

Raintree Steck-Vaughn

Illustrated
SCIENCE
ENCYCLOPEDIA



Volume
15



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OIL – PIA



RAINTREE
STECK-VAUGHN
PUBLISHERS

The Steck-Vaughn Company

Austin, Texas

OIL An oil is a greasy, slippery-feeling, flammable substance. It does not dissolve in water but dissolves readily in organic liquids such as ether or gasoline (see **GASOLINE**). Oils are liquid at normal (room) temperatures. Most are less dense than water.

There are two major kinds of oils: those that come from plant or animal sources, and those that come from mineral sources such as petroleum or coal. Plant and animal oils consist mainly of carbon, hydrogen, and oxygen. Mineral oils consist mainly of just carbon and hydrogen.

Plant and animal oils, sometimes called fixed or fatty oils, include cooking oils such as olive, corn, sunflower, and safflower. Some plant oils (for example, linseed oil, which is produced from flax seeds) are called drying oils. Drying oils are converted to hard solids when they combine with oxygen in the air. For this reason, they are used in paints and varnishes.

Essential, or volatile, oils come mainly from plants. These are the oils that give flavor (such as lemon, mint, and vanilla) and odor (such as rose, lilac, and other flowers).

Plant and animal oils can be converted from liquids to solids (fats) by combining them with hydrogen in

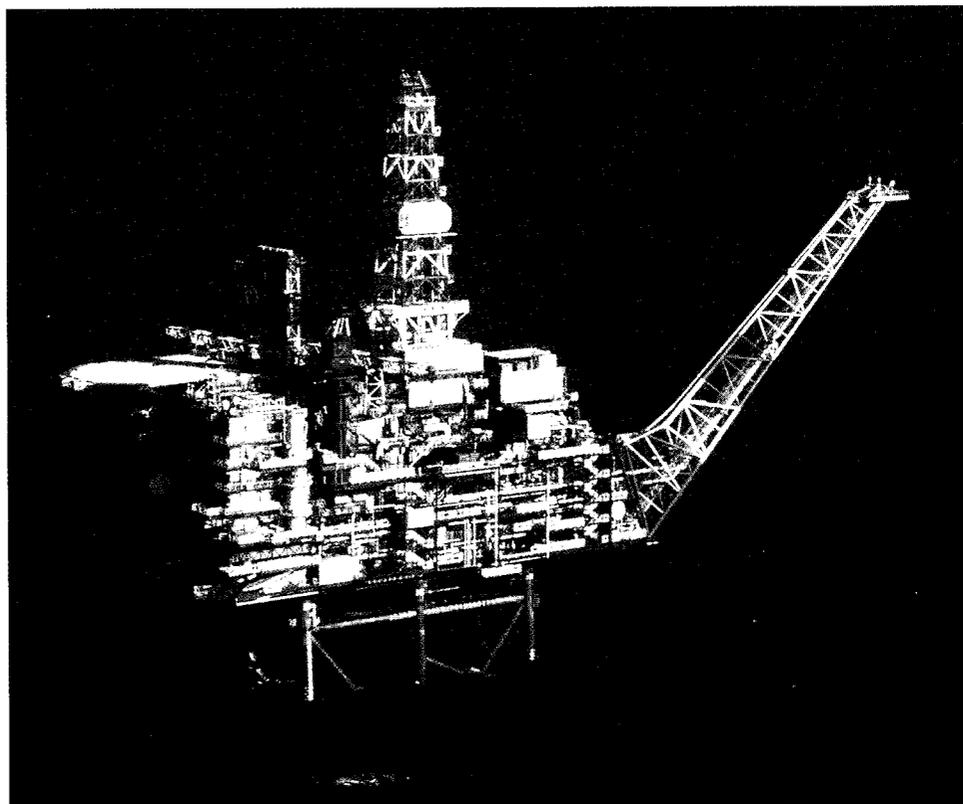
a process called hydrogenation. Margarine is produced in this way from plant oils.

Petroleum is the major source of mineral oils (see **PETROLEUM**). Lubricating oils are produced as a by-product of oil refining. Petroleum is a leading economic commodity in international markets because it is the most important source of energy for industrial and home use.

OIL RIG An oil, or drilling, rig is a movable set of equipment used to drill wells to explore for, or extract, oil and gas from below the earth's surface. Rigs consist of drilling equipment and a tall tower known as a derrick.

The drilling is done using a drill bit that is attached to the end of a series of connected pipes known as the drill pipe. This pipe is lowered into the ground and rotated by a turntable on the floor of the derrick. As the pipe turns, the bit cuts through layers of rock. As the bit drills deeper, more lengths of pipe are added to the drill pipe. The derrick is used to hold pulleys and wires that move the drill pipe in and out of the well.

When wells are drilled offshore, jack-up rigs, semi-submersible rigs, or drillships are used. On jack-up



OIL RIG

This offshore drilling rig is mounted on legs that stand on the seafloor. Rigs such as this are used to extract oil or gas from deposits in rocks under the seafloor.

rigs, which are used in water less than 300 ft. [91 m] deep, the derrick and drill rig are mounted on a floating barge with movable legs, which can be lowered onto the seafloor. In deeper water, semi-submersible rigs are more common. These are held afloat by underwater pontoons and kept in place by anchors on the sea floor. Drillships, which have the derrick and drill rig mounted in the center of the ship, are used in deep-water drilling.

OIL SHALE Oil shale is a fine-grained sedimentary rock that ranges in color from tan to black. It contains a waxy substance called kerogen. Kerogen forms from decayed plants and animals and has a low oil content. Petroleum (oil) can be extracted from oil shale, but it is an expensive process. However, oil shale may become a more important source of petroleum as scientists search for alternative energy sources. Some scientists think that oil shale represents an early stage in petroleum formation. Deposits of oil shale are found in Scotland, Colorado, Utah, and Wyoming.

See also PETROLEUM; SEDIMENTARY ROCK; SHALE.

OLEFIN (ō'lə fīn) Olefins belong to the class of hydrocarbons called aliphatic hydrocarbons. Hydrocarbons are chemical compounds in which the molecules contain only atoms of carbon and hydrogen. Olefins are also known as alkenes (see HYDROCARBON).

The atoms in a molecule are held together by chemical bonds. In an olefin, two of the carbon atoms are held together by a double bond. The simplest olefin is ethene (ethylene) ($\text{CH}_2=\text{CH}_2$). The next simplest is propene (propylene) ($\text{CH}_3-\text{CH}=\text{CH}_2$). Olefins can contain many atoms, but they must have one or more double bonds. Simple olefins are gases. Olefins with more carbon atoms are liquids. Olefins with the most carbon atoms are waxy solids.

Olefins can be obtained from petroleum (see PETROLEUM). The double bond in an olefin can be opened in a chemical reaction. Then, other atoms or groups of atoms become attached to the two carbon atoms (see CHEMICAL REACTION). Because of this property, olefins are considered reactive

substances. They are used as fuels and to manufacture other chemicals, such as alcohols. Olefins are also used to make plastics, such as polyethylene and polypropylene. These plastics are made by a process called polymerization.

See also POLYMER.

OLIGOCENE EPOCH (ō'l'ī gō sēn' ēp'ək) The Oligocene epoch in the earth's history is the division of the Tertiary period that began about 35.5 million years ago and lasted about twelve million years (see GEOLOGICAL TIME SCALE; TERTIARY PERIOD).

The Oligocene epoch was characterized by a temperate to subtropical climate (see CLIMATE). Extensive grasslands existed on most of the continents. *Mesobippus*, a prehistoric relative of the modern horse, appeared during this time. Many modern mammals, including camels, cats, dogs, elephants, and rodents, also appeared (see MAMMAL). Primitive apes developed. *Baluchitherium*, the largest land mammal of all time, thrived during the Oligocene epoch.

Many of the abundant insects of this epoch have been preserved as fossils. Lignite deposits also formed during the Oligocene epoch.

See also FOSSIL; LIGNITE.

OLIVE FAMILY The olive family includes about four hundred species of shrubs, trees, and climbing plants. They are dicotyledons and are mostly tropical and subtropical. The four-petal flowers grow in clusters. Some species, such as jasmine and lilac, have fragrant flowers and are widely cultivated. Forsythia is a shrub grown for its beautiful, bright yellow flowers (see DICOTYLEDON; FLOWER; LEAF). The various species of ash are important timber trees in North America and Europe.

The olive tree is native to Mediterranean countries. It reaches a height of 33 ft. [10 m] and has greenish gray, evergreen leaves. Some olive trees are at least two thousand years old. The fruit, which is purplish black when ripe, is called an olive. It is a popular food. Olive oil is squeezed from the fruit and is used for cooking and in salads. Olives are

**OLIVE FAMILY**

Forsythia, with its bright yellow flowers (above), is one of the many plants that make up the olive family.

sometimes harvested while they are still green. Although some olives are grown in California, most are produced in Italy and Spain.

OMNIVORE (õm'nə vòr') An omnivore is an animal that eats both plants and animals. Most human beings are omnivorous because they eat other animals, such as fish, and plants, such as vegetables and fruit. Other omnivorous animals include bears, pigs, and many birds.

See also CARNIVORE; HERBIVORE.  **PROJECT 65**

ONION (õn'yən) The onion is a biennial herbaceous plant that is usually classified in the lily family. Many varieties are planted as seeds, which produce cylindrical clusters of leaves. During the first growing season, food is stored in a bulb. This bulb is the familiar vegetable called an onion. Some plants produce small bulblets among the leaves. Each bulblet can grow into a new plant. In the second year, clusters of round flowers are produced. The flowers are mainly green or purple, and several varieties of onions are grown for them (see BIENNIAL PLANT; BULB AND CORM; HERBACEOUS PLANT; LILY FAMILY).

Onions have a strong, sharp taste and odor because of an oil they contain. This oil forms a vapor if the onion is cut or peeled. This vapor irritates nerves in the nose, causing the eyes to start tearing. Onions have little food value themselves

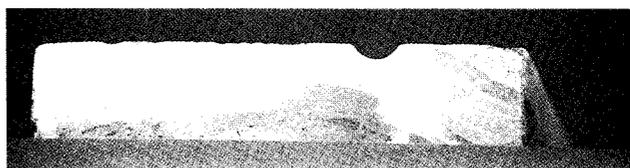
**ONION**

Onions, grown for their bulbs, have a distinctive taste. They are generally used to flavor meat dishes and salads.

but are often added to foods for flavoring. Scallions are young onions that have been harvested early in the first growing season, before bulbs have formed.

ONYX (õn'iks) *Onyx* is a name generally applied to a type of striped calcite that can take a polish (what jewelers call "marble") or to a type of quartz that forms layers rather than crystals (see AGATE; MARBLE).

Onyx marble, also called Mexican onyx, is found on the walls of caves. Mexican onyx varies in color, including brown, green, red, and white. Much of this soft onyx marble is dyed and cut into gemstones or used as a decorative stone.

**ONYX**

Onyx marble is a type of calcite (calcium carbonate) valued for its attractive, banded colors.

Onyx of quartz is harder than onyx marble and can be polished until it is very shiny. It also may be dyed such colors as black, green, red, and white. Jewelers also refer to dyed black agate as onyx.

OOGONIUM (ō'ō gō'nē əm) An oogonium is a one-celled female reproductive structure found in some algae and fungi. It produces eggs for sexual reproduction. It is similar to, but much simpler than, the multicellular archegonium or pistil found in many plants.

See also ARCHEGONIUM; GAMETE; PISTIL; REPRODUCTION.

OOZE Ooze is the muddy deposit found on the ocean floor. There are two main types of ooze: terrigenous and oceanic.

Terrigenous ooze is found along coastlines. Some of it was originally part of the coast but was worn away by waves and ocean currents (see COAST; EROSION).

Oceanic ooze consists of the shells, skeletons, and other remains of small marine organisms. Diatomaceous ooze comes from the microscopic diatoms, which are a group of algae. Diatomaceous ooze has a high silica content (see DIATOM; SILICA). It is widespread in the southern oceans. The shells of foraminifers, a group of tiny sea organisms, make up the ooze found in many shallow regions of the oceans (see FORAMINIFERA). Radiolarian ooze contains the remains of radiolarians, another tiny sea creature (see RADIOLARIAN). Radiolarian ooze is found in parts of the Pacific and Indian oceans. It also has a high silica content.

Ooze also refers to the muddy deposits on the bottoms of rivers, ponds, and other bodies of water.

OPAL Opal is a gemstone—a kind of non-crystalline quartz (SiO_2)—noted for its opalescence, or showy play of colors. The most prized of these stones are the brilliant black opals of New South Wales, Australia. The best black opals show flashes of blue, green, red, and yellow. Other types of opal include the yellow or orange red “fire opal,” the rainbow-colored “harlequin opal,” and the white opal (see PRECIOUS STONE AND GEM).



OPAL

Tiny drops of water trapped in noncrystalline silica cause the flashes of rainbow colors that can be seen in opals.

Unlike most gemstones, opals are not found in the form of crystals. They are found in irregular patches, often filling cavities in rocks (see CRYSTAL).

Chemically, opal consists of hydrated silica (silica and water) (see SILICA). Most scientists believe the color flashes of opal are caused by the water. Each layer of silica in an opal has a slightly different water content, which bends light at a slightly different angle. These different bendings break up the light that strikes the stone into a rainbow of colors. See also REFRACTION OF LIGHT.

OPOSSUM Opossums are marsupials, mammals that carry their young in the mother's pouch after birth. There are many species of opossums. Most of them live in Central and South America (see MAMMAL; MARSUPIAL).

The common opossum, also called the Virginia opossum, is the only kind of opossum found in the United States. This species has grayish white hair, a long snout, and big hairless ears. It is about the same size as a domestic cat. The common opossum can hang upside down by wrapping its tail around the branch of a tree.

Opossums hunt at night. They eat many kinds of animals and plants. When in danger, opossums lie motionless, appearing to be dead. This is how the phrase “playing possum” originated. Opossums must not be confused with the Australian possums, which belong to a different family of marsupials. See also NOCTURNAL BEHAVIOR.



OPOSSUM

Opossums are marsupial mammals that live in the Americas. The many species include the (1) white-eared opossum, (2) Ashby mouse opossum, (3) gray four-eyed opossum, (4) black-shouldered opossum, (5) shrew opossum, (6) monito del monte, and (7) bushy-tailed opossum.

OPPENHEIMER, J. ROBERT (1904–1967) J. Robert Oppenheimer (öp' ən hī' mər) was an American physicist who is most famous for being “the father of the atomic bomb.” Oppenheimer studied at Harvard University in Massachusetts, and the University of Göttingen in Germany, where he received his doctoral degree in physics. After he began teaching physics at the University of California at Berkeley and the California Institute of Technology, he explored the energy processes of subatomic particles. A particle is subatomic if it is smaller than the atom. Oppenheimer also investigated the structure of molecules and the collapse of stars by gravity (see

BLACK HOLE). Oppenheimer taught at U.C.-Berkeley and at the California Institute of Technology until World War II (1939–1945).

The United States fought against Germany in World War II. The United States government wanted to develop an atomic weapon before Germany did. Oppenheimer began to investigate the steps necessary to create an atomic explosion. In 1942, the U.S. Army gathered a group of American and British scientists at the Los Alamos laboratory near Santa Fe, New Mexico. From 1943 to 1945 Oppenheimer led the group, which was called the Manhattan Project. The Manhattan Project's goal was to find a way to use the energy of the atom for military purposes. On July 16, 1945, the first atomic explosion took place at a test site in New Mexico. The atomic bomb was later dropped on the Japanese cities of Hiroshima and Nagasaki, destroying the cities and killing thousands of people (see NUCLEAR WEAPONS).

After the war, from 1947 to 1966, Oppenheimer was named director of the Institute for Advanced Study at Princeton University in New Jersey. The institute is a research center for those scientists who have already received a doctoral degree. As chairman of a committee of the U.S. Atomic Energy Commission from 1947 to 1952, Oppenheimer often spoke about what could happen when atomic energy is used. In 1949, Oppenheimer led a group that opposed the development of the hydrogen bomb, which would be more powerful than the atomic bomb. As a result of the controversy that followed, the U.S. government said Oppenheimer could no longer have information about official secrets. However, the U.S. Atomic Energy Commission did award him their highest award in 1963, the Enrico Fermi prize.



**J. ROBERT
OPPENHEIMER**

J. Robert Oppenheimer was an American scientist who led the Manhattan Project, which developed the first atomic bomb.

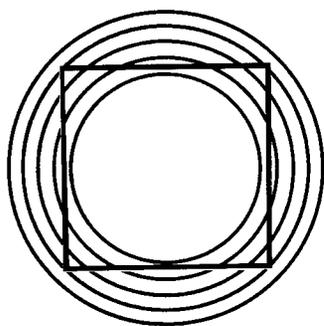
OPTICAL ILLUSION

An optical illusion is a false impression in the brain of what the eyes are seeing. An optical illusion is not the same as a hallucination. In a hallucination, a person sees or hears something that does not actually exist (see HALLUCINATION). An optical illusion is a misleading sensation produced by something that really does exist.

Optical illusions are quite normal. Experiments have shown that other animals besides humans, such as fish and pigeons, also experience optical illusions.

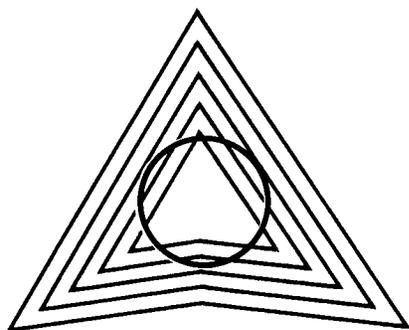
The best-known optical illusions involve size and

shape. Position, color, and movement can also be misleading. The Müller-Lyer arrow illusion involves two parallel lines. One line has an arrowhead at each end pointing toward the line. The other line has an arrowhead at each end pointing away from the line. The lines are actually the same length. However, the line with the arrowheads pointing away from the line appears shorter than the line with the arrowheads pointing toward the line. Another optical illusion involves two circles of the same size each surrounded by other circles. One circle is surrounded by circles that are larger than it.



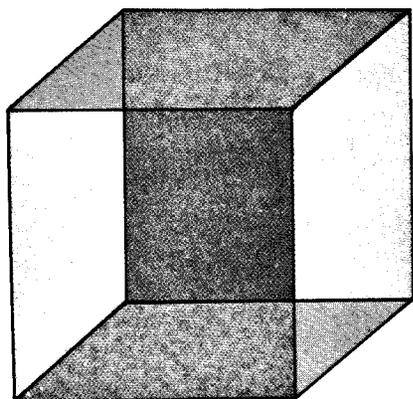
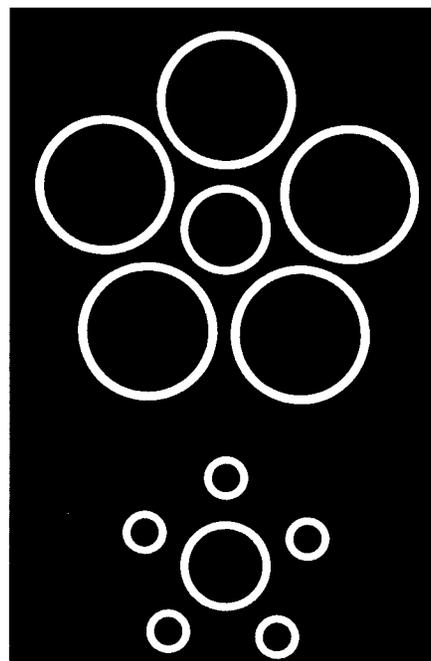
DISTORTION

In the illusion at left (top), the red square seems to have curved sides because of the black circles in the background. The red circle (left, bottom) appears distorted on a background of triangular shapes.



SIMILAR CIRCLES

In the illusion at right, the circle surrounded by larger circles looks smaller than the circle surrounded by smaller circles. Both, however, are the same size.

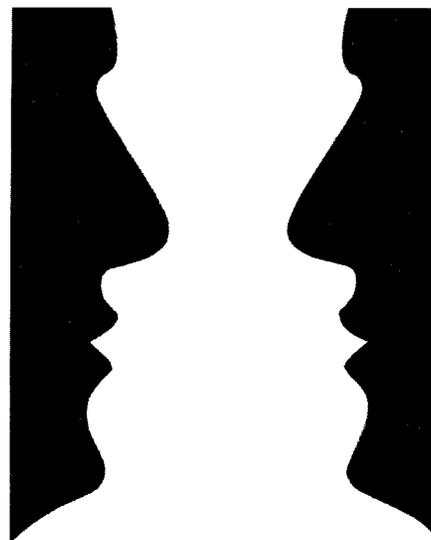


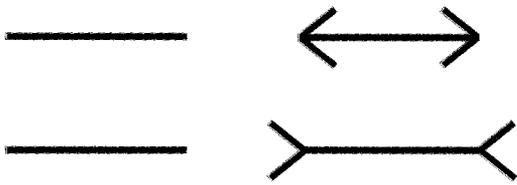
CUBE

In the cube (left), either of the square faces can seem to be nearer the observer.

PEOPLE OR VASE?

The dark areas (right) can be seen as the profiles of two people facing each other or as the background to a vase shape.



ACTIVITY *How to make an illusion*

To make your own optical illusion, first draw two straight lines of exactly the same length (left). Then add arrowheads (right), one pair pointing outward and one pair pointing inward. Now ask a friend to judge which line is the longest, even though you know they are both the same.

The other circle is surrounded by circles that are smaller than it. The circle surrounded by smaller circles appears larger than the circle surrounded by larger ones. The eye is deceived by the relative sizes of the outside circles.

Illusions of shape occur when lines or circles are drawn on or near backgrounds with a strong pattern. A circle or square can be made to appear distorted by placing it on a background that has a strong pattern that is different from the shape of the circle or square.

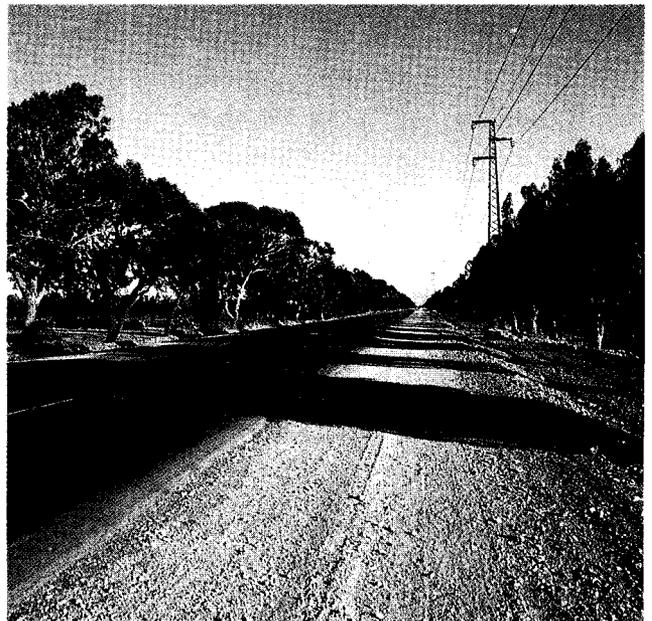
Illusions of movement may occur when the eye is misled by a series of events happening one after another. This illusion is used in advertising signs. A series of electric light bulbs switched on and off in sequence seems to create a moving pattern. In fact, there is no movement at all.

Illusions are sometimes caused by a lack of experience or knowledge. For example, young children have difficulty estimating distances and sizes. Experience gradually teaches them how angles, colors, and brightness are affected by distance. As children grow up, they unconsciously use their past visual experience to interpret what they see. However, the brain can still be deceived. For example, everyone thinks they see the sides of a road or the tracks of a railway coming closer and closer together in the distance. Straight lines coming together like this become a clue to distance. Whenever a person sees lines meeting at a similar

angle, even drawn on flat paper, the meeting point is unconsciously thought of as being far away. This false perception of depth is widely used in TV or movie sets to give the flat image a false appearance of depth, or of being farther away than it really is. Distance also affects the size of objects seen from a distance. For example, a huge ship seen from miles away at sea seems to be very tiny.

Flat images can be given the illusion of depth by using two sets of the same image placed very close to each other, but in contrasting colors (usually red and green). A person wearing glasses with different colored lenses (one to match each color used in the illusion) then “sees” a false image of the object, which appears gray and three-dimensional. Another way of creating false depth relies on using a computer to print precise patterns of dots, which can be used to create a false image within the pattern that is not apparent at first. These are called single image random dot stereograms, or “Magic Eye” pictures. They were first used in the 1960s but are becoming more common with the increasing availability of computers.

See also EYE AND VISION.

 **PROJECT 60**
**NARROWING ROAD**

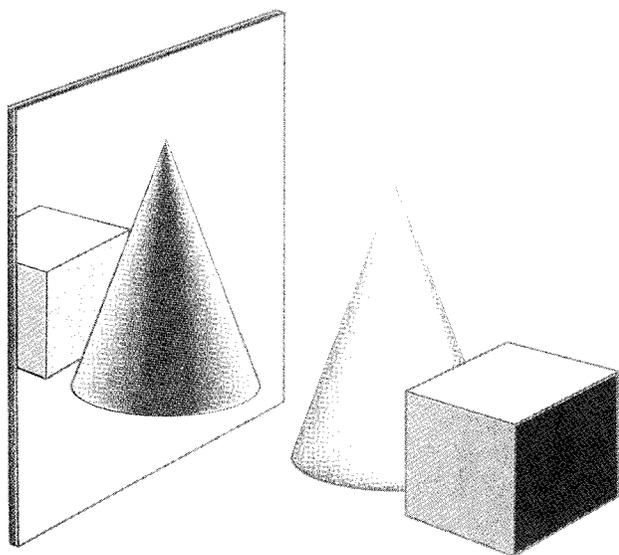
If you look down a long, straight road, it appears to get narrower as it gets farther away. This is an optical illusion—the road obviously stays the same width its entire length.

OPTICS

Optics is the branch of physics that studies the nature and properties of light. It also studies optical instruments, such as microscopes and telescopes (see LIGHT; MICROSCOPE; PHYSICS; TELESCOPE).

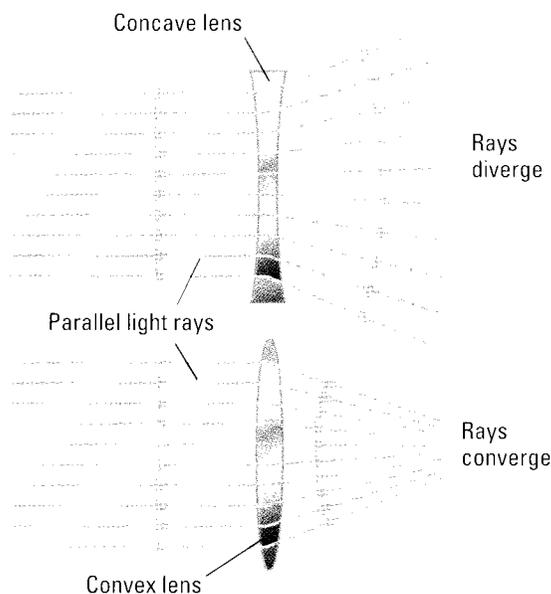
If light can travel through a substance, then the substance is said to be transparent. Glass, water, and air are all transparent substances. The substance in which light is traveling is called the medium. When a ray of light travels from one medium to another, it is bent. This effect is called refraction. If light cannot travel through a substance, then the substance is said to be opaque. Metal and wood are opaque. A ray of light bounces off an opaque surface. This is called reflection. Reflection and refraction are two very important subjects in optics (see REFLECTION OF LIGHT; REFRACTION OF LIGHT).

Reflection When a ray of light strikes an opaque object, it is mostly reflected. A small amount of light is always absorbed because no substance is completely opaque. The line at right angles to the surface where the ray hits is called the normal. The reflected ray makes the same angle to the normal as the incoming, or incident, ray.



MIRRORS AND REFLECTION

A plane (flat) mirror produces an upright image that is reversed left to right. It is a virtual image because it cannot be projected onto a screen.



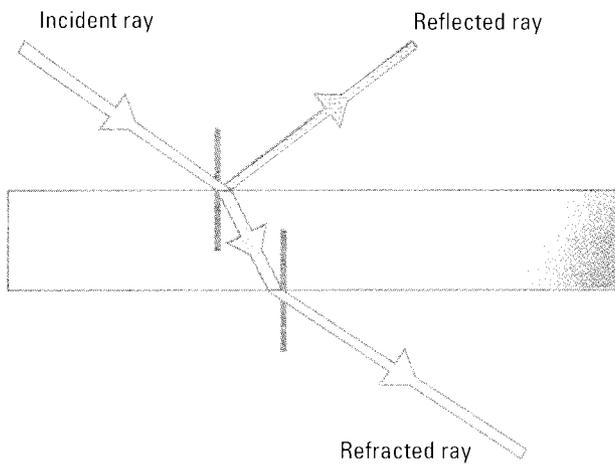
LENSES AND REFRACTION

As a beam of light passes through a concave lens (top), the light rays are refracted in a way that makes the rays spread out, or diverge. With a convex lens (bottom), the light rays are brought closer together, or they converge.

Because the surface of a mirror is smooth and reflects a large amount of light, it is capable of forming an image of an object. Different mirrors produce different kinds of images. A mirror that is curved outward at the center is called a convex mirror (see CONVEX). Its image is called a virtual image. A virtual image can be seen but cannot be projected onto a screen. Flat, or plane, mirrors also produce a virtual image. A mirror that is curved inward at the center is called a concave mirror (see CONCAVE). It produces either a virtual or a real image. A real image can be seen as well as projected onto a screen (see MIRROR).

Refraction Whenever a ray of light travels from one medium to another, the light changes direction. It is refracted. If a ray passes through the surface of a medium at an angle to the normal, then it is bent toward the normal.

An important part of optics is the study of lenses. A lens is a piece of transparent material with curved sides (see LENS). Like mirrors, lenses can produce either real or virtual images. If both sides of a lens are concave, the lens is called a negative or diverging lens. Diverging lenses produce a virtual image.



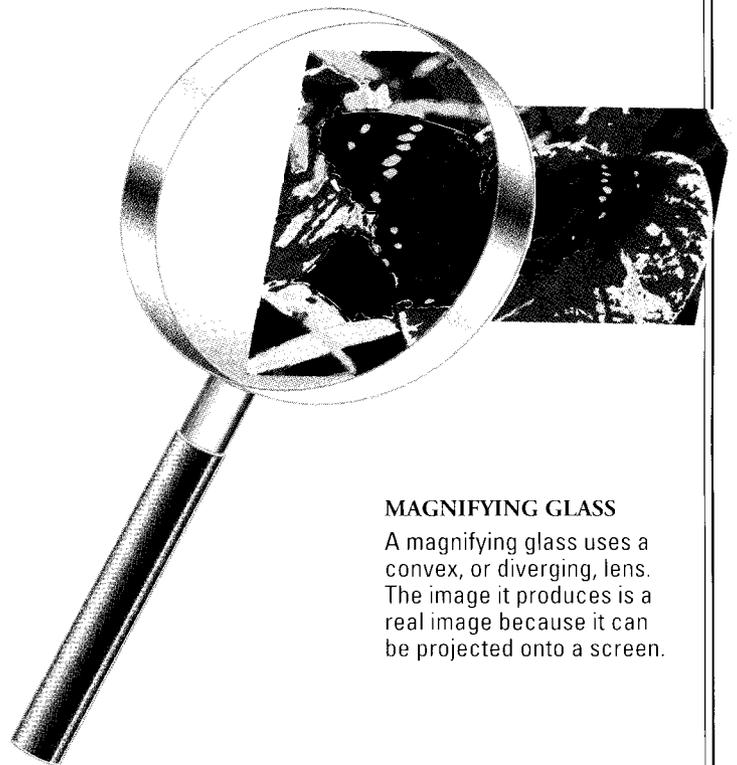
REFLECTION AND REFRACTION

An incident (incoming) light ray is reflected from the surface of a glass block. It is refracted as it passes through the block.

If both sides of a lens are convex, it is called a positive or converging lens. It can produce a real image or a virtual image. When parallel rays pass through a converging lens, they bend inward and meet at a point called the focal point or focus. The distance from the focal point to the center of the lens is called the focal length.

Lenses can have a number of faults. These are known as aberrations (see **ABERRATION**). In an optical instrument, aberrations have to be corrected because they distort the image. For example, different colors of light are refracted in different amounts. When a lens bends blue light more than red light, colored fringes occur along the edge of the image. This is called chromatic aberration. Spherical aberration is caused by the shape of the lens. A lens should bring all points of an image into focus at the same distance from the lens. In spherical aberration, rays from the edge of the lens are focused at a different distance from the rest of the rays. This makes the image fuzzy. Another kind of aberration is called astigmatism. In astigmatism, if a horizontal line in an image is in focus, a vertical line will not be. Correction of aberration is done by using a number of different lenses in combination.

Interference Like all waves, a light wave has a crest (top) and trough (bottom) (see **WAVE**). A light wave also has a wavelength. This is the distance between two corresponding points on two consecutive



MAGNIFYING GLASS

A magnifying glass uses a convex, or diverging, lens. The image it produces is a real image because it can be projected onto a screen.

waves, such as from crest to crest. Two waves can combine to form a single wave. This effect is called interference. Suppose two waves have the same wavelength. If their crests and troughs come together, a large combined wave is formed. This is called constructive interference. If the crests of one wave come together with the troughs of another, the waves cancel each other out. This is called destructive interference. Interference is used in an optical instrument called the interferometer.

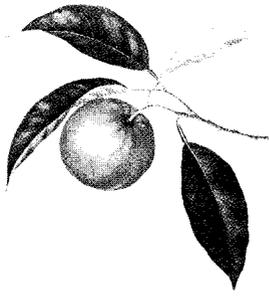
See also **INTERFEROMETER**.

PROJECT 55



COLORED BUBBLES

These soap bubbles show all the colors of the rainbow. The effect is the result of interference, in which light waves either combine or cancel each other out.



ORANGE

Oranges are among the most popular citrus fruits. Shown here is the bitter marmalade orange. In the United States, Florida produces more oranges than any other state. Most Florida oranges are made into juice.

ORANGE The orange is a fruit that belongs to genus *Citrus* of the rue family (see CITRUS FRUIT; RUE FAMILY). Oranges grow on trees that originated in eastern Asia, but they are now grown in warm climates all over the world. The trees can reach a height of about 33 ft. [10 m] and usually live for more than eighty years. The evergreen leaves are large, shiny, and dark green in color. The fragrant white flowers are known as orange blossoms and have long been associated with marriage and weddings. The fruit is a specialized berry with ten to fifteen segments surrounding a central pith (spongy core) (see BERRY; FRUIT). The segments are filled with juice that is rich in sugar, citric acid, minerals, and vitamins. Oranges are an especially good source of vitamin C. A protective rind surrounds the fruit. The rind contains glands that produce orange oil.

There are two main types of oranges: bitter, or sour, oranges and sweet oranges. Most of the oranges grown in the United States are sweet oranges. Florida produces about five times as many oranges as its closest competitor, California. Texas and Arizona also produce large orange crops. Most of the California oranges are sold as fresh fruit. About 75 percent of the Florida oranges are processed into frozen concentrated juice. Florida oranges differ from California oranges in several ways. Florida oranges have thinner skins, more juice, more sugar, less acid, and less natural orange color. Their color is sometimes enhanced by the use of red food dyes. Oranges from throughout the country are commonly treated with ethylene to bring out the orange color and eliminate any green color (see ETHYLENE).

Tangerines, or mandarins, are smaller than oranges and are flattened at the ends. Tangerines have thin,

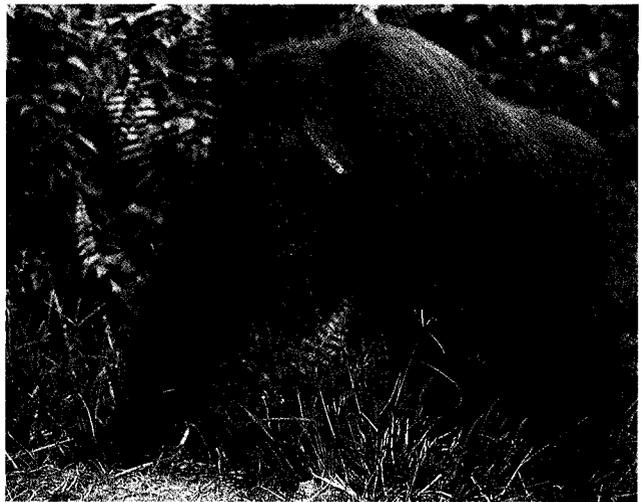
reddish orange rinds that are easily peeled. The segments are easy to separate and are filled with a sweet, tasty juice. Like oranges, tangerines originated in eastern Asia, but they are hardier than oranges and can be grown in slightly cooler areas.

The United States produces more than 20 billion lb. [9 billion kg] of oranges and tangerines every year. Most of the sweet oranges grown in the United States are Valencia oranges. Valencia oranges have a relatively thin rind and few, if any, seeds. They are usually a bright, golden orange color. Another popular variety of sweet orange is the navel orange. The navel orange is actually two fruits in one. There is a tiny, undeveloped fruit embedded at one end of the larger, juicy fruit. This produces the characteristic "navel."

Bitter oranges are often grown for use as rootstocks in grafting sweet oranges or other citrus fruits (see VEGETATIVE PROPAGATION). The rinds are sometimes used to make bitter marmalade. The flowers are sometimes processed into perfume.

Oranges have many uses besides being eaten or squeezed for juice. They are also used as a flavoring for various foods and beverages.

ORANGUTAN (ō rāng'ə tān') The orangutan is a large ape that lives only in the lowland tropical forests of the islands of Borneo and Sumatra in Asia. Its name comes from the Malay words



ORANGUTAN

The orangutan is a large, peaceful ape. Because orangutans have been widely hunted and much of their habitat in Asia has been destroyed, the animals are now rare.

meaning "man of the woods." A male orangutan may grow to a height of 5 ft. [1.5 m] and may weigh 200 lb. [90 kg]. The female is usually about half this size. The male has fatty cheek flaps and a huge air sac that hangs over the chest from the throat. Orangutans have reddish brown hair. They have stocky bodies with short legs and long arms. When an orangutan stands upright, its arms reach to its ankles. Some males have an arm-spread of 7.5 ft. [2.3 m], the longest of the apes (see APE).

Orangutans live alone or in groups of two to five. They live in the trees, climbing slowly and carefully from branch to branch. The orangutan is a herbivore and eats mostly fruits (see HERBIVORE). It builds a new sleeping platform or bed with branches every night or two. This nest is sometimes as high as 80 ft. [25 m] in the trees. After mating and a gestation period (pregnancy) of about 275 days, the female gives birth to one young. The baby orangutan nurses for more than a year and stays close to the mother for several years after that. Orangutans are sexually mature by the time they are ten years old. They live for about thirty years.

Very few orangutans are left in the wild. Their numbers have decreased because of hunters and the growth of human population that destroyed their natural living areas.

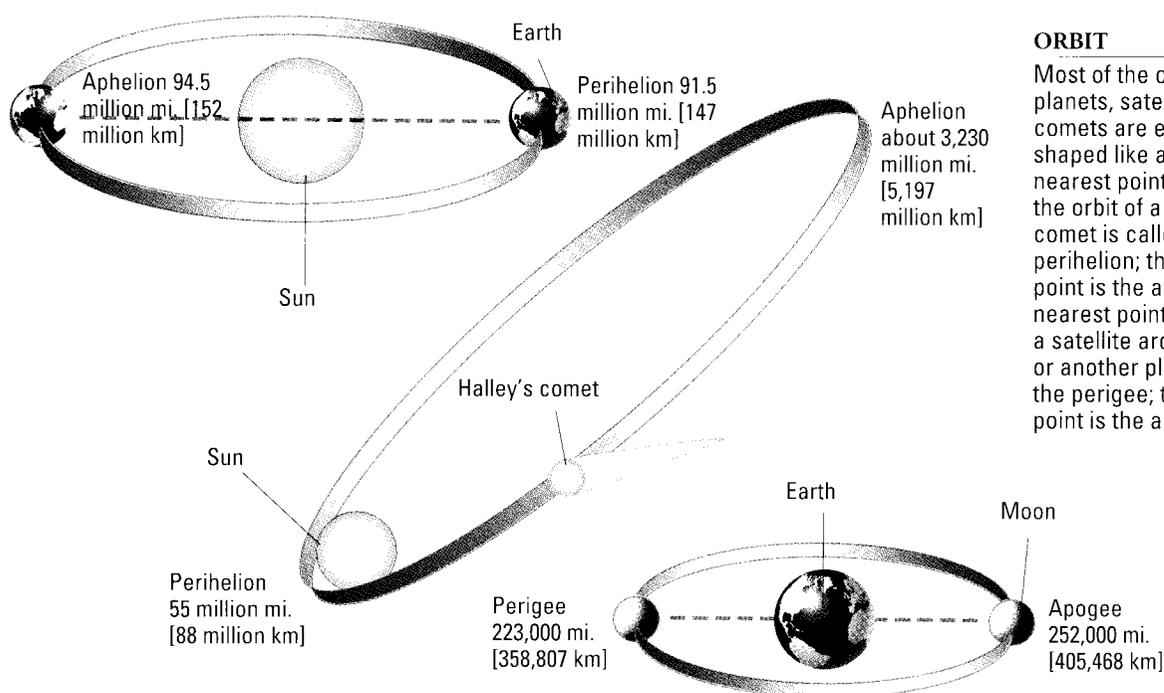
See also ENDANGERED SPECIES.

ORBIT An orbit is the path that one body follows around another larger body. A body follows an orbit because it is trapped in the gravitational field of the larger body (see GRAVITY). For example, the moon follows an orbit around the earth. Therefore, the moon is a satellite of the earth (see SATELLITE). In discussions of the earth's orbit around the sun, the earth is a satellite. In order for a satellite to escape the gravitational field of the body it is orbiting, the satellite must reach a speed known as the escape velocity. Space scientists must calculate the escape velocity necessary for a spacecraft to leave the earth's gravitational field (see ESCAPE VELOCITY).

Most orbits are elliptical (oval-shaped), though some planets have nearly circular orbits around the sun. In the orbit of a body around the sun, the closest point that it comes to the sun is called the perihelion (see PERIHELION). The most distant point is called the aphelion. Orbiting bodies around the sun include planets and comets. In the orbit of a body around the earth or other planet, the closest point is called the perigee. The most distant point is called the apogee. Orbiting bodies around the earth include the moon and artificial satellites.

In atomic theory, electrons can be thought of as traveling in orbits around an atom's central nucleus (see ATOM; ELECTRON; NUCLEUS).

See also COMET; MOON; PLANET; SUN.



ORBIT

Most of the orbits of planets, satellites, and comets are elliptical, or shaped like an oval. The nearest point to the sun on the orbit of a planet or comet is called the perihelion; the farthest point is the aphelion. The nearest point of the orbit of a satellite around the earth or another planet is called the perigee; the farthest point is the apogee.

ORCHID FAMILY

The flowers of the common spotted orchid (right) have a lip that resembles a bee. This attracts real bees, which pollinate the flowers. The orchid of the genus *Phalaenopsis* (far right) is grown for its showy flowers.



ORCHID FAMILY The orchid (ôr'kîd) family includes hundreds of genera (plural of *genus*) and over 20,000 species of plants. They are monocotyledons. Most orchids grow in tropical and subtropical climates. These herbaceous plants are perennial. Most orchids provide their own food by means of photosynthesis. Some, however, rely on decaying organic material as a source of nutrition. They are referred to as saprophytes (see HERBACEOUS PLANT; MONOCOTYLEDON; PERENNIAL PLANT; PHOTOSYNTHESIS; SAPROPHYTE).

The color of the orchid flowers varies enormously from species to species. Some orchids have streaks or spots of color in the petals. The flower has three sepals and three petals. One of these petals is highly modified and is called a lip. The lip may be any of several shapes, depending on the species, and it may be a different color from the other petals. There is a club-shaped reproductive column in the center of the blossom. This column is actually fused stamens and pistils (see FLOWER).

Each species of orchid is pollinated by a specific kind of insect (see POLLINATION). The flower is usually modified in some way to attract that insect. For example, the lips of some orchids look like female insects (see MIMICRY). When a male insect tries to mate with what it thinks is a female insect, it brushes against the flower's reproductive column, picking up or passing on pollen. In many cases, the

lip has special coloring and scent that attracts and guides the insect. Some orchid flowers produce more than two million tiny seeds, each of which can grow into a new plant.

Orchids that grow in temperate areas usually grow in the ground. Most tropical orchids, however, grow high up in the trees (see EPIPHYTE). When a tiny orchid seed, carried by the wind, lodges in the bark of a tree, the seed germinates. It sends out a mass of roots, which hang in the air. Some of these roots have a special spongelike coating that absorbs moisture from the air.

See also DISPERSION OF PLANTS; GERMINATION; ROOT.

ORDER An order, in the classification of living organisms, is a subdivision of a class. It is made up of a group of related families.

See also CLASS; CLASSIFICATION OF LIVING ORGANISMS; FAMILY.

ORDOVICIAN PERIOD (ôr'də vîsh'ən pîr'ē əd) The Ordovician period in the earth's history is a division of the Paleozoic era. It began 510 million years ago and lasted about 71 million years (see GEOLOGICAL TIME SCALE; PALEOZOIC ERA).

About two-thirds of North America and most of Scandinavia were covered by shallow water during the Ordovician period. Life on land is known to

have existed only from fossil arthropod footprints, though life in the seas flourished. Algae were plentiful. Other marine creatures included trilobites, corals, brachiopods, and graptolites. Jawless fish, the first known vertebrates (animals with backbones), appeared during this period. Deposits of oil, lead, and zinc formed (see ALGAE; BRACHIOPOD; CORAL; LEAD; PETROLEUM; TRILOBITE; ZINC).

Some geologists suggest that eastern South America, Africa, the Indian peninsula, Australia, and Antarctica may have been close together during the Ordovician period. This theory is supported by the unusual distribution of Ordovician fossils throughout the world. An ice age occurred near the end of this period. The evidence for this can be found in the rocks of the Sahara.

See also CONTINENTAL DRIFT; FOSSIL.

ORE Many minerals contain metals that are combined with other elements. Minerals from which pure metals can be extracted (removed) are called ores. In addition, ores are any materials that can be mined at a profit. Such ores include salt, gypsum, and limestone (see METAL AND METALLURGY; MINERAL).

Native metals and compound ores are the two types of ores. In native metals, the valuable mineral occurs as a pure metal. It is not chemically combined with other substances. Gold, silver, and



ORE

Cuprite, shown here, is one of the chief ores of copper. It consists mainly of cuprous oxide.

platinum often occur as native metals. Compound ores include oxides, which are compounds of metals with oxygen; carbonates, which are compounds of metals with carbon and oxygen; and sulfides, which are compounds of metals with sulfur.

See also MINING.

ORGAN An organ is any part of an animal or plant that has a characteristic function, shape, and structure. For example, the heart is one of the most important organs in the human body. The root is a vital organ in plants. Several organs may function together as an organ system. The heart, for example, is part of the circulatory system.

See also ANATOMY.

ORGANELLE An organelle is a tiny structure that is part of a cell. Organelles perform special tasks that contribute to the working of cells. Organelles include ribosomes, where proteins are manufactured; mitochondria, where carbohydrates, fats, and protein are converted into energy; the endoplasmic reticulum, the cell's internal transport system; and the Golgi bodies, which store and release various substances from the cell (see CELL). Plant cells also have chloroplasts, which contain substances that make photosynthesis possible. Some organelles are outside the cell. Examples of external organelles are flagella (plural of *flagellum*).

See also CHLOROPLAST; FLAGELLUM.

ORGANIC CHEMISTRY Organic chemistry studies the chemical properties of organic compounds. A compound is a substance composed of two or more elements (see COMPOUND). There are two main classes of chemical compounds— inorganic compounds and organic compounds.

Organic compounds contain the element carbon (see CARBON). Carbon compounds are called organic because many of them are found in living organisms. In the early 1800s, scientists thought that organic compounds did not obey the same laws as inorganic compounds. They thought that organic compounds could only be obtained from living organisms. Then, in 1828, the German

chemist Friedrich Wohler obtained an organic compound from an inorganic compound. He prepared urea from ammonium cyanate. Today, many organic compounds are made from inorganic compounds, both in industry and in laboratories. However, many properties of organic compounds are different from those of inorganic compounds. Therefore, organic chemistry is still treated as a separate branch of chemistry (see CHEMISTRY).

Most substances are made up of groups of atoms called molecules (see ATOM; MOLECULE). Almost all organic compounds contain groups of carbon atoms attached to each other in rings or chains. Usually, the carbon atoms are also attached to hydrogen atoms. Sometimes, though, they are attached to other atoms, such as oxygen and nitrogen. A few simple carbon compounds are classified as inorganic. For example, the gases carbon dioxide and carbon monoxide are inorganic. Most inorganic molecules contain less than ten atoms. Inorganic compounds are found in things that are nonliving, such as the atmosphere and minerals. Many organic molecules contain large numbers of atoms, sometimes hundreds. These atoms can be arranged differently in the molecule. Compounds that have the same atoms but a different arrangement are called isomers.

See also INORGANIC CHEMISTRY; ISOMER.

ORGANISM *Organism* is a general term for any particular form of life. Organisms are usually classified as belonging to one of five groups called kingdoms. Two of these kingdoms are the animal kingdom and the plant kingdom. All organisms consist of one or many cells. Viruses, which do not consist of cells, are on the borderline between living and nonliving matter.

See also CLASSIFICATION OF LIVING ORGANISMS; LIFE; VIRUS.

ORIGIN OF SPECIES *The Origin of Species* is a famous book written by the English naturalist Charles Darwin (see DARWIN, CHARLES). The book's fuller title is *The Origin of Species by Means of Natural Selection*. It was first published in 1859. In it Darwin stated his idea that all existing species of plants and

animals came into being through evolution from earlier and simpler ones (see EVOLUTION; NATURAL SELECTION). Many people did not believe Darwin's ideas at first, and some actually became angry with him—especially with his suggestion that human beings and apes had evolved from a common ancestor. Today most scientists think that Darwin's theories are correct.

ORIOLE The orioles are perching birds that belong to genus *Icterus* in the American blackbird family, Icteridae. The males are usually black and yellow or black and red with white wing flashes. They are known for their warbled songs. The females are usually not as brightly colored and sing simpler songs. Orioles eat insects, sometimes prying them out of trees with their beaks. Most orioles live in warm, wooded areas. The northern oriole and hooded oriole are common in the United States. The eastern and western forms of the northern oriole differ in color. In Europe and Asia, the name *oriole* is given to birds that belong to an entirely different family, the Oriolidae.

See also BIRD; BLACKBIRD; PERCHING BIRD.



ORIOLE

The hooded oriole has a striking plumage of yellow, black, and white. This male oriole was photographed in Arizona.

ORNITHOLOGY (ôr'nə thōl'ə jē) Ornithology is the biological science that studies birds. It deals with all matters involving birds' lives, distribution, classification, and history. Ornithologists, the scientists who study birds, research the activities of birds, which include mating, nesting, care of young, feeding, and migration (see BIRD; MIGRATION).

People have been interested in birds since prehistoric times. Most of the early writings on birds were brief descriptions of or stories about birds. In the Middle Ages, people were interested in training birds for hunting. In the eighteenth and nineteenth centuries, scientists described and classified most known species of birds. In the late nineteenth and the twentieth centuries, many ornithologists concentrated on the anatomy (body structure) and behavior of birds as well as their relationship to other organisms and their environment.

Much information about the distribution and activities of birds has come from a technique known as banding. In banding, a small, numbered metal or plastic band is attached to the leg of a captured bird. The bird is then set free. Amateur bird watchers throughout the world are able to supply scientists with information about the banded birds. In fact, ornithology is one of the few sciences that relies heavily on the observations of amateurs.



ORNITHOLOGY

Ornithologists examine an injured trumpeter swan, which they can identify from the band on its leg. The band around the bird's neck is a temporary one fitted while the swan is in captivity. This will allow the bird to be identified quickly without having to be caught.

Birds were first banded in the nineteenth century. Now, hundreds of thousands of birds are banded every year.

OSCILLATION (ōs'ə lā'shən) Oscillation is the type of back-and-forth movement made, for example, by a pendulum (see PENDULUM). Suppose that a pendulum is held to one side and then let go. It swings to the vertical (up-and-down) position and then moves through that position until gravity stops it on the other side (see GRAVITY). The pendulum then returns through the vertical position and stops when it reaches the point at which it was released. This is called a single oscillation. The time taken for a single oscillation is called the period of oscillation. The number of single oscillations in a second is called the frequency of oscillation (see FREQUENCY). Another example of an oscillation is the movement of a guitar string when it is plucked. The string moves back and forth through the position it has when it is at rest. All oscillations eventually die away. For example, as the pendulum swings, its maximum position from the vertical position becomes smaller. This is called damping. It is caused by the friction of the air gradually slowing the pendulum.

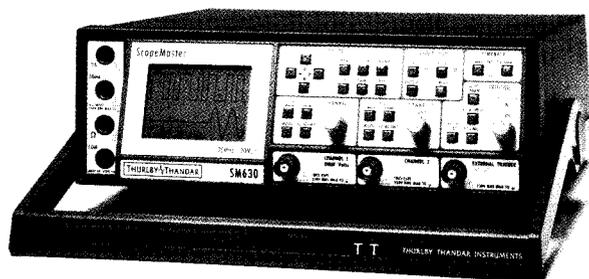
See also FRICTION; PERIODIC MOTION.

OSCILLATOR (ōs'ə lā' tər) Oscillators are electronic devices that change direct electrical current into alternating current of desired frequency. A direct current is a flow of electric charges in one direction. Frequency is the number of vibrations per second (see DIRECT CURRENT).

An oscillator is actually a kind of amplifier. It strengthens a current and then feeds part of the amplified current back into itself to change it into a specific frequency (see AMPLIFIER). Oscillators are used in radio and telephone receivers and in other equipment.

See also ELECTRICITY.

OSCILLOSCOPE (ō sīl'ə skōp') An oscilloscope is an electronic instrument. It is used to show the oscillation (vibration) of an electric signal (see OSCILLATION). An oscilloscope contains a cathode-ray



OSCILLOSCOPE

An oscilloscope displays a variable electric signal as a trace (graph) on the face of a cathode-ray tube. This oscilloscope has two channels and can display two signals at the same time on its screen.

tube similar to the tube found in television sets (see CATHODE-RAY TUBE). The screen of the cathode-ray tube displays the oscillation as wavy lines or other patterns.

As in all cathode-ray tubes, a beam of electrons is directed at the fluorescent screen and appears as a spot of light. As the beam is made to move from left to right, the electrical signal to be studied is fed into the oscilloscope. The beam then moves up and down in correspondence with the oscillations of the signal. The movements of the beam trace a pattern on the screen.

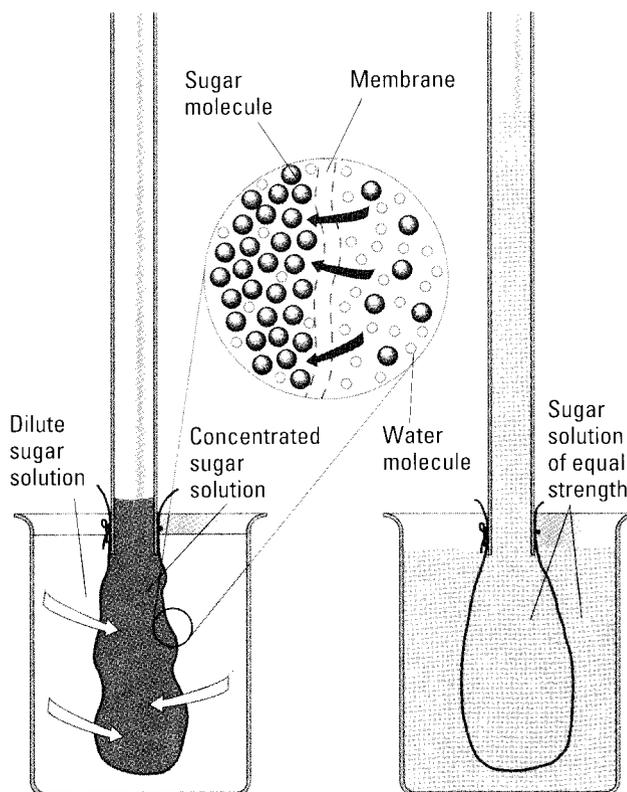
Oscilloscopes are used by engineers to test electronics equipment. They are also used by doctors to study electrical activity of the brain and heart. An oscilloscope can be used to show any kind of vibration, such as sound waves. In this case, a device called a transducer is needed. It changes the sound waves into electric signals.

See also ELECTRONICS; SOUND; TRANSDUCER.

OSMOSIS (ōz mō'sīs) Osmosis is the movement of a liquid, usually water, through a semipermeable membrane from one solution into another solution. A semipermeable membrane is a sheet or layer that allows some, but not all, substances to pass through it. A solution is a mixture of a liquid (solvent) and dissolved particles (solute) (see SOLUTION AND SOLUBILITY). In osmosis, the movement of a solvent is usually from a dilute solution (low concentration of solute) into a stronger solution (high concentration of solute). As a result, the stronger

solution becomes more dilute. The rate of osmosis depends on the difference in the strengths of the solutions. The greater the difference, the faster the rate of osmosis. Osmosis continues until both solutions are in equilibrium, or of equal strength.

The membranes of a living cell are semipermeable (see CELL; MEMBRANE). Plants absorb water and dissolved minerals from the soil by osmosis. Osmosis is then used to move the water and dissolved minerals through the plant, cell by cell. Osmosis also maintains turgor pressure. Turgor pressure is the pressure of water in the cell. It gives the cell form and strength. When there is a decrease in turgor pressure, the plant will seem wilted: it will not have its regular stiffness. Turgor pressure changes are responsible for some types of plant movement (see MOVEMENT OF PLANTS). In the human body, osmosis allows the transfer of water and dissolved nutrients from the blood into the cells. It also helps remove wastes and excess water



OSMOSIS

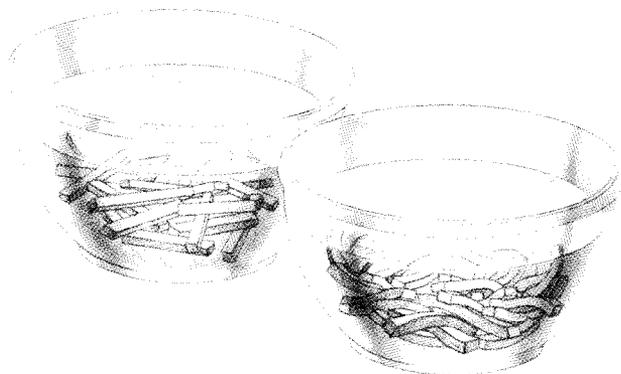
A bag of concentrated sugar solution (above left) is tied to the end of a glass tube and immersed in a dilute sugar solution. The bag (a semipermeable membrane) allows only water to pass through it. Water molecules (inset) pass into the bag. As the solution in the bag becomes more dilute, osmotic pressure forces the liquid up the tube (above right).

from the cells (see HOMEOSTASIS). Osmosis is also important in the removal of wastes and excess water from the blood by the kidneys (see KIDNEY).

A type of reverse osmosis can be caused by adding pressure to the system. Normally, in a system made up of solutions of seawater (salt water) and fresh water separated by a semipermeable membrane, osmosis would cause the water to move from the fresh water into the seawater in an attempt to reach equilibrium. When pressure is applied to the seawater, however, the water moves out of that solution and into the fresh water. This process is sometimes used for emergency purification of seawater for drinking purposes.

 PROJECT 14, 17, 69

ACTIVITY *Watching osmosis*



Take some uncooked French fries (raw potatoes cut into strips). Place half of them in a bowl of very salty water. Place the rest in another bowl of tap water. After one hour, the fries in the salty water will be limp. This is because water from inside the potato has passed by osmosis into the salty water. The other fries will still be stiff.

OSPREY (ös'prē) The osprey is a bird of prey that belongs to the hawk family, Accipitridae (see HAWK). It is often called the fish hawk. It may grow to lengths of 22 in. [55 cm] and may have a wingspan of 54 in. [135 cm]. The wings and back of the osprey are brown. The underside of the body and the head are white. The bird has a dark band running across its eyes that looks like a mask.

Ospreys usually eat only fish. They dive into the water from heights as high as 150 ft. [45 m]. Unlike the bald eagle and most other fish-eating birds of



OSPREY

The osprey is also called fish hawk because it eats fish, which it catches in its sharp talons (claws).

prey, ospreys will plunge completely underwater to catch fish with their powerful talons. Although they are not very numerous, ospreys are found all over the world, including in most coastal and lake areas of North America.

The Long Island Sound area in the northeastern United States was at one time the largest North American breeding ground for ospreys. In the late 1960s, the birds almost disappeared from the area because of water pollution. Pesticides and other chemicals in the water had poisoned the fish that the birds ate (see PESTICIDE; POLLUTION). Chemicals from the poisoned fish collected in the ospreys' bodies and caused their eggshells to be very thin. Most of the eggshells broke before the eggs were ready to hatch. In the 1970s, ornithologists (scientists who study birds) began to bring healthy eggs from other areas to the nests on Long Island Sound. The eggs were hatched by new parents. Today, there is less poisoning of the waters, and ospreys are becoming more numerous.

OSTEOPATHY (ös' tē ōp' ə thē) Osteopathy is a form of medicine that focuses on the relationship between the body's skeletal and muscular framework (see MUSCLE; SKELETON). Osteopaths (doctors who practice osteopathy) use accepted physical, medical, or surgical treatments, but emphasize the importance of normal relationships between the body's

muscles, bones, and joints (see BONE; JOINT). They use physical therapy as the chief treatment (see PHYSIOTHERAPY). Osteopaths treat many types of injury. The most common are back injuries or sports injuries, but any area of the body with a mechanical problem can be treated.

Osteopathy was started in the United States by Dr. Andrew Taylor Still (1828–1917), who became dissatisfied with the often ineffective treatments used in his time. He used his detailed knowledge of human anatomy and engineering to form the principles of osteopathy. The United States remains the chief center for osteopathy in the world.

See also LIGAMENT.

OSTEOPOROSIS (ōs' tē ō pə rō' sīs) Osteoporosis is a disorder in which a person's bones lose density and mass because of a loss of calcium (see BONE; CALCIUM). The bones gradually become thinner, weaker, and more likely to break, or fracture. Osteoporosis is most common in women over the age of 50. Osteoporosis has several causes, but the most common is a deficiency in the hormones regulating calcium intake by the bone (see HORMONE). This happens especially after menopause, when a woman stops having her monthly periods. Other causes include lack of exercise and not having enough calcium in the diet. The main treatment for osteoporosis is to use hormone replacement therapy (HRT) to replace the hormones that the body has stopped making. Other treatments include drugs that reduce the loss of bone or that stimulate the build-up of bone mass. But it is important to reduce the risk of the disease by eating a balanced diet and getting enough exercise.

OSTRICH The ostrich is the world's tallest bird. There is only one living species of ostrich. It grows to heights of 8 ft. [2.4 m]. It cannot fly, but it can run very fast and often reaches speeds of 45 m.p.h. [72 kph]. The male has black plumage, with white plumes on the tail and the wing-tips. The female is brown. The feathers of the ostrich are unlike those of most birds. They resemble the fluffy down of young birds.

Ostriches live in the grasslands of Africa. They

were once very common. However, many were killed for their feathers. Today, large flocks are seen only in a few parts of eastern and southern Africa.

See also BIRD.



OSTRICH

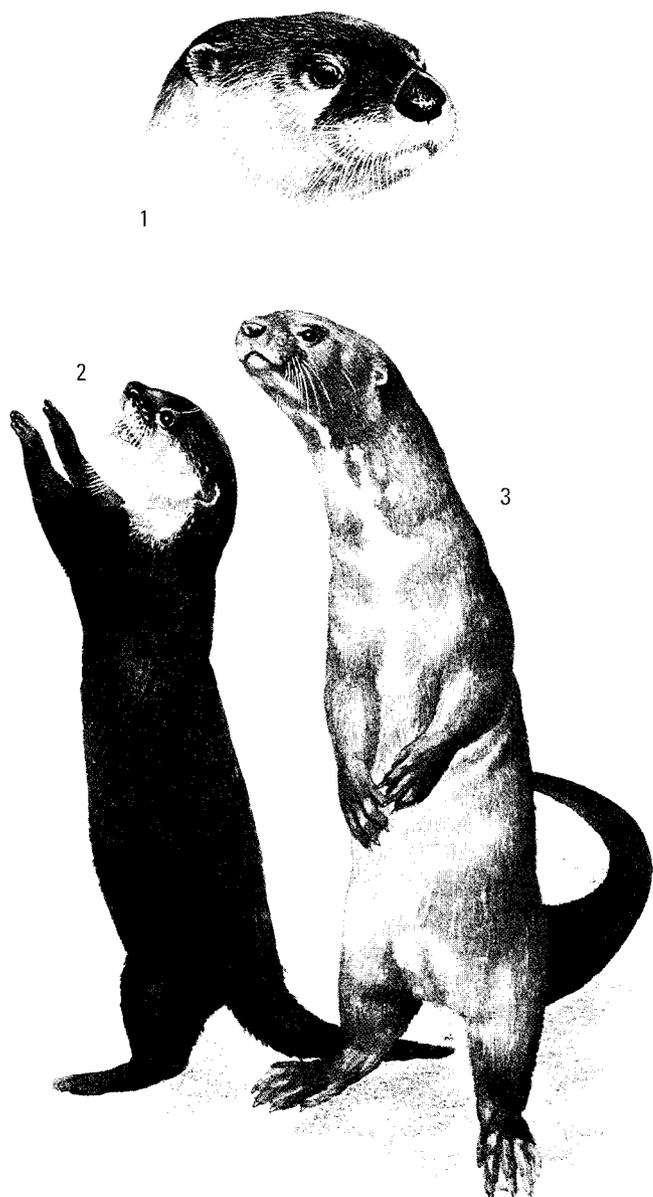
The ostrich is a flightless bird that lives in the grasslands of Africa. It is the world's tallest bird.

OTTER The otter, a carnivorous mammal, is a member of the weasel family, Mustelidae (see CARNIVORE; MAMMAL; WEASEL). Otters live close to water and spend most of their time in it. They are expert swimmers and divers, and they can stay underwater for three or four minutes.

Otters live on every continent except Australia. Most otters weigh from 10 to 30 lb. [4.5 to 14 kg] and grow 3 to 4.5 ft. [0.9 to 1.4 m] in length, including the tail. The giant otter of South America can grow 7 ft. [2 m] long.

An otter has a small, flattened head; a long, thick

neck; and a thick tail that narrows to a point. Special muscles enable the otter to tightly close its ears and nostrils to keep water out. Webbing between the toes helps the otter swim swiftly. Otters have two layers of brownish gray fur. Long, coarse outer hairs, called guard hairs, protect their short, thick underfur. The underfur traps air and keeps the otter's skin dry. Otters live alone, except at breeding time. They eat crayfish, crabs, and various fish. They also eat clams, frogs, insects, snails, snakes, and, occasionally, water birds.



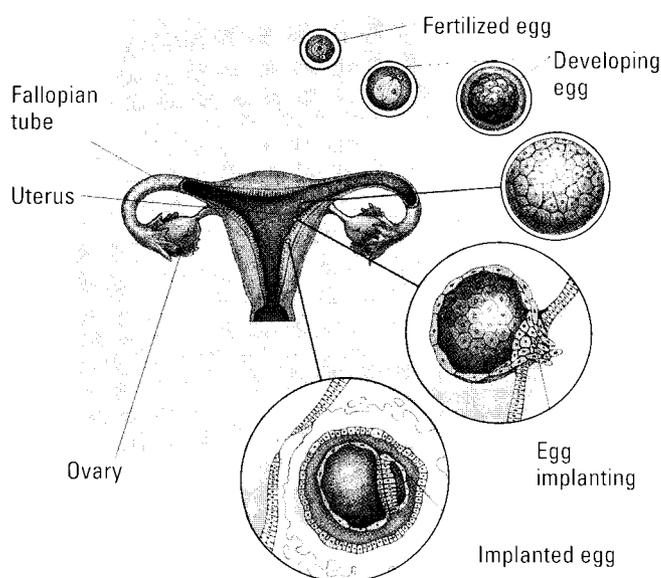
OTTER

The various species of otters can be recognized by the shapes of their noses. (1) The North American river otter has a bare nose, whereas (2) the Oriental short-clawed otter and (3) the spot-necked otter have fur on their noses.

Otters usually live in burrows (holes) in riverbanks or under rocky ledges. Young otters do not swim until they are a few months old.

OVARY (ō'və rē) An ovary is a female reproductive structure. In animals, the ovary produces ova (eggs). It also makes sex hormones that affect the body shape of females, and controls their reproductive behavior (see EGG; HORMONE; REPRODUCTION). In flowering plants, the ovary is an enlarged area at the base of the pistil that produces ovules. The ovules contain eggs.

See also FLOWER; OVULE.



OVARY

The diagram shows the progress of a human ovum (egg) from an ovary along the Fallopian tube to the uterus. In this case the egg has been fertilized and is implanted in the wall of the uterus.

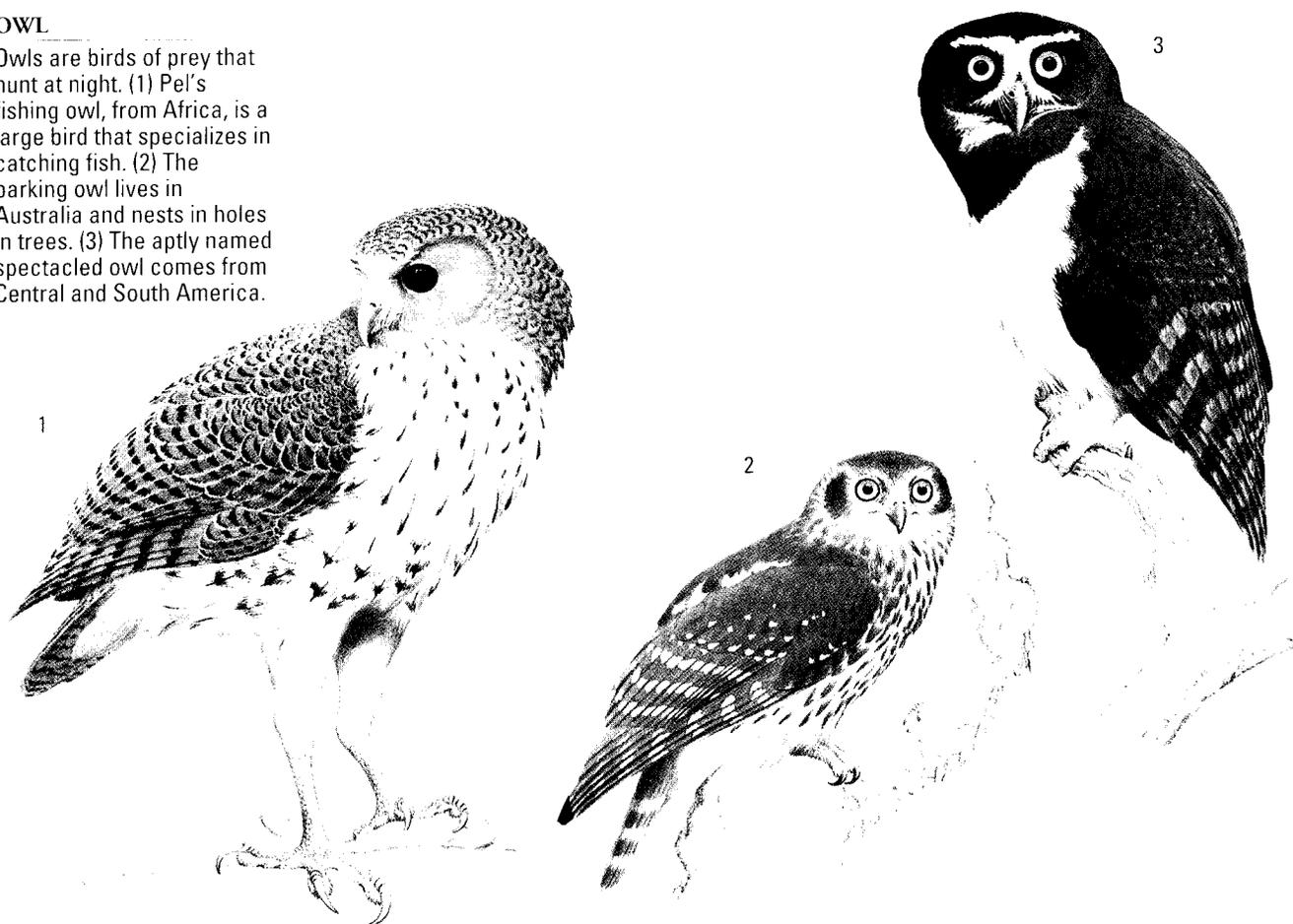
OVULE (ō'vyōōl) An ovule is that part of most plants' reproductive organs that contains the female gamete, or egg. After the egg is fertilized by a pollen grain, which contains the male gamete, the ovule matures into a seed.

The ovules of gymnosperms (plants without flowers or fruits) lie on the scales of structures called cones. In angiosperms (flowering plants), the ovules are protected by female reproductive structures called ovaries, which are part of the pistil.

See also ANGIOSPERM; EGG; FERTILIZATION; GYMnosperm; OVARY; PLANT KINGDOM; REPRODUCTION.

OWL

Owls are birds of prey that hunt at night. (1) Pel's fishing owl, from Africa, is a large bird that specializes in catching fish. (2) The barking owl lives in Australia and nests in holes in trees. (3) The aptly named spectacled owl comes from Central and South America.



OWL An owl is a bird of prey that belongs to the order Strigiformes. It has a large head and eyes, a short neck, broad wings, and sharp talons, or claws.

About 130 species of owls are found around the world. Eighteen species live in North America. Owls vary in size. The largest North American owl is the great gray owl. It grows 22 in. [55 cm] long and has a wingspan of 60 in. [150 cm]. The elf owl is the smallest owl in North America. It grows only 5.25 in. [13.3 cm] long and has a wingspan of 15 in. [37.5 cm].

Most owls are active at night (see NOCTURNAL BEHAVIOR). They have excellent eyesight and hearing, which help them find and catch food. Their main food consists of rodents and other small mammals. The front edges of the owls' wing feathers are soft and fluffy, and they deaden the sound of the wings so that the prey does not hear the owls approaching. During the day, owls sit in trees and old buildings. The call of many owls is an eerie "who."

See also BIRD.

OXALIC ACID (ök sāl'ik äs'id) Oxalic acid, $(\text{COOH})_2 \cdot 2\text{H}_2\text{O}$, is a strong organic (carbon-containing) acid. It occurs as clear, colorless crystals. It is very poisonous and can cause paralysis of the nervous system (see ACID; CRYSTAL). Oxalic acid is found in some mushrooms. Salts of oxalic acid are called oxalates. They are also poisonous. They are found in several plants, including rhubarb, dock, and wood sorrel (see SALTS).

Oxalic acid is used in industry to make inks and dyes and to bleach materials. It is also used as a rust and scale remover. In industry, oxalic acid is manufactured by heating a substance called sodium formate, which changes into sodium oxalate. Sulfuric acid is then added to obtain oxalic acid.

See also SULFURIC ACID.

OXIDATION AND REDUCTION

Oxidation and reduction are two very important processes in chemical reactions. In oxidation, a substance loses electrons; in reduction, a substance gains electrons (see CHEMICAL REACTION).

OXIDATION AND REDUCTION

The formation of rust on the body of an old car is an example of oxidation. In the presence of moisture, oxygen in the air combines with iron in the steel of the car body to form rust (iron oxide).



The most common form of oxidation is when oxygen is added to an element or compound (see COMPOUND). That is why the process is called oxidation. However, other elements besides oxygen can oxidize substances. For example, sodium combines with chlorine to form sodium chloride. The chlorine oxidizes the sodium because it gains electrons from chlorine. In the same way, the sodium reduces the chlorine.

Substances that can oxidize other substances are called oxidizing agents. Many of them contain large amounts of oxygen in their molecules (see MOLECULE). Examples of oxidizing agents include oxygen (O_2), ozone (O_3), hydrogen peroxide (H_2O_2), and nitric acid (HNO_3). Other oxidizing agents, such as chlorine and fluorine, do not contain oxygen. Substances that reduce other substances are called reducing agents. Hydrogen and carbon are common reducing agents (see OXYGEN).

The atoms of all elements contain smaller particles called electrons (see ATOM; ELECTRON; ELEMENT). When an element combines with another element, its atoms gain or lose electrons. Because an electron has a negative electric charge, the atoms of an element that gain an electron also gain a negative charge. When this happens, the element is said to have an oxidation number of -1. If the atoms each gain two electrons, the oxidation number of the element becomes -2. In the same way, if

the atoms each lose an electron, they gain a positive charge. The element's oxidation number is then +1. An element on its own has an oxidation number of 0. If the oxidation number of an element increases, it is said to be oxidized. If it decreases, it is reduced. For example, calcium and oxygen combine to form calcium oxide. When this happens, the calcium atoms each lose two electrons to the oxygen atoms. Therefore, the oxidation number of the calcium increases from 0 to +2. It has been oxidized. The oxidation number of the oxygen changes from 0 to -2. It has been reduced.

OXIDE Oxides are compounds that contain oxygen and one other element. Such compounds include water, which is hydrogen oxide (H_2O); quartz, which is silicon dioxide (SiO_2); and quicklime, which is calcium oxide (CaO). Many minerals consist of oxides. For example, the most important mineral source of aluminum is bauxite, which is aluminum oxide (Al_2O_3) (see COMPOUND; ELEMENT; MINERAL; OXYGEN).

Oxides are commonly formed when an element is oxidized. Some oxides, such as sulfur dioxide (SO_2), dissolve in water to form acids (see ACID). They are called acidic oxides and are usually the oxides of nonmetals. Other oxides are called basic oxides. Some of these, such as sodium oxide (Na_2O), dissolve in water to form hydroxides (see

BASE). Basic oxides combine with acids to form salts. This is called neutralization (see NEUTRALIZATION; SALTS). Basic oxides are oxides of metals. Some oxides are both acidic and basic. They form salts with both acids and bases. They are called amphoteric oxides. Zinc oxide (ZnO) is an amphoteric oxide.

OXYACETYLENE TORCH (ŏk'sē ə sēt'l ĩn tŏrch) An oxyacetylene torch is a very hot torch used for welding and cutting metals (see METAL AND METALLURGY; WELDING AND CUTTING). Mixtures of oxygen and acetylene are used in oxyacetylene torches. Acetylene gas burns in oxygen to produce a very hot flame (see ACETYLENE). The flame has a temperature of about $6,026.4^{\circ}F$ [$3,316^{\circ}C$]. In welding, the heat of the flame melts two pieces of metal that are to be joined. The molten (melted) metals mix together and are then allowed to cool and become solid.

An oxyacetylene torch used for welding has two main parts: a nozzle and a blowpipe. Acetylene and oxygen are kept separately, usually in two cylinders. The gases enter the blowpipe separately through two valves. They are mixed together and then leave the nozzle. The mixture is ignited (set on fire) as it leaves the nozzle. Different proportions of oxygen and acetylene are used for different metals.

For cutting metal, a slightly different kind of torch is used. The flame heats the metal but does not heat it enough to make it melt. A fine stream of oxygen is passed through the center of the flame and directed at a certain point on the metal. The metal oxidizes away (see OXIDATION AND REDUCTION). The torch is slowly moved over the surface of the metal, cutting as it goes.

The flame produced when acetylene burns is very bright. For this reason, oxyacetylene mixtures are sometimes used for lighting, such as in miners' lamps.



OXYACETYLENE TORCH

An oxyacetylene torch is used for welding and cutting metals, particularly steel. This welder wears a mask to protect his face from sparks. The visor in the mask is fitted with dark glass to prevent the bright light from damaging his eyes.

OXYGEN

Oxygen (ōk'sī jən) is an element that, at room temperature, is a colorless, odorless gas (see ELEMENT; GAS). Oxygen is one of the gases in the air. It makes up about 21 percent of the air (see AIR).

Oxygen is important to almost every form of life. People and land animals take in air and extract oxygen from it in their lungs. The oxygen then enters the blood and travels around the body. Fish and most other water animals use the oxygen that is dissolved in the water. They have structures called gills to obtain the oxygen. Plants absorb oxygen during the night. During the day, they give off oxygen by photosynthesis (see PHOTOSYNTHESIS; RESPIRATION).

To obtain pure oxygen, air is first cooled until it liquefies. The different gases in the air that have now turned to liquid boil at different temperatures. This allows them to be separated in a process called fractional distillation (see DISTILLATION). Liquid oxygen is pale blue in color.

When substances react with oxygen, they are said to be oxidized. The body produces energy by oxidizing certain compounds. When fuels burn, they are oxidized. Rust on iron is due to oxidation (see OXIDATION AND REDUCTION; RUST).

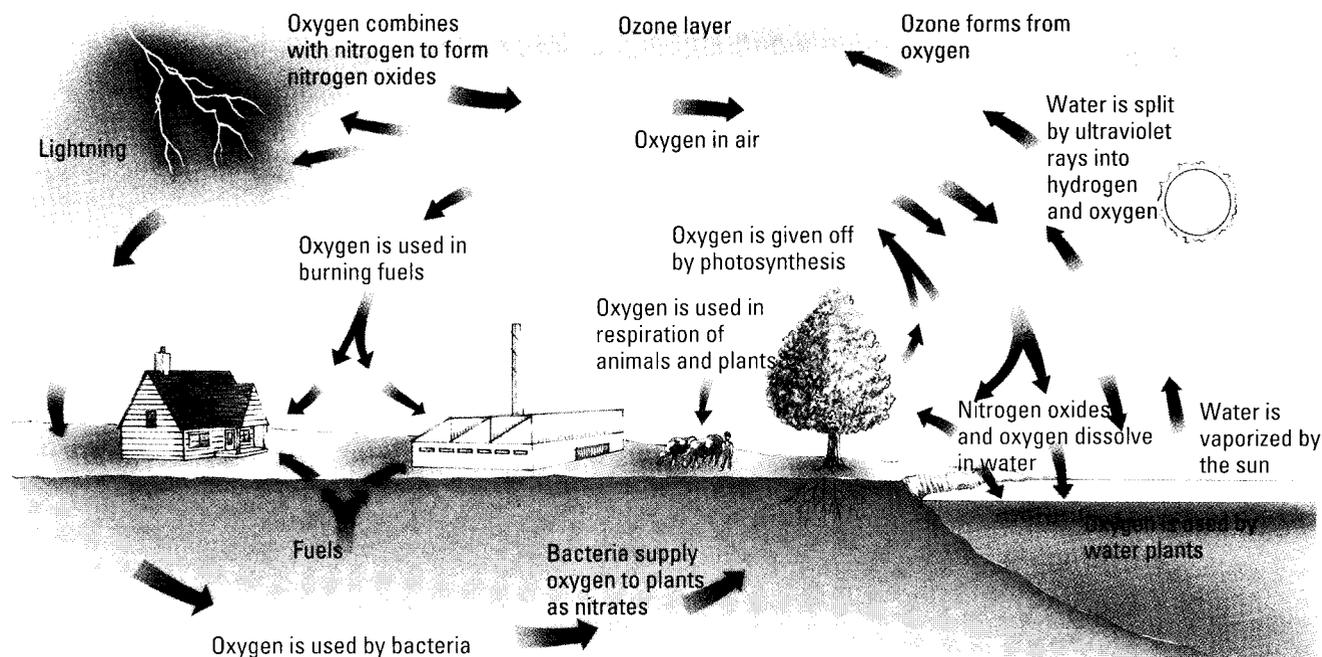
People suffering from severe illness may need more oxygen than normal. They may be placed in special chambers with pure oxygen, or they may breathe in oxygen through tubes connected to an oxygen tank. In welding, acetylene gas is combined with pure oxygen and burned. It gives a very hot flame. Liquid oxygen is used in space rockets to burn the fuel (see OXYACETYLENE TORCH; SPACE EXPLORATION).

Oxygen was discovered by two chemists working independently of each other. Carl Scheele, a Swedish chemist, discovered oxygen in about 1772. Then Joseph Priestley, an English chemist, discovered oxygen in 1774 (see PRIESTLEY, JOSEPH; SCHEELE, CARL WILHELM). Oxygen's atomic number is 8, and its relative atomic mass is 15.9994. The boiling point of oxygen is -297.2°F [-182.9°C]. It freezes at -361.1°F [-218.4°C].

PROJECT 6

OXYGEN CYCLE

Oxygen makes up about 21 percent of the air. It is used in various ways. Lightning causes oxygen to combine with nitrogen in the air, forming nitrogen oxides. Some oxygen in the air is converted into ozone. Oxygen is also used in the respiration of animals and plants, and in the burning of fuels. Oxygen is produced in plants by photosynthesis and then returned to the air. Some oxygen is also formed when water vapor in the air is split into hydrogen and oxygen by the action of the sun's ultraviolet rays.



OYSTER (oi'stər) Oysters are a type of mollusk found in many seas of the world. Oysters often live on the bottom of oceans, mostly in inlets near shore (see MOLLUSCA).

The oyster's shell is made up of two parts called valves. Oysters are known as bivalves (see BIVALVE). A hinge at one end holds the valves together. One valve is deeper and larger than the other and is fixed to a rock or some other object. The oyster's body rests in it, and the other valve acts as a lid. The oyster usually keeps its valves slightly opened. If it is disturbed, the oyster snaps the valves shut.

The mantle, a fleshy organ, lines the inside of the shell, surrounding the body organs. The mantle makes liquid substances that harden and add material to the shell. In this way, the shell becomes larger as the animal grows. Lines on the outside of the

shell show the additions of this material from the mantle.

The oyster's soft body is a grayish mass of tissues consisting mainly of the large gills. The gills are used for breathing and to collect food from the water (see GILLS). Cilia (short, hairlike threads) covering the gills strain tiny organisms from the water and push them towards the oyster's mouth. The oyster has no head. The mouth is an opening at the narrowest part of the body.

Sometimes, a grain of sand or similar object gets into the shell and rubs against the oyster's body. The mantle covers the object with thin layers of shell material. In this way, a pearl is formed. Pearls used as gems come from special pearl oysters. Pearls produced by the kinds of oysters that are used as food have little value (see PEARL).

An oyster has many enemies, such as fish, sea stars, crabs, and sea snails. Human beings are probably the oyster's greatest enemy. More oysters are caught and eaten than any other shellfish. Many coastal areas where oysters like to live have been damaged by pollution, and the oysters have died out.

See also POLLUTION.

OZONE *See* OZONE LAYER.

OYSTER

Oyster beds often become exposed when there is a very low tide. These beds (below) are at Marco Island, Florida. Ridges on an oyster's shell show how liquids from the mantle build new shell material as the animal grows (right).



OZONE LAYER

The ozone layer occurs in the stratosphere at heights of between 10 and 50 mi. [16 and 80 km] (see ATMOSPHERE; STRATOSPHERE). It is called the ozone layer, or sometimes the ozonosphere, because it is the layer in the atmosphere where there is a particularly high concentration of ozone.

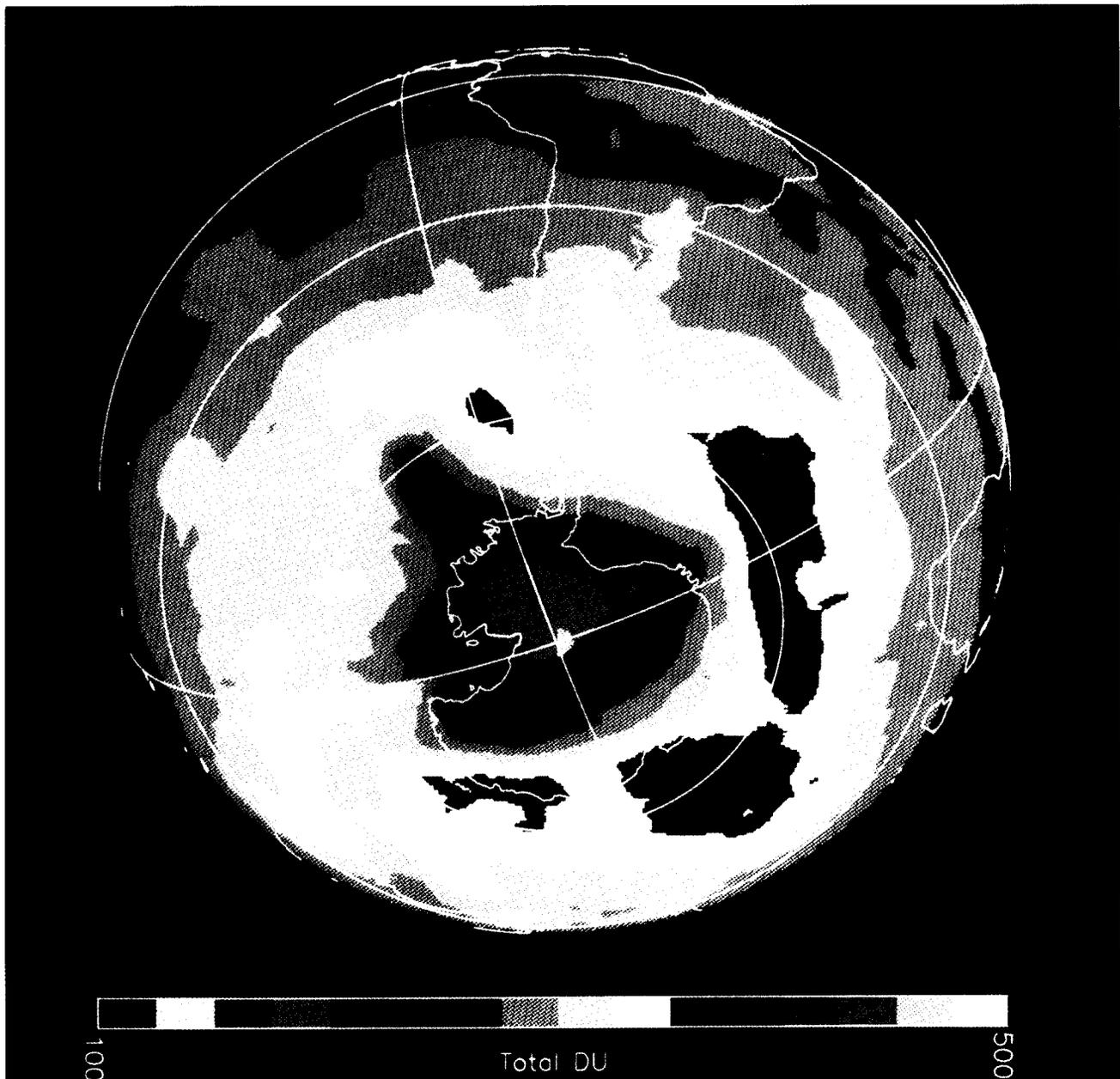
Ozone Ozone (O_3) is a dark blue gas. It is present in small amounts in the earth's atmosphere. It is an

OZONE HOLE

This false-color image, taken by a *Nimbus* satellite, shows a hole (indicated by maroon) in the atmosphere over Antarctica.

allotrope of oxygen (see OXYGEN). This means that ozone molecules contain oxygen atoms, but their number and arrangement are different than in normal oxygen (see ATOM; MOLECULE). Normal oxygen has two atoms of oxygen in each molecule. Ozone has three atoms of oxygen in each molecule. They are arranged in a triangle. Ozone boils at -168°F [-111°C] and freezes at -314°F [-192°C].

Ozone is formed when electricity is passed through the air or through pure oxygen. For example, ozone is formed by sparks in an electric motor



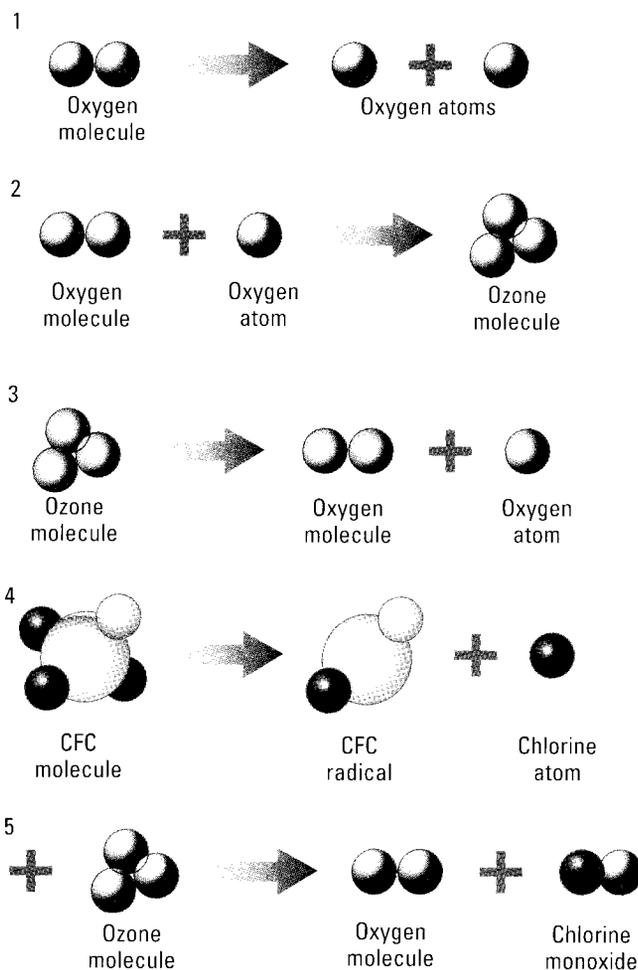
or by lightning in a storm. Ozone is produced in the atmosphere by the action of the sun's rays on normal oxygen. In small quantities, ozone can be used to sterilize water, to purify air, and to decolorize foods. However, when ozone is found in the troposphere, it is regarded as a pollutant (see TROPOPAUSE AND TROPOSPHERE). It is the main gas found in smog (see SMOG). Ozone is formed in the troposphere when gases from automobile exhaust mix with oxygen in the air and are then struck by the ultraviolet rays in sunshine. Ozone in the troposphere can irritate the eyes and lungs. If the ozone levels are high, even breathing can be dangerous. In large cities, special government agencies, such as California's South Coast Air Quality Management District, continually measure ozone levels. A smog alert or ozone alert may be called if the ozone level becomes dangerous for humans and other animals (see POLLUTION).

Importance of the ozone layer Ozone in the stratosphere, by contrast, is very important to the health of animals, especially humans. It is one of the greenhouse gases. Ozone absorbs 95 to 99 percent of the sun's ultraviolet rays, shielding organisms on Earth from their harmful effects. The layer is self-generating, and so the volume of ozone usually remains quite constant. It is produced by the action of ultraviolet rays from the sun on the oxygen in the stratosphere.

Destruction of the ozone layer The ozone layer is being destroyed, however, by chemical compounds called chlorofluorocarbons (CFCs) (see CHLOROFLUOROCARBON). Without a protective layer of ozone in the stratosphere, ultraviolet rays may cause increases in cases of skin cancer around the world.

The main property of chlorofluorocarbons is their stability—they do not react with anything or do so very slowly. As a result, they take a longer time to break down. Once released into the atmosphere, they eventually drift into the ozone layer. There they interfere with the formation of ozone. The result of this is a thinning of the ozone layer, particularly over the North and South poles. This gives rise to the so-called "hole" that appears

every winter. In recent years this "hole" has been increasing in size, and the concentration of the ozone layer is decreasing by about 5 percent per year in the Northern Hemisphere. Ultraviolet light reaching the ground is very dangerous to health, giving rise to skin cancers and genetic mutations. The ozone layer is an important shield against this. Its depletion is seen as a serious threat to many forms of animal life, including humans, and so strenuous measures are being taken to curb the use of the industrial chemicals that are causing it. The United States government ordered that CFCs be phased out by 1996, and worldwide production has been banned entirely as of 2006.



OZONE FORMATION AND DESTRUCTION

(1) Normally, ultraviolet light from the sun hits oxygen molecules in the atmosphere to form free oxygen atoms. (2) These atoms combine with oxygen molecules to form ozone, which (3) may reform oxygen atoms and molecules in a continual process. (4) Pollutants such as CFCs release chlorine atoms when hit by sunlight. (5) The chlorine atoms combine with ozone molecules, destroying them.

P

PACEMAKER A pacemaker is a medical device that causes the heart to beat regularly when the heart's own electrical signals fail (see **CARDIAC MUSCLE**; **HEART**). The heartbeat is usually controlled by specialized nerve tissue that generates electrical signals that coordinate heart contractions. In some types of heart disease this tissue cannot function correctly, so a pacemaker is needed. A temporary pacemaker uses fine wires attached to the heart and is worn by the patient outside the body. A permanent pacemaker is surgically inserted just under the patient's skin. It also uses wires to conduct electrical currents to the heart muscle. Modern pacemakers contain a sensing device that detects any failure in the patient's natural electrical rhythm. The pacemaker then takes over until the natural

pacemaking signal returns. Pacemakers may require no further attention, but their batteries must be replaced periodically.

See also **MEDICAL ENGINEERING**.

**PACK RAT**

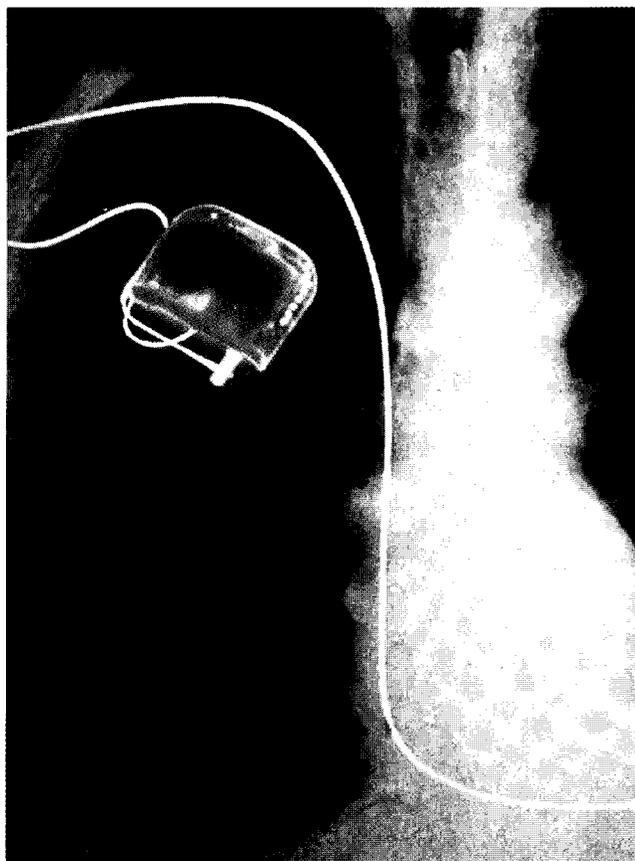
The pack rat gets its name from its habit of picking up and hiding small, bright objects.

PACK RAT The pack rat, sometimes called a wood rat, is a blunt-faced rodent found in North America. The animal has brownish gray fur and, unlike true rats, a hairy tail (see **RAT**; **RODENT**).

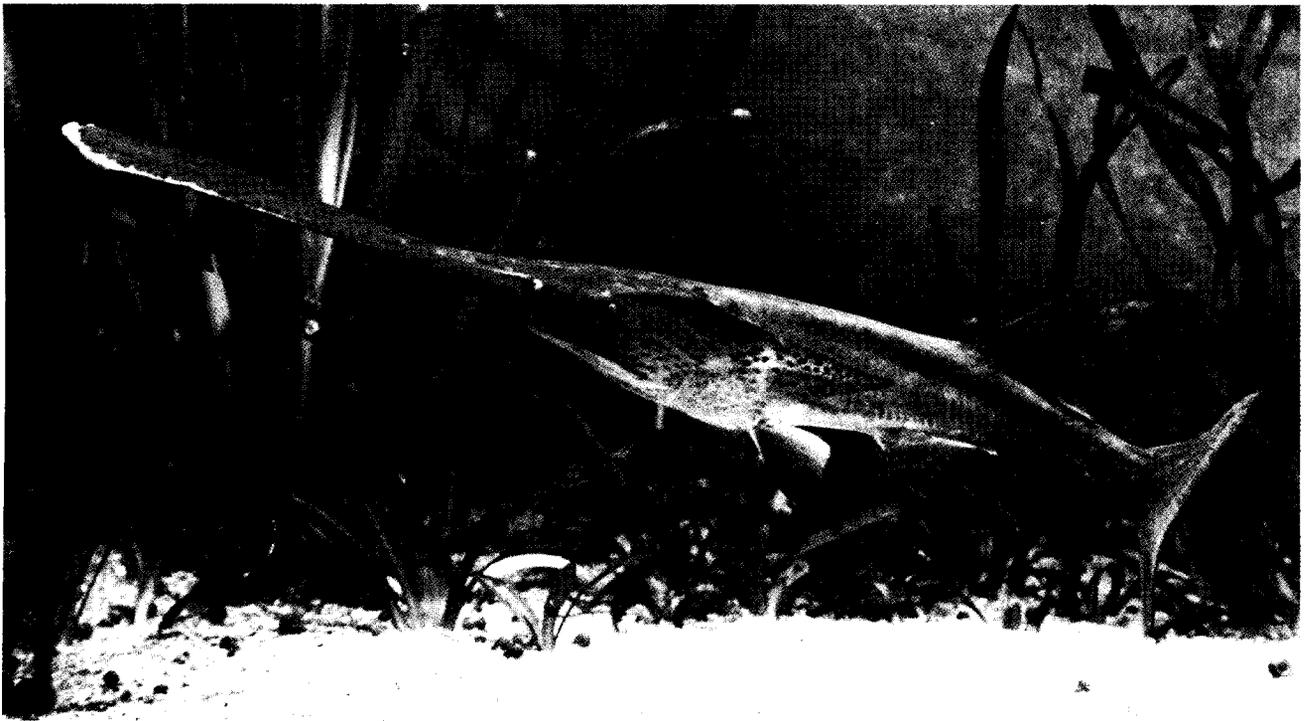
Pack rats usually live in the wild but they sometimes invade farms. Western pack rats often live in mountains, building nests of sticks on rock ledges. Others make their nests in dense clumps of cacti, where they are safe from most enemies. A female has one or two litters a season. Each litter consists of three to six young.

The pack rat gets its name from picking up and hiding small articles, such as nails, silverware, and brightly colored stones. The animal is also known as a trade rat. This is because it often discards an item it is carrying in favor of picking up something else.

PADDLEFISH A paddlefish is a primitive freshwater fish that belongs to the family Polyodontidae. It can grow to 6 ft. [1.8 m] or more in length and more than 99 lb. [45 kg] in weight. The paddlefish gets its name because it has a long

**PACEMAKER**

This colored X ray shows a pacemaker implanted in a patient's chest, just below the right collarbone. A wire carries electric impulses to the heart (lower right). The impulses maintain a regular heartbeat in patients with certain kinds of heart disease.



projection on its snout. The projection is shaped like a canoe paddle. It is not known what the paddle-shaped snout is used for. Some ichthyologists (scientists who study fish) think that the paddlefish may use its paddle to stir up the bottom of a river to find food. The paddlefish is an omnivorous creature, eating a wide variety of small animals and plants. But it probably feeds mainly on the tiny plants and animals in the plankton (see OMNIVORE; PLANKTON).

Paddlefish were once common in the Missouri River. Their numbers have decreased due to the building of dams and to heavy fishing. People eat smoked paddlefish and make caviar out of paddlefish eggs. Recently, paddlefish from the Missouri River were transferred to rivers in Tennessee, where their numbers are now increasing. Another species of paddlefish is found in China.

PAIN Pain is an unpleasant sensation that is usually caused by an injury, disease, or other disorder. It is important because, though disagreeable, it warns the organism that something is wrong.

The sensation of pain is received by special nerve cells called pain receptors. These receptors are located throughout the body as well as in the skin. Pain receptors are connected to nerves that

PADDLEFISH

The paddlefish is a primitive freshwater fish that has a paddle-shaped projection on the end of its snout. Scientists do not know what purpose the projection serves.

eventually lead to the brain. The brain interprets the signal from the pain receptors, identifying the location and intensity of the pain.

Superficial pain is caused by receptors in the skin. A person can usually tell the exact location of superficial pain because the skin has so many pain receptors. Deep pain—pain from the internal organs—is harder to pinpoint because there are fewer deep pain receptors. Sometimes, deep pain may be referred. Referred pain is felt in a part of the body that is some distance from the actual source of the pain. People can also feel pain from psychological causes—psychogenic pain, or psychalgia.

Pain can best be overcome by treating the cause. Pain also can be controlled by certain drugs, such as aspirin. Doctors prescribe narcotics for very severe pain (see NARCOTIC). For chronic (long-term) pain, a surgeon may destroy part of the brain or spinal cord in order to interrupt the pain pathway. Such operations are sometimes successful in relieving the pain.

See also ANALGESIC; ANESTHETIC; NERVOUS SYSTEM.

PAINT

Paint is a mixture of one or more colored powders and a liquid. The colored powder is called a pigment (see **PIGMENT**). The liquid is called a vehicle or binder. The vehicle carries the pigment and allows it to be spread. Many vehicles contain a solvent, a substance that can dissolve other substances (see **SOLVENT**).

There are basically two types of pigments—prime and inert. Prime pigments give paint its color. Inert pigments are materials such as calcium carbonate, clay, mica, or talc. Such substances make paint wear longer when applied.

Vehicles include oils, varnishes, latex, various types of polymers and resins, and a solvent. When a vehicle comes in contact with air, it dries and hardens. This causes paint to become a hard film. This film holds the pigment to the surface that has been painted. Thinners are added to paint to make it more liquid. For example, latex paints are thinned with water. These paints are therefore called water-based paints.

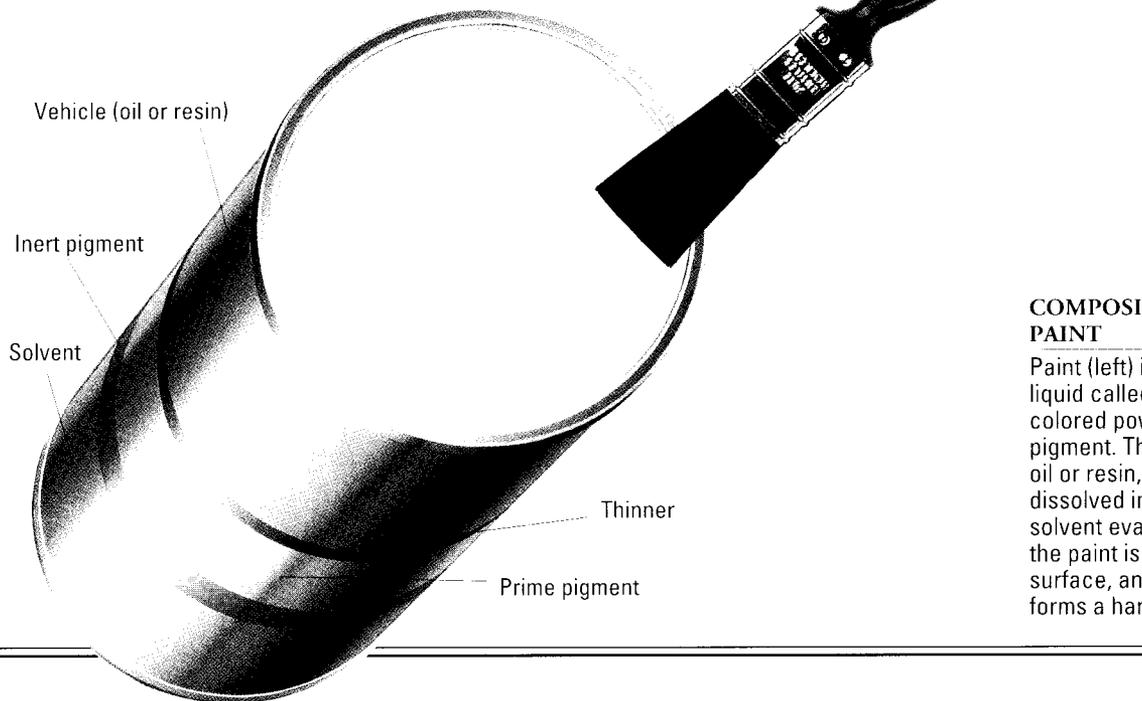
Types of paints Various types of paints are commonly used. Oil-based paints are often used as outside paints and on woodwork and floors. Such paints often protect wood and metal. Latex or emulsion paints include wall paints, masonry paints, and outside paints. Latex paints, so-called

because they originally contained latex (natural rubber), are often preferred over oil-based paints, because they are easier to use. Also, with latex paints, the painting equipment (such as brushes) can be easily cleaned using soap and water. Polyvinyl acetate and acrylic resins have now replaced the latex. They form a stabilized emulsion with water.

Lacquers are often used to cover automobiles. A lacquer is a paint made up of a solution of resins in a solvent. The solvent dries up after the lacquer is put on (see **LACQUER**).

Fire-retardant paints help protect against fire damage. These paints contain chemicals that make the paint puff up when it is near fire. The blister forms a barrier between the flame and the surface.

Metallic paints are made with aluminum or bronze powder. They have many uses, such as on bridges. Wood and plaster primers are used for first coats. These paints fill the tiny openings in the wood or plaster. This allows other paints to stick to the surface without sinking into it.



COMPOSITION OF PAINT

Paint (left) is a mixture of a liquid called a vehicle and a colored powder called a pigment. The vehicle is an oil or resin, usually dissolved in a solvent. The solvent evaporates when the paint is brushed onto a surface, and the oil or resin forms a hard film as it dries.

Enamels contain small amounts of pigments. The low pigment content makes the paint dry with a high gloss. Enamels are often used in bathrooms and kitchens, because they are easy to wipe clean.

Manufacture of paints The first step in manufacturing paints is mixing the powdered pigment with the vehicle. A small amount of the vehicle is put into a large mechanical mixer. The powdered pigment is slowly added to the vehicle, making a heavy paste. Then the paste is put into a mill, or grinder, to break up the pigment particles and scatter them throughout the vehicle. Next the ground paste is poured into a tank, where it is mechanically mixed with more vehicle and such substances as solvents. The paint is mixed until it is nearly thin enough for use. A tinter adds a small amount of pigment to give the paint the exact color and shade desired. Finally, the paint is strained through a type of filter to remove any solid bits of dust or dirt. It is poured into a filling tank and finally into the metal cans or plastic tubs in which it is sold.

Application of paints Paints are usually put on in several coats, or layers, one on top of another. The first coat—the primer—prepares the surface for the rest of the paint. The second coat, or undercoat, is heavily charged with pigment and is matte (not glossy or shiny). The finishing coat is sometimes glossy. Sometimes, only a primer and one

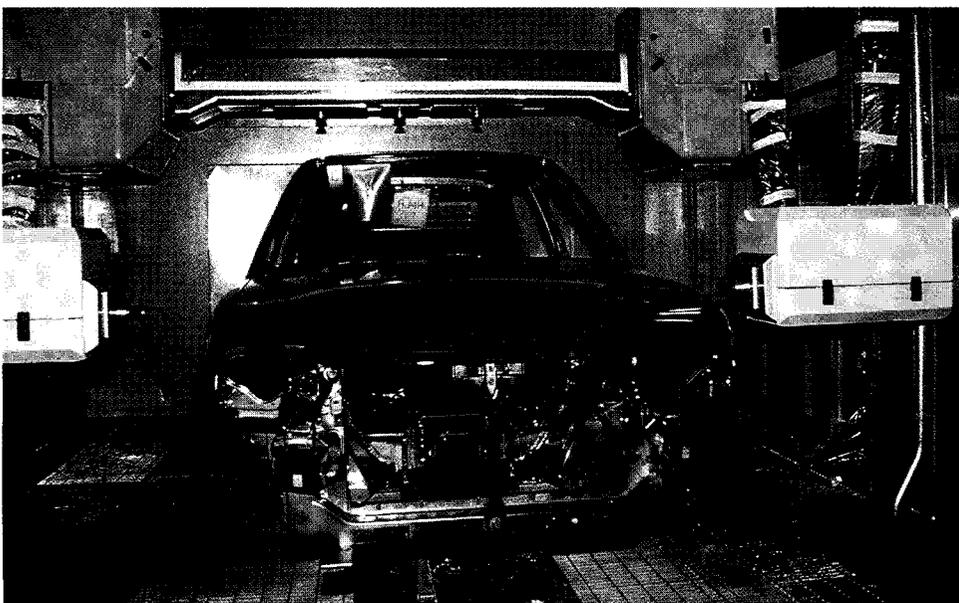
additional coat are used. The way in which the paint is put on depends on the type of job. Brushes, rollers, or sprayers may be used, or the article may be dipped or tumbled in paint. Decorative paints dry in the air, but industrial paints are often heat-dried. This process, called stoving, toughens the paint surfaces.

New kinds of paints are always being produced. Chemists and engineers do research to come up with improved types of paints that contain less volatile solvent and so cause less pollution as they dry. The amount of paint sold in the United States in one year would cover more than 12,000 sq. mi. [32,000 sq km].



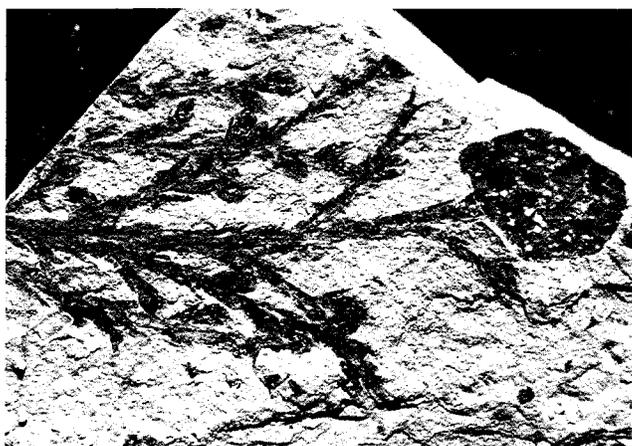
FUN PAINT

Face painting (above) is used to improve costumes. For safety, only specially formulated paints should be used.



CAR PAINT

This car body (left) is being painted using an electrostatic process. The body is given an electric charge. The opposite charge is given to the droplets of paint coming out of the sprays. The unlike charges attract each other and all the paint sticks to the car, with no waste.



PALEOBOTANY

When plants that lived many years ago died, they were covered with layers of soil or volcanic ash. Later, some of the plants became fossilized. The one above is preserved as a layer of the plant's original carbon. The study of fossil plants is called paleobotany.

PALEOBOTANY (pā'lē ō bōt'n ē) Paleobotany is the study of fossil plants (see FOSSIL). Most plants do not have hard parts that can be preserved in rocks. However, sometimes, impressions of plants are found embedded in clay. Plant remnants are also found petrified. A plant becomes petrified when its decaying cells are replaced by silica or calcium carbonate. The result is an exact duplicate of the original plant.

The history of plant life on Earth has been traced by paleobotanists. Primitive, plantlike algae existed during Precambrian times (see ALGAE; PRECAMBRIAN TIME). Psilophytes, the first land plants, existed during the Silurian period (see PSILOPHYTE; SILURIAN PERIOD). During the Pennsylvanian period, huge forests of club mosses, ferns, and horsetails grew. These forests died and decayed, and the remaining organic matter was changed into coal (see COAL; PENNSYLVANIAN PERIOD). Gymnosperms thrived during the Mesozoic era. In the late Mesozoic era, flowering plants (angiosperms) appeared (see ANGIOSPERM; GYMNOSPERM; MESOZOIC ERA). Flowering plants are still the dominant land plants on Earth.

See also EVOLUTION; PALEONTOLOGY; PLANT KINGDOM.

PALEOCENE EPOCH

The Paleocene epoch is the earliest subdivision of the Tertiary period in the earth's history (see

TERTIARY PERIOD). It began about 65 million years ago and lasted 8.5 million years.

A worldwide warming trend occurred during the Paleocene epoch. By the beginning of this period, the dinosaurs and other giant reptiles of the Mesozoic era had become extinct. Mammals, including primates, became more widespread and diversified. Small reptiles, amphibians, and fish were abundant. Flowering plants flourished during the Paleocene epoch. Deposits of natural gas, oil, and coal formed.

There is evidence suggesting that North America and western Europe were part of one continent during the Paleocene epoch.

See also CONTINENTAL DRIFT; GEOLOGICAL TIME SCALE.

PALEOCLIMATOLOGY

(pā'lē ō klī' mō tōl'ə jē) Paleoclimatology is the study of ancient climates, called paleoclimates. Paleoclimatologists try to determine the types of climate that have existed on Earth since the earliest geological ages. Since most evidence of paleoclimates is found indirectly through rocks and fossils, the paleoclimatologist has a difficult job. There are, however, several indications of paleoclimates that many scientists consider reliable.

Hot paleoclimates are often indicated by limestone formations, coral reefs, and fossils of tropical plants. Cold paleoclimates are indicated by evidence of glaciation (coverings of ice). This evidence includes masses of rocks and boulders, moraines, fjords, and drumlins (see CONIFER; CORAL; FJORD; GLACIER; LIMESTONE).

Arid (dry) paleoclimates are indicated by large salt deposits. Humid paleoclimates are indicated by coal deposits, peat bogs, and fossils of tree ferns (see COAL; FERN; PEAT).

Many scientists believe that the warm climates of the past occurred because the continents lay closer to the equator than they do today. Eventually, the continents drifted to their present positions (see CONTINENTAL DRIFT). Some scientists suggest that the sun's radiation has varied because of sunspot activity (see SUNSPOT).

During the last 1.64 million years, there have been at least four ice ages (see ICE AGE).

Paleoclimatologists are working on explanations of why these periods of glaciation occurred.

See also CLIMATE; FOSSIL; GEOLOGICAL TIME SCALE; PALEOBOTANY.

PALEOECOLOGY (pā'lē ō ĩ kōl'ə jē)

Paleoecology is the branch of ecology that studies the relationship of ancient plants and animals to their environment (see ECOLOGY). It uses fossil organisms to uncover where and how these animals and plants once lived (see FOSSIL).

Paleoecologists sometimes uncover fossils of an entire community of organisms that died suddenly, such as sea-bottom fauna buried under a flow of mud. It is possible to see how these animals lived in relation to each other—for example, whether they burrowed in the mud or lived on top of it, which ones preyed on others, and which ones had parasites. It is much more difficult to work out the ecology of animals that lived on land, such as dinosaurs, because they are rarely buried in such a manner (see DINOSAUR). It is known, however, that some horned dinosaurs migrated in herds, because a large number of their fossils have been buried in flood deposits. Fossilized nests, such as those of some duckbills, can give information about how these dinosaurs cared for their young. Fossilized plants found with fossilized animals provide clues about the climate at the times these organisms were alive. The teeth of a fossilized plant-eating animal may indicate the type of

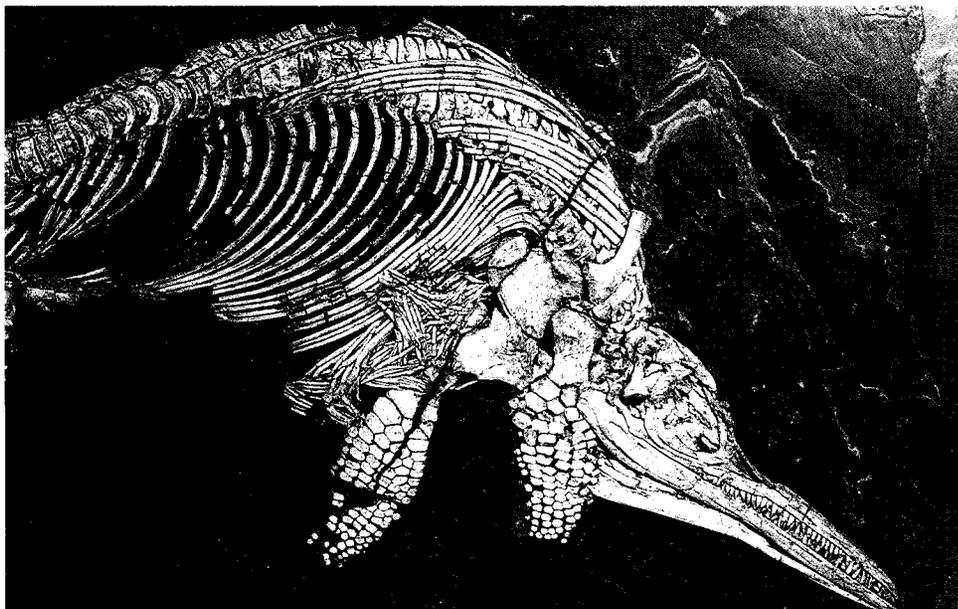
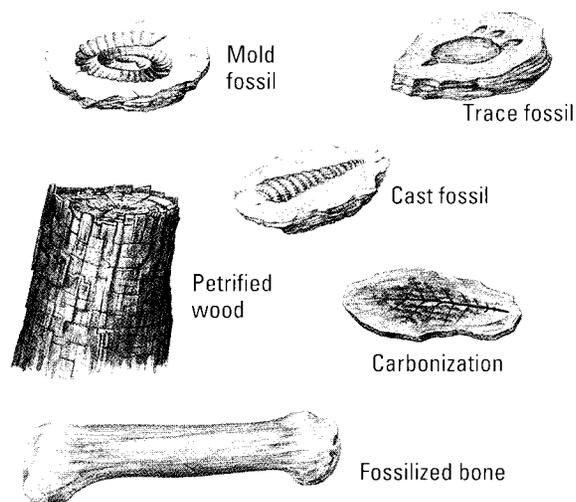
plant it ate. Footprints of animals can also help in understanding how ancient land creatures lived.

PALEONTOLOGY (pā'lē ōn tōl'ə jē)

Paleontology is the study of the fossil remnants of animals and plants (see FOSSIL; PALEOBOTANY).

Fossils are found in layers of sedimentary rock (see SEDIMENTARY ROCK). Through complex methods of dating, paleontologists can find out the age of the fossils and thus the age of the rock in which the fossils are found (see DATING). Paleontologists can also find out whether the rock was formed on land or underwater. Fossils give a good indication of evolutionary processes (see EVOLUTION). Paleontology is also used in prospecting and geology.

See also GEOLOGY; PALEOECOLOGY; PROSPECTING.



PALEONTOLOGY

Paleontology is the study of fossils, which may be formed in various ways (above). Whole bones may be turned to stone, or a dead animal may decay after being buried, leaving a mold. The mold may later fill with minerals to form a cast. A footprint preserved in rock is an example of a trace fossil. Plants may leave traces by carbonization, or become turned to stone (petrified). The fossilized bones (left) are the skeleton of an ichthyosaurus, an aquatic fish-eating reptile that somewhat resembled a modern dolphin.

PALEOZOIC ERA (pā'lē ə zō'ik ē'rə) The Paleozoic era in the earth's history began about 570 million years ago and lasted about 325 million years. It includes seven geological periods: Cambrian, Ordovician, Silurian, Devonian, Mississippian, Pennsylvanian, and Permian. The Mississippian and Pennsylvanian periods are often combined and called the Carboniferous period (see CAMBRIAN PERIOD; CARBONIFEROUS PERIOD; DEVONIAN PERIOD; MISSISSIPPIAN PERIOD; ORDOVICIAN PERIOD; PENNSYLVANIAN PERIOD; PERMIAN PERIOD; SILURIAN PERIOD).

The early Paleozoic era was characterized by algae, trilobites, and other primitive forms of water life. The first fish probably evolved during the Ordovician period. Much of North America was covered by water during the Cambrian and Ordovician periods.

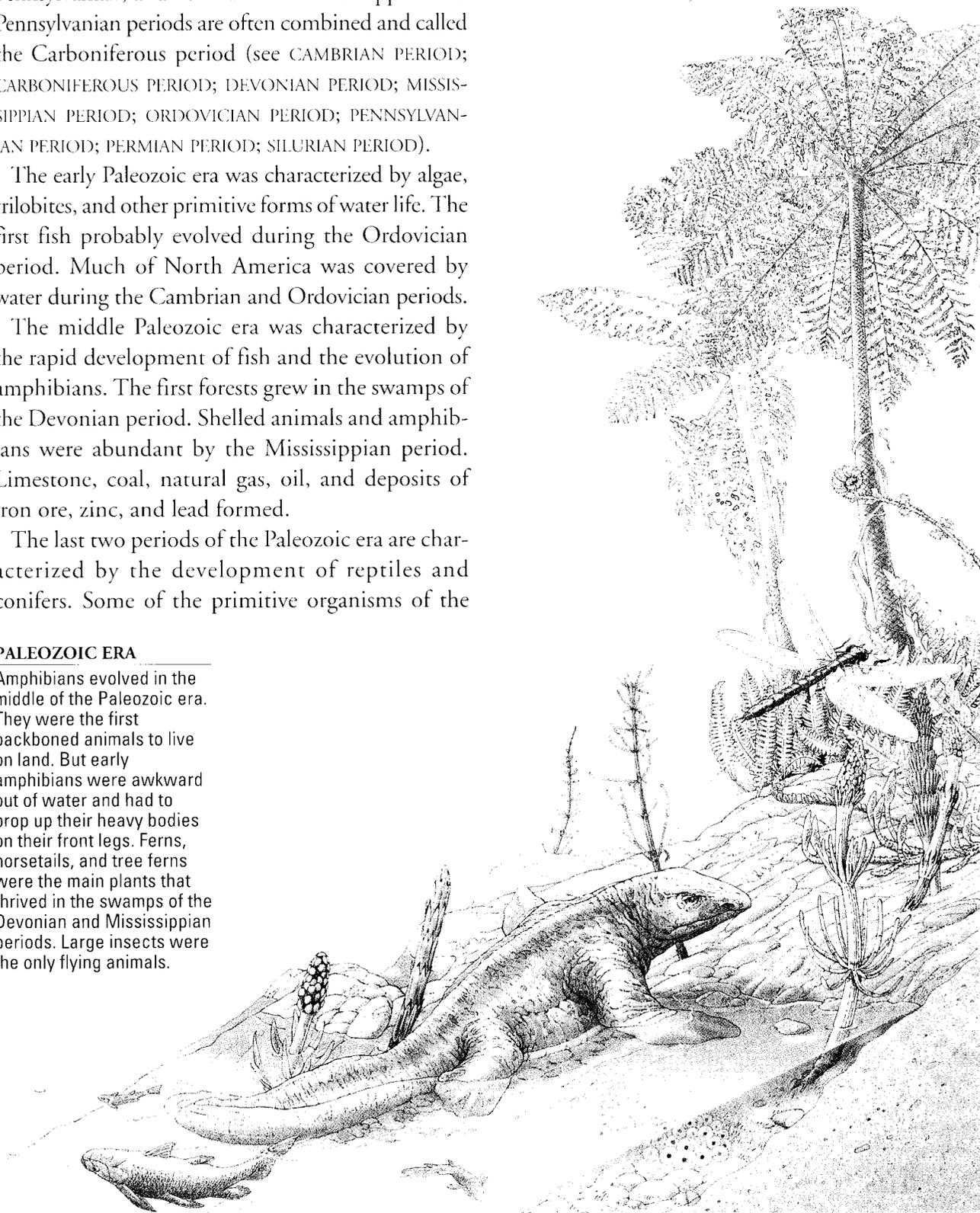
The middle Paleozoic era was characterized by the rapid development of fish and the evolution of amphibians. The first forests grew in the swamps of the Devonian period. Shelled animals and amphibians were abundant by the Mississippian period. Limestone, coal, natural gas, oil, and deposits of iron ore, zinc, and lead formed.

The last two periods of the Paleozoic era are characterized by the development of reptiles and conifers. Some of the primitive organisms of the

Cambrian period became extinct. Fish, amphibians, and reptiles were all plentiful by the end of the Permian period. The Ural and Appalachian mountains formed during this time. Large coal deposits also formed during the Pennsylvanian period. See also EVOLUTION; GEOLOGICAL TIME SCALE.

PALEOZOIC ERA

Amphibians evolved in the middle of the Paleozoic era. They were the first backboned animals to live on land. But early amphibians were awkward out of water and had to prop up their heavy bodies on their front legs. Ferns, horsetails, and tree ferns were the main plants that thrived in the swamps of the Devonian and Mississippian periods. Large insects were the only flying animals.



PALM FAMILY The palm family includes over two thousand species of plants in the tropical and subtropical regions of the world. Although many are scrambling and climbing plants with spiral-growing stems, the best-known species are the palm trees. They can grow 110 ft. [33.3 m] tall, and their trunks are almost always unbranched and have a large cluster of leaves at the top. The leaves often grow as long as 40 ft. [12.1 m] and are the biggest leaves in the world (see LEAF). Unlike other trees, palm trunks do not get thicker as they get older, although clusters of old leaf stalks may build up around them.

Palm trees produce many valuable items used by people. Mats, clothes, and roofs are made from the trunk and leaves. The sap is made into drinks. The fruits of the trees are often delicious. Coconuts and dates are both fruits from palm trees.

PANCREAS (pāng'krē əs) The pancreas is an important organ found in the bodies of human beings and all other animals with backbones. The pancreas produces a strong digestive juice that helps break down food in the small intestine. It also produces the hormones insulin and glucagon (see DIGESTIVE SYSTEM; HORMONE).

The human pancreas is about 5 to 6 in. [12 to 15 cm] long, 1.5 in. [3.8 cm] wide, and 1 in. [2.5 cm] thick. It lies behind the stomach.

Digestive juices from the pancreas flow into the first part of the small intestine, called the duodenum (see INTESTINE). The juices contain enzymes that help digest proteins, starches, sugars, and fats (see ENZYME). The juices are also rich in salts that help neutralize the strong acids secreted by the stomach.

Small clusters of cells, called islets of Langerhans, are scattered throughout the pancreas. They secrete (give off) insulin directly into the bloodstream. The blood carries insulin to cells throughout the body. The cells need insulin to help them use glucose, the sugar that is their main fuel. The islets of Langerhans also secrete glucagon into the blood. Glucagon acts on the liver, causing it to release stored glucose into the blood.

See also BANTING, SIR FREDERICK; DIABETES; INSULIN.

PANDA A panda is one of two species of omnivorous mammals native to Asia (see MAMMAL; OMNIVORE). The giant panda has a white, bearlike body with black hair on its ears, shoulders, and legs and around the eyes. It reaches lengths of over 5 ft. [1.5 m] and can weigh up to 350 lb. [160 kg]. The giant panda feeds mostly on bamboo and other plants. An "extra thumb" on its wrist helps it to hold the bamboo shoots while chewing them.



Lesser
panda



Giant
panda

PANDA

The lesser, or red, panda (top) lives in the mountains of eastern Asia. It spends most of the day asleep in the trees. The giant panda (above) is a very rare animal that lives in the bamboo forests of western China. It may eat more than 20 lb. [9 kg] of bamboo shoots each day.

Bamboo is not very nutritious, and a giant panda has to eat about 20 lb. [9 kg] of food each day. It lives on the ground and stays alone except during mating season. The giant panda is very rare and is protected by law in China. In the past, some biologists regarded the giant panda as a raccoon, others treated it as a bear, and yet others put it in a totally separate family. Recent biochemical studies, however, have shown that it is really a bear.

The lesser panda is also called the red panda or cat-bear. It is much smaller than the giant panda. Its body is about 24 in. [60 cm] long, and its bushy, ringed tail is about 20 in. [50 cm] long. It weighs about 8.8 lb. [4 kg]. Its fur is reddish brown on the back and black on the belly. Its face has white markings. The lesser panda lives in the mountains of eastern Asia and spends most of the day asleep in the trees. Like the giant panda, it feeds largely on bamboo shoots and it also has an "extra thumb." It also eats fruit. Lesser pandas usually stay in groups of two or more. The lesser panda is classified as a member of the raccoon family.

See also BEAR; RACCOON.

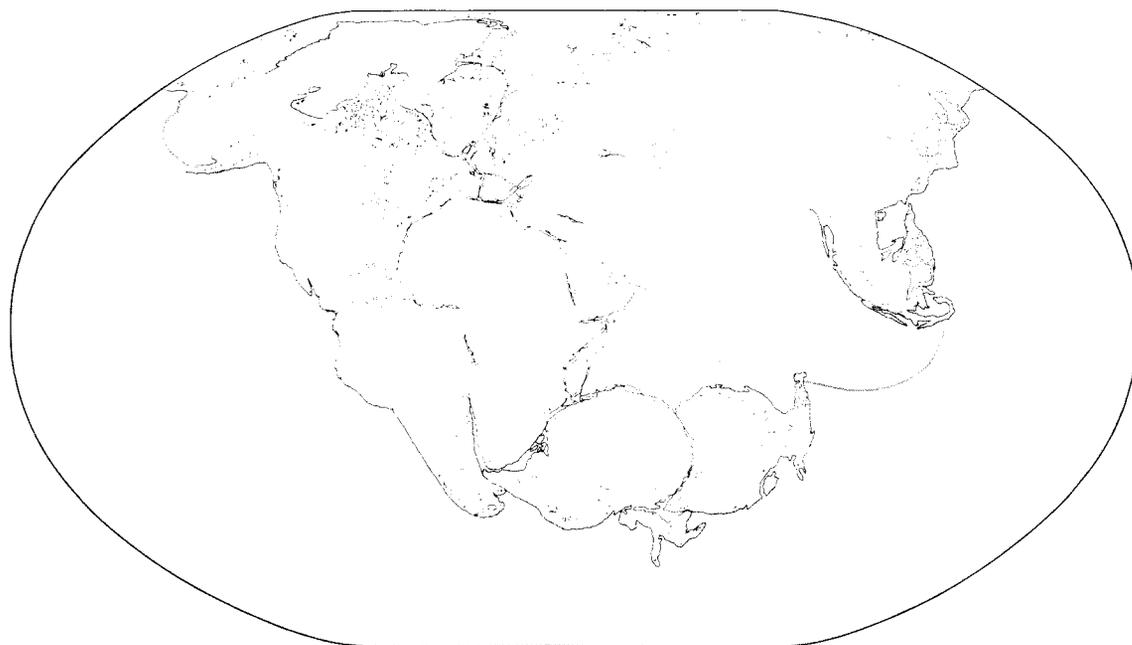
PANGAEA (pān jē'ə) *Pangaea* is the name of the huge landmass that was formed when all the continents came together during the Permian period, about 250 million years ago. During the history of the earth, the continents have been in many

positions relative to one another that are quite different from their positions today (see CONTINENTAL DRIFT; PLATE TECTONICS).

Pangaea was a desert continent surrounded by one vast ocean that geologists call Panthalassa. Pangaea was so huge that most of it was far from the moisture or any climate effect of the ocean. The only areas fit for habitation would have been the coastal regions. The southern part of Pangaea, called Gondwanaland, consisted of what are now South America, Africa, India, Australia, and Antarctica. The northern part, called Laurasia, consisted of North America, Europe, and Asia. About 200 million years ago, Pangaea began to separate. North America and Africa split away from each other first. Then northern North America and Europe split away from one another as the rift system spread northward. By the Tertiary period (about 65 million years ago), the whole supercontinent had split up into the continents that we know today, and they were drifting toward the positions that they now occupy.

PANGAEA

The map shows how Pangaea might have appeared about 200 million years ago if the earth was the same size as it is now. Most of the continents fit together, although the fit would be much better if the earth was 20 percent smaller than it is today.



PAPER

Paper is one of the most useful materials ever invented. The product is involved in nearly every aspect of people's everyday lives. Books, magazines, and newspapers are printed on paper. Education, government, and industry could not operate without paper.

The world's first maker of paper was the wasp. The wasp chews tiny pieces of wood until they form a pulp. The wasp then spits out the wet pulp and smooths it into a thin sheet. When the pulp dries, it becomes paper. It is used by certain kinds of wasps to build their homes (see WASP).

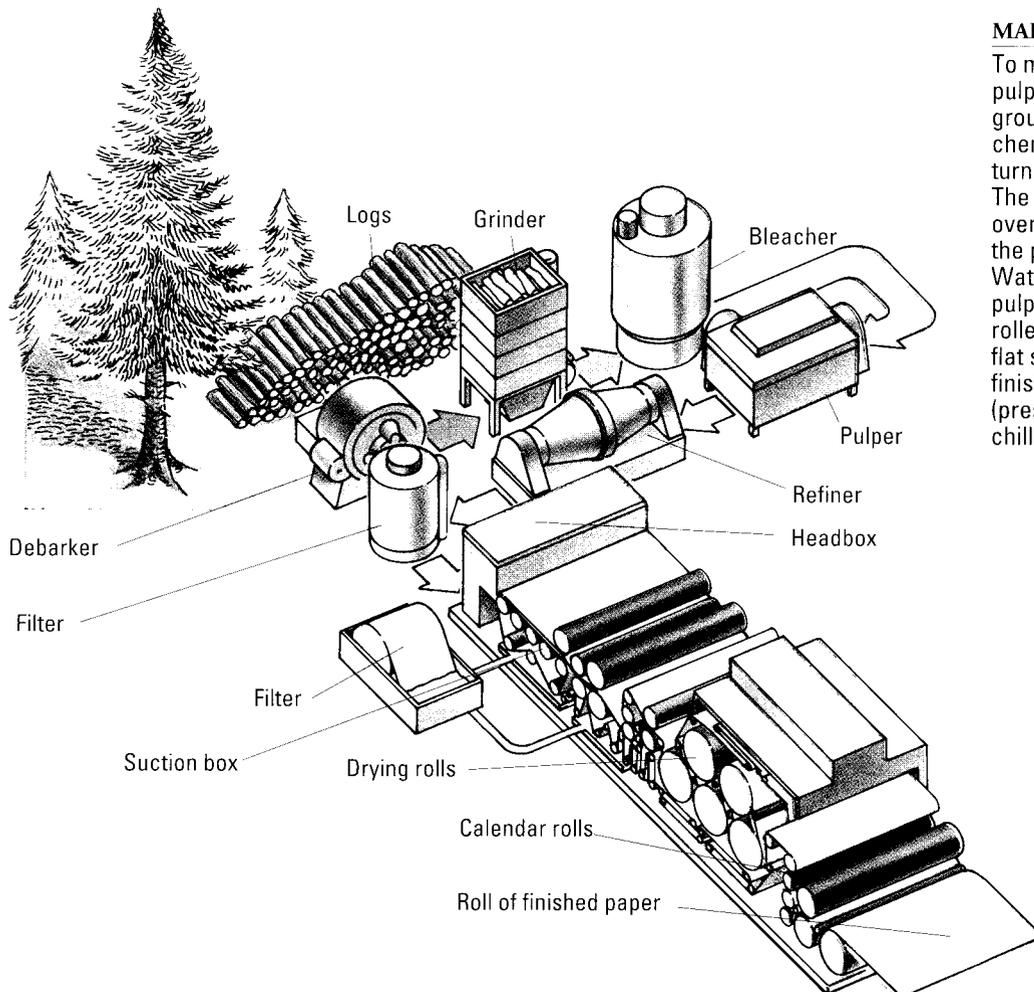
Paper gets its name from papyrus, a sheet made by pressing together the core material (pith) of the Egyptian papyrus plant. Papyrus as a writing material was first developed about 6,000 years ago in Egypt. It was not until about 105 A.D. that paper, as it is known today, was invented. The Chinese were the inventors of this paper.

Paper is made of cellulose fibers. Cellulose is a substance found in most plants (see CELLULOSE). Various types of trees, cotton plants, rice and wheat straws, cornstalks, hemp, and jute are used for making paper.

Most of the paper produced in the United States comes from wood pulp. This pulp is obtained from trees and waste materials of lumbering operations. Some paper is made from pulp recycled from other kinds of waste paper.

How paper is made For many years, rags were the main raw material for paper. Today, rags have been largely replaced by wood pulp. Wood pulp comes from trees such as pine, spruce, and hemlock. Most wood pulp is made by one of two processes: mechanical or chemical.

The mechanical process is used mainly for the production of inexpensive papers, such as paper on



MAKING PAPER

To make paper from wood pulp, debarked logs are ground (or pulped chemically), bleached, and turned into a watery pulp. The pulp is then spread over a belt of wire mesh in the paper-making machine. Water is pressed out of the pulp, and the pulp is then rolled and dried, forming a flat surface. The paper is finished by calendaring (pressing paper between chilled rollers).

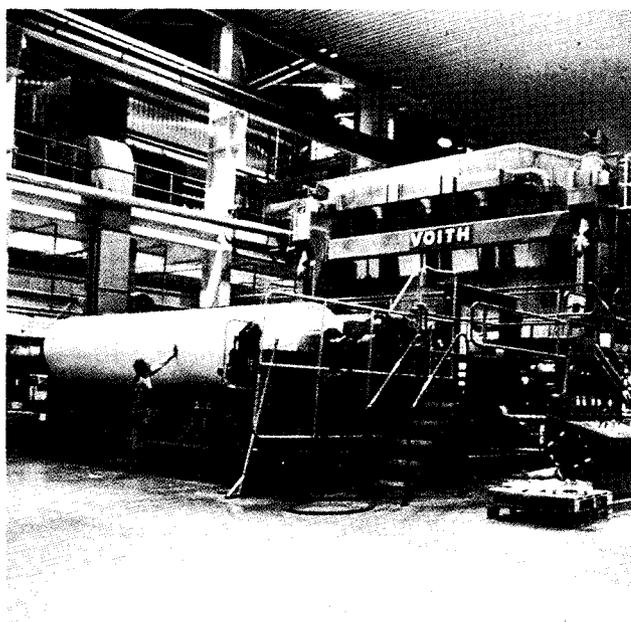
which newspapers are printed. In this process, debarked logs are pressed against a revolving grindstone. The grindstone chips the log into fine pieces that make up wood pulp.

The chief chemical processes for making pulp from wood are the sulfite and sulfate, or kraft, processes. In these processes, the logs are thoroughly washed with water and cut into chips. In the sulfite process, the wood chips are cooked in a digester, which is a steam-heated pressurized tank. The chips cook in a solution of sulfite salts under steam pressure until the wood forms a pulp. In the sulfate process, the wood is cooked in a solution of caustic soda and sodium sulfide.

The pulp produced by the above processes is screened, washed, and bleached. Then it is dried and pressed into sheets. Most paper is made on the Fourdrinier machine. This machine consists of a belt of wire mesh on which watery pulp is spread. The belt passes through a series of rollers, which press the water out of the pulp. The belt then passes under a turning cylinder called a dandy roll. The dandy roll gives the paper a woven or flat surface. Near the end of the machine, the belt passes through two felt-covered couching rolls, which press out more water. It then goes through two sets of smooth metal press rolls. The press rolls give the paper a smooth finish. The last step before cutting is calendaring, or pressing the paper between chilled rollers. Calendaring gives the paper an even smoother finish, called a machine finish. At the end of the Fourdrinier machine, the paper is wound on spools into large rolls. The paper can then be slit into strips and cut into sheets.

“Water marking,” for good quality writing paper, is done by pressing a design into the moist paper at the “wet end” of the machine. Tissue paper is made in the same way as ordinary paper except that it is scraped by a knife edge as it leaves the drying rollers, giving a tissuey finish.

Chemical engineers have found many ways of treating paper to make it strong, fireproof, and resistant to liquids and acids. As a result, paper can, in many instances, replace cloth, metal, and wood. For example, specially treated paper is used to make clothing, such as surgical gowns and disposable



FOURDRINIER MACHINES

Most paper is made on large Fourdrinier machines, named for their inventors, the English papermakers Henry and Sealy Fourdrinier. The machines produce a continuous roll of paper up to 15 ft. [4.6 m] wide, which can be split into strips and cut into sheets.

diapers. The amount of newsprint used per person each year is highest in the United States, followed by Sweden, Australia, Finland, Switzerland, and Singapore.

Paper recycling Paper recycling is the use of waste paper to make new paper. Such discarded items as grocery bags and newspapers are collected, cleaned, and made into pulp. The pulp can be used in making such products as newsprint, paperboard, tissue paper, and writing paper. Beginning in the 1960s, a growing concern about pollution promoted greater recycling efforts to reduce solid wastes. In the following years, the recycling of paper continued to gain importance as concerns about vanishing forests grew (see DEFORESTATION; ENVIRONMENT; FORESTRY). Paper recycling is increasing, especially in the United States. Many communities now have waste recycling programs that encourage or require households and businesses to recycle most of the paper products they use. Cardboard, newspaper, computer paper, and white and colored office paper can all be recycled.

See also RECYCLING.

PARACHUTE A parachute looks similar to a large umbrella but is made of a light fabric. It is used to slow down the fall of a person or object from an airplane in flight or from any great height.



PARACHUTE

A wide, narrow parachute, sometimes called a paraglider, is used by the military and, increasingly, as a sport. The parachute can be steered accurately and used to make cross-country flights.

A parachute operates on simple principles. There are two forces that act upon any falling object—air resistance and gravity. Gravity pulls the object quickly toward the earth. Air, however, resists the object's downward movement. At low speeds, the pull of gravity is much stronger than the resistance of air. Thus, air resistance has little effect. However, air resistance becomes larger as the speed of fall increases. Eventually, when air resistance and the pull of gravity balance, the object reaches a speed called terminal velocity. From that point on, the object falls with constant speed. Large, flat surfaces offer a greater area of resistance than do thin, sharp surfaces. Therefore, an object shaped like a saucer reaches its terminal velocity sooner, so it falls much more slowly than one shaped like a needle (see GRAVITY). The larger the parachute's surface, the more air resistance it meets and the slower it falls.

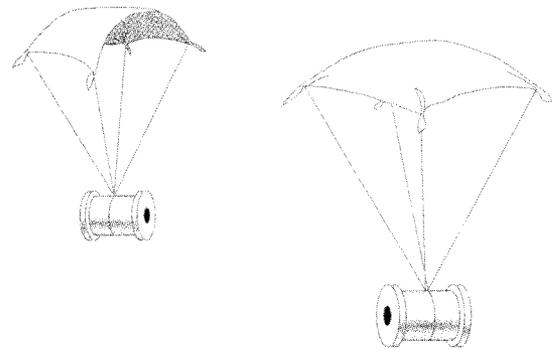
Parachutes designed for human use are made of nylon. In the early years of aviation, parachutes were made of silk. Many sport parachutes measure 11 to 22 ft. [3.4 by 6.8 m] across when open. Parachutes for cargo are generally round and may be as large as 100 ft. [30 m] across.

Parachutes for human use are worn on a harness that consists of a series of straps fitted around the shoulders and legs of the parachutist. The parachute is tightly packed into a compact bundle with a canvas cover. It is worn either as a seat pack (to be sat on) or as a chest or back pack.

Special straps, called risers, are attached to the shoulder portion of the harness. They hold the shrouds, or lines, that are attached to the canopy, which is the umbrellalike part of the parachute. A ring for pulling the rip cord is attached to one of the straps. The rip cord opens the parachute pack. When the cord is pulled, the parachute springs out of its tight confinement, and the air forces it open. Sometimes, a special line, called a static line, is used to open a parachute. The static line is attached to the airplane. When the parachutist jumps from the airplane, the static line pulls open the parachute automatically, and then releases itself. The static line is usually used in military aircraft that carry large numbers of paratroopers (soldiers).

As soon as the parachute canopy opens completely, the air slows the descent of the parachutist so quickly that he or she may be jerked sharply.

ACTIVITY *Show how size matters*



Make two parachutes by tying thin cords onto the four corners of cloth strips and attaching the cords to a small weight. For the first parachute, use a cloth 2 in. [5 cm] wide and 12 in. [30 cm] long. For the second, use a cloth 8 in. [20 cm] wide and 12 in. [30 cm] long. Stand on a chair and drop first one, then the other parachute. Which one falls more slowly? Why?

Caution: Be sure the chair is stable and on a flat surface before you stand on it.

Parachutes with slots in their canopies have been developed to reduce the force of this opening shock.

Parachutists descend at the rate of about 20 m.p.h. [32 kph], or slightly faster. Parachute drops from less than 500 ft. [150 m] above the ground are dangerous because this height does not allow the parachute time to open. Parachutists can control the direction of their descent by pulling on the shrouds. Parachutists often land with great force. Heavy boots and special shock-absorbing techniques help prevent sprained ankles and broken legs. Experienced parachutists can often land very lightly in a standing position.

Parachute jumping has become a popular sport in the United States and Europe. There are many clubs and national and international jumping events in which parachutists try to land on small targets on the ground.

PARAFFIN WAX Paraffin wax is a white, waxy, solid hydrocarbon mixture that has no taste or odor (see HYDROCARBON).

Paraffin wax is made from a mixture of petroleum fractions, which are products separated from petroleum (see PETROLEUM). The fractions are chilled and pressed through a filter to remove heavy oil. The remaining solid is paraffin wax. Paraffin wax is used to put a waterproof coating on cardboard containers such as milk cartons. Paraffin wax is also the main ingredient in candles.

Ordinary paraffin wax melts at 90° to 150°F [32° to 66°C]. Microcrystalline paraffin wax is another type of paraffin wax. It melts at 150° to 185°F [66° to 85°C].

Paraffin wax is used in certain kinds of polishes and as a moisture-proof coating on textiles. Jars in which food is preserved are often sealed with paraffin wax.

PARAKEET A parakeet is a bird that belongs to the parrot family, Psittacidae. A parakeet is a small parrot with a long tail (see PARROT). There are dozens of species, not all closely related, living throughout the tropical areas and Australia. Parakeets eat flowers, fruits, and seeds. They are very colorful and are often kept as pets. The

budgerigar is a parakeet. Other types of parakeets are called lorikeets and lovebirds. The Carolina parakeet, once found in the United States, is now extinct.

See also EXTINCTION.



PARAKEET

The rainbow lorikeet, a type of parakeet, is named for its wide range of bright colors. It lives in Indonesia and feeds on nectar, which it laps with its brush-tipped tongue.

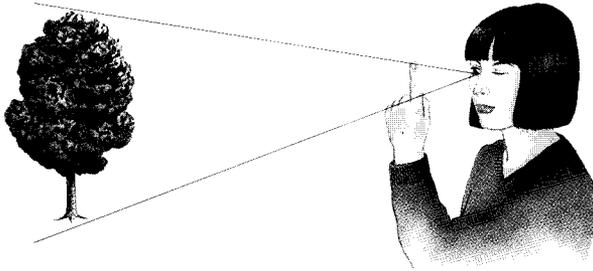
PARALLAX Suppose that you are looking at an object against a background. As you move your head, the object seems to move against the background. This effect is called parallax. In astronomy, parallax is used to find the distances of the planets and the nearer stars from Earth. To measure distance from the earth to a planet using parallax, the position of the planet is first measured at a particular time relative to the background of the stars. Then the planet's position is measured again twelve hours later. In this time, the measuring instrument has moved in space because of the earth's rotation and revolution. Because of the earth's movement, the planet seems to move against the background of stars. The amount that it moves depends on the planet's distance from the earth. Therefore, its distance can be calculated.

To measure distance between the earth and a nearby star using parallax, the positions of the star are measured six months apart. In this time, the earth has moved around to the opposite side of the sun. This large movement of the earth produces a small apparent movement in the star. Therefore,

the star's distance from the earth can be measured.

Parallax can cause inaccuracies when a person reads the dial on a scientific instrument. The pointer on the dial is always a small distance away from the scale. If the person reads the dial at an angle, the pointer gives a wrong reading because of parallax. This can be overcome by having a mirror on the scale. The pointer is lined up with its reflection. This assures that the person is directly above the pointer when taking a reading and, thus, the reading will be accurate.

ACTIVITY *Demonstrate parallax*



Close one eye and hold a finger in front of the other eye. Now move your head from side to side. Notice that objects farther away than your finger seem to move more than the finger as your head moves.

PARALYSIS (pə rāl'ī sīs) Paralysis is the loss of use of muscles. Sometimes, a whole group of muscles becomes completely paralyzed. Other times, muscles can respond at a reduced level, causing only partial paralysis.

Paralysis itself is not a disease. It is caused by disease in the muscles or damage to the brain or to the nerves that stimulate the muscles. For instance, if a person has a badly damaged spinal cord, there will be paralysis of all the muscles below the injury. If the nerves that carry messages back to the brain are also affected, there will be no feeling in the lower half of the body (see NERVOUS SYSTEM).

Doctors divide paralysis into two main types: spastic paralysis and flaccid paralysis. In spastic paralysis, the muscles affected are tense, as though they were pulling. However, the muscles are weak

and cannot be controlled. Spastic paralysis is usually due to damage in the brain or the upper part of the spinal cord. In flaccid paralysis, the muscles are limp and flabby. Flaccid paralysis is due to damage to nerves lower down in the nervous system. Poliomyelitis causes this type of paralysis (see POLIOMYELITIS).

When paralysis continues for a long time, the nerves and the muscles become permanently useless. The nerve cells die, and the muscles become thin and wasted. To prevent this, electrical treatment can be given by physical therapists to keep the muscles active. The electrical impulse makes the muscles contract. However, the person does not regain control of the muscle contractions.

See also MUSCLE.

PARAMECIUM (pär ə mē'shē əm) The paramecium is a one-celled organism that lives in fresh water. It is a protozoan and belongs to the kingdom Protista (see PROTISTA; PROTOZOA).

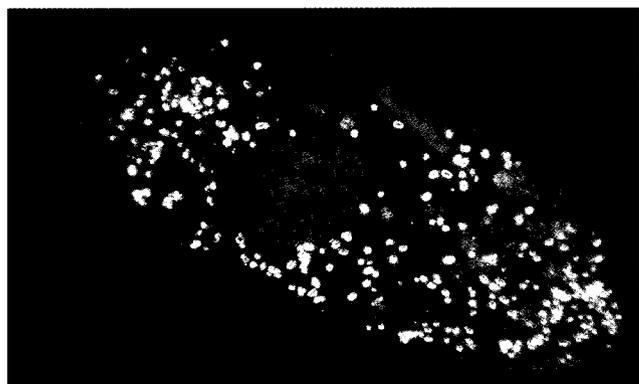
Because of its slipperlike shape, the paramecium is sometimes called a slipper animalcule. Its body is covered with tiny, hairlike cilia, which it uses for movement and for feeding (see CILIUM). On one side of the organism is an oral groove, which leads to the mouth and gullet. Cilia on this groove create a flow of water that carries bacteria and other tiny organisms into the mouth. Food is digested in food vacuoles formed at the end of the gullet (see VACUOLE). Wastes from digestion are ejected through an anal pore (opening). There are two or three contractile vacuoles located near the surface at the ends of the paramecium. These contractile vacuoles regulate the amount of water inside the paramecium and get rid of metabolic wastes by squirting the water and wastes out of the cell (see METABOLISM).

The body of the paramecium has a rigid outer membrane called a pellicle. Just inside the pellicle is a layer of firm, clear cytoplasm called ectoplasm. The watery part of the cytoplasm with its various structures is called endoplasm (see CYTOPLASM; ECTOPLASM; ENDOPLASM).

The paramecium has one large nucleus called the macronucleus and one or more smaller nuclei called the micronuclei (nuclei is plural for *nucleus*).

The macronucleus controls most of the cell's activities and contains genes. The micronucleus also contains genes and functions in sexual reproduction. Paramecia (plural of *paramecium*) usually reproduce asexually by dividing into two new organisms (see ASEXUAL REPRODUCTION; GENE; REPRODUCTION). Occasionally, paramecia reproduce sexually in a process called conjugation. Two paramecia line up next to each other, exchange micronuclei, separate, and divide several times. Conjugation has a revitalizing effect on paramecia. If the animals go on simply splitting in two for a long time, they become weak and eventually die.

See also CELL.



PARAMECIUM

The paramecium is a one-celled, protozoan animal that moves through water by beating its hairlike cilia.

PARASITE A parasite is an organism that lives with or inside another organism—called the host—and takes food from it. Some parasites eat the flesh of the host. Others eat the food that the host has eaten. Parasites always harm the host, though they rarely kill it. If they did kill the host, the parasites would destroy their home and source for food. However, parasites often weaken the host to the point where it may die of other causes, such as disease. Some parasites have parasites—smaller organisms called hyperparasites—within them.

Animal parasites Nearly every animal on Earth has parasites. The average human being has several parasites in his or her body. Also, nearly every major phylum of animals includes species that are parasitic. Most of the animal parasites belong to the phyla (plural of *phylum*) Platyhelminthes,

Aschelminthes, and Arthropoda. In addition, many protozoans, which are one-celled, animallike organisms in the kingdom Protista, are parasites (see ARTHROPODA; ASCHELMINTHES; PLATYHELMINTHES; PROTOZOA).

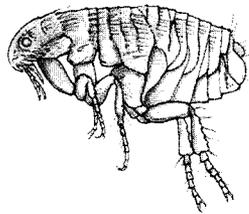
Ectoparasites live on the outside of their hosts. One well-known ectoparasite is the flea (see FLEA). The flea is an insect that lives in the fur and feathers of animals. It feeds by sticking its sharp “beak” into the animals’ skin and sucking out blood. Besides causing an irritation to the host, fleas can also spread serious diseases. The plague is a disease caused by bacteria spread by fleas that live on rats. In the 1300s, an epidemic of plague called the Black Death killed millions of Europeans (see EPIDEMIC).

Endoparasites are parasites that live and feed inside the bodies of their hosts. They feed on blood, tissue fluids, and the food of the hosts. Endoparasites are responsible for some of the world’s most serious human diseases, such as malaria and sleeping sickness (see MALARIA). Malaria and sleeping sickness are caused by microscopic, one-celled organisms that live in the bloodstream of mammals. They are spread by biting insects.

Many endoparasites are worms. Tapeworms live in the intestines of their host (see TAPEWORMS). They attach themselves to the host by means of suckers or hooks. The worms absorb through their skin some of the digested food from the host. Eggs of the tapeworms pass out of the host’s body in the feces. The next generation of tapeworms hatches from the eggs, and some eventually find their way to new hosts.

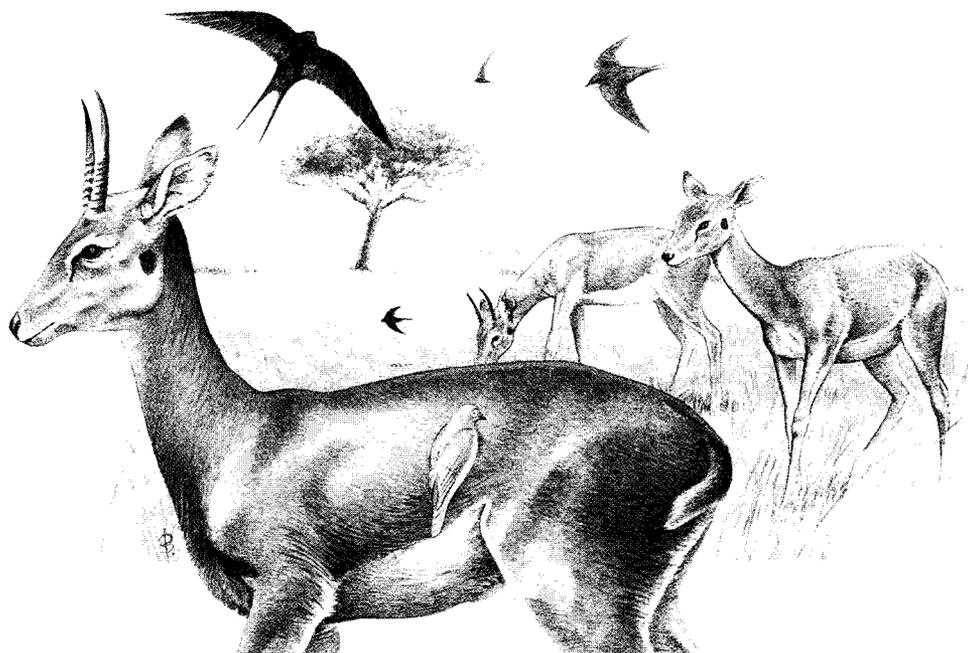
Another parasitic worm—the blood fluke—lives in the blood of its host and causes serious injury to the blood vessels and other organs. The condition caused by the blood fluke is called schistosomiasis (see SCHISTOSOMIASIS).

The wasplike ichneumon flies include some rather specialized endoparasites that attack caterpillars and other young insects (see ICHNEUMON FLY). The female ichneumon lays her eggs in a caterpillar, and her grubs gradually eat the caterpillar from the inside. These parasites do kill their



PARASITE

The flea (above) is the most common external parasite of animals. On the African grasslands (right), birds called oxpeckers "ride" on grazing animals and feed on the parasites.



hosts, but by the time this happens, the ichneumon grubs have grown up and do not need the host any more. Some flies grow up in the same way.

Social parasites Parasites that affect a group of organisms—rather than just one organism—are called social parasites. The best-known social parasites are the cuckoos of Europe, Asia, and Africa (see **CUCKOO**). These birds lay their eggs in the nests of other birds. The young cuckoos hatch along with the host's own young. However, the young cuckoo is usually more aggressive than the other young birds. It may demand more food or even push the other young birds out of the nest. The cuckoo becomes stronger than the host's own young. In this way, the entire population of host birds is affected. Some bees and wasps are social parasites, too, laying their eggs in the nests of other species.

Parasitic plants The reason that there are fewer plant parasites is that most plants are able to produce their own food by photosynthesis (see **PHOTOSYNTHESIS**). Therefore, most plants do not need to parasitize other organisms. However, some plants cannot make their own food and have evolved as parasites. The dodder is one such plant parasite. It is a simple plant that resembles pink cotton. It winds itself around other plants, sends

suckers into them, and absorbs food. Mistletoe is another parasitic plant. It can produce some food by photosynthesis, but it must get its water and minerals from trees that it grows on (see **MISTLETOE**).

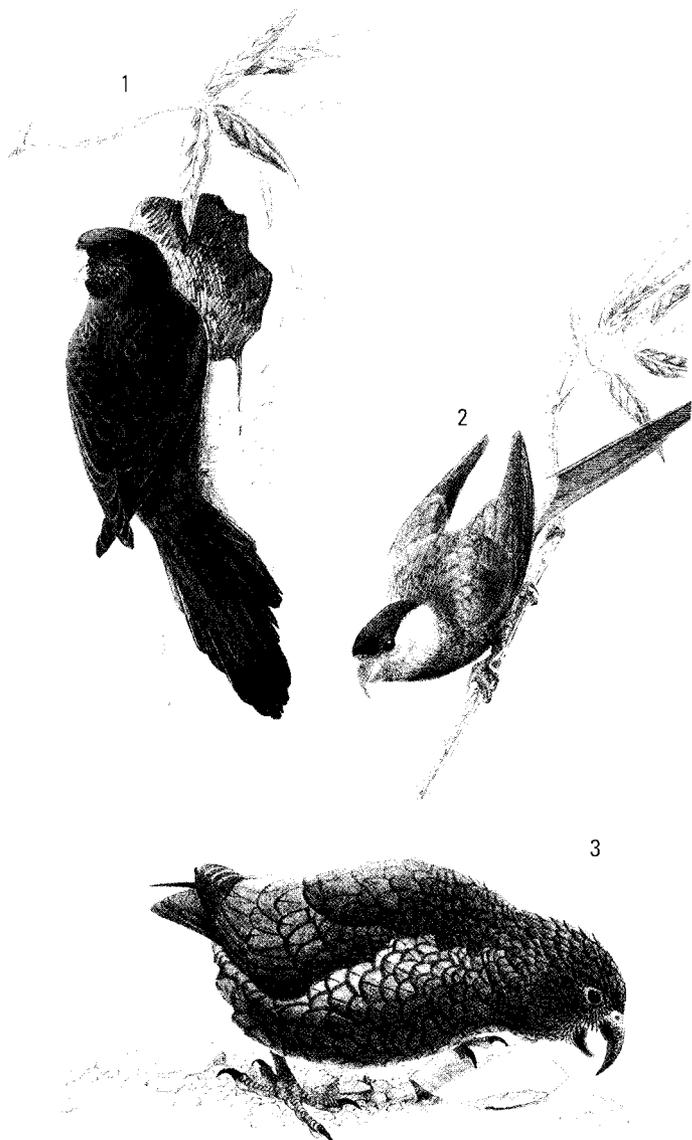
Parasites can sometimes be useful for controlling insect or plant pests. The study of parasites is called parasitology.

PARKINSON'S DISEASE Parkinson's disease is a disorder of the brain that leads to the loss of muscle control (see **MUSCLE**). It is named after the British doctor who first described it, James Parkinson (1755–1824). Parkinson's disease causes tremor (slow shaking), stiffness and weakness in the muscles used for voluntary actions, a stooped posture, and a slow shuffling walk. It is very common in the elderly. If untreated, the disease gradually becomes worse, making it difficult for the person to act independently of others. It is caused by a gradual deterioration in the part of the brain responsible for producing dopamine, which is used to transmit electrical impulses in the nervous system (see **NERVOUS SYSTEM**).

Drugs are used to replace the lost dopamine. Physiotherapy and exercise are also very important in maintaining full use of the muscles (see **EXERCISE**; **PHYSIOTHERAPY**). With treatment, nearly all of the symptoms can be overcome or controlled.

PARROT A parrot is a bird that belongs to the family Psittacidae. It is a stout bird with a heavy bill and strong talons (claws). Most parrots are very colorful. They live in the forests of tropical and subtropical regions throughout the world. There are over three hundred species, but they are not all called parrots. Many of the smaller ones are called parakeets and lorries (see **PARAKEET**). Others are called macaws and cockatoos. They eat seeds, nuts, buds, fruit, and nectar.

Parrots are commonly kept as pets. They may be taught to talk, because they can easily imitate various sounds.



PARROT

Parrots are among the most colorful birds. Shown here are (1) the crimson rosella, (2) the red-capped parrot, and (3) the kea. Parrots are popular pets, but many species have become extinct or endangered because of overcollecting and loss of their natural forest habitat.

PARSEC A parsec is the distance to a star whose position seems to shift by 1 second of arc when viewed from opposite sides of the earth's orbit (see **PARALLAX**). A parsec is equal to 3.26 light-years or 19.2 trillion mi. [30.9 trillion km] (see **LIGHT-YEAR**). The term *parsec* comes from the words *parallax* and *second*.

Parsecs are used to measure distances in the universe. Proxima Centauri, the nearest star to the sun, is about 1.3 parsecs away. The sun is about 8,000 parsecs from the center of the galaxy.

PARSLEY FAMILY The parsley family includes over 2,000 species of herbaceous plants, most of which live in northern temperate regions. They have green, compound leaves growing in clusters around a hollow stem (see **HERBACEOUS PLANT**; **LEAF**). The flowers are usually white or yellow and they grow in umbrella-shaped clusters called umbels (see **INFLORESCENCE**).

The parsley plant is a biennial plant native to the Mediterranean area (see **BIENNIAL PLANT**). It has been introduced worldwide. The leaves of this plant are used fresh or dried as a garnish or flavoring for food. It is a good source of iron and vitamins A and C. Other members of the parsley family include the carrot, celery, and parsnip. This family is sometimes called the carrot family.

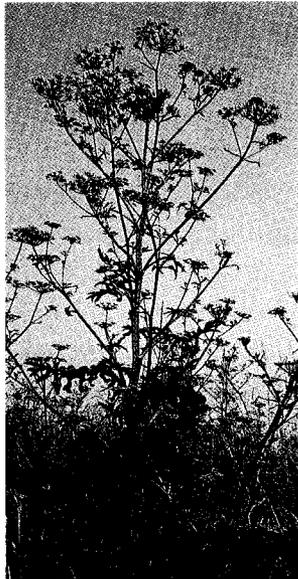
See also **HERB**.



PARSLEY FAMILY

Parsley is a popular herb that is used fresh as a garnish and in salads, and fresh or dried as a flavoring.

PARSNIP Parsnip is a biennial herbaceous plant belonging to the parsley family (see BIENNIAL PLANT; HERBACEOUS PLANT; PARSLEY FAMILY). It has lobed leaves and yellow flowers (see LEAF). Parsnip is cultivated for its large, white, carrot-shaped tap root (see ROOT). The root is harvested after the first growing season and is usually served as a cooked vegetable. It is rich in carbohydrates and vitamins A and C.



PARSNIP

Left to grow wild, the parsnip produces tall stalks with lobed leaves and clusters of small yellow flowers. Parsnip is also cultivated for its large tap root, which is eaten as a vegetable.

PARTHENOGENESIS (pär'thə nō jěn'ī sīs) Parthenogenesis is a type of asexual reproduction in which an unfertilized egg develops into a mature organism. It is common among some invertebrate animals, such as rotifers and insects (see INSECT; ROTIFER). Male ants, bees, and wasps, for example, develop by parthenogenesis, and so do most of the aphids in the summer. Most invertebrates capable of parthenogenesis are also capable of sexual reproduction. Parthenogenesis can be artificially caused in many animals—vertebrates and invertebrates—by treating the unfertilized egg with special chemicals.

See also ASEXUAL REPRODUCTION; REPRODUCTION.

PARTICLE PHYSICS (pär'tī kəl fiz'iks) All matter is made up of tiny particles called atoms (see ATOM). For many years, scientists thought that atoms were the smallest particles of matter. They thought that atoms had no structure. It is now known that atoms are themselves made up of even

smaller particles. The main particles that make up atoms are called protons, neutrons, and electrons (see ELECTRON; NEUTRON; PROTON). They are known as subatomic particles. Since these three particles were discovered, many more subatomic particles have been found. The study of these particles is called particle physics.

Early discoveries The first subatomic particle to be discovered was the electron. Physicists soon realized that the electron was smaller than an atom. Then they discovered that atoms contain electrons. This meant that the atom had to have some sort of structure. Atoms were no longer thought to be the smallest particles that could exist. In 1911, the British physicist Ernest Rutherford used an experiment to investigate the structure of the atom (see RUTHERFORD, ERNEST). Through this experiment, Rutherford found that atoms contain a very small core called a nucleus (see NUCLEUS). He found that almost all of the mass of an atom was contained in its nucleus. The nucleus is surrounded by a number of electrons. The nucleus and the electrons together make up the atom.

Rutherford's theory also explained that the nucleus of a hydrogen atom contained just one particle. This particle is called the proton. It was the second subatomic particle to be discovered. The proton has 1,860 times the mass that an electron has (see MASS). The electron and the proton have equal and opposite electric charges. The electron has a negative charge, and the proton has a positive charge. Atoms have equal numbers of protons and electrons. Thus, electric charge is balanced out in the atom.

However, at first, scientists could not understand how the charges balanced. The nuclei of all the atoms seem to contain too many protons to balance out the charge of the electrons. For example, the nucleus of an oxygen atom is just about sixteen times as heavy as a proton. Therefore, scientists concluded the oxygen nucleus has sixteen protons. However, they knew that the oxygen atom has only eight electrons. If it had sixteen protons, it would have an overall electric charge. However, oxygen atoms do not have an electric charge. Therefore,

scientists concluded that there must be particles in the nucleus besides protons. They named these other particles neutrons. They deduced that the neutron is slightly heavier than the proton and has no electric charge. An oxygen nucleus contains eight protons and eight neutrons. This gives a total mass equal to about sixteen protons. Because there are eight protons to balance eight electrons, the oxygen atom has no electric charge. In 1932, British physicist Sir James Chadwick confirmed the existence of the neutron by experiment (see CHADWICK, SIR JAMES).

The strong nuclear force Realizing that the nucleus contained both protons and neutrons solved the riddle about the atom's mass and neutral charge. However, physicists still had other questions about the atomic nucleus. For example, two bodies with a positive charge repel each other, or push each other away. Therefore, scientists assumed that the protons in the nucleus should repel each other because they all have a positive charge. In this case, the nucleus would fly apart. However, the nucleus is really very stable. Physicists realized that there must be a very strong force holding the nucleus together. This force must be strong enough to overcome the repulsion between the protons. Physicists named this force the strong nuclear force. It only works over very short distances, about equal to the width of the nucleus. This is about 10^{-13} cm. (10^{-13} is one divided by ten thirteen times). The strong nuclear force is caused by tiny particles called gluons. The other recognized fundamental forces affecting matter are gravity, electromagnetism, and the weak nuclear force (see FORCE).

Properties of particles Since 1947, hundreds of particles have been discovered. One way of discovering new particles is by examining cosmic rays (see COSMIC RAYS). Another important method is to use a large machine called a particle accelerator (see ACCELERATORS, PARTICLE). In a particle accelerator, streams of particles are made to travel at very high speeds. The particles then hit other particles or a target consisting of a small amount of an element.

New subatomic particles or elements may then be formed (see ELEMENT).

Subatomic particles can be measured in different ways. They all have a rest mass. This is the mass of the particle when it is still. When it is moving very fast, its mass increases (see RELATIVITY). Many particles have an electric charge. This charge can be either positive or negative. Many particles also have spin. They spin much the same way a football does when it is thrown. The spin, mass, and charge are all fixed for each particle.

Subatomic particles are made up of elementary particles (see ELEMENTARY PARTICLES). An elementary particle cannot be broken down into smaller particles, and its size is too small to measure. All elementary particles have an antiparticle. These antiparticles have the same mass, but they have the opposite charge or spin as the original particle. For example, the antiparticle of the electron is called the positron. It has the same mass as an electron but has a positive charge. A particle and an antiparticle can exist for a very short time together. However, they soon collide and destroy each other. As they destroy each other, they give off a gamma ray (see ANTIMATTER; GAMMA RAY).

Subatomic particles fall into one of two classes. One class, called fermions, is made up of those particles that make up matter (see MATTER). Fermions can be divided into hadrons and leptons, depending on which of the four fundamental forces act on them. Hadrons are made up of quarks and are acted upon by the strong nuclear force (see QUARK). Hadron particles called baryons, which include protons and neutrons, are made up of three quarks each. Hadron particles called mesons are made up of a quark and an antiquark (see MESON). Leptons can be divided into electrically charged particles and uncharged particles. Leptons are acted upon by the electromagnetic force and the weak nuclear force. Electrically charged leptons include the electron, the muon, and the tau particle. The uncharged leptons include the neutrinos (see NEUTRINO). Neutrinos can be transformed into charged leptons by colliding them with atomic nuclei (plural of *nucleus*). The electron neutrino can be transformed into an electron. The muon



PARTICLE PHYSICS

Physicists have now identified more than 300 subatomic particles. Scientists study them using a bubble chamber, in which various particles leave straight or spiral tracks (above). Uncharged particles make straight tracks, whereas charged particles make curved tracks.

neutrino can be transformed into a muon. The tau neutrino can be transformed into a tau.

The other class of particles, called bosons, is made up of those particles that transmit forces. There are four known kinds of bosons—photons, gluons, gravitons, and weakons. Photons transmit the electromagnetic force (see PHOTON). Gluons transmit the strong nuclear force. Gravitons transmit gravity (see GRAVITY). Weakons transmit the weak nuclear force. In the 1980s, scientists proved that the electromagnetic force and the weak nuclear force are two forms of the same force.

The standard model theory Studies of a certain kind of weakon particle that was created in 1989 in particle accelerators confirm much of what scientists call the standard model theory of particle physics. According to this theory, all matter in the universe seems to occur in one of three generations, or categories. Each generation seems to be made up of combinations of two types of quarks, a charged lepton, and an uncharged lepton.

The first generation of matter is made up of the

quarks called *up* and *down*, an electron, and an electron neutrino. The second generation of matter is made up of the *strange* and *charm* quarks, the muon, and the muon neutrino. The third generation of matter is made up of the *top* and *bottom* quarks, the tau, and the tau neutrino. The second and third generations of matter occur only as a result of events involving large amounts of energy, such as those events that occur in particle accelerators. This makes it difficult to observe the particles that make up these two generations. The top quark, for example, was first observed in 1995 at Fermilab, the particle physics laboratory near Chicago. Research in particle physics now centers on discovering the properties of the rare particles, such as the top quark, and determining why particles have the masses they have.

PASCAL, BLAISE (1623–1662) Blaise Pascal was a French scientist, mathematician, philosopher, and theologian. He did original work in many different fields. He studied atmospheric pressure and made an important discovery in hydrostatics (see HYDROSTATICS). His discovery is now known as Pascal's law. It states that pressures applied to a contained liquid are transmitted equally throughout the liquid, in every direction. The unit of pressure in the metric system (the pascal, or 1N/m^2) is named for him (see METRIC



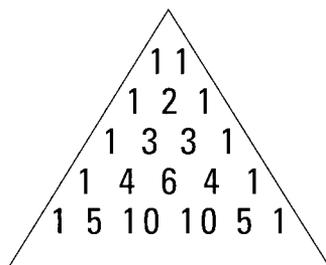
BLAISE PASCAL

Blaise Pascal was a French scientist and philosopher who worked mainly in the fields of physics and mathematics.

SYSTEM). He also studied the mathematical theory of probability (see PROBABILITY). One of his discoveries in probability is called Pascal's triangle.

See also PASCAL'S TRIANGLE.

PASCAL'S TRIANGLE Pascal's triangle is an arrangement of numbers shaped like a triangle. It was discovered by the French scientist and mathematician Blaise Pascal in the 1600s (see PASCAL, BLAISE). The triangle consists of rows of numbers. The top row has two numbers, 1 and 1. Then each row starts and ends in 1. Two numbers next to each other in a row are added together. The number formed is placed in the row beneath the two numbers and halfway between them.



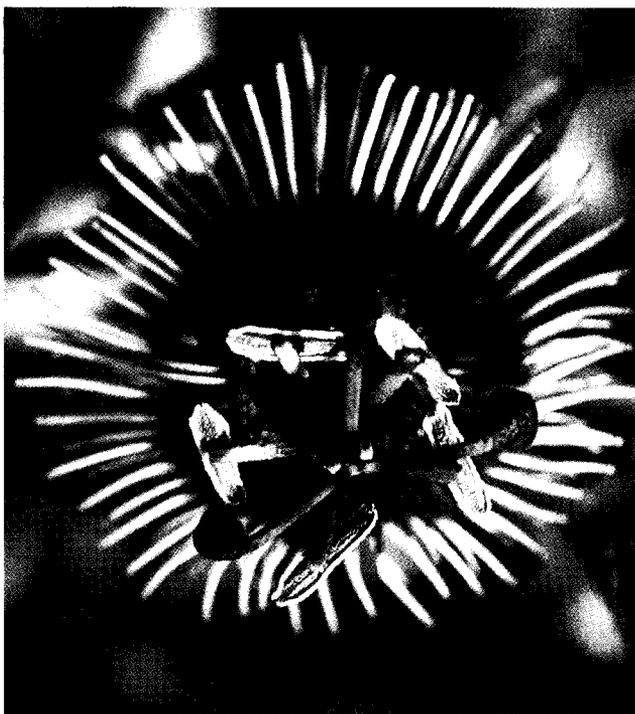
For example, the third row of Pascal's triangle is 1 3 3 1. The first number in the row beneath is 1. The second number is given by $1 + 3$. This number is 4. The third number is given by $3 + 3$ and is 6. In the same way, the fourth number is 4, and the last is 1. Therefore, this row is 1 4 6 4 1. The number of rows in Pascal's triangle can be infinite (endless). Pascal's triangle can be used in a number of different situations. For example, it can be used to determine probabilities when throwing a number of coins.

Pascal's triangle will predict the probability of different combinations of heads and tails turning up (see PROBABILITY). Suppose that you have three coins. If they are thrown, there are four possible outcomes. You can have three heads, two heads and one tail, one head and two tails, or three tails. As there are four possibilities, you need to look at the row in Pascal's triangle that has four numbers. This is the row 1 3 3 1. These numbers tell you the probability of each combination occurring. 1, 3, 3, and 1 add up to 8. Therefore, there is 1 chance in 8

of throwing three heads, 3 chances in 8 of throwing two heads, 3 chances in 8 for one head, and 1 chance in 8 for no heads. The chances are the same for throwing three, two, one, or no tails with three coins.

PASSIONFLOWER The passionflower is any of about five hundred species of dicotyledonous flowering plants belonging to genus *Passiflora* in the passionflower family, Passifloraceae. Most are tendril-bearing climbing plants that live in the tropics (see CLIMBING PLANT; DICOTYLEDON).

Several species are cultivated for their unusual and beautiful flowers. They vary in size from 0.4 to 6 in. [1 to 15 cm] in diameter. There are five petals and five sepals, all of which are similar in color. Inside the petals are one or more rings of brightly colored, threadlike filaments. In the center of the flower is a reproductive stalk called a gynophore. About halfway up the gynophore is a ring of five stamens. Above this ring is the ovary with three styles. Each style ends in a large, lobed stigma, giving it the appearance of a large nail or spike (see FLOWER).



PASSIONFLOWER

The approximately five hundred species of passionflowers produce unusual-looking flowers such as the one above. The flower's five stamens and three styles are clearly evident.

Several passionflower species, often called granadillas, produce edible fruits—the passion-fruit. This fruit is sometimes squeezed for its juice or mixed in fruit punch.

PASTEUR, LOUIS (1822–1895) Louis Pasteur was a French biologist and chemist. Pasteur discovered that yeast causes grape juice to ferment into wine. He also discovered that a similar process causes milk to go sour, butter to turn rancid, and wine to turn into vinegar (see FERMENTATION). He developed a process called pasteurization. In pasteurization, food is preserved by heating it to kill disease-causing microorganisms (see MICROORGANISM; PASTEURIZATION). He also developed a vaccine for rabies (see RABIES; VACCINATION). He first used his vaccine on a human being in 1885, when he treated a child who had been bitten by a rabid dog. The child did not develop rabies. His life had been saved by Pasteur's vaccine. In 1888, he founded the Pasteur Institute, which is a center for medical research. The institute is still in existence today.



LOUIS PASTEUR

Louis Pasteur, the French biologist and chemist, studied fermentation and developed the process of pasteurization.

PASTEURIZATION (pās'chər ĩ za'shən) Pasteurization is a method of preserving food by heating it to kill disease-causing microorganisms in it (see MICROORGANISM; PATHOGEN). The food is then stored in cool conditions. Pasteurization is named after its inventor, Louis Pasteur, a French chemist (see PASTEUR, LOUIS). Pasteurization is most commonly used for milk but may also be used for cheese, beer, and other foods.

For milk, the process of pasteurization traditionally has involved heating the milk to at least 145°F [63°C] for not less than thirty minutes. Then the

milk is quickly chilled to 50°F [10°C] or less. This kills most of the bacteria in the milk and allows it to stay fresh for several days. The process does not affect the taste of the milk. Modern dairies use a faster method in which the milk is heated to at least 161°F [72°C] for fifteen seconds, then cooled.

See also FOOD PROCESSING; MILK.

PATELLA The patella, or kneecap, is a small, flat, triangular bone located on the front of the knee. It protects the knee joint. The patella is not directly connected to any other bone. It is held in place by muscle attachments and ligaments.

See also BONE; LIGAMENT; MUSCLE.

PATHOGEN (pāth'ə jən) Pathogens are organisms that cause disease. Many kinds of bacteria, viruses, fungi, and protozoans are pathogens.

See also DISEASE.

PATHOLOGY (pā thōl'ə jē) Pathology is the study of disease or of any condition that limits health. Pathologists used advanced scientific methods, such as electron microscopy, to help them recognize the changes caused by disease in the tissues and organs of the body (see ELECTRON MICROSCOPE).

Tests by pathologists help physicians diagnose a disease and the extent of its attack. These tests may include the examination of the blood, urine, and tissues. The use of laboratory tests to diagnose disease is called clinical pathology. Pathologists also study diseased parts removed by surgery. For example, persons suspected of having cancer sometimes have the diseased part removed by surgery. It is then analyzed by a pathologist. If the removed part is malignant, or cancerous, further surgery or special treatment may be necessary. Pathologists also examine corpses to determine the exact cause of death. This examination is called an autopsy. Forensic pathology is the use of pathology where the cause of death is, or is suspected to be, homicide.

Comparative pathology is a branch of pathology that compares human diseases with animal diseases. Plant pathology is the study of the diseases of plants.

See also DISEASE; FORENSIC SCIENCE.

PAULI, WOLFGANG (1900–1958) Wolfgang Pauli was an Austrian physicist. He was born in Vienna and studied in Munich, Germany. Later, he worked in the United States. He made important discoveries about the atom. He also worked on a branch of physics called quantum theory (see ATOM; QUANTUM THEORY). In 1930, Pauli deduced that there exists a particle called the neutrino (see NEUTRINO). Pauli studied the radioactive process called beta decay and realized that some unknown particle was being given off. He calculated that the particle should have spin but no mass. He called this particle the neutrino. The neutrino's existence was confirmed by experiment twenty-six years later. Pauli won the Nobel Prize for physics in 1945 for his work in quantum theory.

See also PARTICLE PHYSICS; RADIOACTIVITY.

PAULING, LINUS (1901–1994) was an American chemist known for his studies of chemical bonding. When two atoms combine to form a molecule, they are held together by a bond. Atoms form bonds by means of small particles called electrons. All atoms have electrons (see ATOM; ELECTRON; MOLECULE).

There are different kinds of bonds. In one kind, called the covalent bond, two atoms share some of their electrons. Pauling discovered that these electrons are shared in pairs. A pair of electrons spends part of the time with one atom and part of the time with the other (see VALENCE).

Pauling next investigated compounds that occur in living tissue, especially proteins (see PROTEIN). He worked on the structure of their molecules. For this work, he won the 1954 Nobel Prize for chemistry.



LINUS PAULING

Linus Pauling was one of the very few people to be awarded two Nobel prizes. He received the prize in chemistry in 1954 and the Peace Prize in 1962.

He also won the Nobel Peace Prize in 1962. He won it for his efforts in trying to stop nations from building nuclear weapons. Pauling was one of only a few people who have won two Nobel Prizes.

PAVLOV, IVAN PETROVICH (1849–1936) Ivan Pavlov was a Russian physiologist best known for his work with conditioned reflexes (see LEARNING AND MEMORY; REFLEX). In the early 1900s, Pavlov performed experiments concerned with digestion in dogs. When a dog sees food (the stimulus), it produces saliva (the reflex, or response). Pavlov tried ringing a bell while giving food to a dog. After a while, he found that the dog produced saliva when it heard the bell, even though no food was given. Pavlov called this response a conditioned reflex. He believed that conditioned reflexes were the basis of learning. However, most scientists today believe that the mechanism of learning is much more complicated than this. Pavlov won a Nobel Prize for his work in 1904.

PCBs PCBs, or polychlorinated biphenyls, are a group of two hundred synthetic (human-made) compounds first manufactured in 1930 (see COMPOUND). They are formed by substituting up to ten chlorine atoms for atoms of hydrogen in a hydrocarbon called biphenyl (see HYDROCARBON). In the 1970s, PCBs were shown to be harmful to the environment. The United States Environmental Protection Agency (EPA) banned the manufacture of PCBs in 1979.

Up until 1979, PCBs were widely used in industry as coolants and insulators. They were also used to manufacture a large number of products, such as paints and glues. By the 1960s, some scientists began to worry about the effect PCBs might have on the environment (see ENVIRONMENT). Research showed that many factories were releasing PCBs into the environment in their waste water.

PCBs came to be found in large quantities in various animals, such as fish and ducks. The chemicals caused duck eggshells to become thin, allowing them to be crushed easily. PCBs were also believed to cause some fish to be unable to reproduce. Humans who drank PCB-polluted water or ate

birds, fish, and other animals contaminated with PCBs also became contaminated. High levels of PCBs in pregnant women resulted in birth defects. Children contaminated with PCBs had behavioral problems. PCBs may also cause liver damage and other medical problems. Although new PCBs are no longer being made, old electrical equipment containing them is still being used. Companies using them must take special precautions to make sure the PCBs do not pollute the environment.

PEACH The peach is a deciduous tree belonging to the rose family (see ROSE FAMILY). It is cultivated in temperate areas throughout the world for its tasty fruit. The tree is usually about 20 ft. [6 m] tall. It has thin, pointed leaves with toothed margins. The flowers are usually pink and open before the leaves. They have five petals and five sepals. There are three whorls of stamens surrounding a central pistil (see FLOWER; LEAF).

The peach fruit is a drupe (see DRUPE). It has a fuzzy skin and a large woody pit with a single seed in the center. The two main varieties of peaches are freestone and clingstone. Freestone peaches have pits that separate easily from the fleshy, edible part of the fruit. The pits of clingstone peaches are more firmly attached.



PEACH

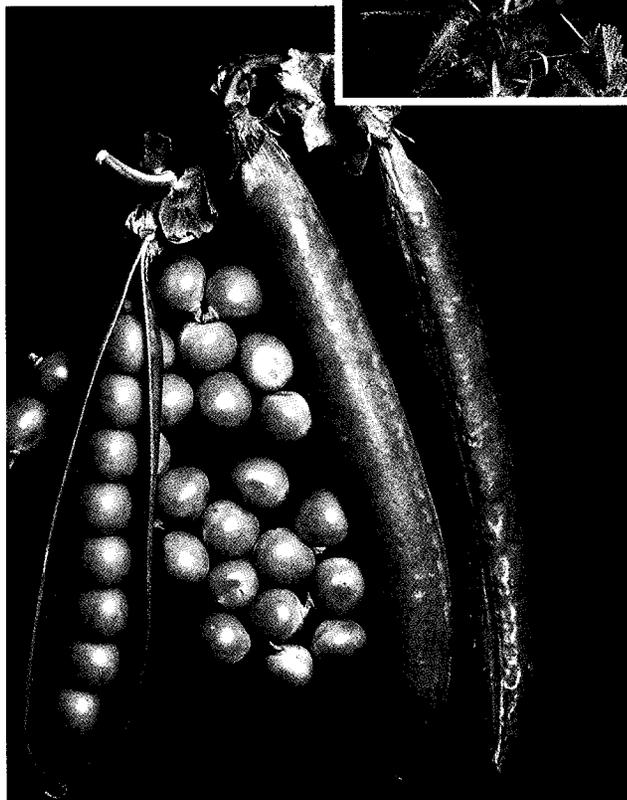
The fruit of the peach tree can be eaten as a fresh fruit or made into jam or jelly. Most of the peaches in the United States are grown in California.

The peach can be eaten as a fresh fruit, or it may be canned or made into jam or jelly. In the United States, the popularity of the peach is second only to that of the apple. The United States produces more peaches than the rest of the world combined. California leads the country in peach production. See also NECTARINE.

PEA FAMILY The pea family, known as the Fabaceae or Leguminosae, includes more than ten thousand species of flowering plants that grow throughout the world. The leaves vary widely, but most are divided into several leaflets (see LEAF). The flowers also vary, but most are butterfly shaped. The seeds are always enclosed in a legume, or pod (see LEGUME). Most members of the family have small, bacteria-containing nodules on the roots. These bacteria change nitrogen in the air into a

PEA FAMILY

Examples of pea plants include the common vetch (right), which grows wild in temperate meadows, and the domesticated pea (below), grown as a crop for humans to eat.



form that can be used by the plant as food (see NITROGEN FIXATION).

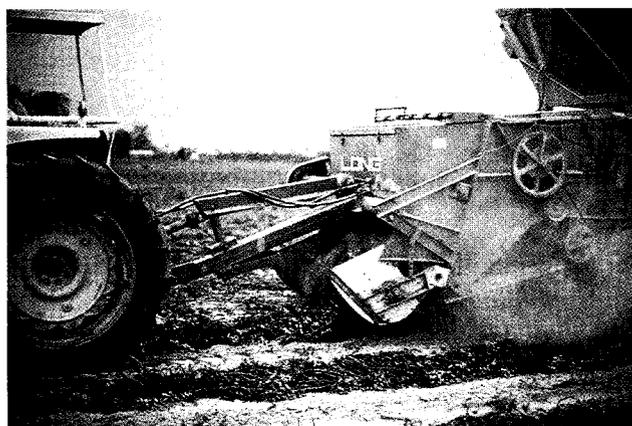
The pea plant is a vine with pinnately compound leaves and tendrils (see TENDRIL). Its seeds are the peas that we eat.

The pea is one of the best vegetables in terms of food value. It provides almost as much protein as meat. It is also a good source of carbohydrates and vitamins A and C. Peas grown in gardens and used for canning or freezing usually grow on low, bushy vines that are about 3.3 ft. [1 m] long. Peas sold as dry peas usually grow on climbing vines that are about 5 ft. [1.5 m] long. Other members of the pea family include alfalfa, clover, lentil, licorice, mimosa, peanut, sweet pea, wisteria, and many kinds of beans.

PEAFOWL A peafowl is a bird that belongs to the family Phasianidae. It is more commonly known as the peacock, though technically, *peacock* is the name for just the male peafowl. The female is called a peahen. There are three species of peafowl. One is native to India. Another is native to south-east Asia. A very rare species lives in Africa.

The peacock has a beautiful train of feathers that he displays during the breeding season. The feathers of the train are just in front of the bird's true tail feathers. Peafowl make harsh and sometimes startling cries at night. The calls are often mistaken for those of a person in trouble. Peafowl are omnivorous, eating fruits and seeds, insects, lizards, and small mammals.

See also OMNIVORE.



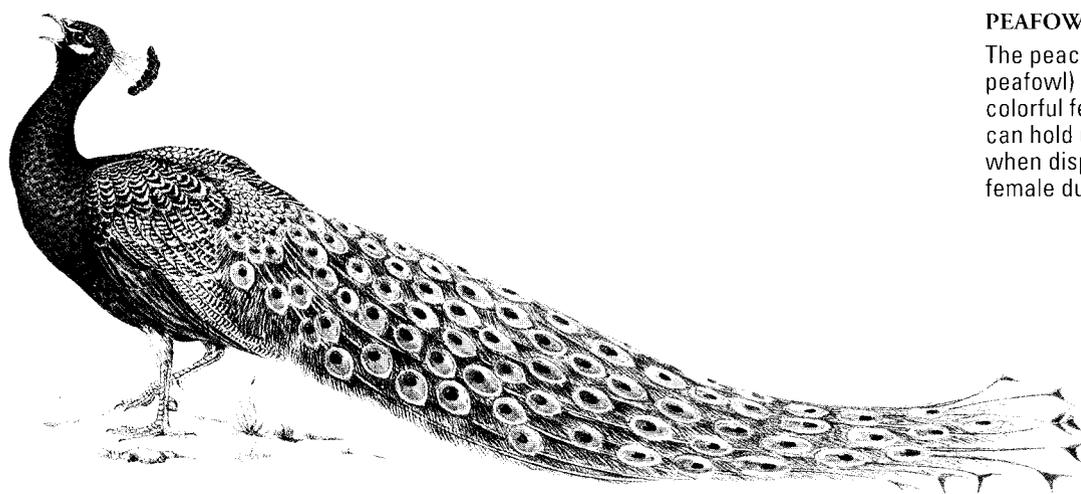
PEANUT

Farmers use machines to harvest peanuts (top). Most of the peanuts grown in the United States are made into peanut butter. They are also roasted and eaten. Peanut oil is used in cooking, as a lubricant, and as a base for making soap.

PEANUT The peanut is a low-growing, annual plant belonging to the pea family (see ANNUAL PLANT; PEA FAMILY). It originated in South America. The plant reaches a height of about 30 in. [75 cm] and a width of about 48 in. [120 cm]. The plant has many small yellow flowers which, when pollinated, die within a few hours (see POLLINATION).

PEAFOWL

The peacock (the male peafowl) has a long tail of colorful feathers that he can hold upright and fan out when displaying to the female during courtship.



When the flower dies, its pollinated pistil forms a little spike called a peg. Its stalk bends over and pushes the peg into the ground, sometimes to a depth of 3 in. [8 cm]. The peg then grows an underground legume or pod (see LEGUME). The legume usually contains two seeds, but it may contain as many as five. It is these seeds that are called peanuts. They are also called groundnuts.

The peanut is almost 50 percent oil. In most countries, peanuts are cultivated for this oil. It is a popular cooking oil, a lubricant, and a base for soap. Once the oil has been removed, the pulpy remains can be used as a high-protein feed for livestock.

Peanuts have more protein, minerals, and vitamins than meat. Most of the peanuts grown in the United States are processed into peanut butter. They also are roasted and eaten or cooked into a variety of foods.

See also CARVER, GEORGE WASHINGTON.

PEAR The pear is a tasty, fleshy fruit that grows on a large tree belonging to the rose family (see ROSE FAMILY). There are many cultivated varieties, but they are nearly all descended from the common pear, which grows wild in Europe and reaches



PEAR

Pears are a popular fruit that may be eaten fresh or canned. Pears may also be made into fruit drinks.

heights of about 60 ft. [18 m]. Some varieties are descended from the oriental pear, or from hybrids between it and the common pear (see HYBRID). Pears have oval leaves with toothed margins. White flowers grow in clusters of up to twelve blossoms, which are followed by cone-shaped fruits with a smooth skin that may be yellow, red, or brown in color. The pear has a central core with as many as ten seeds. The fruit itself contains many tiny, hardened structures called grit cells. These grit cells give the pear a slightly sandy texture.

More than 95 percent of the pears produced in the United States are grown along the west coast. Pears are eaten as fresh fruit. They also may be canned, dried, or processed into fruit drinks. Pears contain large amounts of carbohydrates, vitamins, and minerals. Their popularity in the United States is exceeded only by that of the apple and the peach.

PEARL The pearl is a gem that forms inside the shell of certain mollusks, especially oysters (see MOLLUSCA; OYSTER). The inner layer of a mollusk shell consists of a very smooth and shiny material called nacre or mother-of-pearl. The substance is a form of calcium carbonate. It is secreted (produced) by the outer skin of the animal. This outer skin is called the mantle. Grains of sand and other foreign bodies often get inside the shell and cause irritation. The animal then responds by secreting more nacre around the object and forming a little, shiny ball. This ball is the pearl.

Several kinds of mollusks make pearls. The pearl has the same luster and color as the lining of the shell of the mollusk that produced it. However, few mollusks make the good-quality nacre that is necessary to produce high-quality pearls. The most highly valued pearls come from a few species of oysters found in tropical seas. These oysters are called pearl oysters. Pearl formation in these animals is usually triggered by a tiny parasitic worm that burrows into the mantle.

Pearl oysters are collected by divers in some parts of the Pacific Ocean. Natural pearls are very valuable for use in jewelry. However, most pearls made into jewelry today are cultured pearls. These are obtained by placing little pieces of nacre inside the



PEARL

Small freshwater pearls (top) are produced by oysters that live in river estuaries. Cultured pearls (below) are produced by placing pieces of nacre in oysters kept in saltwater oyster beds. Both types of pearls are made into jewelry.

oysters and waiting for the pearls to grow. When the oyster is seven years old, its shell is opened. There is a valuable pearl in about one out of every twenty such oysters opened.

PEARY, ROBERT EDWIN (1856–1920)

Robert Edwin Peary was an explorer who led the first expedition to reach the North Pole. Peary was born in Cresson, Pennsylvania. He graduated from Bowdoin College in Maine. In 1881, Peary joined the U.S. Navy. He spent the next several years in Nicaragua, a country in Central America, surveying (measuring) land for a planned canal. The canal would join the Atlantic and Pacific oceans. This canal was later built through Panama, another country in Central America.

In the late 1880s, Peary made the first of several trips to the arctic region. Accompanied by explorer Matthew Henson, Peary traveled over Greenland, an island in the arctic region (see HENSON, MATTHEW). This trip took them farther into the arctic wilderness than people of European or African descent had been before. Peary returned to the arctic in 1891, accompanied by his wife and a doctor, Frederick Cook. This time, Peary and his group traveled to northeastern Greenland. He returned with proof that Greenland was, in fact, an island.

Peary began his attempts to reach the North Pole in 1893. He tried to establish routes to the pole both from Greenland and from Ellesmere Island, a Canadian island near Greenland. In 1905, he led an expedition that reached a latitude just beyond 87° north (see LATITUDE AND LONGITUDE). This was the closest that anyone had gotten to the North Pole. The expedition was forced back by harsh weather. In 1909, Peary set out on his third attempt to reach the North Pole. The expedition started with 24 men, 19 sleds, and 133 dogs. As supplies were used up, Peary sent the empty sleds back to the expedition's starting point. The party was gradually reduced to Peary, Henson, and four Eskimos. They reached the North Pole on April 6, 1909.

The doctor on Peary's 1891 expedition, Frederick Cook, said that he had reached the North Pole one year before Peary did. However, his claim was eventually disproved. The accuracy of Peary's claim of having reached the North Pole was investigated by the National Geographic Society in the late 1980s. In 1990, the society stated that photographs supported Peary's claim. Peary wrote several books about his expeditions, including *Northward Over the Great Ice*, *The North Pole*, and *Secrets of Polar Travel*. A portion of northern Greenland is named Peary Land in his honor.

PEAT Peat is partially decayed plant matter that has collected in marshes and swamps over a long period of time. It is generally the first stage in the formation of coal (see COAL). Dried peat is used mainly for fuel in places where coal and oil are scarce. It contains about 55 percent carbon,

compared with coal's 80 to 90 percent. Dried peat varies from a light yellow-brown substance resembling tangled hay to a denser mass of dark brown substance resembling brown coal.

Peat forms in layers. The upper layers contain the remains of plants that rotted and dried in the shallow, acidic waters of a marsh or swamp. The layers are compressed by the weight of the water and each other. The lower layers contain about 90 percent water and look like mud when first removed.

Peat is found throughout the world. The former Soviet Union, Canada, and Finland have the largest deposits of peat. In the United States, the largest peat deposits are in Minnesota. The Dismal Swamp in Virginia also has peat bogs (swamps). Workers dig and stack peat by hand in Ireland and some other countries. Large machines are generally used for this work in the United States, Canada, the former Soviet Union, and other European countries.

Peat is dried by simply exposing it to the air for a period of time. Dried peat is used as fuel to heat houses in Ireland. In Russia, it is used as fuel in some electric power plants. The dark peat also is used as a fertilizer. The fluffy, brown peat is used as a packing material. It is now regarded as a non-renewable resource, and industry is being encouraged to consider alternatives.



PEAT

In Ireland, peat is generally dug out of the ground by hand and piled into heaps to dry. It is used as a fuel to heat houses.

PECCARY (pĕk'ə rē) The peccary is a piglike mammal that lives in the forests and desert scrublands of Central and South America, Mexico, and the southwestern United States. Peccaries make up the family Tayassuidae and are distantly related to the true pigs (family Suidae).

There are three species of peccaries: the collared peccary, or javelina, which lives in South America and as far north as the United States; the white-lipped peccary, which is found in Mexico and Central and South America; and the tagua, or Chacoan peccary, which lives in Paraguay, Bolivia, and Argentina in South America.

Peccaries look like slender, active pigs. They can grow 30 in. [76 cm] tall and are covered with coarse, grizzled, blackish gray fur. Peccaries are rooting animals. They dig in the ground for roots to eat. They live in herds that can range in size from a few peccaries to several hundred. Peccaries are shy animals but fight viciously when cornered. The jaguar is their most dangerous natural enemy. Peccaries are hunted by people for their skin, which is used to make jackets and gloves.

PECTIN Pectin is a white substance found between the cell walls of many fruits. It is a complex carbohydrate made up of sugar molecules (see CARBOHYDRATE). Pectin forms a network of fibers when some fruits are cooked to be made into jelly. Pectin allows the fruit juices to jell, or thicken.

The amount of pectin in fruit depends upon the kind and ripeness of fruit. Some fruits are high in pectin. These include apples, blackberries, cranberries, gooseberries, loganberries, currants, and plums.

Commercial pectins are made by concentrating certain fruit juices. When jams are made from fruits low in natural pectin, commercial pectins are added. Peaches, pineapples, and strawberries are examples of fruits low in pectin.

PECTORALIS MAJOR (pĕk' tə rāl' ĩs mā' jər)

The pectoralis major is the large muscle that covers most of the front of the chest. It originates at the ribs, sternum (breastbone), and clavicle (collarbone). The pectoralis major extends across the chest and is attached by a tendon to the humerus

(the bone of the upper arm). The muscle is responsible for many of the arm's movements. It can pull the arm toward the side of the body or swing it forward in front of the chest.

The pectoralis minor is a smaller muscle that is underneath the pectoralis major. It originates at the ribs and is attached to the scapula (shoulder blade). This muscle is used to move the shoulder forward and downward.

See also BONE; MUSCLE; TENDON.

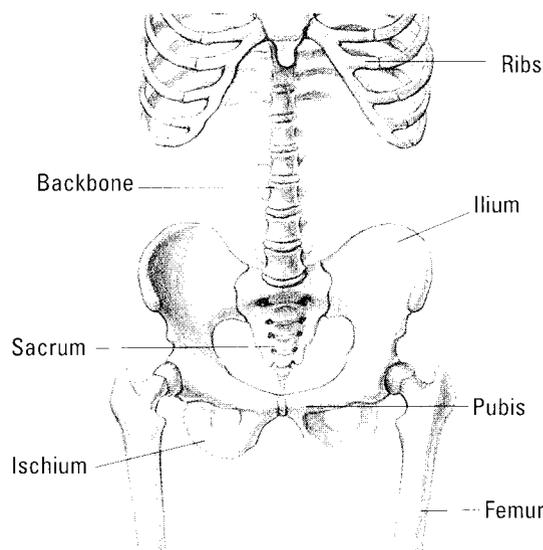
PELICAN The pelican is a large bird that belongs to the family Pelecanidae. There are seven species in the world, but only two species—the brown pelican and the American white pelican—are common in North America. The brown pelican lives along the seashores of western and southeastern North America. The American white pelican winters in those areas, but it nests beside freshwater lakes of western and central North America.

Pelicans grow about 45 in. [112 cm] long. They have webbed feet, a long neck, and a long, broad bill with an elastic pouch that is used to catch fish, the pelican's main food. Brown pelicans often dive from heights of 33 ft. [10 m] into the water to catch fish, but white pelicans fish while swimming on the surface.



PELICAN

The brown pelican lives on sea coasts of North America. It eats fish, which it catches by diving into the sea with closed wings.



PELVIS

The pelvis is attached to the lower end of the backbone by the sacrum. As a result, the pelvis supports the whole of the upper body. Ball-and-socket joints attach the pelvis to the femurs, the upper bones in the legs.

PELVIS The pelvis is a structure made of several bones that are fused together to support the lower abdomen and protect the internal organs. The pelvis has two halves called *ossa coxae*, or hipbones. Each hipbone is made up of three smaller bones: the ilium, ischium, and pubis. The hipbones are fused in front, and each side is attached to the sacrum (bottom bones of the spine) in the back (see VERTEBRAE). The ilium is the flat, blade-shaped bone that can be felt as the bone at the hip. The ischium supports the weight of the upper body when a person is sitting. The two pubis bones form an arch in front.

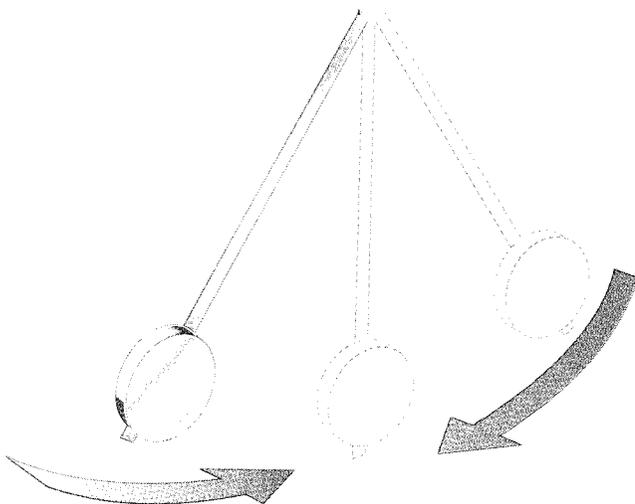
The spine, or backbone, rises from the top of the pelvis. The femurs (thighbones) are connected to the lower pelvis by ball-and-socket joints (see FEMUR; JOINT). These joints are very strong because they must support the weight of the upper part of the body when a person stands. There are many large, strong muscles leading from the pelvis to each femur.

A woman's pelvis is broader and more flared than a man's. This provides extra support during pregnancy for the uterus and the unborn baby. The central cavity of the pelvis is also larger in the woman so that the baby can pass through it during birth.

See also BONE; SKELETON.

PENDULUM A pendulum is a body that hangs from a fixed point and is free to swing. A simple pendulum consists of a heavy mass called a bob on the end of a lightweight cord or rod. If the cord or rod is not light, the pendulum is called a compound pendulum. If a pendulum is held to one side and released, it swings down to the vertical (straight up-and-down) position. It continues moving away from the vertical and slows down until it stops. It then swings back the other way. It stops when it reaches the point at which it was released. The cycle then starts again. This movement of the pendulum is called oscillation (see OSCILLATION). A single oscillation consists of the pendulum's movement from its point of release and back one time.

The time it takes to complete one oscillation is called the period of oscillation. For small oscillations, the period depends only on the length of the rod or cord. It does not depend on the mass of the bob, nor does it depend on the angle through which the pendulum swings (provided the angle of swing is small). For small swings, the time that it takes for a pendulum to complete each swing is the same. Because of this, pendulums are used for timing in clocks. Christiaan Huygens, a Dutch scientist, built the first clock with a pendulum in 1657. See also FOUCAULT PENDULUM.



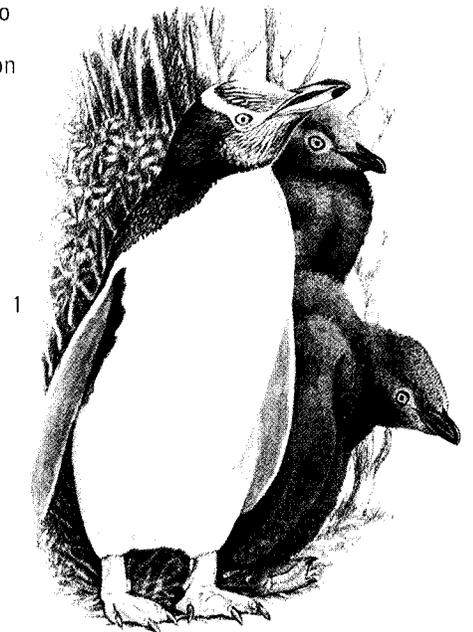
PENDULUM

The time a pendulum takes to make one complete oscillation (swing) depends only on its length, and not on the mass of the pendulum bob. The time is always the same, which is why early clockmakers used a pendulum to regulate clocks.

PENGUIN (pĕn'gwĭn) Penguins are eighteen species of seabirds that belong to the order Sphenisciformes. Their wings have evolved into flippers. As a result, they cannot fly, but they are excellent swimmers. All penguins live in the Southern Hemisphere, but only five species actually live in the Antarctic. The rest are scattered all around the coasts of the southern seas, but only where there are cold water currents. Some live as far

PENGUIN—Care of young

(1) A yellow-eyed penguin stands alongside two nearly full-grown chicks, which, like the young of many kinds of penguins, have brown plumage. (2) Rockhopper penguins, shown with a chick, are easy to recognize by the feathery crests on their heads.

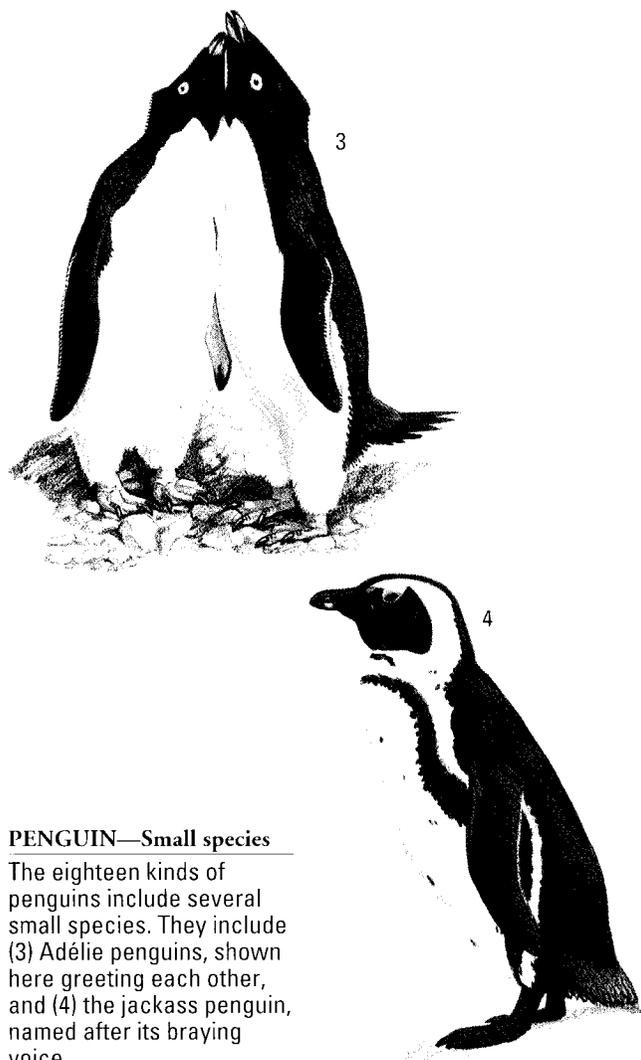


north as the Galápagos Islands, a group of Pacific Ocean islands near the equator. Penguin colonies are called rookeries. A single rookery may contain more than a million penguins.

All penguins walk in an upright position. Because they have stout bodies and such short legs, they walk with a waddling motion. A penguin's body is covered with a thick layer of short feathers that are white on the bird's belly and black or dark blue on its back. These feathers are waterproof and have tiny air spaces that help keep the bird warm. Penguins spend much of their time in icy waters, swimming or looking for food. Their diet consists mostly of fish and squid.

The emperor penguin is the largest penguin. It is about 4 ft. [1.2 m] tall. It breeds on the frozen continent of Antarctica—further south than any other penguin.

See also BIRD.



PENGUIN—Small species

The eighteen kinds of penguins include several small species. They include (3) Adélie penguins, shown here greeting each other, and (4) the jackass penguin, named after its braying voice.

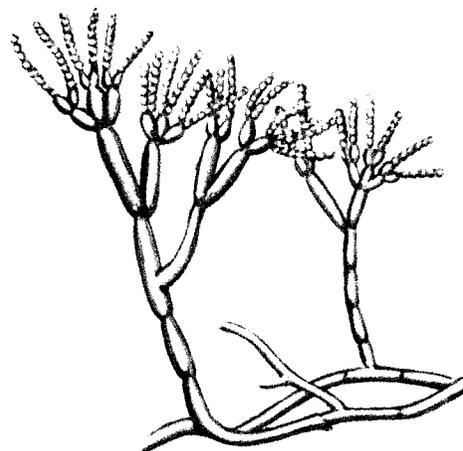
PENICILLIN (pĕn'ĩ sĭl'ĩn) Penicillin is a powerful antibiotic (see ANTIBIOTIC). It is made by molds belonging to the genus *Penicillium*. Penicillin was discovered in 1928 by Alexander Fleming. In 1940, Howard Florey and Ernst Chain purified penicillin for use in medicine (see FLEMING, SIR ALEXANDER; FLOREY, HOWARD WALTER; MOLD). The effectiveness of the drug caused an interest that led to the development of many drugs known as antibiotics.

At first, penicillin could be made only in small amounts. Later, a method was developed in which large amounts of the mold were grown in tanks. Soon, more productive strains of penicillin were found. The strains used by manufacturers today produce almost five thousand times as much penicillin as those first used by researchers. Hundreds of tons of penicillin are made every year in the United States.

Not all harmful microorganisms are destroyed by penicillin. However, most of the bacteria that cause common infections, such as *Streptococcus* and *Staphylococcus*, are very sensitive to penicillin (see BACTERIA; MICROORGANISM).

Penicillin is the least poisonous antibiotic available, though a few people are allergic to it. For these people, even a tiny amount of the drug can cause a serious reaction (see ALLERGY).

Many bacteria are resistant—that is, they can grow even when an antibiotic is present. For example, though the proper dosage of penicillin will kill most *Staphylococci*, some strains resist penicillin and require different antibiotics for treatment.



PENICILLIN

A magnified part of a *Penicillium* mold colony shows the spores (the green circular structures) that reproduce the mold.

PENNSYLVANIAN PERIOD The Pennsylvanian period is the division of the Paleozoic era in the earth's history that began about 323 million years ago. It lasted about 33 million years and is the second half of the Carboniferous period (see CARBONIFEROUS PERIOD; PALEOZOIC ERA).

In North America today, rocks of the Pennsylvanian period contain vast amounts of coal, natural gas, and petroleum (oil). This is because during the Pennsylvanian period, forests of huge ferns grew in the swampy soil. Over time, these plants died and decayed, and layers of soil and rock piled on top of them. After many years, the decayed plants were pressed into coal, petroleum, or natural gas (see COAL; NATURAL GAS; PETROLEUM).

During the Pennsylvanian period, hundreds of insect species, including giant cockroaches, thrived. Amphibians and sea life flourished. Reptiles developed during the Pennsylvanian period.

See also GEOLOGICAL TIME SCALE.

PEONY (pē'ə nē) The peony is a plant with large, attractive flowers. Peonies are shrubs or herbaceous plants making up the peony family, Paeoniaceae. The cluster of leafy shoots—red and bright green in appearance—creates a striking effect a few weeks before the flowers appear in late spring or early



PEONY

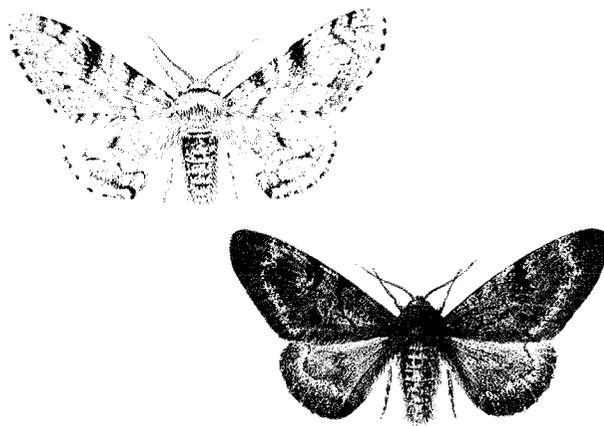
The peony plant blooms with large, beautiful flowers in late spring or early summer. The blossoms are usually white, pink, or red and may be sweetly scented.

summer. The flower blossoms are usually white, pink, or red, and many are sweetly scented. Peonies grow 3 to 4 ft. [90 to 120 cm] high. They are found throughout the world.

Many of the cultivated peonies found in the United States are offspring of two species—the common peony of southern Europe and the Chinese peony. Peonies are hardy plants that live a long time.

See also PERENNIAL PLANT.

PEPPERED MOTH The peppered moth is a European moth that became well known during the twentieth century because it played a central role in studies of evolution and natural selection (see EVOLUTION; NATURAL SELECTION). The moth exists in several forms, but two are of particular interest. One is the normal, or speckled, form, which has white wings with black spots. The other is the black, or melanic, form, which has jet-black wings. The black form was first discovered in the north of England in the middle of the nineteenth century, although it probably existed in small numbers before that time.



PEPPERED MOTH

The light speckled form of the peppered moth (top) became outnumbered by the less conspicuous black form (bottom) when air pollution blackened the bark of trees where the moths rested.

The moths rest on fences, walls, and tree trunks, where the speckled form was originally well camouflaged. But the black moths would have been spotted and eaten by birds before people noticed them. During the Industrial Revolution, soot from the factories began to blacken walls and tree trunks,

giving the black moths an advantage. They were quite well hidden, and it was the speckled moths that were seen and eaten by the birds. As a result, more black moths than speckled moths survived to reproduce. The peppered moth population began to change quite rapidly in industrial areas, with the original speckled form being replaced by the black one. Air pollution helped the spread of the black form, although it did not actually cause the moths to turn black. Now that air pollution is being controlled and trees and buildings are cleaner, the change is being reversed, and the speckled moths are becoming more common again.

The peppered moth belongs to the geometer family. The caterpillars are known as inchworms or loopers, because they move by stretching forward at the front and then arching the body in a big loop as they bring their rear legs up toward the front ones. The caterpillars of the peppered moth feed on a wide range of trees and shrubs.

PEPPER FAMILY The pepper family, Piperaceae, includes ten genera (plural of *genus*) with more than 1,500 species of dicotyledonous flowering plants (see DICOTYLEDON). The family includes herbaceous plants, shrubs, vines, and trees, most of which grow in tropical areas (see HERBACEOUS PLANT). They have simple leaves. The flowers do not have sepals or petals. They grow in dense spikes (see INFLORESCENCE; LEAF). Most of the plants are monoecious, with both male flowers and female flowers on the same plant.

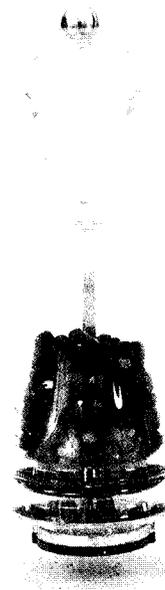
The most important member of the pepper family is the black pepper plant. It is a perennial climbing plant that produces aerial roots (see PERENNIAL PLANT; ROOT). It may reach a length of 33 ft. [10 m]. It produces small berries called peppercorns that turn from green to red as they mature. The peppercorns are usually harvested at maturity, cleaned, and dried. The peppercorns become black as they dry. They can then be ground, sifted, and sold as the spice called black pepper. White pepper comes from the same plant, but the husk is removed from the peppercorn before it is ground.

Red peppers, such as paprika and cayenne pepper, and garden peppers come from plants



PEPPER FAMILY

For commercial production (above), pepper vines are grown on posts on plantations. The dried berries of the plants are the familiar black peppercorns (right), which are ground to produce a hot, spicy flavoring for food.



belonging to genus *Capsicum* of the nightshade family (see NIGHTSHADE FAMILY). They are not related to the pepper family.

PERCENT Percent is a rate or proportion per hundred. It comes from the Latin phrase *per centum*, meaning "by the hundred." For example, the statement "Thirty percent of the students at this school are wearing red sweaters" means that out of every 100 students in the school, 30 of them are wearing red sweaters. In other words, 30 hundredths of the students are wearing red sweaters. Hundredths may be expressed as common fractions, such as $\frac{30}{100}$; as decimal fractions, 0.30; or as percent, 30 percent. Each of these figures represents a ratio of 30 compared to 100. The symbol for percent is %.

Numbers greater than a whole ($^{100}/_{100}$) also can be expressed as percents. To say some thing has increased to 300 percent means it is three times as large as it was.

To change a decimal fraction to a percent, the decimal fraction is multiplied by 100. This is done by moving the decimal point two places to the right and adding the percent sign. For example, $0.25 = 25\%$, $0.50 = 50\%$, and $0.4782 = 47.82\%$. To change a common fraction to a percent, the common fraction is first changed to a decimal fraction. For example, $1/10 = 0.10 = 10\%$.

Such operations can be reversed. For example, $50\% = 0.50 = 1/2$. The percent is divided by 100 by moving the decimal point two places to the left and dropping the percent sign. The decimal fraction may then be changed to a common fraction.

Percents are used in everyday life. Bankers use percents to figure interest on savings accounts. In baseball, team standings and batting averages are based on percents. Scientists often show the results of their observations and experiments with percents.

See also FRACTION; RATIO.

PERCEPTION Perception is the process by which a person or animal makes sense out of the things in its environment. The world consists of various kinds of physical energy. Knowledge of the world comes through the sense organs. For example, the ears sense certain types of mechanical vibrations (sound) in the air. The eyes sense certain wavelengths of electromagnetic energy (light) (see EAR; EYE AND VISION; SENSE).

The sense organs change the various kinds of energy into nerve impulses. These impulses go to the brain (see NERVOUS SYSTEM). Through the process of perception, the patterns of energies become known as objects and events. In this process, the sense organs and the brain transform physical energy into information.

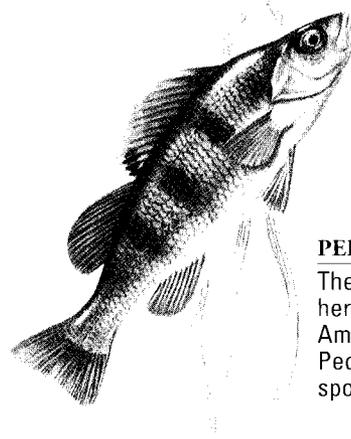
There are three different levels of perception: detection, recognition, and discrimination. Detection is the ability to sense that one is being stimulated by some form of energy. Recognition is being able to identify a particular pattern of

stimulation, such as being able to tell that a particular sound is a tone from a piano. Discrimination is being able to perceive patterns of stimulation as different, such as differences between two similar musical tones.

See also OPTICAL ILLUSION; PSYCHOLOGY.

PERCH A perch is a freshwater fish that belongs to the family Percidae. North American fish included in the perch family are the darters, wall-eye, and yellow perch. The yellow perch is very common in lakes and rivers throughout North America. It often is called simply a perch. The yellow perch ranges between 7 and 16 in. [18 and 40 cm] in length. Its body is green along the top and yellowish on the belly and has orange stripes on the sides. The yellow perch is a popular game and food fish.

Many other fish are called perch, but none of them is a true perch. For example, the white perch is actually a bass (see BASS). There is a family of salt-water fish in North America known as the surf-perches.



PERCH

The yellow perch, pictured here, is common in North American fresh waters. People fish for perch for sport and for food.

PERCHING BIRD Perching birds, or passerine birds, belong to the order Passeriformes. A perching bird has feet that are able to grip a twig or branch in much the same way that a human hand would grasp a branch. The feet of the bird have three toes in front and one toe in back.

Nearly half of all known birds are perching birds. These include all of the songbirds, flycatchers, swallows, crows, warblers, finches, blackbirds, and many more.

See also BIRD.

PERENNIAL PLANT A perennial (pə rĕn'ē əl) plant is any plant that lives for more than two years. Examples of perennial plants include such herbaceous plants as asparagus and rhubarb and all woody plants (see HERBACEOUS PLANT; WOODY PLANT). The leaves and stems of most herbaceous perennial plants, such as asparagus, die off every fall, but they have perennial roots from which new stems grow in the spring. Some plants that are perennial in one climate may be annual in another.

See also ANNUAL PLANT; BIENNIAL PLANT.

PERIANTH (pĕr'ē ānth') The perianth is the calyx and the corolla of a flower. The calyx is made up of the sepals, which are petallike structures around the base of the flower (see CALYX). The corolla is made up of the petals. Sometimes, either the sepals or the petals, or both, may be missing. In the grasses, the perianth is reduced to two tiny scales called lodicules.

See also FLOWER; GRASS.

PERIHELION (pĕr' ə hĕ' lĕ ən) Most of the orbits of planets and comets around the sun are elliptical, or shaped like an oval. The distance of the planet or comet from the sun varies. The nearest point of the orbit of a planet or comet to the sun is called the perihelion; the farthest point from the sun is called the aphelion. For example, the earth is $91\frac{1}{2}$ million mi. [147 million km] from the sun at

its perihelion. Halley's comet is 55 million mi. [88 million km] at its perihelion.

See also ELLIPSE; ORBIT.

PERIOD A period is a unit of the geological time scale (see GEOLOGICAL TIME SCALE). The geological time scale outlines the development of the earth and life on it. The history of the earth is divided into four eras. From oldest to most recent, they are the Precambrian, Paleozoic, Mesozoic, and Cenozoic eras. All the eras except the Precambrian are further divided into periods. The two periods of the Cenozoic era are further divided into seven epochs.

It is convenient to think of the earth's history in terms of periods, as this does away with the confusingly long numbers when we think of it in millions of years. Each period is defined by the kinds of fossils in the rocks formed at the time. For example, the Devonian period is the time that the first forests grew on land, and the time that amphibians first evolved.

PERIODIC MOTION Periodic motion is any motion that repeats itself in a regular way. A pendulum provides a good example of periodic motion. The pendulum is said to oscillate, or swing back and forth, about its vertical, or resting, position. The time taken for the pendulum to make one complete cycle is called the period of oscillation or of motion (see OSCILLATION; PENDULUM). Other examples of periodic motion are the



PERIODIC MOTION

The strings of musical instruments such as guitars and the members of the violin family vibrate with periodic motion when plucked or bowed. The vibrations of the strings produce musical sounds.

movements of pistons in an automobile engine and the balance wheel of a watch, the vibration of a guitar or violin string, and the human pulse. Galileo is said to have used his pulse as a timing device in his studies of the motion of falling bodies.

See also GALILEO; SIMPLE HARMONIC MOTION.

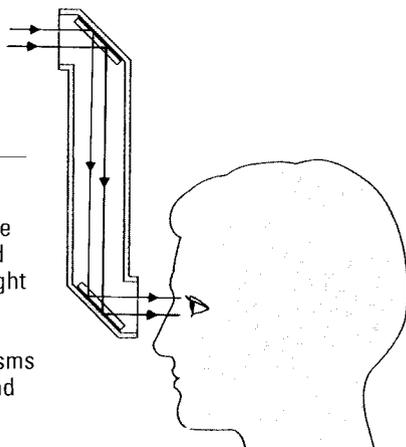
PERISCOPE A periscope is an optical instrument with which a person can see around corners and other obstructions. Some periscopes also have a magnifying feature that makes distant objects appear to be closer. A periscope is somewhat similar to a telescope. Basically, it consists of a long tube with a reflecting mirror or prism at each end. The reflecting surfaces are parallel to one another. They are arranged at an angle of 45 degrees inside the tube (see MIRROR; PRISM; TELESCOPE).

Periscopes are important instruments in submarines and tanks. People aboard a submerged submarine can see events on the surface by looking through a periscope. A submarine's periscope can move up and down and turn to look in a complete circle. Submarines often cruise at what is called periscope depth with only the top of the periscope showing above the surface of the water. Periscopes also allow people in tanks to view battlefield events from inside their armored vehicles.

Periscopes have other uses, too. Simple periscopes made of cardboard are used by some people in large crowds at parades and sporting events. They help the users see over the heads of the people in front of them. Periscopes are also used in industry to observe nuclear reactions and the interiors of

PERISCOPE

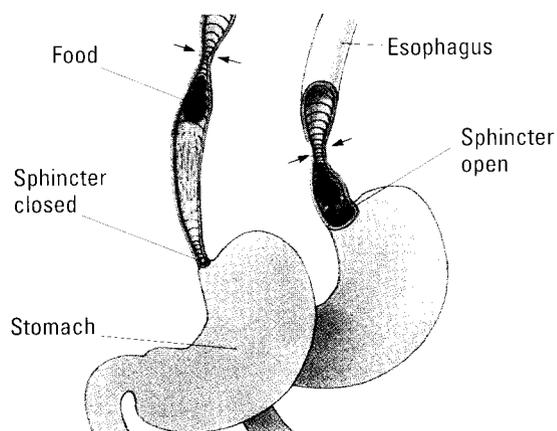
A periscope allows people to see over obstructions. A simple periscope has angled mirrors that reflect light along a vertical tube. More complex instruments have prisms instead of mirrors, and lenses to form a magnified image.



special furnaces and other dangerous devices. The longest periscope in the world measures 90 ft. [27 m]. Located at the National Reactor Testing Station in Idaho Falls, Idaho, it is used to view details of the operation of nuclear reactors.

PERISTALSIS (pě-rĭ stōl'sis) Peristalsis is a special kind of muscle movement that happens in the alimentary canal, also known as the digestive system (see DIGESTIVE SYSTEM). The muscles in the walls of the esophagus, stomach, and intestines squeeze food along the alimentary canal. This squeezing movement is called peristalsis. Long muscles and circular muscles work together to make waves of movement. These muscles are smooth muscles, and we do not have voluntary control of them. Most of the time, we are not aware of their action.

See also ALIMENTARY CANAL; DIGESTION; MUSCLE.



PERISTALSIS

Peristalsis is a wave of muscle contraction that squeezes food along the digestive tract. When food from the esophagus reaches the stomach, a circular sphincter muscle opens to allow the food to enter the stomach.

PERMAFROST Permafrost is a layer of frozen soil (see SOIL). Near the earth's North and South poles, permafrost may be as deep as 5,000 ft. [1,524 m]. Permafrost forms in places where the average yearly temperature is 32°F [0°C] or lower. About 25 percent of the earth's land surface is covered with permafrost, including about 85 percent of Alaska in the United States, 50 percent of Canada and the former Soviet Union, and all of Antarctica. Most permafrost is covered with ice or

snow year-round. However, in the warmest areas, the thin top layer may thaw (unfreeze) in the summer.

Permafrost is often not a very sound base for buildings. Such activities as drilling, mining, and constructing roads that occur near buildings built on permafrost can damage permafrost's ability to bear the buildings' weight. Also, the heat of buildings may thaw permafrost, causing buildings to sink up to 1 ft. [0.3 m] or more.

PERMIAN PERIOD (pûr'mē ən pîr'ē əd) The Permian period is the time in the earth's history that began about 290 million years ago and lasted about 45 million years. It is the last division of the Paleozoic era (see PALEOZOIC ERA).

At the beginning of the Permian period, the southern continents were mostly covered with ice. At the same time, the climate of northern continents remained warm and dry. Significant effects of continental drift are thought to have occurred during the Permian period (see CONTINENTAL DRIFT).

Conifers, the first seed plants, appeared during the Permian period. Fish, amphibians, and reptiles flourished. In the oceans, there were many ammonites and brachiopods. Trilobites died out (see AMMONITE; BRACHIOPOD; TRILOBITE).

Sedimentary rock containing copper formed during this time in parts of Texas and Oklahoma in the United States and in Germany (see SEDIMENTARY ROCK). Great folding also occurred at this time during the formation of the Ural Mountains in western Russia and the Appalachian Mountains in the eastern United States.

See also FOLDING; GEOLOGICAL TIME SCALE.

PERPETUAL MOTION (pər pēch'ōō əl mō'shən) Perpetual motion is motion that goes on forever. Throughout history, people have tried to build perpetual motion machines. These machines were supposed to operate indefinitely. However, all attempts at making such machines have failed.

By the 1850s, scientists had discovered two reasons why perpetual motion machines cannot be invented. These reasons are embodied in two very important laws of physics: the first and second laws of thermodynamics (see THERMODYNAMICS). The first law of thermodynamics says that energy can be neither created nor destroyed. This law is also called the law of conservation of energy (see ENERGY). A perpetual motion machine that attempts to break this law is called a perpetual motion machine of the first kind. One example

PERMIAN PERIOD

This is a view of the Shenandoah Valley in the Appalachian mountain range of the eastern United States. The Appalachians formed during the Permian period.



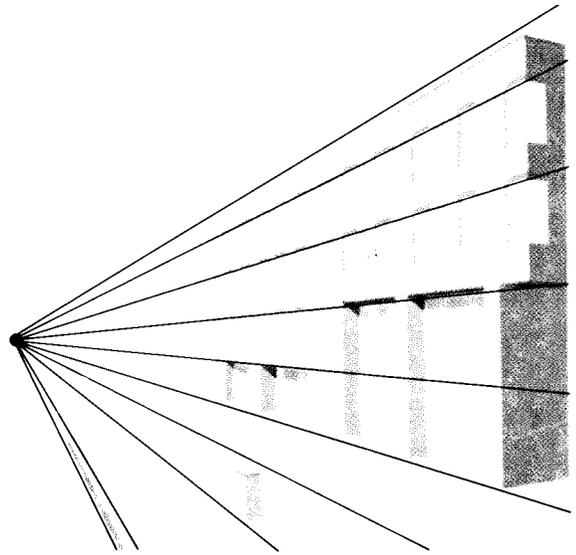
consists of a wheel with spokes. Each spoke has a ball that can move along it between the rim and the hub. When the spoke is near the bottom of the wheel, the ball can fall to the rim of the wheel. As the wheel keeps turning, the ball should fall back to the hub (middle of the wheel). When the wheel moves around a little more, the ball should fall back to the rim again. The force of it hitting the rim is supposed to keep the wheel turning. However, the ball loses energy as it hits the rim, and friction occurs as the ball rolls down the spoke (see **FRIC-TION**). The wheel soon stops.

The second law of thermodynamics states that heat cannot flow from a colder body to a hotter one without adding more energy than is produced. Perpetual motion machines that do not work because they break the second law of thermodynamics are called perpetual motion machines of the second kind. Machines that attempt to turn heat into other forms of energy with complete efficiency violate this law (see **EFFICIENCY**).

Recently, experiments in superconductivity have come close to achieving perpetual motion. In superconductivity, certain substances lose their electrical resistance at very low temperatures (see **SUPERCONDUCTIVITY**). This means that an electric current can flow through the substance forever. However, energy is needed to keep the substance cold. For this reason, machines that employ superconductivity do not qualify as perpetual motion machines.

PERSPECTIVE Perspective is a way of showing a solid object on flat paper. A solid object has three dimensions: length, width, and depth. A surface, such as the top of a piece of paper, has only two dimensions. The third dimension of an object is represented by perspective.

Any object appears to become smaller as we move away from it. This is called linear perspective. For example, the farther side of a cube seems smaller than the nearer side. The two lines that join the two sides do not seem parallel. They are said to converge (come together) at a point on the horizon. This point is called the vanishing point. Artists use the vanishing point to show perspective in drawings.



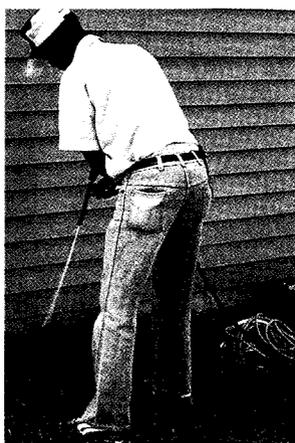
PERSPECTIVE

A perspective drawing is one in which everything appears at the size it would be if viewed in depth by an observer. To give the impression of depth in this picture, the artist selects a point on the horizon where the lines of the building converge—the vanishing point. If the artist added other buildings to the drawing, their vanishing points might be different.

PESTICIDE (pěs'tī sīd') A pesticide is a chemical that is used to kill pests. A pest may be an animal, plant, protozoan, fungus, bacterium, alga, or virus. Some pests spread disease. Others eat or cause other damage to crops and other desirable plants. Some pests are parasites that harm livestock, pets, and human beings (see **PARASITE**).

Pesticides that kill insects are called insecticides (see **INSECTICIDE**). Pesticides that kill fungi (plural of *fungus*) are called fungicides (see **FUNGICIDE**). Pesticides that kill weeds or other plants are called herbicides (see **HERBICIDE**). Rats and other rodent pests are often controlled with anticoagulants. These chemicals keep the rodent's blood from clotting so that the animal bleeds to death from even the tiniest scratch. Pheromones are also used as pesticides. Pheromones are chemicals that are used to attract pests, such as by scent, into a trap, where the pests are captured or killed (see **PEROMONE**). Various poisons have been used to control pests. However, these poisons often have affected other organisms as well, including humans. Scientists are constantly working on new chemicals that will affect only specific, targeted pests.

Because they are poisonous, pesticides must be handled very carefully. It is important to dispose of



PESTICIDE

Farmers use chemical pesticides to kill pests that harm crops. Often the chemicals are sprayed from a low-flying airplane (above). Pesticides also are frequently used around houses (left) to kill such pests as ants, roaches, and termites.

pesticide containers properly, such as at a hazardous waste collection center. The containers should not be rinsed and reused. Rinsing allows the pesticide to enter the sewer system. Also, some pesticide may remain in the container even after rinsing.

The use of pesticides in agriculture has been criticized because residues (traces) of pesticide may remain on crops that are later eaten by humans (see AGRICULTURE). Some pesticide may seep into groundwater or be washed by rain into bodies of water (see GROUNDWATER). This is dangerous to humans and other animals because this water may be used as drinking water.

Some pesticides are short lasting. This means they remain poisonous just long enough to kill the pest. However, some pesticides remain poisonous for years. They may be passed along in the food chain, becoming more concentrated—and thus, more harmful—as they do so (see FOOD CHAIN).

In many cases, a pest becomes resistant to a certain pesticide after repeated exposure. This means that the pesticide can no longer kill the pest. For example, some rats and boll weevils have become

resistant to certain pesticides. When this happens, the pest population may increase rapidly, often becoming a greater problem than before.

Because of these concerns, many farmers have started using a system called integrated pest management (IPM). In IPM, a variety of methods are used to control pests, so pesticide use is decreased. One of these methods is called biological control. In biological control, natural enemies are used to fight off pests.

See also BIOLOGICAL CONTROL.

PETAL The petal is the part of a flower that is usually brightly colored and leaflike in shape. Its main function is to attract insects and birds to the flower for pollination (see POLLINATION). Most monocotyledons have petals in multiples of three. Most dicotyledons have petals in multiples of four or five (see DICOTYLEDON; MONOCOTYLEDON). In many flowers, known as regular flowers, the petals all look alike, but some flowers have petals with several different shapes or sizes. These are called irregular flowers. Sometimes, the petals may be fused to form a cup or tube.

See also FLOWER; MIMICRY.

 PROJECT 61



PETAL

Autumn crocuses have tube-shaped flowers, each with six pale pink petals.

**PETREL**

The storm-petrel got its name from its habit of sheltering alongside ships during stormy weather.

PETREL (pĕt'ŕəl) Petrels are small seabirds that belong to the order Procellariiformes. There are several species of petrels found off the coasts of North America.

Petrels are long-winged, strong-flying birds. They are usually brown and white. All petrels have tube-like nostrils on the top of the beak. Petrels eat fish, shrimp, and microscopic organisms called plankton. The group of petrels known as storm-petrels often follow ships at sea, eating wastes that are thrown overboard.

See also BIRD.

PETRIFIED FOREST A petrified (pĕt'ŕə fĭd') forest is a forest of trees that have been fossilized (see FOSSIL). The fossilization process usually begins when the plants are rapidly buried by volcanic ash, mud, or sand. Water containing minerals seeps through the debris into the buried plants. There, the silica or calcium carbonate in the water replaces the decaying plant cells. The result is an exact duplicate of the original plant. Plants fossilized in this way are sometimes the only record of species that flourished on Earth for a very short period of time.

In a petrified forest, the trees are no longer standing. Instead, many petrified logs lie in scattered positions. They have been disturbed by erosion (see EROSION). The Petrified Forest National Park in Arizona contains the largest and most colorful collection of petrified plants in the world. The trees probably grew about 210 million years ago. Other petrified forests in the United States are found in New York and Wyoming.

See also PALEOBOTANY.

PETRIFIED FOREST

Petrified Forest National Park in Arizona contains the world's most famous collection of fossilized wood. The trees there grew about 210 million years ago. After they died, they were transformed into colorful rocky fossils.



PETROLEUM

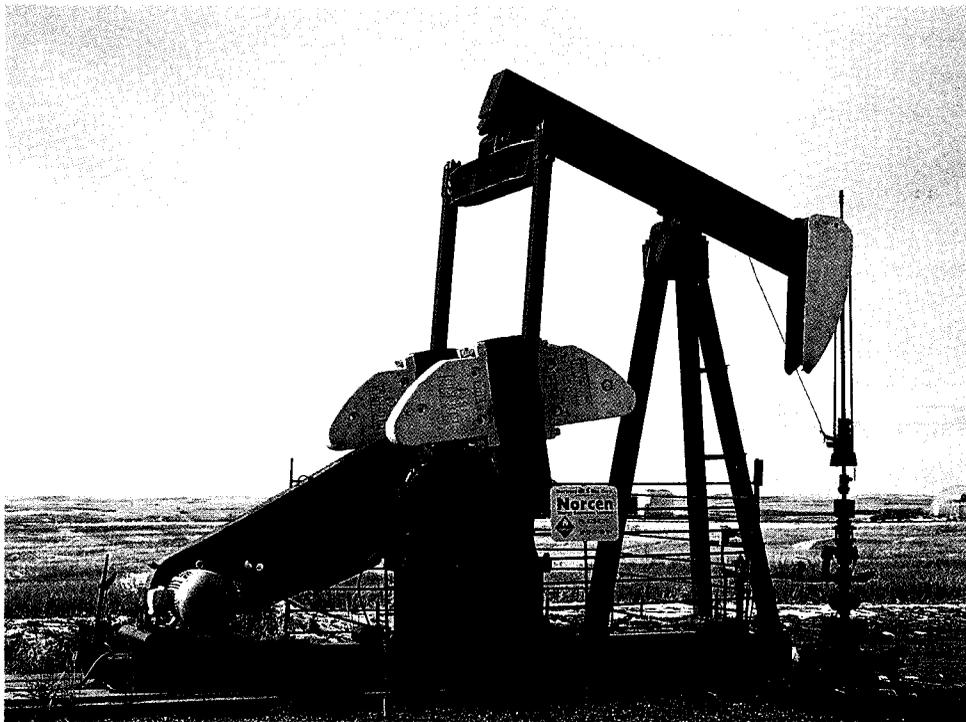
Petroleum is a thick, black liquid usually found saturating rocks beneath the earth's surface. It is one of the most valuable substances found in the earth's crust. Petroleum consists of a mixture of oils from which gasoline, fuel oils, lubricating oils, and other substances are produced. Petroleum is sometimes called "black gold" because it is so valuable to human beings. Petroleum directly from the earth is also referred to as crude oil.

Formation of petroleum The word *petroleum*, meaning "rock oil," comes from the Greek. Petroleum formed from the decayed remains of organisms that lived in shallow seas millions of years ago. These remains were buried in clay or silt brought down by rivers and were decomposed into simple hydrocarbons by bacteria (see **DECOMPOSITION**). Eventually, the clay or silt were buried and enclosed by permeable rocks (porous rocks through which liquids can flow), such as sandstone or limestone. The pressure of these rocks turned the clay or silt into another kind of rock called shale. The simple compounds were changed by pressure into long-chain hydrocarbon oils (see **COMPOUND**; **HYDROCARBON**; **SHALE**). The oil was squeezed out

of the shale and flowed into the permeable rocks. Experts believe that the differences between one kind of petroleum and another come from differences in temperature, pressure, and other conditions, instead of differences in the living creatures from which they were formed.

Where petroleum is found For petroleum to be extracted (removed), it must have collected in reservoirs in the earth's crust. Also, the permeable rocks in which it collected must have been sealed to prevent the petroleum from leaking away. Oil floats on water, and, usually, collects in structures that are sealed on top. The impermeable cap rock that seals an underground reservoir of petroleum is usually shale or rock salt (see **ROCK SALT**).

The most common reservoir for petroleum is an anticline. This is an upfold of rocks that forms an underground dome or ridge (see **ANTICLINE**). Another structure where petroleum is sometimes found is a salt dome. A salt dome is a body of salt that has been forced up, breaking apart and tilting the layers of rock below it and raising those above it into a dome. Petroleum collects in the rocks above the salt dome.



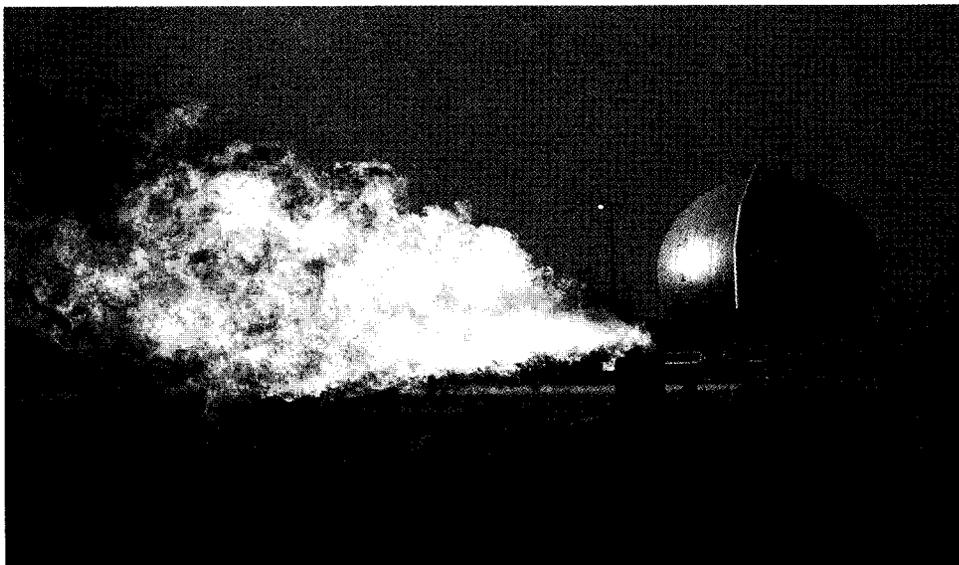
OIL WELL PUMP

Where the underground deposit of petroleum is not under pressure, it is removed using pumps like this one in Alberta, Canada. The shape and action of the pump gave it the nickname of "nodding donkey."



Another type of reservoir can occur when rocks are tilted and then faulted, so that an impermeable shale or other kind of rock is brought next to the permeable one (see **FAULT**). In this way, the oil is sealed on the underside of the fault.

Prospecting for petroleum Possible reservoirs containing petroleum are found by geologists and geophysicists (see **GEOLOGY**; **GEOPHYSICS**). Geologists study surface rocks and map their findings. This increases their knowledge about the structures beneath the ground. The structures can be measured more accurately by geophysicists, who use the principles of seismology (see **SEISMOLOGY**). Seismological methods involve making small explosions in the ground and measuring the



shock waves that pass through the earth's crust. The shock waves are deflected at boundaries between different types of rock. The type and structure of the rock can be established by noting the time the shock waves take to travel to various places around the explosion.

Another method of prospecting for petroleum involves measuring the force of gravity at various

OIL PIPELINE

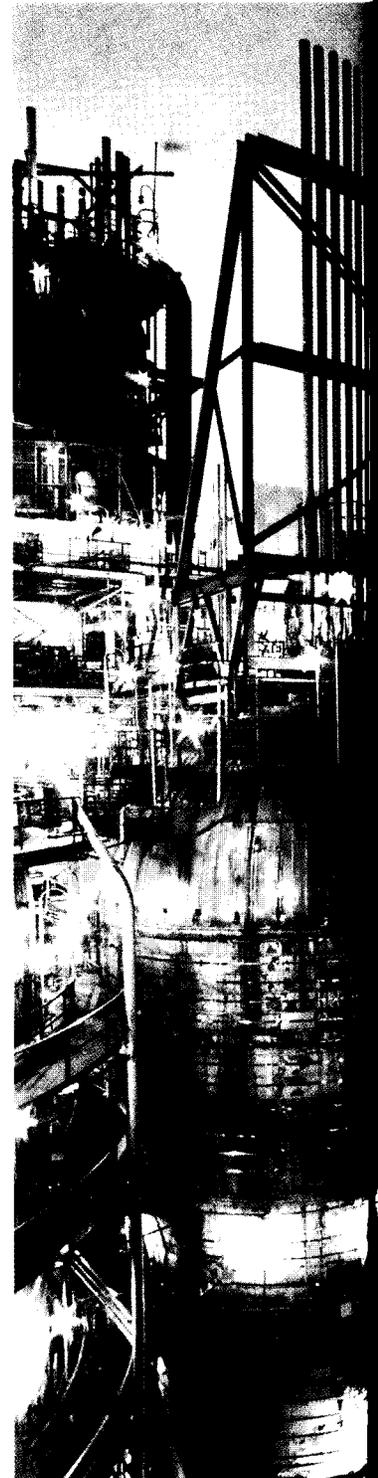
Petroleum from an oil well or offshore drilling rig is usually pumped to an oil refinery along underground pipes, seen here (left) being laid in a trench.

OIL REFINERY

The key equipment in an oil refinery (right) is the fractionating column. This is a tall tower inside which hot petroleum is separated into its various component substances by a distillation process.

BURNING OFF GAS

At refineries where there is no use for light gases such as methane, they are burned off. The refinery shown (below) is in Saudi Arabia.



places. For example, when a salt dome lies beneath the earth's surface, the force of gravity at the surface is slightly reduced (see GRAVITY).

Despite these sophisticated methods, geophysicists can establish only that a reservoir of petroleum may exist. The only way to find out whether the reservoir actually contains petroleum is to drill a hole (see PROSPECTING).



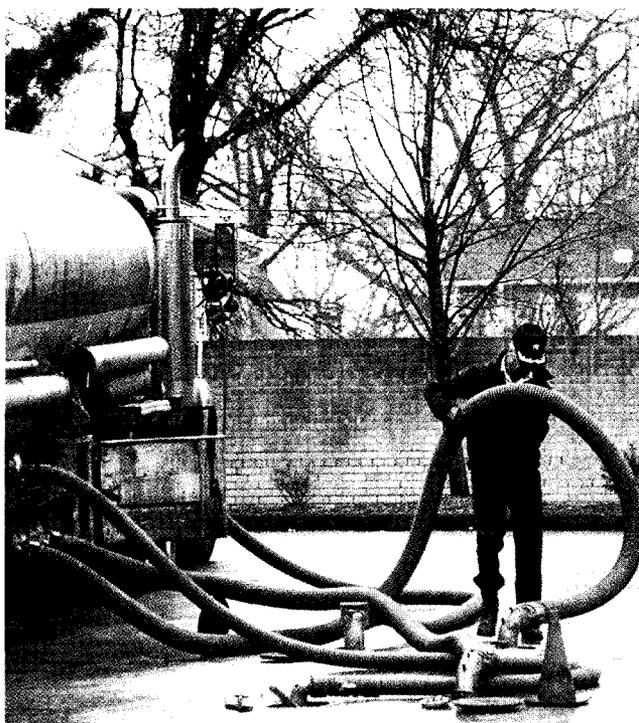
Extracting petroleum Early uses for petroleum included lighting, treating roads, waterproofing, and medicine. In those times, people did not drill for oil but used the oils that leaked naturally out of the surface of the earth. Later, they drilled shallow holes by hand. The first mechanical drilling for oil was done by Edwin Drake in Pennsylvania in 1859. He used a steam engine. Early drilling was done by percussion (breaking up the rock by hammering).

Much drilling today is performed with a rotating (turning) shaft. Different types of bits (the drilling mechanism at the end of the shaft) are used, depending on the hardness of the rock that has to be drilled through (see DRILLING; OIL RIG). The bits break the rocks to fragments, which are washed out with water and soft clay. When geologists want to study the rocks being drilled, a coring bit is used. Coring bits have diamonds around the edges to cut through the rock. They also have a hollow center to hold the core. The core is removed occasionally for examination.

Usually, petroleum is found floating on salty water. Often a layer of natural gas is found on top of the petroleum. This natural gas consists mostly of methane (see METHANE; NATURAL GAS). Often, it is the only useful substance obtained from drilling. Petroleum may be absent or nearly so.

If a reservoir is found, it may be under great pressure. When the drilling reaches the reservoir, the petroleum may burst out in what is called a gusher. Gushers are prevented whenever possible because they are wasteful and cause pollution.

When the pressure falls, petroleum is pumped out of the reservoir. The final stage is to flush out any remaining oil with water. Still, one-fifth to more than one-half of the petroleum may be left behind. It clings to the walls of small holes in the rock. The amount left behind depends on the size of the holes. The smaller the hole, the more petroleum is lost. Since World War II (1939–1945), offshore drilling, or drilling below the ocean floor off the coast, has proved very productive. Most offshore drilling in the United States is done in the Pacific Ocean off the coast of California and in the Gulf of Mexico off the coasts of Louisiana and Texas.



GASOLINE DELIVERY

One of the chief products from petroleum is gasoline. Large tanker trucks deliver gasoline to service stations. The service stations, in turn, supply the gasoline to automobiles and other motorized vehicles.

After the petroleum has been taken out, it is taken by pipeline, truck, rail, or ship to a refinery. There, the petroleum is separated and changed into a number of useful products.

Chemistry of petroleum Petroleum consists of compounds of carbon and hydrogen, called hydrocarbons (see HYDROCARBON). Petroleum also contains small amounts of oxygen, nitrogen, and sulfur. The main compounds of petroleum are paraffins. These compounds have carbon atoms joined into chains by single bonds. Petroleum usually has small amounts of olefins. Olefins are like the paraffins except that some of the carbon atoms have two bonds between them and, therefore, fewer hydrogen atoms (see OLEFIN).

Refining petroleum Petroleum is first heated (distilled) in a furnace, and the gases are passed into a chimney called a fractionating column (see DISTILLATION). The column is hot at the bottom and gets cooler toward the top. When petroleum boils, the lighter substances in the petroleum travel up the

fractionating column. Then they condense into liquids (see CONDENSATION). These liquids are collected in vessels called bubble cap trays, which are placed at intervals up the column. The collected liquids are called fractions. The lightest fractions supply gasoline. Increasingly heavy fractions are used to make kerosene and fuel oil. The fuel oil cannot be separated simply by boiling in air, so residue is reheated in a vacuum, where the fractions boil at a much lower temperature (see VACUUM). This further boiling yields diesel oil, lubricating oil, asphalt, and paraffin wax.

The chief use of refined petroleum today is as gasoline or diesel oil for engines. Petroleum that is not refined does not yield lighter fractions that can be made into these products. To increase the supply of gasoline and diesel oil, the heavier fractions of petroleum are broken down into lighter ones by cracking. Cracking is performed by heating the heavier fractions under pressure, sometimes using a catalyst (see CATALYST; CRACKING).

Petroleum contains a wide range of compounds. Many more are made when it is refined. These compounds are the starting materials for the petrochemical industry. The petrochemical industry produces a wide range of plastics, fabrics, drugs, explosives, and other products.

Production of petroleum New reservoirs of petroleum are being tapped. Some of the most productive are in Alaska and the North Sea between Britain and mainland Europe.

Another new source of oil is oil shale. Oil can also be taken from tar sands. Because oil can be made from coal and hydrogen, coal deposits remain the most valuable source for future oil supplies. Coal is itself a source of energy because it burns. It does not, however, provide the many petrochemicals that are byproducts of petroleum.

Scientists predict that the world's petroleum supply will be used early in the twenty-first century. Therefore, new sources of energy must be found. Whatever these new sources are, the diminishing of the petroleum supply will force us to make huge changes in our way of life.

See also ENERGY.

PEWEE The pewee is a small bird that belongs to the tyrant flycatcher family, Tyrannidae. It is mostly olive brown with white bars on its wings. The pewee grows to 5 in. [12 cm] long. There are two species of pewees that are common in North America. The eastern wood pewee lives in most areas east of the Missouri River. The western wood pewee lives in most areas west of the Missouri. Pewees live in wooded places and eat insects, which they usually catch in midair.

See also BIRD.



PEWTER

Pewter is often used to make ornamental objects, such as this clock and presentation mug.

PEWTER (pyōō'tər) Pewter is an alloy consisting chiefly of tin, with small amounts of antimony and copper (see ALLOY). Pewter has a color similar to silver and a finish that may vary from dull to glossy.

Most pewter contains at least 90 percent tin, which is a very soft metal. Antimony and copper are added to give pewter hardness and strength. At one time, much pewter contained lead. However, lead dissolves in some foods and beverages contained in pewter ware, forming poisonous substances. Lead also causes tarnishing. As a result, in the 1700s, people switched from pewter that contained lead to britannia metal—a pewter that

contains copper instead of lead. This kind of pewter is most common today. Articles such as candlesticks, plates, mugs, and pitchers are often made of pewter.

pH Scientists use a pH number to show the strength of an acid or base (see ACID; BASE). The number is generally on a scale from 0 to 14. A pH lower than 7 indicates that the solution is an acid. A pH greater than 7 indicates that the solution is a base. Strong acids have lower pHs than weak acids. Strong bases have higher pHs than weak bases. A neutral solution is neither an acid or a base. It has a pH of 7.

A solution's pH is defined as the negative logarithm, to the base 10, of its hydrogen-ion concentration. This concentration is expressed in moles of hydrogen ions per liter of solution (see IONS AND IONIZATION; LOGARITHM; MOLE (UNIT); SOLUTION AND SOLUBILITY). For example, a solution with a pH of 6 contains 10^{-6} (one-millionth) of a mole of hydrogen ions per liter.

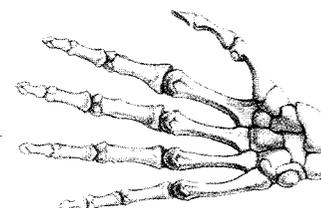
Soil needs to have a suitable pH for plants to grow properly. For example, potatoes grow best in slightly acidic soil. A solution of ammonium sulfate is sometimes added to very acidic soil to lower the pH. Human skin, at about 6.5 pH, is slightly acidic. Ordinary hand soap is a base with a pH that is usually between 7 and 9. Some soap, shampoo, and skin products are chemically adjusted to be closer to the skin's natural pH.  **PROJECT I**

PHALANGE Phalanges are the small bones in the fingers, thumbs, and toes of the human body. Each finger contains three phalanges, and each thumb has two. There are fourteen phalanges in the toes of a foot—three in each toe except the big toe, which has two.

See also BONE.

PHALANGE

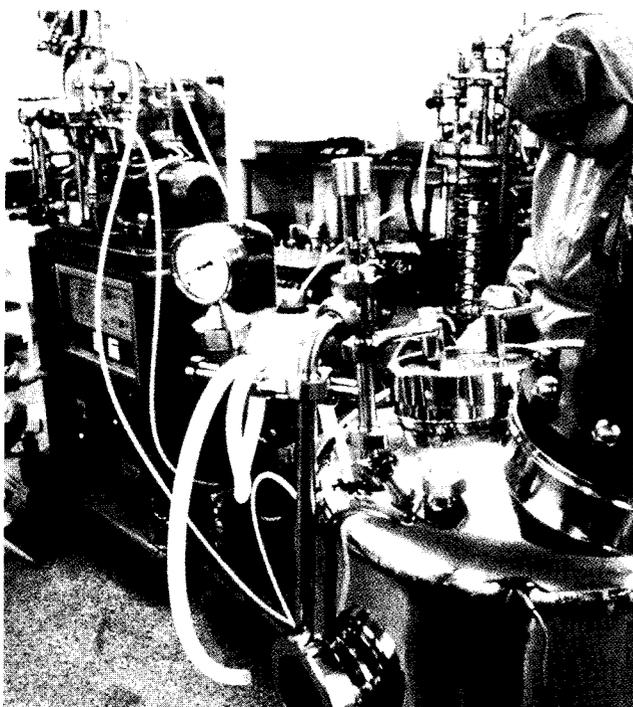
There are three phalanges in each finger and two in the thumb. There are also fourteen phalanges in the toes of each foot.



PHARMACOLOGY (fär'mə kōl'ə jē)

Pharmacology is the branch of science and medicine that studies the effects of drugs on organisms (see DRUG). Pharmacology combines biology and chemistry in finding out how drugs change the workings of tissues and organs.

Pharmacology includes many specialized areas of study. Chemotherapy uses specific drugs to treat disease. Psychopharmacology studies drugs that affect behavior. Pharmacogenetics studies the effects of drugs on hereditary factors. Toxicology studies poisonous and potentially poisonous drugs. Pharmacy involves preparing and giving out appropriate drugs to treat diseases.

**PHARMACOLOGY**

Pharmacology is the study and preparation of medicinal drugs. Here a technician is using a pressure vessel to prepare a batch of a new drug for testing.

PHASE *Phase* has several different meanings in science. In physics, *phase* refers to wave motions such as light and sound. If two waves have exactly the same intensity and frequency and are vibrating together exactly, they are said to be in phase. They can then make each other stronger. If they are completely out of phase, they can cancel each other out (see BEAT; FREQUENCY).

In chemistry, a mixture of water and ice is called

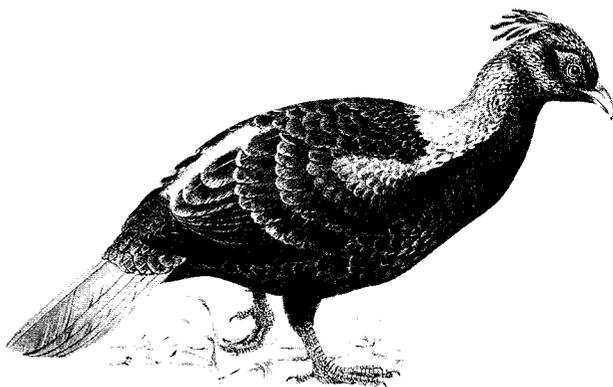
a two-phase system. This is because there is a definite boundary between the water and the ice. Salt dissolved in water is a one-phase system. There is no boundary between the salt and the water.

In astronomy, the moon and other planets go through phases. As the moon goes around the earth, different parts of the moon are lit by the sun. The different appearances of the moon are called phases. In the same way, the planets Mercury and Venus, when viewed from the earth, have different phases as they travel around the sun.

PHEASANT (fēz'ənt) The pheasant is a large bird that belongs to the family Phasianidae. Pheasants are characterized by long, trailing tail feathers. The male is colorful, and the female is generally a mottled brown. This enables her to sit on her eggs on the ground without being seen very easily.

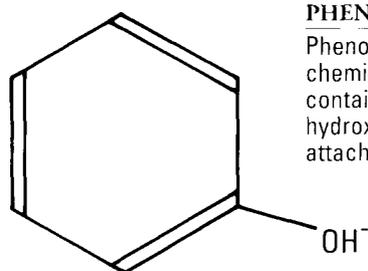
Pheasants are native to Asia, where there are many species. One species, the ring-necked pheasant, has been brought to the United States and Canada, where it has become established in the wild. The ring-necked pheasant is a popular game bird. Although the pheasant lives in many places, it does best in grassy fields. It feeds on grain, seeds, and fruits. The ring-necked pheasant received its name because the male bird has a white ring of feathers around its neck. Ring-necked pheasants grow to about 28 in. [70 cm] long, but some pheasants are much larger than this.

See also BIRD.

**PHEASANT**

The Impeyan pheasant has iridescent feathers that appear to change color as the light changes.

PHENOL (fē'nōl') Phenols are a group of organic (carbon-containing) chemical compounds (see COMPOUND). They contain one or more hydroxyl groups (OH⁻) attached to a benzene ring. They are similar to alcohols (see ALCOHOL; BENZENE). Alcohols, however, usually have a hydroxyl group attached to a chain of carbon atoms. Like alcohols, phenols combine with organic acids to form compounds called esters (see ESTER). Phenols can also act as weak acids. They form salts called phenates. In a phenate, the hydrogen atom in the hydroxyl group is replaced by a metal atom (see ACID; SALTS).



PHENOL

Phenols are a group of chemical compounds that contain one or more hydroxyl groups (OH⁻) attached to a benzene ring.

Phenols are found in coal tar (see COAL GAS). They are used to make dyes, disinfectants, drugs, and plastics. *Phenol* is also the name given to the simplest phenol compound. Its formula is C₆H₅OH. It is also known as carbolic acid. Carbolic acid is obtained from coal tar but can also be made artificially. It is a strong antiseptic and is both poisonous and corrosive.

See also ANTISEPTIC; CORROSION.

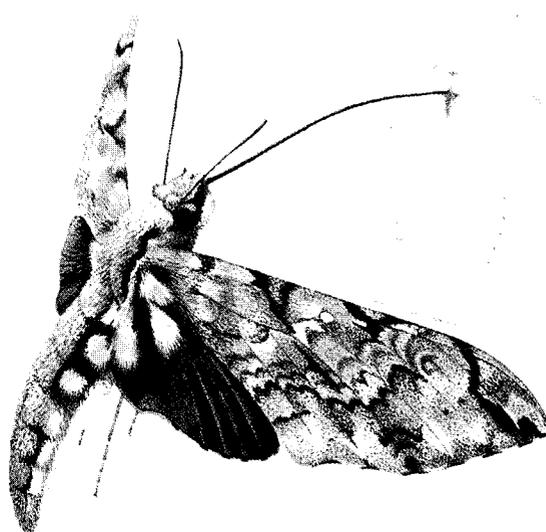
PHENOTYPE (fē' nə tīp') The phenotype of a plant or an animal is what it looks like—its outward characteristics and appearance. It is the way in which an organism's genes show themselves (see GENE). But the phenotype is controlled by environmental factors as well as by the organism's genes. It is therefore possible for two organisms with the same combination of genes to have different phenotypes and to look slightly different if they develop under different conditions. It is also possible for two individuals with different genetic make-ups or genotypes to have similar phenotypes (see GENOTYPE). This is because some of the genes present in the genotype may be masked by stronger, dominant genes.

See also HEREDITY.

PHENYLKETONURIA (PKU) (fēn' əl kē't'n ōōr' ē ə) Phenylketonuria is a hereditary disorder that can lead to mental retardation (see MENTAL RETARDATION). It is caused by the body's inability to process the amino acid phenylalanine, which is typically part of the human diet (see DIET). As a result, phenylalanine builds up in the body and affects the central nervous system, causing epileptic seizures and mental retardation (see EPILEPSY; NERVOUS SYSTEM).

PKU is usually noticed when a child is between four and six months old. PKU is caused by the absence of one particular enzyme. The gene responsible for this absence has been identified (see GENE). It acts recessively, so only when both parents carry the gene is the child at risk. About one in 10,000 babies is born with the disease. Tests are available to detect the gene, and it may soon be possible to treat the cause of the disease directly using genetic engineering techniques. Current treatment consists of giving the child a diet that is low in phenylalanine.

PHEROMONE (fēr'ə mōn') Pheromones are special chemicals produced by animals that make other animals of the same kind behave in a particular way. They are one of the ways in which animals can communicate with one another. When a male cat marks out his territory by spraying trees and



PHEROMONE

Moths are among various animals that produce pheromones, which are chemicals that other animals detect using their sense of smell. Moths use pheromones to attract mates. Pictured here is a large hawkmoth from Madagascar.

other objects with very strong-smelling urine, he is using a pheromone. It tells other male cats to keep away from his territory. This is an obvious example of a pheromone, because the odor is noticeable, even to humans.

Scientists have discovered other pheromones that are not obvious to humans. Moths produce pheromones that attract their mates. Ants use pheromones to mark food trails and to signal when to attack and when to flee. Worker bees mark the nest of their colony with pheromones to help bees who are returning from gathering food distinguish their nest from others. When it is time to mate, the queen bee secretes a pheromone that attracts the drones (see BEE).

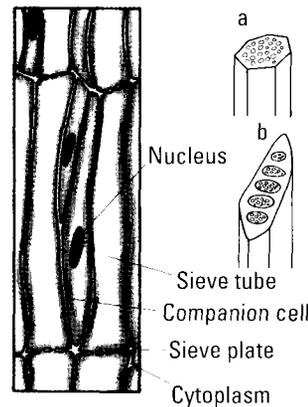
When human beings enter adolescence, their perspiration takes on an odor. The production of the pheromones responsible for this odor is one of the changes in the chemistry of the body that takes place with sexual maturity.

PHLEBITIS (flī bī'tīs) Phlebitis is an inflammation of the wall of a vein (see INFLAMMATION; VEIN). It usually occurs when part of the lining of a vein becomes damaged or diseased. The wall of the vein swells and becomes painful. If the vein is close to the skin, it may appear enlarged and reddened. Phlebitis is dangerous because blood tends to clot wherever the smooth wall of a blood vessel is damaged and roughened. This clot (or thrombus) may increase in size and may eventually block the vein. A blocked vein can create long-term circulatory problems in the area in which it is located. Additionally, a piece of the clot may break off and be carried in the bloodstream. A clot that has broken off and is being carried in the bloodstream is called an embolus. If an embolus carries bacteria with it, it will spread infection to various parts of the body. If the embolus settles in the heart, it can cause a heart attack.

Phlebitis can be treated with drugs that keep the blood from forming clots. If there is an infection, antibiotics may be used to kill the bacteria (see ANTIBIOTIC). In severe cases, a surgeon may have to remove the clot itself or a length of badly damaged vein.

See also CIRCULATORY SYSTEM.

PHLOEM (flō'ēm') Phloem is the food-carrying tissue found in the leaves, stems, and roots of vascular plants (see VASCULAR PLANT). Phloem takes sugar and other foods produced by photosynthesis from the leaves to all other parts of the plant (see PHOTOSYNTHESIS).



PHLOEM

Phloem tissue in angiosperms (left) contains two kinds of living cells—sieve tubes and companion cells. Companion cells have nuclei, which control the working of the sieve tubes. Fluids pass from one sieve tube to another through sieve plates. The two kinds of sieve plates are (a) simple and (b) compound.

The phloem of angiosperms is made up of tube-shaped cells arranged end to end (see ANGIOSPERM). Each cell is called a sieve tube. It is living and has cytoplasm but has no nucleus. Next to each sieve tube is a nucleus-containing companion cell. The companion cell apparently controls the working of the sieve tube cell (see CELL). There are usually fibers extending through the phloem for added strength. There are small holes in the ends of the cells, providing a continuous tube for food transport. The perforated end walls are called sieve plates.

The phloem of dicotyledons is arranged in an orderly ringlike pattern. In woody plants, it is part of the inner bark. The phloem of monocotyledons is arranged in random bundles with the xylem throughout the stem (see DICOTYLEDON; MONOCOTYLEDON; WOODY PLANT; XYLEM).

The phloem of gymnosperms and ferns is made of irregularly shaped cells with many sieve plates on all surfaces (see FERN; GYMNOSPERM). These plants have no companion cells.

PHLOX *Phlox* is a genus of flowering plants that includes about sixty-five species, all but one of which are native to North America. Phlox belong to the family Polemoniaceae.

Most phlox are perennials (see PERENNIAL PLANT). Their simple leaves occur in opposite pairs

**PHLOX**

All but one of the species of phlox come from North America. The one pictured is native to Texas.

close to the ground but often become alternate higher up (see LEAF). Their brilliant flowers grow in clusters, each flower having five petals.

Summer phlox grows to heights of 60 in. [150 cm]. It is a popular garden plant in eastern North America. Blue phlox is noted for its blue or white flowers that bloom each spring.



PHOEBE (fē'bē') The phoebe is a small bird that belongs to the tyrant flycatcher family, Tyrannidae. It has a large head, slender bill, and long tail, which it twitches frequently. There are three species of phoebe in North America: the black phoebe in the southwest, Say's phoebe in the west, and the eastern phoebe in the east. Phoebes eat insects and usually live near water. They nest in rock crevices, under bridges, and beneath overhanging porches.

See also BIRD.

PHOSPHATE Phosphates are compounds that contain phosphorus, oxygen, and at least one other element. They always include the ion PO_4^{3-} (see COMPOUND; IONS AND IONIZATION). Phosphates are found in many different minerals. The most important phosphate is calcium phosphate. Calcium phosphate is found in bones and is used as a fertilizer. If calcium phosphate is treated with sulfuric acid, calcium dihydrogen phosphate is formed. Calcium dihydrogen phosphate is mixed with calcium phosphate to make fertilizers called superphosphates. It dissolves in water and can be more easily absorbed by plants than calcium phosphate. This makes it a better fertilizer.

See also FERTILIZER; MINERAL.

PHOSPHATE

Most of the phosphates manufactured by the chemical industry are used by farmers as artificial fertilizers.

PHOSPHORESCENCE (fɒs'fə rēs'əns)

Phosphorescence is a way that certain materials give off light by means other than heat (see INCANDESCENCE; LIGHT). An atom is made up of electrons moving around a central core called a nucleus (see ATOM). The electrons move around in orbits. Each orbit is a different distance from the nucleus. Electrons in a higher (farther) orbit have more energy than electrons in a lower (nearer) orbit. When radiation is applied to certain materials, their electrons absorb the energy and move into a higher orbit (see RADIATION). The electrons are said to be excited. At some point, the electrons give out the energy as light and drop back to their original orbit. If light is given off by the electrons long after the radiation is removed, it is called phosphorescence (see FLUORESCENCE).

Substances that are naturally phosphorescent include eggshells and ivory. Phosphorescent minerals include barium sulfide, calcium sulfide, and strontium sulfide. Some organisms, such as fireflies, glowworms, jellyfish, and certain tiny sea animals, are phosphorescent. This characteristic is called bioluminescence.

See also BIOLUMINESCENCE; LUMINESCENCE.

PHOSPHORIC ACID (fɒs fɔr'ɪk əs'ɪd)

Phosphoric acid (H_3PO_4) is a compound that contains hydrogen, phosphorus, and oxygen (see COMPOUND). Phosphoric acid is used in soft drinks, food additives, and fertilizers.

PHOSPHORUS (fɒs'fər əs)

Phosphorus (P) is a solid nonmetallic element (see ELEMENT). Phosphorus occurs in several different forms. These different forms are called allotropes (see ALLOTROPE). The best-known form is called white or yellow phosphorus because of its color. White phosphorus is a poisonous, waxy solid with a relative density of 1.8 (see RELATIVE DENSITY). It is very reactive and may catch fire in air. Therefore, it is stored under water. If white phosphorus is heated to 480°F [250°C] or is exposed to sunlight, it changes into another allotrope called red phosphorus. Red phosphorus is not as reactive as white phosphorus and does not catch fire in air. Red

phosphorus is not poisonous and is slightly heavier than white phosphorus. Its relative density is 2.2.

Phosphorus was discovered in 1669 by Hennig Brand, a German alchemist (see CHEMISTRY). It is used in making matches and smoke bombs. The most important compounds of phosphorus are salts called phosphates. Phosphates are salts of acids called phosphoric acids (see PHOSPHATE; PHOSPHORIC ACID). Phosphorus is essential to life. Bones are mainly made of calcium phosphate. It is an essential component of DNA and RNA in body cells (see DNA; RNA). People and animals get the phosphorus they need by eating plants and food such as eggs, milk, and meat.

The atomic number of phosphorus is 15, and its relative atomic mass is 30.9738. It melts at 111.4°F [44.1°C] and boils at 536°F [280°C].

PHOTOCOPIER A photocopier is a machine that uses light-sensitive materials to copy documents or pictures. Today, most photocopiers are electrostatic copiers (see ELECTROSTATICS). This type of copier was invented in 1938 by the American physicist John Chester Carlson.

In electrostatic photocopiers, a drum, belt, or plate coated with a light-sensitive material, such as the element selenium, is charged with static electricity. Light reflected from the document to be copied passes through a lens. When the light strikes the light-sensitive surface of the drum, a positively charged image that corresponds to the dark areas on the original is formed. A negatively charged toner, or powdered ink, sticks to the positively charged areas. The toner is transferred to positively charged paper and heated to create a permanent copy. The first photocopiers produced only black-and-white copies. Now full-color copiers are available.

PHOTOELECTRIC EFFECT The photoelectric effect is any effect in which light energy is converted to electricity. Examples of photoelectric effect usually fall into one of three categories—photoemission, photoconductivity, or photovoltaics. The device that makes use of the photoelectric effect is often called a photoelectric cell, a photo cell, or an electric eye.

Photoemission was first explained by Albert Einstein (see EINSTEIN, ALBERT). Light, like all other radiation, is made up of small particles called photons (see PHOTON). The amount of energy the photons have depends on the frequency of the light. The frequency of light is the number of times that a light wave vibrates in a second (see FREQUENCY). The higher the frequency, the more energy the photons have. If a photon hits an atom of a certain material (called a photoemittive material), it may be absorbed by an electron of that material (see ATOM; ELECTRON). However, if the photon has enough energy, the electron is ejected, or emitted, from the atom. In this way, light energy changes into electrical energy (see ELECTRICITY). If wires are attached to a photoemittive material, the electrons can flow along the wires, forming an electric current.

Photoemission cells are used in motion picture projectors to read film sound tracks. The sound track is printed in a pattern on the edge of the film. A beam of light passes through the sound track and activates a photoemission cell in the projector. The varying width of the sound track produces a varying amount of light that is converted into electrical impulses. These electrical impulses are then converted into sound impulses.

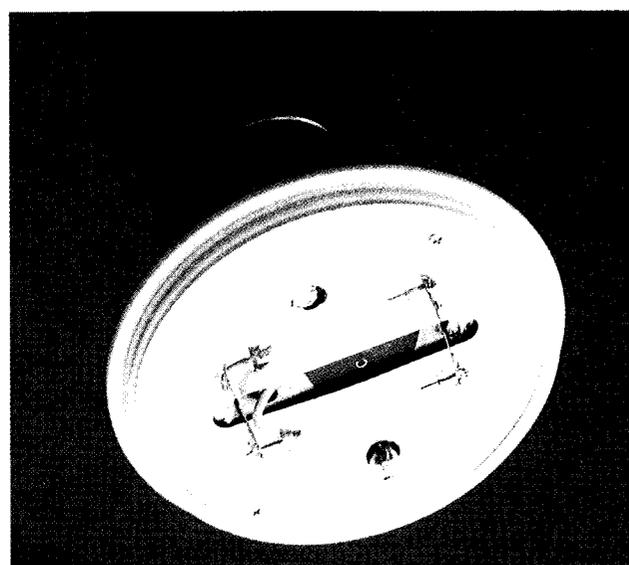
Photoconductivity results from light hitting a semiconductor (see SEMICONDUCTOR). Semiconductors contain free, negatively charged electrons. A free electron is an electron that has left its atom and so is not bound to it. When the electron leaves its atom, it creates a positive charge in the atom. The positive charge attracts an electron from another atom. This process repeats itself, creating an electric current. When light falls on certain semiconductors, the number of electrons leaving their atoms increases. This increases the current. A streetlight is a good example of an application of photoconductivity. As daylight fades, the electrical current in the streetlight's semiconductor comes to a stop. This activates a switch that turns the streetlight on.

Burglar alarms sometimes have electric eyes that operate on the principle of photoconductivity. When the light source to the semiconductor is interrupted by a person walking through the beam of light, a switch is activated that triggers the alarm.

Other examples of electric eyes include automatic door openers and elevator doors. In an automatic door opener, a light shines on a photoelectric cell, producing an electric current. The electric current keeps the doors closed. If the light source is blocked by a person wanting to go through the door, the photoelectric cell stops producing a current, and the door opens. A similar reaction occurs when a person blocks the light of an electric eye in elevator doors. This causes the doors to either stay open until every passenger has passed through or to reopen if they have started to close.

The photovoltaic effect is similar to photoconductivity. In this effect, light falls on two semiconductors, or on a metal and a semiconductor sandwiched together. A boundary develops between these two substances. Free electrons build up along the boundary but cannot flow across it. However, if the two substances are connected in a circuit, then the electrons can flow across the boundary and through the circuit. Photovoltaic cells are used in exposure meters for photography (see EXPOSURE METER). Light falling on the meter causes a current to flow. The size of the current depends on the amount of light. The light can be measured indirectly by measuring the current. Solar cells work on the same principle.

See also SOLAR CELL.



PHOTOELECTRIC EFFECT

The photocell on this photographer's slave flash unit uses the photoelectric effect. When a nearby flashgun goes off, it immediately fires the slave flash.

PHOTOGRAPHY

Photography (fə tɒɡ'rə fē) is the process of taking pictures with a camera (see CAMERA). The word *photography* means "drawing with light." A photograph is a picture "drawn" with rays of light.

Photography enriches our lives in many ways. Illustrations in newspapers, magazines, and books are usually photographs. Photography is an important tool in advertising, business, and industry. It helps people explore the earth, the oceans, and outer space. Some photographs have lasting artistic value.

Photography is one of the most popular hobbies in the world. For example, almost half the families in the United States own a camera. Many people all over the world join camera clubs to meet with other camera enthusiasts. Sometimes, they display their photographs at exhibitions in art galleries and museums.

Motion picture making and video recording are

DEVELOPING AND PRINTING

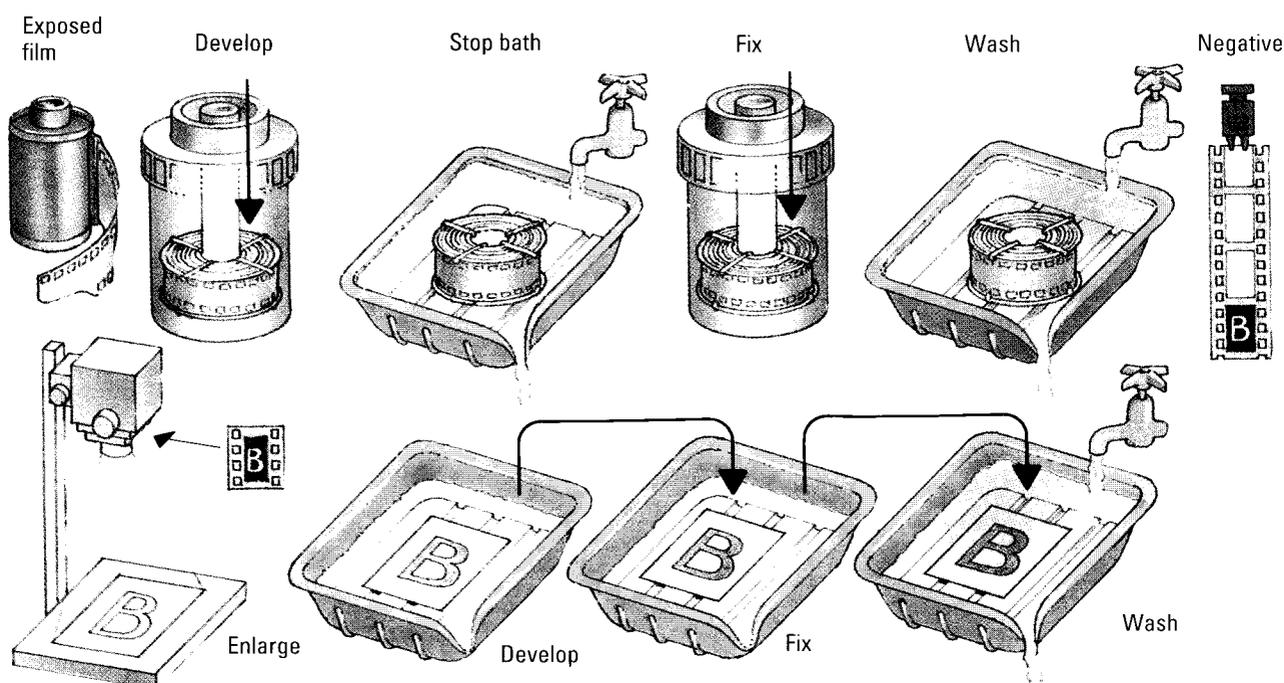
The diagram (below) shows the sequence of stages involved in developing and printing black-and-white film. The exposed film is loaded into a developing tank (in the dark) and moved around in the developer. The film is immersed in a stop bath before being fixed and washed. After drying, the resulting negative is projected onto photographic paper in an enlarger. A similar development process then produces a black-and-white print.

branches of photography. Many principles used in regular photography are used in making motion pictures and videotapes (see MOTION PICTURE; VIDEO RECORDING).

Today's cameras have many features that make taking pictures easier than it was in the past. For example, many cameras now have built-in exposure meters and lenses that focus automatically (see EXPOSURE METER; LENS). Some cameras also have electronic chips that recognize difficult picture-taking situations, such as when a person is standing in front of a brightly lit window (see CHIP). The chip directs adjustments to be made to parts of the camera, so that the photograph is properly exposed.

Exposing the film Proper lighting is the key to taking good photographs. Too much light reaching the film results in photographs that are overexposed. Such photographs have little detail and look foggy. If color film is used, many of the colors do not show up, and the image appears very light. On the other hand, too little light reaching the film results in photographs that are underexposed. Such photographs are too dark. Many details do not show up because of the overall darkness.

Films are made with different speeds, or sensitivities





NATURE PHOTOGRAPHY

Nature is a popular subject with photographers, who often have to endure uncomfortable conditions to get a good shot.

to light. Some films are very sensitive. They are called "fast" films. A fast film is able to take photographs in situations in which there is little light. A fast film is also used when a high shutter speed is needed, such as when photographs are being taken of a fast-moving object. The shutter is the device that allows light to enter the camera. A disadvantage of a fast film is that the photographs can be "grainy" looking. Other films are called "slow" films. Slow films are less sensitive to light than fast films. Slow films can only be used in situations in which there is adequate light. However, slow films produce photographs that are very sharp and show fine detail. In the United States, film speed is set by the American Standards Association (ASA). Slow films generally are numbered under 80. Medium-speed films are numbered from 80 to 125. Fast films are generally numbered over 200.

The exposure of film can be varied in two major ways. First, the exposure time, during which the shutter of the camera is open, can be altered. Second, for any given exposure time, the amount of light entering the camera can be increased or decreased. This is done by changing the size of the aperture, or lens opening, with a diaphragm that blocks off part of the lens. Several different

combinations of aperture settings and shutter speeds make it possible to get the proper settings for all conditions of light. The selection depends on the particular type of photographer's subject being photographed, the effect required, and the camera involved.

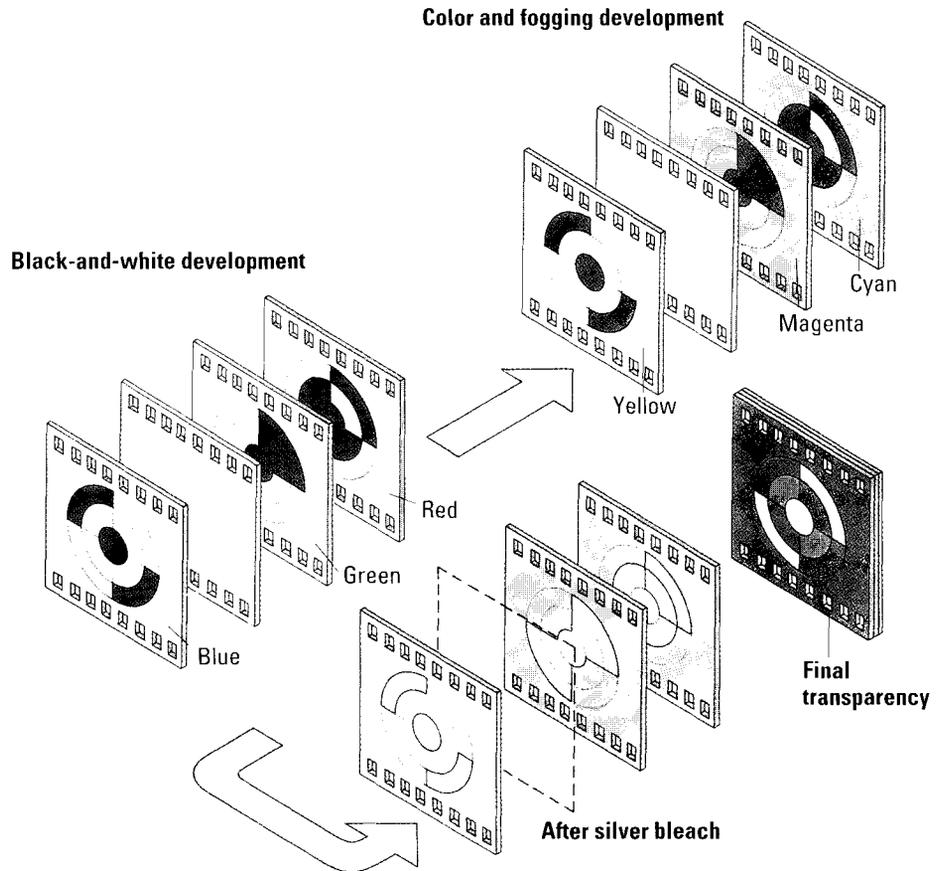
A device called an exposure meter, or light meter, can be used to measure the brightness of the scene being photographed (see EXPOSURE METER). This enables a suitable aperture to be chosen. Most exposure meters work on a photoelectric principle (see PHOTOELECTRIC EFFECT). Many cameras have built-in meters. In dim lighting conditions, such as the interior of a building, an exposure of several seconds may be necessary. Some cameras have a setting that allows the shutter to be held open as long as necessary. Electronic flash units may be used to illuminate the scene or subject in dim light conditions. The flash is synchronized with the opening of the shutter. Flash units, which are built into the camera or attached to it, can also be used in complete darkness.

Developing and printing in black and white

Black-and-white film has a light-sensitive coating of tiny grains of silver bromide. When these grains

COLOR FILM

Color transparency film has three layers sensitive to blue, green, and red light. The image in each layer is reversal-processed to give a dye image in complementary colors—blue turns to yellow, green to magenta, and red to cyan. The film is then developed to produce dyes in red, green, and blue. After bleaching to remove the silver that remains in the film, a color transparency results.



are exposed to light, they tend to break down and deposit dark grains of silver. However, this process is only completed through the chemical actions of a solution of developer. During development, parts of the film that were most exposed to light deposit the most silver and become dark. Meanwhile, unexposed places remain unchanged. In a later stage, called fixing, the unchanged grains are dissolved away, leaving clear film. After fixing, the film is washed and dried. All gradations between dark and bright occur according to the pattern of light in the scene photographed. However, what was light in the scene becomes dark in the developed film, and vice versa. Thus, the developed film is called the negative.

Printing is the process of reversing the dark and light tones of the negative into light and dark tones on the paper. The picture obtained is called a positive. The simplest form of printing is contact printing, in which the negative is in contact with the paper. The printing paper is coated with a light-sensitive emulsion containing silver salts, just

as the film is. After a brief exposure to a bright light, it is developed, fixed, washed, and dried much like film.

Most photographic printing is done by enlarging and not by contact printing. This is because actual-size prints from most film would be too small for general use. In enlarging, a bright, magnified image of the negative is projected onto the printing paper. Development is then finished as described above.

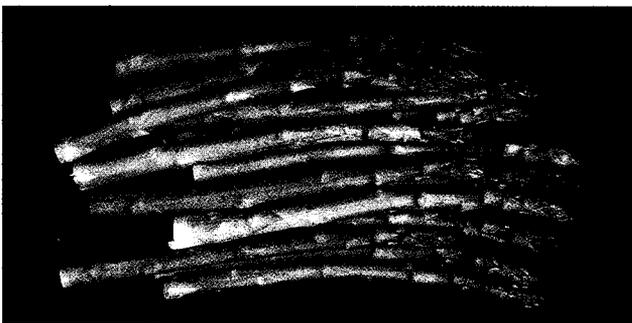
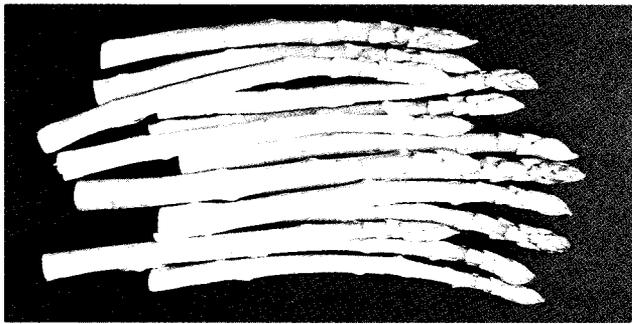
Color photography Color photography is more complicated than black-and-white. Light that looks white to our eyes is really a mixture of all colors of the rainbow (see LIGHT). Any color can be reproduced by blending only three basic colors such as blue, green, and red. These colors are called primary colors of light. In color photography, blue light, red light, and green light are blended in certain proportions to produce any color (see COLOR).

There are two types of color film: (1) negative and (2) reversal. Negative film produces color negatives from which color prints are made. Reversal

film produces color transparencies (slides). A slide is usually viewed in a lighted slide viewer or through a projector that shines the colored picture onto a screen.

Negative and reversal films are made in almost the same way. Each consists of three layers of emulsion on a sheet of plastic. These emulsions are similar to the emulsions on black-and-white film, but each emulsion is sensitive to only one of three primary colors. The first emulsion is affected only by blue light, the second only by green light, and the third only by red light.

When color film is exposed, light passes through the first emulsion and records an image of the blue areas of the scene. A special yellow filter layer prevents unused blue light from reaching the other two primary color layers. Then the light passes



CORRECT EXPOSURE

A photographer has to set the camera for the correct exposure or the photograph will be too light (top) or too dark (middle). The correct exposure results from the correct combination of aperture size and shutter speed (bottom).

through the second emulsion layer, which records only the green areas of the scene. Finally, the light passes through the third emulsion layer, which records the red areas.

Color negative film is developed in a special developer. A silver image forms in each emulsion layer. The developing solution then causes colored dyes to form in each layer by reacting with substances called couplers. A yellow dye forms in the first layer. A magenta (bluish red) dye forms in the second layer, and a cyan (bluish green) dye forms in the third layer. These three colors are complementary, or direct opposites, to the three primary colors of light—blue, green, and red. Complementary colors reproduce the original colors when light is passed through the film.

Each dye acts as a filter to a primary color. The yellow dye absorbs blue light and lets red and green light pass through. The magenta dye absorbs green light and lets red and blue pass through. The cyan dye absorbs red light and lets blue and green pass through. In this way, the original colors of the subject appear in a print.

Color reversal film that produces color slides has a similar developing process. However, there is one extra step. The film is re-exposed after the first development. During the second development, colored dyes form around the silver images of the subject. The silver is then bleached out, leaving transparent film in those areas. In the developed film, a yellow dye surrounds the image made by blue light, magenta dye surrounds the green light image, and cyan dye surrounds the red light image. When the film is projected, each dye holds back light of the complementary color, and the original colors of the subject appear on the screen (see POLAROID CAMERA).

Photography and electronics Since the 1980s, electronics has played a large role in photography (see ELECTRONICS). For example, a kind of specialty camera called an electronic still camera is now available. Electronic still cameras work in much the same way as adjustable cameras. However, instead of recording the image on film, electronic still cameras store the image in digital form on a special

kind of floppy disk (see **COMPUTER**). Storing the image digitally means that different segments of the image are given a number code. The photographer can do several things with such an image. For example, the floppy disk can be inserted into a device called a disk drive that is similar to the disk drives used with computers. The disk drive is attached to a home television set and is used to display the image on the television. The image can be reproduced using the disk drive and a printer similar to those used with computers. The image may also be sent quickly to another location by a device called a modem, which is often built into the camera. A modem is an electronic device that allows information to be sent or received, usually over telephone lines. Communicating by modem has many advantages for photographers. For example, a newspaper photographer can take a photograph in one city. He or she can then connect the modem in the camera to a telephone and send the picture to his or her newspaper many miles away (see **MODEM**). The receiving computer can store the image on another disk, display it, or print it.

Another electronic advancement in photography

is called electronic image manipulation. This process allows a photographer to change his or her photograph after it has been taken. First, the photograph is passed through a device called an optical scanner. The scanner converts the image into digital signals that can be understood by a computer. The photographer views the image on a display screen that resembles a television screen. The photographer uses a hand-held device called a "mouse," to manipulate the image he or she sees. For example, suppose a photograph had a blue flower in its background. Electronic image manipulation allows the photographer to change the color of the flower and place it in a different position in the photograph. Parts of a photograph may also be removed and replaced with parts from another photograph. After the photographer is finished making changes, the new photograph can be printed out on paper. The print can then be fed into a special device that reproduces the image on film.

 **PROJECT 27**

STUDIO PHOTOGRAPHY

Many professional photographers work in a studio, where the lighting can be precisely controlled. Glamour, fashion, and still-life photographs are generally taken in a studio.



PHOTOMETRY (fō tōm'ī trē) Photometry is a branch of science concerned with the measurement of light. Instruments that measure the brightness of artificial light sources are called photometers. Photometers most often use a standard light source. The light source that is to be measured is compared to the standard source. The photometer is placed between these two sources. Some of the light from each source passes through prisms (see PRISM). The prisms deflect the light into an eyepiece. The distance from the photometer to the light sources is then adjusted. At a certain distance, the two sources look equally bright in the eyepiece. By using the inverse square law, scientists can calculate the brightness of the unknown source (see INVERSE SQUARE LAW).

A different method is used for measuring the brightness of daylight. A device called a barrier layer cell is used. This is made of a metal and a piece of selenium. Selenium is a nonmetallic element. When light falls on the cell, a voltage develops in it (see PHOTOELECTRIC EFFECT). This causes a current to flow in a circuit that contains an ammeter or voltmeter. The size of the current depends on the brightness of the daylight. In this way, the brightness of the light can be measured. This system is used in exposure meters for cameras.

See also CANDELA; EXPOSURE METER; FLUX; FOOT-CANDLE; LIGHT; LUMEN.

PHOTON In some ways, light behaves like a wave. For example, light exhibits interference and diffraction (see DIFFRACTION; INTERFERENCE; WAVE). These are wave effects. However, the wave theory of light cannot explain certain phenomena related to light. These can only be explained by regarding light as a stream of particles. These particles are called photons. They were first proved to exist by Albert Einstein in 1905 (see EINSTEIN, ALBERT).

Light is a form of electromagnetic radiation. All electromagnetic radiation, such as radio waves and ultraviolet rays, consists of photons.

See also ELECTROMAGNETIC RADIATION; LIGHT; PHOTOELECTRIC EFFECT.

PHOTOPERIODISM (fō'tō pīr'ē əd īz'əm) Photoperiodism is the response of a living organism to the length of day or night, or both. The photoperiod, also called the critical day length, is the number of hours of light needed to cause this response. Some examples of photoperiodism are the migration of some birds and the breeding of many animals (see MIGRATION).

Photoperiodism most commonly refers to the appearance of flowers on a flowering plant. Short-day plants, such as chrysanthemums, poinsettias, and strawberries, flower when the day is shorter than a certain number of hours. Most short-day plants bloom in the early spring or late fall. Long-day plants, such as spinach and lettuce, flower when the day is longer than a certain number of hours. Most long-day plants bloom in the summer. Neutral-day plants are not affected by the length of the day.

Photoperiodism in plants is controlled by a light-sensitive, bluish pigment called phytochrome (see PIGMENT). Florists often use their knowledge of photoperiodism to produce flowers year-round. They do this by artificially controlling the lengths of the "days" and "nights" in greenhouses where the flowers are grown.



PHOTOPERIODISM

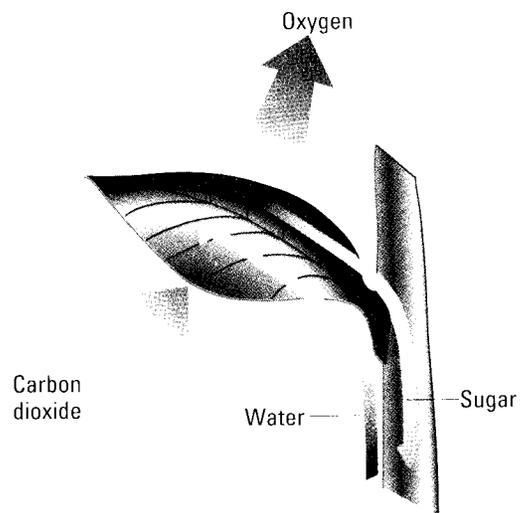
Chrysanthemums are typical short-day plants that bloom in late fall and winter.

PHOTOSYNTHESIS (fō'tō sīn'thī sīs) Photosynthesis is the process by which green plants and certain other organisms make food. It is a complex series of chemical reactions that uses energy from sunlight to make food and oxygen from carbon dioxide and water—all in the presence of the pigment chlorophyll (see CHLOROPHYLL).

Without chlorophyll, photosynthesis cannot take place. In higher plants, chlorophyll is found in structures called chloroplasts. Most of the chloroplasts are found in the cells of the plant's leaves (see LEAF). Water is absorbed by the roots and taken to the leaves (see ROOT). Air containing carbon dioxide enters the leaves through tiny openings called stomata (plural of *stoma*) (see STOMA). These substances that the plant takes in are essential for photosynthesis.

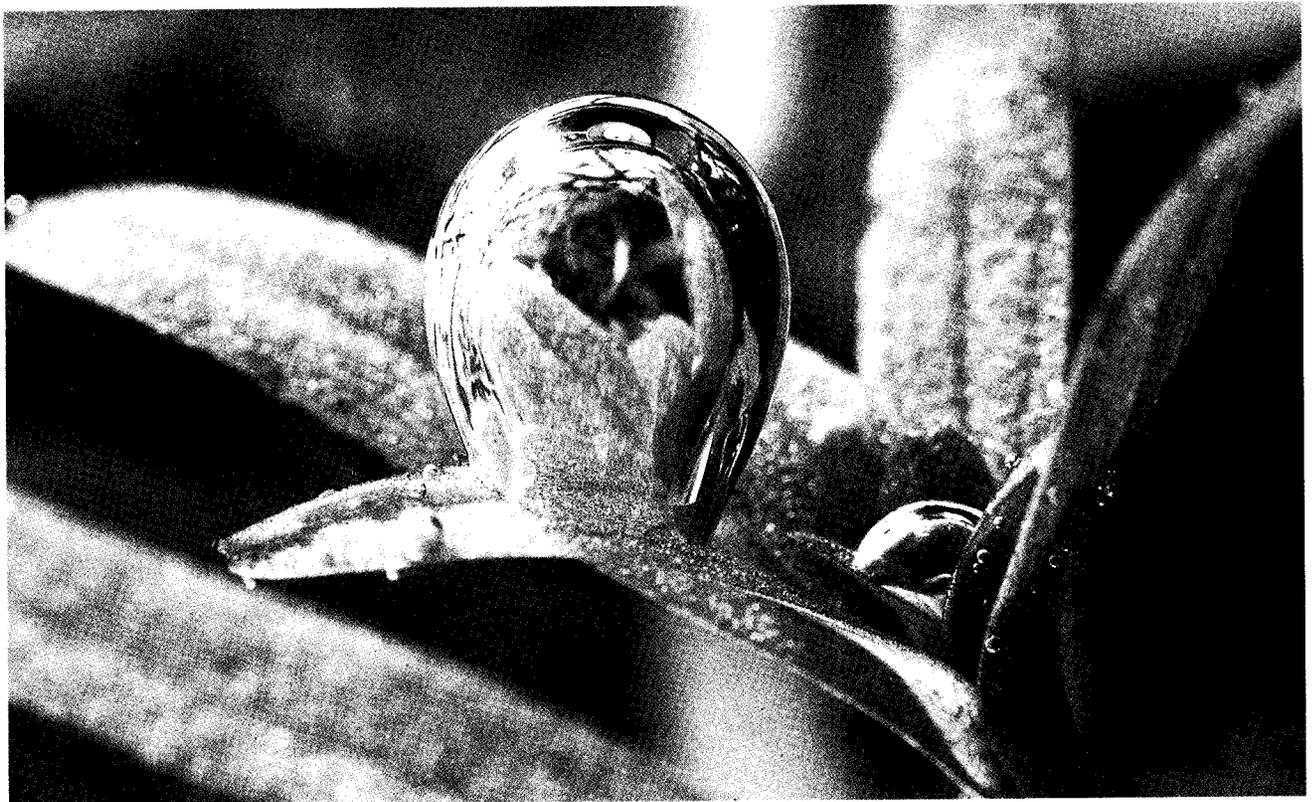
The food made by photosynthesis is glucose, a simple sugar (see GLUCOSE). Glucose is distributed throughout the plant and used by the cells and tissues as a source of chemical energy. Some of the glucose is combined with nitrogen to form amino acids, proteins, or nucleic acids (see AMINO ACID; NUCLEIC ACID; PROTEIN). The nitrogen is usually obtained from the soil in the form of nitrates

Sunlight



PHOTOSYNTHESIS

Photosynthesis (above) involves a complex series of chemical reactions that take place in the green leaves of plants. Overall the process involves the combination of water and carbon dioxide to produce oxygen and sugar, using the energy of sunlight. The production of oxygen by photosynthesis is clearly indicated by this underwater photograph of an aquatic plant called water starwort (below). The oxygen gas has formed a large bubble on a leaf.



dissolved in water absorbed by the roots. Some of the glucose is changed to cellulose and used to build up plant tissues (see CELLULOSE). Some of the glucose is also changed to starch and stored in the leaves, stem, or roots.

Food for almost all living organisms comes either directly or indirectly from photosynthesis. Many animals eat plants for food. Other animals—including human beings—eat plants and plant-eating animals. Thus, photosynthetic plants are a vital part of the food chain (see FOOD CHAIN).

Most plants and animals get the energy they need through respiration (see RESPIRATION). In respiration, food and oxygen are used to make energy, carbon dioxide, and water. Thus, respiration and photosynthesis are opposite reactions and occur in a continuous cycle. The end products of one reaction are the raw materials needed for the other, but plants give out much more oxygen than they use in respiration.

Photosynthetic organisms probably produced most of the oxygen in the atmosphere as the earth was developing. Since that time, the amount of oxygen in the air (about 21 percent) and the amount of carbon dioxide in the air (about 0.04 percent) have remained fairly constant as a result of photosynthesis (see AIR). Of all the photosynthesis that takes place, more than 75 percent takes place in the oceans, in tiny organisms called phytoplankton (see PHYTOPLANKTON). Scientists are constantly seeking ways to use these marine organisms as a food source for human beings. Scientists are also trying to find ways of increasing the amount of photosynthesis that takes place in land plants in hopes of increasing the world food supply. They have found that factors such as temperature, light intensity, water supply, and carbon dioxide supply all affect the rate of photosynthesis. The rate, however, is finally limited by the enzymes that affect the rates of many of the chemical reactions in photosynthesis.

See also ATP; CARBON CYCLE; WATER CYCLE.



PROJECT 68

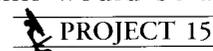
PHYLUM AND SUBPHYLUM (fī'ləm, sūb'fī'ləm) A phylum (plural *phyla*) is one of the major categories used in the classification of

living organisms (see CLASSIFICATION OF LIVING ORGANISMS). Each of the five kingdoms of living organisms is divided into a number of phyla (see KINGDOM). The animal kingdom contains about thirty phyla, including the Mollusca (slugs and snails and their relatives), the Arthropoda (insects, spiders, and crustaceans), and the Chordata. The Chordata includes all the backboned animals, or vertebrates, together with the lancelet and the sea squirts (see SEA SQUIRT). The members of a phylum are all built similarly. In the plant kingdom, the term *division* is sometimes used instead of *phylum*.

A phylum is subdivided into a number of classes (see CLASS). The members of any particular class have more features in common than the members of a phylum. Insects, spiders, and crustaceans belong to three different classes within the phylum Arthropoda.

Sometimes one class or group of classes within a phylum stands apart from the rest because of some particular feature, although the difference is not great enough for these organisms to be put in a separate phylum. In such instances, taxonomists (biologists who specialize in the classification of living organisms) may split the phylum into two or more subphyla. For example, the phylum Chordata is split into three subphyla: the Vertebrata, containing all the backboned animals, or vertebrates; the Urochordata, containing the sea squirts; and the Cephalochordata, containing the lancelets. The last two groups have no backbones, separating them from the vertebrates. They do have a notochord (a skeletal rod resembling a spine) that clearly puts them in the phylum Chordata (see NOTOCHORD).

PHYSICAL CHANGE A physical change is any change that happens to a substance without affecting its chemical composition. For example, a physical change occurs when ice melts to form water. Both ice and water have the same chemical composition: H₂O. Therefore, there is no chemical change. The change is a physical change. If the ice had broken down into hydrogen and oxygen, then this would be a chemical change.



PROJECT 15

PHYSICS

Physics (fiz'iks) is the study of the properties of matter and energy. Physicists try to understand these properties in the universe. They do this by observing and performing experiments. They use their observations and the results of their experiments to derive laws. The laws can be used to predict the results of other experiments. Laws are descriptions of natural phenomena. However, they do not explain why such phenomena occur.

Physicists propose theories to explain why certain events take place. For example, Sir Isaac Newton's theory of mechanics explains how and why things move the way they do (see **NEWTON, SIR ISAAC**). Theories change as physicists make new observations and do new experiments. For example, Newton's theory of mechanics was accepted for more than two hundred years, until the beginning of this century. However, experiments on objects moving at almost the speed of light could not be explained by Newton's theory. A new theory, the theory of relativity, was devised by Albert Einstein to explain these new results (see **EINSTEIN, ALBERT; RELATIVITY**).

Most physical laws are stated mathematically. Mathematics is a very important and powerful tool for physicists. For example, many experiments in physics involve measurements. Physicists also use mathematics to develop, expand, and apply new theories in physics.

Branches of physics Physics is divided into a number of different branches, including mechanics, heat, light, sound, electricity and magnetism, and solid-state physics. There are also branches that cover atomic, nuclear, and particle physics.

Mechanics is the study of solid bodies and fluids and the forces that act on them. The action of forces on solid bodies is studied in two main branches: statics and dynamics. Statics is the study of forces acting on a body at rest, such as the forces acting on a bridge. Dynamics is the study of forces that cause bodies to move, such as the forces acting on a swinging pendulum (see **MECHANICS**).

Heat studies are concerned with the effect

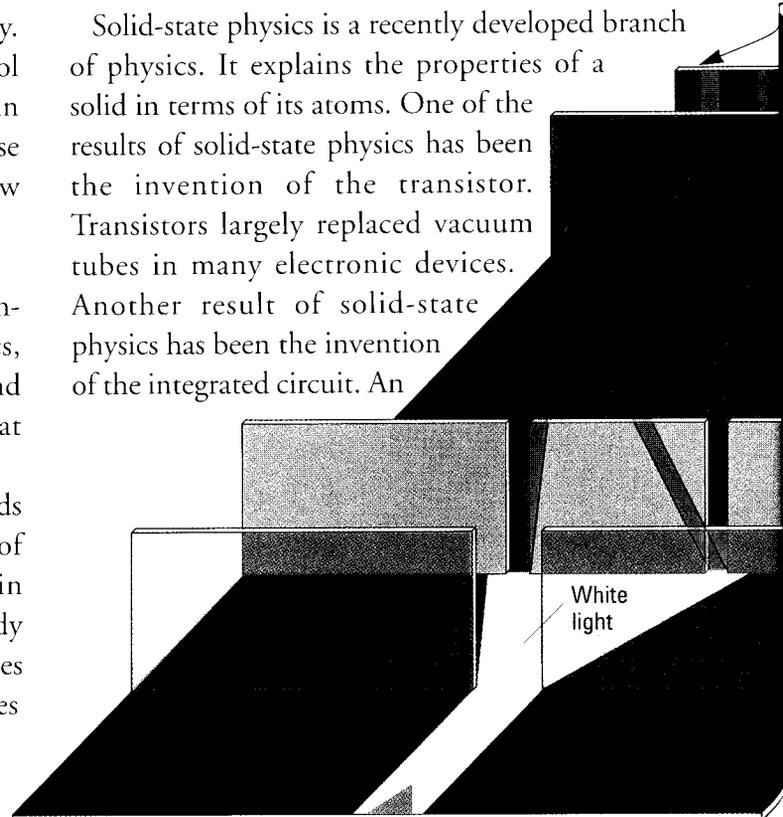
of heat on various substances. Heat is a form of energy. It can be changed into different forms of energy such as mechanical or electrical energy. Thermodynamics is the study of such transformation of energy (see **HEAT; THERMODYNAMICS**).

The study of light is called optics. It includes investigations of the nature and properties of light. An important part of optics is the study of optical instruments such as telescopes and microscopes (see **OPTICS**).

Sound is studied in a branch of physics called acoustics. Acoustics is the study of properties of sound, such as the ways in which sound is transmitted through air and other materials, and how sound is produced (see **ACOUSTICS**).

Electricity and magnetism were once considered to be two separate subjects. During the 1800s, however, several connections were discovered between them. Electricity and magnetism are now studied as a single subject. The study of the connections between electricity and magnetism is called electromagnetism (see **ELECTRICITY; ELECTROMAGNETISM; MAGNETISM**).

Solid-state physics is a recently developed branch of physics. It explains the properties of a solid in terms of its atoms. One of the results of solid-state physics has been the invention of the transistor. Transistors largely replaced vacuum tubes in many electronic devices. Another result of solid-state physics has been the invention of the integrated circuit. An



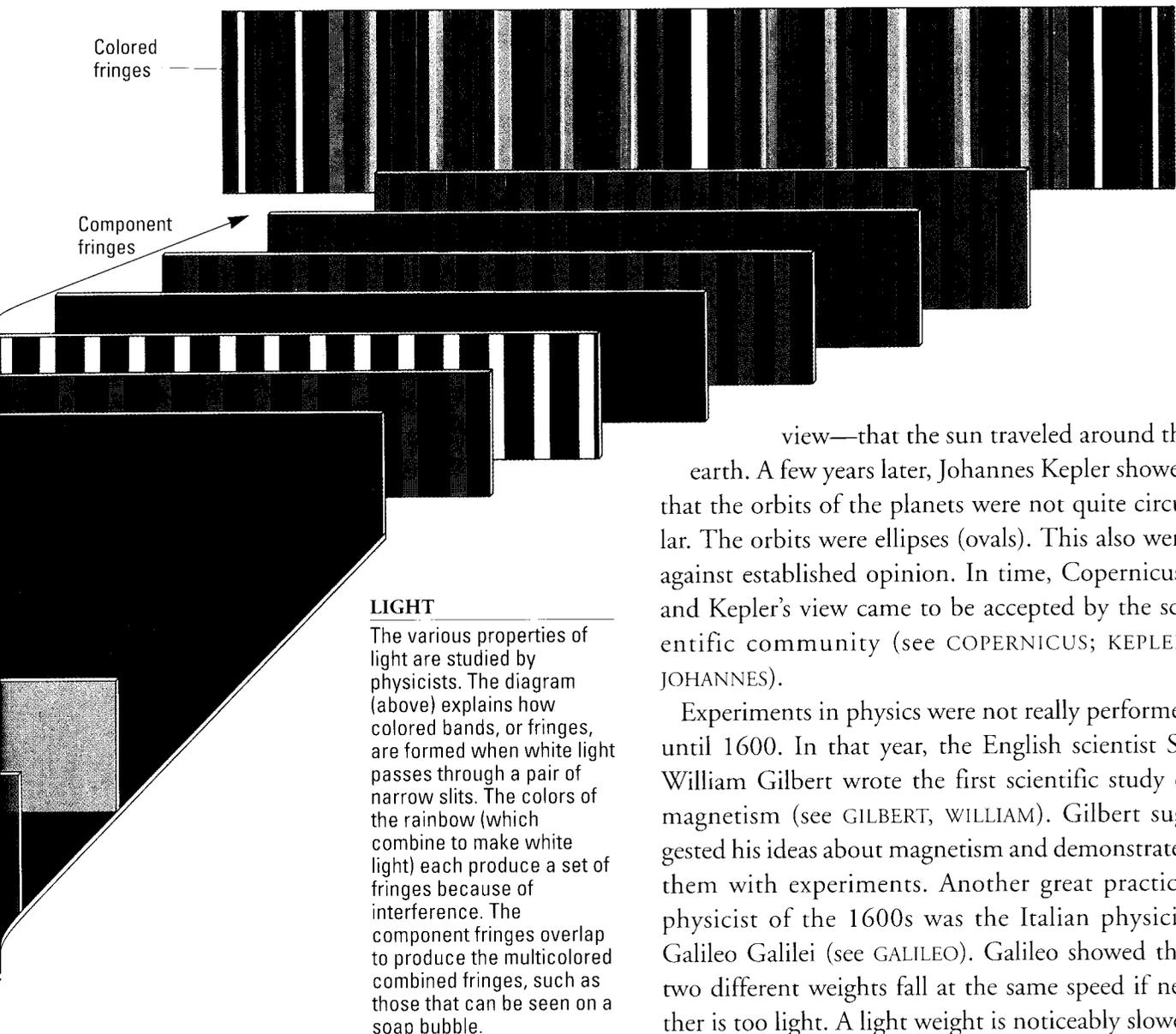
integrated circuit combines the work of several transistors (see INTEGRATED CIRCUIT; SOLID-STATE PHYSICS; TRANSISTOR; VACUUM TUBE).

Atomic, nuclear, and particle physics are also newer branches of physics. Atomic and nuclear physics include the study of the atom and the nucleus. Particle physics is the study of subatomic particles (see PARTICLE PHYSICS). The mathematics needed for these subjects is very advanced. Many of the properties of atoms, nuclei, and particles are explained by quantum theory.

Early history Physics started with the ancient Greeks. They studied it together with biology, chemistry, and astronomy under the title "natural

philosophy." One of the greatest Greek thinkers was Aristotle. Aristotle developed theories on motion and many other subjects in physics. Many of his ideas were accepted until the 1500s (see ARISTOTLE). Archimedes, another Greek scientist, did experiments with levers and floating bodies. Some of his laws are still used today (see ARCHIMEDES).

After the Greeks, little scientific progress was made in Europe until the 1500s. However, the Arabs translated and preserved many of the Greek writings. They also made their own contributions to science. During the 1500s, the Polish astronomer Nicolaus Copernicus gathered evidence that the earth traveled around the sun. This went against the established opinion, which followed Aristotle's

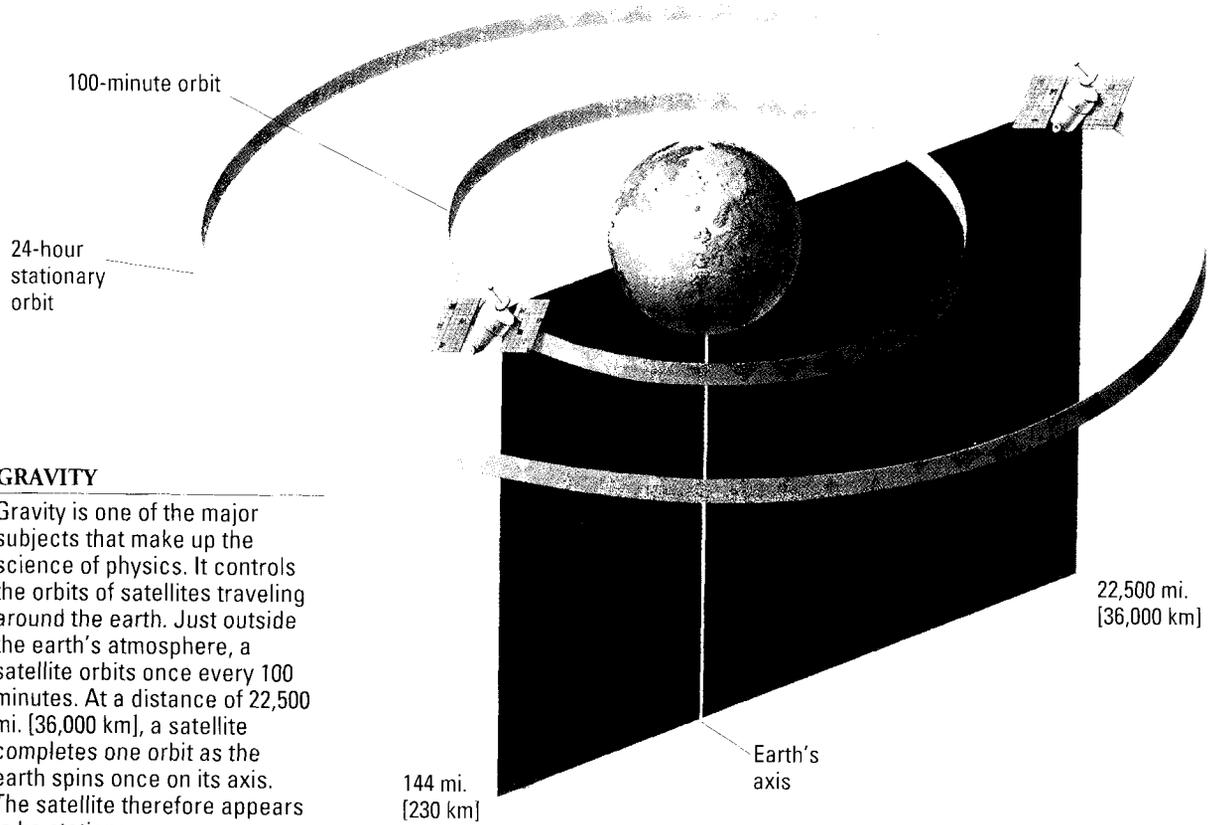


LIGHT

The various properties of light are studied by physicists. The diagram (above) explains how colored bands, or fringes, are formed when white light passes through a pair of narrow slits. The colors of the rainbow (which combine to make white light) each produce a set of fringes because of interference. The component fringes overlap to produce the multicolored combined fringes, such as those that can be seen on a soap bubble.

view—that the sun traveled around the earth. A few years later, Johannes Kepler showed that the orbits of the planets were not quite circular. The orbits were ellipses (ovals). This also went against established opinion. In time, Copernicus's and Kepler's view came to be accepted by the scientific community (see COPERNICUS; KEPLER, JOHANNES).

Experiments in physics were not really performed until 1600. In that year, the English scientist Sir William Gilbert wrote the first scientific study of magnetism (see GILBERT, WILLIAM). Gilbert suggested his ideas about magnetism and demonstrated them with experiments. Another great practical physicist of the 1600s was the Italian physicist Galileo Galilei (see GALILEO). Galileo showed that two different weights fall at the same speed if neither is too light. A light weight is noticeably slowed



GRAVITY

Gravity is one of the major subjects that make up the science of physics. It controls the orbits of satellites traveling around the earth. Just outside the earth's atmosphere, a satellite orbits once every 100 minutes. At a distance of 22,500 mi. [36,000 km], a satellite completes one orbit as the earth spins once on its axis. The satellite therefore appears to be stationary.

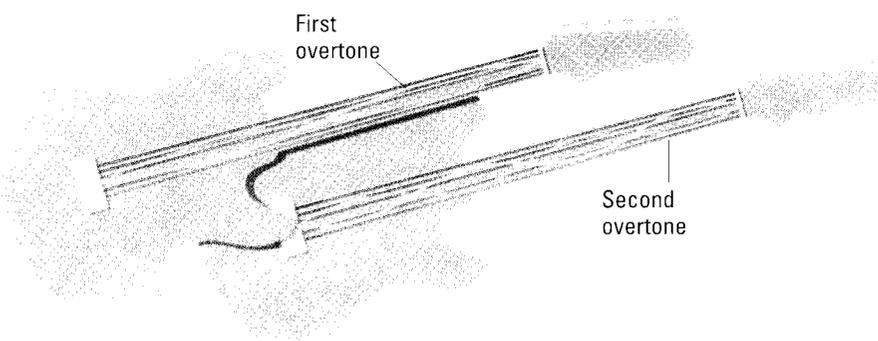


HEAT

Heat is a form of energy, and temperature is a measure of hotness. Pictured above is a modern digital thermometer, which indicates the temperature at the tip of the probe—here 24.4°C [75.9°F].

down by air resistance. According to popular legend, he is supposed to have demonstrated this by dropping weights from the Leaning Tower of Pisa. In addition to discovering laws about the motion of bodies, Galileo also improved the recently invented telescope (see TELESCOPE). He used the telescope to show that the earth moves around the sun. His opponents refused to look through his telescope. They stopped him from writing and from continuing his experiments.

One of the most important scientists of the 1600s was Sir Isaac Newton. Newton's theory of gravity explained the orbits of the planets. In mechanics, his laws of motion were accepted for more than two hundred years. In optics, Newton was the first to show that white light is a mixture of light of different colors. He demonstrated that light consisted of small particles, which he called corpuscles. At the same time, a Dutch physicist, Christiaan Huygens, did experiments that showed that light was made up of waves. The modern understanding of light combines both Newton's and Huygens's ideas.



SOUND

Sounds are produced by vibrations, such as the vibrations of a guitar string. A string vibrating along its whole length produces the fundamental tone. Other vibrations cause harmonics, or overtones.

Energy and matter During the 1700s, scientists started to investigate heat and electricity. At first, scientists thought that heat was a fluid, because when it “flowed” into a material, the material became hot. The experiments by Count Rumford and James Joule showed that heat was a form of energy instead (see JOULES, JAMES PRESCOTT). In the early 1800s, the theory that matter is made up of tiny particles that came to be called atoms became well known. The chemist John Dalton found that atoms combined to form molecules (see ATOM; DALTON, JOHN; MOLECULE).

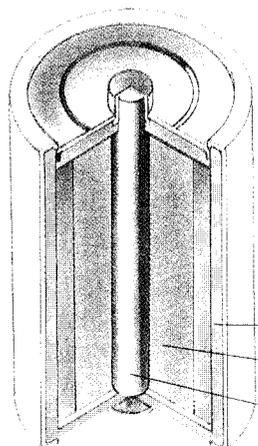
Scientists realized that the movement of atoms or molecules caused an object to feel hot. This led to the kinetic theory of gases. This theory helped explain a number of earlier laws about gases. These discoveries about heat led to the development of thermodynamics. Thermodynamics is the study of ways in which heat energy can be turned into other forms of energy. Thermodynamics helped explain how a steam engine works.

Electricity and magnetism were known to the ancient Greeks. They tried unsuccessfully to

explain these forces. Electricity began to be studied again in the 1700s. The American scientist Benjamin Franklin studied different kinds of electricity—including lightning (see FRANKLIN, BENJAMIN). During the 1800s, great steps were made in understanding electricity. The most important work was done by an English physicist, Michael Faraday (see FARADAY, MICHAEL). He discovered that a wire with a current flowing in it acts as a magnet. His discoveries are the basis of the modern method of generating electricity. In 1873, a Scottish physicist, James Clerk Maxwell, produced a series of equations to describe electricity and magnetism. His equations used the idea of an electromagnetic field (see FIELD; MAXWELL, JAMES CLERK). Using his equations, Maxwell was able to describe a wave. This wave moved through the electromagnetic field. He found that these waves were exactly the same kind as light waves. Maxwell had managed to combine optics with electricity and magnetism. In 1886, a German physicist, Heinrich Hertz, discovered another kind of electromagnetic wave, the radio wave (see HERTZ, HEINRICH).

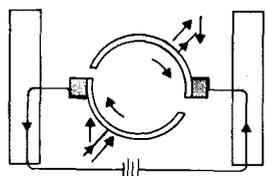
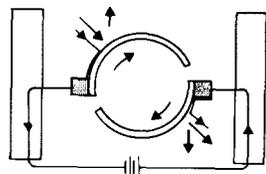
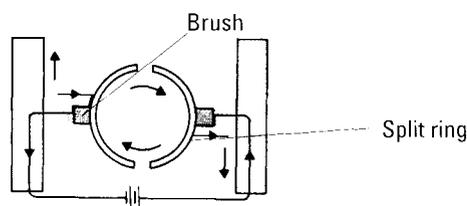
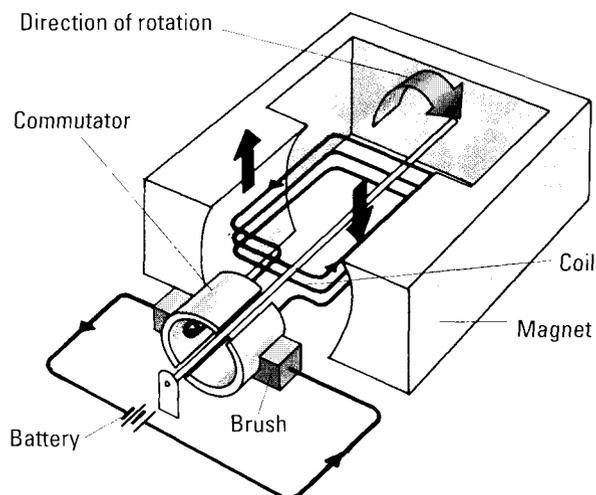
ELECTRICITY

A battery (or cell) is a source of direct current (DC) electricity. A regular flashlight battery has a central carbon anode in a paste electrolyte of ammonium chloride, contained in a zinc case (the cathode).



Cathode
Electrolyte
Anode

Modern history By the end of the 1800s, physicists thought that all the important laws of physics had been discovered. Then a number of discoveries were made that could not be explained. The French physicists Antoine Becquerel and Marie and Pierre Curie discovered that the atoms of some substances were unstable. They gave off particles and radiation called gamma rays. These substances are said to be radioactive (see BECQUEREL, ANTOINE HENRI; CURIE FAMILY; RADIOACTIVITY). Uranium and radium, for example, are radioactive. Radioactivity could not be explained until



ELECTRIC MOTOR

A simple direct current (DC) motor has a current-carrying coil that rotates between the pole pieces of a magnet. A commutator—a split ring with carbon brushes as contactors—reverses the direction of the current each half turn to keep the coil turning in the same direction.

later scientists developed new theories about the structure of the atom.

Another discovery that could not be explained was how certain substances produce an electric current when exposed to light. This is called the photoelectric effect. Only certain frequencies of light generate a current in a particular substance. In 1900, German scientist Max Planck proposed a theory that helped explain the photoelectric effect. Planck proposed that light is given off in packets or particles called quanta (plural of quantum). Each quantum has a specific amount of energy, depending on the light's frequency. This theory, called the quantum theory, helped explain how light produces an electric current in particular substances (see FREQUENCY; PHOTOELECTRIC EFFECT; PLANCK, MAX; QUANTUM THEORY).

In 1913, a Danish physicist, Niels Bohr, produced a model of the atom based on quantum theory. During the 1920s, two German physicists, Werner Heisenberg and Erwin Schrödinger, improved Bohr's model (see BOHR, NIELS; SCHRÖDINGER, ERWIN). With their theory, many effects were explained for the first time.

In 1911, the English physicist Ernest Rutherford discovered that an atom has a central core called a nucleus (see NUCLEUS; RUTHERFORD, ERNEST). During the 1920s and 1930s, the nucleus came to be well understood, and radioactivity was explained. It was discovered that the nucleus itself is made of even smaller particles. These particles are called protons and neutrons. Since that time, scientists studying the atom have learned that protons and neutrons are made up of even smaller particles. These particles are called quarks. Quarks are elementary particles. They cannot be broken down to smaller particles. A complete theory of elementary particles and the forces acting between them, called the standard model, has been developed in recent years (see ELEMENTARY PARTICLES).

Another important theory of this century is the theory of relativity. It was discovered by the German-American physicist Albert Einstein. Relativity replaced Newton's theory of mechanics for objects moving at near light speed. It also gave scientists a more in-depth understanding of gravity.



DANGEROUS EXPERIMENT

Benjamin Franklin proved that lightning is an electric spark by flying a kite in a thunderstorm.

PHYSIOLOGY (fīz'ē ōl'ə jē) Physiology is the study of the functioning of living things. Plant physiologists study how plants work. Animal physiologists study the functioning of various animals' organs and systems. Human physiologists examine the actions of structures and organs in the human body. They learn how these structures and organs work when healthy and when diseased.

Physiology, anatomy, and biochemistry are closely related (see ANATOMY; BIOCHEMISTRY). Anatomy includes the study of the shape and parts of an organism. Biochemistry is the study of the chemicals that make up an organism and the chemical changes that go on in living things. For example, the anatomist studies the structure of the stomach muscles and glands. The biochemist studies the chemicals that make up the stomach cells and the chemical changes that occur when the cells pour gastric juices into the stomach. Physiologists are interested in discovering what body activities make the cells secrete gastric juices when food enters the stomach. They also study the churning movements of the stomach.

Physiology is also closely related to medicine and to pathology, the study of disease (see MEDICINE; PATHOLOGY). In most diseases, parts of the body are not acting the way they should. Doctors study physiology to understand how the healthy body functions. This knowledge allows them to better understand how diseases affect people.

One example of the benefits of physiological research has been control of the disease diabetes mellitus. Diabetes mellitus develops when certain parts of the pancreas do not act the way they should (see DIABETES). Less than one hundred years ago, many people used to die of this disease each year. In 1922, physiologists Frederick Banting and Charles Best completed a long series of experiments with animals (see BANTING, SIR FREDERICK GRANT). These experiments helped them develop a treatment for diabetes mellitus in humans. This treatment has since saved the lives of thousands of diabetic people.

PHYSIOTHERAPY (fīz'ē ō thēr'ə pē) Physiotherapy, also known as physical therapy, is

the use of any physical means and/or exercise to treat a disorder or injury. It is part of the branch of medicine called rehabilitation medicine. Doctors who specialize in this branch of medicine are called physiatrists. Treatments prescribed by these doctors are given by specially trained people called physical therapists, or physiotherapists.

Physiotherapy is helpful in treating many kinds of disabilities and diseases. It is often used in treating various kinds of paralysis and muscle weaknesses that occur from stroke, poliomyelitis, or multiple sclerosis (see MULTIPLE SCLEROSIS; POLIOMYELITIS; STROKE). It is also used in treating heart and lung diseases. Physiotherapy can be prescribed as treatment for amputations, fractures, and other injuries. With the aid of physiotherapy, the person with a disability gains the capability to lead a more independent life.

Many kinds of devices and treatments are used in physiotherapy. Radiant heat lamps, electric heating pads, diathermy (electric heat treatment), hydrotherapy (water treatment), and special baths are used to apply heat to diseased or damaged parts of the body. Heat relieves pain and improves circulation. Cold, used immediately after certain injuries, lessens pain and swelling. Ultraviolet radiation is used to attack pathogens (disease-causing organisms) and to help healing. Ultrasound is used to treat inflammatory conditions of muscles and joints. Manipulation of diseased joints—moving the joint safely beyond the point its surrounding muscles can move it—is used by physical therapists to relax or prevent stiffened joints (see INFLAMMATION; JOINT; ULTRASOUND; ULTRAVIOLET RAY).

Exercise is an important part of physiotherapy. Physical therapists help patients exercise, and they encourage patients to do many physical things on their own. Often, they work with equipment such as pulleys, weights, parallel bars, and stationary bicycles. Splints, braces, crutches, and wheelchairs also help people with disabilities to perform daily activities. Physical therapists help people learn to use all of these devices and develop confidence in doing daily tasks.

Physical therapists work in clinics, hospitals, and

schools for the handicapped. To practice in the United States, they must be licensed.

See also MEDICINE.

PHYTOPLANKTON (fī tō plāngk' tən)

Phytoplankton is the part of the plankton, in the sea or in lakes, that consists of tiny floating algae (see ALGAE; PLANKTON). In the cooler seas the major components of the phytoplankton are diatoms (see DIATOM). These have glassy shells



PHYTOPLANKTON

Phytoplankton in fresh water consists mainly of microscopic algae, shown above with single-celled protozoans.

divided into two halves, which fit together like miniature boxes with lids. When the diatoms die, their empty shells fall to the seabed in countless millions, building up thick layers called diatomaceous ooze. In the warmer seas dinoflagellates are the main algae of the phytoplankton. Both groups of algae are also common in fresh water. The algae of the phytoplankton are the primary producers of food in the sea and in fresh water (see PRODUCER). They are eaten by planktonic animals, or zooplankton.

PIAGET, JEAN (1896–1980) Jean Piaget (pē ə zhā', zhän) was a Swiss psychologist who is best known for his work in the field of child psychology. He suggested the theory that a child's mental abilities, like his or her physical abilities, develop (grow) in a certain order through a series of specific steps.

The four stages of development, as suggested by Piaget, are sensory-motor, preoperational, concrete operations, and formal operations. In the sensory-motor stage (birth to two years old), a child learns about objects, or things, through the use of his or her senses—tasting, smelling, hearing, seeing, and touching objects. In the preoperational stage (two to seven years old), a child begins calling objects by their names. This is the beginning of language for the child. In the concrete operations stage (seven to eleven years old), a child begins to think logically. The child understands likenesses and differences, such as those used in naming objects. The child has begun to think in an organized way. In the formal operations stage (eleven years old to adulthood), the child begins to think abstractly. The child can understand abstract words and concepts such as space, time, and freedom.

From the time Piaget was a young child, he was interested in science. He published a scientific paper when he was only ten years old. He received a doctor's degree in science in 1918. Piaget used his interest in science for his work in psychology. He was among the first to take a biological approach to understanding the development of mental abilities. His theories are widely accepted and respected throughout the world.

See also PSYCHOLOGY.