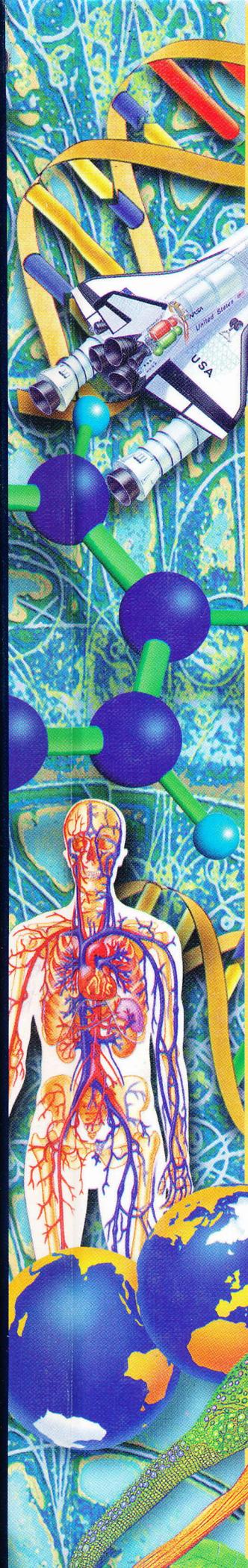


Raintree Steck-Vaughn

*Illustrated*  
**SCIENCE  
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Volume

8



Raintree Steck-Vaughn

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Volume

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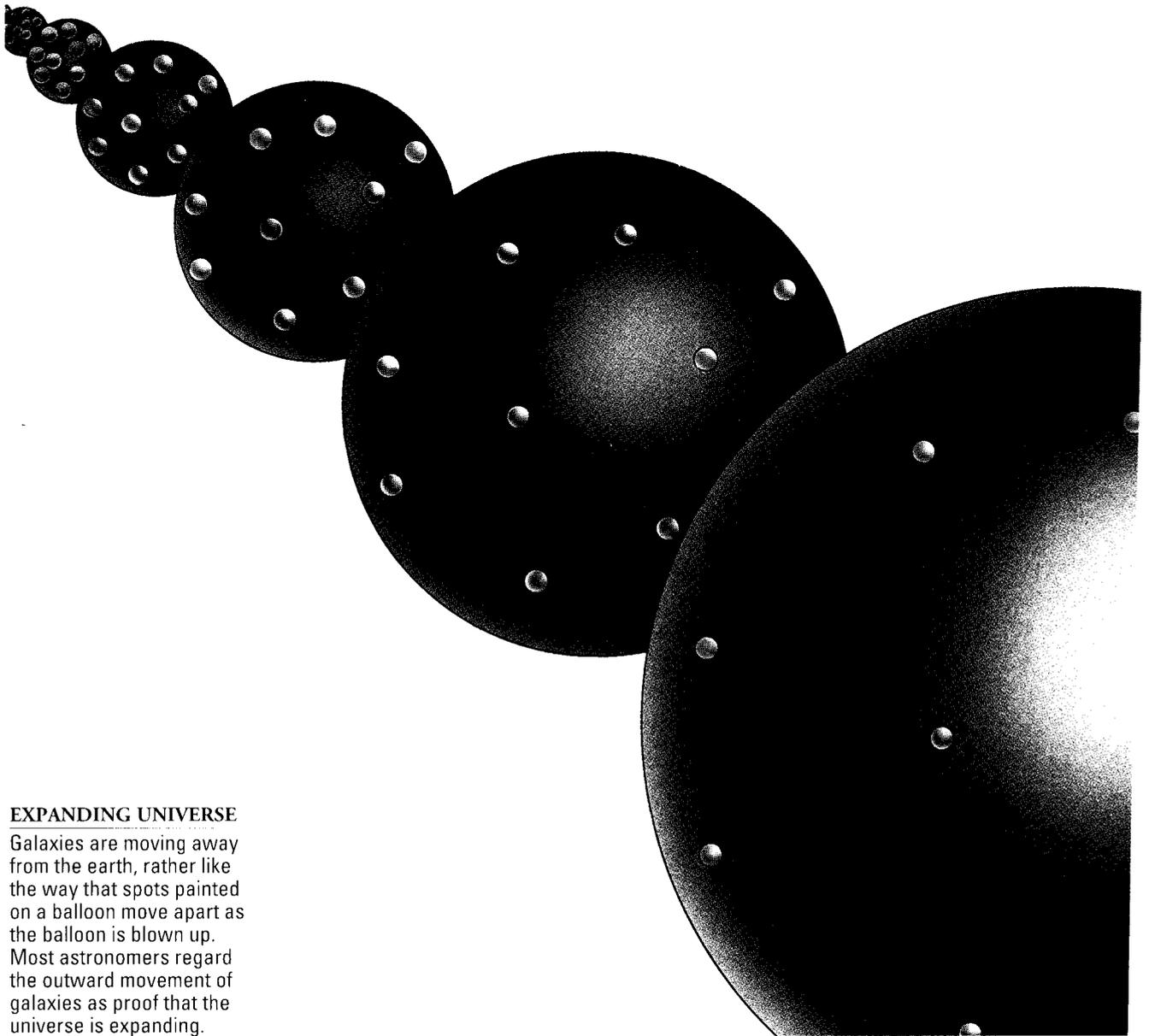
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**EXPANDING UNIVERSE** The expanding universe theory states that the universe is expanding, or that each galaxy or group of galaxies is moving away from every other one. The expansion of the universe was first observed in 1929 by American astronomer Edwin Hubble, who was studying the red shift of distant galaxies (see RED SHIFT). Hubble found that light from distant galaxies exhibited a red shift, indicating that the galaxies were moving away from the earth.

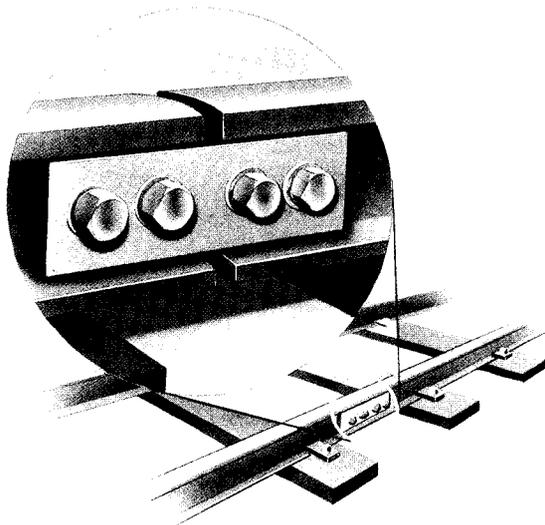
The expansion of the universe is usually taken as evidence for the big bang theory. This theory says that the universe originated in a hot fireball of energy and matter about 15 to 20 billion years ago (see BIG BANG THEORY).

**EXPANSION** Expansion is a process whereby a body increases in volume while keeping the same mass. In other words, the size of a body increases without the addition of more material to the body (see MASS; VOLUME). The term is often used in connection with the heating of a material. Most solids and liquids expand when heated. Heat causes expansion because it increases the vibrations of a material's atoms or molecules. The increased vibrations force the atoms or molecules to move apart. Therefore, the body becomes larger. The process of melting is an extension of the expansion process in solids. If a solid is heated to high temperatures, eventually all the atoms or molecules move about so rapidly that they overcome the forces that bind



**EXPANDING UNIVERSE**

Galaxies are moving away from the earth, rather like the way that spots painted on a balloon move apart as the balloon is blown up. Most astronomers regard the outward movement of galaxies as proof that the universe is expanding.



### EXPANSION

Railroad engineers leave a gap between the ends of rails. When the rails become warm in hot weather, they expand. The gap allows them to do this without twisting the rails.

them together. Then, the solid becomes a liquid.

Different materials expand by different amounts when their temperature is raised. For example, aluminum expands twice as much as iron under the same temperature increase. Gases also expand when heated at a constant pressure. If a gas is heated in a container that prevents expansion, the pressure of the gas increases. Gases expand when heated much more than solids or liquids do.

See also GAS; PRESSURE; STATES OF MATTER.

 **PROJECT 2, 40, 45, 57**

**EXPLOSIVE** An explosive is a substance that produces a violent reaction because of the action of heat or a strong blow. The reaction, called an explosion, involves the release of rapidly expanding gases and other material. Explosions can cause great damage.

Low explosives are caused to explode by burning. Low explosives tend to be less destructive than other kinds of explosives. An example of a low explosive is gunpowder. Gunpowder in a gun is made to burn when a device behind it, called a percussion cap, is struck by the hammer of the gun. The hammer is caused to move when the gun's trigger is pressed. The substance in the percussion cap ignites and causes the gunpowder to explode. The explosion of gunpowder forces a bullet out of the gun (see GUN).

High explosives, which are more powerful than low explosives, are caused to explode because of the action of devices called detonators. The detonators are referred to as primary explosives. Detonators are extremely sensitive to heat. When they are made to explode by heat, they send off shock waves (see SHOCK WAVE). The shock waves act as the strong blow that causes the high explosive to explode. TNT and nitroglycerin are examples of high explosives. Nitroglycerin is the main explosive in dynamite. Dynamite is used in excavating and mining (see EXCAVATION; MINING; TNT).



### EXPLOSIVE

Explosives are used in demolition work. Here a block of apartments is being demolished so that the site can be used for new buildings.

**EXPONENT** In mathematics, such as algebra, the operation of multiplying a number by itself can be shown by an exponent. The exponent (also known as the index) is a small number to the right and toward the top of the base number. For example, the number 4 multiplied by itself 3 times is written as  $4^3$ , where 4 is the base number and 3 is the exponent. Exponents provide a convenient way to express relationships between numbers.

There are five basic laws of exponents. The law of exponents for multiplication states that two or more powers having the same base number may be multiplied by adding the exponents and raising the common base to that power. For example:

$$6^2 \times 6^3 = 6^{2+3} = 6^5$$

The second law states that dividing powers of the same base is done by subtracting exponents:

$$4^4 \div 4^2 = 4^{4-2} = 4^2$$

The third law states that, to raise a power to a power, multiply the exponents:

$$(2^3)^2 = 2^{3 \times 2} = 2^6$$

The fourth law of exponents states that the power of a product is equal to the product of the powers of the factors:

$$(2 \times 3^2 \times 5^3)^2 = 2^{(1) \times 2} \times 3^{2 \times 2} \times 5^{3 \times 2} = 2^2 \times 3^4 \times 5^6$$

The fifth law of exponents states that the power of a quotient is equal to the quotient of each number raised to that power:

$$\left(\frac{3}{4}\right)^3 = \frac{3^3}{4^3}$$

Some exponents need a special explanation. Zero exponents arise in division of powers:

$$4^3 \div 4^3 = 4^0$$

The term *zero power* may seem meaningless. However, since any number divided by itself equals

1,  $4^3 \div 4^3$  must equal 1. Therefore  $4^0$  also equals 1. The zero power of any number except zero is equal to 1. In a similar way, the *first power* of any number must be the number itself. In other words, every number written without an exponent could be written as that number to the first power. A number with a negative exponent is equal to 1 divided by the same number with the corresponding positive exponent:

$$8^{-2} = \frac{1}{8^2}$$

Fractional exponents indicate roots:

$$9^{1/2} = \sqrt{9}$$

See also ALGEBRA; ROOT, MATHEMATICAL.

**EXPOSURE METER** Exposure meters, also called light meters, are devices used in photography to measure the brightness of light. They allow the photographer to adjust the camera's aperture and shutter speed so that the film receives the proper exposure, or amount of light. The proper exposure helps produce a clear photograph (see CAMERA; PHOTOGRAPHY).

Different exposure meters measure the amount of light reflected from the subject or the light falling on the subject. They do this by means of a



#### EXPOSURE METER

A photographer uses an exposure meter to measure how much light falls on an object or scene to be photographed. Using this information, he or she can set the camera's controls to take a clear photograph.

photoelectric effect (see PHOTOELECTRIC EFFECT). Light entering the meter causes an electric current to flow through a circuit in the meter. The size of the current depends on the amount of light. The light can be measured indirectly by measuring the current.

Exposure meters can be held in the hand or built into the camera. Hand-held exposure meters can be used to measure either the light reflected from the subject or the light falling on the subject. Built-in exposure meters usually measure the light that is reflected.

**EXTINCTION** Extinction is the dying out of a species (see SPECIES). Extinction can be a natural occurrence. Over time, some organisms within a species may develop and pass on characteristics that make them better suited to their environment. Those organisms that do not have these characteristics eventually die off. Sometimes, whole species cannot adapt to their environment. These species become extinct (see EVOLUTION). By dating fossils, scientists can determine when extinctions occurred (see DATING).

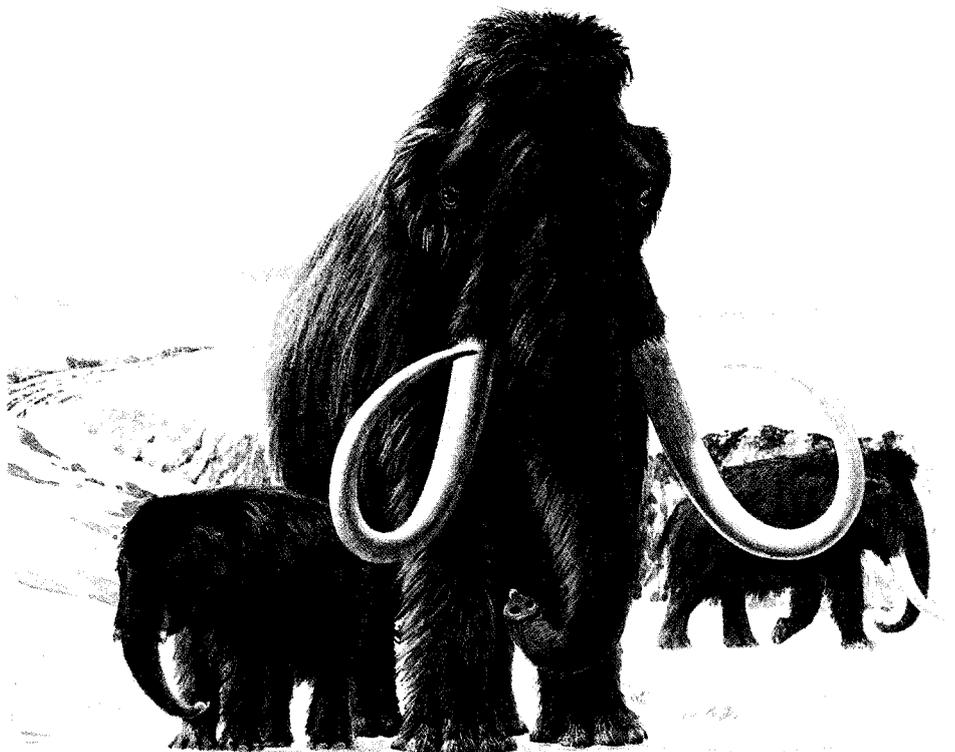
Extinctions do not have to be gradual and involve only certain species. On rare occasions, extinctions

can happen quickly to many species. This type of extinction is called a mass extinction. Mass extinctions occurred about 250 million years ago and again about 225 million years ago. The mass extinction many people are most familiar with is that of the dinosaurs, which occurred about 65 million years ago (see DINOSAUR).

Even though extinction is natural, humans have greatly increased the rate at which species are disappearing from the earth. Many species have disappeared because humans have altered or destroyed their habitat. A habitat is the place where an organism lives. For example, many species in South America are close to extinction because the tropical rain forests in which they live are being cut down. Some species, such as the American bald eagle, the American alligator, and the black rhinoceros, have become endangered (close to extinction) because of excessive hunting (see ENDANGERED SPECIES).

The loss of species can have a far-reaching effect on the environment. The unique characteristics that each species has cannot be replaced. Also, the loss of a species breaks the food chain, which may affect the survival of many other species.

*See also* ENVIRONMENT; FOOD CHAIN.

**EXTINCTION**

The woolly mammoth was hunted by early humans. It became extinct in fairly recent times, after the last ice age.

**EXTRASENSORY PERCEPTION** Extrasensory perception describes a way of being aware of something without the use of the known senses. The known senses are sight, hearing, smell, touch, and taste. For instance, knowing what a person is going to say before he or she says it is an example of extrasensory perception. Extrasensory perception is often abbreviated *ESP*.

There is much debate over whether ESP exists. If it does exist, the way it works is unknown. Most scientists believe that it is best to think of ESP as something that might exist but whose existence has not been proved.

There are four basic areas in the field of extrasensory perception. Telepathy is sometimes called "mind reading." It is the sending of thoughts, feelings, or knowledge from one person to another in some unknown way. For instance, if a person wants someone to call on the telephone, the person may sit and concentrate about that wish. Somehow, the other person "receives" the message and makes the telephone call.

Clairvoyance is a second form of ESP. Clairvoyance involves being mentally aware of something, such as an event or a person, without the use of the known senses or the telepathic help of another person. An example of clairvoyance is when a person in New York is aware that someone in Chicago is very ill, but he or she has found this out in a way other than the known ways of finding things out.

Precognition is a third form of ESP. It involves knowledge of an event before it happens, by means of telepathy or clairvoyance. Psychokinesis, the fourth form of ESP, is the psychological control of physical objects. For example, a person concentrating for "heads" to show on the flip of a coin might be able to influence "heads" to appear.

People have been studying ESP in a systematic way since the late 1800s. In 1882, a group of people met in London and formed the Society for Psychical Research. A similar society was founded in the U.S. in 1888. Research into ESP continues today. In the United States, one of the most noted ESP researchers was J.B. Rhine. Beginning in the 1930s, he headed a research program for ESP at Duke University in North Carolina for many years.

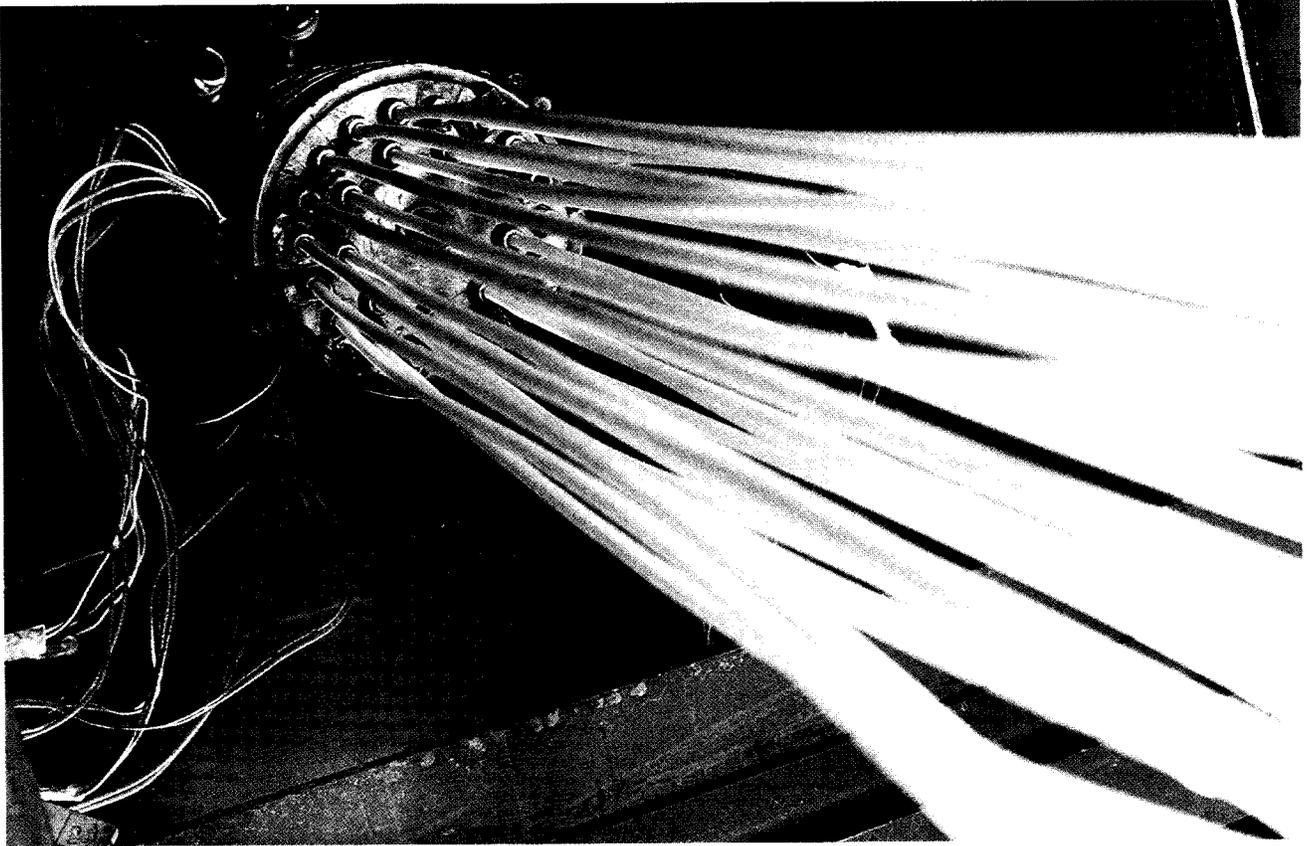
He and his coworkers did much work on telepathy. The ESP researchers used a deck of twenty-five cards with certain symbols on them. Dr. Rhine claimed that many persons could tell what was on the cards even though these persons could not see the cards. He said that the scores they made in telling what was on the cards were better than they would make in just guessing. Other researchers say that Dr. Rhine's experiments were not done scientifically, and therefore his results do not prove that ESP exists.

If ESP does exist, it is clear that people vary widely in ESP capacity. Also, ESP abilities seem to come and go. A person may show positive ESP results in the early stages of an experiment but show chance results later. It has also been suggested that a person may have special ESP abilities for a limited period in his or her life and not at any other time.

The debate over the existence of ESP will no doubt continue until there is reasonable evidence explaining how it is possible. Scientists study ESP because if some people were found to possess these abilities, the importance of ESP could be enormous. For example, a person with ESP abilities might be able to locate valuable mineral deposits and accomplish other things that are expensive or difficult to do today. The fact that nobody has been found who can do such things adds to the question of whether or not ESP exists.

**EXTRUSION** Extrusion is a process used to shape materials—such as metal, plastic, or rubber—into pipes, tubes, or other shapes with a long length. Extrusion is also used to coat cables or wires with substances, such as metal or plastic. The material being extruded is often first softened by heating. It is then forced through one or more openings.

There are three basic methods of extrusion—direct, hydrostatic, and indirect (or reverse). Direct is the most widely used method. In direct extrusion, a ram (plunger) in one end of a cylinder is pushed against a piece of the metal to be shaped, called a billet. This forces the billet through a die opening at the other end of the cylinder (see *DIE*). The billet flows out of the cylinder much like



#### EXTRUSION—Direct

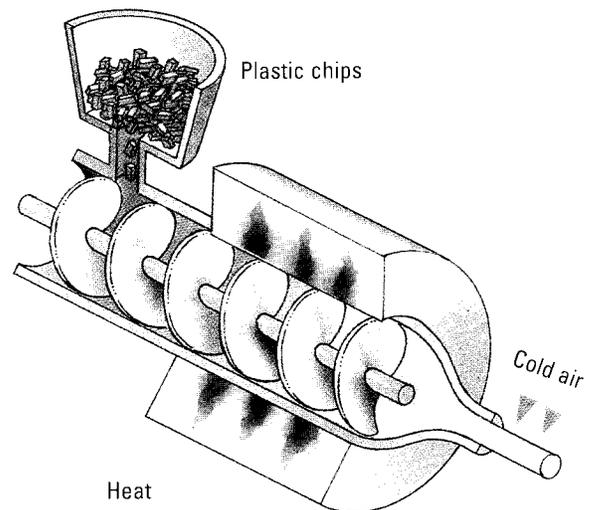
A ram pushes melted plastic through a number of holes to make many extrusions at the same time. Using even higher pressures, some metals can also be extruded in this way.

toothpaste flows out of its tube. Hydrostatic extrusion is similar to direct extrusion. However, in this method, a thick fluid surrounds the billet. The ram pushes on the fluid. The fluid pressure in turn forces the metal through the die opening. In indirect extrusion, a hollow ram is used. The hollow ram has a die attached to one end. The die and hollow ram push against a billet, which is resting against the closed end of a cylinder. The billet is forced out through the die opening and through the ram.

When plastic or rubber is shaped by any of these methods, the ram is replaced by a screwlike device called an auger. The extrusion of synthetic fibers made from plastics also involves a device called a spinneret rather than a die (see FIBER). A spinneret is a platelike device that has many tiny holes.

These methods of extrusion can be done on materials that have not been softened by heating. When material that is at room temperature is

extruded, the process is called cold extrusion. More pressure is needed to shape cold material than heated material. However, cold extrusion products are stronger than heated extrusion products.



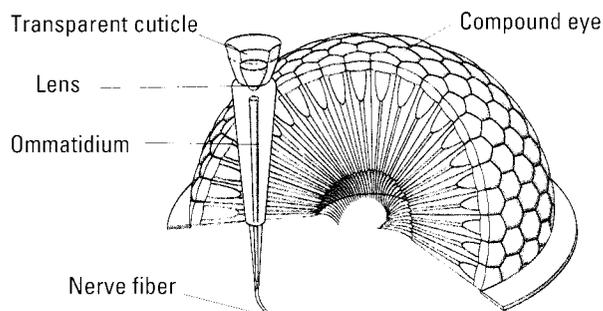
#### EXTRUSION—Shaping

In one type of extrusion machine, a screw feeder forces plastic chips through a heated chamber, where the plastic melts. The molten plastic is squeezed through a shaped nozzle and solidified by a current of cold air. Here, a circular rod is being extruded, but many other shapes can be made in this way.

# EYE AND VISION

The eyes are the sense organs that give human beings and many other organisms the most accurate and detailed information about their surroundings. Most animals have eyes or similar light-sensitive organs. Even many one-celled organisms will react to bright light. Some invertebrates (animals without backbones), such as starfish and jellyfish, have pigmented (colored) spots that are light sensitive. Spiders and snails have simple eyes called ocelli with hard, fixed lenses that cannot focus. These simple eyes can sense light and some movement, but they are unable to form a clear image. Most insects and crustaceans have compound eyes made of hundreds of lenses joined together. Compound eyes form hazy images, but they are especially good for detecting movement. Lobsters have compound eyes at the ends of movable stalks. Many insects and crustaceans have both compound and simple eyes.

Squids and octopuses have eyes and vision much like those of human beings and other vertebrates. They are able to focus and form clear images. Vertebrate eyes are usually adapted to fit an animal's life style. Many nocturnal animals have large eyes to help them see in the dark (see NOCTURNAL BEHAVIOR). Many animals have a third eyelid, or nictitating membrane, to protect the eye from dust or wind. Since fish live in the water, where fluid continually bathes and moistens their eyes, they have no need for eyelids or tear-producing glands.



## COMPOUND EYE

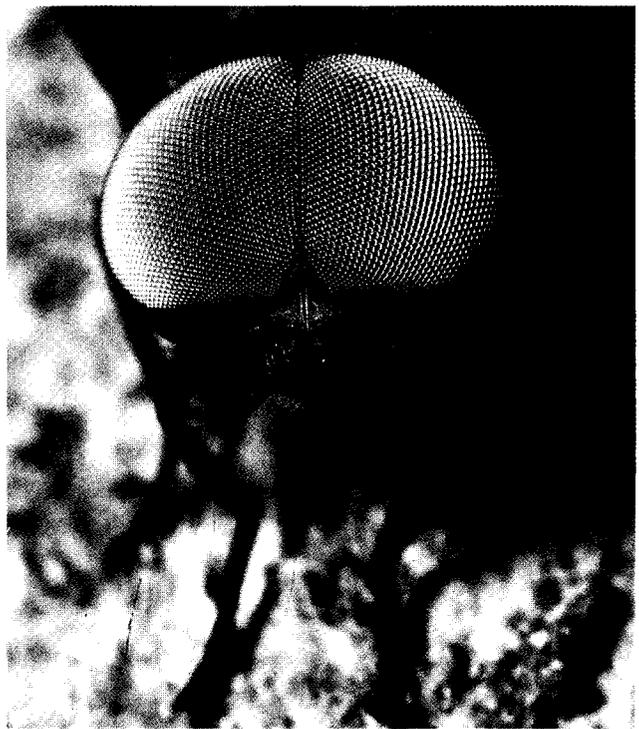
Many insects and crustaceans have compound eyes. These eyes have up to 30,000 tiny lenses with narrow fields of view. The lenses overlap to give good all-around vision. Behind each lens is a light-sensitive unit called an ommatidium, which is connected to the animal's brain by nerve fibers.

The eagle, with its large eyes, has the keenest vision of any animal.

**The human eye** The human eye is a sphere measuring about 1 in. [2.5 cm] in diameter. It rests in the orbit, a bony socket in the skull, and can move in all directions due to the actions of the six ocular muscles. The wall of the eyeball has three layers: the sclera, the uvea, and the retina.

The sclera is the outermost layer and is made of tough fibrous tissue. In the front of the eye, the sclera becomes the transparent cornea. The cornea is clear so that light can enter the eye. The cornea is about 0.5 in. [13 mm] in diameter. Just behind the cornea is the anterior (front) chamber, which is filled with a watery fluid called aqueous humor. The aqueous humor helps the eye keep its shape and transports nutrients throughout the front portion of the eye.

The uvea includes the iris, the ciliary muscle, and the choroid. The iris is the colored part of the eye (usually brown or blue) located just inside the

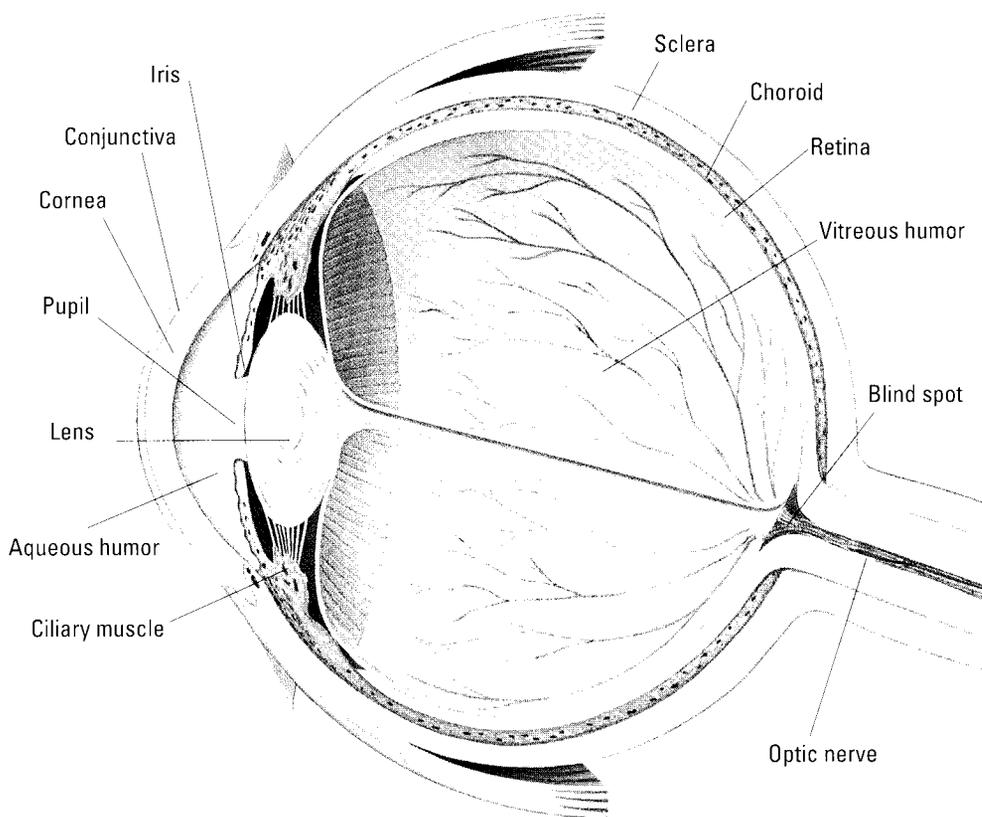


## INSECT EYES

The horsefly pictured above has huge compound eyes to see enemies such as insect-eating birds and lizards.

**HUMAN EYE**

In the human eye, seen here in cross section, the lens assembly divides the eyeball into two chambers. The front chamber, behind the cornea, contains a watery liquid called aqueous humor. The vitreous humor, in the rear chamber, is more jellylike. Light entering the eye is refracted (bent) by the cornea, aqueous humor, lens, and vitreous humor. The shape of the lens changes to focus the light onto the retina.



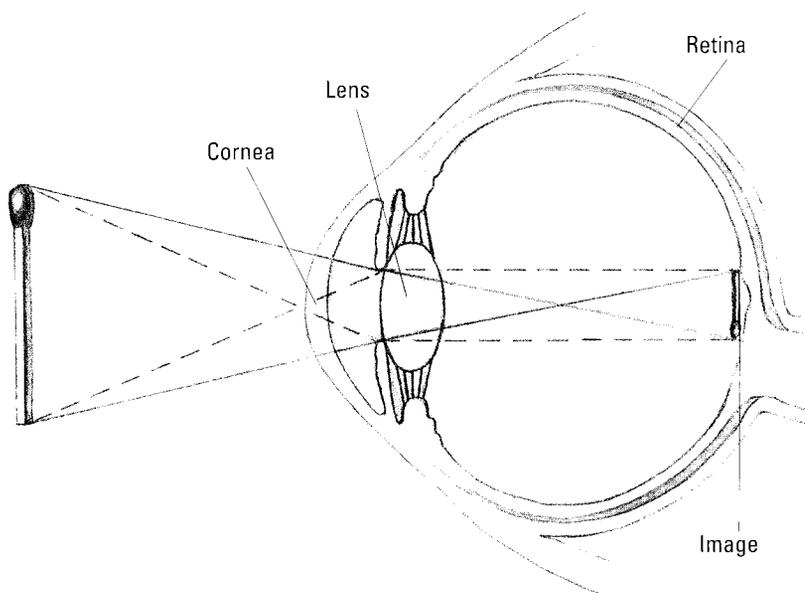
cornea. The iris surrounds the pupil, the opening through which light enters the eyeball. The pupil looks like a black circle in the middle of the front of the eye. There are muscles in the iris that can increase the size of the pupil to let more light in or decrease its size to let less light in. The ciliary muscle is part of the choroid and is attached to the lens. The ciliary muscle controls the shape of the lens to allow the eye to focus on near or distant objects (see

ACCOMMODATION). The choroid surrounds the eyeball just inside the sclera. The choroid is rich in blood vessels.

The retina is the innermost layer of the eye, located just inside the choroid. The retina contains light-sensitive nerve cells. These cells connect to the brain by means of the optic nerve. There are two types of nerve cells in the retina: rods and cones. Rods—long, thin cells—are located

**UPSIDE-DOWN IMAGE**

The path taken by rays of light cross over as they pass through the eye's lens and cornea. As a result, the image focused on the retina is upside-down (just like the images on the film of a camera). It is the brain that turns the image the correct way up, so we see the world as it really is.



throughout the retina and are sensitive to dim light. The rods function primarily for night vision. Cones are nerve cells that are wide at one end and narrow to a point at the other. They are centralized in the rear of the retina in a small area called the macula. This in turn contains a smaller area called the fovea, which gives the clearest vision. Cones are sensitive to bright light. They produce sharp images and are responsible for color vision. The large space enclosed by the retina and the lens is called the posterior chamber and is filled with the clear, jellylike vitreous humor. The vitreous humor helps give the eye its shape and transports nutrients throughout the back part of the eye.

The eyeball is protected by the eyebrows, eyelashes, and eyelids. These keep dust and other irritants out of the eye. They also help limit the amount of bright light and mechanical injury to which the eye is exposed. Each eyelid has three

#### ALL-AROUND VISION

A scrub hare has eyes on the sides of its head. This arrangement gives the animal a wide view of its surroundings.

parts: the skin, the muscles controlling the skin, and the conjunctiva. The conjunctiva is a thin membrane lining the inside of the lid and part of the eyeball. It is kept moist by a constant stream of fluid—tears—produced by the lacrimal, or tear, glands. Blinking, or closing the eyelids, moistens and cleans the surface of the cornea.

**How the eye sees** Vision—the ability to see—has four main stages. First, light rays from an object enter the pupil. Second, these rays are focused by the lens onto the retina. Third, the rods and cones are stimulated and send a message through the optic nerve to the brain. Fourth, the brain interprets the nerve signals from the optic nerve and “sees” the image formed in the eye.

Before light enters the pupil, it passes through the cornea and aqueous humor, causing it to refract, or bend slightly (see REFRACTION OF LIGHT). The pupil widens or narrows to allow the proper amount of light to enter. As light rays travel through the lens, they are refracted even further so that they will focus on the retina. The lens changes



shape in a process called accommodation to control this focusing. Because the lens can only focus on one object at a time, objects at different distances may appear to be blurred. A good example of this can be shown by looking at a tree through a screen door. If a person focuses on the tree, the screen will be blurred, whereas if he or she focuses on the screen, the tree will be blurred.

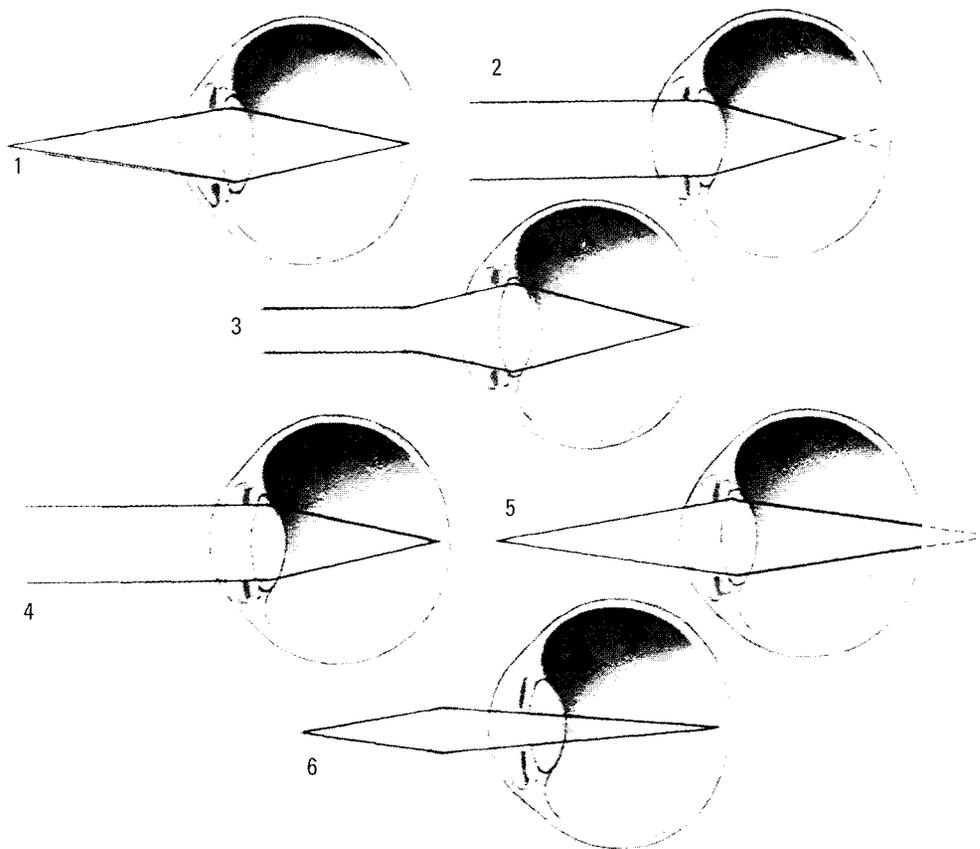
Each eye sends "image signals" to the brain by means of the optic nerve. These nerves pass through a nerve junction called the optic chiasma. The distance between the eyes means that each eye views the world from a slightly different angle. The image recorded by each eye is therefore slightly different from the other. By comparing these two, slightly different images, the brain is able to perceive depth and distance. The ability of the brain to form one image from the images of two eyes is called binocular vision.

The spot where the optic nerve attaches to the retina has no rods or cones. As a result, this spot is not light-sensitive. It is called the blind spot. If the image of an object is focused on the blind spot, the object will seem to be invisible.

**Defects of the eye** Defects of the eye may be hereditary or may be caused by other factors, such as age. With the exception of color blindness, most can be treated with corrective glasses or contact lenses.

Color blindness is an inherited defect in the cones that prevents a person from being able to distinguish differences between certain colors (see COLOR BLINDNESS). Strabismus, a condition in which the eyes do not align properly, is caused by an imbalance in the ocular muscles. As a result, the eyes turn inward or outward. This is a common condition in children that requires surgery only in severe cases. Astigmatism is blurring or distortion of vision due to a defect in the shape of the cornea or lens. Presbyopia is the loss of accommodation, or ability to focus, as a result of hardening of the lens. Most people become somewhat presbyopic as they grow older.

Myopia, or nearsightedness, is caused by an eyeball that is longer than normal. As a result, faraway images are focused in front of, instead of on, the retina. Corrective lenses that are concave (lenses that curve inward) help treat this defect. Severe



#### CORRECTING EYE DEFECTS

Diagrams 1-3 show myopia, or nearsightedness.

(1) A nearby object is seen clearly because light from it is focused on the retina.

(2) A distant object appears blurred because the light is focused in front of the retina.

(3) A concave lens corrects the defect.

Diagrams 4-6 show hyperopia, or farsightedness.

(4) A distant object is seen clearly because light from it is focused on the retina.

(5) A nearby object appears blurred because the light is focused behind the retina.

(6) A convex lens corrects the defect.

myopia can also be treated by altering the shape of the cornea using a laser so the cornea forms a concave lens. Hyperopia, or farsightedness, is caused by an eyeball that is shorter than normal. As a result, nearby images are focused behind the retina. Corrective lenses that are convex (lenses that curve outward) help treat this defect.

**Diseases of the eye** Conjunctivitis is an inflammation of the conjunctiva of the eyelids and eyeball. Its mild form is called pink eye and may be caused by allergies, irritation, or infections. A form of conjunctivitis caused by a virus, trachoma, is the major cause of blindness in Europe and Asia.

A sty is an infection of a gland at the corner of the eyelid. A cataract is a condition in which the lens becomes cloudy or opaque, reducing the amount of light that enters the eye. Treatment of

cataracts may involve surgical removal of the lens and either implantation of an artificial lens or the use of special corrective glasses.

Glaucoma is increased pressure within the eyeball that puts pressure on, and eventually destroys, the cells of the retina. Night blindness is caused by a deficiency of vitamin A, which results in damage to the rods. In a retinal detachment, the retina separates from the choroid and floats in the vitreous humor. This can be caused by a fall, a blow to the head, or by any other trauma to the eye. It is treated surgically and, in many cases, laser beams are used to affix the retina back in place. A corneal abrasion is a very painful scratch on the surface of the cornea. It usually heals with no ill effects. Corneal scarring, however, results from more severe injury or disease. Since the scar interferes with or totally obscures vision, the cornea may be removed and replaced with one from a donor (see TRANSPLANTATION).

**Eye specialists** Healthy persons should have their eyes examined by a specialist every one or two years. These regular examinations help keep the eyes healthy by detecting diseases or disorders.

Ophthalmology is the study of the eye, eye disorders, and eye diseases. An ophthalmologist is a medical doctor who specializes in treating disorders and diseases of the eye. An ophthalmologist can also check a patient's vision and prescribe corrective glasses or contact lenses. An ophthalmoscope is a special instrument that lets a doctor see into the eyeball to examine the retina, blood vessels, and optic nerve. Many diseases that affect other parts of the body also cause changes in the eye. Diseases such as multiple sclerosis can sometimes be detected by an eye examination long before any symptoms appear.

An optometrist can test a person's vision and prescribe corrective glasses. An optician can make corrective glasses or contact lenses according to the prescription of an optometrist or an ophthalmologist. Although ophthalmology and optometry are related, only an ophthalmologist is able to prescribe medication or perform surgery to treat a disease of the eye.



#### EYE TESTING

An optometrist uses this complicated arrangement of lenses to test a person's vision. In this way, the optometrist can detect such minor disorders as myopia (nearsightedness) or hyperopia (farsightedness). He or she can also prescribe corrective lenses that an optician makes into eyeglasses or contact lenses.

## F

**FACSIMILE MACHINE** (fāk sīm'ə lē) The term *facsimile* means "exact copy." Facsimile machines—called fax machines for short—transmit copies of documents electronically. Telephone lines are usually used to transmit the information. Radio waves can also send the information to a satellite dish. Fax machines can be used to transmit copies of handwritten or typed material, maps, photographs, or drawn art. Fax machines were invented in the late 1800s. The machines were mainly used by very large corporations and news-gathering businesses, such as newspapers and news and photo services, during much of the 1900s. Because of recent advancements, fax machines are now widely used in government, businesses, and even some homes and automobiles.

The first step in the transmission of a fax image takes place when the document to be transmitted is inserted into a slot in the machine. A person tells the machine where to send a copy of the document by dialing on a special telephone the receiving



**FACSIMILE MACHINE**

Most modern offices have fax machines. They are also available for public use in such places as railroad stations and, as pictured above, airports.

machine's telephone number. Then, a beam of light inside the machine passes over the document. As it passes over the light and dark portions of the document, the beam is reflected to a device that converts the light waves into an electric current. For example, if a fax machine were to send a copy of a piece of paper that had the letter *s* on it, a large electronic signal would represent the shape of the letter. A small electronic signal would represent the rest of the white paper.

The electronic signals produced are then immediately sent over telephone lines to the fax machine that the sender dialed. The fax machine at the destination receives the signals and passes them to a printer. The printer converts the signals into the same pattern of light and dark as the original image. The process of transmitting information by a fax machine takes about the same amount of time as it does to complete a telephone call. The copy of the original that is received is often called a fax.

**FAHRENHEIT SCALE** (fär'ən hīt' skāl) The Fahrenheit scale of temperature is based on 32°F as the freezing point of water and 212°F as the boiling point of water. There are 180 units between the two points. The Fahrenheit scale was developed in the early 1700s by Gabriel Fahrenheit, a German physicist. Many countries use the Celsius scale instead of the Fahrenheit scale. In the Celsius scale, the freezing point of water is 0°C, and the boiling point is 100°C (see CELSIUS SCALE).

The formula for converting Fahrenheit temperature to Celsius temperature is:  $^{\circ}\text{C} = (^{\circ}\text{F} - 32) \times 0.56$ . The formula for converting Celsius temperature to Fahrenheit temperature is:  $^{\circ}\text{F} = (^{\circ}\text{C} \times 1.8) + 32$ .

**FALCON** A falcon is a bird of prey that belongs to the family Falconidae. It is streamlined, with a narrow tail and pointed wings. This helps the falcon fly extremely fast. Some species can travel at over 100 m.p.h. [160 kph]. This great speed allows falcons to catch other birds in flight. Falcons also eat insects and small mammals. Some falcons can hover and look for prey on the ground below.

There are six species of falcons in North America. Perhaps the best known is the peregrine falcon, one

**FALCON**

Falcons are streamlined birds of prey. Their great speed in flight enables them to catch other birds, insects, and rodents, all of which they eat.



of the fastest birds in the world. This bird has been widely used in the sport of falconry (hunting with falcons). It is found all over the world, especially in coastal and mountainous areas. The peregrine falcon is now an endangered species in most parts of North America (see **ENDANGERED SPECIES**). The widespread use of pesticides has resulted in the poisoning of the bird and has caused its numbers to decrease. Ornithologists (scientists who study birds) are working to restore the peregrine falcon to many areas.

See also **BIRD**; **ORNITHOLOGY**.

**FALLOUT** Fallout is radioactive material that settles to the ground following a nuclear explosion. A great deal of intensely radioactive material is produced during a nuclear bomb explosion (see **NUCLEAR WEAPON**; **RADIOACTIVITY**). This material combines with dust and moisture to form a mushroom-shaped cloud. The radioactive matter is carried by the wind until it returns to the earth as fallout.

Fallout is extremely dangerous to all living things because of the radioactive isotopes it contains. The isotopes usually lose their radioactivity within a few hours or days of the explosion, but a few remain

radioactive for several years. Fallout may cause radiation sickness, cancer, and genetic problems (see **CANCER**; **GENETICS**; **ISOTOPE**). Protection from fallout may be sought in underground chambers called fallout shelters.

**FAMILY** A family, in the classification of living organisms, is a group of closely related members of an order. The organisms in a family are not as closely related as those in a genus, although they do still have many features in common. The names of animal families all end in *...idae*, while family names in the plant kingdom all end in *...aceae*.

See also **CLASSIFICATION OF LIVING ORGANISMS**.

**FARAD** A farad is a unit that measures the capacitance of a capacitor. A capacitor is a device used in electrical circuits. It is made of two or more parallel metal plates, placed close to each other but not touching. One plate has a positive electric charge and the other a negative charge of the same size. This produces a potential difference across the plates (see **CAPACITOR AND CAPACITANCE**; **POTENTIAL**). The capacitance of the device is equal to the charge divided by the potential difference. The capacitance is measured in farads, the charge is

measured in coulombs, and the potential difference is measured in volts. If a charge of one coulomb produces a potential difference of one volt, the capacitance is one farad (see COULOMB; VOLT).

The farad is a very large unit. Usually, the microfarad or the picofarad are used instead. A microfarad is equal to one millionth of a farad. A picofarad is equal to one millionth of a microfarad.

**FARADAY, MICHAEL** (1791–1867) Michael Faraday was a British physicist and chemist who made many important discoveries. In 1813, he became an assistant to Sir Humphry Davy at the Royal Institution in London (see DAVY, SIR HUMPHRY). Faraday was made a professor in 1833 and worked at the institution for the rest of his life. In 1820, Hans Oersted had discovered an electric current created a magnetic field (see ELECTROMAGNETISM). Faraday heard about this and wanted to see if he could reverse the experiment and have a magnetic field produce an electric current. He began by building a sort of transformer. In 1831, he invented a simpler machine to make an electric current from a magnet. This was the first generator (see GENERATOR, ELECTRICAL; TRANSFORMER). Joseph Henry also made a generator at the same

time (see HENRY, JOSEPH). All modern generators and transformers are based on the work of Faraday and Henry.

Faraday's work in chemistry was equally important. He discovered benzene in 1825. By combining his knowledge of chemistry and electricity, he discovered the laws of electrolysis in 1832. Two electrical quantities are named after Faraday. One is the Faraday constant. This measures the quantity of electricity it takes to liberate one mole of a substance. The other is the farad, a unit of capacitance. *See also* BENZENE; ELECTROLYSIS; FARAD; MOLE.

**FAT** Fat is a substance found in animal tissues and in plants, especially in seeds. Fat is also called lipid. Fat is the main form in which animals, including human beings, store excess food for later use.

Fats are made of the elements carbon, hydrogen, and oxygen. During digestion, fats are broken down into fatty acids and glycerol for use by the body (see DIGESTION). Because fats contain more carbon and hydrogen than do carbohydrates, they can supply more energy. Pure fat provides 4,040 calories per pound [8,907 kilocalories per kilogram], compared with a carbohydrate that supplies 1,820 calories per pound [4,012 kilocalories per kilogram] (see CALORIE). Although fats supply more than twice as much energy as carbohydrates, it is more difficult for the body to use fats for energy. Excess fats often end up being stored in the cells and tissues as body fat.

A fat is saturated or unsaturated depending on whether the chemical bonds between the carbon atoms in the molecules contain all the hydrogen atoms they can hold (saturated) or could hold more (unsaturated). Most saturated fats come from animals and are solid at room temperature. Unsaturated fats are liquids and are often called oils. Most of them come from plants. They can be made solid and saturated by adding hydrogen atoms. This process is called hydrogenation. The intake of saturated or unsaturated fat affects the "packaging" of cholesterol in the blood. Cholesterol is a fatty substance that has been linked to heart disease (see CHOLESTEROL). Cholesterol that is packaged as low-density lipoproteins (LDL)



**MICHAEL FARADAY**

Faraday made many key discoveries in physics and chemistry. Some fundamental laws about motion and about electrolysis are named for him.

increases the risk of heart disease. Cholesterol that is packaged as high-density lipoproteins (HDL) lowers the risk of heart disease. Studies have shown that the concentration of HDL can be increased through exercise, weight loss, and reducing one's intake of saturated fats.

Body fat helps insulate against the cold. Animal and plant fats are used to make candles, explosives, medicines, plastics, soap, and many other products.

*See also* DIET.

**FATHOM** A fathom is a unit of length that is mainly used to measure water depth. One fathom equals 6 ft. [1.8 m]. A fathom was originally measured as the distance between the fingertips of the hands when the arms are fully extended to the sides.

**FATIGUE** (fə tēg') Fatigue in a living organism means tiredness or exhaustion caused by a long period of activity. Fatigue is quite normal after a period of hard work and is easily cured by resting. Certain physical and mental illnesses can cause fatigue to develop very quickly and may make you feel tired all the time. Our chemical senses suffer from a form of fatigue if they are exposed to the

same stimulus for too long. A stimulus is something that causes a response. For example, our noses soon get tired of tobacco smoke in a room and we no longer notice it. But if we leave for a while and then return to the room a little later, we can smell the smoke at once.

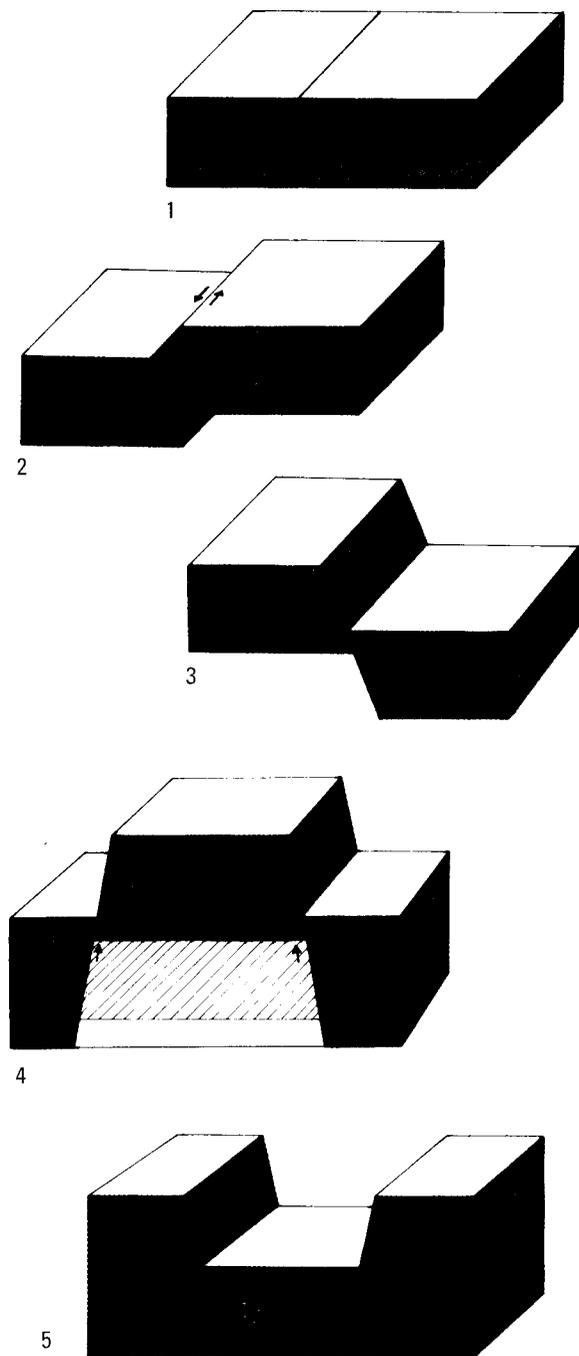
The term *fatigue* also applies to objects made of metal. If a piece of metal such as a wire (a paper clip, for example) is bent repeatedly in the same place, it will break. It breaks because of metal fatigue. Bending causes the atoms in the metal crystals to move and produce imperfections in the crystals. Breaking occurs at these imperfections. Imperfections also occur at notches in a piece of metal, at screw threads, or at welded joints. The wing of an airplane is prone to metal fatigue. Modern production techniques and periodic testing ensure that airplane components do not fail and cause disaster.

**FAULT** A fault is a fracture, or break, in the earth's crust along which movement has occurred. Faults can move horizontally or vertically. This movement may sometimes cause an earthquake. In 1906, the San Andreas fault in California suddenly moved horizontally, causing a very destructive earthquake.



#### **FAULT—Earthquakes**

Movements of the San Andreas fault, shown in this aerial view, have caused several earthquakes in California during this century.



#### FAULT—Earth movements

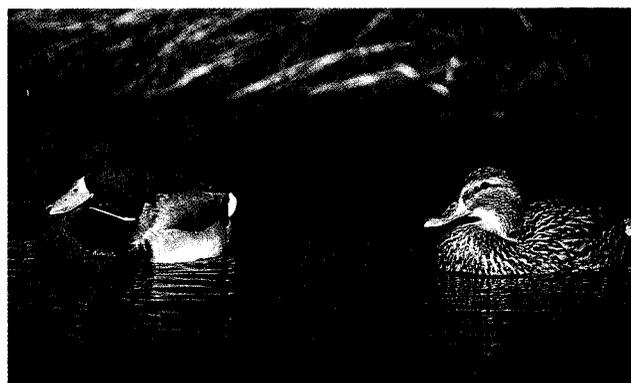
The diagrams show faults and movements along them. (1) A fracture line between two blocks of rock. (2) Two blocks move horizontally along a fracture line. (3) Two blocks move vertically along a fracture line. (4) A block is forced upward from the surrounding rock to form a horst. (5) A block falls to a lower level to form a rift valley.

Faults shape the landscape by their movements. When rocks on one side of a fault shift vertically, a fault scarp, or cliff, is formed on the uppermost surface. A block of rock that rises between two faults is called a horst. A block that has moved down

between the two faults is called a graben. When these form landscape features on the the surface, they are called block mountains and rift valleys, respectively.

See also CONTINENTAL DRIFT; EARTHQUAKE; RIFT VALLEY; SAN ANDREAS FAULT.

**FEATHER** Feathers are specialized outgrowths from the skin found only in birds. Feathers are sometimes called plumes. Feathers are made of keratin and probably evolved from the scales of prehistoric reptiles (see EVOLUTION; KERATIN). Feathers are very light, but strong, and they provide protection and warmth for the bird, as well as making it possible for it to fly. There are two main kinds of feathers: contour feathers and down feathers. The contour feathers cover the body, overlapping each other and giving the bird its smooth, streamlined shape. A contour feather has a hollow stem, or quill, growing from a pocket in the skin, and a flat vane. The vane has a strong, flexible central shaft called a rachis. Hundreds of hairlike barbs grow out from the rachis. Each barb carries hundreds of hooked barbules that interlock to hold the vane together in one continuous sheet. The contour feathers on the outer parts of the wings are larger and stronger than the rest and are called flight feathers. The biggest ones, right at the tip of the wing, are called primaries. Similar large feathers grow on the tail. Ostriches and some other flightless birds do not need smooth, streamlined surfaces. Their contour feathers lack the hooked barbules and are rather fluffy.



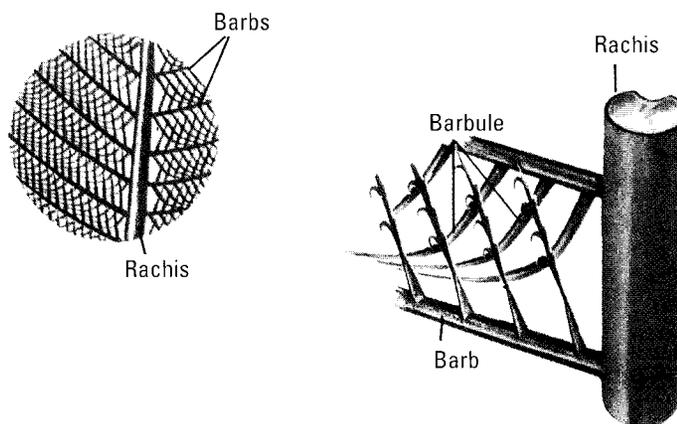
#### FEATHER—Waterproof coating

The feathers of ducks, such as on these mallards, have a thin coating of oil that makes them waterproof.



### FEATHER—Structure

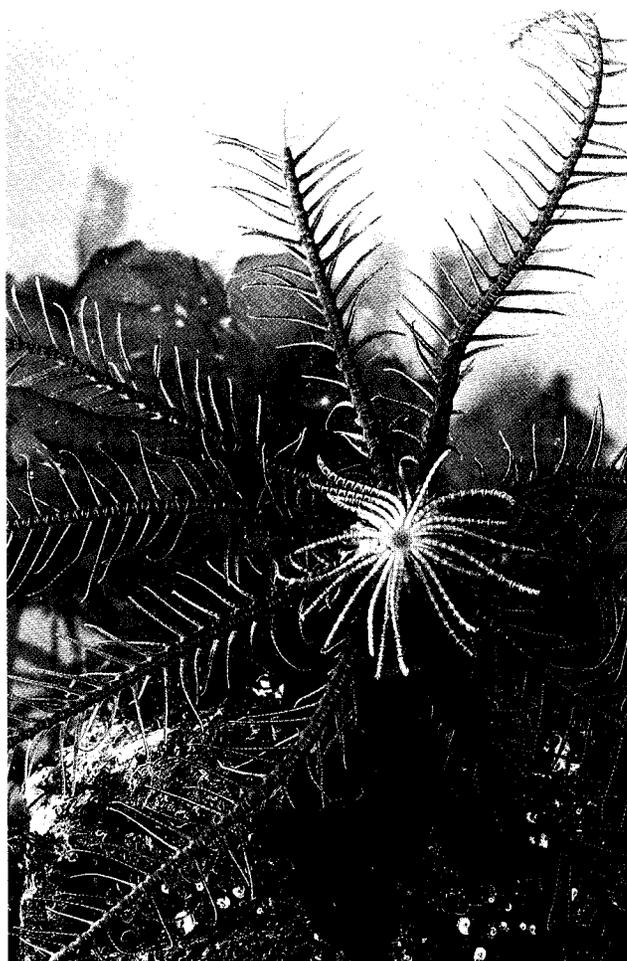
Contour feathers cover the body of a bird. Feathers have a central shaft called the rachis. Hundreds of branches called barbs come out from the rachis. The barbs are held together by small, interlocking barbules to form a continuous sheet called the vane.



Down feathers are soft and fluffy. Each one consists of a short quill with a tuft of unconnected barbs at the tip. The down feathers keep the birds warm by forming an important insulating layer underneath the contour feathers. Ducks and other water birds have an extra-thick layer of down feathers to keep them warm in the water. Baby birds have only down feathers at first, but their contour feathers soon grow through and cover the down. Filoplumes are hairlike feathers with no more than tiny tufts of barbs at the tip. They are scattered among the other feathers, and they are sensitive to touch. They tell the bird when its contour feathers have been disturbed and need attention.

See also BIRD.

**FEATHER STAR** Feather stars are marine animals belonging to the crinoid group of the phylum Echinodermata. They are distantly related to starfish and there are over 500 species (see CRINOID; ECHINODERMATA). A feather star has a central disk, the bottom of which has a circle of tiny stalks called cirri. There are usually ten armlike tentacles, but there may be as many as forty. Each one is covered by two rows of short, feathery branches. The mouth is on the upper surface of the disk, and it receives a constant stream of tiny food particles that



### FEATHER STAR

The rosy feather star has ten long arms. It walks using the light-colored "legs" (cirri) on its central disk.

are filtered from the water by the feathery tentacles. Feather stars are able to move along the ocean floor by means of the cirri. Some are able to swim short distances by waving their tentacles.

Feather stars range in size from 1 in. [2.5 cm] to 3 ft. [90 cm] in diameter. They live in both the Atlantic and Pacific oceans in depths that range from the shallow, offshore waters to about 4,500 ft. [1,370 m].

**FEEDBACK** Feedback is a principle used to control the work done by a machine or system. The work done by the machine or system is called output. Instruments measure the output. This information, called feedback, is relayed back to the computer or control device. The computer or control device compares the information with what the machine or system was originally directed to do. If the machine or system is not operating fast enough, for example, the computer or control device sends back a signal that makes it operate at a faster speed.

Feedback is important, for example, in a home heating system. The heart of the system is the furnace. It is controlled by an electric device called a thermostat (see THERMOSTAT). The thermostat is usually located on the first floor of a house. Sometimes individual rooms have their own thermostats. The thermostat is set at the desired temperature. If the feedback tells the thermostat that the room temperature is lower than the setting, the thermostat sends a signal that turns on the furnace. The furnace then warms the room and the rest of the house. After the room temperature has risen above the thermostat setting, the thermostat turns off the furnace.

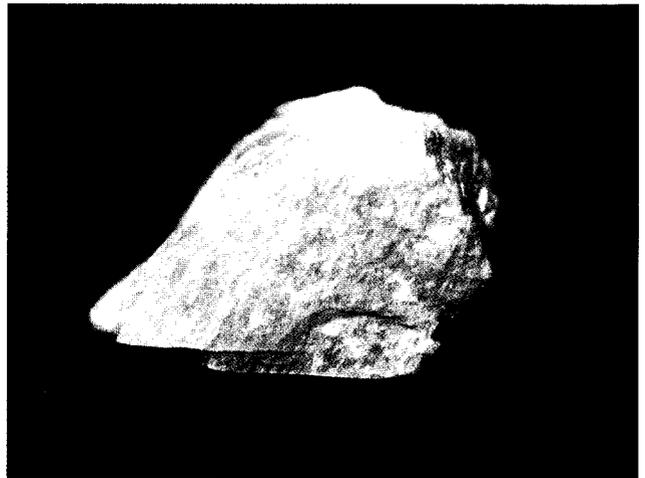
Feedback in the field of automation depends on electrical instruments called sensors (see AUTOMATION). Sensors measure temperature, size, weight, color, and chemical composition of products that are being manufactured. Each sensor sends back its information to a controlling computer. Engineers call this system a feedback control loop. The term *loop* refers to the flow of information in the system. The control loop goes from the computer, through the machine and its output, through the sensor, and finally back to the computer. Control loops

can be closed loops or open loops. In closed loops, the computer automatically adjusts the operation of the machine or system. In open loops, the computer activates a signal that may indicate trouble.

*Feedback* is also a term used in sound amplification. It occurs when the output sound signal from a microphone returns to the microphone and causes a high-pitched squeal in the loudspeaker.

**FELDSPAR** Feldspars, sometimes spelled *felspars*, are the most common group of rock-forming minerals. Feldspar minerals make up more than half of all common igneous rocks, such as granite and basalt (see MINERAL; ROCK).

Feldspar usually occurs as glassy white, reddish, greenish, or bluish crystals. It is mined chiefly from pegmatite. Pegmatite is a rock containing very large crystals of quartz and feldspar (see QUARTZ). In the United States, feldspar is mined in California, Connecticut, North Carolina, and South Carolina.



#### **FELDSPAR**

Feldspar is a common mineral found in many different kinds of rocks. When exposed to the atmosphere, rocks containing feldspar break down into other minerals, especially clay minerals such as kaolin.

Rocks containing feldspar break down when they are exposed to the atmosphere. This process is called weathering (see WEATHERING). The feldspars break down into other minerals, especially clay minerals (see CLAY). Kaolin is a white clay formed from the breakdown of feldspar. Clay materials derived from feldspar are used by pottery

manufacturers to make porcelain and glass. Much potassium can also be found in feldspars and in the soil produced by their weathering. Potassium is needed for all plants to help them grow.

All feldspars contain aluminum, silicon, and oxygen. The different types of feldspar are produced by the amounts and kinds of other elements that are present. One group, called alkali feldspars, contain potassium and sodium in various amounts. Green microcline, commonly known as amazonstone, is an alkali feldspar that is often cut and polished to make ornaments. Moonstone is a milky, translucent (light-admitting) alkali feldspar. People treasure moonstone as a gem.

The other group, called plagioclase feldspars, contain sodium and calcium in varying ratios. Labradorite is a type of plagioclase that may show a range of vivid colors when light strikes it. Rocks containing such crystals are sometimes used to decorate buildings and are made into objects, such as paperweights. Albite, a common sodium-rich variety of plagioclase feldspar, varies in color from white to gray. It has been used to make ceramics and false teeth.

*See also* CERAMICS.

**FEMALE** Humans and most other animals have two separate sexes—the male and the female. The female lays the eggs or gives birth to the babies and is called the mother. The male is the father (see MALE). In many species the two sexes look alike, but in others they may be quite different. Male ducks, for example, have very different colors from female ducks. This is also true of many other birds, especially during the breeding season. The male is usually more brightly colored than the female. The male will use its colors to attract a female mate. The female is often rather drab. This is a great advantage when she needs to hide away and look after her eggs or babies.

Most plant species have both male and female organs in the same flower, but some species, such as the holly, have separate sexes. The male plants produce the pollen and the female plants produce the fruits and seeds.

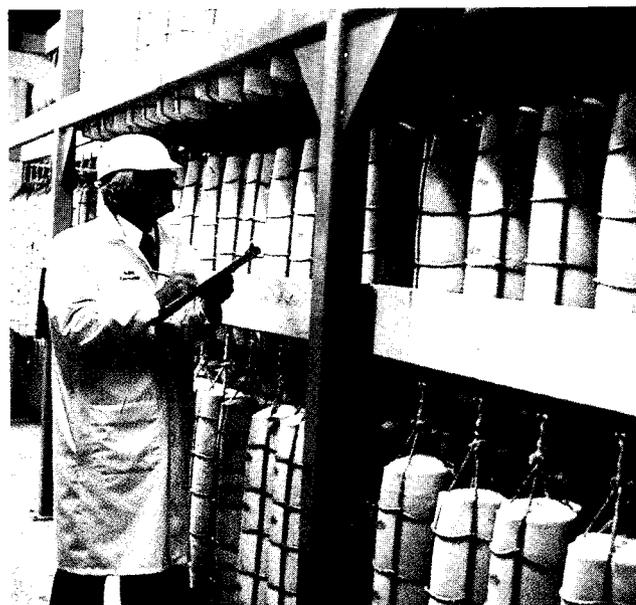
*See also* HERMAPHRODITE; REPRODUCTION.

**FEMUR** The femur is the longest, largest, and strongest bone in the human body. It is located in the upper leg and is sometimes called the thigh bone. It is joined to the pelvis by means of a ball-and-socket joint and to the tibia in the lower leg by means of a hinge joint.

*See also* ANATOMY; JOINT; PELVIS; SKELETON; TIBIA.

**FERMENTATION** Fermentation is a change that occurs in vegetable or animal matter when chemicals called enzymes act upon it (see ENZYME). The process of fermentation changes the chemicals in the matter. As a result, the form, taste, and smell of the matter are changed. Examples of fermentation include the ripening of cheese, the souring of milk, the changing of apple juice to hard cider, and the changing of the alcohol in hard cider to vinegar. The enzymes that cause these changes are produced by the cells of certain organisms. Many come from bacteria and fungi such as mold and yeast (see BACTERIA; FUNGUS; MOLD; YEAST). Familiar fermented foods include sauerkraut and buttermilk. Beer and wine are two of the best-known fermented liquids.

The action of yeast in bread dough is a type of fermentation. An enzyme from the yeast changes the starch in the flour to sugar. Another enzyme then



**FERMENTATION—Cheesemaking**

Fermentation is used in many industrial processes, such as the making of cheese, beer, wine, and vinegar. Here fermentation continues as cheeses are left to ripen, or age, which gives them their special flavor.

breaks down the sugar into carbon dioxide gas and alcohol. The gas forms bubbles, which cause the dough to rise (see BREAD).

Plants are helped by the fermentation of dead plants and animals. Enzymes break down chemical compounds in dead plants and animals. The elements return to the soil, and growing plants use them over again. If the breakdown of dead matter occurs without plenty of oxygen, it may give off bad odors, and the products may be poisonous. This type of fermentation is called putrefaction or anaerobic decomposition.

See also DECOMPOSITION.

**FERMI, ENRICO** (1901–1954) Enrico Fermi was an Italian physicist. He studied nuclear physics and won the Nobel Prize for physics in 1938. Fermi moved to America in 1939 and worked at Columbia University in New York City. In 1942, after several years of work, he designed and operated the first nuclear power reactor. Today, nuclear power reactors are used to make electricity. During World War II (1939–1945), Fermi helped make the first atomic bomb. The element fermium is named after him.

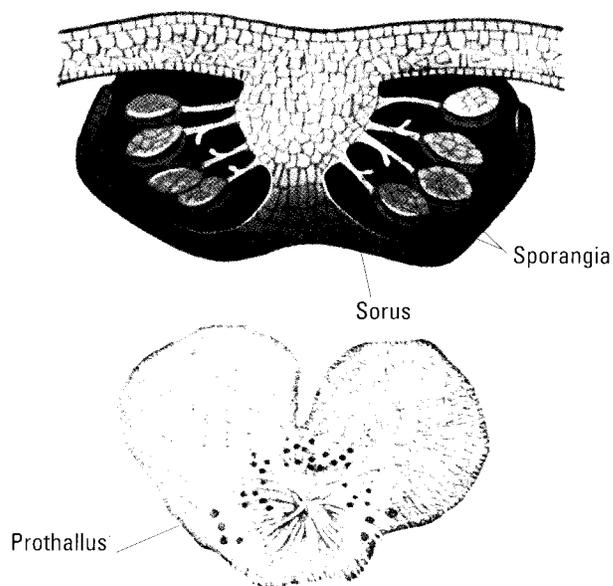
See also NUCLEAR ENERGY; NUCLEAR WEAPONS.

**FERN** A fern is a vascular plant with roots, stems, and leaves but no flowers or seeds (see VASCULAR PLANT). There are over twelve thousand species and they belong to division Pterophyta. Fossils from the Carboniferous period indicate that ferns were in existence over 350 million years ago (see CARBONIFEROUS PERIOD).



#### FERN—Fossil

Ferns are ancient plants. The fossil ferns (above) date from the Carboniferous period.



#### FERN—Structure

Each fern frond (leaf) often has rows of sori (plural of *sorus*). Each sorus has a number of sporangia filled with spores. When a spore is released, it develops into a gamete-producing plant called a prothallus (bottom).

Ferns are found throughout the world but thrive best in warm or hot climates. They range in size from almost microscopic to the tree ferns, which reach heights of more than 70 ft. [21 m]. Some species grow on trees for support and get their moisture from the air (see EPIPHYTE). These species are often called air ferns because they are not attached to the ground. Most ferns, however, grow close on the ground, rarely reaching a height of more than 6.6 ft. [2 m]. A few grow in water.

The stems and roots of ferns are usually underground. Some ferns have specialized underground stems called rhizomes (see RHIZOME). These rhizomes produce many “subplants” along their length. Fern leaves, called fronds, are usually large and divided into leaflets. The fronds often bear rows of brownish sori (plural of *sorus*, which is a cluster of sporangia). The sporangia contain the spores (see SPORANGIUM; SPORE). Some ferns carry their sporangia in separate fronds, which are often narrower than the normal fronds. When the spores mature, the sporangia open, and the spores are spread by the wind (see DISPERSION OF PLANTS). Each spore develops into a tiny, heart-shaped plant

**FERN—Tree fern**

Tree ferns, such as the one on the left of this picture, are the largest ferns. They grow up to 70 ft. [21 m] tall.

**FERN—Bracken**

Many ferns, such as bracken (left), grow in the shade beneath trees in woods and forests.

called a prothallus. The prothallus is flat, with root-like hairs on its bottom surface. Small reproductive structures then form on the prothallus. The male structure, the antheridium, produces flagellated gametes called sperm (see FLAGELLUM). The female structure, the archegonium, produces an egg. In moist conditions, the sperm “swim” to the archegonium, where one sperm fertilizes the egg (see ANTHERIDIUM; ARCHEGONIUM; FERTILIZATION). The fertilized egg, called a zygote, will develop into the large fern plant. This kind of life cycle, in which a spore-producing plant produces a gamete-producing plant which, in turn, produces another spore-producing plant is called alternation of generations (see ALTERNATION OF GENERATIONS).

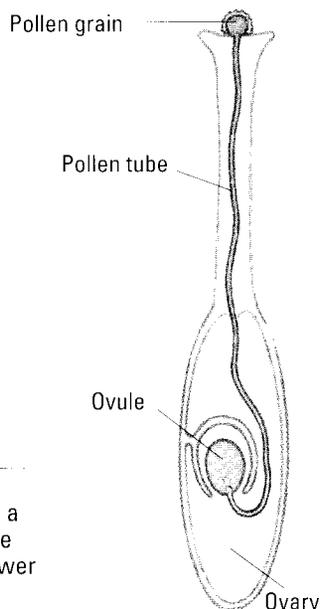
**FERTILITY** Fertility in an animal or a plant is the ability to produce offspring (see REPRODUCTION). Some people have problems reproducing because their reproductive organs do not work properly. They may produce defective eggs or sperm. These problems can often be corrected with hormone treatment (see HORMONE).

The fertility of a soil or a patch of ground is a measure of its ability to sustain plant growth. Fertile soils contain all the minerals or nutrients necessary for a good growth of crops or other plants. Infertile soils lack one or more of the necessary nutrients, or perhaps lack the right quantities of nutrients. They need the addition of fertilizers before they can support crops.

# FERTILIZATION

Fertilization is the process in sexual reproduction in which a male gamete combines with a female gamete to produce a zygote. The zygote develops into a new organism. In animals, the male gamete is called a sperm (or spermatozoon) and is produced by the male sex organs, the testicles (or testes). The female gamete is called an egg (or ovum) and is produced in the female sex organs, the ovaries. Most land animals, including mammals, birds, and reptiles, practice internal fertilization. During internal fertilization, the male deposits sperm inside the female's body, where it joins with the egg. Most aquatic animals, however, practice external fertilization. During external fertilization, the female lays eggs in the water, and the male spreads sperm over them. The sperm swim around until they fertilize an egg. Because many sperm and eggs never meet, animals that fertilize externally usually produce great numbers of gametes to improve chances of fertilization. Some animals are hermaphrodites and produce both male and female gametes. Some hermaphrodites are able to fertilize their own eggs (see GAMETE; HERMAPHRODITE; OVARY; TESTICLE; ZYGOTE).

In flowering plants (angiosperms), the male gamete is formed within a pollen grain. The pollen grain is produced by the anther, part of the stamen.



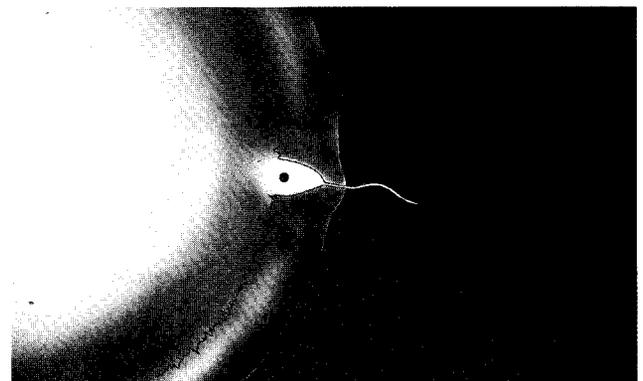
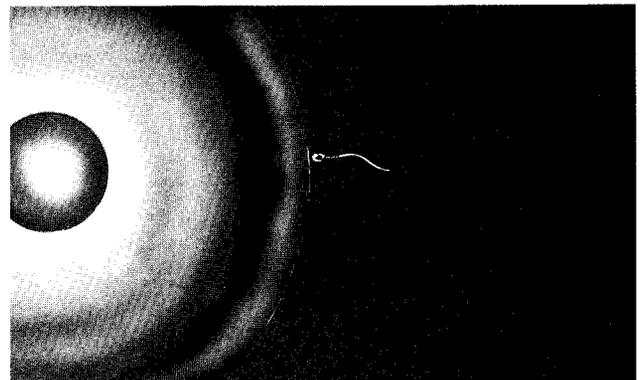
## POLLINATION

Fertilization in flowering plants takes place when a pollen grain grows a tube down the style of the flower to meet an ovule in the ovary.

The female gamete, the egg, is produced within the ovule. The ovule is in the ovary of a pistil (see PISTIL; POLLINATION; STAMEN). The pollen grain grows a tube through the style of the pistil to an ovule in the ovary. Two male gametes travel through the tube to the ovule. One of the gametes fertilizes the egg and begins the formation of the seed. The other unites with two structures called polar nuclei and starts to form the endosperm (see ENDOSPERM; SEED).

In nonflowering seed plants (gymnosperms), pollen from male cones produces sperm. The sperm fertilize eggs in the female cones. These female cones protect developing seeds that contain embryos. Among ferns, fertilization takes place on a prothallus, which is quite separate from the mature fern plant (see FERN).

*See also* POLLINATION; REPRODUCTION.



## MOMENT OF FERTILIZATION

In sexual reproduction, fertilization occurs when a male gamete combines with a female gamete to produce a zygote. The zygote develops into a new organism. The top picture shows a human sperm (with its thin, whiplike tail) swimming toward the egg. Fertilization takes place when the sperm unites with the egg (below).



### FERTILIZER

Farmers often add fertilizer to the soil. The added nutrients produce healthier, faster-growing plants.

**FERTILIZER** A fertilizer is a substance added to the soil to improve the growth of plants. About 95 percent of the fertilizer produced in the world is used in farming. In order for plants to grow, photosynthesis must take place (see PHOTOSYNTHESIS). In order for photosynthesis to occur, plants must be supplied with certain nutrients. Macronutrients are those nutrients that plants use in fairly large quantities. Macronutrients include carbon, hydrogen, oxygen, potassium, phosphorus, nitrogen, calcium, sulfur, and magnesium. Plants need only small amounts of micronutrients, such as manganese, molybdenum, zinc, iron, copper, and boron. Air and water are primary sources for carbon, hydrogen, and oxygen, but the other nutrients must come from the soil.

If soil is lacking any nutrients, fertilizers containing these elements must be added. Tests performed by scientific laboratories on soil samples can determine what fertilizers are necessary. Fertilizers are one of two types: synthetic (human made) or organic.

Synthetic fertilizers are made from minerals. Synthetic fertilizers contain controlled amounts of specific nutrients, usually phosphorus, nitrogen, and potassium. Phosphorus fertilizers are made from the mineral apatite. If apatite is mixed with phosphoric or sulfuric acid, a liquid fertilizer called superphosphate results. Most synthetic nitrogen comes from ammonia and ammonia-containing compounds. Most of the potassium is manufactured from potassium chloride. In addition, lime (calcium hydroxide) is often added to the soil to neutralize acidity (see NEUTRALIZATION).

Organic, or natural, fertilizers are usually made from manure, other animal matter, or plant matter. They provide nitrogen and some other nutrients,

but in varying amounts. Because organic fertilizers have a smaller percentage of the needed nutrients, larger amounts must be used. Animal manure is often mixed with straw and allowed to rot before it is used. Bird guano (droppings) is also used as a fertilizer (see MICROORGANISM). Animal matter such as bone meal and dried blood is sometimes used. Because it is too expensive to use on a large scale, such animal matter is usually used only by home gardeners. Plant matter is sometimes made into a compost pile (see COMPOST). Microorganisms begin to decay the plant matter in the compost pile, releasing needed nutrients. So-called green manure is actually plants that are grown and then plowed into the ground to restore nutrients. Crops of legumes such as alfalfa, clover, and beans are often grown for this purpose in a process of crop rotation. *See also* AGRICULTURE; NITROGEN CYCLE.

### PROJECT 75

**FEVER** Fever is a condition in which the body temperature rises above the normal 98.6°F [37°C]. It is a common sign of disease. Fever is often accompanied by chills, loss of appetite, and a general feeling of weakness. With a rising temperature, the patient may also develop a rapid pulse, headache, and restlessness. The patient may be uncomfortable during this stage, sometimes called the height of the fever. A fever may affect a person continuously for several days. It may also disappear for a few days, only to return again.

Fevers often indicate a serious infection. Some diseases, such as scarlet fever, are so named because the high fever is the most apparent symptom.

*See also* DISEASE; INFECTION.

# FIBER

A fiber generally is a strand of a substance. Fibers are often twisted to form yarn. Yarns in turn can be twisted to form thread. Fabrics are made using yarns or threads.

Some fibers are found in nature. Others are manufactured. The type and arrangement of molecules in a fiber determines its properties. Properties of a fiber include absorbency, strength, and stretchability.

Short fibers are called staples and measure from about 0.5 to 8 in. [1.3 to 20 cm] in length. Most of the fibers occurring in nature are staples. The other major form of fibers are called continuous filaments. They range in length from more than 300 yd. [270 m] for silk fibers to indefinite lengths for manufactured fibers.

**Natural fibers** Natural fibers come from plants, animals, and minerals. The most widely used of all natural fibers is cotton. Cotton comes from the fruit, or boll, of the cotton plant. Staples from cotton are spun into yarns for fabrics. Cotton cloth is absorbent and soft. Linen is made from fibers obtained from the stems of flax plants. The strong fibers obtained from flax are called bast fibers. Fibers from the hemp and jute plants are also bast fibers. Hemp and jute are used to make cords, ropes, and rough fabrics.

Fibers obtained from animals include hair and fur. For example, wool is obtained from sheep. It is widely used in clothing. Wool resists creasing and crushing. Its fibers uncurl when stretched but return to their original state when released. Also, each fiber



## ANIMAL FIBERS

Sheep's wool is one of the oldest animal fibers. People have woven it into cloth for thousands of years.

Sheepshearing is still done by hand, although today electric shears have replaced the hand clippers formerly used.

is covered with rough scales. These rough scales give bulk and warmth to wool clothing and blankets. Silk is also an important animal fiber. It is the strongest natural fiber. Silk is unique among natural fibers because it is produced in a filament. Manufacturers unwind silk filaments from silkworm cocoons (see SILKWORM MOTH). Silk yarn is used for clothing and household fabrics. Cashmere, obtained from certain goats, is used in making knitwear. Mohair, a fabric made from the hair of the Angora goat, is used in suits and knitwear. Hair from alpacas or llamas is used in the manufacture of suits and coats.

**Manufactured fibers** Many of the manufactured fibers are plastics. In studying plastics, chemists have learned how to combine chemicals to make fibers that have certain properties. Such chemicals are melted or mixed in various liquids.

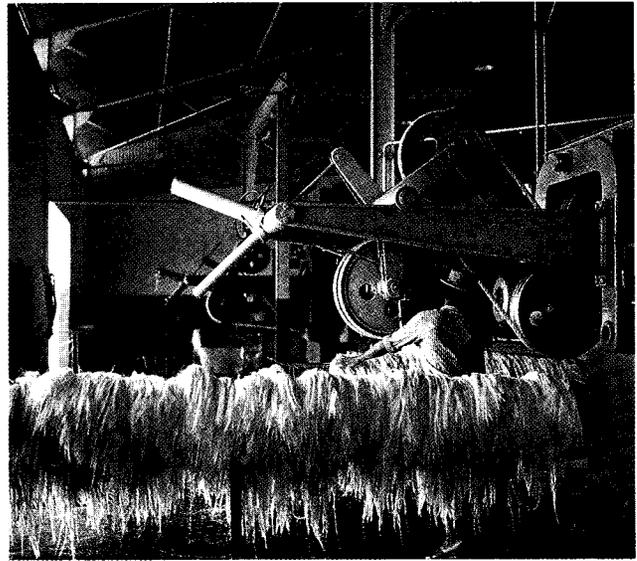
Machines force streams of the chemicals through tiny holes (see EXTRUSION; PLASTIC).

There are two main types of manufactured fibers. In the first group, fibers are processed by people but derived from natural materials, such as plant cellulose. *Cellulosics* is the name for fibers that come from cellulose (see CELLULOSE). The most familiar is rayon. Rayon has many properties that resemble cotton's. Rayon is used in clothing and in such products as tires (see RAYON).

The second type of manufactured fibers are those made entirely from materials produced by people. These are called synthetic fibers. Synthetic fibers are sometimes called noncellulosics. Nylon fibers

#### PLANT FIBERS

Sisal is a fiber obtained from the leaves of an agave plant (below left). The sisal fibers are hung in the sun to dry (bottom), before being processed (below right) and made into cord and rope.



were the first synthetic fibers (see NYLON). Lightweight and very strong, nylon is widely used in the manufacture of carpets, ropes, tires, and clothing. Polyester fibers are durable and regain their shape after being stretched or wrinkled (see POLYMER). Dacron and Kodel are types of polyester. Acrylic fibers, such as Acrilan and Orlon, are soft and durable. Many imitation furs and wools are made from acrylic fibers (see ACRYLIC). Olefin fibers are strong and stain resistant. These properties make olefin fibers, such as Herculon, useful in carpets and upholstery (see OLEFIN).

Fiberglass is a synthetic fiber made from glass and resin. When woven, it is quite strong and resists stretching (see FIBERGLASS). Yarns called Lastex are made from manufactured rubber fibers wrapped in cotton, nylon, or other fibers.

Although synthetic fibers have replaced natural fibers in many instances, it is unlikely that natural fibers will be completely replaced. Certain properties in natural fibers, such as the warmth of wool, have not yet been fully matched by synthetic fibers.

**Dietary fiber** *Dietary fiber* refers to parts of plants that are generally not digestible by humans. Whole-grain products, legumes, fruits, and vegetables are good sources of dietary fiber. There are several kinds

of dietary fiber, each of which has a different chemical structure. A major characteristic of a particular fiber is whether or not it can dissolve in water. This solubility or insolubility determines its biological effect.

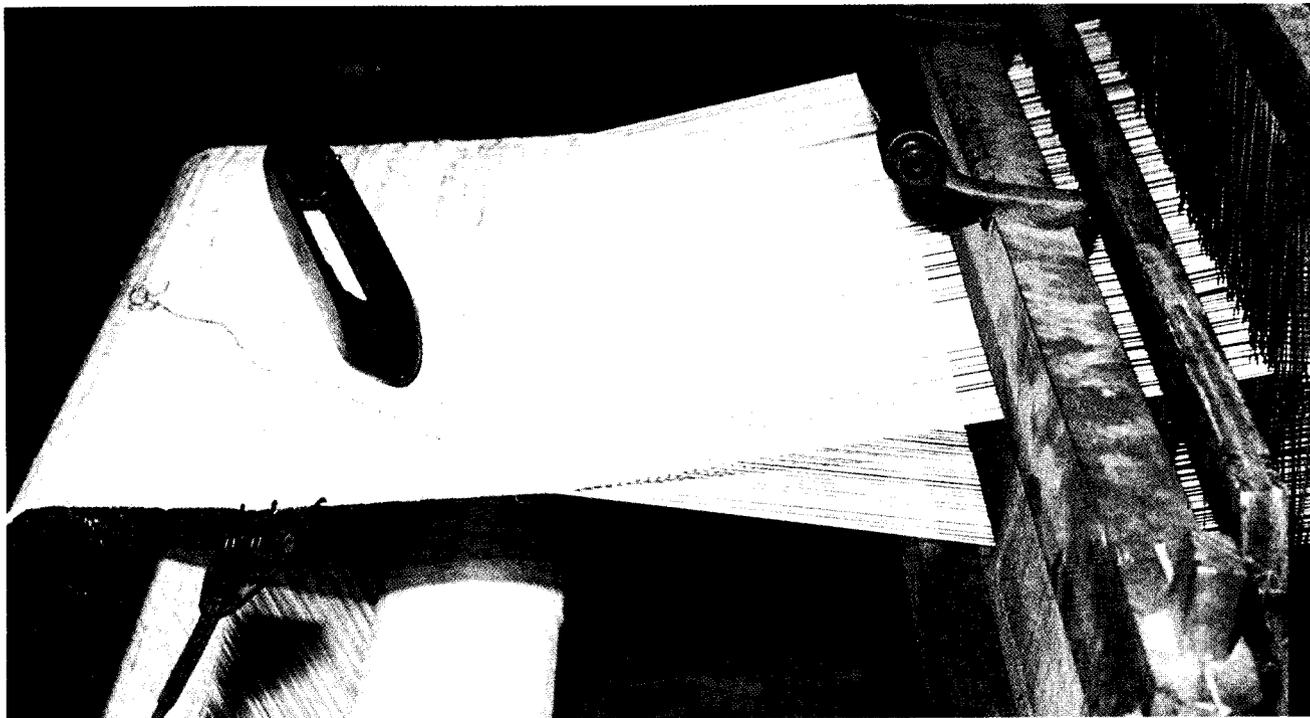
The relatively low fiber intake in the developed countries of the world, such as the United States, may be related to certain diseases. Fiber became considered important in the diet because low fiber intake was linked to disorders of the colon (part of the large intestine), such as constipation, hemorrhoids, and colon cancer. Researchers established this link after discovering that inhabitants of countries in which fiber intake is large, such as Uganda, have a lower incidence of these disorders.

Relationships also may exist between fiber intake and the control of blood glucose (sugar) in people with diabetes, heart disease, and obesity. Although there is uncertainty about these relationships as well as the relationship of fiber to disorders of the colon, the dietary guidelines set by the U.S. Department of Agriculture and the U.S. Department of Health and Human Services recommend an increase in fiber intake.

*See also* DIET.

#### FIBERS FOR FABRICS

The fabric that is woven from the thread made from flax fibers is called linen.



**FIBERGLASS** Fiberglass is a synthetic (human-made) material composed of tiny threads of glass and resin (see RESIN). It is strong, durable, and fire-proof. Fiberglass is used for such things as curtains, because it also is waterproof and needs no ironing.

The first step in making fiberglass is to melt glass in an electric furnace. The melted glass goes out small holes in the bottom of the furnace, where it is caught by a spinning drum. The high speed of the drum forces the melted glass into fine fibers. These fibers are then processed according to their intended use (see EXTRUSION).

Fiberglass is an excellent insulator (see INSULATION). Many people insulate their homes with fiberglass to conserve energy. Fiberglass-reinforced plastics (GRP) are very strong and very light. They are used to make boat hulls, car bodies, and many other products.



#### FIBERGLASS

The hull of this boat is made of plastic reinforced with strands of fiberglass.

**FIBER OPTICS** Fiber optics is a branch of physics that has many applications in the communications field, especially in telephone systems. Fiber optics involves transmitting light through hair-thin strands of glass, called optical fibers. The first optical fibers were developed in 1955 in England. In 1966, researchers at Standard Telecommunications Laboratories in England demonstrated that fibers of very pure glass could be

used to transmit data by light over very long distances. Early optical fibers could carry a light signal 1.6 mi. [2.5 km] before an amplifier was needed to strengthen the signal (see AMPLIFIER). Today's optical fibers can carry light more than 62 mi. [100 km] without amplification.

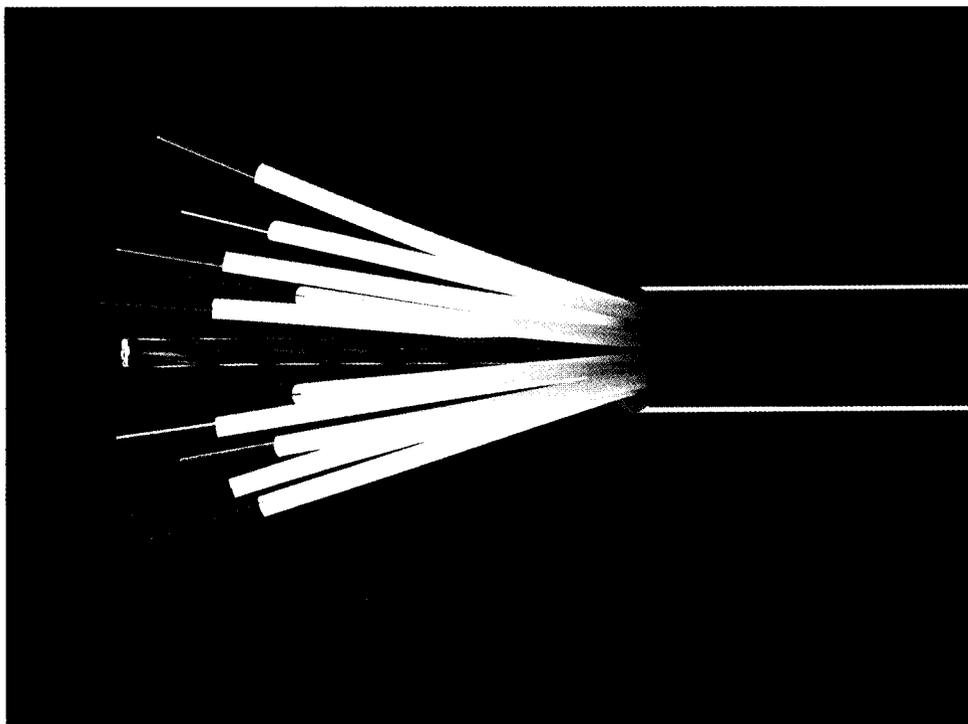
An optical fiber consists of a core of very pure glass surrounded by a layer of glass that is formulated differently. The outside layer is called cladding. When a beam of light is sent down the length of the fiber, the cladding acts like a mirror, keeping the light beam inside the fiber. The light travels the length of the fiber without escaping through its sides. The light source is a laser or a light-emitting diode (LED) (see LASER; LED). Because the fibers are flexible, they can guide light around corners.

Optical fibers are now used to send telephone signals long distances (see TELEPHONE). Previously, copper wires had been used. The telephone signals were sent in the form of electricity passing through overhead lines or underground cables. However, copper is heavy and takes up a large amount of space. Also, the electricity passing through the copper wires and cables can be interrupted easily by electrical interference.

Optical fibers are preferred over copper wires because they are lightweight and small. Also, because optical fibers transmit light, there is no electrical interference.

Communication begins in a fiber-optic telephone system when a person speaks into the telephone mouthpiece. The sound energy is changed into electrical energy in the form of impulses. These impulses are transmitted to a laser. This device changes the impulses into light, which is sent out through an optical fiber. The optical fibers are often bundled into cables (see CABLE). The light is eventually converted back into electrical energy. This electrical energy is converted into sound by a telephone receiver (see TELEPHONE). A pair of optical fibers can carry 4,000 telephone signals. An optical cable containing only 100 fibers can therefore transmit 200,000 signals at one time.

Fiber optics also has many applications in medicine, especially in lighting places that are hard to reach. Doctors use fiber optics to light places inside



#### FIBER OPTICS

Several optical fibers are included in a single fiber-optic telephone cable. The telephone signals pass along the cable in the form of pulsating laser light.

the body that would otherwise require surgery to examine. For example, a catheter (a very narrow tube) that contains optical fibers can be used to examine the heart. One bundle of fibers carries light into the body to illuminate the heart. A second bundle of fibers carries the image out to an eyepiece. The doctor can view the image through the eyepiece or look at it on a video monitor screen. The stomach and knee joints are other areas that doctors often examine by means of these optical fiber devices, called endoscopes (see ENDOSCOPY).

Fiber optics is also used to treat cancer (see CANCER). Tiny, light-sensitive devices called porphyrins are injected into the cancerous organ. The porphyrins attach themselves only to cancer cells and are rejected by healthy cells. Optical fibers shine infrared rays onto the cancer cells. When the rays hit the porphyrins, they destroy the cancer cells.

**FIBULA** (fīb'yə lə) The fibula is a long, fairly thin bone that is the outer of the two bones in the lower leg. It is joined to the other, larger bone, the tibia, by ligaments at both ends. In addition, the fibula and tibia are joined by a membrane that extends the length of the bones. The lower end of the fibula forms the “bump” on the outer part of the ankle.

*See also* LIGAMENT; SKELETON; TIBIA.

**FIELD** In physics, the word *field* is used to describe a region in which a force can affect a body without actually contacting that body. For example, small pieces of iron placed a short distance from a magnet are attracted toward the magnet. This action is said to be due to the presence of a magnetic or force field.

Such a field can be investigated by sprinkling iron filings on a card held over a magnet. The filings form patterns. These patterns show the lines of magnetic force extending from the north and south poles of the magnet (see MAGNETISM). A magnetic field is also set up when an electric current flows through a wire (see ELECTROMAGNETISM).

Near an electric charge, a charged particle experiences a force. The region in which this force occurs is called an electric field. The force may be one of attraction or repulsion. This depends on whether the charges are like or unlike. Unlike charges—that is, one positive and one negative charge—are attracted. Like charges, such as two positive charges, repel each other (see ELECTRICITY).

An electric field, like a magnetic field, can be represented by lines of force. Electrostatic fields can be examined by placing a lightweight, charged ball in the field and watching how it moves (see ELECTROSTATICS).

**FIELD**

Lines of force in magnetic fields are pictured above. The directions of the lines indicate that like poles repel each other, and unlike poles attract each other.

A gravitational field is the region in which there is a gravitational force of attraction between bodies. This force depends on the mass of the objects and their distance apart. The moon is in the earth's gravitational field. The moon is kept in its orbit by the force of gravity between itself and the earth.

See also GRAVITY; MASS.

**FIG** There are about 800 species of figs. They are trees belonging to the genus *Ficus* of the mulberry family and they nearly all live in tropical and subtropical parts of the world. The best-known species is the European fig, a deciduous tree that ranges in height from 3.3 to 40 ft. [1 to 12 m] (see DECIDUOUS TREE). It has large, rough leaves and produces an edible, pear-shaped fruit. This fruit is actually formed from a cluster of hundreds of tiny flowers

enclosed in a green pouch. Tiny insects bore into the pouch to lay eggs, and while doing so, they pollinate the flowers. The pouch then grows into the purplish brown fruit (see POLLINATION).

Figs were some of the earliest cultivated fruits. They remain an important food in many Mediterranean countries and are cultivated in many other countries. They can be eaten fresh, dried, or preserved in other ways. Figs have a mild laxative effect and are a good source of bulk in the diet. In the United States, most figs are grown in California and Texas.

See also BANYAN.

**FIG**

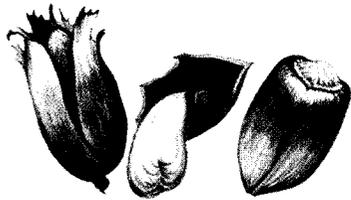
The fig was one of the earliest cultivated fruits. Figs can be eaten fresh, dried, or preserved in other ways.

**FILBERT** The filberts are a group of fifteen species of trees and shrubs that belong to genus *Corylus* of the birch family. They grow in many parts of the Northern Hemisphere and have large, oval, deciduous leaves with toothed margins (see BIRCH; DECIDUOUS TREE; LEAF). The leaves alternate on the stem. The male flowers are in long catkins that appear in the winter (see CATKIN). The female flowers are much smaller and grow in clusters. Each female flower has two red stigmas. Both sexes are on one plant (see MONOECIOUS; STIGMA). Filberts vary in height from 10 to 120 ft. [3 to 36 m].

Filberts produce edible nuts that are also called filberts. These nuts are roundish and about 1 in. [2.5 cm] long. Members of genus *Corylus* are also called hazels and the nuts are often called hazelnuts. Forked branches from the American filbert

**FILBERT**

The nuts of giant filberts, shown here, are longer than the rounder type commonly called hazelnuts.



(*Corylus americana*) were once used as “divining rods.” According to tradition, these divining rods could be used to find underground water.

See also NUT.

**FILTER** A filter is a device used to separate solids, liquids, gases, electrical signals, or chemicals, or to purify a liquid by chemical or biological action. A mechanical filter is used to remove solid particles from liquids and gases. All mechanical filters have tiny holes. The holes allow gas or liquid to pass through, but they are too small to allow solid particles to pass through. A deposit of solids builds up on the filter that has to be removed from time to time. Pressure may be needed to force the gas or liquid through the filter. Sometimes, a pump is used to suck the gas or liquid through the filter. However, a liquid usually drips through the filter under the force of gravity.

Filtering is important to industry and science for purifying materials. To purify something means to remove unwanted particles. Filters are used in water installations to purify the water supply. They remove dust from the air in air conditioning systems. Factory chimneys remove particles from waste gases, reducing pollution released into the air. Vacuum cleaners use filters to trap the dust that they suck in.

Sometimes, a filter is used to trap particles that are important. Precious metals can be separated from other materials by filtering. Prospectors do this when they are panning for gold. Filters are used in medical laboratories to separate bacteria and viruses out of infected material. The exact size of the holes in these filters is known. This allows microorganisms of a particular size to be filtered and examined. This method is also used in hospitals to produce sterile liquids (see MICROORGANISM;

STERILIZATION). Sterile liquids contain no microorganisms.

In electronics, filters separate electric signals with different frequencies. The electric field of a high-frequency signal vibrates faster than the electric field of a low-frequency signal. Electronic filters can block signals of certain frequencies and allow others to pass through.

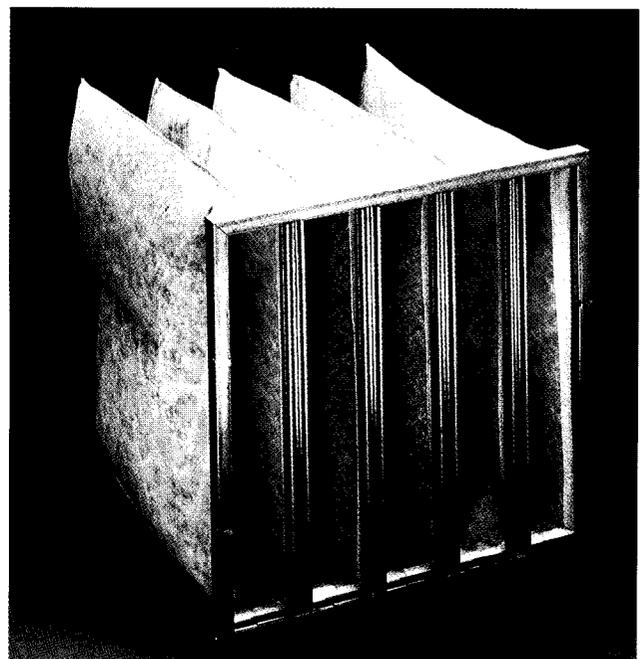
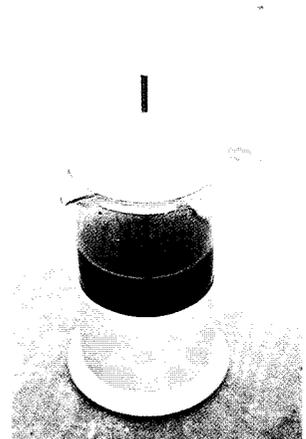
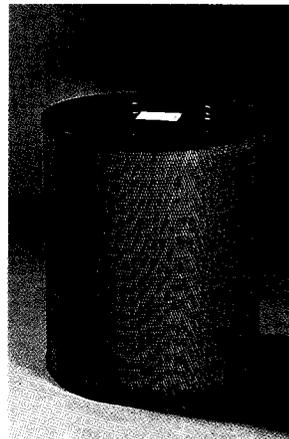
In physics, the word *filter* has a different

**FILTER—Circular filter**

Designed for filtering hot air at high rates of flow in nuclear installations, circular filters can be disposed of safely.

**FILTER—Coffee filter**

Coffee is made in this pot by pouring boiling water on ground coffee. It is filtered before drinking by pressing down on the knob.



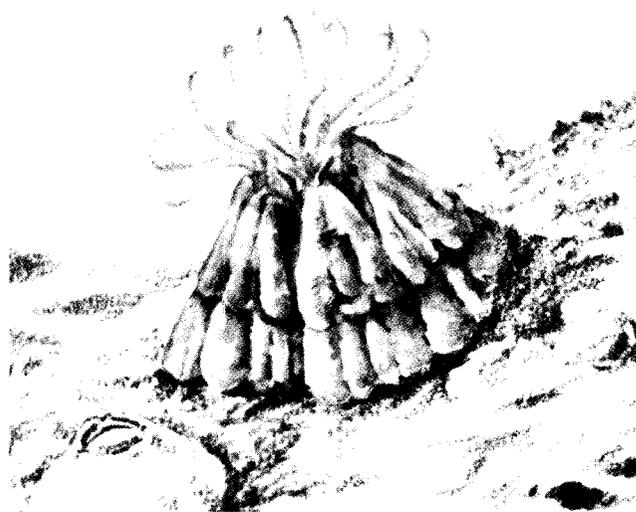
**FILTER—Bag filter**

A multisection bag filter is used in large air conditioning systems in stores, offices, and factories.

meaning. It is a device that is used to separate certain colors from light (see SPECTRUM). White light is a mixture of different colors. A filter allows only one color to pass through it. All the other colors are absorbed by the filter. Color filters are used in photography and in lighting (see PHOTOGRAPHY). Sunlight and artificial light consist of electric fields vibrating in all directions. Polarizing filters allow light rays whose electric fields vibrate in only one direction to pass through and block all the others. Polarizing filters in some sunglasses reduce glare by blocking reflected light and stopping it from reaching the eyes.  **PROJECT 21**

**FILTER FEEDING** Filter feeding is a method by which many water-dwelling animals obtain food. Filter-feeding animals strain food out of the water, while remaining still. Bivalves are the best known filter feeders. A water current is drawn in through the bivalve. The food particles are trapped by a slimy substance on the gills. Many aquatic worms and crustaceans are also filter feeders.

*See also* ANNELIDA; BIVALVE; CRUSTACEAN.



#### **FILTER FEEDING**

The feathery structures on a barnacle are actually its legs. The legs sweep through the water to trap small particles of food.

**FINCH** A finch is a songbird that belongs to the finch family, Fringillidae. Finches grow 4 to 7 in. [10 to 17.5 cm] in length. Finches have short, heavy bills, which they use to crack seeds. Seeds are



#### **FINCH**

The brightly colored bullfinch is a member of the finch family, Fringillidae.

their main source of food, although nestlings are fed mainly on insects. Male finches are very colorful. Females are usually a dull brown. Some finches fly in flocks and migrate long distances. Finches are found from cool temperate areas to the tropics.

*See also* BIRD; MIGRATION.

**FINLAY, CARLOS** (1833–1915) Carlos Finlay was the first scientist to discover how the viral disease called yellow fever was spread (see VIRUS; YELLOW FEVER). Finlay was born in Cuba to a Scottish father and a French mother. Wanting to be a doctor, he studied in Europe and continued his studies at Jefferson Medical College in Pennsylvania.

For many years, yellow fever had been a serious problem in tropical regions, such as Cuba. In the first stages of the disease, the victim suddenly became ill with such symptoms as dizziness, fever, and body aches. This was followed by internal bleeding. The victim's skin soon turned a yellowish color. Some victims went into a coma and died. There was no cure for yellow fever, and scientists did not know how it was spread.

Finlay came to believe that mosquitoes spread yellow fever, for several reasons. First, yellow fever did not occur in areas that had high altitudes. These areas also did not have mosquitoes. Yellow fever did occur in swampy locations, where mosquitoes were very common. Finlay also found there was a relationship between a particular species of

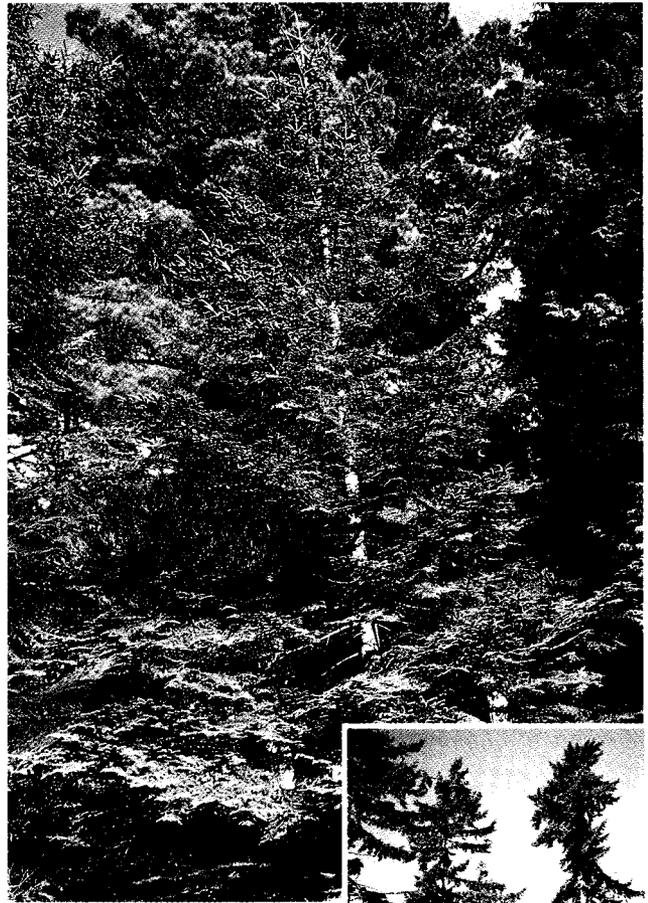
mosquito, *Aedes aegypti*, and the number of cases of yellow fever. An area that had more of these mosquitoes also had more cases of yellow fever. However, Finlay had trouble proving his theory.

In 1900, a group of doctors from the United States traveled to Cuba. The group, called the U.S. Army Yellow Fever Commission, was led by Walter Reed (see REED, WALTER). The group wanted to control an epidemic of yellow fever among U.S. soldiers in Cuba. Finlay met with the commission to discuss his research. The commission carried out many of its own experiments but still did not find out how yellow fever was spread. They then performed more research using Finlay's theory about mosquitoes.

After many tests—and after the U.S. doctor James Carroll (1854–1907) allowed himself to be bitten by an infected mosquito and died of the disease—the doctors discovered that yellow fever was transmitted by the *Aedes aegypti* mosquito that had fed on the blood of a yellow fever victim during the first three days of the illness. Steps were then taken to rid tropical areas of that specific species of mosquito. A short time later, yellow fever was almost completely wiped out. An important result was that the Panama Canal was able to be completed. Construction had been delayed because of outbreaks of the disease. The Panama Canal links the Pacific and Atlantic oceans and is one of the world's most important waterways.

The commission published a report of its findings but did not mention Finlay and his research. Finally, in 1954, the International Congress of Medical History declared that Finlay was responsible for discovering how yellow fever was spread.

**FIR** Firs are evergreen, coniferous trees belonging to the pine family. There are about 50 species of true firs, all with flat needles attached to the twigs with suckerlike bases. Their cones stand upright on the branches and they fall to pieces when the seeds are ripe. Several species grow in North America and they are important timber trees. The balsam fir also yields a resin that is used to make a strong, clear glue. The Douglas fir is not a true fir, although it belongs to the same family. Its cones hang from the branches and



#### FIR

The noble fir (above) is a true fir tree that grows in northern Europe. The confusingly named Douglas fir (right) is actually a pine, and grows much taller than any true fir.



do not break up. The Douglas fir is one of the world's tallest trees. It grows up to 250 ft. [75 m] in height and is a very important timber tree.

**FIRE** Fire is the heat and light that come from burning materials. A material that burns is one that can combine quickly with oxygen. Burning, then, is a process of rapid oxidation. Most materials that burn are made up of chemical compounds containing large amounts of carbon and hydrogen. *Combustion* is another name for burning. In 1774, Antoine Lavoisier, a French chemist, discovered the essential part played by oxygen in combustion (see COMBUSTION; LAVOISIER, ANTOINE; OXIDATION AND REDUCTION).

Some substances combine with oxygen very slowly. No light and very little heat are produced.

Rusting is an example of slow oxidation (see RUST).

There must be certain conditions before fire can occur. First, a substance that can burn, called a fuel, must be present. Wood is a good fuel. Water is not. Second, there must be a good supply of oxygen present. The oxygen usually comes from the air. Third, the fuel must be heated until it reaches its ignition temperature, or kindling point. The kindling point is the temperature at which the fuel can easily combine with oxygen. Before matches were invented, fires were started by borrowing wood or coal from another fire. If no fire was nearby, a pile of twigs could be set on fire with sparks. The sparks often were produced by striking metal against a hard stone called flint.

Some substances, such as paper, have low kindling points. Some fuels, such as coal, must be heated considerably before they can burn. The chemical called white phosphorus must be kept under water at normal temperature. If not, it bursts into flame.

Fire has been used by people for thousands of years. In prehistoric times, it kept people warm and protected them from dangerous animals. Fire also provided light and cooked food. Human beings are



#### FIRE

Each year, there are approximately 2.5 million accidental fires in the United States alone. The fire pictured above is being fought with a ladder truck.

the only animals that ever created and used fire.

Today, fire is used to heat water to make steam. Steam is used to run hundreds of different kinds of engines. Fire is used in many ways by industry, such as in making steel and in separating metals from their ores. Fire from burning gasoline, oil, or jet fuel powers airplanes, automobiles, and boats.

In spite of the helpful ways fire can be used, it can also be harmful if it gets out of control. Fire has destroyed homes and other buildings. It can ruin entire towns, forests, and prairies. Fire prevention is a big job. There are more than 335,000 fire fighters in the United States. Modern buildings are built so that they cannot easily catch on fire.

See also FIRE PROTECTION.

**FIREFLY** A firefly, or lightning bug, is any of about two thousand species of beetles that produce light—without heat—from special organs on their abdomens (see BEETLE; BIOLUMINESCENCE). The light is produced by the oxidation of a chemical called luciferin. The firefly controls this process by altering the oxygen supply to the light-producing organs. Therefore, it can control the length and rhythm of the flashes of light from its abdomen. Different species produce different colored lights at different rhythms. In the adult, this flashing attracts a mate of the same species.

Fireflies range in length from 0.2 to 0.78 in. [5 to 20 mm]. Most are dark brown or black with bright contrasting colors on the thorax (see THORAX). Because fireflies taste bad to birds and other predators, their coloration and flashing lights probably warn these enemies to stay away (see WARNING COLORATION). The eggs, larvae, and pupae of some species are also faintly bioluminescent. The larvae feed on earthworms, insects, and snails. The adults may feed on nectar (a sweet liquid found in many flowers) or nothing at all. They live for a short time.

Most fireflies live in tropical or humid temperate areas. Most are nocturnal (active at night) and rest on plants during the day. The females of some species are wingless and look like larvae. Both the wingless females and the larvae are often called glowworms, but this name is given to a different kind of luminous beetle in Europe.

# FIRE PROTECTION

Fire protection is the control and extinguishing of fires. About 2.5 million fires are reported to fire departments in the United States each year. The fires cause thousands of deaths and billions of dollars' worth of property damage. Sometimes, fire can destroy an entire city. In 1871, a fire swept through the city of Chicago. It destroyed eighteen thousand buildings and resulted in the death of three hundred people. During World War II (1939–1945), firebombs dropped on cities started fires, which destroyed large areas.

One of the chief hazards of fire is toxic (poisonous) smoke. Many human-made substances, such as plastics and chemicals, give off toxic fumes when they burn. If inhaled, the smoke can have harmful effects on the lungs. Dense, heavy smoke can cause asphyxiation (death or unconsciousness because of lack of oxygen).

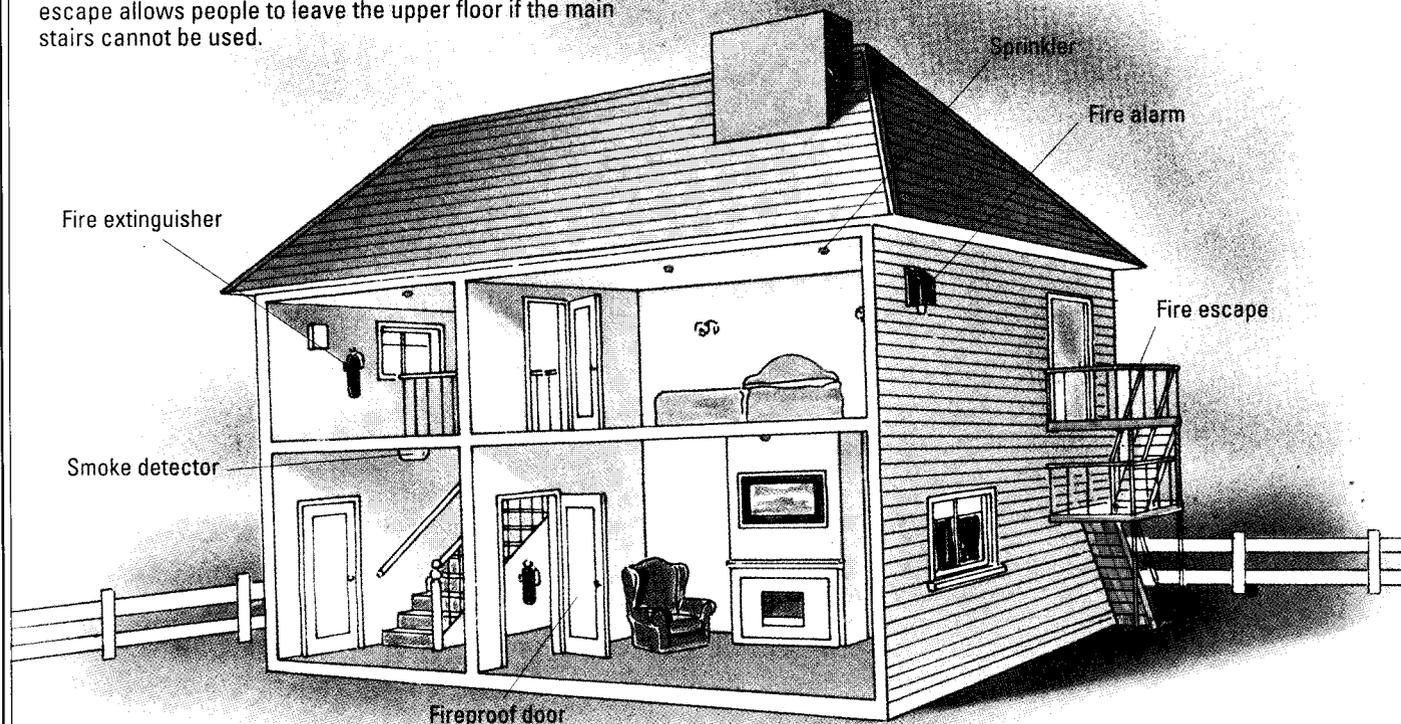
Carelessness with matches and cigarettes is one of the chief causes of fire. Fires in the home are often

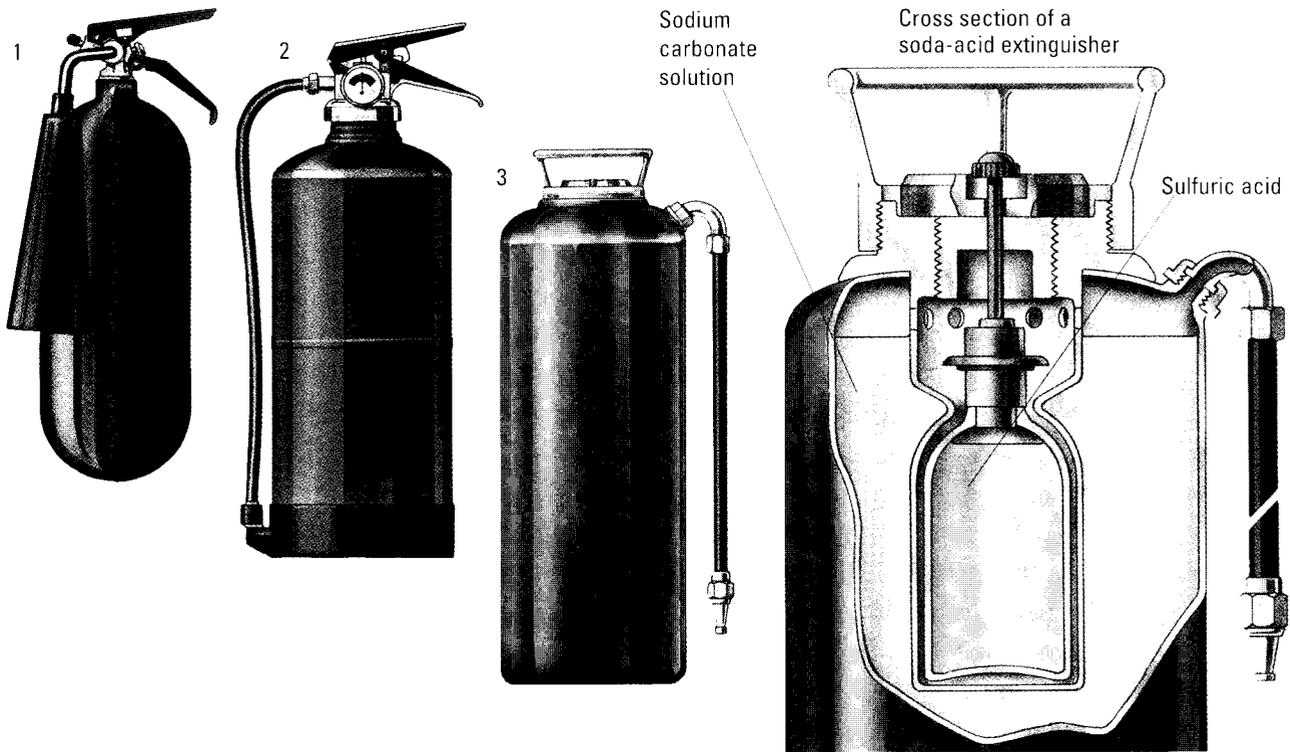
caused by defective electrical wiring. Many fires start in kitchens when cooking oils become ignited. Improper storage of flammable liquids, such as gasoline and cleaning fluids, is another cause of fires in the home. Gasoline, for example, should never be kept in a plastic or glass container. It should be stored in a metal container and placed in a cool place.

Fires can be prevented or slowed down by fireproof materials such as brick, stone, and chemically treated wood and fabrics. Asbestos, which does not burn, was widely used in different kinds of building materials until medical researchers discovered that the fibers can cause lung cancer. Now substitute fireproof materials have been developed. Wood and plastics that are treated with fire-resistant chemicals are difficult to ignite, and they burn slowly if they are ignited. Special paints also help slow the spread of fire. Fire doors used in most large buildings keep fires from spreading. Most public buildings have

## FIRE PROTECTION IN THE HOME

This house has several fire protection devices. A sprinkler system in the ceilings releases water to douse a fire, and there are fire extinguishers on both floors. A smoke detector and fire alarm give warning if a fire breaks out. The fire escape allows people to leave the upper floor if the main stairs cannot be used.





### FIRE EXTINGUISHERS

There are various types of fire extinguishers, and only the correct type should be used for a particular fire. (1) A carbon dioxide gas extinguisher should be used on fires involving electricity or flammable liquids or gases. (2) A dry powder extinguisher can be used to smother most kinds of fire. (3) A soda-acid extinguisher uses a chemical reaction to squirt water onto a fire involving materials such as wood and paper. It should not be used on electrical fires.

automatic sprinkler systems. Nozzles located in room ceilings spray water when the temperature in the room rises above a certain point. Many homes now have smoke detectors. These devices sound an alarm when there is smoke in the room.

Fire extinguishers are required by law in public buildings, factories, and schools. Most fire extinguishers consist of a metal container filled with chemicals and/or water.

There are different types of fire extinguishers, rated according to the type of fire they are designed to be used against. Fires are divided into four types, or classes. Water extinguishers are used only against class A fires, which involve materials such as wood and paper. Water extinguishers put out a fire by absorbing heat from it. Foam extinguishers are used against class A and B fires. Class B fires involve flammable liquids and gases. Foam from the extinguisher covers the burning materials and starves the

fire of the oxygen it needs to keep going. Gas extinguishers containing carbon dioxide are used to fight class B and class C fires. Class C fires involve electrical equipment. Carbon dioxide is heavier than air. It settles over the burning materials and cuts off their supply of oxygen. Dry chemical extinguishers contain chemical powder. Like gas extinguishers, they are used to fight class B and C fires. Multipurpose dry chemical extinguishers can also be used on class A fires. Class D fires involve materials such as magnesium or sodium which burn very fiercely. Class D fires require extinguishers filled with special heat-absorbing chemicals.

The correct type of extinguisher must be used for each type of fire. Water extinguishers must never be used on electrical fires because water conducts electricity, possibly leading to electric shocks. An extinguisher's rating, and the type of fire or fires it is designed to be used against, is shown on a label on the extinguisher.

Many people keep one or more fire extinguishers at home and in their automobiles to use in case of an emergency.

Fire escapes are steel stairways mounted on the outside of multistory buildings. They are required by law on most older multistory buildings. New

multistory buildings are required to have enclosed concrete stairways that can be sealed off from other parts of the building. Stairways are necessary because elevators do not always work during fires. Most large buildings also have fire alarm systems that ring bells to alert the occupants. Some alarm systems automatically alert the local fire department.

Public buildings are inspected regularly by local fire departments for fire hazards. Fire fighters give talks and demonstrations at schools to teach children about the dangers of fire. Chambers of commerce and other civic groups promote fire prevention through newspaper and television. Every year, in the week preceding October 9, the United States observes National Fire Prevention Week. October 9 is the anniversary of the Chicago fire, which occurred in 1871.

The first fire-protection laws were passed in ancient Rome. In 18 B.C., the Roman leader Augustus set minimum thicknesses for building walls. He also formed a group of people called the vigiles who patrolled the streets to watch for fires.

Today, putting out fires is the responsibility of public fire departments. Fire departments are often alerted to these fires by fire alarms and calls from individuals.

Fire departments usually have three kinds of trucks: ladder trucks, pumpers, and rescue trucks. One kind of ladder truck has a long, metal extension ladder that can reach as high as 100 ft. [30 m], or eight stories. Another kind of ladder truck has a cagelike platform attached to a lifting device called a boom. A fire fighter rides on the platform to operate a high-pressure water nozzle. The boom can

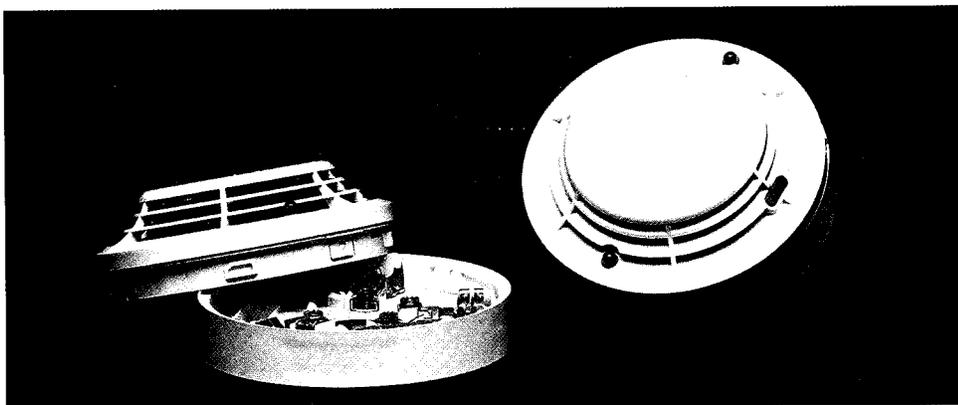
extend to 150 ft. [46 m]. Pumpers increase the pressure of water from hydrants and other sources. The pumps force water through long hoses under high pressure. This allows fire fighters to direct powerful streams of water on fires from safe distances. Pumpers must deliver at least 750 gal. [2,840 liters] per minute. Pumpers contain several sizes of hoses for different types of fires. For example, hoses that have a small diameter are used on brush fires and grass fires. Rescue trucks contain special tools for special jobs. They carry oxyacetylene torches for cutting through metal and hydraulic jacks for lifting heavy objects. They also carry diving gear, fire-resistant suits, and emergency medical supplies and equipment. Rescue trucks often are called for emergencies other than fires, such as medical emergencies.

Fire fighters wear special clothing to protect themselves from flames, falling objects, and other hazards. They wear heavy, waterproof, knee-length coats made of fire-resistant fabric. Other clothing includes helmets, gloves, and boots. Fire fighters also use breathing equipment that allows them to breathe while in smoke-filled buildings.

Airports have their own kind of fire trucks called crash trucks. Crash trucks are pumpers that spray foam or dry chemicals on burning airplanes. Water cannot put out most aircraft fires. Fireboats are boats used to fight fires on ships, piers, and waterfront buildings. Fireboats have pumps that draw water from lakes, oceans, and rivers. Large gunlike nozzles direct water onto the fire. Large fireboats can pump 10,554 gal. [40,000 liters] of water per minute onto a fire up to 200 ft. [60 m] away.

*See also* FIRE.

 PROJECT 6



## SMOKE DETECTOR

A smoke detector is a useful fire-protection device for homes, offices, and factories. It detects the presence of smoke and sounds an alarm to give an early warning that a fire has started.

# FIRST AID

First aid is the help given to a sick or injured person before a doctor or other health-care provider arrives. First aid is used after accidents, injuries, and medical emergencies. If the emergency is life-threatening, such as choking, poisoning, or severe bleeding, first aid may mean the difference between life and death for the person needing help.

The American Red Cross advises people to follow four steps, in order, in giving first aid before professional help arrives:

1. Remove the person from further danger.
2. Check that air passages—the nose, mouth, and throat—are open. Give cardiopulmonary resuscitation (CPR), artificial respiration (rescue breathing), or the Heimlich maneuver for choking victims, if needed. It is important to keep in mind that a person who is choking may not be able to speak to tell you he or she is choking.
3. Stop severe bleeding. This is done by elevating the wounded area above the rest of the body, covering it with a clean cloth, and pressing hard over the wound.
4. Give first aid for poisoning (see POISON). Call the local Poison Control Center or hospital for

advice immediately. Keep handy the container of poison with its label. Follow the instructions given by the person at the Poison Control Center or hospital.

A person who is injured may go into shock. Shock is a serious state of collapse that happens when the body overreacts to an injury (see SHOCK). In severe shock, the person may lose consciousness or even die. The following steps are the first aid for shock:

1. Keep the person lying down.
2. Keep the body temperature normal. Use blankets in cold weather.
3. Keep talking calmly to the person, even if the person does not answer you.
4. Call the rescue squad or paramedics.

First aid should also be given to people who have burns, snake or other animal bites, sprains, broken or dislocated bones, head or neck injuries, or over-exposure to heat or cold. First aid for a heart attack is CPR. Basic first-aid information can be found in the beginning of most telephone books. Classes in first aid are offered in most communities by the American Red Cross, the local fire department, or an adult education center.

*See also* BURNS.

## FIRST AID

First aid is the help given to a sick or injured person before a health-care provider can get to the scene. These students are learning how to give artificial respiration. This will prepare them to come to the aid of anyone having trouble breathing.

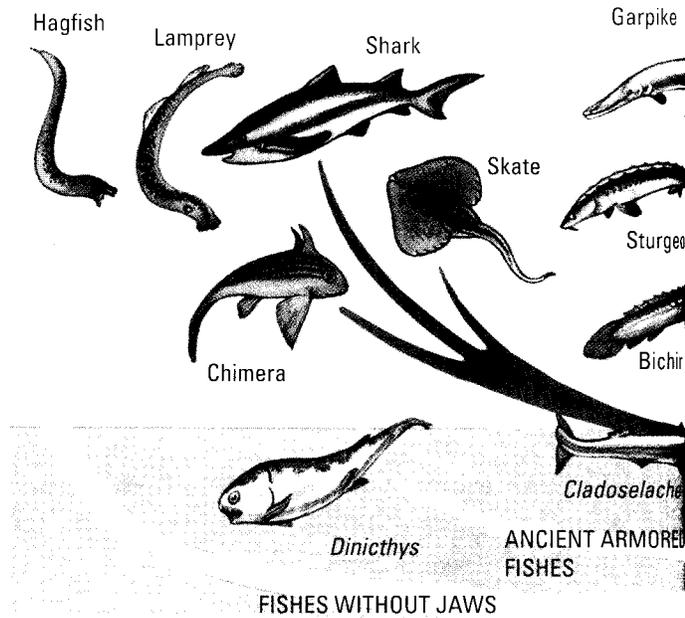


# FISH

Fish are cold-blooded, vertebrate animals. Fish first evolved about 500 million years ago. Many fossils of fish have been found. During the Devonian period—the Age of Fishes—many types of fish appeared. Most have now become extinct—that is, they have died out. About twenty thousand species are alive today in three main groups: the jawless fish, the cartilaginous fish, and the bony fish (see COLD-BLOODED ANIMAL; FOSSIL; GEOLOGICAL TIME SCALE; VERTEBRATE).

**Jawless fish** These primitive fish belong to the class Agnatha. Most of them are parasitic (see PARASITE). They do not have true jaws. Instead, they have suckerlike mouths, which they use to attach themselves to other fish and to suck out blood and other tissues. Jawless fish also do not have a true backbone or bones. Their skeleton is composed of cartilage (see CARTILAGE). The group includes the hagfish and lamprey. Hagfish are saltwater scavengers of other fish. Scavengers feed on dead or almost-dead organisms. Many lampreys also live in the sea, but they enter fresh water to spawn. Many lampreys are parasites. There are three species of hagfish and fourteen species of lampreys in North America (see SPAWNING).

**Cartilaginous fish** Cartilaginous fish belong to the class Chondrichthyes. These fish do not have any true bones in their bodies. Instead, their skeletons are made up of cartilage. Their bodies are covered with pointed scales, which make the skin rough. Although cartilaginous fish are



## EVOLUTION OF FISH

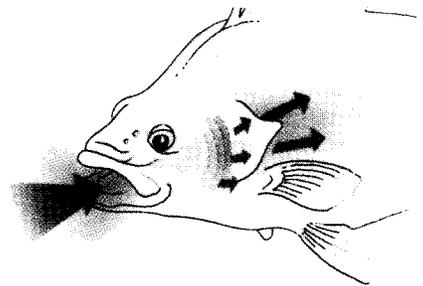
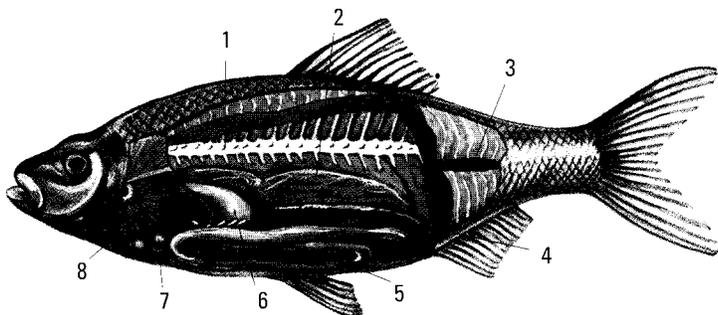
The diagram above shows how today's fish probably evolved from extinct ancestors based on ostracoderms (meaning "shelled skins") such as *Hemiclaspis*.

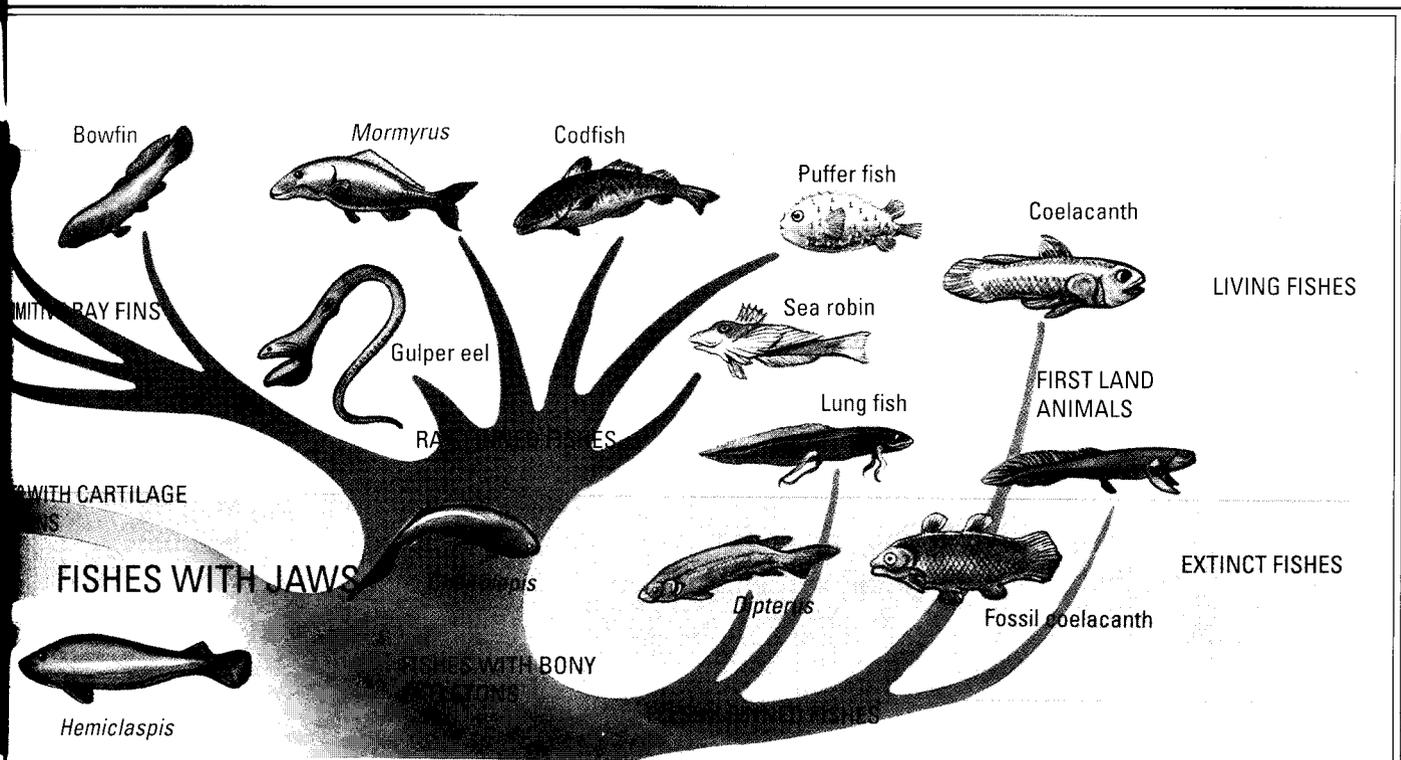
evolutionally more modern than the jawless fish, they are more primitive than the bony fish.

The cartilaginous fish include many species of sharks and rays. The largest of all living fish is the whale shark, which may reach a length of 60 ft. [18.9 m]. Most sharks are carnivorous (meat eaters), but the whale shark and a few others eat

## PARTS OF A FISH

The cross section of a fish (below left) shows the bones and organs of a typical bony fish. (1) Backbone; (2) swim bladder; (3) trunk muscles; (4) ovary; (5) intestine; (6) stomach; (7) heart; (8) gills. A fish breathes (below right) by swallowing water and passing it through its gills. The gills extract oxygen from the water.





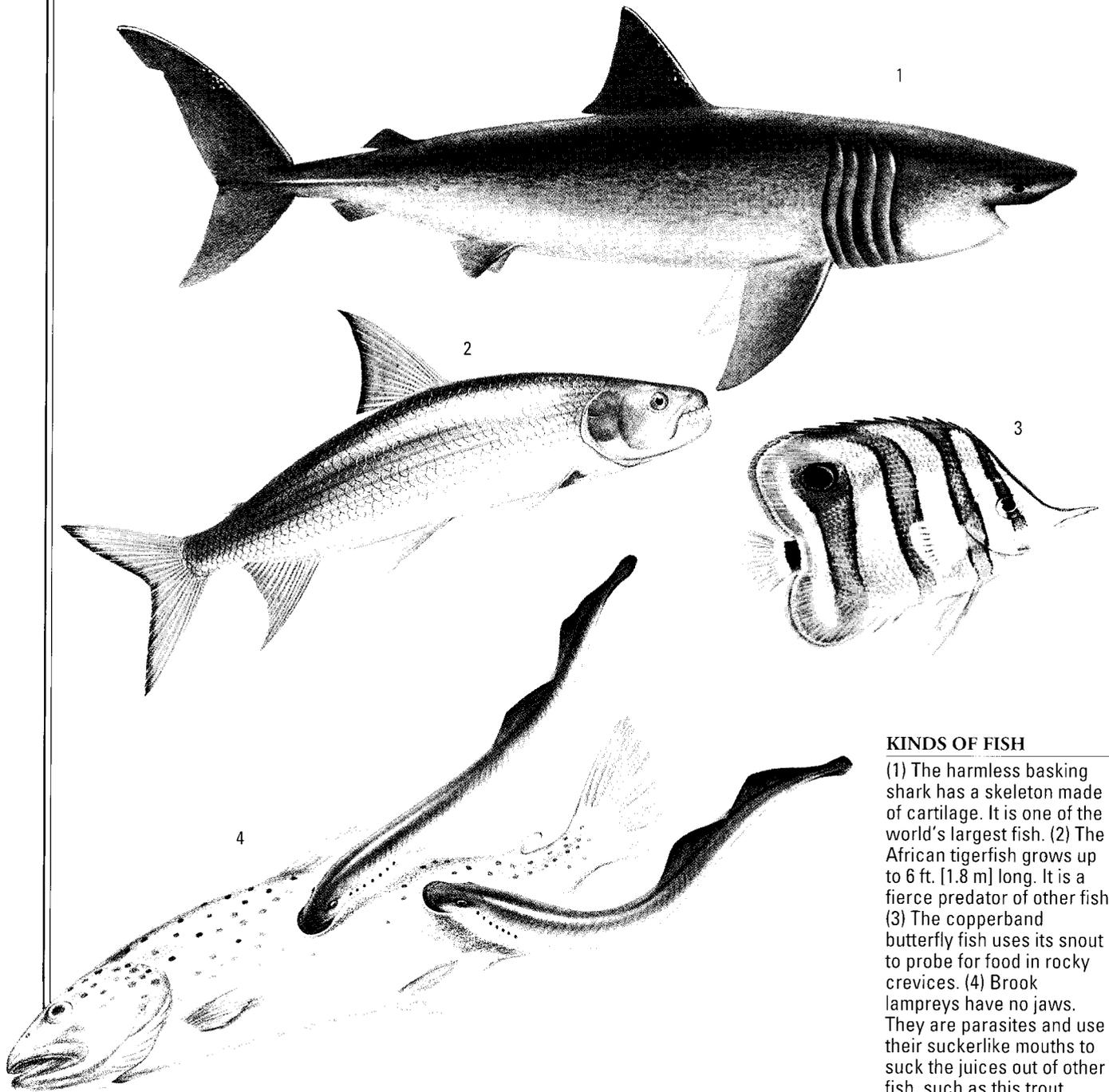
plankton (see PLANKTON). Some sharks have to keep moving because they are unable to pump water across their gills. They swim with their mouths open so that a fresh supply of water always enters their mouths. Their gills then extract oxygen

from the water (see GILLS). In contrast, modern bony fish take water into their mouths, force it over the gills, and then out through the openings of the gill covers. These fish can do this while remaining motionless.



**FISH OUT OF WATER**

Mudskippers are hard to see against the mudflats on which they live. They get their name from their habit of skipping across the mud, using their pectoral fins like "legs."



**KINDS OF FISH**

(1) The harmless basking shark has a skeleton made of cartilage. It is one of the world's largest fish. (2) The African tigerfish grows up to 6 ft. [1.8 m] long. It is a fierce predator of other fish. (3) The copperband butterfly fish uses its snout to probe for food in rocky crevices. (4) Brook lampreys have no jaws. They are parasites and use their suckerlike mouths to suck the juices out of other fish, such as this trout.

Rays have flat bodies. Most of them live close to the ocean bottom, where they feed mostly on crabs and invertebrates, such as worms. Some rays, such as the manta ray, live near the surface and feed on plankton and tiny fish. Skates are a kind of ray. They spend most of their time on the ocean floor. Skates eat small fish and invertebrates.

**Bony fish** Bony fish are relatively modern fish

and most of them belong to the class Osteichthyes. They have a skeleton made up of bones. This group includes most of the freshwater fish and a large number of the saltwater fish. There are many different types of bony fish, but most of them have smooth scales covering their bodies, gills that are covered by a cover known as operculum, a swim bladder used for buoyancy, and fins.

*See also* EVOLUTION.

**FISSION** An atom has at its center a core called the nucleus. Sometimes, the nucleus can break into two parts that are roughly the same size. This breaking up of a nucleus is called nuclear fission. When this happens, large amounts of energy are released. If the fission is controlled, such as in a nuclear power plant, this energy can be a source of power. If the fission is uncontrolled, the energy can be used to create an atomic explosion (see **ATOM**; **NUCLEAR ENERGY**; **NUCLEAR WEAPONS**; **NUCLEUS**, **ATOMIC**).

Fission can be caused by a nucleus being hit by a neutron. A neutron is a small subatomic particle. A nucleus from a heavy element—that is, one that contains a large number of protons and neutrons—is usually very unstable. It is easily split by a collision.

The mass of a nucleus is greater than the combined mass of the fission fragments. Therefore, when the nucleus is split, some of its mass disappears. The missing mass is converted into energy.

Albert Einstein was the first person to discover that mass can be converted into energy (see **EINSTEIN**, **ALBERT**). Even a very small mass converts to a large amount of energy. Much of this energy is given off as large quantities of heat and as particles that have a high velocity (speed in a certain direction).

A material often used in fission is an isotope of uranium. It is called uranium-235 (see **ISOTOPE**; **URANIUM**). When the nucleus of a uranium atom is struck, it usually splits into two smaller nuclei. The nucleus also releases two or three neutrons. These neutrons then collide with other nuclei and cause further fission. The reaction quickly accelerates and is called a chain reaction (see **CHAIN REACTION**). If it is uncontrolled, the process leads to an atomic explosion. This was used in the atomic bombs that were dropped on Japan in 1945, during World War II.

In a nuclear power plant's nuclear reactor, the fission process is controlled. This is done by removing some of the neutrons that are given off and stopping an explosive chain reaction from occurring. The neutrons are removed by rods that absorb them. These rods are usually made of

cadmium or boron. Not too many neutrons can be absorbed, however, or the reaction will stop. The rods are inserted or removed to make sure that the reaction is going at the right speed.

Nuclear power plants convert the heat from fission into another form of energy—electricity. Large amounts of electricity are produced this way. For example, 3.3 million lb. [1.5 million kg] of coal are needed to produce the same amount of energy as 2.2 lb. [1 kg] of uranium-235.

See also **FUSION**.

**FITCH, JOHN** (1743–1798) John Fitch was an American inventor who designed and built one of the first steamboats.

In 1787, Fitch demonstrated his steam-powered vessel on the Delaware River, near Philadelphia, Pennsylvania. Fitch's steamboat was propelled by six paddles on each side. The paddles were driven by a steam engine.

Fitch did not receive credit for starting the Steamboat Age. That honor went to Robert Fulton, another American. In 1807, Fulton built one of his own design. He called it the *Clermont* and successfully tested it on the Hudson River in New York (see **FULTON**, **ROBERT**).

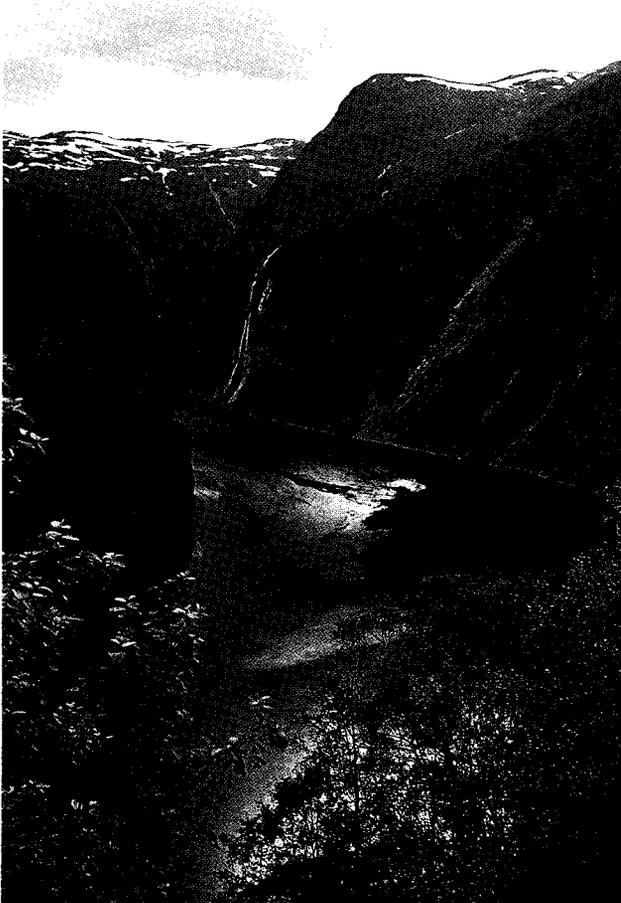
Fitch had constant financial troubles. He was never able to attract enough public support for his steamboats. In 1790, he built another steamboat and placed it in regular passenger service between Philadelphia and Burlington, New Jersey. Unfortunately, there was not enough demand for passage to make the idea pay.

Fitch finally gave up on his steamboat efforts. Before his steamboat days, Fitch was a successful brassworker and silversmith in Trenton, New Jersey. He also served as a lieutenant in the Revolutionary War.

**FJORD** (fyôrd) A fjord is a long, narrow inlet of the sea. Fjords are the result of erosion and glaciation. Millions of years ago, rivers cut valleys through rock. Later, during the ice age, these valleys were deepened by glaciers. When the glaciers retreated, the sea level rose and flooded the valleys, forming fjords.

Fjords are usually very deep and often have steep walls with waterfalls. They are common along the coasts of Alaska, Greenland, New Zealand, and Norway.

See also EROSION; GLACIATION.



**FJORD**

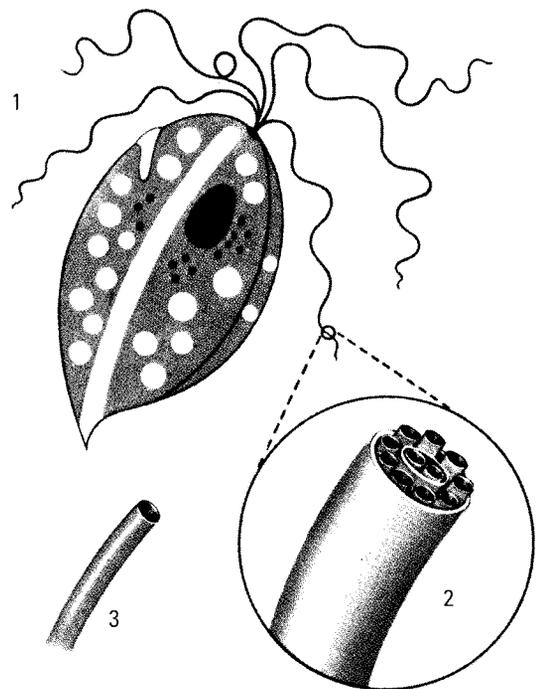
Geiranger Fjord is a long inlet of the sea on the coast of Norway. It was formed when a glacier melted at the end of the last ice age.

**FLAGELLATE** (flāj'ə lār') A flagellate is any of several kinds of microorganisms that have one or more whiplike flagella (plural of *flagellum*). Although most flagellates are protozoans, some are algae or bacteria (see ALGAE; BACTERIA; FLAGELLUM; MICROORGANISM; PROTOZOA). Flagellates use flagella to swim through the water or other liquid in which they live. Algal flagellates contain chlorophyll and are able to carry on photosynthesis (see PHOTOSYNTHESIS).

Free-living flagellates, such as those species that belong to the genera (plural of *genus*) *Euglena* and *Chlamydomonas*, live by themselves and usually

contain chloroplasts (bodies containing chlorophyll). Colonial flagellates, such as volvox, live in an attached group and move about by collectively waving their flagella. Many flagellate algae live in the sea and form a major part of the plankton, a vital food for many sea animals (see PLANKTON). *Noctiluca* is a genus of bioluminescent planktonic flagellate (see BIOLUMINESCENCE). Parasitic flagellates usually live in the blood or intestines of a mammal host and cause serious diseases (see PARASITE). Trypanosomes are parasitic flagellates that live in human blood and cause sleeping sickness.

**FLAGELLUM** (flə jĕl'əm) A flagellum is a hair-like structure extending from a cell. It is usually used for movement through water or another liquid. The structure of a flagellum is much like that of a cilium, only a flagellum is longer (see CILIUM). With the exception of the bacterial flagellum, all flagella (plural of *flagellum*) have a circle of nine fibers surrounding two other fibers. Although most flagellated organisms have one or two flagella, some have many, which are easily confused with cilia (plural of *cilium*).



**FLAGELLUM**

Pictured are: (1) A flagellate named *Trichomonas*, which is a microscopic parasite in humans; (2) a section of one flagellum of *Trichomonas*, highly magnified; (3) a section of a flagellum of a bacterium, also highly magnified.

Many protozoans and some algae move by flagella (see FLAGELLATE). Some lower invertebrates (animals without backbones), such as the sponges and the cnidarians, use flagella to create a stream of water through their bodies for feeding and respiration. Some bacteria have a single flagellum that is composed of only one protein molecule. The gametes, or sex cells, of some algae, fungi, slime molds, mosses, and ferns also have flagella. Also, the sperm of many animals, including human beings, have flagella to allow them to swim to and fertilize the eggs.

**FLAMINGO** A flamingo is a tall bird that belongs to the family Phoenicopteridae. It has very long legs and a long, slender neck. Flamingos wade in shallow water, feeding on small animals and plants that they sieve from the water with their large, boat-shaped beaks.



#### FLAMINGO

A flamingo uses its hooked beak (above) to feed. It holds its head upside-down (right) and sieves small particles of food by drawing water through the hairlike bristles fringing its beak.

The greater flamingo is the only species of flamingo in North America. It occurs mainly in the Caribbean region but is occasionally seen in Florida. This flamingo grows to 42 in. [105 cm] tall and has red to pink feathers. The color of the feathers comes from a chemical found in many of the crustaceans that the flamingo eats. If the flamingo stops eating them, its feathers will gradually turn white.

See also BIRD; CRUSTACEAN.

**FLAMMABLE** *Flammable* refers to a substance that can be easily ignited (set on fire) and then burns quickly. Substances that are flammable include gasoline and wood. *Flammable* and *inflammable* have the same meaning.

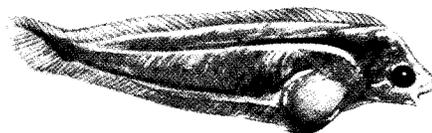
See also COMBUSTION.

**FLATFISH** A flatfish is a saltwater fish that belongs to the order Pleuronectiformes. Flounder, sole, halibut, plaice, and turbot are types of flatfishes. They are called flatfishes because their bodies have a flat shape. These fish are interesting to look at because both of their eyes are on one side of their head. When flatfishes hatch from their eggs, they look like most other fishes, with an eye on each side. Soon, however, one side of the skull

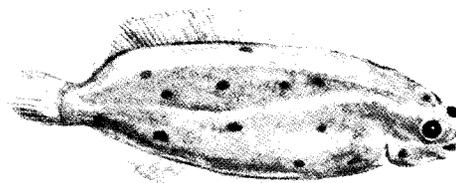
Newly hatched



Young sole



Adult sole



#### FLATFISH

The very young sole (above top) is much the same shape as other young fish. As it grows, it flattens out, and the left eye moves to the right side of the head.

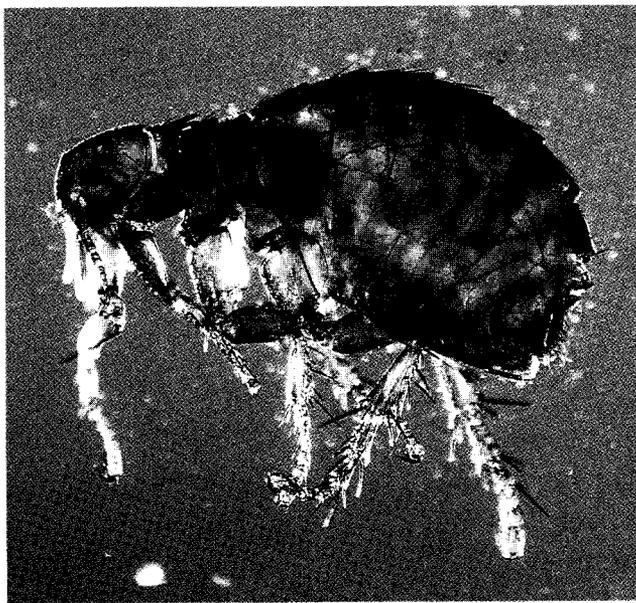
grows faster than the other. This pushes one eye over to the other side and twists the mouth. After this happens, the flatfish begins to lie on the sea floor on its blind side—the side with no eyes.

There are three families of flatfishes. The family Bothidae includes the turbot and other left-sided species—those fish with their eyes on the left side. The Pleuronectidae includes the plaice and other right-sided fish with pointed snouts and with their eyes on the right side. The Soleidae includes the soles, which are also right-sided but which have smoothly rounded snouts.

Most of these flatfishes live on the bottom of shallow coastal waters. They eat bottom-dwelling animals. They cannot swim very well, but they can escape enemies by camouflaging themselves. They do this by adapting colors of the surrounding bottom or by burying themselves in sand. Many species are important food fishes and commercially valuable.

See also CAMOUFLAGE; FISH.

**FLEA** A flea is any one of about 1,800 species of tiny parasitic insects belonging to the order Siphonaptera (see PARASITE). Fleas have short antennae and brown, wingless bodies that are



**FLEA**

Fleas are parasitic insects that suck the blood of other animals, usually birds or mammals. When fleas bite humans, they may pass on diseases such as bubonic plague or typhus.

flattened from side to side (see ANTENNAE). Their long hind legs are very strong and allow fleas to jump great distances. The common human flea is only about 0.1 in. [3 mm] long, yet it is able to jump more than 13 in. [330 mm]. Fleas suck blood from a host by using their sharp, beaklike mouth parts. However, they do not feed continuously. They may live for more than a year without eating. Although most fleas will bite hosts of several species, some are parasites on only one specific type of mammal or bird.

After having sucked blood from a host, a female flea may lay hundreds of eggs on the host or in its nest. The wormlike larvae live in the host's nest or sleeping quarters, where they feed on debris, including the droppings of the adult fleas. The process of metamorphosis may take less than a month or more than a year (see METAMORPHOSIS).

Fleas spread disease. Bubonic plague is spread by the rat flea (*Xenopsylla cheopis*) and other species. The common cat flea (*Ctenocephalides felis*) and the common dog flea (*Ctenocephalides canis*) sometimes bite human beings and may transmit disease-causing tapeworms.

See also DISEASE; INSECT; TAPEWORM.

**FLEMING, SIR ALEXANDER** (1881–1955) Sir Alexander Fleming, a British scientist, discovered penicillin, the first antibiotic drug. In 1928, he was studying bacteria and noticed that some of his experiments were spoiled because the bacteria were dying. Instead of throwing them away, he decided to try and find out what was killing the bacteria. There was a mold, called *Penicillium notatum*, growing where the bacteria had died. Fleming found out that this mold made a substance that killed bacteria. He called the substance penicillin. It took ten years to find a way of getting a large amount of pure penicillin from the mold. Howard Florey and Ernst Chain discovered how to do this.

Penicillin was first used to cure a sick person in 1941. Fleming, Florey, and Chain shared the Nobel Prize for medicine in 1945 for this work.

See also ANTIBIOTIC; FLOREY, HOWARD; PENICILLIN.

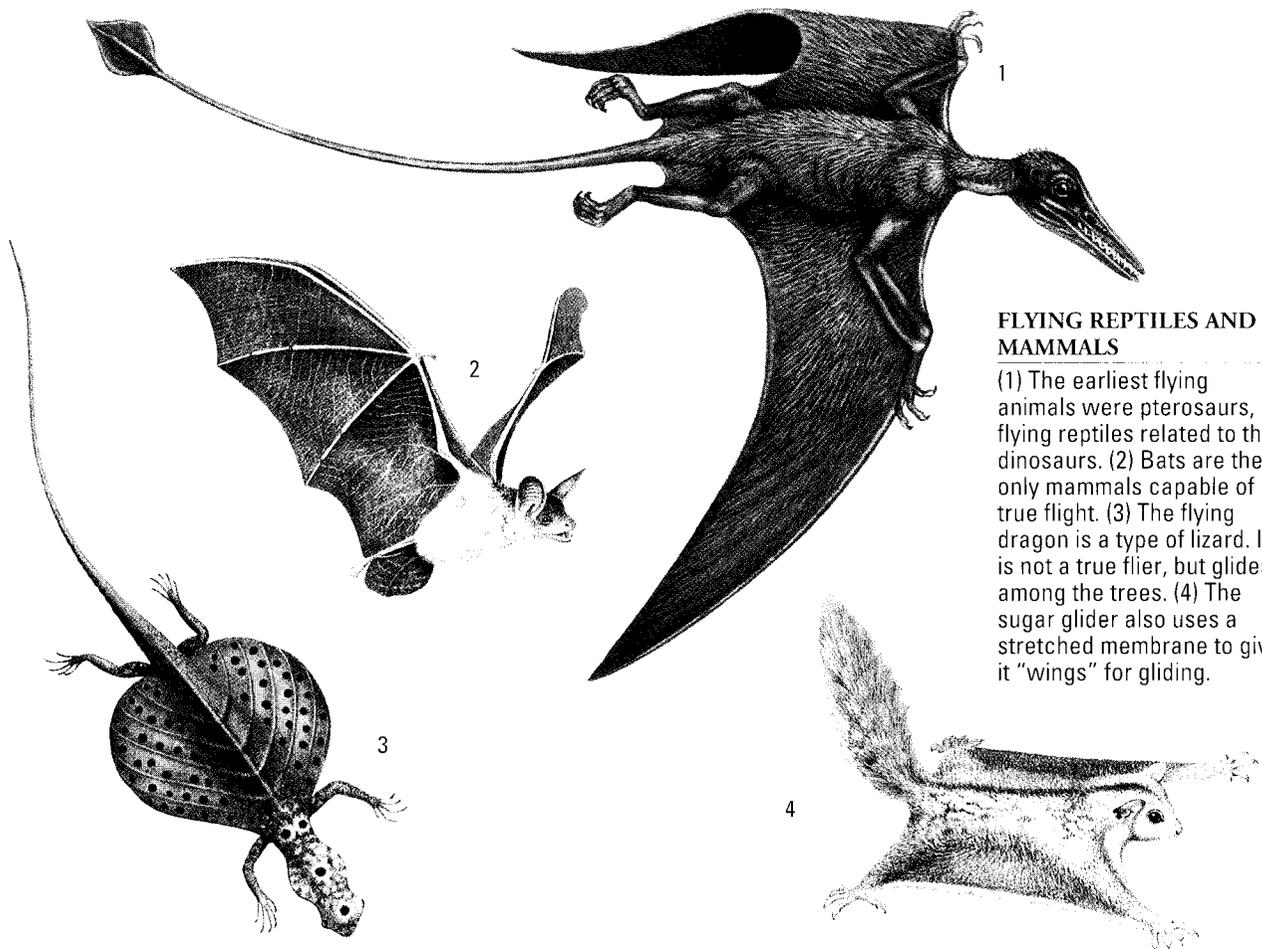
# FLIGHT

Anything that flies through the air must generate two distinct forces—thrust to push it forward, and lift to get it off the ground and keep it aloft (see **FORCE**). Airplanes get thrust from their engines and lift from their wings, but flying animals must generate both thrust and lift with their wings (see **AERODYNAMICS**). Several animals, including some frogs and snakes, can glide through the air, but only three groups of animals have truly developed the ability to fly. These are the insects, the bats, and the birds (see **BATS**; **BIRDS**; **INSECTS**).

Some birds, such as vultures and albatrosses, can soar and glide on outstretched wings with very little effort, but most birds have to flap their wings rapidly to keep aloft. The power is provided by large muscles attached to the breastbone. It may look as if the wings are simply moving up and down, but the wing movements are actually quite complicated. On the downstroke, the feathers push

hard against the air and the wings twist around to force the air backward as well as downward. This creates the thrust that pushes the bird forward. On the upstroke, the big flight feathers separate and allow the air to pass between them with little resistance. The lift needed to keep the bird up in the air is provided by the shape of the wing. Air rushing over the curved upper surface moves slightly more quickly and exerts less pressure than the air moving across the flatter lower surface, so the wing is pushed up by air pressure from below (see **AIRFOIL**). The lifting force obviously has to be greater than the weight of the bird's body. The bird's weight is low because it has hollow bones.

The amount of lift generated by the wing depends on its size and on the speed of the air flowing over it. Small birds have to fly quickly in order to maintain enough lift. Birds with larger wings can fly more slowly, but large wings also create a lot of



## FLYING REPTILES AND MAMMALS

(1) The earliest flying animals were pterosaurs, flying reptiles related to the dinosaurs. (2) Bats are the only mammals capable of true flight. (3) The flying dragon is a type of lizard. It is not a true flier, but glides among the trees. (4) The sugar glider also uses a stretched membrane to give it "wings" for gliding.

drag or air resistance. Although the smooth, streamlined outline of the body and wings helps to reduce the amount of drag, there is a limit to how much drag can be reduced (see DRAG).

The shapes of birds' wings vary a great deal and are closely linked to the birds' lifestyles. Most songbirds have relatively short, triangular wings. These are "all-purpose" wings, allowing quick takeoff and fairly good ability to maneuver in the air. Swifts and swallows have longer and narrower wings. These wings are very maneuverable in the air, but make the birds less efficient at taking off. In fact, swifts can hardly get off the ground at all. Eagles have long, broad wings that generate a lot of lift and enable these birds to soar slowly through the air. The wings also help the eagle to have a quick, efficient takeoff, which is very important when the bird is carrying prey. Pheasants and other game birds have broad, short wings that give them a quick takeoff. The pheasant can probably take off more quickly than any other bird of its size,

although this uses a lot of energy and the bird soon glides back to the ground.

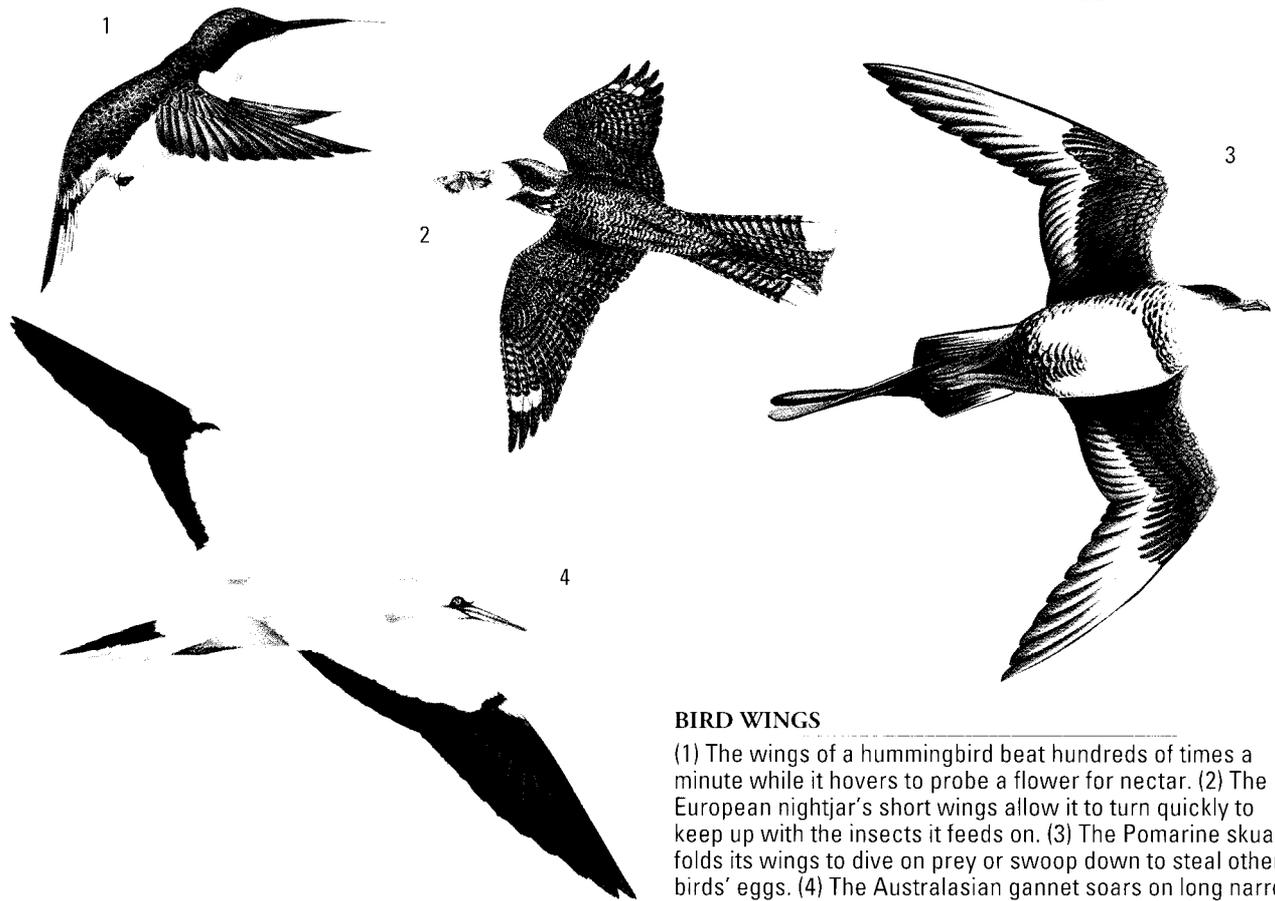
Birds can change direction by making slight changes to the shape or position of one wing, or by changing the position of the tail feathers. The tail is also used as a brake. Some birds also use their feet as brakes when landing.

The shape of the wing of an airplane also produces lift, just as a bird's wing does. Fast-moving air over the upper curved surface of the wing has lower pressure than the slightly slower-moving air passing the flatter, lower surface of the wing. This difference in pressure produces the lift that keeps the airplane in the air. The blades of a helicopter act like a rotating wing, also providing the lift that enables the machine to fly.

 PROJECT 38

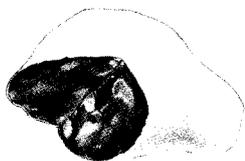
FLYING INSECT

Many insects can fly, including the plain tiger (right), a colorful butterfly from tropical Africa.



BIRD WINGS

(1) The wings of a hummingbird beat hundreds of times a minute while it hovers to probe a flower for nectar. (2) The European nightjar's short wings allow it to turn quickly to keep up with the insects it feeds on. (3) The Pomarine skua folds its wings to dive on prey or swoop down to steal other birds' eggs. (4) The Australasian gannet soars on long narrow wings, watching for fish in the water below.

**FLINT**

A pale outer layer usually covers a flint pebble (above). Its dark gray or brown color is revealed when the nodule is broken. Prehistoric people used flint to make tools and weapons, such as this spearhead (right). Flint also occurs as dark gray lumps in chalk or limestone (below).

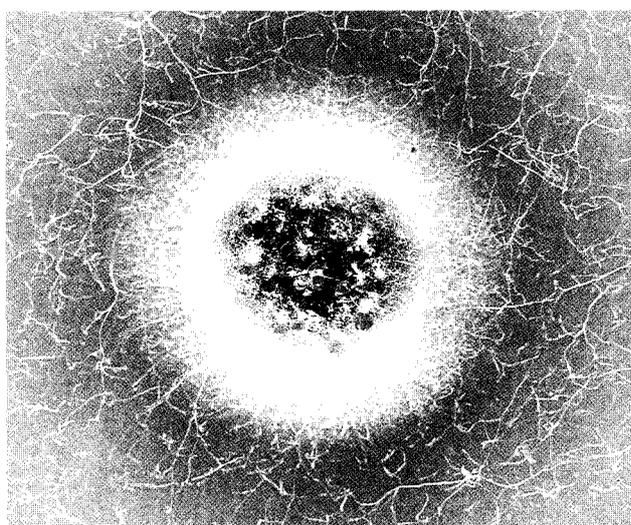


**FLINT** Flint is a form of natural silica, like quartz, but not forming crystals. Flint is most often found in the form of fine-grained, dark gray lumps in chalk and limestone. After it has been exposed to weathering, flint usually changes color to yellow or brown. It is easy to chip and can be shaped into pieces with sharp edges. This property made it valuable in prehistoric times. Prehistoric people made spear tips, knives, and arrowheads from flint. Later, people learned that flint gave a spark when it was struck against hard metal. They began using flint to start fires. Today, the primary use of flint is for abrasives.

See also ABRASIVE; QUARTZ.

**FLOREY, HOWARD WALTER** (1898–1986) Howard Florey was born in Australia. He worked in Britain on the study of diseases. Florey was one of the scientists who discovered how to get pure penicillin from the mold that makes it. He shared the 1945 Nobel Prize for medicine with Ernst Chain and Alexander Fleming for this work. Florey was knighted in 1944 and made Baron Florey of Adelaide in 1968.

See also ANTIBIOTIC; FLEMING, SIR ALEXANDER; PENICILLIN.

**FLOREY**

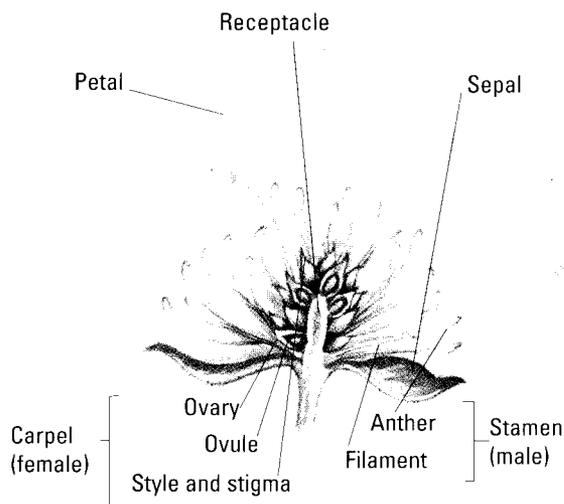
Florey and his coworker, Ernst Chain, developed a method of extracting penicillin from *Penicillium* mold (above). They shared a Nobel Prize with penicillin's discoverer, Sir Alexander Fleming.

# FLOWER

The flower is the structure in all angiosperms (flowering plants) that is responsible for sexual reproduction (see ANGIOSPERM). Its function is to produce seeds that will grow into new plants. There are at least 200,000 kinds of flowers. They range in size from the microscopic duckweed blossom at 0.016 in. [0.4 mm] in diameter to the tropical *Rafflesia arnoldi* at 3 ft. [90 cm] in diameter. Flowers may be any of hundreds of shapes and colors. The colors and distinctive fragrances attract

birds and insects needed to help with pollination (see POLLINATION). Flower fossils have been found that date back more than 125 million years (see FOSSIL). Flowers grow everywhere in the world except in ice-covered areas near the North and South poles and in the open seas. Some flowers grow wild, while others are cultivated by florists and gardeners. In the United States alone, there are more than 32,000 kinds of wildflowers.

**Parts of a flower** The flower consists of a number of highly modified leaves, which are clustered at the tip of a stalk. The flower parts are all attached to an enlarged section of the stalk called the receptacle. There are four whorls, or circular sets, of parts growing from the receptacle: the calyx, the

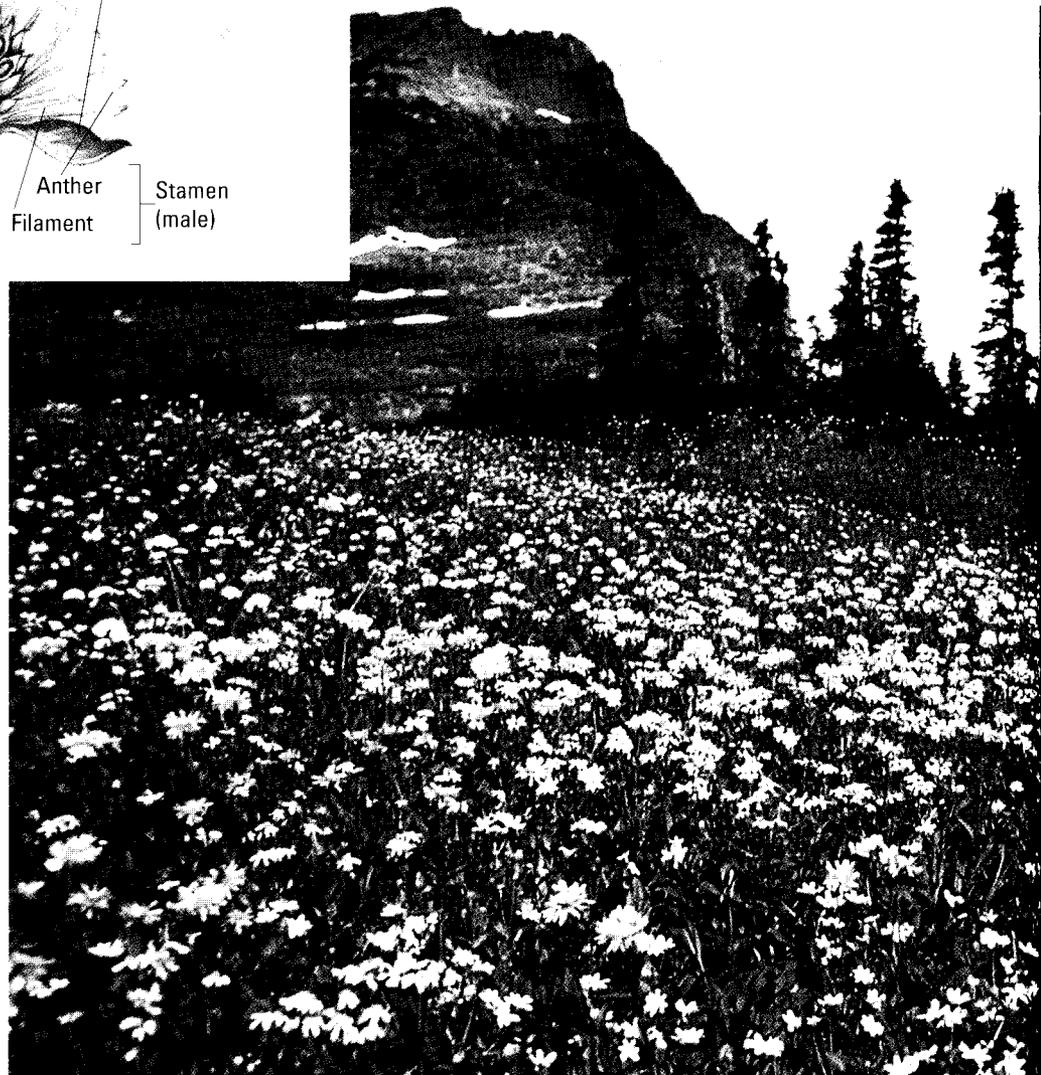


## PARTS OF A FLOWER

A buttercup is a typical angiosperm flower with both male and female parts. The various structures are shown in this cross section.

## SHORT LIFETIME

At high altitudes, such as the Rocky Mountains (right), plants have a very short growing season. They have to flower and produce seeds in far less time than plants at lower altitudes.



corolla, the stamens, and the pistils. The calyx is made of several green, leaflike sepals, which protect the developing flower bud. In some cases, the sepals may be brightly colored. The corolla is made of several, usually brightly colored, petals. The petals vary enormously in shape and are sometimes absent, depending on the species. The calyx and corolla together form the perianth (see CALYX; PETAL; SEPAL).

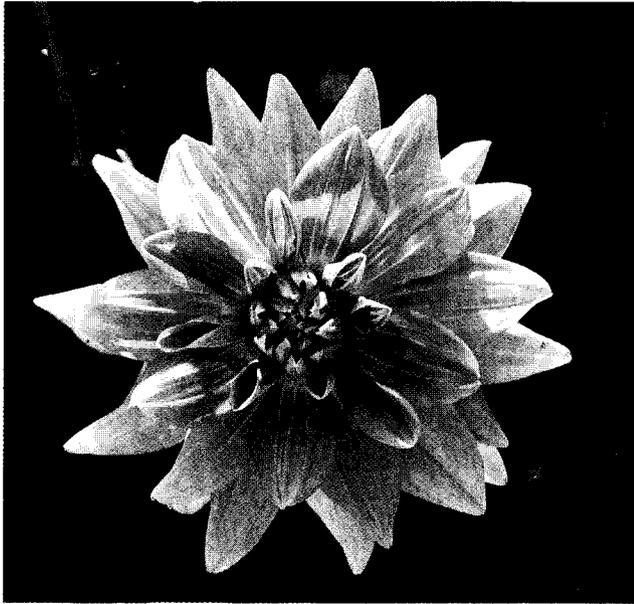
Inside the perianth are the reproductive structures of the flower. The stamens are the male reproductive structures. The number of stamens varies from zero to several hundred, depending on the species. A stamen consists of a thin filament

(threadlike structure) supporting a thick, knoblike anther. The anther contains the pollen sacs that produce pollen. Pollen produces male gametes. Inside the whorl of stamens are the female reproductive structures: the pistils, or carpels. The pistils have a stigma, a style, and an ovary. The stigma is the sticky part at the top of the pistil. The style is a thin tube that leads from the stigma to the ovary. The ovary is an enlarged area at the base of the pistil that produces ovules, which contain the eggs (female gametes). The number of pistils varies from zero to several dozen, depending on the species. Some flowers have pistils that are fused together. These are called compound pistils. Although the

**SPECTACULAR FLOWER**

Some of the most spectacular flowers grow on cacti (right). The flowers attract pollinating birds and insects.





**FLOWER SHAPES**

Flowers vary greatly in shape. The dahlia (above) is a member of the composite family, which also includes daisies and dandelions. The flowerhead has bright ray flowers with disk flowers at the center. The hosta (above right) has a stalked inflorescence bearing many trumpet-shaped flowers. The camellia (below right) is a tree or shrub that bears pink or white flowers with seven petals.

number of stamens and pistils may vary, each flower must have at least one stamen or pistil (see ANTHHER; OVARY; PISTIL; STAMEN; STIGMA).

**Variation of flowers** Flowering plants are either monocotyledons, such as the orchid, or dicotyledons, such as the geranium (see DICOTYLEDON; MONOCOTYLEDON). Monocotyledons, the smaller of the two groups, usually have flower parts in multiples of three. Dicotyledons usually have flower parts in multiples of four or five. Complete or perfect flowers, such as the rose, have all the flower parts. Incomplete or imperfect flowers, such as the pasque flower, are missing one or more of the whorls. Many flowers have either stamens or pistils, but not both. A flower with just stamens is male and is called staminate. A flower with just pistils is female and is called pistillate. A dioecious plant, such as the poplar, is either male or female, having either staminate or pistillate flowers, but not both. A monoecious plant, such as corn or oak, has both staminate and pistillate flowers on the same plant (see MONOECIOUS).

Flowers have a symmetry that is either radial or



bilateral. Radially symmetrical flowers; such as the rose, can be divided in several ways to produce equal sides. Bilaterally symmetrical flowers, such as the snapdragon, have only one way of being divided into two equal sides. Some flowers, such as the tulip, grow singly, but most are clustered in groups called inflorescences (see INFLORESCENCE). Bracts are the leaflike structures under an inflorescence. In composite flowers, such as the daisy and dandelion, each flowerhead is actually made up of many tiny flowers called florets (see COMPOSITE FAMILY). Each floret has its own stamens and pistils, and each one produces its own separate seed.

See also FERTILIZATION; PLANT KINGDOM; REPRODUCTION.

**FLUID** A fluid is a substance that is capable of flowing. Any liquid or gas can be a fluid. For example, water at ordinary temperature is a fluid and a liquid. Air is a fluid and a gas. A slight pressure or force changes the shape of a fluid. However, fluids are also elastic. They tend to return to their former shape when the pressure is removed (see **ELASTICITY**; **GAS**; **LIQUID**).

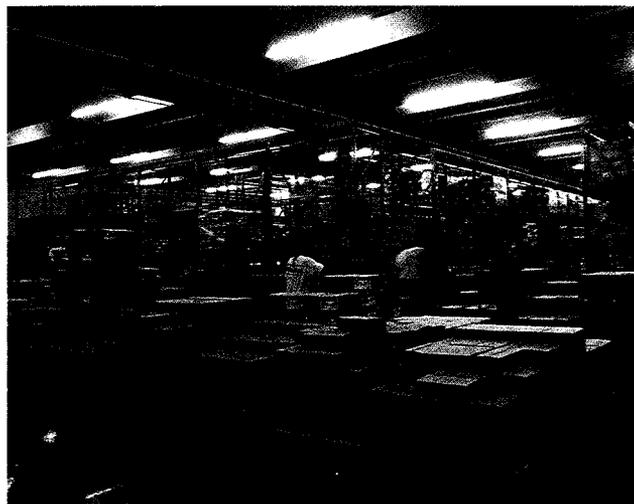
A liquid tends to always occupy the same volume (see **VOLUME**). A gas readily changes its volume by expanding or contracting to fill or fit into any container in which it is placed. A gas is a compressible fluid, while a liquid is said to be incompressible. That is, it cannot be forced into less space. However, in reality, no liquid is totally incompressible.

There are three types of fluids. A perfect fluid is without friction. In other words, a perfect fluid offers no resistance to flow except that of inertia. Inertia is the tendency of matter to remain at rest unless acted upon by an outside force (see **FRICTION**; **INERTIA**). An elastic fluid has greater forces resisting changes to size or shape than forces resisting flow. A viscous fluid, such as syrup, is thick and slow flowing. This is due to the fluid's internal friction.

See also **HYDRAULICS**; **VISCOSITY**.  **PROJECT 4, 40**

**FLUORESCENCE** (flŭō rĕs' əns) Fluorescence is a way 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 the electrons stop giving off light as soon as the radiation has been removed, it is called fluorescence. If the electrons continue to give off light long after the radiation has been removed, it is called phosphorescence (see **PHOSPHORESCENCE**).

Many natural substances are fluorescent.



#### **FLUORESCENCE**

Fluorescent lighting is common in stores and warehouses. It provides an even overall light and casts few shadows.

Minerals such as fluorite glow in brilliant colors when exposed to ultraviolet rays (see **ULTRAVIOLET RAY**). Fluorescence takes its name from fluorite.

Fluorescent substances have many uses. Electric current causes fluorescence in neon signs and certain light bulbs. Mercury vapor is a fluorescent substance used in highway lights. Fluorescent screens are used in television picture tubes and electron microscopes. Paints and inks used in some artwork—for example, in advertising—contain fluorescent substances.

Compact fluorescent light bulbs have been developed to replace the ordinary incandescent household light bulb. Fluorescence is more energy-efficient than incandescence. A 200-watt compact fluorescent bulb is the same size and gives the same light as a 100-watt incandescent while consuming only a fifth of the electricity, thus helping to protect the environment.

See also **ELECTRIC LIGHT**; **LUMINESCENCE**.

**FLUORIDE** (flŭōr' id') Fluorides are compounds of the element fluorine with one other element or group of elements. Most fluorides are salts. They are made by reacting hydrofluoric acid with a metal oxide or hydroxide (see **COMPOUND**; **HYDROXIDE**; **OXIDE**). Calcium fluoride occurs in nature as the mineral fluor spar. It is used in steel making. The mineral cryolite is sodium aluminum fluoride. It is used as a source of aluminum.

Hydrogen fluoride is used for etching glass and as a catalyst in the chemical industry. Fluorides are also added to the water supply of many communities as a way to fight caries (tooth decay).

About half the population of the United States drinks fluoridated water. Many scientists claim that fluoridation helps strengthen the enamel of the tooth, thus decreasing the number of cavities. Those people against fluoridation say that it is unnecessary and that the long-term effects of fluoridation have not yet been determined.

*See also* CARIES; CATALYST; FLUORINE.

**FLUORINE** (flŭŏr' ēn') Fluorine (F) is an element usually found as pale yellow gas. Fluorine is a member of the halogen group of elements (see HALOGEN). It was discovered by the French chemist Henri Moissan in 1886. It is an extremely poisonous gas and one of the most reactive of all the elements. Fluorine always occurs combined with another element. It is so reactive that it even forms compounds with the noble gases xenon, krypton, and radon (see COMPOUND; ELEMENT; NOBLE GAS). Its most common mineral is fluorspar, which is calcium fluoride.

Fluorine is a very difficult gas to handle because it is so reactive. It attacks both glass and metal. Therefore, fluorine has few uses. However, several of its compounds are widely used. One very useful group of fluorine compounds are the fluorides. Sodium fluoride in small amounts is used to fluoridate water to fight caries (tooth decay) (see FLUORIDE). Another group of compounds are the fluorocarbons. Fluorocarbons are compounds of fluorine and carbon. Freons are a group of fluorocarbons. They are very unreactive and are used as refrigerants (see CHLOROFLUOROCARBON). Plastics made from fluorocarbons are tough and resistant to corrosion and chemicals. They are also good insulators against heat and electricity. Fluorocarbon plastics are used for nonstick coatings in cooking utensils and to make artificial joints in surgery. Fluorine also became important during World War II (1939–1945), when it was used in producing pure uranium-235 for atomic bombs.

The atomic number of fluorine is 9. Its relative

atomic mass is 18.998. The boiling point of fluorine is  $-306^{\circ}\text{F}$  [ $-188^{\circ}\text{C}$ ]. Its freezing point is  $-364^{\circ}\text{F}$  [ $-220^{\circ}\text{C}$ ].

**FLUOROCARBONS** Fluorocarbons are chemical compounds in which some or all of the hydrogen atoms in a hydrocarbon are replaced with atoms of fluorine. Fluorocarbons are very unreactive chemically and very resistant to heat. They are used as refrigerants and to make coatings, such as Teflon, for nonstick frying pans. Fluorocarbons have been used widely as propellants in aerosol cans. However, it has been shown that fluorocarbons can destroy some of the ozone in the ozone layer high in the atmosphere (see OZONE LAYER). Therefore, the use of fluorocarbons as propellants is decreasing. The destruction of the ozone layer allows more ultraviolet (UV) radiation from the sun to penetrate the earth's atmosphere. Too much exposure to UV radiation can cause skin cancer.

*See also* CHLOROFLUOROCARBONS.

**FLUX** The word *flux* means "flow." It is used in several different branches of physics. Flux often means the rate at which something flows through a certain area. Flux is used in the study of light. Light is a form of energy. Therefore, a beam of light is a



**FLUX**

Nuclear physicists design and build complex instruments to measure the flux, or rate of flow, of subatomic particles that they use in their experiments.

flow of energy. The amount of light energy flowing through a certain area in one second is called the luminous flux. It is measured in lumens in the *Système Internationale* (SI) (see *LUMEN*). Nuclear physicists often use beams of subatomic particles (particles that make up atoms). The flux of a beam is the number of particles flowing through a certain area in one second.

Flux is also used in connection with electric and magnetic fields. Because fields do not flow, the flux in these cases involves measuring the electric or magnetic field itself. The SI unit of magnetic flux is the weber. The SI unit of electric flux is the coulomb (see *COULOMB*; *FIELD*; *WEBER*).

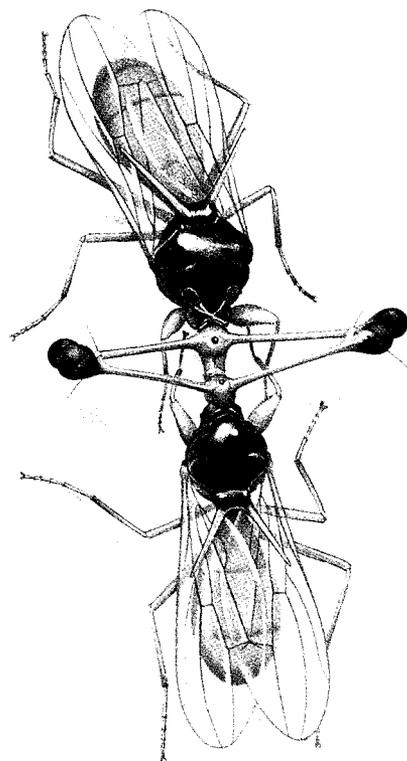
Flux has a different meaning in chemistry. Flux is any substance that lowers the melting point of a substance to which it is added. For example, in soldering, a flux is added to a solder to keep metal oxides from forming. If oxides did form, they would not melt at the temperature of the solder and would remain solid. This would prevent the solder from making a strong joint (see *OXIDE*; *SOLDERING AND BRAZING*). A flux can also be added to an ore before smelting. Besides lowering the melting point of the ore, it helps separate impurities from the metal being extracted.

See also *SMELTING*.

**FLY** A fly is any of about 90,000 species of two-winged insects belonging to the order *Diptera*. Although many small, flying insects are improperly called flies, only the true flies have two wings instead of four. The true flies include the crane fly, fruit fly, horsefly, housefly, mosquito, and tsetse fly. Many kinds of flies are considered pests because they bite, and some carry diseases such as malaria. Other flies, though, help with pollination, and others are predators or parasites of harmful insects. Some flies, such as the fruit flies, reproduce so quickly that they are important in genetic research (see *MALARIA*; *PARASITE*; *POLLINATION*).

Flies range in size from an almost microscopic midge, at 0.02 in. [0.5 mm] long, to the largest, a crane fly at 3 in. [75 mm] long. The body of the fly is covered with an exoskeleton and sensitive hairs (see *SKELETON*). The head has two large compound

eyes, each of which has up to four thousand lenses (see *EYE AND VISION*). The mouth parts form a long, hollow proboscis, which is used for sucking liquids. Liquids are the only food of flies. "Biting" flies use the proboscis to stab a victim, inject saliva to prevent the blood from clotting, and suck out the blood. The two antennae vary in size and



#### FLY

Various kinds of horseflies (top) are common in the southern United States and Central America. The females suck blood from animals such as cattle and horses. The male African stalked-eyed flies (above) measure each other's size using their eye-stalks. The larger wins any contest over territory.

structure, according to the species. They are used to detect motion and odors in the air (see ANTENNAE).

Flies include some of the fastest of the flying insects. The buzzing sound they make is due to the beating of their wings. The wings are attached to the thorax. The hind wings have been reduced to form two short, clublike structures called halteres. These structures are used for balance in flight. There are six jointed legs with claws or special sticky pads called pulvilli. The fly breathes through ten pairs of spiracles along its thorax and abdomen (see ABDOMEN; SPIRACLE; THORAX).

Most flies reproduce quickly and in large numbers. The female may lay 1 to 250 eggs at a time, depending on the species. These eggs develop into larvae, some of which are called maggots. After molting several times, the larva becomes a pupa. The pupa hatches into a fully grown adult.

*See also* INSECT; METAMORPHOSIS.

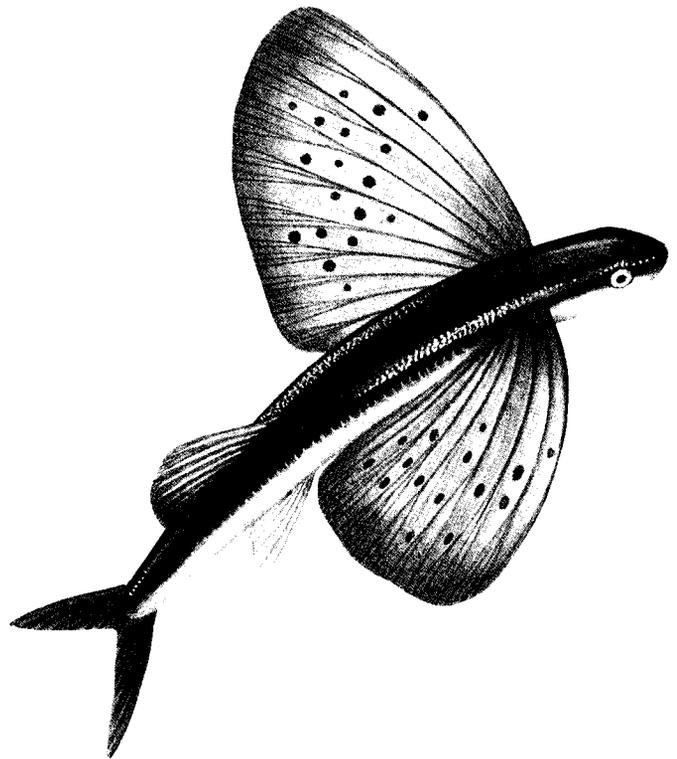
**FLY-BY-LIGHT AND FLY-BY-WIRE** The flying controls of early aircraft were connected to the control surfaces (ailerons, elevators, and rudder) by cables (see AERODYNAMICS; AIRPLANE). Pulling on the controls in the cockpit pulled one or more of the cables, and they in turn moved the control surface. As airplane speeds increased, the force needed to operate the controls became too great for a pilot to manage. Hydraulic systems were introduced to help pilots (see HYDRAULICS). Hydraulic rams, called actuators, move the control surfaces when the pilot operates the controls. Modern aircraft—such as the A320 Airbus—use a different control system, called fly-by-wire. When the pilot of a fly-by-wire airplane operates the controls, electrical signals are sent along wires to a set of computers. The computers then send electrical signals to hydraulic actuators attached to the control surfaces. Several computers are used, so that if one computer develops a fault, the others detect the fault and correct the computer's commands. The computers do more than just pass information on. They are programmed to fly the plane safely. If they detect a dangerous situation, they can take over control of the aircraft and fly it to safety before giving control back to the pilot. The high speed of

computerized information processing also enables the plane to respond more quickly to turbulent air conditions. This gives the passengers a more comfortable flight.

Fly-by-light is the next step up from fly-by-wire in aircraft control systems. In the fly-by-light system, information is sent from the cockpit controls to control surfaces as pulses of light along fiber-optic cables instead of as electrical signals along wires. Fly-by-light allows more information to be sent faster than does fly-by-wire. Light signals are unaffected by electrical interference, so fly-by-light is more reliable than fly-by-wire. In addition, fly-by-light uses a cable that is much lighter than the wire used in fly-by-wire.

*See also* FIBER OPTICS; FLIGHT.

**FLYING FISH** A flying fish is a saltwater fish that has large fins on its sides that act in a way similar to wings. There are several species, some with two large fins and some with four. Flying fish swim in schools. Often, they are chased by predator fish. To escape, the flying fish swim very fast, break through the water's surface, stretch out their large



**FLYING FISH**

A flying fish glides at high speed over the surface of the ocean, using its large pectoral fins as "wings."

fins, and glide over the water. This is why they are called flying fish. By the time they reenter the water, the predators often have become confused and have left. Flying fish feed on plankton. They are found in the warmer parts of both the Atlantic and Pacific oceans.

*See also* FISH; PLANKTON.

**FLYWHEEL** A flywheel is a device in some kinds of engines that converts bursts of energy into a continuous supply of energy. An engine is a device that is used to release chemical energy stored in a fuel. The engine burns the fuel and changes it into kinetic (movement) energy. In some engines, the energy conversion is continuous. Steam turbines and jet engines are examples of engines that work like this. Other engines do not convert energy continuously. The energy is supplied in bursts. An example of this type of engine is the gasoline engine. In a gasoline engine, a mixture of air and gasoline is exploded inside a cylinder. The explosion pushes the piston along the cylinder in bursts. This kind of engine contains a flywheel. A flywheel is a heavy wheel and therefore has a large amount of inertia (see INERTIA). The bursts of energy make the flywheel rotate. Its inertia keeps it rotating in between the bursts. In this way, it converts the intermittent bursts of energy into a smooth, continuous movement.

*See also* ENGINE.

**FOCUS** Focus is the point where light rays meet, or converge, after passing through a convex lens or the curved cornea and lens of the eye (see CONVEX; EYE AND VISION; LENS).

Heat and sound waves can be brought to a focus in similar ways to light rays. A cathode-ray tube brings a beam of electrons to a focus on a phosphorescent screen.

*See also* CATHODE-RAY TUBE.

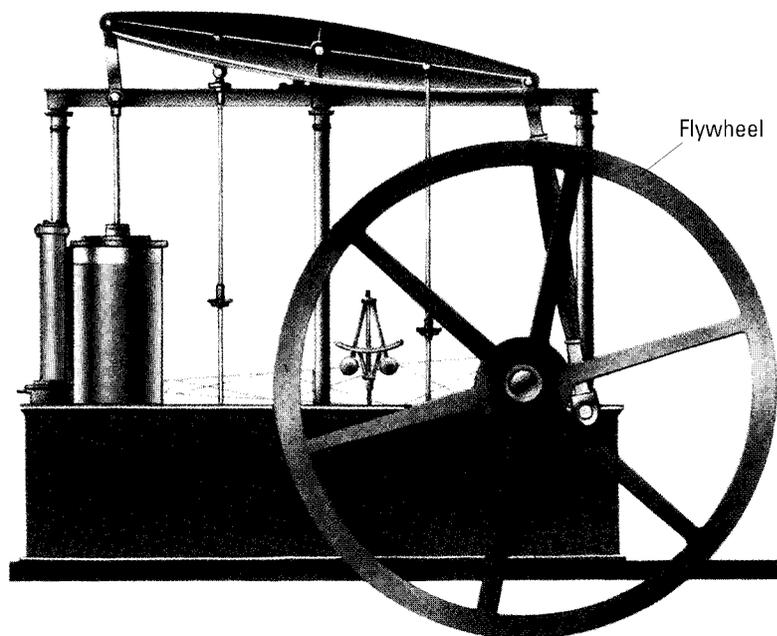


**FOG** Fog is a cloudlike mass of water droplets that forms near the ground or on the surface of a body of water. There are several different ways that fog forms.

Radiation fog occurs on clear, cool nights if the temperature falls to the dew point. When this happens, water vapor in the air condenses and forms fog. Water vapor that condenses on objects is called dew (see CONDENSATION; DEW; DEW POINT). Radiation fog is common in valleys.

When warm, moist air blows over colder air, advection fog forms. Advection fog may also form when warm air settles over a cold body of water or over a snow-covered area. Advection fog is very common in the British Isles.

Frontal fog occurs at a weather front where two air masses of different temperatures meet. Steam fog occurs when cold air absorbs moisture over a warmer body of water. Steam fog usually only occurs in cold northern climates (see AIR MASS; FRONT).



#### FLYWHEEL

James Watt's early steam engine of 1769 had a single cylinder and a large, heavy flywheel to smooth out the motion.



**FOG**

Radiation fog is common in Palm Springs Valley, California. On cool nights, water vapor condenses out of the air as the temperature falls.

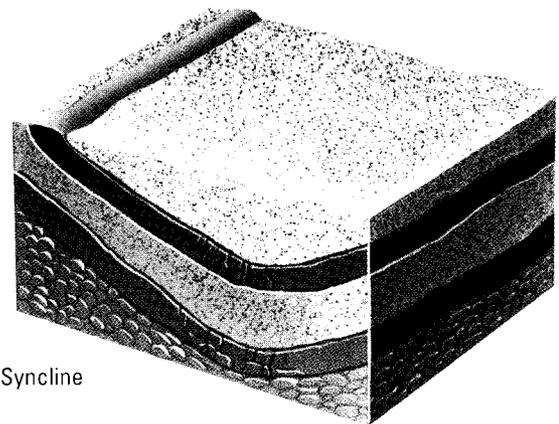
The international definition of fog is a visibility of less than 1,100 yd. [1 km]. Many auto accidents occur each year because drivers have trouble seeing through dense fog. Airline travel is often delayed because of fog. However, fog is a less serious hazard to aircraft and ships since the invention of radar. See also ACID RAIN; MIST; PRECIPITATION.

**FOLDING** Folding is a process that produces folds, or bends, in rock. Folding is caused by great compressional (sideways) forces acting on layers of rock in the earth's crust.

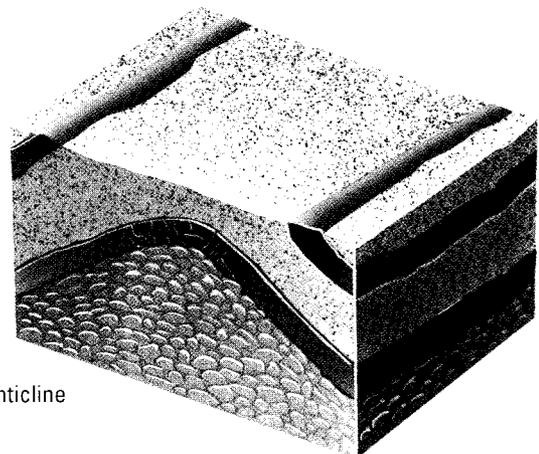
Folding is responsible for some of the earth's greatest mountain ranges. There is evidence that the Himalaya mountains in Asia are the result of folding. Scientists believe that India, at one time, was separated from the Asian mainland. Because of continental drift, India eventually collided with the Asian mainland (see CONTINENTAL DRIFT). This collision caused a folding up of the sedimentary rock that had accumulated on the seabed, producing the Himalaya mountains. This theory is supported by the discovery of fossils of sea animals on the upper slopes of Mount Everest, the tallest mountain in the world, which is part of the Himalayas (see MOUNTAIN).

Gentle folding creates a series of symmetrical arches, or upfolds, called anticlines, and downfolds called synclines.

See also ANTICLINE; SYMMETRY; SYNCLINE.



Syncline



Anticline

**FOLDING**

Bends in layers of rock (strata) are caused by folding. Downward folds are called synclines and upward folds are called anticlines.

Food is any substance that provides an organism with nourishment. Food provides chemical substances, such as vitamins, proteins, carbohydrates, fats, and minerals, which are needed for the building of new cells and tissue, for energy, and for regulating the organism's body processes.

Organisms obtain food in a variety of ways. Saprophytes obtain food from the dead, rotting remains of other organisms. Parasites obtain food from other living organisms (see PARASITE; SAPROPHYTE). Plants containing the green pigment chlorophyll manufacture their own food through a series of complex chemical reactions, called photosynthesis (see PHOTOSYNTHESIS). Photosynthesis is of particular importance because almost all animals depend on photosynthetic plants for food.

Some animals, called herbivores, eat only plants. Other animals, called carnivores, eat only meat. The meat usually comes from herbivores. An omnivore eats both plants and meat. Most human beings are omnivores. If plants were to die out, herbivores would lose their source of food and also die out. Once herbivores died out, the carnivores would soon die from starvation (see FOOD CHAIN).

**How people produce food** People produce food in many different ways. Agriculture, or farming,

developed thousands of years ago. Until about a hundred years ago, most farmers in the United States produced only enough food for their own needs. Today, modern equipment and farming methods have greatly increased the American farmer's productivity (see AGRICULTURE).

People raise many animals that provide meat and dairy products. Cattle, horses, goats, sheep, and pigs are important food animals in various parts of the world. In the United States, the cow is the major source of dairy products. Chickens provide people with both meat and eggs.

Fishing is an important source of food, especially in areas near the sea. Some countries, such as Japan, consume much more fish than red meat.

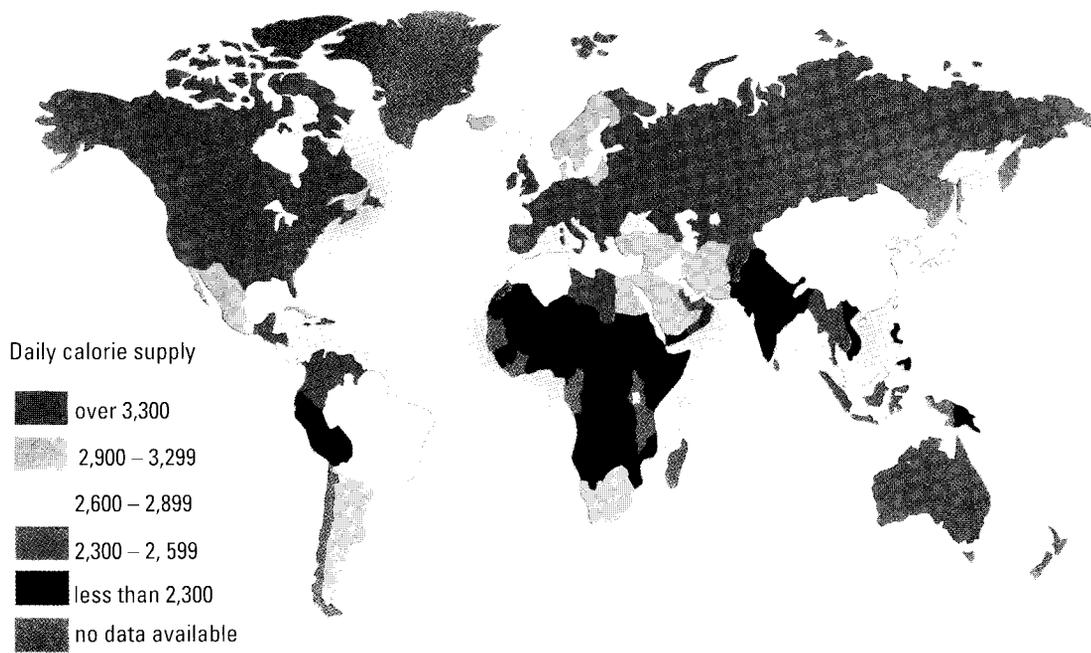
The wealthy, industrialized areas of the world consume the most food. These areas include the United States, Canada, and Europe. Many countries are able to import food if it cannot be produced at home. For example, Britain imports about 75 percent of its meat and grows less than half the other food its people require.

The people of the poorer countries of the world

#### OPEN-AIR MARKET

In many rural societies, farmers take their food crops directly to market. This large variety of fruits and vegetables is on sale at a market in Kenya, Africa.





**DAILY CALORIE SUPPLY**

This map shows how the average daily calorie supply available per person varies widely across the world. In highly developed countries, it is more than 3,300 calories per person. In the poorer nations of Africa and Asia, it is less than 2,300 calories per person.

usually eat only what they are able to produce themselves. In some parts of Asia, the people live almost entirely on rice.

**How the body uses food** The human body must break down food into simpler substances before the food can be used by cells of the body. The body does this through a process called digestion (see DIGESTION). The products of digestion travel through the body in the bloodstream. Some of the food provides energy. Some is used to repair or replace cells, and some is stored as fat.

Each person requires a certain amount of food each day, according to size, weight, age, and amount of activity. A person who eats too little loses weight, becomes weak, and may develop poor teeth and vision. A person who overeats becomes overweight and is more likely to develop diseases such as heart disease and diabetes (see DIABETES; HEART DISEASE).

The body uses the different substances found in food, called nutrients, in different ways. Carbohydrates are the main source of energy for

the body (see CARBOHYDRATE). They are found in fruits, vegetables, cereal, bread, and pasta. Fats are a more concentrated form of energy but are more difficult for the body to use (see FAT). They are plentiful in meat, eggs, dairy products, nuts, and seeds. Proteins are tissue-building foods, and are abundant in meat, eggs, and milk, as well as in vegetables, grains, dried peas and beans, and nuts (see PROTEIN). In addition to carbohydrates, fats, and proteins, the body requires many vitamins and minerals for proper functioning. The foods eaten in a normal, healthy diet will provide these additional nutrients.

See also DIET; METABOLISM; MINERAL; NUTRITION; VITAMIN.

**PROJECT 65**

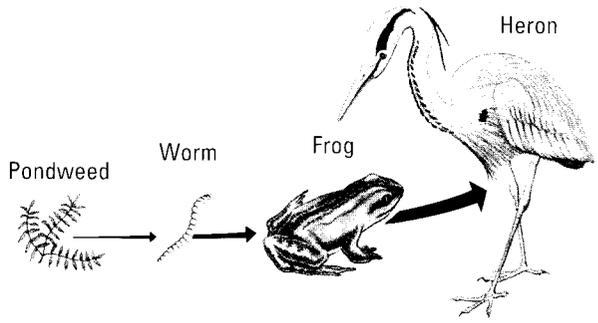


**MODERN SUPERMARKET**

A supermarket sells a wide range of fresh and processed foods. As a result, all the food a family needs can be bought in a single store.

**FOOD CHAIN** A chain is one long object made up of many smaller objects called links. Each link is attached to the next one. The term *food chain* refers to a situation found in nature. One animal eats a plant or another animal. That animal is then eaten by another animal. Each animal is a link in a "chain" of animals. A common food chain is grass-cow-human. A food chain in the ocean is plankton-snail-small fish-larger fish-shark.

All food chains begin with plants or other organisms (such as algae) that can make their own food (see PHOTOSYNTHESIS). Animals must eat other living things to get food.



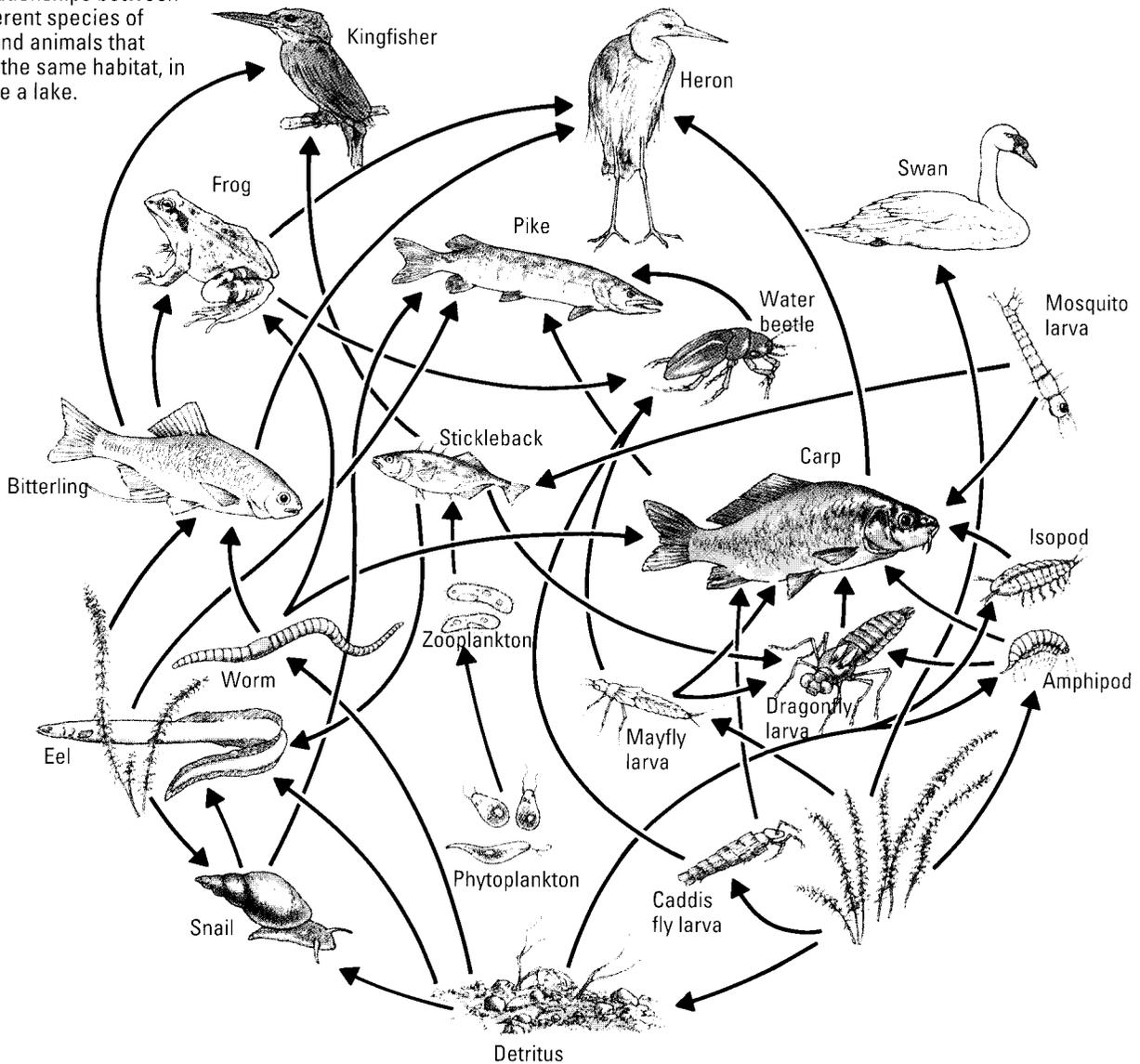
**FOOD CHAIN—Simple links**

A simple food chain (above) has only three or four levels. It starts with a producer (such as a plant), which feeds a primary consumer (such as a worm), which, in turn, is eaten by a secondary consumer (such as a frog). The final place in the food chain may be occupied by a predator (such as a heron, which eats the frog).

**FOOD CHAIN—**

**A food web**

A food web diagram shows the very complex interrelationships between the different species of plants and animals that occupy the same habitat, in this case a lake.



Although most animals, including humans, are able to eat many different foods, some animals can survive on only one kind of food. The Australian koala, for example, eats nothing but eucalyptus leaves. If all the eucalyptus trees were eliminated, the koalas would die out as well—and so would many of the insects that feed on the eucalyptus. The animals that feed on the insects would have to look for something else to eat in order to survive, and this could cause many environmental problems.

There are many food chains in an ecosystem (see ECOSYSTEM). Because most animals can eat more than one kind of food, or are preyed on by more than one kind of predator, many of the chains are connected. They form what is called a food web. For example, the grass in a meadow can be eaten by cottontails, voles, and grasshoppers. These three grass-eating animals can all be eaten by coyotes—and by owls and hawks. Cottontails and voles are also eaten by snakes, and grasshoppers may be eaten by songbirds. Songbirds may in turn be eaten by coyotes, owls, hawks, and snakes. But the birds do not feed entirely on grasshoppers. They eat caterpillars and perhaps the seeds of the grass in the meadow. The food web is already getting quite complex, with many cross-connections between individual food chains, and only a few animals have been considered. In a mature ecosystem, where there may be hundreds of different plant and animal species, the web is very complex. But a complex web means that the ecosystem is more stable. The loss of one animal species would not necessarily cause a break in the food chain because predators would be able to eat something else. Loss of plant species might cause more of an upset because many insects and other animals, such as the koala, do rely on just one plant species for survival. Loss of several plant species, as when tropical forests are cleared, can lead to environmental disasters.

See also ECOLOGY; ENVIRONMENT.

**FOOD POISONING** Food poisoning occurs when people or animals consume food contaminated with harmful bacteria, bacterial toxins

(poisons), or harmful chemicals. Food can become contaminated in many ways, such as from bacteria in the air or water or from flies or other insects. Food that is not properly cleaned, cooked, or refrigerated before eating may also become contaminated. Chemicals that may cause food poisoning include copper, lead, zinc, and the chemicals in certain herbicides and pesticides.

Symptoms of food poisoning may include vomiting, cramps, and diarrhea. In some types of food poisoning, a person's muscles may be paralyzed.

Food spoiled by bacteria usually has an unpleasant taste and smell. People generally avoid such foods. However, bacteria in food can sometimes produce dangerous—even deadly—substances without causing much change in flavor. These substances are the toxins that cause food poisoning. Often, bacteria called *Salmonella* cause food poisoning. *Staphylococcus* is the bacteria that probably causes the most common type of food poisoning. It is mild in comparison to others, and recovery is usually rapid.

Botulism is a far more serious type of bacterial food poisoning. Botulism is caused by the toxins produced by the bacterium *Clostridium botulinum*. In some cases, botulism may cause respiratory failure and death, but can be treated by administering an antitoxin.

Besides bacteria, other microorganisms can cause food poisoning. They are often found in animals rather than humans. However, if a person eats the flesh of a poisoned animal, food poisoning could occur. Turkeys have died in great numbers after eating food contaminated by a fungus called *Aspergillus*. Some species of this fungus produce aflatoxins. These are poisons and also carcinogens (substances that can cause cancer).

People can unintentionally poison their own food and that of animals by careless use of herbicides and pesticides. Some of these chemicals are very poisonous. If food, such as grain and fruit, is heavily treated with such chemicals, poisoning may follow, even if the food is washed before it is eaten.

See also BACTERIA; BOTULISM; FOOD PROCESSING; HERBICIDE; PESTICIDE.

# FOOD PROCESSING

Food processing is the science and industry of preparing, preserving, and packaging foods for distribution and marketing. Food processing includes any procedures that happen to foods after harvest or slaughter, such as the milling of flour, the chopping of meat, the adding of colors or flavors, and the various means of preserving food for storage and transport.

Food preservation is the science of treating food so that it will keep, over a period of time, its color, flavor, nutrients, and texture. Food preservation also involves treating food so that it will not spoil due to chemical changes or be contaminated by disease-causing microorganisms, called pathogens. Microorganisms, such as bacteria, molds, and yeasts, are the most common causes of food spoilage (see BACTERIA; MICROORGANISM; MOLD; YEAST).

These microorganisms grow in all kinds of food. Some bacteria form acids, which turn food sour. Molds change the flavor of some moist foods, such as bread. Yeast may ferment food, or make it alcoholic (see FERMENTATION). Some bacteria produce hydrogen sulfide. Hydrogen sulfide is a gas that may, in combination with iron in food, turn food black and give it the odor of rotten eggs.

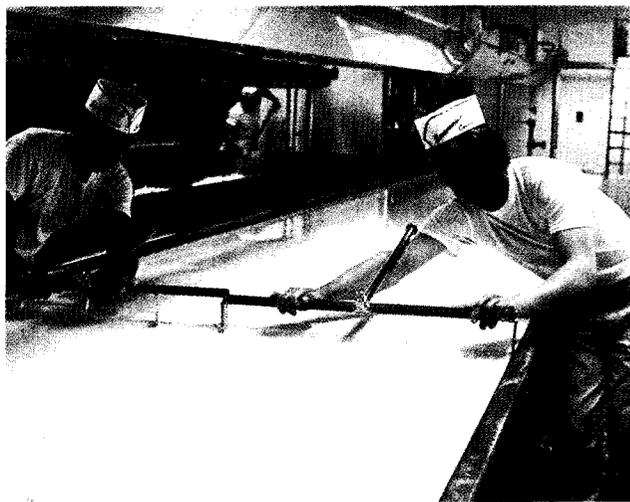
**Food additives** Processed foods often contain chemicals that help preserve food. These chemicals, which include benzoic acid, potassium and sodium nitrate, and sulfur dioxide, are called preservatives. Under certain conditions, sodium nitrate can combine with other chemicals to form compounds that cause cancer. Thus, the U.S. Department of Agriculture limits the amount of sodium nitrate that can be used.

Other chemicals that are added to processed foods include flavor enhancers, such as monosodium glutamate (MSG); natural or artificial flavorings; and natural or artificial colorings. One group of artificial flavorings is artificial sweeteners, which are substituted for sugar. Saccharin and cyclamates were popular sugar substitutes in the 1960s, but they were banned because they were

thought to cause cancer (see CANCER; CARCINOGEN). Many processed foods now contain aspartame as a sweetener. Aspartame is many times sweeter than sugar, so a lesser amount is used. This results in fewer calories than if sugar were used as a sweetener (see ASPARTAME). Vitamins and minerals also may be added to processed foods. Milk, cereals, flour, and fruit juices often have artificially produced vitamins or minerals added to them. Since 1973, the U.S. Food and Drug Administration requires a label on all processed foods that shows all ingredients, including any additives. Food companies now must also list information on the amount of carbohydrates, fat, minerals, protein, and vitamins contained in each serving of the food. In recent years there has been a trend towards foods with fewer additives, because of worries about the side effects and long-term effects of some of the 2,500 food additives in use today.

**Using heat to preserve food** Some bacteria—such as those in yogurt, cheese, and buttermilk—are healthful and may even help preserve food. However, most bacteria can cause food to spoil unless they are killed. One way to kill the bacteria is through heat.

The process of heating milk to about 145°F [63°C] to destroy harmful bacteria is called pasteurization.



## MAKING CHEESE

Making cheese out of fresh cow's milk is a type of food processing that preserves the excellent food value of milk.



#### INSPECTING

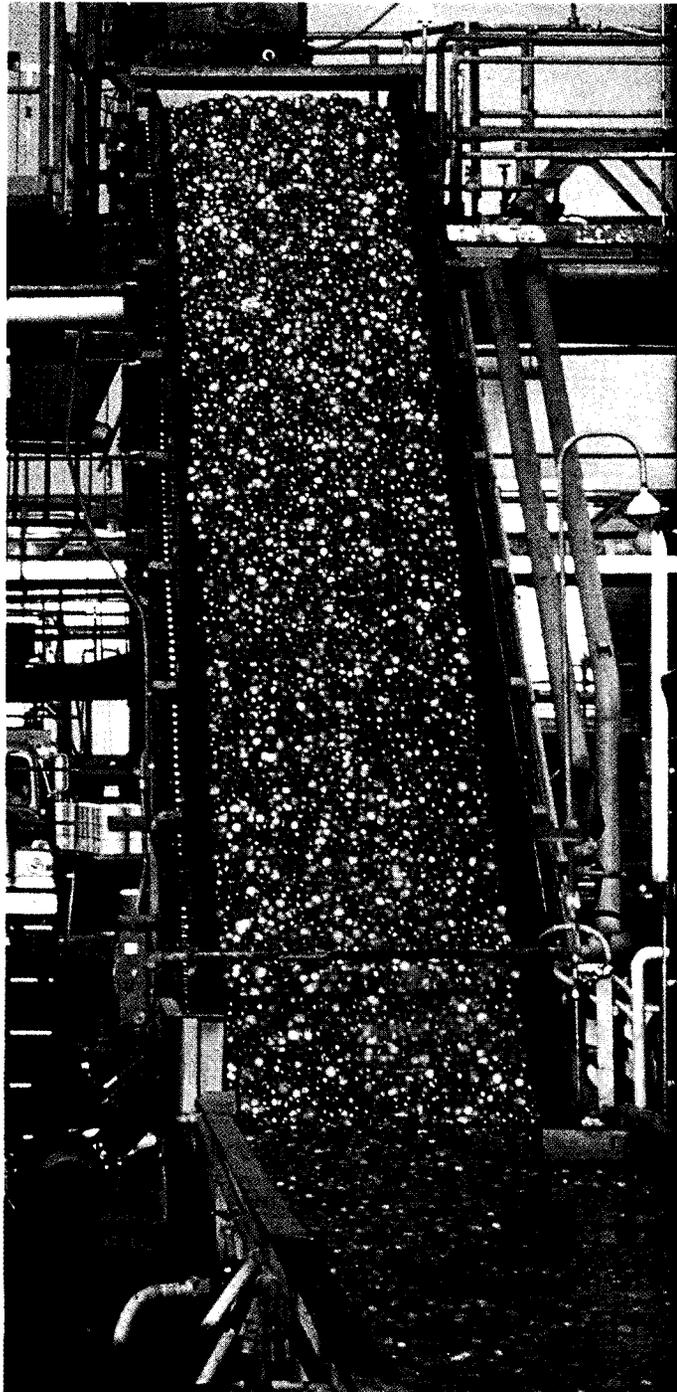
A worker at a food factory checks tortellini pasta after it has been cooked and before it is packaged.

Beer and wine can be pasteurized too. The process is named after Louis Pasteur, who developed it in the 1850s (see PASTEUR, LOUIS; PASTEURIZATION). After milk is pasteurized, it is usually homogenized. Homogenization is a process that breaks up the fat molecules that all milk contains, so they do not rise to the top and form a layer of cream. Homogenization gives the milk a richer taste. Sometimes, milk is preserved using a method called ultrahigh-temperature treatment (UHT). The milk is heated to 300°F [149°C] by steam, which kills all the bacteria in the milk. Then, it is cooled and packaged. Packaged UHT milk does not need refrigeration. It can sit on a shelf for months without spoiling. UHT-treated milk is more popular in Europe than in the United States.

Canning, the most common method of food preservation, also uses heat. Canning involves sterilizing food, or making it free of pathogens (see CANNING). Canning also involves keeping air away from food. Heating food to high temperatures destroys pathogens and stops enzyme activity. Temperatures of 212°F to 250°F [100°C to 121°C] are needed to kill pathogens. Fish, other meat, and most vegetables are heated to about 248°F

[120°C]. The sterilizing time depends on the temperature, the container, and the type of food. Unfortunately, besides destroying pathogens, the high temperatures used in canning also destroy many of the vitamins these foods contain when they are fresh.

After heating, the food is packed into airtight metal or glass containers. To achieve this, air is removed from the containers, and the containers are then sealed with airtight lids. This keeps air



away from food and also keeps out microorganisms. Most canned foods keep for more than a year.

**Using cold to preserve food** Cold storage keeps food fresh at low temperatures. Cold storage temperatures, ranging from 30°F to 50°F [-1°C to 10°C], do not stop spoilage. However, they do slow pathogen growth and enzyme action. The cold-storage life of foods depends on the type of food, the storage temperature, and the amount of moisture in

the air of the storage room. Keeping the air in motion around cold-storage food helps maintain a constant temperature. It also removes gases that some foods give off. Some of these gases reduce the storage life of fruit. In meat processing, cold storage is used to stop spoilage and to tenderize meat.

**CANNING**

Canning is used to preserve meat, fruit, and vegetables. Here tomatoes are being washed at a cannery in Modesto, California.



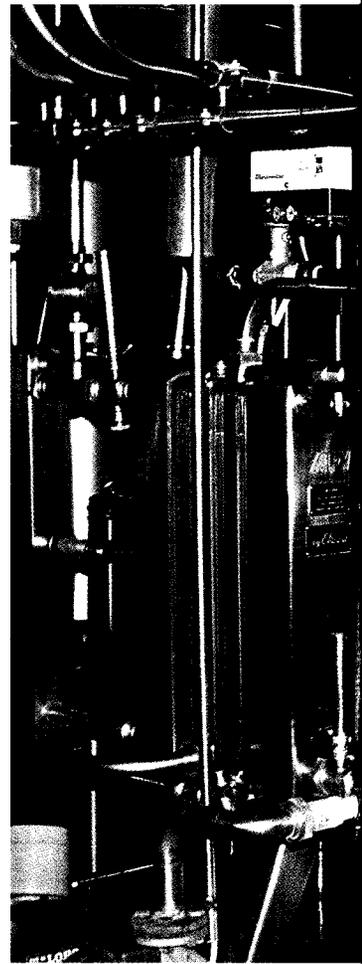


**COOKING**

Filled, unbaked quiches (unsweetened pies) are loaded onto a conveyor that takes them to an oven. After cooking, they are cooled and placed in chilled storage.

The slowing of enzyme action helps break down the tougher tissues of the meat.

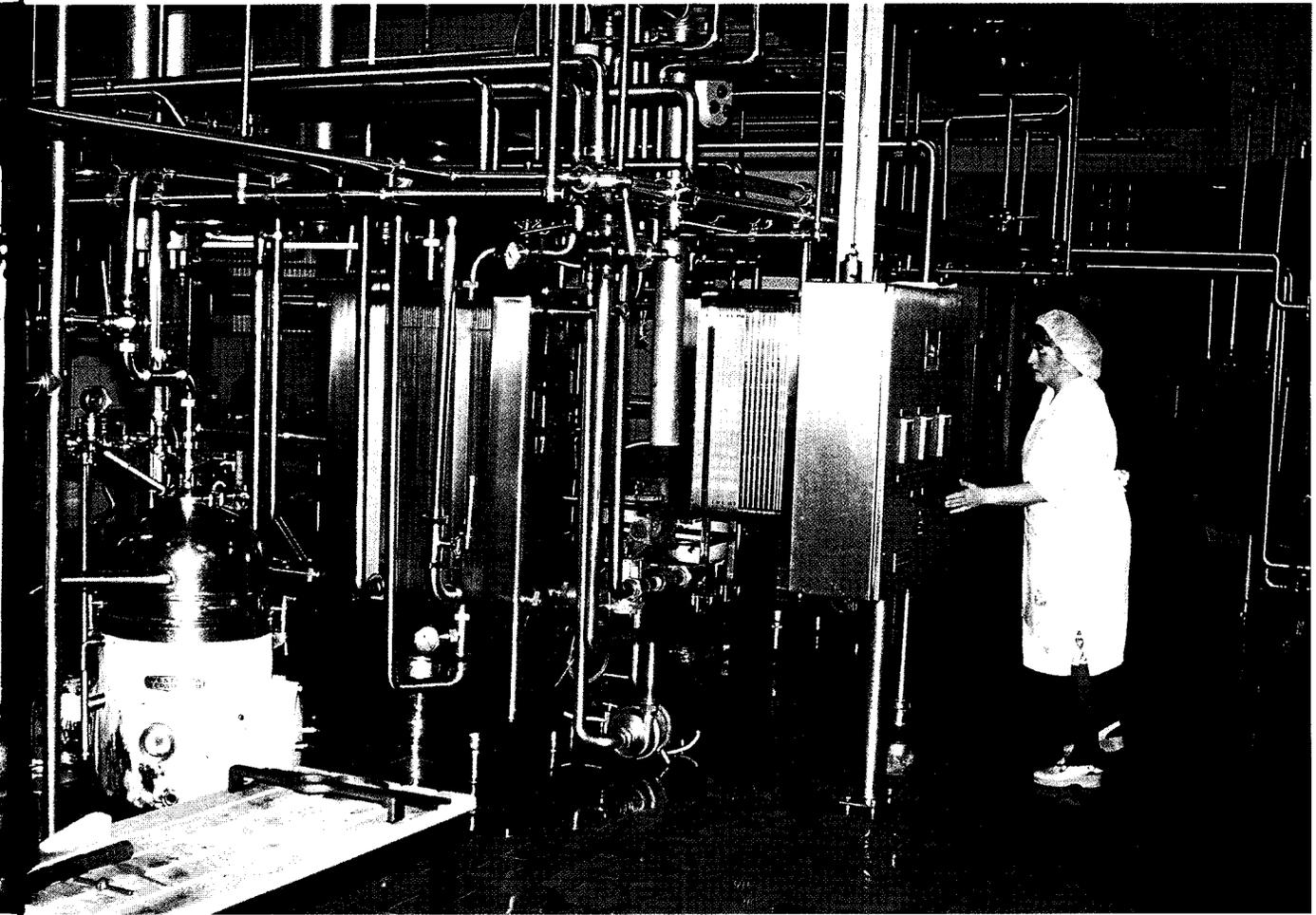
Freezing is second to canning as one of the most widely used methods of food preservation. Freezing is an effective way of preserving foods, because pathogens cannot grow at low temperatures and enzyme action is slowed down a great deal. Between 1916 and 1929, the American inventor Clarence Birdseye developed a quick-freezing



**PASTEURIZING MILK**

Milk is pasteurized to kill any harmful bacteria by carefully heating it to a temperature of 145°F [63°C]. The milk is kept at that temperature for several minutes while it is pumped along pipes.

process. This process cools food quickly to -31°F [-35°C]. During slow-freezing, the water inside the cells of food has time to freeze and grow into large ice crystals. These break up the cells, releasing enzymes. In quick-freezing, the water forms smaller ice crystals, which have little effect on the cell structure. On thawing a slow-frozen product, water drains from the broken cells, carrying the nutrients with it. The food then spoils very quickly because of the release of enzymes. A quick-frozen food, however, has its cells intact and does not lose nutrients or flavor. Commercial food processing companies freeze most kinds of fruits and vegetables and



some kinds of fish, poultry, other meat, and dairy products. Food companies also freeze a variety of precooked foods ranging from french-fried potatoes to complete dinners.

### Using dehydration to preserve food

Drying, also called dehydration, removes most of the moisture from food. Pathogens cannot grow on dry food. Enzyme action cannot take place in the absence of moisture. Drying also reduces the size and weight of foods. This makes foods easier to transport and store. Food processors often use various methods before drying to prevent changes caused by enzymes. For example, they may blanch vegetables and fruits. In blanching, the foods are briefly exposed to steam or boiling water. Sun-drying is the oldest method of drying food. Processors spread the food on trays and expose it to the air. Kiln-drying uses heat from a furnace or stove to evaporate moisture from food. Dehydrators use a vacuum to make water evaporate

at a low temperature. Dehydrators take less time than the other means of drying. In spray-drying, liquid food is sprayed through nozzles into specially designed drying chambers. Food particles collect at the bottoms of the chambers as powder.

Freeze-drying removes water from food while the food is still frozen. The frozen food is cooled to about  $-30^{\circ}\text{F}$  [ $-34^{\circ}\text{C}$ ]. It is then placed on a tray in a vacuum chamber or room (see VACUUM). Heat is then applied. In this method, the frozen water in the food is evaporated without melting.

### Other methods of preserving food

Curing is a method of preserving foods that has been used for many years. Curing consists of salting, smoking, cooking, and drying, or some combination of these treatments. In some kinds of curing, other chemicals besides salt are used. The most widely used ones are sugar, vinegar, and wood smoke. Salt is used in large amounts to control the growth of pathogens. Because salt has a strong taste, processors use large



**FROZEN FOODS**

A wide range of frozen foods is displayed in supermarket freezers. Frozen foods can be stored in home or commercial freezers for many weeks.

amounts only in foods to which salt adds flavor, such as beef and pork. Sugar in large amounts helps preserve foods such as jams, jellies, and frozen fruits. Vinegar is used to pickle many foods, such as cucumbers, onions, herring, and sardines. Vinegar gives such foods a sour taste, but one that many people like. The acetic acid in vinegar slows pathogen growth. Wood smoke contains chemicals

that also slow the growth of pathogens. In addition, smoking changes the odor and flavor of food. Smoking preserves fish and other meat well, if combined with salting and drying.

Ultraviolet rays can destroy pathogens, but they are not commonly used in preserving food. Ultraviolet rays are used to kill spores in the air in bakeries, control mold in packaged cheese, and reduce bacterial damage in meat (see IRRADIATION; SPORE; ULTRAVIOLET RAY). Molds and bacteria can also be killed using high doses of X rays or gamma rays. This process is called irradiation (see X RAYS). An advantage of X-ray irradiation is that it can be performed after the foods are packaged. When many people think of radiation, they also think of nuclear bombs and the harmful effects of radiation. Because of this, irradiated food has not yet become widely accepted. Another experimental method uses ultrasound to preserve food by killing bacteria (see ULTRASOUND).

*See also* FOOD; FOOD POISONING.

**COLD STORAGE**

Sides of beef are kept in cold storage until they are transported in refrigerated trucks to supermarkets and butcher stores.



**FOOTCANDLE** A footcandle is a unit of illumination. *Illumination* refers to the amount of light falling on an area of surface. One footcandle is equal to the illumination produced by a source with an intensity of one candle at a distance of one foot.

An illumination of ten to twenty footcandles may be enough for ordinary bookreading purposes. As many as fifty footcandles may be required by a draftsman. The sunlight at noon gives an illumination of five thousand to ten thousand footcandles.

**FORCE** In physics, a force is something that causes a change in the movement or shape of an object. A change in movement may be from standing still to moving. It may be from moving at one speed to moving faster (acceleration), or it may be from moving in one direction to moving in another. The study of forces and how they affect objects is called mechanics.

Forces need not produce an apparent change. A book lying on a table is being pulled by the force of gravity, which keeps it lying on the table. It does not fall because the table exerts a counterforce against it (see DYNAMICS; GRAVITY).

Forces can change the shape of an object. When a rubber ball hits the ground, it becomes squashed



**FORCE**

When two running football players collide, the one exerting the most force pushes the other one backward.

for a moment. Elastic forces in the ball then cause it to return to its original shape (see ELASTICITY).

A force always has a particular strength and always acts in a particular direction. The strength of a force is usually measured in units called newtons (see NEWTON). The amount of acceleration produced by a force depends on the mass of the body. The larger the mass, the less the acceleration (see MASS). The strength of a force can be calculated by letting it accelerate an object. The acceleration of the object and its mass can both be measured. From these quantities, the strength of the force can be calculated.

Scientists now recognize four fundamental forces that act upon all matter. This includes pieces of matter that can be seen, as well as tiny, subatomic particles invisible to the human eye. Two of these forces, gravity and electromagnetism, produce effects with which people are familiar (see ELECTROMAGNETISM). However, the other two forces act upon something that cannot be seen—the nucleus of an atom. The force that holds the nucleus together is called the strong nuclear force. The weak nuclear force is another form of the electromagnetic force.

*See also* NUCLEUS; RADIOACTIVITY.

**FORD, HENRY** (1863–1947) Henry Ford was an American manufacturer and inventor who developed the first mass-produced automobile. Ford began producing his Model T auto in 1908. His production methods involved moving assembly lines. Moving assembly lines were completely new to the industry at that time. These assembly lines allowed Ford to offer more cars to the American public at a lower price than anyone before him. Between 1908 and 1927, Ford's company, the Ford Motor Company, built and sold over fifteen million Model Ts. That was more than half of all the cars sold in the United States during that period.

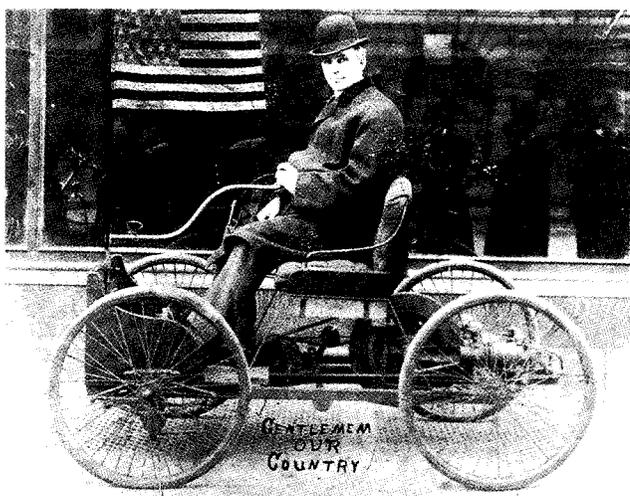
In Ford's moving assembly line, the main parts of a car were put together as the car moved along on a slow-moving conveyor system (see CONVEYOR). The workers stayed in one place and performed their special jobs as the cars passed their station. It

took about ninety-three minutes to put a car together with this system. Ford's methods revolutionized American industry. Today, many products are built on assembly lines.

In the early 1900s, only wealthy persons could afford to own an automobile. Ford, however, believed that everyone should be able to own a car. He made only a small profit on each Model T that was sold. However, he sold so many that the company was able to grow and prosper.

Ford also shocked his fellow manufacturers with another theory. He believed that it was important for manufacturers to pay their employees high wages. The average skilled worker at that time was receiving \$2.50 a day. Ford raised the salaries of his skilled workers to \$5 a day. He also shortened their workday from nine hours to eight hours. Later, he raised the minimum for skilled workers to \$6. Ford felt that the higher wages would allow his workers to purchase the cars they were building. That is exactly what happened. Ford sales went up dramatically as the thousands of Ford Motor Company workers began to purchase cars.

In 1932, Ford introduced a powerful V-8 (eight-cylinder) engine. Up to that time, most automobiles contained six-cylinder engines. The V-8 engine was soon adopted by other manufacturers. Today, the more fuel-efficient four-cylinder engines are widely used in autos (see ENGINE).



#### HENRY FORD

Henry Ford built his first automobile, shown here, in 1896. Within a few years, he was producing inexpensive cars for the mass market.

Ford made millions of dollars and looked for ways of helping others. He contributed heavily to many charitable causes. A large part of Ford's fortune went toward creating the Ford Foundation. The Ford Foundation is the world's largest foundation. A foundation is an organization that works to improve human welfare. The Ford Foundation gives money for scholarships and aids economic growth in underdeveloped countries. The foundation also provides money for special studies on mental health, education, and other important matters. Ford also established Greenfield Village, a group of historical landmarks and buildings in his hometown, Dearborn, Michigan. The Ford Museum is next to Greenfield Village and covers about 200 acres [81 hectares].

**FORENSIC SCIENCE** Forensic science is the application of science and technology to civil and criminal law. It is not a branch of science, but a particular way of using many branches of science, including ballistics, biology, chemistry, medicine, and photography. Forensic scientists work with the police and other investigative agencies to help establish how and when a crime was committed. Forensic scientists analyze evidence found at the scene of the crime. Often, their scientific work leads to the capture of the criminal (see BALLISTICS; BIOLOGY; CHEMISTRY; MEDICINE; PHOTOGRAPHY).

Forensic medicine is one of the best-known aspects of forensic science. It is especially important in the case of violent death or injury. When a person is suspected of having died from unnatural causes, a doctor examines the body in detail. The doctor must decide how long the person has been dead. One way the doctor does this is by measuring the temperature of the body. He or she also notes the temperature of the surroundings and the amount of clothing on the body. A doctor knows that a dead body cools at a certain rate under normal conditions. From these measurements, he or she can determine the approximate time of death. More complicated methods are used when the body has been dead for a long period of time.

Forensic doctors must also determine the actual cause of death. If the victim died of a stab wound,

doctors must be able to figure out the size and shape of the weapon. Also, they must determine if it was made by a knife or other instrument. In the case of gunshot wounds, doctors work with ballistic experts to determine the caliber, or size, of the bullet. The bullet or bullets are examined under a microscope for signs that tell what type of gun was used. Most guns leave identifiable marks on the bullets they fire. Forensic doctors also determine at what angle the bullet entered the body and the distance from which the bullet was fired.

Many techniques of chemical analysis are used by forensic scientists. Tiny fragments of paint embedded in a hit-and-run victim's skin can lead to exact information about the year, model, and make of the car that struck the person. Forensic scientists analyze paper and ink, for example, in cases of forgery. The almost-invisible trademarks, called watermarks, that are found on most paper can lead scientists and detectives to determine where and when the paper was purchased. Ink can be analyzed and traced to its source of supply.

Bloodstains on clothing and other objects at the scene of the crime are analyzed. From these stains, forensic scientists can determine the blood type. A tiny bit of dust found in a victim's shirt pocket or a bit of mud clinging to a shoe can lead to information about where the crime took place.

Fingerprints are an important part of forensic science. Criminals sometimes leave their fingerprints on objects, such as doorknobs and drinking glasses, at the scene of the crime. Fingerprint experts sprinkle a fine white powder on these objects. It sticks to the fingerprints and makes them visible. Every person has individual fingerprint patterns, and everyone who is arrested by the police has his or her fingerprints recorded. The fingerprint experts check the prints they find at the crime scene against the files of fingerprints kept by police. In this way, they can often determine the identity of the criminal. The largest file of fingerprint records is kept in Washington, D.C., by the Federal Bureau of Investigation (FBI). Local police can also check with the FBI fingerprint files when they are trying to identify someone.

In the 1980s, research in genetics revealed a new

way of identifying people (see GENETICS). Every cell in the human body contains the same genetic code, made from a material called DNA (see DNA). DNA extracted from bloodstains, hairs, or other body substances left at the scene of a crime can be compared to samples taken from the suspected criminal. If the two DNA samples match exactly, then they must have come from the same person. This method is called DNA profiling. Since a person's DNA profile is as unique as a fingerprint, the technique has become known as genetic fingerprinting (see GENETIC FINGERPRINTING).

Photography is another method that is used in criminal and civil investigations. A camera can often capture details that are not readily visible to the unaided eye. Forensic scientists also make use of infrared or ultraviolet light and X rays to examine evidence.



#### FORENSIC SCIENCE

Analyzing bloodstains is an important part of forensic science. Here a scientist is taking a sample of dried blood from some clothing found at the scene of a crime.

**FORESTRY** Forestry is the practice of managing forests. There are many different ways to manage a forest. Paper and wood companies own huge forests. They cut down trees to make products from them and then plant new trees (see LUMBER). Other forests are recreation areas, places to fight soil erosion, or wildlife refuges. A refuge is an area where hunting is prohibited or restricted.

Foresters do many things. They chop down trees, plant new trees, study the genetics of trees, fight forest fires, prevent plant diseases, and study the best ways to use a forest. Many foresters are ecologists so that they can understand more about forests and the different ecosystems found there (see ECOLOGY).

Forests are valuable natural resources (see NATURAL RESOURCE). Because new trees can be planted in a forest, forests are a renewable resource. However, reforestation, or replacing a cut forest, is a complicated and lengthy process. Forests are complex ecosystems that contain many different plants and animals. It may take two hundred years or more to replace such a diverse forest, which is often referred to as an old-growth forest.

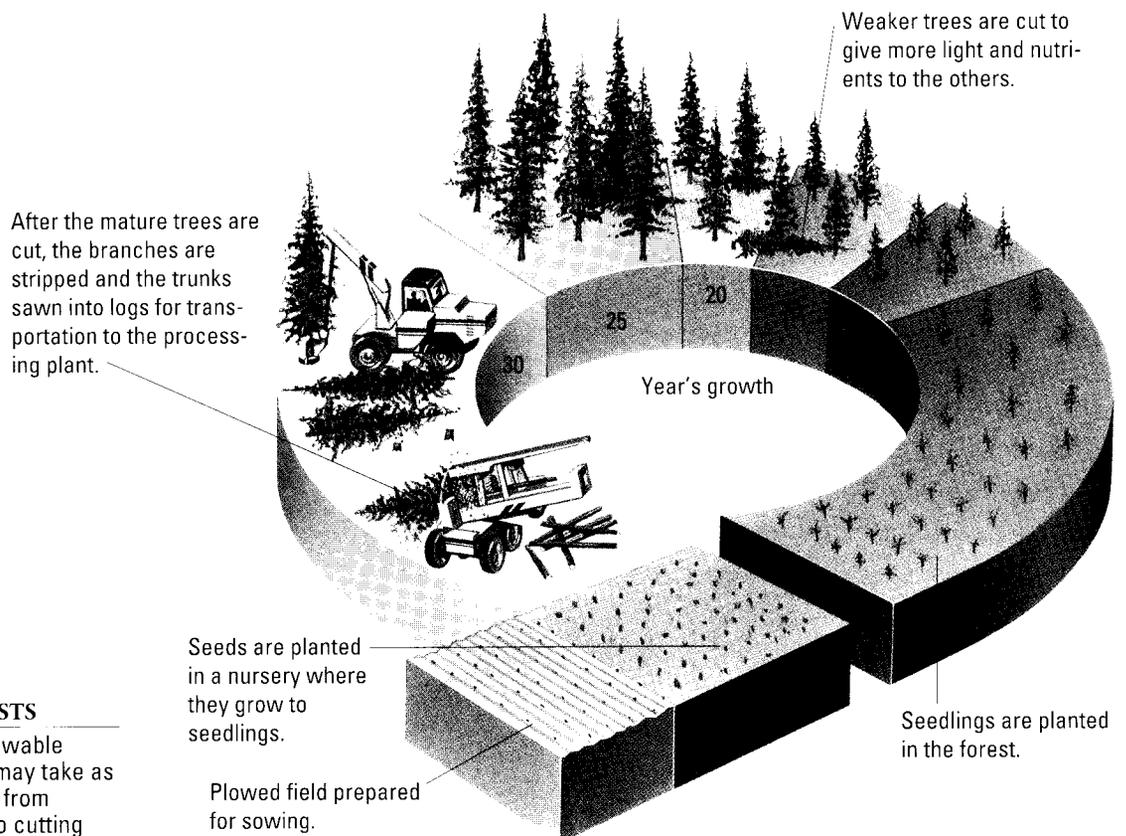
Sometimes, forests are replanted with a single kind of fast-growing tree that can be cut again within twenty years or so. However, these single-species forests, called new-growth forests, cannot provide a habitat for a variety of wildlife. Also, entire single-species forests may be threatened by the spread of a disease to which the species is susceptible. In a diverse forest, however, only one species of many may be affected by such a disease.

Consumers need wood and wood products, such as paper, but forests must be preserved. This can be done by cutting down fewer trees and planting new ones. Cutting down all the trees in a forest leads to serious problems. For example, erosion and flooding may result because the runoff of water is no longer stopped or slowed by trees or other plants. Federal laws require the U.S. Forest Service to protect forests while managing them to provide timber for industry. However, the Forest Service has been criticized for allowing the lumber industry to cut too many trees without protecting the other valuable uses of forests.

See also CONSERVATION; DEFORESTATION; TREE.

**FUTURE FORESTS**

Trees are a renewable resource, but it may take as long as 30 years from planting seeds to cutting mature trees (right).



**FORGING** Forging is a means of shaping metal by heating it, then hammering or pressing it into the desired form. When a metal is forged, it loses its grainy structure. It becomes fiberlike. The fiberlike structure gives more strength to the forged object.

One of the oldest forms of forging was hand forging, carried out by blacksmiths in making horse-shoes. The blacksmiths heated iron bars in a fire. They made the fire burn fiercely by blowing air through it with bellows. They gripped the hot iron with tongs and placed it on a heavy anvil. They then beat the iron into shape with a heavy hammer.

Most forging operations today are performed with mechanical hammers. A single forging hammer may weigh more than 1,000,000 lb. [450,000 kg]. A single forged piece, called a forging, can weigh more than 400,000 lb. [182,000 kg]. Tools called dies do the shaping (see DIE). One die fits on top of the metal and another on the bottom. When the dies are pressed together, they squeeze the hot metal into the required shape.

Machine forgings, also called flat-die forgings, are made on machines known as double-frame hammers. In such machines, the lower die is held still. The upper die, driven by steam or another source of power, moves up and down in a series of blows.

In drop-hammer forging, also called impact-die forging, the hot metal is forced into shapes that are cut into the upper and lower dies. The upper die moves up and down repeatedly. Power to lift the die is provided by electricity or another source. However, the die falls of its own weight. A drop hammer can produce objects much faster than smith forging. Drop-hammer forging also produces shapes that smith forging cannot produce.

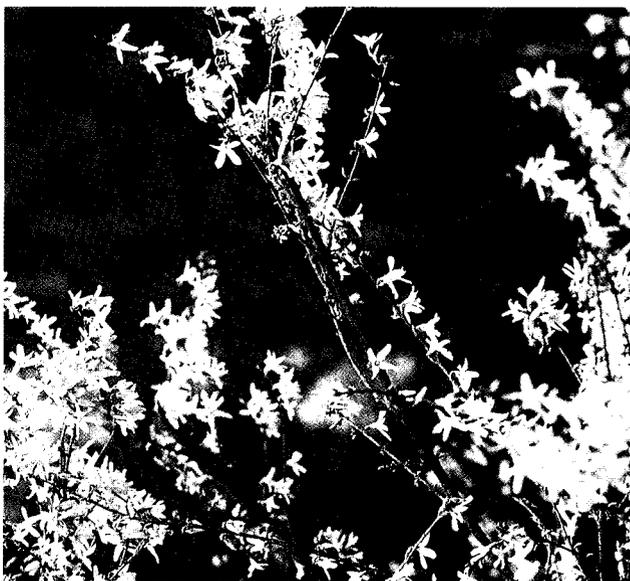
Press forging is carried out by a squeezing action, as opposed to a series of blows. The dies are similar to the ones used for drop-hammer forging. The dies are squeezed together by either mechanical or hydraulic pressure.

Upset forging is involved with operations such as making heads on nails or bolts. The metal is struck along its length to shorten it and increase its diameter. Other forms of forging include punching holes in metal, bending it, and welding (fusing) pieces of metal together.

**FORMALDEHYDE** (fôr mäl'də hīd') Formaldehyde (CH<sub>2</sub>O) is a colorless gas with an irritating odor. Its boiling point is -6°F [-21°C]. It is used in industry to produce a number of artificial resins, pharmaceuticals, and dyes. These resins are used as varnishes and coatings for electrical insulators (see RESIN). Formaldehyde is the first member of a group of organic (carbon-containing) compounds called aldehydes. Formaldehyde is soluble (dissolvable) in water. A solution of formaldehyde is called formalin. Formalin was once widely used in biological and medical studies to preserve specimens. However, it is no longer used in this way because it is believed to cause cancer.

**FORSYTHIA** (fôr sīth'ē ə) Forsythias are hardy, deciduous shrubs belonging to the olive family. The shrubs may grow as tall as 9 ft. [2.7 m] with spreading branches. The bell-shaped flowers are bright yellow, giving rise to the nickname, golden bell. The flowers grow in clusters and bloom in the spring before the leaves open. Forsythias are native to eastern Asia, but several species are now cultivated throughout the world. Because forsythia is a hardy plant that grows well in a variety of soils, it is a popular garden plant and is used by many states as a decorative ground cover along highways.

*See also* DECIDUOUS TREE; FLOWER.



**FORSYTHIA**

The yellow flowers of forsythia are a welcome sight in early spring, when there are few other plants in bloom.

# FOSSIL

Fossils are the remains of ancient organisms. They have been preserved in various ways, sometimes for hundreds of millions of years or even longer. The earliest rock structures that might be fossils are about 3.5 billion years old.

Animal fossils usually consist only of teeth, shell, or bone fragments. Sometimes, an animal fossil is discovered intact. Often, the outline of a plant or animal is embedded in sedimentary rock (see **SEDIMENTARY ROCK**). Rocks containing fossils often originated beneath the sea but have been lifted by Earth movements to form mountain ranges and new land areas. Erosion then wears away the rock, sometimes enough to expose the fossil.

**Fossil formation** An important condition of fossil formation is the rapid burial of the dead organism. If the dead organism is exposed to the weather, it will quickly decompose (decay). However, if the dead organism is quickly covered by sediment, it has a much better chance of preservation.

Another important factor in fossilization is the presence of hard parts. Bones, teeth, and shells in animals and woody tissue in plants are the most common remains that are preserved.

Very few creatures have been preserved in their original state. An exception is the woolly mammoth, some of which have been discovered intact in Alaska and Siberia. They were so well preserved in ice that their meat was still fresh (see **MAMMOTH**). Some complete skeletons have been found in California where prehistoric animals were trapped when they sank into tar pits.

Fossils that have partially or completely turned to stone are called petrified fossils. Sometimes, groundwater dissolves the remains of a plant or animal. Minerals then replace the remains. This process of petrification is called replacement. Replacement often leaves a perfect replica of the original organism.

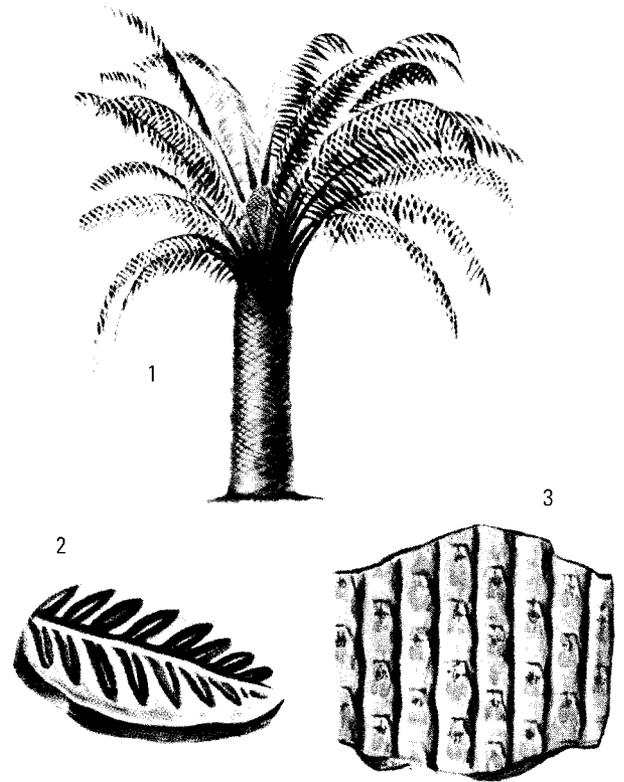
Another method of petrification is called permineralization. This occurs when minerals fill in air spaces in the bones or in other hard parts of the

fossil without changing its original shape. The minerals actually strengthen the fossil. The Petrified Forest National Park in Arizona has thousands of petrified logs. In these logs, every molecule of woody tissue has been replaced by stone (see **PETRIFIED FOREST**).

Fossils of plant leaves and soft-bodied animals are often formed by a process called carbonization. In carbonization, an organism, such as a jellyfish, may decompose after a rapid burial until all that remains is a thin film of carbon smeared on rock. This film often shows much detail of the original organism.

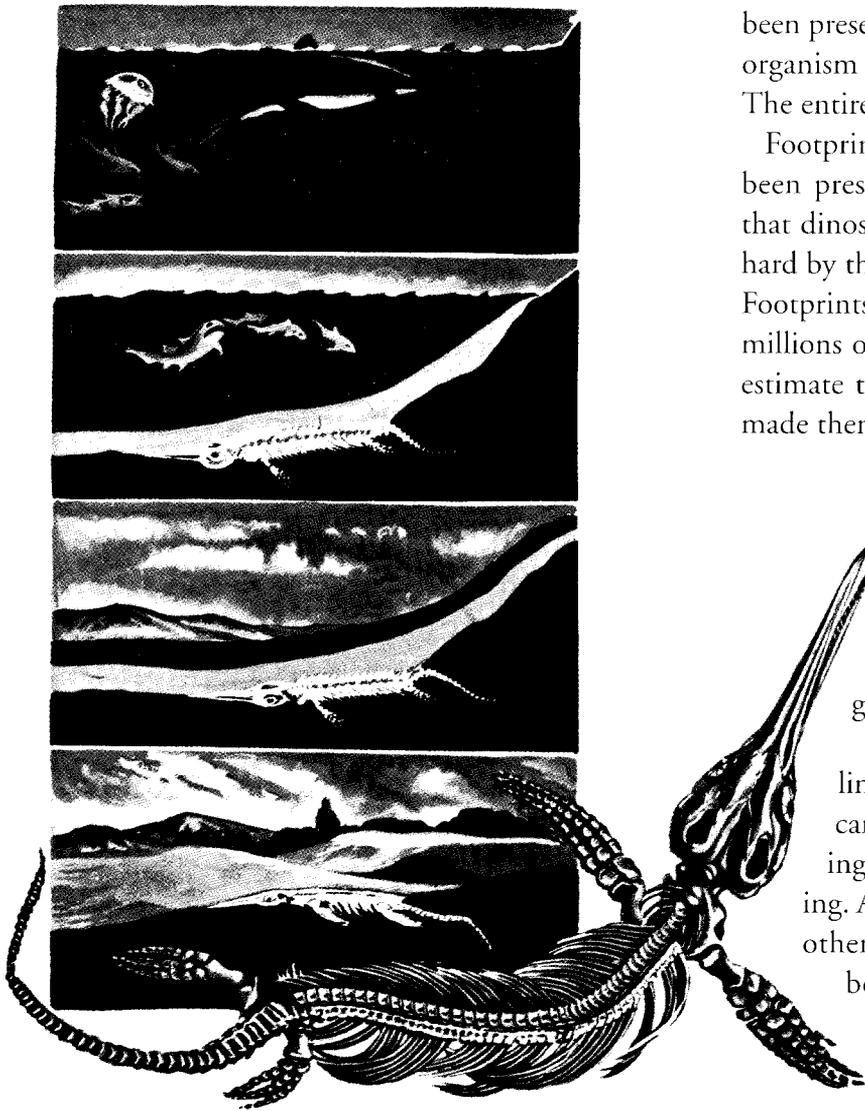
Sometimes, a buried organism is completely dissolved, leaving a space in the rock. This space, called a mold, corresponds to the original shape of the organism. Paleontologists (scientists who study fossils) can fill this mold to produce an exact replica, or cast, of the original organism.

Some insects and other small organisms have



## ANCIENT PLANTS

(1) Cone-bearing cycads first grew during the Permian period (290 to 245 million years ago) and still grow today. (2) Leaf fossils are often found as black outlines in rocks. (3) A fossil cast of tree bark is pictured.



**FOSSIL REPTILE**

The fossilization of an ichthyosaur (a prehistoric marine reptile) is shown in the drawings above. From top to bottom: The animal dies, and its body sinks into mud at the bottom of the sea. The flesh and bones decay, leaving a fossil cast. The layers of mud and sand that cover the fossil thicken and turn into rock. The bed of the sea is raised during an upheaval of the earth's crust and becomes land. The land is eroded by wind and rain, and eventually the fossil appears.

been preserved by sap from trees. The sap traps the organism and then hardens into an amber shell. The entire organism is often preserved.

Footprints, animal droppings, and eggs have also been preserved as fossils. Paleontologists believe that dinosaur footprints made in mud were baked hard by the sun before being covered by sediment. Footprints have been found that were covered for millions of years. By studying them, scientists can estimate the size and weight of the creatures that made them.

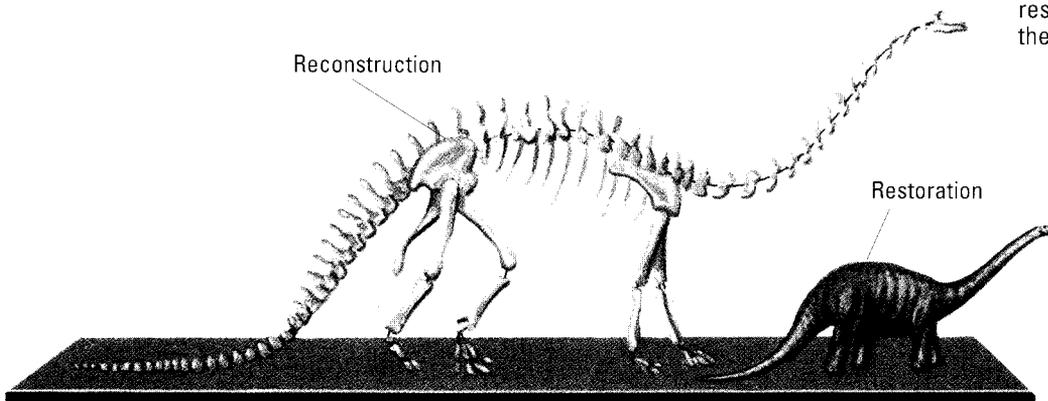
**The importance of fossils** Until fairly recently, people believed that the earth had only existed for a few thousand years. Fossils were thought to be the remains of animals killed during the great flood told of in the Bible.

Today, fossils provide an important link to the history of the earth. Scientists can study the progress of evolution by finding the age of fossils, using methods of dating. A better understanding of the climate and other conditions of the primitive earth has been obtained from fossils. Fossils may also provide clues to the geologist in locating coal and oil deposits.

*See also* DATING; EARTH; EVOLUTION; GEOLOGICAL TIME SCALE; PALEONTOLOGY.

**RECONSTRUCTION**

Scientists can reassemble fossil bones to make the skeleton of an animal, even if some of the bones are missing. From this reconstruction, other scientists can make a restoration that shows what the animal looked like.



**FOSSIL FUEL** Fossil fuels are sources of energy that were formed millions of years ago from the remains of animals and plants (see ENERGY; FOSSIL; FUEL). The three most important fossil fuels are coal, natural gas, and petroleum, or oil (see COAL; NATURAL GAS; PETROLEUM). Fossil fuels provide most of the energy used by humans. These fuels are responsible for powering most of the machines of the modern world. The burning of fossil fuels, however, has led to serious environmental problems.

Most of the world's coal deposits were formed in the Carboniferous period in the earth's history, which began about 363 million years ago and lasted about 73 million years (see CARBONIFEROUS PERIOD). During this period, much of the earth was covered with swamps. As the plants and animals that lived in these swamps died, they sank to the bottom of the swamps. They gradually decayed and were covered with sediment (see DECOMPOSITION). New organisms grew, and the cycle repeated until there were many layers of decayed matter and sediment. The many layers produced great pressure.

#### FOSSIL FUEL

Coal is a fossil fuel formed underground more than 300 million years ago. In this open-cast coal mine near Cologne, Germany, huge excavators plow along a 3 mi. [5 km] deposit of coal.

Over time, this pressure, combined with chemical reactions, changed the layers into fossil fuels.

Much of the world's oil was formed in the Cretaceous period, 146 to 65 million years ago (see CRETACEOUS PERIOD). At this time the oceans were warm and stagnant, and dead animal and plant material built up on the seabeds without rotting away. When this dead material was buried, it turned to oil, which seeped through the rocks and became concentrated in areas that are now oil fields.

Some of the most famous natural gas fields were formed when coal from the Carboniferous period decomposed. The coal decomposed while it was still buried beneath sandstones that were formed in later Permian times (see PERMIAN PERIOD). This gas became trapped in tiny spaces between the grains of the sandstone.

Fossil fuels consist mainly of hydrocarbons, which are compounds of hydrogen and carbon (see HYDROCARBON). Hydrocarbons make good fuels because when they burn, they release large amounts of energy. Besides providing energy, fossil fuels can also be used to make many products, such as dyes, inks, paints, and plastics.

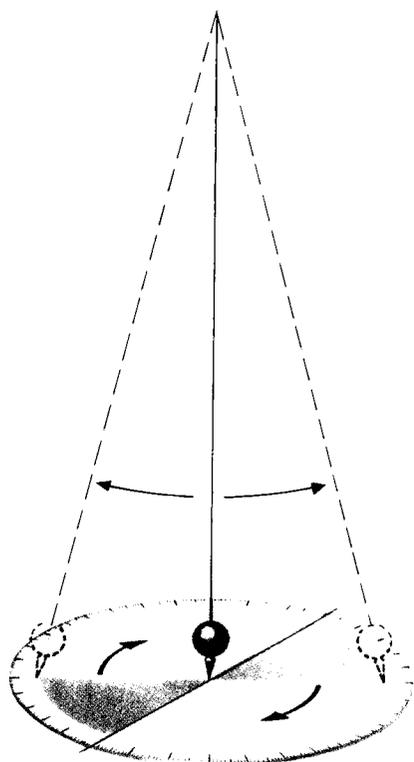
Fossil fuels are a nonrenewable natural resource. This means that they cannot be replaced. Once they are gone, they are gone forever (see NATURAL



RESOURCE). Some scientists estimate that there is enough coal to last for more than two hundred years. However, the world's supply of natural gas and petroleum is expected to run out in the next sixty to one hundred years. Scientists are researching ways to conserve fossil fuels. They are also trying to develop alternative sources of energy, such as solar energy (see SOLAR ENERGY).

**FOUCAULT PENDULUM** (fōō kō' pēn'jə ləm) The Foucault pendulum was built by a French physicist named Jean Foucault in 1851. Using the pendulum, Foucault was able to demonstrate that the earth rotates on its axis.

Foucault hung a heavy ball on the end of a steel wire 66 yd. [60 m] long. He then made the ball swing back and forth in a straight line. Very slowly, the direction of the wire and the ball turned so that they, in time, made a revolution. This effect was not caused by gravity, because gravity only acts in a vertical direction. The effect was caused by the rotation of the earth. Mathematicians have calculated how big the effect should be. Their results



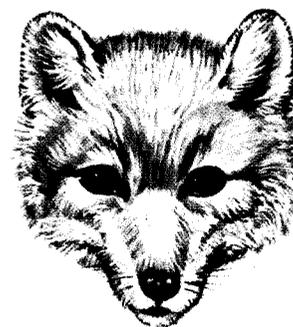
**FOUCAULT PENDULUM**

A Foucault pendulum demonstrates that the earth rotates on its axis once every 24 hours.

agree with the experiment. At the poles of the earth, it takes twenty-four hours for the pendulum to make a complete revolution. Nearer to the equator, the time becomes longer. At the equator itself, the effect does not happen at all.

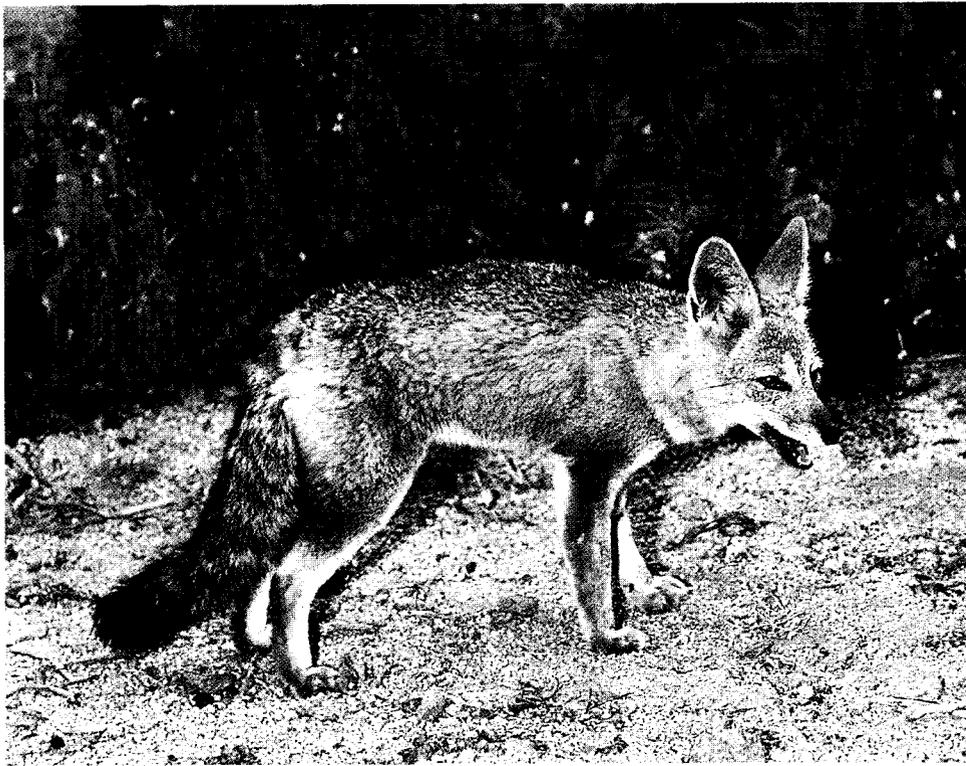
See also PENDULUM.

**FOX** The fox is a carnivorous (meat-eating) mammal of the dog family, Canidae. It has a pointed snout and big, bushy tail. There are about twenty



**FOX—Ear size**

These foxes have ears adapted to the climate in which they live. The common fox (top) that lives in temperate climates has average-sized ears. The fennec fox (middle) of the desert has large ears that lose body heat and so keep the fox cool. The arctic fox (bottom) that lives in a cold climate has small ears that lose very little body heat.



**FOX—Desert fox**

The large-eared gray fox lives in the Atacama Desert, Chile, where it searches for food among the dry, scrubby vegetation.

species, the largest of which is the Cayman fox, or red fox, which lives throughout the Northern Hemisphere. This fox is usually about 4 ft. [1.2 m] long, including the tail, and about 1 ft. [0.3 m] high. Its color ranges from rich reddish brown to beige and silvery gray. The female fox is called a vixen and the male is called a dog.

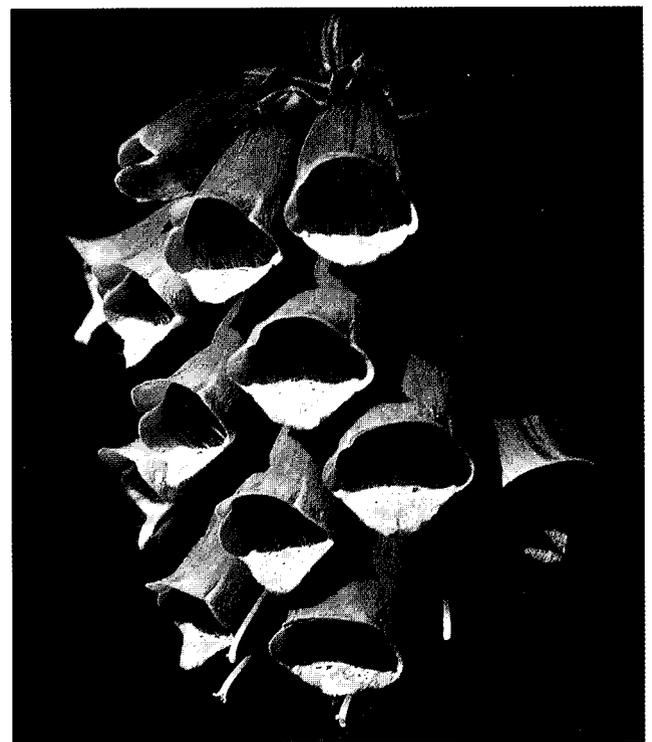
The fennec fox and Blanford's fox live in the deserts of Africa and Asia. They weigh little more than 2.2 lb. [1 kg]. They are the smallest of the foxes.

Foxes hunt at night, using their keen senses of sight, smell, and hearing. They feed mainly on rodents and various other small animals and will occasionally eat poultry. Foxes usually live in burrows, sometimes digging their own, but often making use of existing holes. The common fox, for example, often lives in old rabbit burrows. Sometimes, foxes find a home in a hole in a tree.

*See also* MAMMAL.

**FOXGLOVE** The foxglove is any of about thirty species of biennial, herbaceous plants belonging to the genus *Digitalis* (see BIENNIAL PLANT; HERBACEOUS PLANT). This genus is native to Europe, but several species are cultivated in gardens in other parts of the world. They grow as tall as 5 ft. [1.5 m]

and produce spikes of bell-shaped flowers. Each flower is up to 2.4 in. [6 cm] long. The color of the flowers varies from purple to pink to white, depending on the species. The best-known species



**FOXGLOVE**

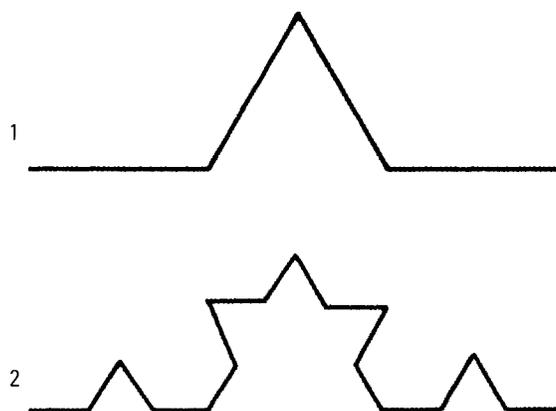
The leaves of the purple-flowered common foxglove contain digitalis, a substance used to treat forms of heart disease.

is the common foxglove, which has purple blossoms with spotted interiors. The large, oval, greenish gray leaves of this species contain digitalis, a poisonous alkaloid (see ALKALOID). Digitalis can be used in small amounts, however, to treat certain heart diseases.

**FRACTAL** A fractal is an irregular, repeating shape that cannot be classified as one belonging to classical geometry. Classical geometry studies such shapes as circles and triangles (see GEOMETRY). Fractal geometry studies broken or irregular shapes, such as those found in nature. The shape of a coastline, the course of a river, and the silhouette of a mountain ridge are examples of fractal shapes. Fractal shapes repeat themselves so that any portion of the shape is but a smaller version of the entire shape. An example is the large, branched limb of a tree that is similar in shape to a small, forked twig of the same tree.

A famous fractal shape is Koch's curve, first drawn by German mathematician Helge von Koch in 1904. Koch's curve involves dividing a straight line into three equal sections. The middle section is removed and replaced by two other sections of the same length, so that an upside-down  $v$  connects the two original sections. The same procedure is applied to each of the four new sections. The pattern repeats itself indefinitely in a snowflakelike shape.

The study of fractal geometry is important in engineering and physics. Fractal geometry is also the basis for art that is generated by a computer.



**FRACTAL**

A fractal is an irregular, repeating shape that does not belong to classical geometry. A famous fractal shape is Koch's curve, shown in its first (1) and second (2) stages above.

**FRACTION** *Fraction* means a part of something. The word comes from the Latin word *fractum*, meaning "a breaking." In their simplest forms, fractions are parts of a whole. If a whole is divided into two equal parts, the parts are called halves. Three equal parts are thirds, four are fourths, five are fifths, six are sixths, and so on. In mathematics, one-half is written as  $\frac{1}{2}$ . One-third is written  $\frac{1}{3}$ , one-fourth  $\frac{1}{4}$ , one-fifth  $\frac{1}{5}$ , one-sixth  $\frac{1}{6}$ , and so on.

Fractions can represent ratios. A ratio is a comparison of two quantities. For example, a baseball team that has won  $\frac{2}{3}$  of its games has won two games for every three games played.

Fractions can show one number divided by another. The top number is divided by the bottom number.  $\frac{3}{4}$  means  $3 \div 4$ . The top figure, in this case the three, is called the numerator. The bottom figure, the four, is called the denominator. A fraction having the number one as the numerator is called a unit fraction.

If the numerator is greater than the denominator, the fraction is greater than one. For example, five-fourths, written as  $\frac{5}{4}$ , is greater than one, or  $\frac{4}{4}$ . The fraction  $\frac{5}{4}$  can also be written as  $1\frac{1}{4}$ , which is one and one-fourth. Fractions greater than one are called improper fractions. Fractions less than one are called proper fractions. All fractions mentioned so far are called common fractions, or simple fractions. A common fraction is a fraction whose numerator and denominator are both integers. Integers are whole numbers, such as zero, one, two, three, and so on. A complex fraction is a fraction having another fraction in the numerator or denominator or both. Some examples of this are:

$$\frac{\frac{1}{3}}{7} \quad \frac{7}{\frac{1}{3}} \quad \frac{\frac{1}{3}}{\frac{1}{7}}$$

Fractions with denominators of ten or multiples of ten, such as one hundred or one thousand, are called decimal fractions. Decimal fractions are most often written simply as the numerator, but with a period, called a decimal point, at the front. For example,  $\frac{8}{10}$  is written as .8 or 0.8, and  $\frac{18}{10}$  is written as 1.8. Also,  $\frac{8}{100}$  is written 0.08,  $\frac{8}{1000}$  as 0.008, and so on. Fractions can be

converted to decimals by dividing the denominator into the numerator. For example,  $\frac{3}{4} = 3 \div 4 = 0.75$ . Most calculators express fractions in the decimal form.

*See also* ALGEBRA; ARITHMETIC.

**FRACTURE** A fracture is a break in a bone. There are several kinds of fractures. A simple fracture is a clean break in a bone. In a compound fracture, the broken bone sticks out through the skin. A comminuted fracture is a bone that has splintered or shattered. A greenstick fracture is a partial break of a bone. An impacted fracture involves the ends of two bones rubbing against or collapsing into each other.

A fracture causes pain and inflammation in the area around it (see INFLAMMATION). Older people with brittle bones are most apt to get a fracture. Children are less susceptible to fracture. Children's bones are more susceptible to bending or greenstick fracture. The bending is actually a series of many very tiny fractures, rather than one large break.

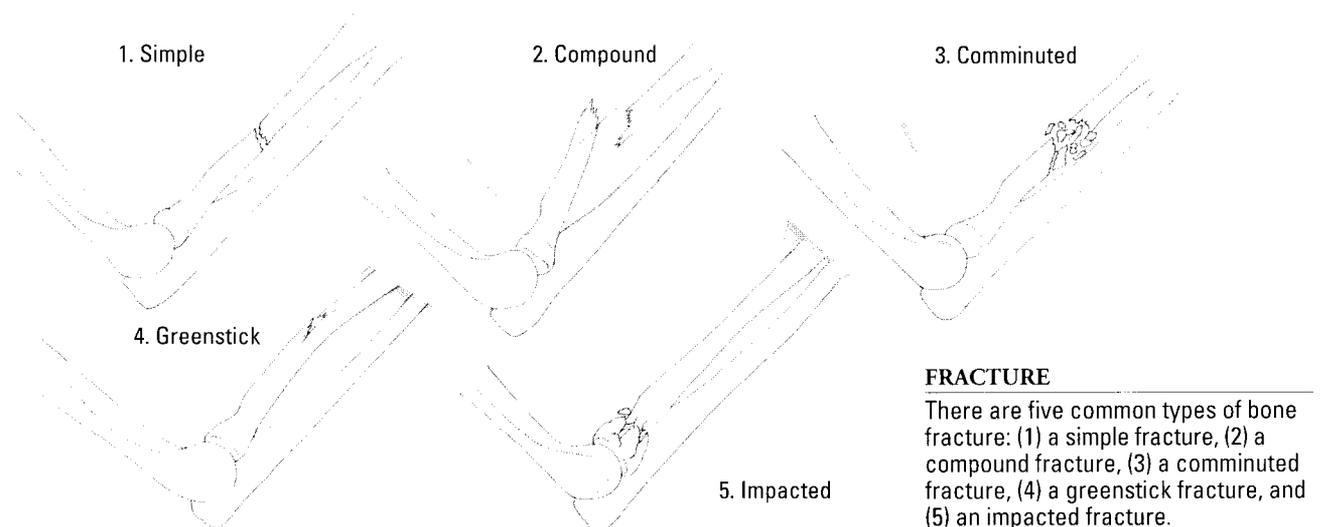
Usually, when a fracture or bending occurs, a doctor must restore the bone to its proper position so it heals properly. This is called setting the bone. Sometimes, an operation is necessary to properly set a bone. A plaster cast is often applied to the

fractured limb to assure healing. The healing of a fracture or a bending may take several months.

### FRANKLIN, BENJAMIN (1706–1790)

Benjamin Franklin was a famous American statesman, philosopher, printer, and journalist. In 1776, Franklin helped draw up the Declaration of Independence. In 1787, he helped draw up the Constitution of the United States.

Franklin also achieved fame as a scientist. He was among the first persons in the world to experiment with electricity (see ELECTRICITY). In 1752, he conducted his well-known electrical experiment. He flew a homemade kite during a thunderstorm. A bolt of lightning struck the kite wire and traveled down to a key tied to the end, causing a spark. This experiment showed that lightning is electricity (see LIGHTNING). It should be noted that this is a very dangerous experiment and should not be repeated. Franklin then invented the lightning rod. A lightning rod is a metal pole, usually set on the top of a building. It is connected with water or moist earth at one end. Lightning rods lessen the chance of damage caused by lightning. The soundness of this invention was shown when lightning struck Franklin's home. The lightning rod saved the building from damage. Many authorities agree that Franklin created many electrical terms, such as



#### FRACTURE

There are five common types of bone fracture: (1) a simple fracture, (2) a compound fracture, (3) a comminuted fracture, (4) a greenstick fracture, and (5) an impacted fracture.

*armature, condenser, and battery* (see BATTERY; CONDENSER; ELECTRIC MOTOR).

Franklin had other scientific interests besides electricity. He became the first scientist to study the movement of the Gulf Stream in the Atlantic Ocean. He spent much time charting the stream's temperature, speed, and depth. Franklin discovered that disease spreads rapidly in poorly ventilated rooms. He also showed that acidic soil can be improved by using lime.

Franklin's other inventions include the Franklin stove. By arranging the flues (pipes) in his stove in a certain way, Franklin made his sitting room twice as warm with one-fourth as much fuel as he had been using. Franklin's invention of bifocal eyeglasses is used by people everywhere. This invention allowed both reading and distant lenses to be set in a single frame.

Benjamin Franklin refused to patent any of his inventions. He would not use them for profit. He preferred to have them used freely for the comfort and convenience of everyone.

Franklin's scientific work won him many honors. The Royal Society of London elected him to membership. This was a rare honor for a person living in the colonies.

### **FREEZING AND FREEZING POINT**

A substance is freezing as it solidifies when heat is taken away from it. All substances but one freeze when they are cooled to low-enough temperatures.



#### **FREEZING AND FREEZING POINT**

Icicles form when water from melted snow on a warm roof drips into freezing air.

Most gases, when cooled, become liquids at first. At an even lower temperature, the liquid becomes a solid. One substance, helium, does not solidify no matter how low the temperature. It can only be solidified by being cooled under pressure. Without pressure, helium remains a liquid even at a fraction of a degree from absolute zero (see ABSOLUTE ZERO).

The temperature at which a substance actually turns into a solid is called its freezing point. However, this temperature is not always the temperature at which the same solid would turn back into a liquid. Supercooling may occur. This means that the liquid remains a liquid, even below its freezing point (see SUPERCOOLING).

If a substance is dissolved in a liquid, then the liquid freezes at a lower temperature. The greater the amount of substance dissolved, the lower the freezing point of the liquid. This effect is used to melt ice. When salt is scattered on the ice, the ice slowly dissolves. The salt solution has a lower freezing point than pure water. The same effect is used when antifreeze is added to a car radiator.

See also GAS; LIQUID; SOLID.  PROJECT 7, 11, 12

**FREQUENCY** The frequency of an event is how often that event occurs per unit of time. For example, the number of times that you go to school in a week is a frequency. The frequency may be five times per week. Scientists use the word *frequency* in connection with vibrations. If you pluck a guitar

string, it vibrates. The number of times it vibrates in a second is its frequency. The frequency determines the pitch (musical tone) of the sound. A tightly stretched string vibrates quickly. It produces a high pitch. A complete vibration is called a cycle. Sound waves that can be heard by humans vary from about 20 to 20,000 cycles per second. One cycle per second is equal to one hertz (see HERTZ).

There are many different kinds of electromagnetic radiation, such as X rays, visible light, and radio waves (see ELECTROMAGNETIC RADIATION). These radiations are different because they have different frequencies. Radio waves have frequencies up to about a million million hertz. The frequencies of visible light are much greater than those of radio waves. They are about a million billion hertz. The frequencies of X rays are higher still. They are about a billion billion hertz.

The distance between the start of one wave and the start of the next is called the wavelength (see WAVE). For example, the wavelength of waves on the sea is the distance between the top of one wave and the next. The speed of the wave can be found by multiplying the frequency by the wavelength. For any electromagnetic radiation, the speed is the same for all frequencies. In a vacuum, it is about 186,000 mi. [299,000 km] per second. Visible light has a greater frequency than radio waves. However, they both travel at the same speed. Therefore, the wavelength of light is less than that of radio waves. The speed of sound in air is around

1,100 ft. [330 m] per second. This speed is the same for all frequencies. The frequencies of audible sound waves vary from about 20 to 20,000 hertz. Therefore, the wavelengths range from about 0.6 in [15 mm] to 50 ft. [15 m].

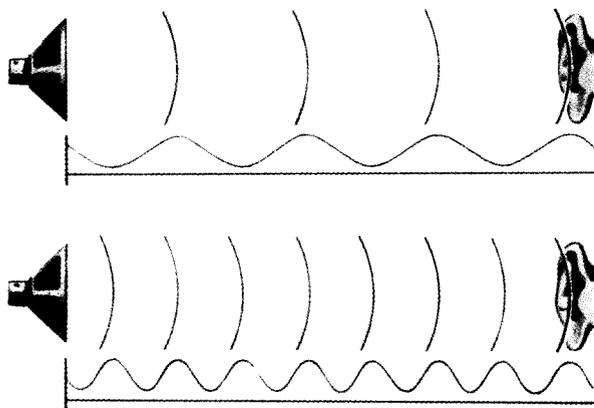
See also SOUND.

 PROJECT 54

**FREUD, SIGMUND** (1856–1939) Sigmund Freud (froid) was an Austrian doctor. His studies of the hidden workings of the human mind greatly advanced the treatment of mental illness (see MENTAL ILLNESS). Freud believed that mental illness was caused by fears and unpleasant thoughts that people have tried to forget. Freud thought that not acknowledging unpleasant thoughts caused changes in behavior. Freud treated people with mental illness by letting them relax and talk of anything they were thinking about. He believed that this helped them get the hidden fears and thoughts out of their minds. This was the beginning of the science of psychoanalysis. Freud also believed that he could help people by getting them to remember dreams. He analyzed the dreams to understand what was worrying his patients. Freud later began to think that sexual problems were very important in causing mental illness. Some other psychiatrists, such as Alfred Adler, did not agree with him about this.

Freud's methods are still used to treat some diseases, such as neurosis. Doctors try to choose the right treatment for different mental illnesses.

See also PSYCHIATRY; PSYCHOANALYSIS; PSYCHOLOGY.



#### FREQUENCY

A very low-pitched musical tone of 33 hertz (cycles per second) is being produced by the upper loudspeaker. The pitch of the tone from the other loudspeaker is an octave higher, at 66 hertz.

**FRICTION** Friction is the force that resists the movement of one object over another. Friction is a very common effect of everyday life. Without friction, automobiles would not be able to move. Their wheels would turn around on the same spot because they would not be able to grip the road. People would not be able to walk without friction. This can be shown by comparing walking on a normal surface with walking on ice. There is much less friction between feet and ice than between feet and a normal surface. This lack of friction makes it very difficult to walk on ice.

When someone starts to push a book along a table, the book does not move at first. A force has

to be applied to overcome the friction between the book and the table (see **FORCE**). The book only moves after the force overcomes the friction. Once the book is moving, it slows down if the force is removed. The book is slowed down by friction. Without friction, the smallest force can cause the book to move. In addition, without friction, the book would move even if the force were removed.

Friction is caused by the fact that most surfaces are not completely smooth. They are covered with tiny bumps. When two surfaces touch, these bumps tend to interlock. Before one of the surfaces can move, the interlocking, or friction, has to be overcome. Suppose that one of the materials is very hard and the other is very soft. When they touch, the bumps on the hard material push into the soft material and form "valleys" in it. At the same time, the soft material is forced into the valleys of the hard material. This makes the shapes of their surfaces match up. The force needed to overcome this friction can be extremely large. Friction may also be caused by chemical bonds that are formed between surfaces. Such bonds are responsible for the friction between liquids and solids or gases and solids. These bonds have to be broken before the friction is overcome.

The frictional force between two objects does not depend on the amount of surface in contact. For example, suppose a book on its side is pushed along a table. There is a frictional force between the two. The book is then placed on its end and pushed

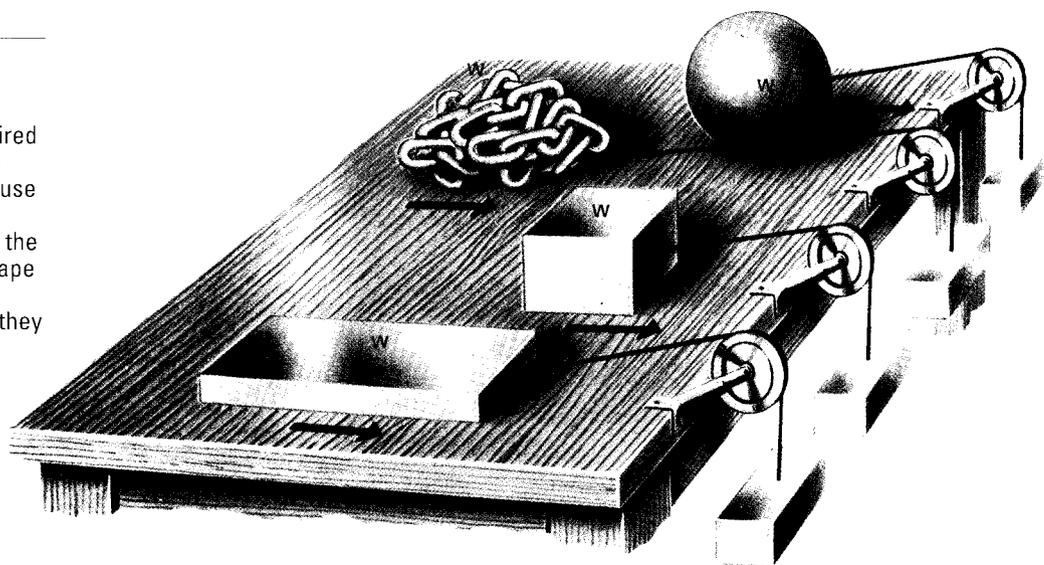
along. The force of friction between the book and the table remains the same.

Friction can be reduced by lubrication. Lubrication involves making a surface smooth or slippery. A substance called a lubricant forms a thin layer between the two surfaces. It prevents the bumps and valleys from interlocking. There is still some friction between the lubricant and the surface, but it is much less. Lubricants can be solids, liquids, or gases. In an air-cushion vehicle, a cushion of air is used to reduce friction (see **AIR-CUSHION VEHICLE**). In some heavy machinery, graphite is used as a lubricant. Graphite is a form of carbon. It is a solid and can withstand very high pressures without breaking down chemically (see **CARBON**). This is a very important property for any lubricant. The most common lubricant is oil. Oil is an excellent lubricant since it greatly reduces the friction between surfaces. It is widely used in engineering. If there were no lubricant used, friction would cause machine parts to become hotter and hotter and to wear away quickly. However, engineers do not rely solely on lubricants to reduce friction. For example, ball bearings are used if one part has to rotate inside another. The friction between two rolling surfaces is much less than between two sliding surfaces (see **BEARING**).

Friction also plays a part in the weather. Without friction, wind speeds would be much greater. The molecules in the air are slowed down by friction with the earth's surface. Friction affects the wind

### FRICITION

These objects resist movement because of friction with the table surface. The force required to drag any one of them along is the same, because they all have the same weight and are made of the same material. Their shape does not affect their frictional resistance as they move.



speed at heights up to 549 yd. [500 m]. Above this height, wind speeds can be twice what they are on the ground.

### PROJECT 36

**FROG** The popular description of a frog is that it is an amphibian with smooth, slippery skin and strong legs used for jumping (see AMPHIBIAN). Although there are many families of frogs throughout the world, the true frogs of North America belong to the family Ranidae. Frogs are able to crawl out of water. They must, however, keep their skin wet, so they usually do not travel far from water. They often sit in shallow water or in the wet grass near a pond's edge, waiting for an insect to fly by. Frogs catch insects by shooting out their long tongues. Frogs also eat small fish, snakes, and other frogs. Frogs lay many eggs in water. The eggs are surrounded by jelly that softens and swells as soon as the eggs get into the water. The eggs hatch into tadpoles, which swim like fish until they change into adult frogs. Frogs that live in colder climates hibernate during winter (see HIBERNATION). The bullfrog, the largest frog in North America, is often raised for food.

*See also* TOAD.



### FROG

The bullfrog, the largest species of frog that lives in North America, is named for its deep-throated croak.

**FRONT** A front is the boundary between two different air masses. The air masses differ in such variables as temperature or dew point (see AIR MASS; DEW POINT; TEMPERATURE).

In the Northern Hemisphere, warm air from the equator is separated from cold air from the Arctic



### FRONT

A weather front is often marked by a band of low, dark clouds and steady rain. This stormy sky in Iceland is caused by a polar front.

Circle by the polar front. Here, the heavy cold air is constantly pushing underneath the lighter warm air. As the warm air is pushed up, it expands and cools. This causes clouds to form and precipitation (rain or snow) to occur along the polar front. If air currents in the upper atmosphere, called the jet stream, are just right, a depression may develop (see DEPRESSION; JET STREAM).

There are two main types of fronts. A cold front occurs when a cold air mass meets and moves under a warm air mass. A warm front occurs when an advancing warm air mass overtakes a retreating cold air mass. Sometimes, the air at a front does not mix, and the front stalls. This is called a stationary front. When a cold front catches up to a warm front, it pushes all the warm air above the cold air. This is called an occluded front.

*See also* COLD FRONT; METEOROLOGY; POLAR FRONT; WARM FRONT; WEATHER.

**FROST** Frost is ice crystals that coat objects on the earth's surface. Frost forms in a way similar to dew. On a clear, still night, when the dew point drops below 32°F [0°C], water vapor in the air changes directly to the solid state by a process called sublimation. This results in the deposit of ice crystals on surfaces. The deposit is called frost or hoarfrost (see DEW; DEW POINT; SUBLIMATION).

Each year, frost injures fruit grown in the southern United States and California. Some fruit growers use heaters that raise the temperature of the air around the plants to prevent frost damage.

*See also* WEATHER.

All flowering plants produce fruits. A fruit is a mature ovary with its enclosed seeds. It is produced by the flower. After pollination, a male gamete produced within the pollen grain fertilizes an egg (female gamete) within an ovule. The ovule is inside an ovary, which is part of a pistil. The fertilized egg develops into an embryo, and the ovule develops into a seed that contains the embryo. At the same time, other changes are taking place in the flower. The anthers and the stigmas begin to waste away. The petals and the sepals usually drop off. Most importantly, though, the ovary begins to get larger as it develops into the fruit containing one or more seeds (see FLOWER; POLLINATION; REPRODUCTION).

There are many types of fruits, but they all have the same functions. They protect the developing seeds and help disperse these seeds (see DISPERSION OF PLANTS).

## FRUIT HARVEST

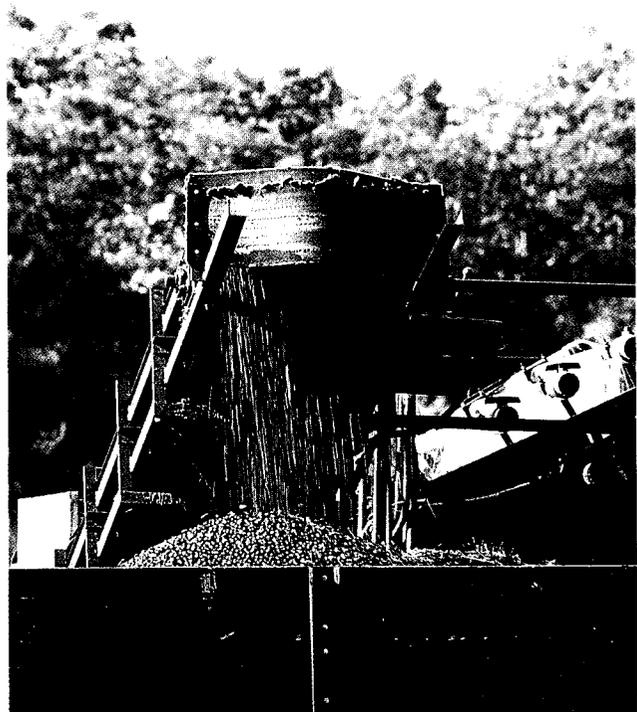
A worker rakes ripe cranberries to the center of a collecting vat (below) before the fruit is loaded into a truck (below right). The acid fruit of cranberries is usually sweetened and made into jelly or cranberry sauce.



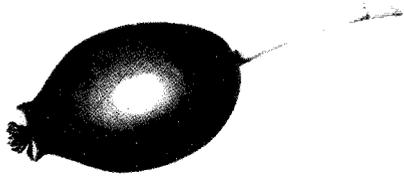
**Types of fruits** Ripe fruits are either dry or fleshy, depending on the wall surrounding the seeds. This wall is called the pericarp. Dry fruits have a dry, often woody, pericarp. The seeds of many dry fruits are used for food. Fleshy fruits have a juicy, edible pericarp that is also used for food.

Dry fruits are either dehiscent or indehiscent (see DEHISCENCE; INDEHISCENCE). Dehiscent fruits open when the seeds reach maturity. This releases the seeds for dispersion by the wind or other agents. Dehiscent fruits may be capsules that split along three or more seams, legumes that split along two seams, or follicles that split along one seam. Indehiscent fruits remain closed. The fruits do not release their mature seeds. Indehiscent fruits are often dispersed by animals. Nuts and grains are the most familiar of the indehiscent fruits. The germinating seed eventually breaks through the fruit wall.

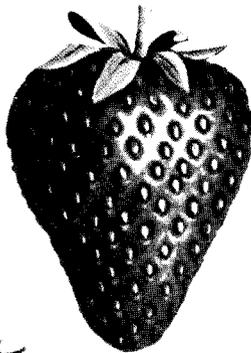
Fleshy fruits may be berries, drupes, or pomes. Berries develop from one or more pistils. They have a fleshy pericarp and small seeds. Citrus fruits, grapes, and tomatoes are all berries. Drupes are formed from one pistil. The pericarp is fleshy, but



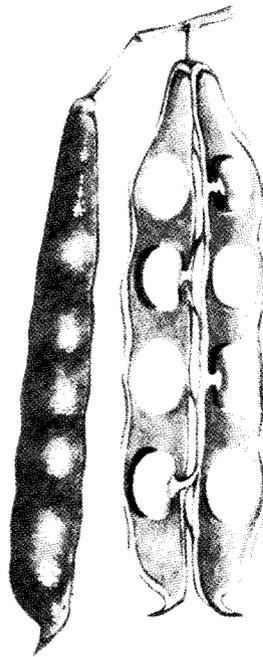
Rose hip (pome)



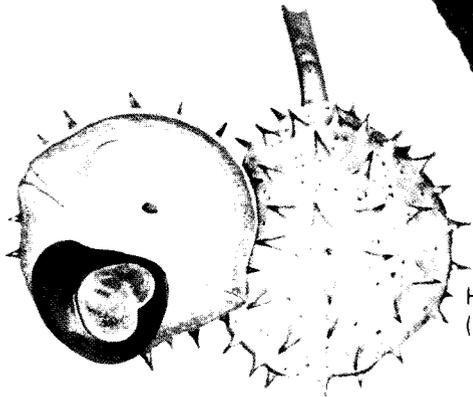
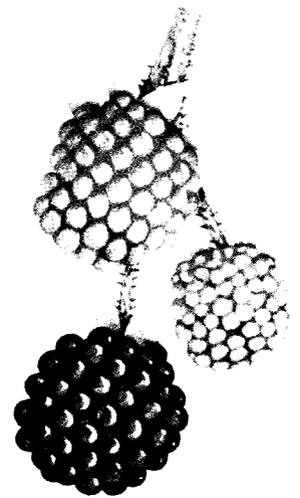
Strawberry (pome)



Bean (dehiscent)

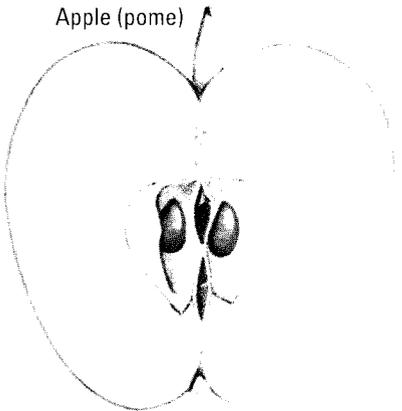


Blackberry (drupelet)

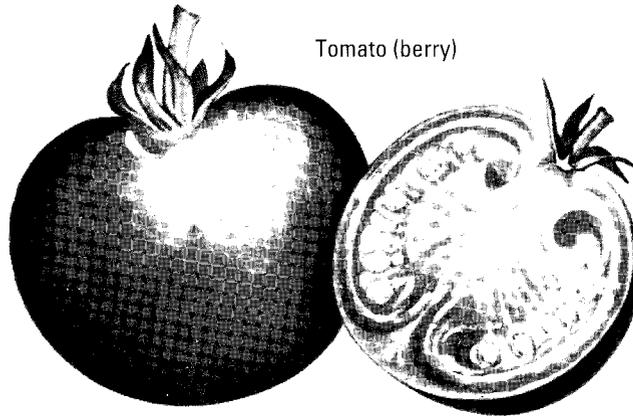


Horse chestnut (drupe)

Apple (pome)



Tomato (berry)



Poppy (dehiscent)



**COMMON FRUITS**

The rose hip, apple, and strawberry are examples of pomes. Pomes usually have their seeds at the center of the fruit. The horse chestnut is a drupe (with hard, woody pits), and the blackberry is a drupelet. The tomato is a typical many-seeded berry. Beans and poppies have dehiscent fruits, which release their seeds when ripe.

its inner part is a hard, woody pit. The seed is inside the pit. Apricots, cherries, peaches, and plums are drupes. Blackberries and raspberries are actually collections of tiny drupes, called drupelets, that develop from several pistils of one flower. A pome develops from structures other than just the pistil and is often called a false fruit. Apples and pears are pomes. The juicy, edible pericarp comes from the receptacle of the flower. The pistils form the tough core, which contains the seeds. The strawberry is another type of false fruit because the fleshy pericarp

comes mostly from the upper part of the stem. Pineapples and mulberries are formed from several flowers and are called compound fruits.

**Importance of fruits** Fruits form an important part of a balanced diet (see DIET). They provide carbohydrates, minerals, and vitamins. Fleshy fruits are a good source of water and contain large amounts of cellulose. Cellulose is not digested by the human body and provides part of the fiber needed in the diet. Most fruits are tasty and, except for the cellulose, are easily digested.

The United States produces and uses more fruit than any other country in the world. Until fairly recently, people were able to buy only those fruits that were native to their area and only during certain

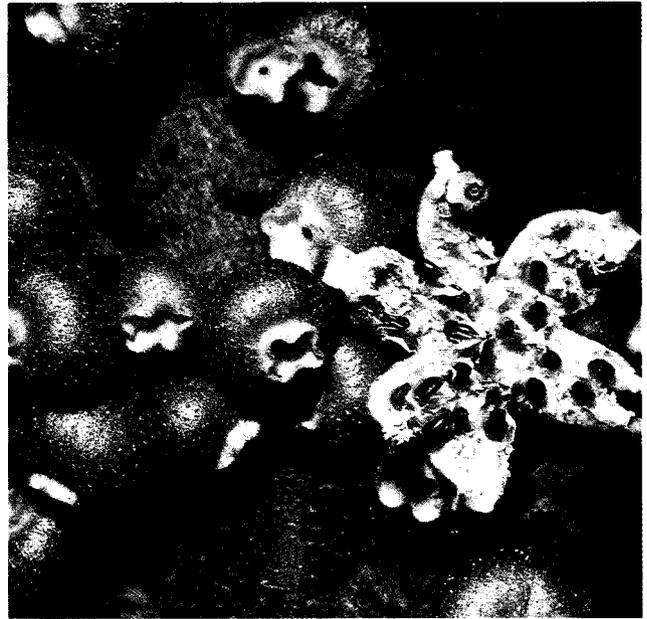
times of the year. As food preservation methods have improved, however, consumers have been offered a wide variety of fruits year-round (see FOOD PROCESSING).

Breeding is used to develop new varieties of fruits and to improve the quality of current varieties (see BREEDING). Many of the most popular fruits are actually hybrids produced after years of experimentation (see HYBRID). Seedless fruits are popular with consumers but must be reproduced by special methods.



**Fruit or vegetable?** Although botanists (scientists who study plants) have a definite way of defining what a fruit is, the word is commonly misused to indicate just fleshy fruits. Beans and tomatoes are usually considered vegetables even though they contain seeds and are, by definition, fruits. In some cases, a fruit may be seedless, but it always comes from the pistil of a flower. A vegetable is any other edible part of a plant, such as the leaves, stems, or roots.

*See also* VEGETABLE.



#### WILD FRUIT

Crab apples (above) are a type of wild apple. The fruit falls to the ground and rots before the seeds are released. The fruit called little lemon (above right) grows on a tree native to the rain forest of Costa Rica. Its ripe fruit bursts open on the tree to release the seeds.

#### CITRUS FRUIT

There are many types of citrus fruits, including oranges, lemons, grapefruit, and tangerines. They grow in warm climates such as southern Spain, where this worker (right) is putting ripe oranges into crates for transportation.



**FRUIT FLY** *Fruit fly* is the name given to two families of small flies, Tephritidae and Drosophilidae, that cause extensive damage to fruit. The larvae of some members of the family Tephritidae feed on orchard fruits (see FLY). The most important of these flies is the Mediterranean fruit fly. It lives in warm areas throughout the world. It has a large head with large, green compound eyes (see EYE AND VISION). The female lays about five hundred eggs at a time in various fruits, especially citrus fruits and cherries. Within days, the eggs hatch into maggots, which destroy the fruit. When the fruit falls to the ground, the maggots emerge and turn into pupae. The pupae grow into adults, and the cycle then begins again (see METAMORPHOSIS).

Mediterranean fruit flies were first detected in the United States in 1929 in Florida. Within a year, it was thought that they had all been killed. When they reappeared in 1956, international laws were established to try to control their spread. Some species of Tephritidae attack only certain weeds. These flies are often imported as a means of biological control of those weeds (see BIOLOGICAL CONTROL).

Members of the family Drosophilidae are often called pomace flies or vinegar flies because they

sometimes breed in fermenting juices, such as crushed grapes used for making wine. They reproduce quickly. One species, *Drosophila melanogaster*, is used extensively in genetic research because it has four large chromosomes. These chromosomes are easily seen in cells from the salivary glands.

See also GENETICS.

**FUCHSIA** (fyoo'sha) *Fuchsia* is a genus of about one hundred species of flowering shrubs belonging to the evening primrose family (see EVENING PRIMROSE FAMILY). Native to New Zealand and the warmer parts of North and South America, fuchsias are now grown throughout temperate, subtropical, and tropical regions of the world. Some species grow as tall as 40 ft. [12 m]. The drooping flowers grow from the axils of the leaves. The flowers have a long, colored calyx tube and a corolla of four petals, usually of a different color. The blossoms are up to 2 in. [5 cm] long. In wild varieties, the blossoms are red or purple. Cultivated fuchsias may be any of several colors. Some species of fuchsia are called lady's-eardrops. They are often grown as houseplants. The genus was named in honor of the sixteenth-century German botanist Leonhard Fuchs.

See also FLOWER.



#### FUCHSIA

Fuchsias are valued for their colorful, drooping flowers. Most are grown as houseplants or garden shrubs, but some, called standard fuchsias, are trained to have a single tall stem topped with blossoms.

A fuel is a material that is used as a source of energy. The energy in a fuel can be put to many different uses. Fuels are used to drive engines in airplanes, automobiles, ships, and trains. In these engines, the fuel is usually mixed with air and burned. When a fuel burns, it gives off a large amount of heat. This heat is used to drive the engine (see ENGINE). The heat can also be used for warmth or to drive other kinds of machines. For example, the heat can be used to turn water into steam. The steam may then be used to drive a turbine. The turbine, in turn, can drive a generator to produce electricity. In this way, the energy of a fuel can be converted into electrical energy (see GENERATOR, ELECTRICAL; TURBINE).

*Heat value* is the name given to the amount of heat energy a certain quantity of fuel can produce.

## NUCLEAR FUEL RODS

Stainless steel tubes, such as the ones shown here, are used to hold pellets of uranium at nuclear power plants. Radioactive materials, such as uranium, contain much more energy than regular solid fuels such as coal.



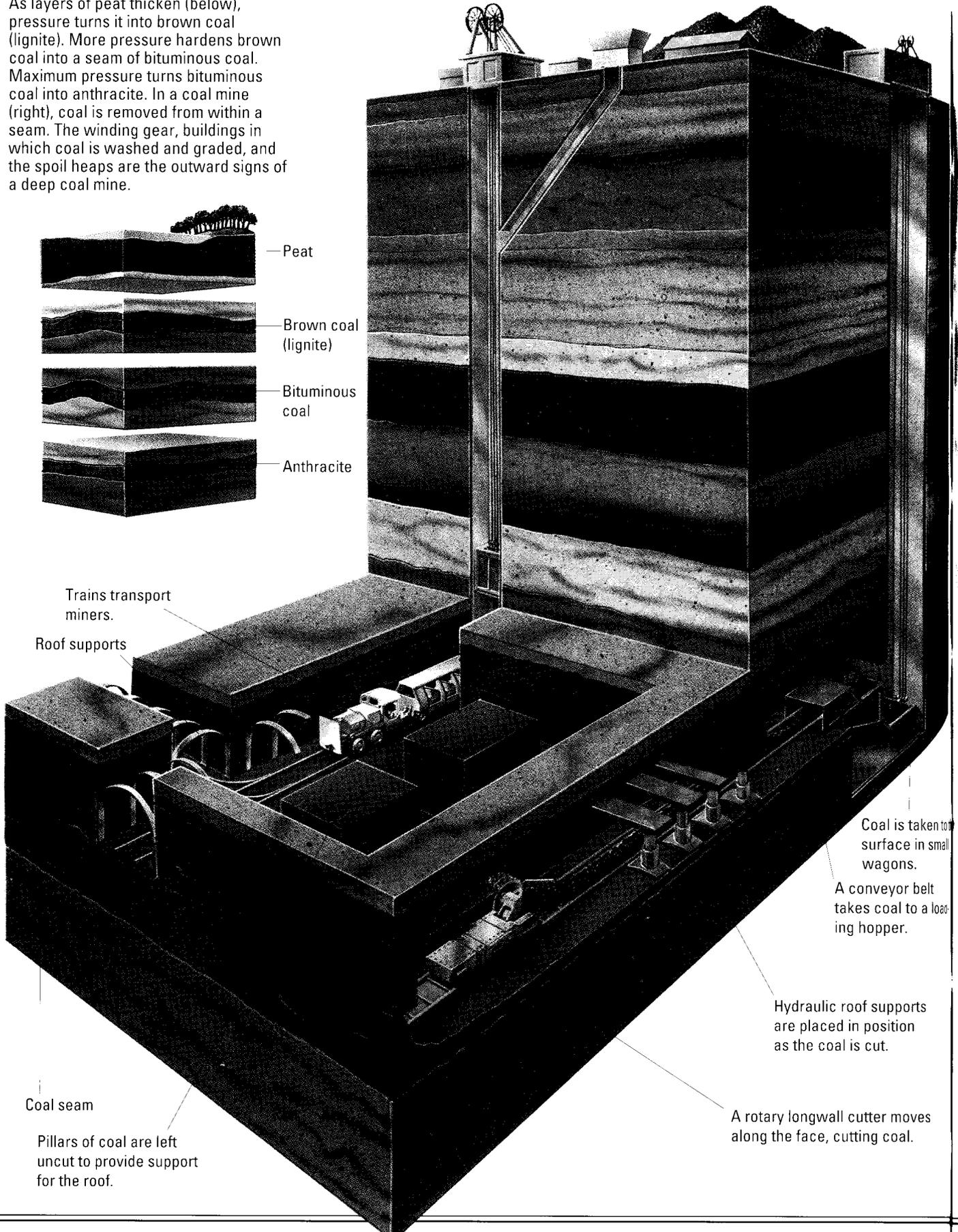
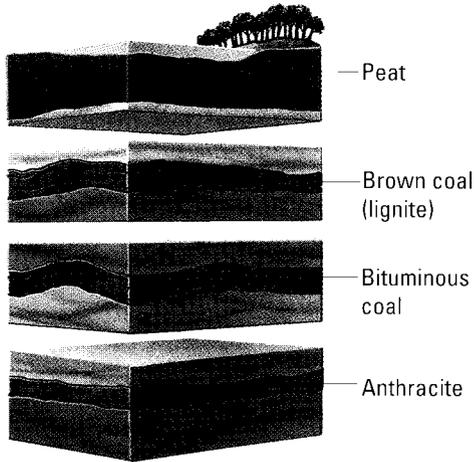
The heat value of a fuel depends on its chemical makeup and on the amount of water and ash it contains. For example, peat has more water than coal, so it has a lower heat value than coal. Peat is a soft substance with fibers that grows in bogs (wet, spongy areas) in several parts of the world (see COAL).

There are many different kinds of fuels. They can be divided into solid fuels, liquid fuels, and gaseous fuels.

**Solid fuels** Solid fuels include wood, coal, coke, and peat. Wood has been used as a fuel for thousands of years. It was the first fuel to be used by people. Few countries rely on it as a fuel today. Coal is a much more important fuel. It, too, has been used for many years. It was used for smelting metals by

**COAL FORMATION AND MINING**

As layers of peat thicken (below), pressure turns it into brown coal (lignite). More pressure hardens brown coal into a seam of bituminous coal. Maximum pressure turns bituminous coal into anthracite. In a coal mine (right), coal is removed from within a seam. The winding gear, buildings in which coal is washed and graded, and the spoil heaps are the outward signs of a deep coal mine.



Trains transport miners.

Roof supports

Coal is taken to surface in small wagons.

A conveyor belt takes coal to a loading hopper.

Hydraulic roof supports are placed in position as the coal is cut.

Coal seam

Pillars of coal are left uncut to provide support for the roof.

A rotary longwall cutter moves along the face, cutting coal.

400 B.C. (see SMELTING). Coke is made by heating coal without any air being present. Peat is used as a fuel only in a few countries, such as Ireland. Paraffin and tallow are two other kinds of solid fuel. They are used mainly for candles.

**Liquid fuels** Most liquid fuels are obtained from petroleum. An example is gasoline, which is used in automobiles. Liquid fuels can also be obtained from coal. They are given off when coal is converted into coke. Sometimes, alcohol is used as a liquid fuel. Usually, it is mixed with gasoline before being used. A mixture of petrol and alcohol, used as a fuel, is called gasohol. Oils obtained from vegetables and animal fat were once used for fuel. However, they burn with a very smoky flame. They are also rather expensive and are no longer used for fuel (see GASOLINE; PETROLEUM).

**Gaseous fuels** The most important gaseous fuels are natural gas, coal gas, and water gas. Natural gas occurs in large deposits under the ground. It is a very convenient source of fuel and is widely used. Coal gas is a mixture of gases that are given off when coal is converted into coke. Natural gas has largely replaced coal gas as a fuel for homes and factories. As natural gas supplies continue to decrease,

however, coal gas may again be used more and more. Water gas is a mixture of hydrogen and carbon monoxide. It is made by passing steam over red-hot coke. It is used in industry. Butane gas is a convenient source of fuel. It can be obtained from natural gas. Butane is compressed into containers and used as a portable source of fuel, especially by campers. Fuel gas can also be made by treating animal manure with anaerobic bacteria, which digest the manure in the absence of oxygen. A by-product of the process is methane gas. Gaseous fuels are very clean. They do not produce much smoke or ash when they burn (see BUTANE; COAL GAS).

**Nuclear fuel** Industrialized countries burn enormous amounts of coal, gas, and oil. The earth's supply of these fuels may soon be used up. Scientists are now looking for other sources of fuel. One alternative source that is currently being used on a large scale is the metal uranium. One isotope (form) of uranium atoms can be split into two lighter atoms, with the release of larger amounts of heat energy.

The energy in fuels such as coal, gas, and oil is chemical energy. Chemical energy comes from the bonds that hold the atoms together. Radioactive

#### FUEL FROM OIL

Petroleum (crude oil) is a source of several liquid fuels, such as gasoline and kerosene. Waste gas is being burned off at an oil well in Saudi Arabia (right).



fuels contain nuclear energy (see NUCLEAR ENERGY; RADIOACTIVITY). This energy comes from the force that holds an atom's nucleus together. The bonds that hold the nucleus together are stronger than the bonds that hold atoms together. Therefore, radioactive materials contain much more energy than substances such as coal. This energy can be released in a process called fission (see FISSION). However, fission has disadvantages, and even uranium supplies will not last forever. Scientists are trying to control thermonuclear energy, or energy released by fusion (see FUSION). This is the energy that makes the sun and other stars shine. Thermonuclear energy could be obtained from hydrogen. Water is a compound of hydrogen and oxygen, and there are huge amounts of water on the earth. Hydrogen could be extracted from this

#### GEOTHERMAL ENERGY

The heat in water and steam from below the ground, a form of geothermal energy, can be used as an alternative to nonrenewable solid or liquid fuels. This geothermal power station is at Wairakei, on North Island, New Zealand.

water, providing a virtually unlimited supply of energy. Another energy source that is renewable is biomass. Biomass, which includes wood and aquatic plants, can be burned to produce heat or converted into methane for gasoline (see BIOMASS).

**Alternative energy** The sun gives off large amounts of energy as heat and light. This energy is called solar energy. It is possible to convert solar energy into electrical energy. So far, this has only been done on a very small scale. Geothermal energy is energy produced deep within the earth. In a few places, pipes buried at great depths bring superheated steam to the earth's surface to drive turbines to generate electricity. In Iceland and New Zealand, hot water from geothermal wells is used to heat buildings. Tidal power and wind power are other possible energy sources. With many of these alternatives, however, there are difficulties to overcome before they can be used on a large scale.

*See also* ENERGY.



**FUEL CELL** Fuel cells are devices used to generate electricity. They do this by converting the energy given off in a chemical reaction into electrical energy. Batteries also obtain electricity from chemical reactions (see BATTERY; ELECTRICITY). However, batteries run down after a while and have to be replaced or recharged. Fuel cells do not run down as long as they are supplied with fuel.

The first fuel cell was built in 1839. It used the gases hydrogen and oxygen as fuels. Hydrogen and oxygen combine to form water. When they combine, they give off energy. The fuel cell converts this energy into electricity. It works on the opposite principle to electrolysis. In electrolysis, an electric current is passed through a liquid. If the liquid is

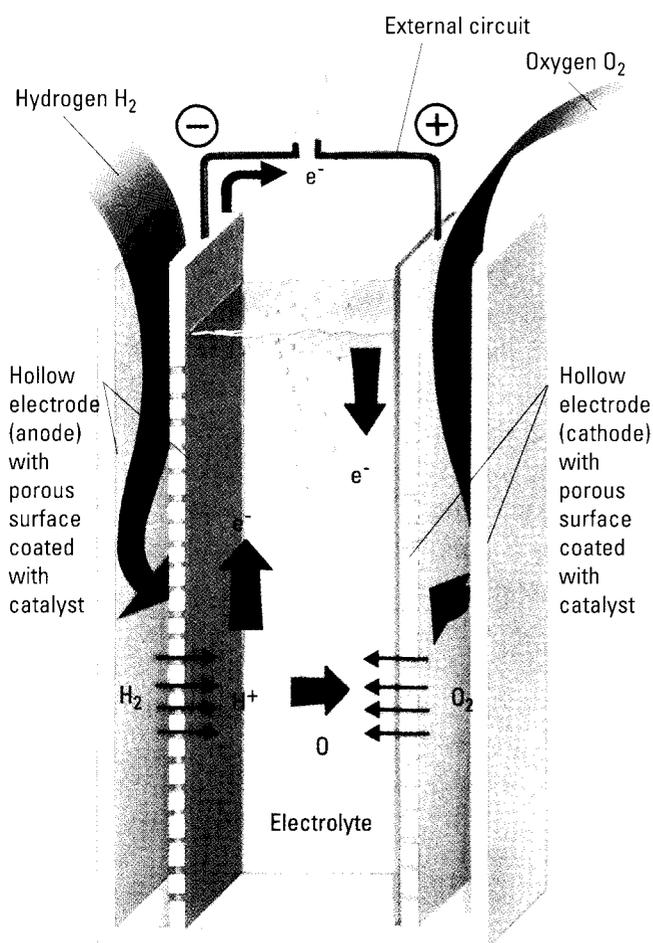
water, the current causes the water to break down into hydrogen and oxygen (see ELECTROLYSIS).

Modern fuel cells use liquid hydrogen and liquid oxygen. They can be stored in a much smaller space than gaseous hydrogen and oxygen. Another advantage is that the liquids can be made much purer than the gases. Scientists are experimenting with different kinds of fuel cells.

Fuel cells have been used as a source of power in manned spacecraft. For example, they were used in the Apollo missions (see APOLLO PROJECT). The crew used the water produced by the fuel cell for drinking. Fuel cells are also used to power lamps in buoys at sea. Electric cars have been designed so that they can be powered by fuel cells. Electric cars powered by fuel cells do not produce pollution.

**FULCRUM** (fŭl' krəm) The fulcrum is the point of support at which a lever turns (see LEVER). On a seesaw, for example, the fulcrum is at the center of the seesaw. With a crowbar, the fulcrum is usually close to the weight or load being lifted. This allows the crowbar to increase the force being applied to lift the weight.

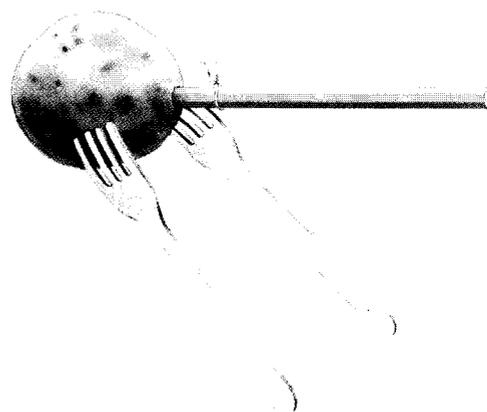
See also MACHINE, SIMPLE.



#### FUEL CELL

This diagram shows the simplest kind of fuel cell containing a liquid electrolyte (a material that conducts electricity). Hydrogen and oxygen gases are fed into the cell. On passing the catalyst (a substance that causes or speeds up a chemical reaction), the hydrogen forms positively charged hydrogen ions, H<sup>+</sup>, and negatively charged electrons, e<sup>-</sup>. The electrons flow through an external circuit, making an electric current. The hydrogen ions move to the opposite electrode.

#### ACTIVITY *Finding the fulcrum*



Cut a slice of raw potato or modeling clay about 1 in. [2.5 cm] thick. Push the pointed end of a pencil into the slice. Then add two forks as shown in the diagram. Suspend the pencil with a thread or string. The fulcrum is the point where the thread supports the pencil. Adjust the position of the fulcrum until balance is obtained.  
**Caution: Be careful when cutting the potato and pushing the pencil and forks into it.**

**FULTON, ROBERT** (1765–1815) Robert Fulton was an American engineer. He was born in Little Britain, Pennsylvania. He began work as a portrait painter. In 1786, he went to London, England, to study with the American painter Benjamin West. While he was in England, he became interested in the development of canals. He could not find anyone else in England who was interested in his ideas and inventions for canals, so he went to France in 1797.

There, Fulton developed ideas for a torpedo, but they were not used. The French Emperor Napoleon asked Fulton to design a submarine. This was built in 1800 and was named the *Nautilus*. It was designed to attach an explosive charge to the wooden hull of an enemy ship. The instruments on board the *Nautilus* were operated by hand while the submarine was underwater. The crew submerged the submarine by letting water into its tanks. One crew member turned a wheel to drive the propeller that moved the submarine underwater. To make the *Nautilus* surface, the crew had to pump the water out of the tanks. The submarine had a sail for traveling on the surface of the water. The *Nautilus* was very hard to operate and was never used in battle.

Fulton is most famous for building steamships. He built his first experimental steamship in Paris, France, in 1803. In 1806, Fulton returned to America. His first successful steamship was called the *Clermont*. It was launched on the Hudson River in 1807 and made the 150-mile trip from New York to Albany in thirty-two hours.

**FUNGICIDE** A fungicide is a type of chemical pesticide used to kill harmful types of fungi (plural of *fungus*) (see FUNGUS; PESTICIDE). Fungi can cause

many diseases in plants, human beings, and other animals. Large amounts of crops are destroyed each year by fungi, such as mildew, mold, and smut. Some seeds become infected with fungi, which prevent them from germinating (see GERMINATION). Ringworm is the name of a group of common and very contagious human diseases caused by fungi. Plant diseases caused by fungi are usually controlled by spraying the crops with fungicides. Human diseases caused by fungi can be treated with special fungicidal ointments and powders. Antibiotics are sometimes used to kill fungi in humans. Unfortunately, antibiotics also kill helpful bacteria, which usually keep the fungi under control (see ANTIBIOTIC).

Fungicides are either inorganic or organic. *Organic* refers to a compound that contains the element carbon. (A compound is a chemical substance made up of two or more elements.) Organic fungicides, such as formaldehyde, are made of poisonous compounds of carbon, hydrogen, and oxygen. Inorganic fungicides use compounds of metals, such as copper and mercury, to kill fungi. Some natural substances are also used as fungicides. Creosote, obtained from distilling wood or coal tar, has been painted on wood that is exposed to water. This helps prevent dry rot, a fungus-caused disease of the wood. However, use of creosote is now restricted because it may cause cancer.

It is important that fungicides kill fungi but do not harm plants or animals. Because many fungicides are poisonous to plants or animals, they are often used in controlled, limited areas. Most foods that have been sprayed with fungicides must be washed carefully before being eaten.

See also HERBICIDE; INSECTICIDE; PESTICIDE; POISON.

#### FUNGICIDE

Farmers may spray their crops with fungicides to control some plant diseases. Food that has been sprayed should be washed carefully before it is eaten.

