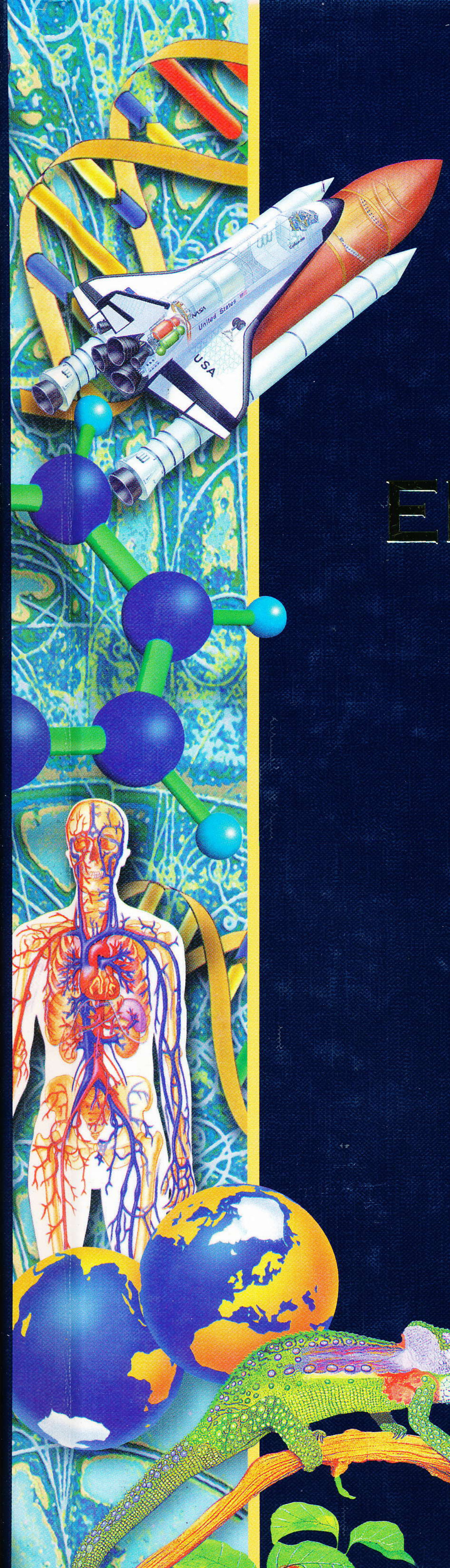
Raintree Steck-Vaughn

Illustrated SCIENCE ENCYCLOPEDIA

Volume
7



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ECH – EXO

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ECHIDNA (ĭ kĭd′nə) The echidna is an egg-laying mammal native to Australia and New Guinea. Like the platypus, the echidna is a monotreme (see MAMMAL; MONOTREME; PLATYPUS).

There are probably five species of echidnas, the largest being about 31 in. [78 cm] in length. Although they are of different sizes, all species of echidnas have a similar appearance. Echidnas are covered with long, dark hair and sharp spines. They have a thin, beaklike snout and a sticky tongue. They have short legs and long, sharp claws for digging. If threatened, an echidna may roll up in a ball, exposing its spines to an enemy, or it may burrow into the ground for protection. The animals can tunnel into the ground with amazing speed.

Echidnas feed by day and night. They use their claws to dig into ant or termite nests and lick up the insects with their sticky tongue. In their feeding habits, echidnas are similar to anteaters, which is how they got their nickname, *spiny anteaters* (see ANTEATER).

The female echidna lays one egg, which she keeps in a pouch on her belly. This pouch, similar to that of the marsupials, develops only during the mating season (see MARSUPIAL). After the egg hatches, the young echidna stays in the pouch for several weeks, feeding on milk from the mother. Echidnas may live as long as fifty years in captivity.

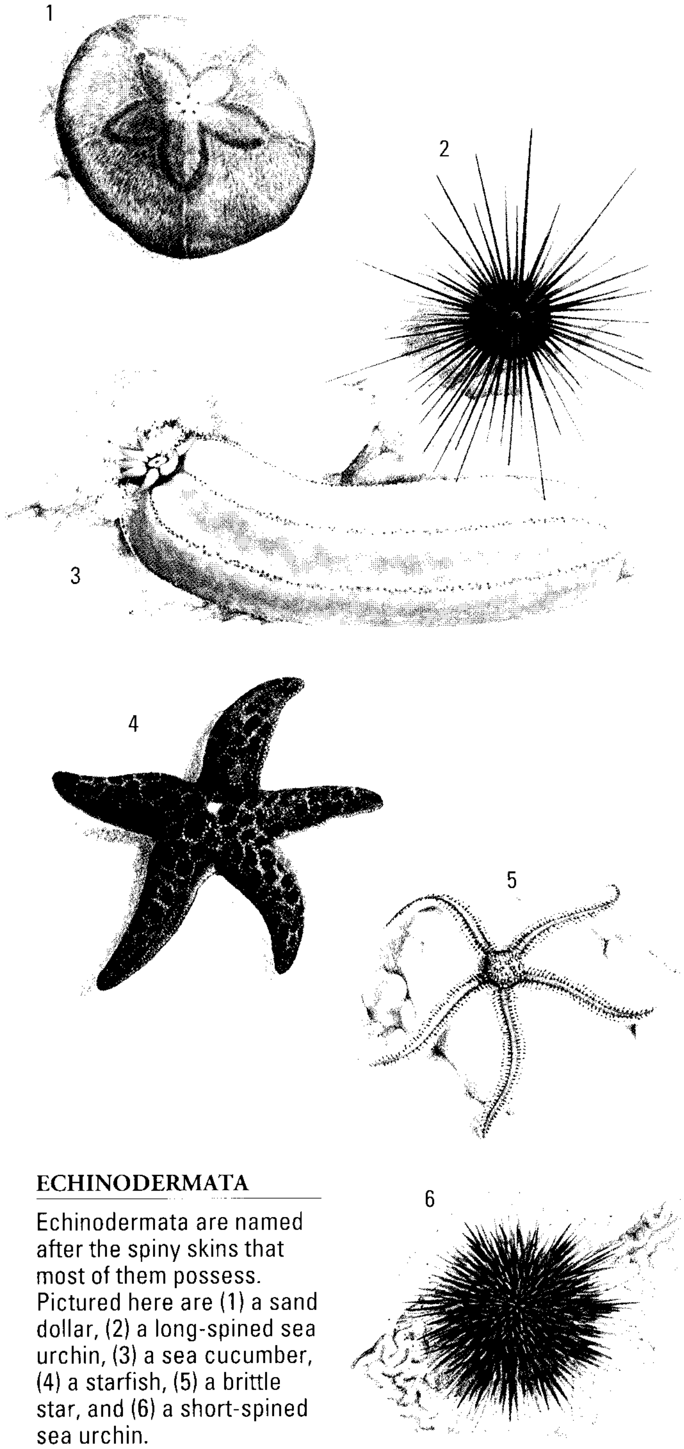
ECHIDNA

The short-beaked echidna, found throughout Australia, is also called a spiny anteater because it feeds on ants and termites, which it licks up with its sticky tongue.

ECHINODERMATA (ĭ kī′nə dûrm′ət ə) Echinodermata is a phylum of invertebrate marine animals (see INVERTEBRATE). Included in Echinodermata are the starfish, brittle star, crinoid, sea urchin, sand dollar, and sea cucumber. Echinoderms are found in every ocean. They inhabit all parts of the ocean, from the waters near the shore to the deepest ocean trenches. Some echinoderms stay anchored in one place. Others float with the water currents. Most slowly crawl along the ocean floor, using small suckerlike projections called tube feet. They feed by filter feeding (sucking up tiny organisms floating in the sea water), by picking food particles off the sea floor, or by preying on other animals.

Echinoderm means "spiny skin." The hard, spiny skeleton of the echinoderms, made of calcium carbonate, gives them their name. Most echinoderms are circular and have five arms that extend symmetrically from the central part of the body.

Unique to the echinoderm is its water vascular system. This system is made up of a series of tubes



ECHINODERMATA

Echinodermata are named after the spiny skins that most of them possess. Pictured here are (1) a sand dollar, (2) a long-spined sea urchin, (3) a sea cucumber, (4) a starfish, (5) a brittle star, and (6) a short-spined sea urchin.

running throughout the echinoderm's body. The tubes are filled with seawater. The echinoderm pumps water in and out of its tube feet, which are attached to the tubes of the water vascular system. The tube feet aid in feeding, respiration, and excretion of wastes, as well as in movement. Echinoderms do not have brains, but they do have a well-developed nervous system (see NERVOUS SYSTEM).

ECHO An echo is a sound that has been reflected (bounced back) from a surface. If a person shouts in a large valley, he or she usually soon hears the echo of the shout. The sound has reflected off rocks in the valley. Sound waves travel about 1 mi. [1.6 km] in five seconds. Therefore, the time it takes to hear an echo varies with the distance the sound must travel to get back to the caller. For example, if the valley is 0.5 mi. [0.8 km] wide, the echo will return in five seconds from when the caller first shouted. If the valley is narrower, the echo will return sooner. If it is wider, the echo will take longer to return. A person may hear more than one echo from a single sound. This occurs when sound waves bounce from place to place, producing several echoes.

Sometimes an echo is not heard even though the reflected sound waves reach the ear. The echo may not be heard if the original sound is too weak or if the reflecting object is too small. It is very difficult to tell the difference between the sound and its echo if the reflecting object is less than 30 ft. [9 m] away.

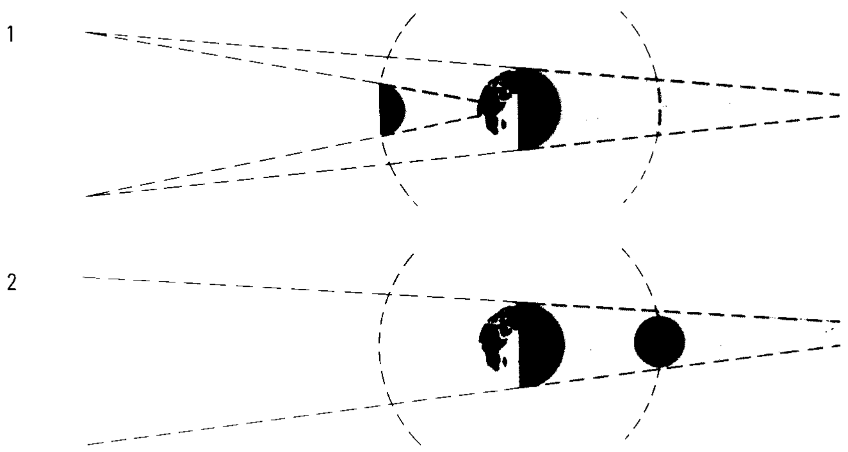
Sound waves traveling through water also produce echoes. Sonar uses underwater echoes to measure depth and to locate underwater objects. For example, fishers sometimes use sonar to detect schools of fish.

See also RADAR; SONAR; SOUND. **PROJECT 48**

ECLIPSE An eclipse occurs when a heavenly body is obscured by a shadow or by another heavenly body. There are two kinds of eclipses visible from the earth: a solar eclipse and a lunar eclipse.

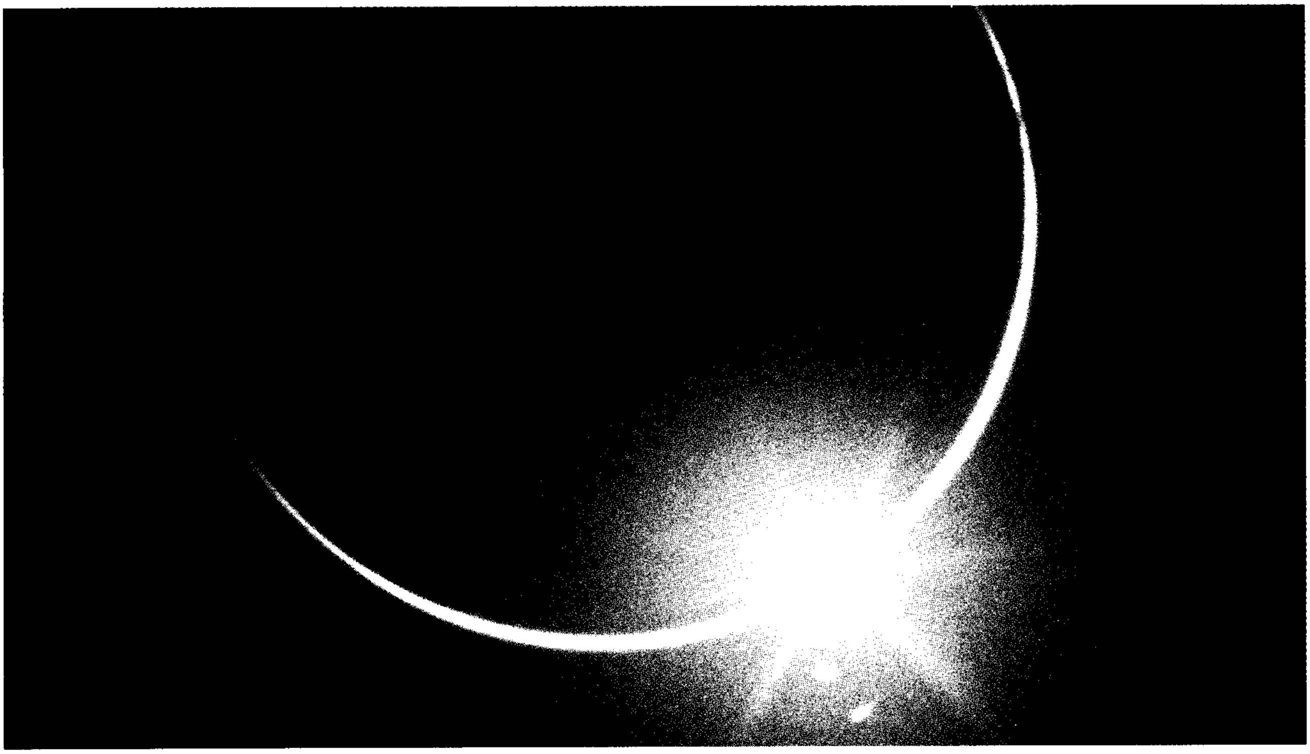
A solar eclipse is an eclipse of the sun. It occurs when the moon moves directly between the sun and the earth, so that the moon's shadow falls on the earth. If the sun seems to be covered completely, it is called a total eclipse. During a total eclipse, the day seems to turn to night. A total eclipse lasts for a maximum of seven minutes, forty seconds. During a total eclipse, the outer atmosphere of the sun, called the corona, becomes visible. This aspect of eclipses is of great interest to astronomers.

Not all solar eclipses are total. In most eclipses, only part of the sun appears to be covered. These



ECLIPSE

There are two kinds of eclipses. (1) In a solar eclipse, the sun cannot be seen because the moon is between the earth and the sun. (2) In a lunar eclipse, the moon cannot be seen because it is in the shadow of the earth. In the solar eclipse (below), the sun is just disappearing behind the moon's disk.



are called partial eclipses. In an annular eclipse, the central portion but not the rim of the sun is blocked by the moon. The disk of the sun looks larger than that of the moon. Solar eclipses are rare and visible from only a small area on the earth. Looking directly at the sun during an eclipse or any other time, even through dark glasses, is dangerous and may severely damage the eyes.

A lunar eclipse occurs when the earth is directly between the sun and the moon, so that the moon lies in the shadow of the earth. A lunar eclipse can usually be seen by all people on the night side of the earth. The moon takes on a reddish color during a lunar eclipse. A lunar eclipse can occur only when the moon is full. Looking directly at a lunar eclipse will not damage the eyes.

For thousands of years, eclipses have fascinated as well as confused people. Many people thought solar eclipses were bad omens. The ancient Babylonians and the ancient Chinese were among the first to keep accurate records of eclipses and to discover their regular cycle.

See also ASTRONOMY.

ECLIPTIC The ecliptic is the sun's apparent path across the sky. The plane of the ecliptic is the plane in which the earth travels in orbit around the sun. Since the moon and other planets are roughly in the same plane, they also follow the ecliptic.

See also ASTRONOMY; CELESTIAL SPHERE.

ECOLOGY Ecology is the study of organisms and their relationship to other organisms and to their surroundings, or environment. It is a branch of biology. A biologist may study a mouse to find out its size, color, and how long it lives. An ecologist would study what plants a mouse eats, what animals eat the mouse, and how the number of mice affects the number of animals that eat it.

An ecological system, or ecosystem, is any naturally occurring unit that includes living and nonliving elements, which interact to produce a stable system over time (see ECOSYSTEM). In a large ecosystem, energy is passed along by one organism eating another. This is called a food chain (see FOOD CHAIN). Ecologists (scientists who study ecology) study how plants and animals live and interact in their habitat (a particular area in which a population lives). They study how the population of each animal or plant changes over time.

Modern technology allows us to change many things about our environment, altering ecosystems. For example, we can dig new lakes, drain old ones, and build dams. Sometimes, when we change things, we change other things we did not intend to change. In the 1960s, the Egyptians built the Aswan High Dam on the Nile River. The dam's main purpose was to hold back water that occurs during the annual flood. Holding back the floodwaters, however, kept the silt that is naturally deposited by the floodwaters from reaching farmers' fields downstream from the dam. Farmers now have to add costly fertilizers to their fields (see FERTILIZER). In addition, holding back the floodwaters meant that a particular kind of snail was not killed each year. This meant that a tiny worm that breeds in the snails also was not killed. The worm carries the disease schistosomiasis. Scientists blame the dam for an increase in the spread of this disease in Egypt (see SCHISTOSOMIASIS).

Ecologists now try to learn more about the environment so they can predict changes before they occur. In the early 1970s, the United States was planning to build a number of large jet airplanes called supersonic transports (SSTs). Ecologists predicted that the jets would damage the environment of the atmosphere. Thus, Americans decided not to build SSTs.

Human activities continue to greatly change the environment. Activities such as excessive construction, pollution, and deforestation are affecting many organisms. For example, logging activities in national forests in California, Oregon, and Washington have placed a species of spotted owl in danger of extinction. Many other organisms are threatened by environmental changes caused by humans.

See also CONSERVATION; DEFORESTATION; ENVIRONMENT; POLLUTION.

ECOLOGY
Logging can cause sudden and drastic changes to the environment, as in the Yosemite National Park, California, shown here. As a result, birds such as the spotted owl are in danger of extinction.

ECOSYSTEM

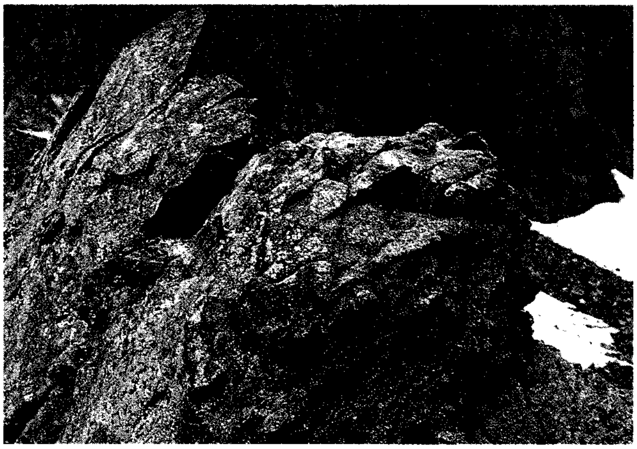
An ecosystem is any naturally occurring unit that includes living and nonliving elements, which interact to produce a stable system over time. An ecosystem can be a small system, such as an animal's intestines or a decaying log. Larger ecosystems include a pond or a wooded preserve. The largest ecosystem is called the biosphere, which is the entire portion of Earth, including the atmosphere, that supports life.

Nonliving and living elements both determine what an ecosystem is like. Nonliving elements include temperature, rainfall, soil composition, sunlight, the slope and drainage of the land, or the chemical composition of seawater. Such nonliving elements help determine the kinds of living organisms that will thrive in a particular area. A large area that is characterized by certain specific types of living organisms and other characteristics is called a biome. Terrestrial biomes include deserts, tundra, grasslands, evergreen forests, and tropical rain forests. Freshwater biomes include lakes, rivers, and wetlands. Marine biomes include the oceans and estuaries (see BIOME; ESTUARY; LAKES AND PONDS; RAIN FOREST).

Living elements that make up an ecosystem include communities of organisms. A community consists of groups within a single species or several species that live together casually in the same area. For instance, giraffes, zebras, and several antelope species often share the same range on an African savanna. These animals form a community.

The living elements in an ecosystem determine how energy is transferred within the ecosystem. All ecosystems include organisms that can convert energy, such as sunlight, into food. These organisms are called producers. In terrestrial biomes, the producers are usually plants. In freshwater and marine biomes, they are often protists, such as different types of algae (see ALGAE; PROTISTA). In deep-sea vents at the bottom of the ocean, where no sunlight penetrates, the producers are a type of bacteria that convert hydrogen sulfide from the vents into food.

The producers in an ecosystem support all the rest of the living organisms within the ecosystem. Energy in the ecosystem flows from the producers



HARSH ENVIRONMENT

These lichens (above) growing on bare rock have to survive the freezing winters of the Antarctic. The lichen community makes up a small ecosystem.

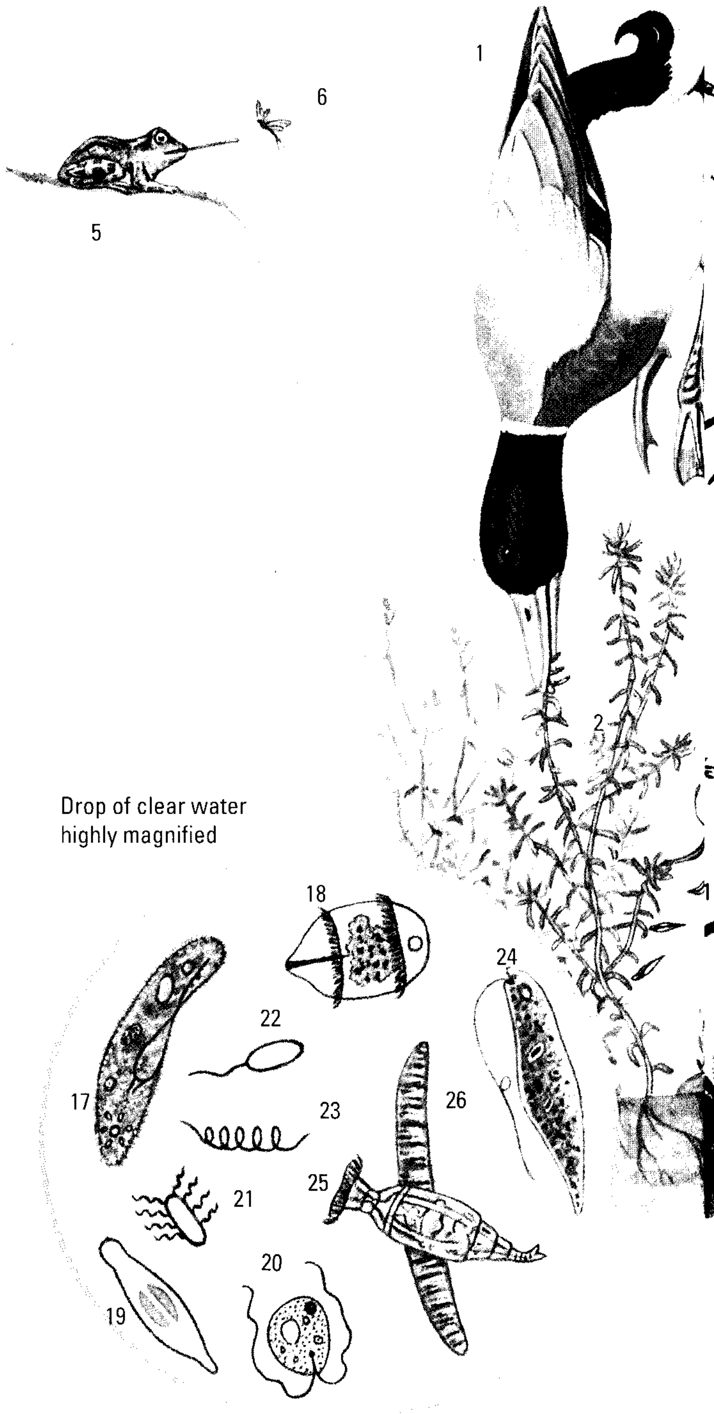
RAIN FOREST

Little light gets through the dense tree foliage to reach the floor of a tropical rain forest (left). Even in these gloomy conditions, lush vegetation thrives.

to the organisms that eat them, the consumers. These feeding relationships are called food chains (see FOOD CHAIN). In a woodland ecosystem, for example, trees, shrubs, and other green plants are the main producers. Deer, rabbits, and mice eat grass, seeds, and leaves, obtaining energy directly from plant foods. Bobcats, wolves, and foxes prey on the deer, rabbits, and mice. They obtain their energy by eating the animals that ate the green plants. In this way, energy flows from producers to various types of consumers within the woodland.

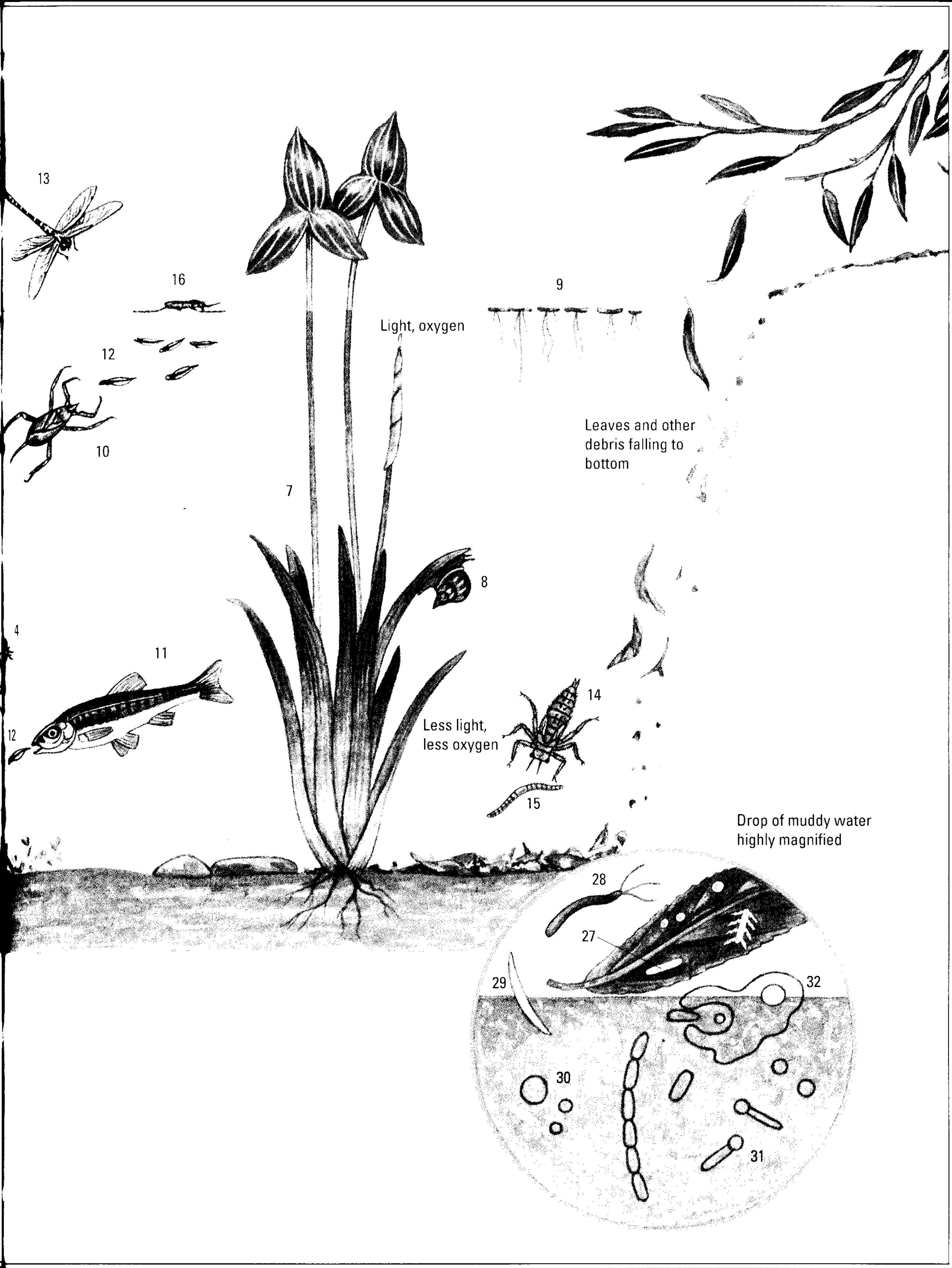
Decomposers, such as beetles, earthworms, fungi, and various microorganisms, in an ecosystem digest the remains of plants and animals that have died. In this way, the decomposers help recycle energy and nutrients through an ecosystem (see MICROORGANISM).

The stability of an ecosystem depends on the quality and balance of the nonliving elements that make up the ecosystem and the health of the living organisms in the ecosystem. To try to understand the complex interrelationships among living and nonliving elements within an ecosystem, ecologists (scientists who study ecology) must study a wide variety of factors. They might take soil samples and record weather patterns for successive years in a particular ecosystem. They might collect plants and take a census (count) of different plant communities. They probably observe animal habits and



AQUATIC ECOSYSTEM

A freshwater pond is an ecosystem that provides homes for a wide variety of species. These range from bacteria and other microscopic organisms to vertebrates such as fish, frogs, and waterfowl. The illustration shows some of these organisms and some of the ways in which they support each other's lives to produce a balanced ecosystem. Macroscopic (visible to the human eye) pond life shown includes: (1) duck feeding on (2) underwater plant; (3) hydra feeding on (4) water flea; (5) frog feeding on (6) fly; (7) arrowhead (an aquatic plant); (8) pond snail; (9) duckweed (the smallest aquatic flower); (10) water scorpion and (11) minnow, both feeding on (12) tadpoles; (13) dragonfly; (14) dragonfly nymph feeding on (15) small annelid worm; (16) pond skater. The pond's microscopic life is shown in two magnified drops of water—one from the clear, oxygenated water (right) and one from the muddy, oxygenless water (far right). The microscopic pond life includes: (17) paramecium being attacked by (18) didinium and attacking (19) diatom; (20) small flagellate; (21 and 22) aerobic bacteria; (23) spirochete; (24) euglena; (25) rotifer; (26) oscillatoria; (27) bacteria feeding on leaf; (28) spirillum, a large bacterium; (29) another diatom; (30 and 31) anaerobic bacteria; (32) ameba feeding on bacteria and diatoms.



13
16
9
Light, oxygen
12
10
Leaves and other
debris falling to
bottom
7
8
4
11
14
Less light,
less oxygen
12
15
Drop of muddy water
highly magnified
28
27
29
32
30
31

behavior patterns, social adaptations, territories, and nesting and feeding sites. Disruption or destruction of even a few elements in the ecosystem can threaten the well-being of the entire system. The soil may lose nutrients and become infertile; plants may not grow well and may not reseed; animals may lack sufficient food sources to reproduce.

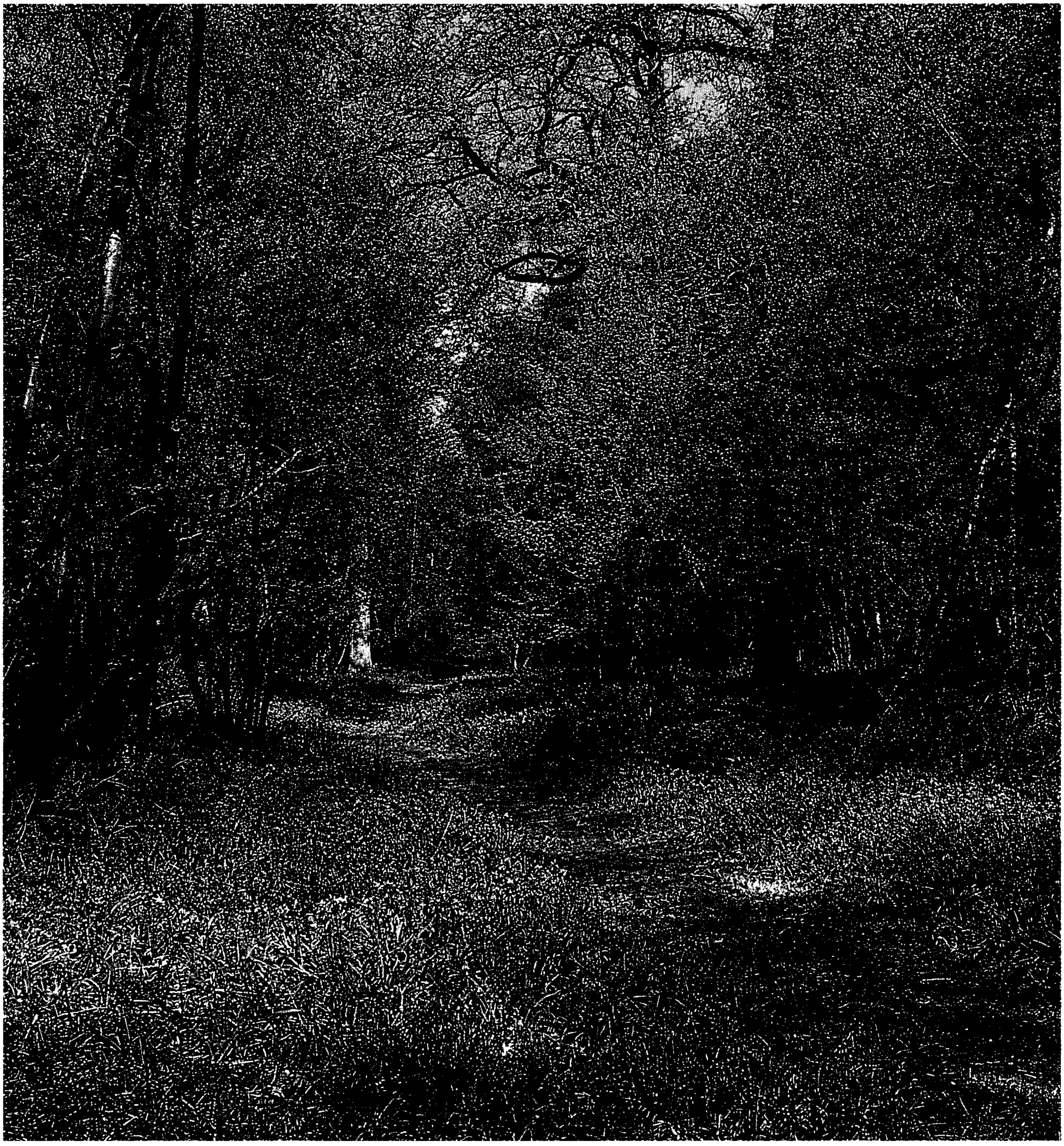
Human beings share the earth with nearly ten million other species of living things, including plants, animals, and microorganisms. Studying ecosystems and resolving conflicts between the different uses of ecosystems can help preserve the earth's organisms, improve the quality of life, and conserve natural environments for future generations.

See also CONSERVATION; ECOLOGY; ENVIRONMENT; POLLUTION.

PROJECT 73

WOODLAND ECOSYSTEM

In a woodland ecosystem, the trees and other plants are the producers, and are at the beginning of the food chain.



ECTOPLASM Ectoplasm is the semisolid, jelly-like outer layer of the cytoplasm within a cell. Cytoplasm is the mixture of water, salt, and organic material that lies between the cell membrane and the membrane of the nucleus. Ectoplasm plays an important role in cell division and movement.
See also CELL; CYTOPLASM; ENDOPLASM.

ECZEMA (ĕk′sə mə) Eczema is a common form of dermatitis, which is any inflammation of the skin. In eczema, the skin turns red, and fluid-filled blisters, called vesicles, may form. Also, crusts and scales may develop on the surface of the skin. Eczema usually causes the skin to itch. If scratched, the skin may become infected by bacteria.

Doctors believe eczema is caused by many things. The most common cause is an allergy, which is an abnormal sensitivity to certain substances (see ALLERGY). The substances may be in something the person eats or touches. Some plants give off certain substances that cause eczema. For instance, oils produced by poison ivy cause a form of eczema when the oils come in contact with an allergic person's skin.

Curing eczema is often very difficult. The most important part in treating eczema is to find out, if possible, what caused the rash. A doctor may use skin tests to determine how the person reacts to various substances. This may help find the cause of eczema. Treatment usually involves removing the cause. Other important aspects of treatment are controlling the itching with medicated creams or baths and reducing emotional stress.

EDISON, THOMAS ALVA (1847–1931) Thomas Alva Edison was one of the greatest inventors in history. He changed the lives of millions of people with inventions such as the electric light, phonograph, and motion picture camera. His concept of inexpensive electricity generated by huge electric-power stations made it possible for people to enjoy the benefits of electricity in their homes. Edison patented 1,093 inventions during his lifetime.

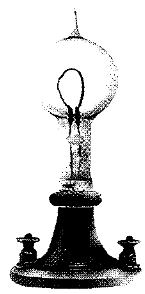
Edison also improved the inventions of other people, such as the telephone, typewriter, and electric generator. He predicted the use of atomic energy and experimented in the field of medicine. He always tried to develop practical devices that would need little maintenance or repair.

Edison had only three months of formal schooling. He was born in Ohio but spent most of his life in New Jersey.

In 1869, Edison made improvements in the stock ticker, an electric device that transmits news of stock prices and displays them on a paper tape. He patented his improvements and was paid $40,000 for them by the leading manufacturer of

THOMAS ALVA EDISON

Many of Thomas Edison's inventions made use of electricity. Chief among these was the electric filament lamp (below), which originally used a carbon filament in a glass bulb containing a vacuum.



Edison is shown (left) in his New Jersey workshop.

stock tickers. That was a huge amount of money in 1869. Edison used it to open a workshop and laboratory in Menlo Park, a suburb of the city of Newark. He became known as the "Wizard of Menlo Park" because of his many inventions.

Edison improved the typewriter in 1874 by substituting metal parts for wooden parts. In 1876, he improved the telephone by adding a carbon transmitter. Edison astounded the world in 1877 with his invention of the phonograph, or "talking machine," as it was then called.

In 1879, Edison worked out the principles for making an electric light bulb. He experimented for two more years to find a filament, or wire, that would give good light when electricity flowed through it. On October 19, 1879, Edison placed a filament of carbonized thread in a bulb. When electricity flowed through the thread, it glowed brilliantly, producing a bright light. In 1881, Edison designed one of the world's first electric-power-generating stations.

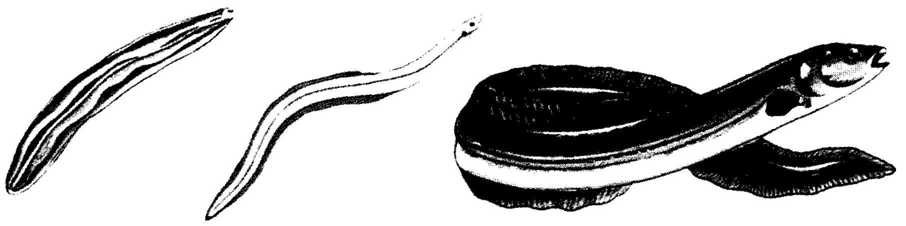
Edison developed a motion picture camera in the late 1880s. He experimented with it in a small building near his workshop that was painted black inside and out. Edison made many experimental films inside this building, including the first boxing match ever filmed. In 1889, he combined the motion picture camera with the phonograph to produce the first films with sound. Until then, motion pictures had been silent. The actors' words had been shown on the screen in printed form. "Talking pictures" revolutionized the motion picture industry.

Throughout Edison's life, his work was his greatest joy. He spent long hours every day in his workshop. The inventor received many awards for his achievements. The United States presented him with the Distinguished Service Medal for his design work on torpedoes during World War I (1914–1918). France awarded him the Legion of Honor. President Dwight D. Eisenhower declared his Menlo Park workshop a national monument in 1956. Henry Ford, the well-known industrialist, once suggested that the period when Edison lived should be called the Age of Edison because of the great inventor's many contributions to humankind. *See also* ELECTRICITY; ELECTRIC LIGHT; INVENTION; MOTION PICTURE; SOUND RECORDING; TELEPHONE.

EEL An eel is a long, snakelike fish that lives in both salt water and fresh water. It is a member of the order Anguilliformes. There are eight families and fifty-five species of eels in North American waters. All but the American eel live only in the ocean. Many of these saltwater eels, such as the moray eel, grow large and have many sharp teeth. They can be dangerous to skin divers (see ELECTRIC FISH).

The American eel is a member of the family Anguillidae. Adults live in freshwater streams and ponds. When it is time for them to reproduce, they swim down the rivers and travel to the Sargasso Sea, an area in the Atlantic Ocean southwest of the islands of Bermuda, where the eels spawn (see SPAWNING).

After hatching, the young eels (called elvers) swim to reach the stream in which their parents lived. Males, which grow to 2 ft. [0.6 m] in length, do not travel many miles upriver, but the females, which grow to 4 ft. [1.21 m] in length, may swim hundreds of miles upriver. Eels even travel through underground water passages. Some end up in landlocked ponds and lakes. However, only the eels that can return to the Atlantic Ocean are capable of reproducing.



EEL

Adult American and European eels live in fresh water but swim to the sea to spawn. The marine larva (far left) is known as leptocephalus. The larva hatches and turns into an elver (center). Elvers then swim to reach the stream where their parents lived. An adult European eel is pictured near left.

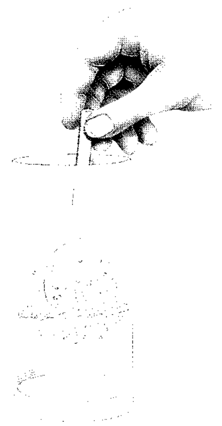
EFFERVESCENCE (ĕf'ər vəs' əns) Effervescence is the making of small bubbles of gas in a liquid. The gas may be made by a chemical reaction in the liquid.

Effervescence can be seen when tablets or powders that are meant to calm an upset stomach are added to water. The ingredients in the tablets or powders include weak acids and bicarbonates. They dissolve and react together, producing bubbles of carbon dioxide gas.

Effervescence also occurs when a gas under pressure has dissolved in a liquid, and the pressure is then released. This happens, for example, when the cap is removed from a bottle of soda. Carbon dioxide gas dissolved in the soda water leaves the solution and forms bubbles. PROJECT 10

ACTIVITY *Watching bubbles in water*

Place one-third of a cup of warm water into a clear glass. Add one teaspoon of baking powder and stir. Watch the powder bubble as it dissolves. This effervescence is caused by bubbles of carbon dioxide.



EFFICIENCY (ĭ fĭsh'ən sē) In physics, efficiency is the amount of energy a machine provides compared with the amount of energy the machine uses. In other words, efficiency is the amount of work put out by a machine divided by the amount of energy put into the machine. This can be written as a formula or equation:

$$\text{Efficiency} = \frac{\text{output energy or work}}{\text{input energy or work}}$$

Some of the energy put into a machine is lost as heat in overcoming friction (see FRICTION). Therefore, the efficiency is always less than 1. Scientists express efficiency in percentages. For example, the efficiency rating of a four-stroke-cycle gasoline engine may be as low as 25 percent. The inefficiency of the engine is due to the high heat loss of the cooling system and the friction of its moving parts.

In most machines, the input energy is not fully converted to output work. An electric motor, for example, may consume 500 watts of electricity to provide 400 watts of useful mechanical power. (Power is the rate at which work is done.)

$$\text{Efficiency} = \frac{\text{output work}}{\text{input energy}}$$

$$= \frac{400}{500} = 0.8 = 80\%$$

The 100 watts of input power that are not converted to useful output power are converted to heat in the motor. Heat is produced by the electric current passing through the coils or wires in the motor. Heat is also produced by mechanical friction of the motor's moving parts.

The term *efficiency* is also used in connection with things besides machines. An electrical transformer can be more than 98 percent efficient. The human body has an efficiency of about 24 percent. *See also* ENERGY; MACHINE.

EFFLORESCENCE (ĕf'lə rĕs'əns) Efflorescence is a change that occurs in certain crystals. The crystals become covered with dry powder. This happens most often when the air is dry (see CRYSTAL). The change occurs because molecules of water evaporate from the crystals (see MOLECULE). Washing soda (hydrated sodium carbonate) is an example of a substance that effloresces. It contains ten molecules of water for each molecule of sodium carbonate. Its formula is $Na_2CO_3 \cdot 10\ H_2O$. The water in the crystals is called water of crystallization. Up to nine molecules of this water can be lost from each washing soda molecule. The crystals may eventually crumble into a powder.

The opposite of efflorescence is called deliquescence. When this happens, crystals take up water from the air around them.

EGG

An egg is a female reproductive cell. Most animals reproduce by means of eggs. Generally, the young develop after the eggs are fertilized. Many insects, however, can reproduce without fertilization. Fertilization occurs when the egg joins with a sperm, or male reproductive cell. Fertilization produces a single cell called a zygote. This zygote develops into a new organism.

Eggs and reproduction There are two ways in which eggs are fertilized: externally and internally. In external fertilization, the egg and sperm join outside the organism's body. Animals that live in or around water, such as fish and frogs, usually fertilize their eggs externally. A female lays the eggs in water. There the eggs mix with and are fertilized by sperm that a male releases into the water near the eggs.

Eggs that are fertilized in water do not have a hard shell to protect them, as birds' eggs do. Often, as in the case of frogs and salamanders, their only protection is a thin outer layer of a soft, jellylike material. Therefore, such eggs must always be kept wet. If they do dry out, the embryo inside them quickly dies. The embryo is the organism at an early stage of growth.

Most animals that live on land, such as insects, reptiles, birds, and mammals, reproduce by means of internal fertilization. The males place their sperm cells inside the female's body, where the sperm fertilizes one or more eggs.

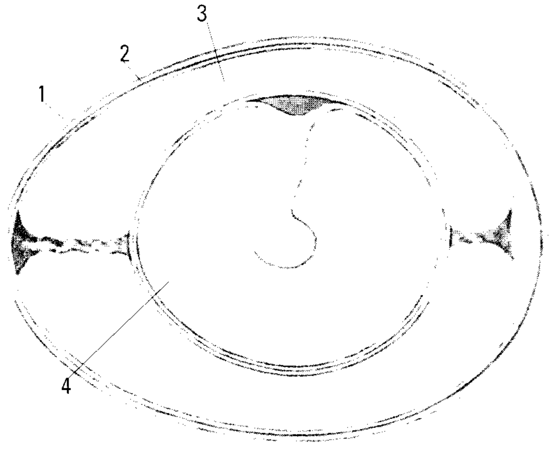
Most nonmammals, such as birds, snakes, turtles, and alligators, then lay their eggs. That is, they force the fertilized eggs out of their bodies. The eggs of some reptiles, however, are hatched inside the mother's body. Once outside, the eggs are then incubated, or kept at the proper temperature, to help the embryo develop until it hatches. Sometimes, as in the case of birds, the parent birds sit on the eggs to keep them at the right temperature. Other animals, such as alligators, build nests out of plants. As this material decays, it produces the heat needed to keep the eggs warm.

The eggs of almost all mammals are very small. The eggs remain within the mother's body while the embryo develops. In humans, development takes nine months. When the young are large and strong enough to survive on the outside, the mother forces them out of her body in the process called birth.

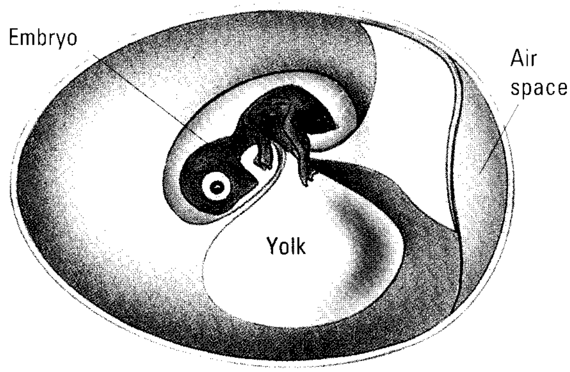
Eggs come in various sizes, shapes, and colors. For example, the ostrich egg is more than 6 in. [15 cm] long. Other eggs are so tiny that a powerful microscope is needed to see them. Some animals, such as many birds, produce only a few eggs at a time. Humans produce only one egg at a time.

REPTILE EGGS

Many reptiles lay eggs with leathery shells. Here young Burmese pythons wriggle out of their shells.



PARTS OF AN EGG
The chief parts of a bird's egg include (1) shell, (2) shell membranes, (3) albumen (white), and (4) yolk.



EMBRYO
As a bird embryo develops inside an egg, the yellow yolk provides nourishment. When the chick is fully grown, it hatches by pecking its way out of the shell.

Other animals produce a very large number of eggs. For example, the American oyster releases hundreds of millions of its eggs into the water each year.

Parts of an egg The most familiar egg is that of the chicken. Chicken eggs are typical of birds' eggs. They have five main parts: shell; membranes; white; yolk; and germ, or embryo.

A chicken egg's shell is like armor. It is the egg's first line of defense from harm. At first glance, an eggshell looks solid. However, it is actually full of pores, or tiny holes. These holes allow gases to pass in and out of the egg. Without this exchange, the developing embryo would soon die.

Two very thin membranes, or skins, are located just inside the eggshell. They surround the white and the other internal parts of the egg. Like the shell, the membranes allow gases to pass in and out of the interior of the egg.

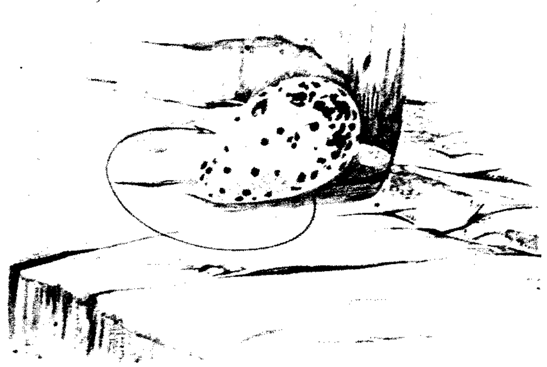
The egg white looks simple, but it is actually made up of four separate layers that alternate. Two of the layers are thin and runny, and two are thicker and more jellylike. The white surrounds and protects the yolk. Part of the white is twisted into two ropelike structures, one at either end of the yolk. These are chalazas, and they help hold the yolk in place, while at the same time allowing it to turn and twist. This twisting prevents the yolk from crushing the embryo when the egg is moved.

The yellow yolk is contained in a protective sac. The yolk provides the nourishment the embryo needs to grow and mature. The germ, or embryo, is the most important part of any egg. It is the part that develops into a new animal—in this case, a chicken. All the other structures of the egg are necessary for this process to occur.

Importance of eggs Besides their role in reproduction, eggs are an important source of food for people. Eggs of such animals as birds, fish, turtles, and sea urchins are prized for their taste. Chicken eggs are a good source of protein, iron, and phosphorus. They also provide several important vitamins. However, eggs also contain cholesterol, a fatty substance that has been linked with some types of heart disease.

Eggs have many other important uses. They are used to make ink, varnish, soap, shampoo, fertilizer, animal feed, and vaccines.

See also EMBRYO; FERTILIZATION; GAMETE; REPRODUCTION; ZYGOTE.



EGG SHAPES
The egg of a guillemot is very pointed so that it rolls around in a small circle when disturbed. As a result, it is less likely to be knocked off a rocky ledge.

EGGPLANT The eggplant is a perennial plant that produces a large, edible, dark purple fruit also called eggplant. The eggplant is a member of the nightshade family and is closely related to the potato (see NIGHTSHADE FAMILY; PERENNIAL PLANT). It is native to India and is now grown throughout the world in warm temperate or tropical areas.

The plant is bushlike, growing as tall as 8 ft. [2.4 m]. It has large, grayish, prickly leaves, and purple or blue flowers measuring about 2 in. [5 cm] in diameter. The fruit reaches a length of 2 to 12 in. [5 to 30 cm] and may be purple, brown, yellow, red, white, or striped. The purple variety is the most popular for eating.

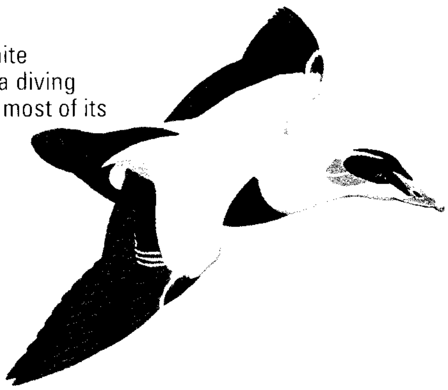
EGGPLANT
The fruit of the eggplant is firm and has many seeds along its center.

EGRET (ē'grĭt) The egret is any of several species of long-legged birds belonging to the heron family and characterized by long, elegant feathers called plumes (see HERON). Egrets usually live in warm areas in or near lakes or marshes, though some species inhabit open grasslands. The egret has an S-shaped neck and keeps its head tucked between its shoulders when in flight. The egret's plumes appear only during the mating season. They were at one time considered valuable additions to hats and decorations for Asian ceremonial costumes. Egrets were once in danger of extinction because hunters killed millions of them for their plumes and left the helpless young to starve (see EXTINCTION). The Audubon Society and other conservation groups helped establish laws to protect the birds in many areas (see AUDUBON, JOHN JAMES). There are now sanctuaries (protected areas) for egrets and other shorebirds in South Carolina, Florida, Louisiana, Texas, and some other states.

The most common egrets in the United States are the great white egret (once called the American egret) and the cattle egret. The great white egret is about 35 in. [90 cm] tall with a wingspan of about 6 ft. [1.8 m]. This species produces the longest plumes. The smaller cattle egret stands about 20 in. [50 cm] tall with a wingspan of about 3 ft. [1 m]. The cattle egret feeds on small insects stirred up by the movement of cattle and other large mammals through open grasslands. Some cattle egrets ride on the backs of the cattle and water buffalo. They pick ticks and other insects from the animals' skin. Cattle egrets came to South America from Africa, reaching the United States around 1945.

EGRET
During its courtship display, the great white egret stretches its head and neck vertically and raises the long showy plumes on its back.

EIDER (ī'dər) The eider is a sea duck that belongs to the family Anatidae. It is a heavy-bodied duck with a short neck and wings. There are four species of eiders in North America. Two species are found mainly in Alaska. The other two species live throughout the northern part of the continent. The feathers from these ducks have been used as stuffing for pillows, mattresses, sleeping bags, and clothing. They are very light but hold warmth well. *See also* DUCK.



EIDER
The black and white common eider is a diving duck that spends most of its time at sea.

EINSTEIN, ALBERT (1879–1955) Albert Einstein (īn′ stīn′), a German-American scientist, was one of the greatest contributors to modern physics. Einstein was born in Ulm, Germany, but soon moved to Munich. After public school in Munich and in Aarau, Switzerland, Einstein studied math and physics at the Swiss Polytechnic Institute in Zurich. He was graduated in 1900. He became a Swiss citizen at the age of twenty-two. From 1902 to 1909, he was employed at the patent office in Bern, Switzerland. During these years, Einstein published the first part of his famous theory of relativity. In 1914, he became a professor at the Prussian Academy of Science in Berlin, Germany. In 1921, Einstein received the Nobel Prize for physics. In 1932, Princeton University offered Einstein a lifetime professorship. He accepted the offer and became a United States citizen in 1940.

Einstein's ideas Einstein's theory of relativity greatly changed scientific thought with new concepts of time, space, motion, and gravitation. His formula, $E=mc^2$, is one of the most important equations in science. In this formula, E stands for energy, m for mass, and c^2 for the speed of light multiplied by itself. This formula shows that if matter, which is any material or substance, is completely changed to energy such as heat or light, the amount of energy produced is huge. With the knowledge of this formula, it became possible to imagine the atomic bomb and later to make it.

Many of Einstein's ideas were difficult to understand. Some of them, however, came out of other, quite basic ideas. For example, to a person living in New York, Pittsburgh is west. To a person living in Arizona, Pittsburgh is east. The direction of Pittsburgh is relative. It depends on where a person is. The same kind of idea is true for things that move. For example, if a person is sitting in a train, and another train begins to pass by the window, it is difficult for the person to tell which train is moving. Therefore, motion is relative. Einstein built on these ideas. He included the motion of light itself

ALBERT EINSTEIN
One of the greatest scientists of the twentieth century, Einstein is best known for his theory of relativity. This provided the theoretical basis for nuclear power. Here Einstein and his wife relax while on a boat trip.

in his thinking. He joined together space and time in a new theory of relativity (see RELATIVITY). He reasoned that since the speed of light is constant, distance (or space) and time, which define the speed of light, must be relative.

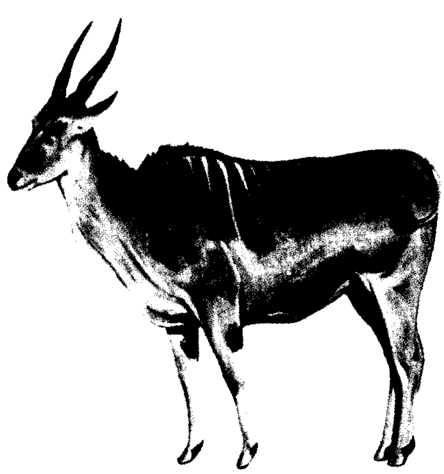
Einstein also made great advances in the quantum theory first suggested by Max Planck (see QUANTUM THEORY). He explained how the phenomenon known as the photoelectric effect occurs (see PHOTOELECTRIC EFFECT).

Einstein was also concerned with the force of gravity and electromagnetism (see ELECTROMAGNETISM; GRAVITY). Einstein tried to combine electromagnetism and gravitational force in a single theory called unified field theory. He spent the last twenty-five years of his life working on this theory, but he never formulated a theory with which he was completely satisfied.

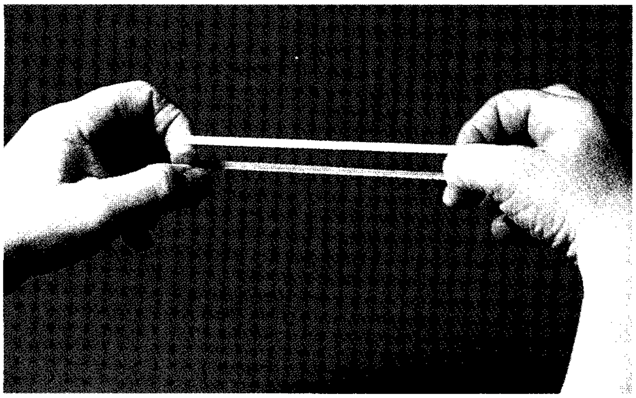
ELAND The eland is an oxlike mammal native to the plains of Africa. It is the largest of the antelopes, standing 6 ft. [1.8 m] tall at the shoulder and weighing as much as 2,090 lb. [950 kg] (see ANTELOPE; MAMMAL). It has spirally twisted horns, about 3.3 ft. [1 m] long, humped shoulders, and a dewlap (flap of skin) hanging from the neck. The eland is brown, with eight to fifteen white vertical stripes running down its sides. It has a black stripe running along the length of its back.

The eland grazes in herds of two hundred or more in open plains and light forests of central and southern Africa. People have domesticated the eland, and it has become a valuable farm animal. It is easily trained and has an immunity to many diseases found in Africa. The eland can also survive drought, surviving for weeks without water.

There are two major species of elands. The common eland is pale brown in color and lives in both central and southern Africa. The larger Derby eland is reddish brown, has heavier horns, and lives only in central and western Africa.



ELAND
The eland, found in Africa, is the tallest and heaviest of the antelopes.



ELASTICITY
A rubber band is elastic. It returns to its original length after being stretched.

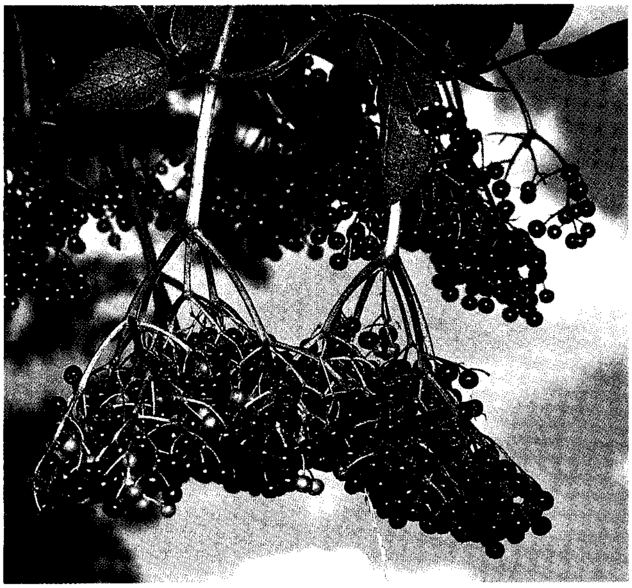
ELASTICITY When an object is stretched or compressed, several things can happen. The object can stay stretched or compressed, it can break, or it can return to its orginal shape. If it springs back to its original shape, it is said to have elasticity. Rubber and steel are elastic materials. All solid materials have some elasticity.

Force is needed to stretch an object. The amount it stretches is proportional to the force. If the force is doubled, the object will stretch twice as far. This is called Hooke's Law, which was discovered by Robert Hooke, an English physicist, in 1678 (see HOOKE, ROBERT).

An object can only be stretched elastically a certain distance, then it will either break or stay stretched. When either of these things happens, the object has passed its elastic limit. If it has not broken, only a small extra force is needed to stretch it still further.

When an object is stretched, it is said to be under stress. There are other ways of stressing an object. One way is by twisting it. This is called torsion.

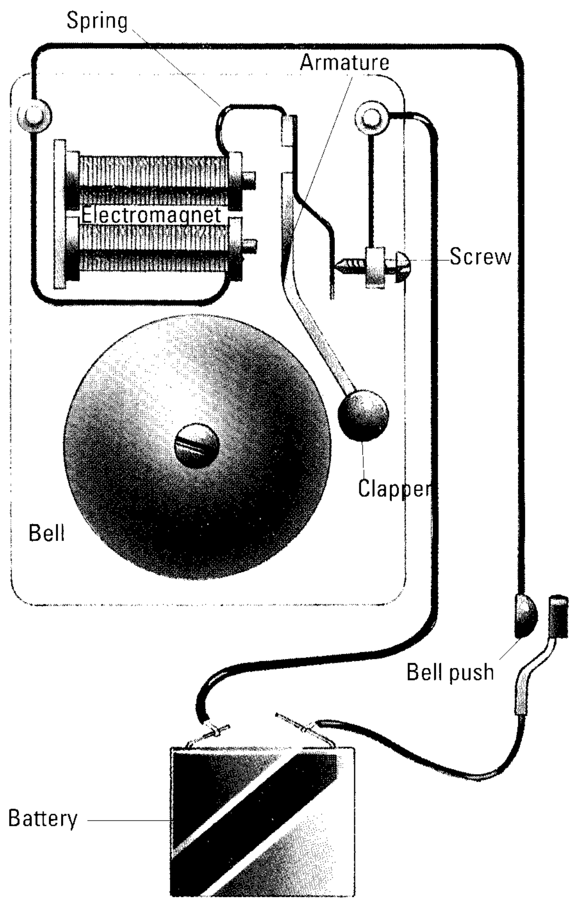
Only elastic materials return to their original shape when twisted and then let go. Hooke's law applies to this type of stress. In this case, measuring the angle that the object is twisted gives a measure of the force applied to the object. For an elastic object, this angle is proportional to the twisting force. Again there is an elastic limit. If the object is twisted too far, it will break or remain twisted.



ELDERBERRY
Elderberries provide food for birds and other animals. They can also be made into jelly or wine.

ELDERBERRY The elderberry is a small black or red berry produced by the elder plant. The elder plant is any of forty species of trees or shrubs belonging to the honeysuckle family and growing in temperate regions throughout the world (see HONEYSUCKLE FAMILY). The elder plant has leaves divided into several pointed and toothed leaflets. There are large clusters of small, white, saucer-shaped flowers that are followed by small fruits called elderberries. Elderberries are a food source for wildlife, and the berries of some species can also be processed into jelly, medicine, or wine.

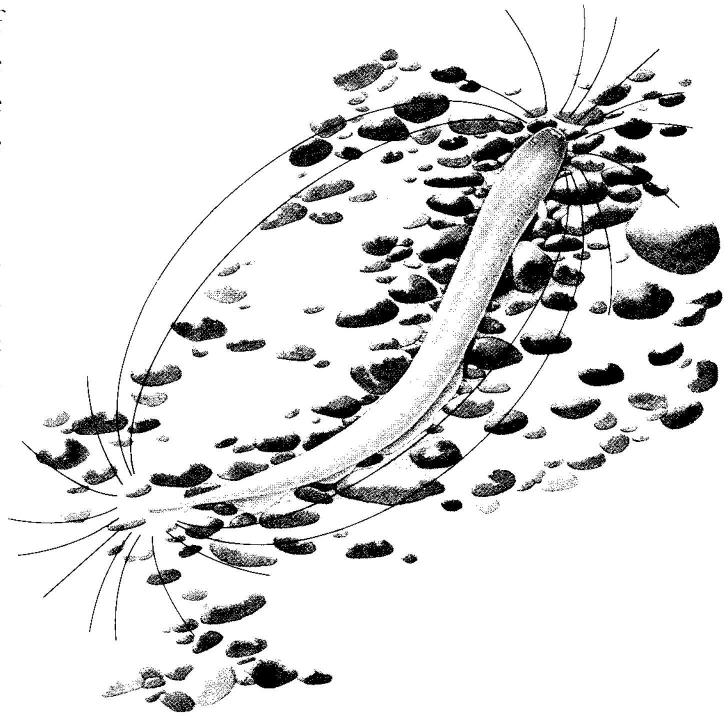
ELECTRIC BELL The doorbell in the average home is an electric bell that works on the principle of electromagnetism (see ELECTROMAGNETISM). Pushing the button of an electric doorbell completes an electric circuit, causing the doorbell to ring (see CIRCUIT, ELECTRIC). The circuit includes a metal movable part called an armature. At one end of the armature is a clapper that produces a ringing sound when it hits the bell. Also attached to the armature is a spring that presses against a screw. The armature is made of iron or another metal that can be magnetized. An electromagnet, which is powered by the circuit, magnetizes the armature, attracting the armature toward the electromagnet and the bell. However, as the armature moves toward the bell, the spring moves away from the screw, breaking the circuit. Because the circuit is broken, the electromagnet no longer attracts the metal armature. Thus, after striking the bell, the armature moves away from the electromagnet. When the spring again makes contact with the screw, the circuit is completed again. Then the armature again moves toward the electromagnet, causing the clapper to hit the bell. The repeated completing and breaking of the circuit causes the doorbell to make its vibrating ring.



ELECTRIC BELL
The diagram shows a battery-powered doorbell, a common type of electric bell.

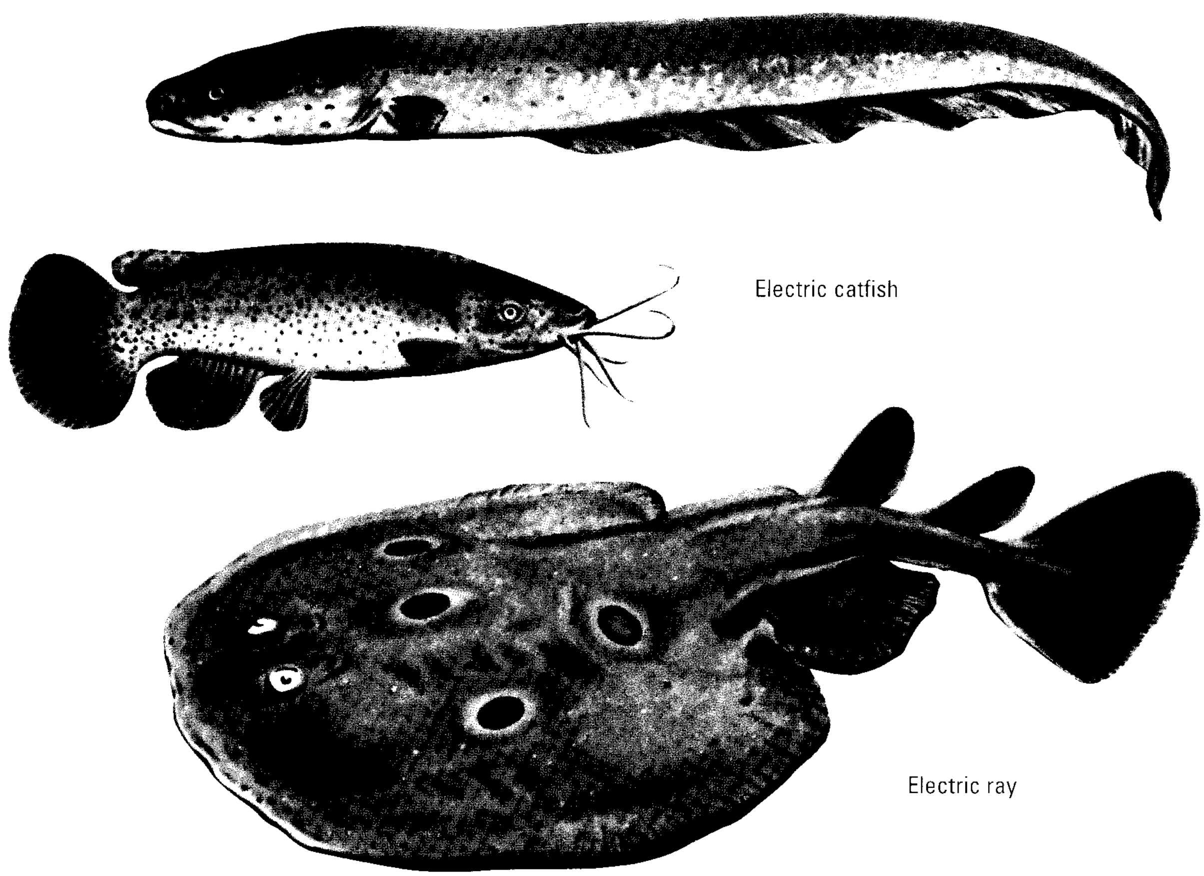
ELECTRIC FISH A number of species of fishes are known as electric fishes because they are able to produce electricity in their bodies. The better-known electric fishes are the electric eel, the electric catfish, and the electric ray (see CATFISH; EEL; RAY). They produce electricity with special muscles. Most muscles contract when a nerve stimulates them. A special "electric" muscle cannot contract. When a nerve stimulates it, an electric current is produced. The electric eel is able to produce a discharge up to 650 volts. This is enough to stun any large animal in the water.

Electric fish usually use electricity to defend themselves. Some of the fish use it to stun and capture prey. Fish also use the electric field they produce to find their way in muddy water.



ELECTRIC FISH—Electric field
Objects in the water distort the weak electric field produced by an electric eel (above). The changes in the field are detected by the eel and help it to locate objects.

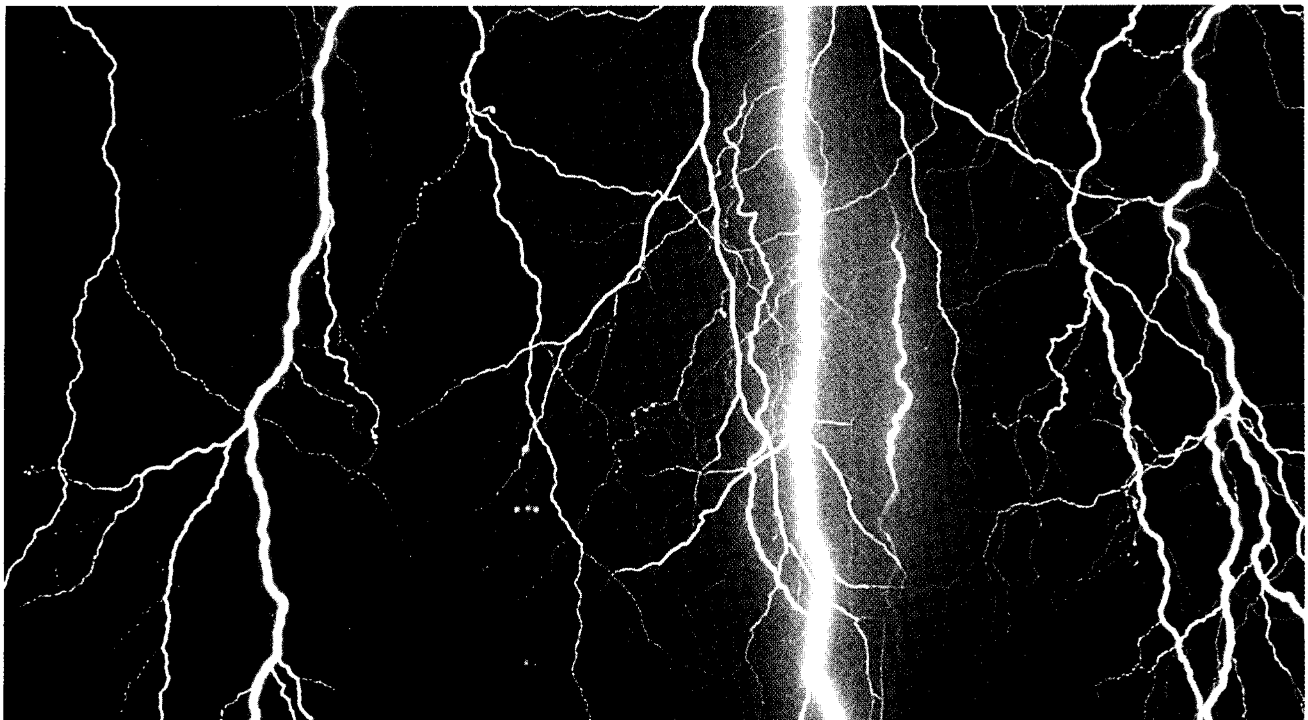
ELECTRIC FISH—Best-known
The best-known electric fishes are the electric eel (which produces shocks up to 650 volts), the electric catfish, and the electric ray, all pictured below.



Electricity is the energy associated with charged particles, whether they are stationary or moving. Stationary charged particles cause static electricity (see ELECTROSTATICS). Moving charged particles cause electric current (see CURRENT, ELECTRIC). Electric current is associated with electromagnetism because a changing electric field, which is generated by an electric current, produces a magnetic field, and a changing magnetic field induces an electric current (see ELECTROMAGNETISM).

How we use electricity People have harnessed electricity and put it to many uses. Our homes are full of electrical appliances, such as refrigerators, washing machines, microwave ovens, and television sets. Office workers rely on electricity for electric typewriters, computers, and photocopying machines. Industries use electricity to run much of their equipment, including motors, conveyor belts, and robotic arms. Our world would not be the same without the telephone and the electric light. In fact, electricity is one thing that has made the modern world modern.

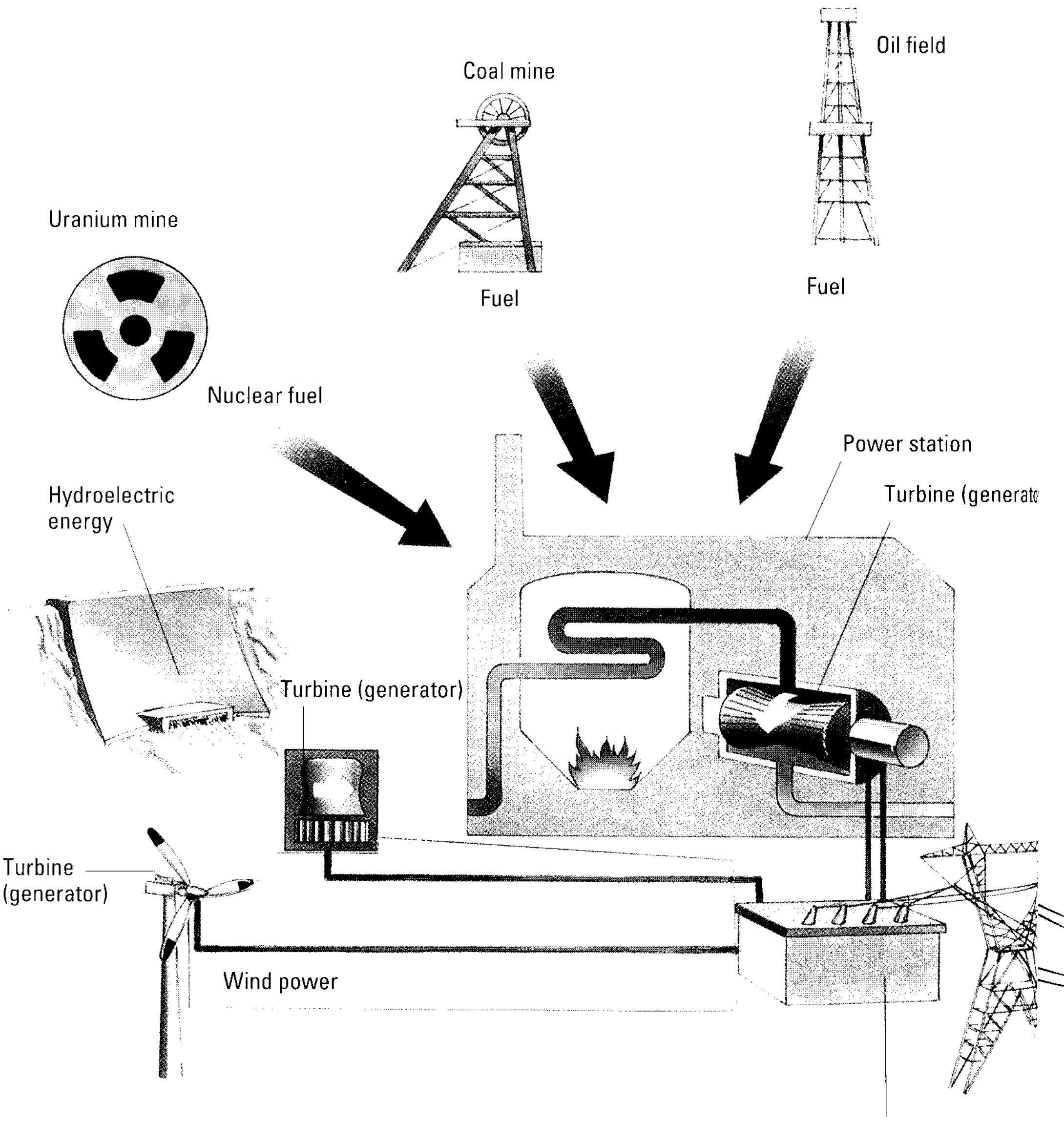
How we get electricity To use electricity, we must control its flow. Electric circuits channel the flow of electric current (see CIRCUIT, ELECTRIC). Electric circuits need a source of electricity, such as



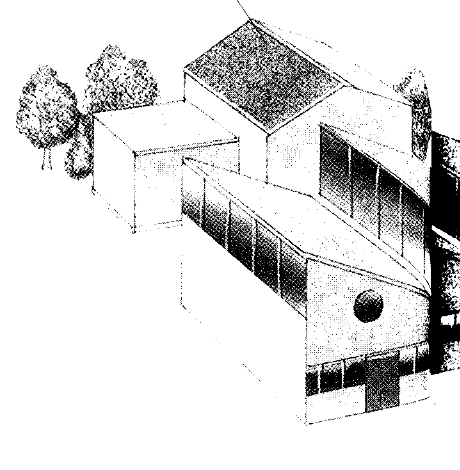
LIGHTNING STRIKE
Flashes of lightning strike buildings in Tampa Bay, Florida. Lightning is a huge spark that jumps from electrically charged clouds to the ground.

ELECTRICITY GENERATION

Heat from a nuclear reactor or from burning coal or oil is used to make steam to drive a steam turbine. The turbine spins a generator to produce electricity. Alternatively, fast-flowing water from behind a dam turns a water turbine that drives a generator, or a small generator is turned by rotating propeller blades driven by the wind. The voltage of electricity from a power station or hydroelectric plant is increased to thousands of volts by a step-up transformer. The electricity is carried across country by power lines suspended from pylons. Step-down transformers reduce the voltage for use in homes and factories.



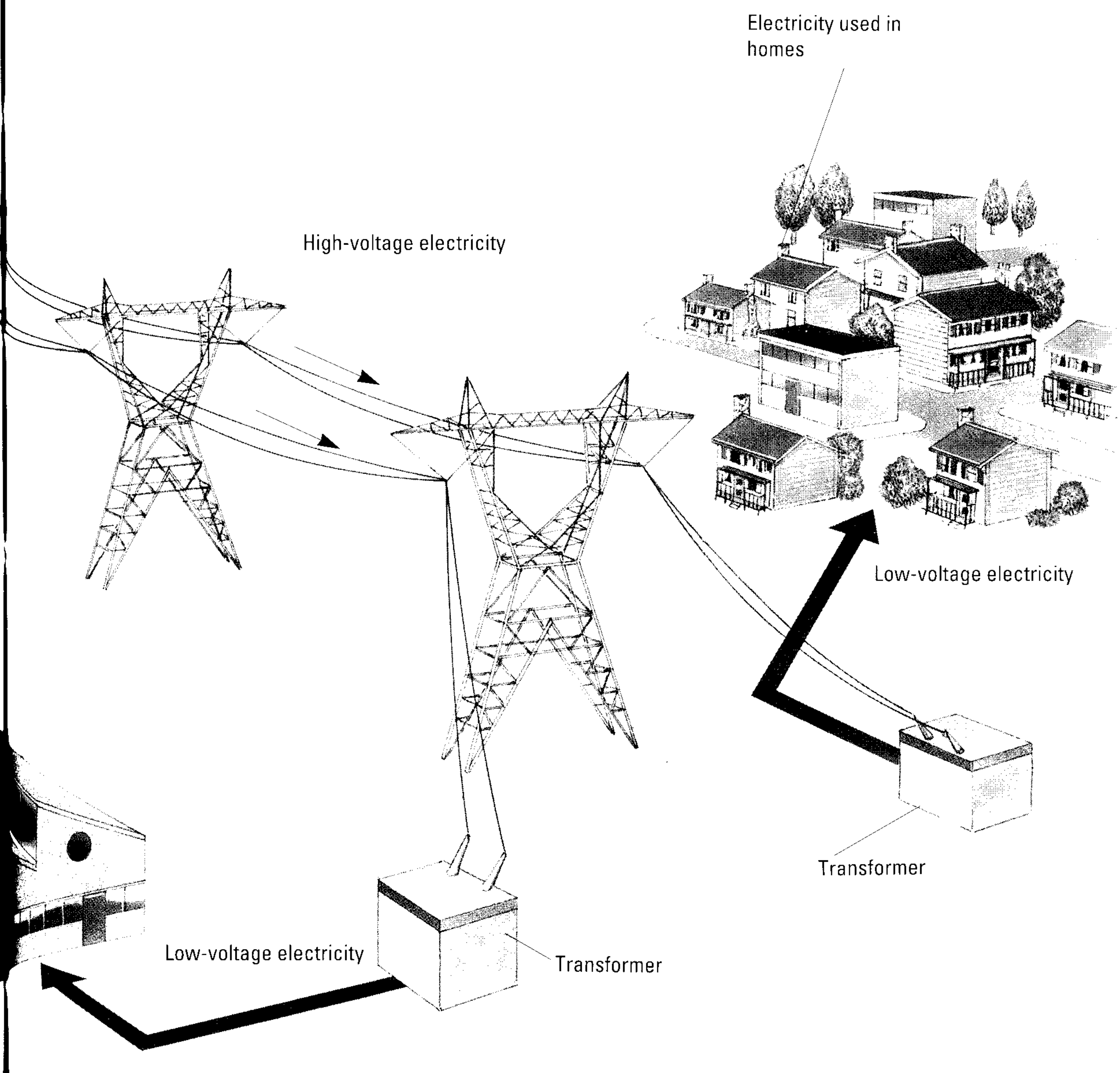
Electricity used in factories

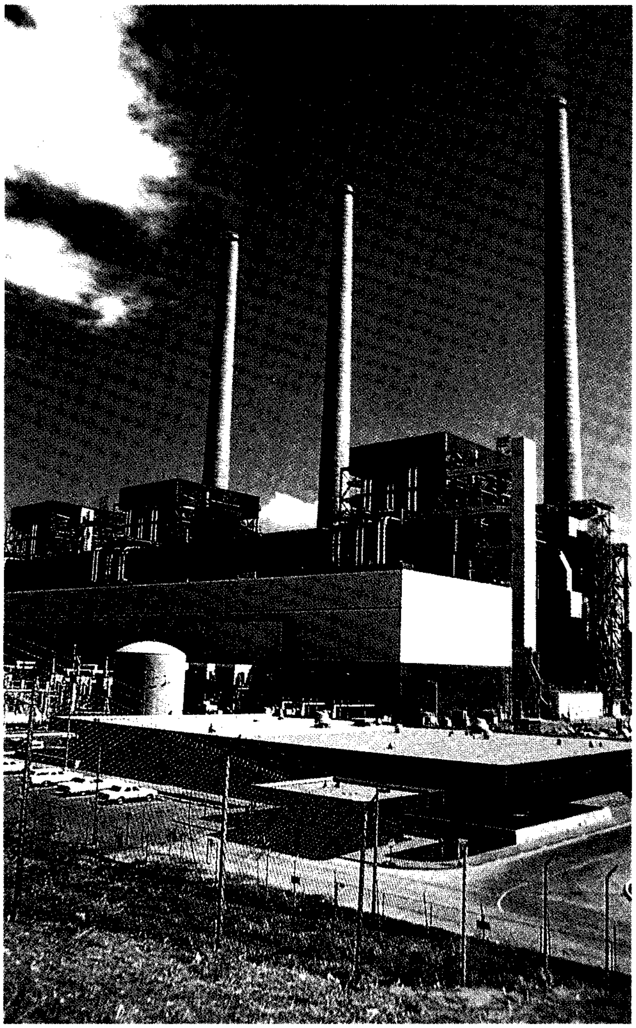


a battery, a solar cell, or a generator. Batteries and solar cells are useful for small, portable devices. They are also used in cars and other vehicles that do not have continuous connection to a stationary power supply. However, most electricity we use in our homes, factories, and offices is supplied by generators (see GENERATOR, ELECTRICAL). The generators in power plants produce electricity that travels over power lines. This electricity is usually in the form of alternating current (see ALTERNATING CURRENT). Ultimately, this electricity is fed into our homes through wires that run through the walls.

Generating electricity requires tremendous amounts of energy. Such energy is needed to power the huge turbines that drive the generators in power plants (see ENERGY; TURBINE). Most power plants today use nonrenewable sources of energy, such as coal, petroleum (oil), natural gas, or uranium, to generate electricity. Renewable sources of energy, such as solar energy, wind energy, geothermal energy, and water power, will likely become increasingly important for generating electricity in the future (see HYDROELECTRIC POWER).

How electricity is measured Scientists and engineers use a number of different terms to describe and measure electricity. *Voltage,* given in volts, measures electrical potential. Voltage is also known as electromotive force (see ELECTROMOTIVE FORCE). Current strength is measured in *amperes,* also called *amps.* Resistance to the flow of electricity in a circuit is measured in *ohms.* Electrical power is measured in *watts.* The amount of electrical power used in the average household over the course of a month is measured in the thousands of watts, or *kilowatts.* The amount of electrical power generated by a power plant is measured in the millions of watts, or *megawatts* (see AMPERE; OHM; WATT).





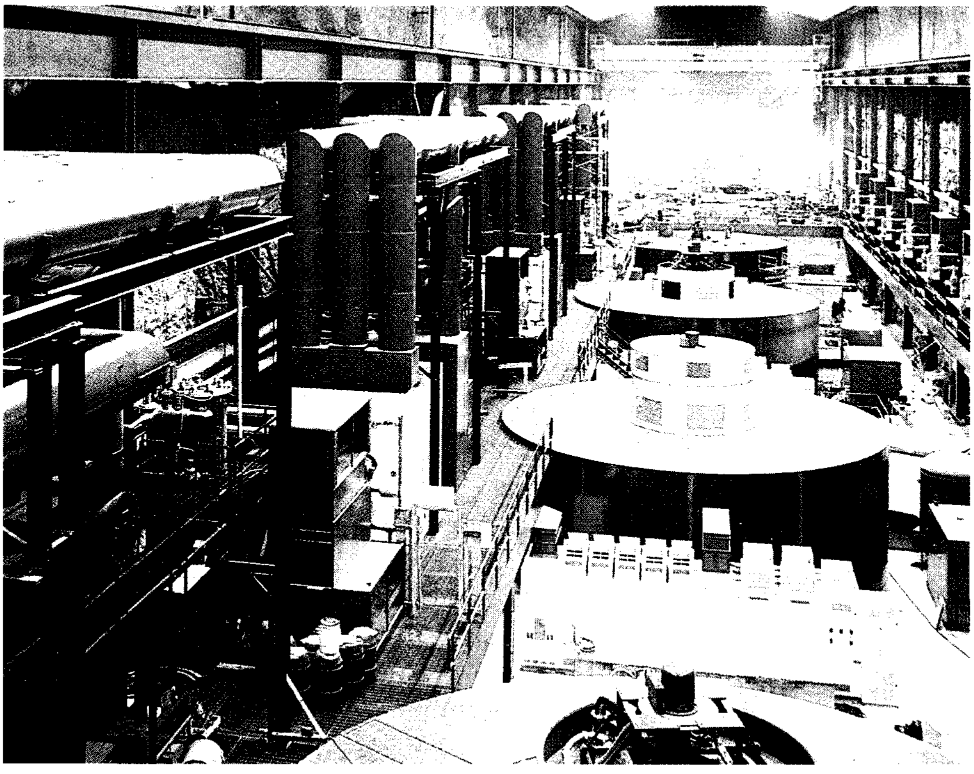
How electricity was discovered A Greek philosopher named Thales made the first recorded observation of electricity around 600 B.C. He rubbed a piece of amber with cloth. The amber then attracted other objects. This happened because the amber acquired an electric charge. Electricity got its name from the Greek word for amber, *elektron.*

In time, people noticed that other materials, when rubbed, were able to attract and repel objects. By the early 1700s, scientists were doing experiments with such objects. In the middle 1700s, Benjamin Franklin began doing experiments with lightning, which he proved was a form of static electricity (see FRANKLIN, BENJAMIN).

In 1780, another effect of electricity was noticed. An Italian named Luigi Galvani touched the back leg of a dead frog with his knife. When he did this, the leg twitched. He hypothesized that this was due to electricity (see GALVANI, LUIGI). Another Italian, Count Alessandro Volta, found out what was happening (see VOLTA, ALESSANDRO). The knife was made out of brass and iron. These metals acted on a certain liquid in the frog's leg. This produced electricity. Volta built the first battery, based on his findings, in the late 1790s (see BATTERY).

THERMAL POWER STATION

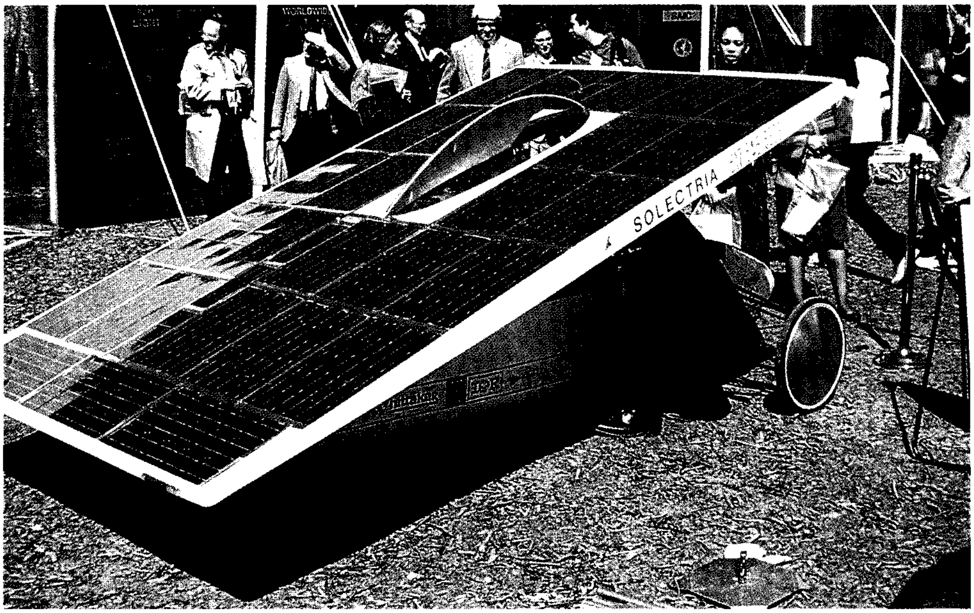
A power plant that uses the heat from burning coal, oil, or gas to make steam to drive turbines is known as a thermal station. These stations are designed to minimize the amount of harmful products of burning that pass up their smokestacks into the atmosphere.



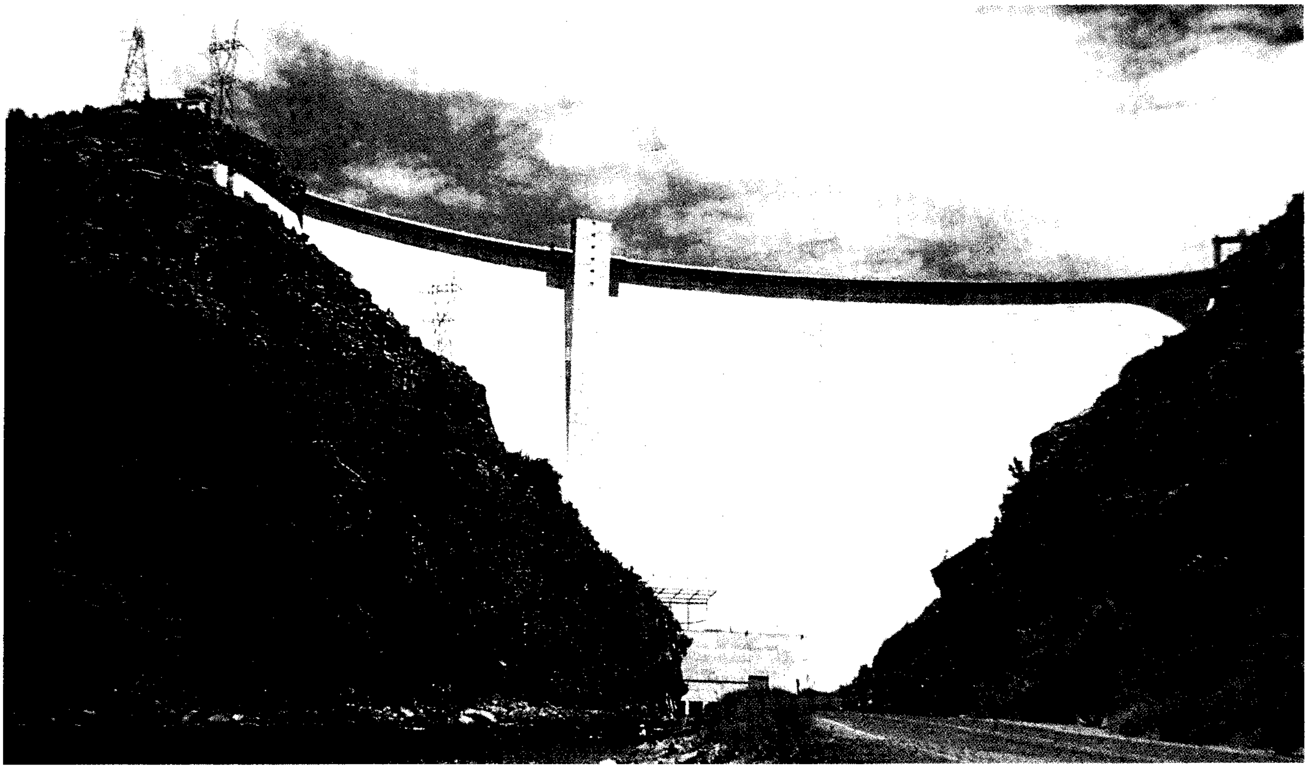
HYDROELECTRIC POWER PLANT

In this power plant (right) the water collected from behind the dam spins turbines that, in turn, rotate huge electrical generators.

SOLAR POWER
Solar cells convert the energy of sunlight into electricity. A large number of solar cells are used to power this experimental car, which is totally pollution free.



CLEAN POWER
Hydroelectric power stations are favored because they cause no atmospheric pollution. However, they need a large reservoir of water and have to be sited carefully to avoid causing damage to the surrounding environment.



In the early 1800s, scientists began experimenting with electrical circuits. In 1831, the British scientist Michael Faraday discovered the connection between electricity and magnetism. He took a circuit that did not have any current running through it. Then he moved it around inside a magnetic field. This produced a current in the circuit. Faraday had discovered a very good way of producing electricity. Faraday also discovered the opposite effect. He placed a wire with a current running through it between the poles of a magnet. When the current changed, the wire moved. This effect is now used in electric motors (see FARADAY, MICHAEL).

The discovery of the principles of electromagnetism led to the development, in the late 1800s, of generators that could produce huge quantities of electricity. With this development, electricity soon came into wide use throughout the United States and Europe. Electricity quickly became a necessity of our modern world.

PROJECT 29, 30, 31, 34, 53, 56

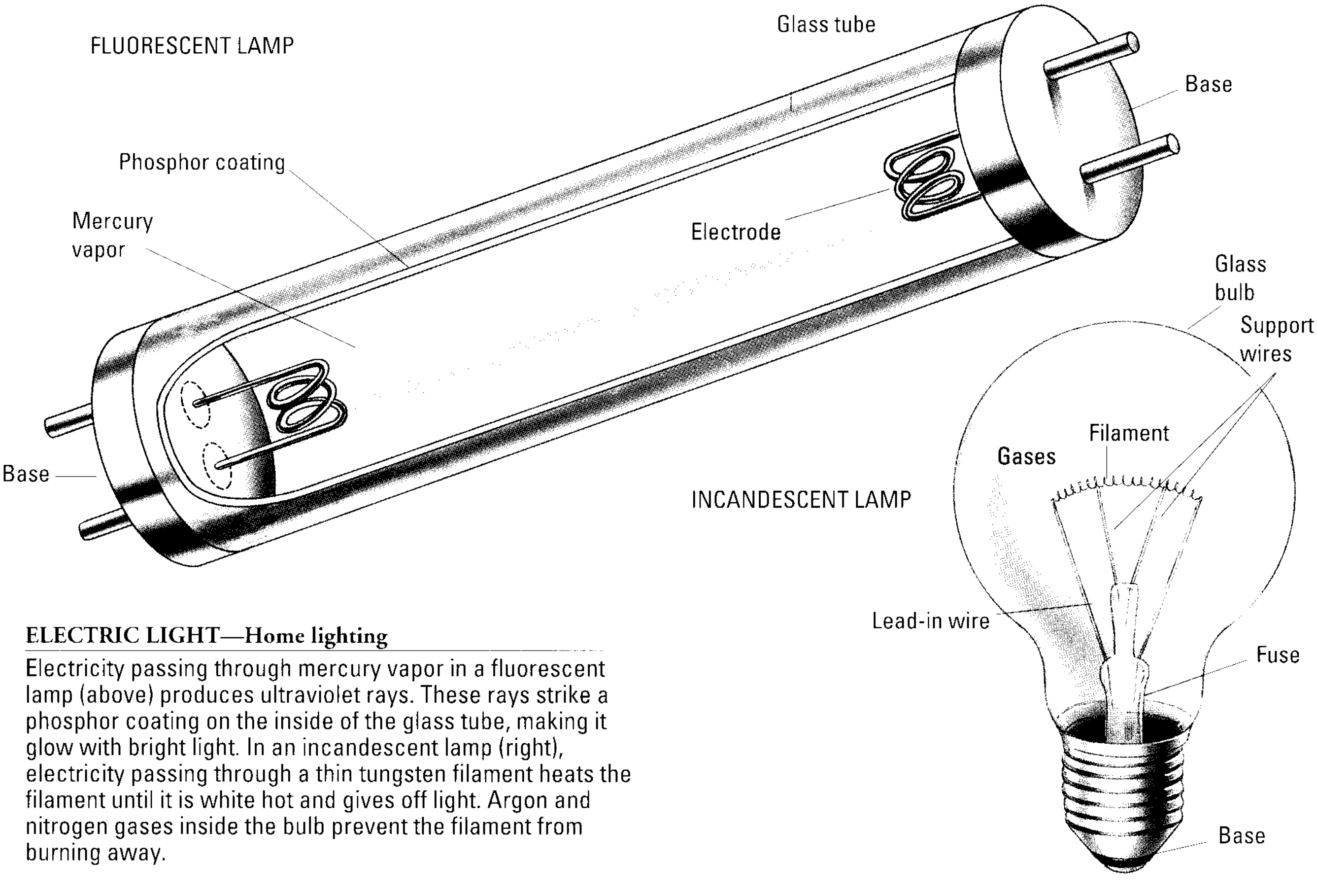
ELECTRIC LIGHT An electric light is a device that uses electricity to produce visible light. Electricity can be used to produce light in three ways. Electricity can be passed through a wire so that the wire glows red hot or white hot. Electricity can be made to pass through a gas. This makes the gas glow and give off light. Electricity can be passed through other gases that then release ultraviolet rays. These rays cause other substances to glow (see ELECTRICITY).

The first electric lights were incandescent lights (see INCANDESCENCE). An incandescent light contains three basic parts—a base, a wire called a filament, and a glass enclosure called a bulb. The base is connected to the electric circuit (see CIRCUIT, ELECTRIC). The electric current flows from the base to the filament. The bulb encloses the filament so that air does not cause the filament to burn up. The filament has resistance to the electricity flowing through it (see RESISTANCE, ELECTRICAL). In overcoming the resistance, the electric current heats the filament to 5,400°F [3,000°C]. This causes the filament to glow white hot.

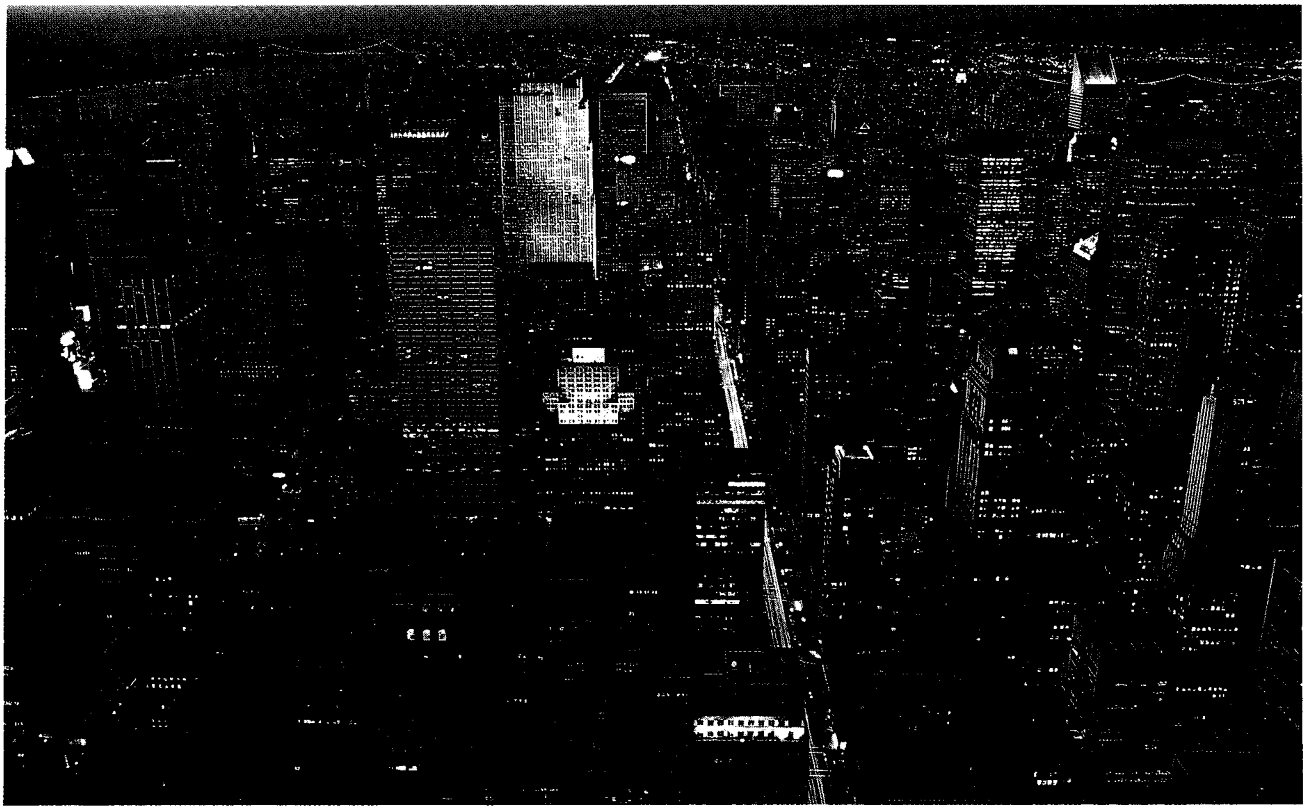
The first incandescent lights were invented by Thomas Edison (see EDISON, THOMAS ALVA). Edison experimented for more than two years to find a filament that would give good light when electricity flowed through it. In 1879, he successfully used a burned cotton thread as a filament.

Today's incandescent lights have filaments made of the metal tungsten (see TUNGSTEN). Tungsten gives a much whiter light than carbon when it glows. The filament is shaped like a coil. The bulb contains the gases argon and nitrogen (see ARGON; NITROGEN). These gases do not react with the metal of the filament, so the metal does not burn (see EVAPORATION). Most light bulbs in today's homes use between 40 and 150 watts of electric power (see WATT).

Many of the lights that are used to light streets and business signs are tubes containing gas. When electricity is passed through the gas, the energy excites the atoms. The atoms give off this extra energy as light (see ATOM). Different gases glow in different colors. Neon gas glows bright red (see NEON). Metal halide gas glows white. Sodium



ELECTRIC LIGHT—Home lighting
Electricity passing through mercury vapor in a fluorescent lamp (above) produces ultraviolet rays. These rays strike a phosphor coating on the inside of the glass tube, making it glow with bright light. In an incandescent lamp (right), electricity passing through a thin tungsten filament heats the filament until it is white hot and gives off light. Argon and nitrogen gases inside the bulb prevent the filament from burning away.



ELECTRIC LIGHT—City lighting

As night falls, buildings in midtown Manhattan, New York, become ablaze with light. Automobile headlights have created streaks of light in this long-exposure photograph.

vapor glows yellow. Mercury vapor glows bluish white light. Lights with such gases as neon, metal halide, sodium vapor, and mercury vapor are called high-intensity discharge lamps. *Lamp* can refer to the bulb as well as to the appliance that contains it.

Arc lamps are another type of discharge lamp. In an arc lamp, electricity jumps over the gap between two electrodes, producing an electric arc (see ARC, ELECTRIC; ELECTRODE). The arc causes the ends of the electrodes to be very hot. The arc and the ends of the electrode give off bright light because of the intense heat the arc produces. Arc lamps are sometimes used for motion picture projectors and searchlights.

Another kind of discharge lamp is called a fluorescent lamp (see FLUORESCENCE). A fluorescent lamp contains mercury vapor. When an electric current is passed through mercury vapor, the mercury vapor gives off bluish white light. The mercury vapor also produces invisible rays called ultraviolet rays (see ULTRAVIOLET RAY). The bulb has a special coating of powder inside its glass. The powder is called a phosphor. When a phosphor is struck by ultraviolet rays, it glows. The light it gives off may be white or any of several different colors.

Today's scientists are researching ways to produce light using less energy. For example, they have coated the phosphors that line fluorescent bulbs with special substances. These new bulbs use the same amount of electricity as the old bulbs, but they give off far more light.

New kinds of incandescent lights have also been developed. In the older kinds of incandescent lights, the filaments gradually decay. As this happens, the tungsten from the filament coats the inside of the bulb, blocking some of the light. The improved lights, called halogen lights, have a bulb that is filled with one of the gases called halogens, such as iodine vapor (see HALOGEN). The gas combines with the tungsten that evaporates from the filament. The gas carrying the tungsten circulates throughout the bulb. When the gas comes in contact with the hot filament, the tungsten is redeposited back on the filament. This process repeats over and over. The result is the filament is continually rebuilt, and the bulb is kept clean.

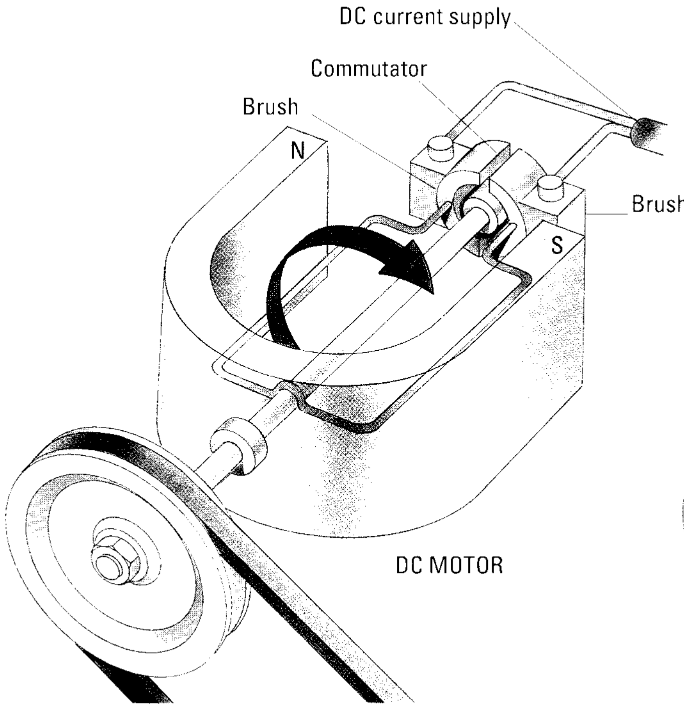
ELECTRIC MOTOR An electric motor is a machine that uses electricity to do work. A major use of electric motors is to make wheels and shafts turn. Washing machines, vacuum cleaners, and fans all have turning wheels and shafts powered by electric motors. Some electric motors do not turn wheels and shafts. The linear electric motor is an example of such a motor.

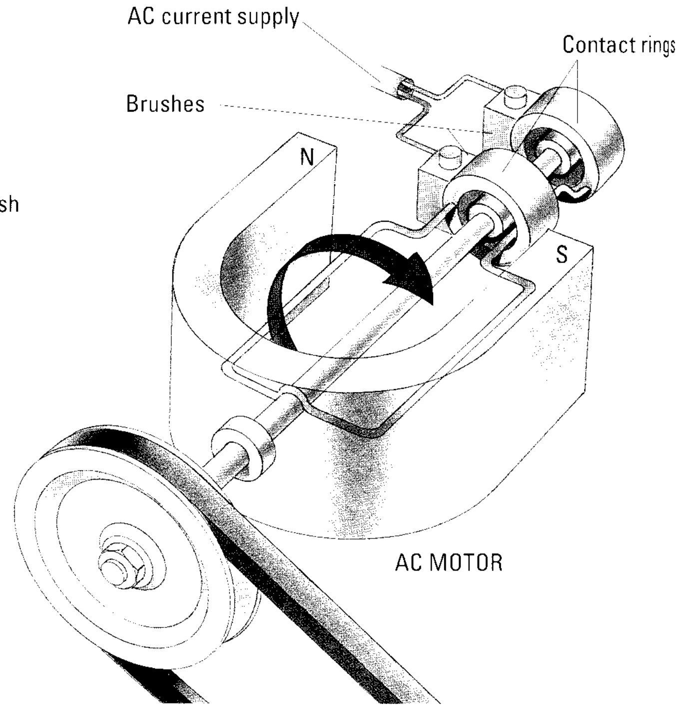
Electric motors employ the principles of electromagnetism (see ELECTROMAGNETISM). Electricity passes through wires in the motor, creating a magnetic field. Magnetized parts of the motor, such as iron parts or wires carrying electric current, turn as they are attracted to and repelled by the magnetic field.

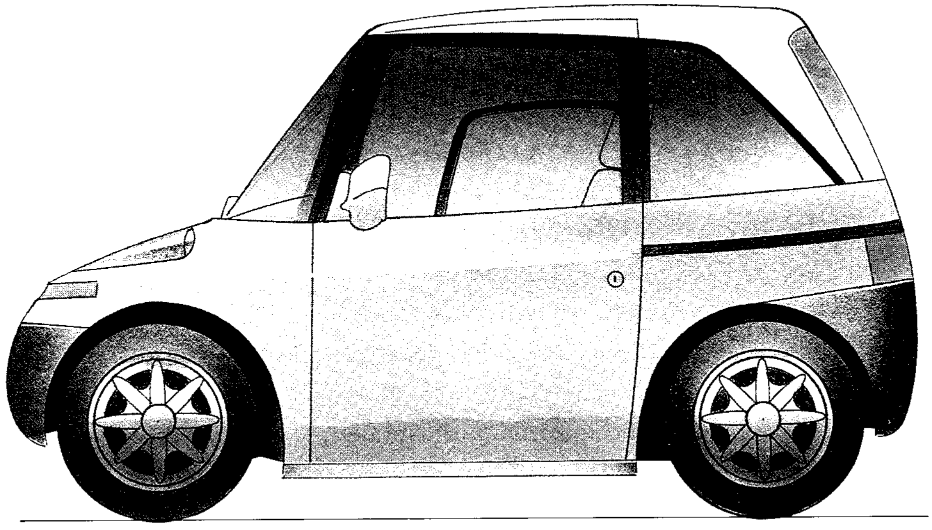
An electric motor has two main parts. One part is fixed and does not move. This part is called the stator. Inside the stator is a part that can turn. This is called the rotor or armature. The armature consists of coils of wire. They are wound around

ELECTRIC MOTOR—Principles

A DC electric motor (below left) has a commutator to reverse the direction of current flow every half turn, to keep the motor rotating continuously in the same direction. Alternating current (AC) changes direction sixty times every second, and so an AC motor (below) needs no commutator.







ELECTRIC MOTOR—
Electric car

Road vehicle engineers continue research into producing an economical electric car, using batteries or fuel cells to power its motor.

ELECTRIC MOTOR—
Electric locomotive

Most types of electric railroad locomotives pick up high-voltage AC current from overhead wires. Rectifiers on board the locomotive change the AC to lower-voltage DC, which powers DC traction motors that turn the locomotive's wheels.

pieces of soft iron, called cores. The iron increases the strength of the magnetism when electricity passes through the coils. The stator in simple motors is a permanent magnet (see MAGNETISM). In other motors, it is made of coils of wire, like the armature. Coils like this are called a field winding.

Some electric motors use direct current electricity, or DC, and others use alternating current, or AC (see ALTERNATING CURRENT; DIRECT CURRENT). In a DC motor, the coils of the armature are fed with electric current through pieces of carbon on each side. The pieces of carbon are called brushes. The brushes touch a ring of metal pieces fixed around the shaft of the armature. This ring is called the commutator. Electric current flows from one carbon brush, through the metal piece of the commutator touching the brush, into the coils of the armature. From the armature, it flows out again through a second metal piece of the commutator, directly opposite the first piece, into the other carbon brush. The commutator turns with the shaft, and current flows through one coil of the armature at a time.

As soon as electricity flows through the armature coils, it makes the armature into a magnet. The north pole of the armature is attracted by the south pole of the stator. The south pole of the armature is attracted by the north pole of the stator. This makes the armature turn. The shaft of the motor rotates as the armature turns. The armature turns quickly because the attraction between the armature and the stator is strong. The armature builds up momentum and continues to turn in the same direction until the commutator switches the direction of the current flowing through the armature (see MOMENTUM). This occurs when the armature has made about half of a complete rotation.

When the commutator switches the direction of the current, the north pole of the armature switches and becomes a south pole. As soon as it does this, it is pushed away from the south pole of the stator. Now it is the north pole that attracts it, so the armature keeps on turning. In most electric motors, there are several separate coils in the armature. It acts like a magnet with many different north and south poles. The poles change continually as the armature spins and makes the commutator change the direction of the current. The more separate coils there are, the more smoothly the motor turns.

Electric motors that use AC work in a different way. In one kind, the alternating current is passed around coils in the stator. The result is a moving magnetic field. When there is a moving magnetic field, it causes current to flow in wires nearby. This is called induction. Induction makes an electric current flow in the coils of the armature. This makes the coils behave like magnets. The moving magnetic field of the stator makes the coils of the armature spin. The armature turns the shaft of the motor. This kind of electric motor is called an induction motor.

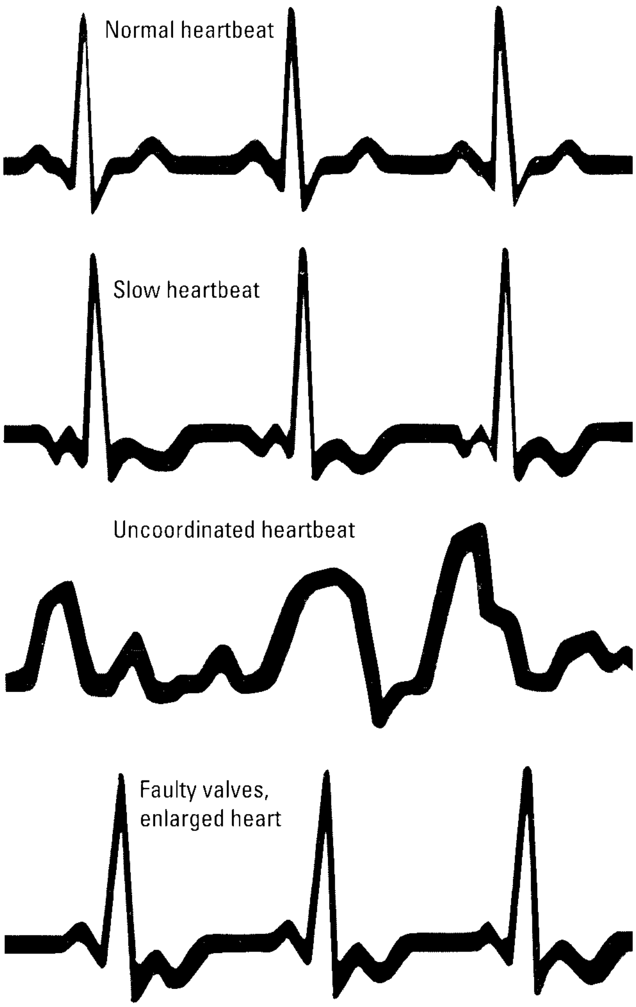
Another type of electric motor that uses alternating current is called the synchronous motor. In this type, the armature spins at the same speed as the turning magnetic field of the stator. Electric clocks usually have synchronous motors, because they must have a constant speed of rotation to keep time correctly. Synchronous motors are also used in other scientific instruments, such as astronomical telescopes, that must turn smoothly.

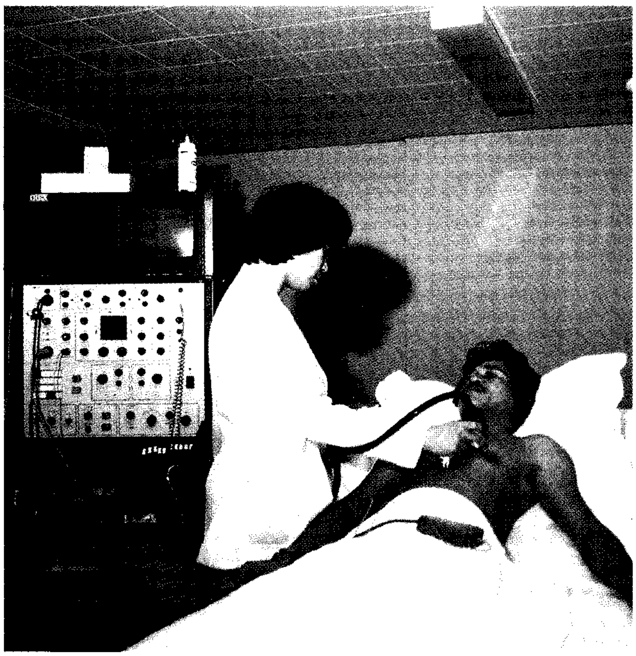
See also CURRENT, ELECTRIC; ELECTRICITY.

ELECTROCARDIOGRAM (ĭ lĕk′trō kär′dē ə grăm′) An electrocardiogram, abbreviated ECG or EKG, is a recording of the electrical activity of the heart. The ECG from a normal heart shows impulses of a certain size and shape when recorded with a special machine called an electrocardiograph. When the heart is not beating normally because of disease or some other disorder, the ECG changes. Such changes help the doctor to diagnose why the heart is not beating normally.

An electrocardiograph has wires with electrodes at the ends (see ELECTRODE). The electrodes are attached to the patient's skin on the chest, arms, and legs. They pick up tiny changes in electrical activity from twelve points around the heart. These electrical impulses are sent through a voltage amplifier to make a recording with a pen across a moving strip of paper. Certain machines (some of which can be worn throughout the day) record the electrical activity on magnetic tape that can be played back for viewing on an oscilloscope (see OSCILLOSCOPE).

See also HEART.





ELECTROCARDIOGRAM
An electrocardiogram (top) allows a physician to diagnose various heart defects and to monitor a patient under treatment. Here a doctor examines a patient having an ECG.

ELECTRODE An electrode is the terminal of any electric source. In other words, an electrode is an electrical conductor by which an electric current enters or leaves a medium (see CONDUCTION OF ELECTRICITY).

For example, in electrolysis, a current enters and leaves a solution by way of two electrodes, the anode and cathode (see ELECTROLYSIS). Electrons flow from the cathode, which is the negative electrode, through a circuit, to the anode, which is the positive electrode.

Some vacuum tubes, besides having a cathode and anode, have other electrodes called grids. Ordinary transistors have three electrodes, called the emitter, base, and collector.

See also ARC, ELECTRIC; CURRENT, ELECTRIC.

ELECTROENCEPHALOGRAPH (ĭ lĕk′ trō ĕn sĕf′ə lə grăf′) The electroencephalograph is an instrument that measures and records electrical impulses from nerve cells in the brain by the attachment of electrodes, or conductors, to the scalp. The recording of the electrical activity of the brain that the electroencephalograph produces is called an electroencephalogram (abbreviated EEG).

Normal EEGs are rhythmic and are the same on both sides of the brain. The normal frequencies are from 1 to 50 Hz. *Hz* stands for hertz (cycles per second). In a healthy, awake adult, the most common rhythms are called alpha waves, which have a frequency of 8.5 to 13 Hz. When the person concentrates, the alpha waves decrease, giving way to smaller, faster waves (beta waves). During sleep or when a person is unconscious, brain waves become very slow (delta waves).

Brain waves originate from the nerve cells in the brain. If these nerve cells become damaged by a head injury, an infection in the brain, lack of oxygen, or an overdose of certain drugs, the EEG will be changed. Using the EEG, doctors are able to diagnose epilepsy and to locate brain tumors.

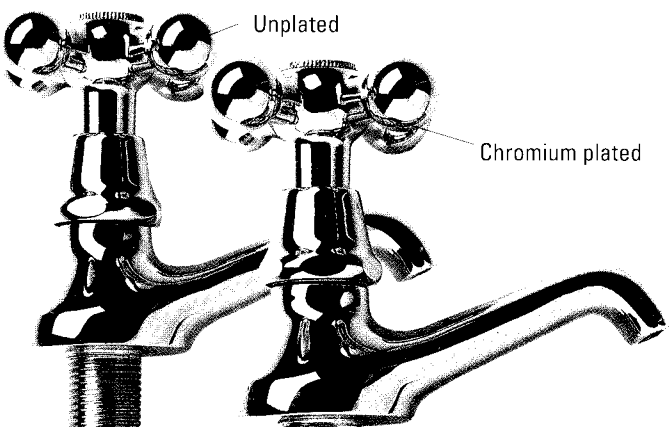
See also BRAIN; EPILEPSY.

ELECTROLYSIS (ĭ lĕk trŏl′ə sĭs) Electrolysis is the use of electricity to split up a substance into its different parts. Electrolysis can be used to extract metals from their ores, to purify metals, and to prepare gases from liquids. Electrolysis is also used to put a layer of one metal on top of another. This is called electroplating.

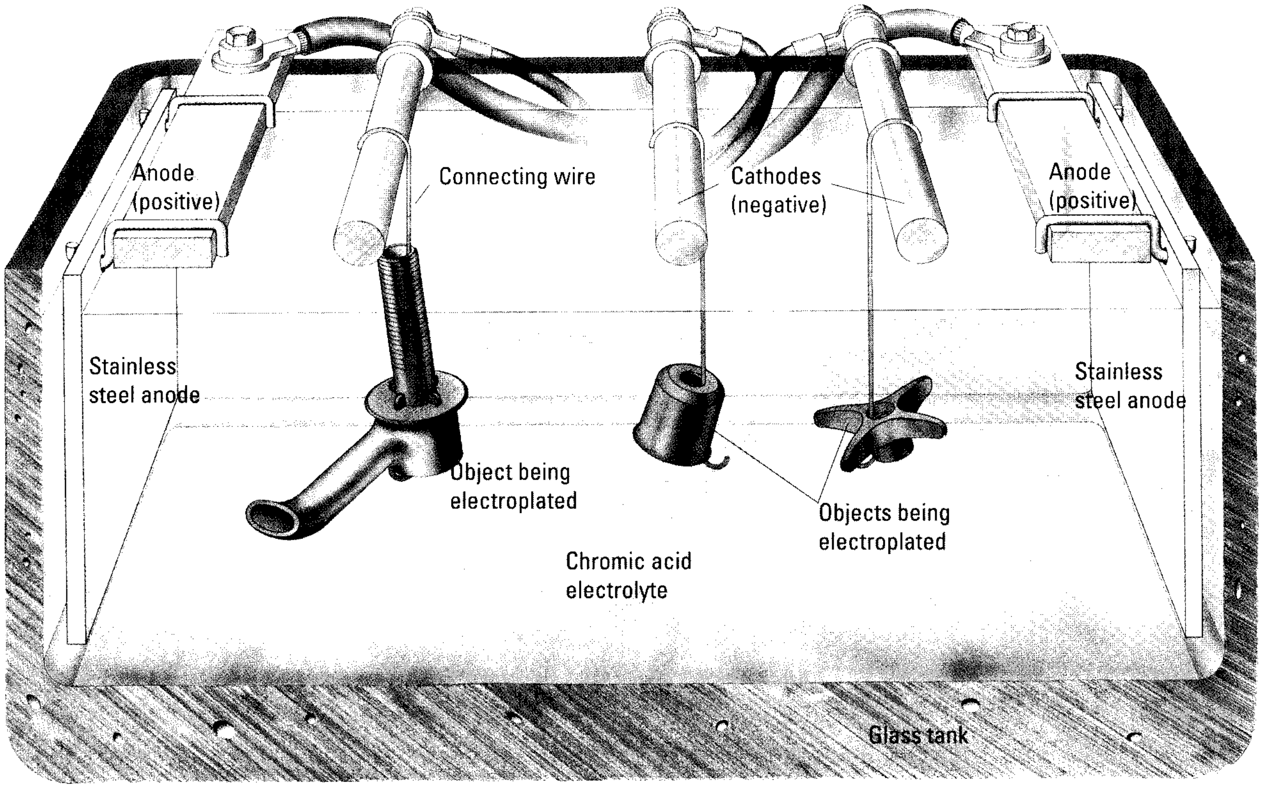
Electrolysis only works with substances that can be dissolved or melted and that will conduct an electric current. Substances that have these properties are called electrolytes.

When an electrolyte is melted or dissolved in water, its atoms or groups of atoms form ions. Ions are particles that bear electric charges. If the charges are positive, the ions are called cations. If they are negative charges, the ions are called anions. Because they are electrically charged, ions can carry an electrical current through a solution (see IONS AND IONIZATION; SOLUTION AND SOLUBILITY). Hydrochloric acid is an example of an electrolyte. It forms hydrogen ions with a positive charge (cations), and chloride ions with a negative charge (anions).

To electrolyze a substance, two electrodes are used (see ELECTRODE). One is connected to the positive side of a battery or a DC electrical generator (see BATTERY; GENERATOR, ELECTRICAL). The other is connected to the negative side. When the electrodes are dipped into the solution, the ions



ELECTROLYSIS—Electroplating
Faucets are usually made of brass, a yellow metal that easily corrodes. To prevent this from happening, faucets are electroplated with the silvery metal chromium.



ELECTROLYSIS—Plating bath

Electroplating is a major industrial application of electrolysis. The electrolyte is contained in an electrolytic cell—called a bath—with anodes dipping into it. The objects to be electroplated are connected by wires to the cathodes. This diagram shows how faucets are electroplated with chromium in a bath of chromic acid.

immediately start moving. The cations in the solution are attracted to the negative electrode (the cathode). The anions, with a negative charge, are attracted to the positive electrode (the anode).

When hydrochloric acid is electrolyzed, the hydrogen ions, which are the cations, travel to the cathode, and the chloride ions, which are the anions, travel to the anode. When the ions reach the electrodes, their electric charges are neutralized. The hydrogen ions become molecules of hydrogen gas, and the chloride ions become molecules of chlorine gas. Bubbles of the two different gases rise up from the electrodes.

When sodium chloride (common salt) is melted, it too can be electrolyzed. The result in this case is metallic sodium and chlorine gas. The sodium appears at the cathode, and chlorine bubbles up from the anode.

When a solution of sodium chloride is electrolyzed, the result is different. At the cathode, the sodium is released, but immediately it reacts with the water in the solution. This makes hydrogen gas and sodium hydroxide solution. At the anode, chlorine gas bubbles up as before.

Pure gases such as hydrogen, chlorine, and oxygen can easily be prepared by electrolysis. Pure metals such as sodium, potassium, and aluminum are also prepared in this way. Electrolysis is a useful means of purifying, or refining, metals.

Electrolysis is often carried out in a special container. The container is called an electrolytic cell. The cell must be made of material that is strong enough to resist corrosion by hot liquids. The temperatures reached in electrolysis are often very high. The electrolyte, and the substances that are made from it, may be very corrosive substances. The electrodes must also be made of noncorroding materials. If they are not, they will be eaten away when they are dipped into the electrolyte (see CORROSION). Sometimes expensive metals, such as platinum, are used to make electrodes. Carbon rods may also be used. The electrodes do not need to be two rods. The lining of the electrolytic cell sometimes serves as one electrode.

In 1832, the scientist Michael Faraday stated two laws about electrolysis. The first says that the amount of a substance that forms at an electrode is proportional to the quantity of electricity that is passed through the electrolytic cell. The second law says that when the same amount of electricity is passed through different electrolytes, the amounts of different substances that are formed are proportional to their equivalent weights. (A substance's equivalent weight is the mass of that substance that combines with or replaces one gram of hydrogen, eight grams of oxygen, or 35.5 grams of chlorine in a chemical reaction. It is the combining power of the substance.)

See also FARADAY, MICHAEL.

ELECTROMAGNETIC RADIATION

Electromagnetic radiation is the energy that a charged particle gives off as it moves through space or vibrates. A vibrating charged particle generates both an electric and a magnetic field (see ELECTROMAGNETISM). These fields form at right angles to each other and to the direction of motion of the charged particle.

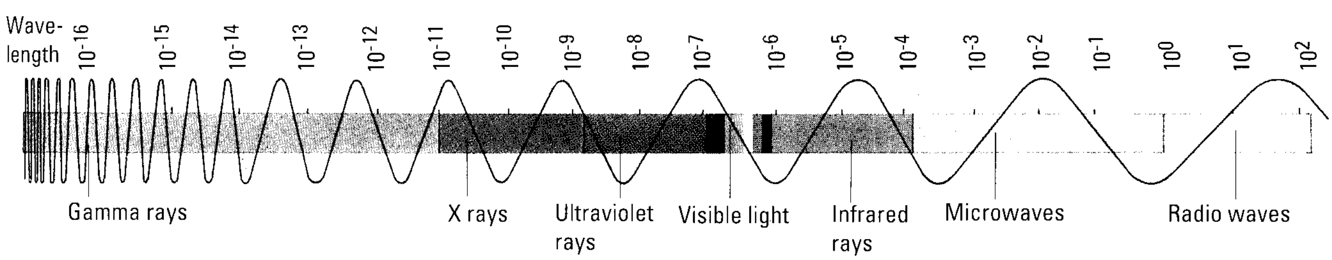
As the charged particle vibrates, the electric and magnetic fields oscillate. This oscillation can be described as a wave (see OSCILLATION; WAVE). The frequency of vibration of the charged particle determines the wavelength of the wave. Thus, electromagnetic radiation has a range of wavelengths. This range is called the electromagnetic spectrum. The radiation with the shortest wavelength is gamma rays. The radiation with the longest wavelength is radio waves. X rays, ultraviolet rays, visible light, infrared rays, and microwaves also fall within the electromagnetic spectrum.

Electromagnetic waves, unlike sound waves, do not need a medium, such as air or water, to travel. Electromagnetic radiation can travel in a vacuum. In fact, it moves faster in a vacuum than in any medium. In a vacuum, its speed is 186,281 mi. [299,790 km] per second. This is called the speed of light.

The existence of electromagnetic waves was first suggested in 1864 by a Scottish mathematician, James Clerk Maxwell. In 1873, Maxwell worked out a series of four equations to describe how electromagnetic radiation behaves. In 1887, Heinrich Hertz, a German physicist, confirmed Maxwell's predictions when he detected radio waves. Ten years later, X rays and gamma rays were detected. In the early 1900s, Max Planck, Albert Einstein, and other scientists worked out the quantum theory. This theory helps explain how electromagnetic radiation transmits energy (see EINSTEIN, ALBERT; HERTZ, HEINRICH; MAXWELL, JAMES CLERK; PLANCK, MAX; QUANTUM THEORY). Using Maxwell's equations and modern theories, engineers and scientists have worked out many useful applications of electromagnetic radiation, including radio, television, and telephone transmission; photovoltaic cells; and microwave ovens.

ELECTROMAGNETIC RADIATION

Electromagnetic radiation ranges from gamma rays, at the short-wavelength end of the electromagnetic spectrum, to radio waves at the long-wavelength end of the spectrum. Visible light is the only electromagnetic radiation that humans can detect. It lies at about the middle of the electromagnetic spectrum.



ELECTROMAGNETISM

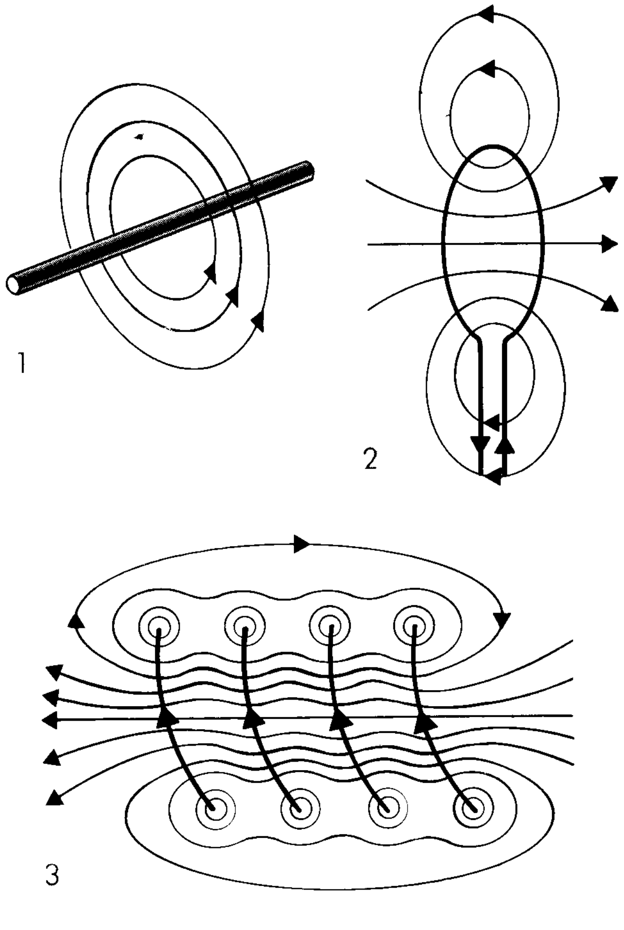
Electromagnetism refers to magnetism produced by an electric current. It also refers to the branch of physics that studies the connections between electricity and magnetism (see ELECTRICITY; MAGNETISM).

The study of electromagnetism began in the early nineteenth century. A Danish scientist named Hans Christian Oersted placed a magnetized needle near a wire that had a current flowing through it. He noticed that when the current changed, the needle moved. From this, he realized that the current was producing a magnetic field.

How electromagnetism works An electric current is caused by the movement of electrons through a wire. Electrons are very tiny charged particles. Any charged object produces an electric field. Because the electrons are moving, they also produce a magnetic field (see CURRENT, ELECTRIC; ELECTROMAGNETIC RADIATION; ELECTROSTATICS). Thus, the current produces a magnetic field around the wire that carries the current. The strength of the magnetic field varies with the strength of the current. It also varies with the distance from the wire, falling off with greater distance.

LIFTING SCRAP

Electromagnets are useful in places such as scrap yards, where large amounts of iron and steel must be moved from place to place.

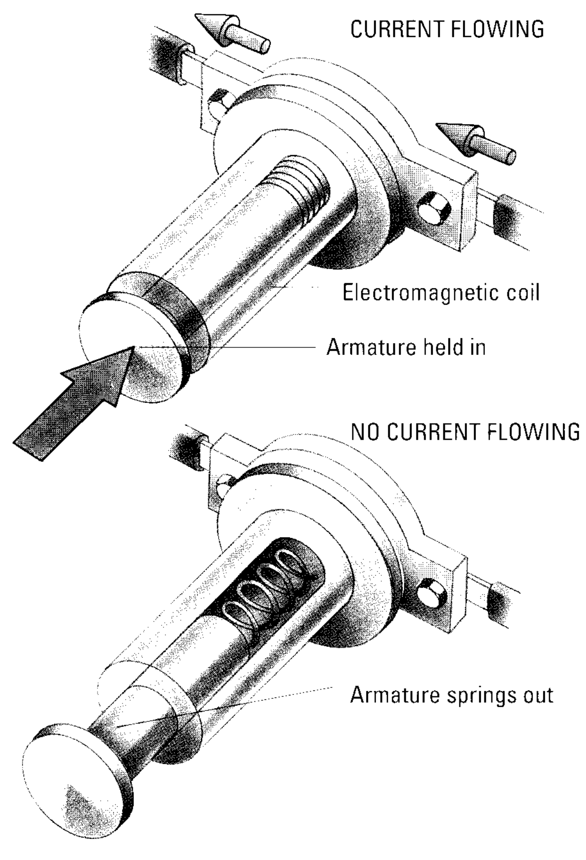


MAGNETIC FIELDS

An electric current flowing along a wire (top left) creates a magnetic field encircling the wire. In a wire bent into a single turn, the magnetic field consists of many loops (top right). With a coil of wire (below), the fields around the turns of wire combine to form one strong field.

The lines of force created by the magnetic field can be shown very easily. Suppose you have a single strand of wire passing through a card. The wire and the card are at right angles. Some iron filings are scattered on the card. Iron filings are very small pieces of iron. A current is then passed through the wire. Since iron filings are magnetic, they line up with the magnetic field produced by current in the wire. The iron filings form rings around the wire along the lines of force of the magnetic field.

A strong magnetic field can be made by passing a current through a solenoid. A solenoid is a long coil of insulated wire wound around a tube. When a current is passed through it, each turn of the coil



SOLENOID SWITCH

A sliding, spring-loaded electromagnet can be used as a switch. When electric current flows in the solenoid—a cylindrical coil—surrounding an iron armature, a magnetic field holds the iron back against the tension of the spring. When the current to the solenoid is turned off, the armature springs out.

produces the magnetic field. A solenoid usually has many turns, each producing a magnetic field. These fields combine to form a large magnetic field. The solenoid behaves like a bar magnet. It has a north pole and a south pole. The field can be increased by putting an iron bar inside the solenoid. The iron becomes magnetized. Its field combines with the field caused by the current to form an even larger magnetic field. A solenoid with an iron bar inside it is known as an electromagnet. The first electromagnet was built in England in 1825 by William Sturgeon.

Just as an electric current can be used to make a magnet, a magnetic field can be used to create an electric current. This can be done by moving a piece of wire in a magnetic field. Moving the wire causes a current to flow in it. The current is said to be induced (see INDUCTION).

Uses of electromagnetism Generators that produce electricity use electromagnetism. Most generate current through induction, as described above.

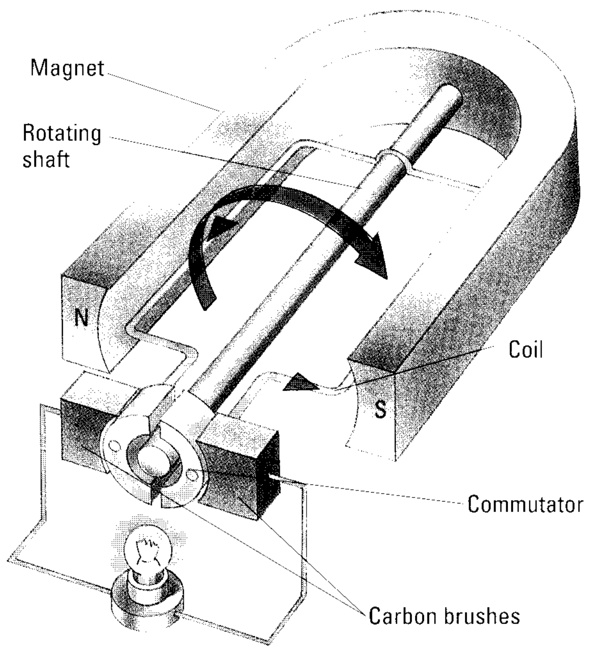
Many industries use powerful electromagnets to lift iron and steel. Such magnets are also used for separating iron and steel from nonmagnetic metals, such as copper and brass. These metals are not attracted to a magnet.

The speaker in a radio contains an electromagnet. It converts the electric signal into a mechanical force. This force is then used to produce sounds.

Particle accelerators are very large machines used in nuclear physics research. These accelerators use extremely large electromagnets to make subatomic particles travel very fast. There is an accelerator at Berkeley, California, that has an electromagnet weighing more than 4,000 tons [3,628 metric tons]. Scientists are also experimenting with powerful electromagnets to confine gases in an extremely small space. This would allow them to control fusion reactions to generate unlimited electricity.

See also ACCELERATORS, PARTICLE; FUSION.

PROJECT 33, 37



DYNAMO

One of the first—and one of the most important—applications of electromagnetism was the dynamo. This electrical machine converts mechanical energy (of a rotating shaft) into direct current (DC) electricity. The electricity is produced in a coil of wire rotating in a magnetic field. A commutator keeps the current flowing in the same direction.

ELECTROMOTIVE FORCE An electric circuit always contains a device that makes the electric charges move. This device provides the power for the circuit and is said to have an electromotive force. Electromotive force is usually shortened to *EMF.* The strength of an EMF is measured in volts (see CIRCUIT, ELECTRIC; VOLT).

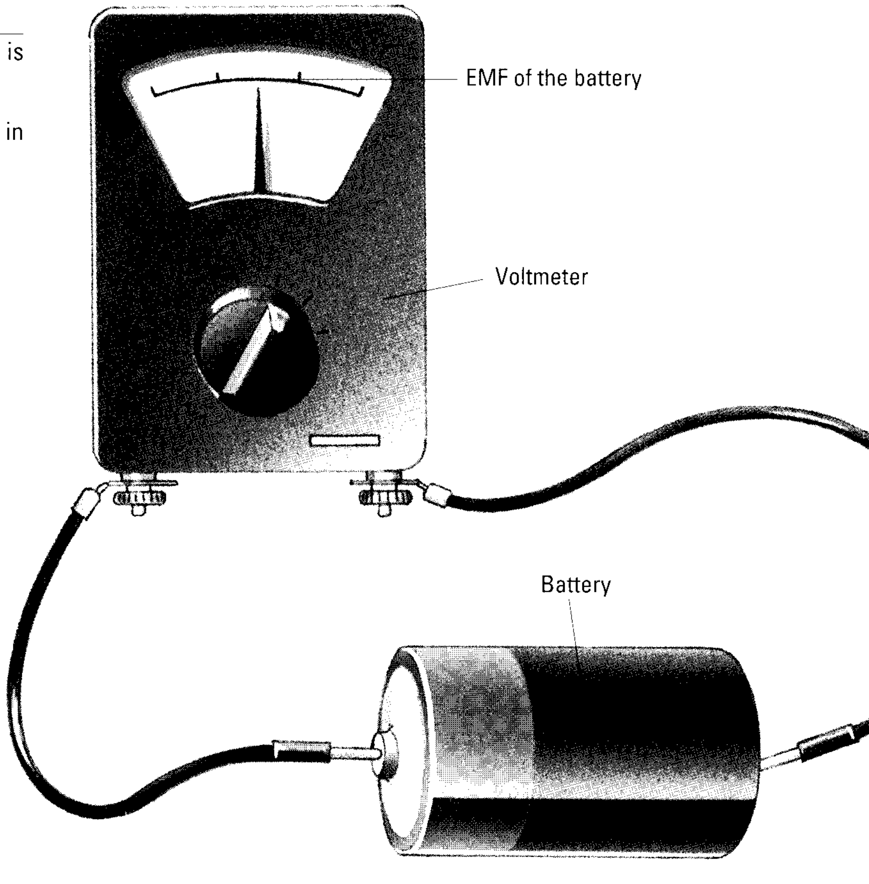
The most common devices for providing an EMF are the electric cell and the generator. In an electric cell, or battery, an EMF is produced by chemical reaction. In a generator, electromagnetism is used to produce an EMF (see ELECTROMAGNETISM). Sometimes other methods are used. For example, heat can be used to produce an EMF. This can be done by putting a thermocouple into a circuit. If one of its junctions is heated, a current flows (see THERMOCOUPLE). Many kinds of photoelectric devices give an EMF when light shines on them (see PHOTOELECTRIC EFFECT). Another device that can be used is the fuel cell. Like the electric cell, it uses chemical reactions to produce an EMF. Fuel cells may someday be used to power electric cars.

ELECTROMOTIVE SERIES The electromotive series is a list of metals that shows how reactive the metals are (see CHEMICAL REACTION). At the top of the list are the most reactive metals. Potassium is the first, followed by sodium. These metals are so reactive that they will burst into flame if put into water. In nature, they are always found as compounds, never as single elements (see COMPOUND).

At the bottom of the list are the metals that react least with other substances. Platinum and gold will not react even with strong acids. Metals low on the list do not corrode readily (see CORROSION).

The electromotive series is useful for predicting when two metals are put close together, which will undergo corrosion. For example, if a nut is made from an element high in the series, and it is used with a bolt made from a metal much lower in the series, corrosion will occur. The nut will gradually be eaten away. For this reason, shipbuilders, engineers, builders, and others are careful when they must use two metals together.
See also BATTERY.

ELECTROMOTIVE FORCE
Electromotive force (EMF) is the electrical force produced by an electric cell, or battery. Measured in volts, the EMF "pushes" electrons along the wires, forming a circuit.



ELECTRON An electron is a subatomic particle that has a negative electric charge (see ATOM). An electron has an extremely small mass. It has about 1/1836 the mass of a hydrogen atom. The electron was discovered by the British physicist Sir Joseph John Thomson in 1897.

The atoms of all elements contain electrons. The negative charges of the electrons are balanced by an equal number of positively charged protons in the atom. The protons are in the nucleus of the atom, and the electrons orbit them. Each chemical element requires a specific number of electrons and protons in order to remain neutral. This number is called the atomic number of the element.

An electric current is the flow of electrons through a wire. An electron microscope produces images by focusing a beam of electrons on microscopic objects. These are only two of the many uses of electrons. PROJECT 53

ELECTRONIC MUSIC Electronic music is made up of sounds that are produced by electronic equipment, such as synthesizers.

The basic unit of an electronic instrument is usually an oscillator (see OSCILLATOR). The signal from the oscillator is sent through an amplifier and played back to the listener through a loudspeaker or headphones (see AMPLIFIER; LOUDSPEAKER). More complicated instruments can be constructed by using many oscillators that produce a variety of sounds. These sounds can imitate those of traditional musical instruments, or they can be new and different from the usual musical sounds.

Composers using electronic instruments have a wide choice of sounds that can be varied in pitch, loudness, duration, and other musical characteristics. These instruments can even make nonmusical sounds, called "noise." Any sound can be recorded and processed by a computerized synthesizer to make an infinite range of new sounds. Using a synthesizer, composers put the sounds together to form a song or other composition (see SOUND).

Synthesizers give musicians great flexibility. Using synthesizers, musicians can produce many different types of sound with the flick of a switch. They can improvise and make new sounds as they play along. They can add or subtract parts of a sound to change the tone quality.

ELECTRONIC MUSIC

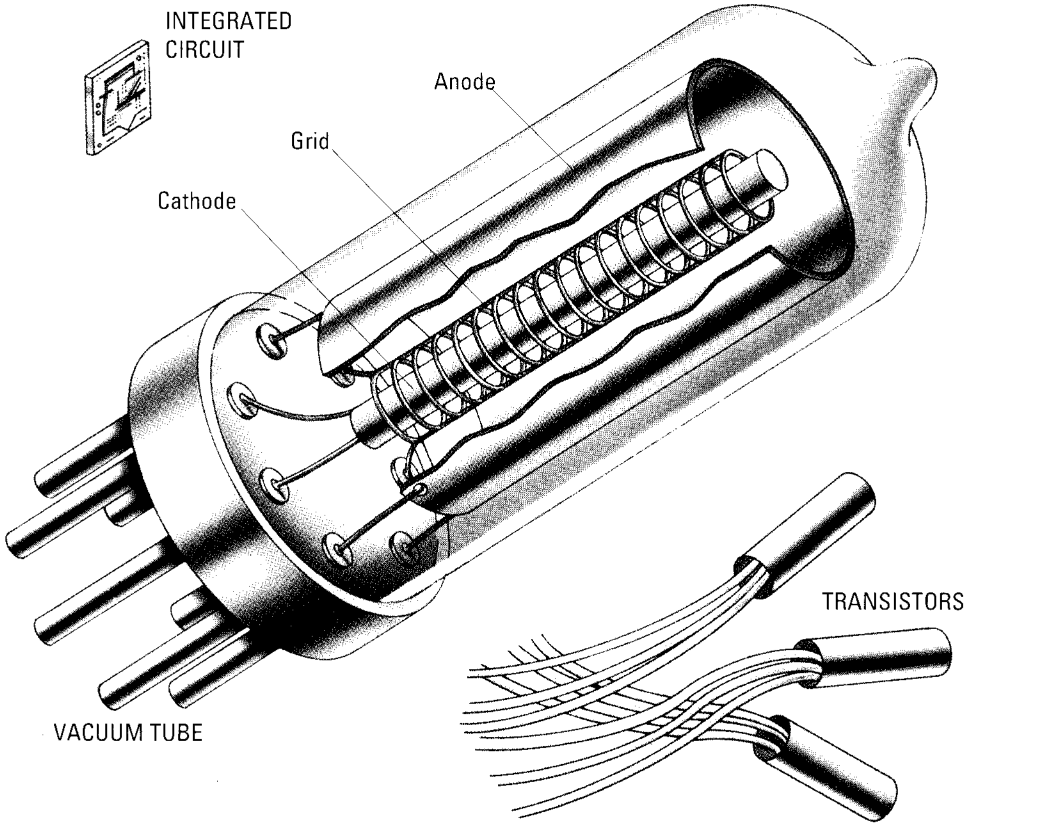
Today's electronic music is often produced by musicians who use computer-controlled instruments. In addition, some musicians use computers to compose new music.

ELECTRONICS

Electronics is a field of science and engineering based on the use of electronic devices. An electronic device is one through which electrons can be made to flow in controlled pulses (see ELECTRON; ENGINEERING). An electric device, on the other hand, is one in which electrons are made to flow in a continuous stream (see ELECTRICITY). There are two basic kinds of electronic devices—electron tubes and solid-state devices. An electron tube is a glass tube through which electrons flow. The tube may be filled with certain gases. However, most electron tubes contain practically no air at all. They are called vacuum tubes (see VACUUM TUBE). A solid-state device is a device in which electrons flow through certain solid materials (see SOLID-STATE PHYSICS). These materials, which include silicon and germanium, are called semiconductors (see GERMANIUM; SEMICONDUCTOR; SILICON). Examples of solid-state devices are the integrated circuit and the transistor (see INTEGRATED CIRCUIT; TRANSISTOR). Modern electronic equipment mostly uses solid-state devices.

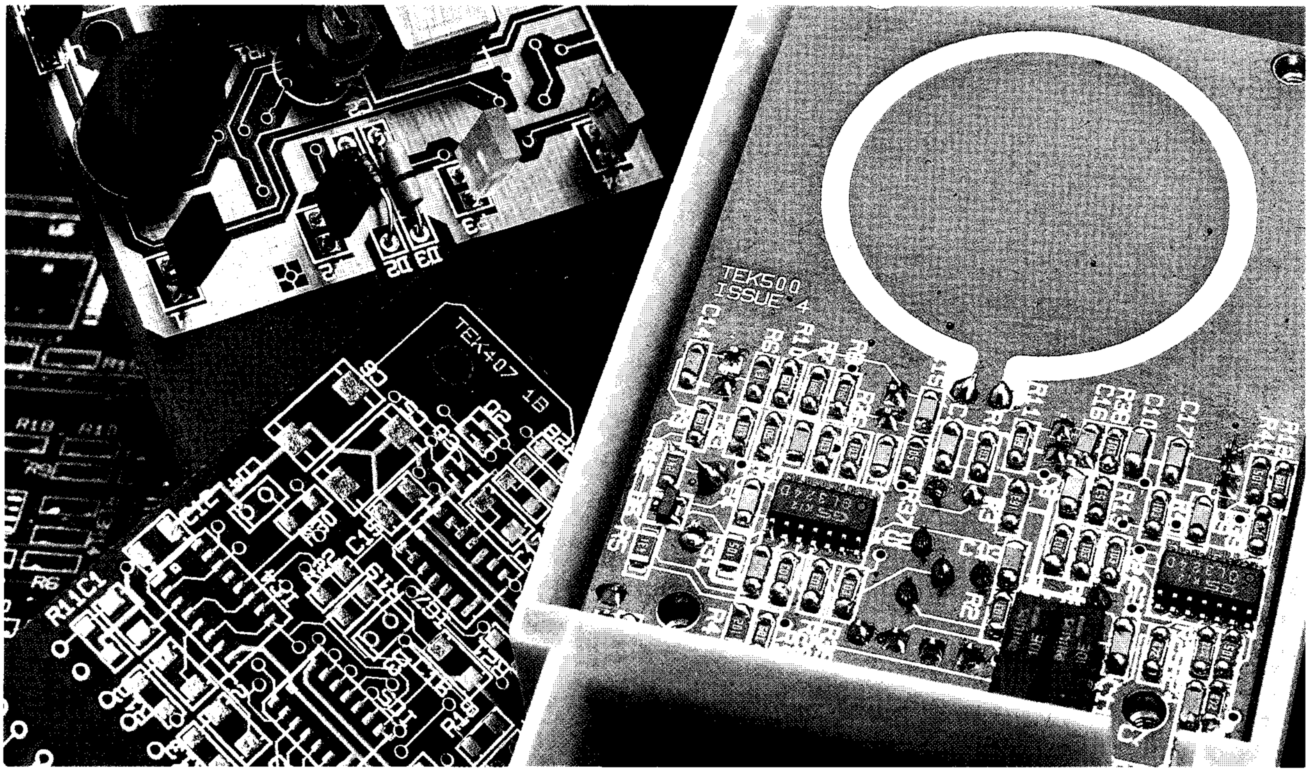
Many people use equipment operated by electronic devices every day. Radios, televisions, microwave ovens, videocassette recorders, and computers are all examples of electronic equipment (see COMPUTER; MICROWAVE; RADIO; TELEVISION; VIDEO RECORDING). Medical science makes use of electronic equipment, such as hearing aids and artificial pacemakers. Artificial pacemakers regulate the heartbeat of people who have certain heart disorders. Other medical equipment that operates by electronics includes computed tomography scanners, ultrasound imaging machines, and X-ray machines (see COMPUTED TOMOGRAPHY; ULTRASOUND; X RAY). Modern air, sea, and space travel depend on electronic radar and navigation equipment (see NAVIGATION; RADAR).

How electronics works Electronic devices work by controlling the flow of electrons to produce one of three results. The devices amplify, oscillate, or rectify an electric current (see AMPLIFIER; OSCILLATOR; RECTIFIER). When electronic



ELECTRONIC DEVICES

In a vacuum tube, electrons flow through a vacuum from a heated cathode (negative electrode) to an anode (positive electrode). Current applied to a third electrode, called a grid, controls the flow of electrons. Similar control is achieved by a transistor, a much smaller solid-state device based on a semiconductor such as silicon. Transistors and other components can be formed on a chip of silicon to make an integrated circuit.



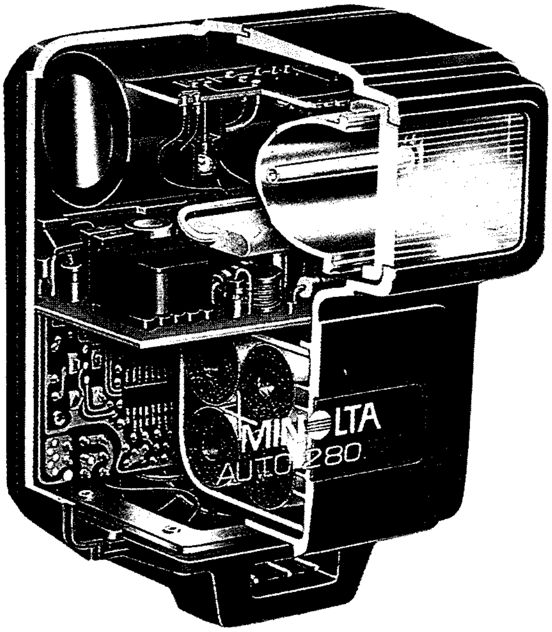
devices are joined into circuits, they are able to perform various functions. For example, a computer is an electronic device whose functions include being able to quickly solve complex mathematical problems.

An electronic device called an amplifier increases the strength of electric signals. Some devices, such as microphones, produce weak signals. An amplifier is needed to boost the power of these signals so that they can be heard by people. An oscillator changes direct electric current to a signal of a particular frequency (see FREQUENCY). Oscillators allow radio and television stations to produce the high-frequency signals they need to transmit sound and pictures. The oscillators in radio and television receivers allow a particular frequency designated by a channel to be selected. A rectifier converts alternating electric current to direct current (see ALTERNATING CURRENT; DIRECT CURRENT). The current from most electric-power plants travels as alternating current. Some equipment, such as electric lights, can use this type of current. However, other kinds of equipment, such as radios and televisions, need direct current to operate. These kinds of equipment have rectifiers in them to provide them with the direct current they need.

SHRINKING CIRCUITS

Modern electronics uses printed circuits, onto which various components such as capacitors, resistors, transistors, and silicon chips are mounted.

History of electronics The first electron devices were developed in the mid-1800s. These devices were gas-discharge tubes, or tubes from which some air had been removed. Only a thin mixture of gases, such as hydrogen and nitrogen, was left in the tube. Experimenters attached an electrode at each end of the tube (see ELECTRODE). When a battery was connected to the electrodes, the tube glowed in bright colors (see BATTERY). The experimenters thought that the cathode, which is the electrode connected to the negative terminal of the battery, must be giving off invisible rays that caused these colors. Scientists named these rays cathode rays. In further experiments, practically all of the air was removed from the tubes. These tubes were called vacuum tubes. In 1878 William Crookes of Britain developed a special kind of vacuum tube to study cathode rays. The Crookes tube became the model for later cathode-ray tubes, including the picture tubes in today's television sets and radar screens (see CATHODE-RAY TUBE; CROOKES, SIR WILLIAM).



ELECTRONIC FLASHGUN

A capacitor in a photographer's electronic flashgun stores an electric charge. The charge is applied between the electrodes of a discharge tube containing xenon gas, producing an extremely brief, intense flash of light.

In 1895, the German physicist Wilhelm Roentgen discovered another kind of ray using a Crookes tube. He noticed that a fluorescent screen that had been placed a short distance from the tube glowed when the tube was in use (see FLUORESCENCE). He found that the fluorescent screen glowed even when the Crookes tube was wrapped in heavy black paper. Roentgen believed that invisible rays were causing this effect. He named these rays X rays. He experimented by replacing the fluorescent screen with photographic paper and placing various substances between the tube and the paper. Using his own hand and that of his wife, Roentgen found that X rays could pass through flesh, but not bone, and leave an image on the paper. Soon, physicians began using X rays to study the internal structure of animals and humans (see ROENTGEN, WILHELM CONRAD; X RAY).

In 1897, Joseph J. Thomson of Britain discovered that cathode rays were actually streams of negatively charged atomic particles (see ATOM). He named the particles electrons.

The science of electronics grew as devices were invented to control the flow of electrons in useful ways. In 1904, John Ambrose Fleming of Britain built the first vacuum tube that could be used commercially. Fleming's vacuum tube had two electrodes and was called a diode. The diode acted as a rectifier. Diode tubes soon became the standard receiving device in radio sets.

Then, in 1907, American inventor Lee De Forest further developed the vacuum tube by building a triode (see DE FOREST, LEE). A triode has three electrodes. About 1912, De Forest and another American inventor, Edwin Armstrong, discovered independently how to use a triode as an amplifier and an oscillator. The triode amplifier and oscillator led to the beginning of American radio broadcasting in 1920.

Vacuum tubes led to the invention of many other kinds of electronic equipment. In 1923, the Russian-American scientist Vladimir Zworykin used cathode-ray tubes to build the first television camera tube that was capable of broadcasting signals and the picture tube that was used to receive those signals. A vacuum tube oscillator that could produce microwaves was first built in 1921. In the late 1930s, two vacuum tubes were developed that could produce microwaves. These tubes, called the magnetron and the klystron, were once used widely in radar, but have now been replaced with solid-state devices.

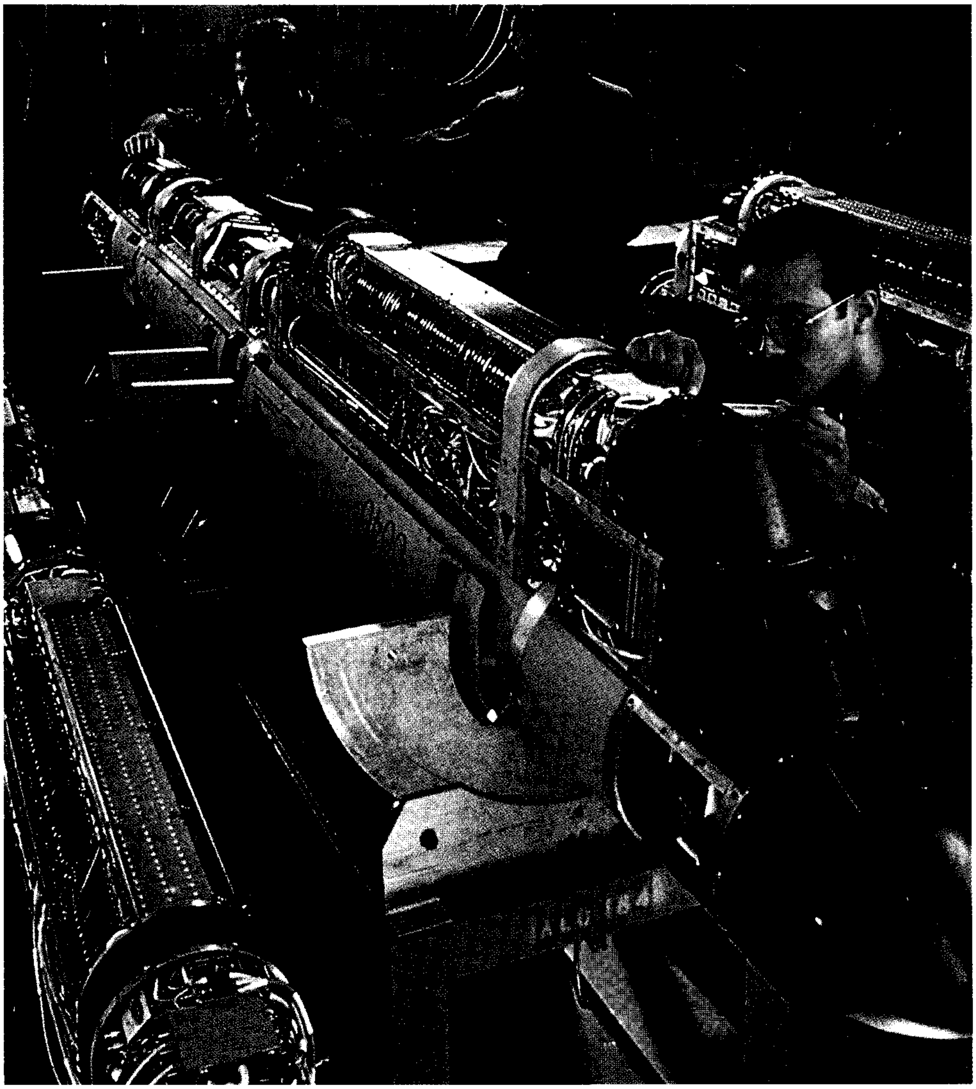
Modern electronics A major breakthrough in electronics occurred in the late 1940s when the first solid-state device, the transistor, was developed. This tiny device can perform the same functions as a vacuum tube. However, transistors have many advantages over vacuum tubes. They are sturdier, more durable, and smaller. They also use less power to transmit signals.

The first transistors were made of crystals of germanium. Then it was found that silicon could serve as well as germanium. This was fortunate because silicon is so plentiful. It exists in nature as silicon dioxide, which is ordinary sand. Using silicon, laboratories could make thousands of transistors quickly and inexpensively. This was important because in the 1950s and 1960s the United States government's space program and the computer industry needed thousands of transistors. Transistors also were used in radios, record players, television sets, hearing aids, and many other electronic devices.

The availability of the transistor put in motion a dramatic shift toward miniaturization of electronic devices. This started in the late 1950s and 1960s, when several laboratories developed the integrated circuit. This device consists of a single silicon component, called a chip, that combines the functions of several individual electronic components (see CHIP). This accomplishment was only the beginning. In the years that followed, techniques were developed whereby hundreds and even thousands of electronic circuits could be put on a single chip.

To produce these chips, engineers first make a drawing of the electronic circuitry on sheets several hundred times the size of the final product. These sheets are later reduced in size photographically. They are then printed on chemically treated silicon chips and further processed. The finished product is a true miniature of the original drawing. Some of these chips can pass through the eye of a needle with room to spare.

Application of the integrated circuit to computer design pointed the way toward miniaturization of computers. The room-sized monsters of the 1940s gave way to less cumbersome models. In the early 1970s, scientists devised a way to have just one chip perform most of the computer's main functions. This silicon chip, called a microprocessor, was a boon to the computer industry. Because of microprocessors, home computers, video games, and pocket calculators became a reality. The microprocessors have also proved vital to space technology. As scientists continue researching how to improve microprocessors, they will become even more important to the continuing development of electronics.



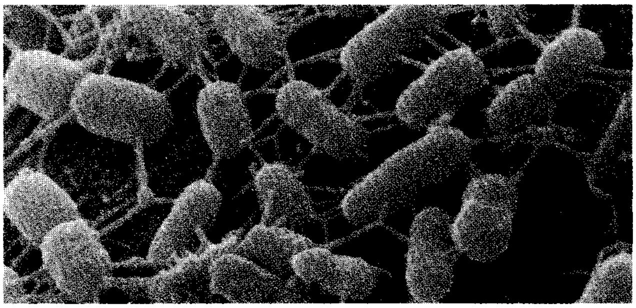
MISSILE CONTROL

Advances in the field of electronics have been vital to military and space technology. The development of very small, yet powerful, electronic guidance and control systems has made the production of modern missiles possible.

ELECTRON MICROSCOPE

An electron microscope is a microscope that can magnify objects up to a million times (see MAGNIFICATION). An electron microscope works on a principle similar to that of a regular light microscope. In a light microscope, a bright light is directed through a specimen (object to be magnified) and into the microscope's objective lens. The light rays are focused by the lens, producing a magnified (enlarged) image (see LENS; MICROSCOPE).

There are two kinds of electron microscopes: transmission and scanning. In a transmission electron microscope, a beam of fast-moving electrons is passed through a very thin slice of the specimen. The electrons are focused by magnetic lenses onto a fluorescent screen (see FLUORESCENCE). On the screen, the magnified image can be observed directly or photographed. A scanning electron microscope works in the same way as a television camera (see TELEVISION). A scanning electron microscope scans the surface of a specimen with a fine beam of electrons. A picture is obtained that shows detail of the specimen's surface.



BACTERIA

These rod-shaped bacteria were found on a used kitchen towel. This electron microscope picture shows the bacteria about 1,500 times larger than actual size.

Through the use of electron microscopes, scientists have obtained much new knowledge about viruses, bacteria, and even the atom. Electron microscopes are found in many hospitals, universities, and laboratories.

See also ELECTRON; SCANNING TUNNELING MICROSCOPE.

SCANNING ELECTRON MICROSCOPE

A scientist uses a scanning electron microscope to study the surface of an object. A camera fitted to the microscope makes a permanent record of the highly magnified image.

ELECTROPHORESIS (ĭ lĕk´ trō fə rē′sĭs) Electrophoresis is a method used to separate or identify different substances in a solution (see SOLUTION AND SOLUBILITY). A concentrated solution of the substances to be separated is placed in the middle or at one end of a sheet of wet paper or a gel. An electric current is passed through the solution between electrodes at either end of the paper or gel. Many substances, such as large biological molecules like proteins or DNA, have an electric charge. When the current passes, the molecules are attracted to one of the electrodes (see ELECTRODE).

The speed at which different molecules move depends on their size and on their electric charge. When the molecules have separated, the current is switched off. The molecules can be seen by staining them with a dye or, in some cases, they are visible in UV light (see ULTRAVIOLET LIGHT).

Electrophoresis has been used to separate proteins in blood, and it is also used for DNA fingerprinting and to analyze genes. Another use is to detect the presence of poisons or drugs in the body. *See also* DNA; GENETIC FINGERPRINTING.

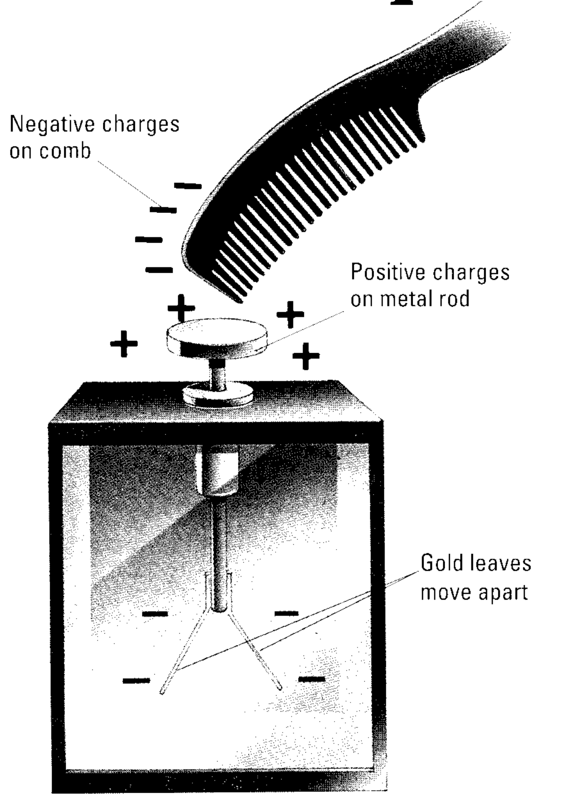
ELECTROSCOPE The electroscope is an instrument used to detect electric charge (see CHARGE). The electroscope can also be used to tell whether the charge is positive or negative. Electroscopes can also detect X rays and other electromagnetic radiation.

The gold-leaf electroscope is a common type of electroscope. Abraham Bennet, a British scientist, invented the gold-leaf electroscope in 1787. The instrument consists of two slender strips of gold foil hanging from a metal rod. The metal rod acts as a conductor (see CONDUCTION OF ELECTRICITY). A nonconductor, such as wood, holds the conductor in a stand. The stand is often made of glass.

When the conductor has no electric charge, the foil strips hang straight down. If the conductor is charged with electricity, the strips become charged. Both strips receive the same kind of charge. Because bodies with like charges repel each other, the strips move apart. The amount of movement gives an indication of the strength of the charge. The electroscope can be used to measure high voltages (see VOLT). William Henly, a British scientist, added a scale of numbers to the electroscope, so that the electroscope could measure the strength of the electric charge. This type of electroscope is called an electrometer.

To find out whether a charge is positive or negative, the activated electroscope is tested with a known charge. For example, if a known positive charge makes the foil strips fall back together, the unknown charge is negative. If the strips spread farther apart, the unknown charge is positive.
See also ELECTROSTATICS.

PROJECT 56



ELECTROSCOPE
Negative charges on the comb draw positive charges onto the metal rod. This leaves negative charges on the gold leaves, which move apart.

ELECTROSTATICS Electric charges can be either moving or still. In an electric circuit, electric charges move in a wire. Thus, current is composed of moving charges. However, if an object is rubbed, it sometimes gains an electric charge, but the charges do not move in the object. They are said to be static, and the object has static electricity. The study of static electricity is called electrostatics (see CHARGE; CIRCUIT, ELECTRIC; CURRENT, ELECTRIC; ELECTRICITY).

ELECTROSTATICS

The amber shown above has been rubbed and has become electrostatic. Having gained an electric charge, it is able to attract lightweight objects.

When materials such as amber are rubbed, they are able to attract light objects such as feathers. The ancient Greeks knew this. In the 1500s, William Gilbert found that many other materials behaved in the same way when rubbed. He called this effect *electric,* after the Greek word *elektron,* which means "amber." He found, for example, that glass could be electrified by rubbing it with silk. However, he could not find a way to electrify metals (see GILBERT, WILLIAM). In 1729, Stephen Gray discovered another difference between metals and other materials. He found that electricity can flow along metals but not along nonmetals. Metals are said to conduct electricity and are called conductors. Conductors other than metals have been discovered since then. One such conductor is graphite. Materials in which electricity does not flow are called insulators (see CONDUCTION OF ELECTRICITY).

A very important discovery was made in France around 1733 by the scientist Charles DuFay. He found that there are two different kinds of electric charge. They are called positive charge and negative charge. He found that bodies having the same kind of charge repel, or push each other away. Bodies with opposite charges attract each other. In both cases, there is a force acting between the two bodies. The English scientist Joseph Priestley studied this force. He found that for spherical objects, the strength of the force depends on the distance between the two bodies. He made this discovery in 1766. He showed that the electric force obeys the inverse square law. This law says that the force increases as the two bodies get closer together. If the distance between the two is halved, the force becomes four times as strong (see INVERSE SQUARE LAW).

In 1787, the gold-leaf electroscope was invented to detect electric charge (see ELECTROSCOPE). It was soon used to investigate the charge on a hollow body. The electroscope showed that all the charge lies on the outside surface. The inside surface has no charge at all. The electroscope was used to detect the strength and distribution of other objects as well.

In the late 1800s, scientists realized that many electric effects are caused by charged atomic particles called electrons. Electrons are negatively charged particles. When two materials are rubbed together, electrons are sometimes pulled out of the atoms. They get transferred from one material to another. When glass is rubbed with silk, electrons move from the glass to the silk. Since the electrons have a negative charge, the silk becomes negatively charged. The glass has lost electrons, so it gains a positive charge. Ebonite, a hard black rubber, can become charged by being rubbed with fur. In this case, electrons move from the fur to the ebonite. The ebonite becomes negatively charged and the fur positively charged (see ELECTRON).

Electric charge can be stored in capacitors. Capacitors are made out of two conductors placed close together but not touching. Usually, a capacitor has two pieces of metal foil separated by some insulating material. One way to charge a capacitor is by connecting it to a battery. The battery sets up a potential difference across the capacitor. This causes the pieces of foil to have opposite charges. The foil remains charged even when the battery is removed.

See also BATTERY; CAPACITOR AND CAPACITANCE; POTENTIAL.

Elements are the simple materials from which everything in the universe is made. An element is made of atoms. In any element, there are only atoms of one kind. During a chemical reaction, an element cannot be broken down into anything else but its own kind of atoms. There are over one hundred different elements that occur in the universe. Some of them are very common. Carbon, for example, is an element that is found in every living animal and plant (see ATOM; CHEMICAL REACTION).

Elements can occur by themselves. For example, gold occurs in nature as a pure metal, containing only atoms of gold. Pure hydrogen gas is another element that can exist by itself. In nature, however, elements are usually found linked to other elements. When two or more different elements are linked together, they form a chemical compound. Water, for example, is a compound of the elements hydrogen and oxygen. Sodium chloride (common salt) is a compound of the two elements sodium and chlorine (see COMPOUND).

Elements can mix together without forming a compound. Air is a mixture of the elements nitrogen, oxygen, and argon. It is not a compound, because the elements are not joined together chemically.

Metals make up more than three-quarters of all the elements. However, many of the nonmetallic elements are abundant in nature. Oxygen, hydrogen, carbon, and silicon are very common nonmetallic elements.

Most elements are found to be solids. Bromine and mercury are liquids. The elements oxygen and nitrogen are gases.

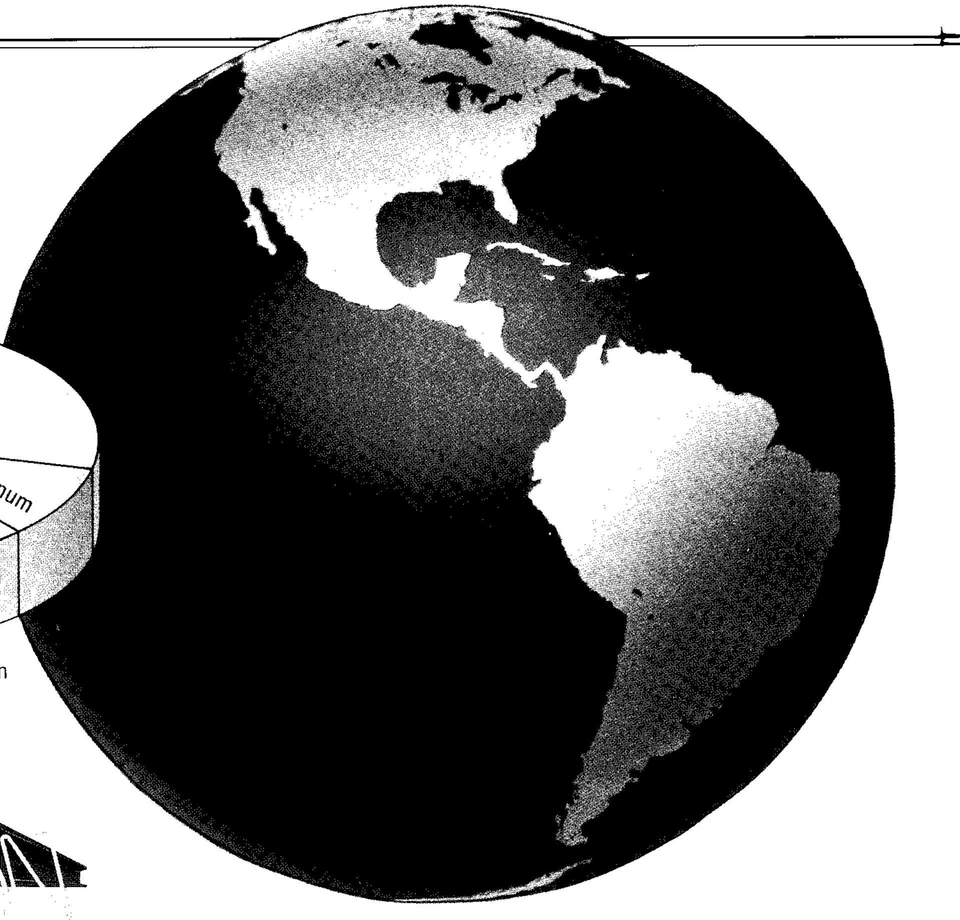
GOLD NUGGETS
Gold is one of the few elements that occurs naturally uncombined with other elements. Called native gold, it has been prized since ancient times.

Chemical names and symbols The names of the elements give clues about what sort of substances they are. For example, nearly all of the metallic elements have the ending *-ium.* Some of the metals that have been known for a very long time do not end with *-ium. Gold, zinc, iron,* and *nickel* were in use long before the custom of naming metals with words ending with *-ium* was adopted.

Most of the elements have names that come from Latin and Greek words. *Hydrogen* comes from the Greek word for *water maker,* because it can be burned to make water. *Krypton* comes from the Greek word for *concealed,* because it was so hard to discover in the atmosphere. *Bromine* was named for the Greek word for *stench,* because of its bad smell. Some elements are named for places or for scientists. *Francium* is named for France, and *einsteinium, nobelium,* and *curium* for the scientists Einstein, Nobel, and Curie respectively.

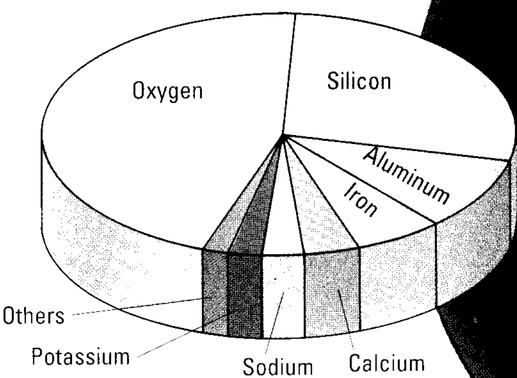
The symbol for an element is a kind of shorthand for the name. The symbols are either one or two letters. Often the symbol comes from the English name. Thus *O* stands for oxygen and *S* for sulfur. The chemical symbol may be based on the Latin name, such as *Na* for sodium *(natrium* in Latin) and *Ag* for silver *(argentum* in Latin).

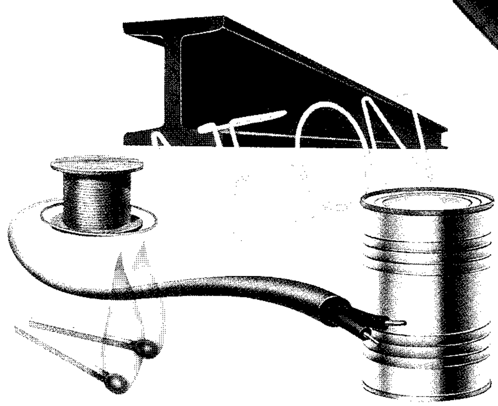
The abundance of the elements The most abundant element in the universe is the gas hydrogen. The sun and the stars consist mostly of this element. On earth, the most abundant element is oxygen. Oxygen is found in the atmosphere, in the oceans as a component of water, and in many minerals. The next most abundant element is silicon. Silicon is found in nearly every rock found on Earth, except for limestone.



EARTH'S ELEMENTS

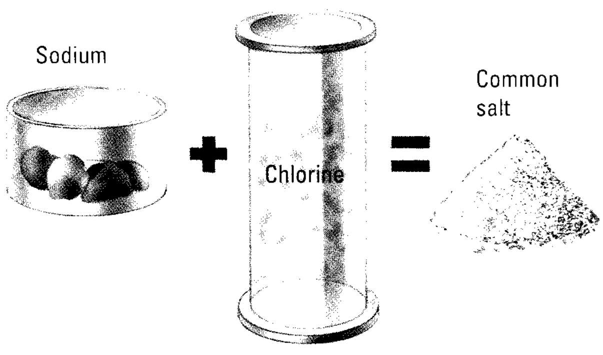
Major elements in the earth's crust are oxygen, silicon, aluminum, iron, calcium, sodium, and potassium. At nearly fifty percent, oxygen is the most abundant element.





USES OF ELEMENTS

Common uses of various elements are pictured above. The metallic elements shown are copper in electric wire, tin coating on a food can, and iron in the steel girder. The heads of the matches contain the nonmetal sulfur, and the advertising sign contains the gas neon.



COMBINING ELEMENTS

The element sodium is a highly reflective, shiny metal. Chlorine is a greenish poisonous gas. But when the two combine in a violent chemical reaction, the product is sodium chloride (common salt), which people use to bring out the flavor of food.

Some elements are very rare. Radium is one example. It is one of the radioactive elements. Radioactive elements are rare because they gradually change into different elements (see RADIOACTIVITY). Radium eventually changes into the more common element lead. This kind of change is called radioactive decay. To obtain just one-tenth of a gram of radium, Marie and Pierre Curie had to work hard for many months. They had to extract it from several tons of the rocky ore called pitchblende (see CURIE FAMILY).

Properties of the elements The properties of the elements depend on the arrangement of the electrons in their shells. This is because when atoms of elements react with others, the electrons of each atom form bonds. Elements with full outer shells tend to be inert. That is, they do not react easily with other elements and thus do not easily make compounds with other elements. Helium, neon, and argon, called noble gases, are some elements with full outer shells. They do not react with other elements (see NOBLE GAS).

Elements with only a few electrons in their outer shells are more reactive. They form compounds readily with other elements. They may lend electrons to other elements, or they may share electrons with them. They also may borrow electrons from other elements to fill their outer shells. These are all ways in which atoms may combine together to form compounds (see VALENCE).

The periodic table In 1869, the Russian chemist Dmitri Mendeleev drew a table of all the elements that were then known. He arranged them by their atomic weight (now known as relative atomic mass). He showed that there was a pattern when the elements were arranged in this way. Elements with the same sorts of properties occurred at regular intervals, or periods, in the table. Mendeleev's periodic table is still used today, but the elements are now arranged by atomic number rather than relative atomic mass. Scientists can add the many elements that had not been discovered in those days (see MENDELEEV, DMITRI; PERIODIC TABLE OF THE ELEMENTS, VOL. 23; RELATIVE ATOMIC MASS).

Human-made elements Artificial elements can be made from natural elements. This is done by bombarding the natural elements with subatomic particles in an atomic reactor or particle accelerator. Some of the artificial elements are highly radioactive and dangerous. Some artificial elements, such as plutonium (Pu), last for millions of years.

See also ACCELERATORS, PARTICLE. PROJECT 16

ANCIENT ELEMENT

Iron was one of the first elements used by humankind and is still used to make horseshoes.

ELEMENTARY PARTICLES An atom is made up of tiny particles called subatomic particles, or elementary particles (see ATOM). These include electrons, which are negatively charged; protons, which are positively charged; and neutrons, which are electrically neutral. These particles are 100 million times smaller than atoms. They form the basic units of matter. Physicists group them into families by mass, spin, function, and charge. Electrons are examples of leptons, which are small particles. Protons and neutrons are made up of even smaller particles called quarks. Gauge bosons have the function of transmitting force, such as the photon that transmits light and other waves.

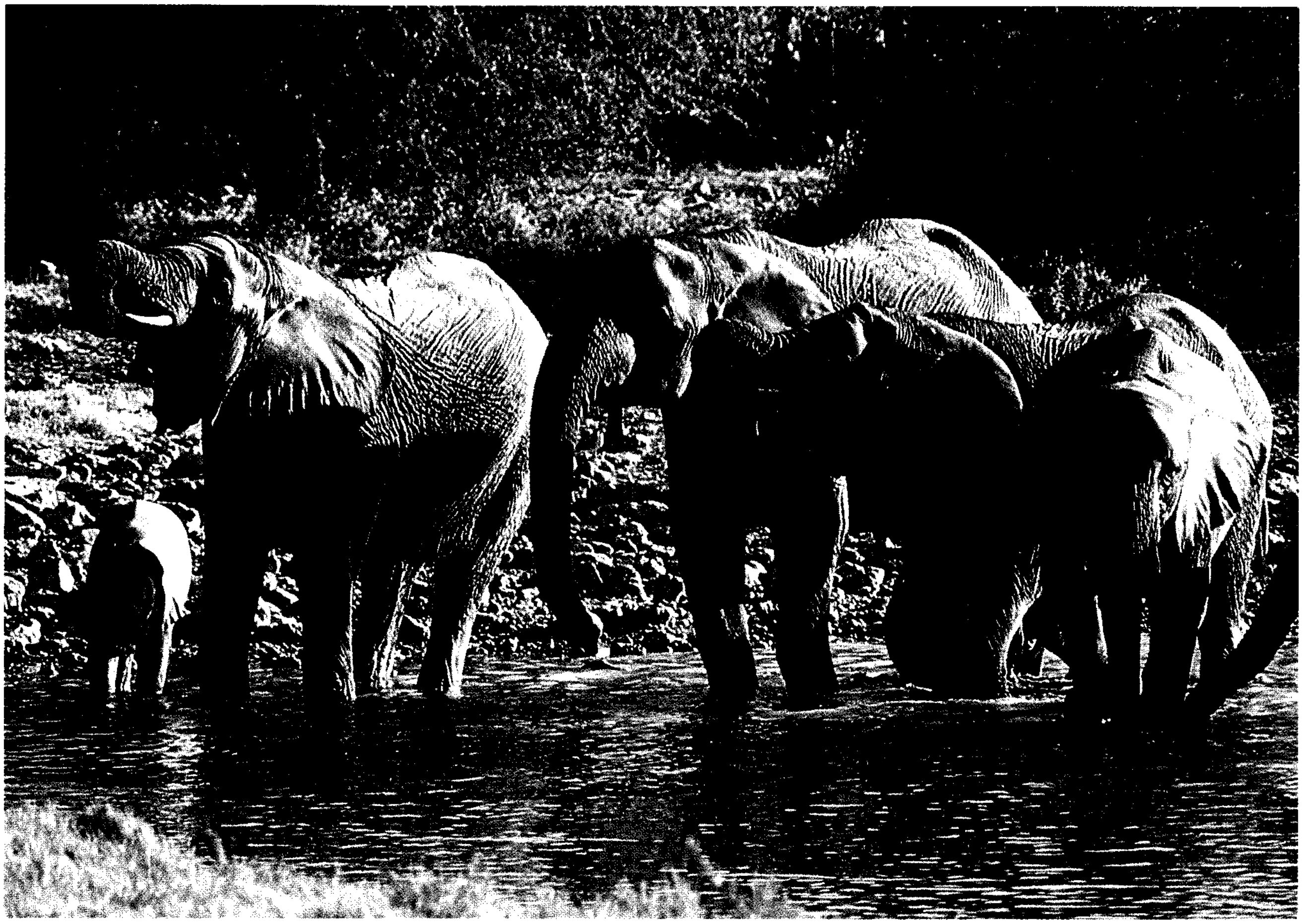
ELEPHANT The elephant is the largest living land animal. These mammals belong to the order Proboscidea (see MAMMAL). Elephants have fairly large brains, weighing about 11 lb. [5 kg], small eyes, and large ears. An elephant's tusks are made of ivory and are actually incisor teeth from the upper jaw (see TEETH). An elephant's trunk may be 6 ft. [1.8 m] long and weigh 308 lb. [140 kg]. It is boneless, contains more than forty thousand muscles, and can lift objects as small as a peanut or as large as a log weighing hundreds of pounds. The tip of the trunk is very sensitive, and, like a human hand, can feel an object to determine its shape, texture, and temperature.

A wild elephant eats constantly, consuming as much as 605 lb. [275 kg] of food per day. The elephant, a herbivore (plant eater), uses its trunk to uproot trees and other plants to get to juicy leaves that are otherwise out of reach. It drinks by sucking water into its trunk and squirting it into its mouth.

Elephants are sometimes called pachyderms (meaning "thick-skinned" in Greek) because their skin is about 1 in. [2.5 cm] thick. In spite of the thickness of the skin, elephants are very sensitive to insect bites and will leave an otherwise favorable area to avoid insects. Since the elephant lacks a pro-

ELEPHANT—Drinking

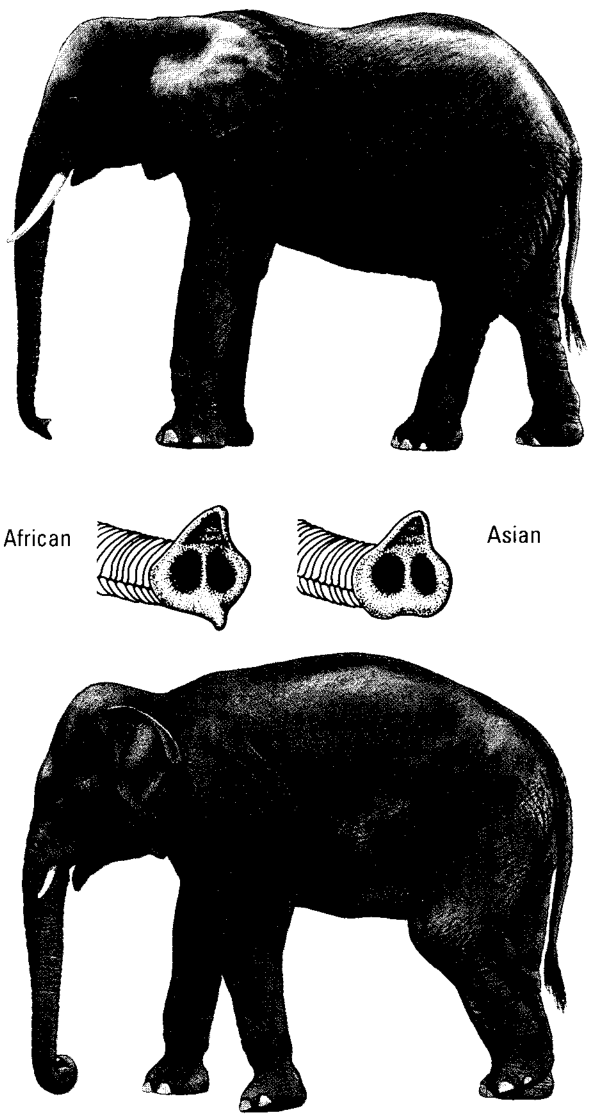
Female African elephants and their calves gather at a water hole to drink.



tective layer of fat under the skin, it is sensitive to very hot or very cold weather.

An elephant has large, round feet and legs that can measure 20 in. [50 cm] in diameter. The feet spread out under its weight but become smaller when lifted. Although elephants walk at about 6 m.p.h. [10 kph], a frightened elephant may run as fast as 25 m.p.h. [40 kph].

A female elephant (cow) is pregnant for twenty to twenty-two months before giving birth to a calf weighing about 198 lb. [90 kg]. The calf nurses for three or four years, is sexually mature by age fourteen, and is fully grown by age twenty. Most elephants live to be about sixty years old.



ELEPHANT—African and Asian

An African elephant (top) is larger and has larger ears than an Asian elephant (bottom). It also has two lips, not one, at the end of its trunk.

Elephants are social animals, roaming in herds of ten to a hundred or more. The leader is usually a female. When elephants move from one area to another, they walk in single file with the female leader at the head followed by the other females, the calves, and finally, the males (bulls). If threatened, the bulls form a protective circle around the cows and calves. Adult elephants are rarely attacked by other animals, though they sometimes fight among themselves. Rogue elephants are loners that will attack any animal or person they see. Rogues are usually old bulls that have been chased out of the herd by younger bulls. Their violent behavior is probably caused by pain from disease or decayed teeth.

There are two main species of elephants. The African elephant is dark gray, has two fingerlike structures on the tip of its trunk, and has huge ears, 4 ft. [1.2 m] wide. The African bull may be 11.5 ft. [3.5 m] at the shoulder and weigh as much as 12,100 lb. [5,500 kg]. Both bulls and cows have tusks that may be as long as 9.9 ft. [3 m] and weigh as much as 143 lb. [65 kg] each. Generally, the female is smaller and has smaller tusks than the male. African elephants are found throughout much of Africa south of the Sahara desert.

The Asian (or Indian) elephant is smaller than the African elephant. It lives in India and southeast Asia. It has an arched back, two bumps on its forehead between the ears, and one fingerlike structure on the tip of its trunk. Its ears are also smaller, measuring about 2 ft. [0.6 m] across. The bull stands about 9 ft. [2.7 m] at the shoulder and weighs about 11,000 lb. [5,000 kg]. Most Asian elephants are light gray, though some are white with pink eyes. The bull's tusks are about 5 ft. [1.5 m] long. Most female Asian elephants have no tusks.

The numbers of African and Asian elephants are decreasing at an alarming rate. The Asian elephant is listed by the U.S. government as an endangered species (see ENDANGERED SPECIES). This means the numbers of Asian elephants are so small that they may soon become extinct, or die out in the world, although there are some in captivity. Many work in the forests. There are only about 35,000 to 54,000 alive in the world today. The African elephant is only listed as threatened. This means the species is less in danger of extinction. There are about 600,000 African elephants alive today. Scientists are able to more accurately estimate the numbers of African elephants because they live in only a few specific areas of Africa.

There are two main reasons for the decline in the number of African and Asian elephants. The first is the loss of habitat due to clearing of land for agriculture and other development. The second reason, which applies only to African elephants, is the hunting of elephants for their ivory tusks. Steps have been taken to stop the decline in numbers, however. For example, sanctuaries have been set up in both Africa and Asia. Sanctuaries are places where predators are controlled, and hunting is illegal. In addition, the United States and most other countries have prohibited the trade of ivory.

However, many countries do not have enough land to set up adequate sanctuaries. It is also difficult to enforce laws against poaching (illegal hunting), and poachers have sophisticated weapons that allow them to kill many elephants in a small amount of time. Poaching has continued because not all countries have banned the sale of ivory. There is also a large illegal trade of ivory in those countries where legal trade does not exist.

ELEPHANT SEAL The elephant seal, or sea elephant, is the largest of the seals. There are two very similar species—the southern elephant seal, which lives in and around the Antarctic, and the northern elephant seal from the Pacific coasts of California and Mexico. The male (bull) may reach a length of 20 ft. [6 m] and a weight of 6,050 lb. [2,750 kg]. The female (cow) is usually about half this size. This mammal gets its name from the fact that the bull has a large nose that hangs over its mouth. This nose can be inflated to form a trunk-like snout 15 in. [38 cm] long (see MAMMAL; SEAL).

Every year, the bulls engage in intensive fighting to establish large groups of females as mates. A cow gives birth to one calf that nurses for several weeks before joining the adults in the daily hunts for food. These seals are carnivores (meat eaters), feeding on squids and fishes, some of which live several hundred feet below the surface of the ocean.

Elephant seals have been hunted by humans for their skins and their blubber (fat). The blubber from one elephant seal can yield as much as 2,090 lb. [950 kg] of oil. Until recently, the hunting was so extensive that the elephant seal was facing extinction. Only the total prohibition of seal hunting in certain areas has allowed the animals to increase their numbers beyond the endangered level (see ENDANGERED SPECIES).

ELEPHANT SEAL
A young bull elephant seal roars at the camera on a beach in the Falkland Islands.

ELK An elk is a member of the deer family (see DEER). The American elk is a brownish deer that was called *wapiti* by the American Indians. The male (bull) stands about 5 ft. [1.5 m] tall at the shoulder and may weigh as much as 990 lb. [450 kg]. Its antlers may spread more than 5 ft. [1.5 m] and have twelve or more points. The female (cow) is smaller and does not have antlers (see ANTLER).

American elk are herbivores (plant eaters) and graze in large herds. They usually spend the winters in valleys where snowfall is light, returning to the mountains in the spring. In the fall, bulls fight for mates and for leadership of the herd. Pregnant females give birth to one calf in May or June.

Natural enemies of the American elk include bears, coyotes, and wolves. Elk once roamed over most of North America. Extensive hunting by humans has now limited their range mostly to areas west of the Rocky Mountains.

The European elk is the same species as the American moose (see MOOSE). It is the world's largest deer, measuring 7.6 ft. [2.3 m] at the shoulder and weighing 1,804 lb. [820 kg]. The bull's antlers may have a spread of 6 ft. [1.8 m]. The cow is smaller than the bull and does not have antlers. Both have coarse brown hair and white legs. The European elk is found in Scandinavia and northeast Europe.

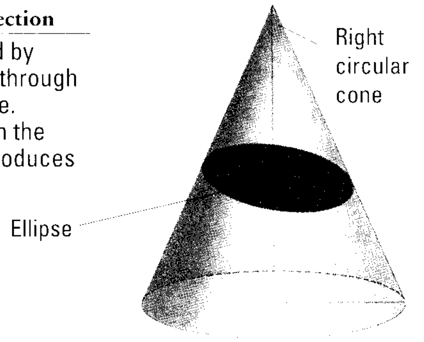
ELK

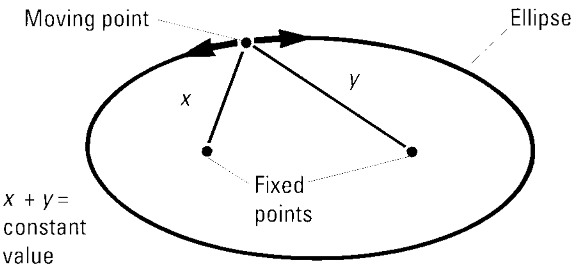
This male American elk, or wapiti, has fourteen points on its antlers. It uses the antlers to fight other males in battles over females during the fall.

ELLIPSE (ĭ lĭps′) An ellipse is an oval-like shape. It has rounded sides, and it is longer than it is wide. Ellipses can be drawn by using a pencil moving in a loop of string around two fixed points. The

ELLIPSE—Conic section

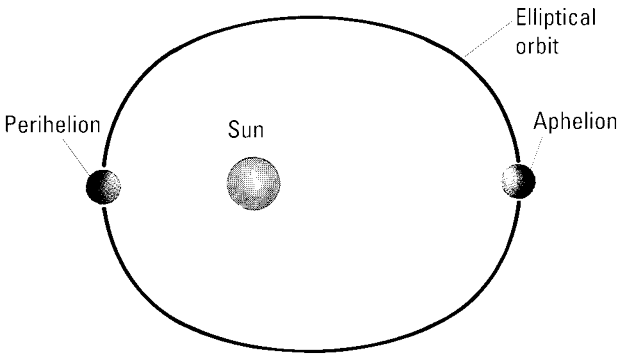
An ellipse is formed by cutting at an angle through a right circular cone. Cutting parallel with the base of the cone produces a circle.





ELLIPSE—As an equation

An ellipse can be defined as the path of a point that moves in such a way that the sum of its distances from two fixed points is constant. If the distances are called x and y, an ellipse is represented by the equation $x + y = C$, where C is a constant. The two fixed points are called foci (plural of focus).



ELLIPSE—Planet's orbit

The orbit of a planet, such as the earth, around the sun takes the form of an ellipse. The sun is at one focus of the ellipse. The point at which the planet is nearest the sun is called the perihelion; its farthest point from the sun is the aphelion.

flat surface formed after cutting at an angle through a cone is elliptical.

In nature the orbits of the planets around the sun are ellipses. The point where the planet is nearest the sun is called the perihelion, and the point where it is farthest from the sun is called the aphelion.

ELM The elm is any of twenty or so species of large, deciduous shade trees that grow throughout North America, Europe, and Asia (see DECIDUOUS TREE).

The American elm reaches heights of 100 ft. [30 m] or more and may live for more than two hundred years. Clusters of small, greenish flowers grow in the axils before the leaves appear (see AXIL). The flowers produce flattened fruits with wings. These fruits are released as the lopsided, tooth-edged leaves begin to open. Since elm wood is very hard, it is a valuable source of lumber for use in making furniture, barrels, and boats. Elm wood is also a popular fuel.

There are several other important species of elms. Slippery elm has a gluey inner bark that, if chewed, gives relief to a sore throat. It was once used as a treatment for the disease cholera. Rock or cork elm is known for its corky bark and its extremely hard wood. The English elm is the tallest of the elms, reaching heights of more than 130 ft. [40 m].

Elm trees are often the victims of disease. Dutch elm disease causes the most widespread destruction of elms. This disease is caused by a fungus carried by a bark beetle and can result in the death of the tree within a few weeks. Another disease, phloem necrosis, results in the death of the leaves. Phloem necrosis is caused by a virus carried by the leafhopper insect. Both of these diseases spread very rapidly, often affecting hundreds of trees before their presence is even known. Insecticides and fungicides have had limited success in controlling these diseases. There has been some success, however, in breeding an elm tree that is resistant to these diseases.

ELM

Elm trees are among the earliest to change the color of their leaves in the fall.

EMBRYO

An embryo (ĕm′brē ō′) is a living thing in its earliest stages of development. An embryo is formed by the union of a male sex cell with a female sex cell (see CELL). The sex cells are also called germ cells or gametes. Because these sex cells contain chromosomes from the parents, the embryo inherits characteristics from both parents (see HEREDITY).

During prenatal (before birth) development in humans, a single fertilized egg divides into the billions of specialized cells in the newborn baby. Once the basic body shape and organs have begun to form, which occurs by the end of the first eight weeks, the embryo is called a fetus. At the end of a normal, nine-month pregnancy, the fetus will be about 20 in. [50 cm] long and weigh about 7.3 lb. [3.3 kg] (see PREGNANCY).

Fertilization of the egg takes place in the woman's body in a structure called the fallopian tube. The fallopian tube is part of the female reproductive system and leads from the ovary (where the eggs are produced) to the uterus (where the baby develops) (see REPRODUCTIVE SYSTEM). The fertilized egg is called a zygote. As the zygote moves down the fallopian tube toward the uterus, it begins to divide by mitosis. Mitosis is the process of cellular division in which the entire cell, including the chromosomes, produces a copy of itself and then divides. This division produces two identical cells that are identical to the original cell (see MITOSIS).

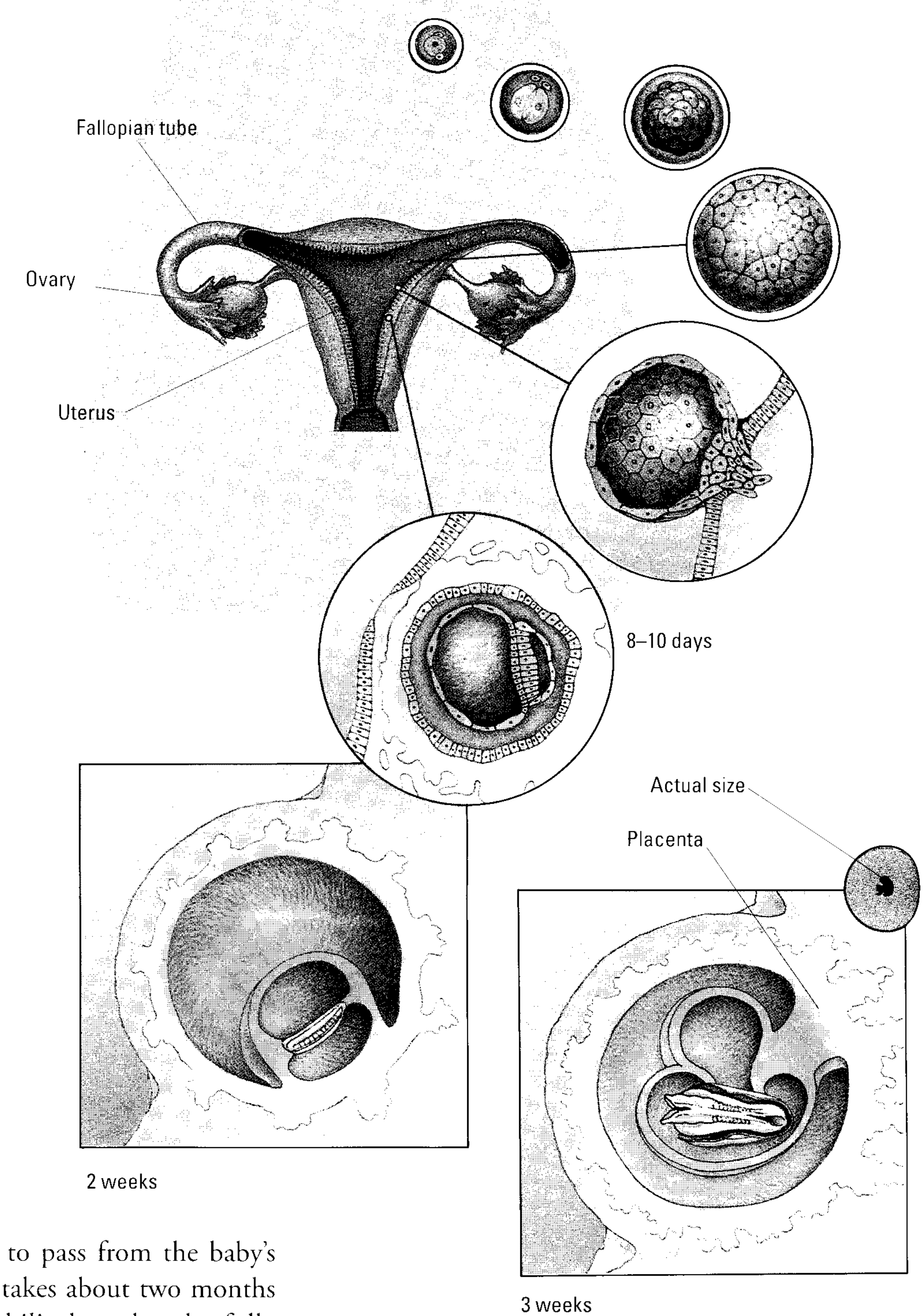
The two cells become four cells, then eight, and so on until a small, solid ball of cells called a morula is formed. This mass of cells continues dividing, forming a hollow, tennis-ball-like blastula. The blastula has an inner and an outer layer of cells. In preparation for the blastula, the wall of the uterus becomes thick and rich in blood (see MENSTRUAL CYCLE). The outer layer of the blastula, the trophoblast, attaches itself to the thickened wall of the uterus and begins the formation of a placenta and an umbilical cord. These structures allow oxygen and food to pass from the mother's blood to the

HUMAN EMBRYO

After about eight weeks of development in the mother's womb, a human embryo is called a fetus. This fetus has been in the womb for about ten weeks.

EMBRYO DEVELOPMENT

This sequence of diagrams shows the development of a human embryo from a fertilized egg to a 12-week-old fetus. The growing embryo is supplied with food and oxygen from the mother's blood, which passes from the placenta along the umbilical cord.



baby's blood, and wastes to pass from the baby's blood to the mother's. It takes about two months for the placenta and umbilical cord to be fully developed.

The inner layer of the blastula, the embryoblast, develops into an embryonic disk. The embryonic disk develops into a tube-shaped gastrula with three layers of cells: the outer ectoderm, the inner endoderm, and the middle mesoderm. Each of these layers produces specific structures in the baby. The ectoderm develops into the skin, hair, nails, nervous system (including the brain), part of the eye, and part of the ear. The endoderm produces most of the digestive tract and its associated organs. It also produces the tissue that lines or surrounds internal organs. The mesoderm develops into the other internal tissues and organs, such as the heart, kidneys, muscles, bones, and blood.

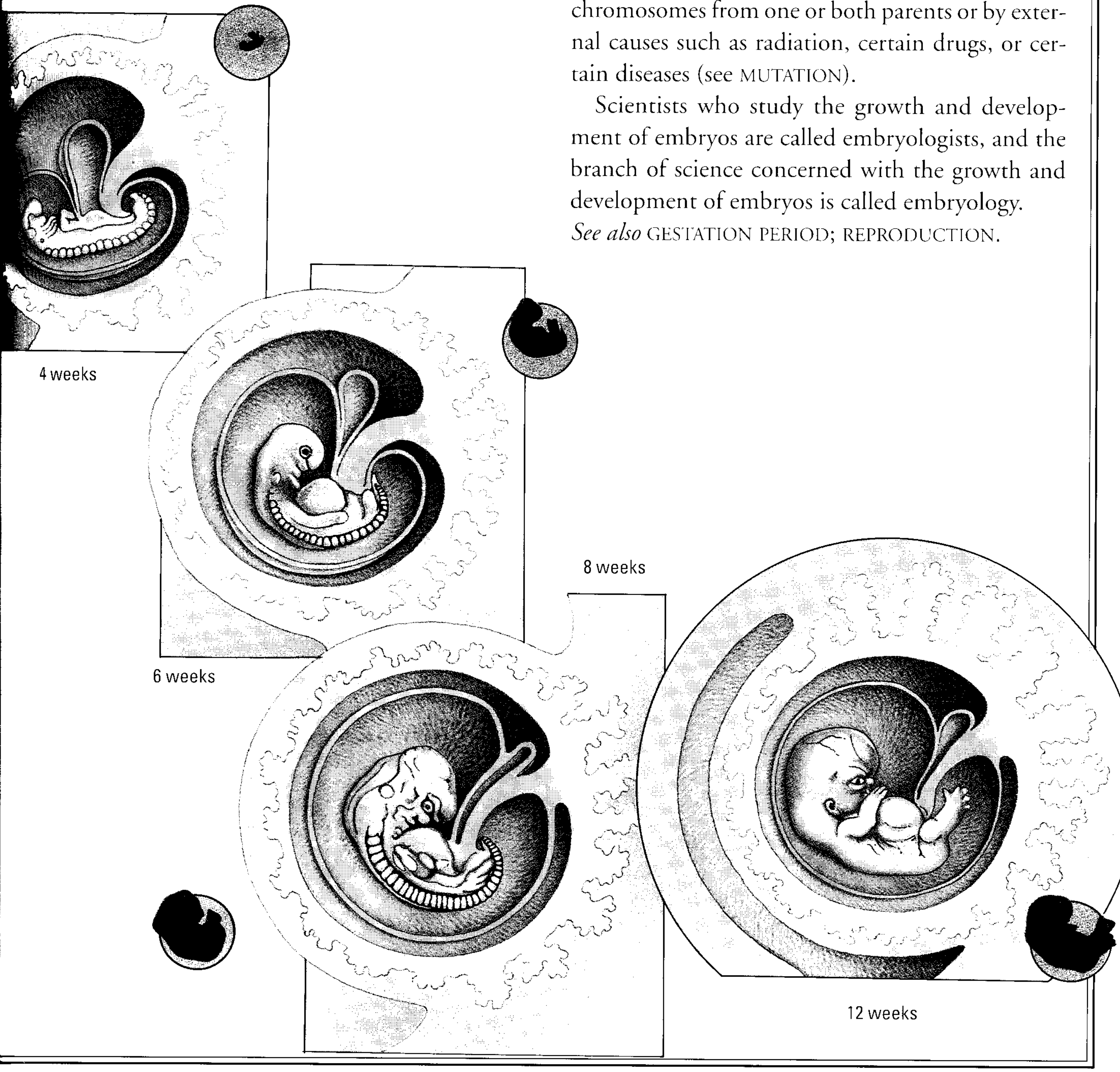
The development of all of these structures is the result of cellular differentiation (see DIFFERENTIATION, CELLULAR). The process involved is not clearly understood, but cells specialize to perform certain functions in specific tissues or organs. After about four weeks, the embryo is about 0.25 in. [6 mm] long. The head is large and bent over. There are small swellings called buds on the side of the embryo. These buds will develop into arms and legs. There are blocks of tissue called somites arranged along the embryo's body. These somites will develop into bones and muscles. Within eight weeks of fertilization, cellular differentiation is virtually complete and the embryo is about 1 in. [25 mm] long.

These first eight weeks are the most important in the development of the child because it is during this time that all the adult structures are established and begin to grow. At eight weeks, the fetus can be recognized as being human, with human features and structures.

Birth defects, though relatively rare, are usually a result of some malfunction during these first two months. The malfunction may be caused by faulty chromosomes from one or both parents or by external causes such as radiation, certain drugs, or certain diseases (see MUTATION).

Scientists who study the growth and development of embryos are called embryologists, and the branch of science concerned with the growth and development of embryos is called embryology.

See also GESTATION PERIOD; REPRODUCTION.



4 weeks

6 weeks

8 weeks

12 weeks

EMERALD The emerald, a rich green gemstone, is a variety of the mineral beryl (see BERYL). The highest-quality emeralds come from Colombia. Colombia is also the largest producer of these gems. Emeralds are also mined in South Africa, Zimbabwe, Russia, and the United States (North Carolina).

A natural emerald crystal has a hexagonal form. Large and perfect emeralds are about equal in value to diamonds. One of the largest emeralds known to exist is displayed in a museum in Russia. This emerald weighs about 6 lbs. [2.7 kg]. The gemstone known as oriental emerald is actually a form of the mineral corundum and is not a true emerald.

EMERALD

This gold necklace has rows of green emeralds surrounded by diamonds. Like the gemstone aquamarine, emerald is a form of the mineral beryl.

EMERY Emery, a dull gray material, is a variety of the mineral corundum (see CORUNDUM). It is used as an abrasive to grind metals, gems, and optical lenses. Emery is mined chiefly in Russia and the United States (see ABRASIVE).

Emery is crushed into tiny pieces or a fine powder. It may then be mounted on paper or mixed with cement and formed into grinding wheels. Manufactured abrasives, such as aluminum oxide and silicon carbide, have largely replaced emery for industrial uses.

EMOTION An emotion is a reaction involving a feeling or feelings. Common emotions include happiness, love, hope, desire, fear, anxiety (worry), anger, hate, and sadness. Emotional reactions can be aroused by thoughts or by outside events.

Children are born with emotional reactions to only a few things, such as pain and hunger. However, they soon learn to respond emotionally to other things. For example, when a child first meets a snarling dog, the child may have no emotion toward the dog. However, if the dog tries to bite the child, the child develops fear of the dog. Having learned the fear of snarling dogs, the child may avoid them in the future.

Emotional responses are an important form of self-defense. They result in changes in the functioning of the body that help give protection against danger. For example, the adrenal glands pour the hormone adrenaline, also called epinephrine, into the bloodstream when a person is afraid. This increases the rate of the heartbeat and the depth of breathing and releases emergency nutrient supplies from storage for use by the muscles. All these responses help the person meet the danger or flee from it (see ADRENAL GLANDS).

If changes in body function caused by emotions continue for a long time, vital tissue damage can result. For example, constant anxiety can eventually lead to stomach ulcers. Strong emotions also can make it hard to think and to solve problems. For example, a student taking a test may be so worried about failing that he or she cannot think properly. The body responds to worry in the same manner that it does to fear. It prepares to fight or flee from danger. This may make it difficult for a student to sit quietly and concentrate. Thus, the worry drains mental energy needed for the test.

See also PSYCHOSOMATIC DISORDER.

EMPHYSEMA (ĕm′fĭ sē′mə) Emphysema is a lung disease in which the walls of the alveoli (air sacs) and the capillaries (tiny blood vessels) that they contain are destroyed. The alveoli and the capillaries are the point at which oxygen and carbon dioxide pass in and out of the bloodstream in the lungs. The destruction of the alveoli results in large air spaces that trap carbon dioxide inside the lung. This excessive amount of carbon dioxide that is not exhaled obstructs the flow of oxygen. Persons suffering from emphysema have difficulty breathing. They also may suffer from frequent lung infections, such as bronchitis, that make their breathing difficulties even worse.

Emphysema is usually the result of smoking. However, emphysema may also be the result of a person's heredity or occupation, such as coal mining. Emphysema cannot be cured, but it can be treated by drugs and by physical therapy in which the patient learns new breathing techniques. In severe cases, the victim may have to breathe oxygen through a special mask that is attached to an oxygen tank.
See also BRONCHITIS; LUNG.

EMULSION An emulsion is a preparation consisting of one liquid dispersed, or evenly distributed, in another. In contrast with a solution, the two liquids in an emulsion do not dissolve in each other. Instead, tiny drops of the dispersed liquid remain suspended in the other liquid (see COLLOID; SOLUTION AND SOLUBILITY).

Emulsions are not stable. The liquids usually separate from each other after a certain time. An emulsifying agent, such as soap, may be needed to stabilize the emulsion and prevent it from separating.

Many common substances, including cosmetic lotions, foods, lubricants, medicines, and paints, are emulsions. Oil and water form the most common emulsions. An emulsion can be formed by either droplets of oil dispersed in water or droplets of water in oil. For example, milk is an emulsion of butterfat in water.
See also SUSPENSION.

ENAMEL Enamel is a glasslike substance applied as a coating to metal. Enamel is commonly used as a protective surface for such things as cooking utensils and kitchen and bathroom fixtures. It is produced in many colors.

An enamel coating is applied to an object by first grinding sand, borax, and metallic compounds into a fine mixture of particles. This mixture is applied to the object to be enameled by firing (melting) the mixture onto the metal. The heat melts the enamel and combines it with the surface of the article.

There are several types of decorative enameling. Cloisonné, or celled enamel, is made by bending and soldering metal strips together to make a design (see SOLDERING AND BRAZING). The holes in the design are filled with different-colored mixtures of enamel, and the object is fired. The heat melts the enamel to bind it with the metal. Champlevé, or inlaid enamel, is made by filling designs engraved in metal with enamel.

ENAMEL
This southeast Asian incense burner is an elaborate example of cloisonné enamel.

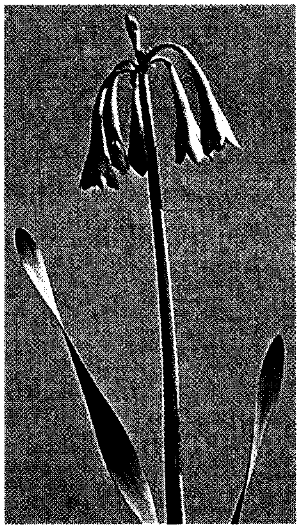
ENDANGERED SPECIES

Endangered species are plants and animals whose numbers are so small that they may soon become extinct, or die out. Endangered species are often in danger because of human activities. These include such actions as destroying the habitat in which a species lives to make room for a housing development, or poisoning members of a species with sewage or other pollution.

Direct action against a species, such as collecting and hunting, also may push it to extinction. Collectors have caused the extinction of such plants as certain orchids and cacti. These plants become part of valuable collections or are sold for a large profit. Hunters in search of ivory and valuable skins are endangering the African elephant and have pushed the Indian tiger close to extinction.

In recent years, some countries have passed strict measures to protect their endangered species. Many countries have limited or outlawed hunting of certain endangered species. Some countries have created sanctuaries for endangered animals. Sanctuaries are places where predators are controlled and hunting is illegal. Many countries have outlawed trade in the products of endangered species, such as ivory from elephants.

See also CONSERVATION; EXTINCTION; SPECIES.



ORCHID

Some orchids, such as this South African species, are highly valued by plant collectors and as a result are in danger of becoming extinct.

RHINOCEROS

The black rhinoceros of Africa is hunted for its horns, which local people believe have magical powers. Overhunting has made it an endangered species.

ENDOCRINE (ĕn′də krĭn) The word *endocrine* refers to a type of gland. A gland is a group of cells that work together to secrete chemicals into the body. The chemicals secreted by endocrine glands are called hormones (see GLAND; HORMONE). Hormones regulate body processes, such as growth, reproduction, and digestion.

Unlike other glands, endocrine glands secrete their hormones directly into the bloodstream without first sending them through a duct (tube). The endocrine glands are located at various places in the body, and each gland has one or more specific jobs. For example, the pituitary gland is at the base of the brain and regulates body growth and development. Because the hormones of the pituitary gland control the functions of other endocrine glands, the pituitary is often called the "master" endocrine gland. The parathyroid glands in the throat regulate calcium levels in the blood. The adrenal glands, attached to the kidneys, regulate the body's use of proteins and carbohydrates and the balance of salt and water in body tissues. Hormones from the adrenal glands also stimulate bursts of energy when a person becomes excited or frightened. The islets of Langerhans, in the pancreas, secrete insulin to control levels of blood sugar. The ovaries and testes are the reproductive glands in females and males, respectively. In addition to producing eggs (ovaries) and sperm (testes), these glands produce hormones that affect the bodily changes that occur when a child develops into an adult.

When one or more of the endocrine glands does not work properly, serious disorders or even death can result. For example, if too little insulin is produced by the pancreas, too much sugar remains in the blood, causing diabetes (see DIABETES). If the pituitary gland produces too much growth hormone while a person is growing, the person may become a giant. If too much of the same hormone is produced after a person is fully grown, a disorder called acromegaly results. Some parts of the body grow too large, and the body becomes deformed. If the pituitary gland produces too little growth hormone, a person may become a dwarf. If the adrenal glands do not produce enough of the hormone cortisol, Addison's disease can result. This disease causes weakness, digestive problems, heart problems, and brown coloring of the skin. Another disease, called Cushing's syndrome, occurs when the adrenal glands produce too much cortisol. The syndrome is most common in women between the ages of twenty and forty. Its symptoms include weak muscles, high blood pressure, excessive hair growth, and accumulation of fat on the face and neck. The disease is named for Dr. Harvey Cushing, who first described the disease in 1932.

Many hormonal disorders can be treated by controlling the production of, or replacing, specific hormones. Sometimes, X rays may be used on a gland, or a gland may be removed.

The complex endocrine system is studied by medical specialists called endocrinologists. Endocrinologists now know that the endocrine system works with the nervous system in regulating body function. Because the nervous system and the endocrine system help regulate each other, the two systems are sometimes referred to as the neuroendocrine system.

See also ADRENAL GLANDS; ANATOMY; GROWTH; NERVOUS SYSTEM; REPRODUCTION.

ENDOPLASM Endoplasm is the thin, liquid inner layer of the cytoplasm within a cell. Cytoplasm is the mixture of water, salt, and organic material that lies between the cell membrane and the membrane of the nucleus. Endoplasm contains many kinds of organelles. These are tiny structures, such as the endoplasmic reticulum and mitochondria, that carry out various cell functions.

See also CELL; CYTOPLASM; ECTOPLASM; ORGANELLE.

ENDORPHIN (ĕn dôr′fĭn) Endorphins are chains of amino acids produced in the nervous system and certain glands of humans and other vertebrates (see AMINO ACID; GLAND; NERVOUS SYSTEM). Vertebrates are animals that have a backbone. Scientists believe endorphins are involved in relieving pain and regulating such body functions as appetite, cell growth, and sexual development. Endorphins are also believed to help promote a feeling of well-being in humans.

Endorphins are believed to be produced in different areas, including the adrenal glands, brain, pituitary gland, and spinal cord. Scientists have found that endorphin levels increase during times of pain, stress, or exercise. For example, endorphin levels appear to steadily increase throughout pregnancy and reach a peak just before and during labor (see ADRENAL GLANDS; BRAIN; HORMONE; SPINAL CORD).

Scientists are researching how endorphins carry out their functions. They are also researching whether a human can control the amount of endorphins his or her body produces. Answers to these questions may affect several areas of medicine. For example, if scientists can learn how endorphins influence cell growth and division, they may be able to apply that knowledge to finding a cure for cancer or paralysis. Knowing how endorphins affect appetite may help treat bulimia.

See also BULIMIA; CANCER; PARALYSIS.

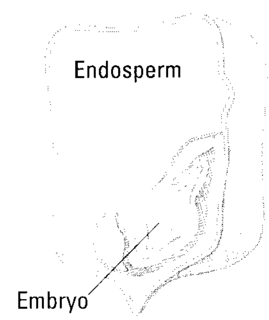
ENDOSCOPY Endoscopy is the visual examination of the inside of any body cavity with an endoscope. An endoscope works by allowing light to travel down a tube to illuminate the cavity. An image then travels back up the tube through a lens and can be seen by a doctor. It shows or confirms the presence of many medical problems, such as arthritis, cancer, and ulcers. The first endoscopes were rigid. This limited use of the instrument to the esophagus, stomach, and bladder (see ESOPHAGUS; STOMACH). Development of a flexible fiber-optic tube in the 1970s meant that the respiratory system, intestines, and spaces in the joints could also be examined (see DIGESTIVE SYSTEM; JOINT).

Various tools can be attached to the endoscope and operated from outside the body. Modern endoscopes allow samples of tissue to be taken for further examination in a process called biopsy. Many forms of treatment can also be carried out inside the body using an endoscope. For example, blood vessels that are bleeding can be closed using an electric current or laser operated through an endoscope.

See also FIBER OPTICS.

ENDOSCOPY

Surgeons use an endoscope to see inside a patient's abdomen. The image picked up by the endoscope is shown on a video monitor screen.



ENDOSPERM

The endosperm is a food-storing tissue that surrounds and nourishes the embryo in a seed. In some seeds, such as this corn seed, the endosperm provides edible material.

ENDOSPERM An endosperm is a food-storing tissue that surrounds and nourishes the embryo in a seed (see EMBRYO; SEED). In some seeds, such as the bean and the pea, the endosperm is completely absorbed before the seed matures. In others, such as wheat, part of the endosperm remains until the seed germinates (sprouts). It is the endosperm that provides most of the edible material in cereal crops and in oil-producing seeds, such as corn. The coconut has a liquid endosperm, the coconut milk.

ENDOTHERMIC REACTION An endothermic reaction is a chemical reaction that absorbs heat. For example, when table salt (sodium chloride) dissolves in water, heat is absorbed. Thus, the solution of table salt in water is an endothermic reaction. A chemical reaction that gives off heat is called an exothermic reaction.

See also EXOTHERMIC REACTION. PROJECT 16

ENERGY

Energy is the ability to exert a force over a distance, or to do work. There are many different kinds of energy. All living things need energy to grow. Plants get energy from the light of the sun. This is electromagnetic energy (see ELECTROMAGNETIC RADIATION; PHOTOSYNTHESIS). Heat and light are both forms of energy. Animals get their energy by eating plants or other animals. The food is digested and provides a source of chemical energy for the animal.

Through metabolism, the chemical energy derived from food is changed to other forms of energy for the body's work (see METABOLISM). These forms of energy include mechanical energy to drive muscle contraction, electrical energy for brain and nerve activity, thermal energy to maintain body temperature, and other types of energy needed to make certain compounds such as fats, proteins, and glycogen.

We need energy to heat our houses. This energy is often provided by burning fuels, such as coal or gas. Fuels contain chemical energy. When they are burned, the chemical energy is turned into heat energy. Most forms of energy can be converted into other forms.

If an object is moving, the energy of its movement is called kinetic energy. When you run, you possess kinetic energy. This energy comes from the chemical energy of the food you eat. Another kind of energy is called potential energy. This is stored energy. The water behind a dam has potential energy. If the dam were to break, the water would rush down. The potential energy would have been converted into the kinetic energy of the moving water. The water's potential energy can be used to produce electricity. The water flows through a turbine and causes its blades to rotate. The potential energy of the water behind the dam is converted to the kinetic energy of moving water, which is then turned into the kinetic energy of the blades. A generator converts the kinetic energy into electrical energy (see GENERATOR, ELECTRICAL; HYDROELECTRIC POWER; TURBINE).

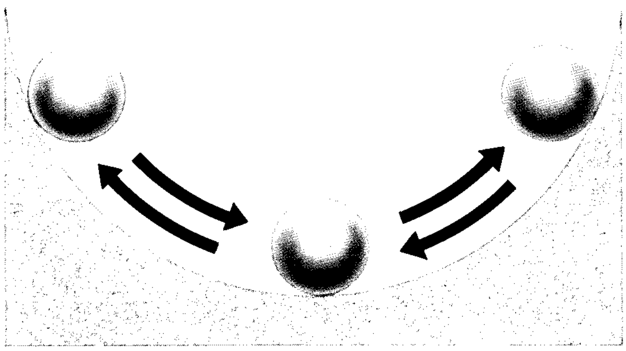
Albert Einstein was the first person to show that mass is equivalent to energy. For example, the mass of the nucleus of an atom is not the same as the sum of the masses of its protons and neutrons. The mass of the nucleus is slightly smaller due to the nuclear energy needed to bind these particles together in the nucleus (see ATOM; EINSTEIN, ALBERT).

A nuclear power station converts some of this nuclear energy into electrical energy. Stars also convert some of their mass into nuclear energy. Some of this energy is given off as light, which we can see from the earth.

DAM
Hydroelectric dams like this one convert one kind of energy into another kind. The potential energy of the water behind the dam is converted into the kinetic energy of flowing water. The water turns turboalternators to produce electrical energy.

CONSERVATION OF ENERGY

A marble rolling in a bowl resembles a rollercoaster. At its highest point it possesses potential energy, which changes to kinetic energy as it rolls down. As it climbs up the other side, kinetic energy is converted back to potential energy. In this way, energy is conserved.



Conservation of energy The law of conservation of energy states that in a closed system, when energy changes from one form to another, no energy is lost or gained. For example, when 1 gal. [3.8 liters] of gasoline is burned in a car engine, about 100,000 kilojoules (kJ) of chemical energy are converted into heat energy. Although only about 25,000 kJ are actually obtained for running the engine, the remaining 75,000 kJ do not disappear. They are wasted by heating the engine's cooling water and by heating the air with the exhaust gases. Some energy, too, is used in overcoming the friction forces in the engine.Thus, the heat energy produced by the fuel is equal to the energy used in running the engine plus the energy wasted in heating the surroundings (see FRICTION; JOULE).

If nuclear energy is involved in the energy change, the change in the mass of the fuel has to be taken into account. Then the law of the conservation of energy becomes the law of the conservation of mass and energy. In this case, the energy produced is equal to the loss in the mass of the fuel (see NUCLEAR ENERGY).

Energy supplies The economic law of supply and demand applies to energy as well as to goods and services. The price people pay for something is influenced by what happens to the supply or demand for it. For example, when petroleum (oil) is in short supply, the price of petroleum will rise. It will cost people more, then, to heat their homes and factories. The price of products made from petroleum—gasoline, for example—will also rise. Petroleum and natural gas are examples of fossil fuels (see FOSSIL FUEL; NATURAL GAS; PETROLEUM). The supply of most fossil fuels is limited. However, coal is one fossil fuel that can still be found abundantly in nature (see COAL). Coal provides almost one-third of the world's energy and about one-fifth of the energy used in the United States. Scientists estimate that enough coal exists in the United States to provide energy for the next two hundred years. Because coal is an abundant resource, scientists are researching new ways to use coal. However, there is a disadvantage to using more coal. Burning

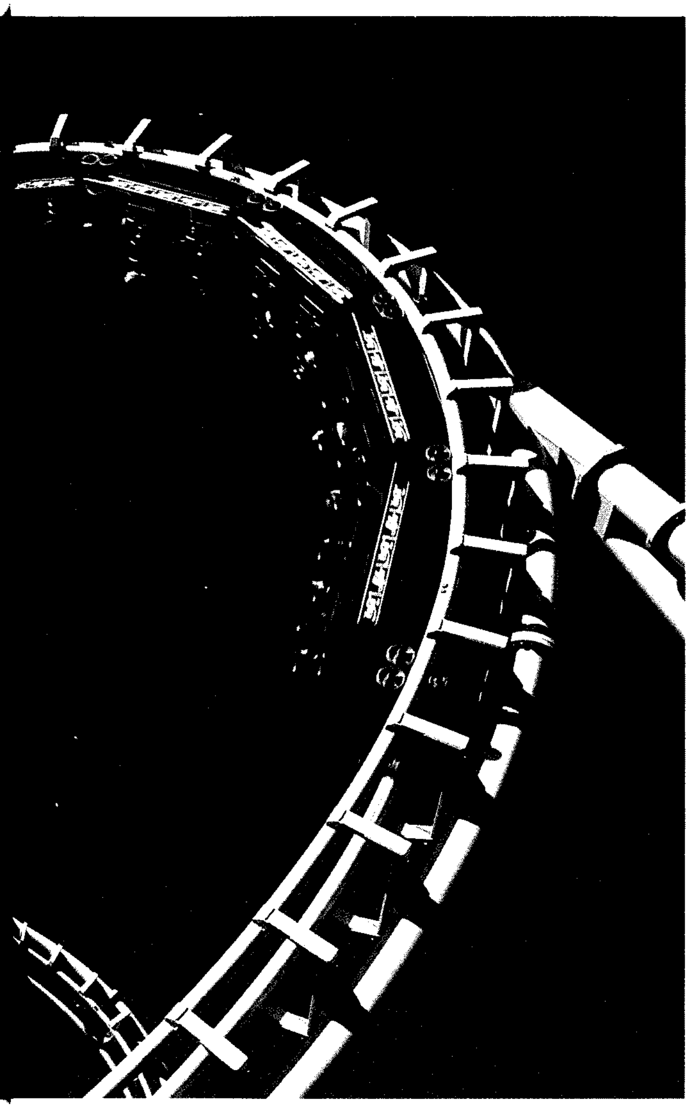
ROLLERCOASTER

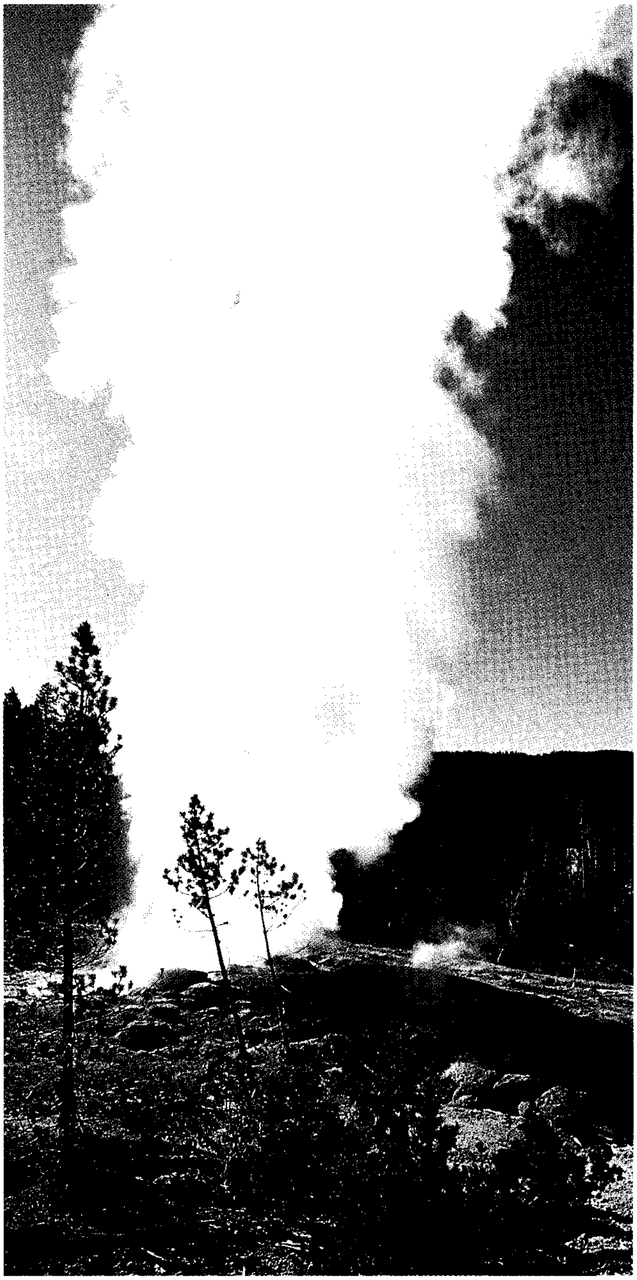
A rollercoaster is a thrilling amusement park ride that involves the continual interchange of potential and kinetic energy. The principle is explained by the diagram at top left.

coal releases polluting particles and gases into the atmosphere (see POLLUTION).

The challenge is to find energy sources that are both renewable and safe for the environment. Hydrogen may someday be the ideal fuel. Hydrogen is the most abundant element in the universe (see HYDROGEN). It releases great amounts of energy when burned. Hydrogen is also a "clean" fuel. This means it releases no pollutants when it burns. In addition, the by-product of burning hydrogen is water. The disadvantage of hydrogen is that it is very explosive. Before it can be used as a fuel, scientists must develop ways to safely store, transport, and burn hydrogen.

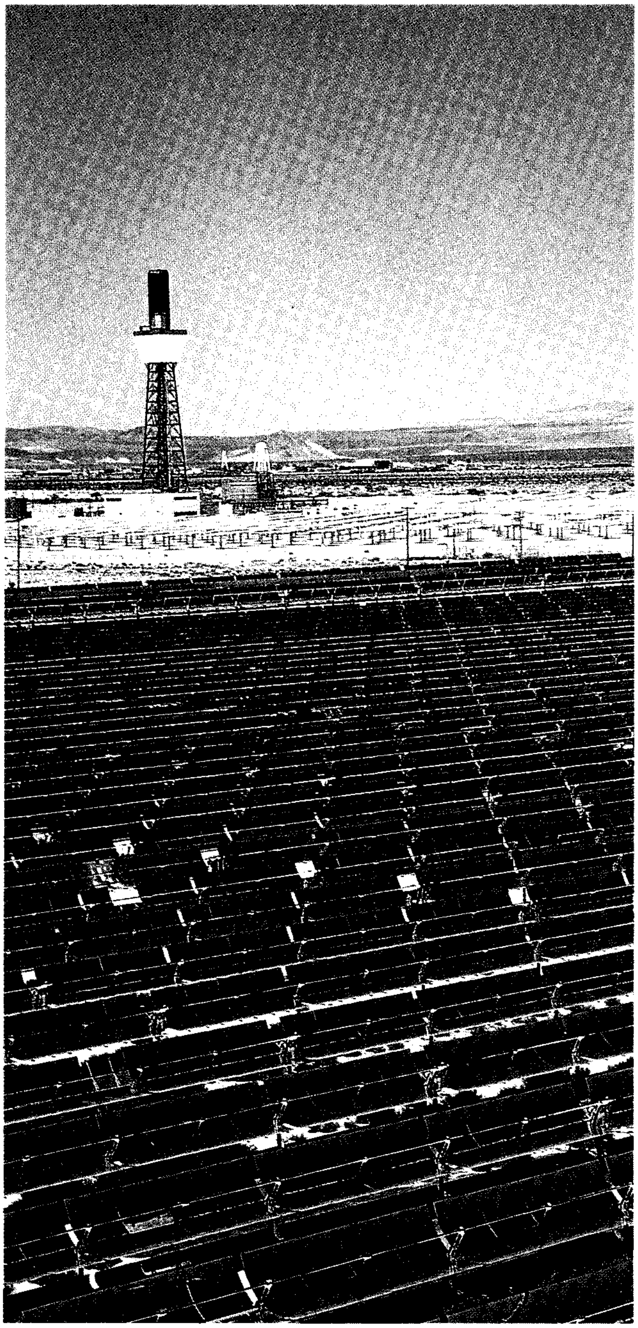
Another alternative fuel is gasohol. Gasohol is a mixture of gasoline with ethanol or methanol (see GASOLINE). Ethanol is an alcohol made from the fermentation of certain grains or vegetables (see ALCOHOL). Methanol is an alcohol made from methane (see METHANE). By combining ethanol or methanol with gasoline, less gasoline is used.





GEOTHERMAL ENERGY
The heat energy from underground rocks is known as geothermal energy. Sometimes water in the rocks boils and causes steam to shoot out of the ground in a geyser. This geyser, called *Steamboat*, is in Yellowstone National Park, Wyoming.

Nuclear fission is also an energy alternative. Fission involves the breaking up of the nucleus of an atom (see FISSION; NUCLEUS, ATOMIC). However, fission produces large quantities of dangerous wastes. Also, many people are afraid to live near, or work in, nuclear-powered industries that might



SOLAR ENERGY

The energy of the sun's radiation can be captured by rows of solar cells. The cells produce electricity.

accidentally give off radiation. Scientists are researching ways to produce energy from nuclear fusion. Fusion involves the joining of two or more atomic nuclei (see FUSION). Fusion produces no nuclear waste. However, fusion requires very high temperatures, which are difficult to achieve. The extreme amount of energy released from fusion can also be destructive unless the reaction is properly controlled.

A safer source of energy might be the geothermal energy from deep within the earth. This heat energy comes to the surface as geysers and volcanic eruptions (see SPRING AND GEYSER; VOLCANO). Some geothermal sources are hot enough to be of practical use in producing electricity. The heat warms water circulating in pipes and converts it into steam. The steam drives a turbine. The turbine then drives a generator that produces electricity. Geothermal power already is serving the needs of more than a million people in one part of California. In Iceland, steam from volcanoes heats swimming pools, schools, and homes. However, geothermal energy does have disadvantages. It produces waste heat and some offensive odors.

Much progress has been made in using the radiant energy of the sun. Solar heating of homes and other buildings is gaining acceptance. Also, solar

WAVE ENERGY

As waves crash on a beach, they give up their kinetic energy. Sea waves are powerful enough to carve caves in rock and undermine cliffs. Scientists are working to find ways of harnessing the energy of waves.

cells for converting radiant energy to electricity are being used for such tasks as cooling homes and powering calculators (see SOLAR CELL).

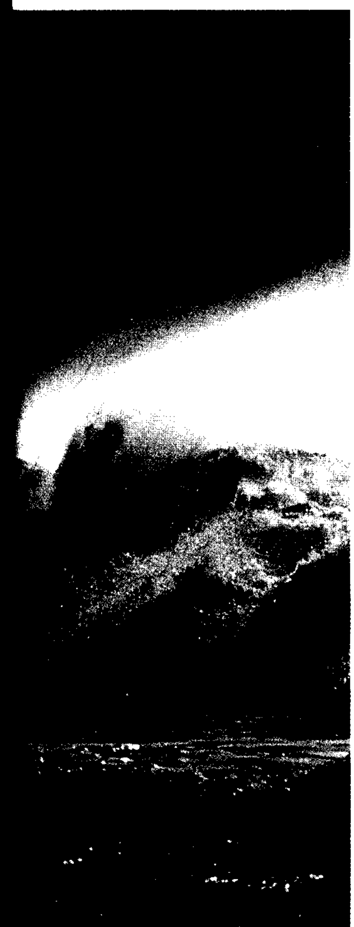
Another possibility lies in the energy from the motion of ocean tides. Some countries, such as Japan, are already using this energy source, but only on a small scale. In the United States, the windmill is making a comeback—mostly as a turbine for generating electricity.

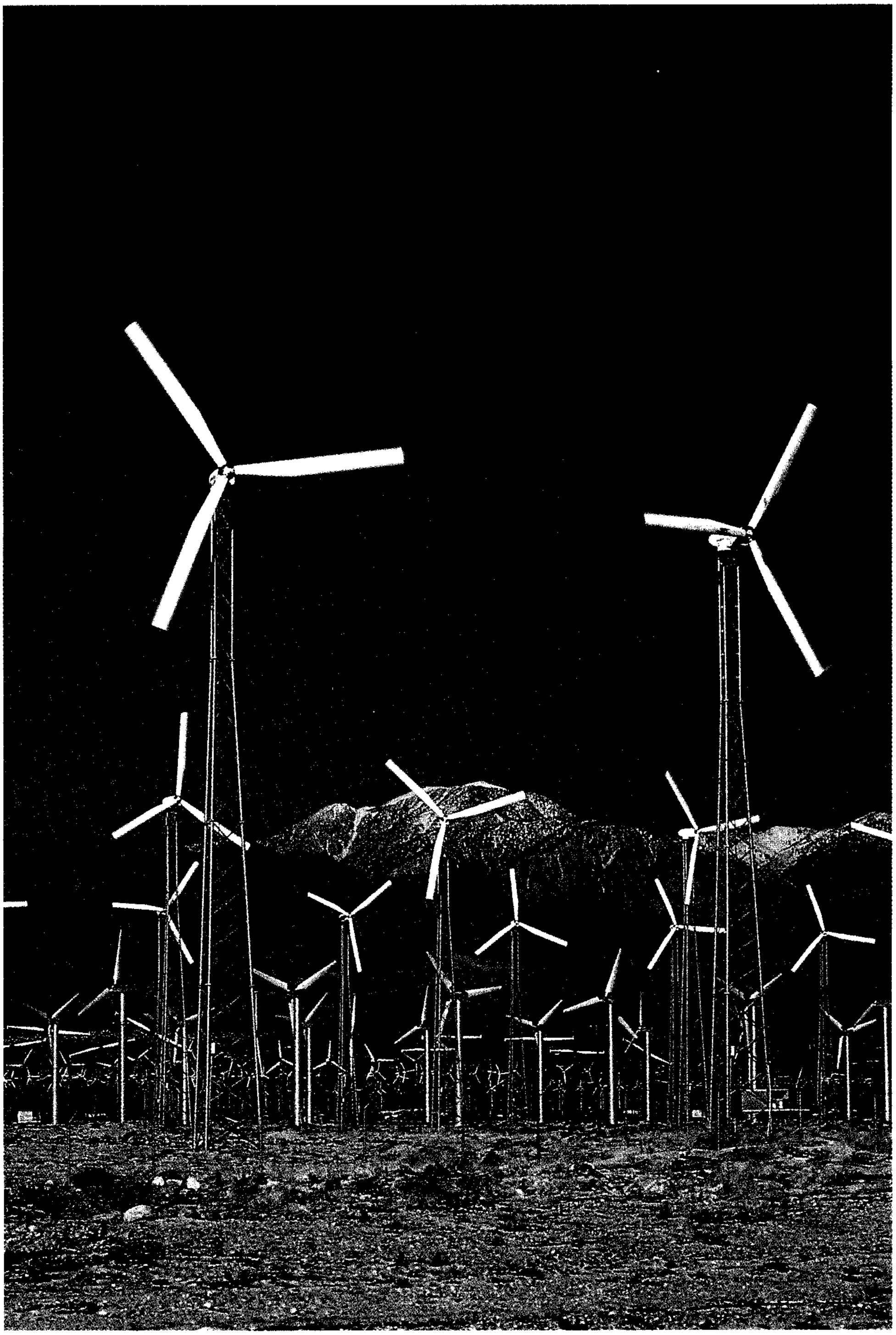
Scientists are researching another energy source that can be renewed. This source, called biomass, includes wood, sawdust, grain, and aquatic plants (see BIOMASS). Biomass can be burned to produce heat. It can be fermented to produce ethanol (see FERMENTATION). Also, through certain chemical processes, biomass can be converted into methane or a synthetic (human-made) form of oil called biocrude.

PROJECT 34, 35, 39, 51, 59, 70

WIND ENERGY

The modern version of a windmill is a three-bladed propeller on top of a tall lattice structure. As the propellers turn, they drive an electric generator mounted at their hub. This wind farm is located near Palm Springs, California.





ENGINE

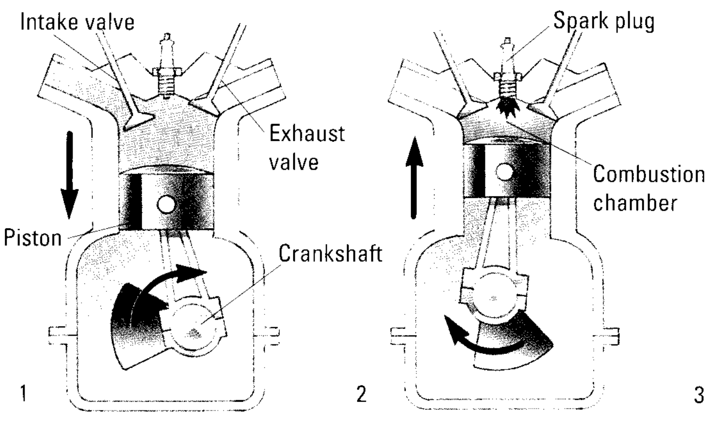
An engine is a device that uses the energy in a fuel to do work (see FUEL). Most engines use gasoline, oil, kerosene, coal, or coke (coal that is heated to high temperatures without air) for fuel. The fuel is burned, usually inside the engine, producing heat and high-pressure gases. The heat and gases in turn drive the parts of a machine. These machines have a variety of uses, including drilling, digging, and pumping. One of the most important uses of engines is to power automobiles (see AUTOMOBILE).

Early engines used steam to drive machines. The steam came from water being heated outside the engine. Until the middle of the twentieth century, most locomotives were powered by steam (see LOCOMOTIVE). At the beginning of the twentieth century, even some automobiles were run on steam.

Nearly all of today's cars and trucks are powered by engines called internal combustion engines. These are engines in which fuel, such as gasoline, is burned inside the engine. This is in contrast to external combustion engines, such as steam engines, in which fuel is burned outside the engine. The most commonly used internal combustion engines are gasoline and diesel engines (see DIESEL). The rest of this article will concentrate on internal combustion engines that use gasoline.

FOUR-STROKE CYCLE

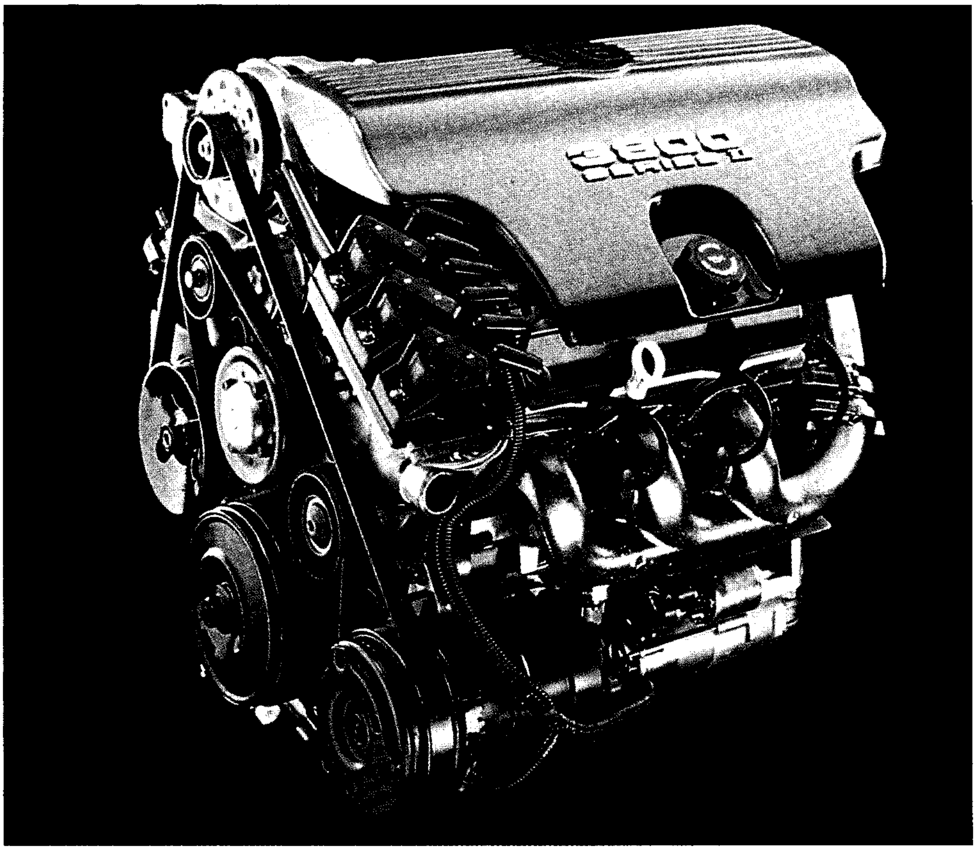
A gasoline engine works in four stages. (1) On the intake stroke, the intake valve opens to allow a fuel/air mixture into the cylinder as the piston descends. (2) On the compression stroke, the piston moves up to compress the mixture in the combustion chamber. (3) On the power stroke, the spark plug ignites the fuel, and the hot, expanding gases force the piston down. (4) On the exhaust stroke, the exhaust valve opens as the rising piston forces the exhaust gases out of the cylinder.



The first practical gasoline internal combustion engine was invented about 1860 by Etienne Lenoir, a French inventor. In 1861, Nikolaus Otto, a German engineer, invented a more efficient gasoline-powered internal combustion engine with pistons that worked on a four-stroke cycle. This kind of engine is still used today.

The first gasoline-burning internal combustion engines that worked well in motorized vehicles were made in 1885 by the German automobile pioneers Karl Benz and Gottlieb Daimler (see BENZ, KARL). Between 1890 and 1897, another German engineer, Rudolf Diesel, developed the diesel engine. It burned oil, rather than gasoline, as fuel. In the late 1950s, Felix Wankel of Germany invented the rotary engine. The rotary engine uses a device called a rotor instead of pistons.

Parts of a piston engine A main part of a piston engine is a heavy boxlike structure called the cylinder block. The cylinder block holds tubes called cylinders. Most cars have four, six, or eight cylinders. Inside the cylinders are devices that move up and down, called pistons. Bolted to the top of the cylinder block is a structure called the cylinder head. The upper end of each cylinder, which is closed off by the cylinder head, forms an area called a combustion chamber. Each combustion chamber has a pair of valves. One valve, called the intake valve, lets a mixture of fuel and air enter the cylinder. The fuel and air were originally mixed in the carburetor. From the carburetor, the mixture traveled through the intake manifold before reaching

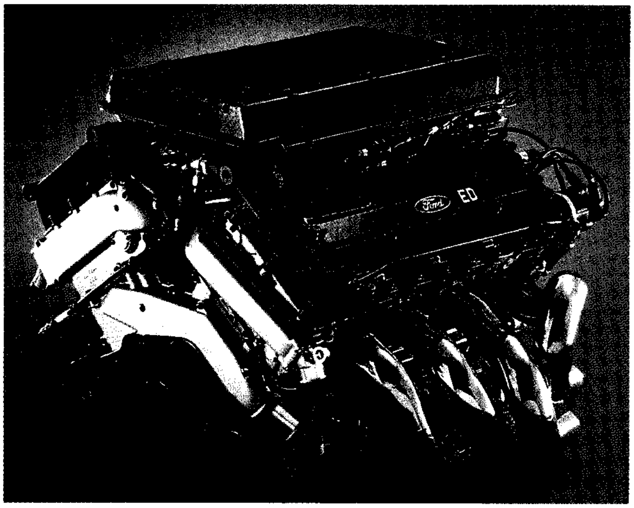


MODERN GASOLINE ENGINE
This gasoline engine, used in medium-sized family automobiles, has six cylinders arranged in a "V" formation. It produces just over 200 horsepower.

the intake valve (see CARBURETOR). In many modern automobiles, the fuel is delivered by a different system. Instead of passing through a carburetor, the fuel is sprayed directly into the cylinders in small amounts. This system is called fuel injection. The other valve in the combustion chamber allows waste gases, called the exhaust, to escape. This valve is called the exhaust valve. The exhaust comes from the explosion of the fuel mixture in the combustion chamber.

Each movement of a piston up or down in its cylinder is called a stroke. Most gasoline engines work on a four-stroke cycle. This means that each piston goes up and down twice for each explosion. Each piston moves up and down at a different time. The up-and-down motion of each piston is repeated over and over again. On the first downstroke, called the intake stroke, the piston is forced to the lower part of the cylinder by the turning of the crankshaft. The crankshaft is an unevenly shaped barlike device that runs along the bottom of the cylinder block. The crankshaft is linked to the bottom of each piston by a connecting rod. The crankshaft is first forced to turn when the engine is switched on, pulling down the piston. The movement of the piston to the lower part of the cylinder draws the fuel-air mixture into the combustion chamber.

The downward motion of the piston causes the crankshaft to turn, forcing the piston back up again. This is its second stroke, called the compression stroke. The piston squeezes the mixture in its combustion chamber. An electric spark from a spark plug attached to the top of each cylinder ignites the mixture, and it explodes. The piston is forced down by the explosion for its third stroke, called the power stroke. The piston is forced to the top again by the turning of the crankshaft for the fourth stroke, called the exhaust stroke. This time, the piston pushes the burned gases out of the cylinder. The gases leave the engine as exhaust fumes through the exhaust valve. The exhaust valve and the intake valve are opened and closed by the action of the camshaft, which runs along the length of the engine. The camshaft is linked to the crankshaft by a chain, called a timing chain, that loops around gears at one end of each of the shafts. The turning of the crankshaft forces the camshaft to turn. The



RACING CAR
A specially modified Ford V-8 engine is popular in some types of high-performance cars.

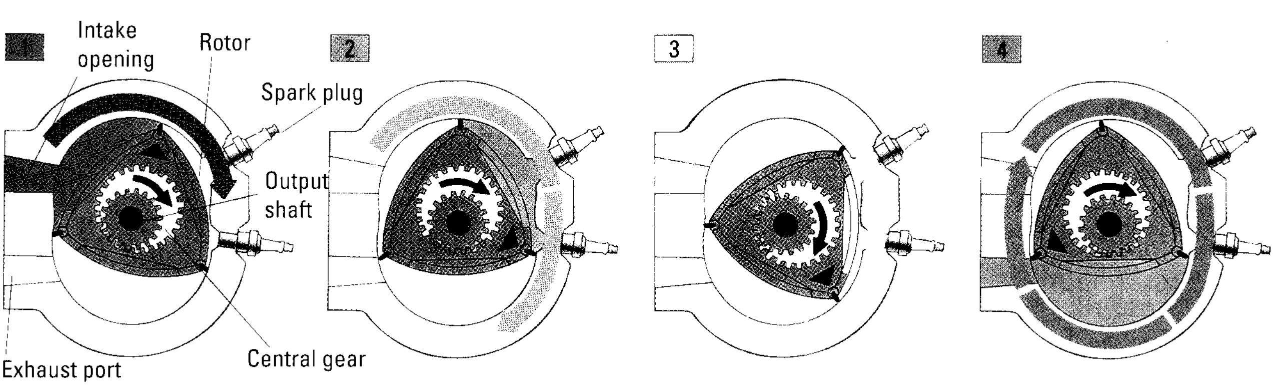
turning of the camshaft opens and closes the valves.

A device called a flywheel is bolted to one end of the crankshaft. The flywheel keeps the shaft turning smoothly between the strokes (see FLYWHEEL). The energy generated by the motion of the pistons and the crankshaft is passed on to the wheels through other parts of the automobile, such as the transmission, the drive shaft, and the differential.

Several systems are required to keep this whole process going. A fuel system either supplies the fuel to the cylinders or mixes the fuel with the appropriate amount of air in the carburetor so that the fuel will explode properly. The ignition system provides sparks to ignite the mixture at the right time. A cooling system prevents the engine from overheating. The lubrication system keeps all the moving parts oiled, so they move freely. Otherwise, if there was too much friction, the metal would wear, and the engine would overheat (see FRICTION).

The Wankel engine The Wankel engine is a type of gasoline-powered internal combustion engine called a rotary engine. A rotary engine works with a rotor instead of pistons. A rotor is a rotating device that moves inside the combustion chamber, which is stationary. In the Wankel engine, the rotor is shaped like a triangle. The combustion chamber is oval shaped. Because of the way the rotor fits inside the combustion chamber, it divides the chamber into three chambers. These chambers are uneven in size because of the triangular shape of the rotor. As the rotor turns inside the chamber, a pathway is opened from outside the combustion chamber. This pathway, called the intake opening, allows the fuel-air mixture into the first chamber. As the rotor moves, the fuel-air mixture passes into a second chamber, where it is compressed and ignited by a spark plug. The rotor turns again, and the exhaust from the explosion fills the third chamber. Another spin of the rotor allows the gas to leave the combustion chamber through another pathway called an exhaust port. At the same time, the intake opening is opened again and more of the fuel-air mixture is allowed into the first chamber. This process keeps repeating. Wankel engines are used to power a number of different kinds of automobiles and aircraft. Wankel engines are simpler than piston engines. However, they are also less durable and require more fuel.

WANKEL ENGINE
The Wankel engine works in four stages. (1) During the intake stage, the fuel/air mixture is drawn in through the intake opening. (2) During compression, the spark plugs ignite the fuel. (3) In the power stage, expanding gases turn the rotor around. (4) Finally, in the exhaust stage, exhaust gases are forced out of the exhaust port.



ENGINEERING

Engineering is the study and development of ways to use materials for human purposes. Engineering involves invention, design, and planning. Scientists in many different fields rely on engineers to invent the technologies they need to carry out their research. Engineers do everything from designing rockets to designing medical equipment. However, all engineers have one thing in common. They put scientific knowledge to practical use.

Until the mid-1700s, there were only two divisions of engineering—military and civil. Military engineers designed weapons and engines for warfare. They also built roads for soldiers to use and fortified (strengthened) walls and ditches against enemies. Civil engineering dealt with the building of aqueducts (structures that carry water from one place to another), bridges, canals, and roads for towns and cities. Early engineers designed irrigation systems, which allowed farmers to grow more food. This helped lead to the start of cities because no longer did everyone have to be a farmer. Some of the structures built hundreds of years ago are still in use today (see AQUEDUCT; BRIDGE; CANAL; IRRIGATION).

Today, many more fields of engineering exist. Some of the major fields are civil, mechanical, mining and metallurgical, chemical, and electrical engineering. Each of these major fields includes a number of specialized fields. Some engineers have received training in several such specialized fields as well as other areas of science. For example, a biomedical engineer uses his or her knowledge of

EUROTUNNEL

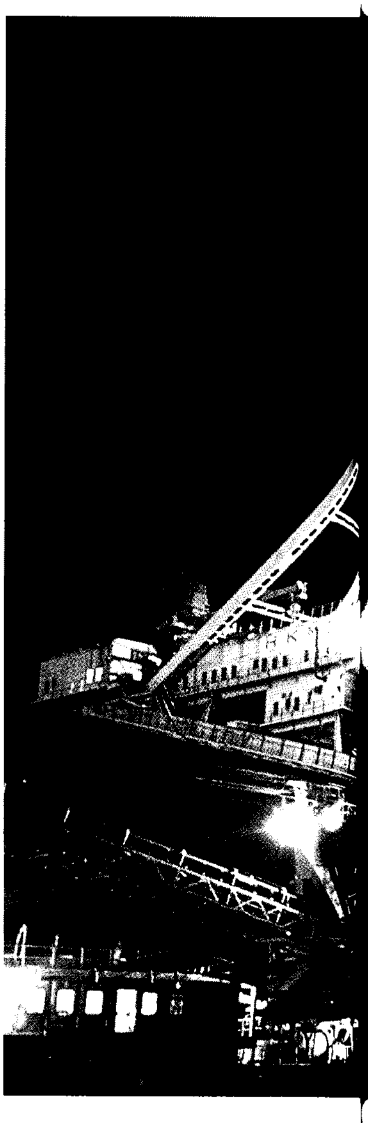
Opened in 1994, Eurotunnel runs for 22 miles [35.2 kilometers] below the English Channel between Dover, England, and Calais, France. It has two railroad tracks for trains carrying passengers, cars, and trucks.

COMPUTER-AIDED DESIGN

Today's engineers can use computers to help design structures and test them. As a result, they do not have to build scale models or actual structures before the design can be finalized.

biology, medicine, and engineering to create artificial body parts, pacemakers, and equipment for diagnosing illnesses (see MEDICAL ENGINEERING). Another important engineering field is aerospace engineering. This field combines knowledge about aeronautics, physics, and space to develop commercial and military aircraft, missiles, and spacecraft.

Civil engineering Civil engineering is the design and building of large construction projects, such as airports, bridges, canals, dams, hospitals, railroads, and roads (see AIRPORT; DAM; RAILROAD). Safety is most important in designing these structures. Civil engineers must study the soil and rock beneath the proposed project. Their research will tell them how much weight the soil and rock can safely hold. This will help them design the structure so it does not exceed that weight limit. They must also know the strengths of all the materials they use. Civil engineers advise builders on the



MINING

A huge excavator works all day and all night to dig out coal from an open-cast mine. Mechanical engineers work together to design such machines.

maximum load that is safe for bridges. They have to know how much water a dam can safely hold. Teams of architects and civil engineers work closely together on these large projects. For example, an architect produces a pleasing and effective design. The civil engineer makes sure that suitable materials are used to build the architect's design. Civil engineers also have to know about the equipment that is used in building. For example, they have to decide how to move materials, using bulldozers, cranes, mechanical shovels, and other equipment.

Civil engineering is one of the largest branches of engineering. Specialized fields of civil engineering include coastal engineering (the design of harbors, bridges, and construction along coasts), construction engineering, railroad engineering, water-supply engineering, and traffic and highway engineering (see BUILDING CONSTRUCTION).

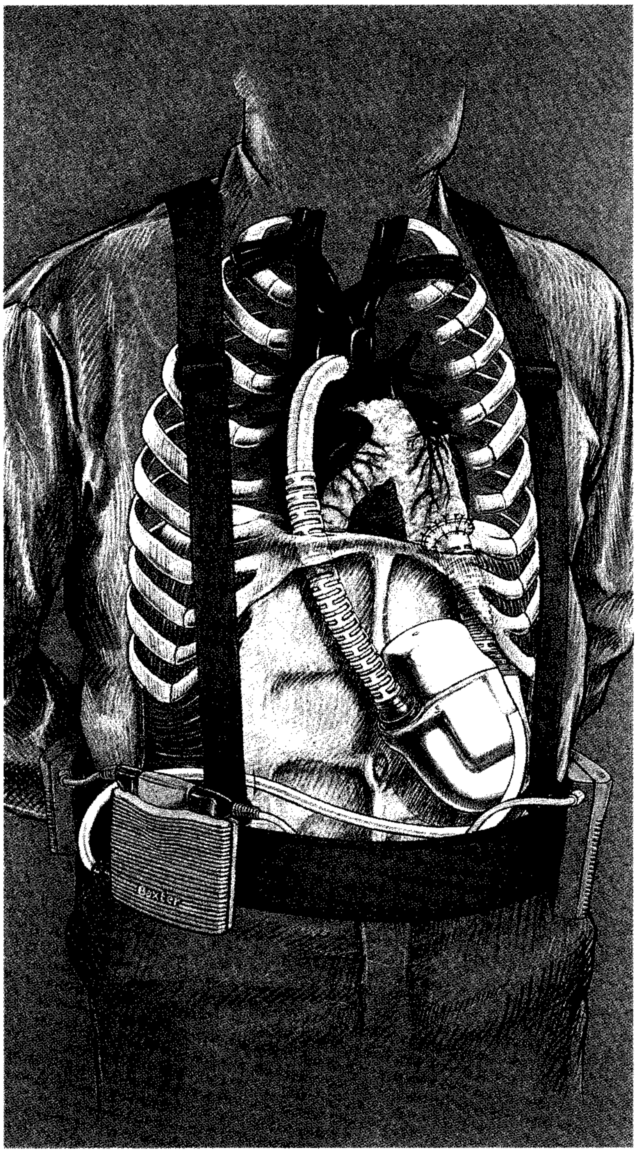
Mechanical engineering Mechanical engineers study, use, design, and build machinery. Every industry uses machines of some kind. For example, farmers use tractors, planters, and harvesting machines. Plastic makers use machines for melting, mixing, molding, rolling, and stamping. The electric-power industry uses machines to produce electricity from coal, oil, and nuclear fuels. Mechanical engineers design all these machines and many others.

Mechanical engineering has several specialized branches. For example, aeronautical engineers design aircraft. Automotive engineers design cars, engines, and machines for building them (see AERONAUTICS; AUTOMOBILE). Marine engineers design docks, ships, and submarines. Nuclear engineers design specialized machinery for producing power from nuclear fuels.

Mining and metallurgical engineering Mining engineers and metallurgical engineers discover mineral deposits and design the equipment to bring the minerals out of the earth (see MINING). They also design ways to extract metals from ores. A mining engineer works closely with geologists. Geologists are scientists who study mineral and rock formations.

Mining engineers must know the best way to construct mine shafts (openings in the earth). They must know about machinery that circulates air in the shafts and about drills and other digging equipment. Mining engineers may specialize in coal mining, gold mining, petroleum mining, uranium mining, or other fields. They need knowlege of civil, mechanical, and electrical engineering.

Metallurgical engineers are experts in extracting, or separating, minerals out of ores and preparing them for use. For example, metallurgical engineers design ways to extract iron from iron ore. Physical metallurgists test minerals and metals for strength and hardness.



ARTIFICIAL HEART
An artificial heart is an example of biomedical engineering. It is an electrically powered pump that replaces a patient's diseased heart.

Chemical engineering Chemical engineers find ways that chemicals can be changed into useful products. A chemical engineer may specialize in one kind of product. Drugs, dyes, explosives, fertilizers, paints, plastics, soaps, and hundreds more products are specialty areas of chemical engineering. The chemical engineer must also understand how to handle large quantities of chemicals. Some chemicals are dangerous and must be handled with special care (see CHEMICAL INDUSTRY).

Electrical engineering Electrical engineering deals with the construction and use of different kinds of electrical equipment. Electrical equipment is used in power plants, radio and television broadcast systems, radar, telephone systems, and air-conditioning systems. There are many specialties of electrical engineering. For example, electronics engineers design and build electronic circuits for products such as computers. Communications engineers are experts in designing radio, television, radar, and telephone equipment.

Other engineering fields A number of engineering specialties involve the life sciences. Biochemical engineers study the human body and invent new medicines. Food engineers design ways to safely process, package, store, and transport foods for market. Agricultural engineers design specialized farm equipment and buildings. Environmental, forest, river, and marine engineers study the impact of building and industry on the environment. They devise systems that preserve or improve the environment. Genetic engineers study ways to improve breeds of plants and animals and to produce better products from them.

ENKEPHALIN (ĕn kĕf'ə lĭn') An enkephalin is one of two chemical substances, each of which is made up of a chain of five amino acids (see AMINO ACID). They are called met-enkephalin and leu-enkephalin. They were first discovered in 1975. Chemically, they are very similar to endorphins and are thought to perform similar functions (see ENDORPHIN). Enkephalins act directly on nerve cells at many places in the brain and spinal cord. They transmit nervous impulses and play a part in movement, mood, behavior, sensing pain, and regulating hormones (see BRAIN; NERVE CELL; NERVOUS SYSTEM; SPINAL CORD). Enkephalins are also found in the nerves and glands of the digestive system (see DIGESTIVE SYSTEM). Like endorphins, enkephalin levels appear to increase during pregnancy and during times of pain, stress, and exercise.

ENTOMOLOGY (ĕn'tə mŏl'ə jē) Entomology is the study of insects. This vast group of organisms includes three-fourths of the known animal species (see INSECT). Entomologists (scientists who study insects) study the body structure and function, behavior, ecology, and classification of insects. The field of entomology also often includes organisms closely related to insects, such as spiders and centipedes (see ARTHROPODA).

Many entomologists study the effects that insects have on human life. For example, medical entomologists study such insects as mosquitoes, which can carry diseases. Some entomologists study the effect of insects on farm crops, while others study certain insects called parasites, which live off other organisms (see PARASITE).

Some entomologists help develop new ways of controlling insects that are harmful to humans. Some develop insecticides. Others find nonchemical ways to control insect populations—for example, by using insects' parasites or other enemies, or by sterilizing the males so offspring cannot be produced (see BIOLOGICAL CONTROL; INSECTICIDE).

Entomology helps people understand the function of insects in the ecosystems of the earth (see ECOSYSTEM). Entomologists realize that most insects are harmless or even beneficial to humans and their crops and animals.

ENTOMOLOGY
Entomologists experiment with chemicals to attract and trap weevils that attack coconut palms.

ENTROPY (ĕn'trə pē) Entropy is a measure of the randomness, or internal disorder, of matter. If a substance could be made to cool down to the temperature of absolute zero, all the atoms and molecules of the substance would stop moving and be held in fixed positions. At such a time, there would be no disorder and thus, no entropy.

A balloon filled with the gas helium provides an example of high randomness. The helium atoms move about freely within the balloon, colliding with each other and with the walls of the balloon. *See also* ABSOLUTE ZERO; ATOM; MOLECULE; THERMODYNAMICS.

ENVIRONMENT

Every organism is affected by many outside influences. These influences include soil, air, water, temperature, sunlight, wind, and many other things. These influences are commonly referred to as environmental conditions. The total of all environmental conditions acting upon an organism is its environment.

There are many different environments on Earth. Biologists refer to a large area identified by a particular kind of climate and by the presence of characteristic plants and animals as a biome (see BIOME). The environment or biome of an evergreen forest is often well shaded, cool, and moist. The desert environment or biome is usually hot and dry. The environment at the bottom of the ocean is cold and dark, with a tremendous amount of pressure. The characteristics of the environment determine the organisms that can live in that place. For example, an oak tree will not grow at the bottom of an ocean, nor will a fish live on desert sands. Often, organisms are able to change an environment (see SUCCESSION).

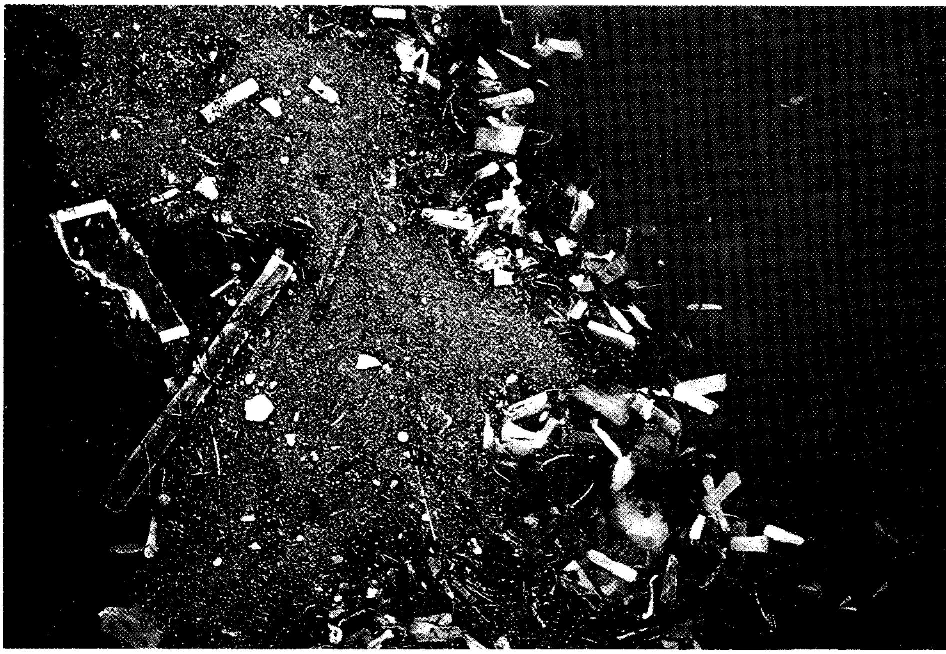
Humans are able to alter environments more than any other organism. People can dam rivers, drain lakes, and even make it rain. By changing the environment, people have been able to make life more comfortable in certain ways.

In changing the environment, people have also done great damage to it. Human actions have already damaged or destroyed the natural resources in many different regions. For example, we have polluted the air around our cities; we have damaged lakes and rivers by dumping pollutants in them; we have eroded our soil by using improper farming techniques; we have destroyed forests by clearcutting huge stands of trees; and we have killed off many species of wildlife by changing their habitats.

Environmental scientists study the effects of humans on the environment and suggest ways to solve problems. One way is to recycle wastes, such as aluminum or paper.

See also CONSERVATION; DEFORESTATION; ECOSYSTEM; NATURAL RESOURCE; POLLUTION; RECYCLING.

DRY LANDSCAPE
Chaparral is a dry environment with cacti and other drought-resistant plants. This example is near Tucson, Arizona. It is hot and dry in the summer, but cool and moist in the winter.



ENVIRONMENTAL ISSUES
The sea becomes polluted with garbage thrown overboard from ships and domestic waste dumped at sea. Eventually much of it is washed ashore where it will pollute beaches.

ENVIRONMENTAL ISSUES Environmental issues are topics concerning the problems facing our environment (see ENVIRONMENT). They include topics such as the continued destruction of the rain forests, the pollution of the seas, the pollution of the air, and global warming (see GREENHOUSE EFFECT; POLLUTION). Other environmental issues concern the building of new roads and the destruction of the surrounding countryside. This destruction kills off many species of wildlife because their habitats are changed. Almost all of these environmental problems can be linked to the rapidly increasing human population.

Biologists and other scientists have become very concerned about environmental issues in recent years. The United Nations staged an international conference—the Earth Summit—in Brazil in 1992 to discuss such issues. Delegates agreed on the need for an overall program of action for changing human activities in order to lessen environmental damage. If nations cooperate in this way, the whole of humankind will benefit.

ENZYME (ĕn′zīm′) Enzymes are proteins, made in the cells of organisms, that speed up chemical reactions. The millions of chemical reactions that make up the metabolism of an organism are controlled by enzymes (see CHEMICAL REACTION; METABOLISM; PROTEIN).

Unlike most chemical reactions, an enzyme-controlled reaction occurs at about the body temperature of an organism—about 98.6°F [37°C] in humans. A chemical reaction, such as the breakdown of sugar, that requires high temperatures in order to occur outside the body, occurs at body temperature when controlled by enzymes. The body breaks down sugar in a rapid series of enzyme-controlled reactions that release energy slowly. In this way, the body benefits as much as possible from each chemical reaction.

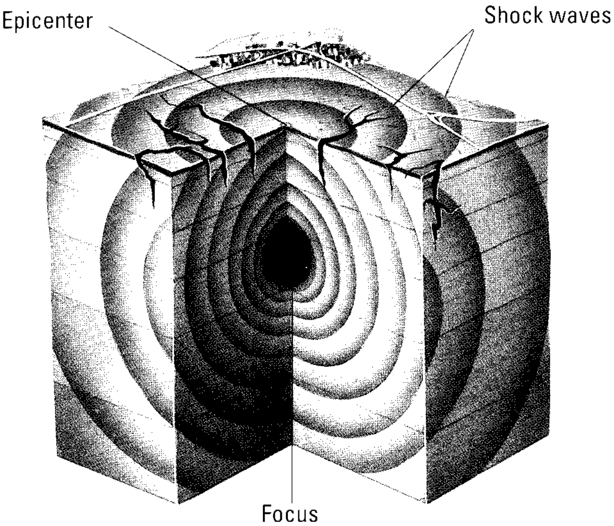
Enzymes are very sensitive substances and may be destroyed at high temperatures. If a person's body temperature rises to 108°F [42°C], many enzymes stop working, and the person may die.

An enzyme works by combining with another chemical substance called a substrate. When the enzyme and substrate combine, a chemical reaction occurs that changes the substrate. The new substrate is then released. The enzyme, which was unchanged during the combination and reaction, can join with more of the original substrate. Thus, the enzyme is reused. Enzymes are said to be specific—that is, one kind of enzyme will only act on one kind of substrate. Some enzymes need an additional substance to allow combination with the substrate. These substances are called coenzymes. Many vitamins are coenzymes (see VITAMIN).

EOCENE EPOCH
Many different types of mammals thrived during the Eocene epoch, which ended about 35.5 million years ago. They included animals that resembled modern rhinoceroses and hippopotamuses, ratlike carnivores, and small hoofed mammals related to modern antelopes and horses.

EOCENE EPOCH (ē′ə sēn′ ĕp′ək) The Eocene epoch, a division of Earth history, is the part of the Tertiary period that started about 56.5 million years ago and lasted about 21 million years. Mammals were well established by this time. Small ancestors of the horse and camel appeared. Primitive whales and rodents developed during this epoch. Many modern plants evolved during the Eocene epoch.
See also GEOLOGICAL TIME SCALE.

EPICENTER The epicenter is the point on the earth's surface directly above the point where an earthquake originates. Earthquakes originate at a point in the bedrock called the focus. Shock waves produced at the focus spread through the bedrock in all directions. The most violent shaking usually occurs at the epicenter.
See also BEDROCK; EARTHQUAKE.



EPICENTER
The greatest effects of an earthquake are felt at the epicenter, which is located on the surface directly above the source of the earthquake (the focus).

EPIDEMIC An epidemic is an outbreak of disease in which a large number of people are affected within a short period of time (see DISEASE). Originally, the term *epidemic* was only applied to those outbreaks that involved infectious diseases (diseases caused by organisms called pathogens), especially diseases that could be spread from person to person. Today, the term *epidemic* also refers to certain diseases, such as cancer and heart disease, that may have been caused by environmental or genetic factors.

A disease that has spread throughout a particular region is known as an endemic. If the disease spreads throughout the world, it is known as a pandemic. A disease that spreads rapidly among other animals besides humans is known as an epizootic.

Throughout history, there have been epidemics of such diseases as cholera, influenza, measles, and tuberculosis (see CHOLERA; INFLUENZA; MEASLES; TUBERCULOSIS). The most serious epidemic was a form of bubonic plague that spread throughout Europe in the 1300s. It was referred to as the Black Death and caused about 60 million deaths. The disease is transmitted to humans by fleas from rats infected with the disease. The most recent epidemic facing the modern world is AIDS. At this time, there is no known cure for AIDS (see AIDS).

Methods of ending or controlling epidemics include vaccinations against the disease; isolating individuals with the disease so they do not spread it; and maintaining good sanitation to control the breeding of disease-causing organisms (see VACCINATION).

Epidemiology is the study of epidemics. Epidemiologists study the causes of the disease and how the disease is spread.

EPILEPSY Epilepsy is a disease in which a person has seizures. Seizures occur when a part of the brain is not working properly, causing a group of nerve cells to become too active. This abnormal brain activity causes unusual movements or behavior in the person having the seizure. Seizures may occur occasionally in people who do not have epilepsy, due to head injury, brain disease, or the abrupt withdrawal of certain kinds of drugs. These seizures generally stop when the cause is treated. There are several kinds of seizures. Partial seizures start in one area of the brain and may spread to other parts. Generalized seizures start everywhere in the brain at once.

There are different names for different seizures. The grand mal attack is the most severe kind of generalized seizure. It is a form of convulsion (see CONVULSION). A person having a grand mal seizure loses consciousness and may fall if he or she is not supported. The muscles jerk violently. The seizure lasts a few minutes; then the person may go into a deep sleep.

The petit mal attack is a milder form of generalized seizure. A person having a petit mal attack may lose awareness, or "go blank." The seizure lasts for only a few seconds, and the person may not even realize he or she has had an attack. Most petit mal attacks occur in children. About half of those with petit mal epilepsy will get better as they get older, and the other half will probably go on to have the more serious types of epilepsy.

A psychomotor seizure is a kind of seizure during which the person acts strangely for only a few minutes. Sometimes the person walks around aimlessly or tugs at his or her clothes.

Epileptic seizures may occur at any time. Some people who have epilepsy have frequent seizures. Others have seizures relatively rarely.

Very little is known about the causes of epilepsy. The disease may be caused by brain damage due to infection, physical injury, tumors (abnormal tissue growths), or other structural defects that occurred while the brain was developing during pregnancy. Epilepsy is not contagious. However, in some cases, it may be inherited. Children of parents with epilepsy have an increased chance of having seizures compared with other children.

Doctors treat epilepsy with certain drugs that reduce or eliminate seizures. It is very important for a person with epilepsy to take these medications regularly. It is also important for anyone who has had a seizure to see his or her doctor so that the seizures can be treated. With proper treatment, most people with epilepsy can lead normal lives.

EPIPHYTE (ĕp′ə fīt′) An epiphyte is any plant that grows upon another plant (called the host) for physical support. Epiphytes are different from

EPIPHYTE

The staghorn fern is an epiphyte that uses rain forest trees for support. Its funnel-shaped leaves trap rainwater.

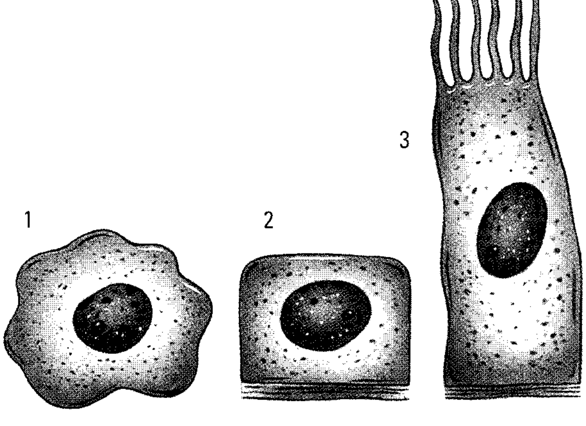
climbing plants, which have roots in the ground, and from parasitic plants, which get food from their hosts (see CLIMBING PLANT; PARASITE). Epiphytes are often called air plants. They have special roots and leaves that absorb water from the moist air, and they get their minerals from dust and from animal droppings. They have no attachment to the ground. Most epiphytes are tropical plants. These include certain orchids, ferns, and members of the cactus family. Temperate epiphytes include some ferns and many mosses and liverworts.

EPITHELIUM (ĕp′ə thē′lē əm) Epithelium is an important tissue found in human beings and other animals, and in a few plants. It is made up of cells that are closely bound to each other to form sheets. Epithelial tissue acts mainly as a protective covering, but it also has one or more of the following functions: absorption, contraction, secretion, or sensation.

In human beings, epithelium covers the body and lines the passages of systems that open to the outside, as well as the organs in these systems. Specifically, epithelium lines the digestive tract as well as the respiratory, reproductive, and urinary tracts.

There are three main types of epithelium, based on the structure of the cells that make up the tissue. Squamous epithelium is made of thin, flattened cells with irregular edges. It lines the mouth and esophagus and covers the skin. Cuboidal epithelium is made of small, boxlike cells. It lines some body cavities and helps make up many glands (see GLAND). Columnar epithelium is made up of long, narrow, column-shaped cells. It lines most of the alimentary canal and forms the innermost layer of the epidermis (see ALIMENTARY CANAL; SKIN). Some specialized columnar epithelial cells have hairlike structures called cilia on their outer surface. Cilia move fluids or other substances in one direction. Ciliated epithelium lines much of the respiratory system (bronchi, trachea, nasal passages), female reproductive system (fallopian tubes, uterus), and male reproductive system (vas deferens, epididymis).

See also CILIUM.



EPITHELIUM

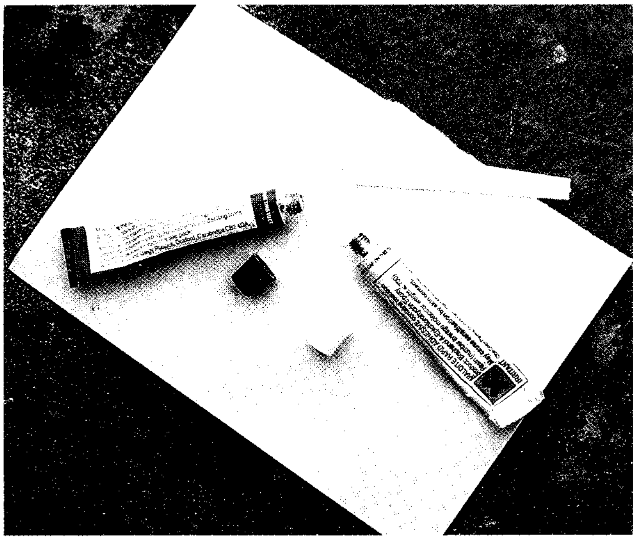
Epithelium tissue lines many of the passages and cavities in the human body. The three main types of epithelium are called (1) squamous, (2) cuboidal, and (3) columnar.

EPOCH (ĕp′ək) An epoch is a unit of the geological time scale. The geological time scale outlines the development of the earth and life on it. The history of the earth is divided into four eras. From oldest to most recent, they are the Precambrian, Paleozoic, Mesozoic, and Cenozoic eras. All the eras except the Precambrian are further divided into periods. The two periods of the Cenozoic era are further divided into seven epochs.

See also GEOLOGICAL TIME SCALE.

EPOXY RESIN Epoxy resin is a type of plastic. It belongs to the group of plastics called thermosets. Thermosets become permanently rigid when heated. Epoxy resins are able to resist many corrosive chemicals, high temperatures, and effects of weathering, such as rust. They also harden quickly and can make strong bonds. These characteristics allow many different products to be made with epoxy resins. For example, epoxy resins can be used to line fuel tanks because they will not chemically react with a fuel such as gasoline. Epoxy resins coat electronic parts in a rocket because they resist the heat generated when the rocket is launched. Epoxy resins also are used as adhesives to repair products made of ceramic, concrete, glass, metal, or wood, and to stick different materials together. These adhesives are sometimes called superglues. When epoxy resins are combined with glass fibers, fiberglass is formed. Fiberglass can be used to make

the bodies of cars and the hulls of small boats, and it is used as insulation.
See also ADHESIVE; FIBERGLASS; PLASTIC; RESIN.



EPOXY RESIN
For use as an adhesive, epoxy resin comes in two tubes containing adhesive and hardener. An amount of each must be thoroughly mixed before using.

EPSOM SALT Epsom salt is a powdered form of magnesium sulfate. It is named for the springs in Epsom, England, where it was first obtained. It occurs dissolved in seawater and in most mineral waters. It also occurs in association with minerals such as epsomite, gypsum, and limestone.

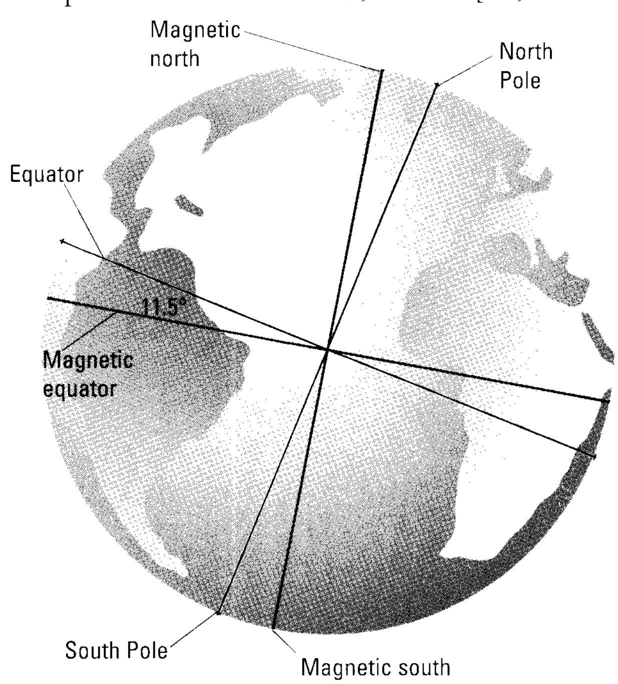
Epsom salt is used as a laxative. It causes a great deal of water to be retained in the feces, so that they become loose and pass quickly. Epsom salt should not be taken frequently, because it interferes with the absorption of food materials. It should never be taken when there is abdominal pain. Epsom salt is also mixed with water to make a solution for soaking inflamed body parts, especially the feet and hands.

EQUATION In chemistry, an equation is a statement, made up of symbols and formulas, that shows the changes that occur during a chemical reaction. A symbol stands for an element. *Fe,* for example, is the symbol for iron. *S* is the symbol for sulfur. A formula shows the proportion of elements in a compound. A compound is a substance that contains two or more elements. For example, the formula for iron sulfide is FeS. An example of a chemical equation is: Fe + S ►FeS. This means that the combination of iron and sulfur produces iron sulfide.

In mathematics, an equation is a number sentence that shows how two mathematical phrases are equal. For example, in the equation $3 + 2 = 5$, *3 + 2* and *5* are both mathematical phrases. Another example of an equation is $1 + 4 = 3 + 2$.
See also ALGEBRA; ARITHMETIC; CHEMICAL REACTION; CHEMISTRY; ELEMENT; MATHEMATICS.

EQUATOR The equator is an imaginary line around the middle of the earth, located halfway between the North and South poles. The equator represents 0° latitude on a map. The equator is divided into 360° of longitude (see LATITUDE AND LONGITUDE).

Because of the slight bulge of the earth at the equator, the equatorial circumference (the length of the equator's circle) is a little longer than the polar circumference (the length of a circle around the earth that runs through both poles). The equatorial circumference is 7,927 mi. [12,756 km], while the polar circumference is 7,899 mi. [12,713 km].

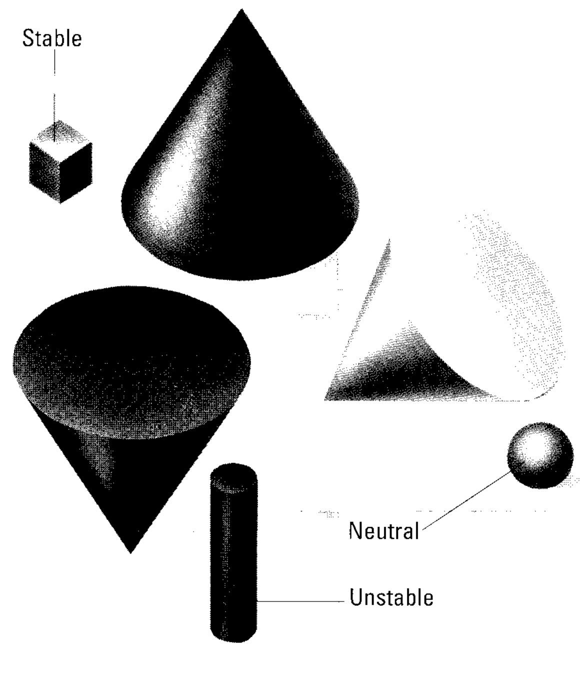


EQUATOR
The equator runs around the earth midway between the poles. It corresponds to latitude 0°. The magnetic equator, between the north and south magnetic poles, is inclined at an angle of about 11.5° to the true equator.

EQUILIBRIUM (ē′kwə lĭb′rē əm) Equilibrium is a state of rest or balance due to the action of equal opposing forces. When two or more forces acting on a body oppose or neutralize each other so that the body does not move, the forces are said to be in equilibrium. For example, at the exact time that the forward force of a football fullback is neutralized by the equal opposing force of a tackler, the forces are in equilibrium. Then, the fullback stops moving.

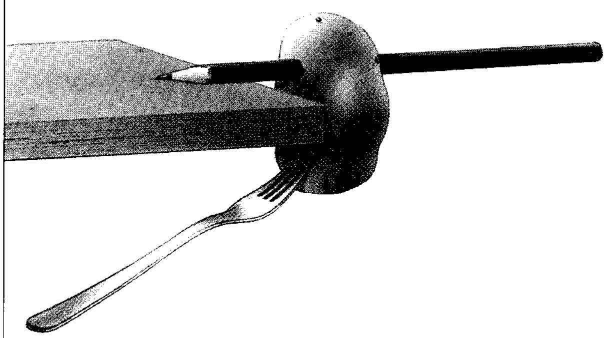
The ease with which the equilibrium of a body may be upset determines its type of equilibrium. If the center of gravity of an object must be raised in order to tilt it, the object is said to be in stable equilibrium. For example, a book lying on a table is in stable equilibrium. A pencil balanced on its point is in unstable equilibrium. The slightest tipping of the pencil lowers its center of gravity, causing the pencil to fall. A ball resting on a floor is in neutral equilibrium. Movements will neither raise nor lower its center of gravity.

A chemical equilibrium is a state of balance that is reached when chemical changes have apparently stopped.
See also CHEMICAL REACTION; GRAVITY.



EQUILIBRIUM
Examples of the three types of equilibrium—stable, neutral, and unstable—include a cube, a ball, and a narrow cylinder balanced on one end. A cone can have any of the three types, depending on how it is positioned.

ACTIVITY *Testing equilibrium*



Cut a slice of raw potato or modeling clay about 1 in. [2.5 cm] thick. Push the point of a pencil through the slice until it sticks out about 1 in. [2.5 cm] on the other side. Push a dinner fork into the potato as shown in the diagram. Now place the pencil point on the edge of a table and adjust the position of the potato until the pencil is balanced and steady. Give the long end of the pencil a slight tap. The pencil is in stable equilibrium so it will return to the balanced position after it is disturbed.
Caution: Be careful when cutting the potato and pushing the pencil and fork into it.

EQUINOX The equinox is one of two days during the year when the sun is directly over the equator at noon. The equinoxes occur on September 22 or 23 and March 20 or 21. On both these days, day and night are of nearly equal length all over the world. The March equinox is called the vernal, or spring, equinox because it signals the official start of spring in the Northern Hemisphere. The September equinox is called the autumnal equinox because it is the first day of autumn in the Northern Hemisphere.
See also SEASON; SOLSTICE.

ERA An era is a unit of the geological time scale. The geological time scale outlines the development of the earth and life on it. The history of the earth is divided into four eras. From oldest to most recent, they are the Precambrian, Paleozoic, Mesozoic, and Cenozoic eras. The Precambrian era is further divided into three eras. The Paleozoic, Mesozoic, and Cenozoic eras are divided into periods. The two periods of the Cenozoic era are divided into epochs.
See also GEOLOGICAL TIME SCALE.

EROSION

Erosion is the gradual wearing down and carrying away of the earth's materials. Natural, or geological, erosion is a slow process caused by wind, rainfall, oceans, running water, and ice (see WEATHERING). Soil erosion is sometimes the result of the abuse of land by people.

In geological erosion, the weather plays a major role. The wind is constantly wearing away rock, especially in dry areas. In moist areas, water fills the cracks in rocks. If the temperature falls below the freezing point, 32°F [0°C], the water freezes. Since ice occupies more space than water, the rocks are broken apart by the expanding ice. This rock debris may fall down cliffs or mountainsides, forming the piles of rock often seen below cliffs or along steep, rocky coasts. These piles are called talus or scree.

Ocean waves pounding against the coast are constantly changing the shoreline. In some places, waves batter and erode the land. In other places, the eroded material is deposited to form new land.

Running water is another important factor in erosion. Rivers carry pebbles, sand, and other debris that constantly rub against the riverbed. The Grand Canyon in Arizona is a result of the erosion caused by the Colorado River. Some of the material carried by a river may be deposited at the river's mouth, forming a delta (see DELTA).

The huge sheets of ice known as glaciers also carry material from one location to another. When the glaciers retreated during the last ice age, they made significant changes in the landscape of the Northern Hemisphere (see GLACIATION).

Soil erosion may occur because people change the land and make it much more vulnerable to geological erosion. Natural vegetation, such as grass and trees, holds the soil securely in place. When the vegetation is removed, the soil can be washed away by a heavy rainfall. Farmland is subject to severe erosion, especially in times of drought.

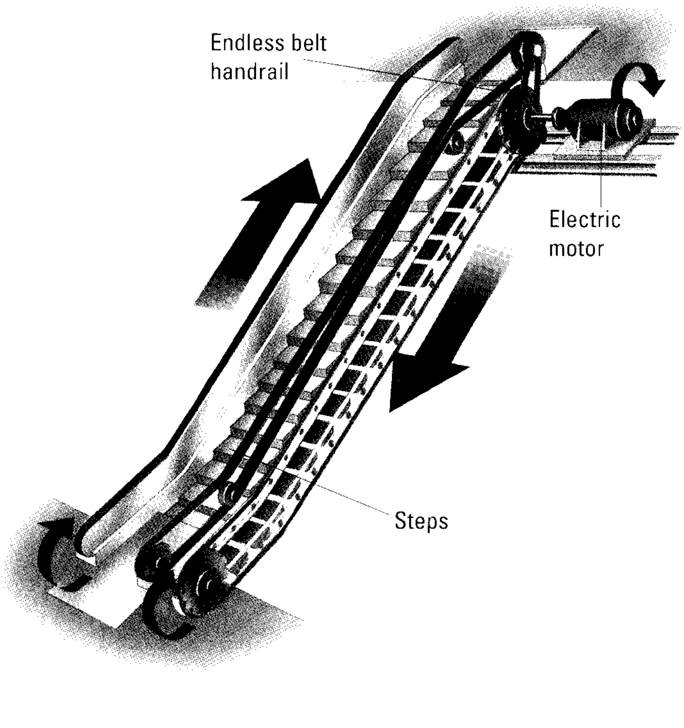
See also GEOMORPHOLOGY; SOIL EROSION.

LOST LAND

Erosion by the sea can undermine cliffs so that they collapse, as happened to this coastal road (above). The Maryland house (right) toppled into a river after the water eroded its foundations.

ESCALATOR An escalator is a moving stairway found in large stores and public buildings, such as railroad, bus, and airline terminals. Passengers stand on steps mounted on a conveyor belt (see CONVEYOR). The belt is driven by an electric motor. The passengers are carried either up or down depending upon the direction the escalator is running. Escalators usually operate at speeds of 1 1/2 ft. [0.45 m] to 2 ft. [0.61 m] per second. Store escalators move at the slower speed to give customers time to look around at the goods. Escalators in offices and airports move more quickly because speed is more important there. At the top and the bottom, the steps fold to make a flat, moving platform that is level with the landing. This allows the passengers to step on and off the escalator easily. Moving handrails are on either side of the steps. The handrails move at the same speed as the steps.

An escalator can handle about ten times the hourly capacity of an average elevator. The first escalator was displayed in 1900 at the Paris Exposition by the Otis Elevator Company.



ESCALATOR

An escalator is a sloping conveyor belt with steps for carrying people between the floors of a building. In one hour, it can carry up to ten times as many passengers as an ordinary elevator.

ESCAPE VELOCITY The escape velocity of an object is the speed that it must reach to break away from the gravitational pull of some other body. For example, the escape velocity of a satellite is the speed that it has to reach to break away from the earth's gravitational hold upon it. That speed is 25,000 m.p.h. [40,225 kph.]
See also GRAVITY; VELOCITY.

ESOPHAGUS (ĭ sŏf ə gəs) The esophagus, or gullet, is a muscular tube in vertebrates (animals with backbones) that leads from the back of the mouth (pharynx) to the stomach. It is part of the alimentary canal (see ALIMENTARY CANAL). The esophagus is made of bands of muscles that contract in waves to force food along. These waves of contraction are called peristalsis. Both striated and smooth muscles make up the esophagus (see MUSCLE). Control of peristalsis is involuntary. The direction of the contraction is usually from the mouth to the stomach.

The length of the esophagus varies from animal to animal. For example, a fish has a very short esophagus, while a giraffe has a long one. The esophagus of a bird is modifed with a saclike storage structure called a crop (see CROP).

The human esophagus is located behind the trachea (windpipe) and is about 12 in. [30 cm] long and about 1 in. [2.5 cm] in diameter. It is able to stretch and expand to allow the passage of large particles of food. There are special sphincter muscles at both ends of the esophagus. When food enters the mouth, it is mixed with saliva. The upper esophageal sphincter, located between the pharynx and the esophagus, opens to let the food into the esophagus and quickly closes to keep the food from backing up into the mouth. Lubrication is added by mucus-secreting glands along the walls of the esophagus as peristalsis pushes the food through. The lower esophageal, or cardiac, sphincter, located between the esophagus and the stomach, opens to let the food pass into the stomach. The sphincter then closes to prevent gastric fluids in the stomach from entering the esophagus. Heartburn is a condition caused by gastric juice leaking into the esophagus and causing a stinging or burning sensation.

Ruminants, such as cows, are able to cause the esophagus to undergo a reverse peristalsis. This brings food from the stomach back up into the mouth. This returned food, or cud, is chewed and swallowed again.
See also DIGESTION; RUMINANT.

ESTER Esters are a group of chemical compounds (see COMPOUND). They are formed by the reaction of an alcohol with an acid. Esters are organic chemicals. That is, they contain carbon. All acids contain an acidic hydrogen atom. This atom can be replaced by a metal to form a salt, or it can be replaced by a hydrocarbon group to form an ester (see HYDROCARBON).

An example of an ester is ethyl acetate. It is made when acetic acid reacts with ethanol. Ethanol is an alcohol (see ETHANOL). It is also called ethyl alcohol. In ethyl acetate, the ethyl group replaces the acidic hydrogen in acetic acid.

Many esters have a pleasant odor. The flavor of fruits and the perfumes of flowers are caused mainly by esters. Esters are used as solvents (substances that dissolve other substances) and in manufacturing other chemicals. They are also used as artificial flavors and perfumes.

ESTIMATION Estimation is a mental process having to do with mathematics. To estimate, a person mentally computes a rough answer to a mathematical problem. Researchers find that in daily life, most people estimate rather than do detailed computations.

The skill of estimating often involves rounding off numbers. For example, if a can of cat food costs 99 cents, a person will estimate that each can will cost $1. If a person plans to buy six cans, the total cost can be estimated at $6.

The ability to estimate is useful in most occupations. For example, umpires in baseball use estimation rather than take exact measurements to decide whether a pitch is a ball or a strike. Meat cutters become skilled at estimating how much meat weighs a half pound before they weigh it. Carpenters estimate how much lumber they will need to build a house.

ESTROUS CYCLE (ĕs′trəs sī′kəl) The estrous cycle is the period of preparation for reproduction that occurs in most female mammals (see MAMMAL; REPRODUCTION). During the estrous cycle, changes occur in the body of the female. For example, the lining of the uterus thickens, and an egg is released (see REPRODUCTIVE SYSTEM). The estrous cycle is regulated by environmental factors, such as temperature and number of daylight hours, and by hormones, which are chemicals produced by the endocrine glands inside the body (see ENDOCRINE; HORMONE). Some mammals have only one estrous cycle each year, but small mammals may have several. During the estrous cycle, estrus occurs. This is the point in the estrous cycle when an egg is released and when the female can become pregnant. In most species of mammals the female will mate only during estrus. At this time, she is said to be in heat. Some mammals, such as humans, apes, and some kinds of monkeys, have a monthly menstrual cycle rather than an estrous cycle.
See also MENSTRUAL CYCLE.

ESTUARY An estuary occurs where a river runs into an ocean or sea. The estuary is that part of the river near its mouth where there is a mixture of fresh water, from the river, and salt water, from the ocean or sea. Rivers often widen at their mouths, giving their estuaries a funnel shape.

The biological importance of estuaries was ignored until recently. Many estuaries were seriously damaged by the dumping of sewage, waste chemicals, and other pollutants into rivers and oceans. Fortunately, such plants as cattails and grasses grow in the marshes that are often part of estuaries. These plants help filter pollutants from the water.

Estuaries are important ecosystems (see ECOSYSTEM). Estuaries frequently provide protection for ducks, geese, swans, and other water birds. Estuaries also serve as breeding areas for many other organisms at the bottom of the food chain (see FOOD CHAIN). These organisms serve as food sources for young fish and other wildlife. This makes estuaries a rich environment for many types of wildlife.

ESTUARY

Estuaries, such as this one in Victoria, Australia, provide feeding grounds and nesting sites for many kinds of water birds.

Estuaries have been important historically in other ways. They have often provided good harbors. Many important ports in the United States and other countries are located on estuaries. The rich supplies of seafood in estuaries have also been important in the human settlement and development of many areas.
See also DELTA; POLLUTION.

ETHANOL Ethanol (C_2H_5OH) is the alcohol in alcoholic beverages (drinks) and the alcohol that is used in industry. It is also called ethyl alcohol. It can be made in several different ways. In alcoholic drinks it is made by fermenting grain for beers and whiskeys, and fermenting grapes to produce wine (see FERMENTATION). In industry it is manufactured by heating water and ethylene gas under pressure in the presence of a catalyst, phosphoric acid (see CATALYST; ETHYLENE). Ethanol is used to make other chemicals such as detergents, fragrances, and flavorings. It is a very good solvent, meaning that it can dissolve other substances. It is used in the manufacture of varnishes and lacquers. Mixed with gasoline, it is sold as gasohol.

ETHER Ether ($C_2H_5OC_2H_5$) is a pleasant-smelling liquid. It boils at 94.1°F [34.5°C]. Its vapor is very flammable. Ether must, therefore, be handled very carefully and kept well away from flames. Ether is made by reacting ethanol with sulfuric acid. Ether was widely used as an anesthetic. It is used in industry for dissolving waxes, oils, and in the manufacture of many other products.

Chemists actually call the ether described above *diethyl ether.* They use the word *ethers* for the group of chemical compounds that have two hydrocarbon groups attached to an oxygen atom, including diethyl ether.
See also HYDROCARBON.

ETHYLENE (ĕth'ə lēn') Ethylene (C_2H_4) is a colorless gas with a faint smell resembling that of ether (see ETHER). It is made by removing some of the hydrogen from ethane. It is also obtained by refining petroleum. Ethylene is used as an anesthetic, a fuel, and in making other chemicals (see ANESTHETIC). It also helps ripen fruit. In a molecule of ethylene, the two carbon atoms are joined together by a double bond (see BOND, CHEMICAL). Its formula can be written as $CH_2{=}CH_2$.

A large amount of ethylene is used to make the plastic called polyethylene. In order to make polyethylene, ethylene is polymerized (see POLYMER). This splits open the double bond, and long chains of CH_2 groups are formed. Chemists sometimes called ethylene *ethene.*

EUCALYPTUS (yo͞o'kə lĭp'təs) Eucalyptus trees include some of the world's tallest and fastest-growing trees. There are about 500 species and some of them grow as tall as 330 ft. [100 m]. Native to Australia, these members of the myrtle family have been introduced to nearly all other warm parts of the world (see MYRTLE FAMILY). Eucalyptus trees are now found in warm regions of North and South America, Asia, Africa, and Europe. The most common species found in the United States is the blue gum eucalyptus, which is widely grown in Florida, California, and Texas. Because it grows so quickly, it is often planted as a windbreak around orchards of citrus trees. Like all eucalyptus trees, it has tough, evergreen leaves and nectar-filled flowers. Each flower is enclosed in a woody cup, with a lid that falls off when the flower opens.

Eucalyptus is an important source of lumber and is used for telephone poles, ships, and railroad ties. The bark is a source of tannin, which is used in some medicines, and of a resin, called Botany Bay kino, that can be used to preserve and protect wood (see RESIN). The leaves are rich in an oil that can be used as a deodorant or an antiseptic, and is also used in many cold remedies.

See also ANTISEPTIC.

EUCALYPTUS

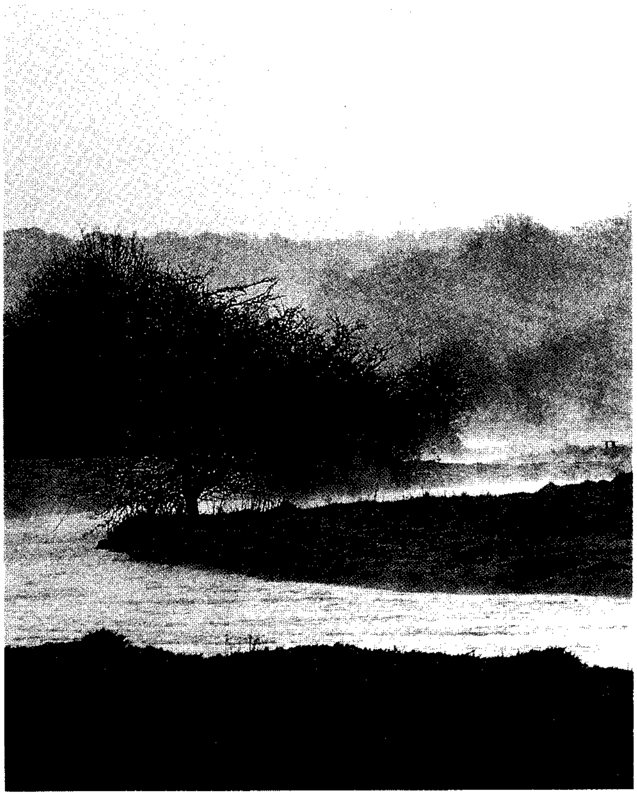
Eucalyptus trees came originally from Australia, where they are known as gum trees. This tree is known as cider gum.

EVAPORATION Evaporation occurs when a substance changes from a liquid or solid into a gas. The form of a substance depends on the temperature or the amount of pressure to which it is subjected. For example, water in a dish in a warm room soon dries up. Wet clothes hung on a clothesline on a dry sunny day lose their moisture in a short time. Heat in the air changes the water in the dish and in the clothes to water vapor, a gas. The warmer and drier the air, the more rapidly evaporation occurs (see VAPOR).

Evaporation can take place at any temperature. Ice and snow send off vapor. This can be observed a day or two after a snowstorm. The snow disappears, even though the temperature has never risen above freezing. The water evaporates directly from the solid without first becoming a liquid. The formation of a gas in this way is called sublimation.

Evaporation in plants is called transpiration. Plants absorb moisture through their roots. They lose the moisture by evaporation through their leaves. The more leaf surface that is exposed, the more rapid the transpiration (see TRANSPIRATION).

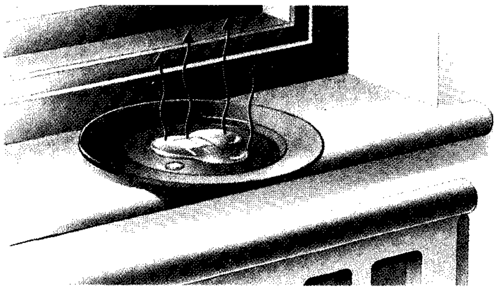
When a liquid evaporates from the surface of an object, that surface becomes much cooler, because it requires heat to change a liquid into a gas. For example, sponging a fevered patient with alcohol reduces body temperature. Heat is drawn from the



EVAPORATION

In the early morning, water evaporates from a river, which is warmer than the surrounding air. If the air is cold enough, the water vapor condenses to form mist.

ACTIVITY *Checking evaporation rates*



Pour one tablespoonful of water onto a dinner plate. Place the plate on a warm windowsill, above a radiator for example. Check the plate after 6 hours, 12 hours, and 24 hours. What happens to the water? How long before it all evaporates?

body by the evaporation of the alcohol. In this sense, evaporation is a cooling process.

Such substances as ether and ammonia evaporate very rapidly. The rapid evaporation of liquid ammonia absorbs much heat. Thus, liquid ammonia is used in certain types of refrigerators.

The process of evaporation is vital to plant and animal life. Water evaporates from oceans, rivers, ponds, lakes, and the moist earth and later falls as rain.

See also RAIN; VOLATILE LIQUID. PROJECT 9

EVENING PRIMROSE FAMILY The evening primrose family includes more than six hundred species of herbaceous plants, trees, and shrubs (see HERBACEOUS PLANT). Members of the evening primrose family grow throughout North America and in parts of Europe. The most common evening primrose, *Oenothera biennis,* is a wild flower that grows as tall as 6 ft. [1.8 m]. It has hairy, stalkless leaves measuring about 6 in. [15 cm] long. The flowers are usually large, about 4 in. [10 cm] wide, and may be bright yellow, white, or pink. They open and release their scent at night and are visited by moths.

EVENING PRIMROSE FAMILY

The seeds of some kinds of evening primrose yield an oil that is used in medicines.

EVERGREEN An evergreen is a tree or shrub that has leaves throughout the year. Many evergreen trees in North America are conifers, such as the pine tree (see CONIFER). Their needlelike leaves can survive cold, windy winters, unlike the broad leaves of deciduous trees (see DECIDUOUS TREE). Some evergreens do not have needles. Their leaves are tough and leathery so that they too can survive in cold weather. Although evergreens are always clothed with leaves, the leaves do not live forever. Most die in a year or two, but they do not all die and fall at the same time, so the trees are never without leaves. Evergreens are generally considered to be softwood trees, while deciduous trees are considered hardwoods.

EVERGREEN

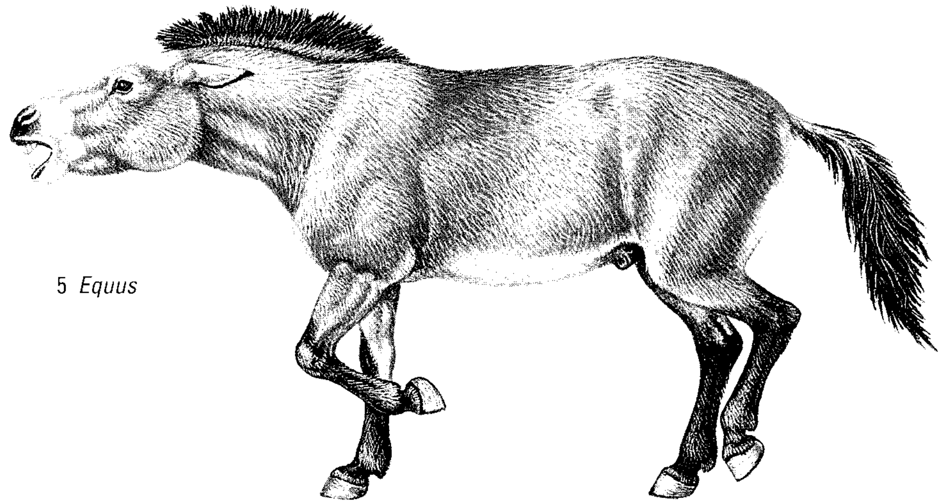
Evergreens are plants that have leaves throughout the year.

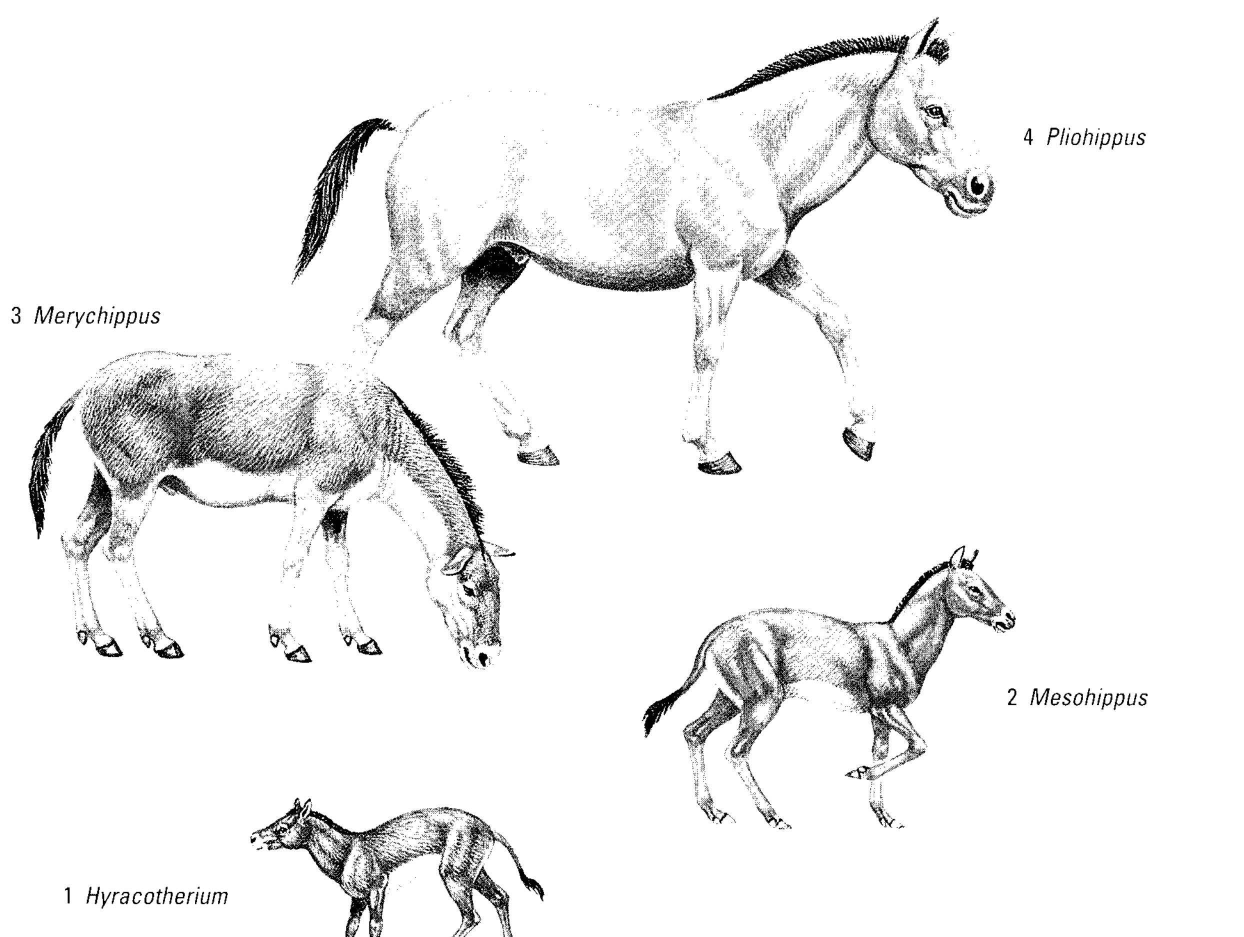
EVOLUTION

Evolution is the process by which all living things on Earth today descended from ancestors that lived millions of years ago. According to the theory of evolution, organisms have evolved, or changed, and continue to evolve.

History of the theories of evolution The idea of evolution was first suggested by the Greeks about 2,500 years ago. The Greek philosopher Aristotle proposed that there may have been a gradual development of various species over a period of

EVOLUTION OF THE HORSE
The original ancestor of the horse, called (1) *Hyracotherium*, was a small animal about the size of a modern dog. It had four toes on each foot and probably lived in undergrowth, more than 50 million years ago. (2–4) It evolved through several stages, gradually getting larger, until (5) it developed into the modern horse, *Equus*.



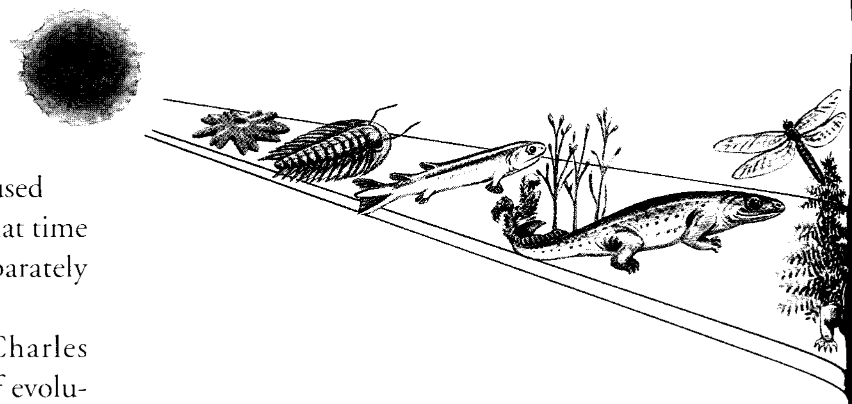


thousands of years (see ARISTOTLE). The first modern suggestions of the theory of evolution were made in the early 1700s by a French scientist, George Louis Buffon. Buffon suggested that perhaps the horse and the ass were related. His ideas caused a religious uproar, because most people at that time believed that each species was created separately and that none was related to another.

Erasmus Darwin (grandfather of Charles Darwin) was one of the next proponents of evolution. He based his ideas about evolution on his observations of domesticated animals and of vestigial organs (see VESTIGIAL ORGAN). Erasmus Darwin published his ideas in 1794.

In 1809, Jean Lamarck proposed the first systematic theory to explain evolution. His theory has come to be known as "the inheritance of acquired characteristics." Lamarck thought that animals acquired specific physical traits as they adapted to their environment. For example, he thought a giraffe might acquire a longer neck by stretching up to eat the leaves off of high branches of trees. The giraffe with the longer neck, Lamarck proposed, could pass this trait on to his or her offspring. Lamarck also proposed that if an organism does not use an organ or body structure, that structure would waste away and not be passed on to future generations. Lamarck was not the first person to come up with this idea of the inheritance of acquired characteristics, although he was the first to publicize the idea widely. Although the inheritance of acquired characteristics was later demonstrated to be a false explanation of how traits could be passed from one generation to the next, the theory was widely discussed (see LAMARCK, JEAN BAPTISTE).

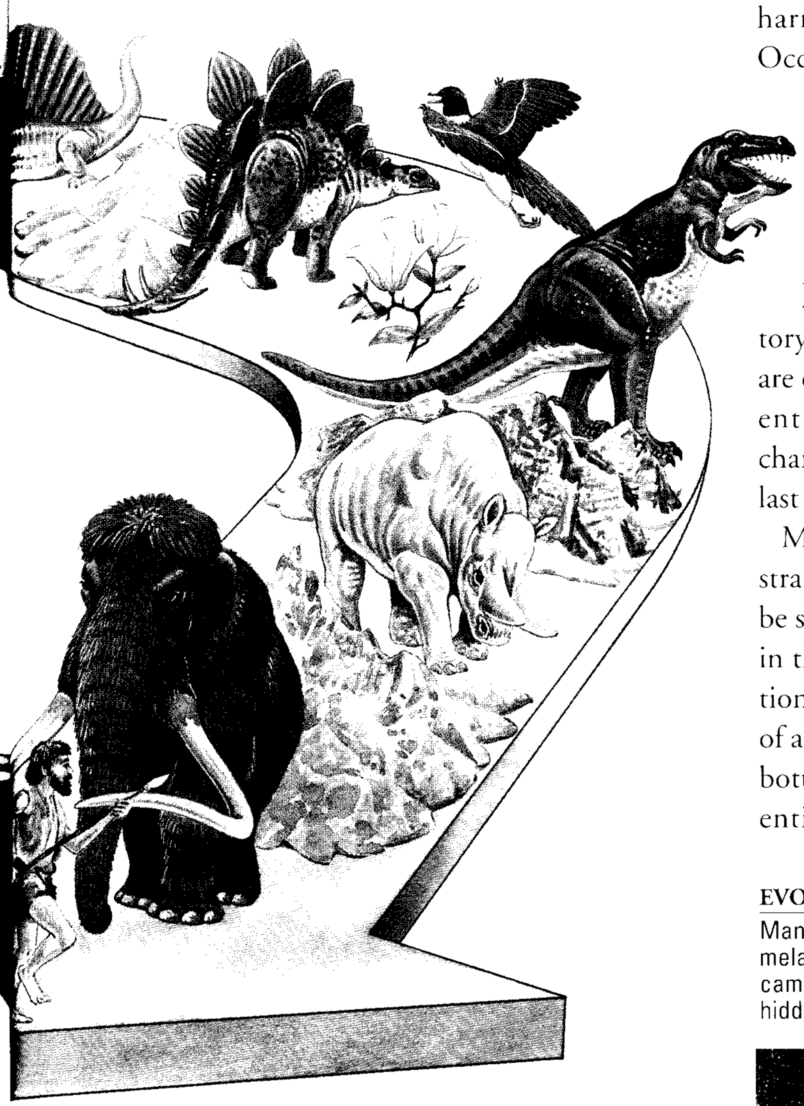
The next major advances in evolutionary theory came about as a result of the work of Charles Darwin. Darwin formulated his theory of evolution while on a round-the-world voyage between 1831 and 1836, and published it in 1859 in the book *The Origin of Species.* He proposed that organisms evolve as a result of natural selection. By natural selection, he meant that organisms that were best adapted to their environment would be the most likely to survive and reproduce. Thus, the



DEVELOPMENT OF LIFE
Life on Earth began to evolve 3.5 billion years ago, about a billion years after the earth itself came into being. The diagram (right) shows how single-celled organisms evolved into many-celled creatures such as arthropods and mollusks. Fish were next to evolve, which in turn gave rise to amphibians and then reptiles. Birds and mammals evolved from reptilian ancestors.

organisms with the most helpful adaptations would increase in the next generation of organisms. If the environment changed, organisms with different adaptations would be more likely to survive. Thus, a species would evolve, or change over time. Animals or plants that were not well suited or could not change simply died out. Darwin's general theory has become accepted by scientists and is the basis for modern biology (see ADAPTATION; DARWIN, CHARLES; ENVIRONMENT; SPECIES). Alfred Russel Wallace came to the same conclusions as Darwin at about the same time but, although the two men presented some of their work jointly, Wallace was always overshadowed by Darwin and never received the full credit that was due to him.

Genetics and evolution The characteristics that are passed from one generation to the next are controlled by chromosomes and genes. Chromosomes are threadlike structures found in every living cell. Each chromosome has a number



of genes arranged in a particular way. Genes are units on the chromosomes and are made up of DNA (deoxyribonucleic acid), which can be thought of as a complex chemical coding system. Genes determine how the cells of an organism develop. During sexual reproduction, genes from both parents are passed to the offspring. This results in new combinations of the genes and may cause variations in size, color, or other characteristics of the organism. Because of natural selection, organisms with harmful variations usually die out. The remaining organisms are well adapted to their environment and may pass their useful variations to their offspring (see CHROMOSOME; DNA; GENE).

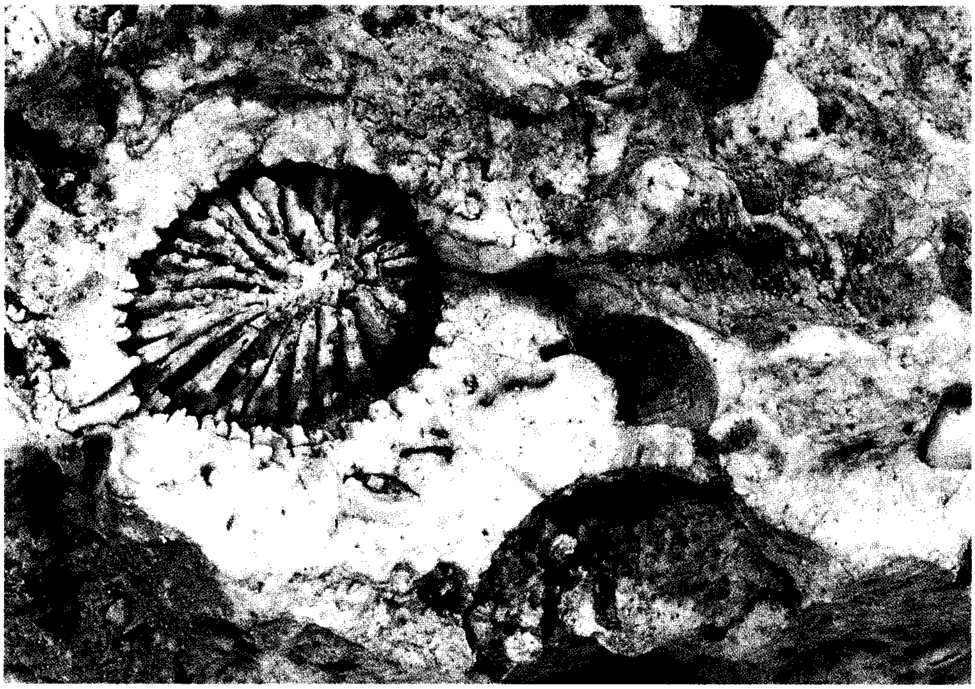
Mutations are changes that occur as the result of some gene combinations. Most mutations are harmful to the organism and may even kill it. Occasionally, a mutation results in an advantageous variation. When this happens, the mutated organism may survive and pass on the variation to its offspring (see MUTATION).

Fossils as evidence of evolution The history of life on Earth is preserved in fossils. Fossils are evidence of ancient life. By studying fossils, scientists can observe some of the evolutionary changes that have occurred in organisms during the last 3.5 billion years.

Most fossils are preserved in layers of rock called strata. The fossils in the uppermost strata tend to be similar to modern organisms, while those fossils in the lower strata often represent an earlier evolutionary stage of an organism. For example, a fossil of an early kind of sea urchin shell was found in the bottom of a chalk deposit in England. As the scientists searched higher up in the deposit, they

EVOLUTION IN ACTION
Many animals, such as the speckled moth (top) and the melanic moth (bottom), have developed various kinds of camouflage through evolution. Their coloring can keep them hidden from enemies, increasing their chances of survival.

FOSSILS
Fossils are found in rocks formed from sediments that settled at the bottoms of ancient seas and lakes. As a result, many fossils are of animals that lived in water, such as fish and mollusks (shellfish).



found sea urchin fossils of a more advanced evolutionary stage. At the highest level, they found modern-looking sea urchins (see FOSSIL).

Other evidence of evolution Other evidence of evolution can be seen when observing the bodies of animals. The arms of humans, the flippers of whales, and the wings of bats all show similarity in their muscle and bone structure. These similarities indicate the possibility of a common ancestry.

There are many parts of the human body that no longer serve any purpose. These parts are called vestigial organs. People have about one hundred vestigial organs. The appendix is an example of a vestigial organ in humans. It is, however, of great importance in plant-eating mammals, such as the rabbit and the kangaroo (see MAMMAL). At some evolutionary stage, our ancestors must have needed the appendix but changes in diet mean that we no longer need this structure.

Evolution and distribution of organisms Evidence of evolution is particularly apparent in isolated regions. Australia has a number of mammals that evolved in a different manner from the mammals of the other continents. Millions of years ago, Australia separated from the major landmass, and the new mammals that were evolving on this landmass could not get to Australia (see CONTINENTAL DRIFT). Australia's mammals, such as the platypus and kangaroo, thus followed their own evolutionary paths, without competition from the "newer" types of mammals that evolved on other continents.

The Galápagos Islands in the Pacific Ocean are another isolated place where a unique set of organisms have evolved. The Galápagos Islands are separated from South America by hundreds of miles of ocean. It was here that Charles Darwin noticed that each island had distinct species of birds and reptiles. Each species had followed a slightly different evolutionary path from the mainland organisms. Thus, the organisms on the Galápagos Islands evolved to suit the environment on each particular island, without significant influence from the mainland.

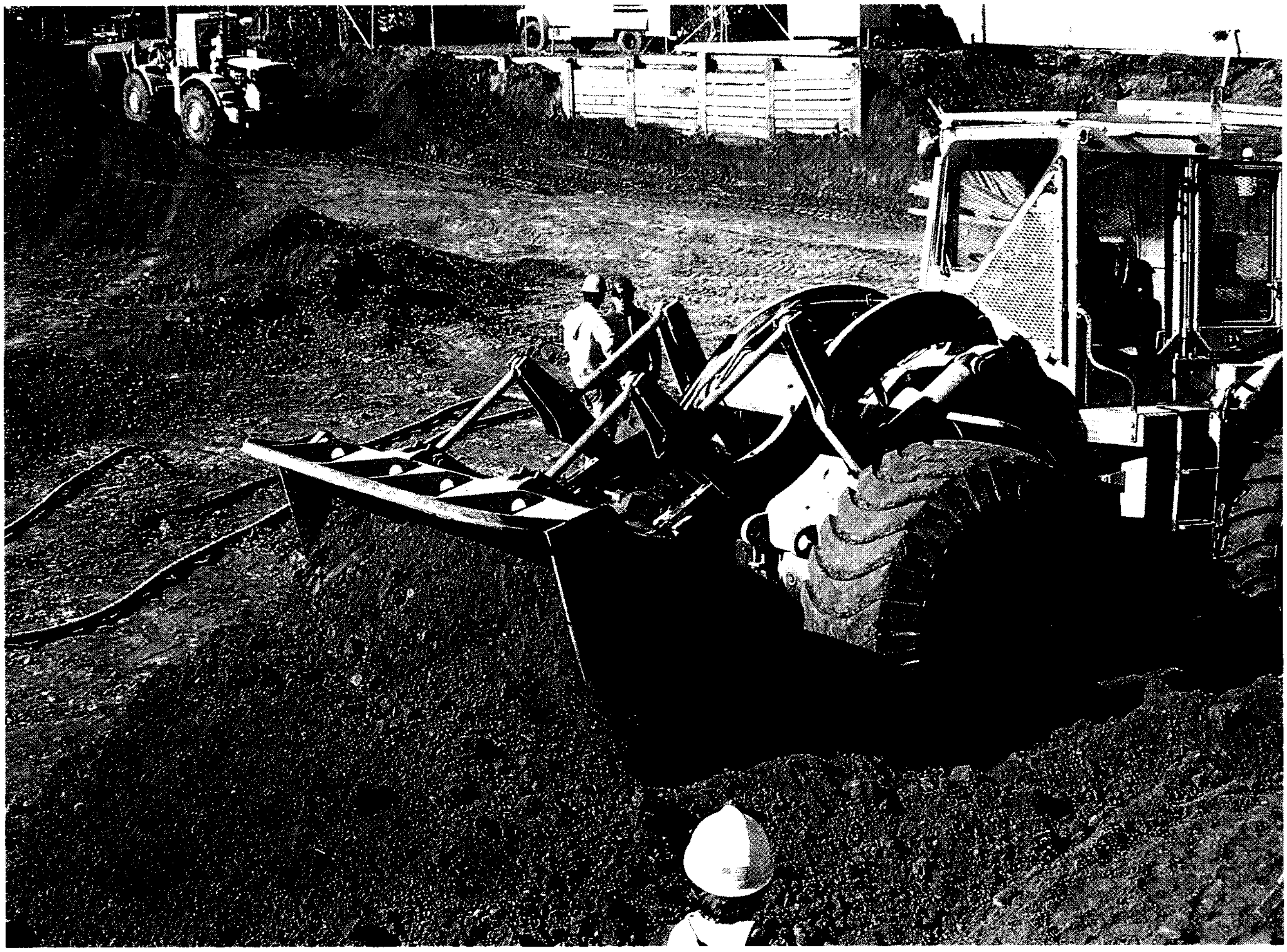
Scientists continue to search for undiscovered species of organisms in remote places to learn more about how evolution occurs. They study the fossil record to learn how organisms have changed over time. Genetics also yields more clues about how organisms are able to pass traits to their offspring. By putting together clues from the various branches of science, scientists are developing a better understanding of the process of evolution and how it has led to the diversity of life on Earth.

EXCAVATION Excavation is the removal of soil or rock from the ground. Excavation is often done before a building or other structure is built. For example, engineers must be sure that a structure will be built on firm ground (see ENGINEERING). Sometimes, it is necessary to excavate down to bedrock to make sure the ground is firm. Bedrock is the solid rocky layer of the earth's crust that lies just below the surface (see BEDROCK). Many times before substances such as coal and ores can be mined, the overlying soil or rock, or overburden, must be excavated (see MINING). When tunnels are built, huge amounts of rock often have to be excavated. This process is begun by drilling a hole, called a shot hole, in the rock. Explosives are placed in the hole and detonated. The broken-up rock is then excavated. Underwater excavation, called dredging, is done to deepen and clear navigation channels (see DREDGING).

Various machines are used for excavation. For example, a large machine called a dragline has a long steel beam, called a boom. A cable runs along the length of the boom and slightly beyond. At the end of the cable is a bucket. The bucket is dragged along the ground, scooping up soil and rock. On other machines, the bucket acts as a digger. The digging bucket is attached to a rigid arm and is forced forward or dragged backward into the ground. Some machines have buckets with interlocking sides that act as jaws. When the bucket is dropped on the ground, the "jaws" are brought together to gather up soil and rock. The bucket is then lifted.

EXCRETION (ĭk skrē′shən) Excretion is the process by which a living organism removes the waste products of metabolism from its body. When proteins are metabolized (used) by an organism,

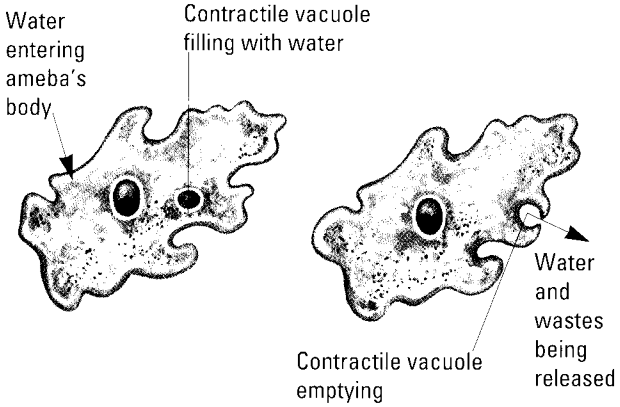
EXCAVATION
The digging bucket on this machine can remove large amounts of soil at excavation sites. The machine has large wheels that allow it to move over rough or muddy ground.



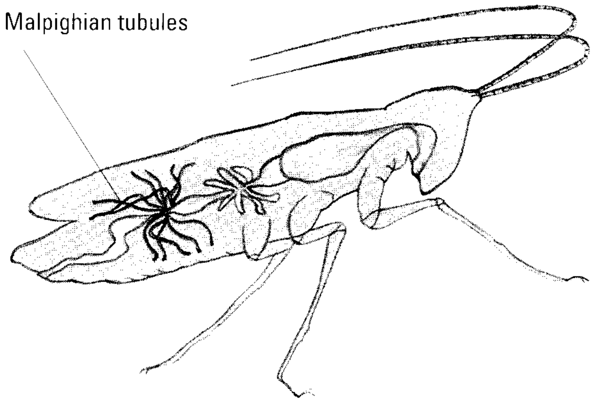
nitrogen-containing wastes such as ammonia, urea, and uric acid are produced. Because these wastes are poisonous when they build up, they must be removed from the body. Metabolism produces other wastes, such as carbon dioxide and water, which also must be removed from the body (see METABOLISM).

Some simple organisms, such as the ameba and paramecium, allow wastes to diffuse across their body wall into the surroundings (see DIFFUSION). Many simple organisms accumulate wastes in spaces called contractile vacuoles, which "squirt" the wastes out of the body. Most animals have evolved elaborate excretory systems that filter wastes and foreign substances out of the blood. In vertebrates (animals with backbones), the kidneys perform not only this function but also help regulate the chemical composition of the blood by removing excess salts. All these wastes, along with excess water from the blood and body tissues, form urine which is stored in the bladder before being eliminated. Although many factors influence the amount and composition of urine, an average adult eliminates about 35 fl. oz. [1 liter] of urine per day (see KIDNEY; URINE).

The skin is another important organ of excretion in humans. An average adult loses about 24 fl. oz. [0.7 liter] of water and a small amount of salt each day in perspiration. If the person is active or perspiring heavily, he or she loses much more. This excretion is controlled by the sweat glands and serves primarily to keep the body cool (see SKIN; SWEAT GLAND).



EXCRETION—Simple animal
The microscopic, single-celled ameba above collects wastes in a baglike vacuole, which bursts to release the wastes into the water surrounding the animal.



EXCRETION—Insects
In a typical insect, a network of Malpighian tubules collects wastes from around the body. These wastes pass into the animal's digestive system and are excreted with the waste products of food.

The lungs are also excretory organs, because they eliminate carbon dioxide and water vapor. An average person gives off about 7 fl. oz. [0.2 liter] of carbon dioxide per minute. For some animals, such as dogs, the lungs are vital for temperature control. Although dogs have sweat glands, a healthy dog rarely perspires. Instead, it gets rid of excess moisture and cools itself by panting, breathing heavily with its mouth open and its tongue out (see LUNG).

Some animals have other specialized excretory structures. Marine fishes excrete excess salt through their gills (see GILLS). The scales on the wings of butterflies and moths often contain excreted wastes. Insects use much of their nitrogen-containing wastes to build strong exoskeletons (see SKELETON). Insects also have specialized, tiny tubes called Malpighian tubules, which concentrate their wastes and recycle virtually all the water that the wastes contain.

Plants often handle wastes by converting them into oils or solids that are transported to the cells of the bark or leaves for storage. Substances considered wastes in other organisms, such as nitrogen-containing compounds, water, and carbon dioxide, are actually vital to a plant's food-making process and growth.

See also PHOTOSYNTHESIS.

EXERCISE Exercise is any activity to develop or maintain physical fitness. Exercise as part of a fitness program reduces the risk of heart disease and allows the performance of ordinary activities without feeling tired (see HEART DISEASE). It also reduces levels of stress, increases resistance to disease, and increases feelings of well-being. But exercise is only one part of being fit and healthy. If you are overweight or continue eating a poor diet, exercise will be of little or no benefit to you (see DIET).

Exercise should improve or maintain three things:

- stamina, or ability to keep going, with aerobic (oxygen-demanding) exercises—especially good for the heart and lungs,
- muscular strength,
- flexibility—for suppleness and joint mobility.

Most people achieve fitness through sports, but people can exercise almost anywhere to keep fit. Exercise must be started gently, built up gradually, and done regularly. Exercising for at least twenty minutes, two or three times a week is enough for most people. Athletes have to exercise harder and for much longer periods.

ACTIVITY *Exercise: how much effort?*

To benefit from exercise, your heart must work at a training level for at least twenty minutes during exercise. This level is determined by subtracting your age from 220, then multiplying by 65 percent. The figure you get is an approximate pulse rate (in beats per minute) that exercise needs to cause to improve stamina.

How quickly the pulse returns to normal (about 70) also shows how fit you are. A fit person's pulse should be normal within two to three minutes of ending the exercise.

But remember: If it hurts, STOP.

EXOBIOLOGY Exobiology is a branch of biology that deals with the search for and study of extraterrestrial life—that is, life on other planets.

The question of life on other planets is an ancient one that has been argued by philosophers, scientists, writers, and religious scholars for thousands of years. Some contend that life does or may exist on other planets; others say it does not.

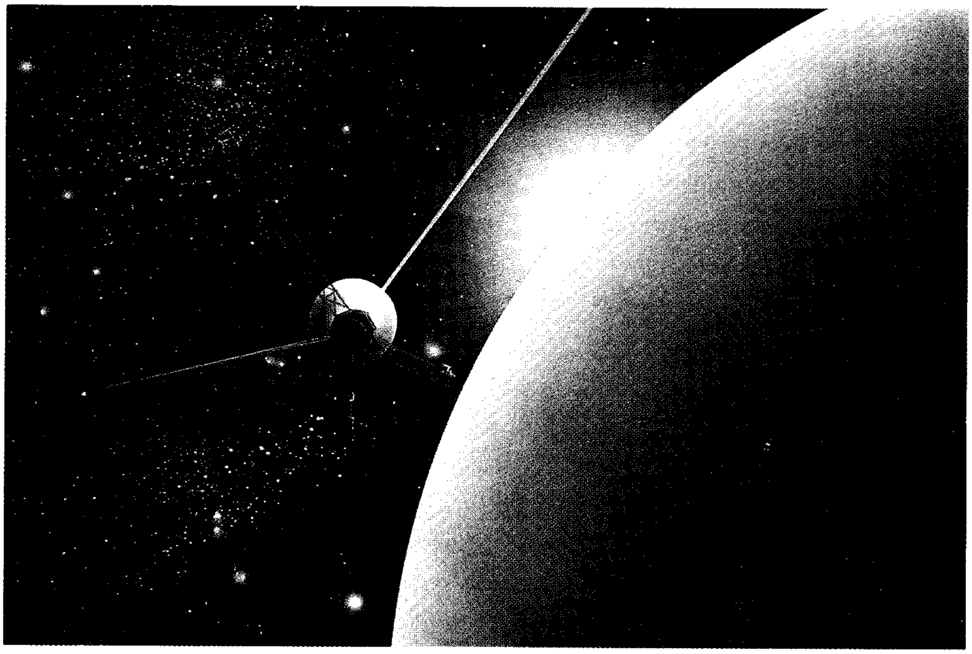
Physical and chemical processes occurred on Earth 3.6 billion years ago, during its early formation, that gave rise to life forms as we know them. Fossil records, meteorites, and information gained from space probes and radio astronomy are examined by exobiologists for evidence that similar biological activity might have occurred on other planets.

Scientists have developed many instruments to learn about stars, planets, comets, asteroids, interstellar dust (*interstellar* means "among the stars"), and the moons of other planets, such as Jupiter and Saturn. Radio telescopes detect, collect, and record radiation received from distant galaxies and other sources in space (see RADIATION). Space probes are sent into the universe to transmit photographs of the surfaces of other planets and other information back to Earth.

Radio astronomers have detected complex molecules in the great clouds of gas and dust in interstellar space. Some are compounds of carbon, which may be forerunners of more complex molecules of living matter.

Astrophysicists and exobiologists deal with many of the same questions about life (see ASTROPHYSICS). Many advocate the possibility of extraterrestrial intelligence. They reason that if the conditions for life and the existence of intelligent beings arose in our solar system, then the same thing could have happened in another star system.

The National Aeronautics and Space Administration (NASA) space program has concerned itself with the search for information about space. NASA sent two *Viking* space probes to Mars in 1976. The probes collected soil from Mars and conducted experiments with it. Nothing was found that proved that microorganisms or any life forms exist on Mars (see MICROORGANISM).



EXOBIOLOGY
One of NASA's *Voyager* probes flew close to the planet Jupiter, where it detected evidence of the organic gas methane.

The *Voyager* space probes, also sent by NASA, have shown that the orange haze surrounding Saturn's largest moon, Titan, is a nitrogen atmosphere in which complex organic molecules could have formed. Further investigation may reveal whether such molecules actually have formed.

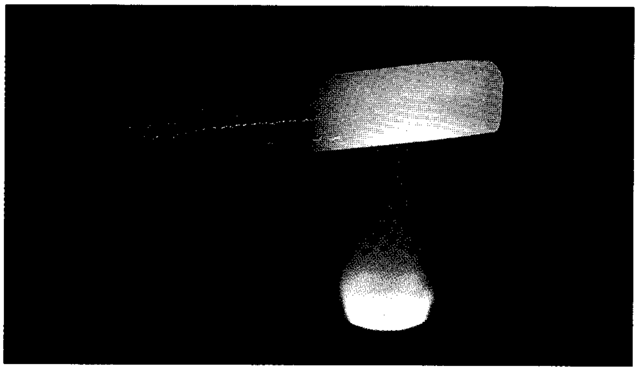
In recent years, NASA has also used radio telescopes to search for life in other parts of the universe. Project SETI (Search for Extraterrestrial Intelligence) has involved using radio telescopes to scan the galaxy for signals from other planets. Computers aid the search, allowing scientists to monitor millions of different frequencies of radio waves. In this way, they hope to pick up nonrandom signals that may be transmitted by intelligent beings elsewhere in the universe. Although government funding for the program was cut in 1993 as part of efforts to reduce the country's expenses, scientists plan to continue the research with money from private donors.

See also ASTRONOMY; RADIO ASTRONOMY; UNIVERSE.

EXOTHERMIC REACTION (ĕk′sō thûr′ mĭk rē ăk′shən) In a chemical reaction, the compounds involved sometimes give off heat (see CHEMICAL REACTION; COMPOUND). When this happens, the reaction is called an exothermic reaction. The opposite can also happen. The compounds can become colder and absorb heat from their surroundings when undergoing chemical reactions. This type of reaction is called an endothermic reaction (see ENDOTHERMIC REACTION). In an exothermic reaction, the reacting compounds contain more energy than the products. As the reaction takes place, the extra energy is given off as heat.

A common example of an exothermic reaction is the burning of a fuel such as natural gas. Natural gas is a mixture of hydrocarbons (see HYDROCARBON). These react with the oxygen in the air to form carbon dioxide and water vapor. When the fuel burns, only part of this energy goes into the byproducts, carbon dioxide and water. The rest is given off as heat.

PROJECT 16



EXOTHERMIC REACTION
Natural gas combined with oxygen from the air can produce what is called an exothermic, or heat-producing, reaction. In this case, the exothermic reaction results in the blue flame pictured above.