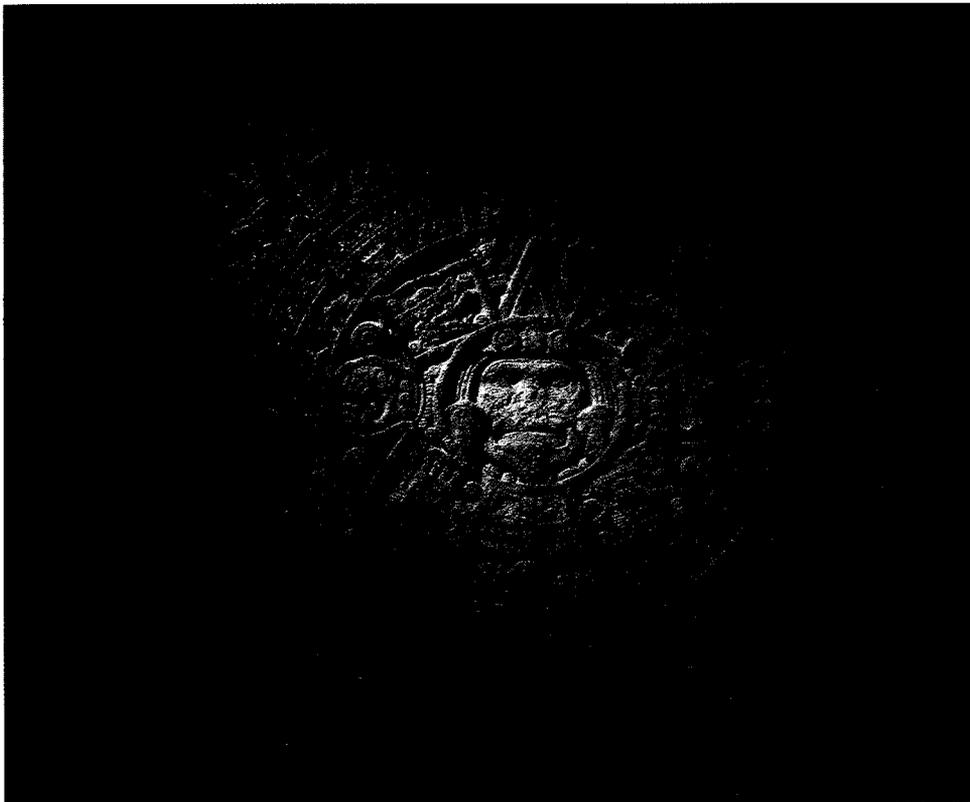
Roman calendar This early calendar of ancient Rome had 10 months and 304 days. The extra 61 days were ignored. Politics soon had an effect on the calendar. Politicians added extra days or months to prolong their time in office or to collect extra taxes.

Julian calendar Based on astronomy, this calendar was started by and named for Julius Caesar, a Roman emperor of the 1st century B.C. It had 12 months of 30 and 31 days alternately. February, however, had 29 days. Every fourth year, a day was added to February. Julius also moved the beginning of the year from March 1 to January 1. In order to adjust the calendar to the seasons, Julius declared that 46 B.C. would have 455 days. He also renamed many of the months. All these changes prompted the Romans to call this the "year of confusion."



MEDIEVAL CALENDAR

This circular French calendar was made in the early 1400s. It has the signs of the zodiac around the outer rim. The calendar shows seasonal activities throughout the year. This picture shows workers harvesting and sheepshearing outside a duke's castle in July.

**AZTEC CALENDAR**

This calendar stone once stood on the platform of the Great Pyramid at Tenochtitlán, Mexico. The symbols surrounding the central mask of Tonatiuh represent the earthquake that the Aztecs believed would end the world.

The Julian calendar was 11 minutes, 14 seconds longer than the actual solar year. This resulted in a gain of 1 day every 128 years.

Gregorian calendar By the 1580s, the Julian calendar was 10 days ahead of the solar year. Pope Gregory XIII dropped 10 days from October in 1582. He also decreed that one day should be added to February every 4 years. However, a “century year” is a leap year only when it can be divided by 400: thus 2000 will be a leap year, but 1900 was not. This calendar is very accurate, gaining only 26.3 seconds each year. The Gregorian calendar is accurate to a day every 3,323 years.

The beginning of the Gregorian calendar was set as the year that Jesus Christ was assumed to have been born. Any years before that date are referred to as *B.C.*, or “before Christ.” Years after that date are referred to as *A.D.*, or “anno Domini” (“in the year of our Lord”). By the 1900s, the Gregorian calendar was in universal use. It is generally considered the standard calendar of modern times.

Religious calendars Several religions have developed calendars that are still in fairly widespread use.

In the United States, the most common of these is the Hebrew calendar. It starts at what is claimed to be the time of creation: 3 months before 3760 B.C. Thus, the year in the Hebrew calendar is the year in the standard calendar plus 3760. The new year begins in the fall. There are 12 months, alternately 29 and 30 days long. Seven times every 19 years an extra 29-day month is added, and 1 extra day is added to 1 month.

The Islamic calendar dates from Muhammad’s flight from Mecca in A.D. 622. It is based on 12 lunar months, alternately 29 and 30 days long. It is 11 days short of the solar year.

Calendar reform Several changes have been suggested for the calendar. All of these have months and years beginning on the same day of the week. In some of them, all months have the same number of days. The thirteen-month calendar proposes 13 months of 28 days each. An additional day would be added at the end of every year. This day would not be given a date—that is, it would not be assigned to a particular month. Every 4 years, a leap-year day would be added. It has been suggested that these days be made worldwide holidays.

CALIBRATION (kāl' ə brā' shən) Calibration involves determining, checking, or adjusting the scale of a measuring instrument. The measuring marks on a thermometer are calibrated in degrees. Rulers are calibrated in inches and feet or in centimeters and millimeters. Automobile speedometers are calibrated in miles per hour, kilometers per hour, or both.

The measuring marks on any instrument must be positioned accurately. The calibration of an instrument is checked against a standard measure, or an accurate copy of a standard measure.

Standard measures are those measurements accepted as standard by all the world's scientists and mathematicians. Some standard measures, such as the kilogram, have an actual physical standard. The weight of a kilogram is the weight of a special cylinder of platinum-iridium alloy kept in the International Bureau of Weights and Measures in Paris, France. The standard meter is defined as the distance that light travels in a vacuum in $1/299,792,458$ of a second. This measurement is known to all scientists and mathematicians. It would be almost impossible to keep it in a physical form.

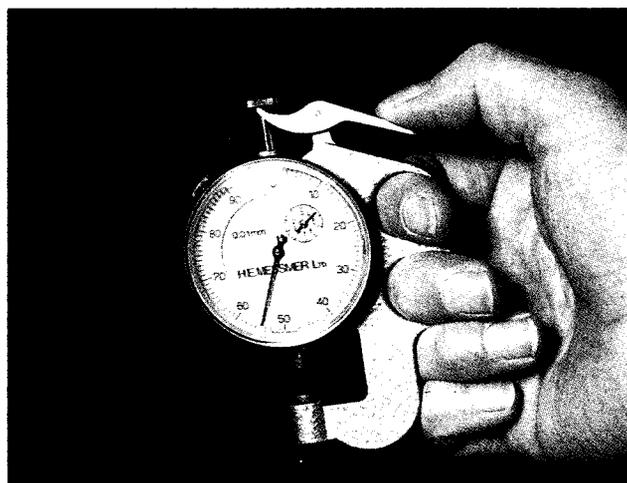
In time measurement, the second is not defined as the particular part of a minute or hour, but by the number of vibrations of certain radiation produced by an atomic clock.

CALIPER, MEASURING A measuring caliper is an instrument used to make certain kinds of small measurements.

Many calipers look like geometry compasses with legs joined at one end. The other ends of the legs are curved inward for an outside caliper and outward for an inside caliper.

An outside caliper can be used to measure the outside diameter of a pipe or the outside dimension of any solid. An inside caliper can measure the inside diameter of a pipe or the inside dimension of any hollow object. A micrometer caliper can make very tiny measurements with great accuracy. Some micrometers are able to measure 0.0001 in. [0.0025 mm].

See also MICROMETER.



CALIPER, MEASURING

This engineer's caliper has a clocklike dial that gives a direct reading of very small measurements.

CALORIE The calorie is a unit used to measure energy. One calorie is the amount of heat needed to raise the temperature of one gram of water by one degree Celsius.

Food scientists use the large calorie, or kilocalorie, to measure the amount of energy in food. One kilocalorie is equal to 1,000 calories. It is usually abbreviated as *kcal*.

The calorie and the kcal are not used as much now as in the past. Scientists prefer the joule. One calorie is equal to 4.2 joules. Like the calorie, the joule is a small unit. Therefore, the kilojoule is often used, especially to measure the energy of food. One kilojoule is equal to 1,000 joules. Therefore, 1 kcal is equal to 4.2 kilojoules (see JOULE).

The term *calorimetry* refers to methods for measuring the amount of heat produced or taken in by some process. Direct calorimetry involves burning. For example, the calorie (or energy) value of a food item can be determined by the amount of heat released when the food is burned in an instrument called a bomb calorimeter.

Indirect calorimetry methods are used in some situations. For example, scientists can measure how many calories a person is expending during a certain activity by measuring how much oxygen is consumed and how much carbon dioxide is produced.

See also BRITISH THERMAL UNIT.

CALYX (kā'lik) The calyx is the outer part of a flower. It is made of leaflike parts called sepals that protect the developing flower bud. The calyx surrounds and protects the bases of the flower petals and the reproductive structures (see FLOWER; PISTIL; SEPAL; STAMEN). Before a flower opens, it is usually completely enclosed in the calyx. As the flower blooms, the calyx separates into the sepals. If the sepals remain joined at their bases, the calyx forms a tube that protects the ovary. Although most flowers have green sepals, some have brightly colored sepals that are easily mistaken for petals. Some flowers have no calyx.

See also PLANT KINGDOM.



CALYX

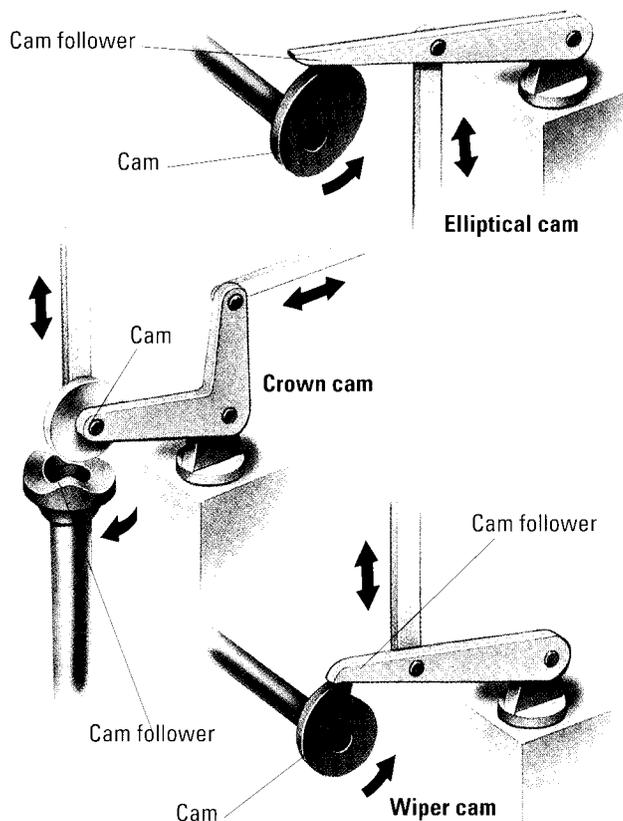
A flower's calyx is made up of several leaflike sepals, which unfold as a flower bud opens. In a few plants, such as this fuchsia, the calyx is even more colorful than the petals.

CAM A cam is a mechanical arrangement that changes motion in one direction to motion in another direction. Cams in a standard automobile engine change the vertical (up and down) motion of the pistons into the rotary (circular) motion of the drive shaft. In a trip hammer, the cam changes the rotary motion of an electric motor shaft into the vertical motion of a fast-moving hammer.

Cams are usually metal disks or cylinders that have irregular shapes, like a circle with a bump or

gouge in its edge or surface. As the cam turns on its shaft, its irregular edge or surface makes contact with another piece of metal. This piece is called the cam follower. It is held against the cam, usually by a spring. Each time the cam turns, the follower is forced to move up or down as it makes contact with the high or low point of the edge of the cam.

Cams come in many shapes and sizes. Some of the most common kinds of cams include the elliptical cam, the crown cam, and the wiper cam.

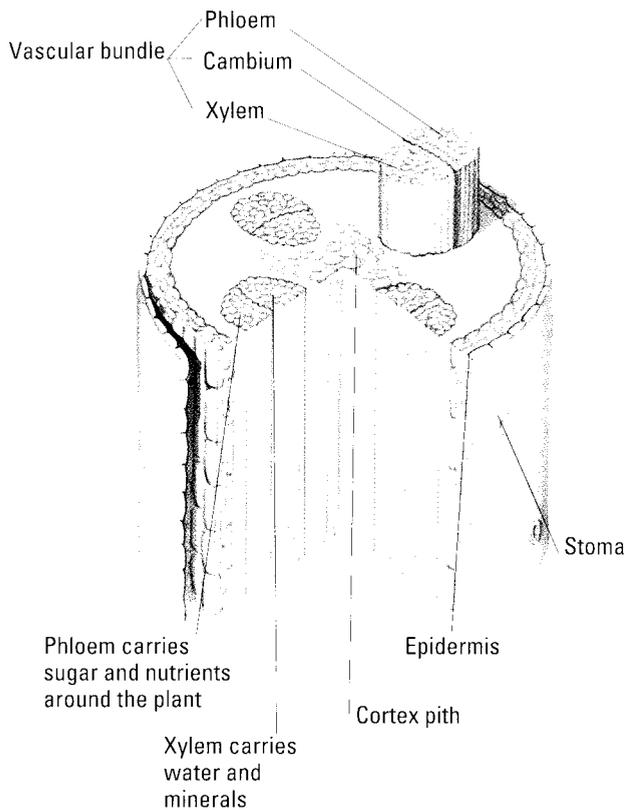


CAM

Cams are very useful devices in mechanical engineering because they change a circular motion into a straight motion, and vice versa. The three types illustrated here are the elliptical, crown, and wiper cam.

CAMBIUM Cambium is a ring of cells in the stems and roots of many vascular plants (see VASCULAR PLANT). The cells of the cambium separate the xylem from the phloem. The xylem is the tissue that carries water and dissolved minerals from the roots to the leaves of the plant (see XYLEM). The phloem is the tissue that carries sugar and other foods produced by photosynthesis from the leaves to all other parts of the plant (see PHLOEM; PHOTOSYNTHESIS).

The cells of the cambium are continually dividing to produce new cells. Those on the inside of the ring turn into xylem, and those on the outside turn into phloem. In a tree trunk, the new xylem forms wood and causes the trunk to get thicker. A new ring of wood is made each year, forming what are called annual rings (see ANNUAL RING). By counting the rings of a tree trunk after the tree has been cut down, a person can tell how old the tree was. Cambium also helps heal wounds that occur when a plant has been injured.



CAMBIUM

The cambium of young stems occurs in small vascular bundles. In older stems, the bundles link up to form complete rings around the stem.

CAMBRIAN PERIOD (kām'brē ən pīr'ē əd)

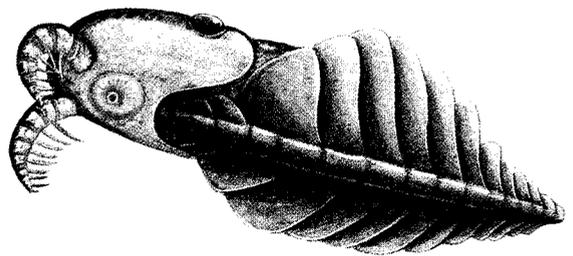
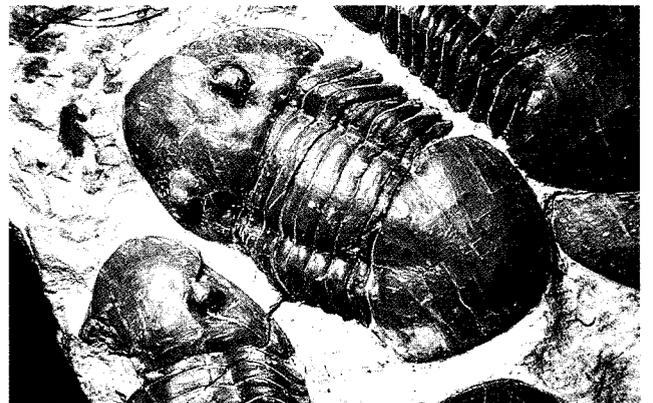
The Cambrian period is a span of about 60 million years in the earth's history. It began 570 million years ago, marking the beginning of the Paleozoic era (see PALEOZOIC ERA). Rocks that formed more than 570 million years ago, or before the Cambrian period began, do not contain many fossils. Called Precambrian rocks, they indicate that plant and animal life that had begun to develop before the

Cambrian period did not have hard parts, shells, or skeletons (see PRECAMBRIAN ROCK). Rocks formed during the Cambrian period are rich in fossils.

During the Cambrian period, the continents were entirely different from what they are now (see CONTINENTAL DRIFT). Sedimentary rocks formed in the seas (see SEDIMENTARY ROCK). When these rocks were pushed up into mountains by pressures from within the earth, the sea waters were pushed aside. The North American mountain ranges that are parallel to the Atlantic and Pacific coastlines were formed during the Cambrian period.

No plant or animal life existed on land during the Cambrian period. However, in the Cambrian seas, many invertebrates with shells or outer skeletons had appeared. (Invertebrates are animals without a backbone or other interior skeleton.) These included brachiopods, mollusks, trilobites, and the earliest forms of coral (see BRACHIPOD; CORAL; MOLLUSCA; TRILOBITE). Geologists use the fossils of trilobites to classify Cambrian rocks.

See also EVOLUTION; FOSSIL; GEOLOGICAL TIME SCALE.



CAMBRIAN PERIOD

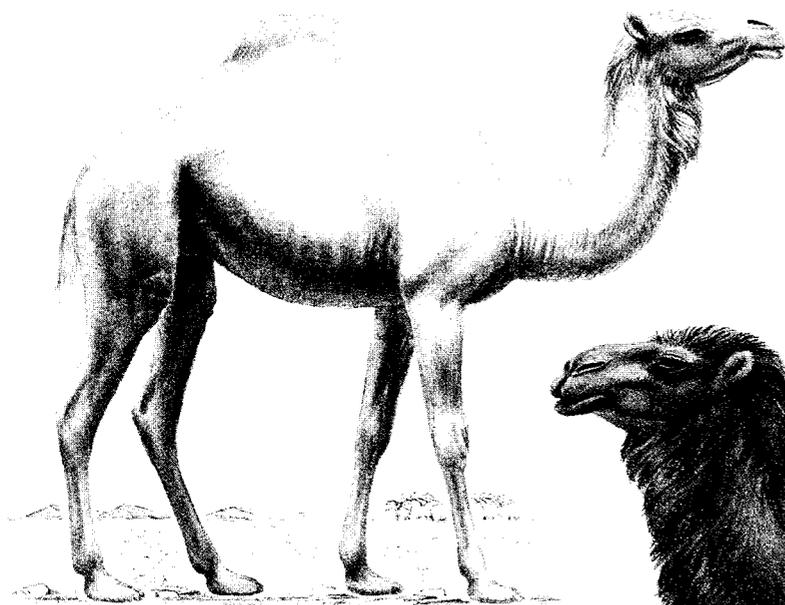
Trilobites (top) were an abundant form of life in the Cambrian period. Their oval bodies had hard, protective outer skeletons, divided into segments. Trilobites ranged from 1/2 in. [1 cm] to over 2 ft. [61 cm] long. *Anomalocaris* (above) was a large predator—an animal that hunts and preys on others.

CAMEL The camel is a large, strong mammal native to Africa and Asia. It may weigh as much as 1,500 lb. [680 kg] and measure 6.6 ft. [2 m] at the shoulder. Both the one-humped Arabian camel and the two-humped Bactrian camel store large amounts of fat in their humps. The fat is used by the camel's body when food is scarce. The humps do not contain water. A camel can go without water for days or even months. This is partly because it gets some moisture from its food and partly because it keeps most of the water it has in its body rather than losing it by excessive sweating or urinating. This ability to go without water helps make camels ideally suited to the desert. In addition, the camel's two-toed feet have broad pads that spread out, allowing the animal to walk or run on sand with little difficulty. The eyes of all camels have three eyelids. The innermost lid wipes sand and dust off the eyeball. The other two lids have long

lashes, which keep out most of the blowing dust and sand. The lashes also provide protection from the sun.

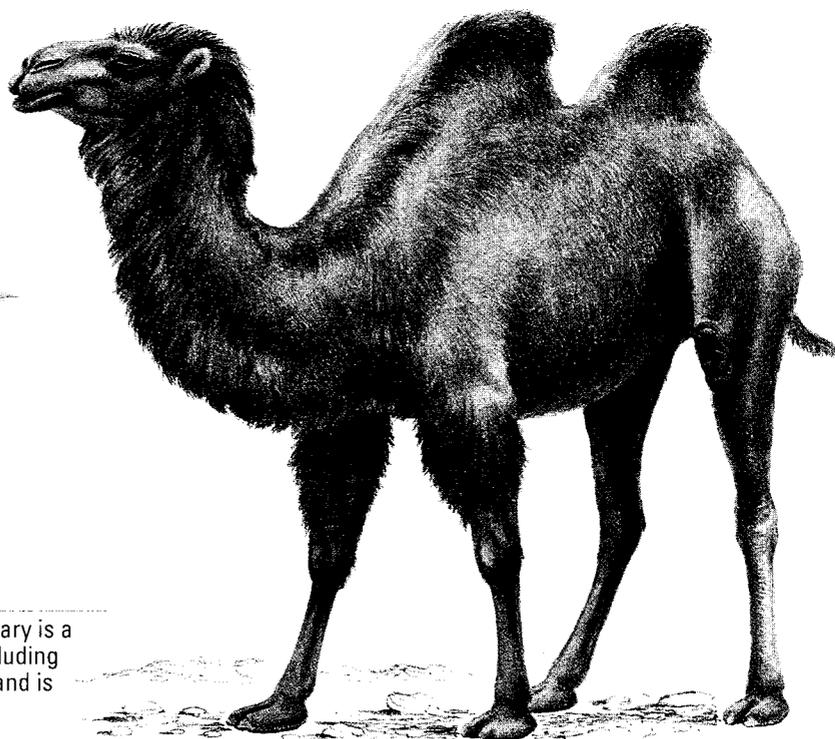
Camels eat plants. They chew their food only a little before swallowing it. The food is later brought back up into the mouth as cud. The camel chews this cud and swallows it again. It goes to the camel's three-chambered stomach, where digestion is completed (see RUMINANT).

Camels can be trained. However, their behavior remains unpredictable. Most of the 3 million Arabian camels and 1 million Bactrian camels have been domesticated for human use. Camels are used instead of horses in desert areas of Africa, Australia, and Asia. Their wool is shed every spring and can be used for cloth or blankets. Their hides provide a strong leather. Their milk can be drunk, their flesh eaten, and their dung used as fuel. Their bones can be dried and used in making jewelry and tools.



Arabian camel

Bactrian camel

**CAMEL**

The Arabian camel has just one hump. The dromedary is a special breed of Arabian camel used for riding, including camel racing. The Bactrian camel has two humps and is native to the cold deserts of Central Asia. It has a thicker coat than the Arabian camel.

CAMERA

A camera is an instrument that is used to make photographs (see PHOTOGRAPHY). The camera has become one of the most important means of communication and expression in modern culture. It is also important to scientists such as astronomers and biologists. A camera is basically a dark box with a window, called a lens, on one side. The lens allows light reflected from an image to enter the box and fall on a strip of film that is sensitive to light. The image on the film is inverted (upside-down). In most cameras, the exposed film is removed from the camera and developed through a chemical process. A photographic print is then made from the developed film, or negative.

History The first camera was called *camera obscura*, or “dark chamber,” because that is exactly what it was—a dark room used by artists for sketching outdoor scenes. The camera obscura was known to the Chinese in the fourth century B.C. The Arab scholar Alhazen used one to observe solar eclipses in about 1000 A.D. The camera obscura was invented independently in Europe in the 1500s. The writings of the great Italian artist and scientist Leonardo da Vinci (see LEONARDO DA VINCI) include a description of the camera obscura. Artists used a portable camera obscura. Its walls were supported by poles. Light entered through a small hole in one wall and was reflected onto a frame containing thin tracing paper. Artists traced the image of the outside scene that could be dimly seen on the paper. The camera obscura was improved in the 1600s. It became a box about 2 ft. [61 cm] long with a hole in one end. Light from an image entered the box and was reflected by a mirror onto a flat piece of ground glass (glass with a roughened surface) in the top of the box. This form closely resembled the single lens reflex (SLR) camera of today.

The first permanent photograph was taken by a Frenchman, Joseph Nicéphore Niépce, in 1826. In 1839, Louis Daguerre, another French inventor, introduced the daguerreotype. In a daguerreotype, a permanent image was made on a thin metal plate.

Daguerreotypes were also called tintypes (see DAGUERRE, LOUIS; DAGUERRETYPE).

In 1888, American manufacturer George Eastman introduced the Kodak box camera. It was small, inexpensive, and easy to operate. The Kodak box camera made photography available to millions of people (see EASTMAN, GEORGE). The Leica camera was developed in Germany in 1924. It was the first 35 mm camera (named for the width of the film).

Harold Edgerton, an American, invented the electronic flash in 1931. Color photography began in the 1930s and early 1940s when the Kodak company introduced color film.

In 1947, Edwin Land, an American, invented the Polaroid Land camera. Film was developed inside the camera, and a black-and-white photographic print could be produced in sixty seconds. In 1963, the Polaroid Corporation introduced cameras that produced instant color photographs. In 1978, the company made cameras that allowed people to take instant movies (see POLAROID CAMERA).

How a camera works The light that comes into a camera can be compared with the light that would enter a dark room through a small hole in a window shade. The light would produce a weak, upside-down image of the scene outside on the opposite wall of the room. It works the same way the human eye works. The light that comes through a camera lens produces an inverted image of its subject on the film (see LENS). The distances between the subject and the lens and between the lens and the film determine most of the sharpness of the image on the film. Many cameras have a mechanism for focusing to adjust the lens-to-film distances. They are called adjustable cameras. Cameras without focusing mechanisms are called fixed-focus cameras.

The lenses of all but the simplest cameras are made up of a series of different lenses next to one another. These are called compound, or achromatic, lenses. They are necessary because all lenses have defects that produce distorted images.

Combinations of lenses reduce these defects (see **ABERRATION**).

The shutter is a device that allows light to enter the camera. Its action is something like quickly opening and closing a venetian blind. The shutter is usually located behind the lens. It opens when the shutter release button is pressed. It closes quickly after the correct amount of light has been let in to register on the film. The shutter stays closed at other times to keep out light. How long the shutter is open is important. The time determines how long the film is exposed to light. Most cameras have adjustable shutter speeds. They may vary from a few thousandths of a second to more than ten seconds. Light entering the camera is also controlled by the diaphragm. The diaphragm is a device that changes the size of the hole through which light enters. To allow more light in, the hole, called an aperture, is widened. To reduce the amount of light, the size of the aperture is made smaller.

These different apertures are called *f* stops. Common settings are *f*/1.2, *f*/2, *f*/2.8, *f*/4, *f*/5.6, *f*/8, *f*/11, and *f*/16. The *f*/1.2 setting allows much more light to enter than the *f*/16 setting. The *f*/1.2 setting is used for dim light conditions. The *f*/16 setting is used on bright, sunny days. Some cameras

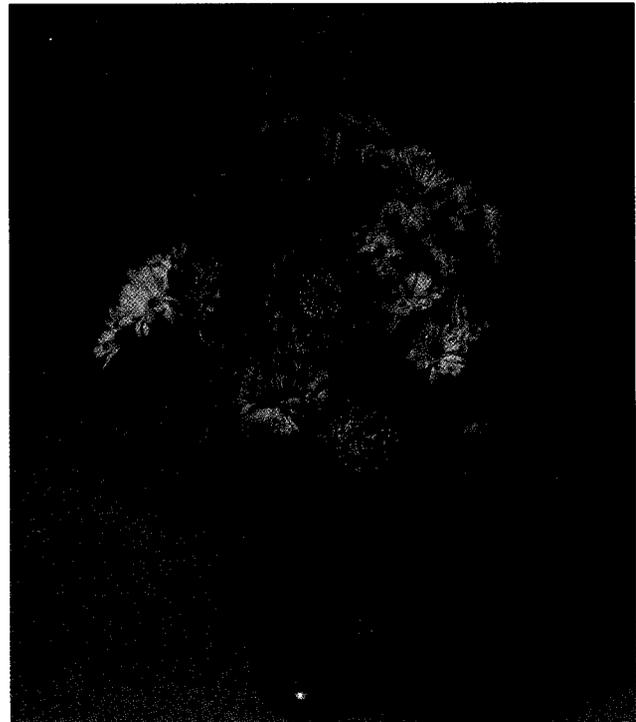
have a built-in exposure meter that "reads" the amount of light coming through the lens. The operator adjusts the aperture and the shutter. Other cameras have mechanisms that control exposure automatically. Most automatic cameras control either the diaphragm or the shutter. Some cameras can control both.

Most cameras can be fitted with a flash attachment, which allows pictures to be taken in very dim light. When the shutter opens, the flash gives off a bright burst of light, which illuminates the subject. The light and camera speed are coordinated for proper exposure.

The viewfinder and film advance are two other devices found on most cameras. The operator looks through the viewfinder to see the subject. Except in a single-lens reflex camera, the viewfinder is usually a separate lens system. Some cameras have range finders for accurate focusing. The operator looks through the eyepiece of a range finder and sees two images of the subject. He or she turns a knob to make these two images move together until they

COLOR FILTERS

Photographers can use a filter in front of the camera lens to alter the color of light reaching the film. The colors of flowers (below left) have been dramatically changed by using a blue filter (below right).



form one image. The knob is linked mechanically to the lens. When there is a single, sharp image in the range finder, one knows that the lens is properly focused (see RANGE FINDER). Some cameras have a device that automatically focuses the lens.

The film advance moves the film through the camera. It can be a lever that is pulled or a knob that is turned. The film advance unrolls the exposed film and moves it to a position behind the lens. After the picture is taken, the film advance moves the exposed portion out of the way and places unexposed film behind the lens again.

Fixed-focus cameras The simplest cameras are fixed-focus cameras. Their lenses are not adjustable. The diaphragms are preset and there is usually one shutter speed of about 1/100th of a second. Some models can be loaded with film in a drop-in cartridge.

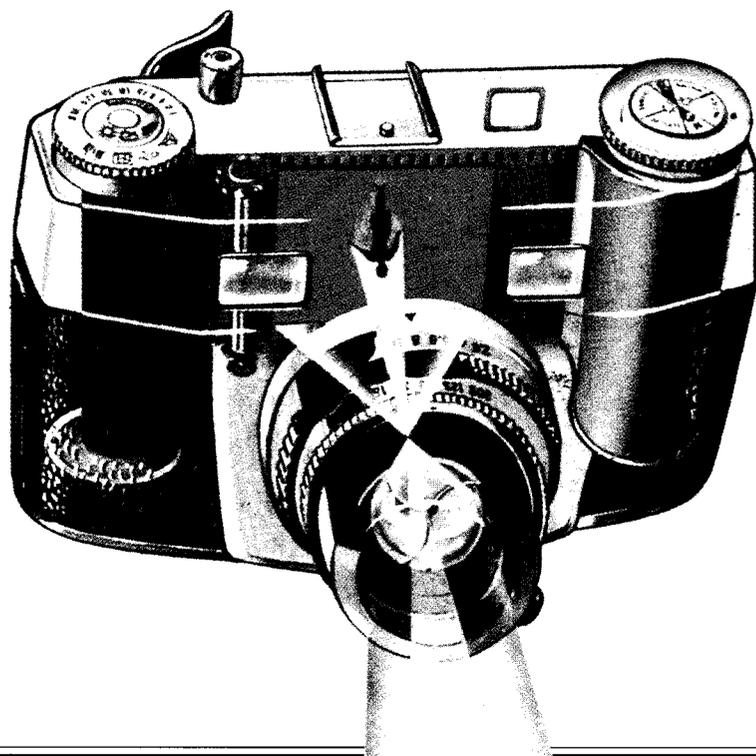
Fixed-focus cameras take satisfactory pictures in ordinary daylight but not in dim light. Some models have built-in flash units. Other versions may have low-powered telephoto lenses, which allow the camera to photograph distant objects. Fixed-focus cameras weigh less and cost less than other kinds of cameras. Some models are small enough to fit into a pocket.

Adjustable cameras Professional photographers and people who want high-quality photographs use adjustable cameras. These cameras offer a wider range of picture-taking possibilities with better results. They have adjustable diaphragms, lenses, and shutter speeds. Their lenses are of high quality to produce sharp images.

The most popular adjustable cameras are the 35 mm and 2 1/4 by 2 1/4 models. The actual image size on 35 mm film is 1 by 1.5 in. [24 by 36 mm]. The image size on 2 1/4 by 2 1/4 film is 2.25 by 2.25 in. [57 by 57 mm].

The regular lens of many adjustable cameras can be replaced by other lenses such as telephoto and wide-angle lenses. A telephoto lens makes the subject appear closer and larger than it really is. A wide-angle lens covers a wider area. It usually makes objects appear smaller and farther away. Other special accessories make it possible to take pictures under water or through a telescope or microscope.

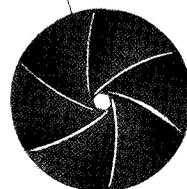
The most widely used of the 35 mm models have single-lens reflex viewfinders. They have a viewfinder that allows the operator to look directly through the lens of the camera. The image enters the lens, bounces off a mirror, and goes into the viewfinder. Because the operator can see the exact image that will be focused on the film, the



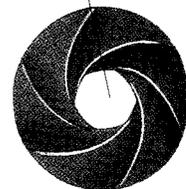
CAMERA PRINCIPLE

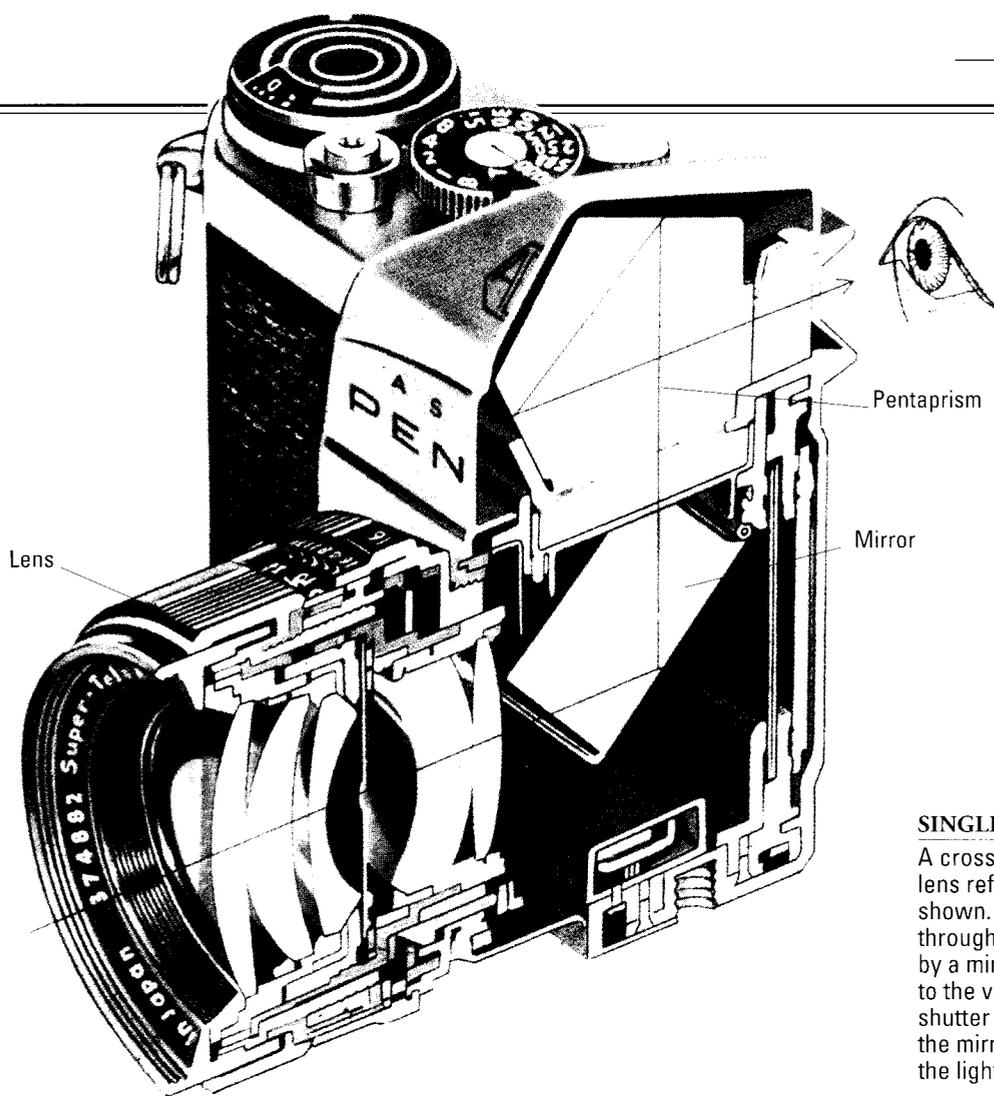
Light passes through the camera lens, forming an inverted (upside-down) image on the film (left). The image formed on the retina of the human eye is also upside-down; the brain "turns" it right side up.

Iris diaphragm



Aperture





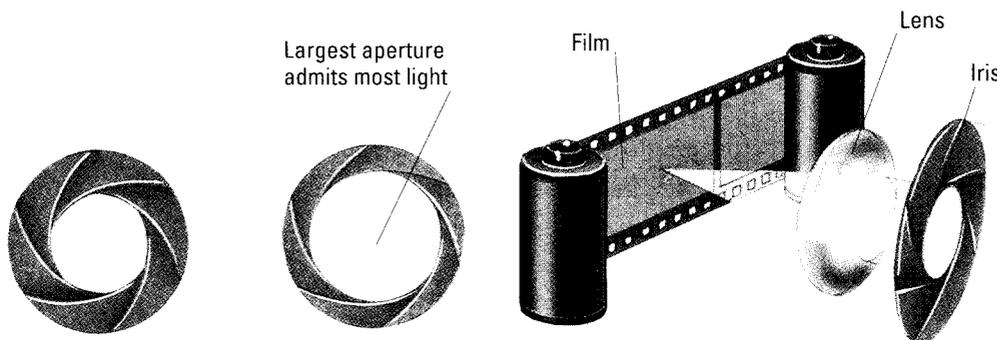
SINGLE-LENS REFLEX

A cross section of a single-lens reflex camera is shown. The light coming through the lens is reflected by a mirror and pentaprism to the viewfinder. When the shutter release is pushed, the mirror moves up, and the light hits the film.

positioning of the subject is easier than with other cameras. When the shutter release is pushed, the mirror lifts out of the way to allow the image to reach the film. Because they are lightweight and handy, 35 mm cameras are used by most newspaper photographers. Some sports photographers use 35 mm cameras that have motorized film advances. These move the film rapidly through the camera. They allow the photographer to take sequence, or "freeze-action," photos of fast-moving sports activities.

A 35 mm camera can take twenty or more pictures with one roll of film. Black-and-white film is made into paper prints. Color film may be made into slides, called transparencies, or into prints. Slides require a projector and a screen for proper viewing.

Some 2 1/4 by 2 1/4 cameras are of the twin-lens reflex type. The twin-lens reflex camera has two lenses, one above the other. The top lens is the viewing lens, and the bottom lens is the picture-taking lens. The photographer holds the camera at



CONTROLLING LIGHT

The amount of light passing through a camera lens is controlled by the shutter speed and the aperture. In many cameras, the aperture size can be varied by an iris diaphragm to produce a small aperture in bright light and a large aperture in dim light.

about waist level and looks down to see the image on a flat screen on top of the camera. Twin-lens reflex cameras are larger and heavier than 35 mm models. Some photographers prefer $2\frac{1}{4}$ by $2\frac{1}{4}$ cameras because they feel that the larger film size gives a better image.

Instant cameras Instant cameras are cameras that can make a print within seconds after the picture is taken without first developing the film into a negative. The Polaroid Corporation has pioneered most developments in this type of camera. Some of the less expensive models are of the fixed-focus type. Other models have adjustable lenses and shutter speeds. A special packet containing several sheets of film is loaded into the camera. Each sheet of film has a pod, or small plastic container, with the chemicals needed to develop it. When the sheet is exposed, the camera automatically ejects the picture. As the piece of film leaves the camera, it is passed between two hard rollers. These rollers break the pod, spreading the developing chemicals over the film. In seconds, the developed picture is ready.

Other types of cameras Subminiature cameras are pocket-sized cameras that take very small pictures. They use film that ranges in width from 0.37 to 1 in. [9.5 to 25 mm].

View cameras are the largest cameras in general use. They have large, accordionlike bodies with glass viewing screens at the rear covered by a cloth hood. Some models may measure up to 6 ft. [1.8 m] long and weigh up to 500 lb. [230 kg]. Film sizes can be as large as 11 by 14 in. [28 by 36 cm]. The photographer puts his or her head under a cloth hood to view the subject directly through the lens. View cameras are often used in studios for portraits and for close-up advertising pictures. Some view cameras have a Polaroid attachment that produces an instant photo.

Autofocus cameras are designed to measure automatically the distance from the object using sound waves (sonar) or infrared beams.

Stereo cameras take pictures that appear to be three-dimensional when viewed through a special device called a stereoscope. These cameras have two



INSTANT CAMERAS

Instant cameras use special film that is developed immediately after a photograph is taken. Each piece of film has its own pouch of chemicals. A pair of rollers squeezes the chemicals onto the film as it leaves the camera. The photograph is fully developed within a minute or so.

lenses. They photograph the same subject from two slightly different angles. The stereoscope causes the two images to appear to blend together, and the picture seems to have depth. Stereo cameras are used mostly by engineers and scientists.

Motion-picture cameras take pictures one after another in sequence. They have battery-powered motors that advance the film and open and close the shutter. Professional photographers use large models that require 35 mm or 16 mm film. Many 8 mm motion-picture cameras have zoom lenses. These are adjustable telephoto lenses that allow the photographer to make the size of the image larger or smaller. A projector and screen are necessary to view motion-picture film (see MOTION PICTURE).

Television cameras have only one thing in common with motion-picture cameras: the lens. Light enters the television camera and falls on a photoelectric element. The element converts the light image into electric signals that can be recorded on magnetic tape, or transmitted "live" to your television set. Portable television cameras are becoming increasingly popular. Television cameras with a built-in video cassette recorder are commonly called camcorders (see TELEVISION; VIDEO RECORDING).