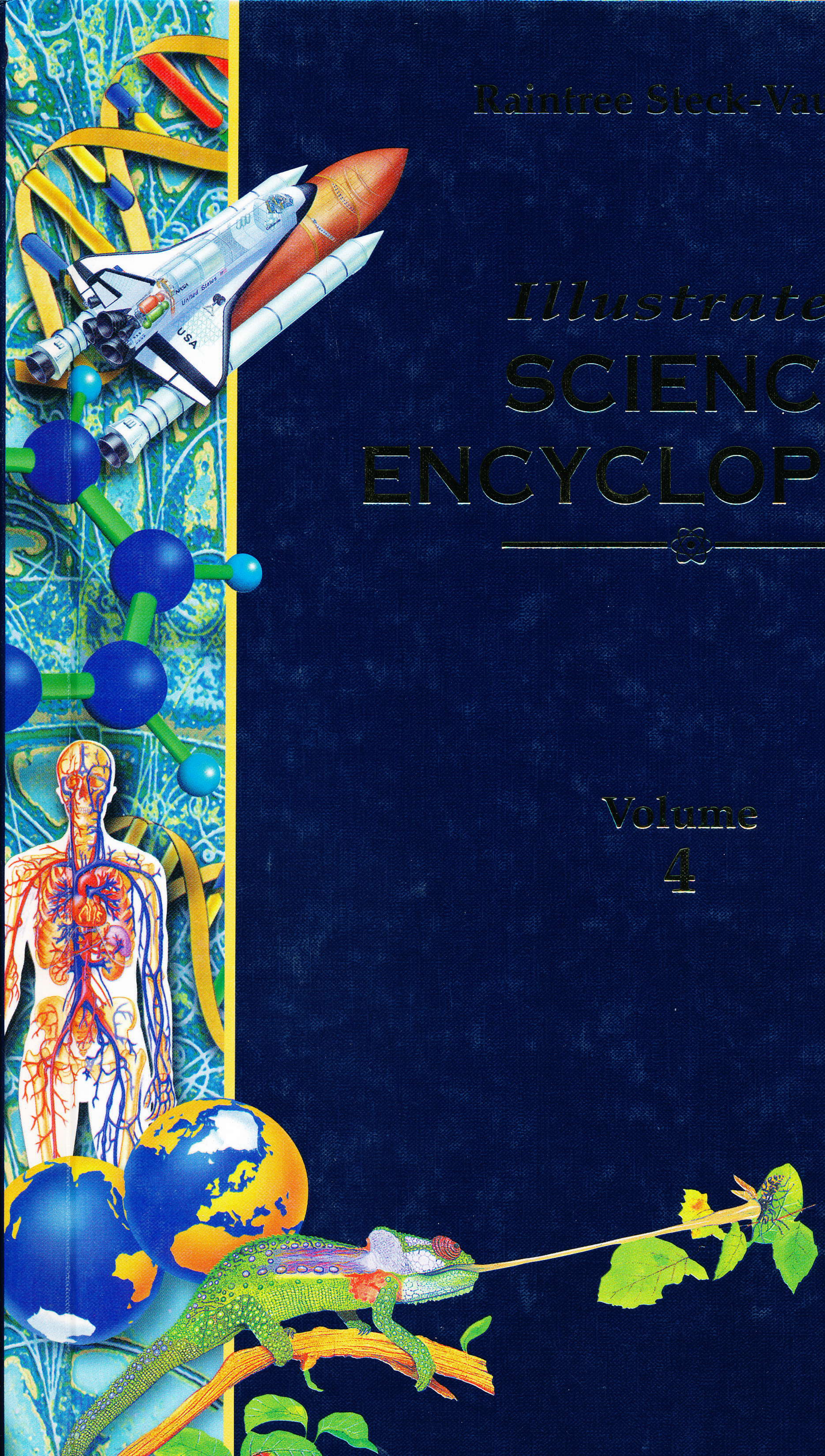
Raintree Steck-Vaughn

Illustrated SCIENCE ENCYCLOPEDIA



Volume
4

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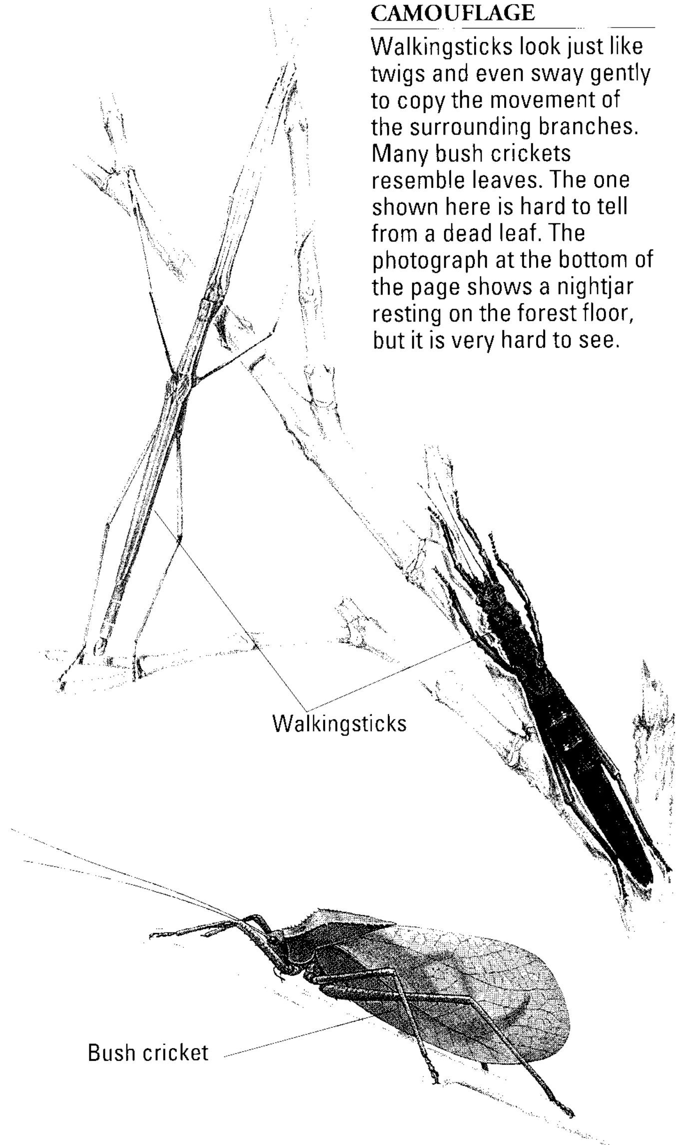
CAMOUFLAGE (kăm′ə fläzh′) Camouflage refers to the concealment of some object by means of patterns and/or colors that make the object hard to see. To camouflage an object in a forest, a person might cover it with leaves or with branches from a tree. This would hide the object so others could not see it easily. During wars, armies camouflage buildings and weapons so the enemy cannot see them. Soldiers may wear camouflage uniforms as well.

Many animals are able to camouflage themselves according to changing conditions. For example, the chameleon, a small lizard, changes its colors. If it is on a green leaf, it turns green. If it is on a brown twig, it turns brown (see CHAMELEON). Some animals change color with the season. The snowshoe hare, for example, is brown in summer and white in winter. The white fur camouflages the hare in the snow. Countershading is a common type of camouflage in fishes. The underside of the body is a lighter shade than the top of the body. This helps the fish blend in with any shadows it may make. Other animals are able to avoid being seen by enemies because they look like another object. For example, the insect called the walkingstick looks like a twig (see WALKINGSTICK).

Camouflage also helps some animals catch their food. Because they blend in with the surroundings, their victims do not see them quickly enough to escape being caught.

See also MIMICRY; PROTECTIVE COLORATION.

CAMOUFLAGE
Walkingsticks look just like twigs and even sway gently to copy the movement of the surrounding branches. Many bush crickets resemble leaves. The one shown here is hard to tell from a dead leaf. The photograph at the bottom of the page shows a nightjar resting on the forest floor, but it is very hard to see.



CANAL A canal is a large ditch or open channel built to carry water. Canals range in size from small, narrow waterways about 4 ft. [1.2 m] deep to canals about 70 ft. [21 m] deep and more than 300 ft. [91 m] wide. Most often, canals have been dug across dry land to connect bodies of water. Other canals have been formed by making existing water bodies wider and deeper.

The canals built in Egypt, Babylonia, and China thousands of years ago were all level canals. A level canal can be built only where the water levels at both ends of the canal are the same. The Suez Canal, opened in 1869, is a level canal that was built along the boundary between Asia and Africa to connect the Mediterranean Sea with the Red Sea and thus the Indian Ocean.

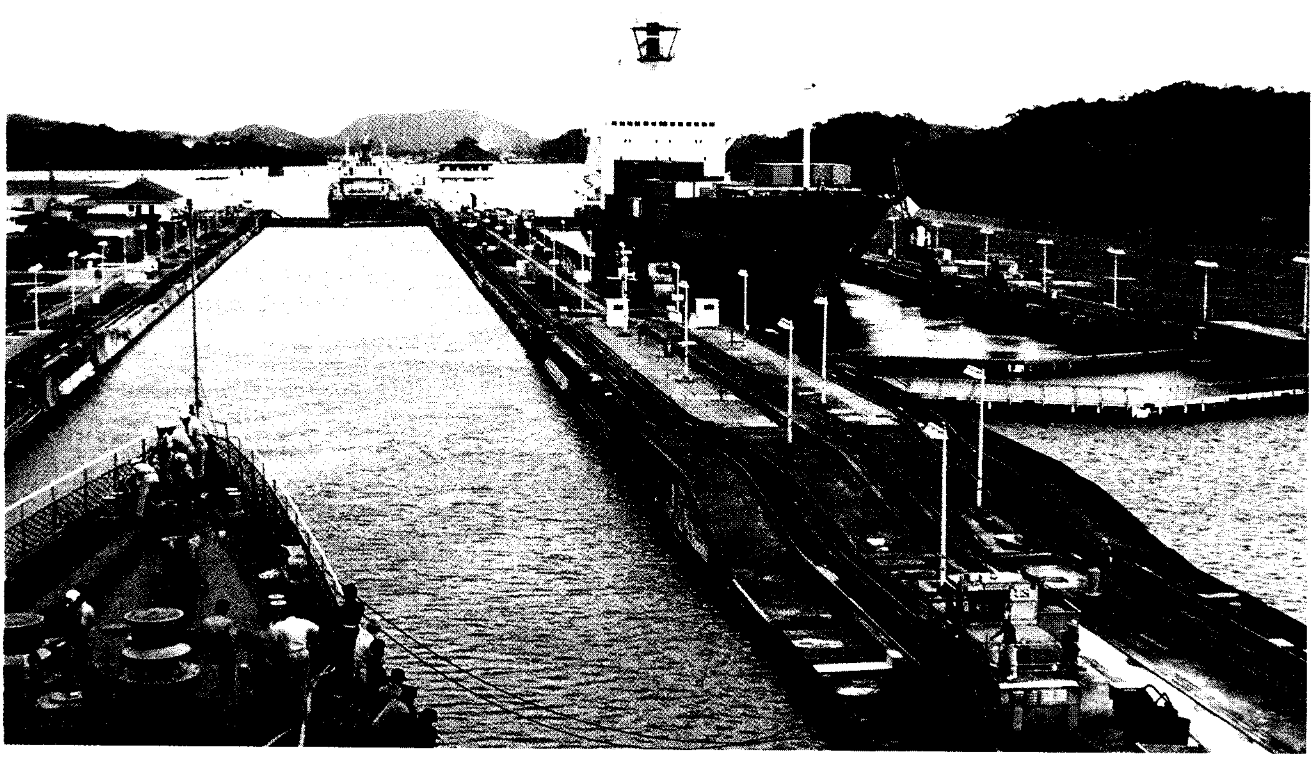
The Suez Canal was once the busiest canal in the world. More than twenty thousand ships passed through it every year. The Suez Canal shortens the voyage between Britain and India by 6,000 mi. [9,700 km].

Other canals are not level canals. They have locks, or basins, to raise or lower the water level along the canal. The earliest known lock canal was built in China in A.D. 984. Locks make raising a ship to a higher water level quite simple. The ship moves along the canal into a lock. Watertight gates close behind it. Water is poured in until the lock is filled to the level of the water in the lock ahead, raising the ship. Then the gates in front open. The ship moves on. Most lock canals have several locks, something like short flights of steps. The ship is raised a little in each lock. When ships are going in the opposite direction, water is drained out of the locks. The Panama Canal in the country of Panama in Central America connects the Atlantic and Pacific oceans by six locks and an artificial lake (see LOCK (NAVIGATIONAL)).

The Panama and Suez canals are considered the most important canals in the world. In building the Panama Canal, the United States employed thousands of workers, using giant steam shovels and dredges to build the 51 mi. [82 km] waterway. The canal was completed in 1914, costing $380 million. More than fifteen thousand ships go through

CANAL

The Panama Canal crosses the narrowest part of Panama in Central America to link the Atlantic and Pacific oceans. Construction was begun by the French Panama Canal Company and completed by the United States.



the canal each year. The Panama Canal makes it possible for a ship to sail from New York City to San Francisco without having to travel around the southern tip of South America. The canal shortens this trip by more than 7,000 mi. [12,600 km]. In 1977, the United States Senate approved a treaty to return ownership of the Panama Canal to the government of Panama by the year 2000.

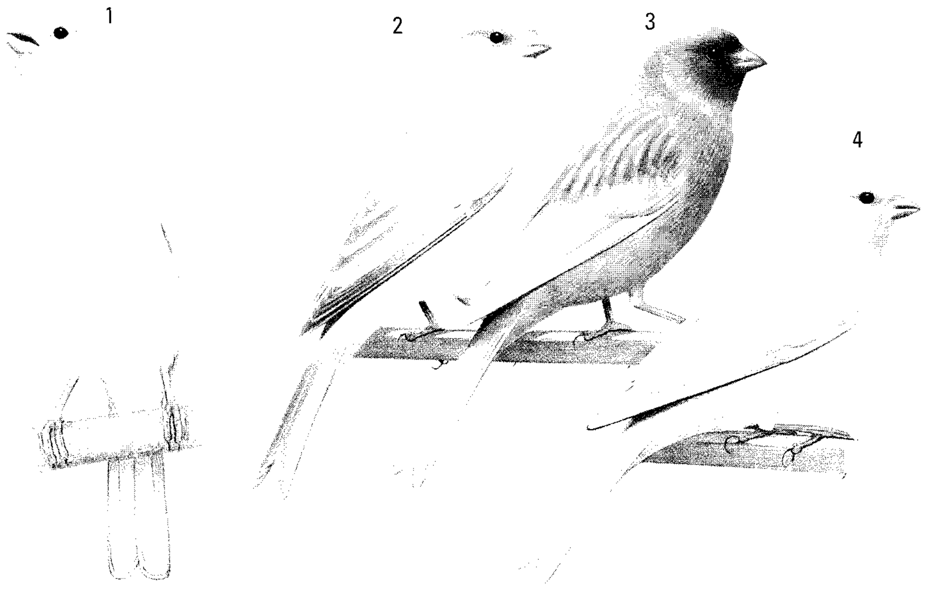
Some canals connect inland cities to the sea. The Houston Ship Channel in Texas has made Houston one of the largest seaports in the United States. This is a rare seaport, since Houston is more than 51 mi. [81 km] from the Gulf of Mexico. Other canals open inland waterways to large ships. The Erie Canal, completed in 1825, stretches 363 mi. [584 km] across the state of New York. This canal connects Lake Erie with the Hudson River. The United States and Canada completed the St. Lawrence Seaway in 1959. It is about 200 mi. [320 km] long. Its lock canals opened the Great Lakes to ocean-going ships. These ships can now travel inland past Detroit as far as Chicago, Illinois, or Duluth, Minnesota.

Most canals are used for transportation. Some, however, are used to irrigate land or to carry sewage from large cities. Most canals are less important these days because of competition from air, rail, and road transport. Russia, Belgium, the Netherlands, France, and Germany still have important canal systems in use.

CANARY The wild canary is a greenish yellow bird of the finch family, seldom more than 8 in. [20 cm] in length. These birds are found on the Canary Islands, after which they are named. Wild canaries live in pairs but often flock together. They build nests of dry moss and grass in branches about 10 ft. [3 m] from the ground. A wild canary usually lays four or five eggs. In the United States, the name *wild canary* is often given to the American goldfinch, which looks somewhat like a tame canary. Wild canaries can sing but not as clearly and musically as the tamed birds. The tamed birds were bred for the quality of their song.

These birds were taken to Europe early in the 1500s. They became popular cage pets because of their sweet song. Selective breeding has produced many kinds of canaries. Tame canaries are usually bright yellow. Some are orange, red, white, or pale yellow. Different types of canaries are named for their song style. For example, rollers have a rolling, gurgling song. Canaries feed on seeds and leaf buds. They also need a great deal of water for bathing and drinking.

Each year, canaries replace some of their songs with different songs. As a result, canaries have been used in laboratory experiments on learning. Because they are more sensitive to poisonous gases than humans are, canaries have been used to discover such gases in coal mines or during wartime, when poison gas has sometimes been used as a weapon.



CANARY

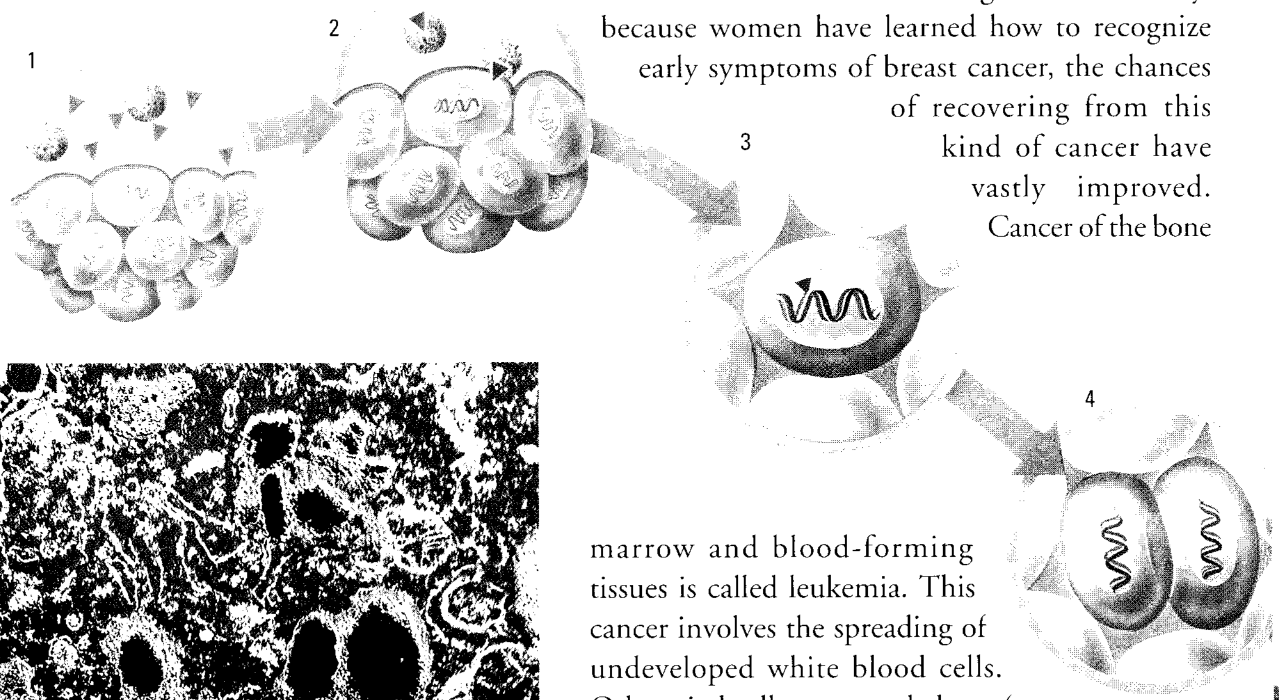
Canaries are popular cage birds that come in a variety of colors, often with unusual names. Shown here are (1) the original yellow canary, (2) a Frosted Gold Agate Opal, (3) a Frosted Rose Brown Ino, and (4) a Silver Isabel Ino.

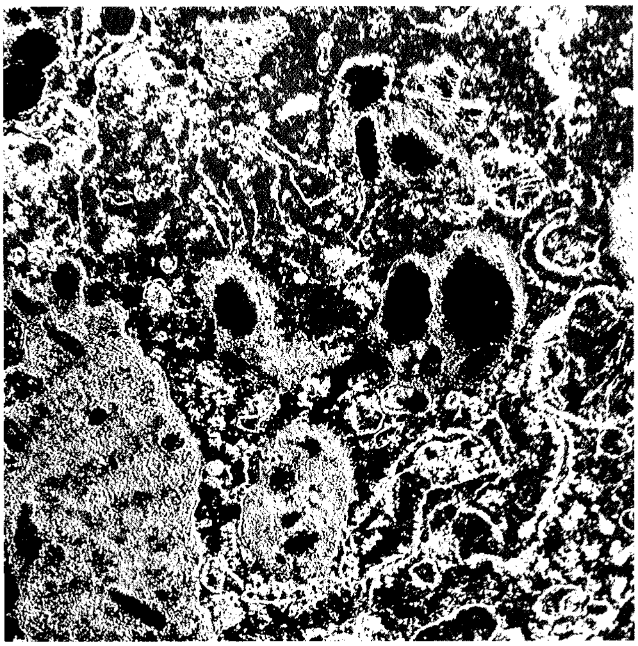
CANCER

Cancer is a disease in which cells multiply without control. When cancerous cells grow like this, they destroy healthy normal tissue and may even cause death. Cancer cells can grow in any tissue of the body. They build up into large clumps of tissue known as malignant tumors. Clumps of tissue that are not cancerous are said to be benign tumors. A benign tumor does not invade healthy tissue. A malignant tumor can take the place of an organ, thereby destroying it.

Cancer cells can break away from a tumor and be carried through the bloodstream or other fluids. These "breakaway" cells settle in other parts of the body, where they multiply and start more tumors. The movement of cancer cells to other parts of the body is called metastasis. The tumors can eventually destroy the organs necessary for life.

More than one hundred types of cancer attack human beings. Skin cancer is the most common type but can usually be cured completely. A usually fatal kind of skin cancer called malignant melanoma, however, grows quickly and can metastasize, which means to move to another location on the body. Lung cancer is the leading cancer killer of both men and women and mostly occurs in those who smoke cigarettes. Recently, because women have learned how to recognize early symptoms of breast cancer, the chances of recovering from this kind of cancer have vastly improved. Cancer of the bone marrow and blood-forming tissues is called leukemia. This cancer involves the spreading of undeveloped white blood cells. Other vital cells are crowded out (see LEUKEMIA). Cancer of the lymphatic system is called lymphoma. The most common form of lymphoma is called Hodgkin's disease.





MALIGNANT MELANOMA

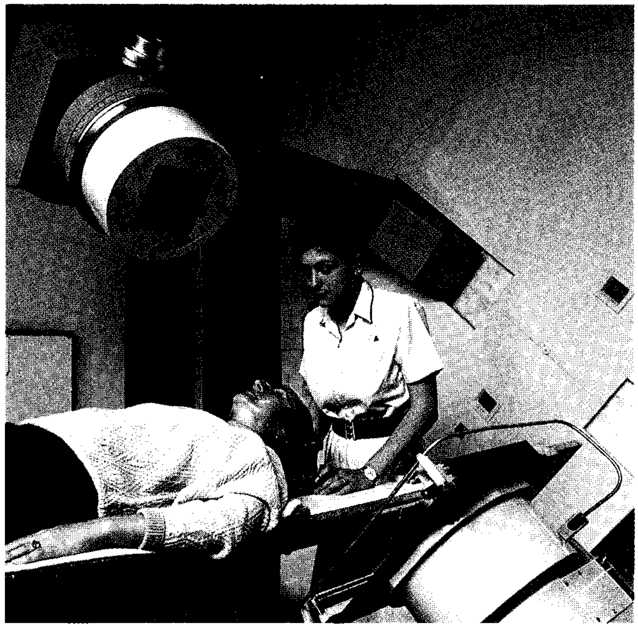
A melanoma is a cancer that attacks the skin's pigment cells (melanocytes), making them release extra pigment (shown in red). The cancer may then spread to other tissues, such as lymph nodes. This electron-microscope picture of part of a human lymph node has been artificially colored to show various types of cells.

People can develop cancer through contact with one or more cancer-causing agents, called carcinogens (see CARCINOGEN). Carcinogens include pollution, cigarette smoke, various chemicals, certain types of radiation (including the sun's rays, which can cause skin cancer), and viruses. Also, scientists believe that a person may inherit a tendency to develop cancer. Only a few kinds of cancer, however, are known to be passed from generation to generation with any regularity. The exact causes of cancer are still not completely understood. Many doctors think that a combination of events leads to most cancers.

If a doctor suspects that a patient may have cancer, he or she may perform a biopsy to find out if the tumor is malignant. In a biopsy, a small piece of tissue is removed from the tumor, then looked at under a microscope. This is done to check for the presence of cancer cells, which look different from normal cells. There are four basic ways of treating cancer. If a cancer is discovered before a metastasis has occurred, a surgeon can cut away the tumor to try to cure the patient. Another treatment, radiation therapy, involves the use of X rays, gamma rays, and X rays from radioactive substances, such as radium and some forms of cobalt, to kill cancer cells (see RADIATION THERAPY). A third way to slow or kill cancer is by drugs. This method, called chemotherapy, has become very important. Certain drugs have proven effective in treating leukemia and lymphoma. Also, certain drugs can make cancer cells easier to kill by rays. In biological therapy, the person's immune system is treated with highly purified proteins. The proteins help activate it to destroy cancer cells, which it recognizes as "foreign" (see IMMUNITY).

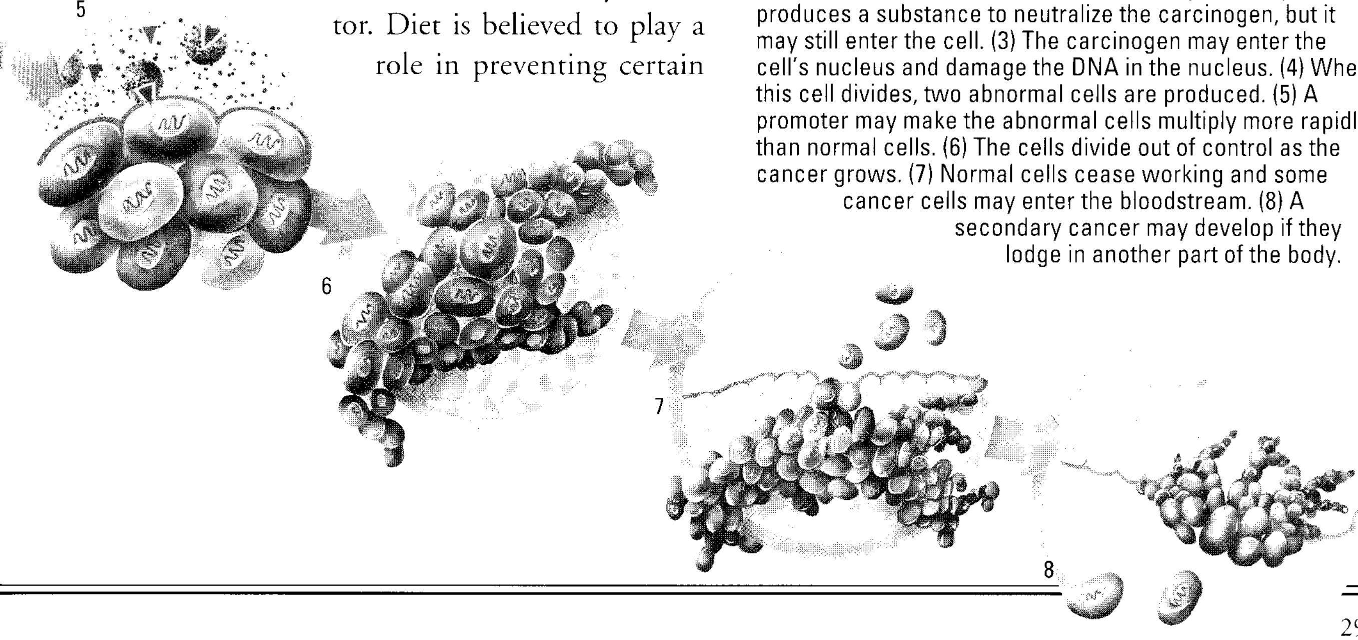
Every person should be aware that sores that do not heal, nagging coughs, lumps under the skin, and great difficulty in swallowing or digesting food are possible warning signals of cancer that should be checked by a doctor. Diet is believed to play a role in preventing certain types of cancer. A low-fat, high-fiber diet including generous amounts of fruits, vegetables, and whole-grain products may be beneficial.

Numerous organizations spend billions of dollars fighting cancer in the United States. International organizations share scientific findings, collecting much knowledge about cancer. Such knowledge is helping point the way toward the eventual control of cancer.



CANCER TREATMENT

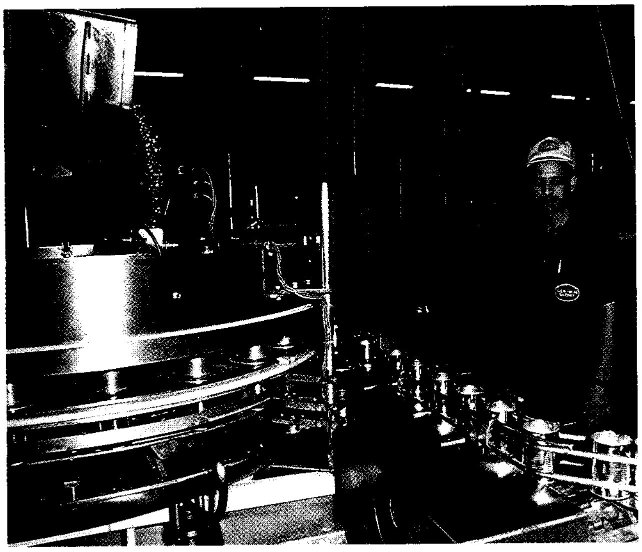
Radiotherapy is a powerful way of treating cancerous tumors. Here a radiographer uses a laser beam to line up a patient (wearing a protective face mask) so that the radiation beam is aimed exactly at the tumor.



SPREAD OF CANCER

(1) A carcinogen enters the body and reacts with parts of a cell to begin cancer formation. (2) The body normally produces a substance to neutralize the carcinogen, but it may still enter the cell. (3) The carcinogen may enter the cell's nucleus and damage the DNA in the nucleus. (4) When this cell divides, two abnormal cells are produced. (5) A promoter may make the abnormal cells multiply more rapidly than normal cells. (6) The cells divide out of control as the cancer grows. (7) Normal cells cease working and some cancer cells may enter the bloodstream. (8) A secondary cancer may develop if they lodge in another part of the body.

CANDELA (kăn dĕlʹə) The candela is the standard unit of measurement for luminous intensity, or the brightness of a source of light. The more candelas a source of light produces, the brighter it is. One of the seven basic units of the SI, or international system, candela is abbreviated *cd.* The candela is used to calculate other units of light measurement that involve distance from the light source, such as lumens and footcandles (see FOOTCANDLE; LUMEN).



CANNING
Newly made cans speed along to the canning machine, where they will be filled and have their lids sealed in place.

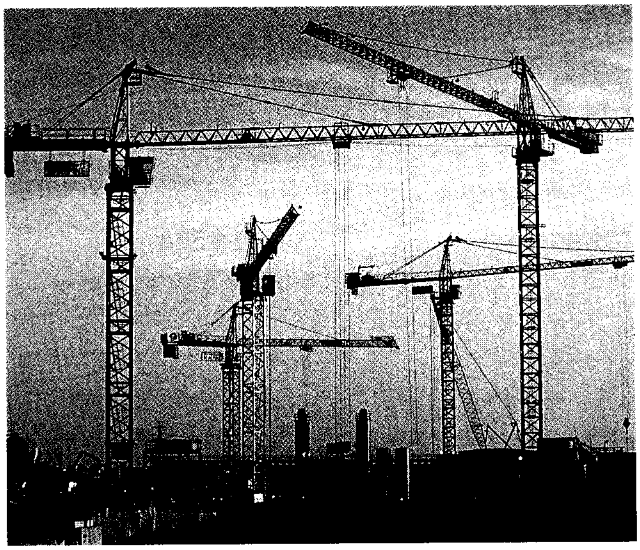
CANNING Canning is the process by which foods are preserved by being sterilized and then packed in cans or glass jars (see STERILIZATION). Because air and, thus, disease-causing microorganisms, have been removed from the containers, canned food remains fresh for years (see MICROORGANISM). The canning process was invented in 1795 by Nicholas Appert, a French chef. Today, it is widely used to preserve fruits, juices, meats, and vegetables.

The industrial canning process begins when the food to be preserved is cooked in large stainless-steel vats at high temperatures—212°F to 250°F [100°C to 121°C]. The high temperatures destroy any microorganisms in the food. The food is then loaded into a dispensing machine. The machine measures out portions of the food and, often, some kind of liquid, into empty cans or jars as they pass along a conveyor, or moving belt. Any remaining air is then removed from the cans or jars by a vacuum device, and lids are attached to the containers with a seal that keeps air out. Next, the freshly filled containers are heated at very high temperatures. This heating sterilizes the containers and the foods they hold. Sometimes, the canning process is somewhat different. The cans and food are sterilized before filling.

Canning can also be done in the home. A pressure cooker is used to cook the food, which is usually placed in glass jars rather than cans. It is important to follow the correct procedure, or food poisoning could result.

See also FOOD PROCESSING.

CANTILEVER (kănʹtl ēʹvər) A cantilever is a beam that is fixed at one end to a wall or other structure and is unsupported at the other end. The beam may be made of wood, iron, steel, or reinforced concrete. A simple form of cantilever is a diving board over a swimming pool. Cantilevers are widely used by engineers in the construction of bridges. Cantilever beams can be long and are useful in bridge building when the span to be crossed is quite wide (see BRIDGE). Certain cranes, such as the hammer head cranes used around docks and in erecting steel structures, are designed with cantilever arms so they can have a long reach.



CANTILEVER
These tower cranes are examples of cantilevers. The main arm that lifts the load gives such cranes a long reach.

CANYON

The Yellowstone River flows through a spectacular canyon in Montana. A steep-sided valley such as this is the result of many thousands of years of erosion by the river that flows through it.

CANYON A canyon is a deep valley with steep sides. Canyons are formed by the erosion of land over tens of thousands of years. A narrow canyon with nearly upright sides is called a gorge. Canyons form some of the most spectacular scenery in the world. The Snake River Canyon in Oregon and Idaho is about 5,500 ft. [1,680 m] deep and 40 mi. [64 km] long. Many small canyons are found in the Canadian Rockies. Huge canyons occur under the oceans.

See also EROSION; GRAND CANYON.

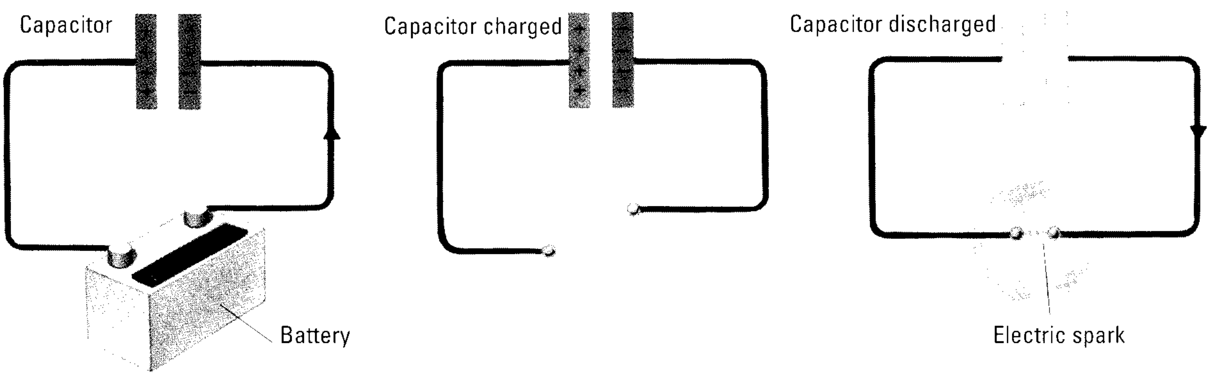
CAPACITOR AND CAPACITANCE A capacitor (kə păs′ĭ tər) is an electrical device used to store, or hold, an electric charge. The charge held by a capacitor is used to control the supply of electricity within a circuit. The ability of a capacitor to store a charge is called capacitance (kə păs′ĭ təns) (see CIRCUIT, ELECTRIC).

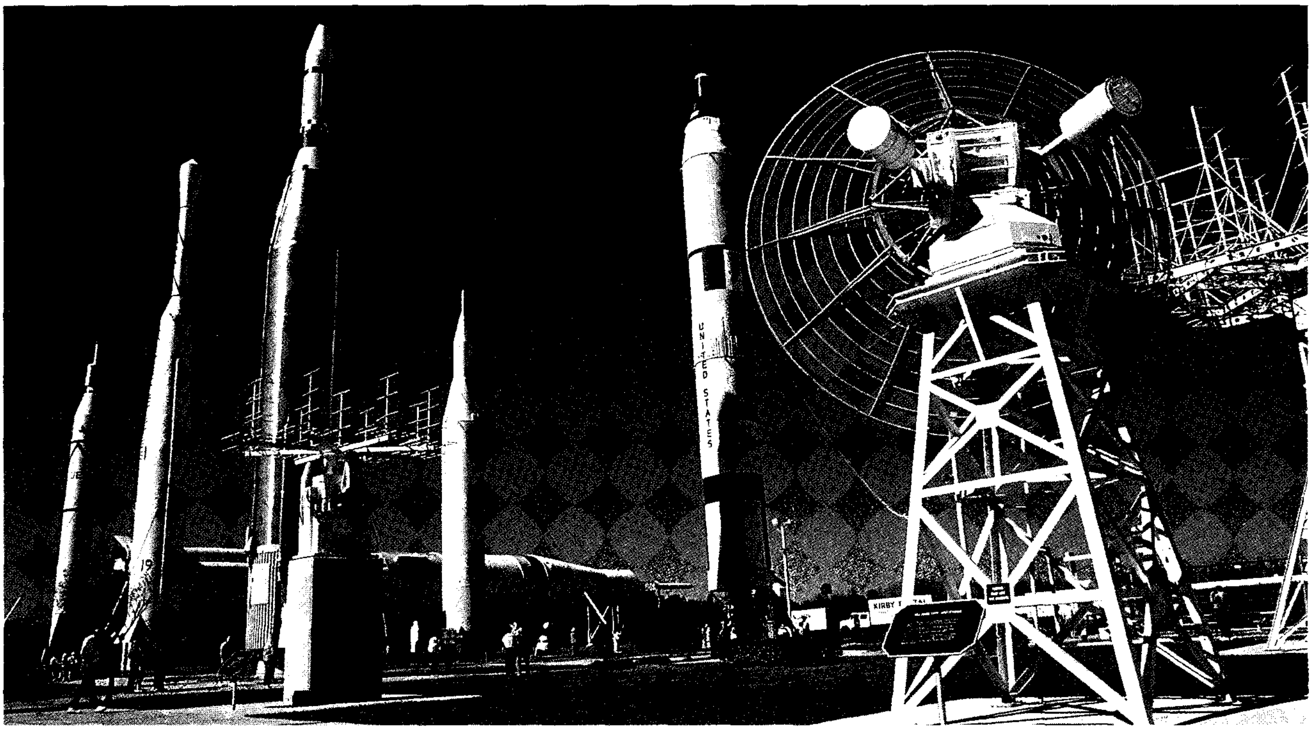
Although capacitors vary widely in shape, size, and purpose, all capacitors are basically alike in design. They consist of two or more metal plates that are separated by insulation. When a current is passed into a capacitor, these plates build up an electric charge. The charges of the capacitor plates then become supplies of electricity, like the oppositely charged terminals of a battery. The capacitor is included in a circuit to release its charge when needed. The charge of a capacitor is called an electrostatic charge. The insulating material that separates the plates of a capacitor is called the dielectric.

The capacitance of a capacitor is determined by its properties and design. Capacitance increases if the plates of the capacitor are made larger or moved

CAPACITOR AND CAPACITANCE

When a voltage is applied to a capacitor (left), electrons (- sign) are pushed to one metal plate and pulled away from the other, leaving positive charges (+ sign) behind. When the voltage is removed, the charges are held by their electrical attraction (center). If the wires touch, the capacitor discharges (right).





CAPE CANAVERAL
Old rockets stand on display in the Rocket Garden at the John F. Kennedy Space Center, Cape Canaveral. A tracking aerial unit is at the right foreground.

closer together. The capacitance is also determined by the insulating material that separates the plates of a capacitor. The unit of measurement for capacitance is the farad. The farad is determined by dividing the charge of the capacitor by the electromotive force, or voltage, applied to its plates. The unit of measurement for charge is the coulomb. If one volt gives a capacitor a charge of one coulomb, the capacitor has a capacitance of one farad (see COULOMB; FARAD; VOLT).

Capacitors are found in almost all electric and electronic machines and equipment. They are classified according to their dielectric. Ceramics, glass, mica (a mineral), plastic, air, and liquids are the most commonly used dielectric materials.

CAPE CANAVERAL Cape Canaveral in Florida is the site of the John F. Kennedy Space Center. Cape Canaveral is also home to the NASA (National Aeronautics and Space Administration) Launch Operations Center and to the first tracking station in the Atlantic Missile Range, which is an area that extends 9,000 mi. [14,000 km] across the South Atlantic Ocean. A tracking station has instruments that are used to follow the flights of missiles, rockets, and other spacecraft. All U.S. spacecraft that carry men or women are launched from Cape Canaveral. It is referred to as launch control. The Lyndon B. Johnson Space Center near Houston then monitors the flight. The Johnson Space Center is referred to as mission control.

Many important events in U.S. space travel have occurred at Cape Canaveral. For example, the United States launched its first satellite, *Explorer 1,* from Cape Canaveral in 1958. The spacecraft of the first American in space, Alan Shepard, was launched from Cape Canaveral in 1961. The spacecraft of the first American to orbit the earth, John Glenn, was also launched from the site in 1962. In 1969, Neil Armstrong, Michael Collins, and Edwin Aldrin, Jr., rocketed to the moon from Cape Canaveral. Space shuttles have also been launched from the cape. Space shuttles are reusable spacecraft that carry astronauts.

Cape Canaveral was renamed Cape Kennedy in 1963 by President Lyndon B. Johnson in memory of assassinated President John F. Kennedy. In 1973, the name was changed back to Cape Canaveral.

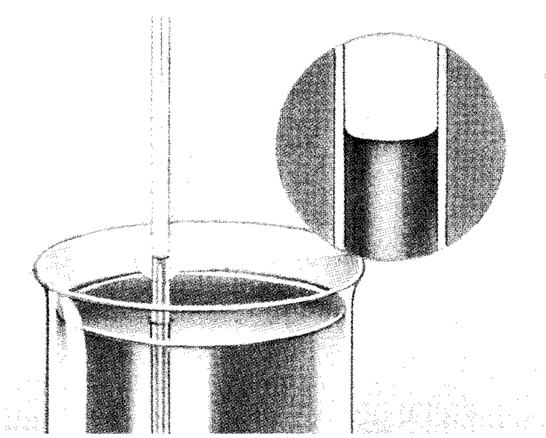
See also ARMSTRONG, NEIL ALDEN; GLENN, JOHN HERSCHEL; NASA; SPACE EXPLORATION.

CAPILLARY (kăp′ə lĕr′ē) A capillary is a tiny blood vessel that carries blood to and from the cells and connects arteries and veins. The thin walls of capillaries allow the exchange of materials, such as food, oxygen, and wastes, between the blood and body tissues.
See also CIRCULATORY SYSTEM.

CAPILLARY ACTION If a narrow glass tube is lowered into water, the water rises up the tube a short distance. This is the result of capillary action. The attraction between the molecules in the glass surface and the molecules in the water surface causes the rising of the water. This attraction between solid and liquid is stronger than the attraction of water molecules among themselves. The surface tension of a liquid can be calculated from the distance it rises in a capillary tube of known diameter (see SURFACE TENSION).

Towels, sponges, and dry earth are porous substances that contain narrow tubes or passages. These substances soak up water by capillary action. Sap moves up the xylem from the roots to the stems and leaves of plants by capillary action (see SAP; XYLEM). PROJECT 5

ACTIVITY *Capillary action*



Put some water into a jar or beaker. Add a few drops of ink or food dye to make the water show up more clearly. Dip a drinking straw into the water. Notice how the water rises a short distance up the straw. It is drawn by capillary action. If you look carefully at the surface of the water in the straw, you will see that the surface curves upward where it meets the inside of the straw.

CARAT A carat is a unit of weight used by jewelers to measure gemstones and pearls. The term is an Arabic word meaning "seed" or "bean." In ancient times, the seeds of coral trees were used as weights for precious stones. These stones were described as being of so many "seeds' weight" or "beans' weight." The carat weighs 0.007 oz. [200 mg].

The term *carat* is also used to tell how much gold there is in an alloy (see ALLOY). When used this way, carat is usually spelled *karat.* Pure gold is 24 karats fine. If 14/24 of an alloy is gold, the alloy is 14 karats fine.
See also DIAMOND; GOLD.

CARBOHYDRATE A carbohydrate is a chemical that contains the elements carbon, hydrogen, and oxygen. The ratio is always 2 parts hydrogen to 1 part carbon to 1 part oxygen. Carbohydrates are one of the major kinds of nutrients (nourishing substances) needed by all living things (see DIET). They are the major source of energy released in respiration (see RESPIRATION).

All sugars and starches are carbohydrates (see STARCH; SUGAR). Some of the most common carbohydrates are glucose, sucrose, fructose, lactose, and cellulose. Glucose is a simple sugar that is often used in a solution for hospital patients who are unable to digest solid food. The glucose solution is given intravenously—that is, through a needle that is inserted into a vein. Sucrose is the sugar known as ordinary table sugar. Fructose is often found in fruits. Lactose is the sugar found in milk. Cellulose is a carbohydrate found in the walls of plant cells. Cellulose is a major part of woody tissue and is responsible for most of wood's strength. It cannot be digested by the human body, but it provides dietary fiber, which is needed for good health (see CELLULOSE; FIBER). Some plant-eating animals, such as horses and cows, are able to digest cellulose because they have special bacteria and protozoa in their stomachs. It is these microorganisms that actually digest the cellulose. Some insects, such as termites, also contain cellulose-digesting microorganisms. Termites often do great damage to houses and other wooden structures.
See also PHOTOSYNTHESIS.

CARBON

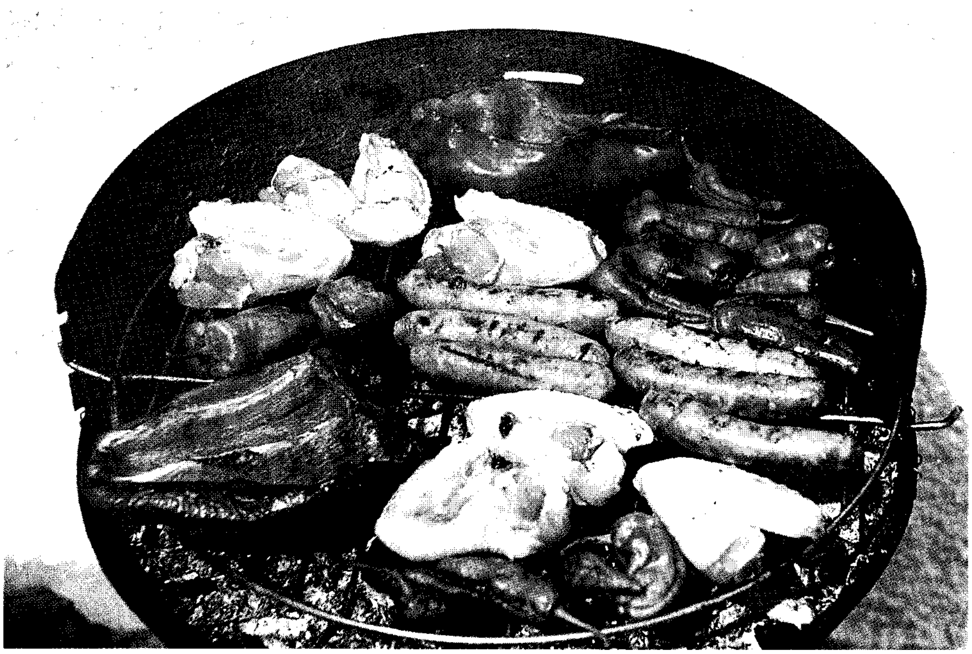
Carbon (C) is a nonmetallic element that is found in three different forms, called allotropes (see ELEMENT). These allotropes are diamond, graphite, and amorphous carbon. These allotropes are different because their atoms are joined together in different ways. The atoms of diamond are held together very strongly. This makes diamond one of the hardest substances known. The atoms of carbon in graphite are not held together so strongly. It is one of the softest substances known. Diamond and graphite are crystalline forms of carbon. Powdery forms of carbon are called amorphous carbon. Charcoal, coal, and carbon black (soot) are examples. Amorphous carbon will burn in air and combine with oxygen to form carbon dioxide (see CHARCOAL; COAL; CRYSTAL; DIAMOND; GRAPHITE).

Carbon is very common. Diamond, graphite, and coal are found in nature. Carbon also occurs in nature as compounds in minerals such as limestone, chalk, and marble. Oil and natural gas contain carbon compounds called hydrocarbons (see HYDROCARBON).

Carbon forms more compounds with other elements than does any other element. Over a million compounds of carbon are known. This is because carbon atoms can join together to form very large molecules. Any compound that contains carbon is said to be *organic.* The special branch of chemistry that studies carbon compounds is called organic chemistry (see COMPOUND; ORGANIC CHEMISTRY).

Uses of carbon Carbon has many uses. Diamonds are used in jewelry. Because they are so hard, they are also used in industry as cutting edges for tools. Graphite is soft and slippery. When

CARBON'S USES
Carbon is used in many different forms. The most commonly used natural form of carbon is coal (above). Other forms of carbon are shown below. Pencil "lead" is actually graphite, another form of carbon. Diamond is a different and much rarer natural form. Carbon is also the raw material for making synthetic diamond used in cutting teeth of rock drills. Other everyday products, such as ink and tires, contain carbon.



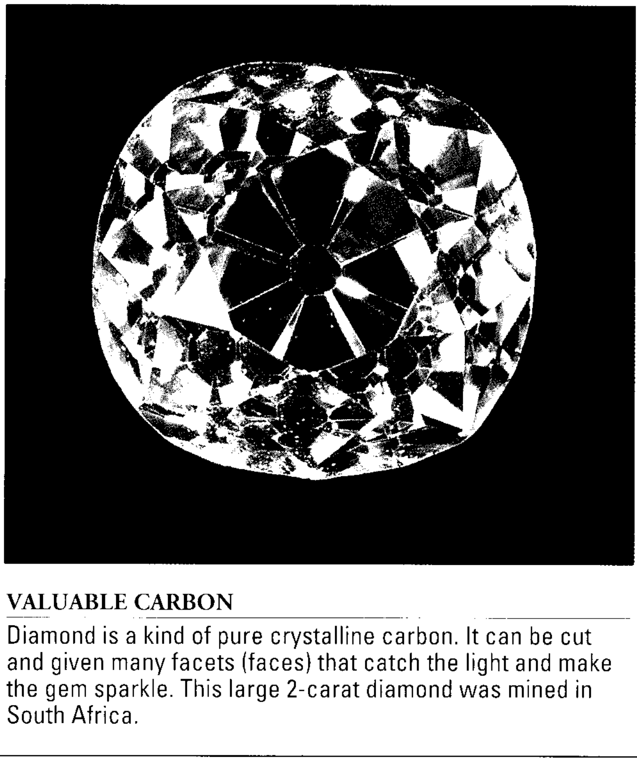
CARBON FOR COOKING
Charcoal is almost pure carbon. It burns without producing smoke or fumes and is ideal for a barbecue.

powdered, it is used to lubricate machinery. In its solid form, it is used for pencil leads. Coal is widely used as a heating fuel and to make coke. Coke is a purer form of coal. Coke is also used as a heating fuel, and it is added to iron to make steel (see COKE). Charcoal is used as a cooking fuel and in filters to remove fumes, odors, and impurities from air and water. Carbon black is a very fine powder used in making black printing ink.

The compounds of carbon also have many different uses. Silicon carbide is a very hard material that is used as an abrasive called Carborundum. Many of the most useful carbon compounds are polymers. All plastics are polymers, and they all contain carbon (see PLASTIC; POLYMER).

Carbon in life Carbohydrates are an important group of carbon compounds that are necessary to life. These compounds are combinations of carbon, hydrogen, and oxygen atoms (see CARBOHYDRATE). The carbon in living things comes from the carbon dioxide in the air (see CARBON CYCLE; CARBON DIOXIDE). A small part of carbon dioxide contains an isotope (a different form of an element) called carbon-14. This isotope is radioactive. When things die, the carbon-14 in their bodies starts to decay and change into ordinary carbon. By measuring how radioactive something is, scientists can tell how long it has been dead. This is called radiocarbon dating (see DATING; RADIOACTIVITY).

Carbon's atomic number is 6. Its relative atomic mass is 12.011. Carbon does not melt. Instead, it changes directly from a solid to a gas. This is called sublimation (see SUBLIMATION). Carbon sublimes at about 6,332°F [3,500°C]. The relative density of carbon varies. That of diamond is between 3.1 and 3.5; graphite is between 1.9 and 2.3; amorphous carbon is between 1.8 and 2.1 (see RELATIVE DENSITY).



VALUABLE CARBON
Diamond is a kind of pure crystalline carbon. It can be cut and given many facets (faces) that catch the light and make the gem sparkle. This large 2-carat diamond was mined in South Africa.

CARBON CYCLE Carbon is a necessary element for all living things. The main source of carbon for life is the carbon dioxide in the air (see CARBON; CARBON DIOXIDE). This gas is taken from the air by plants and returned to it by all organisms. This is a continuous cycle necessary to life. It allows the limited carbon dioxide in the air to be constantly reused.

Green plants take in carbon dioxide and combine it with water from the soil to make sugars and other more complex carbon compounds. This process is powered by the energy of sunlight and is called photosynthesis (see PHOTOSYNTHESIS). Green plants return carbon dioxide to the air in two ways. During the night, they give off carbon dioxide. They also give off carbon dioxide when their remains decay after they die.

Animals, including humans, use other animals and plants as food. The food is made up of compounds containing carbon atoms. These compounds include carbohydrates, proteins, and fats, all of which are broken down by digestion into smaller molecules. These smaller molecules are used for growth and rebuilding tissues. Also, as the molecules are broken down, energy is released. Carbon dioxide is a waste product formed during these chemical reactions. It is returned to the air as animals exhale. Like plants, animals also give off carbon dioxide when they decay after death. The decayed remains of both plants and animals form fuels such as coal, oil, and natural gas. When these fuels are burned, carbon dioxide is released into the atmosphere.

See also RESPIRATION.

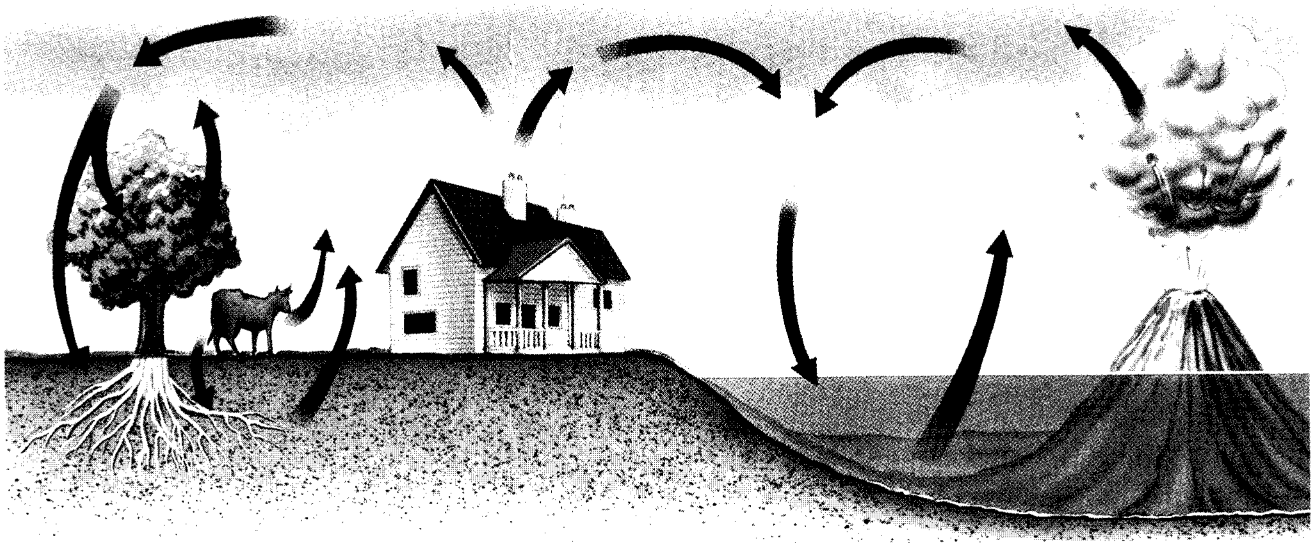
CARBON DIOXIDE Carbon dioxide (CO_2) is a colorless gas. It is heavier than air and makes up about 0.04 percent of the earth's atmosphere. There is fifty times more carbon dioxide in the ocean than in the atmosphere. Joseph Black, a Scottish physician, discovered carbon dioxide in 1756.

When carbon burns, it combines with oxygen in the air. If the oxygen supply is plentiful, carbon dioxide is formed. Additional carbon dioxide is released into the air by all living things during respiration (see RESPIRATION). For example, when a person exhales, his or her breath contains about 5 percent carbon dioxide. Carbon dioxide is also released when organisms decay and when fuels are burned (see CARBON CYCLE).

Carbon dioxide does not burn and does not support combustion. For this reason, it is widely used in fire extinguishers. Carbon dioxide dissolves easily in cold water. It is the bubbly gas put into soda pop under pressure. This is called carbonation. Fermentation, a process used in making a variety of foods and beverages, also produces carbon dioxide.

CARBON CYCLE

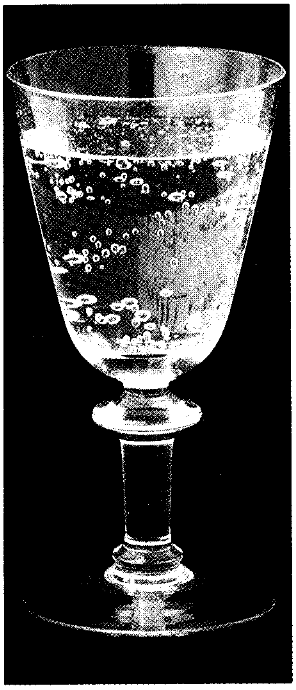
Plants use carbon dioxide gas to make food, but the amount of carbon dioxide in the air remains more or less constant. This is because carbon dioxide is continuously recycled through the carbon cycle. Carbon dioxide is released into the air when animals breathe out, when plants and animals decay, and whenever anything burns.



For example, the action of yeast in bread dough produces bubbles of carbon dioxide that cause the bread to rise (see FERMENTATION).

When carbon dioxide is cooled below -109.3°F [-78.5°C], it becomes a solid material known as dry ice. Dry ice does not melt into a liquid under less than 1 atmosphere pressure. When it warms, it changes directly into a gas (see SUBLIMATION). Dry ice is an excellent refrigerant.

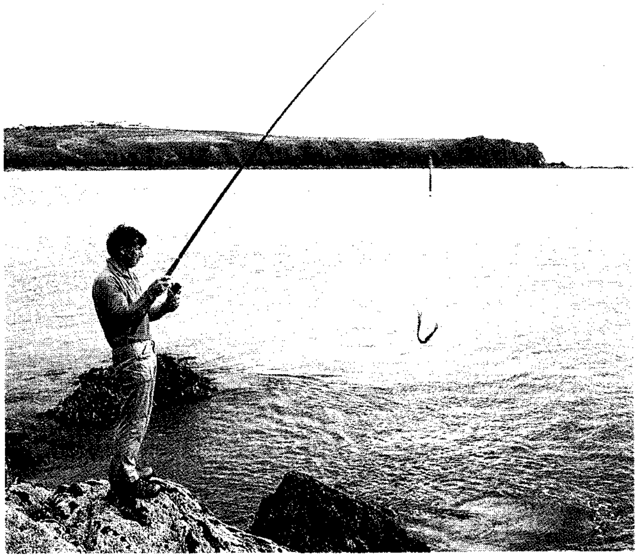
In addition to sunlight and water from the soil, plants need carbon dioxide from the air (see PHOTOSYNTHESIS). Carbon dioxide in the air absorbs heat from both the sun's rays and the earth. It holds this heat, acting like a blanket over the earth. This is known as the greenhouse effect. Many people believe that the greenhouse effect is intensifying, which could greatly affect the earth's climate (see GREENHOUSE EFFECT). PROJECT 6, 10



CARBON DIOXIDE
The bubbles in carbonated, or fizzy, drinks are carbon dioxide gas. The gas remains dissolved in the liquid while it is in a sealed bottle or can. When the container is opened and the pressure released, the bubbles come out of solution and the drink fizzes.

CARBON FIBERS Carbon fibers are long strands of carbon. They are used to make a strong, lightweight material by laying them in a synthetic liquid resin that sets hard. The fibers may be woven together for added strength. Before the resin sets, the fibers can be molded into any shape. Some golf club shafts, tennis rackets, fishing rods, car bodies, and parts of aircraft and rockets are made from carbon fiber.

The first carbon fibers were made at the end of the nineteenth century by the American inventor Thomas Alva Edison. He made them by heating strips of bamboo to carbonize them for use as electric light filaments. Since the 1960s, carbon fibers have been made by carbonizing fibers of a synthetic textile material called polyacrylonitrile, better known as the material Courtelle. The fibers are carbonized by heating them in a vacuum.



CARBON FIBERS
Carbon fibers can be molded into almost any shape. Their combination of lightness and strength is ideal for fishing rods, which have to be long and thin, but also strong and light.

CARBONIFEROUS PERIOD (kär′ bə nĭf′ ər əs pĭr′ē əd) The Carboniferous period was a geological period that began approximately 363 million years ago. It lasted for 73 million years. The period is divided into an older part, the Mississippian period, and a more recent part, the Pennsylvanian period (see GEOLOGICAL TIME SCALE).

During the Mississippian period, vast deposits of carboniferous limestone were formed. Coal, natural gas, oil, and deposits of lead and zinc also began to form. Shelled animals, fish, and amphibians were plentiful. The first mosses appeared. Many coral reefs were formed.

In the Pennsylvanian period, layers of coal were formed from the rich plant life growing in the swamps (see COAL). These plants included trees

CARBONIFEROUS PERIOD

Dense forests grew on swampy land in the Carboniferous period. As these plants died, they were buried under thick layers of mud. As they sank ever deeper, the increasing pressure changed them into coal. Sometimes the shape of one of those plants can be found as a fossil in a piece of coal today (inset).

that grew to a height of 100 ft. [30.5 m]. Large insects lived, and giant ferns grew in the forests. The first reptiles appeared at this time.

The Carboniferous period is often called the "age of amphibians" because the first true amphibians emerged and multiplied (see AMPHIBIAN). Also, life in the sea was abundant and included coral, mollusks, trilobites, and many different types of fish (see TRILOBITE).

CARBON MONOXIDE Carbon monoxide (CO) is a colorless, tasteless, odorless, and highly poisonous gas. It was first prepared in the laboratory in 1776 by J.F. de Lassone, a French chemist. In 1800, William Cruikshank, a British chemist, identified the composition of carbon monoxide.

Carbon monoxide can be produced by faulty stoves and furnaces that do not have enough oxygen to burn their fuel completely. Automobile engines also produce large amounts of carbon monoxide. Carbon monoxide contributes to air pollution. Cigarette smoke contains a very small amount of carbon monoxide. This tiny amount can be harmful, especially to people who have arteriosclerosis or emphysema (see ARTERIOSCLEROSIS; EMPHYSEMA; POLLUTION).

Because carbon monoxide has no color, no taste, and no smell, people may breathe it without realizing that they are being poisoned. Carbon monoxide prevents the hemoglobin in the blood from supplying oxygen to the body. Without oxygen, a person soon dies. One way to prevent carbon monoxide poisoning is to make sure that all gas-burning appliances and fixtures are well ventilated. Also, car engines should never be run in a closed garage.

Carbon monoxide is used in industry as a fuel. Coal gas and water gas contain carbon monoxide (see COAL GAS). Carbon monoxide is sometimes used to separate metals from their ores and to purify metals. Chemists also use carbon monoxide to make other chemical compounds.

CARBURETOR (kär′bə rā′tər) A carburetor is that part of a gasoline engine that mixes gasoline and air. This supplies an air-gasoline vapor mixture for fuel. A carburetor is basically a barrel (a metal tube) with a narrow part in its middle, called the venturi.

As the engine runs, a vacuum is created by the movement of the pistons. This vacuum sucks air into the carburetor from the outside. Before entering the carburetor, the air passes through a filter that traps dirt. As the air passes through the venturi, it is mixed with gasoline that is pumped in through one or more nozzles. The resulting gasoline and air mixture passes out the other end of the barrel into an intake manifold. The intake manifold carries the fuel vapor to the place where it is ignited in the engine.

Carburetors may have one or more barrels. Most engines have only a single-barrel carburetor, but racing engines can have six barrels or more. The added barrels allow more fuel vapor to flow, resulting in higher speeds. Not all gasoline engines have a carburetor. Some engines have a fuel-injection system that squirts fuel into the cylinders.
See also ENGINE.

CARCINOGEN (kär sĭn′ə jən) A carcinogen is any substance that causes a growth of cancerous body tissue. Examples of carcinogens are certain chemicals and certain viruses.
See also CANCER; VIRUS.

CARDIAC MUSCLE Cardiac muscle is the special muscle that makes up the major part of the heart. Unlike other muscles in the body, cardiac muscle does not become tired (fatigued).

Cardiac muscle is made up of long, branching muscle cells containing many bundles of muscle protein. The cells are separated by disks. This structure allows the heart muscle to shorten itself (contract) in a highly coordinated way when it receives nerve impulses, so each chamber of the heart can contract when it should and relax back to its former size (rest) when it should.

Cardiac muscle cells also contain a lot more mitochondria than other muscle cells (see CELL; MITOCHONDRIA). These use up food and oxygen molecules to give the cells the energy to contract. This means that cardiac muscle needs a constant supply of food and oxygen from the cardiac arteries to work, and is easily damaged if the supply is cut off or restricted.
See also HEART; HEART DISEASE.

CARDINAL The cardinal is a songbird that belongs to the finch family, Fringillidae (see FINCH). It is found in the central and eastern United States and in a small area of the southwestern United States and Mexico. The cardinal reaches a length of 7.75 in. [19.4 cm] and has a crest on its head. The crest is a group of feathers that form a point. Male cardinals are bright red. The females are reddish brown. Although most songbirds migrate to warmer areas for the winter, cardinals live in the same place all year round.
See also MIGRATION.

CARDINAL
A male cardinal perches on a bush in the Sonoran Desert of Arizona. The cardinal is a seed-eating bird. Like other seed eaters, it has a large, powerful bill for cracking the shells to get the nutritious food inside.

CARIBOU (kăr′ə bo͞o′) The caribou is a large deer of North America that is closely related to the reindeer of northern Europe and Asia. Like the reindeer, it has antlers on both the male and the female. Caribou usually travel in large herds, grazing on grass and other small plants. Caribou are well known for their migrations, which cover hundreds of miles. The male may reach a height of 5 ft. [1.5 m] at the shoulder, a length of 8.25 ft. [2.5 m], and a weight of 704 lb. [320 kg]. The female, smaller than the male, gives birth to one calf in the late spring. The hoof of the caribou is flat with a deep division, or cleft. This cleft allows the foot to spread out for support on snow and on icy ground.

There are two types of caribou. The barren ground caribou spends the summer on the tundra (windswept plain) of Alaska and northern Canada, and moves south into the forests for the winter. The woodland caribou, larger and darker than the barren ground caribou, lives all year in forests of the northwestern United States and Canada.

Eskimos and some northern Native Americans hunt the caribou. They use its meat for food and its hide, bones, tendons, and horns for other items they need.

See also REINDEER.

CARIBOU

This male caribou lives on the Alaskan tundra in summer. Its huge antlers will fall off at the beginning of the winter, after the mating season, and its fur will grow longer to protect it from the cold. Females are smaller than males and have much smaller antlers.

CARIES Caries, or tooth decay, is the most common disease of the teeth. It is the most common cause of tooth loss in people under the age of thirty-five (see TEETH).

The development of caries involves a substance called plaque. Plaque is a sticky film that is always forming on the teeth. When food particles remain on the surface of a tooth, the bacteria in plaque act on the sugars and starches in the food to form an acid. This acid attacks and begins to dissolve tooth enamel, which is the hard, protective covering of the tooth. If not treated, the decay creates a hole in the enamel and continues through the dentin (the layer of the tooth beneath the enamel) toward the inside of the tooth. As the decay nears the pulp (the soft center of the tooth), the nerves in the pulp become irritated, and a toothache develops. If the caries reaches the pulp, the pulp may become infected, and an abscess may form. An abscess is a pus-filled sac that forms near the root of the tooth. It contains harmful bacteria that can enter the bloodstream and cause infections in other parts of the body (see BACTERIA; INFECTION).

Caries usually forms where the teeth touch one another, along the gum line, or on the chewing surfaces of the molars. The best way to prevent caries is to keep the teeth clean. Dentists recommend brushing the teeth after every meal and using dental floss once a day. Brushing removes food and plaque from the surfaces of the teeth. Flossing removes food and plaque from between the teeth. Use of a fluoridated toothpaste also helps prevent caries. Many dentists "paint" children's teeth with fluoride compounds. Some communities add fluoride compounds to their water supplies to help strengthen enamel and prevent caries.

During regular dental checkups, the dentist can find caries and other problems of the teeth before they become serious. The dentist or dental hygienist can also clean the teeth to remove calculus, a hard, yellowish substance formed by the buildup of plaque (see DENTISTRY). At the early stages, caries is reversible. Fluoride pastes may be applied directly to the surface of a small caries site if the decay has not penetrated the dentine too deeply. This process will often encourage the replacement of the enamel. This is called remineralization. But once the decay has gone too far, the dentist must remove the decayed area with a small drill. Once the dentist has removed the decay, he or she fills the hole with easily molded metal mixtures (amalgams), containing silver or gold. Recently, plastics and other synthetic (human-made) compounds have been used to fill caries with great success.

CARNEGIE, ANDREW (1835–1919) Andrew Carnegie was an American industrialist and philanthropist who founded United States Steel Corporation. His philosophy was to acquire wealth first and then to distribute it for the general good.

Carnegie was born in Scotland on November 25, 1835. He and his family moved to the United States in 1848 and settled near Pittsburgh, Pennsylvania. Carnegie was a classic example of the

"American dream." His first job paid $1.20 a week. He soon worked his way up through several companies. By the time he was twenty-four years old, Carnegie had made wise investments and was on his way to becoming a multimillionaire.

In 1864, Carnegie became interested in iron and steel. He brought the Bessemer process of steel production to the United States in 1868 (see BESSEMER, SIR HENRY; STEEL). In the next thirty years, Carnegie bought or established several other steel companies, all of which prospered. In 1899, they were merged to form the Carnegie Steel Company. This was renamed United States Steel Corporation in 1901.

Carnegie, by then one of the wealthiest men in the country, set about distributing his money for worthy purposes. During his lifetime, Carnegie gave away more than $350 million. He left large sums of money to several foundations that carry on his charitable work.

CARNIVORE (kär′nə vōr′) A carnivore is an animal that eats meat. Many carnivores belong to the order of mammals called Carnivora. This order includes cats, dogs, wolves, bears, and weasels. Carnivorous animals have special teeth for tearing and slicing meat. They also have special enzymes in their bodies for digesting the meat.

See also CARNIVOROUS PLANT; HERBIVORE; OMNIVORE.

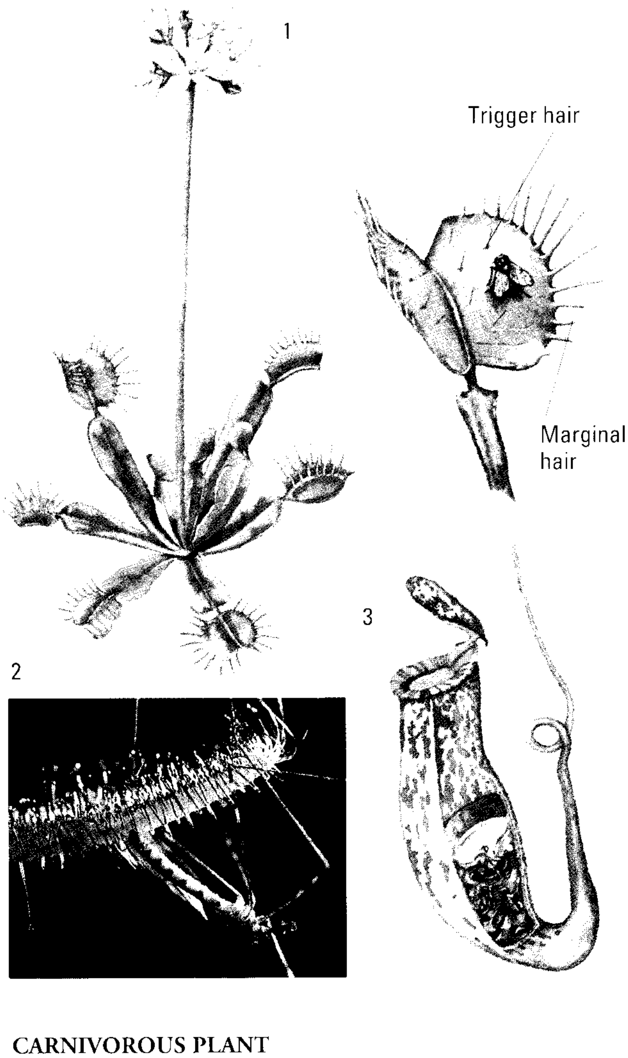
PROJECT 65

CARNIVORE

This tiger's skull shows the huge canine, or eyeteeth, used for stabbing and tearing the prey, and the razor-sharp cheek teeth with which the carnivores slice up the meat. The jaws are worked by powerful muscles attached to the skull.

CARNIVOROUS PLANT Carnivorous (kär nĭv′ər əs) plants are species of plants that capture and absorb insects for food. These plants are able to produce their own food through photosynthesis as other plants do, but they get nitrogen from the insects. Also called insectivorous plants, they usually grow in areas where nitrogen is scarce, such as bogs. There are many different kinds of insectivorous plants, but the best known is the Venus's-flytrap, which traps insects on its spiky leaves. The pitcher plant attracts insects to a colorful sac and then drowns them in the liquid inside. The sundew plant has sticky tentacles on which insects become stuck.

See also INSECTIVORE; VENUS'S-FLYTRAP.



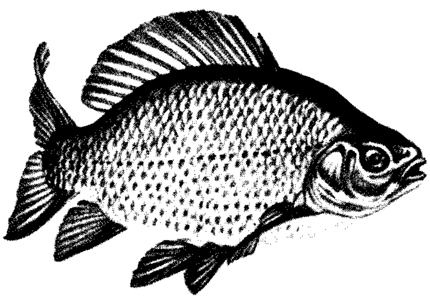
CARNIVOROUS PLANT

(1) When an insect touches one of the trigger hairs on the leaf of the Venus's-flytrap, the trap snaps shut around it like a cage. Juices from the leaf digest the trapped insect. (2) This crane fly has become trapped on the sticky tentacles of a sundew plant. (3) The pitcher plant contains a liquid in which insects drown before being digested.

CAROTENE Carotene is an orange yellow pigment found in plants. It gives a carrot its orange color. Carotene also gives colors to yellow and orange flowers and causes leaves to turn yellow or orange in the autumn. Carotene helps a plant make food during photosynthesis (see PHOTOSYNTHESIS). In the liver of humans and other animals, carotene is changed into vitamin A (see VITAMIN). When carotene combines with oxygen, another yellowish pigment, called xanthophyll, is formed (see XANTHOPHYLL). There is some evidence to suggest that carotene may be important in preventing certain types of cancer.

CARP The carp is a freshwater fish that belongs to the carp and minnow family, Cyprinidae. The carp is a large fish. Most people do not realize that it is closely related to the goldfish. The carp is thick-bodied, with two pairs of barbels (thin, fleshy growths) at the corners of its mouth. The fish can weigh as much as 60 lb. [27 kg] and reach a length of more than 3.3 ft. [1 m] (see GOLDFISH; MINNOW).

Carp are native to Europe and Asia. They were brought to the United States in 1832. By 1896, carp were widespread in the United States. Carp are able to live in badly polluted water. Carp are a popular food fish in Asia, Europe, and some parts of the United States.



CARP
The carp likes still or slow-moving water, where it feeds on a wide range of insects and other small animals.

CARRIER A carrier has two meanings in medicine. People can be carriers of a disease if they have the disease-causing organism in their bodies but do not show the symptoms of that disease. This happens for bacteria (e.g., cholera) and viruses (e.g., AIDS). Carriers can pass on the disease without knowing they are infected.

The other type of carrier is involved in some diseases caused by a specific gene (see GENETICS). Sometimes, an individual has to have one set of that gene from both parents before the disease develops (this is called a recessive gene). If only one recessive gene is present, the disease does not develop. However, the person can pass on the disease-causing gene to his or her children. That person is a carrier for that gene, as are the children. For example, hemophilia and color blindness are inherited from carriers (see COLOR BLINDNESS; HEMOPHILIA).

CARROT The carrot is an edible orange root that belongs to the parsley family. Although the carrot produces stems and leaves above the ground, it is the underground root that is eaten as a vegetable. Carrots are rich in sugar, iron, and carotene (see CAROTENE; PARSLEY FAMILY).

Carrots are grown throughout the world. They can be roasted and ground to be used as a coffee substitute. The Romans and Greeks used them as medicine.

CARROT
Carrots store food, mainly in the form of starch, in the outer part of the root.

CARSON, RACHEL LOUISE (1907–1964) Rachel Carson was an American writer and marine biologist. Carson is best remembered for her books, especially *Silent Spring,* published in 1962. This book warned of the consequences of unwise use of pesticides. The book said that pesticides pollute the earth's water. This pollution harms and kills organisms that live in the water, thus breaking the food chain. The book led to restrictions on the use of pesticides in many parts of the world (see FOOD CHAIN; PESTICIDE).

Carson was born in Springdale, Pennsylvania. She was graduated from the Pennsylvania College for Women in 1929. Carson then studied and worked at a marine biology laboratory at Woods Hole, Massachusetts, and at Johns Hopkins University in Baltimore, Maryland. In 1936, she joined the U.S. Bureau of Fisheries (now the U.S. Fish and Wildlife Service). She became editor of the bureau's publications.

CARTILAGE Cartilage is a type of strong connective tissue found in the bodies of vertebrate animals (see CONNECTIVE TISSUE; VERTEBRATE). Cartilage has many roles in the human body. It provides support for certain body parts, such as the ears and nose. It also connects bones, such as the ribs and breast bone. Cartilage can cushion, too. There is a great deal of cartilage around the knee, where the tissue helps absorb the shock of walking and running.

Before an animal is born, most of its skeleton is cartilage. Much of the skeleton changes into bone soon after birth. The skeleton of sharks and other primitive fishes is all cartilage. Cartilage is also called gristle.

See also ARTHRITIS; BONE; SKELETON.

CARTOGRAPHY (kär tŏg′rə fē) Cartography is the art and science of making maps. A map is a representation, usually on a flat surface, of all or part of the features of the earth and other planets.

See also MAP AND MAPPING.

CARVER, GEORGE WASHINGTON (1864–1943) George Washington Carver was an African-American who is famous for his research in agriculture. He began the science of chemurgy, which is the use of agricultural products in industry.

Carver was born a slave on a farm near Diamond Grove, Missouri. Carver's parents were killed when he was young, and he was raised by the people who had been his owners. Carver became a free person when slavery ended in 1865. As a child, he was very interested in nature. Carver eventually became known as "the plant doctor" because he had learned so much about plants and their growth.

Carver was graduated from Iowa State Agricultural College, which is now Iowa State University, in 1894. Carver then took a job at the college as an assistant botanist (see BOTANY). While he studied to get his master's degree, Carver took care of the college's greenhouse. During this time, he developed a collection of over twenty thousand species of fungi, several of which were named after him (see FUNGUS).

In 1896, Booker T. Washington invited Carver to head the new Department of Agriculture at the Tuskegee Institute in Alabama. Washington was an African-American leader, educator, and founder of Tuskegee Institute, a college for blacks. Despite the fact that Carver had to set up his department with few resources, his work there greatly changed agriculture in the South. Carver's goal was to increase the productivity of southern farms in order to help small farmers make a profit. He persuaded southern farmers to grow crops such as peanuts, pecans, and sweet potatoes, which return nutrients to the soil. These farmers had been planting crops such as cotton, which remove nutrients from the soil. To increase the demand for these new products, Carver invented uses for them. He developed over 300 products from the peanut, including instant

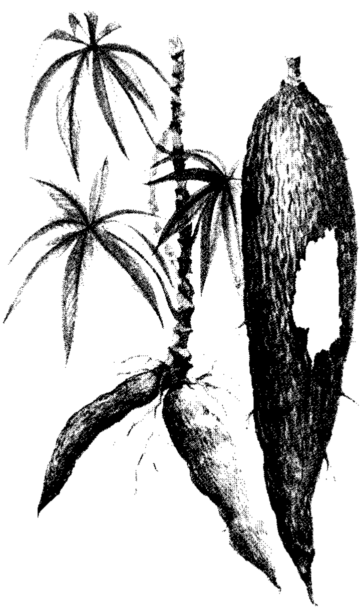
GEORGE WASHINGTON CARVER
George Washington Carver became famous as an agricultural researcher.

"coffee," ink, plastics, and soap. He developed 118 products from the sweet potato, such as flour, rubber, and shoe polish. Carver's experiments in chemurgy also led to the creation of synthetic, or human-made, marble from sawdust. When World War I (1914–1918) prevented the United States from importing dyes from Germany, Carver created over 500 dyes from 28 different plants.

Carver won many awards for his work, including election to England's Royal Society in 1916. In 1953, the U.S. Congress established the George Washington Carver National Monument on the Missouri farm where he was born.

CASEIN (kā sēn') Casein is the main protein in milk. Lumps of casein, called curd, can be separated from milk by adding acids such as lemon juice or by allowing the milk to sour. Pure casein is a white, tasteless, odorless, custardlike material. It can be eaten as a food or used to make cheese. Commercially produced casein is washed, dried, and ground into a powder. This powder is used in cosmetics, medicines, glues, and plastics. Casein plastic was first produced in 1897. It is still used today to make buttons, buckles, and knitting needles.

CASSAVA (kə sä'və) The cassava is a small, evergreen shrub belonging to the spurge family (see SPURGE FAMILY). Cassava, also known as manioc, is raised in South America, Central America, and the southern United States for its edible roots. These often reach a length of 3.3 ft. [1 m] and a diameter of 8 in. [20 cm].



CASSAVA

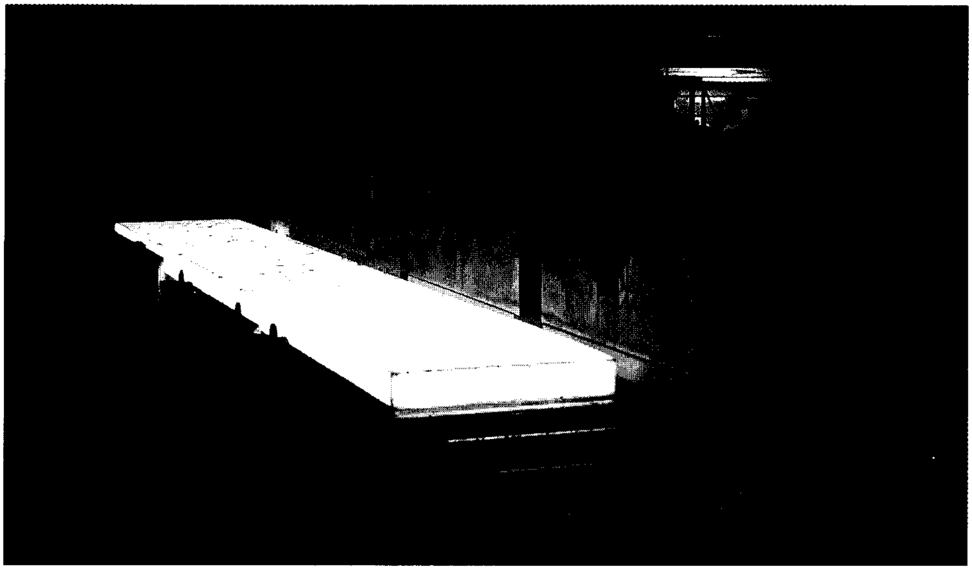
Originally from tropical America, cassava is now one of the most important food crops throughout the tropics. Its starch-filled roots can weigh over 22 lb. [10 kg].

There are two main varieties of cassava. One is sweet cassava, whose roots can be eaten raw or cooked like potatoes. The other is bitter cassava. Its roots contain a poison that must be removed before the roots can be used. Purified bitter cassava roots are used to make tapioca, flour, and laundry starch.

CASTING Casting is a way of shaping an object. First, the material of which the object is to be made is turned into a liquid by heating it. Then, the liquid is poured into a mold and left to harden. The shaped object also is called a casting, or a cast. Egyptians were casting bronze in molds more than 3,500 years ago.

Before materials are cast, a pattern is made. These patterns are used to make the molds from which the casts will be made. One-piece patterns are called loose patterns. Loose patterns are used to shape very large objects. Usually, only a few of these objects need to be made. A match-plate pattern is made by dividing the pattern into halves. A split pattern is made of halves that can be fitted and locked together.

Many metals are cast in green sand. Green sand is a mixture of sand, clay, water, and a binder. The binder holds the grains of sand together. If a metal is going to be cast from a split pattern, one-half of the pattern is placed on a board, with the flat side down. The board is then surrounded by two boxes, making up a flask. Sand is packed very hard around the pattern, filling the spaces between the pattern and sides of the flask. The board is then removed. The other half of the pattern is fitted to the first half. Sand is packed around this half. The top half of the flask is called the cope, and the bottom half is called the drag. After the pattern is taken out of the sand, the cope and the drag are fitted together to make a mold. A small opening, called the gate, is formed in the cope, allowing the substance to be poured into the mold. The substance cools in the mold, forming a solid. The sand is then broken away. This type of casting, called sand casting, is widely used.



CASTING

Materials that melt and flow, such as iron and steel, can be cast in different shapes by melting them and pouring them into a mold. Steel cast in slabs is rolled into strips in this strip mill. The steel strips will be used as a raw material for manufacturing articles elsewhere.

Permanent-mold casting is similar to sand casting. The difference is that the mold, or die, is made of metal. The same die may be used many times, instead of a new one being made for each cast. Pit molding is needed to make extremely large casts. Such casts are molded in a deep pit. It may take up to several weeks to complete the cast in a pit mold. In centrifugal casting, molds are spun around while the metal is being poured.

Shell molding, die casting, and the lost wax process are three methods used to make accurate castings. In shell molding, the pattern halves, from 0.25 to 0.5 in. [6 to 13 mm] in thickness, are held together by weights or clamps. The pattern is heated and placed in the molding substance. This substance is a mixture of sand and a type of plastic. In die casting, the liquid metal is forced into a mold. The casts are removed after they cool. In the lost wax process, wet plaster of Paris is placed around a wax pattern. The mold is usually baked. The wax runs out or evaporates, leaving a very accurate mold. This method is often used to make dental plates.

CAST IRON Cast iron is an alloy of iron, carbon, and other elements (see ALLOY). This alloy usually contains between 2 and 5 percent carbon, making cast iron very hard and brittle. Because it can absorb great shocks, cast iron is an important construction material. It also is widely used to make machine frames and engine blocks.

Cast iron is made by melting pig iron, which is iron with nothing added to it. Pig iron is made in a blast furnace. In gray cast iron, which contains 1 to 3 percent silicon, flakes of graphite (a form of carbon) are present. The graphite makes gray cast iron easy to process by machine. White cast iron, with a smaller amount of carbon and silicon, contains no graphite. White cast iron is very hard. It is almost impossible to process by machine. Malleable cast iron is made by heating and gradually cooling white cast iron. This method allows the formation of graphite, making the alloy easier to roll and hammer into shape. Malleable cast iron is often used instead of cast steel. Malleable cast iron is cheaper to make and is much easier to melt.

See also CARBON; IRON.

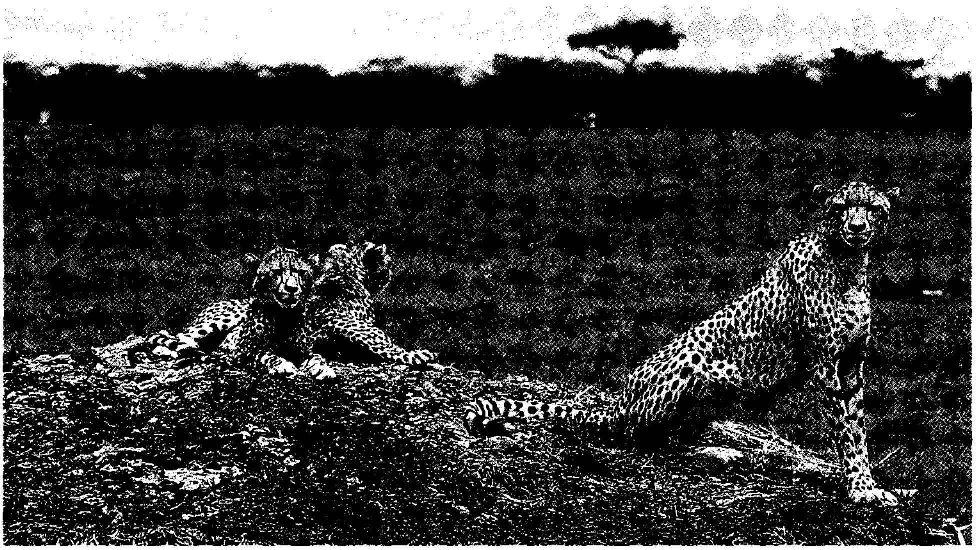
CAST IRON

The strength of cast iron makes it suitable for making items ranging from vehicle engine blocks to machine frames. This fire hydrant is also made from cast iron.

CAT A cat is a mammal that is a member of the family Felidae. Of the thirty-eight species of cats found around the world, only one is kept as a house pet. Cats are carnivorous (see CARNIVORE). In the wild, they are generally nocturnal (active at night), preying on other mammals and birds. In addition to highly developed night vision, cats have keen hearing and sense of smell. Other features all cats share are thick fur, twenty-eight to thirty long pointed teeth, a rough tongue, and sharp claws. All but the cheetah can draw their claws back into their paws. Cats are native to all parts of the world except Antarctica, Australia, New Zealand, and some parts of Oceania. There are many different kinds of cats. The lion, tiger, leopard, jaguar, cheetah, and puma are large cats. They may occasionally attack humans. The bobcat, lynx, ocelot, and margay are smaller, less dangerous cats.

There are about thirty-six varieties, or breeds, of domestic cats. House cats weigh about 8 lb. [3.6 kg] when fully grown. They are popular as pets and valuable for killing rats and mice in situations where those animals are considered pests. Cats are more independent than dogs. They have good memories and learn rapidly. Cats also have a strong homing instinct, and their cleanliness is well known. After mating, the female is pregnant for about two months. She gives birth to a litter of from two to five kittens, and she feeds them milk for about eight weeks. If well cared for, cats can live for fifteen years or longer.

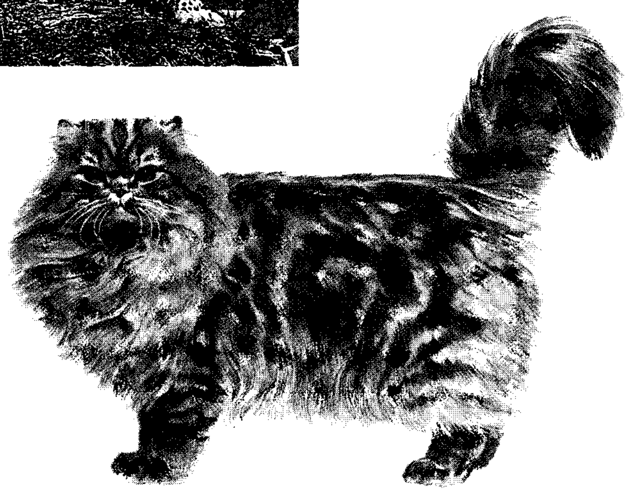
Short-haired breeds are derived from an African species domesticated by the ancient Egyptians about four thousand years ago. The Crusaders brought these animals to Europe, where they were interbred with small native wildcats. Long-haired domestic cats first appeared in Europe in the 1500s. Persian and Angora cats are among the most



CAT

The cheetah (left) is one of the larger cats. It is the fastest of all land animals. It can run at speeds of 70 m.p.h. [112 kph] for short distances. It lives in small family groups and hunts antelopes. The cats pictured below are just two of the many breeds of domestic cats.

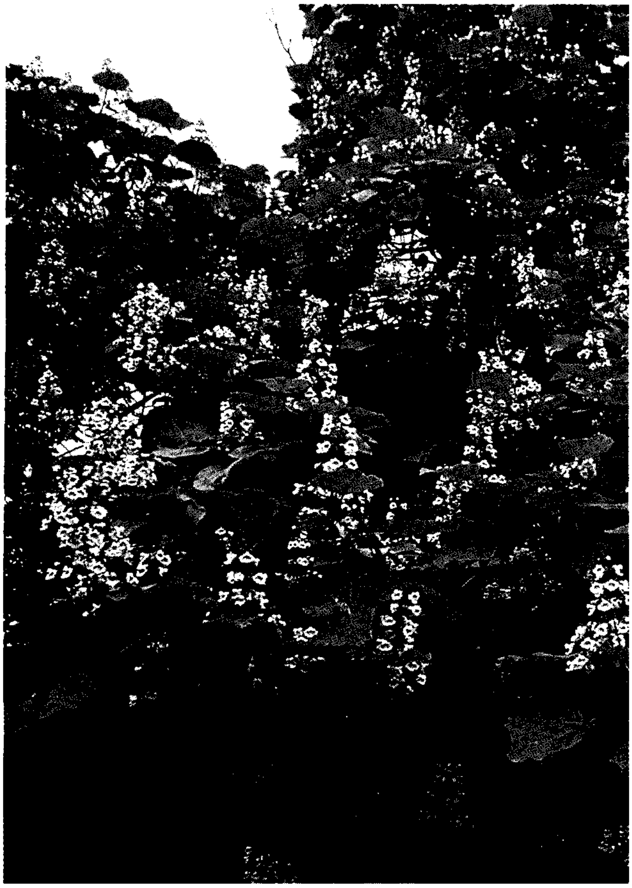
Blue-cream British shorthair



Persian red tabby longhair

popular of the long-haired breeds. Varieties of short-haired cats are much more numerous. They include the Siamese, most popular of all breeds, as well as the Burmese, Abyssinian, Maltese, Manx, and Russian Blue. The most common modern breed is the American, or domestic, shorthair, of which the calico type is a favorite variety.

CATALPA (kə tăl′pə) A catalpa is a tree that belongs to the genus *Catalpa.* There are two species of catalpa in North America, the southern catalpa and the northern catalpa. The southern catalpa grows to about 60 ft. [18.3 m], but the northern catalpa can reach 120 ft. [36.6 m] in height. Both species grow lovely white flowers and are planted for decoration. The catalpa seed pod looks like a string bean, and the trees are sometimes known as bean trees.



CATALPA
Catalpa flowers grow in large, candle-shaped spikes. The long, slender seed pods are dark brown or black when they are ripe. In addition to the two species that grow in North America, there are bean trees in the West Indies and in eastern Asia. There are many cultivated varieties of catalpa as well.

CATALYST (kăt′l ĭst) A catalyst is a substance used to change the speed of a chemical reaction. The catalyst itself does not change during this process. For example, potassium chlorate can be heated to obtain oxygen. Without the presence of a catalyst, this process occurs slowly. The same reaction happens rapidly when a small amount of manganese dioxide is added. The manganese dioxide remains unchanged.

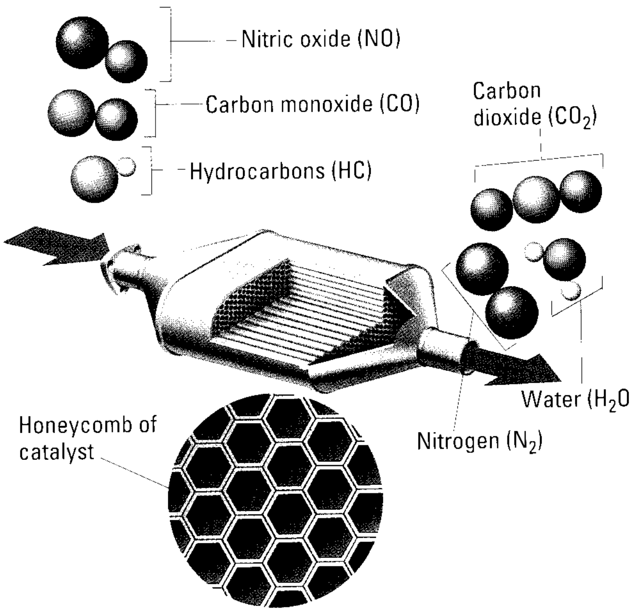
A catalyst may also be used to slow down a reaction. For example, gypsum is added to Portland cement to slow the hardening process. This reduces the possibility of cracking in the cement.

Catalysts may work in two ways. Surface, or contact, catalysts work by adsorption. The reacting chemicals are adsorbed to form a concentrated layer at the surface of the catalyst. Being concentrated, the chemicals react more quickly. For example, hydrogen and oxygen combine at the surface of powdered platinum to make water (see ABSORPTION AND ADSORPTION). Without the use of contact catalysts, many industrial processes could not be effectively performed.

Homogeneous, or chemical, catalysts take part in a chemical reaction. They form compounds with the reacting chemicals. These compounds react, forming the product and reforming the original catalyst.

Small amounts of catalysts are necessary to make many chemical products, such as plastics, rubber, gasoline, oils, sulfuric acid, and ammonia. In plants and animals, organic catalysts, called enzymes, speed up many body processes. For example, ptyalin is an enzyme found in human saliva. It speeds up the change of dissolved starch to dissolved sugar during digestion (see ENZYME).

CATALYTIC CONVERTER (kăt′l ĭt′ ĭk kən vûr′tər) A catalytic converter is a device designed to reduce harmful emissions from a gasoline engine. When gasoline is burned inside an engine, gases harmful to people and the environment are produced. They include carbon monoxide, hydrocarbons, and nitrogen oxides (see CARBON MONOXIDE; HYDROCARBON). Breathing carbon monoxide can cause drowsiness,



CATALYTIC CONVERTER
This steel container houses a honeycomb of precious metals that trigger chemical reactions in automobile exhaust gases as they flow through it. These reactions transform harmful engine exhaust gases into gases that are less harmful to people and the environment.

unconsciousness, or even death, depending on how much is breathed in. Some hydrocarbons can cause cancer. Nitrogen oxides make breathing difficult and cause acid rain (see ACID RAIN).

A catalytic converter is fitted in the engine's exhaust pipe. Exhaust gases flow through a honeycomb of materials inside the converter. The honeycomb is coated with a thin layer of precious metals, usually platinum, palladium, and rhodium. They act as a catalyst and trigger rapid chemical reactions in the exhaust gases (see CATALYST). A honeycomb is used because it has a huge surface area over which chemical reactions can take place.

There are two types of catalytic converters. A two-way converter changes carbon monoxide into carbon dioxide, and hydrocarbons into carbon dioxide and water (see CARBON DIOXIDE). A three-way converter also changes nitrogen oxides into nitrogen gas, carbon dioxide gas, and water. A car fitted with a catalytic converter must not use fuel that contains lead because lead coats the precious metals inside the converter and stops it from working.

See also AUTOMOBILE; NITROGEN; OXYGEN.

CATERPILLAR The caterpillar is the larval stage of a butterfly or moth. Butterflies and moths go through four life stages: egg, larva (caterpillar), pupa, and adult (see BUTTERFLY AND MOTH; LARVA; METAMORPHOSIS). The caterpillar's body is divided into a head, thorax, and abdomen. Together, the thorax and abdomen are made up of thirteen segments. Most segments have a pair of spiracles, which are openings used for breathing (see ABDOMEN; THORAX).

The head has strong jaws, which the caterpillar uses to eat its way out of its eggshell. Later, these jaws are used for eating leaves and other plant material. A few caterpillars eat insect eggs and larvae. The caterpillar's head also has two tiny antennae and up to six small eyes (see ANTENNAE). Below the mouth is an organ called a spinneret, which squirts out a liquid that hardens into a fine thread. This thread can be used for holding on to a surface as the caterpillar moves along. Some caterpillars hang from trees on this thread. Others use it to swing from one place to another. Later it may be used to make a cocoon.

The first three body segments make up the thorax. Each of these segments has a pair of clawed legs, which later become the legs of the adult butterfly or moth.

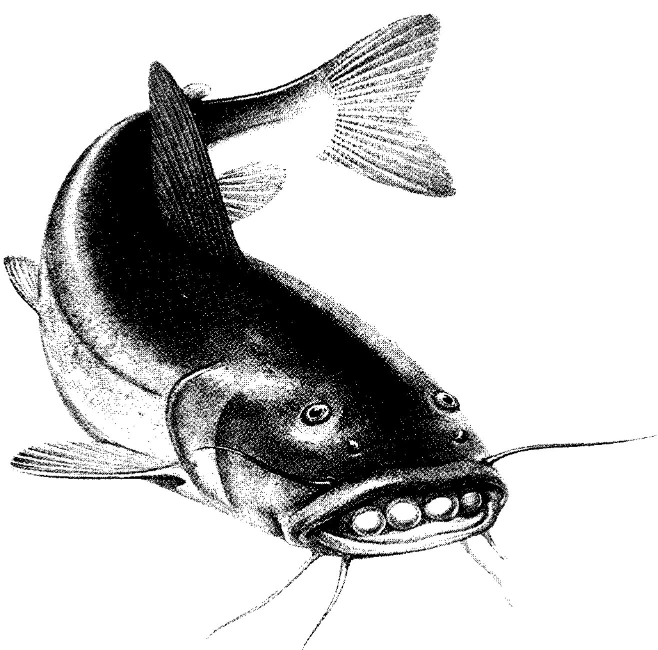
CATERPILLAR
These caterpillars belong to the buff-tip moth that lives in Europe and Asia. They have a bad smell, and their bright colors warn birds that they also taste bad. These caterpillars live in groups and can do much damage to forest trees.

The other ten segments make up the abdomen. The stumpy, fleshy legs on these sections are lost when the caterpillar enters the pupal stage. Caterpillars shed their skins several times before reaching the pupal stage.

Birds, insects, and small animals eat caterpillars. Caterpillars protect themselves with either special structures or poisons. Some caterpillars have hairy or barbed bodies. Some of these hairy caterpillars also produce a poison, which can be injected through special stingers into a predator. Other caterpillars can spit a poison at an attacker. Many have bitter or poisonous body fluids. These caterpillars are often brightly colored so that birds and other predators learn not to eat them (see WARNING COLORATION).

Many caterpillars feed only at night. Some build protective tents or webs. Many caterpillars have protective coloring, or camouflage, that helps them blend in with their surroundings. Some can even change colors so that they are brown when on a twig or green when on a leaf (see CAMOUFLAGE).

CATFISH Catfish is a name for many kinds of fishes. Although there are saltwater catfishes, most species are found in fresh water. There are many catfish families. The freshwater catfish family of North America is the Ictaluridae. This family includes bullheads, madtoms, and catfishes. There are seven fishes that are called catfish found in eastern and central North America. Some species, such as the flathead catfish and blue catfish, can weigh more than 100 lb. [45 kg]. Such catfishes live near the bottom of slow-moving rivers and lakes. They have four pairs of barbels (thin, fleshy growths) around their mouths. These barbels look like the whiskers of a cat, which is how the fish got its name. The barbels are used by the fish to find food.



CATFISH

This fierce-looking catfish is a saltwater species belonging to the family Ariidae. The male protects the eggs by keeping them in its mouth. Four large eggs can be seen in this picture.

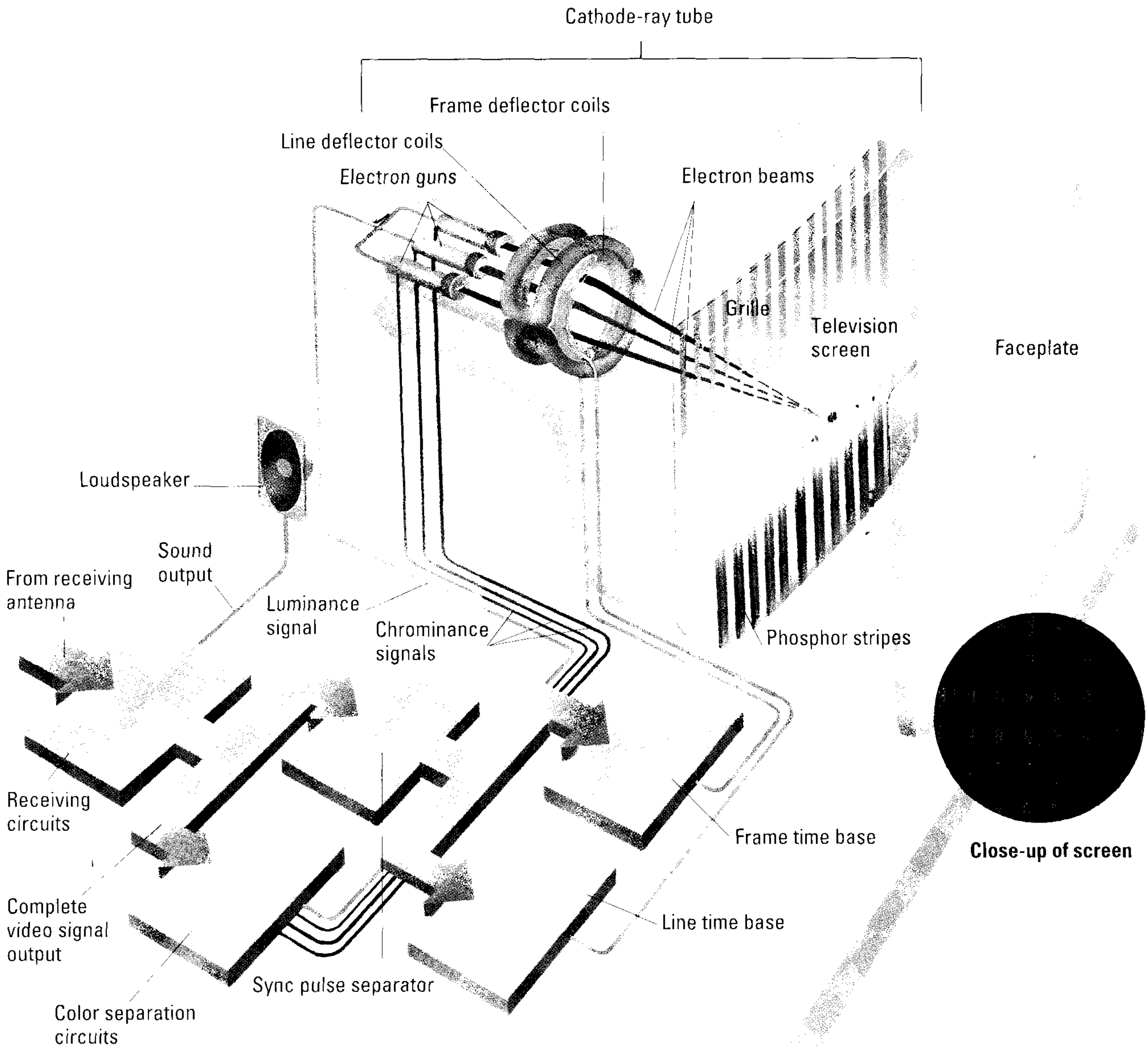
The walking catfish belongs to a different family. This catfish is able to leave water and crawl to another body of water. In the United States, it is found only in Florida.

See also FISH.

CATHODE-RAY TUBE A cathode-ray tube is a funnel-shaped electronic device that encloses a vacuum (a space that contains no matter). The flattened end of a cathode-ray tube is used for the screens of radar and television sets and oscilloscopes (see OSCILLOSCOPE; RADAR; TELEVISION).

The narrow end of a cathode-ray tube contains a cathode. A cathode is a negatively charged electrode (see ELECTRODE). It is also known as the electron gun because it emits a stream of negatively charged electrons (see ELECTRON). Magnetic or electrostatic fields focus these electrons into a steady beam, called a cathode ray (see ELECTROSTATICS; MAGNETISM). This beam is directed at the flat end of the tube, or the screen. The screen is coated with fluorescent substances (see FLUORESCENCE). When the electron beam hits these substances, a spot of light is produced.

The strength of the electron beam, which affects the brightness of the spot of light, can be controlled by adjusting the anode, or positive electrode. The anode is located between the electron gun and the screen. The beam can be made to move by several sets of oppositely charged plates. The plates are located above and below and on either side of the beam. The plates can move the electron beam in a horizontal or vertical direction and also in curves or



CATHODE-RAY TUBE

The cathode-ray tube in a television set contains electron guns that fire beams of electrons at the screen. They make the inside coating on the screen glow to form red, green, and blue points or stripes. Coils of wire in the neck of the tube produce a changing magnetic field that makes the electron beams sweep from side to side across the screen and also from top to bottom to produce a picture that fills the screen.

zigzags. A picture is produced by the electron beams moving very rapidly down the screen one line at a time. The movement is so rapid that it cannot be seen by the human eye.

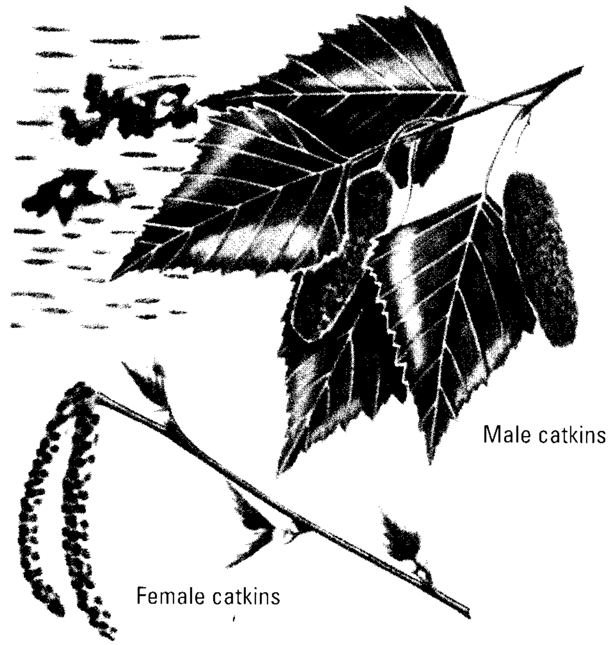
See also ELECTRONICS; TELEVISION.

CATION (kăt'ī'ən) A cation is an atom (or a group of atoms) with a positive electrical charge because it has lost one or more electrons. It is called a cation because it is attracted towards a cathode, the negative electrode in an electric circuit. If electrodes are dipped in a solution containing copper sulfate, and an electric current is passed through the solution between the electrodes, positive copper ions (cations) are drawn through the solution towards the cathode, and negative sulfate ions (anions) are attracted to the anode.

See also ANION; ELECTROLYSIS; IONS AND IONIZATION.

CATKIN A catkin is a flower spike made of very small flowers, which often do not have any petals. Each catkin is either male or female and produces either pollen or seeds. Most catkins hang from the twigs and are pollinated by the wind, although some are pollinated by insects.

See also FLOWER; INFLORESCENCE; POLLINATION.



CATKIN

Male birch catkins open at the same time as the leaves. The wind blows their pollen to small female catkins. Seeds then grow in the female catkins. Ripe female catkins hang among the leaves and eventually break up to release their seeds.

CATS'-EYES Cats'-eyes are studs set in the road surface to help drivers see the road at night. They consist of glass reflectors fixed to a rubber pad which sits inside a metal base. When a vehicle approaches at night, light from its headlights is reflected back to the driver. Cats'-eyes are so named because they look like a cat's bright eyes at night. Lines of cats'-eyes are set into the road along the edges and between the lanes. At night they look like lines of glowing lights in the road surface. Cats'-eyes were invented by Percy Shaw, a British engineer, in 1934. His first cats'-eyes soon became useless because of dirt on the glass reflectors. He solved this problem by changing the design so that the weight of a vehicle driving over them pressed the rubber pad down and automatically wiped the reflectors clean.

CATTLE Cattle are hooved mammals belonging to the family Bovidae (see MAMMAL). Cattle have been domesticated for many centuries and are now reared in almost every country in the world. They supply people with meat, milk (from which other dairy products, such as cheese and yogurt, are made), and hides for leather goods. Cattle also supply other substances used in making medicines, soap, and glue. In some countries, cattle are used in place of horses for farm work.

Cattle have large, heavy bodies, long tails, and cloven (divided) hoofs. They may grow as tall as about 5 ft. [1.5 m] and weigh as much as 2,035 lb. [925 kg]. They have short hair and can be black, white, brown, yellow, or red.

A cow is the female of cattle. A bull is the male. A steer is a male with its testicles (reproductive glands) removed. A heifer is a cow that has not yet given birth to a calf. *Calf* is the name given to baby cattle.

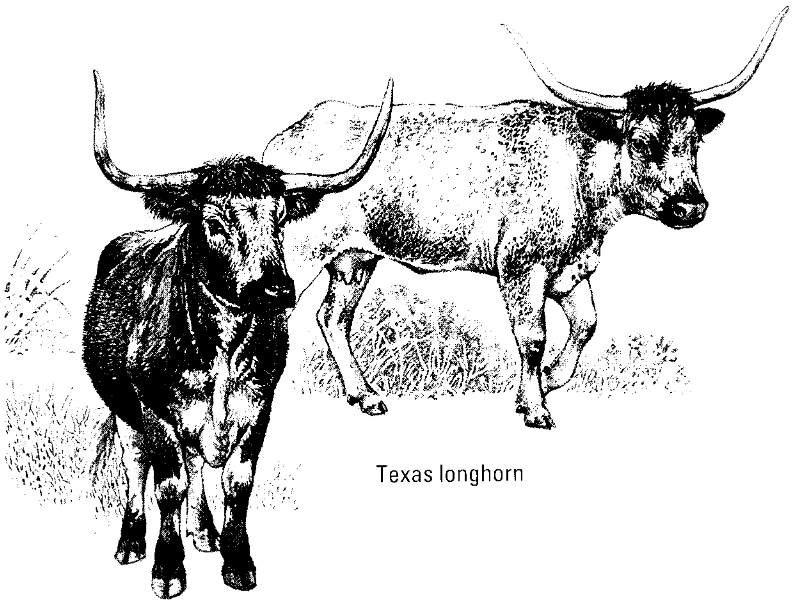
Cattle have teeth in the back of both their upper and lower jaws and in the front of the lower jaw. The absence of upper teeth in the front of the mouth prevents cattle from biting into their food. They have to tear grass out of the ground by jerking their heads back and forth. The stomach of cattle has four compartments. When something is eaten, it is chewed slightly and swallowed. It goes to one of the compartments in the stomach. Later, it is brought back up into the mouth. This returned food is called cud. The animal chews the cud and swallows it again. The cud now goes through the other compartments in the stomach and continues through the digestive system (see RUMINANT).

Most cattle have small, unbranched horns. Farmers prefer hornless, or polled, cattle because the horns can cause injuries. Breeding has eliminated horns in some varieties. Special chemicals have been used to remove horns from other varieties.

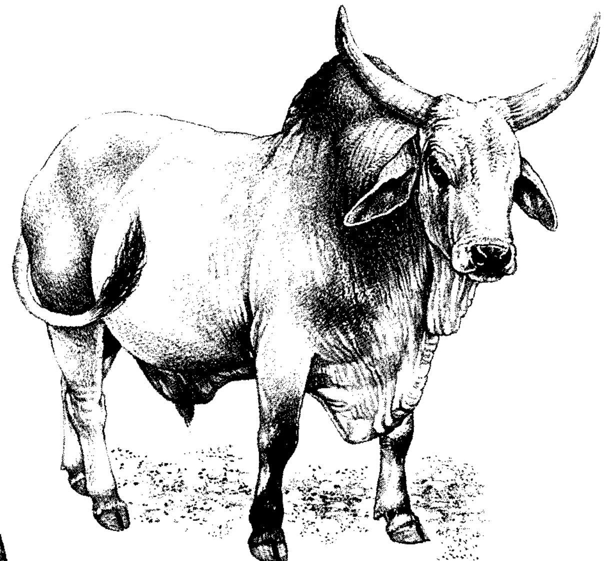
Between and in front of its hind legs, the cow has a saclike udder with four teats. Each of these teats leads to a separate compartment where milk is stored. Although some farmers still milk cows by hand, most larger dairy farms use machines that remove the milk by suction. Cows produce milk for about ten months after giving birth to a calf.

CATTLE

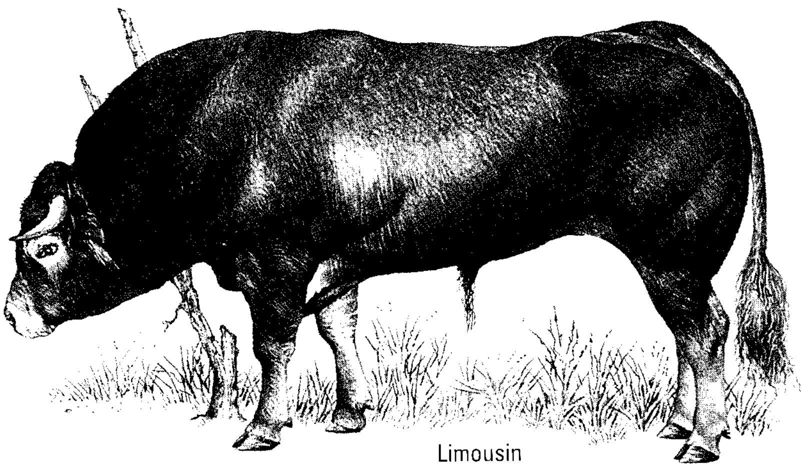
Different breeds of cattle are used for different purposes. The Kankrej is used for pulling carts and plows in its native India, but has been introduced to Latin America as a beef animal. The longhorns and the Limousin are also beef cattle, but the Normandy and the Finn are dairy breeds.



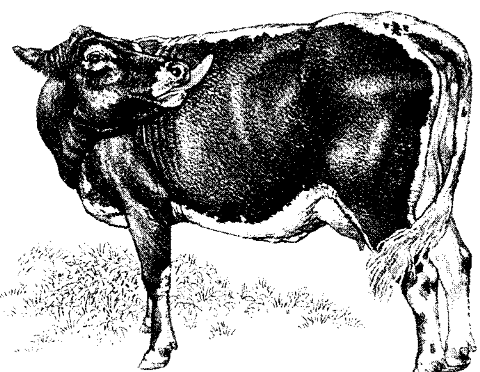
Texas longhorn



Kankrej



Limousin



Finn

Normandy

There are three major types of cattle. Beef cattle, such as Angus, Brahman, and Hereford, are raised for their meat. Meat from a calf that is less than three months old is called veal. Dairy cattle, such as Jersey, Guernsey, and Ayrshire, are raised for their milk. Holstein is the principal breed of dairy cattle in the United States. Dairy cattle are productive for about five years and are then slaughtered for their meat. Dual-purpose cattle, such as milking shorthorn and red poll, are raised for both meat and milk. The calves usually grow quickly and, when slaughtered, provide more veal than most other types of calves.

See also AGRICULTURE; ANTIBIOTIC; HORMONE.

CAVE

A cave is a natural opening in the earth that is big enough for a human or other animal to enter. Most caves are formed by the action of water on rocks such as limestone or dolomite. The water is a very weak acid, because it contains dissolved carbon dioxide. This acid dissolves the rock, forming passages and large open spaces. Water may come from rainfall or underground streams.

Many limestone caves have icicle-shaped stone formations called stalactites and stalagmites. Stalactites hang from the ceiling, and stalagmites rise from the floor (see STALACTITE AND STALAGMITE). Besides limestone caves, other types of caves include ice caves, lava caves, and sea caves. Most ice caves are formed within glaciers (see GLACIER). Lava caves are found near the base of a volcanic mountain (see VOLCANO). They are actually hollow spaces in hardened lava deposits. Sea caves are formed by the action of waves on seaside cliffs.

LIMESTONE CAVES

Limestone caves are formed as the calcium carbonate rock is slowly dissolved by streams of water flowing through cracks. Stalactites and stalagmites consist of limestone (calcium carbonate) that comes out of solution.

People and animals have long used caves for temporary shelter. Most caves are wet and cold year-round. Deeper caves usually have a twisting passage that keeps sunlight from reaching more than a few feet into the cave. Few organisms are able to live in the total darkness of most caves. Some animals, such as bats and snakes, live in caves for protection from the weather. These animals are usually nocturnal, carrying on most of their activity at night (see NOCTURNAL BEHAVIOR). Frequently bears and other animals that hibernate choose a cave for shelter during the winter (see HIBERNATION).

Some people have lived in caves for long periods of time. Drawings done by prehistoric people have been found in caves. Some of this early art dates back to about 20,000 B.C. In France, stone tools have been found in caves. Some of these tools are about 500,000 years old. It is likely that prehistoric cave dwellers lived at the entrance to the cave, or just outside of it. There are still isolated groups of cave dwellers living in Spain and in the Philippines.

Some famous caves in the United States are Carlsbad Caverns in New Mexico and Mammoth Cave in Kentucky.

STALACTITES AND STALAGMITES

Pillars of limestone link the floor and ceiling of this cave. The pillars formed over thousands of years where stalactites growing from the ceiling of the cave joined up with stalagmites growing upward from its floor. Colored lighting is used to dramatize the cave's interior for visitors.

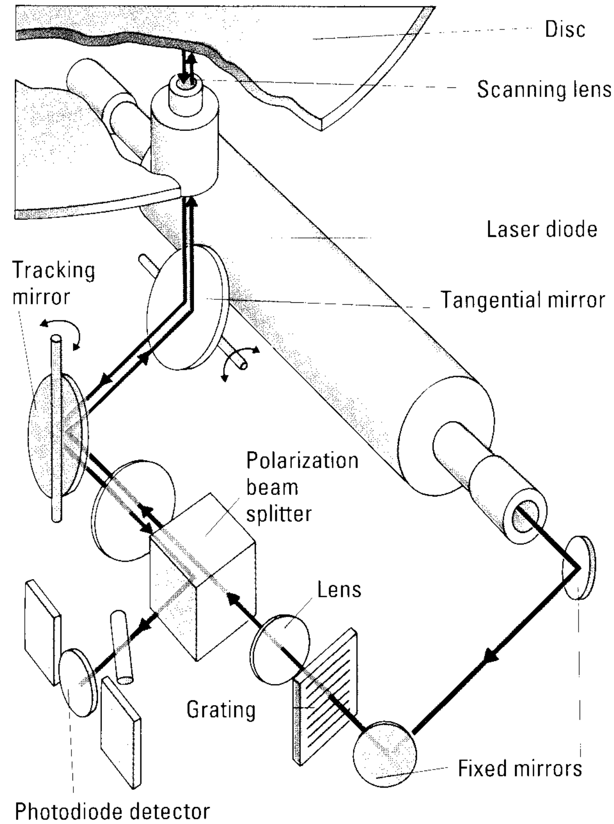
CAVENDISH, HENRY (1731–1810) Henry Cavendish was a British chemist and physicist. He made many important findings in the study of electricity. Cavendish gave himself electric shocks to estimate the strength of the current by the amount of pain he received. Because of his unusual methods and his careless attitude toward publishing his discoveries, Cavendish was looked upon as a colorful but odd personality during his life.

As a physicist, Cavendish made the first accurate device for measuring the force of gravity. He used a torsion balance, made up of a rod suspended by a wire. He placed a small ball at each end of the rod. Two large balls were brought toward the small balls. The rod swung slightly toward the large balls. This was caused by the gravitational attraction between the large and small balls. Cavendish measured the force involved to find the gravitational constant. From this, he determined the mass of the earth (see GRAVITY).

As a chemist, Cavendish was the first to discover the properties of hydrogen. He called the element "inflammable air." He showed that water is a compound of hydrogen and oxygen. Cavendish also removed the oxygen and nitrogen from a sample of air. The inert gas remaining was later discovered by Sir William Ramsay, who called it argon (see RAMSAY, SIR WILLIAM).

CAVITATION (kăv′ĭ tā′shən) Cavitation is the formation of bubbles or cavities (hollow places) behind a body that is moving rapidly in a liquid. For example, cavitation can occur behind the blade of a boat's propeller when the boat is moving. As a boat moves through water, the propeller pushes against the water. This thrusts the boat forward. If cavitation occurs, the propeller spins in a pocket of water vapor and air and does not work in the way it was designed. Cavitation also absorbs a great deal of energy, reducing a propeller's efficiency. Proper design can prevent cavitation from occurring.

CD-ROM The name CD-ROM stands for Compact Disc Read-Only Memory. A CD-ROM looks like an audio compact disc, but it is designed to be played by a drive unit connected to a computer



CD-ROM
Mirrors reflect a laser beam onto a CD-ROM disc. A lens focuses it onto a tiny spot. The position of the spot on the disc is controlled by swiveling mirrors. Reflections of the beam from the disc are guided onto a photodiode detector, a device that changes the flickering reflections into electricity.

instead of a compact disc player. Information stored on the disc is read by a laser and fed into the computer. The information may be sounds, music, text, drawings, photographs, movies, or video clips. Two or more different forms of information can be presented at the same time. While a photograph and text are shown on the computer screen, music may be playing through loudspeakers connected to the computer. The computer selects which part of the disc to read according to a computer program and also in response to keys pressed or a mouse clicked by the computer user. An entire multi-volume encyclopedia, with pictures, text, and added speech, animation, and film footage, can be stored on one disc. The use of different forms of information together, stored on CD-ROM and accessed by computer, is known as multimedia.

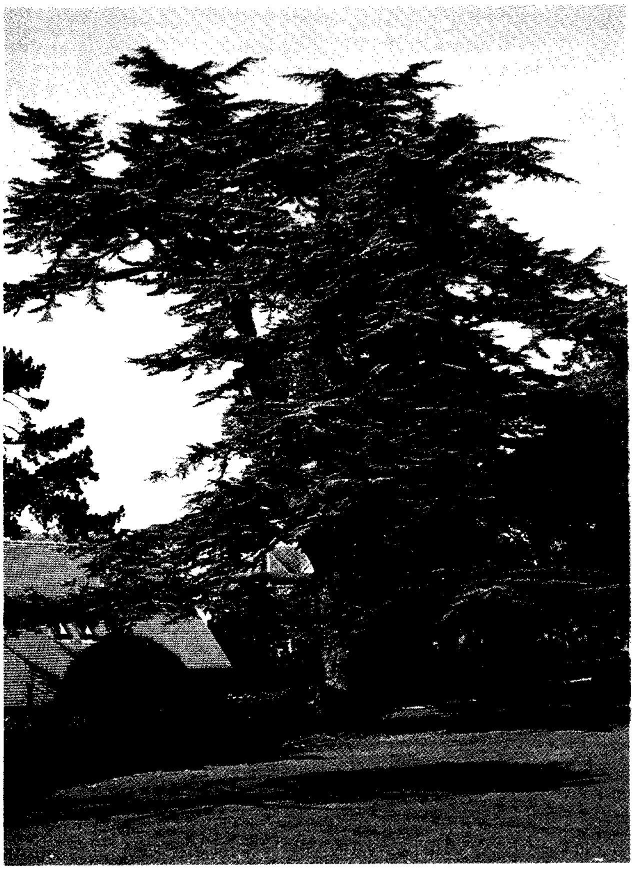
When CD-ROM was introduced in 1985, it was used mainly for training in education, business, and industry. The ability to jump to any part of a

disc within a second or so, called random access, is very useful for this training. A student or trainee can follow a course on a disc in his or her individual way, repeating lessons, looking at extra examples, or skipping unnecessary information. In recent years, the use of CD-ROM has become increasingly popular in schools and homes.
See also COMPUTER.

CEDAR Cedar is the name given to a number of evergreen trees that grow in many parts of the world. True cedars are coniferous trees that belong to the pine family, Pinaceae (see CONIFER; EVERGREEN). They are native to Africa, Asia, and Europe. Some true cedars are planted for ornamental purposes in warm areas of the United States. The best-known true cedar is the cedar of Lebanon, which has large, horizontal branches.

The cedars that are native to North America are not true cedars. They are members of the cypress family, Cupressaceae. These cedars include the northern white cedar, western red cedar, Atlantic white cedar, and eastern red cedar. The northern white and western red cedars are also called arborvitae (see ARBORVITAE).

Cedars are found in many different types of places. Atlantic white cedars are commonly found in swamps. Eastern red cedars can be found growing in old pastures. The wood of cedar trees is very strong. It rots very slowly, which also makes it a good wood with which to build. Cedar wood is often used in furniture, fence posts, shingles, and poles.
See also JUNIPER; SUCCESSION.



CEDAR
The cedar of Lebanon is easily recognized by its large, spreading branches. It is commonly planted in parks and large gardens, but is now rare in its native home around the eastern Mediterranean. It has upright, barrel-shaped cones and sharp, bluish green needles.

CELERY Celery is a biennial plant in the parsley family (see BIENNIAL PLANT; PARSLEY FAMILY). Native to Europe, celery has edible leaf stalks that can be cooked or eaten raw. In ancient China, celery was used as a medicine. The top of a celery plant has delicate leaves and small flowers. The seeds of the celery plant are used as a spice. Gray brown and about 0.1 in. [.25 cm] long, celery seeds are among the smallest seeds of all the cultivated plants. A variety of celery called celeriac has a swollen stem that is used as a vegetable.

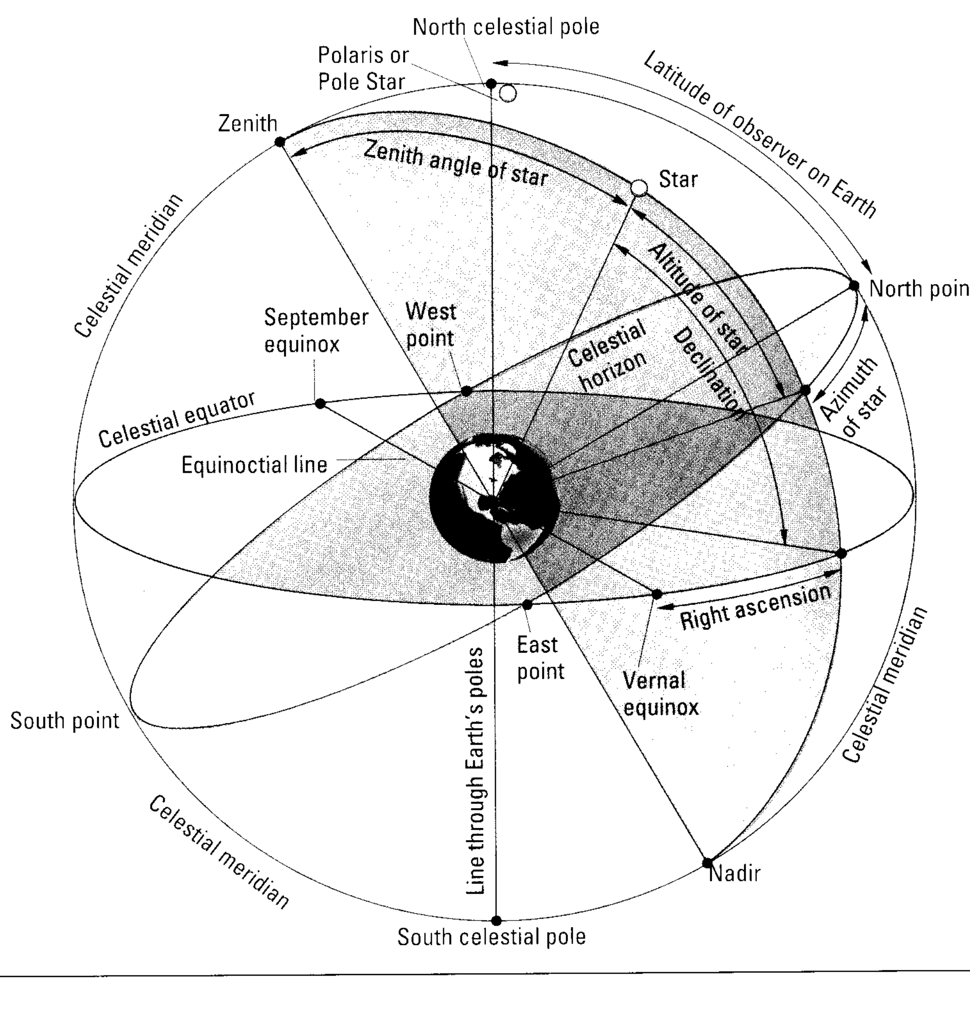
CELERY
This bunch of celery, trimmed and ready for market, clearly shows the swollen food-filled leaf stalks that can be eaten. The best-quality celery has almost-white stalks. Celery grown for making soups is greener, and the stalks do not form such a tight bunch.

CELESTIAL SPHERE (sə lĕs'chəl sfîr) The celestial sphere is used by astronomers to describe the positions of celestial (heavenly) bodies and as an aid in plotting maps of the heavens. The celestial sphere is an imaginary sphere of enormous radius (distance from the center to the outer surface), having the earth as its center. The points where the earth's axis, if continued into outer space, would pass through the celestial sphere are called the celestial poles. The celestial equator is the circle where a plane (flat surface) through the earth's equator would meet the celestial sphere.

Any point on the earth can be described by its latitude and longitude (see LATITUDE AND LONGITUDE). Points on the celestial sphere are described in a similar manner. Celestial latitude is called declination. Declination is measured from the celestial equator in the same way that latitude is measured from the earth's equator. Celestial longitude is called right ascension. The longitude of the earth is measured from the Greenwich meridian. In a similar way, right ascension is measured from a point on the celestial equator called the vernal equinox. The vernal equinox is the point where the sun crosses the celestial equator at the beginning of spring in the Northern Hemisphere.

There are other important points on the celestial sphere. The zenith is the point directly above the observer. The nadir is the point directly opposite the zenith on the celestial sphere. The celestial horizon is the circle that passes midway between the zenith and the nadir. The points where the celestial equator and the celestial horizon cross are called the east and west points. The prime meridian for a given observer goes through the zenith, nadir, and celestial poles. The points where the prime meridian crosses the horizon are the north and south points.

CELESTIAL SPHERE
The earth lies at the center of the celestial sphere, which is a huge imaginary sphere. The positions of heavenly bodies, such as stars and galaxies, on the celestial sphere can be described in terms of their declination (celestial latitude) and right ascension (celestial longitude).



CELL

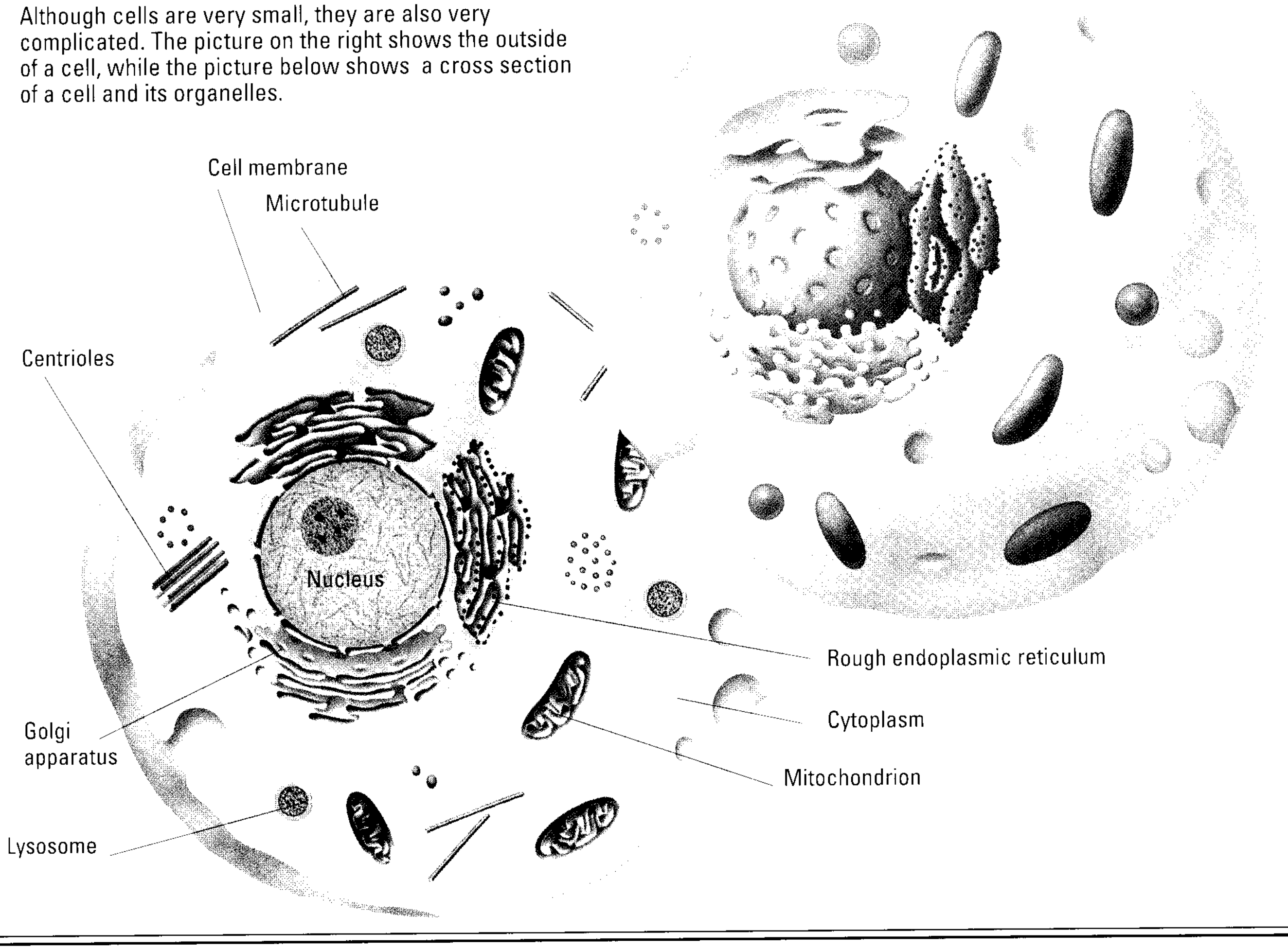
The cell is the basic unit of life. All living organisms are made up of one or more cells. The only possible exception is the virus. Viruses are acellular (not made of cells), but scientists are divided on the issue of whether a virus is a living organism (see VIRUS). Some cells, such as the yolk of an egg, are large enough to be seen with the naked eye. Most cells, however, are extremely small and can be seen only with the aid of a microscope (see MICROSCOPE).

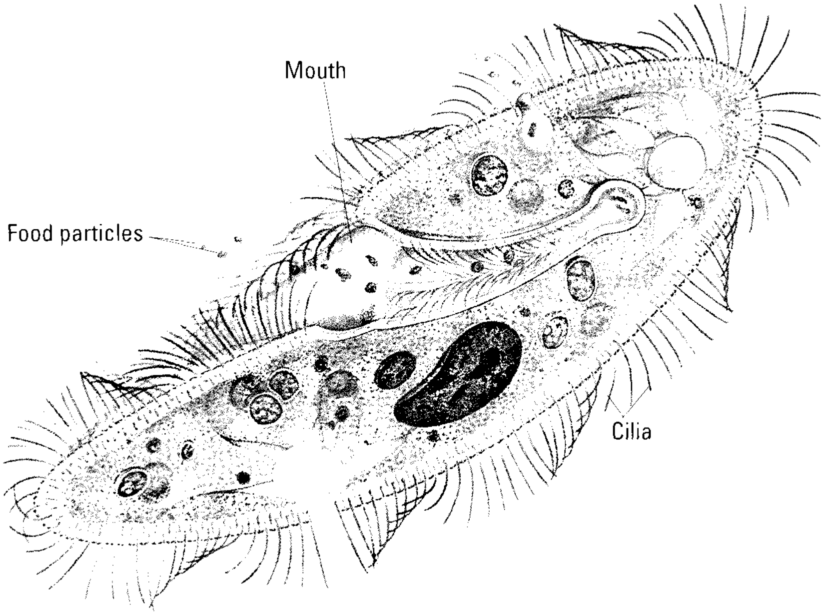
Some organisms consist of only one cell. This cell carries on all the functions of life (gas exchange, intake of food, excretion of wastes, growth, reproduction, and death). These one-celled organisms may live alone or in groups. Most organisms, however, are made up of many cells. The human body, for example, contains more than 10 trillion cells. In multicellular organisms, groups of cells are specialized to perform specific functions. A group of cells gathered together to perform a single function is called a tissue. A group of tissues gathered together to perform related functions is called an organ (see ANATOMY).

History In the seventeenth century, the first microscopes were developed (see LEEUWENHOEK, ANTON VAN). For the first time, scientists were able to look "inside" an object—beyond the outside features and into its internal structure. In 1665, Robert Hooke, an English scientist, looked at a piece of cork under a microscope. He noted that cork was made up of many tiny, boxlike structures. Hooke called these structures *cells.* In 1838, the German scientists Matthias Schleiden and Theodor Schwann proposed the cell theory. The cell theory states that all living things are made of cells (see SCHWANN, THEODOR).

CELL

Although cells are very small, they are also very complicated. The picture on the right shows the outside of a cell, while the picture below shows a cross section of a cell and its organelles.





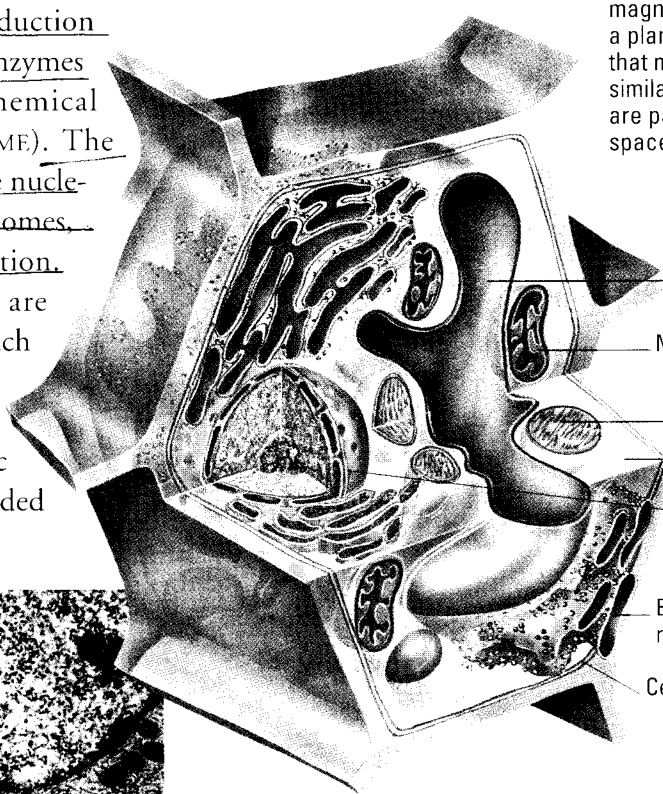
SINGLE-CELLED ANIMAL
Paramecium (left) is a single-celled animal just visible to the naked eye. It lives in water and swims by waving the tiny hairs, or cilia, that clothe its body. The cilia also bring microscopic bacteria and other food particles into its mouth.

BRAIN CELLS
The photograph below, magnified many thousands of times, shows some of the cells in the human brain.

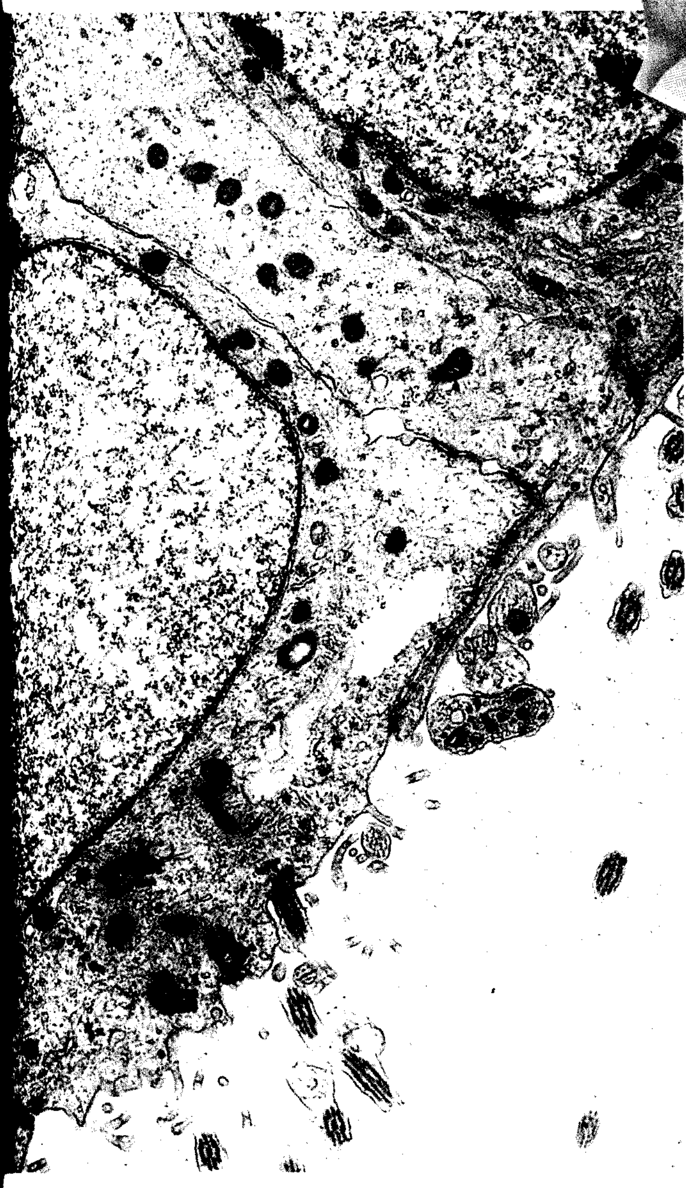
Cell structure Cells vary greatly in shape and size. The shape of a cell is usually related to its function. For example, an ameba cell has no particular shape. It is a jellylike blob that changes shape as it moves. On the other hand, some muscle cells in humans and other animals are long and thin, allowing them to contract when doing work. Cells vary in size from the tiniest, a bacterial cell measuring 0.0002 in. [0.0005 cm] long to the largest, an ostrich egg yolk measuring 3 in. [7.6 cm] long. Most cells, however, are about 0.001 in. [0.0025 cm] long. The size of a multicellular organism depends on the number of cells, not the size of the cells.

In spite of the differences in shape and size, all cells have the same basic structure. All cells are enclosed in an outer "skin" that is usually called the cell membrane (or plasma membrane). The cell membrane holds the cell together and separates it from its surroundings. The cell membrane is semipermeable—that is, it allows some substances through but not others. Within the cell membrane of most cells are the nucleus and the cytoplasm.

The nucleus is frequently called "the control center" of the cell because it directs most of the cell's activities. The nucleus is enclosed by a nuclear membrane which, like the cell membrane, is semipermeable. The nucleus contains special structures called chromosomes (see CHROMOSOME). The chromosomes contain genes, which control the heredity of the cell and ensure that all new cells produced from it are of the same kind (see GENE). Basically, the genes control the production and functioning of proteins called enzymes which, themselves, control the chemical processes within the cell (see ENZYME). The nucleus may also include one or more nucleoli. The nucleoli help produce ribosomes, the cell's centers of protein production. Cells with a well-defined nucleus are called eukaryotic cells. Some cells, such as bacteria, some algae, and red blood cells, do not have a well-defined nucleus. They are called prokaryotic cells. Their nuclear material is suspended in the cytoplasm.

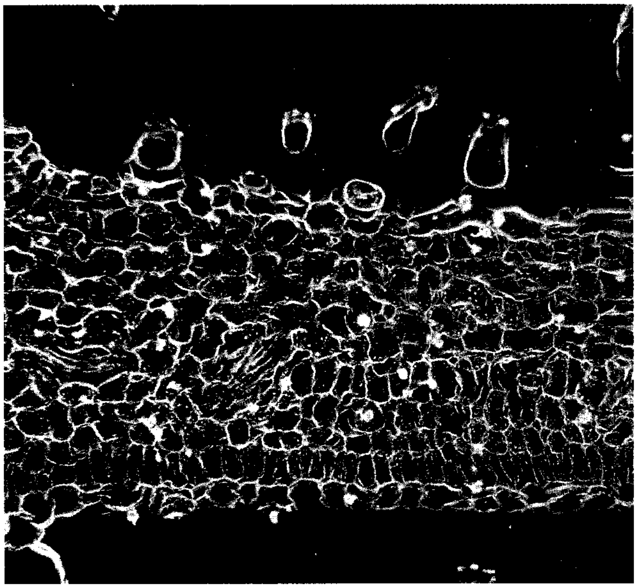


PLANT CELL
This very highly magnified drawing of a plant cell shows that many organelles, similar to tiny organs, are packed into a tiny space.



The cytoplasm is located in the cell between the cell membrane and the nuclear membrane (see CYTOPLASM). The cytoplasm is made up of a watery liquid, usually containing dissolved substances such as enzymes and digested food, and several kinds of structures called organelles. The semisolid, jellylike outer layer of the cytoplasm is the ectoplasm. The thin, liquid inner layer of the cytoplasm is the endoplasm (see ECTOPLASM; ENDOPLASM). The organelles include mitochondria, endoplasmic reticulum, ribosomes, lysosomes, centrioles, and Golgi bodies. Each organelle performs a special function to keep the cell working properly (see ORGANELLE).

Most cells have one or more mitochondria. The mitochondria are the "powerhouses" of the cell, producing most of the energy needed for cellular activities (see MITOCHONDRIA). The endoplasmic reticulum is a network of canallike passages between the cell membrane and the nuclear membrane. Ribosomes are tiny structures where proteins are made in the cell (see RIBOSOME).



CELL
This highly magnified section of a tobacco leaf shows several kinds of cells. The leaf is infected with a fungus disease, which is causing cells to break away from the surface.

Lysosomes are small, enzyme-containing structures that help break down many substances such as food and, in the case of white blood cells, bacteria. The centrioles are rod-shaped structures that are active in cell reproduction. The Golgi bodies store and release various substances from the cell.

Plant cells contain several additional structures. They have a strong cell wall surrounding the cell membrane. The cell wall usually contains cellulose and gives plants additional support and protection (see CELLULOSE). The cytoplasm of plant cells also contains organelles called chromoplasts and leucoplasts. Chromoplasts known as chloroplasts contain chlorophylls, the green pigments needed for photosynthesis (see CHLOROPHYLL; CHLOROPLAST). Other chromoplasts contain pigmented substances other than chlorophyll (see CHROMOPLAST). Leucoplasts are usually white or clear and are used to store starch. Most plant cells, and some animal cells, also contain vacuoles (see VACUOLE). Vacuoles are fluid-filled or gas-filled spaces in the cell that transport various materials within the cytoplasm.

Cell growth and reproduction Cells can grow in size only a little. The growth of multicellular organisms (plants and animals) is caused by an increase in the number of cells. The cells of an elephant, for example, are about the same size as (though much more numerous than) those of a mouse. Cells usually increase in number by splitting in two by a process called mitosis (see MITOSIS). In mitosis, a parent cell divides into two daughter cells, which are identical in appearance and genetic structure to the parent. In one-celled organisms, this process is a type of asexual reproduction called fission (see ASEXUAL REPRODUCTION).

Cells sometimes divide in a process called meiosis (see MEIOSIS). In meiosis, a parent cell divides twice, producing four daughter cells. Each of these daughter cells has half the number of chromosomes of the parent cell. Meiosis is characteristic of the production of gametes, or sex cells (see GAMETE). In sexual reproduction, a male gamete (sperm) joins with a female gamete (egg) to produce a zygote (see FERTILIZATION). This zygote has the full number of chromosomes.

Cell diseases Cells, like all living things, grow old and die. Some cells live for only a few minutes, while others may live for hundreds of years. In the human body, cells die at the rate of about 3 billion per minute. These cells are replaced, however, by new cells produced by mitosis.

Cells usually grow, function, and reproduce in an orderly and efficient way. There are certain diseases, however, that interfere with the normal course of events. In cancer, some cells seem to go wild and reproduce in unusually large numbers (see CANCER). These cells are different from normal cells and often have altered genetic codes. The cancerous cells exist in such great numbers that they interfere with the normal functioning of the other cells. Some viruses kill cells by interfering with the normal hereditary material in the cell. As the virus reproduces, it destroys the host cell, releasing hundreds of new viruses to attack other cells.

If the chemical reactions within a cell are interfered with or altered, the result is a metabolic disease (see METABOLISM). Many metabolic diseases are caused by a change, or mutation, in the genetic code.

See also CYTOLOGY; HEREDITY; MUTATION.

CELL, ELECTRICAL An electrical cell is a structure used to generate electrical current. In the late 1790s, the Italian physicist Alessandro Volta discovered that certain chemical reactions produce electricity. Placing a copper rod and a zinc rod in a container of acid, Volta found that a wire strung between the tops of the two rods carried an electric current. This was the first electrical cell, or combination of chemicals to produce electricity (see VOLTA, ALESSANDRO).

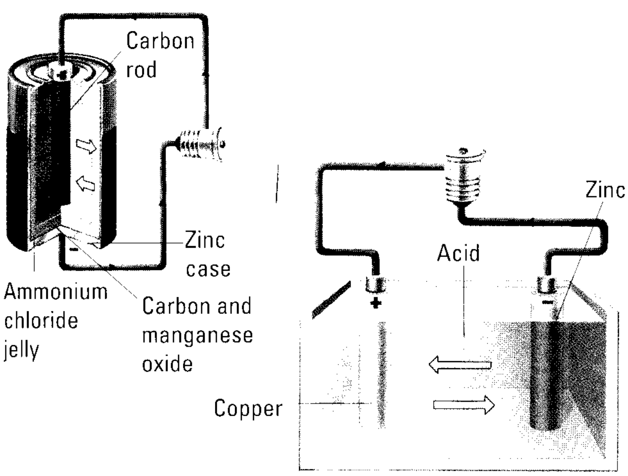
An electrical cell basically consists of two different plates called electrodes that are separated by chemicals called the electrolyte. The reaction of the electrolyte and the electrodes produces electricity at the electrodes. When the positive and negative terminals of a circuit are attached to the electrodes, the electrical cell provides a flow of electrons, or current, through the circuit. In some electrical cells, the electrolyte is a liquid. These cells are called wet cells. Other cells have a solid electrolyte and are called dry cells. The standard automobile battery is a series of wet cells, which are similar to the cell invented by Volta. The batteries used to supply electricity for flashlights and radios are dry cells. Dry cells usually consist of a zinc case containing a paste of chemicals and a carbon rod. The case and the rod are the electrodes. The paste of chemicals is the electrolyte (see BATTERY).

Cells like those of the automobile battery can be recharged. This means they can receive a supply of electricity after they have discharged, or lost their charge. The cell of a flashlight battery cannot be recharged, because its chemicals finish reacting together and change into other chemicals that do not produce electricity. Cells that can be recharged are called secondary cells. Cells that cannot be recharged are called primary cells. The recharging of secondary cells involves the reversing of their chemical reactions. A source of electricity supplied to the electrodes causes the electrolyte to take up rather than give off electrons. In automobiles, the chemical reaction of the cells of the battery is reversed by a supply of electricity from the generator, or alternator.

All electrical cells produce voltage, which supplies current only after the electrodes have been connected to the terminals of a circuit. A dry cell produces 1.5 volts. Each of the storage cells in an automobile battery produces 2 volts. By connecting cells in a series, higher voltages are obtained. The 12-volt car battery consists of six 2-volt cells. All cells provide direct current (see DIRECT CURRENT).

Today, scientists are finding more and more uses for two other kinds of electrical cells: fuel cells and solar cells. In the fuel cell, the electrolyte and electrodes are constantly replaced or renewed by the chemical combination of oxygen with hydrogen, or a hydrocarbon fuel. The solar cell is a semiconductor that produces electricity when struck by sunlight.

See also CIRCUIT, ELECTRIC; CURRENT, ELECTRIC; ELECTRODE; HYDROCARBON; PHOTOELECTRIC EFFECT; SEMICONDUCTOR.



CELL, ELECTRICAL
In an electrical cell, chemical reactions force electrons around circuits. A copper rod and a zinc rod, placed in acid, form a cell (right). In a modern battery (left), a carbon electrode replaces the copper, while the zinc casing is the negative electrode. The liquid acid is replaced by a paste.

CELLOPHANE Cellophane is a thin, flexible, synthetic (human-made) material that resists moisture. Most cellophane is transparent and either colorless or slightly tinted. Cellophane that is not transparent may have any color. In 1908, Jacques Brandenberger, a Swiss chemist, invented cellophane. It is made from cellulose, which comes from plants (see CELLULOSE).

Cellulose is obtained from wood fibers by a chemical process. Cellulose is then mixed with sodium hydroxide (caustic soda). This mixture is treated with carbon disulphide, forming viscose, a sticky liquid. Viscose is shaped into a thin sheet, then placed in sulfuric acid. The acid hardens the sheet to form cellophane. The cellophane is then dipped into liquid that removes impurities from cellophane and makes it flexible. Manufacturers coat cellophane with a substance, such as synthetic resin, to make the cellophane moisture proof (see RESIN).

Most cellophane made in the United States is used to package products, especially food products, that need protection from moisture. Cellophane is sometimes laminated (stuck) to aluminum foil or paper to make special wrapping materials. Cellophane is also used in the manufacture of such products as drinking straws, envelopes, and tapes used for sealing and mending.

CELLULOSE Cellulose is the substance that makes up most of the cell walls of plants. It gives strength to a plant's leaves, roots, and stems. Cellulose is a carbohydrate, being made of carbon, hydrogen, and oxygen. Plants make cellulose from sugars. These sugars are built up from carbon dioxide and water in the process of photosynthesis. Cotton and flax fibers are almost all cellulose. Wood is about one-half cellulose. Paper is almost entirely cellulose. The substance is also present in all foods obtained from plants (see CARBOHYDRATE; PHOTOSYNTHESIS).

Cellulose is a major form of dietary fiber and important to digestion (see FIBER). Cellulose makes up the bulk and roughage that aid the movements of the intestines. Cellulose helps prevent disorders such as constipation.

Cellulose reacts with several strong acids and bases. For example, when ordinary paper is placed in a strong solution of sulfuric acid, the cellulose in the paper swells. It forms a hard, waterproof paper that is used for legal documents, maps, and diplomas.

Cellulose is one of the most widely used chemical substances. It is especially used in the manufacture of explosives and many plastics.

See also CELLOPHANE; CELLULOSE ACETATE; RAYON.

CELLULOSE ACETATE Cellulose acetate is a substance made from cotton linters, which are short cotton fibers. These linters, made chiefly of cellulose, are treated with acetic acid, acetic anhydride, and sulfuric acid. Sulfuric acid acts as the catalyst (see CATALYST; CELLULOSE). When the reaction is complete, the mixture is added to water. Cellulose acetate separates as white flakes. The flakes are dissolved in acetone. This solution is then pumped through small holes in a device called a spinneret, where the acetone evaporates in warm air. The cellulose acetate comes out of the spinneret in the form of long fibers. Chemicals called plasticizers and solvents are often added to cellulose acetate to make the fiber more flexible and useful. Dyes may be added to color it.

Cellulose acetate is used in bulk form as a plastic. Knife and toothbrush handles are familiar objects made from cellulose acetate. The plastic is also used in making magnetic sound recording tapes, electrical insulation, and fireproof motion-picture film. The material is also used in thin sheets for wrapping various products. Cloth made from cellulose acetate fibers is silky and does not crease (see RAYON).

Cellulose acetate is used to make cellulose acetate butyrate. Because it stands up well under all weather conditions, cellulose acetate butyrate is often used in streetlight globes, automobile taillight covers, and outdoor signs.

CELSIUS, ANDERS (1701–1744) Anders Celsius (sĕl′sē əs) was a Swedish scientist who invented the Celsius, or centigrade, temperature scale. Celsius introduced his scale in 1742. It is used throughout the world today and is part of the metric system of measurement. Celsius also made many contributions to the field of astronomy. He was a professor at the University of Uppsala in Sweden, where he built the Uppsala Observatory.

Celsius made many observations of the aurora borealis, or northern lights, and participated in an Arctic expedition that verified Isaac Newton's theory that the poles of the earth are slightly flattened. He wrote important works on the shape of the earth and measured the distance between the earth and the sun.

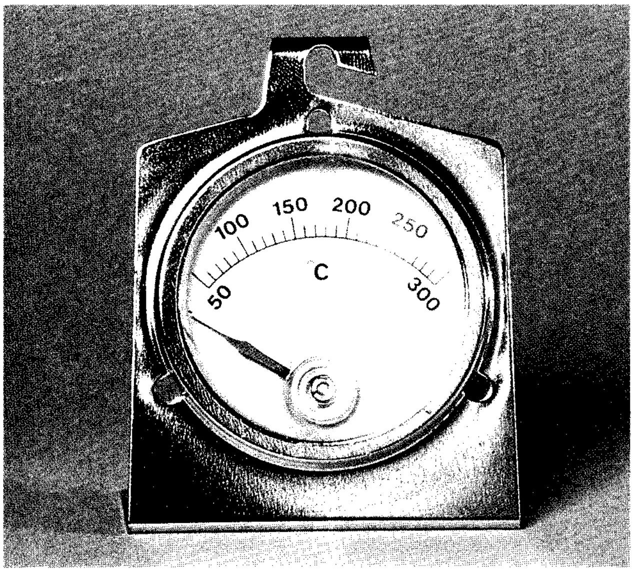
See also AURORA; CELSIUS SCALE.

CELSIUS SCALE (sĕl′sē əs skāl) The Celsius scale is a scale used to measure temperature. It is part of the metric system of measurement and is used throughout the world (see METRIC SYSTEM). The Celsius scale is based on 0° as the freezing point of water and 100° as the boiling point of water. The scale is divided into 100 equal parts between these two points. The Celsius scale is often called the centigrade scale, because *centigrade* means "divided into 100 equal parts." The Celsius scale was invented in 1742 by Anders Celsius, a Swedish scientist (see CELSIUS, ANDERS).

The Celsius scale has been used as the measurement of temperature throughout most of the world for many years. In the United States, the Celsius scale is coming into wider use, though the Fahrenheit scale is still used as the common measurement of temperature. The Fahrenheit scale is based on 32° as the freezing point of water and 212° as the boiling point of water. There are 180 divisions between the two points.

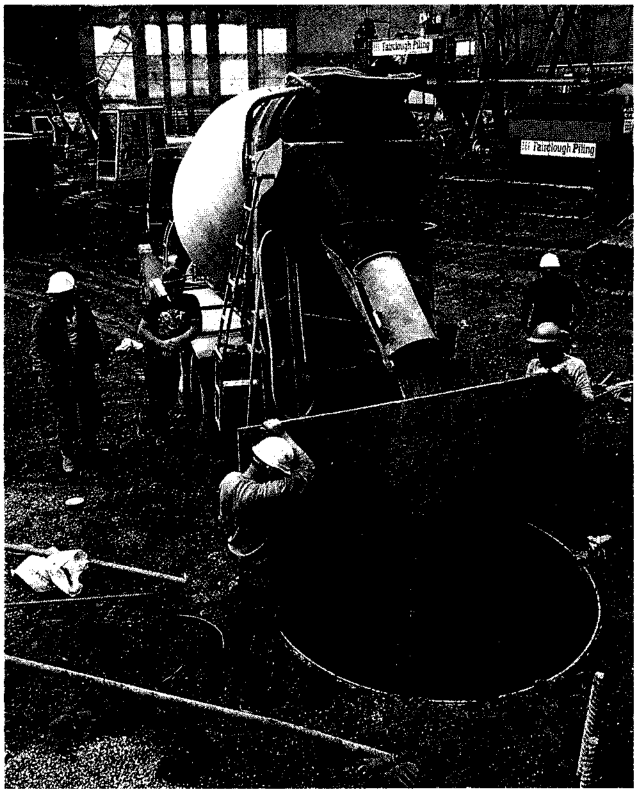
Temperatures below the freezing point in the Celsius scale are given in minus degrees. The lowest temperature possible in theory is absolute zero. It is expressed as -273.15°C [-459.67°F].

See also ABSOLUTE ZERO; FAHRENHEIT SCALE; THERMOMETER.



CELSIUS SCALE

When Anders Celsius invented his temperature scale, he originally made 0° the boiling point of water and 100° the freezing point. He later reversed the scale so that the freezing point of water is at 0°.



CEMENT AND CONCRETE

Concrete made from cement, sand, and gravel is often used in building construction because it can be poured as a liquid and then it sets rock hard. Here, it is being poured into a steel casing to form part of a building's foundations.

CEMENT AND CONCRETE In its broadest meaning, cement is any substance that makes things stick together. Early people probably used sticky clay to hold together stones to make their houses. Common library paste and other kinds of glue are all forms of cement.

Concrete (kŏn′krēt′) is a strong building material. It is made by mixing a cement with other materials. The use of concrete goes back thousands of years to the ancient Egyptians and Greeks. The ancient Romans made a concrete by mixing slaked lime (calcium hydroxide) with a volcanic ash. The result was called hydraulic concrete because it would harden under water. The Romans called it pozzolana. Many of the buildings of ancient Rome, such as the Colosseum, are still standing because they were made of solid concrete.

After the fall of the Roman Empire in the fifth century A.D., the art of making cement was lost until John Smeaton, a British engineer, rediscovered how to make it in 1756.

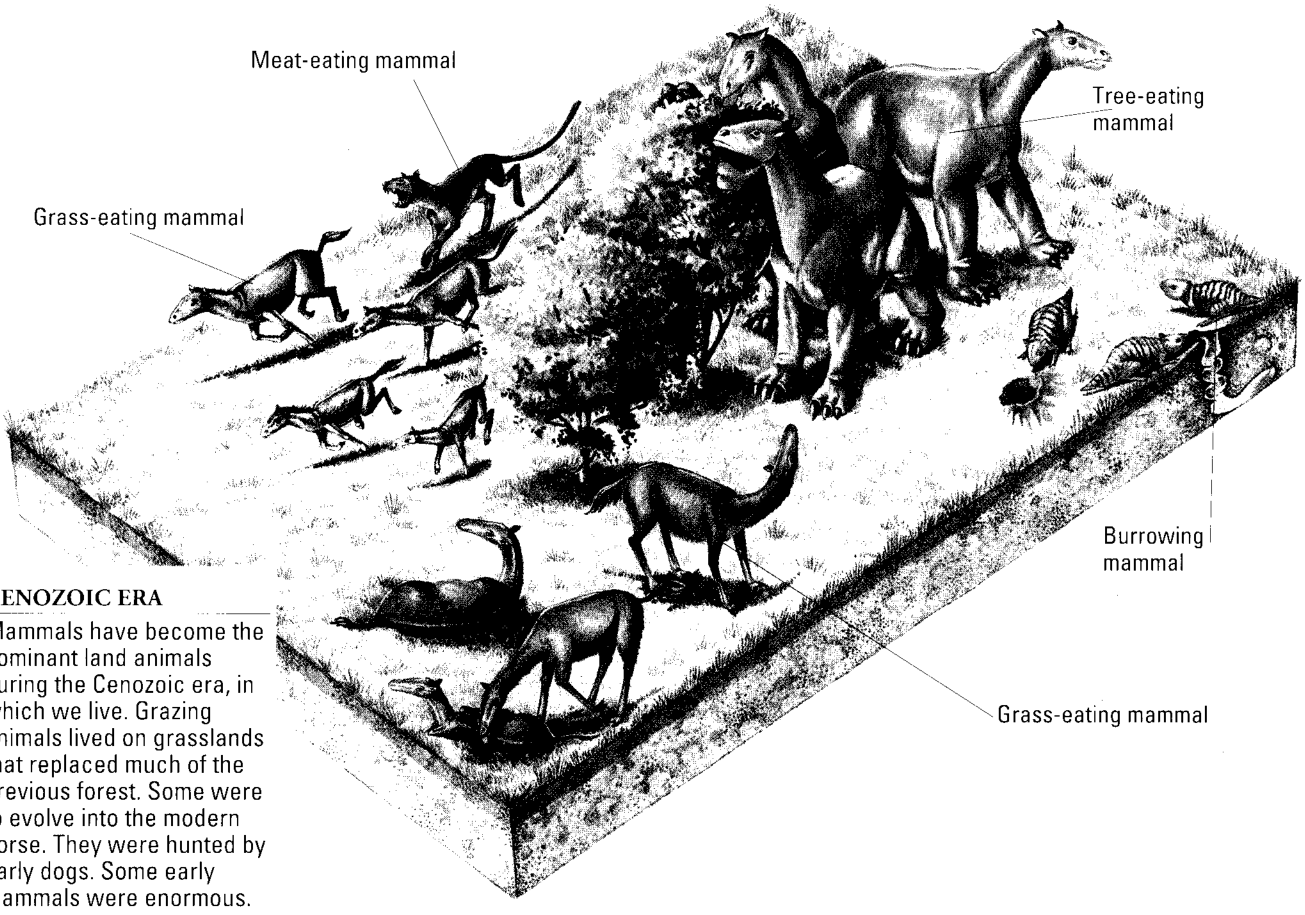
The most common kind of cement used in making concrete is called Portland cement, or hydraulic cement. It is a fine gray powder made of limestone, silica, and alumina. The first Portland cement was made by an Englishman, Joseph Aspdin, in 1824. He burned a mixture of one part clay to three parts limestone in a very hot oven, called a kiln, until the raw materials melted together to form a hard mass called a clinker. When the clinker cooled down, he ground it into a fine powder. He called the powder Portland cement because it resembled a stone he had found on the Isle of Portland, England. Today, Portland cement is manufactured in a definite way so that it has become a standard product throughout the world (see PORTLAND CEMENT).

Concrete is made by mixing cement with a fine aggregate, usually sand, a coarse aggregate, usually gravel, and water. The fine sand mixes with the coarse gravel, and the two are held together by the pasty mixture of cement and water. The materials must be mixed carefully in the right proportions. Too much water, for instance, makes a thin paste, and the hardened concrete is less durable.

Special techniques have been developed so that concrete can be mixed in large quantities at a central plant and then taken to the building site in specially designed trucks. The trucks have turning drums to keep the freshly mixed concrete from hardening along the way. Concrete can stand up against strong pushing by other parts of a structure. Thus, it is said to be strong in compression. It is weak in tension, however, and may be pulled apart relatively easily. The tension of concrete can be increased by use of steel wires embedded in the concrete. The result is called reinforced concrete, which is used in many types of construction.

The United States produces more cement and uses more concrete than does any other country.

CENOZOIC ERA (sē′nə zō′ĭk ĕr′ə) The Cenozoic era covers the last 65 million years of the earth's history. It is divided into two periods: the Tertiary period and the Quaternary period. The Tertiary period lasted approximately 63 million years. The Quaternary period covers the past 2 million years. The Tertiary period is further divided



CENOZOIC ERA
Mammals have become the dominant land animals during the Cenozoic era, in which we live. Grazing animals lived on grasslands that replaced much of the previous forest. Some were to evolve into the modern horse. They were hunted by early dogs. Some early mammals were enormous.

into five segments called epochs. The shorter Quaternary period is divided into the Pleistocene and Holocene (or Recent) epochs.

By the time the Cenozoic era began, most of the giant reptiles were extinct. Mammals became the dominant land animal, which is why the Tertiary period is often called the "age of mammals." Birds, insects, and flowering plants also evolved to a state similar to those of today. The Quaternary period saw the rise of human beings (see EVOLUTION).

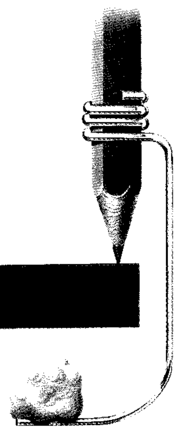
The modern landscape took shape during the Cenozoic era. Tall mountain ranges, such as the Rockies, Alps, and Himalayas, were formed. During the later part of the Cenozoic era (Pleistocene epoch), widespread glaciation occurred, forming many of the land features of Europe, Asia, and North America as worldwide climatic patterns changed. As the earth warmed up again, the glaciers retreated (melted).

See also GEOLOGICAL TIME SCALE; GLACIATION; ICE AGE.

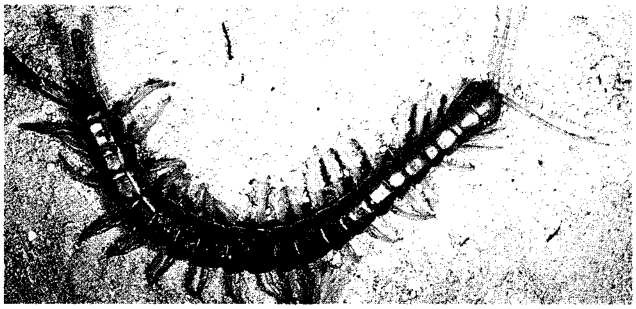
CENTER OF GRAVITY The center of gravity is that point where all the mass or weight of an object seems to be concentrated. It is also called the center of mass. If the object is symmetrical, such as a coin or a ruler, the center of gravity is at the midpoint or center of the object (see GRAVITY; SYMMETRY).

The position of the center of gravity is important in the balance of an object. If the center of gravity is directly over the base of an object, the object will not wobble. If the object is at an angle so that the center of gravity is not above the base, the object may fall. An object with most of its weight at the bottom, such as a telephone, has a low center of gravity and cannot easily be tipped over. An object such as a floor lamp, which has the weight of the shade and bulb at or near the top, has a high center of gravity and can be easily knocked over. It is important that automobiles and ships be designed with a low center of gravity to prevent them from overturning.

ACTIVITY *The center of gravity*



Here's how to make a pencil balance on its point by lowering its center of gravity. Take a length of wire about 3 in. [7.5 cm] long. Twist one end of the wire around the lower part of the upright pencil and bend the wire around underneath the point. Place a large piece of modeling clay onto this end of the wire. Now stand the pencil on its point at the edge of a table, with the modeling clay about 2 in. [5 cm] under the table. The pencil will stand up because its center of gravity is below its point. If the pencil is tilted slightly, the center of gravity rises. Then the center of gravity falls back to its lowest position, so that the pencil is returned to its upright position.



CENTIPEDE
This large, tropical centipede clearly shows how the body is divided into segments, each with one pair of legs.

CENTIPEDE The centipede is a worm-shaped arthropod belonging to the class Chilopoda (see ARTHROPODA). There are more than three thousand known species, mostly varying in size from 1 to 2 in. [2 to 5 cm]. However, some tropical centipedes reach 12 in. [30 cm].

The head of a centipede has a pair of antennae and three pairs of mouth parts (see ANTENNAE). The body is segmented, each segment having a pair of legs and usually one pair of small openings for breathing, called spiracles. Most centipedes have fifteen to twenty-three segments, but some have more than one hundred. The legs on the first segment are modified to form fangs. These fangs are called "poison claws" because they are filled with poison. This poison is injected into prey such as insects, worms, mollusks, and even other centipedes.

Centipedes live in the soil under rocks or logs. If disturbed, the larger ones can give people painful bites. Some species of centipedes are bioluminescent (see BIOLUMINESCENCE). *See also* MILLIPEDE.

CENTRAL HEATING Central heating is a system for warming a large area, such as a house, from one heat source. Heat is delivered where it is needed. Most central heating systems serve only one building. Some, however, heat several buildings, such as those at an apartment complex.

There are two main types of central heating systems. A direct system moves warm air throughout the area being heated. An indirect system carries steam or hot water through pipes to devices called convectors or radiators, which give off heat. Both systems use electricity or a type of fuel, such as petroleum (oil) or natural gas, as a source of heat.

In central heating systems, the temperature can be controlled by one or more thermostats. The thermostat has a bar made of two different metals. Each metal expands when warm and contracts when cold, but at different rates. When the air warms, one metal expands more than the other. This makes the bar bend in one direction far enough to touch an electrical contact and shut the furnace off (see BIMETALLIC STRIP; THERMOSTAT).

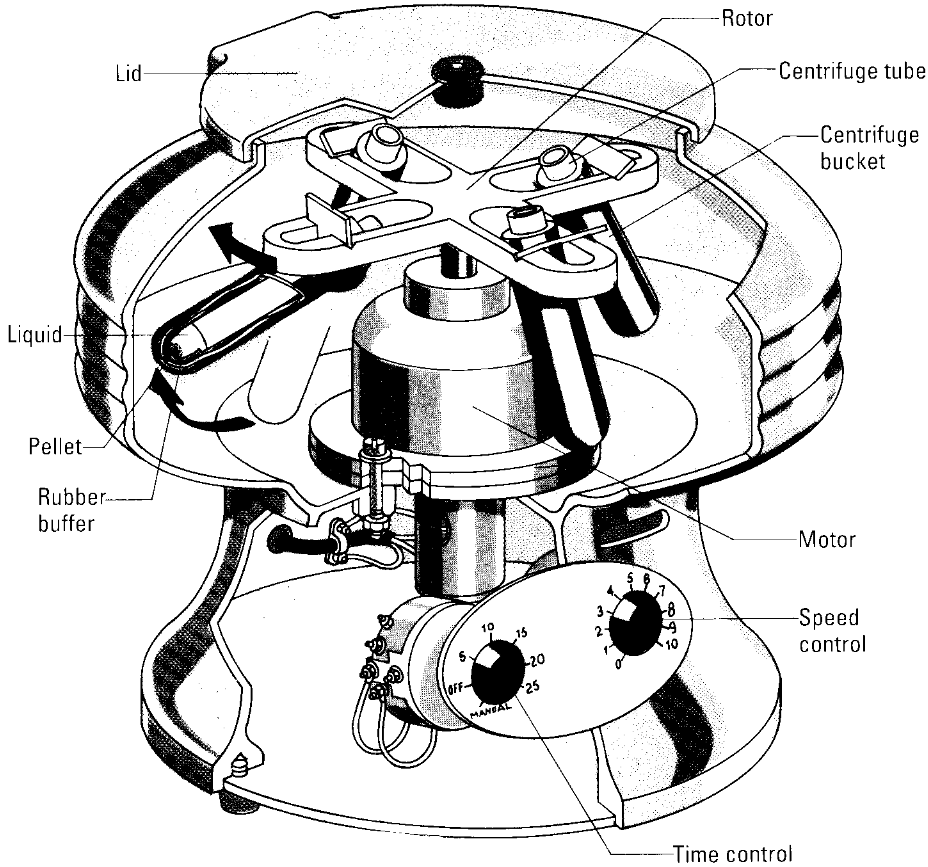
In a steam heating system, the steam moves through pipes to one or more radiators. In a radiator, the steam condenses to form water (see CONDENSATION). As the steam condenses, it releases heat. This heat flows out to warm the surrounding air by convection (see CONVECTION). The cooled water is returned to the furnace, where it is reheated into steam. The radiators in a steam heating system have valves that allow the escape of air. In a hot-water heating system, hot water travels from the boiler to the radiators, where it passes on its heat to the surrounding air. In some systems, hot water passes through pipes coiled under the floor. In warm-air (also called forced-air) heating, air is warmed in a furnace and then forced through a system of ducts, or pipes, to each room. Another system of ducts carries cool air from the rooms back to the furnace. Many homes have warm-air systems. These systems do more than just heat the air. For example, with a humidifier, a forced-air system adds moisture to the air, increasing the humidity throughout the home. The ducts and blower can be used as part of a unit for central air conditioning.

Radiant heating involves the use of a continuous loop of hot water pipe or electric cable. This pipe or cable may be installed on the floor, wall, or ceiling. Heat leaves the pipe or cable by radiation. Radiation does not directly raise the temperature of the air within a room. It affects only the objects it strikes. Radiation distributes heat more evenly than convection. All radiant heating systems limit the temperature difference between the floor and the ceiling to only a few degrees.

Electric heating differs from other central heating systems. It requires no fuel in the building being heated. The fuel used to produce the electricity is burned at an electric power plant that may be far away. Electric heat is produced by heating electric units. These units produce heat by passing electricity through a material that resists the flow of current. This type of electric heating is called resistance heating. Resistance heating warms a room in the same way as radiant heating.

A heating system that uses a heat pump operates much as a warm-air system. However, the heat pump uses a condenser, pump, and other equipment to get heat from outside air or the ground and pump it into the building (see CONDENSER). During the summer, a heat pump works in reverse. It cools a building by pumping heat from the inside to the outside.

Besides central heating, two other new methods of heating are geothermal and solar heating. In geothermal heating, cold air is carried in pipes through warm earth below the frozen ground. The air absorbs the warmth and carries it into the house. Solar heating uses the radiant energy from the sun directly. Solar energy not only provides warmth but can also be used to run machines. Huge reflectors are needed to "collect" enough sunlight to heat large areas. Solar heating is likely to be more commonly used in the future. The fuels required in central heating systems are extremely expensive and becoming more scarce every year.
See also ENERGY; FUEL; HEAT; SOLAR ENERGY.



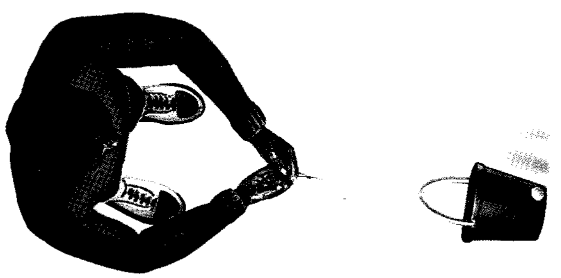
CENTRIFUGE
A common type of laboratory centrifuge holds four tubes that are spun rapidly. As the rotor spins around, the tubes swing from a vertical to a horizontal position. Any solids suspended in the liquid in the tubes come together to form a pellet at the bottom of the tubes.

CENTRIFUGE (sĕn′trə fyo͞oj′) A centrifuge is a device that spins around at high speed. It is usually an electric motor to which two or more containers are attached. When the motor is turned on, the containers spin. The centrifuge is used to separate liquids that are mixed together or solid particles that are mixed in a liquid. As it spins, the heavier liquid or solid particles move to the outside of a container, and the lighter substances remain on the inside. This is how cream is separated from milk. Ordinary centrifuges can turn at from eight hundred to six thousand times per minute. An ultracentrifuge can reach speeds of eighty thousand turns per minute. Centrifuges are used in many scientific, industrial, and medical laboratories.

CENTRIPETAL FORCE Centripetal (sĕn-trĭp′ĭ tl) force acts to keep an object moving in a circle. According to Isaac Newton's first law of motion, a moving object travels in a straight line unless a force acts on it (see DYNAMICS). When a stone is tied to a string and swung around, the tension in the string supplies centripetal force that acts on the stone to keep it from moving off in a straight line.

An example of centripetal force is the gravitational force that keeps a satellite in orbit around its

ACTIVITY *Spin a ball*



Use centripetal force to spin a ball in a circle. Put a table tennis ball in a small toy bucket and tie a string to the handle. Let the bucket dangle by the string and then swing it in a circle. Swing the bucket faster and faster while raising your arms to a level position so that finally the bucket is swinging in a vertical circle. The ball will stay in the bucket. Centripetal force keeps the ball moving in a circle.
Caution: Be sure no one is close to you when you swing the bucket.

parent body, as the moon orbits the earth. In another example, a car traveling around a bend in the road is kept from skidding off by the centripetal force supplied by friction between the tires and the pavement (see FRICTION; GRAVITY).

According to Newton's third law of motion, every force creates an equal but opposite reaction. In the example of the stone and string, centripetal force is balanced by a force exerted by the string on the hand of the person holding it. This force is known as centrifugal force.

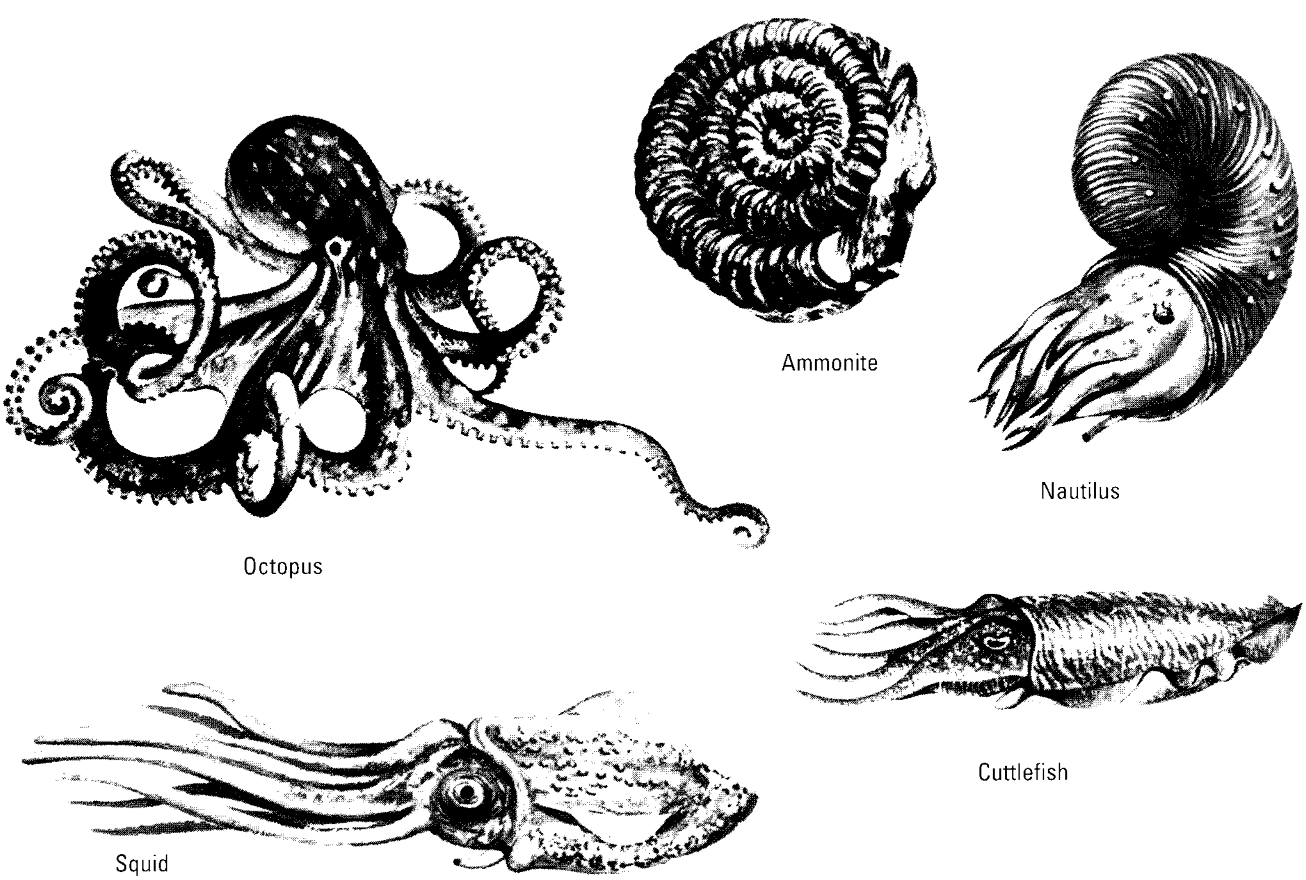
CEPHALOPOD (sĕf′ə lə pŏd′) Cephalopods are saltwater animals that belong to the class Cephalopoda, in the mollusk phylum (see MOLLUSCA). The octopus, squid, cuttlefish, nautilus, and ammonite (an extinct animal similar to the nautilus) belong to Cephalopoda. There are some 750 species.

Cephalopods are soft-bodied animals without any bones. A thick fold of "skin" called the mantle partly surrounds their bodies. In other mollusks, such as clams, the mantle produces a hard shell that encloses the body. The nautilus is the only living cephalopod with a shell. The cuttlefish and squids have a small trace of a shell inside their bodies, but the octopuses do not.

Cephalopods are all predatory animals (or hunters), feeding on shrimp, crabs, fish, and also other cephalopods. Cephalopods breathe with gills in the mantle cavity. After the water travels through the gills, it passes out through the siphon, a short spout. When this water is forced out of the siphon quickly, the animal moves backwards rapidly. Cephalopods use this method to escape from their enemies. They also squirt an inky liquid into the water, which makes the water cloudy and hard for their enemies to see through.

CEPHALOPOD

The pictures below show the main groups of cephalopods. Apart from the nautilus, cephalopods catch prey with sucker-covered arms or tentacles. The octopus has eight arms. The squid and the cuttlefish both have ten arms—eight short ones and two long ones that can shoot out when prey approaches. The nautilus has up to ninety short arms, which have no suckers and merely grab small animals and shove them into the mouth. The ammonite, often found as a fossil, was a cephalopod that became extinct millions of years ago.



CERAMICS

Ceramics are objects made from materials such as clay, feldspar, sand, and talc that have been fired into permanent form. The word *ceramics*, which also refers to the art of making these objects, comes from the Greek word *keramos*, meaning "potter's clay." The term *ceramic* describes products that are made from materials other than a metal or a plastic.

Pottery is the oldest form of ceramics, dating back to prehistoric times. The oldest way of fashioning clay into pottery is by a rotating wheel called the potter's wheel. Many new methods have since been developed.

Clay and other materials used in ceramics form most of the earth's crust. These minerals, called silicates, are crushed and ground into fine particles. The particles are mixed and added to water. Water makes the particles flexible for shaping. Jiggering is a common method used to shape clay ceramics. In jiggering, a machine presses the clay into a spinning mold of the desired shape. Slip casting, another method, is done by pouring liquid clay into a mold. Some products, such as abrasives or insulators, are made by pressing the clay into a mold. Extrusion shapes bricks by forcing the clay through an opening in a shaping device (see CASTING).

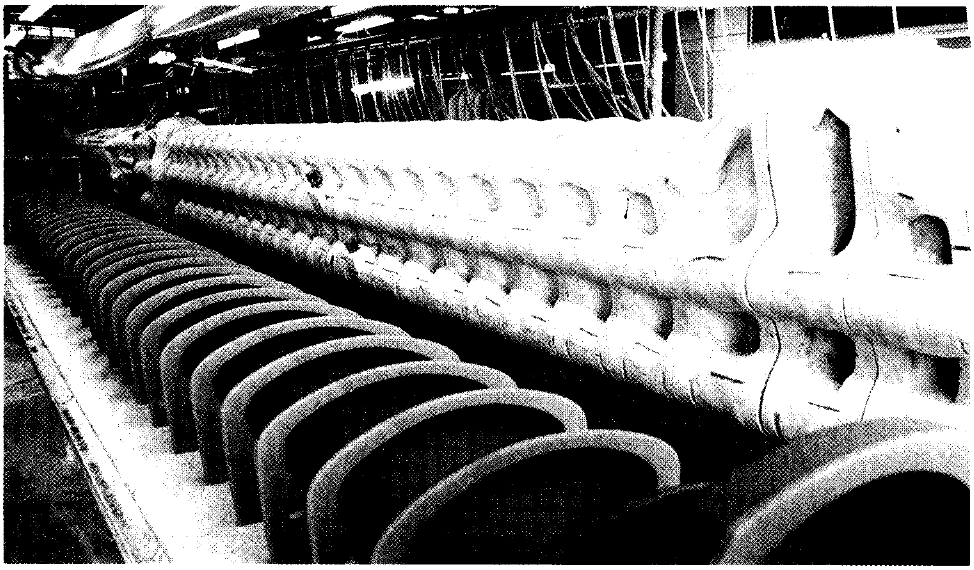
After the product has dried, it is fired, or heated. This process takes place in a special type of furnace called a kiln (see KILN). Ceramics are fired at temperatures ranging from 1202°F [650°C] to 3002°F [1650°C]. Firing hardens the product into permanent form and makes it strong and durable.

Many ceramic products are coated with a glassy covering called a glaze. Glaze seals the surface and prevents the product from absorbing liquids. It also gives a smooth surface to the product and makes it easier to clean. Some glazes are used for decoration.

One important use of ceramic materials is in

MAKING POTTERY
Pottery making begins with shaping the soft, wet clay. Circular objects, such as plates and bowls, can be made by shaping a lump of clay on a rotating potter's wheel (below left). This technique is called throwing. The wheel is powered by a foot-operated treadle or, more often nowadays, by an electric motor.

DECORATING
Fine china is often decorated with intricate designs by highly skilled painters (above).



FIRING AND COLOR

Firing clay by heating it inside a kiln to a temperature in excess of 1,200°F [648°C] transforms it into a rock-hard material. The color of the sinks is determined by the chemical substance used to glaze them. The glaze takes on its final color only after firing. Changing the chemical make-up of the glaze changes its color.

making abrasives, which are materials used for grinding. Manufacturers use extremely hard ceramic materials, such as alumina and silicon carbide, for grinding, polishing, and sanding many surfaces.

Clay and shale are used to make construction products, such as bricks and drainpipes. Cement is made chiefly of calcium silicates (see CEMENT AND CONCRETE). Gypsum is used in the manufacture of plaster. Bathtubs, sinks, and toilets are made of porcelain, which is made of clay, feldspar, and quartz.

Ceramics make excellent bowls, cups, and plates. In addition to not absorbing liquid, ceramics resist acids, salts, and extreme heat. Most ceramic dinnerware is made from a mixture of clay, feldspar, and quartz.

Some ceramic materials, such as alumina and porcelain, do not conduct electricity. These materials are useful as insulators—for example, in electric power lines and television sets. Barium titanate is a ceramic material used in making capacitors, electrical devices used to store, or hold, an electric charge.

It was discovered in 1986, however, that certain ceramics have the ability to be superconductors. A superconductor is a substance that conducts electricity without resistance (see RESISTANCE, ELECTRICAL; SUPERCONDUCTIVITY). Superconductors allow electricity to be carried long distances without losing any voltage (see VOLT). Until 1986, all superconductors were made of metals. Metals have to be cooled to near -459.69°F [-273.16°C] before they are superconductive. These temperatures are difficult and costly to achieve. However, ceramics become superconductive at -234°F [-148°C]. This temperature is much easier to reach. Ceramic superconductors do have some disadvantages, however. They are expensive to produce and difficult to make into wire.

The ceramic material silica is used in making a great number of glass products (see GLASS). The glasslike substance called porcelain enamel is used as a protective coating on many metal products, such as refrigerators, stoves, and washing machines (see ENAMEL).

Refractories are another important group of ceramic products, often used for lining furnaces. Refractories resist heat and chemical action. Certain types of refractories are used for rocket nose cones. Ceramic substances used in making refractories include alumina, magnesium compounds, and silica.

Experts in ceramics are continually developing new uses for their material. Different types of porcelain are used to make false teeth and artificial bone joints. Uranium oxide ceramics are used as fuel elements for nuclear reactors. Alumina is used in making certain lasers, which produce extremely strong light.

See also CLAY; FELDSPAR; FLINT; GYPSUM; QUARTZ; SHALE; SILICA.

CEREAL CROP Cereal crops are annual plants that are among the most important food plants (see ANNUAL PLANT). They have a high starch content and are a good energy source. With the exception of buckwheat, all the cereal crops are members of the grass family (see BUCKWHEAT FAMILY; GRASS). Cereal crops were cultivated as early as 5000 B.C. in Asia. They are now raised throughout the world. Farmers constantly try to improve the quality of their crops through genetic control (see BREEDING; HYBRID).

Cereal crops are grown for human use and animal use. Corn can be eaten cooked or can be processed into flour, syrup, oil, or other forms. Once processed, corn can be used in many foods such as bread and breakfast cereals. Wheat is usually ground into flour and used for breads and other foods. Rice is the main food in the diets of half the people in the world. Most Asians rely on rice as their major food. The outer covering of rice, the husk, is rich in vitamins. Millet is another major cereal crop, especially important in Africa.

Cereal crops used for animals are in the form of feed. About half of the corn grown in the United States is used for livestock feed. Mixed feed is made of one or more grains from cereal crops, vitamins, protein supplements, and drugs.

Cereal crops have many other uses. They are an important ingredient in many medicines, explosives, and alcoholic beverages (see ALCOHOL).

CEREAL CROP

Plant scientists are constantly experimenting with different strains of cereals to improve on the yield of existing crops and their resistance to pests and diseases. New strains are tested in the laboratory and also in field trials to ensure that they have no unwanted characteristics.

CEREBELLUM (sĕr′ə bĕl′əm) The cerebellum is the second largest part of the human brain. It lies toward the rear of the cerebrum. The cerebellum is concerned with the sense of balance, position of the body, and coordination of bodily movements. Certain animals that need good balance and coordination, such as birds and mammals, have a larger, more developed cerebellum than do fish and reptiles.

See also BRAIN.

CEREBRAL PALSY (sə rē′brəl pôl′zē) Cerebral palsy is a brain disorder that results in the impairment of muscle control and coordination. Cerebral palsy may be caused by brain damage that occurs before or during birth or during the first few years of life. The brain damage may be due to head injuries or to certain infections—for example, German measles in a pregnant woman. Cerebral palsy is rarely inherited. Some people with cerebral palsy have sight or hearing problems or mental retardation. Most people with cerebral palsy can learn to function with their disability through physical or occupational therapy.

See also BRAIN.

CEREBRUM (sə rē′brəm) The cerebrum is the largest part of the human brain. It is divided into two halves called cerebral hemispheres. The outer surface of each hemisphere is called the cortex and contains a large number of nerve cells (neurons). These nerve cells receive messages from the sense organs, such as the eye and the ear. The messages are used by the brain to interpret the surrounding environment. It then sends out signals to the rest of the body.

Different parts of the cerebral hemispheres are called lobes. Cells in these lobes receive messages from various kinds of sense organs. For example, the temporal lobes are near the ears and serve as centers for hearing. The occipital lobes are centers for the sense of sight.

See also BRAIN.

CHADWICK, SIR JAMES (1891–1974) Sir James Chadwick was a British physicist who discovered the neutron, a part of the atom. He also discovered the existence of isotopes and played an important role in the development of the first atomic bomb during World War II.

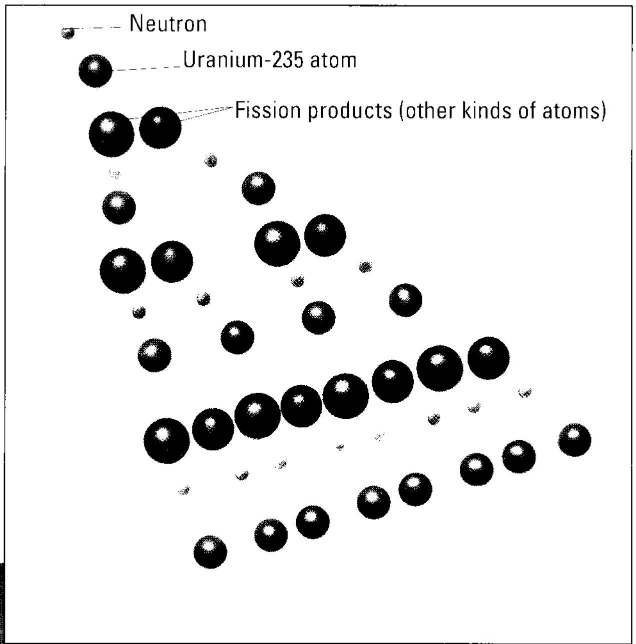
In 1932, Chadwick showed that radiation from the element beryllium, caused by the bombardment of alpha particles, is actually a stream of electrically neutral particles. He called these particles neutrons and pointed out that they were about equal in mass, or weight, to protons.

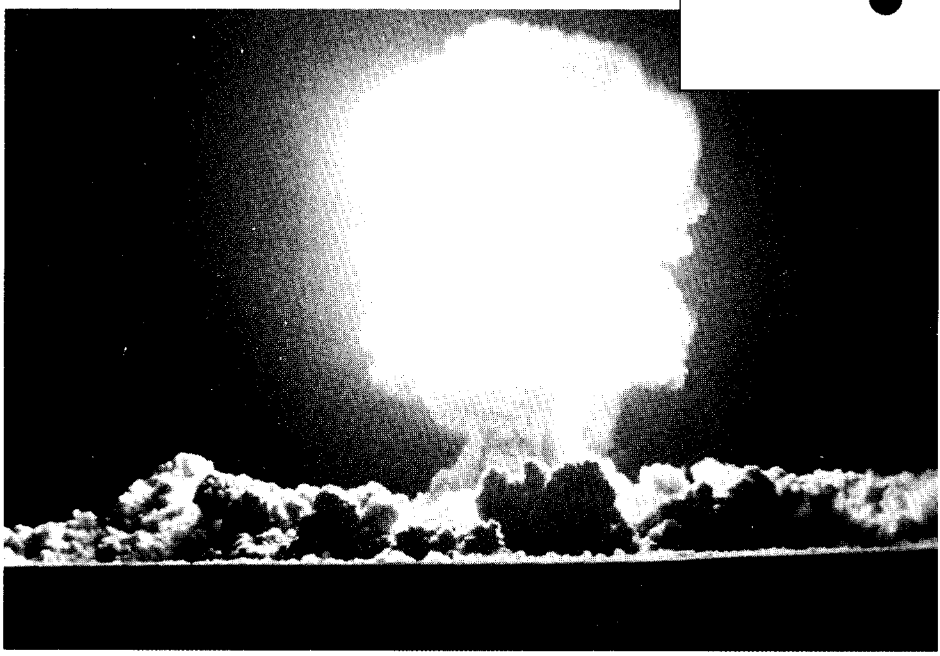
Chadwick also explained the existence of isotopes. Isotopes of an element are different forms of that element that have the same chemical properties but differ in other ways. For example, atoms of different isotopes have different relative atomic masses (atomic weights). Chadwick showed that this is because the isotopes contain a different number of neutrons in their nuclei. In 1935, Chadwick was awarded the Nobel Prize for physics (see ELEMENT; ISOTOPE).

Chadwick's discovery of the neutron, and research on chain reactions caused by nuclear fission, contributed to the development of the first atomic bomb. Chadwick also spent several years working with Ernest Rutherford on the transmutation of elements. This is the process whereby elements give off electrically charged particles known as alpha and beta rays. These change the makeup of the original atom in the element. Because of the changes, the new atom is of a different chemical element (see RUTHERFORD, ERNEST; TRANSMUTATION OF ELEMENTS). Chadwick earlier studied with Hans Geiger, the German nuclear physicist who invented the Geiger counter and who made important contributions to the understanding of radioactivity.

See also ATOM; GEIGER COUNTER; NUCLEAR WEAPONS; RADIOACTIVITY.

CHAIN REACTION A chain reaction is a reaction that triggers a series of other reactions. An example of a chain reaction is shown by ten





CHAIN REACTION

The nuclear energy of uranium is released in a chain reaction (above). Occasionally, a uranium nucleus splits into two, producing two other nuclei and two or three neutrons. This is called fission. In ordinary uranium (uranium-238 or U-238), these neutrons are absorbed or lost from the material. But in a reactor or bomb, the uranium has been "enriched" so that it contains many atoms of U-235. The neutrons hit other U-235 nuclei and trigger more fissions, and so on. If the release of energy is uncontrolled, there is a nuclear explosion (left).

dominoes standing in a row, one behind the other. The first is pushed to hit the second domino. The second domino hits the third domino. The reaction continues until all the dominoes fall.

A nuclear chain reaction begins with fission. Nuclear fission is the splitting of an atomic nucleus. When the atomic nucleus is split, a large amount of energy is released. Nuclear fission occurs, for example, when a neutron strikes the nucleus of an atom of uranium or plutonium. The nucleus breaks into two smaller nuclei and releases neutrons. Each of these neutrons may strike more uranium or plutonium nuclei, releasing still more neutrons. This continuous process is called a chain reaction. A nuclear chain reaction can produce a large amount of energy. This energy may be controlled and changed into electricity. An atomic bomb explosion is an example of an uncontrolled chain reaction.

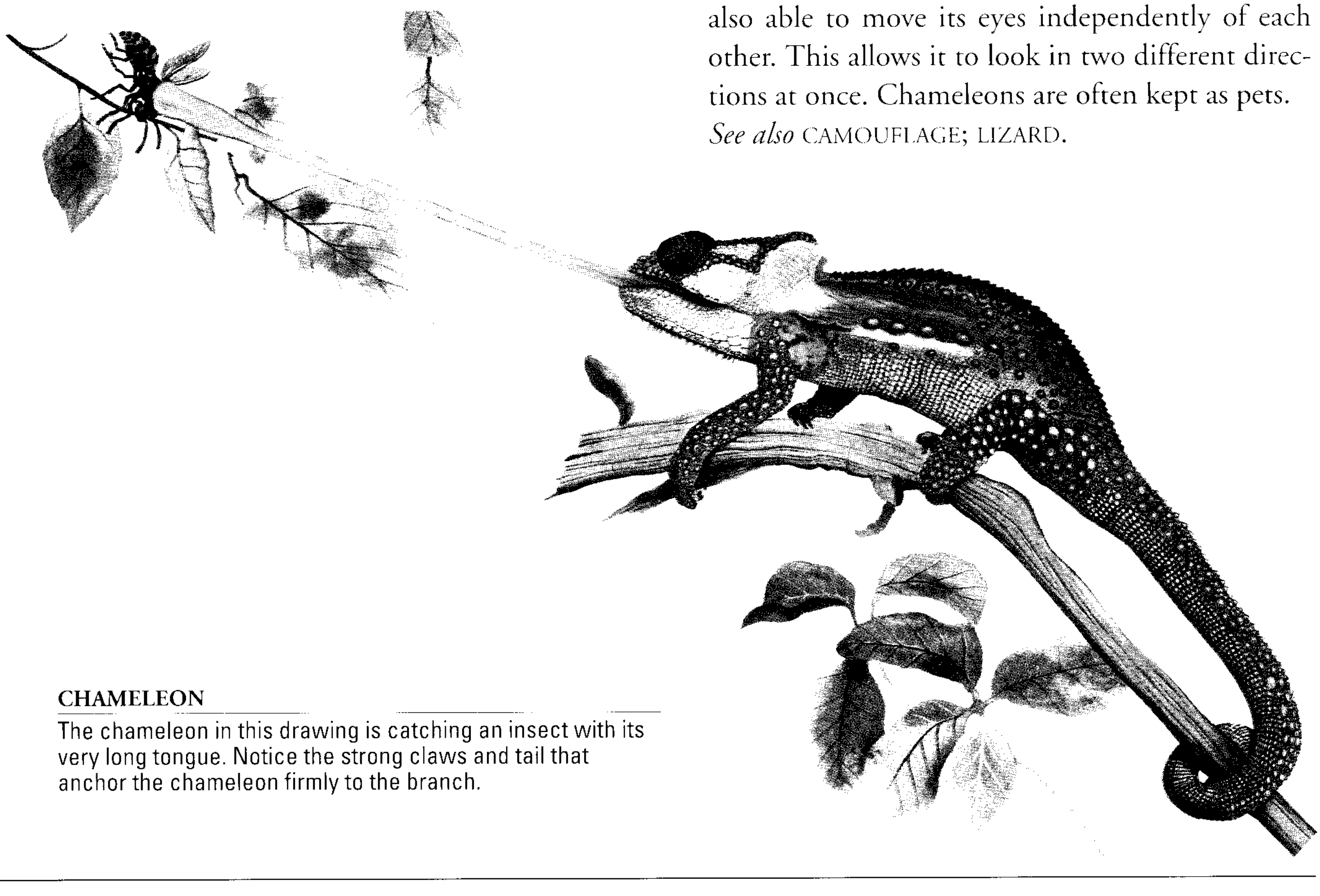
See also ATOM; FISSION; NUCLEAR ENERGY; NUCLEAR WEAPONS.

CHALK Chalk is a soft white or grayish form of limestone. It is composed largely of calcium carbonate. The calcium carbonate comes from the shells of the tiny sea creatures called foraminifers. Many chalk deposits contain bands of a harder substance called flint, a variety of quartz (see CALCIUM CARBONATE; LIMESTONE).

Many chalk deposits formed during the Cretaceous period, about 136 million years ago. The White Cliffs of Dover, a large chalk deposit in England, were formed during this period. Chalk deposits are also found in South Dakota, Texas, and Alabama. Although blackboard chalk is called chalk, it is actually made mostly of gypsum.

CHAMELEON (kə mēl′yən) A chameleon is a lizard that belongs to the family Chamaeleonidae. There are over eighty species of chameleons. Most are found in Africa. Most chameleons are small, sometimes reaching 8 in. [20 cm] in length. They feed mainly on insects, which they catch by firing out their long, sticky tongues at high speed. They are best known for their ability to change the color of their skin to match their surroundings. If a chameleon sits in a green bush, it turns green. If it sits in brown leaves, it turns brown. A chameleon is also able to move its eyes independently of each other. This allows it to look in two different directions at once. Chameleons are often kept as pets.

See also CAMOUFLAGE; LIZARD.



CHAMELEON

The chameleon in this drawing is catching an insect with its very long tongue. Notice the strong claws and tail that anchor the chameleon firmly to the branch.

CHAMOIS (shăm'ē) The chamois is a goatlike mammal with short, curved horns (see MAMMAL). It lives in the mountains of Europe and western Asia, spending summers near the snow-covered peaks. In the winter, the chamois moves down to the forests lower on the mountain. The chamois is reddish brown in color and grows to a height of 30 in. [75 cm] at the shoulder and a weight of 132 lb. [60 kg].

Chamois live in bands of ten to fifteen members. They are able to make enormous leaps across ravines and from rock to rock. Chamois are hunted for their skins. These skins can be made into a very soft leather, which is also called chamois. Soft, synthetic (human-made) leathers and sheepskin are often sold as chamois cloth.

CHAMOIS
Chamois graze on the sparse vegetation high on the rocky slopes of the Alps and other European mountains during the summer. They may go above 11,500 ft. [3,500 m]. They move down to lower ground for the winter, when their coats become thicker and much darker.

CHARCOAL Charcoal is a black, brittle substance that is porous, or full of tiny holes. Most charcoal consists mainly of amorphous carbon. Amorphous carbon is a powdery form of the element known as carbon (see CARBON). Charcoal also has a small amount of impurities, such as hydrogen and sulfur compounds.

Charcoal is manufactured by heating plants rich in carbon or by heating animal remains, such as bones, in ovens that contain little or no air. As the substance is heated, most of the hydrogen, nitrogen, and oxygen in the substance escape. The end product is charcoal.

Wood charcoal, so called because it is made from wood, is the most common type of charcoal. It consists chiefly of carbon. It has some ash (the incombustible residue of carbon-containing substances that is left after burning) and impurities. Bone charcoal, also called boneblack, is made from animal remains, mostly bones. Bone charcoal is made up mainly of ash, along with some carbon and impurities. Activated charcoal is charcoal from which most of the impurities have been removed. It is made by treating charcoal with steam and air heated to at least 604.4°F [318°C].

Charcoal has many uses. It makes an excellent fuel. Many people burn charcoal in outdoor barbecues. Artists use wood charcoal for drawing. In powdered form, wood charcoal is used in filters and also in gunpowder. Bone charcoal is used in pigments, or coloring matter. These pigments are used in dyeing leathers and coloring inks and paints. Powdered forms of wood, bone, and activated charcoal are used to remove unwanted colors, flavors, and odors from gases and liquids. Charcoal performs these tasks by adsorption (see ABSORPTION AND ADSORPTION). Activated charcoal is the kind that best takes up other substances by adsorption.

CHARCOAL
The brittle nature and jet black color of wood charcoal make it ideal for drawing. As it is moved across paper, it leaves a loose, black powdery deposit behind. It can make a thin, solid line like a pencil, or it can be spread across the paper to cover larger areas by rubbing it with a finger.

CHARGE When an object can cause electrical effects it has electrical charge. All atoms, the basic units of matter, are made up of particles called protons, electrons, and neutrons. Protons are particles with positive charge. Electrons are particles with negative charge. Neutrons are neutral particles, having no charge. The charge of an atom is determined by the numbers of electrons and protons. Because all matter is made up of atoms, all objects contain charged particles. Depending on the number of electrons and protons in its atoms, the charge of an object may be neutral, positive, or negative. An object has a negative charge when it has more electrons than protons. The charge is positive when there are fewer electrons than protons. When an atom loses an electron, it becomes a positively charged ion. In electrochemistry, this is called a cation. When an atom gains an extra electron, it becomes a negatively charged ion, called an anion in electrochemistry. When the number of electrons and protons is equal, the positive and negative charges cancel each other out, producing a net charge of zero (see ATOM; IONS AND IONIZATION).

Objects with the same type of charge (both positive or both negative) repel one another. Objects with opposite types of charge (one positive and one negative) attract one another. The unit for measurement of a charge is the coulomb.

See also COULOMB; ELECTROSTATICS.

PROJECT 53, 56

CHARLES'S LAW Charles's law states that the volume a gas occupies under constant pressure varies with its absolute temperature. Absolute temperature is measured on a scale in which zero equals absolute zero (-459.69°F or -273.16°C). Charles's law was formulated in 1787 by Jacques Alexander Charles, a French chemist. He did not publish his theory but explained it to another French chemist, Joseph Gay-Lussac. Gay-Lussac published the theory in 1802. Consequently, Charles's law is sometimes known as Gay-Lussac's law.

If the absolute temperature of a gas under constant pressure doubles, its volume also doubles. Similarly, if the absolute temperature decreases by a half, the volume decreases by a half. Gases become liquids or solids when their temperatures are lowered far enough.

See also BOYLE'S LAW; GAS.

CHEETAH A cheetah is a large member of the cat family, Felidae. It is found in Africa and southwestern Asia. Because of the black spots on its golden body, the cheetah is often mistaken for a leopard. The two big cats can be told apart by the black line that runs from the cheetah's eye to the corner of its mouth. Cheetahs also have a thinner body and longer legs. The length of their head and body is up to 5 ft. [1.5 m] and they weigh up to 140 lb. [63.6 kg]. Unlike other cats, the cheetah has nonretractable claws. The claws always stay out, like those of a dog. Perhaps the best-known fact about the cheetah is its speed. It is the fastest animal on land. Cheetahs are able to run at 70 m.p.h. [112 kph] while chasing antelope, their major prey. However, the cats can maintain these speeds only over very short distances.

See also CAT; LEOPARD.

CHEETAH

The cheetah is also known as the hunting leopard. People living in southwest Asia used to train the animals to hunt gazelles and other antelopes. Cheetahs themselves have also been hunted for their fine fur, which has made them very rare animals in many areas today.

CHEMICAL ANALYSIS

Chemical analysis is the way a chemist finds the identities and amounts of chemicals in a substance. There are two main kinds of chemical analysis. In qualitative analysis, a chemist tries to find out what elements and compounds (mixtures of elements) various kinds of matter are made of (see COMPOUND; ELEMENT). In quantitative analysis, the chemist is concerned with how much of each element or compound is in various kinds of matter. Thus, if the chemist wants to know if salt contains iodine, he or she does a qualitative analysis. If the chemist wants to know how much iodine is in salt, he or she does a quantitative analysis.

The methods used in qualitative analysis depend on whether the substance is organic or inorganic. Organic substances contain carbon. Inorganic substances generally do not. If a substance is inorganic, the various elements or groups of elements present can be identified by the way they react with certain test chemicals, called reagents. If a substance is organic, analysis is more difficult. The general type of organic compound present can be identified by how it reacts with other chemicals. The actual compound is found by measuring a physical property,

QUALITY CONTROL
Chemical analysis is used to check the quality of many products. Here a laboratory worker is taking samples of paint for analysis.

SUBSTANCE CONTENT
Through the use of sensitive scientific instruments, chemists are able to analyze substances to identify their chemical content.

such as its melting or boiling point. The physical property chosen to be tested must be one that is different for each of the various compounds of one general type. The result must then be checked to see that no mistakes have been made.

In quantitative analysis, inorganic substances are usually first dissolved to form solutions (see INORGANIC CHEMISTRY). The amounts of compounds present in the solutions may be found by measuring the strength of the solutions by volumetric analysis. Volumetric analysis is performed by reacting amounts of the solution and a test solution together. In this way, a chemist finds out how much of one solution is needed to react completely with a certain amount of the other. The amounts of compounds present in solution can also be found by precipitating (a way of removing) each compound from the solution as a solid. The solid is then separated, dried, and weighed. This method is called gravimetric analysis. In organic chemistry, each of the compounds present may have to be separated from the substance. The amounts of these compounds are measured. If the compounds cannot be separated, special derivatives of the compound may have to be made. (A derivative is a compound obtained from another compound.) The amounts of these derivatives are measured (see ORGANIC CHEMISTRY).

The methods of chemical analysis depend on the chemical makeup of the compounds being analyzed. Chemists today use certain machines to measure the physical properties of the compounds present. Different methods are used to identify certain physical properties. Mass spectroscopy is concerned with the masses of atoms present (see SPECTROSCOPE). Chromatography is concerned with the amounts of the compounds that are absorbed by special substances (see CHROMATOGRAPHY). X-ray diffraction is analysis using X rays (see X RAY). Polarimetry is analysis of certain compounds using polarized light (see POLARIZED LIGHT). Polarography is a technique in which analysis is performed using electrochemical methods. Radiochemistry is the study of chemical processes by using radioactive materials (see RADIOACTIVITY).

Chemical analysis has many important uses. Food chemists must be able to identify and measure the amount of any impurities in food and drink. A forensic scientist working in crime detection depends on chemical analysis (see FORENSIC SCIENCE). Chemical analysis has wide use in industry. The purity of products in the chemical industry must be constantly checked. Very often, small amounts of impurities can harmfully affect the usefulness of products. For example, the presence of only 0.01 percent of phosphorus can greatly lower the quality of copper as an electrical conductor. Chemical analysis is also extremely important in medicine. Of great importance are the analyses of blood, urine, and stomach fluids to identify certain diseases.

See also CHEMICAL INDUSTRY; CHEMICAL REACTION.

PROJECT 5

CHEMICAL AND BIOLOGICAL WARFARE Chemical and biological warfare is the use of chemical and biological substances to kill or disable large numbers of people or to destroy their food supply. These weapons usually destroy life without harming property.

Modern chemical warfare began in World War I, when chlorine gas was first used by the Germans. Chlorine affects the lungs, causing choking and making it difficult to breathe. Gas masks were developed to keep the soldiers from breathing the gas. Chlorine disabled so many soldiers that the Germans devoted much more research to harmful gases. Before the end of World War I, gases of many types were used by all the armies involved in the war. Mustard gas was one of these gases. It is absorbed through the skin, making gas masks useless. The gas causes blistering of the skin and irritation of the lungs. Although mustard gas is not related to mustard, their odors are similar. Another gas, nerve gas, interferes with the normal action of the nerve cells and can cause convulsions, vomiting, and death. Many types of nerve gas are tasteless, odorless, and colorless.

CHEMICAL AND BIOLOGICAL WARFARE
If a chemical or biological attack is likely, modern soldiers have to fight in sealed suits to prevent harmful materials from reaching their skin. They wear masks that filter the air they breathe. These NBC (nuclear, biological, chemical) suits also protect soldiers from fallout (radioactive particles) from a nuclear attack.

Other gases, such as tear gas, have a temporary effect. Tear gas causes irritation of the nose, mouth, and eyes; excessive tearing; and violent coughing. Tear gas has been used in controlling crowds during riots as well as in warfare.

Some chemicals are used to kill plants. These defoliants were widely used in the Korean and Vietnam wars. Defoliants were sprayed on fields and jungles from airplanes and helicopters. In the Vietnam War, United States forces used such defoliants as Agent Orange to destroy the communists' hiding places and food crops. Much of Vietnam's landscape was scarred and perhaps permanently damaged as a result.

Biological warfare uses disease-causing microorganisms such as bacteria and viruses (see BACTERIA; VIRUS). It is sometimes called germ warfare. This type of warfare has been used for thousands of years. For example, toward the end of the French and Indian War (1756–1764), British soldiers gave blankets infected with smallpox to the Native Americans. The Native Americans were fighting with French soldiers against the British.

In 1975, an international treaty banning biological warfare was approved. It prohibits production, possession, or use of biological agents. The forty countries that signed the treaty agreed to destroy their stored biological agents.

CHEMICAL FORMULAS AND EQUATIONS Chemical formulas and chemical equations describe the makeup and reactions of chemical substances. Chemists use chemical symbols to stand for the elements. For example, the symbol for oxygen is *O*, and the symbol for hydrogen is *H*. However, not all the symbols consist of the first letter of the English name for the element. That would not be possible: there are 105 elements and only 26 letters. Some elements, therefore, have symbols consisting of two letters. For example, *Cl* stands for chlorine and *Al* stands for aluminum. In some elements, letters from the Latin names for the elements are used. *Na* stands for sodium because the Latin for sodium is *natrium*. *Au* stands for gold because the Latin for gold is *aurum. Pb* stands for lead because the Latin for lead is *plumbum.*

To make up the formula for a chemical compound (mixture of two or more elements), chemists combine the symbols of the elements present. Water is a compound containing two atoms of hydrogen and one atom of oxygen. Its formula is H_2O. Table salt consists of one atom of sodium and one atom of chlorine. Its formula is NaCl.

Chemical equations use these symbols and formulas to show what happens when atoms react together. Hydrochloric acid is a common acid, with the formula HCl. Sodium hydroxide (also called caustic soda) is a common base, with the formula NaOH. When these two compounds are mixed together, they react. This means that the atoms of one compound rearrange themselves with the atoms of the other compound. You can see this clearly in the equation below. When hydrochloric acid reacts with sodium hydroxide, the atoms rearrange themselves so that table salt and water are formed.

$$HCl + NaOH \rightarrow NaCl + H_2O$$

A chemical equation has to "balance." That is, there must be the same number of atoms of each element on each side of the equation. If you count the number of hydrogen atoms in the above equation, you will see there are two on each side.
See also ATOM; ELEMENT; COMPOUND.

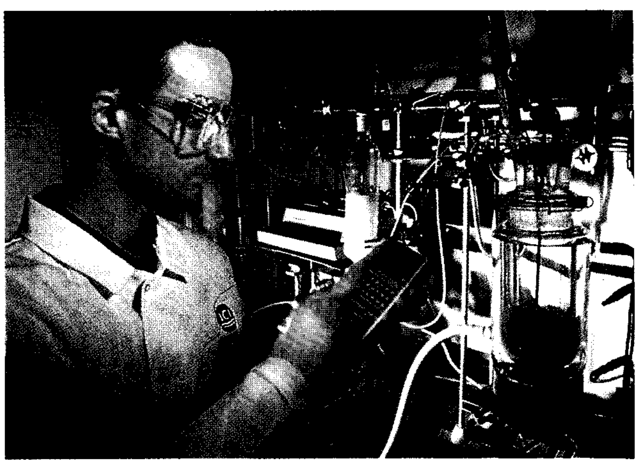
CHEMICAL INDUSTRY

CHEMICAL INDUSTRY Manufacturers involved in the production of anything made with chemicals make up the chemical industry. An almost countless number of products are made with chemicals. By producing more and more such products, the chemical industry has brought about many changes in our way of life.

A brief history Early developments in the chemical industry came during the 1600s. Scientists such as Robert Boyle, Joseph Priestley, Antoine Lavoisier, and others led the way to modern chemistry and the chemical industry (see BOYLE, ROBERT; LAVOISIER, ANTOINE; PRIESTLEY, JOSEPH). In 1635, John Winthrop, Jr., started America's first chemical plant in Boston. He produced saltpeter for gunpowder and alum for tanning hides. Still, most of the chemicals used by the colonists came from Europe. By 1900, many dyes and drugs were being manufactured in Germany, England, and France. Discoveries at this time included Bakelite resins by Leo Baekeland, and synthetic (human-made) ammonia by Fritz Haber (see AMMONIA; BAEKELAND, LEO; BAKELITE).

The development of synthetic plastics and fibers came during the 1920s (see FIBER; PLASTIC). Shortly after, the first petrochemicals were produced for commercial purposes. A petrochemical is any substance obtained from petroleum, such as gasoline. World War II (1939–1945) sparked the American chemical industry to produce a great deal of war materials. Wartime proved many synthetic materials to be as useful as, and sometimes more useful than, natural materials. After the war, there was a great demand for chemical materials such as nylon and synthetic rubber. The chemical industry has grown rapidly since World War II. The United States is now estimated to produce about 40 percent of the world's chemicals.

The types of chemical products There are three main types of materials made by the chemical industry. One is basic chemicals, both inorganic and organic compounds. (A compound is a mixture

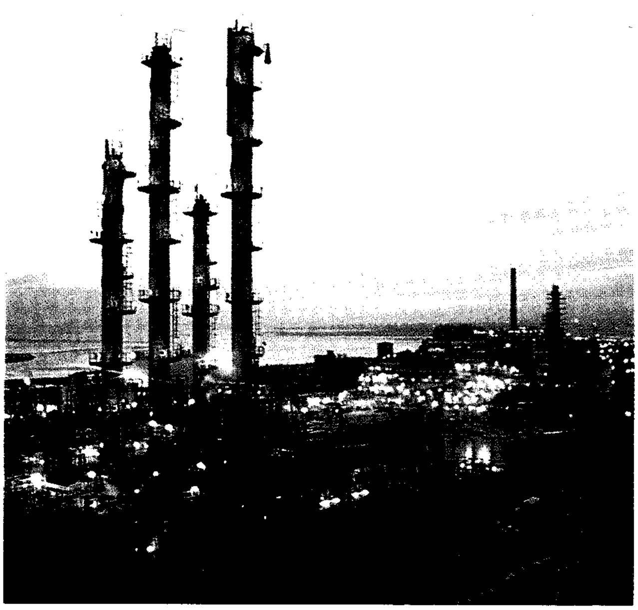


CHEMICAL INDUSTRY—Research
Industrial processes for the production of large quantities of chemicals begin with small-scale production in the laboratory. Once a process is working, the next stage is to scale the process up for production of commercial quantities.

of two or more elements. Organic compounds contain carbon; inorganic ones generally do not.) The materials for these basic chemicals come from the air, earth, and sea. Crude petroleum is the most important raw material for basic chemicals (see PETROLEUM). These include ethylene for antifreeze and xylene for paint and for synthetic fibers. Limestone rock supplies lime used to make products from which acetylene gas is then made. Furfural, made from corn cobs, is a chemical often used in making plastics. The chemical industry gets magnesium from the sea and iodine from seaweed.

Basic chemicals may be used by themselves or made into intermediate chemicals, the second type of chemical products. Intermediate chemicals include synthetic fibers, plastic materials, fats, and oils. All intermediate chemicals are eventually made into finished products. As an example, the basic chemicals urea and formaldehyde are used to make an intermediate chemical. This chemical is a synthetic resin (see RESIN). The resin can be molded into items such as handles and light fittings.

The third type of chemical materials, the finished chemicals, include soaps, paints, cosmetics, drugs, and many other products. These products are ready for use in the home or in manufacturing.



CHEMICAL INDUSTRY—Production
Modern chemical production takes place in plants that occupy large areas. In this plant, organic solvents (liquids that dissolve other substances) are being separated by distillation in the four tall towers.

Making chemical products The first step in the manufacture of chemical products is research. Chemical research tries to satisfy the needs of various manufacturers and consumers. For example, at one time, the best paint was made with lead and thinned with linseed oil. This paint had an unpleasant smell and dried very slowly. Also, lead was found to be harmful to health. Research chemists invented new lead-free paints that can be mixed with water. Some of these paints dry in twenty minutes.

The next step in making chemical products is the obtaining of raw materials. Chemical companies try to locate near the raw materials they need. For example, factories that make petroleum are often set up near the oil fields of the southwestern United States.

The third step is manufacturing. When a company decides to manufacture a product, chemical engineers are needed. Chemical engineers break down the laboratory methods into certain steps of physical operations and chemical processes. Some physical operations put the raw materials into the desired form. Common physical operations include mixing, grinding, distillation, extraction, fluidizing, evaporation, drying, and filtration.

Mixing is usually a simple process. Sometimes large, complicated machines are used to mix and blend powders, liquids, and other substances. The object of grinding is to produce particles of a certain size. For example, the ball mill grinder is made of a rotating drum that contains steel or flint balls. The balls reduce the size of the particles as they tumble over each other. Distillation is the separation of a mixture of liquids into different parts by boiling (see DISTILLATION).

When a mixture of two liquids cannot be separated by distillation, extraction is used. For example, it is used to remove acetic acid from weak acetic acid solution. The solution is treated with ethyl acetate, which dissolves the acetic acid. This extract is then distilled so that pure acetic acid is obtained. Fluidizing is used for moving solids in a particle form and for keeping particles in suspension in a fluid. Evaporation is one of the main ways to obtain substances dissolved in water. The most common evaporators are steam-heated. The steam passes through tubes in the solution. The hot solution gives off water vapor. Therefore, the solution becomes more concentrated. If the dissolved substance could undergo a chemical change if heated too much, vacuum evaporation is used. In this system, the pressure above the liquid is reduced. This lowers the boiling point (see EVAPORATION).

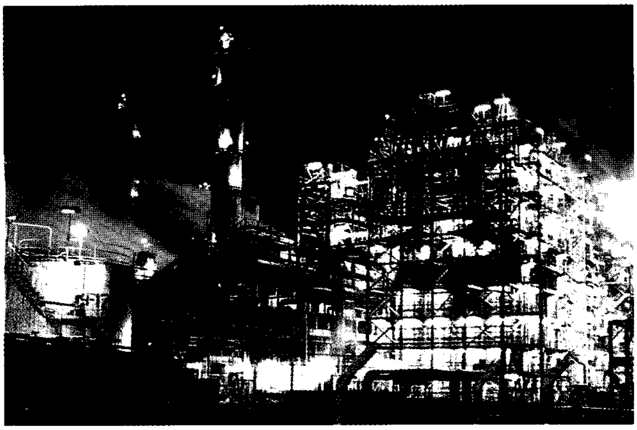
Drying is often the last stage in the manufacturing of a product. Solids are often dried by blowing warm air over or through them in special types of driers. Watery mixtures are dried on steam-heated drums. These drums are constantly revolving. The watery mixture sticks to the surface of the drum. The drying takes place as the drum rotates. The dried mixture is then scraped off. A similar instrument is used in filtration. In filtration, the drum's surface has many holes in it and is covered with a filter cloth. The liquid is sucked through to the inside of the drum (see FILTER).

Chemical processes include esterification, which is the formation of a chemical compound called an ester from the reaction of an acid and alcohol (see ESTER). Hydrolysis, the splitting of a compound into its parts by adding water, is also used (see HYDROLYSIS). Another common chemical process is polymerization, which involves making larger molecules out of smaller ones (see POLYMER).

Disposing of wastes is one of the basic problems in chemical production. Wastes are often the impurities separated from raw materials, intermediates, and final products. The United States chemical industry spends millions of dollars each year to dispose of wastes in ways that do not pollute the air or bodies of water. However, pollution by chemical wastes continues to be a problem. The chemical industry often works with the federal, state, and local governments to try to solve waste problems (see POLLUTION; WASTE DISPOSAL).

The importance of the chemical industry

It is hard to imagine how important the chemical industry is. In the home, many textiles (woven materials) are made from synthetic fibers. Chemical treatments make even natural cotton and woolen materials almost wrinkle free, water-repellent, and nearly shrinkproof. Refrigerators cool food by means of synthetic substances that absorb heat. Many wallpapers and paints are chemically treated so they are washable.



CHEMICAL INDUSTRY—Plant
Chemical production plants can be huge, with miles of pipes carrying chemicals between storage tanks and the reaction vessels where the chemical processes occur.

Chemical fertilizers help farmers produce more abundant crops. Chemical insecticides and herbicides protect crops from pests and diseases. Chemical feed supplements, which include antibiotics and hormones, are used with livestock. Despite the advantages of such chemicals, however, they can have harmful effects on the environment and on health. Many farmers are using fewer such chemicals (see AGRICULTURE; ANTIBIOTIC; HORMONE). Another use of chemicals is in hydroponic farming, in which chemical solutions replace soil (see HYDROPONICS).

Almost every industrial manufacturer uses chemicals. In many cases, synthetic rubber has replaced natural rubber. Steel makers use oxygen to make steel and metals for alloys (mixtures of metals).

The industry's contribution in health has been mainly in the production of various medicinal drugs. Most medicines are chemical products. Synthetic vitamins aid in nutrition.

In transportation, the chemical industry produces alloys that make light and strong materials used in building trucks, cars, planes, ships, and trains. Crude petroleum is processed to produce fuels. The average new automobile has about 309 lb. [140 kg] of plastic parts that are made from chemicals.

The chemical industry plays a key role in national defense. The industry produces the fuel that propels rockets, missiles, and airplanes. Chemical companies make synthetic fluids, such as silicone lubricants, for high-speed aircraft.
See also CHEMISTRY.

CHEMICAL REACTION A chemical reaction happens when elements and compounds (combinations of elements) react together to produce different compounds. Food changes in cooking. It also changes when people eat it. These are examples of chemical changes, or chemical reactions.

Chemical reactions also occur when compounds break down into simpler compounds or elements. In chemical reactions, the atoms of elements change the ways in which they are joined to each other. The chemical nature of the substance taking part in the reaction changes. This change may be shown by a difference in the substance's appearance. Also, the substance may feel harder or softer. A chemical change is different from a physical change. If a change is purely physical, the chemical nature is not changed. However, in a chemical change, physical changes may also occur (see ATOM; COMPOUND; ELEMENT).

There are four main kinds of chemical reactions. Combination, also called synthesis, takes place when two or more elements or compounds unite to form a new compound. For example, hydrogen (H) and oxygen (O) combine to form water. This can be written as below:

$$2H_2 + O_2 \rightarrow 2H_2O$$

Hydrogen has a strong affinity (attraction) for oxygen. Therefore, the two easily combine to form water.

Decomposition means the breaking down of a compound into two or more simpler compounds or elements. For example, if mercuric oxide (HgO) is heated, it decomposes into mercury and oxygen. A chemist shows this reaction by writing:

$$2HgO + \text{heat} \rightarrow 2Hg + O_2$$

Replacement, also called substitution, occurs when a compound loses some elements but gains others in their place. A replacement reaction between zinc (Zn) and sulfuric acid (H_2SO_4) produces zinc sulfate ($ZnSO_4$) and hydrogen (H_2).

$$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2\uparrow$$

Because hydrogen is easily replaced in acids by metals, zinc and sulfuric acid produce hydrogen. Also, hydrogen is a gas. It rapidly leaves the test tube or wherever the reaction is taking place, as is shown by the upward arrow.

The fourth kind of reaction is called double decomposition or double replacement. This happens when two compounds exchange atoms or groups of atoms. For example, silver nitrate ($AgNO_3$) and sodium chloride (NaCl) in solution form sodium nitrate ($NaNO_3$) and silver chloride (AgCl).

$$AgNO_3 + NaCl \rightarrow NaNO_3 + AgCl\downarrow$$

Silver chloride is formed by double composition because it does not dissolve. All the other compounds are soluble, or dissolvable (see SOLUTION AND SOLUBILITY). Silver chloride leaves the solution as a precipitate (substance separated out as a solid), as is shown by a downward arrow. It takes no further part in the reaction. Therefore, the reaction continues in the same direction.

Not all reactions go completely in one direction. Often, an equilibrium, or balance, is reached. In this case, the reacting compounds and the products are all present in certain proportions (amounts). If one of the compounds or products is removed, as happened to silver chloride in the reaction described, the reaction goes in the direction that produces more of that substance. This goes on until the equilibrium is reached again.

Temperature, pressure, and other conditions may also affect the equilibrium and the direction of a reaction. In such a case, the reaction is said to be a reversible reaction. It can be made to go in either direction, depending on the conditions.
See also CHEMICAL FORMULAS AND EQUATIONS.

CHEMISTRY

Chemistry is the science of the elements. It deals with the properties and chemical reactions of the elements and their compounds (combinations of elements). It also studies the way in which these elements and compounds can be made (see CHEMICAL REACTION; COMPOUND; ELEMENT).

Many materials that we take for granted were first made by chemists. For example, plastics are chemical compounds that have thousands of different uses. Many drugs that are now used to fight illness are made by chemists.

There are several branches of chemistry. Inorganic chemistry is the study of elements and compounds that are found in nonliving material. Organic chemistry is the study of carbon compounds. Many of them are found in living things. Physical chemistry studies how physical properties, such as heat and pressure, affect chemical reactions. Biochemistry studies the chemical makeup and behavior in living things (see BIOCHEMISTRY; INORGANIC CHEMISTRY; ORGANIC CHEMISTRY; PHYSICAL CHEMISTRY).

ALCHEMY

The science of chemistry developed out of the ancient practice of alchemy. Alchemists tried to turn base metals, such as iron, into gold. They invented apparatus for distilling liquids and used accurate balances for weighing chemicals.

Early history Many years before chemistry became a science, people knew how to combine certain substances in order to make things. For example, by 2000 B.C., people of Egypt made bronze by melting tin and copper together. They also made glass jewelry, perfume, and wine. All of these objects involved the production and control of chemical changes (see CHEMICAL REACTION). However, the people did not know why these changes took place.

The great thinkers, or philosophers, of China, India, and Greece formed the first theories, or systems of thought, about chemistry and the nature of matter. The *Shu Ching,* a Chinese book written about 350 B.C., claimed that all matter was made of earth, fire, water, metal, and wood. Empedocles, a Greek philosopher, believed there were four main "elements," namely earth, fire, water, and air. Democritus, a leading Greek philosopher, taught 2,300 years ago that all things were made of atoms. His idea was that atoms were hard pieces of matter so tiny they were invisible. This theory is based roughly on the same rule as the modern atomic theory of matter (see ATOM; DEMOCRITUS).

Alchemy and Arab chemistry Alchemy was one of the earliest forms of chemistry. It combined science, magic, philosophy, and religion. The alchemists tried many ways of changing substances into gold. They also tried to produce a substance that would give people a long and healthy life or let them live forever. Alchemists did little to advance an understanding of nature. However, they did develop many useful chemical methods. They found ways of making chemical changes in various substances. They improved methods of taking metals from ore and learned how to make and use various acids. They also designed laboratory equipment, such as balances, for weighing chemicals (see ALCHEMY).

Alchemy took place mainly in Alexandria, a Greek city in Egypt. In A.D. 642, after the Arabs conquered Egypt, alchemy spread to Arabia. Arabian chemists developed a theory that different metals could be made by combining various amounts of sulfur and mercury. For centuries, this theory was accepted in many other places.

The 1500s During the 1500s, alchemists and physicians began to use their knowledge of chemistry in the treatment of disease. Although drugs had been made and used for centuries, people did not understand how the drugs worked. The medical chemistry of this period is called iatrochemistry. Iatrochemists were the first to study chemical effects on the body. Their work sparked an interest in the chemistry of the body. As scientists began to learn more about medicine, they lost interest in many theories of alchemy.

The 1600s The birth of modern chemistry came in the 1600s. New theories were developed by several scientists. Jan Baptista van Helmont, a Belgian chemist and physician, believed that air and water were the only elements. In one experiment, he measured the growth of a tree that he fed only with water. The experiment led van Helmont to the theory that water was the basic element of all plants. Van Helmont invented the word *gas.* He studied the gases released by burning charcoal.

Robert Boyle, an Irish chemist, is often looked upon as the last important alchemist and also the first real chemist. He accepted some of van Helmont's ideas about gases, especially the study of air. Boyle taught that theories must be supported by experiments. By his experiments, he proved that air, earth, fire, and water were not elements. His book, *The Skeptical Chemist,* did much to mark the final break between alchemy and chemistry (see BOYLE, ROBERT; BOYLE'S LAW).

The 1700s During this period, many elements were discovered. The study of gases led to the discovery of oxygen. The role of oxygen in chemical reactions became the key to modern chemistry.

The early gas experiments of the 1700s were based on the theories of Georg Stahl, a German chemist. Stahl believed that a substance called phlogiston escaped when a material burned. The noted chemists Karl Scheele, Joseph Priestley, and Henry Cavendish accepted the phlogiston theory. Scheele thought that the heat produced by chemical reactions was made up of two substances: phlogiston and fire air. Fire air was actually oxygen. Priestley, a British chemist, also produced oxygen, calling it dephlogisticated air, meaning "air without phlogiston" (see CAVENDISH, HENRY; PRIESTLEY, JOSEPH; SCHEELE, KARL).

Antoine Lavoisier, a French chemist, offered a theory that opposed the theories proposed by Scheele, Priestley, and Cavendish. Lavoisier did not believe that phlogiston was released when a material burned. He believed that the material combined with a substance already present in the air (see COMBUSTION). Lavoisier called the substance oxygen. He showed that oxygen combined with metals to form compounds. By 1800, Lavoisier's theories were widely accepted (see COMPOUND; LAVOISIER, ANTOINE).

The 1800s During this era, chemists discovered about half of the more than one hundred known elements. Sir Humphry Davy, a British chemist, discovered sodium and potassium by electrolysis (see ELECTROLYSIS). He developed a new theory that explained the effects of electric current on chemical compounds (see DAVY, SIR HUMPHRY).

Chemistry began to be broken down into different branches. There were three main ones: inorganic, organic, and physical chemistry (see INORGANIC CHEMISTRY; ORGANIC CHEMISTRY; PHYSICAL CHEMISTRY).

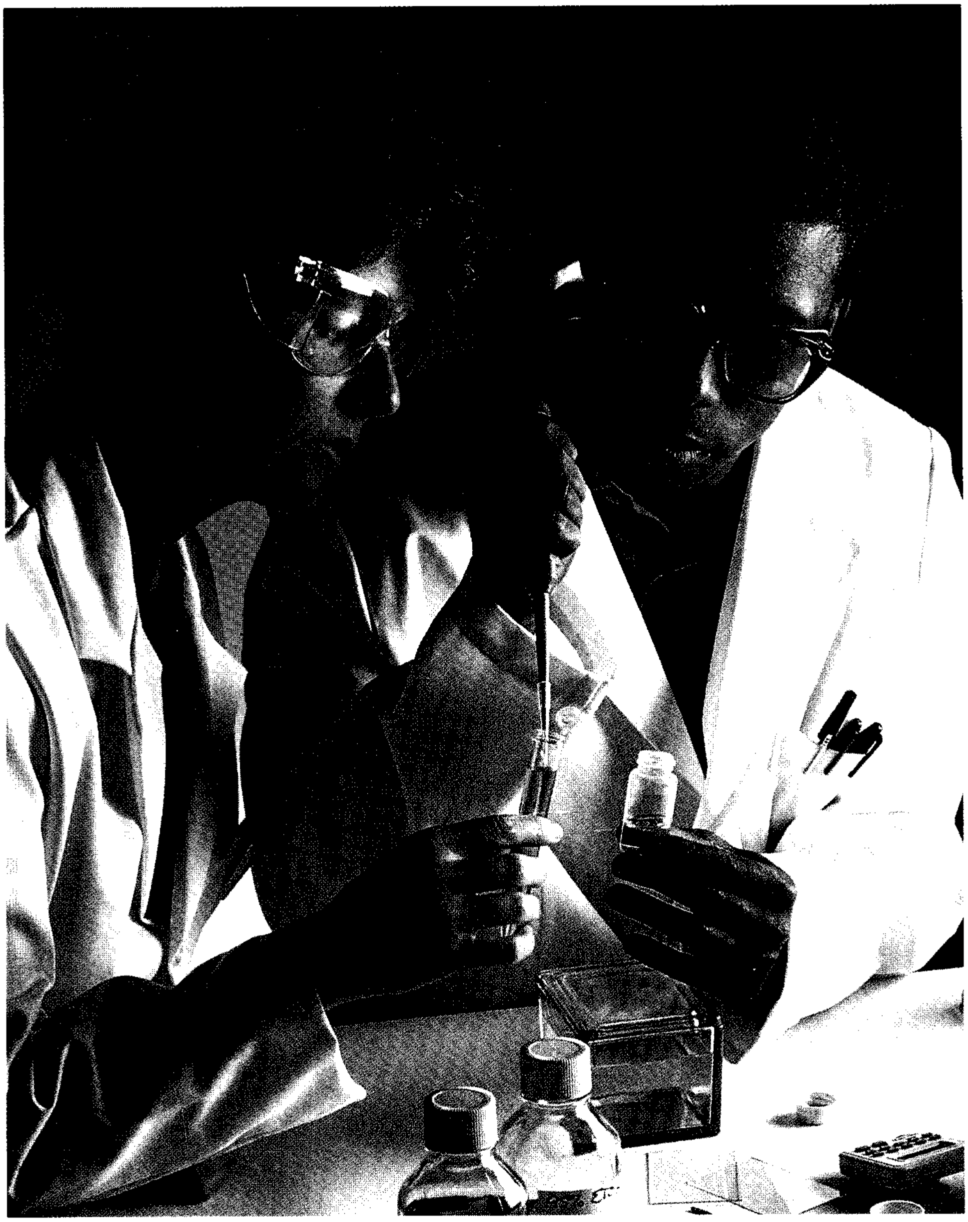
In 1803, John Dalton, a British chemist, stated that elements are made up of atoms. These atoms simply combine to form compounds. This was an important step forward in understanding chemical reactions. However, it was still very difficult to assign correct formulas to compounds (see CHEMICAL FORMULAS AND EQUATIONS; DALTON, JOHN).

By 1826, Jöns Berzelius, a Swedish chemist, made up a table of atomic weights that was fairly accurate. However, Berzelius and other chemists could not agree on various results in figuring out atomic weights. Atomic weight is now known as relative atomic mass (see BERZELIUS, JÖNS JAKOB; RELATIVE ATOMIC MASS).

In 1860, Cannizzaro, an Italian chemist, brought out the work of an earlier scientist, Amedeo Avogadro. In 1811, Avogadro had suggested that equal volumes of gases at the same temperature and pressure contain an equal number of molecules. Cannizzaro showed how Avogadro's theory could be used in measuring atomic weights (now called relative atomic mass). The theory proved the accuracy of the weights measured by Berzelius. Correct tables of atomic weights (now called relative atomic mass) and molecular weights (relative molecular

COMPUTERS

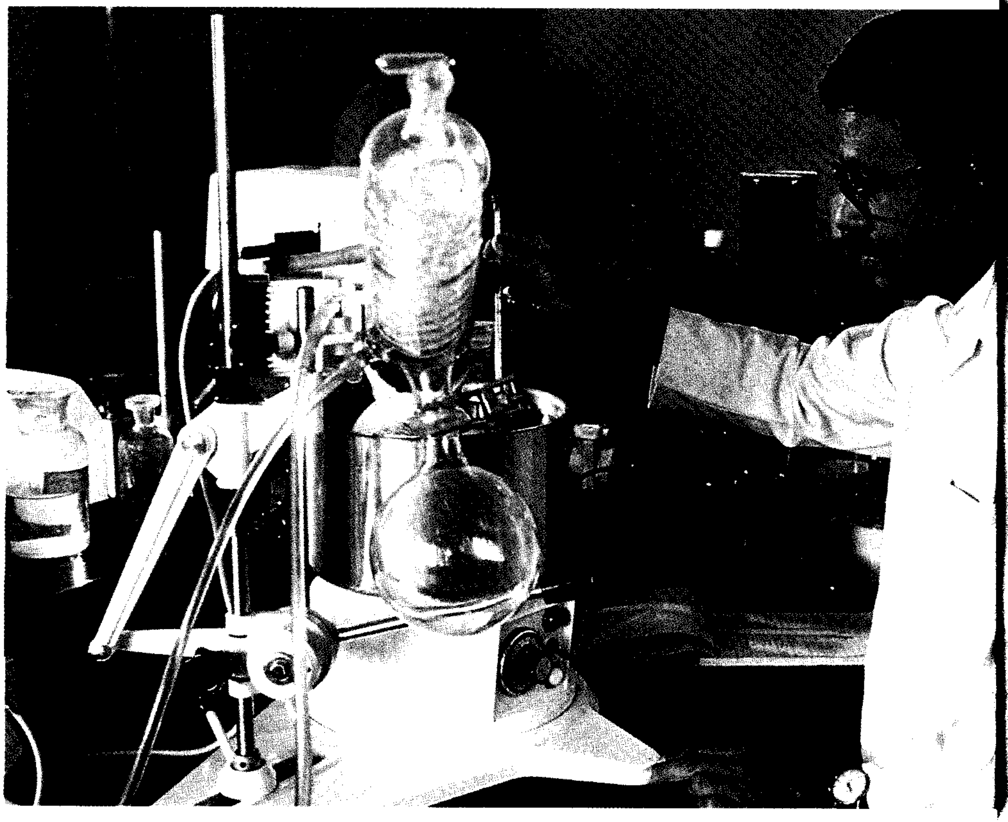
Computers programmed with data about complex molecules can produce pictures showing how atoms are arranged in the molecules (above). Chemists use this information to produce chemicals, such as medicines, with molecules that are just the right size and shape.



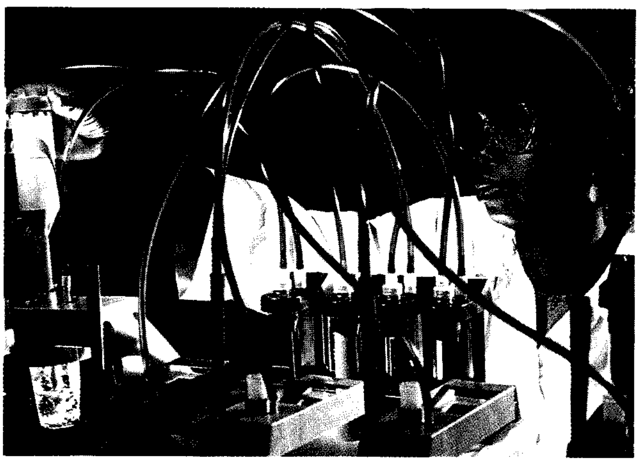
DISPENSING LIQUIDS

These chemists, working at a laboratory bench, are using a pipette (left). This is a device that dispenses a known volume of liquid.

CONTROLLED BOILING
Chemists often use distillation to separate and purify liquids (right). The liquid is carefully heated until it boils. Then the vapor is cooled in a condenser so that it turns back into pure liquid.



MAKING NEW DRUGS
Most drugs are organic chemicals—that is, compounds of the element carbon. They are usually made in a series of reactions, one step at a time. A chemist (below) checks the apparatus that maintains quality control of a pharmaceutical product.



mass) could now be drawn up (see AVOGADRO, AMEDEO). In 1869, Dmitri Mendeleev, a Russian chemist, introduced the first periodic table of the elements by arranging, according to atomic weight, all the elements that were known then (see ELEMENT; MENDELEEV, DMITRI).

Physical chemistry rapidly advanced in the 1800s. Thomas Graham, a Scottish chemist, proposed a law that became known as Graham's law of diffusion. It explains how two gases mix together. He also worked with colloids (see COLLOID; DIFFUSION).

In the 1870s Josiah Willard Gibbs, an American physicist, developed the phase rule, which concerns the coexistence of phases, or temporary forms, of matter. The three phases are solid, liquid, and gas. For example, water, which is normally a liquid, can be made to form steam, which is a gas. Water can also be frozen to form ice, a solid. Later on, Wilhelm Ostwald, a German chemist, suggested the theory of ions (see IONS AND IONIZATION).

The chemical industry began to develop during the 1800s. New artificial drugs, fertilizers, and dyes were manufactured. Germany led the world in the chemical industry. The development there of synthetic rubber in the 1900s was the beginning of the enormous industry of manufacturing plastics (see CHEMICAL INDUSTRY).

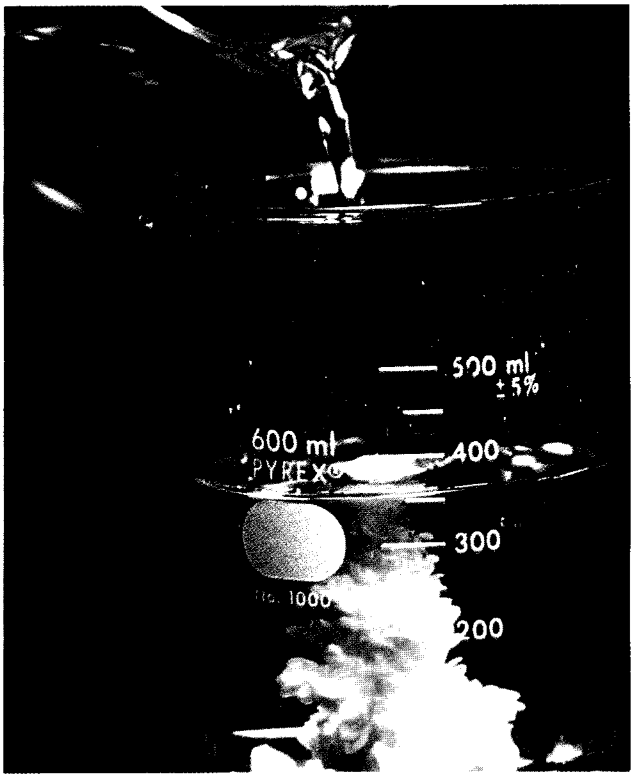
The 1900s In 1911, Ernest Rutherford, a British physicist, proposed a new theory of atomic structure. Rutherford thought that the atom had a nucleus with a positive electric charge. This nucleus was surrounded by electrons carrying a negative electric charge. Other physicists developed this idea further, discovering protons and neutrons (see RUTHERFORD, ERNEST).

In 1916, Gilbert N. Lewis, an American chemist, explained the action of electrons in chemical bonds, which are forces that hold atoms together. In 1934, Frederic and Irene Joliot-Curie discovered that artificial radioactivity could be produced. This was done by bombarding various elements with alpha particles (see CURIE FAMILY; RADIOACTIVITY). By the 1930s, scientists knew how to produce energy by splitting the nucleus of the uranium atom. After 1940, chemists and physicists were able to produce new artificial elements by nuclear reactions. A dozen new elements have been found this way. Glenn T. Seaborg has been one of the leading United States scientists in this field (see ISOTOPE; SEABORG, GLENN THEODORE; TRANSURANIC ELEMENT).

During the 1950s, scientists took major steps in biochemistry. James Watson, an American biochemist, and Francis Crick, a British biologist, created a model of the structure of a DNA molecule (see BIOCHEMISTRY; CRICK, FRANCIS HARRY COMPTON; WATSON, JAMES DEWEY). Crick and Watson used the measurements done by Maurice Wilkins, a British biophysicist. In 1962, the three men shared a Nobel Prize. Biochemists have since learned how DNA and RNA affect heredity (see DNA; RNA).

During recent years, chemists in the United States have developed special devices for exploring space. Many of these devices were designed to analyze the soil on the moon. Others are designed to look for chemical signs of life on different planets, especially Mars.

See also PHYSICS; SCIENCE.



INSOLUBLE PRODUCT
Some chemicals are made by a precipitation reaction. A colorless solution of potassium iodide is added to a colorless solution of lead nitrate (above). The bright yellow precipitate is the insoluble salt lead iodide, which is used in photography.

CRIME DETECTION
Forensic chemists help solve crimes by analyzing samples and items from the scene. Scientists at the FBI laboratory in Washington, D.C., examine a handgun for traces of blood (right).

CHERNOBYL (chûr nō'bl) Chernobyl (also Chornobyl), a city in north central Ukraine in the former Soviet Union, was the site of a nuclear power plant accident in 1986 (see NUCLEAR ENERGY). The accident, called a "meltdown," occurred in the part of the nuclear plant called the nuclear reactor. It is recognized as one of the world's worst nuclear disasters. In a meltdown, the coolant in the reactor fails to cool the core, which it surrounds. The core contains the nuclear fuel and is extremely hot. If not cooled, the core melts and can release dangerous amounts of radiation (see RADIOACTIVITY). At Chernobyl, explosions in the reactor flung radioactive dust into the atmosphere. The dust clung to leaves and grass and settled in soil and water. The dust was inhaled by people and animals.

It is believed that the accident at Chernobyl was caused by design flaws present in the nuclear plant and by violations of safety rules. Initial reports claimed that the accident killed seven firefighters, who were trying to control the fire that started from the extreme heat, and twenty-four plant workers. But some nuclear experts report that 10,000 deaths may have been linked to the accident. Many plant workers were hospitalized, and people from Chernobyl and neighboring communities had to be quickly evacuated. Many had severe cases of radiation sickness. In severe cases of radiation sickness, the skin is burned, the body's ability to fight infection is weakened, and death may result. The long-term effects of the disaster may not be evident for many years. However, some animals affected by the disaster have already given birth to young that are deformed. Also, the land around Chernobyl is contaminated and can no longer be farmed.

The power plant is still producing nuclear energy today despite plans to close the plant down due to safety concerns. Measures to clean up the site have cost an estimated $1 billion.

Western nations have agreed to give $800 million to the Ukraine to help with the cost of closing Chernobyl's remaining reactors safely.

CHERRY The cherry is a tree that belongs to the rose family, Rosaceae (see ROSE FAMILY). The cherry tree produces small, round fruit about the size of a marble. The fruit has a single stony pit and is related to the plum, peach, and apricot. There are many varieties of cherries, but the ones people usually grow in gardens and orchards are the sour red cherries or the sweet black ones.

The sour cherry trees are cultivated mostly in the eastern part of the United States. The fruit is used for making pies, puddings, and other types of cooked food. The sweet cherries grown in the United States come from the Pacific Northwest. Such cherries are often eaten raw. Both kinds of cherries can be easily preserved and shipped.

In North America, the wild black cherry tree grows in southern Canada and in the northern, western, and southern regions of the United States. It is the main lumber tree of the cherry family, growing from 30 to 60 ft. [9 to 18 m] in height. The fine-grained wood is used for making furniture. Some medicines are made from its bark and roots.

The flowering Japanese cherry trees are popular ornamentals. Species have been cultivated for their white and pink flowers. In 1912, the mayor of Tokyo, Japan, presented three thousand of these trees to the United States. They were planted around the Tidal Basin and in Potomac Park, in Washington, D.C., where they are visited by many tourists when they bloom in the spring.

CHERRY

The Okame cherry is a very popular ornamental variety, grown for its clusters of double pink flowers. The ornamental cherries do not normally produce fruit.

CHESTNUT The chestnut is a tree that belongs to the family Fagaceae. It bears a nut of the same name. There are several different kinds of chestnuts in North America and Europe.

The American chestnut was once one of the most abundant and one of the largest trees in the eastern United States. It was a valuable tree. The wood was used for building, and for telephone poles, railroad ties, and charcoal. The delicious nuts were eaten by people and wildlife. In 1910, a disease was brought to New York City on Chinese chestnut trees imported from Asia. The disease, the chestnut blight, killed almost every American chestnut within five years. American chestnut trees are able to grow new sprouts from their roots. Trees whose trunks have been dead nearly seventy years still grow shoots. When the shoots get old enough to form bark, the blight kills them. Scientists are working on a cure for the blight so that the American chestnut can be saved from extinction. *See also* NUT.

CHESTNUT
The sweet chestnut of Europe, also called Spanish chestnut, has catkinlike flowers and nuts in prickly seedcases.

CHICKEN POX Chicken pox is a common infectious disease of childhood. Usually, children between the ages of five and nine are affected, though the disease is common between the ages of one and fourteen. Adults rarely are affected.

Chicken pox is caused by a virus, which is an organism that is so small that it cannot be seen under an ordinary microscope. The disease can spread easily because the virus can be carried by droplets in the air. The virus is one of a group that causes the blisters known as herpes. In older adults, it may reappear as a painful skin disease called shingles (see HERPES; VIRUS).

Two to three weeks after a child has been around other children with chicken pox and has been infected, small red spots may show up on his or her skin. These spots look like blisters on a red base and are filled with a clear fluid. Often, the blisters are very itchy. At this time, the disease can be spread most easily because the viruses are in the fluid. If the child scratches a blister or breaks it accidentally, he or she can release the virus and infect other children.

With chicken pox, an otherwise healthy child usually will not become very sick, though he or she may feel very uncomfortable. He or she may have a low-grade fever, with a temperature rarely above 102°F [38.9°C]. The child may be tired and lose his or her appetite.

Chicken pox does not last very long. After four or five days, the blisters dry up, and small scabs are formed. These scabs should not be scratched or else they may become infected.

A person seldom has chicken pox more than once. Because the disease is so mild in children, and so contagious, doctors make no effort to prevent children from catching it. Chicken pox can be very serious in adults or in people of any age with cancer or other diseases of their immune system.

CHICKWEED Chickweed is the name given to any of several species of annual or perennial weeds belonging to the pink family (see ANNUAL PLANT; PERENNIAL PLANT; PINK FAMILY; WEED). Chickweed is found throughout North America, Europe, and Asia. Chickweed grows close to the ground and has weak, branched stems with small, oval leaves. The small white flowers bloom year-round in mild climates and may even bloom under the snow in cooler regions.

Chickweed spreads quickly and often invades cultivated lawns and fields. Many generations of chickweed may be produced in a single season. Chickweed seeds become sticky when wet and are often carried on the fur of animals or the feathers of birds (see DISPERSION OF PLANTS). Chickweed is also called starwort, tongue grass, and winterweed.

CHICKWEED
The greater water chickweed is an aquatic plant that grows in the shallow waters of ponds and slow-flowing rivers.

CHICORY Chicory is a small, perennial plant of the composite family (see COMPOSITE FAMILY; PERENNIAL PLANT). Chicory grows wild throughout North America, Europe, and Asia and is cultivated in the United States and southern Canada. The chicory plant has many branches growing from a stiff, hairy stem, which itself grows to be 3 to 5 ft. [0.9 to 1.5 m] long. The leaves, which are about 1.5 in. [3.8 cm] across, are lobed and look like those of the dandelion plant. Although the small flowers may be white or pink, they are usually bright blue. There are relatively few flowers on each plant.

The chicory's tap root is long and filled with stored food (see ROOT). The root is often dried, ground, and mixed with coffee to produce a beverage that is darker and richer than coffee. Some people prefer to use pure chicory root as a substitute for coffee.

In addition to the roots, many people eat blanched chicory leaves in salad. The leaves blanch, or turn white, if the plant is grown in darkness. Many farmers grow chicory as a pasture food for cattle. Chicory is sometimes called succory.

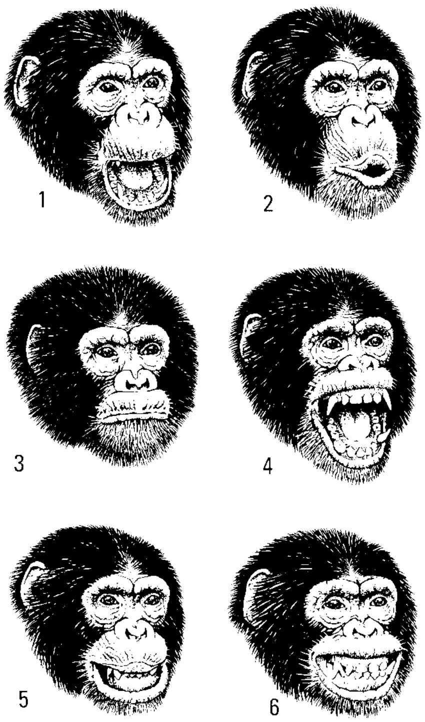
CHILDBIRTH Childbirth is the process by which a human baby is born. The baby develops from an embryo to a fetus in the mother's uterus. The uterus is a hollow, muscular organ inside the abdomen of a female. It usually takes about nine months for a baby to fully develop. After nine months, hormones in the mother cause muscles in her uterus and abdomen to push the baby out of the uterus into the vagina, or birth canal (see HORMONE). These muscle contractions are called labor. The mother also pushes with her abdominal muscles. The baby leaves the mother's body through the vagina. During the first pregnancy, labor can last as long as thirteen hours or more. Later pregnancies usually have shorter labor.

After the baby is born, one of the first things the doctor does is cut the umbilical cord on the baby's abdomen. The umbilical cord connects the baby to the mother's uterus via the placenta (or afterbirth), which is pushed out of the uterus after the baby is born. The placenta and umbilical cord carried oxygen and food from the mother to the baby before the baby was born. Wastes also were passed from the baby to the mother through the umbilical cord and placenta.

See also EMBRYO; PREGNANCY; REPRODUCTION; REPRODUCTIVE SYSTEM; UMBILICAL CORD; UTERUS.

CHIMPANZEE The chimpanzee is the ape with a body and a brain most like those of human beings. The chimpanzee is the most widespread of the anthropoids and the one that has received the most medical and psychological study (see ANTHROPOID; APE; PRIMATE). A male chimpanzee may grow to be about 5.5 ft. [1.7 m] tall and weigh about 175 lb. [79 kg] . The female is usually shorter and lighter. Chimpanzees have long, dark brown or black hair; large ears; long hands; and, like all apes, no tail. Their feet have thumblike big toes, which aid in climbing trees.

The chimpanzee rarely stands upright. It spends much of its time in trees, where it makes a new nest



CHIMPANZEE

Chimpanzees are very popular zoo animals, especially because of their wide range of facial expressions. The drawings show a chimpanzee with several different expressions: (1) a playful face; (2) begging for food; (3) an angry face; (4) a frightened face; (5) a resigned, or "I give up," face; and (6) an anxious face.

every night. Chimpanzees live in a family group with one male, several females, and the young. Chimpanzees communicate with each other by means of vocal sounds and body gestures. Their faces show a range of emotions. Chimpanzees show their affection by kissing and hugging or by gently touching each other's bodies. They are rarely aggressive. The adults spend at least an hour a day grooming each other. Chimpanzees look for food during the day and sleep at night. Although they usually eat fruits and plants, they also eat insects and other small animals.

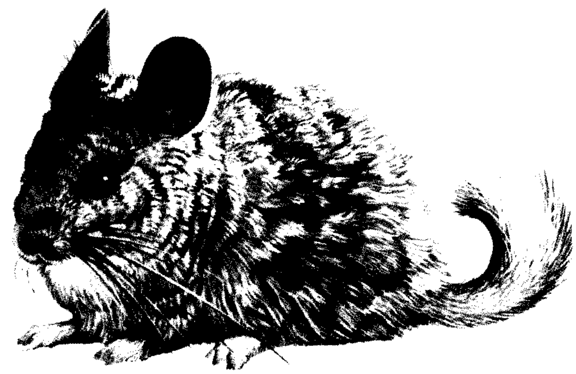
The female starts mating when she is eleven or twelve years old. After an eight-month pregnancy, the mother gives birth to one baby. Twins are rare. The mother takes care of the baby until it is old enough to fend for itself (six to seven years). Chimpanzees in the wild live to be about forty years old.

Chimpanzees are the most intelligent of the apes. Their brain size and structure are similar to those of human beings. Chimpanzees can imitate behavior and have been taught to do various tasks. More importantly, however, chimpanzees show an ability to solve problems. They will make tools to help solve these problems. They have been observed putting sticks together or stacking boxes to reach food. They have a good memory and will remember people or tasks for years.

In the mid-1900s, scientists tried to teach chimpanzees to speak English. Chimpanzees do not have the proper vocal structures to make human sounds, and the experiment failed. However, chimpanzees have been taught sign language. One chimpanzee even invented new words, such as *water bird* for duck.

See also GOODALL, JANE.

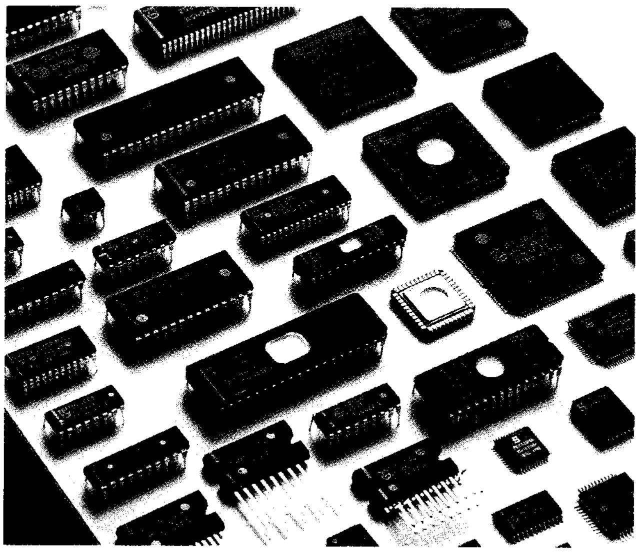
CHINCHILLA (chĭn chĭl'ə) The chinchilla is a rodent native to the Andes Mountains of South



CHINCHILLA

Chinchillas are sometimes kept as pets, although they do not like being handled very much.

America. It grows to about 12 in. [30 cm] long and weighs 18 to 28 oz. [500 to 800 g]. Related to the guinea pig, the chinchilla has long hind legs and a bushy tail about half as long as its body. The chinchilla sleeps in its burrow during the day and comes out at night to feed on roots and grasses. Chinchillas are hunted for their thick, blue gray fur, which is used to make fur coats. They are also raised on farms, or chinchilla ranches, for their fur. The first chinchillas were brought to California from Chile in 1923. Today, there are chinchilla farms in the United States and Canada.
See also GUINEA PIG; RODENT.



CHIP
Chips are made in a wide range of shapes and sizes. Many of them have metal contacts along two sides. These contacts link the chip to the rest of the circuit. The simplest chips may contain only a handful of components. The most complex chips contain hundreds of thousands of components.

CHIP *Chip* is a term used in electronics to refer to a small wafer of silicon that contains many electronic components. Some chips are so small that they are able to pass through the eye of a sewing needle (see ELECTRONICS; SILICON).

Early digital computers used vacuum tubes instead of chips (see COMPUTER; VACUUM TUBE). The tubes controlled the flow of electrons used to process information. To perform different computer operations, the tubes had to be physically rewired like an old wire-and-plug telephone switchboard. Rewiring could take several days. In the late 1940s, scientists invented a small "sandwich" of semiconducting materials (mostly crystals of germanium) called a transistor. Silicon crystals were later used in transistors. Transistors replaced vacuum tubes in computers because they were smaller, worked faster, and had fewer failures (see GERMANIUM; SEMICONDUCTOR; TRANSISTOR).

The first computers built with transistors were made like early radios, with a tangle of wires connecting the different components to form electronic circuits. Soon electronics manufacturers began "printing" the circuit wiring directly onto a board. The transistor and the miniaturized, board-printed circuit made it possible to reduce the size of a computer significantly. Eventually, researchers found that any number of transistors (along with the connections between them) could be etched onto one chip the size of a pea. These chips contained the electronic components needed for operating the computer.

Then, in the early 1970s, a major breakthrough occurred. A complex chip, called a microprocessor, was designed that would act as the entire central processing unit of a computer. A microprocessor can be thought of as a "computer on a chip." Today's microprocessors contain thousands of components on a chip smaller than a fingernail.

Microprocessors have led to the development of advanced medical equipment, computer-based video games, electronic music systems, pocket-sized calculators, and personal computers.
See also CALCULATOR; INTEGRATED CIRCUIT.

CHIPMUNK The chipmunk is a small, reddish brown rodent with black-and-white stripes on its face, back, and sides. Belonging to the family

CHIPMUNK
Chipmunks carry food back to their burrows in cheek pouches that open into their mouths.

Sciuridae, it is a close relative of the squirrel and the groundhog. The chipmunk has strong hind legs. Although it sometimes climbs trees, the chipmunk spends most of its time in its burrow or on the ground in search of food. It feeds mainly on nuts and fruits and stores its food in its burrow. The chipmunk sleeps through much of the winter. Chipmunks are native to Asia and North America. There are more than a dozen species of chipmunks found in the United States, all of which are about 8 in. [20 cm] long.

See also GROUNDHOG; RODENT; SQUIRREL.

CHIROPRACTIC (kī′rə prăk′tĭk) Chiropractic is a science based on the theory that health and disease are related to the function of the nervous system. The theory is that irritation of the nervous system causes disease, and the maintenance of health depends on its normal function.

Chiropractors practice chiropractic by moving joints, usually the spine, to stimulate the nervous system and restore normal function (see JOINT). Chiropractic can help treat many conditions, such as backache, headache, dizziness, and asthma. Chiropractors are trained not only to find and treat these conditions, but also to tell them from diseases that would be better treated by other medical methods.

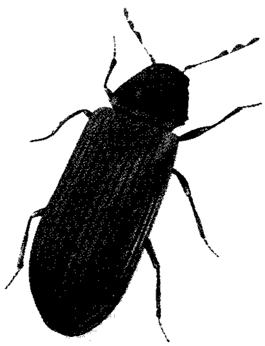
Chiropractic is a relatively new science. It began in the United States in 1895, but chiropractors were not given a legal right to practice throughout the U.S. until 1974. Today chiropractic is recognized as having a role in the treatment of many disorders. Chiropractors often work alongside medical doctors.

CHIROPRACTIC

A chiropractor uses chiropractic to move (manipulate) a patient's spine between the shoulder blades. Chiropractors usually manipulate the spine because of its importance in the body's nervous system and because many people suffer from backache.

CHITIN (kīt′n) Chitin is the rigid material that forms most of the exoskeleton, or outer covering, of insects and other arthropods. The molecules of chitin contain nitrogen, carbon, hydrogen, and oxygen. These molecules are arranged in long chains, which in turn are grouped into fibers. Chitin is secreted by underlying cells in the body of the animal. It is often combined with chalky materials, which increase its toughness. In most crustaceans, such as crabs and lobsters, the chitin becomes impregnated with calcium carbonate and the animals' shells are thick and strong. Most insects, such as flies and moths, have thin coats of chitin. With the exception of its nitrogen content, chitin is similar to the cellulose of plant cells.

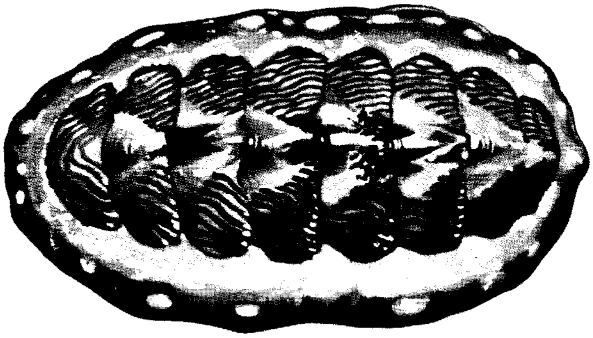
See also ARTHROPODA; CELLULOSE; CRUSTACEAN; SKELETON.



CHITIN

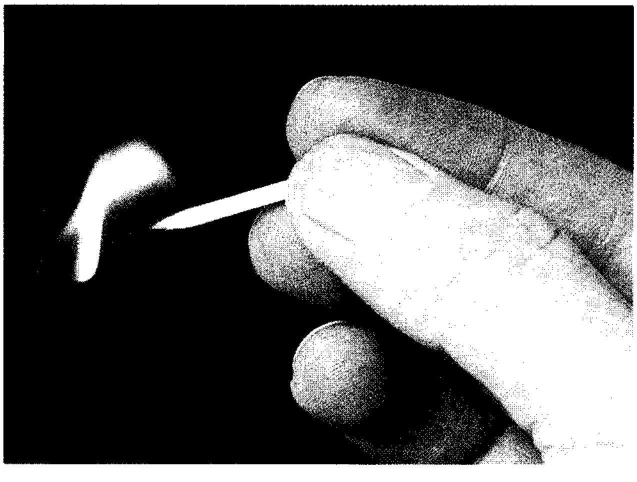
Beetles, such as this furniture beetle, have tough wing cases, or elytra, that protect the delicate hindwings beneath them. The elytra get their strength from chitin.

CHITON (kīt'n) The chiton is a mollusk of the class Amphineura (see MOLLUSCA). Its shell is often brightly colored and consists of eight overlapping plates. With a muscular foot like that of the snail, the chiton holds onto rocks of the seacoast. It feeds on algae, which it scrapes from the surface of rocks. Although chitons are found along various rocky coasts of North America, they are most abundant and varied on the shores of California. Most chitons are 1 to 2 in. [2.5 to 5 cm] long, but a large species of the Pacific coast grows to a length of 12 in. [30.5 cm].



CHITON
Chitons are often called coat-of-mail shells because of the way in which their shell plates overlap.

CHLORATE (klōr'āt') A chlorate is a compound (combination of elements) of one or more metals, chlorine, and oxygen. The *-ate* ending on a compound indicates that it contains three or more elements (see ELEMENT). Chlorates are dangerous chemicals. If they are mixed with something that burns easily, they can cause an explosion. This is because chlorates contain so much oxygen. Potassium chlorate is used to make explosives, matches, and fireworks. Sodium chlorate is used as a weedkiller.



CHLORATE
Potassium chlorate is the source of oxygen that makes match heads burst into flame when a match is struck.

CHLORDANE Chlordane is an insecticide containing chlorine, carbon, and hydrogen. It is a colorless liquid that does not dissolve in water. Most uses of chlordane have been banned by the United States government because the chemical may cause cancer.

CHLORIDE A chloride is a compound (combination of elements) that contains chlorine and another element, often a metal. The *-ide* ending indicates that the compound contains only two elements (see ELEMENT). The most common chloride is sodium chloride, which is ordinary table salt. Another important chloride is silver chloride, which is sensitive to light and is used in photography.

CHLORINE (klōr'ēn') Chlorine (Cl) is a poisonous, yellow green gas with a strong, choking odor that nevertheless has many uses. Chlorine belongs to the halogen family of chemical elements (see ELEMENT; HALOGEN). In 1774, Karl Scheele, a Swedish chemist, discovered chlorine by treating hydrochloric acid with manganese dioxide. In 1810, Sir Humphry Davy, a British chemist, showed that chlorine was an element (see DAVY, SIR HUMPHRY; SCHEELE, KARL WILHELM).

Chlorine is found in nature only in compounds—that is, with other elements. Chlorine does not exist alone in nature. The most common chlorine compound, sodium chloride (ordinary table salt), is found in oceans, salt lakes, and rock salt (see CHLORIDE). Chlorine can also combine with organic (carbon-containing) radicals (see RADICAL). Chlorine is manufactured by passing an electric current through a water solution of sodium chloride (see ELECTROLYSIS).

Chlorine is a bleach and is present in bleaching powders and fluids. Chlorine is often used to purify water. It is also used to kill bacteria in waste material and to make insect and weed killers. Chlorine is used to process certain foods. It is also used in the manufacture of drugs, dyes, metals, and plastics. Chlorine has been used to produce various types of industrial chemicals, such as chlorofluorocarbons (see CHLOROFLUOROCARBON).

One of the most useful chlorine compounds is hydrochloric acid, which is used in dyeing processes and in cleaning metal. Another compound, chloroform, is a solvent (substance that can dissolve other substances) and an anesthetic (substance that causes loss of feeling). Chlorine is used in manufacturing chlorinated compounds that are used in pulp bleaching and textile processing. Polyvinyl chloride, or PVC, is a well-known plastic.

Chlorine's atomic number is 17. It has a relative atomic mass of 35.45. Chlorine melts at -149.7°F [-100.98°C] and boils at -30.2°F [-34.6°C].

See also CHLORATE.

CHLOROFLUOROCARBON (klôr′ō flo͝or′ ō kär′bən) Chlorofluorocarbons are synthetic, or human-made, chemicals made of the elements chlorine, fluorine, and carbon. Commonly called CFCs, the chemicals were developed in the 1930s. CFCs have since been shown to be a serious environmental hazard. The U.S. government has ordered that CFCs be phased out by 1996. European countries ended their use of CFCs in 1995.

Freons are a group of CFCs used as refrigerants in air conditioners and refrigerators. They once were used to make plastic foams. Freons also were used as propellants in aerosol cans until such use in the United States was banned in 1978 (see AEROSOL).

CFCs escape into the air when products containing them are used. CFCs then drift many miles above the earth's surface into the upper stratosphere (see ATMOSPHERE). There, CFC molecules are broken apart by the sun's ultraviolet rays. The chlorine atoms that are freed destroy the ozone layer (see OZONE LAYER). In a single year, one chlorine atom can destroy a hundred thousand or more ozone molecules. The ozone layer protects plants and animals from the harmful effects of the sun's ultraviolet rays. Without that protection, for example, humans are at greater risk of developing skin cancer. Studies have also shown that increased ultraviolet rays may damage many forms of life, altering the fragile food chain.

CHLOROFORM Chloroform ($CHCl_3$) is a colorless liquid with a strong, sweet smell. Chloroform is used in the manufacture of chlorofluorocarbons (see CHLORINE; CHLOROFLUOROCARBON). Chloroform is also used as an industrial solvent (substance that dissolves other substances), such as in the manufacture of antibiotic drugs, dyes, and pesticides. Because chloroform has anesthetic properties, it was once commonly used to deaden pain. Other anesthetics have now replaced chloroform. When used as an anesthetic, chloroform was found to have harmful effects on the heart, liver, and kidneys (see ANESTHETIC).

In 1976, the United States Food and Drug Administration (FDA) banned the use of chloroform in drugs and cosmetics. The FDA did this because tests showed that the compound could cause cancer in laboratory animals. Chemically known as trichloromethane, chloroform freezes at –83.2°F [–64°C] and boils at 143.6°F [62°C].

CHLOROPHYLL Chlorophyll is a green pigment found in plants, algae, and some bacteria. In plants, it is usually concentrated in the cells of the

CHLOROPHYLL—Concentration
Most of a plant's chlorophyll is concentrated in its leaves. The leaves are arranged so that they can get the most sunlight to make the most food.

CHLOROPHYLL—Breaking down

In the fall, the leaves of many deciduous trees change from green to brilliant red and gold. This change happens because the chlorophyll breaks down and all useful food material is taken back into the twigs. The red and yellow pigments have been in the leaves all the time, but they do not show up until the chlorophyll has gone. These pigments are not needed by the tree and remain in the falling leaves.

leaves. Chlorophyll is needed so the plant can make food by photosynthesis (see PHOTOSYNTHESIS). Chlorophyll is contained in small, flattened bodies called chloroplasts. Certain plant cells may contain from one to several hundred chloroplasts.

Chlorophyll contains the elements carbon, hydrogen, oxygen, nitrogen, and magnesium. There are several forms of chlorophyll, the most common of which are chlorophyll a and chlorophyll b.

If a plant is kept out of the light, much of the chlorophyll breaks down. The leaves turn from green to yellow, and photosynthesis stops. If the plant is kept in the dark for several weeks, it will die, having starved to death.

See also ALGAE; BACTERIA; CHLOROPLAST; PLANT KINGDOM.

PROJECT 68

CHLOROPLAST Chloroplasts are organelles, or tiny structures, that are part of living plant cells. Chloroplasts contain chlorophyll and other substances that allow the plants to carry on photosynthesis to make their food (see CHLOROPHYLL; ORGANELLE; PHOTOSYNTHESIS).

Chloroplasts are usually located in a plant's leaves. The chlorophyll that chloroplasts contain is what gives leaves their green color. Chloroplasts are also found in the green stems of some kinds of plants, such as cacti. Each plant cell may contain anywhere from one to hundreds of chloroplasts.

See also CHROMOPLAST.

CHOLERA Cholera is a very contagious intestinal disease that causes massive, watery diarrhea, resulting in rapid loss of body fluids and salts. If untreated, cholera may result in dehydration, shock, and death. It is caused by a bacterium, *Vibrio cholerae,* that produces a toxin (poison) that acts in the intestines. The bacteria are most often spread by contaminated food and water, or sometimes by contact with an infected person who is involved in preparing food. Cholera is common in India and other Asian countries where there are unsanitary conditions. Every year, cholera kills many people in India. Children aged one to five years are more susceptible to the disease than adults in these areas. But when an area that does not usually have cholera experiences an epidemic (a widespread outbreak of disease), usually due to contaminated water, children and adults are affected equally.

Cholera symptoms last from two to seven days. Antibiotics can reduce the severity of the disease by helping the body's natural defenses kill the bacteria (see ANTIBIOTIC). The patient must receive rehydration therapy, involving special salt and sugar solutions taken by mouth or through the veins if the patient is too ill to drink. This is necessary to replace lost body fluids and prevent dehydration. There is a cholera vaccine that produces short-term immunity against the disease but will not prevent it from spreading (see IMMUNITY). So vaccination against cholera is not recommended for travelers. The only good prevention against cholera is careful hygiene.

CHOLESTEROL (kə lĕs'tə rôl') Cholesterol is a fatty substance made in the bodies of human beings and other animals. Cholesterol is found in the blood, tissues, and organs, particularly the brain, liver, and arteries.

Deposits of cholesterol and other substances may form on the inside walls of the arteries, causing them to roughen, harden, and narrow, allowing less blood to flow. This condition is called atherosclerosis, a form of arteriosclerosis. The deposits, called plaques, may become the site of blood clot formation. If this occurs in a coronary artery (an artery that supplies blood to the heart), the result can be a heart attack (see ARTERIOSCLEROSIS; HEART DISEASE).

Cholesterol is used by the body to produce several of the chemicals known as hormones. Cholesterol is also used to produce bile salts used in digestion. Deposits of hardened cholesterol in the bile, however, may settle in the gallbladder as gallstones (see GALLBLADDER).

Although the body produces its own cholesterol, people also take in cholesterol when they eat animal foods, such as meat, eggs, and dairy products. High intakes of cholesterol may raise the blood cholesterol level and thus increase the risk of heart disease.

The relationship between cholesterol in the blood and heart disease is dependent on how the cholesterol travels throughout the body. Cholesterol must be combined with protein to be soluble (dissolvable) in blood. This combination is called a lipoprotein. Lipoproteins are classified by their density, which is determined by the ratio of protein to cholesterol and other fats. For reasons that are not fully understood, cholesterol that travels throughout the body as low-density lipoproteins (LDL) increases the risk of heart disease; and cholesterol that travels as high-density lipoproteins (HDL) lowers the risk of heart disease.

Exercise, weight loss, and reducing one's intake of cholesterol and saturated fats in food help increase the concentration of high-density lipoproteins.

See also DIET; FAT.

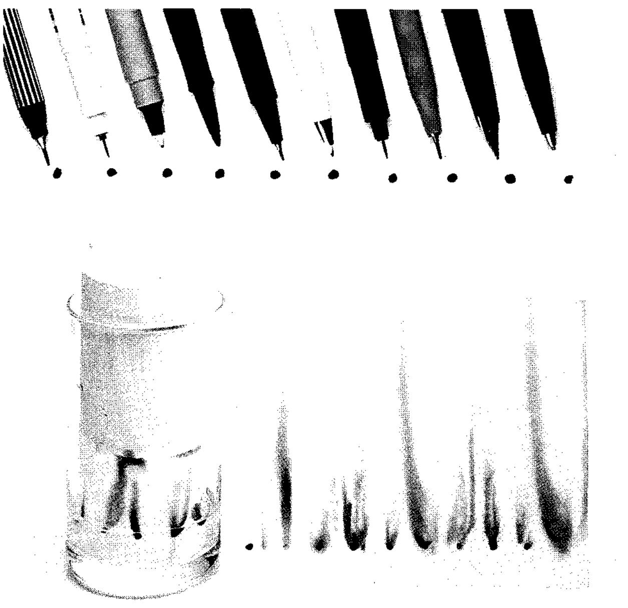
CHORDATA Chordata is a phylum of the animal kingdom (see PHYLUM AND SUBPHYLUM). It includes amphibians, birds, fish, lancelets, mammals, and reptiles. All chordates have three features sometime during their lives: a notochord (a hard but bendable rod of cartilage extending along the body), a hollow nerve tube that runs above the notochord, and gill slits (see CARTILAGE; GILLS; NOTOCHORD). These features are present only in the embryo of some chordates (see EMBRYO). Humans are chordates, but the gill slits and notochord disappear before they are born. Gill slits develop into gills in fishes and some amphibians.

CHORDATA

These small sea squirts look like bags of jelly, with no sign of a skeleton. But they are chordates. They have simple gill slits, through which they filter food as well as oxygen. Their young stages are tadpolelike creatures with a stiff notochord in their tails.

CHROMATOGRAPHY (krō′mə tŏg′rə fē) Chromatography is a way of separating and identifying the various substances in a mixture. This method may be done in several ways.

Paper chromatography, sometimes called adsorption chromatography, is based on the fact that porous paper adsorbs different substances to different extremes (see ABSORPTION AND ADSORPTION). The mixture to be studied is first dissolved in a liquid. A small drop of the solution is then placed about 0.4 in. [1 cm] from the edge of a strip of paper, such as filter paper. After the solution dries, the paper, with the sample spot at the bottom, is hung vertically in a glass vessel. In this position, the lower edge of the paper strip makes contact with a layer of solvent in the vessel. The solvent rises among the fibers of the paper by capillary action. In doing this, the solvent carries the various substances in the sample spot to different heights on the paper strip, thereby separating the substances (see CAPILLARY ACTION; SOLUTION AND SOLUBILITY).



CHROMATOGRAPHY

A simple experiment shows how chromatography can be used to separate a mixture of substances. Black ink from any make of ballpoint or felt-tip pen looks the same. Black dots were drawn on a piece of blotting paper using ten different pens. The paper was then curved into a cylinder and placed in a beaker containing a small amount of alcohol mixed with water. As the liquid rose up the blotting paper (by capillary action), it separated the inks into the dyes that they were made from. The dried paper—the chromatogram—shows that all the inks are actually mixtures.

Substances that were strongly adsorbed by the paper, and mix only slightly in the solvent, rise a short distance. Substances that were not strongly adsorbed by the paper, and dissolve easily in the solvent, are carried to higher levels. If the substances in the original mixture were colored, a group of colored spots can be seen between the position of the sample spot and the top of the paper strip. Each spot contains one of the substances in the original mixture. The paper strip is now called a chromatogram. It is removed from the glass vessel and dried. Certain substances can often be identified by the heights they reach on the chromatogram. To be accurate, it is necessary to perform the chromatography under certain strict conditions. This means using a standard type of paper and solvents. The substances in each spot can be removed from the paper by treatment with a certain solvent. This process is called elution. Once a solution of the purified substance has been obtained, it can be identified by chemical tests.

Chromatography can also be used to separate and identify mixtures of colorless substances. In order to do this, the chromatogram is sprayed with certain chemicals. The chemicals react with the substances to be studied, producing colored compounds.

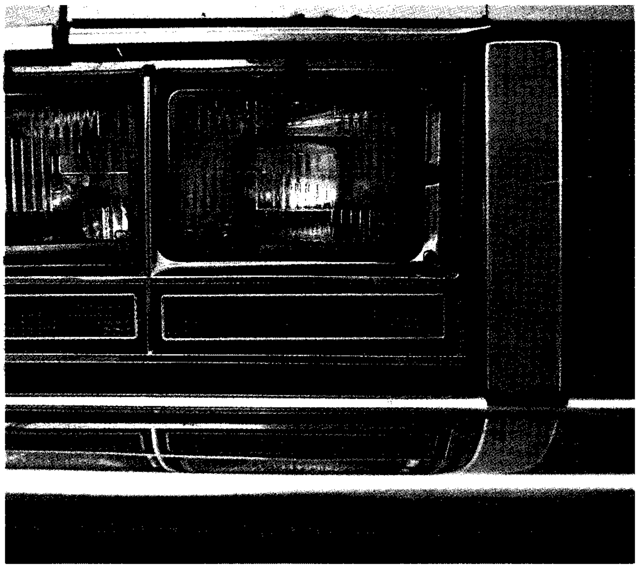
Thin-layer chromatography is almost the same process as paper chromatography. In thin-layer chromatography, the paper is replaced by a sheet of glass on which a thin layer of an absorbent substance—such as silica gel—has been placed.

In adsorption chromatography, as described before, the adsorbent material, such as the paper, is often called the stationary phase. The solvent is called the moving phase. In partition chromatography, both the moving phase and the stationary phase are liquid. The stationary phase is often held by a sheet of solid material, such as a paper strip or silica gel. The moving phase passes up or down on the solid material. The distance moved by a certain substance in the sample spot depends on the difference in solubilities of the substance in each of the two liquid phases.

Gas chromatography is a type of partition chromatography. The stationary phase is a solid or a liquid. The moving phase is a gas. Gas chromatography is often used to study substances that form vapors. Chemists use gas chromatography to find out what chemicals are present in mixtures such as petroleum products, smog, and cigarette smoke (see CHEMICAL ANALYSIS). PROJECT 5

CHROMIUM Chromium (Cr) is a hard, brittle, gray metallic element (see ELEMENT). Chromium, sometimes called chrome, occurs only as a combined metal—that is, combined with other elements. It is usually found combined with iron and oxygen in a mineral called chromite. It is mined chiefly in Albania, South Africa, the former Soviet Union, Turkey, and Zimbabwe.

Chromium resists corrosion (see CORROSION). It becomes very shiny when polished. Because of these properties, chromium is widely used to coat, or plate, other metals. Chromium is also used to harden steel. Its alloys are used to make safes, ball bearings, and the cutting edges of various tools. Alloys (combinations of metals) that have more than 10 percent chromium are called stainless steel. Stainless steel is used to make eating utensils and kitchen equipment. Many chromium compounds are important in industry. Potassium dichromate is used in tanning leather. Lead chromate, also called chrome yellow, is a pigment (coloring substance) for paint. Some chromium compounds are used in the aircraft industry to anodize aluminum, or coat it with a thick, protective, oxide film.



CHROMIUM
Chromium plating is common on automobile trim. The shiny chromium looks attractive and prevents the steel trim from rusting.

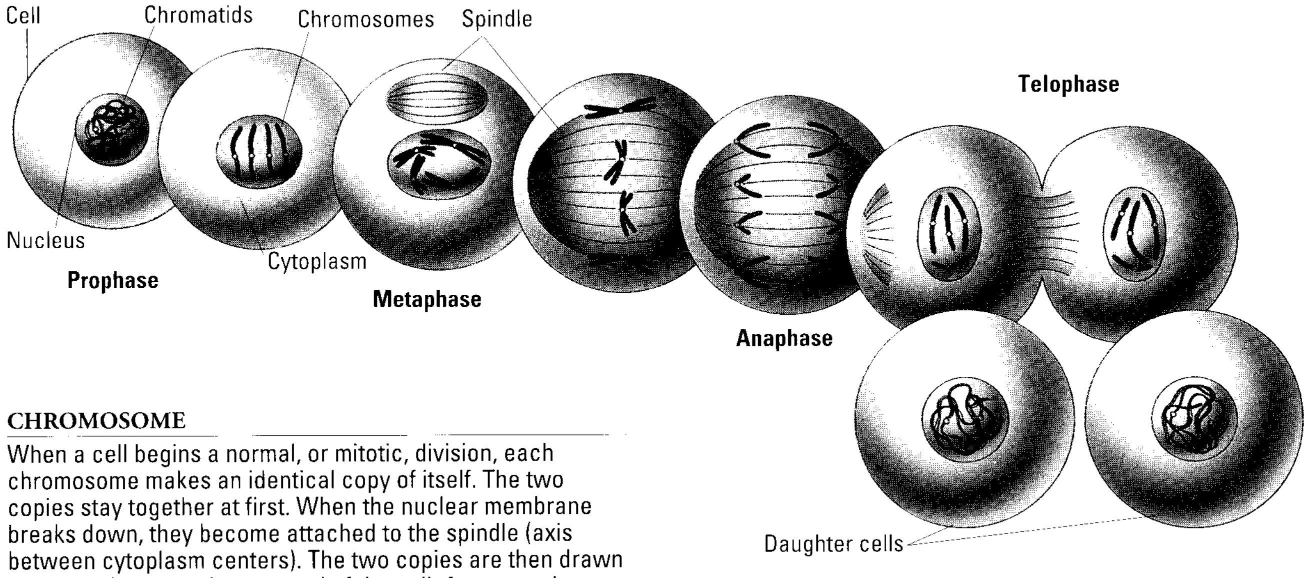
Chromium has an atomic number of 24. Its relative atomic mass is 51.99. Chromium melts at about 3,452°F [1,900°C] and boils at 4,874°F [2,690°C].

CHROMOPLAST Chromoplasts are any of the various organelles, or tiny structures, within plant cells that contain pigments (coloring matter). Chromoplasts may have different colors. Chloroplasts, which contain the green pigment chlorophyll, are one kind of chromoplast (see CHLOROPHYLL; CHLOROPLAST). Red, yellow, orange, and brown chromoplasts are responsible for the colors of the leaves of deciduous trees in fall (see DECIDUOUS TREE). Such chromoplasts also give some flowers, fruits, and roots their colors.
See also CAROTENE; PIGMENT; XANTHOPHYLL.

CHROMOPLAST
The color of these leaves in the fall is due to chromoplasts in the plant's cells.

CHROMOSOME Chromosomes are small, threadlike bodies found in the nucleus of every cell. They contain chains of DNA (deoxyribonucleic acid) called genes. Genes control the inherited characteristics of an organism (see CELL; DNA; GENE).

Each species of organism has a specific number of chromosomes. For example, human beings have forty-six, and cows have sixty. Most organisms have



CHROMOSOME
When a cell begins a normal, or mitotic, division, each chromosome makes an identical copy of itself. The two copies stay together at first. When the nuclear membrane breaks down, they become attached to the spindle (axis between cytoplasm centers). The two copies are then drawn apart. Each goes to its own end of the cell. A new nuclear membrane forms around each new group of chromosomes. Then the cell divides to give two identical daughter cells.

chromosomes arranged in pairs. The forty-six human chromosomes are actually twenty-two ordinary pairs plus one pair of sex chromosomes. There are two kinds of sex chromosomes, the X chromosome and the Y chromosome. They are named X and Y because of the way they look under a microscope. In the body cells of the human female, there are two X chromosomes. The male has one X and one Y in each body cell.

Chromosomes can be seen only at certain times, and then only with a powerful microscope. Chromosomes "appear" in the nucleus just before a cell splits into two daughter cells. In mitosis, each chromosome splits lengthwise into two chromosomes, one for each daughter cell. In meiosis, the chromosomes do not split, so each daughter cell has only half the regular number of chromosomes. These cells develop into gametes—sperm or egg. The egg produced by a human female has an X chromosome and twenty-two regular chromosomes. The sperm produced by a human male has either an X or a Y chromosome, plus twenty-two regular chromosomes. When an egg and a sperm combine to form a zygote, it has forty-four regular chromosomes and two sex chromosomes, or forty-six in all (see MEIOSIS; MITOSIS; REPRODUCTION).

The relationship between chromosomes and heredity was first suggested in 1902. In 1920, an American biologist, Thomas Morgan, published his studies showing that inherited characteristics were controlled by genes linked on chromosomes. He used the fruit fly because it has only four pairs of chromosomes. Morgan's research showed that in the fruit fly there were four groups of linked characteristics. In later experiments, Morgan mapped the chromosomes, finding the exact positions of specific genes responsible for specific inherited characteristics.

See also GENETICS; HEREDITY; MORGAN, THOMAS HUNT; X CHROMOSOME; Y CHROMOSOME.

CHRONOMETER A chronometer is an instrument that is used to measure time very accurately. It is more accurate than an ordinary watch or clock. Chronometers are used by aircraft pilots, auto racers, and ship navigators. The marine chronometer is the best known type of chronometer. Sea navigators need accurate timepieces so that they can determine their position. The first marine chronometer was built in 1764 by John Harrison, an Englishman. It lost only five seconds on a voyage that lasted six weeks.

The time on a marine chronometer is usually preset to coincide with Greenwich Mean Time (GMT). This is the international marine standard time. A navigator uses a sextant to measure the position of the sun in the sky (see SEXTANT). Then, by knowing the time in GMT, he or she can work out the longitude of the ship (see LATITUDE AND LONGITUDE).

Marine chronometers are very delicate instruments. Some of them contain a thousand parts. Chronometers are kept inside wooden boxes to protect them from dust and corrosion by the salty air. Inside the box they are specially mounted. This allows them to stay in a horizontal position no matter how the ship moves. Marine chronometers must be kept away from the magnetic influences of compasses and vibrations from engines.

The most accurate chronometer is the atomic clock. The atomic clock was invented in 1948. Atomic clocks are controlled by the vibrations of atoms or molecules. They are accurate to within millionths of a second per year. Sea navigators can receive radio signals that give them time checks from an atomic clock on land.

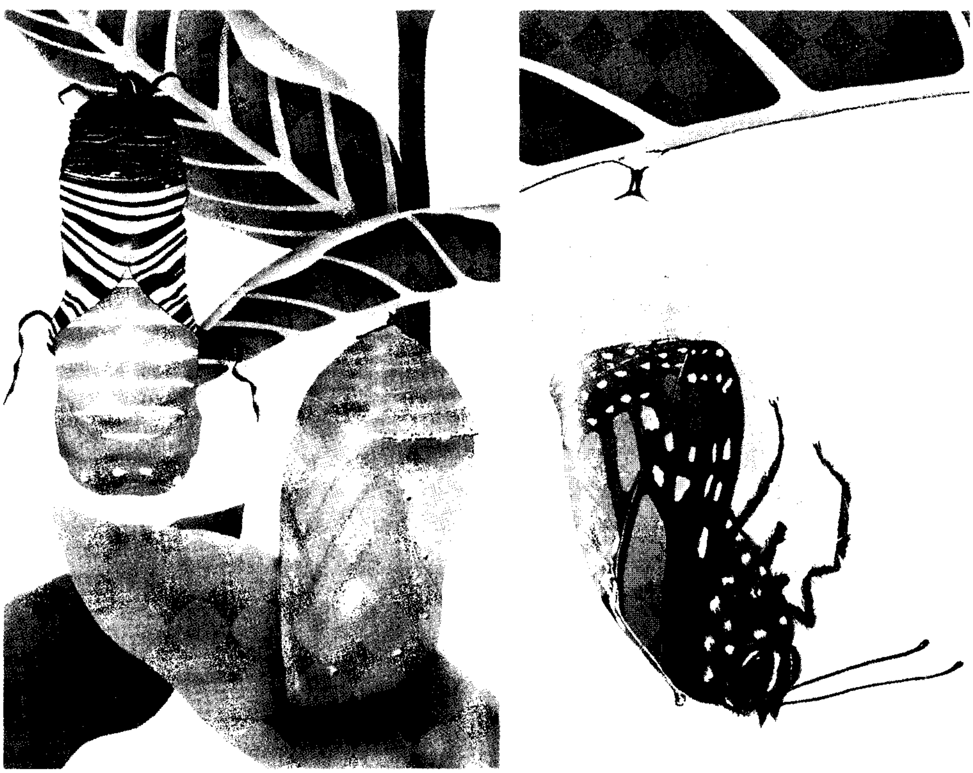
See also CLOCK AND WATCH.

CHRYSALIS (krĭs′ə lĭs) Chrysalis is the name given to the third stage in the life of a butterfly. It is also known as a pupa. The fully grown caterpillar turns into a chrysalis after it molts its skin for the last time. The chrysalis has a hard coat and often bears shiny golden or silver spots. The name actually comes from a Greek word meaning "golden." Many butterfly chrysalises hang from plants, but others lie on the ground and are wrapped in flimsy cocoons. The cocoons are made of silk and are spun by the caterpillars before they turn into chrysalises. The chrysalis does not feed or move and seems totally inactive, but important changes are taking place inside it as the adult butterfly takes shape. When the butterfly is ready to come out, the chrysalis splits open.

See also BUTTERFLY AND MOTH; COCOON; METAMORPHOSIS; PUPA.

CHRYSANTHEMUM (krĭ săn′thə məm) The chrysanthemum is a flowering herbaceous plant or occasionally a shrub. It is a member of the composite family. Most of the more than one thousand species of chrysanthemum are perennial (living more than two years), but some are annual (living only one year). The name of this plant comes from two Greek words meaning "golden flower" (see COMPOSITE FAMILY; HERBACEOUS PLANT).

The chrysanthemum blossom is actually a group of several flowers, and it may measure 8 in. [20 cm] across. Chrysanthemums bloom near the end of



CHRYSALIS

A fully grown caterpillar hangs from a leaf and wriggles out of its skin, revealing the hard-shelled chrysalis, or pupa (far left). After a few weeks, or even months, the chrysalis splits open and the new butterfly struggles out (left).

the year, when the days have fewer than twelve hours of sunlight. They are called short-day plants (see PHOTOPERIODISM). Since florists can control the number of hours of sunlight that a plant receives, they can cause chrysanthemums to bloom at any time during the year. New plants are produced by cutting or division (see VEGETATIVE PROPAGATION).

The chrysanthemum was grown in China in 500 B.C. All the colors that have developed from the original yellow are hybrids. Chrysanthemums were brought to Europe in 1789 and have spread throughout the world. A common nickname for the chrysanthemum is *mum.*

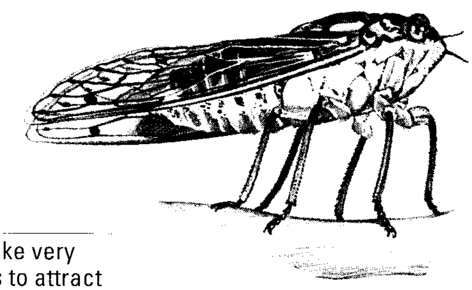
See also HYBRID.

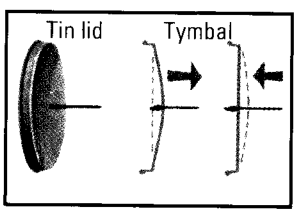
CICADA (sĭ kā´ də) The cicadas are fairly large insects belonging to the family Cicadidae. The largest has a body length of 3 in. [8 cm]. With four usually transparent wings, cicadas move among the plants they use for food. Cicadas are bugs and they suck sap from plants with their strong beaks. Most of the 4,000 species of cicadas live in the warm regions of the world. More than 100 species are found in the United States. The male cicadas make loud, shrill noises; the female cicadas are usually quiet. The sound of a cicada is produced by vibrating membranes (thin sheets of tissue) called tymbals on the sides of its body.

The life cycle of the cicadas includes long periods underground, where they prepare for a brief adult life above the ground. The seventeen-year cicada, a species living in the central and eastern United States, spends thirteen to seventeen years underground. The green-and-black dog-day cicada is also found in the United States. Most cicadas spend from two to five years underground.

Female cicadas lay their eggs in slits that they cut in the twigs of living trees. After about a month or so, the eggs hatch and the young, called nymphs, drop to the ground. The nymphs then bury themselves deep in the soil. They live by sucking the sap from the roots of trees. They reach the surface by crawling up the roots and trunk of a tree. A short time after they have left the ground, the cicadas lose their outer skins, which split down the back (see MOLTING). Then they fly away to mate, lay eggs, and live for a few weeks. Cicadas are commonly but incorrectly called locusts.

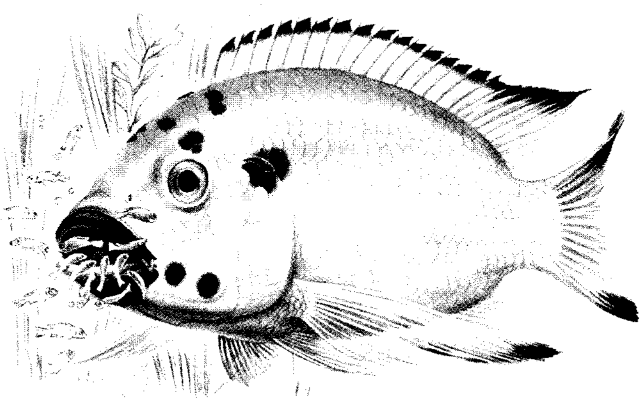
See also BUG (INSECT); INSECT; LOCUST.





CICADA

Male cicadas make very loud, shrill noises to attract females. The sounds are produced by vibrating a little membrane, called a tymbal, on each side of the body at very high speed. The action is similar to that of bending a tin lid in and out.



CICHLID

This type of cichlid is called a mouth breeder because it keeps its eggs and young in its mouth.

CICHLID (sĭk′lĭd) A cichlid is a freshwater fish that belongs to the family Cichlidae. Cichlids are found in tropical waters of South America, Africa, and southwestern Asia. There are over two hundred species in the world. These colorful fish look similar to the sunfishes of North America (see SUNFISH). Some species of cichlids carry their eggs and newly hatched fish in their mouths until the small fish can protect themselves. Some cichlids are popular with sport fishers. Others are used for food. Some are kept as aquarium fish. In the United States, a well-known fish called the oscar, which is sold in pet stores, is a cichlid.

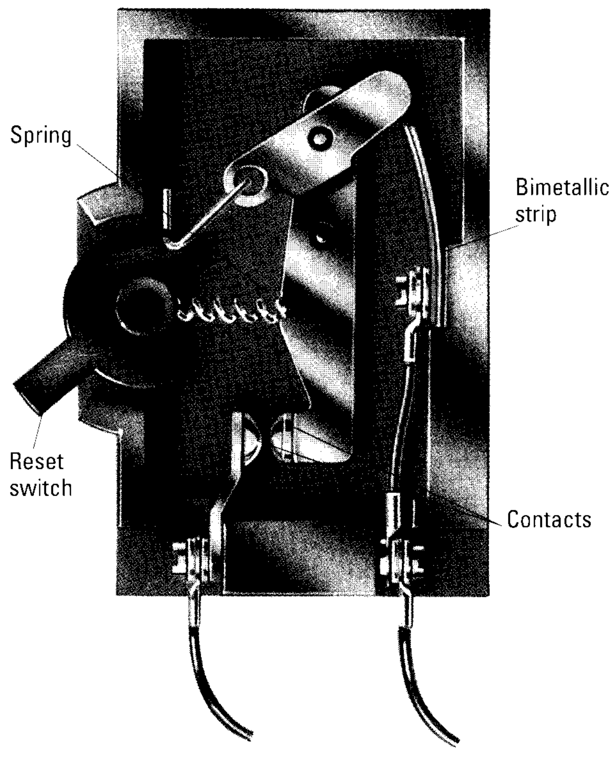
CILIUM (sĭl'ē əm) A cilium is a movable, hairlike structure found on certain kinds of living cells (see CELL). It can be used to move the cell. For example, the single-celled paramecium moves itself by using many waving cilia. Cilia also move objects along the cell's surface. The trachea (windpipe) in humans has cilia inside of it to move mucus and dust particles up from the lungs (see TRACHEA). Cilia are similar to flagella, but they are shorter.
See also FLAGELLUM; PROTOZOA.

CIRCADIAN RHYTHM (sər kā'dē ən rĭth'əm) Daily rhythms of rest and activity are called circadian rhythms—from the Latin words *circa* and *dies,* meaning "about a day." These rhythms are controlled partly by a built-in biological clock (see BIOLOGICAL CLOCK) and partly by the surrounding conditions. Conditions during the daytime are obviously very different from those at night. In addition to the darkness, nighttime is usually cooler than the daytime, and the air is more moist, or more humid, at night. Animals and plants are usually active at night or by day, but not both. Butterflies, for example, fly by day, but most moths fly at night. Most flowers open by day, but those that are pollinated by moths open and give out their scent at night. Slugs and snails normally hide away in the daytime and search for food at night because their soft bodies would dry up in the drier daytime air. Hedgehogs and other animals that feed on slugs and snails also have to go out at night and rest by day. Woodlice, for example, are thought to move about in the evening because, having spent all day in damp places, they get waterlogged and need to get out into the air to lose some of the extra moisture.
See also BIORHYTHMS.

CIRCUIT BREAKER A circuit breaker is an automatic switch that stops or starts the flow of an electric current. If too much electricity flows through a circuit, fire or damage to equipment that is plugged into the circuit may result (see CIRCUIT, ELECTRIC). Circuit breakers help prevent such problems.

Like fuses, circuit breakers are designed to allow only so much electricity to pass through a circuit, the path along which an electric current flows. If more electricity passes through the circuit than it is designed to carry, the contacts in the circuit breaker open. Contacts are the points at which the path of electricity can be broken. The mechanisms used to open a circuit breaker's contacts include a bimetallic strip. If too much electricity flows through the bimetallic strip, it heats up and bends, breaking the circuit. The residual current device (RCD) is a type of circuit breaker designed to protect people from receiving electric shocks. If someone touches a metal part of a machine that is carrying electricity, an electric current flows through his or her body into the earth. An RCD detects the flow of current to earth and automatically disconnects the electricity supply. Residual current devices were previously known as earth leakage circuit breakers (ELCBs).

Once the load of electricity has been decreased, the switch can be closed. This allows electricity to begin flowing again. There is no fuse to repair or replace (see FUSE, ELECTRIC).



CIRCUIT BREAKER
When the electric current flowing through this circuit breaker rises above a preset limit, the bimetallic strip inside it heats up and bends, tripping the switch into the off position. The bimetallic strip cools and straightens, allowing the circuit breaker to be switched on again.

CIRCUIT, ELECTRIC An electric circuit is a path along which an electric current may flow (see CURRENT, ELECTRIC). There are three main parts to an electric circuit. The first is a source of electric energy, such as a battery or generator (see BATTERY; GENERATOR, ELECTRICAL). The second is an output device, such as a motor or bulb. The third is a connection between the source and the output device, such as a wire or cable. One example of a simple circuit is in a common flashlight. Electrons from the negative terminal (electrode) of a battery pass through the filament (threadlike wire) in a bulb and return to the positive terminal (see ELECTRODE).

Various devices can control the current flowing in an electric circuit. A switch may turn a light on or off. When the switch is off, a gap separates the connecting wires. The current cannot complete its path. A circuit with this type of gap is called an open circuit. A closed circuit has no gaps in the path of the current.

The word *circuit* may also mean a complete electrical unit or section, such as an amplifier, within a larger piece of equipment, such as a radio receiver.

There are many very complicated types of electric circuits. However, they all work in one of two main ways, or a combination of these two ways. In the flashlight circuit mentioned before, the same current passes through the bulb, battery, and switch. The components (parts) of this circuit, namely the bulb and switch, are said to be in series with the battery. This unit therefore has a series circuit. In any series circuit, the current passing through each component is the same.

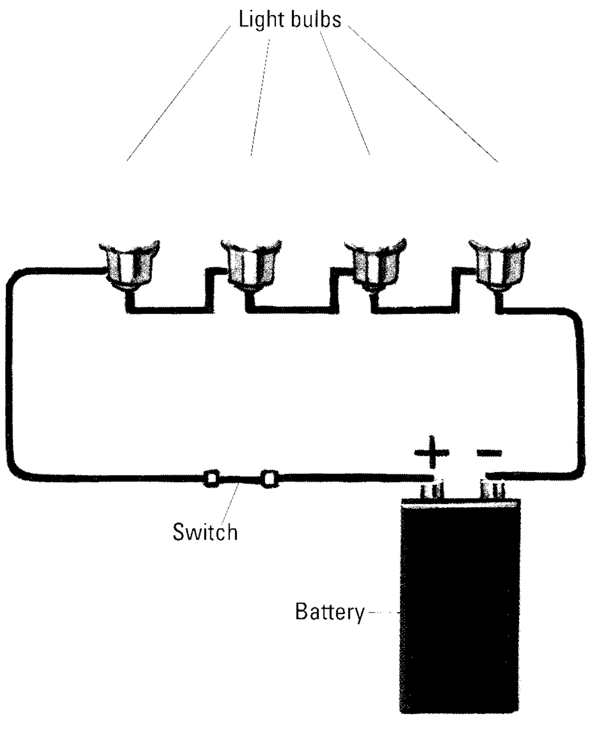
In a parallel circuit, two or more separate circuits, or parts of a circuit, are fed by a common source of electric energy. In this type of circuit, the currents passing through each individual circuit may be quite different. All household lights and appliances are connected in parallel because a parallel circuit allows all devices to operate on the same voltage. The voltage does not change if a piece of equipment is added or removed (see VOLT). However, the total current passing through the fuse or circuit breaker may increase or decrease. The total current is the sum of the currents used by each piece of equipment (see CIRCUIT BREAKER; FUSE, ELECTRIC).

A short circuit occurs when a circuit having a very low resistance is connected to a source of voltage, such as the main supply in a house (see RESISTANCE, ELECTRICAL). A large current flows through the resistance. The resistance often becomes very hot and sometimes melts. Short circuits can cause fires. *See also* CONDUCTION OF ELECTRICITY; ELECTRICITY.

PROJECT 29, 30

CIRCUIT, ELECTRIC

An electric circuit is a path along which an electric charge can flow. Here a battery, four light bulbs, and a switch are all in the circuit. The battery pushes negatively charged electrons from one of its terminals (-) around the circuit and back to its positive (+) terminal. The electrons flow through a thin wire, called a filament, in each bulb. The filaments get hot and glow, giving out heat and light. If any bulb burns out, breaking the filament, the circuit would be broken and the current would stop. Turning the switch off is a way to put a gap into the circuit and stop the flow of current.

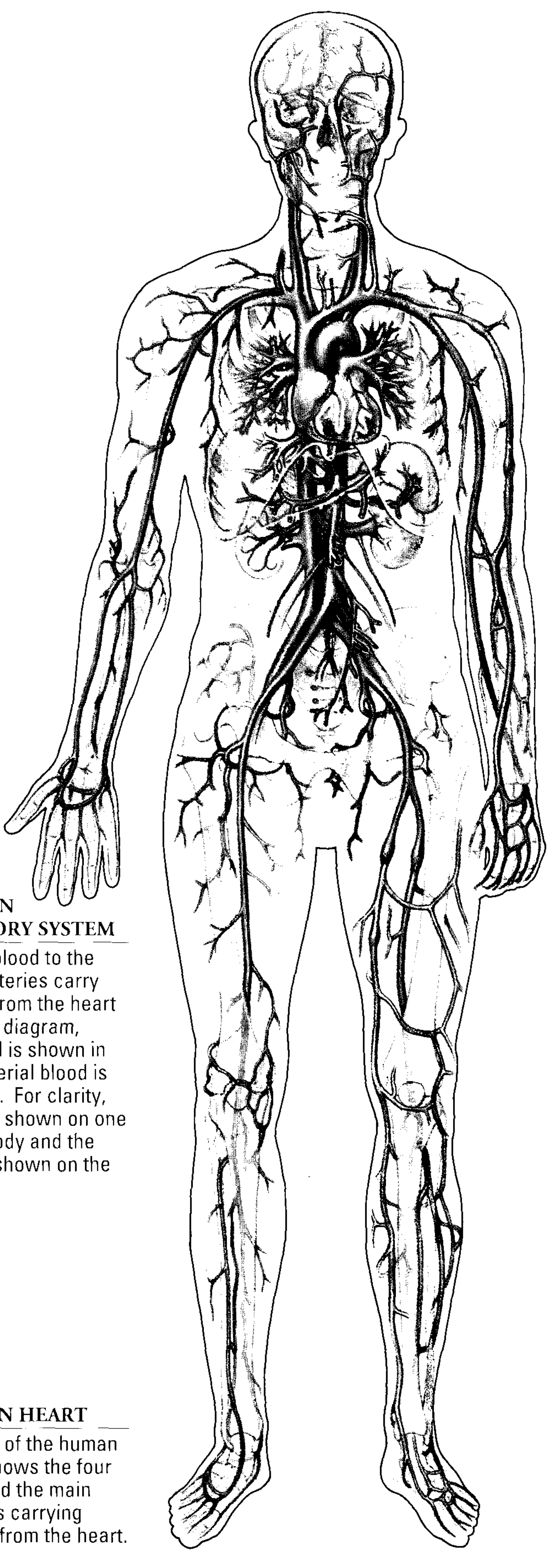


CIRCULATORY SYSTEM

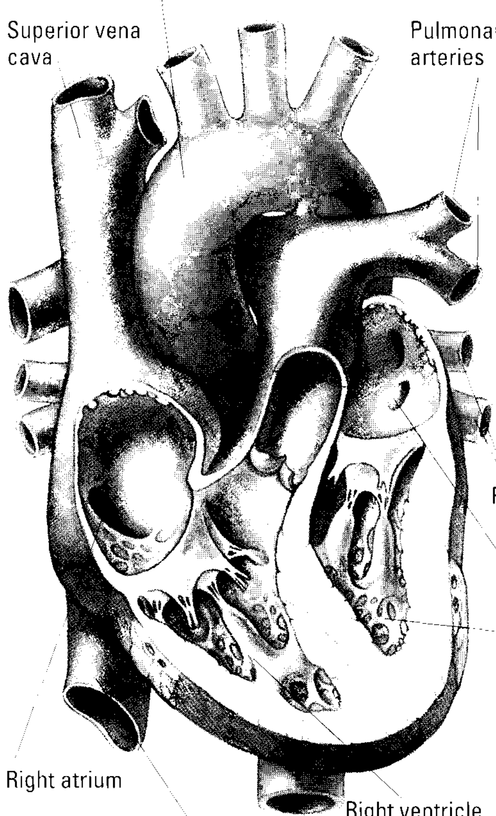
The group of organs in animals that passes blood throughout the body is called the circulatory system. Blood must reach every cell in the body to provide food and oxygen and to carry away waste products. In simple animals that have only a few cells, blood and a circulatory system are not necessary. Food, oxygen, and waste products can pass freely throughout the body, reaching every cell. This is not possible in larger, more complicated animals that have millions of cells in tissues that are several inches thick. A circulatory system evolved in these animals to pass the blood to each cell.

In most of these animals, the system has a muscular pump, called a heart, to move the blood through long blood vessels. Blood vessels are tubes that carry the blood to and from the cells in all parts of the body.

There are two types of circulatory systems: an open system and a closed system. Some members of the animal phyla Arthropoda and Mollusca have open systems. Open systems do not have blood



THE HUMAN CIRCULATORY SYSTEM
Veins carry blood to the heart, and arteries carry blood away from the heart (right). In the diagram, venous blood is shown in blue, and arterial blood is shown in red. For clarity, the veins are shown on one side of the body and the arteries are shown on the other side.



THE HUMAN HEART
This diagram of the human heart (left) shows the four chambers and the main blood vessels carrying blood to and from the heart.

vessels. Blood is pumped into open spaces called sinuses. The blood bathes the cells surrounding each sinus. Some members of the phyla Mollusca and Annelida and all vertebrates (animals with backbones) have a closed system in which blood remains in blood vessels and reaches every cell by means of a branching network.

In a closed circulatory system, there are three main kinds of blood vessels. These are the arteries, capillaries, and veins. An artery is a large vessel that carries blood away from the heart. The arteries divide into many branches, which themselves split up into smaller branches, and then into very small vessels called capillaries. The capillaries carry blood to and from the cells and then connect with the veins. Veins carry blood away from the cells back to the heart. The closer to the heart they are, the bigger veins are. Scientists guess there are about 60,000 mi. [96,540 km] of blood vessels in the human body.

The heart is vital to keep the blood moving in the circulatory system. If the heart stops pumping, the animal will die. The mammalian heart is divided into four chambers: two ventricles and two atria (plural of *atrium).* Blood is pumped from the right ventricle into the pulmonary artery. The pulmonary artery carries the blood into the lungs, where it absorbs oxygen and releases carbon dioxide (see LUNG). The blood returns to the left atrium of the heart through the pulmonary vein. The left atrium pumps the oxygenated blood into the left ventricle of the heart, which pumps it to the rest of the body through the aorta. The aorta is the largest artery in the body. It carries blood to other arteries. The blood absorbs food when it circulates through the small intestine (see DIGESTIVE SYSTEM). Wastes from the cells are removed from the blood when it circulates through the kidneys (see KIDNEY). After the blood passes through the entire body, delivering food and oxygen and removing waste, the blood returns to the heart through the venae cavae (singular: *vena cava),* the two largest veins of the body. The deoxygenated blood enters the right atrium, which returns it to the right ventricle. The blood is then pumped to the lungs to receive more oxygen and make another trip.

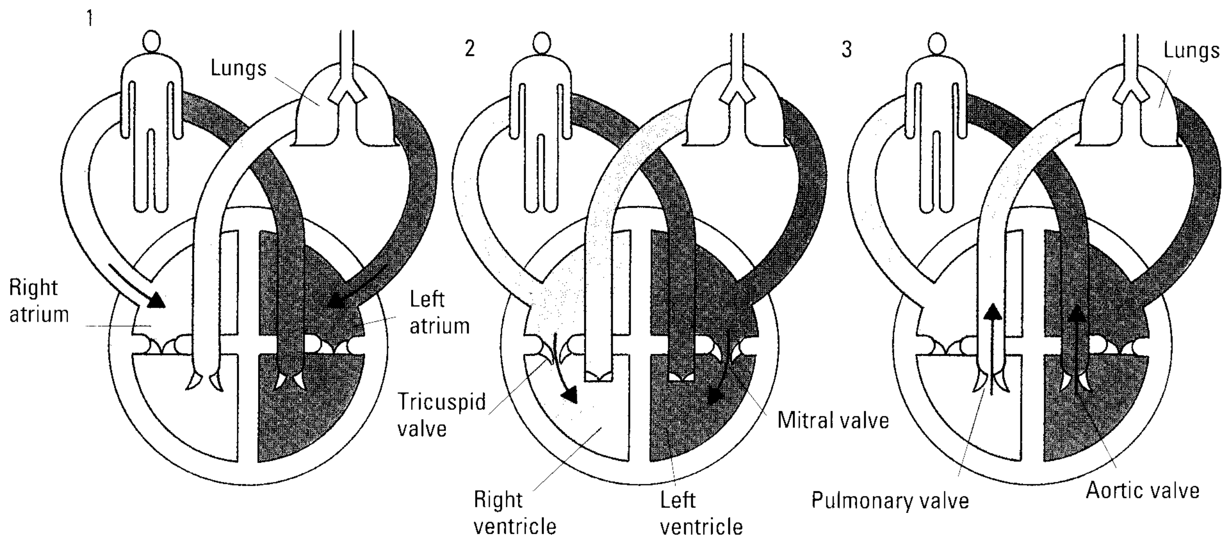
Other vertebrates that have closed circulatory systems have a different arrangement than mammals. In fish, the blood receives oxygen through the gills but does not return to the heart before traveling to the body. In the hearts of amphibians and reptiles, oxygenated and unoxygenated blood are not kept separate, but are mixed before traveling throughout the body.

See also ARTERIOSCLEROSIS; ARTERY; BLOOD; CAPILLARY; HEART; HEART DISEASE; STROKE; VEIN.

PROJECT 64

HEARTBEAT

The pictures below show the sequence of a complete heartbeat: (1) deoxygenated blood from the body and oxygenated blood from the lungs enter the atria; (2) the tricuspid and mitral valves open and blood flows into the ventricles; (3) the pulmonary and aortic valves open, forcing blood to the lungs and the body.



CIRRHOSIS (sĭ rō′sĭs) Cirrhosis is a disease in which the liver tissue becomes scarred, changed in outward shape, and useless (see LIVER). Cirrhosis is commonly caused by excessive use of alcohol; by use of certain drugs; by inhaling poisonous fumes; by hepatitis, which is an inflammation of the liver; as well as by other, less common problems. Although the liver can heal after injury, once the liver tissue is scarred, it cannot be repaired. When scarred, the liver may stop its work of making proteins and purifying the blood. This is known as cirrhosis.

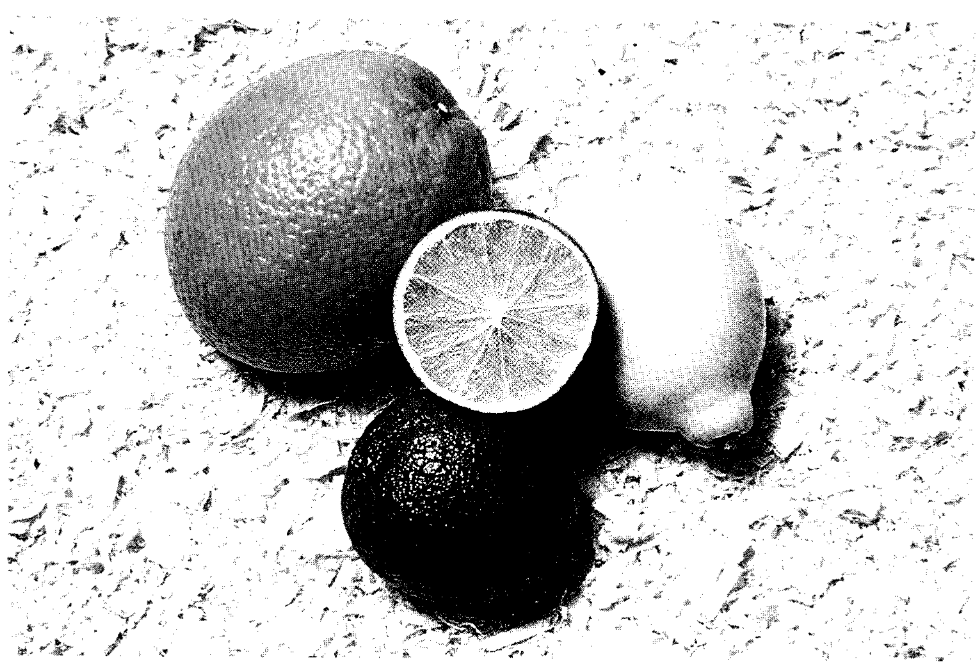
Cirrhosis can block the blood vessels to the liver. This causes other blood vessels around the liver to become bigger. The newly enlarged vessels are fragile and may break, resulting in internal bleeding. Many people with cirrhosis become weak and lose weight, and liver cancer may often develop. In some people, the abdomen swells up with excess body fluids. The skin and eyes of a person with liver failure may become very yellow; this is called jaundice. Jaundice occurs when some of the liver fluid, which becomes part of bile, backs up into the blood.

Cirrhosis may develop slowly or very quickly, depending on its cause. Some early cases of cirrhosis can be treated with medicines, proper diet, and avoidance of alcohol, drugs, and fumes that are harmful to the liver. There is also the possibility of surgery to help treat or cure some people with cirrhosis. Surgery may include shunting, in which some of the blood is directed around the diseased liver, or liver transplantation, in which a healthy liver from a deceased donor is used to replace the patient's diseased liver (see TRANSPLANTATION). If not controlled, cirrhosis can lead to coma and death.

CITRUS FRUIT A citrus fruit is the fruit of any of the evergreen trees and shrubs of the genus *Citrus.* The sixteen species of citrus fruits are members of the rue family (see EVERGREEN; RUE FAMILY). Citrus trees grow 10 to 26.5 ft. [3 to 8 m] tall and have long, shiny, pointed leaves. Citrus flowers are usually white with five overlapping petals. Citrus trees thrive in warm areas where there is little frost and wind. They are native to India and southeast Asia, and were first cultivated in China in 1000 B.C. They are now grown in warm areas of the United States, as well as other areas of the world.

Citrus fruits contain seeds surrounded by a juicy, edible pulp. This pulp is divided into sections and is enclosed in a pith (layer of spongy tissue) and a colored rind. The pith and rind are usually called the "skin." The pith and rind are easily peeled to expose the pulp. Citrus fruits are a popular and tasty food. Some of them are the orange, grapefruit, lemon, lime, tangerine, shaddock, and kumquat.

Citrus fruits can be eaten raw, squeezed for their



CITRUS FRUIT—Pulp and rind

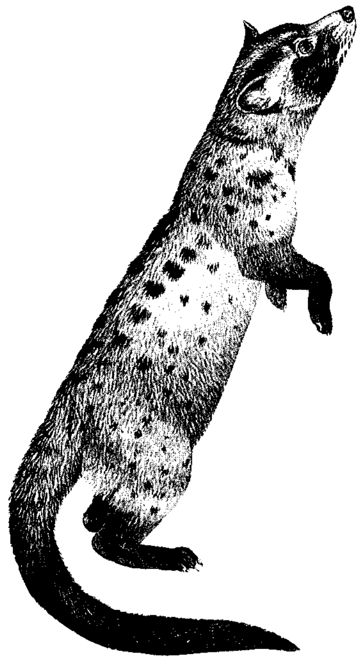
Oranges, lemons, and limes are all citrus fruits. Each fruit is a thick-skinned berry, and the flesh or pulp is divided into a number of sections or segments. These are clearly seen in the lime that has been cut in half. Some species have strongly scented flowers that are used in perfumes.

juice, or cooked in a variety of foods. They are rich in necessary vitamins and minerals (see DIET). Most citrus fruits are a good source of vitamin C, a necessary part of the diet. A deficiency of vitamin C can result in fatigue and diseases such as scurvy.
See also FRUIT; VITAMIN.

CITRUS FRUIT—Easy-peel oranges
Mandarin oranges have a loose skin, which makes them very easy to peel.

CIVET (sĭv'ĭt) Civets are carnivorous (meat-eating) mammals native to the forests of Africa and southern Asia (see MAMMAL). Each of the fifteen species is catlike in appearance with a long, bushy tail and a pointed snout. Civets vary in color from black and brown to tan and gray. Most are spotted and have tails with rings of different colored fur. Some species may grow as long as about 3 ft. [0.9 m] and may weigh about 24 lb. [10.9 kg].

Most civets live alone or in pairs in burrows in the ground. They hunt at night for birds, frogs, rodents, and other small animals. Some civets eat plants and animal eggs. Civets are good climbers, using their tails for support.



CIVET
Civets belong to the mongoose family. Because of their catlike behavior, they are sometimes called civet cats.

Most species of civets have a special gland near the base of the tail. This gland produces and sprays a foul-smelling liquid, which can be used to mark out a territory or to scare away an enemy. Some perfume manufacturers use the liquid as a base for certain perfumes.
See also MONGOOSE.

CLASS A class, in the classification of living things, is a subdivision of a phylum. A class is made up of a group of related orders.
See also CLASSIFICATION OF LIVING ORGANISMS.

CLASSIFICATION OF LIVING ORGANISMS Biologists try to arrange all living things (also called organisms) into groups. This helps explain one organism's relationship to another organism. To do this, biologists must study all groups of organisms and compare them. This study is called taxonomy. A scientist who studies taxonomy is called a taxonomist. Taxonomists have identified hundreds of thousands of animals, plants, and other organisms. Each one is assigned a name and a place in the classification system. Some organisms are easy to classify. A moose, for example, is very similar to a deer and belongs to the deer family. Other organisms are hard to classify. For example, not all taxonomists agree on how to classify certain one-celled organisms. Taxonomy tries to describe nature's living creatures in a neat, clear-cut manner. However, organisms are not naturally organized in a neat, clear-cut manner, so taxonomy is never perfectly correct.

The modern method of classifying organisms was started by a Swedish naturalist named Linnaeus (see LINNAEUS, CAROLUS). All classification names are Latin, which is a common scientific language. If the names were in English, scientists in non-English-speaking countries would not easily understand them. By using Latin names, a Russian scientist can understand what organisms an American scientist is talking about. It is important that the name for an organism be the same all over the world. In the United States, there is a fish called a bluegill. In the northeastern part of the country, the same fish is often called a johnny roach. In the southern part of the country, the same fish is often called a bream. In England, however, there is a totally different fish called a bream. This can become very confusing. Therefore, the bluegill is assigned the scientific name *Lepomis macrochirus,* regardless of where it is found.

Most scientists use a five-kingdom system of classification. Each organism belongs to one of these five kingdoms. The plant kingdom includes all multicellular plants. The animal kingdom includes all multicellular animals. The kingdom Protista includes protozoans (one-celled, animallike organisms) and all algae except blue-green algae. The fungus kingdom includes all types of fungi. The kingdom Monera includes bacteria and blue-green algae. These kingdoms are broken down into phyla (plural of *phylum)* or divisions. Organisms with similar characteristics are assigned to the same phylum. For example, all animals with a backbone belong to the phylum Chordata. Phyla and divisions are broken down into different classes. All animals with backbones that have hair and milk-producing glands are assigned to the class Mammalia. Classes are broken down into different orders. Orders are divided into different families. Families are split into different genera (plural of *genus).* Genera are broken down into different species. A species is a particular kind of plant or animal. It is only between members of the same species that fertile offspring can be produced. There can be many organisms in the same genus but only one organism in each species. The scientific name (binomial nomenclature) of an organism refers to the name of its genus and species written together. Therefore, *Lepomis macrochirus* (bluegill) belongs to the genus *Lepomis* and the species *macrochirus.*

See also ANIMAL KINGDOM; FUNGUS; MONERA; PLANT KINGDOM; PROTISTA.

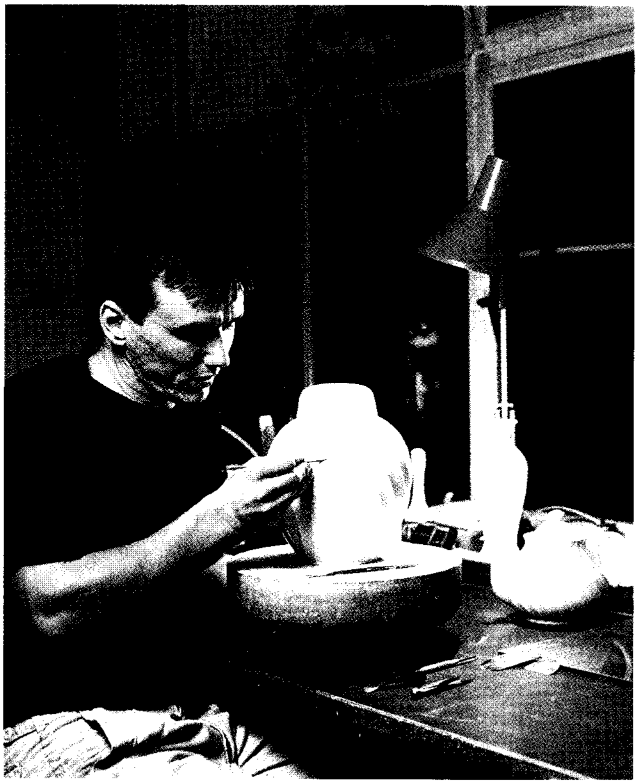
CLAVICLE (klav'i kəl) The clavicle is a long, slender bone found in the chest of mammals. One end of the clavicle attaches to the sternum (breastbone), and the other end attaches to the shoulder blade at the shoulder. The clavicle connects the arm to the upper body and props the shoulder out away from the chest. The clavicle is also called the collar bone. Fractures of the clavicle are fairly common.

See also SKELETON; STERNUM.

CLAY Clay is a soft, flexible substance found in most soil and in many rocks. It is made up of tiny, sheetlike particles of clay minerals along with

CLAY—Pottery

A Mexican potter makes a large bowl out of clay. While the clay is wet, it is soft and easily worked. The potter will place the bowl in a kiln, or oven, and bake it at a high temperature. The baked pot will be hard, waterproof, and fairly strong.



CLAY—Modeling
When shapes are modeled in clay, they must be made to precise dimensions to allow for the shrinkage that occurs when wet clay dries out during the firing process.

quartz and other minerals. Clay minerals are similar in composition and shape to mica but are much smaller in size (see MICA). Clay is the smallest of the three kinds of soil particles. The other two kinds of soil particles are sand and silt (see SAND; SILT; SOIL). Clay can be brown, red, or gray depending upon its content. Iron oxide, for example, colors clay red. Clays that contain large amounts of carbon compounds are gray.

Clay plays an important role in agriculture. It absorbs ammonia and other gases needed for the growth of plants. Clay also helps soil retain the nourishing substances supplied by manure and other fertilizers. However, too much clay in the soil prevents the movement of air and water through the soil and makes the soil stiff and heavy.

There are two general types of clay: expandable and nonexpandable. Expandable clay swells up when water is added to it. It can become liquid if enough water is added. Nonexpandable clay becomes soft when water is added, but it does not swell up or become liquid. Expandable clays called bentonites are used in drilling for petroleum (see PETROLEUM). Other types of expandable clays are used as chemical agents in the refining of petroleum. Nonexpandable clay is used in the ceramics industry to make bricks, tile, pottery, and porcelain. Molded clay objects are placed in special ovens called kilns. The intense heat removes the water from the clay and makes it hard and impenetrable. It cannot be softened again by adding water (see CERAMICS).

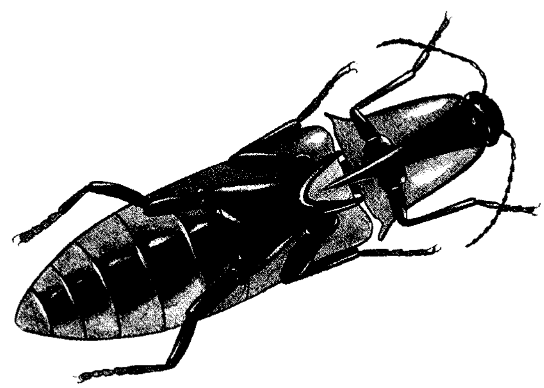
Kaolin, or china clay, is a white clay derived mainly from decomposed feldspar. Kaolin is used to make porcelain. Kaolin is also added to paper to give it whiteness, strength, and a shiny surface. Fire clay contains a large amount of silica, a material that is highly resistant to heat. Bricks made from fire clay are used to build fireplaces and to line industrial furnaces.

See also FELDSPAR; KAOLIN; SILICA. PROJECT 21

CLICK BEETLE Click beetles belong to the family Elateridae and there are about 7,000 species. They are narrow, hard insects that measure 0.12 to 2 in. [3 to 54 mm]. Click beetles are able to flip themselves up if they fall on their backs. The fallen beetle flips in the air with a loud *click* and rights itself.

The larvae of the click beetle are called wireworms. They damage crops by eating the roots in the soil.

See also BEETLE; LARVA.



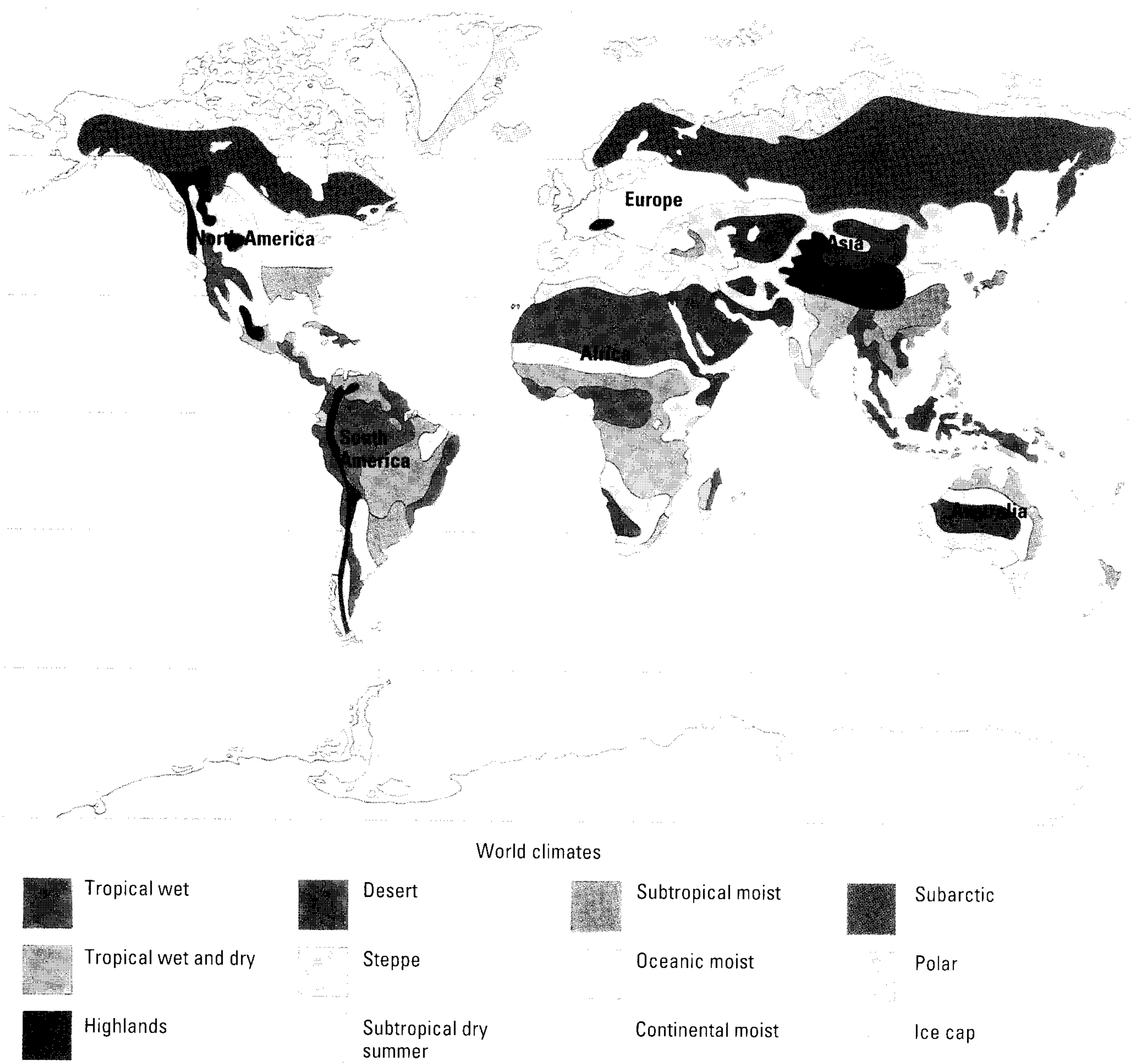
CLICK BEETLE
A click beetle is named for the sound it makes when it flips over from its back onto its legs. The picture shows a beetle lying on its back.

CLIMATE

Climate is the average weather experienced by an area over a period of years. It is often described in terms of temperature and precipitation (rain, snow, and other moisture that falls to the earth). For example, the climate of a tropical island may be described as a tropical wet climate. This means average temperatures are in the 85° to 100°F [29° to 37.5°C] range, and there are periods of rain during many days of the year.

Climate influences the kinds of houses we live in, the clothes we wear, the food we eat, and the transportation we use. We can control the effects of climate in our homes with insulation, heating, and air conditioning.

Climate and weather are not the same. Weather is the condition of the atmosphere during a given period of time. Weather changes from day to day. Scientists determine the climate of an area by studying its daily weather over several years (see WEATHER). The study of climate is called climatology, and the people who do that work are called climatologists. Climatologists must consider many characteristics of the atmosphere, including temperature, precipitation, humidity, sunshine, wind,



DESERT

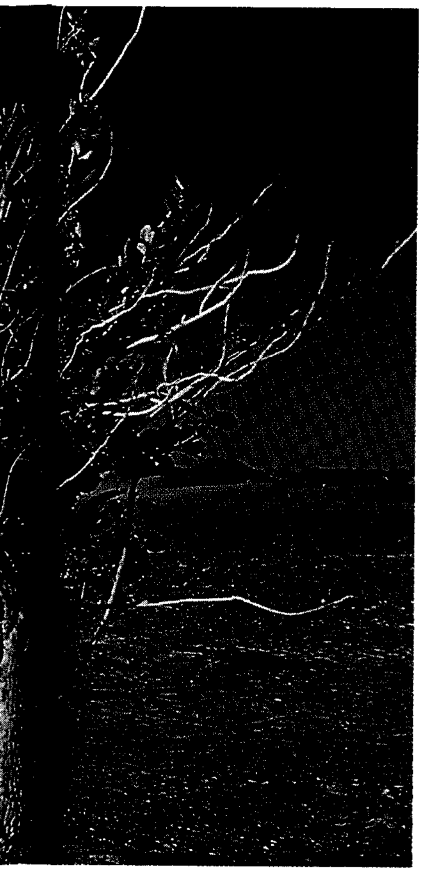
Deserts are places where there is less than 10 in. [25.4 cm] of rain per year, and where this low rainfall quickly evaporates. Some of the world's deserts are covered with sand, which the winds can build up into huge dunes. Desert plants store water in thick, fleshy leaves.

air pressure, and cloudiness. Climatologists divide the earth into various climate zones—places within which the climate is similar. There are many ways to do this. The map with this article shows one commonly accepted way, in which there are twelve zones. They are: (1) tropical wet, (2) tropical wet and dry, (3) highlands, (4) desert, (5) steppe, (6) subtropical dry summer, (7) subtropical moist, (8) oceanic moist, (9) continental moist, (10) subarctic, (11) polar, and (12) ice cap. The climate of each of these zones is different.

Why climates differ Climates differ for a number of reasons, including differences in latitude (location north or south of the equator), differences in how quickly the temperatures of land and water change, and differences in the surfaces of land. Latitude is the most important factor. Areas at different distances from the equator receive different amounts of heat. This is because the position of the sun in the sky varies with latitude. In areas near the equator, the sun shines almost directly overhead at noon throughout most of the year. These direct rays of the sun produce high temperatures on the ground. Consequently, these areas have warm to hot climates.

At the North and South poles, the sun never gets very high above the horizon. The rays of the sun are slanted and produce much less heat on the ground. Thus, these areas have cold climates. Areas in the middle latitudes between the equator and the poles have temperatures that are between those of the other two areas. These areas have temperate (neither very hot nor very cold) climates.

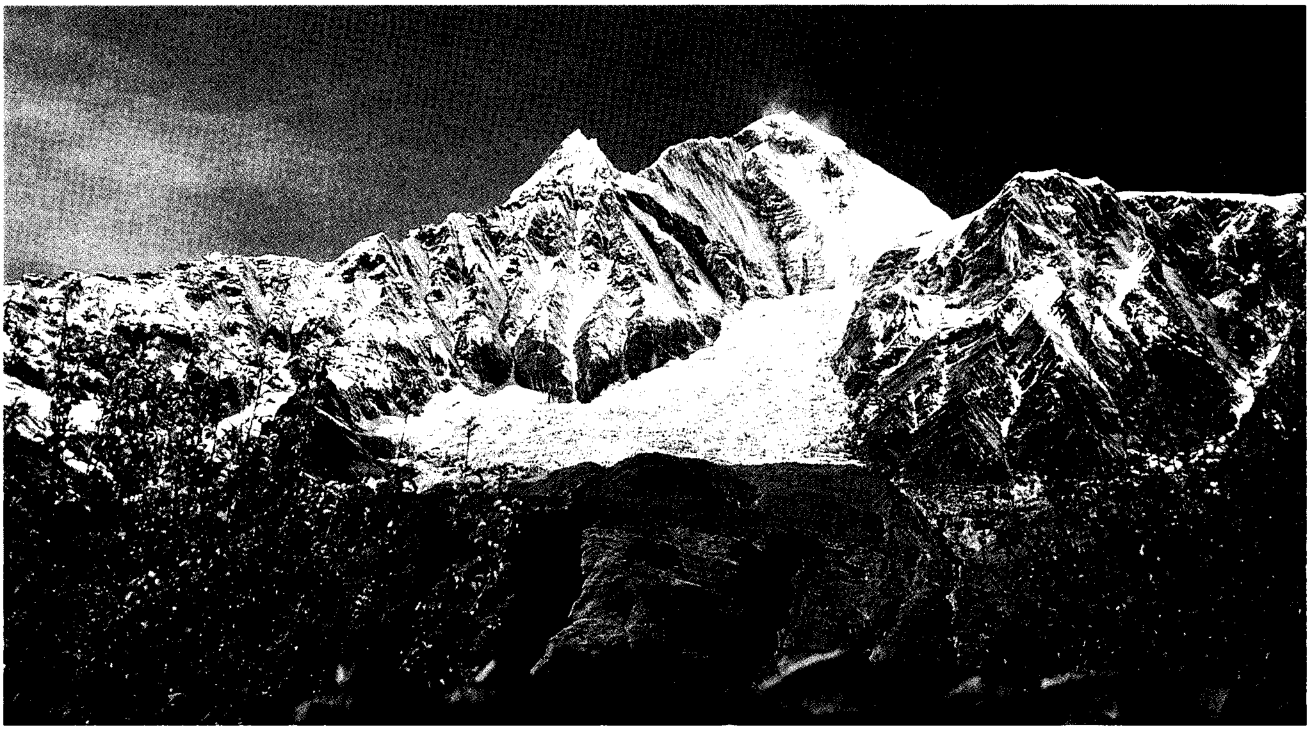
Differences between land and water also play a major role in world climate. For example, two places at the same latitude may have different climates because one of them is near a large body of water, and the other is not. Water heats and cools more slowly than land does. Bodies of water stay cooler than the nearby land in the summer. Cool breezes blow from the water onto the shore and



CLOUD FOREST
Some high mountains are wrapped in clouds most of the time. The climate is moist and cool. Dense forests resembling the rain forests of the tropics can grow here. In these cloud forests in Venezuela, parasitic creepers and vines hang from the trees that climb toward the light.

help keep the shore cooler than inland areas. In the winter, the water stays warmer than the nearby land, and breezes off the water make coastal climates warmer than inland climates in winter. The New England states, for example, are at the same latitude as some of the midwestern states. However, those parts of the New England states that border the Atlantic Ocean tend to have warmer winters and cooler summers than do the midwestern states. Areas that border oceans may have their climates further affected by ocean currents. The Gulf Stream is a current that brings warm water from the Caribbean Sea, through the Atlantic Ocean, to the vicinity of the British Isles. It keeps the British Isles warmer than coastal areas of Canada and mainland Europe, which are at the same latitude.

Differences in the surface of the land account for many differences among climates. Mountains, for example, can have a major effect on the climate of



MOUNTAIN MICROCLIMATES

Different microclimates occur at different heights on mountains. The mountainside is often cool and moist. But very high on tall mountains, like these in the Himalayas of Nepal, there is little rain or snowfall. The peaks have an unchanging covering of snow, which feeds the glacier seen here.

nearby lowlands. As air rises to pass over a mountain, it becomes cooler and releases its moisture in the form of rain or snow. A place located on a mountain slope is generally cooler and wetter than a place at a lower elevation. For example, the Cascade mountain range that runs through western Oregon and Washington keeps moisture-laden air from the Pacific Ocean from reaching eastern areas of those states. Thus, those areas have dry climates. Even gentle slopes can affect climate. In the Northern Hemisphere, places located on gently sloping land that faces north tend to have cooler climates than places located on sloping land that faces south.

Mountains themselves may have several climates. A mountain may have a dry, warm climate at its base and a wet, cold climate at its peak. The climate of mountains is often described in terms of *microclimates,* which are the climates of very small, specific areas. A valley also may have several microclimates, which can affect the crops grown there. For example, one part of a valley may receive slightly more sunshine or rain than another.

The climate of a large city is affected by many artificial objects. Tall buildings and street pavements tend to absorb heat from the sun and send it back into the lower atmosphere. Also, escaping heat from the heating systems of the buildings in winter and hot exhaust gases of thousands of vehicles help warm the air. City temperatures tend generally to be warmer than those in the suburbs.

The changing climate Climate changes slowly over a period of many years. For example, the climate of North America has been warmer in this century than it was fifteen thousand years ago, when glaciers covered Canada and the northern part of the United States. There have been many "ice ages" before that one, with warmer periods in between (see GLACIATION).

Climatologists have theorized that changes in the earth's orbit around the sun or changes in the sun itself have resulted in changes in the heat from the sun's rays. Another reason given for periods of cooling is the presence of dust from volcanic eruptions in the upper atmosphere. Scientists point out that this dust can remain in the upper atmosphere for years, and it may prevent some sunlight from reaching the earth.

A factor that may work in favor of long-term

SNOWY ISLANDS
Icy Coronation Island is one of the South Orkney Islands. It lies a few hundred miles outside the Antarctic Circle. Little vegetation can grow where the only water available is in the form of snow.

worldwide warming is the so-called greenhouse effect (see GREENHOUSE EFFECT). Carbon dioxide in the air prevents heat from escaping from the atmosphere. It does let sunlight reach the earth, however. Since 1900, the level of carbon dioxide in the atmosphere has increased greatly because of the large amounts of fossil fuels burned in home furnaces, factories, and automobiles (see FOSSIL FUEL). Carbon dioxide is a by-product of this burning. Global temperatures have also risen since 1900. But, puzzlingly, most of the rise was before 1940, while most of the rise in carbon dioxide levels was after that date.

Chlorofluorocarbons also contribute to the greenhouse effect. Chlorofluorocarbons are synthetic, or human-made, chemicals consisting of the elements chlorine, fluorine, and carbon. Chlorofluorocarbons are used as refrigerants and to make plastic foams (see CHLOROFLUOROCARBON). Some scientists believe the trapped heat resulting from the greenhouse effect will lead to global warming. They believe this warming could create serious dangers to life on Earth because global climates would be affected. For example, if rainfall levels drop in some places, crops could fail and certain areas could become desertlike. If too much rain falls in other places, flooding and erosion could occur. In either case, many species of plants and animals could become extinct (see EXTINCTION). The raised temperature would cause the upper layers of the ocean to expand, raising sea levels. Melting of polar ice could cause ice sheets to slip off the land in Antarctica, further raising sea levels. Coastal areas of the continents might be flooded. Salt water from the oceans could also flood into and pollute coastal aquifers (see AQUIFER).

Climatologists are trying to gain a better understanding of long-range climate changes so they can predict their effects on world food production. Periods of extreme wet or dry weather, for example, can seriously affect the amount of food crops grown in the world. Advance knowledge of these changes in climate would help farmers prepare for them.

See also ATMOSPHERE; METEOROLOGY.

CLIMBING PLANT A climbing plant relies on another plant or a structure such as a wall or fence for support. Climbing plants usually have relatively weak stems, and many have evolved special structures for attaching themselves to their supports. Most of these involve thigmotropism, the ability of some plants to grow in a certain direction in response to touch (see MOVEMENT OF PLANTS).

Some plants, such as hops and morning glory, have stems that grow in a spiral fashion around the stems of other plants. Some plants, notably peas and grapes, produce tendrils—long, slender structures that coil around twigs or other objects with which they make contact (see TENDRIL).The stem of ivy produces roots that stick to or grow into walls or tree trunks. The Virginia creeper has sticky pads that cling tightly to walls. Roses, blackberries, and some other climbers have curved prickles that hook over the twigs and branches of other plants and hold the climbers in position.

See also EPIPHYTE.

CLIMBING PLANT—Clematis

The clematis climbs with the aid of its leaf stalks, which twist around neighboring twigs or any other suitable support, such as wires or trelliswork. Many kinds of clematis are grown in gardens, where they quickly cover walls and fences with their beautiful flowers.

CLIMBING PLANT—Virginia creeper

The Virginia creeper is found throughout the United States and has been taken to many other countries. It climbs up walls, clinging on by means of sticky pads on its coiled tendrils.

CLINOMETER (klī nŏm′ĭ tər) A clinometer is an instrument used by surveyors and civil engineers to measure the slope of such landforms as hills by reference to a spirit level or a plumb bob. Clinometers can be used to measure the height of an object if the distance from the observer to the object is known.

Pocket models carried by surveyors usually consist of a flat base with a built-in spirit level (an alcohol-filled glass tube with an air bubble in it) and folding metal arms, called vanes, at each end. The surveyor first makes sure that the bubble is in the middle of the spirit level tube. That indicates that the clinometer is being held in a horizontal position. The surveyor then looks in an eyehole in the rear vane, through a vertical slit in the front vane. The vertical slit is marked in degrees. The top of the hill as seen through the front slit gives the angle of inclination (slope).

In the plumb bob type of clinometer, a plumb bob, which is a weight attached to a line, hangs from the sighting device. As the device is tilted upward to view the top of the hill, the string moves across a protractorlike face and indicates the angle of inclination.