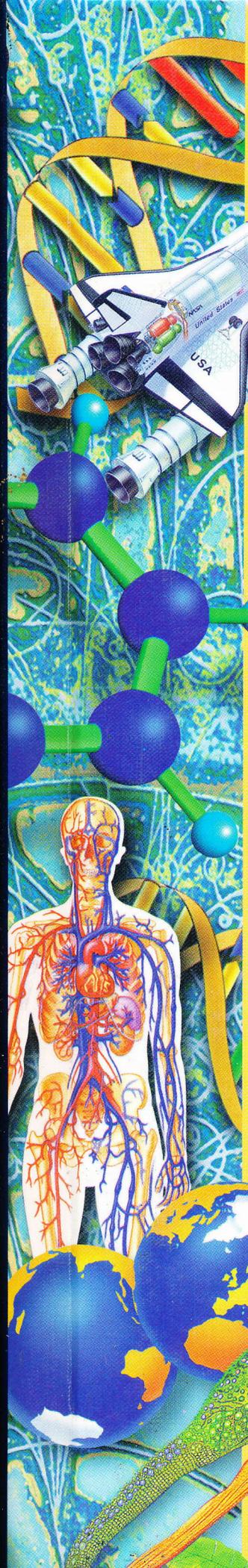


Raintree Steck-Vaughn

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HAB – IMM



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HABITAT

H

The habitat of a plant or animal is where it lives. The habitat has particular physical conditions, such as temperature, soil, and moisture, and also has its own special type of vegetation. Mountaintops, deciduous forests, seashores, deserts, tundra, prairies, and lakes are all major habitats. Each is inhabited by a wide range of animal and plant species that have become adapted to the particular conditions of the habitat. Many migratory birds and other animals, such as frogs and toads, roam widely for part of the year and then return to their primary habitats to breed. On

FOREST HABITAT

Koalas feed only on the leaves of the Australian eucalyptus tree. As a result, they never stray from their forest habitat.

the other hand, there are many very specialized plants and animals that can survive only in one very limited habitat. Eelgrass, for example, which is not a true grass, grows in shallow coastal waters and needs a muddy bottom for its roots. It is limited to a narrow area just below low-tide level. It cannot survive in the air, so it cannot grow above low-tide level. It also cannot grow in deeper water because the mud cuts off the sunlight that the plant needs to make food. Australia's famous koala is also severely limited. It feeds entirely on the leaves of certain eucalyptus trees and cannot survive outside the eucalyptus forests (see EUCALYPTUS; KOALA).

All the inhabitants of a particular habitat make up a community in which each species fills its own ecological niche. This niche is not simply a place to live but a way of living. In other words, the ecological niche is the role played by each species in its community. Two species cannot live together in the



H A B I T A T

same place if they have exactly the same requirements because they would compete with each other. One species would eventually have some advantage over the other. However slight the advantage might be, the species with the advantage would gradually replace the other, less well-adapted species. So, although two species may occupy the same habitat, they can never share the same ecological niche. The hawk and the owl provide a simple example. They often occupy the same habitat and eat the same kinds of food. They are not in competition, however, because hawks feed by day and most owls feed at night.

Many different kinds of plants and animals live in each community. Within the major communities there are many smaller communities. The leafy

canopy of a deciduous forest is one such division, and the decaying leaf litter on the forest floor is another. Each supports a very different group of animals. These divisions can be divided into even smaller habitats that are sometimes known as microhabitats. A clump of moss, the space under a piece of loose bark, and a decaying bird's nest are all examples of such microhabitats. Even a single leaf can be regarded as a microhabitat, for it can support a surprising number of other organisms. Mites and gall wasps, for example, can cause the formation of hundreds of pimplelike or buttonlike galls on a leaf. Leaf-mining insects can be tunneling through the leaf tissue at the same time. Fungi, bacteria, and viruses can also invade the leaf tissues.

PROJECT 73

UNUSUAL HABITAT

Some plant species survive in the most unlikely habitats. This flower is growing among fallen rocks in a stone quarry, where there is hardly any soil.



HACKBERRY

Hackberry trees produce edible fruits and have soft yellow-colored wood. The tree is a member of the elm family.



HACKBERRY The hackberry tree is common in the central and eastern United States. It is a medium-sized tree, growing to heights of 80 ft. [24 m]. Hackberry leaves are simple and pear-shaped. The tree produces small, dark, purple edible fruit in the fall. This fruit is a popular food of many birds, squirrels, and other rodents. The wood of the hackberry is sometimes cut for furniture and boxes. However, the trees are often made useless by diseases.

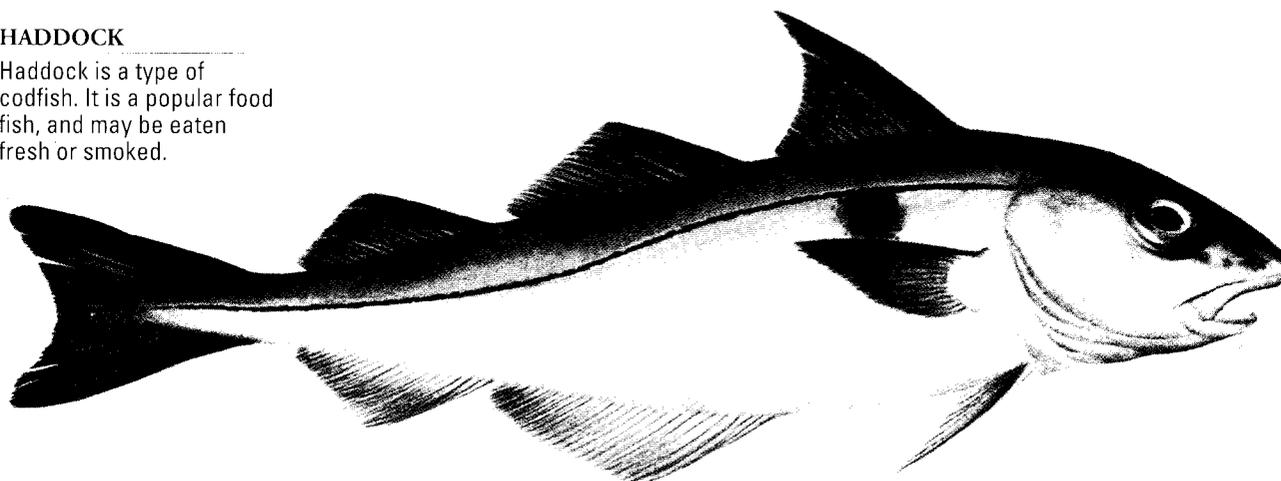
HADDOCK A haddock is a saltwater fish that belongs to the cod family Gadidae. It is found in the North Atlantic Ocean. Haddock resemble cod, having a brownish color and three fins along the back.

Haddock feed on worms, crustaceans, and other invertebrates on the ocean bottom (see CRUSTACEAN; INVERTEBRATE). Haddock may sometimes reach weights of 24.5 lb. [11 kg]. This fish is an important food for people.

See also COD.

HADDOCK

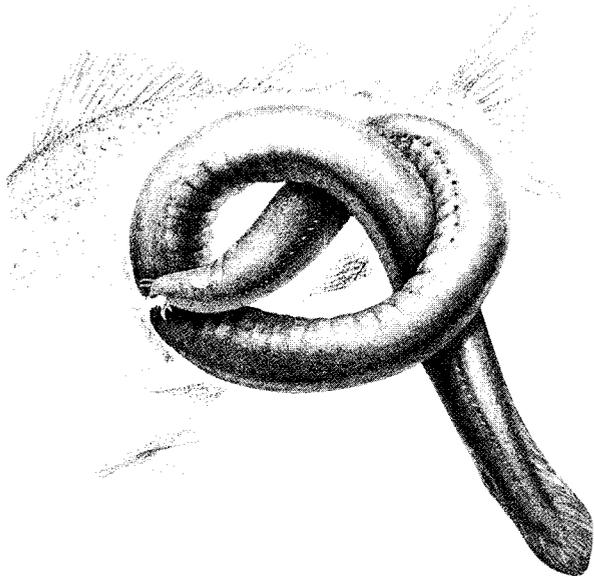
Haddock is a type of codfish. It is a popular food fish, and may be eaten fresh or smoked.



HAFNIUM (häf'nē əm) Hafnium is a chemical element. Hafnium absorbs neutrons strongly. Neutrons are the subatomic particles that bring about nuclear fission in a nuclear reactor (see NUCLEAR FISSION). Rods made of hafnium are used in nuclear submarines to control the rate of energy production in the reactor. Pushed into the core of the reactor, the hafnium rods absorb neutrons and slow down the reactor (see NUCLEAR POWER).

In nature, hafnium is always found combined with zirconium, a chemical element it closely resembles. The symbol for hafnium is Hf and its atomic number is 72. Hafnium melts at about 4,404°F [2,227°C]. Its relative atomic mass is 178.49. Hafnium was discovered by Dirk Coster and Georg von Hevesy in 1923, in Copenhagen, Denmark. The Latin name for Copenhagen is *Hafnia*, so the element is named for the place where it was discovered.

HAGFISH A hagfish is a saltwater fish that belongs to the family Myxiniidae. Two species live in the Pacific Ocean off North America. One species lives in the Atlantic Ocean off North America. Hagfish are among the most primitive living vertebrates (animals with backbones). They feed primarily on dead or almost-dead fishes. They penetrate the bodies—first eating out the intestines and then the flesh, leaving nothing but skin and bones. They have rasplike tongues, but no jaws. Hagfish may reach lengths of 24 in. [60 cm]. Their bodies produce large amounts of slimy mucus.



HAGFISH

A hagfish can tie itself into a knot to help it burrow into its prey.

HAHN, OTTO (1879–1968) Otto Hahn was an important German atomic scientist. In 1938, he was working with Fritz Strassmann on making radioactive substances from uranium (see RADIOACTIVITY). They used neutrons to increase the radioactivity of the uranium. A surprising thing happened. Hahn found that some much smaller atoms were coming out of the experiment. He thought this was so strange that he hardly dared publish his discovery. The experiment was published in 1939 by Lise Meitner (see MEITNER, LISE). It was, in fact, the discovery of nuclear fission. Hahn received the Nobel Prize for chemistry in 1944.

See also FISSION; NEUTRON.

HAIL Hail is pellets of ice that fall during some thunderstorms. Hail forms when water droplets are forced upward by the updraft of a thunderstorm cloud, or thunderhead (see CLOUD). The water droplets may reach an area of the thunderstorm where the temperature is below the freezing point, 32°F [0°C]. If this happens, the water droplets become coated with ice and fall back down to a warmer area of the thunderhead. Here, they acquire a new coat of water, and the updraft carries them up to the subfreezing region again. This process continues until the updraft of the thunderstorm is cut off, and the contents of the clouds spill out in the form of a downpour. If the frozen water droplets are large enough so as not to melt on their way down, they reach the surface in the form of hail.

Most hailstones are not much larger than a pea. Some hailstones, however, have been recorded that are the size of potatoes. Large hailstones can cause severe damage to crops and to property.



HAIL

Hailstones are round chunks of ice that form when raindrops freeze in a thundercloud. Large hailstones can batter plants and knock them down.

HAIR

Hair is the material that grows out of the skins of mammals (see MAMMAL). The thickness, length, and color of hair vary widely. Hair may grow only on certain parts of the body, as it does in human beings, or it may cover most of the body, as in animals such as sheep.

Some kinds of hair have special names. Fur is the soft, dense hair that covers the body of animals such as cats and rabbits. Wool is the long, curly hair on animals such as sheep. Bristles are the short, stiff hairs on animals such as hogs. Quills are sharp, spiny hairs on animals such as porcupines.

The main content of hair is keratin (see KERATIN). Claws, nails, hooves, reptile and fish scales, and the feathers of birds also consist of keratin. Each hair is made up of a root and a shaft. The root is a soft, thickened bulb at the base of the hair. The shaft is the rest of the hair. Each hair is anchored in a follicle, a tiny sac below the surface of the skin. At the very bottom of the follicle is the papilla. The papilla is a tiny bump where new hair grows rapidly. The papilla contains an artery (blood vessel) that nourishes the root of the hair.

Hair grows by forming new cells at the base of the root. As new cells form around the papilla, the old

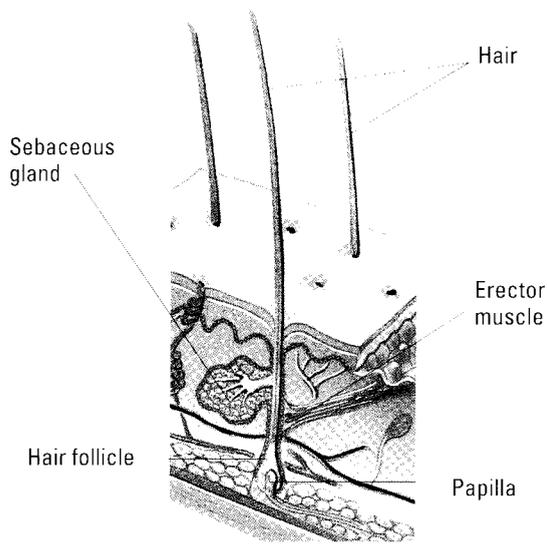
ones are pushed away and die. The new cells force the rod of dead cells out of the follicle. In this way, old cells from the root become part of the shaft. In most cases, only one hair grows from each follicle. Hair continues to grow as long as the papilla provides nourishment for new cells. Many factors, such as age, diet, and condition of the skin, influence the activity of the papilla. Climate and seasonal change also affect the production of hair. During hot weather, many mammals shed a large amount of hair. During cold weather, they tend to gain a thicker covering of hair.

The color of hair comes from melanin. Melanin is a brown or black pigment (colored substance) deposited in the hair cells as they form in the root. The presence or absence of melanin is responsible for hair color (see PIGMENTATION). As people grow older, pigment is no longer deposited in the newly forming hair cells. The hair gradually becomes gray or white. Some animals in snowy areas shed the pigmented hairs of their brown summer coats in

HAIR FOR WARMTH

The hairs in a polar bear's fur grow close together. The resulting thick coat keeps the animal warm in the freezing climate of the Arctic.





PARTS OF A HAIR

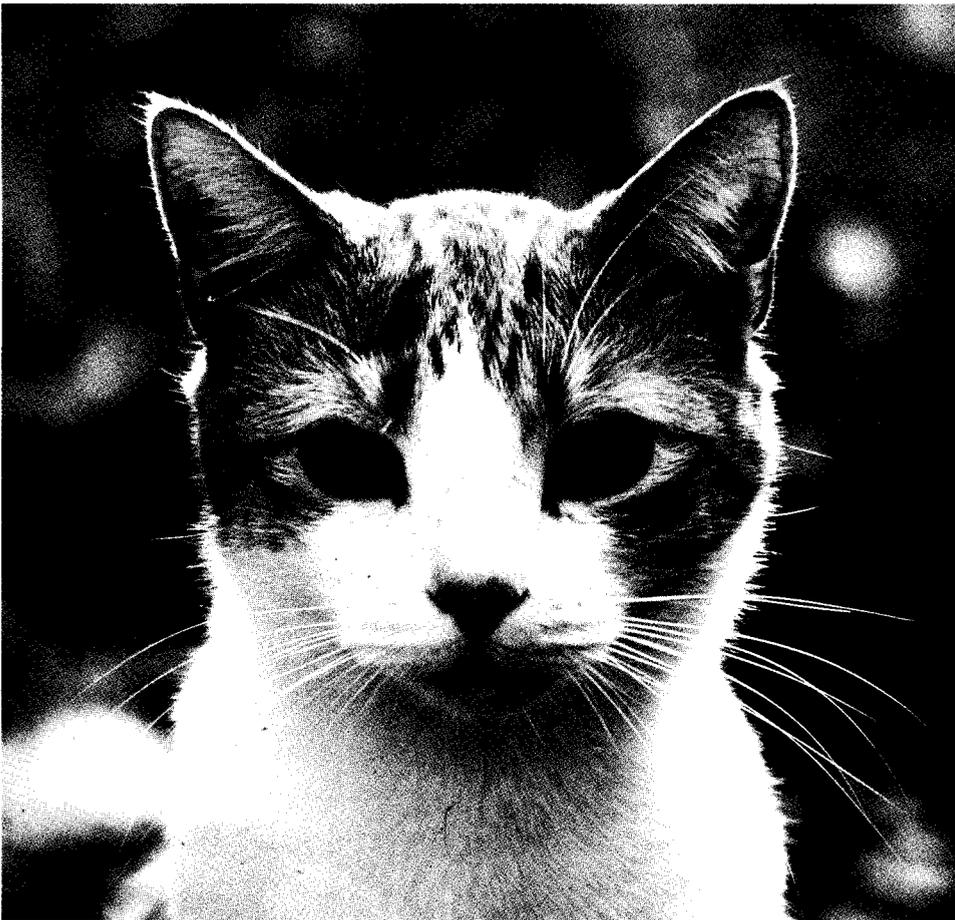
The root of a hair forms a bulb inside a follicle, below the surface of the skin. The shaft of the hair is made up of dead cells pushed outward by new cells formed in the follicle. Tiny muscles can pull on the root to make the hair "stand on end" when it is cold.

late fall. They gain winter coats of white. This gives them a natural camouflage against the snow (see CAMOUFLAGE). Baldness results when the hair on a

person's scalp is no longer replaced after it falls out. Some diseases can cause baldness. However, baldness is determined largely by heredity (see HEREDITY).

Hair provides warmth, protects the skin, and responds to touch. Hair retains warmth by trapping a layer of air next to the skin. In a cold wind, a person's body hairs "stand on end." Tiny muscles pull on the roots of the hair to increase the thickness of the insulating layer of air. Hair also protects animals by cushioning their body against blows. It also, as mentioned, can provide a camouflaging coloration. Many mammals have tactile hairs, such as cat's whiskers, that are very sensitive to touch. These hairs help the animals feel their way through narrow places or in dark places.

People make wide use of the hair of many animals. For example, the wool of sheep is spun into yarn for garments and blankets, and rabbit fur is made into felt. Manufacturers also use animal hair to make carpets, stuffing for upholstery, bristles for brushes, and many other products.



SENSITIVE HAIRS

A cat's whiskers are long hairs that are sensitive to touch. They help the cat to feel its way through narrow spaces in the dark.

HALF-LIFE A half-life is the length of time it takes for half the atoms of a particular radioactive substance to decay. For example, suppose 0.22 lb. [100 g] of a certain isotope has a half-life of sixteen years. This means that in sixteen years, 0.11 lb. of that 0.22 lb. will have decayed. In another sixteen years, 0.055 of the remaining 0.11 lb. will have decayed, and so on.

This happens because the atoms of radioactive isotopes are unstable. This means that the atoms decay, or break down, to make simpler atoms. When such atoms break down, they give off radioactivity. The breaking down of any of these atoms is by chance. In other words, the breakdown of atoms has no pattern or system (see *ATOM*; *ISOTOPE*; *RADIOACTIVITY*).

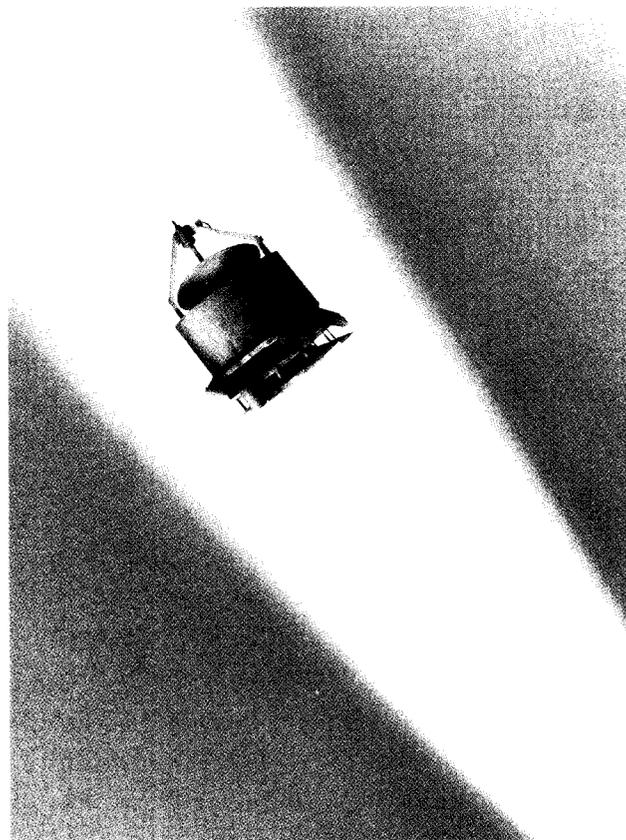
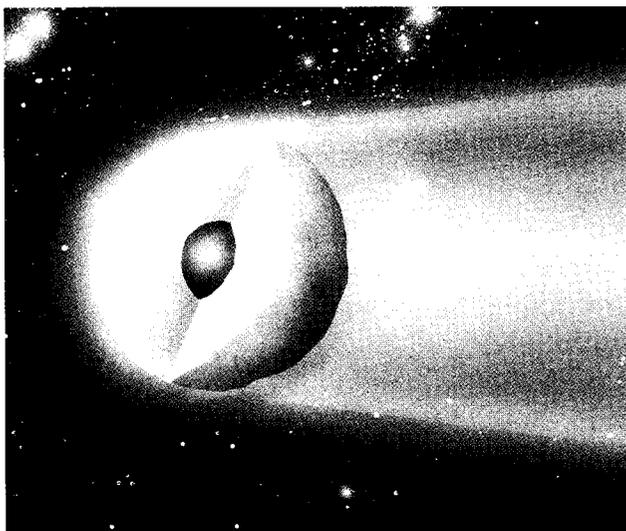
A certain mass (amount) of an isotope at first decays quickly. It contains many unstable atoms. When many of these atoms have decayed, the isotope decays less quickly. It contains fewer unstable atoms. However, the chance of any unstable atom's decaying remains the same.

Stating an isotope's half-life is a useful way to show the rate at which the isotope decays. The half-life of some isotopes is less than one millionth of a second. Other isotopes have half-lives of many millions of years.

HALIBUT A halibut is a flatfish belonging to the family Pleuronectidae. It is the largest of the flatfishes (see *FLATFISH*). Some halibut may reach lengths of about 12 ft. [3.65 m], though most of those caught are much smaller. Halibut feed off other fishes swimming close to the sea floor. Other flatfishes feed strictly on the sea floor. There are three North American species of halibut: the Atlantic halibut, the Pacific halibut, and the much smaller Greenland halibut from the northern parts of both oceans. The halibut is an important food for people.

HALLEY'S COMET Halley's comet is a famous, bright comet that passes through the solar system every seventy-six years. It is named for the English astronomer Edmond Halley, who first calculated the comet's orbit, or path, around the sun.

When Halley's comet appeared in 1910, the head of the comet was brighter than the brightest star, and its tail stretched across more than half of the horizon. Halley's comet last appeared in 1986. It is supposed to make its next appearance in 2061.



HALLEY'S COMET

Halley's comet, shown as a cutaway (top), has a core made of frozen dust particles and ice, surrounded by a cloud of cold vapor. In 1986 it was photographed by the *Giotto* spacecraft (bottom), which passed through the comet's tail.

HALLUCINATION (hə lōō' sə nā' shən)

People are said to have hallucinations when they see or hear things that do not really exist. People may have hallucinations if they take certain drugs or drink too much alcohol, or if they are mentally ill (see MENTAL ILLNESS). Being sick with a fever, living away from other people for a long time, and being very tired may also cause hallucinations.

HALLUCINOGEN (hə lōō' sə nə jən)

A hallucinogen is a drug that causes the user to experience hallucinations, or illusions (see HALLUCINATION). This means the drug user sees or hears things that do not really exist. For example, the person may see colors, shapes, or even people that are not really there.

Hallucinogens have been used for centuries in many parts of the world as part of religious ceremonies and to enhance meditation. In the United States, it is illegal to manufacture, distribute, or possess hallucinogens except for government research.

Hallucinogens include lysergic acid diethylamide (LSD), mescaline, and psilocybin. The experiences that these and other hallucinogens produce depend on the drug, the amount used, the environment in which it is used, and the user's personality. Some users claim hallucinogens provide pleasant experiences, while others say the experiences are frightening. The experiences are referred to as "trips." People under the influence of hallucinogens may harm themselves or others. The experiences may also have lasting effects on users, such as prolonged depression, recurring hallucinations, or even mental illness (see DEPRESSION; MENTAL ILLNESS).

Hallucinogens are not addictive (see ADDICTION). However, some users become psychologically dependent on hallucinogens and develop an increased tolerance to them. This means they must use larger and larger amounts of the drugs to achieve the same effects.

HALOGEN The halogens are a group of elements that have similar chemical properties. For example, they are all nonmetallic. They are very reactive elements. They have a strong and

**HALOGEN**

Iodine is the heaviest of the halogens. It is also the only halogen that is a solid at ordinary temperatures. It consists of deep violet crystals (above) that look almost black.

unpleasant smell (see ELEMENT). The four main halogens are fluorine (chemical symbol F), chlorine (Cl), bromine (Br), and iodine (I). A fifth element, astatine (At), is grouped with them, but it is rare, radioactive, and very unstable. It has a half-life of less than a minute (see HALF-LIFE).

Fluorine and chlorine are greenish yellow gases. Bromine is a brown liquid. Iodine forms purplish black crystals. They are all corrosive substances (see CORROSION). With metals, they form compounds called halides. Sodium chloride (common salt) is the most common halide. With hydrogen, the halogens form strong acids, such as hydrochloric acid. Because they are so reactive, they are always found as compounds. Fluorine is the most reactive halogen, and iodine the least reactive.

See also CHEMICAL REACTION; HALON.

HALON Halons are chemicals made by combining hydrocarbons with halogens. Halogens are a group of elements that have similar chemical properties. The four main halogens are bromine, chlorine, fluorine, and iodine. Hydrocarbons are compounds that contain only the elements hydrogen and carbon (see COMPOUND; HALOGEN; HYDROCARBON). Halons have the ability to displace air. That is, they remove oxygen from the air. They are easily compressed, which makes them good propellants. They are also nontoxic (nonpoisonous). Because of these properties, Halons have been used in some fire extinguishers.

Halons have been found to be harmful to the environment. For example, when fire extinguishers are used, Halons drift into the earth's upper stratosphere (see ATMOSPHERE). Once there, the halogens are freed by the sun's ultraviolet rays. They then destroy the ozone layer (see OZONE LAYER). The ozone layer protects organisms from the harmful effects of the sun's ultraviolet rays. Because of their harmful effects, the U.S. government has ordered that Halons be phased out by the year 2000 as part of the Clean Air Act.

HALOPHYTE (hāl' ə fīt') Halophytes are plants that grow in salty soil, usually on coastal dunes and salt marshes, although some can be found far inland. Their cells and tissues have very concentrated sap, with a high osmotic pressure that helps them to absorb water from the salt-laden soil (see OSMOSIS). Many of the plants also have features that help them to conserve their hard-won water. They often have fleshy, waxy leaves and hairy stems. In this respect they resemble many desert-



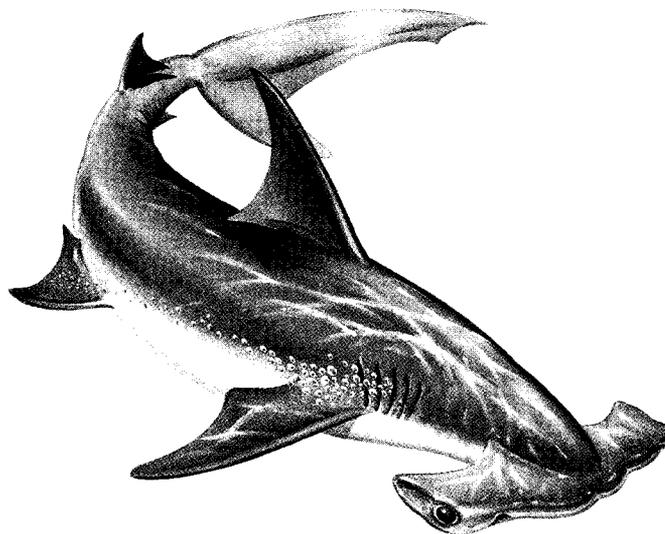
HALOPHYTE

Sea lavender is a halophyte—that is, a plant that can grow in salty soil.

living plants. Common halophytes include saltwater cordgrass, asparagus, and members of the goose-foot family (see GOOSEFOOT FAMILY).

HAMMERHEAD SHARK A hammerhead shark is a saltwater fish that belongs to the family Sphyrnidae. It is called *hammerhead* because its head is shaped like a hammer, with its eyes at the ends of the hammerlike sides. Apart from its strange-looking head, the hammerhead shark is similar to other sharks. It prowls shallow, warm seas, sometimes wandering into cooler regions in summer. It eats invertebrates (animals without backbones) and other creatures such as flounders, skates, and rays that live on the bottom of the ocean. A hammerhead is one of the few sharks that is known to attack humans. There are five species found off North America. All species are found in the Atlantic Ocean. Two of the species are also found in the Pacific Ocean.

See also SHARK.



HAMMERHEAD SHARK

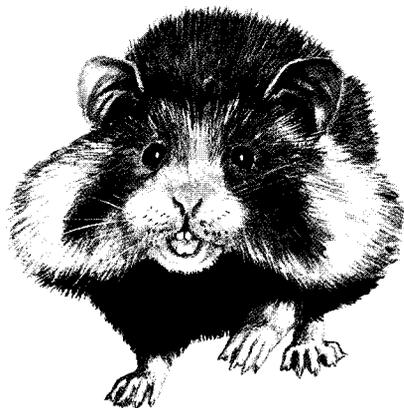
The hammerhead shark is a fierce hunter of animals that live near the bottom of warm seas. It has been known to attack humans.

HAMSTER Hamsters are small rodents of the family Cricetidae. All hamsters have pouches in their cheeks where they can put food until they find a place to store it. Hamsters are native to Eurasia. The two best-known species are the common or European hamster and the golden hamster.

The common hamster is about 8 to 12 in. [20 to 30 cm] long and lives in burrows. It feeds at night, eating mostly vegetable matter and grain. It also may eat some insects and frogs. The common hamster is considered a pest by farmers.

The golden hamster is about 6 to 8 in. [15 to 20 cm] long and weighs about 4 to 5 oz. [110 to 140 g]. The golden hamster is a popular pet. Although it was originally described in 1839, little was known about the golden hamster until 1930, when a female and twelve young were found in Syria, in the Middle East. All domesticated golden hamsters have descended from this single litter.

See also RODENT.



HAMSTER

The common hamster can carry a great deal of food in its cheek pouches.

HAMSTRING The hamstrings are a group of powerful muscles at the back of each of the thighs in human beings. They are attached at one end to the hip bone and at the other end to the two bones in the lower half of each leg. When the hamstrings contract (shorten), they cause the knee to bend. This is just one of the movements that takes place during walking.

HARDNESS One of the methods used to identify minerals is the hardness test. This was devised by Friedrich Mohs, a German mineralogist. In 1822, Mohs drew up a list of common minerals. He placed the names of the minerals in order of hardness. Each mineral in the scale can scratch all other minerals with a lower number. The list is known as Mohs scale.

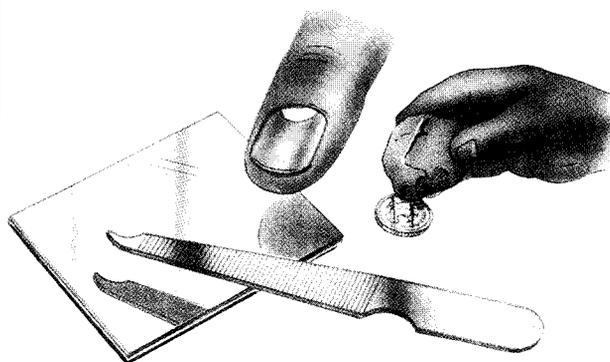
MOHS SCALE

Hardness	Mineral	Simple hardness test
1	Talc	Crushed by a fingernail
2	Gypsum	Scratched by a fingernail
3	Calcite	Scratched by a copper coin
4	Fluorite	Scratched by glass
5	Apatite	Scratched by a penknife
6	Feldspar	Scratched by quartz
7	Quartz	Scratched by a steel file
8	Topaz	Scratched by corundum
9	Corundum	Scratched by diamond
10	Diamond	Hardest natural substance

Mineralogists often carry around a box containing pieces of the above minerals for testing samples in the field. For example, if they find a mineral that is scratched by feldspar but not by apatite, its hardness lies between 5 and 6 on the hardness scale.

Hardness of metals is often tested in industry. When materials must be accurately tested, as in the manufacture of tools, machinists use an instrument called a sclerometer. The sclerometer registers the force required to dent or scratch the material with a stylus (pointed instrument) of diamond or borazon (a compound of boron and nitrogen).

ACTIVITY *Testing hardness*



If you do not have a full set of hardness minerals, you can use everyday objects to test hardness. Try it yourself. Your fingernail has a hardness of about 2.5, a coin is about 4, glass is about 5.5, and a steel file is about 7.5. If a mineral can scratch a coin, but is scratched by a piece of glass, then its hardness must be between 4 and 5.5.

Caution: Handle the glass very carefully.

HARE A hare is a small, furry mammal with ears and legs that are longer than those of a rabbit (see MAMMAL; RABBIT). Both hares and rabbits belong to the family Leporidae. Hares may grow to a length of 28 in. [70 cm] and a weight of 11 lb. [5 kg]. They are usually brown, gray, or white in color. Most hares have small, bushy, white tails.

Unlike rabbits, hares tend to live alone. They do not dig tunnels, but rest during the day in sheltered beds of grass called forms. Hares are often seen bounding over the fields by day, but they are most active at night. They are herbivores and they graze on a wide range of plants including cereal crops. Regardless of whether the hare is asleep or awake, its nose and ears are constantly on the alert for possible enemies. Some hares are able to use their powerful hind legs to run as fast as 40 m.p.h. [65 kph].

Most hares mate three or four times a year. Each time, after a gestation period of about 42 days, the female gives birth to a litter of one to five leverets, or baby hares. Unlike baby rabbits, which are blind and helpless, newborn hares have fur and can run soon after they are born. Predators such as foxes, weasels, and birds of prey usually keep the hare population under control. In some areas, though, hunters have killed many of these predators. As a result, the hare population has grown rapidly.

Hares live throughout North America and Europe. The most common European species is the



HARE—Jackrabbit

The American jackrabbit is actually a hare that is common in the southwestern states. It is always on the alert, and its huge ears detect the slightest sound.

HARE—Boxing

The male European brown hare stands on its hind legs and "boxes" with other males during the mating season.

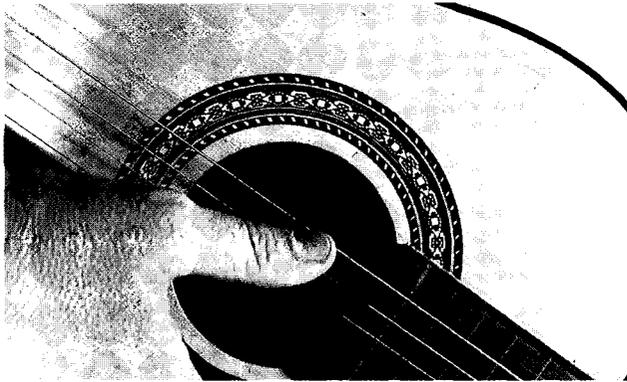


brown hare. It has brown fur with white fur on its belly, and long ears tipped with black fur. In North America, hares are often incorrectly called rabbits. The snowshoe rabbit is a hare that changes its color from brown in the summer to white in the winter (see PROTECTIVE COLORATION). The jackrabbit lives throughout most of the southwestern United States. It is easily recognized by its huge ears.

HARMONICS Anything that vibrates produces harmonics. If you pluck a guitar string, it vibrates. The string can vibrate in many different ways. The string can become shaped like a loop. The loop moves back and forth across a line where the string was originally. The string can also vibrate so that the point in the middle stays still. Then, two loops on either side move back and forth. If there are two points keeping still, there are three equal loops moving back and forth. These different vibrations in one string are called harmonics. A vibrating string usually has many different harmonics at the same time. When the string is part of a musical instrument, its harmonics give the string its tone.

When the string vibrates along its whole length, the harmonic is called the first harmonic, or the fundamental. If the string vibrates in halves, it is called the second harmonic, and so on. The higher the harmonic, the higher the pitch is. The fundamental has the deepest pitch. It is also the loudest harmonic. Higher harmonics become softer.

The number and loudness of a tone's harmonics determine the timbre (quality) of the tone. Even when they play the same note, different musical instruments produce different sounds, largely because of their different timbres. Many things besides musical instruments produce harmonics. For example, electric currents can vibrate electrically and produce harmonics.  **PROJECT 54**



HARMONICS

A vibrating string usually has many different harmonics at the same time. When a string is part of a musical instrument, as in this guitar, its harmonics give the string its tone.

HARTEBEEST The hartebeest is a large African antelope (see ANTELOPE). Because its shoulders are much higher than its hindquarters, the back slopes sharply to the rear. The hartebeest's head is long and narrow. Its ears are large. Two curving horns extend from a bony ridge high above the ears.



HARTEBEEST

The red hartebeest of southern Africa is easily recognized by its long, curved horns.

The red hartebeest of southern Africa grows from 4 to 5 ft. [1.2 to 1.5 m] in height. It has a rust-colored coat with a white patch at the rump. Red hartebeests have become scarce. Swayne's hartebeest of Ethiopia and the Tora hartebeest, found in Egypt and Ethiopia, are considered endangered. *See also* ENDANGERED SPECIES.

HARVESTMAN The harvestman is a long-legged arachnid commonly called daddy longlegs. The harvestman is related to the spider (see ARACHNID; SPIDER). It differs from the true spiders in its single body unit, lack of silk glands, and lack of poison fangs. Harvestmen are found in leaf litter and among low-growing vegetation. They feed mainly on other small animals, dead or alive, and also eat plant material. Tiny pincers on the head tear and crush the food so that it can be swallowed. There are about 5,000 known species, most often living in the tropical forests. The largest have bodies about 0.8 in. [20 mm] long.



HARVESTMAN

A spiderlike harvestman feeds on a fly. This one was photographed in the Great Smoky Mountains in Tennessee.

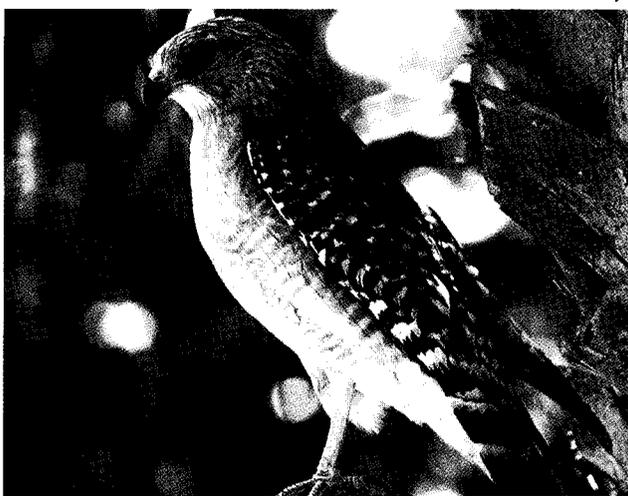
HARVEY, WILLIAM (1578–1657) William Harvey was an English doctor. He studied at Cambridge, England, and at Padua, Italy. His professor in Italy was Fabricius. Fabricius had discovered valves in the large veins of the human arm. Harvey showed that these valves kept the blood flowing in one direction.

Harvey returned to London in 1602 and became a hospital doctor. In 1616, he gave a series of lectures about the circulation of blood in the body. He had decided by then that blood must go from the heart into the arteries. He also saw that it returned to the heart through the veins. Until then scientists had thought that blood just washed around in the arteries and veins. At first, Harvey's ideas were not believed by other scientists. Harvey did not know about the tiny capillaries that bridge the gap between arteries and veins. However, before he died, the capillaries were discovered, and Harvey's ideas were accepted.

See also CIRCULATORY SYSTEM.

HAWK A hawk is a bird of prey that belongs to the family Accipitridae. It is a flesh-eater and captures live lizards, snakes, small mammals, and sometimes birds, fish, and insects for food (see CARNIVORE). Hawks have strong, sharp talons (claws), which they use to capture and kill the prey. Hawks also have sharp beaks, which they use for tearing the prey apart. Hawks have excellent eyesight, and some of them soar high in the air in order to spot animals on the ground. They dive from the sky to capture the animals. Some hawks catch other birds in full flight.

Hawks were once considered pests by humans because some of them ate farmers' chickens. Many



HAWK

Hawks, such as the red-shouldered hawk above, were once hunted ruthlessly because some of them preyed on farmers' chickens. It is now known that hawks are more helpful than harmful to humans because they eat large numbers of mice and rats.

hawks were shot and poisoned. Because of this, only a few hawks are common today. We know now that hawks are more helpful than harmful to people. They eat many more mice and rats than they do chickens.

HAWKING, STEPHEN WILLIAM

(1942–) Stephen William Hawking is a British physicist. He was born in Oxford, England. He received a bachelor's degree from Oxford University in 1962 and a doctoral degree in physics from Cambridge University in 1966. In 1980 Hawking was appointed the Lucasian Professor of Mathematics at Cambridge, a position once held by Sir Isaac Newton (see NEWTON, SIR ISAAC).

Hawking's theories have helped connect two basic areas of physics: Albert Einstein's theory of relativity and quantum mechanics. Quantum mechanics deals with the structure of subatomic particles and how they act. Hawking is most famous for his theories regarding the existence of singularities. Hawking believes a singularity is a black hole that has a diameter of zero (see BLACK HOLE; EINSTEIN, ALBERT; PARTICLE PHYSICS; QUANTUM THEORY; RELATIVITY).

When Hawking was in his early twenties, he contracted amyotrophic lateral sclerosis (ALS). ALS is a rare and incurable nerve disease. It is also known as Lou Gehrig's disease. ALS has left Hawking unable to move most of his muscles. He has slight movement in his hands and fingers. Unable to speak, he communicates through a computer and a speech synthesizer. A synthesizer is an electronic device that can produce sound.

Hawking was inducted into England's Royal Society in 1974. His books include *The Large-Scale Structure of Space-Time* and *A Brief History of Time*.

HAWKMOTH The hawkmoth is any of several species of large, powerful moths belonging to the family Sphingidae of the order Lepidoptera (see BUTTERFLY AND MOTH). Hawkmoths have stout bodies with narrow, pointed forewings and shorter hindwings. Some species have wingspans of 5 in. [13 cm]. Hawkmoths fly very rapidly, some of them in the daytime, and some hover in front of

flowers while feeding. These characteristics have led to the moth's nickname, hummingbird moth. They have a hollow, tonguelike proboscis, which is used to suck nectar from the flowers. The tongues of some hawkmoths are about 10 in. [25 cm] long—much larger than the body. Hawkmoths are also called sphinx moths.

The caterpillar (larva) of the hawkmoth is called a hornworm because it has a sharp, curved horn on its rear end. The most common North American species are the tomato hornworm and the tobacco hornworm. They may grow to be 4 in. [10 cm] long. Although the larvae may damage crops, the adults are useful pollinators (see POLLINATION). The larvae are controlled by insecticides and by natural means. Braconid wasps, such as *Apanteles congregatus*, are natural predators that lay their eggs in the larvae.

The death's head moth, found in Europe and Africa, is named for the skull-like pattern on its wings.



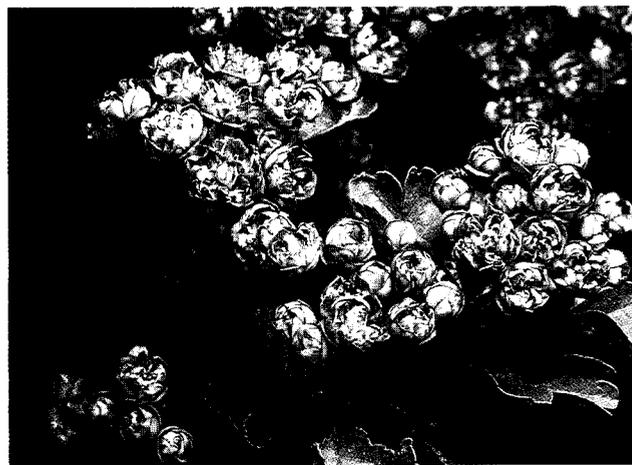
HAWKMOTH

The striking pattern on this hawkmoth from Trinidad scares away birds and other predators.

HAWTHORN The hawthorn is any of several species of small deciduous trees or shrubs belonging to the genus *Crataegus* of the rose family. The stems have many thorns, and toothed or lobed leaves. The flowers usually grow in clusters at the ends of the stems. They have five petals and may be white, red, or pink. The fruits, or haws, resemble small apples and may be red, orange, blue, or black (see DECIDUOUS TREE; ROSE FAMILY).

The English hawthorn is frequently planted to form hedges because it grows very quickly. It blossoms in May and produces red haws. Its leaves change color, to red or yellow, before dropping off in the fall. The English hawthorn is also called may, mayhaw, red haw, or scarlet haw.

The downy hawthorn is a common United States species. It has white flowers and orange haws.



HAWTHORN

Hawthorn blooms in the late spring. Deep pink flowers like these are less common than the white-flowered variety.

HAY FEVER Hay fever is also known as allergic rhinitis, pollinosis, or summer catarrh. It is characterized by sneezing, an itchy and running nose, itching of the membranes of the mouth and eyes, and redness of the eyes (conjunctivitis). It is estimated that 50 million people are affected by hay fever in the United States.

Hay fever is caused by an allergy to many substances, but chiefly to pollen (see ALLERGY). The appearance and concentration of pollen depends upon locality, season, and weather. Dry, sunny, summer conditions cause a lot of pollen to be in the atmosphere. This pollen triggers hay fever.

Diagnosis is confirmed by use of a skin test, in which some pollen is injected under the skin to see if a hive forms (see HIVES). If it does, this shows an allergy. Although the ideal treatment would be to remove the allergy-causing agent from the air, this is impractical in most cases. Most people with hay fever need to take a drug, such as an antihistamine or corticosteroid, to reduce the itching (see ANTI-HISTAMINE; STEROID).

HEALTH Health is a state of bodily well-being. A healthy person is free from disease and also has a body that is fit. Good health also means having a fit mind and a good outlook on life. A healthy person has the ability to get along with other people and to cope with the stresses of daily life. Good health depends on taking care of one's body. Proper food, plenty of exercise, cleanliness, and proper rest and relaxation are all important in maintaining good health. So are regular medical and dental checkups. These help to maintain the body and mind in a fit condition so they are better able to resist disease.

Many communities have public health departments whose aim is to maintain good health among people. Among the duties of the public health department are the provision and maintenance of safe water supplies, the removal of sewage and other hazardous wastes, and the provision of immunization programs and other ways to combat transmissible diseases such as malaria.

See also HYGIENE.



HEALTH

A person's health can be checked during physical exercise. Here a doctor measures a man's blood pressure while he pedals an exercise bicycle.

HEARING AID A hearing aid is an electronic device that improves a person's ability to hear. Many people who are deaf and hard-of-hearing depend on such a device.

There are two general types of hearing aids: air-conduction aids and bone-conduction aids. The air-conduction aid amplifies sound and brings it

directly to the ear. Some people, however, cannot use this type of hearing aid because they cannot receive sound waves through the inner and outer ear. These people use bone-conduction aids that bring sound waves to the bony parts of the head behind the ear. The bone transmits the vibrations to the cochlea (see EAR). Hearing becomes possible when the nerve cells of the cochlea are stimulated.

Hearing aids today are basically electronic devices that resemble miniature telephones. They consist of a microphone, an amplifier, a receiver, and a battery power supply. The receiver fits in the ear, in the case of the air-conduction type, or behind the ear, for the bone-conduction variety. Hearing aids are compact and easy to carry and conceal. New methods of electronic miniaturization have made it possible to design hearing aids small enough to fit within the ear canal. Researchers have recently developed an electronic implant for the cochlea that enables people who are deaf to hear loud sounds such as sirens and automobile horns.

Air-conduction aids and bone-conduction aids have been used for many years. The principle of bone-conduction was known in the 1600s. The ear trumpet, a simple hornlike device, was used to improve hearing even earlier. In the late 1700s, the audiphone was invented. It was a device shaped like a fan. Users held the edge between their teeth, and bent the fan towards the sound. The sound vibrations traveled from the teeth to the jawbone, the skull, and the auditory nerves.

In 1872, Alexander Graham Bell began experimenting with electric devices that would help children who were deaf to hear. Although he never invented a hearing aid, his work did lead to the development of the telephone (see BELL, ALEXANDER GRAHAM). The first electronic hearing aid was developed around 1900. It was bulky and inconvenient to use. The vacuum tube aid was the next type to come along. It consisted of a crystal microphone, a vacuum tube amplifier, and batteries. In 1953, the electronic transistor hearing aid was introduced. It completely replaced the vacuum tube aid because it was much smaller and less expensive to operate. This is the type in use today. *See also* TRANSISTOR; VACUUM TUBE.

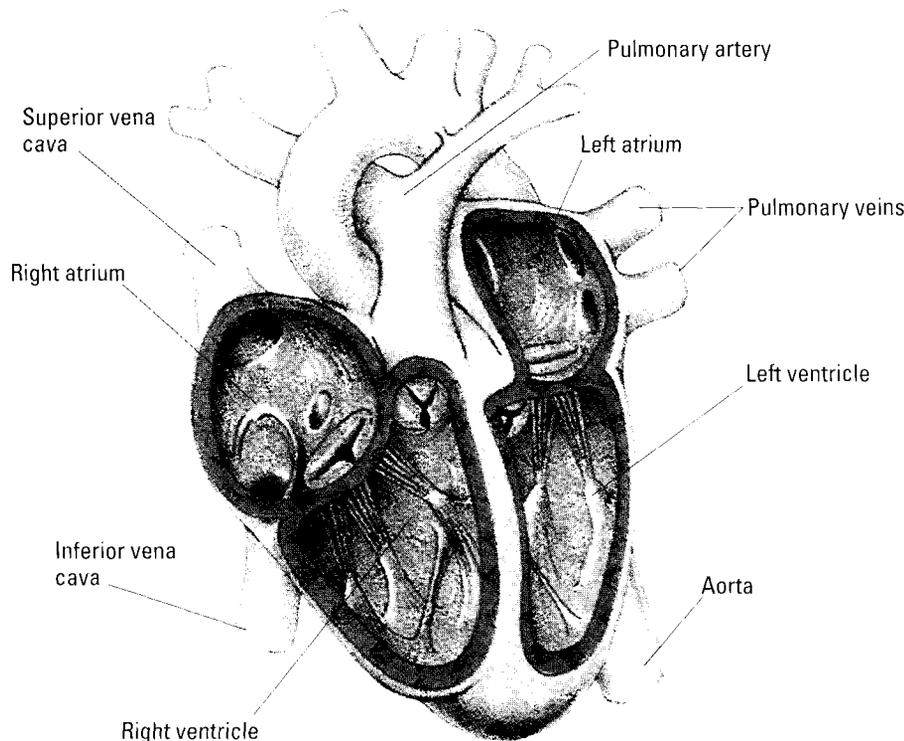
HEART

The heart is an organ that pumps blood around the body of many animals, including humans. The human heart is about the size of a closed fist. It lies in the chest between the two lungs. It is not in the center of the chest. Instead, it lies just a little to the left side of the body. The heart is hollow and divided into four chambers. The walls of these four chambers are made of powerful muscle. When the muscle in the walls contracts (shortens), it makes the chambers smaller. This squeezes the blood out of the heart into blood vessels called arteries (see ARTERY). In the human heart, a wall of muscle completely separates the right and left sides. Blood in the two sides cannot mix. The two sides of the heart work together. Each pumps blood through its two chambers at the same time. The right side pumps its blood to the lungs. The left side pumps its blood to all other parts of the body.

The two lower chambers of the heart are called ventricles. The left ventricle has very thick walls of muscle. It is the most powerful pumping chamber of the heart. It pumps blood into a large artery

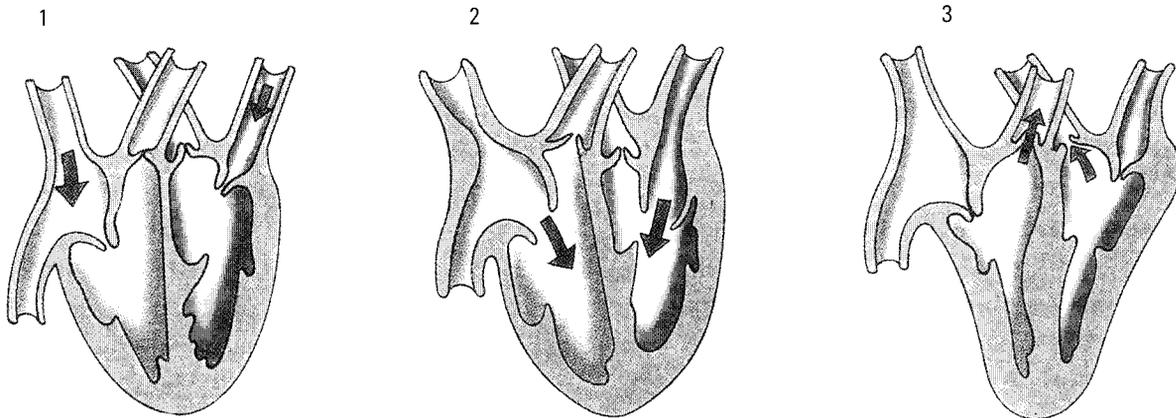
called the aorta (see AORTA). The aorta branches out into many smaller arteries. The arteries carry blood that is rich in oxygen to all parts of the body. The left ventricle releases its blood into the arteries in rapid squirts. These squirts of blood make the pulse that can be felt in some arteries just beneath the skin (see PULSE). As the blood travels around the body, it gives up its oxygen and picks up a waste chemical called carbon dioxide. The blood then has to be returned to the right side of the heart. From there, it can be pumped to the lungs to pick up oxygen. Blood travels back to the heart through blood vessels called veins (see VEIN). The veins empty their blood into two large vessels called venae cavae (plural of *vena cava*) (see VENA CAVA).

The venae cavae empty blood into an upper chamber of the heart called the right atrium (also called the right auricle). The right atrium contracts and squeezes blood into the right ventricle. The right ventricle forces its blood into a blood vessel called the pulmonary artery. The pulmonary artery takes blood to the lungs. In the lungs, the blood



A DOUBLE PUMP

The heart is like two pumps side by side. The right side (on the left of the diagram) receives deoxygenated blood from the veins. The left side pumps oxygenated blood into the arteries.



ONE COMPLETE HEARTBEAT

(1) Blood from the main veins (blue) and from the lungs (red) flows into the upper chambers, called atria. (2) The atria contract, forcing the blood into the lower chambers, called ventricles. (3) The ventricles contract, forcing the blood into the aorta (leading to the body's arteries) and the pulmonary artery (leading to the lungs).

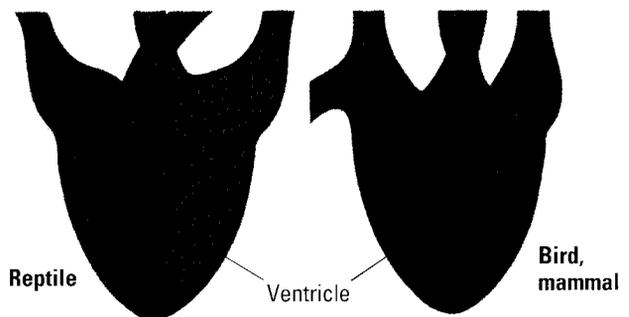
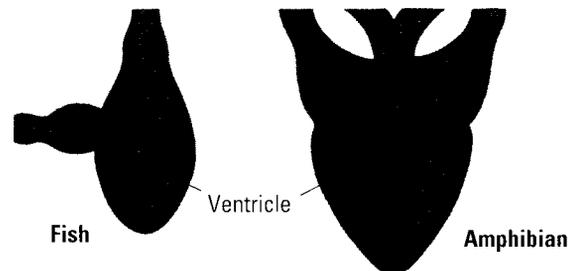
loses its carbon dioxide. This is breathed out. At the same time, the blood takes up more oxygen (see LUNG). When the blood is rich in oxygen, it is carried to the left side of the heart. It is carried in blood vessels called the pulmonary veins. The pulmonary veins empty blood into the left atrium (also called the left auricle). The blood then passes into the left ventricle. It can now start its long journey around the body again. The blood has to keep flowing in one direction only. The heart has valves (flaps) that keep the blood from flowing backward. There are valves between the atria (plural of *atrium*) and ventricles. There are also valves at the exit from each ventricle.

The brain stem regulates heartbeat (see BRAIN). Sometimes the heart gets messages that make it change the speed of its beat to go faster or slower. These messages can come from special nerve signals. They can also come from hormones, which are special chemicals carried in the blood (see HORMONE). The part of the heart sometimes called the "pacemaker" has the job of starting each heartbeat, setting the pace of the beat, and causing contraction of the heart muscle. The pacemaker lies between the two atria. It is in a small group of muscle cells that send out regular electrical signals. In response to these signals, the atria and ventricles contract. The

atria always contract just before the ventricles. The contraction of the chambers is called the systole. The short period of rest that follows is called the diastole. The systole and diastole repeat alternately throughout the life of a person. In a healthy adult, the heart usually beats about 70 times a minute. During very heavy work or other exercise, the heart may beat more than 140 times a minute.

See also CIRCULATORY SYSTEM; HEART DISEASE.

 **PROJECT 64**



HEART VARIATIONS

Among vertebrates (animals with backbones), the heart varies in complexity. It is simplest in fish, which have a two-chambered heart with one atrium and one ventricle. Amphibians have a three-chambered heart, with two atria and an undivided ventricle. A reptile's heart has four chambers, but the ventricles are not completely divided. Birds and mammals, including humans, have four-chambered hearts.

HEART DISEASE The heart is the hardest-working organ in the human body. We rely on it to work efficiently every moment of every day. Any disorder that stops it pumping properly can be a threat to life. Heart disease is very common. More people are killed every year in the United States by heart disease than by any other disease. There are many kinds of heart disease. Several of these kinds are discussed below.

Congenital disease A congenital disease is one that a person is born with. Most babies are born with healthy hearts. However, in about one in every two hundred babies, something goes wrong. Sometimes a valve grows with the wrong shape. It may be too tight, or it may fail to close properly. Sometimes a gap is left in the septum (wall) between the two sides of the heart (see HEART). This is often called a septal defect. When a baby's heart is poorly formed, it cannot work efficiently. The blood does not pick up enough oxygen. As a result, the blood becomes purplish, and the baby's skin looks blue. Fortunately, it is now possible to save the lives of many "blue babies."

Rheumatic disease The disease called rheumatic fever may cause harm to the heart. When rheumatic fever occurs, it usually does so in a young person who has had a sore throat caused by

bacteria called group A *Streptococci*. The tissues of the heart become inflamed. If it is badly affected, the heart fails. Usually, it recovers. However, the results of the damage may show years later. The valves of the heart may be left with scars. As a result, they cannot work properly. This puts a strain on the heart. Eventually, the heart may fail (see RHEUMATIC FEVER).

Atherosclerosis, hypertension, heart attack The arteries that supply blood to the heart itself are called the coronary arteries. They give the heart muscle the oxygen it needs to carry on its work.

The disease atherosclerosis, the most common kind of arteriosclerosis, can affect the coronary arteries. In atherosclerosis, the walls of the arteries become thickened and less elastic, and the insides of the arteries become roughened and narrowed by the accumulation of hard material called plaques (see ARTERIOSCLEROSIS). If this happens in the coronary arteries, the narrowed, hardened arteries carry less blood to the heart than they should. One result may be pain in the chest known as angina pectoris. In addition, the roughened artery walls, together with the slower flow of blood through the arteries, can cause a blood clot to form. If such a clot occurs in a coronary artery and the artery becomes blocked, part of the heart



HEART DISEASE

Heart surgeons today are able to correct what, in the past, would have been fatal heart problems. In some cases, the hearts are repaired. In others, the damaged or diseased hearts are replaced with healthy ones. Aorta replacement surgery is shown at left.

muscle dies. The person has a "heart attack," which can be fatal.

The disease hypertension, also known as high blood pressure, can increase the risk of a heart attack. (Blood pressure is the pressure that the blood exerts against the walls of the arteries as it travels through them.) Hypertension may have no symptoms, so a person may not be aware of having it unless the blood pressure is measured.

Treatment and prevention Since the mid-1960s, medical science has made tremendous progress in the treatment and prevention of heart disease. Foremost among the newer drugs are a family of compounds called beta adrenoceptor blocking drugs or, simply, beta blockers. They control the sudden rushes in blood flow that may be caused by pain, emotion, or physical activity. The beta blockers lessen the aftereffects of heart attacks, can prevent second attacks, and can lower the blood pressure of people who have hypertension.

Surgical techniques have also progressed rapidly. In 1982, the first completely mechanical heart was implanted in a person. The patient lived for 112 days and died from other problems. Heart transplants, first performed in 1967, are no longer considered experimental. In transplant surgery, the healthy heart of someone who has died replaces the diseased heart of another person.

Surgeons are also able to implant mechanical devices in people's bodies to keep their hearts functioning. The artificial pacemaker is the most common of these devices. It does not heal the diseased heart, but it relieves the symptoms of an irregular heartbeat, maintaining the steady beat needed for normal living. Artificial valves of plastic and metal may also be used to replace faulty heart valves.

Bypass surgery is used to repair clogged or damaged coronary arteries. Doctors use part of a patient's own vein, often from the leg, surgically implanting it near the heart to route blood around the blockage.

Another medical technique, called angioplasty, clears blocked coronary arteries. The technique involves the use of a catheter, which is a narrow

tube, and a tiny balloon (see ANGIOPLASTY).

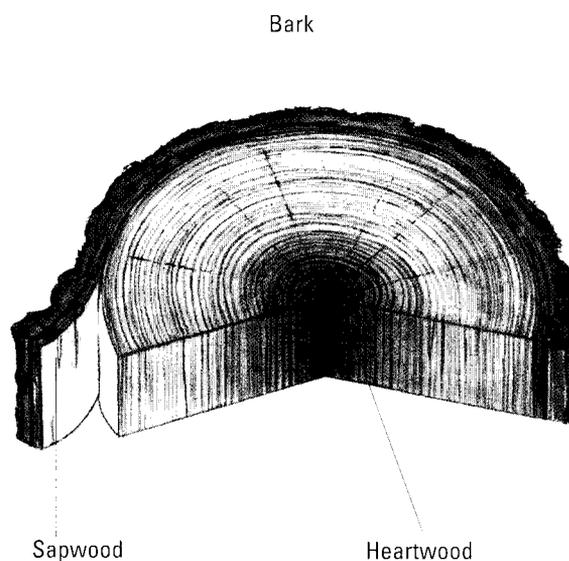
Preventive care is also getting better as scientists learn more and more about the causes of heart disease. A diet high in saturated fat and cholesterol can increase the risk for atherosclerosis and heart attack, so doctors stress the importance of a diet low in fats. The sodium in table salt is known to be hazardous for persons who have hypertension, so doctors also recommend reducing sodium intake (see DIET). Other factors are also linked to heart disease. These include stress, lack of exercise, excessive weight, and smoking.

See also CIRCULATORY SYSTEM; STROKE.

HEARTWOOD Heartwood is the central part of a tree trunk. It is made up of dead, non-functioning cells that contain tannin and other chemicals. These chemicals make the heartwood appear darker than the surrounding sapwood. Sapwood is softer than heartwood and is made up of living cells.

Heartwood is very strong and resistant to decay. Each year, one or more layers of sapwood cells are converted into heartwood. Heartwood is sometimes called duramen.

See also TREE.



HEARTWOOD

The heartwood is the central, hardest part of a tree trunk. It is surrounded by soft sapwood, which is protected by an outer covering of bark.

HEAT

All matter contains heat. Heat is a form of energy. The heat energy present in any object is connected with its temperature. If the object gains heat energy, its temperature rises. If it loses heat energy, its temperature falls. There is an important difference between heat and temperature. The amount of heat energy depends on the amount of matter present. For example, a heated swimming pool contains much more heat than a pan of boiling water, even though the pan has a higher temperature. This is because there is much more water in the swimming pool than in the pan.

All matter is made up of tiny particles called atoms. In most substances, these atoms are grouped together in molecules. A molecule is the smallest collection of the atoms in a substance that can exist in a free (isolated) state. The molecules in substances are continually moving. Movement is a form of energy. It is called kinetic energy. The heat energy in matter is the total kinetic energy of all its molecules. The temperature depends on how fast the molecules are moving (see *ATOM*; *MOLECULE*; *KINETIC ENERGY*). Temperature is measured by a thermometer in units of degrees Fahrenheit or Celsius. Heat energy is measured in calories or joules (see *CALORIE*; *JOULE*). It is measured by an instrument called a calorimeter.

As the temperature of a substance drops, its molecules move more slowly. Eventually, a point could

be reached where the molecules would stop moving altogether. The temperature at this point is called absolute zero. At absolute zero, the substance has no heat energy at all. In fact, though scientists have cooled substances to within a fraction of a degree of absolute zero, no substance can be cooled down to absolute zero. Matter always contains some heat energy (see *ABSOLUTE ZERO*).

Heat has two common effects on a body. One is that it can cause bodies to change their states. For example, it can turn a solid into a liquid, such as ice into liquid water, or it can turn a liquid into a gas, such as liquid water into steam. In a solid, the molecules are kept at fixed points by forces acting between the molecules. The molecules can only move a short distance about their fixed points. They cannot move through the whole of the solid, unlike the molecules in liquids and gases. As the temperature rises, the molecules move farther away from their fixed points. Eventually, they can move so far away that the structure of the solid breaks down and becomes a liquid.

In a liquid, the forces between the molecules still have some effect. That is why a liquid has a definite volume. However, the molecules are not held to any one place. They can move freely throughout the liquid. Then, as the heat increases, the liquid turns into a gas. The molecules are able to move too fast for the forces between them to have much effect.

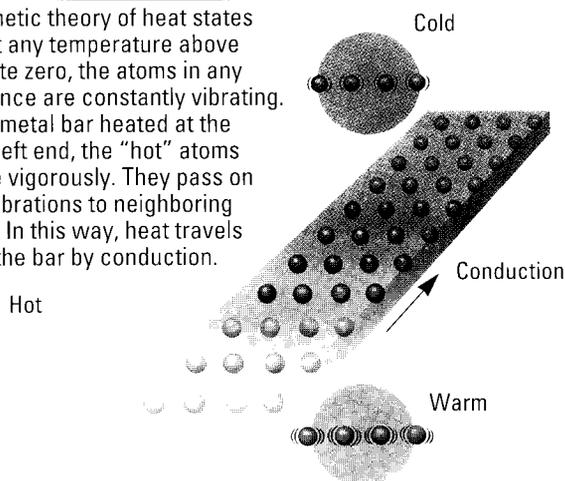
Another effect of heat is that it causes substances to expand. When molecules move faster, they take up more room. Therefore, the hotter the substance, the larger its volume. Solids and liquids expand only a very little with increased temperature. Gases expand much more.

Sources of heat Many chemical reactions produce heat. These reactions are called exothermic reactions (see *CHEMICAL REACTION*; *EXOTHERMIC REACTION*). An example of an exothermic reaction is the burning of a fuel. When a fuel burns, it combines with the oxygen in the air. This reaction gives off a large amount of heat.

One form of energy can be converted into another

KINETIC THEORY

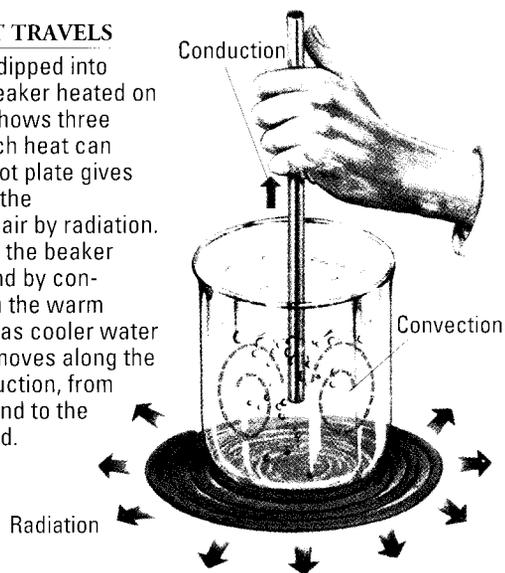
The kinetic theory of heat states that, at any temperature above absolute zero, the atoms in any substance are constantly vibrating. In this metal bar heated at the lower left end, the "hot" atoms vibrate vigorously. They pass on their vibrations to neighboring atoms. In this way, heat travels along the bar by conduction.



form. Heat can be produced from several different forms of energy. For example, heat can be produced by friction (see FRICTION). When two objects are rubbed together, energy is needed to overcome the friction between them. This energy is converted into heat, and the objects become warm. The most important source of heat is the sun.

HOW HEAT TRAVELS

A metal rod dipped into water in a beaker heated on a hot plate shows three ways in which heat can travel. The hot plate gives off heat into the surrounding air by radiation. The water in the beaker moves around by convection, with the warm water rising as cooler water sinks. Heat moves along the rod by conduction, from the heated end to the unheated end.



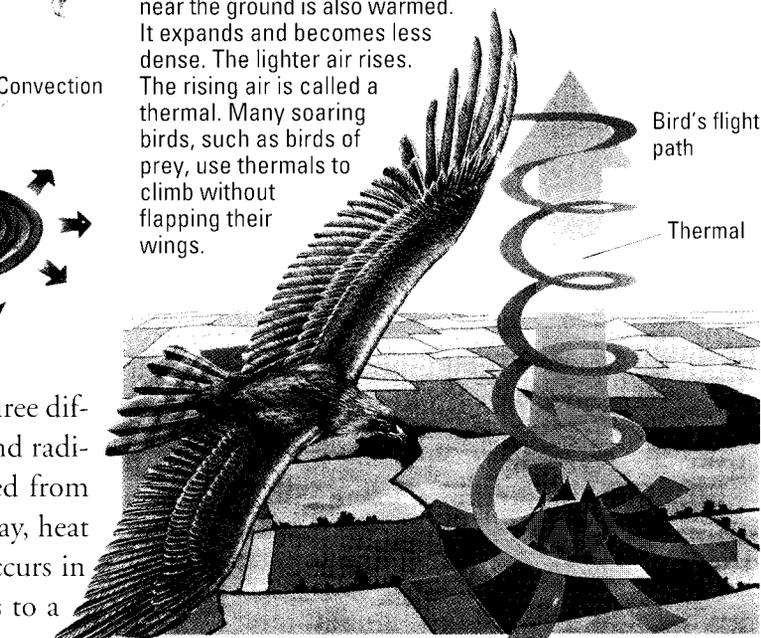
Movement of heat Heat can travel by three different methods: conduction, convection, and radiation. In conduction, the heat is transferred from one atom or molecule to another. In this way, heat moves through a substance. Conduction occurs in solids and in liquids. It also occurs in gases to a small extent. Suppose a person puts a metal cooking pot over a flame. The handle of the pot becomes hot, even though it is not in the flame. The atoms in the part of the pot nearest the flame become hot and start to move quickly. They collide with atoms nearby and pass on some of their energy. The energy is slowly transmitted farther away from the flame. In this way, all of the pot becomes hot. Some solids, such as plastics, do not transmit much heat. They are called insulators. Other substances, such as metals, transmit most of their heat. They are called conductors (see CONDUCTION, HEAT).

In convection, heated matter moves from one point to another. Convection can occur in both gases and liquids. It does not occur in solids. As an example, the air around a fire becomes heated. As it becomes heated, it expands. The air becomes lighter

and rises. This causes convection currents in the air. Winds and currents in the sea are partly caused by convection currents. They are caused by one part of the atmosphere or the sea being hotter than another part (see CONVECTION). Heat can also travel without matter being present. It travels in the form of infrared radiation. This is how the heat from the sun reaches the earth through space. When infrared radiation hits an object, it heats the object up. Infrared radiation is given off by the atoms and molecules of all hot objects (see INFRARED RAY).

THERMALS

The ground is warmed by heat from the sun during daytime. Air near the ground is also warmed. It expands and becomes less dense. The lighter air rises. The rising air is called a thermal. Many soaring birds, such as birds of prey, use thermals to climb without flapping their wings.



History of heat Before 1800, scientists thought of heat as a fluid. They called the fluid *caloric*. Then a number of scientists demonstrated a connection between heat and energy. The most important of these scientists was a British physicist, James Joule. He showed that a falling weight can heat water. He concluded that some of the kinetic energy of the weight was converted into heat (see JOULE, JAMES PRESCOTT). At the same time, John Dalton, British chemist, put forward his atomic theory. His theory said that all matter is made up of atoms (see DALTON, JOHN). In time, scientists combined these two theories and other knowledge, and concluded that heat is caused by the motion of atoms or molecules. See also THERMODYNAMICS.

 PROJECT 39, 40, 45

HEATH FAMILY The heath family, Ericaceae, contains nearly 1,350 plant species. Many of these are evergreens (see EVERGREEN). These plants are found in temperate climates and in high elevations of the tropics. They grow best in sandy, acidic soil. Well-known members of the heath family include the rhododendron, mountain laurel, azalea, blueberry, and cranberry.



HEATH FAMILY

Rhododendrons (top) and ericas, or heathers (bottom), are evergreen members of the heath family.

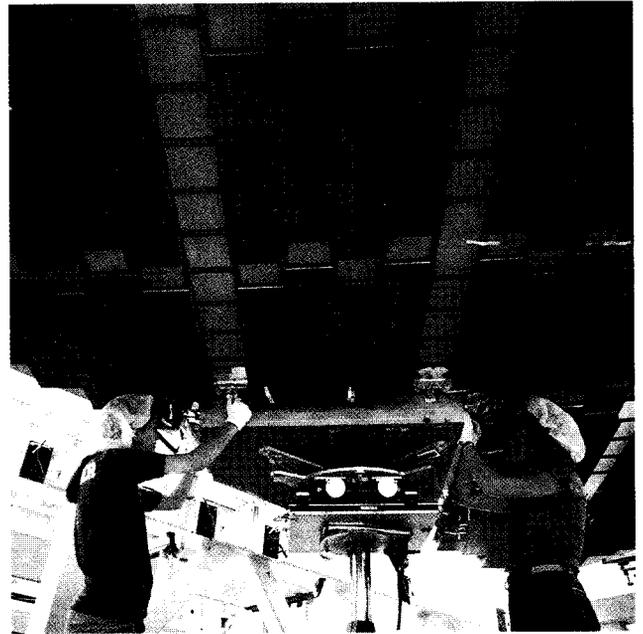
HEAT SHIELD A heat shield is a covering on the nose cone of a rocket or the body of a spacecraft. It may be made of various materials, such as carbon, tungsten, or ceramic tile. The shield protects parts of the spacecraft, including the

astronauts and instruments, from the extreme heat that is produced when the craft reenters the earth's atmosphere from space.

As a returning spacecraft enters the atmosphere, it hits air molecules. The molecules cause friction, which produces heat (see HEAT). The farther the craft enters the atmosphere, the more molecules there are. Therefore, the friction is greater, and the heat becomes more intense. A thermal protection system (TPS) is therefore necessary to control the temperature.

The most common heat shields are called ablative shields and heat sinks. Ablative shields burn up and melt, and thus they vaporize in the extreme heat. The air stream carries the hot gases and vapors and molten particles away from the spacecraft. Heat sinks absorb heat and thus prevent it from reaching important areas of the craft.

In early 1981, a major development in space transportation began when the space shuttle *Columbia* was launched in Florida. The *Columbia* was the first reusable spacecraft and so required a thermal protection system that could be reused. A reusable surface insulation (RSI) made of ceramic tile was developed. These tiles resist temperatures



HEAT SHIELD

Here thermal tiles are being applied to a spacecraft. The tiles form a heat shield that prevents the craft from burning up from the heat caused by friction with the air when it reenters Earth's atmosphere.

of more than 8,000°F [4,425°C]. A special shield made of glass fibers replaced the standard ablative shield used in previous craft. In addition, a special carbon material was used for the nose area and the leading edges of the wings—areas that are most affected by heat.

More than 150 tiles were lost during *Columbia's* first flight, but the mishap did not harm the craft. The tiles that were left kept the heat low enough, and there were no burn-throughs where the missing tiles were. When the *Columbia* was launched the second time, in November, 1981, only 12 of the tiles were lost.

See also SPACE EXPLORATION.

HEAVY ELEMENT *Heavy element* is a term commonly used in nuclear physics to describe elements with high atomic numbers, such as uranium (atomic number 92) and plutonium (94). If one element is said to be heavier than another, this often indicates that it has a higher atomic number. See also ELEMENT.

HEAVY WATER Water molecules each contain two atoms of hydrogen and one of oxygen. This is written H₂O. Hydrogen has an isotope called deuterium (see ISOTOPE). Deuterium has the same chemical properties as hydrogen and can replace hydrogen in its compounds. (A compound is a chemical substance made up of two or more elements.) If deuterium replaces the hydrogen in water, then heavy water is formed. Heavy water is also known as deuterium oxide, and its formula is D₂O. Heavy water occurs naturally in small amounts. About 1 part in

4,500 parts of ordinary water is heavy water.

Deuterium is heavier than ordinary hydrogen. This makes heavy water heavier than ordinary water. One cubic centimeter of water weighs 1 gram at 68°F [20°C]. The same volume of heavy water at that temperature weighs 1.1 grams. Its freezing and boiling points are also slightly different. Water freezes at 32°F [0°C] and boils at 212°F [100°C]. Heavy water freezes at 38.8°F [3.8°C] and boils at 214.5°F [101.4°C].

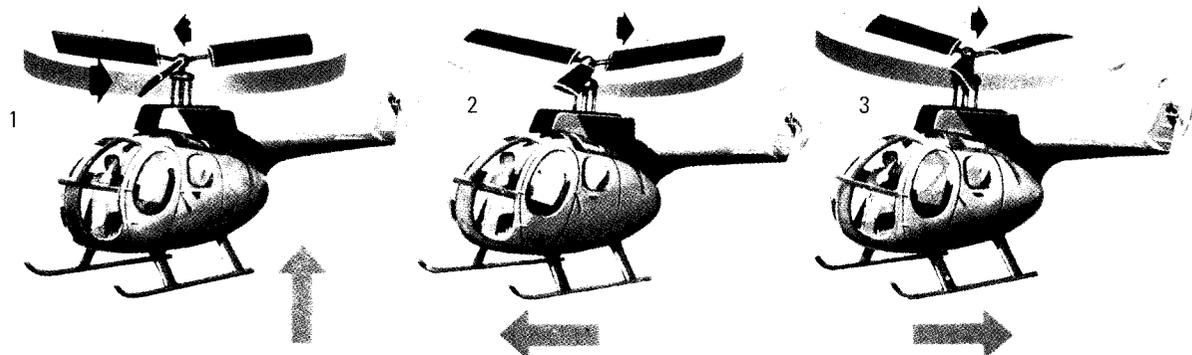
If an electric current is passed through water, hydrogen and oxygen gases are given off. This is called electrolysis (see ELECTROLYSIS). If the water contains some deuterium, then it too is given off. However, deuterium is given off more slowly than ordinary hydrogen. As the current flows, the water becomes richer in heavy water. This is how heavy water is obtained from ordinary water. Heavy water is sometimes used in nuclear reactors to control the reaction. It is also used to keep the reactor cool.

See also DEUTERIUM; ELEMENT; NUCLEAR ENERGY.

HELICOPTER A helicopter is an aircraft that is lifted into the air and kept flying by a number of horizontal blades. These blades together are called the rotor. They rotate (move around in a circle) very fast and allow the helicopter to fly in any direction through the air. The rotor takes the place of both the wings and propellers of a regular fixed-wing aircraft. Helicopters can fly straight up or

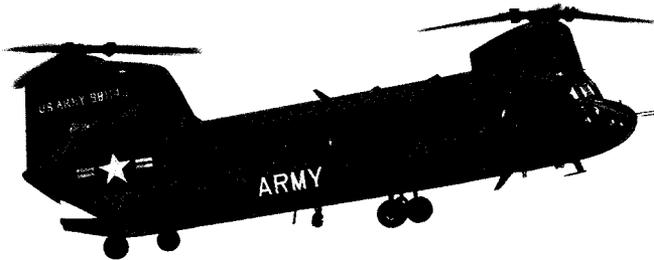
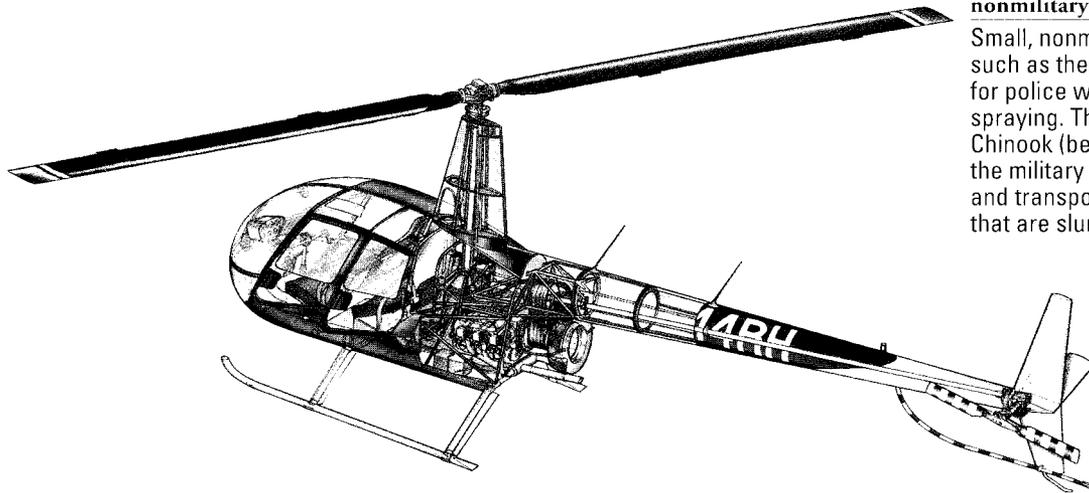
HELICOPTER—How it moves

A helicopter moves by changing the pitch, or the angle, of its main rotor blades. (1) A sharp pitch makes the aircraft move up. A medium pitch lets it hover. Changing the pitch on the rear blade makes it move forward (2) or backward (3).



HELICOPTER—Military and nonmilitary

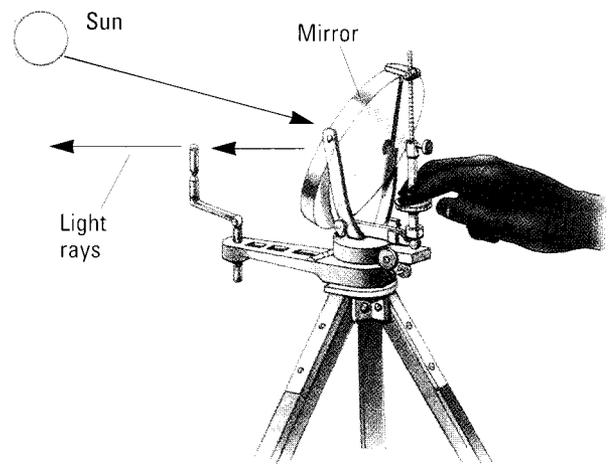
Small, nonmilitary helicopters, such as the R-44 (left), are used for police work and crop spraying. The twin-rotor Chinook (below left) is used by the military for carrying troops and transporting heavy loads that are slung beneath it.



HELIOGRAPHY The word *heliography* is derived from the Greek word *helios*, meaning “sun.” During the 1700s, the branch of astronomy concerning the description of the sun was called heliography. In the early 1800s, heliography meant photography. During the late 1800s, heliography was the name given to a method of sending messages by the reflection of sunlight. This was done by an instrument called a heliograph. The heliograph used mirrors to reflect the sunlight. The messages were sent in flashes, representing Morse code symbols. These flashes could be seen 30 mi. [48 km] away (see MORSE CODE).

down and do not need a runway. They can also fly forward, backward, or sideways, or they can hover in one position. This is all done by altering the pitch of the blades. The pitch is the angle at which the blades are set. If the blades lie flat, the helicopter moves downward. If they are pitched up, then the helicopter moves upward. By tilting the rotor, the helicopter can be steered in the desired direction.

Some helicopters also have a small, vertical rotor at the back. This helps stabilize the helicopter. As the main rotor rotates, its motor tends to cause the helicopter to rotate in the opposite direction. The tail rotor works against this rotation and prevents it from happening. The tail rotor also allows the helicopter to change direction. Some large helicopters have two, or even four, main rotors and no tail rotors. These rotors spin in opposite directions. This cancels out the twisting effect of each rotor. Therefore, no tail rotor is needed.



HELIOGRAPHY

A heliograph had a mirror that could be adjusted to reflect the light of the sun. The reflection could be aimed at a particular spot, perhaps many miles away. Moving the mirror slightly made the light appear to flash. The flashing light was used to send messages in Morse code.

HELIUM

Helium (He) is a colorless, gaseous element. It is the second lightest gas after hydrogen. The atomic number of helium is 2, and its relative atomic mass is 4.0026. Helium boils at -452°F [-268.9°C]. This is the lowest boiling point of any element. Unlike every other element, helium does not turn into a solid by cooling alone. It has to be pressurized as well. It solidifies at -453.5°F [-269.7°C] and under a pressure 103 times that of the atmosphere. Helium is one of the noble gases and is very unreactive (see ELEMENT; INERT GAS).

Helium was first discovered in 1868 by the British chemist Sir Joseph Lockyer and the French chemist Pierre Janssen. They used an instrument called a spectroscope to discover helium in the sun (see SPECTROSCOPE). Helium is named after the Greek word for sun, *helios*. Helium was not found on Earth until 1895. Then, the British chemist Sir William Ramsay discovered helium in the mineral clevite (see RAMSAY, SIR WILLIAM).

Several radioactive elements give off helium when they decay. That is why it occurs in certain minerals. Helium can also be obtained from natural gas. The gas wells in Colorado and Texas contain as much as 8 percent helium. Helium is also formed during thermonuclear fusion of hydrogen (see FUSION). This is how the sun and other stars obtain their energy. Stars contain vast amounts of helium. For this reason, helium is the second most abundant element in the universe, after hydrogen (see STAR).

Since helium is so light, it is used for filling gas balloons. Hydrogen was once used for this, but hydrogen is a dangerous gas because it burns explosively in air. Helium is much safer to use because it is so unreactive (see BALLOON). Helium is also used in the gas breathed in by deep-sea divers. They used to breathe ordinary air, which contains nitrogen, but this is dangerous. Deep down in the sea, the pressure is very great. This causes the nitrogen in the air to dissolve in the blood. In the past, if a diver surfaced too fast, the rapid decrease in pressure caused some of the dissolved nitrogen to form bubbles in body tissues and block small blood vessels.

The result, called caisson disease or the bends, could be very painful and could even kill the diver. Today, divers breathe a mixture of oxygen and helium. Helium does not easily dissolve in the blood and so is much safer to use (see CAISSON DISEASE). Breathing helium makes divers speak with a high, squeaky voice. This is because sound travels three times as fast in helium as it does in air. This raises the pitch of a sound.

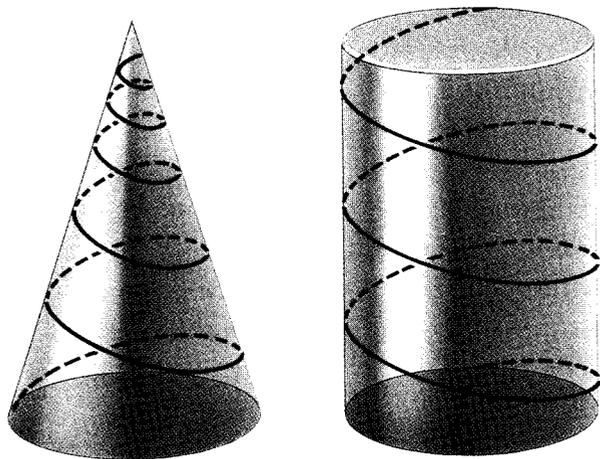
Like all gases, helium can be liquefied. There are two kinds of liquid helium, helium I and helium II. Helium I changes into helium II below -456°F [-271°C]. Helium I is a normal liquid, but helium II is very strange. It is called a superfluid. If helium II is placed in a container, it creeps up the sides. Eventually it flows over the top and down the outside of the container. This happens because a superfluid has almost no viscosity (see VISCOSITY).



HELIUM IN STARS

Helium was first discovered in the sun and is now known to be in all stars and galaxies. The helium is formed as a product of a nuclear fusion reaction. In the reaction, hydrogen is turned into helium with the release of much heat and light. A spiral galaxy is shown here.

HELIX If a line, thread, or wire is curved so that it can be wound around a cylinder or cone in a single layer, a helix results. A helix is shaped like a screw thread. In mathematical terms, the helix is any spiral curve that crosses the surface of a cone or cylinder at a constant angle. In nature, many molecules have a helical shape, including the double helix of DNA (see GENETICS).

**HELIX**

A conical helix is formed by a line wound around a right circular cone (left). A line wound around a cylinder produces a cylindrical helix (right).

HELMHOLTZ, HERMANN VON (1821–1894) Hermann von Helmholtz was a German scientist. He was first a surgeon and then a physicist. He made many discoveries connected with vision and hearing. He studied color vision and invented the ophthalmoscope, an instrument for examining the interior of the eye. He also wrote a book about how the ear works.

As a physicist, Helmholtz studied sound, electricity, and light. His work helped develop the theory of the conservation of energy. His work on electromagnetism led to the electromagnetic theory of light.

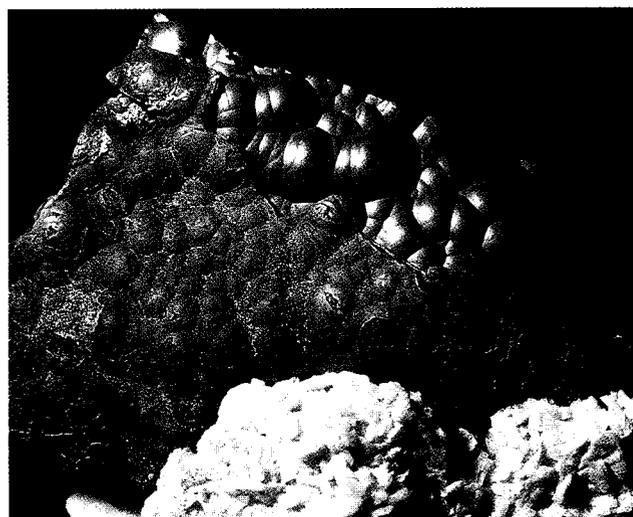
See also ENERGY; LIGHT.

HEMATITE Hematite (Fe_2O_3) is an important iron ore. It is ferric oxide, a compound of iron and oxygen. Hematite can be black, brownish red, or dark red. A fresh scratch on hematite is blood red.

The word *hematite* means “bloodlike.” The ore occurs in various forms, such as shiny crystals, grainy rock, and loose, earthy material. One interesting variety is kidney ore. It is so called because it is shaped in round masses that look like kidneys. One form of hematite, called red ocher, is used to color paint.

Large amounts of hematite occur in Canada, Brazil, China, and Britain. The United States has the world’s largest and most productive hematite mines, around Lake Superior.

See also IRON; ORE.

**HEMATITE**

Hematite varies in color from metallic black to dull red. This sample of kidney ore has both types. Hematite is the most important iron ore. It is also used in polishing compounds.

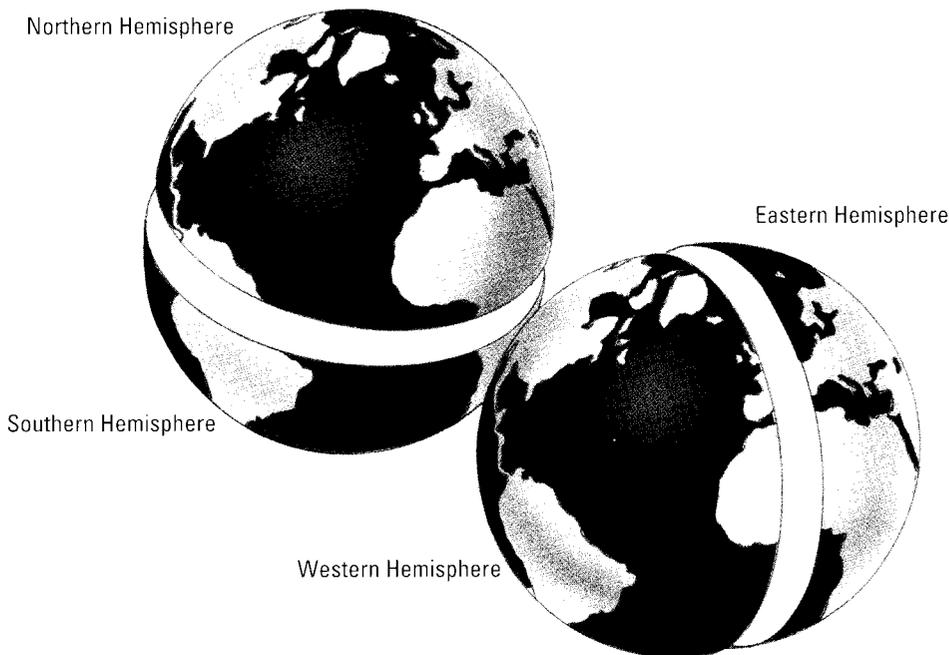
HEMISPHERE *Hemisphere* means “one-half of a sphere,” particularly one-half of the earth. The earth can be divided into two sections by the equator. The area north of the equator is the Northern Hemisphere, while the area south of the equator is the Southern Hemisphere.

The earth may also be divided into the Eastern and Western Hemispheres. The dividing line between these hemispheres is the prime meridian, at 0° longitude. The area east of the prime meridian to 180° longitude is the Eastern Hemisphere, and the area west of the prime meridian to 180° longitude is the Western Hemisphere.

See also LATITUDE AND LONGITUDE; MAP AND MAPPING.

HEMISPHERE

The earth can be divided into two pairs of hemispheres. Division along the equator produces the Northern and Southern Hemispheres (left). Division along the prime meridian produces the Eastern and Western Hemispheres.



HEMLOCK The hemlock is any of several species of biennial and perennial poisonous plants belonging to two genera (plural of *genus*) of the parsley family. The poison hemlocks belong to genus *Conium*, while the water hemlocks (which are also poisonous) belong to genus *Cicuta* (see BIENNIAL PLANT; PARSLEY FAMILY).

The most common poison hemlock is *Conium*

**HEMLOCK**

Poison hemlock has finely divided leaves and small white flowers, all growing on spotted hollow stems.

maculatum, which grows in most parts of the world. It reaches a height of about 4 ft. [1.2 m] and has many branches. The hollow stems usually have red spots. The plant's leaves are divided and look much like those of the parsley plant. A deadly poison, coniine, is produced by this plant. It is believed that the Greek philosopher Socrates was given a poison hemlock drink as a death sentence.

European water hemlock grows in marshes and is extremely poisonous. American water hemlock produces poisonous tubers (swollen underground stems) and leaves. This plant is also called musquash root or beaver poison.

See also POISONOUS PLANT.

HEMLOCK TREE The hemlock tree is any of ten species of large, evergreen conifers belonging to the genus *Tsuga* of the pine family (see CONIFER; EVERGREEN; PINE). Native to North America and Eastern Asia, these trees usually have purplish or reddish bark and long, thin branches. The leaves are short, blunt, and needlelike. Cones grow from the ends of the branches.

The eastern hemlock reaches heights of about 100 ft. [30 m]. The wood is soft and coarse and splinters easily. It is often used in building crates and for making paper pulp. Eastern hemlock is also called Canadian hemlock or hemlock spruce.

The western hemlock can be taller than 200 ft. [60 m]. Its wood provides valuable lumber. It is also called hemlock fir or Prince Albert's fir. Some other plants are also called hemlock (see HEMLOCK).



HEMLOCK TREE

The western hemlock is the largest type of hemlock tree.

HEMOGLOBIN Hemoglobin is an iron-containing protein found in the blood of many animals. Its function is to carry oxygen from the lungs to the tissues of the body. It does this by forming weak, easily broken bonds with oxygen molecules. As the blood travels through the body, these bonds are broken, and hemoglobin gives up the oxygen to the tissues.

In its normal state, hemoglobin is dark red in color. When it combines with oxygen to form oxyhemoglobin, however, it becomes bright red. It is hemoglobin that gives blood its color. In vertebrates (animals with backbones), hemoglobin is found in the red blood cells.

During the formation of the red blood cells in the bone marrow, hemoglobin is also formed. When the red blood cells die, the body breaks them up and reuses their parts. Iron from the hemoglobin is transferred back to the marrow to be put into new red blood cells.

Hemoglobin can also combine with substances other than oxygen. Often, these are permanent

bonds and, because of this, some hemoglobin molecules are unable to carry as much oxygen as they could before. If hemoglobin cannot carry enough oxygen, the body's tissues may not receive enough oxygen to work properly. This may be serious enough to cause death. Carbon monoxide (found in automobile exhaust fumes and in smoke from fires), for example, forms a stable compound with the hemoglobin molecule, and can cause death. Many other poisons also work by combining with hemoglobin molecules in this way.

Several different types of hemoglobin have been identified. Hemoglobin-A, or HbA, is the most common, normal variety. A shortage of hemoglobin-A can result in anemia. Hemoglobin-S, or HbS, is an abnormal type of hemoglobin that is present in sickle cell anemia. This disease is hereditary and can cause severe pain and even death.

See also ANEMIA; BLOOD; SICKLE CELL ANEMIA.

HEMOPHILIA (hē mō fil' ē ə) Hemophilia is a disease in which the blood fails to coagulate (clot) normally. There are several types of hemophilia, each caused by a lack of a specific substance (called a factor) that helps blood clot. The most common type is called hemophilia A and is caused by a lack of what scientists call factor 8.

For a person with hemophilia, any cut may prove serious. The wound continues to bleed and thus cannot start to heal. In an ordinary person, a blood clot quickly forms and plugs the wound. The blood dries and becomes solid. It prevents further blood loss. If the blood will not clot, even a simple operation, such as extracting a tooth, becomes dangerous. Bleeding into the joints is another danger. A slight knock on the knee, for example, may cause bleeding inside the joint. The joint swells and becomes very painful. Many hemophiliacs (people with hemophilia) become crippled as a result of such bleeding.

Fortunately it is possible to protect hemophiliacs to some extent. They can be given transfusions of normal blood before operations, and the clotting factors that are missing can be injected after an injury. There is no treatment yet available that will last for a lifetime, but researchers continue to try to find solutions.

Hemophilia is an inherited disease. That is, it is a disease passed on by parents to their children. In some cases of hemophilia, only males show symptoms of the disease, but females can carry it. A mother may pass on the disease to her sons.

See also HEMORRHAGE.

HEMORRHAGE (hēm' ər ij) *Hemorrhage* means "bleeding." However, the word is normally used only when a great deal of blood is lost at one time. When an artery is cut, the blood is bright red in color. It spurts out. When a vein is cut, the blood is darker in color, and flows steadily. When the small blood vessels called capillaries are damaged, the blood only oozes out (see CIRCULATORY SYSTEM).

A large hemorrhage is very dangerous. A person can bleed to death in less than five minutes if a big artery is damaged. Serious hemorrhage sometimes occurs inside the body, without being seen. For example, an ulcer (sore) in the stomach can cause bleeding into the stomach or outside it. Hemorrhage from an artery in the brain can cause a stroke (see STROKE). Some diseases, such as hemophilia, make people more likely to have hemorrhages.

See also HEMOPHILIA.

HEMP Hemp is a tall annual plant that is usually cultivated for its fibers (also called hemp) or its seeds. It is also the source of the drugs marijuana and hashish. Some botanists classify hemp as a member of the nettle family, others as a member of the mulberry family. Some botanists classify it as a member of a totally separate family, Cannabaceae (see CLASSIFICATION OF LIVING ORGANISMS).

Hemp grows well in subtropical or warm temperate areas. It grows a long tap root (see ROOT). The single stem is hollow and may be as tall as 20 ft. [6 m]. The leaves are made up of five or seven leaflets on stalks. The hemp plant is dioecious—that is, either male or female. The male plant has staminate flowers growing in clusters in the axils. The yellowish green flowers have five stamens and five sepals. The female plant has pistillate flowers

that are much smaller and less colorful than those of the male plant. The pistillate flowers consist of one sepal wrapped around one pistil (see FLOWER).

Hemp fibers are actually long strands of collenchyma growing inside the stem (see COLLENCHYMA). The fibers are removed by a process called retting. In retting, the stem is soaked or exposed to moisture in the air. This causes the non-fibrous parts to rot. The stem is then beaten to separate the fibers from the rotted matter. Hemp fibers are used in making rope, twine, sailcloth, canvas, and carpets.

Hemp fiber is strong but is not easily bleached or dyed. Hemp seeds are often used as commercial birdfeed. The seeds contain about 30 percent oil, which can be processed into paints or soaps. Frequently, the oil is used for cooking purposes.

See also MARIJUANA.



HEMP

The female hemp plant (above) has fibrous stems and small, plain flowers. Male plants have larger, showy flowers.

HENRY When an electric current flowing through a loop or coil of wire is changing, an extra induced voltage appears across the loop or coil (see CURRENT, ELECTRIC; INDUCTION). The loop or coil is said to have an inductance. This inductance is measured in henries. When the current is changing at one ampere per second and the induced voltage is one volt, the coil has an induction of one henry (see AMPERE; VOLT).

The henry is named after Joseph Henry, an American physicist who pioneered the study of induction in coils.

See also HENRY, JOSEPH.

HENRY, JOSEPH (1797–1878) Joseph Henry was an American physicist. He was born to a poor family in Albany, New York. He was apprenticed to a watchmaker and studied medicine and mathematics in his spare time. Eventually, he became a professor at Albany Academy. Henry was interested in magnetism and read about Michael Faraday's discovery of electromagnetic induction in 1831 (see FARADAY, MICHAEL; INDUCTION). Henry discovered self-induction (induction within a single circuit) in 1832. Later, he designed working electric motors. The unit of inductance is called the henry after him.

See also HENRY.

HENSON, MATTHEW ALEXANDER (1867?–1955) Matthew Alexander Henson was an African-American explorer who accompanied Robert Peary on his expedition to the North Pole in 1909. Henson, Peary, and four Eskimos were the first humans to reach the North Pole (see PEARY, ROBERT EDWIN).



MATTHEW HENSON

Matthew Henson was one of the six people who first reached the North Pole in 1909 in an expedition led by U.S. naval officer Robert Peary.

Henson was born on a Maryland farm. Both of his parents died when he was young, and he was then raised by an uncle. As a teenager, Henson worked as a cabin boy on a ship that traveled to such places as China, France, Japan, Russia, and Spain. He met Peary in the late 1880s and joined him on a surveying (measuring) expedition across Nicaragua, a country in Central America. For about the next twenty years, Henson accompanied Peary on explorations to areas near the North Pole. During that time, he learned the Eskimo language, how to lead a team of sled dogs, and how to survive in very cold and dangerous conditions. On April 6,

1909, Henson, Peary, and four Eskimos reached the North Pole.

In the years that followed, Henson's contributions to Peary's success were virtually ignored. It was not until 1945 that Henson received his first real recognition—a special medal from the U.S. Congress. In 1950, Henson was honored by President Harry Truman in a special ceremony. In 1954, he was invited to the White House by President Dwight Eisenhower for a ceremony marking the forty-fifth anniversary of the date he and Peary reached the North Pole. Henson wrote of his experiences in the book *A Negro Explorer at the North Pole*.

HEPATITIS Hepatitis is a disease in which the liver becomes inflamed and tender. Hepatitis can cause nausea, weakness, loss of appetite, and, in severe cases, liver failure. Along with these symptoms, hepatitis can also produce jaundice. This is a condition in which the fluids and tissues of the body take on a yellow color. Jaundice is particularly noticeable in the skin and eyes.

There are two types of hepatitis—viral and toxic. Viral hepatitis is caused by a virus or as a complication of other diseases, such as mononucleosis and yellow fever (see MONONUCLEOSIS; VIRUS; YELLOW FEVER). Toxic hepatitis is a reaction to alcohol, other drugs, or other chemicals.

The two most common forms of viral hepatitis are infectious hepatitis (hepatitis A) and serum hepatitis (hepatitis B). Infectious hepatitis is most often spread through contaminated food and water. Infection may cause few or no symptoms. Infectious hepatitis usually lasts about two to six weeks, and is not considered as serious as serum hepatitis.

Serum hepatitis was once transmitted largely through the transfusion of contaminated blood. However, tests were developed in the 1970s to test for contaminated blood. Today, serum hepatitis is spread similarly to the way the disease AIDS is spread—through improperly sterilized medical equipment, hypodermic needles shared by drug users, and sexual contact with an infected person. Symptoms of serum hepatitis last about six to

twelve weeks. People who have had the disease may carry the virus for many years and spread it to others. In severe cases, serum hepatitis may cause cirrhosis (scarring) of the liver and liver cancer.

See also AIDS; CIRRHOSIS; LIVER.

HERB In botany, the word *herb* is usually used in reference to a herbaceous plant, meaning any plant that does not contain any woody tissue (see HERBACEOUS PLANT). However, many people commonly use the word *herb* to mean any plant or part of a plant that can be used as a medicine, food seasoning, or coloring. In the preparation of foods, an herb is usually some part of a plant used to add flavor. Mint or parsley are examples of herbs used to flavor food.



HERB

Fennel (top) has a strong flavor similar to aniseed. Chives (bottom) have pinkish purple flowers at the ends of the leaves. The chopped leaves have a mild, onionlike flavor.

For many years and in many different cultures, herbs have been used in homemade medicines. For example, the gel inside the leaves of the aloe vera plant is believed to relieve the pain from a burn. Synthetic, or human-made, drugs have largely replaced the use of homemade medicine in industrialized countries, such as the United States. However, synthetic medicines often have dangerous side effects. This has led to increased interest in so-called natural healing methods, including the use of herbs, in recent years. Some herbs are used in modern medicines. For example, foxglove leaves contain the substance digitalis. Digitalis may be given to a patient to help regulate his or her heartbeat.

HERBACEOUS PLANT Herbaceous (hûr bā' shəs) plants are plants with soft, green stems instead of woody stems. The stems are often juicy or fleshy. Since they contain only small amounts of xylem, the stems are relatively weak (see XYLEM). Some herbaceous plants are annuals and die off after one season. Most biennial and perennial herbaceous plants die down in the fall and grow new stems and leaves in the spring. The roots survive the winter underground. Examples of herbaceous plants include basil, catnip, geranium, peppermint, petunia, and tansy.

See also ANNUAL PLANT; BIENNIAL PLANT; HERB; PERENNIAL PLANT; WOODY PLANT.



HERBACEOUS PLANT

Begonias are herbaceous plants whose leaves die off in the fall.

HERBICIDE Herbicides are chemical pesticides that kill plants. Usually, herbicides are used to kill weeds growing among more desirable plants, such as food crops (see PESTICIDE; WEED). At one time, sodium chloride (salt) and petroleum-based substances were the most widely used herbicides. Since World War II (1939–1945), however, many other substances have been used.

Herbicides are either selective or nonselective. Selective herbicides kill certain weeds but do not harm other plants. Defoliant and soil sterilant are nonselective herbicides. Defoliant cause leaves to fall off plants, killing the plants. Soil sterilant kill plants and may prevent other plants from growing in the soil (see CHEMICAL AND BIOLOGICAL WARFARE). There are both inorganic and organic herbicides. Inorganic herbicides, such as sodium chloride, sulfuric acid, and copper sulfate, are usually nonselective. Organic herbicides contain elements in combination with such elements as carbon, hydrogen, and oxygen. Some organic herbicides work by affecting the growth hormones of plants (see GIBBERELLINS; HORMONE). Others kill selected species of plants by interfering with their metabolism (see METABOLISM).

Herbicides are also classified by the way in which they work. Contact herbicides, such as sulfuric acid and paraquat, kill only those parts of a plant with

which they come into contact. Certain contact herbicides are used to kill the above-ground parts of a potato plant before harvesting the underground tubers (potatoes). Translocated herbicides enter through the leaves and are transported throughout the plant, killing the leaves, stems, and roots (see VASCULAR PLANT). This is especially effective in controlling weeds with extensive roots or rhizomes. A rhizome is an underground stem that often looks and acts like a root (see RHIZOME).

There has been growing concern about the widespread use of herbicides because many have been shown to, or are suspected to, cause cancer (see CANCER). Tests have shown that herbicides can seep through the soil and contaminate groundwater that may later be used as drinking water (see GROUNDWATER). Herbicides may wash off farmland to which they have been applied and contaminate lakes, rivers, and streams. Herbicides can also cling to the outside of food crops or be absorbed into their tissues.

Because of the possible danger of using herbicides, many scientists suggest that farmers reduce the amount they use. This can be done through certain farming practices. For example, on a test farm in Maryland, a dense trailing plant called vetch was planted between rows of corn (see VETCH). As the vetch grew, its leaves covered the



HERBICIDE

In Third World countries, farmers use backpacks to spray herbicides onto their crops to kill weeds. This farm worker wears a mask to prevent breathing in the poisonous chemical.

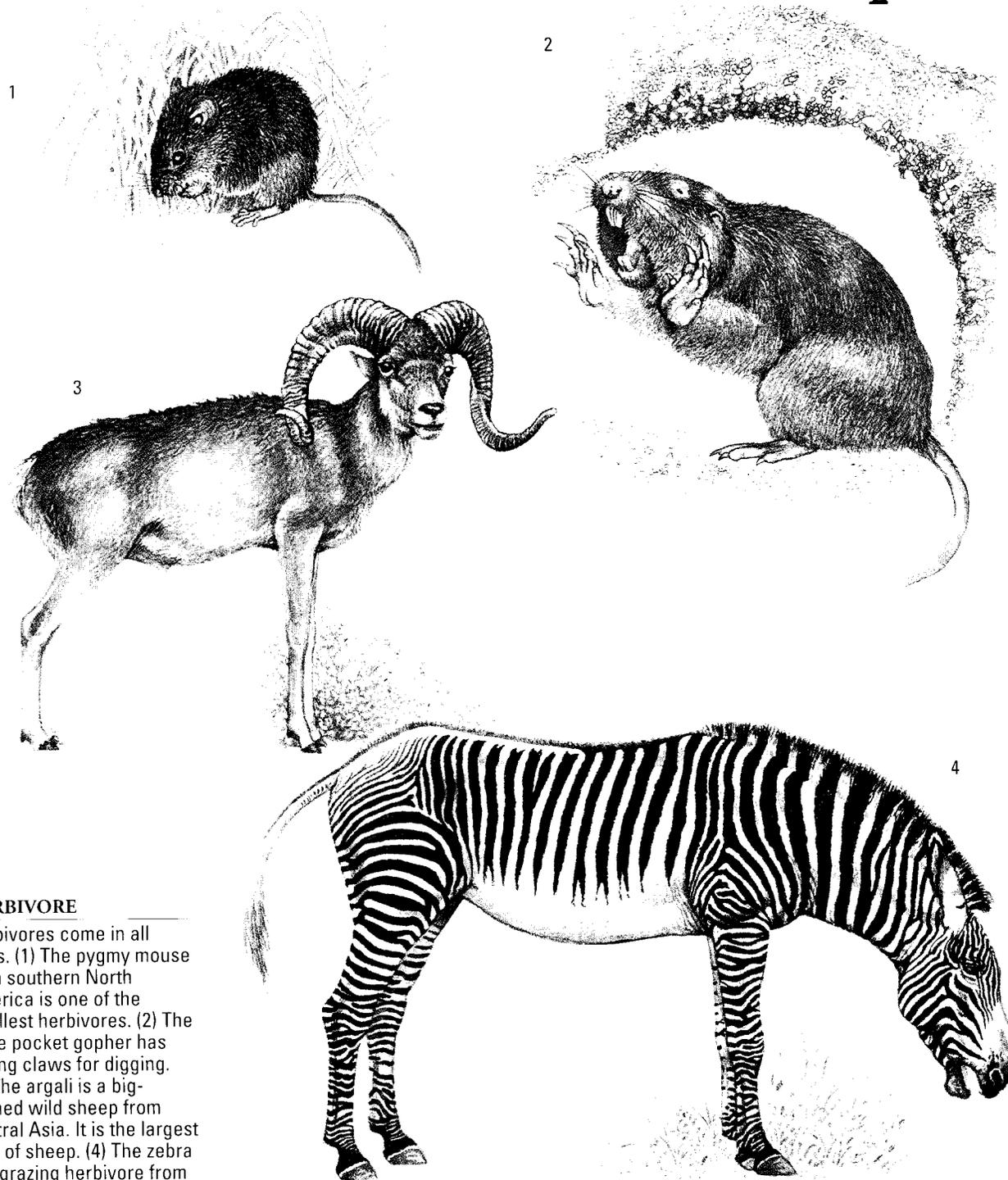
soil between the corn. This prevented weeds from growing there. Other experiments have shown that farmers can still have profitable crops even if they simply cut back on the amount of herbicides used. *See also* AGRICULTURE.

HERBIVORE A herbivore is any animal that eats only plants. Such animals are also sometimes

called vegetarians. Herbivores include rabbits, deer, cows, cardinals, squirrels, and honeybees. Animal herbivores often have specially designed teeth to chew the plants they eat. Their digestive systems have special enzymes (proteins that cause or speed up chemical reactions) and may be specially constructed to digest the plant matter.

See also CARNIVORE; INSECTIVORE; OMNIVORE.

 **PROJECT 65**



HERBIVORE

Herbivores come in all sizes. (1) The pygmy mouse from southern North America is one of the smallest herbivores. (2) The large pocket gopher has strong claws for digging. (3) The argali is a big-horned wild sheep from central Asia. It is the largest kind of sheep. (4) The zebra is a grazing herbivore from the plains of Africa.

HEREDITY

Heredity is the passing of characteristics from parents to offspring. The study of heredity is called genetics (see GENETICS). In most cases, the genetic characteristics of an organism are determined when a male gamete (sperm) combines with a female gamete (egg) to form a zygote (see REPRODUCTION). This zygote has characteristics that it has inherited from both parents. As the zygote develops into an embryo, these characteristics become more obvious. These characteristics are controlled by tiny structures called genes. The genes are on chromosomes, which are located in every cell of an organism. It is the genes that “tell” each cell what it should do in order to become a working part of the organism (see CHROMOSOME; DIFFERENTIATION, CELLULAR; GENE).

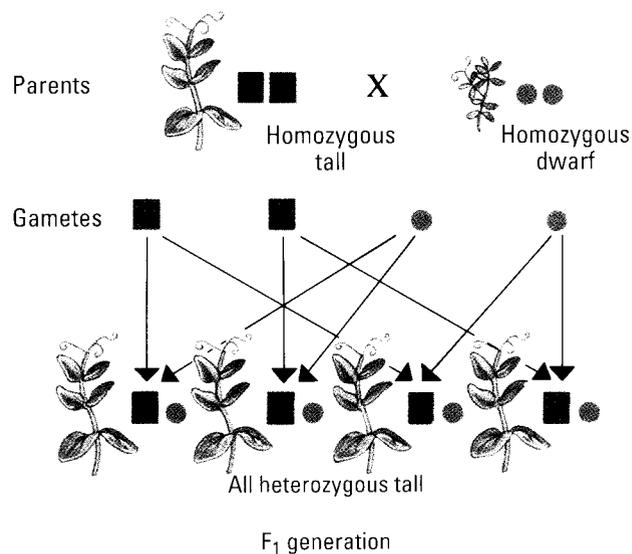
The most important work in genetics was that of Gregor Mendel, an Austrian monk (see MENDEL, GREGOR). In the 1860s, Mendel developed two laws that helped explain heredity.

Mendel’s first law Mendel’s first law is also called the law of segregation. It states that genes exist in pairs called alleles, one allele on each of a pair of chromosomes. During meiosis (the process of cell division that produces gametes), these pairs separate so that only one of these genes is passed from parent to offspring (see MEIOSIS). This gene pairs up with a similar one from the other parent.

Mendel used pea plants in his experiments because they can either self-fertilize or cross-fertilize (see FERTILIZATION; POLLINATION). He found that if the plants self-fertilized for several generations, the offspring were always identical to the parents. Such offspring were called purebred or homozygous. Mendel then decided to breed two different types of homozygous pea plants—dwarf and tall. The first generation— F_1 —produced from this cross were all tall. However, when he allowed members of the F_1 generation to self-fertilize, he found a mixture of tall and dwarf plants in a ratio of three to one.

These results can be explained by studying the

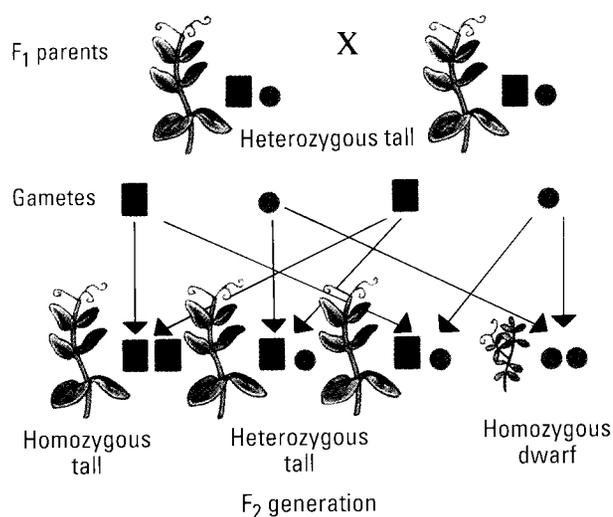
genes of these plants. In peas, there are separate genes that determine whether the plant is tall or dwarf. These genes are alleles, located on separate chromosomes of a chromosome pair. A homozygous tall plant has only genes for tallness, and a homozygous dwarf plant has only genes for dwarfness. A hybrid plant is produced by mating two different homozygous plants (see HYBRID). Genetically, the hybrid is heterozygous. That is, it has one gene for tallness and one gene for dwarfness. The plant appears tall, however, because tallness is dominant over dwarfness (see DOMINANCE). In the diagram below, the genes for tallness are represented by boxes and the genes for dwarfness by circles. All the offspring will be tall in the F_1 generation because they contain the dominant gene for tallness. However, they also contain the recessive gene for dwarfness.



FIRST GENERATION

Mendel found that the offspring from breeding purebred tall (homozygous) pea plants with purebred dwarf (homozygous) plants produced an F_1 generation of offspring that were also crossbred tall (heterozygous) plants.

If the F_1 generation is allowed to self-fertilize, the genes on the chromosomes separate into the gametes and recombine. The second generation of offspring— F_2 —will consist of tall and dwarf plants in the ratio three to one. The tall plants may be



SECOND GENERATION

When Mendel interbred the tall (heterozygous) F₁ pea plants from his first experiment, he obtained F₂ offspring in which only one plant in every four was dwarf (homozygous). Of each of the three tall plants, one was homozygous and two were heterozygous.

either homozygous or heterozygous because tallness is dominant. The dwarf plants, however, are all homozygous because dwarfness is recessive. A recessive characteristic only shows up when an organism is homozygous for that characteristic.

Mendel's second law Mendel's second law is also called the law of independent assortment. It states that each pair of genes is inherited independently of any other pair of genes. This law is important when studying two or more characteristics at the same time. Mendel used peas having homozygous round, yellow seeds and peas having homozygous wrinkled, green seeds. When he crossed these two, he found that all the offspring (F₁) had round, yellow seeds. This showed that round was dominant over wrinkled, and yellow was dominant over green. When members of the F₁ generation were allowed to self-fertilize, they produced four kinds of seeds: round-yellow, round-green, wrinkled-yellow, and wrinkled-green.

This law applies only if the two pairs of genes are not linked. Linked genes are located on the same chromosome. They are usually inherited together because it is the chromosomes that separate into the gametes.

Later experiments Although Mendel completed his work in the 1860s, it was ignored until about 1900. In 1910, Thomas Hunt Morgan, an American biologist, was the first to propose the idea of linked genes (see MORGAN, THOMAS HUNT). He also mapped the locations of genes on the chromosomes. In addition, Morgan showed that there can sometimes be an exchange of genes or parts of chromosomes during meiosis. This exchange is called crossing-over.

Other scientists did experiments with mutations. Mutations are changes in an offspring caused by changes in the genes. Mutations can cause characteristics in the offspring that were not present in the parents. Mutations occasionally occur naturally. However, mutations are more often caused by exposure to radiation, drugs, or other factors (see MUTATION).

Hereditary diseases Some diseases and disorders are inherited by a child from his or her parents. Frequently, the disease is caused by recessive genes. In order for the child to have the disease, then, he or she must be homozygous for the recessive, disease-causing gene. Since the normal, nondiseased condition is dominant, heterozygous parents may be carriers but will have no signs of the disease themselves. Diseases such as hemophilia and sickle cell anemia are hereditary.

In hemophilia, the blood does not clot properly. This can cause excessive bleeding when there is an injury. Hemophilia occurs mostly in males. The most serious danger comes from internal bleeding. Hemophiliacs often carry chemicals that they can inject to stop the bleeding in case of injury (see HEMOPHILIA).

Sickle cell anemia is a hereditary blood disease that occurs mainly among African-Americans. Many African-Americans are born with some abnormal hemoglobin molecules in their blood (see HEMOGLOBIN). A large amount of these abnormal hemoglobin molecules causes sickle cell anemia. An affected person may seem perfectly normal until the onset of a sickle cell crisis. A crisis occurs if the body is deprived of oxygen due to intense exercise, emotional upset, or other factors. This

lack of oxygen causes the abnormal hemoglobin cells to turn from a round shape to an elongated shape called a sickle. Sickled cells clog blood vessels and hold back the flow of blood. This further deprives the body of oxygen and causes great pain throughout the body. Since 1970, some chemicals have been shown to return sickled cells to their normal shape. Because these chemicals have dangerous side effects, researchers are still seeking a safe cure (see SICKLE CELL ANEMIA).

Other hereditary disorders include albinism, color blindness, Tay-Sachs disease, Gaucher's disease, neurofibromatosis, and muscular dystrophy (see ALBINO; COLOR BLINDNESS). Tay-Sachs occurs in Jewish children of eastern European descent. It causes brain damage, blindness, and death by age three or four. Gaucher's disease may affect the spleen, liver, bones, or nerves. Neurofibromatosis (NF) is commonly referred to as the elephant man's disease. NF is an incurable condition in which nerve tumors develop below the skin surface, causing disfigurement. In 1990, scientists discovered that NF may be caused by a mutant gene that is unable to perform its normal tasks of fighting tumors. Muscular dystrophy refers to a group of over twenty hereditary diseases that weaken the

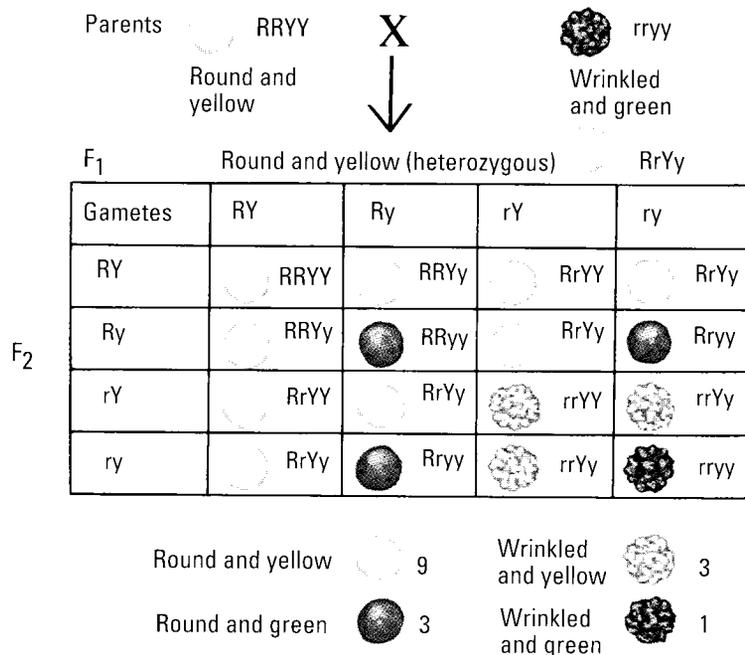
muscles holding the skeleton together. Muscular dystrophy can seriously affect movement and posture. With some other diseases, such as cancer and diabetes, the tendency to get the disease is inherited, but the disease itself is not.

Inheritance The genes that a child receives from his or her parents are the basis for biological inheritance. These are the basic characteristics inherited from the parents. It is the biological inheritance that determines what type of organism develops from a fertilized egg. It also determines the basic physical and mental traits of that organism.

Another major factor in the development of an organism is its environment or cultural inheritance. The environment includes all outside factors from the time the egg is fertilized until the organism dies. Studies have shown that the environment can affect the intelligence, appearance, and other characteristics of an organism. Identical twins have identical biological inheritances. However, it has been shown that twins who have been raised in separate and different environments develop into two quite different people. They may have different physical and mental traits which, apparently, are the result of differences in the environment.

SECOND LAW

Mendel's second law shows that, among pea plants, the gene for round seeds is dominant over that for wrinkled seeds. Also, yellow is dominant over green. Mendel bred peas with round and yellow seeds (both dominant characteristics) with plants that had wrinkled and green seeds (both recessive). All the offspring—the F₁ generation—were heterozygous plants with round and yellow seeds. But when he interbred these plants, the F₂ generation showed all four possible combinations in the ratio 9:3:3:1.



HERMAPHRODITE (hər mǎf' rə dīt') A hermaphrodite is an organism that has both male and female reproductive organs (see REPRODUCTION; REPRODUCTIVE SYSTEM). Many plants are hermaphrodites because their flowers have both stamens (male structures) and pistils (female structures). Such plants are called monoecious plants (see MONOECIOUS).



HERMAPHRODITE

Land snails are hermaphrodites, which means that they have both male and female reproductive organs. When they mate, two snails come together and fertilize each other's eggs.

Many of the lower invertebrates (animals without backbones) are hermaphrodites. Most of these animals are slow moving (for example, snails and slugs) or are attached to some other organism or structure (for example, barnacles). Many are parasites (see PARASITE). Although hermaphrodites theoretically have the ability to fertilize their own eggs, very few species do. This is often a result of the positions of the reproductive organs. The earthworm, for example, is not able to fertilize itself. Two earthworms, however, can fertilize each other. Barnacles and other organisms form mating chains, each creature fertilizing the next. Some organisms show successive hermaphroditism. That is, male and female organs develop at different times so that self-fertilization is impossible.

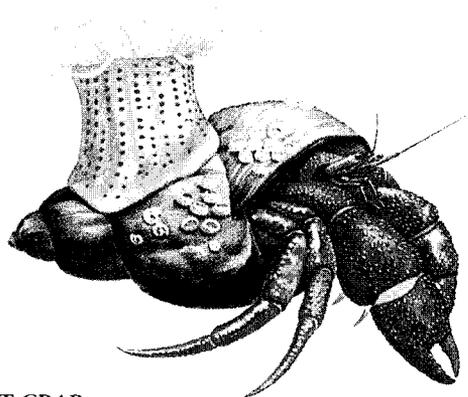
Very few vertebrates (animals with backbones) are hermaphrodites. Some hermaphroditic fish fertilize their own eggs by laying the eggs and then spreading milt (sperm) over them. As a rule, though, hermaphroditism among vertebrates is rare and is usually abnormal. Occasionally, a

human being or a mammal will show pseudohermaphroditism. This means that outwardly, the creature appears to be either male or female. However, the organism has the internal reproductive structures of both sexes. This is extremely rare and is caused by a chromosomal defect.

See also CHROMOSOME; FERTILIZATION; POLLINATION; SEX.

HERMIT CRAB The hermit crab is a crab in which the hind end of the body is not folded under the rest (see CRAB). Unlike other crabs, the hermit has soft, unprotected rear parts. It protects itself by living inside an empty shell of a sea snail. The hermit crab carries the snail shell around with it. Only the hermit crab's front end is visible. If the crab is alarmed, it can retreat inside the shell and plug the entrance with one of its claws. Of course, the crab's "house" does not grow with the crab. The hermit crab, as it grows, changes its shell for a larger one. Sometimes one hermit crab pulls another one out of the shell it wants. Each hermit crab lives alone in its adopted shell. Large groups of hermit crabs often crowd areas on the bottom of the ocean where seashells are plentiful.

The robber crab, also called the coconut crab, is a large hermit crab found in the Indian and Pacific oceans. The robber crab may grow to 2 ft. [61 cm] in length. When fully grown, the robber crab gives up living in shells. It develops plates of armor on the rear part of its body. This type of crab lives on land. It is well-known for climbing coconut palms, and often feeds on the broken nuts on the ground.

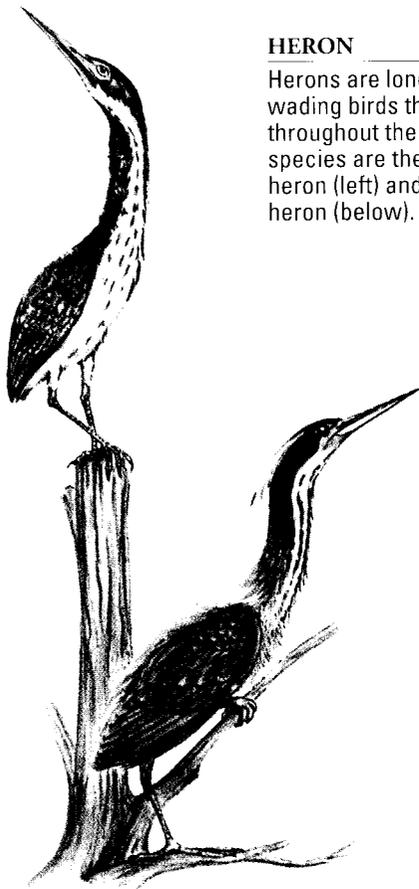


HERMIT CRAB

The hermit crab protects the soft part of its body by living inside an empty mollusk shell, usually a sea snail.

HERNIA A hernia is a rupture (break or tear) in a part of the body. It is caused by an organ pushing through the tissue that normally covers it. Hernias occur most commonly in the abdomen. A loop of intestine may push its way through a weak part of the abdominal wall and form a bulge under the skin. This happens usually in the groin, where the abdomen meets the thigh. Sometimes it happens near the umbilicus. Surgeons repair hernias by stitching the torn tissues together and pushing the bulge back into place. This is called “reducing” the hernia. See also HIATUS HERNIA.

HERON A heron is a bird that belongs to the family Ardeidae. It has a very long neck, a long bill, and long legs. The bird itself may be large or quite small. Herons wade into shallow water and capture small fish and frogs for food. During the breeding season, many species grow long, colorful feathers, called plumes, on their heads. Herons are found throughout the world. There are twelve species in North America. The largest is the great white heron. It can grow 38 in. [95 cm] tall. It is pure



HERON

Herons are long-legged wading birds that live throughout the world. Two species are the lined tiger heron (left) and the agami heron (below).

white. Herons spend a great deal of time on the ground, but they fly well and often nest high in the trees. Bitterns and egrets are types of herons.

HERPES Herpes is the name of certain types of conditions of the skin or mucous membrane that are characterized by blisters. These conditions are all caused by viruses that belong to the herpes viruses group, though the term *herpes* is used mainly for two types, herpes simplex and herpes zoster. As a group, these viruses are believed to cause more human illness than any other group.

Two types of herpes simplex are known. One causes cold sores, also called fever blisters—an eruption of blisters that often occurs during or after one of several diseases that are associated with fever. The most common of these diseases are colds, influenza, and pneumonia. The blisters usually appear around the mouth and on the lips (called herpes labialis); about the nose, the rest of the face, and the ears; and in the mouth and pharynx.

The second type of herpes simplex causes genital herpes (see SEXUALLY TRANSMITTED DISEASE). Such infections in the genital areas have become more common in recent years. In this form of herpes, the first sign is usually a mild itching, followed by blistering. The blisters usually develop in clusters; they later break open and then crust over. Fever and headaches may also occur.

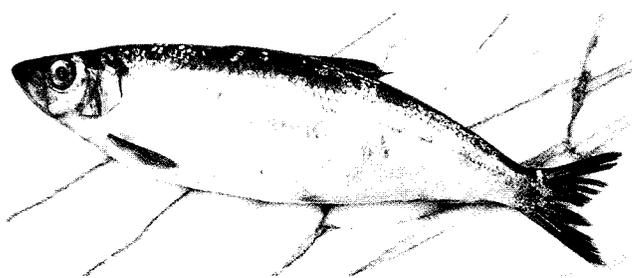
There is no cure for the two types of herpes simplex. However, certain drugs may speed the healing of blisters and reduce the severity of recurrent blisters.

Herpes zoster (caused by the varicella-zoster virus) is also called shingles. In this disease, the virus attacks a sensory nerve. The skin over the nerve usually breaks out in blisters a few days after the beginning of the disease, and the patient has severe pain along the route of the nerve. The virus that is responsible for shingles is the same one that causes chicken pox in children.

HERPETOLOGY (hûr' pî töl' ə jē) The study of amphibians and reptiles is called herpetology. A scientist who studies amphibians and reptiles is called a herpetologist. Herpetologists study many different things about the animals. They study how

the animals' bodies are put together, how they are related to other animals, and how and where they live. By learning more about amphibians and reptiles, scientists also learn more about the earth and its past (see AMPHIBIAN; REPTILE).

HERRING The herring is a saltwater fish that belongs to the family Clupeidae. It is a silvery fish that grows to about 12 in. [30 cm] in length. Herrings are found in the northern waters of both the Atlantic and Pacific oceans. They swim in huge schools—groups of thousands of fish. Herring feed on plankton, which are small organisms floating in the water (see PLANKTON). The herring is an important food for people.



HERRING

The herring is an important food fish that is caught in northern oceans.

HERSCHEL, SIR WILLIAM (1738–1822)

William Herschel was a famous astronomer. He was born in Germany and later moved to England (see ASTRONOMY). Herschel is best known for discovering the planet Uranus (see URANUS). He also studied nebulae, which were then thought to be single planets surrounded by milky clouds of light. Herschel proved that what were called nebulae were actually huge collections of stars.

Today, astronomers use the term *nebulae* to mean clouds of gases and dust in outer space (see NEBULA; STAR). With the help of his sister Caroline, Herschel observed and recorded 2,500 nebulae. He referred to them as “island universes.” Herschel made his discoveries using telescopes he designed himself. These telescopes were far better than those of any other astronomer working at the time (see TELESCOPE).

In 1816, Herschel was knighted by King George III for his contributions to astronomy. Herschel also discovered two satellites of Uranus and

infrared rays. His son, Sir John Frederick William Herschel, also was a well-known astronomer.

See also INFRARED RAY.

HERTZ The frequency of a wave is the number of vibrations, or cycles, passing a stationary observer in one second. Frequency is measured in hertz, abbreviated Hz. The old name for this unit is cycles per second. The hertz is named after the German physicist, Heinrich Hertz, who was the first to produce electromagnetic waves.

See also FREQUENCY; HERTZ, HEINRICH.

HERTZ, HEINRICH (1857–1894) Heinrich Hertz was a German physicist. He was born in Hamburg. Hertz was the first to prove the existence of electromagnetic radiation. He found he could detect a spark jumping between two charged rods. He used a copper ring with a small gap in it. When the spark jumped between the rods, a spark also passed over the gap in the copper ring, which was several yards away from the rods. He deduced that some kind of radiation went through the air. This was the discovery from which radio was invented.

See also ELECTROMAGNETIC RADIATION; HERTZ; RADIO.

HIATUS HERNIA A hiatus hernia is a condition in which part of the stomach bulges upwards into the chest through the hiatus opening normally only occupied by the esophagus in the diaphragm (see DIAPHRAGM; DIGESTIVE SYSTEM). The cause of this is unknown, but it tends to occur in people who are overweight and in those who smoke. It may cause no symptoms, but in some people the acidic juices from the stomach flow back into the esophagus. This may cause heartburn or even swelling of the esophagus. The pain can be mistaken for a heart attack. The hernia is diagnosed either by direct examination with an endoscope or by giving the patient a drink of fluid that shows up on an X ray (see ENDOSCOPY; RADIOGRAPHY). The usual treatment is avoiding large meals and losing weight or stopping smoking. An operation to return the bulging part of the stomach to below the diaphragm can be performed in severe cases.

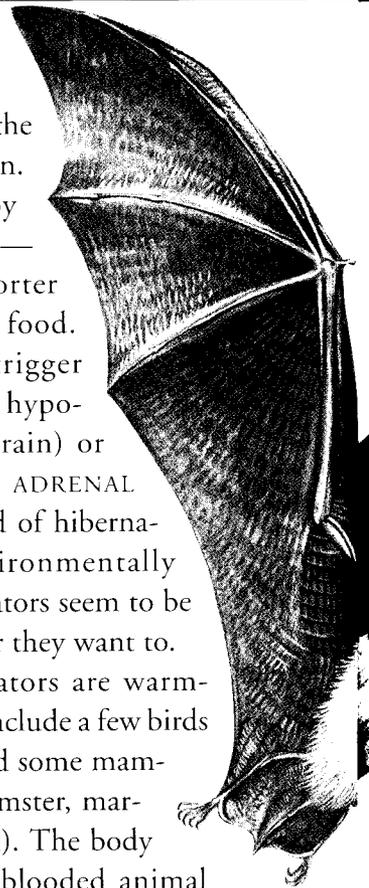
HIBERNATION

Hibernation is a deep sleep that some animals go into during the winter. In the winter, many animals have trouble finding food. Since the weather is cold, their bodies need much more energy than usual just to keep warm. For many animals, hibernation is the only way to survive during this time.

Before an animal hibernates, it eats a great deal of food. Much of this food is stored as fat in the animal's body. This fat is used as a source of energy during hibernation. During hibernation, an animal's metabolic rate is greatly lowered (see METABOLISM). The body temperature is much lower than normal and is usually about the same as the air temperature. Breathing and heartbeat slow. The animal's control systems, however, stay active. Thus, if the weather gets too cold, metabolism, heart rate, and breathing rate increase; body temperature rises; and more stored fat is used. As a result, the animal may wake up and move to a warmer place, if necessary.

Scientists do not know the exact cause of hibernation. It may be brought on by environmental changes—lower temperatures, shorter days, and less available food. These changes may trigger changes in the animal's hypothalamus (part of the brain) or adrenal glands (see ADRENAL GLANDS; BRAIN). The end of hibernation may also be environmentally directed, but true hibernators seem to be able to wake up whenever they want to.

The only true hibernators are warm-blooded animals. These include a few birds (such as the poorwill) and some mammals (such as the bat, hamster, marmot, and ground squirrel). The body temperature of a warm-blooded animal



WINTER SLEEP

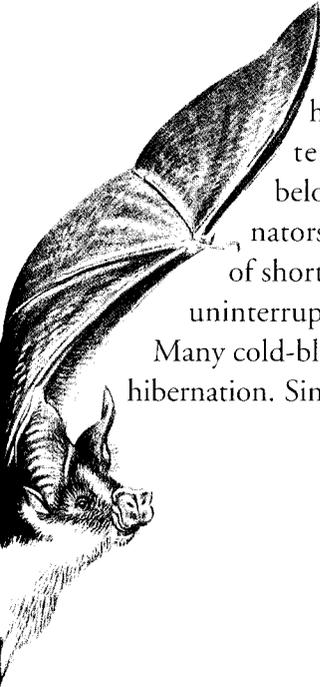
In the colder parts of the world, amphibians and reptiles enter a deep sleep in winter. This is not true hibernation because their temperature is always the same as their surroundings, even when they are awake.

usually stays fairly constant when it is active and is not greatly affected by the air temperature. During true hibernation, the animal's body temperature drops to well below normal. Most true hibernators actually go through a series of shorter naps rather than one long, uninterrupted sleep.

Many cold-blooded animals enter a type of hibernation. Since these animals' temperature

HIBERNATING BAT

The leaf-nosed bat (left) is a mammal. It is therefore warm-blooded, and its period of winter sleep is true hibernation.

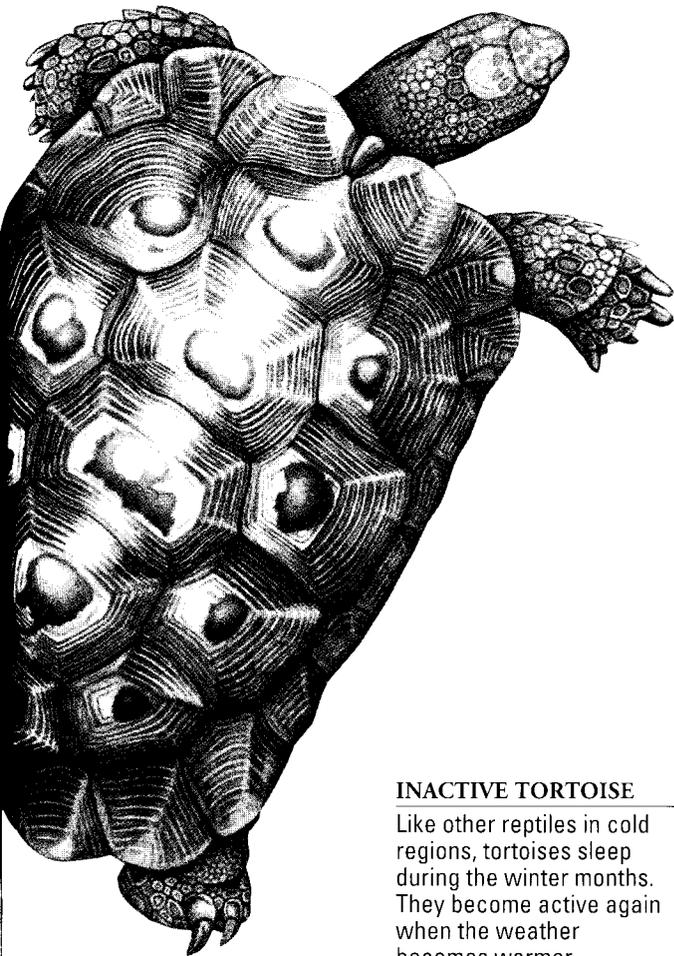


is usually close to the air temperature anyway, it is not considered a true hibernation. All amphibians and reptiles living in cold areas sleep through winter. Some bury themselves in soil or at the bottom of a pond to keep from freezing. As the weather warms up, the metabolic rate increases and the animals become active. Many insects enter a form of hibernation sometimes as adults, but more often in one of the earlier stages of their life history.

Some animals, such as bears, sleep during the winter, but their body temperature stays near normal. This type of winter sleep is called carnivorean lethargy. Some animals enter a true hibernation every day. Bats, for example, hibernate during the day and become active at night. This is known as diurnal hibernation.

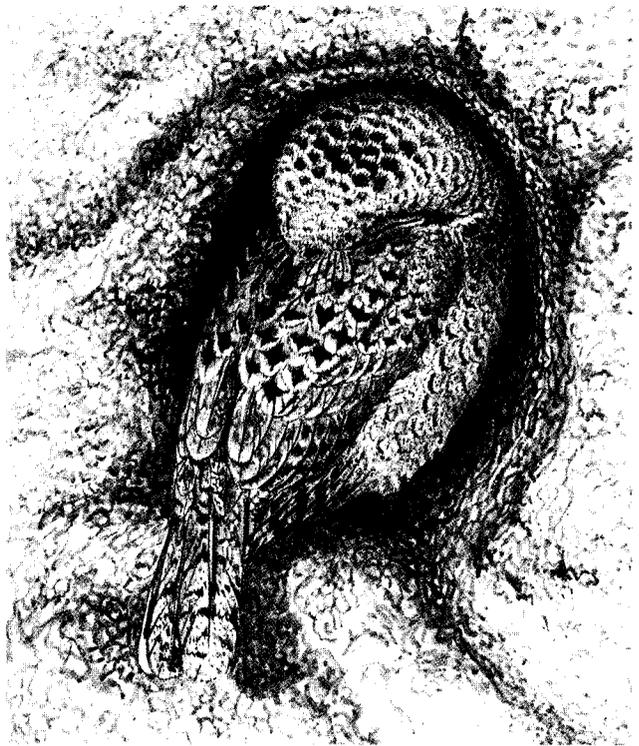
Other animals enter a deep sleep during the summer, particularly when the weather is very hot and water is scarce. This summer sleep is called estivation. Many desert animals estivate. Also, animals that live in or near the water may estivate if their water source dries up.

See also DORMANCY.



INACTIVE TORTOISE

Like other reptiles in cold regions, tortoises sleep during the winter months. They become active again when the weather becomes warmer.



SLEEPING BIRD

The poorwill (above) is a type of nightjar. It is the only bird that is known to hibernate. It has been known to return to the same place every winter to hibernate.

HIBISCUS Hibiscus is a genus of two hundred to three hundred species of flowering plants belonging to the mallow family. Some are herbaceous plants, while others are trees or shrubs (see HERBACEOUS PLANT; MALLOW FAMILY; WOODY PLANT). They grow in tropical and temperate regions throughout the world and many are cultivated in gardens. The large, bell-shaped flowers are made up of five petals, which may be white, yellow, pink, or red.

The swamp rose mallow is common in marshes in the eastern United States. Its white or pink flowers often measure more than 7 in. [18 cm] across. *Hibiscus esculentus* produces a seed pod called okra or gumbo. It is a popular food in many parts of the country, and is often cooked in stews or soups.



HIBISCUS

The hibiscus shrub bears large, showy flowers.

HICKORY The hickory is any of a group of trees that grow throughout the eastern United States. Hickories belong to the walnut family. They have long leaves made up of many oval or rounded leaflets. The trees also produce large nuts, which are eaten by wildlife and people. There are ten species of hickories in North America. The pecan tree is a type of hickory. The wood of hickory trees is used for the handles of tools such as axes and hammers because it is very strong.



HICKORY

Pecans grow on a type of hickory tree.

HI-FI Hi-fi, or high-fidelity, systems are made up of electronic equipment that reproduce a source sound very accurately over its full frequency range without producing background noise. Hi-fi systems were first introduced in the 1950s. The early systems reproduced monophonic sound—sound that seems to come from one direction. Modern hi-fi systems, also known as stereophonic sound systems or stereos, reproduce stereophonic sound, or sound that comes from two directions. This involves a long series of recording and reproducing processes in which the sound is broadcast through two or more channels. Hi-fi systems are made up of three different types of components, or parts: the program source, the amplifier, and the speakers. The program source can be a record player, tape player, compact disc player, or radio. The amplifier strengthens or amplifies the weak electronic signals given off by the program source. A hi-fi system can have a pair of speakers that change the electronic signals into sound. There are also quadrasonic or surround-sound systems that use more than two channels and speakers.

HIPPARCHUS (hī pār' kəs) (about 160—about 126 B.C.). Hipparchus was a Greek astronomer. All that we know about him comes from the writings of Ptolemy. Ptolemy tells us that Hipparchus built an observatory at Rhodes, an island off the

southwestern coast of present-day Turkey. Hipparchus is the earliest systematic astronomer known. He discovered the precession of the equinoxes and catalogued more than a thousand stars (see PRECESSION). Hipparchus must have been a brilliant mathematician as well as an outstanding scientist. He invented trigonometry and worked out the distances of the sun and moon from Earth. He also used a system of latitude and longitude to show where places on Earth are located.

See also LATITUDE AND LONGITUDE; PTOLEMY; TRIGONOMETRY.

HIPPOCRATES (hĭ pŏk' rə tēz') (about 470–about 377 B.C.). Hippocrates was a Greek doctor. He is called “the father of medicine.” Modern medical students make a promise to be ethical in their work. This is called the Hippocratic Oath.

Hippocrates is supposed to have written a large number of books. Most of these were probably written by other Greek doctors working at the same time. They are known as the Hippocratic collection. Some of the descriptions of diseases in these books are very clear and accurate. The diseases can be recognized from the descriptions even today. No other medical books as scientific as these were written until modern times.

HIPPOPOTAMUS *Hippopotamus* is the name given to two species of mammals native to central and western Africa (see MAMMAL). Although its name comes from two Greek words meaning “water horse,” the hippopotamus is more closely related to the pig than to the horse. The river hippopotamus is also called the great African hippopotamus. It has a large body, short legs, and feet with webbed toes. It may grow to be 16.5 ft. [5 m] long and 5 ft. [1.5 m] tall at the shoulder. The largest weigh close to 6,600 lb. [3,000 kg]. The eyes, ears, and nostrils are all on the top of the head. This allows the animal to see, hear, and breathe while most of its body is under water. The hippopotamus has special oil glands to keep its grayish skin moist. The oil is sometimes red, giving rise to the incorrect belief that the animal sweats blood.

The hippopotamus has large, curved teeth. Its

canine teeth are enlarged into tusks, which may be 2 ft. [60 cm] long. The hippopotamus is a good swimmer and, on land, can run as fast as 30 mi. [48 km] per hour. Hippopotamuses roam in herds of as many as thirty animals, spending most of the day in the water. At night, hippopotamuses leave the water and graze on land. An average hippopotamus eats about 132 lb. [60 kg] of food each day.

A female hippopotamus first mates when she is five or six years old. After a pregnancy of about eight months, she gives birth to one calf. The newborn calf may weigh as much as 110 lb. [50 kg]. The calf is able to swim almost immediately. It nurses under water, surfacing every few minutes for air. Hippopotamuses live for about thirty years.

The pygmy hippopotamus is much smaller and darker than the river hippopotamus. It weighs about 506 lb. [230 kg] and is about 6 ft. [1.8 m] long. It stands only 2.5 ft. [75 cm] tall at the shoulder. This animal spends relatively little time in the water and usually wanders through forests and grasslands.

Hippopotamuses have been widely hunted for their hides, meat, and ivory tusks. Although protected by law in most places, these animals are often killed illegally. The pygmy hippopotamus is an endangered species and may soon be extinct (see ENDANGERED SPECIES).



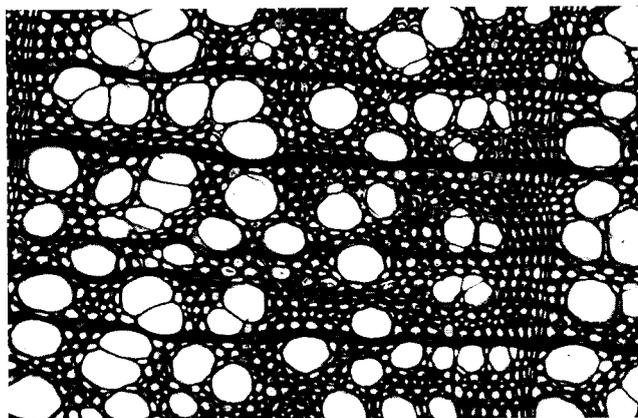
HIPPOPOTAMUS

The hippopotamus spends most of the day in water. In deeper rivers, it grazes on underwater plants. It naps during the day, and at night goes onto dry land to graze on low-growing plants.

HISTOLOGY Histology is the microscopic study of plant and animal tissue. A tissue is made up of similar cells that work together to perform a specific function (see **TISSUE**). Histologists examine tissue to learn about its structure, functions, and properties. A biopsy is the examination of a specific tissue sample taken from a living organism. Biopsies give scientists valuable information about disease processes. An autopsy includes histological examination after an animal's death (including a human's death) and helps doctors and scientists learn more about the cause of death and disease in general.

Histology as a science progressed slowly until the nineteenth century, when the compound microscope began to acquire a form resembling its current one (see **MICROSCOPE**). The microtome, an instrument for slicing thin portions of tissue, was invented by Englishman John Hill in about 1770. Much-improved designs appeared during the eighteenth century, enabling histologists to study tissue more accurately than before. In 1907, the American biologist Ross Granville Harrison discovered that living tissues could be grown outside the organ from which the tissues were taken. That process is called culturing. The electron microscope, developed in the early twentieth century, and the scanning electron microscope, introduced in 1968, made possible great advancements in the study of tissue.

See also **ELECTRON MICROSCOPE**.



HISTOLOGY

Histologists (scientists who study histology) use microscopes to study plant and animal tissue. This microscope photograph shows a thin section of beechwood, which has been stained to show up the various kinds of cells.

HIV HIV stands for human immunodeficiency virus, and is responsible for AIDS and AIDS-related complex (see **AIDS**.) It was first discovered in 1984. It gains access to the body through contaminated blood, nonsterile needles, or sexual intercourse. Once in the blood, it is attracted to a special type of white blood cell—the helper T cell—which protects the body against infections. The HIV virus attaches itself to the surface of the T cell and empties its contents into the cell. These contents consist of an enzyme molecule and a strand of RNA containing all the genetic information needed to make more HIV viruses (see **RNA**). The enzyme makes the T cell use the RNA strand to manufacture more viruses. These viruses burst out of the cell, killing it in the process, and float in the blood. HIV cannot survive for long outside the body, which means that it cannot be caught easily.

HIVES *Hives* is the name given to a certain allergic disorder of the skin. The scientific name for hives is *urticaria*. This condition is characterized by the sudden appearance of small raised areas on the skin. Itching and redness usually accompany the appearance of the bumps. In some cases, hives disappear quickly, whereas in other cases they linger. Hives commonly appear on covered areas of the skin but rarely on the palms, soles, or scalp. The disorder is attributed to an allergic reaction, which occurs soon after the allergic person eats, breathes, or otherwise comes into contact with the substance that causes the allergy (see **ALLERGY**).

Many foods cause allergic hives, but not everyone is allergic to these foods. In the same way, some medications can cause hives, and even animal fur and dust can bring on hives. Different fabrics, plants, pollen, and other environmental substances can cause hives. There are so many possible reasons for hives that, if they persist or recur frequently, a doctor should examine the patient to determine the cause and the best treatment.

HOLISTIC *Holistic* comes from the Greek word *holos*, meaning “whole.” It is used chiefly to refer to holistic medicine, which concentrates on human beings as a functioning whole. This contrasts with

much of orthodox medicine, which focuses only or mainly on a specific disease and its treatment. Holistic medicine is based on the belief that treatment should aim at the whole person, not just the parts of the body where the symptoms occur. Doctors practicing holistic medicine will use many treatments in preference to and in addition to drugs or surgery, such as acupuncture or hypnosis (see HYPNOSIS). A holistic approach is also used by many practitioners of "alternative" medicine, such as homeopaths, herbalists, and acupuncturists (see ACUPUNCTURE; HOMEOPATHY).

HOLLY FAMILY The holly family includes about four hundred species of trees and shrubs with shiny green leaves and red fruits. Most species are evergreen and many have spiny leaves (see EVERGREEN). The name probably comes from the fact that these popular Christmas plants were once thought to be holy trees. The flowers are clustered in the axils of the leaves. Most members of the holly family are dioecious. That is, each plant has either male flowers or female flowers, but not both.

The American holly (*Ilex opaca*) may grow to a height of 100 ft. [30 m]. Its red fruits are called berries, but they are actually drupes (see DRUPE). The fruits are poisonous and grow only on the



HOLLY FAMILY

This unusual holly bush has variegated leaves, meaning they have two colors, in this case golden yellow and dark green.

female trees. English holly is often grown with hawthorn in hedges. The leaves of a South American species, *Ilexpara guariensis*, are brewed to make a beverage called maté.

The wood from members of the holly family is very hard. It is used to make musical instruments and furniture.

HOLLYHOCK Hollyhock is a herbaceous plant belonging to the mallow family (see HERBACEOUS PLANT; MALLOW FAMILY). Although native to China, it is widely cultivated in the United States for its spikes of colorful red, pink, purple, or yellow flowers. The 3-in. [7.5-cm] blossoms grow near the top of a thick stem. This stem, with its spike of flowers, may grow to be as tall as 9 ft. [2.7 m]. The leaves are usually large, hairy, and heart-shaped with five to seven lobes (see LEAF). Although most varieties are perennial, some are annual or biennial. See also ANNUAL PLANT; BIENNIAL PLANT; INFLORESCENCE; PERENNIAL PLANT.



HOLLYHOCK

Hollyhocks are tall plants belonging to the mallow family. These hybrid garden varieties have showy, double flowers.

HOLOGRAM

A hologram is a three-dimensional photograph created by using holography (see HOLOGRAPHY). Holograms can now be mass-produced very cheaply, and they have many uses. Because they cannot be produced without specialized equipment, holograms are often used on bank and credit cards to make counterfeiting more difficult. They are also used for decoration on magazine and book covers and on jewelry. Many artists now use holograms in their artwork.

Holograms were first developed for science and industry. They have been used in microscopy to examine microorganisms in three dimensions. Holograms can also be produced using field-emission electron microscopes in order to study the three-dimensional shape of a surface at the atomic level. Using a laser beam, a moving object can be frozen in time and recorded on a series of holograms. This makes it possible to measure the speeds and directions traveled by tiny particles. A similar technique is used to study the interactions of subatomic particles. Holograms taken before and after a stress test can be compared to show how an object reacted to the stress (see STRESS AND STRAIN). This technique, called holographic interferometry, is very useful for testing quality during a manufacturing process.

Normally, holograms are produced by recording the interference pattern of two beams of light, but they can also be created from the interference patterns created by other types of rays or waves. Holograms made using X rays instead of beams of light are being developed to make it possible to study biological cells. In acoustic holograms used for geophysical and underwater exploration, the interference patterns of high-frequency sound waves are recorded. Holograms made using microwaves are used to make very precise maps of the surface of the land.

How holograms are made To create a three-dimensional image by holography, a beam of light from a laser is split into two beams by a special device. One of the two beams, called the object

beam, illuminates the object to be recorded and reflects its image on a photographic plate or film. The other beam, called the reference beam, shines directly on the plate or film. What is actually recorded is the sum of light from the object beam



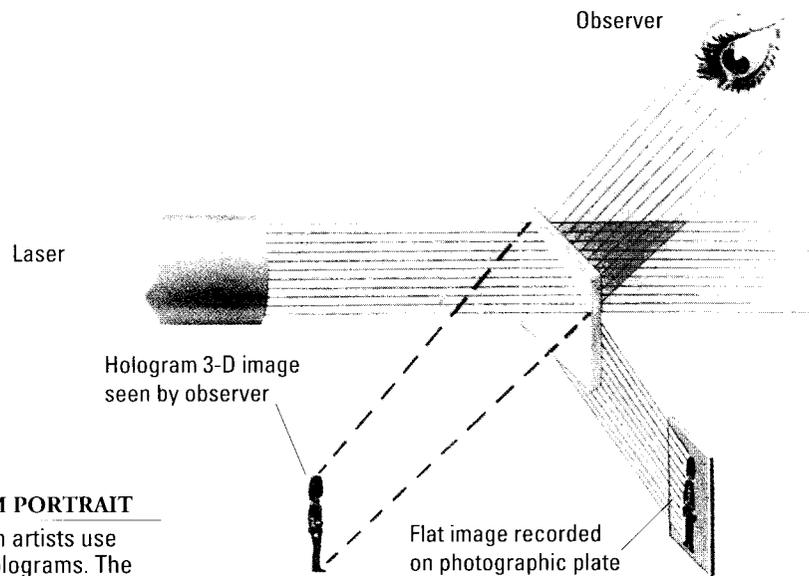
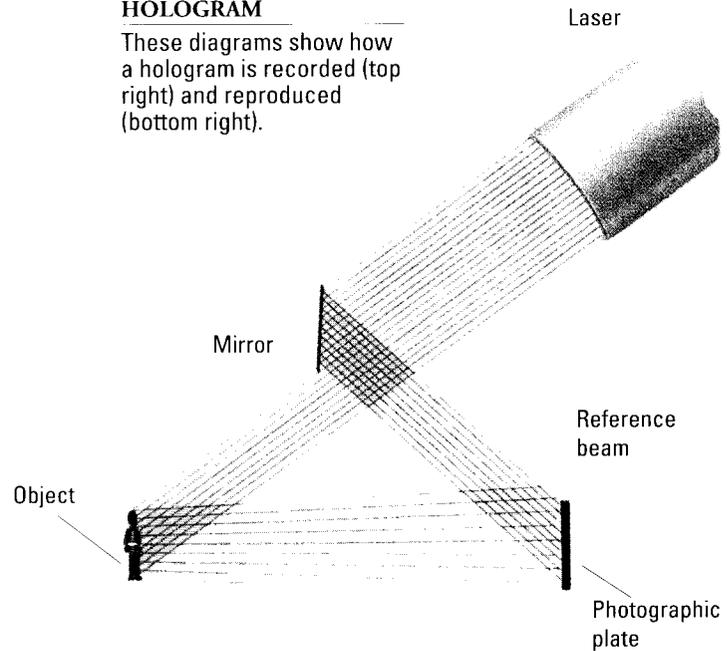
and the reference beam. The combined light waves interfere with each other, creating light and dark patches, called an interference pattern (see INTERFERENCE).

The photographic plate or film, when developed, is called a hologram. The image on it does not resemble the object at all. Instead, the

hologram appears to be a complex pattern of stripes and whorls. To view a hologram, light from the same direction as the reference beam is then directed onto the hologram, illuminating it. The hologram changes the light to reconstruct the light patterns from the original object, producing a three-dimensional image.

RECORDING A HOLOGRAM

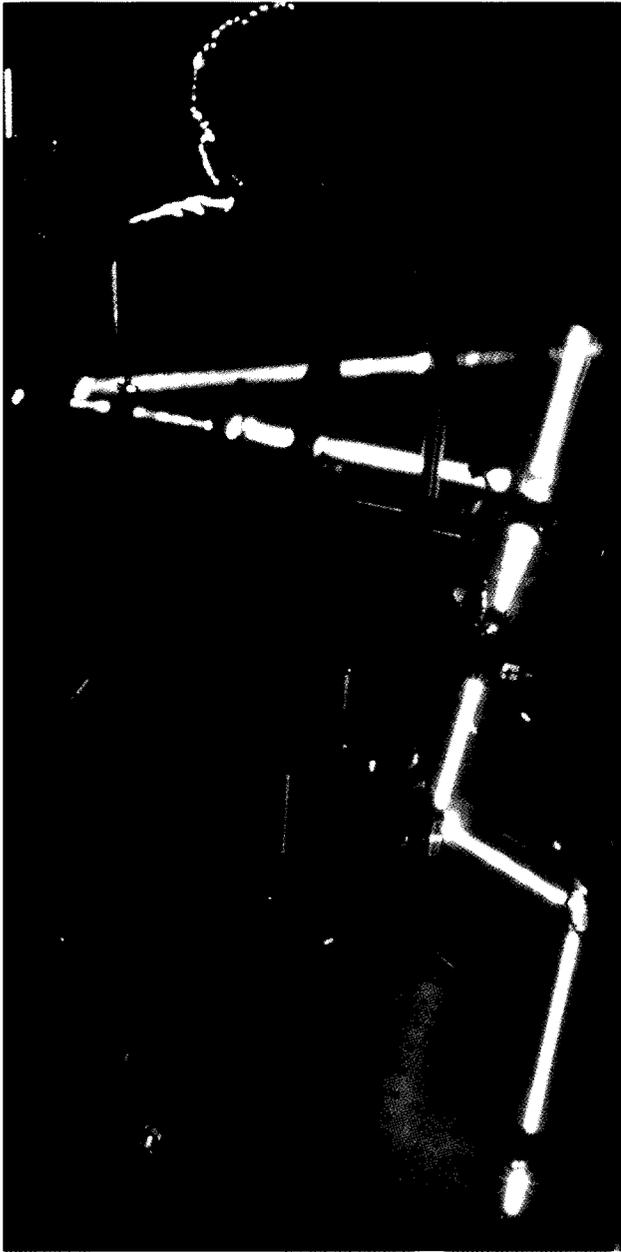
These diagrams show how a hologram is recorded (top right) and reproduced (bottom right).



HOLOGRAM PORTRAIT

Some modern artists use lasers and holograms. The portrait (left), called "Margot," was made at the Museum of Holography in Paris, France, using a beam of red laser light.

HOLOGRAPHY Holography is a technique for recording and viewing a photographic image in three dimensions. In conventional photography, light reflected from an object forms an image on film that is exposed to it. The film is then chemically processed and can be used to make a photograph. An ordinary photograph presents a flat image in two dimensions—height and width (see PHOTOGRAPHY). Holography creates a third dimension—depth. The image changes when seen from slightly different angles. An observer must refocus



HOLOGRAPHY

Workers must use protective goggles to shield their eyes when using hologram-making equipment.

his or her eyes to see the foreground and the background. He or she is able to see around and behind the object viewed (see HOLOGRAM).

Holography was invented in 1947 by the Hungarian-born scientist Dennis Gabor, who was working in England. Gabor received the Nobel Prize for physics in 1971. Gabor wanted to use holography to improve the capabilities of the electron microscope. However, his original application of holography did not prove to be practical.

In the 1960s, the field of holography was expanded by the invention of the laser. Emmett Leith and Juris Upatnieks achieved remarkable results by applying laser beams to the process of holography. A laser beam is a narrow, concentrated beam of light (see LASER). The work of Leith and Upatnieks opened the way for many research applications of holography.

HOMEOPATHY (hō' mē ōp' ə thē) Homeopathy is a system of medicine based on the idea that "like cures like." In other words, a person suffering from a disease will have certain symptoms. The homeopathic remedy for each disease is taken from a single animal, mineral, or plant and produces exactly the same set of symptoms in a healthy person who takes some of that substance.

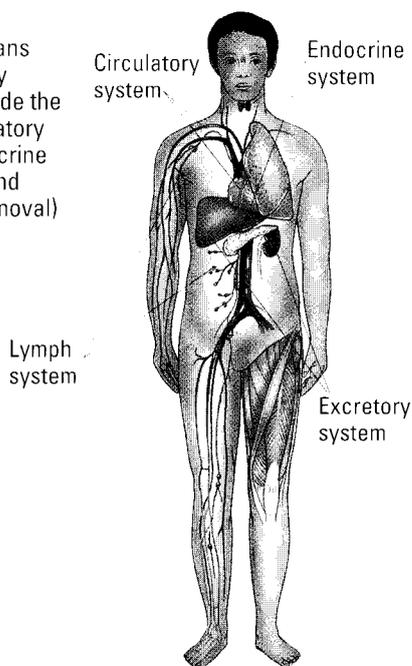
Homeopathic remedies are prepared by greatly diluting (lessening the strength of) the substances that produce the symptoms. Because they are so diluted, even poisonous substances can be safe.

A German medical doctor named Samuel Hahnemann originated homeopathy around the year 1800. In order to develop remedies, Hahnemann and other early homeopathic doctors tested thousands of homeopathic remedies to determine the symptoms produced in a healthy person. These tests were often done on themselves. They kept detailed records, so that the symptoms and remedies could be matched again. As some of the substances they tested were poisonous and not sufficiently diluted, some of the early homeopaths died doing research.

HOMEOSTASIS (hō' mē ō stā' sīs) Homeostasis is the ability of a living thing to keep a steady, stable condition within its body. This internal environment is controlled by different body processes,

HOMEOSTASIS

Homeostasis in humans involves various body systems. These include the lymph system, circulatory (blood) system, endocrine (hormone) system, and excretory (waste-removal) system.



such as respiration (the changing of food energy into a form the body can use), circulation of blood, and balance of body fluids. The nervous system and the hormones of the endocrine system play a major role in homeostasis (see HORMONE; NERVOUS SYSTEM). The excretion (removal) of wastes is an important part of homeostasis. In warm-blooded animals, excretion helps maintain a constant body temperature.

Scientists believe that homeostasis shows the degree of evolution of a species. The steadier a living thing's internal systems are, the more independent it is of the external environment, and the more developed (advanced) it is. The maintenance of social structures in populations of organisms is also regarded as homeostasis between organisms.

See also ENVIRONMENT.

HOMINID A hominid is a member of the group of animals to which human beings belong. The hominid group also includes human ancestors, such as *Homo erectus* and *Australopithecus africanus*. The term *hominid* is most commonly used when referring to them (see HOMO ERECTUS; HOMO SAPIENS).

HOMO ERECTUS *Homo erectus* is a species of early humans, dating from about 1.5 million years ago to about 200,000 years ago. *Homo erectus* was the first hominid to leave the continent of Africa

and to spread throughout the continents of Europe and Asia (see HOMINID). *Homo erectus* had a brain that was about two-thirds the size of modern humans' brain, walked upright, and probably communicated using sounds and facial expressions. They were able to make simple tools and to use fire. Their remains have been found in Tanzania, South Africa, Algeria, Java and China (where they were once known as *Pithecanthropus*), Spain, France, Greece, Hungary, and Germany. *Homo erectus* was probably descended from the earlier hominid *Homo habilis* and gave rise to *Homo sapiens*—modern humans (see HOMO SAPIENS).

HOMO SAPIENS *Homo sapiens* is the zoological name for the modern human being. The species probably arose from the earlier species *Homo erectus* about a quarter of a million years ago, but paleoanthropologists—scientists who study early humans—are not sure of the details. One theory, called the “out-of-Africa” theory after the title of a novel set in Africa, suggests that *Homo sapiens* developed from the African population of *Homo erectus*. They then spread throughout the world, wiping out the populations of *Homo erectus* elsewhere (see HOMO ERECTUS). An alternative theory, the so-called “multiregional” theory, is that *Homo sapiens* arose through interbreeding of the various populations of *Homo erectus* in various parts of the world. There were originally several subspecies of *Homo sapiens*, including an early form found in Swanscombe, England (*Homo sapiens swanscombensis*). By the end of the Pleistocene Ice Age, the two most important were *Homo sapiens neanderthalensis*, or Neanderthals, and *Homo sapiens sapiens*, or Cro-Magnons (see CRO-MAGNON; NEANDERTHAL). Neanderthal remains were originally found in the Neander Gorge in Germany. Cro-Magnon remains were originally found in Cro-Magnon caves in France. Neanderthal people died out about 30,000 years ago, while the Cro-Magnons survived. It is possible that the two subspecies interbred so much that the Neanderthal characteristics became totally masked by the Cro-Magnon features. The surviving Cro-Magnons were the ancestors of modern human beings.

See also HUMAN BEING.

HONEY LOCUST The honey locust is a tree that grows in the central United States. It grows to about 80 ft. [24 m] tall. Its leaves resemble those of a fern. Many—but not all—honey locust trees have thorns on their branches. The seeds of the tree develop inside a dark brown pod that looks somewhat like a large string bean and contains a sweet pulp. The honey locust is common around lakes and streams and is widely planted in towns.



HONEY LOCUST

The honey locust has fernlike leaves and edible, sugary seedpods.

HONEYSUCKLE FAMILY The honeysuckle family includes about 450 species of flowering dicotyledons (see DICOTYLEDON). Most are shrubs or climbing plants native to temperate areas throughout the world. Two common shrubs in this family are the viburnum and the elder.

The plants in this family that are commonly called honeysuckles belong to the genus *Lonicera*. Most are evergreens with opposite, oval leaves that often link up around the stem (see EVERGREEN; LEAF). The flowers are trumpet shaped with four petals above and one petal below. The petals form a long tube that makes it difficult for most insects to pollinate the flower. Hawkmoths and hummingbirds are the usual agents of pollination, because they are able to reach into the base of the flower to get the nectar (see HAWKMOTH; POLLINATION). Many of the flowers open and give off their scent only in the evening. The flowers give rise to red, orange, or black berries. These berries are a popular food for birds.

The common honeysuckle is a climbing plant that

grows to a height of about 20 ft. [6 m]. It has clusters of yellowish, purple-edged flowers. The sweet honeysuckle has clustered, purplish white flowers.



HONEYSUCKLE FAMILY

Honeysuckle is a climbing vine that often twines around other plants for support. This hybrid variety is valued for its large white flowers.

HOOKE, ROBERT (1635–1703) Robert Hooke was an English scientist. He made discoveries in many branches of physics and chemistry. He was also a clever designer. He helped Robert Boyle design an air pump (see BOYLE, ROBERT). In 1678, Hooke discovered that the amount that an elastic body bends or stretches out of shape (strain) is in direct proportion to the force (stress) acting on it. This is called Hooke's law (see ELASTICITY). Hooke also made the first Gregorian telescope (an early reflecting telescope) (see TELESCOPE). He improved the microscope and used it to look at parts of plants and animals. He observed cork from a tree. He saw small boxlike structures, which he named *cells*. He is credited with the discovery and naming of cells (see CELL).

HOP Hop is one of four species of herbaceous plants belonging to the genus *Humulus* (see HERBACEOUS PLANT). Closely related to hemp, it also is classified in one of three families: mulberry family, nettle family, or the family Cannabaceae (see HEMP). Hops are native to temperate areas throughout the world.

The common hop is a tall, perennial, climbing plant with large, toothed leaves. It is a dioecious

plant with either staminate (male) flowers in clusters or pistillate (female) flowers in a cone-shaped catkin. This catkin is covered with thin scales called bracts. The catkins are dried and used in brewing beer.

See also CATKIN; FLOWER; PERENNIAL PLANT.



HOP

The catkinlike female flowers of the hop plant are dried and used to flavor beer.

HORIZON The horizon is where the land or sea seems to meet the sky. It is also called the visible horizon. At sea, where there are no visual obstructions, the horizon appears about 2.5 mi. [4 km] away.

The horizon appears farther away when viewed from a high place. This is because the earth is round. For example, an airplane pilot flying at a height of 1 mi. [1.6 km] sees the horizon 98 mi. [158 km] away. This is because the pilot is seeing



HORIZON—Skyline

At the seashore with an uninterrupted view all around, the horizon is where the sea seems to meet the sky.



HORIZON—Distance

The distance to the horizon varies depending on the height of the observer above the ground. The higher the viewpoint, the farther away the horizon appears.

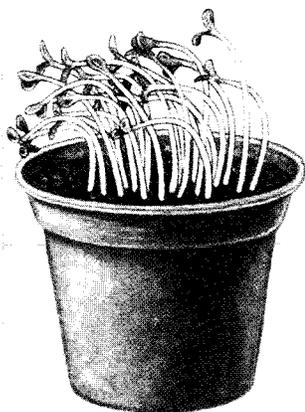
farther over the curvature of the earth than a viewer at sea level.

The celestial horizon is the circle that passes midway through the zenith (the point directly above the observer) and the nadir (the point directly opposite to the zenith on the celestial sphere). The celestial horizon is also called the astronomical horizon.

See also CELESTIAL SPHERE.

HORMONE A hormone is a chemical substance that is produced in one part of an organism and has an effect on another part of that organism. The word *hormone* comes from a Greek word meaning “to set in motion.” Both plants and animals produce hormones. Hormones are vital body substances that act as “chemical messengers” to control body development and function (see HOMEOSTASIS).

Plant hormones Hormones are important in the growth and development of plants. Most plant hormones are concentrated in the growing regions, such as the tips of stems and roots. The major plant hormones are auxins, cytokinins, and gibberellins. Auxins have several functions, including causing the elongation of cells and the development of fruit. Auxins produced in the tip of the stem prevent lateral, or side, branches from growing. Auxins are also responsible for the tropisms, or bending movements of plants (see MOVEMENT OF PLANTS). Cytokinins work closely with auxins by controlling cellular division and cellular differentiation (see DIFFERENTIATION, CELLULAR; MITOSIS).



HORMONE—Tropism

The bending of plants toward the light is caused by growth hormones. More of these hormones (auxins) are produced on the side of the stem away from the light, which grows more.

Gibberellins cause a plant to grow larger. All three of these hormones are closely related. Growth of a plant is controlled by the balance of these hormones.

Human hormones Most human hormones are produced by the endocrine, or ductless, glands (see GLAND). They are called ductless because they secrete hormones directly into the blood and not into tubes or other structures. The blood carries the hormones throughout the body until they reach the “target” organ or tissue. Although the amount of each hormone in the blood is very tiny, it is tightly controlled within certain limits. Too much or too little of a hormone often has a harmful effect on the body. The major endocrine glands are the pituitary, the thyroid, four parathyroid glands, two adrenal glands, the sex glands, and the islets of Langerhans.

The pituitary gland is located at the base of the brain. It is sometimes called the master gland because it secretes hormones that control most of the other glands. The pituitary itself is controlled by the hypothalamus, which is part of the brain (see BRAIN). The pituitary has three sections: the anterior lobe, the intermediate lobe, and the posterior lobe. The anterior lobe produces six hormones. Adrenocorticotrophic hormone (ACTH) controls

the cortex of the adrenal glands (see ADRENAL GLANDS). Thyroid stimulating hormone (TSH) controls the thyroid gland. Follicle stimulating hormone (FSH) and luteinizing hormone (LH) control the sex glands. Prolactin stimulates the production of milk in a mother who is breastfeeding her child. Growth hormone (GH) is sometimes called somatotropin. GH affects growth by controlling the way the body uses food in building tissues. Too much GH during childhood or adolescence can cause a person to become a giant. Too little can cause a person to be a dwarf. If an abnormally large amount of GH is produced in an adult, the result can be the disease known as acromegaly.

In the 1980s, it became possible to produce large amounts of GH by genetic engineering (see GENETICS). The process involves combining DNA from cells that produce GH with DNA from cells that will divide rapidly, such as cancer cells (see DNA). One possible use of human GH is to help short children grow taller. Some athletes have used GH and other hormones to boost their endurance and performance. However, the use of hormones is illegal in organized sports, and continued use of hormones can lead to serious side effects.

In 1990, scientists reported that treating aging men with GH reversed some signs of aging. The hormone treatments caused better skin tone, loss of fat, and gain of lean muscle and bone tissue. However, human GH does not help the body rebuild certain other parts, such as the brain, eyes, ears, ligaments, or tendons. Also, scientists found that GH treatments may cause serious side effects, such as arthritis, diabetes, high blood pressure, or heart failure. Scientists are continuing their experiments to determine other possible dangers of using GH to slow the effects of aging.

The only hormone produced by the intermediate lobe of the pituitary is melanocyte stimulating hormone (MSH). In some vertebrates (animals with backbones), MSH controls color in the skin. The function of MSH in human beings, however, is unknown.

The posterior lobe of the pituitary produces two hormones. Vasopressin is also called antidiuretic

hormone (ADH). ADH controls the amount of water in the blood. Too little ADH can result in the disease diabetes insipidus (see **DIABETES**). This disease is characterized by the loss of great amounts of water. It can lead to dehydration and death. Oxytocin causes the muscles of the uterus to contract when a pregnant woman begins labor (see **PREGNANCY**). It also helps cause the release of milk as a mother breast-feeds her baby. Recent experiments indicate that these two hormones are actually produced by the hypothalamus and are simply stored in the posterior lobe of the pituitary.

The thyroid gland is located on both sides of the trachea (windpipe) in the throat. It produces two hormones that control body metabolism (see **METABOLISM**). Thyroxine and triiodothyronine regulate the rate at which cells use food to produce energy. Too much of these hormones can cause the condition known as hyperthyroidism. This is characterized by increased metabolism, which results in nervousness, weight loss, weakness, increased heartbeat, and an abnormal bulging of the eyeballs. Too little of these hormones may cause the disease hypothyroidism. This is characterized by decreased metabolism and results in sluggishness, weight gain, slow heartbeat, and general tiredness. In order for the thyroid gland to function properly, there must be enough iodine in the diet. Iodine is commonly added to table salt to prevent this deficiency (see **SODIUM CHLORIDE**). If there is a lack of iodine, goiter, or swelling of the thyroid gland, may result. If a pregnant woman has too little iodine in her diet, she may give birth to a child with mental or physical retardation.

The parathyroid glands are embedded in the thyroid gland. They produce parathyroid hormone, or parathormone. This hormone controls how the body uses calcium and phosphorus. These minerals are vital for proper functioning of muscles, bones, and nerves. Too little parathormone can result in tetany, a general contracting of muscles that eventually can cause death. Too much parathormone can cause an excess of calcium in the blood. This may result in many problems, including kidney and bladder stones, kidney failure, increased blood pressure, and blood clots.

The adrenal glands are located on top of the kidneys. These glands have two sections: the outer adrenal cortex and the inner adrenal medulla. The adrenal cortex produces several hormones. Corticosterone and cortisol control the metabolism of carbohydrates, fats, and proteins. An injury or disease that affects the adrenal cortex may result in the underproduction of cortisol. This condition is called Addison's disease. An overproduction of cortisol results in Cushing's syndrome. Aldosterone controls the salt balance in the body. Cortisone helps the body adjust to changes in the environment and reduces inflammation. Androgens are male sex hormones that females also produce, in lesser quantities.

The adrenal medulla produces two hormones. Epinephrine and norepinephrine are also called adrenaline and noradrenaline. These hormones stimulate the nervous system in times of great stress. They increase the heart rate and the amount of energy available to the muscles.

The sex glands are the testes (testicles) and the ovaries (see **REPRODUCTIVE SYSTEM**). The testes produce testosterone, a male sex hormone. The ovaries produce several hormones. Estriol (an estrogen) and progesterone control the menstrual cycle (see **MENSTRUAL CYCLE**). Progesterone is also important during pregnancy. Relaxin helps widen the vagina (birth canal) just before the birth of a baby.

The islets of Langerhans are part of the pancreas (see **PANCREAS**). They produce two hormones, insulin and glucagon. Insulin causes the cells to actively take up glucose, thus decreasing the amount of sugar in the blood. Too little insulin results in the disease diabetes mellitus. Too much insulin can cause the disease hypoglycemia, which is characterized by low blood sugar (see **INSULIN**). Glucagon balances insulin, performing the opposite function. Glucagon releases sugar into the blood.

There are other hormones that are not produced by the endocrine glands. The hormones produced by the stomach, duodenum, and small intestines function in the digestion of food. They control the production of digestive juices (see **DIGESTION**).

Hormones in other animals Most other mammals produce hormones similar to those of human beings. Other animals all produce hormones, though not as much is known about their functions. Pheromones are special hormones released into the environment by fish, insects, and some other animals. Pheromones signal others of the same species and may be a mating signal or a warning of danger. The process of metamorphosis is also controlled by hormones (see METAMORPHOSIS).

How hormones work Hormones are generally divided into three groups. The steroids, such as those produced by the sex glands and the adrenal cortex, are relatively simple chemicals. The second group is made up of proteins and polypeptides (all made from amino acids). The third group is the amine group. Thyroid and adrenal medulla hormones are amines.

Hormone research Realizing the importance of hormones, scientists have tried to develop synthetic (human-made) substitutes for the hormones. These can be used to treat hormonal deficiencies that may have been caused by malfunction, injury, or disease of one of the endocrine glands. In addition, hormones have been shown effective in treating other diseases. For example, cortisone is often used as a treatment for arthritis and allergies. Synthetic sex hormones are used in birth control pills. Birth control pills prevent a woman from producing an egg, and thus prevent her from becoming pregnant (see CONTRACEPTION). Synthetic

plant hormones have been used for many years to increase crop production.

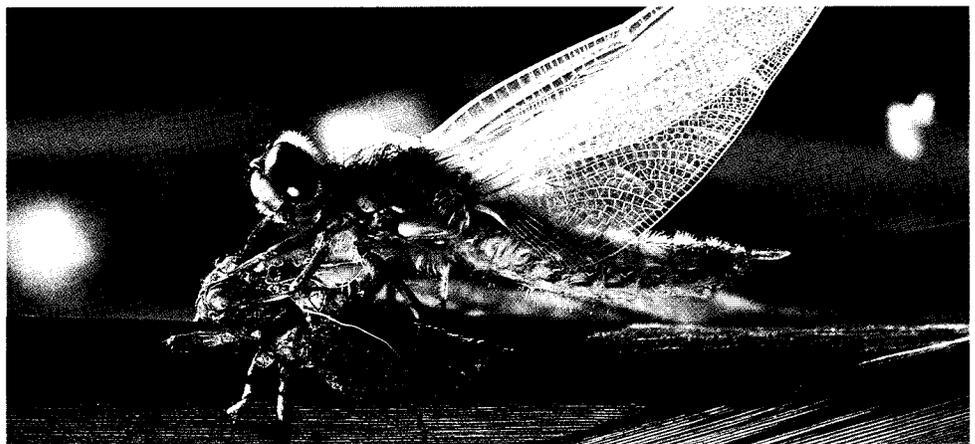
Recently, scientists have been able to produce bovine growth hormone (BGH), the growth hormone for cattle. Bovine growth hormone is sometimes called bovine somatotropin (BST). BST has been used to make cows produce more milk. Because the effect of hormone residues in milk is not fully known, there is some concern among consumers about BST-produced milk. There have also been experiments to produce the growth hormone for pigs, which is called porcine somatotropin. In one experiment, the pigs that were injected with porcine somatotropin had greater weight, leaner meat, and more efficient digestion. However, they also suffered from more health problems, such as arthritis, ulcers, and kidney disease.

Much remains to be understood about hormones and the endocrine system. Research has suggested that a person may adjust better after traveling across several time zones if the body has slightly increased amounts of a hormone called melatonin. Scientists are researching ways to clone the hormone and inject it into a person to help lessen the symptoms of the condition called "jet lag" (see JET LAG). Other research into melatonin suggests that some people secrete an excessive amount of melatonin during the winter when they do not get enough sunlight. Depression, food cravings, tiredness, and other symptoms can result as part of the condition called seasonal affective disorder (SAD). The treatment for SAD consists of exposure to special fluorescent lights that make up for the lack of sunlight.

 PROJECT 67

HORMONE—Molting

As it grows, a dragonfly periodically sheds its old skin. The timing of this molting is controlled by a hormone.



HORNBILL The hornbills are forty-five species of tropical African and Asian birds that belong to the family Bucerotidae. They have huge bills, which are usually filled with air spaces and covered with a thin layer of hard, bonelike material. The air spaces keep the bill lightweight. Hornbills have large heads and wings and long tails. They range in size from 15 to 60 in. [38 to 150 cm] in length. Their feathers are usually brown or black with white markings. Most hornbills live in the tops of trees and eat fruits and insects.

In most species, a female lays her eggs in a hollow tree. The male then fills up the opening in the tree with clay and mud, locking the female and her eggs inside. A small hole is left so that the male can feed the female while she stays with the eggs, but it is not big enough to let enemies enter the nest. After the eggs have hatched, the male helps the female break out of her "prison." They may then fill up the opening again, leaving the baby hornbills inside. The adults feed the babies through a small hole until the babies are almost fully grown. The young hornbills are then freed.

See also BIRD.



HORNBILL

The great hornbill lives in forests in Asia. It is a large bird, growing up to nearly 4 ft. [1.2 m] long from the tip of its curved beak to its tail.

HORNBLENDE Hornblende is a shiny green, brown, or black mineral. It often occurs in the form of dark, needlelike crystals. Hornblende is a common mineral in igneous and metamorphic rocks (see MINERAL; ROCK). Some metamorphic rocks are composed entirely of hornblende. The chemical composition of hornblende is quite variable. It is a silicate and contains aluminum and other elements, such as sodium, potassium, iron, and magnesium.

See also SILICA.



HORNBLENDE

Hornblende is a common mineral found in igneous and metamorphic rocks.

HORNET *Hornet* is the name given to several species of large wasps. They are social insects that live in papery nests made from wood and other plant fibers that the hornets have chewed and formed into a papier-mâché-like substance. A hornet colony consists of one or more queens (fertile females—that is, females which can reproduce), many workers (sterile females—that is, females which cannot reproduce), and, at times, several males. A queen starts the colony in the spring by building a small nest in which she lays only a few eggs. The eggs develop into larvae, which mature into workers (see LARVA). The workers then increase the size of the nest, feed the queen and any developing larvae, and protect the nest. The queen now lays many eggs. By the end of the summer, a single nest may have thousands of hornets. Most are workers, but there are also new queens and males, which fly away and mate.

When colder weather arrives in the fall, almost all the hornets die and the nest is abandoned. Only the new young queens survive, and they hide away until the spring. Then the process is repeated as the queens come out of hibernation and start new nests. Hornets rarely use the same nest twice.

Two common hornets are the baldfaced hornet and the giant hornet. Hornets can inject a strong poison with their stingers. This poison causes swelling and intense pain. Hornets are helpful to humans, however, because they feed their larvae on flies, caterpillars, and other insects that humans consider pests.

See also WASP.

HORSE The horse is an ungulate, or hoofed mammal, belonging to the order Perissodactyla (see UNGULATE). The horse evolved from a small animal called eohippus that lived in North America and Europe more than 50 million years ago.

Horses are bred in four main categories: ponies, light horses, draft horses, and coach horses. The largest are draft horses, which weigh up to 2,420 lb. [1,100 kg]. A type of pony called a Shetland is the smallest horse. Shetlands weigh about 308 lb. [140 kg]. The height of a horse is measured in "hands" from the ground to the withers, a point between the shoulder blades on the back of the horse. A hand is the average width of a man's hand, or 4 in. [10 cm]. The largest draft horses grow to a height of 20 hands (6 ft. 8 in. [200 cm]). The average horse is about 15.2 hands (5 ft. 2 in. [155 cm]) tall.

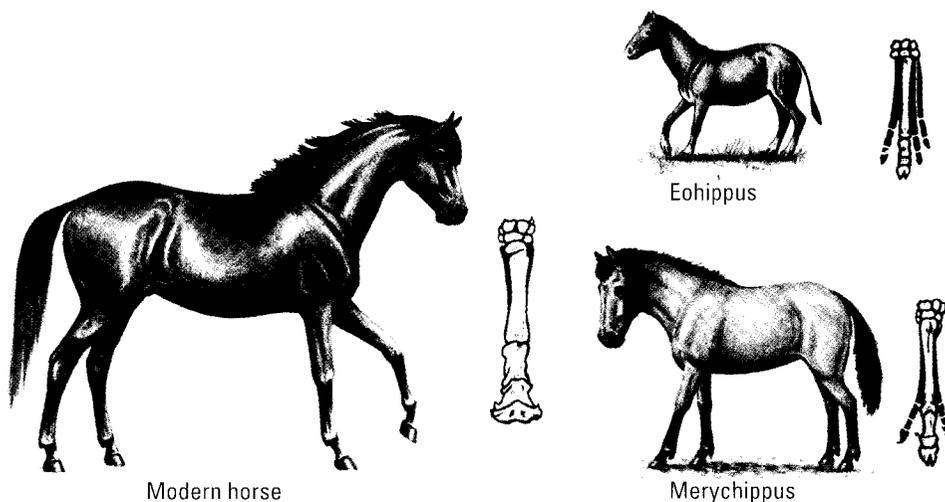
Any full-grown horse that is shorter than 14.2 hands (4 ft. 10 in. [147 cm]) is called a pony.

A horse's body is covered with hair that may be a solid or mixed color, or it may be spotted or splotched. It has a long tail, which is used to brush away insects. The horse has large, keen eyes that can move in opposite directions at the same time. Its ears can be moved to "catch" faint sounds. Most male horses (stallions) have forty teeth, while most females (mares) have thirty-six teeth. The age and health of a horse can be determined by counting the number of teeth and examining their condition.

The legs of a horse are well suited for running. The front legs are thinner than the hind legs and can withstand the shock of absorbing the horse's weight. The hind legs are larger and more muscular to provide the strength needed for running and jumping. The foot of the horse is made of one toe with a strong, hard hoof. The rear of the foot has a tough, elastic pad that acts like a rubber heel in absorbing shocks.

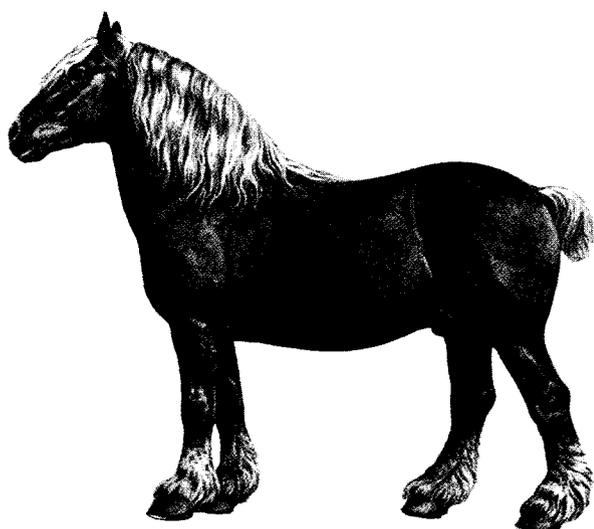
The mare has a pregnancy of about eleven months, after which she gives birth to one baby, called a foal. A male foal is a colt, and a female foal is a filly. The foal is able to walk and run a few hours after birth. It is full-grown by the time it is five years old. Stallions usually start mating when they are two years old, and mares mate when they are three or four. Horses live for about thirty years.

The most popular pony breeds in the United States are the Welsh, the Shetland, the Connemara,

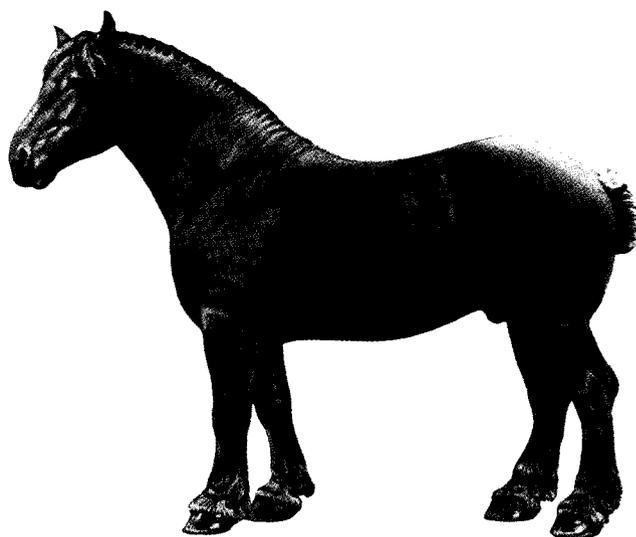


HORSE—Evolution

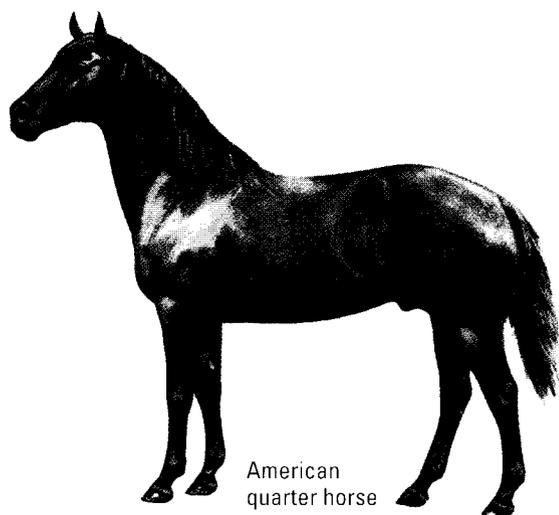
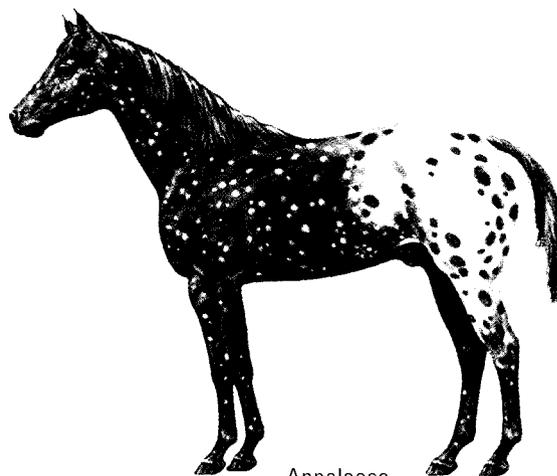
The modern horse (far left) differs greatly from its ancestors, two of which are shown at near left. Note the difference in the bone structure of the feet. Eohippus lived in the Eocene epoch, about 50 million years ago. Merychippus lived during the Miocene epoch, about 20 million years ago.



Italian heavy draft



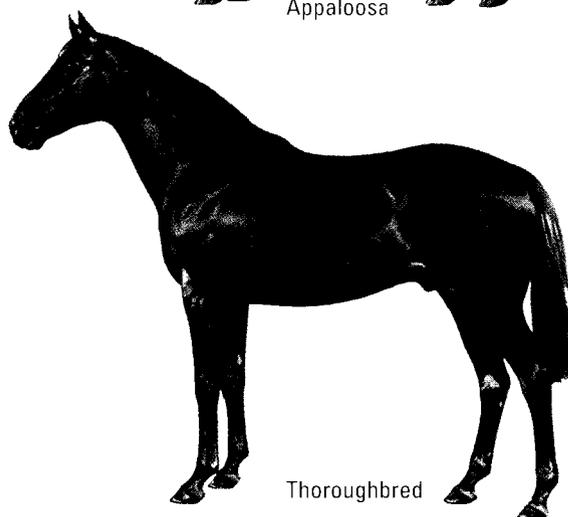
Percheron

American
quarter horse

Appaloosa

and the Pony of America. Welsh ponies were used in the coal mines of the country of Wales. The Connemara is the largest pony breed. The Pony of America is a cross between a Shetland stallion and an Appaloosa mare.

The many breeds of light horses include Arabians, thoroughbreds, and the American quarter horse. Arabians have a thick face with concave sides and a prominent forehead. They are known for being able to run long distances without tiring. Thoroughbreds are able to run fast, so they are raised for racing. The breed of horse that is used widely by cowhands in the western United States is the American quarter horse. The quarter horse has a wide range of abilities, which include stamina, strength, and sturdiness. Many light horse breeds were developed especially for their coloring: pinto, paint, Appaloosa, buckskin, white, cream, and



Thoroughbred

HORSE—Breeds

Draft horses are the heaviest types of horse. They include the Italian heavy draft and the Percheron, the world's commonest cart horse. Riding horses are lighter. The American quarter horse is used on ranches. The Appaloosa was first bred from mustangs by Native Americans. The Thoroughbred, originally from England, is used for racing.

HORSE—Marsh dwellers

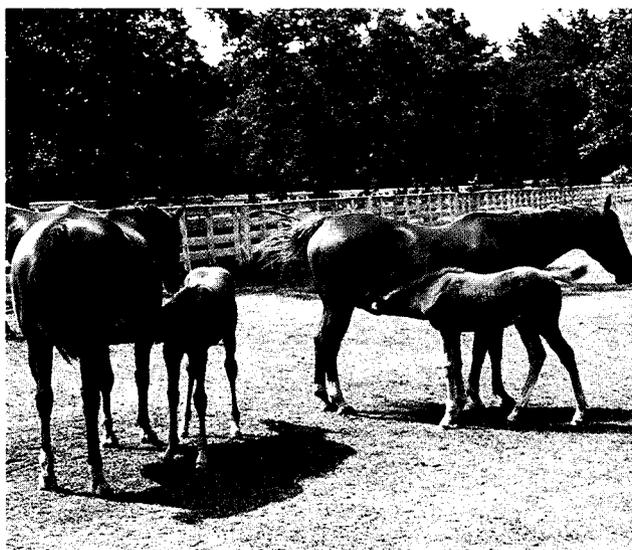
The semiwild horses (left) of the Carmargue, France, graze on grasses that grow among the reeds of the marshes.



Morocco spotted horses are all light horse breeds.

Draft horses have strong, large muscles. The main draft horse breeds are the Percheron, the Suffolk, the Clydesdale, the Shire, and the Belgian. Draft horses were originally bred to pull heavy loads, such as on farms. However, draft horses were largely replaced by trucks and tractors in the early 1900s.

Coach horses are breeds, both small and large, that are raised specifically for pulling carriages. The



HORSE—Breeding

After a pregnancy lasting about eleven months, mares give birth to one baby (foal). A foal can stand and walk when it is a few hours old and soon starts drinking milk from its mother.

breeds include the Hackney, Cleveland Bay, French Coach, and the American Carriage Horse.

Horses are herbivores (plant eaters) and eat grass by biting it off near the ground. Horses have been domesticated for thousands of years and have been used for many purposes. The only truly wild horse still in existence is Przewalski's horse, but even this stocky, light brown animal can now be seen only in zoos and reserves. The other so-called wild horses of today are actually domestic horses that escaped and started to live in the wild again. The number of these "wild horses," called mustangs in the United States, has dropped from several million in the 1800s to fewer than twenty thousand today. For this reason, federal laws have been established to protect them against hunters.

HORSE CHESTNUT A horse chestnut is a tree that originally came from eastern Europe and western Asia and is now found throughout the United States. It is very closely related to the American buckeyes. It is planted as an ornamental tree because it provides good shade and has lovely flowers. The flowers are pink or white. They grow in conical clusters. Large seeds grow inside a green, spiny case. The tree is called a chestnut because the seeds of the tree resembles the nut of the American

chestnut. However, the two trees are not closely related. The horse chestnut tree grows to 80 ft. [24 m] in height.

See also CHESTNUT.



HORSE CHESTNUT

Horse chestnut flowers grow in upright clusters that, because of their shape, are sometimes known as "candles."

HORSEFLY The horsefly is any of numerous species of stout-bodied flies with large, brilliantly colored compound eyes (see *EYE AND VISION*). The female bites human beings, horses, and other



HORSEFLY

Pictured is a front view of the head of a horsefly, showing its mouth parts and brilliantly colored eyes.

animals. After making the bite with the sharp, needlelike mouth parts, she sucks blood. Male horseflies usually feed on nectar and do not bite animals. Larvae develop from eggs, which are usually laid near brooks or streams. The larvae eat earthworms and other small, soft animals (see *LARVA*).

Horseflies may carry disease-causing parasites and bacteria (see *PARASITE*). The horsefly is sometimes called the gadfly.

See also FLY.

HORSEPOWER Horsepower is a unit of power equal to 746 watts (see *WATT*). Power is the rate at which work is done. Originally, one horsepower was reckoned to be the power of one horse. It was used to describe early steam engines. If a steam engine had a horsepower of two, then it could do the work of two horses.

For an automobile engine, the horsepower can be calculated from the rate of work of the pistons. This is called the indicated horsepower. Some of this power is used to overcome friction inside the engine (see *FRICTION*). The rest of the indicated horsepower drives the automobile. This is called the brake horsepower.

HORSERADISH Horseradish is a perennial, herbaceous plant belonging to the mustard family (see *HERBACEOUS PLANT*; *MUSTARD FAMILY*; *PERENNIAL PLANT*). It is native to Europe. It has long, toothed leaves growing from large roots. The roots are grated for use in making the sharp-tasting relish that is also known as horseradish or horse-radish sauce.



HORSERADISH

Horseradish has large thick roots that are grated to make horseradish sauce.

HORSESHOE CRAB The horseshoe crab is a sea animal belonging to the phylum Arthropoda. The animal is not a true crab. It is more closely related to spiders and scorpions (see ARTHROPODA; CRAB). It is among the last members of a large group of animals that lived millions of years ago. The horseshoe crab lives in the Atlantic Ocean from Maine to the West Indies. The animal is also found in the Pacific Ocean from Japan south along the China coast. The horseshoe crab is sometimes called a king crab. However, it is not related to the Alaskan king crab or the Japanese king crab, both of which are true crabs.

The front end of the horseshoe crab's body is covered with a wide, horny shield. When seen from underneath, this shield has a horseshoe-shaped rim, from which the animal got its name. The animal's body has two segments. One is made up of a large head and thorax. The other includes a smaller abdomen (see ABDOMEN; THORAX). A long, sharp spine sticks out from the end of the abdomen. The body of the horseshoe crab may be 24 in. [61 cm] in length, including the spine. The animal has six pairs of legs. The legs end in claws, which are used to seize and tear apart food.

The horseshoe crab stays mostly in 13 to 36 ft. [4 to 11 m] of water. It crawls onto beaches in early summer to lay its eggs.

HORSETAIL The horsetail is any of about twenty species of primitive land plants belonging to division Sphenophyta. Horsetails are distantly related to ferns and club mosses. They grow in damp places nearly all over the world. They are rarely more than 2 or 3 ft. [60 or 90 cm] high. Some look just like pencils sticking up from the ground or the water, but others have whorls of slender green branches. Horsetails grow from perennial rhizomes (see PERENNIAL PLANT; RHIZOME).

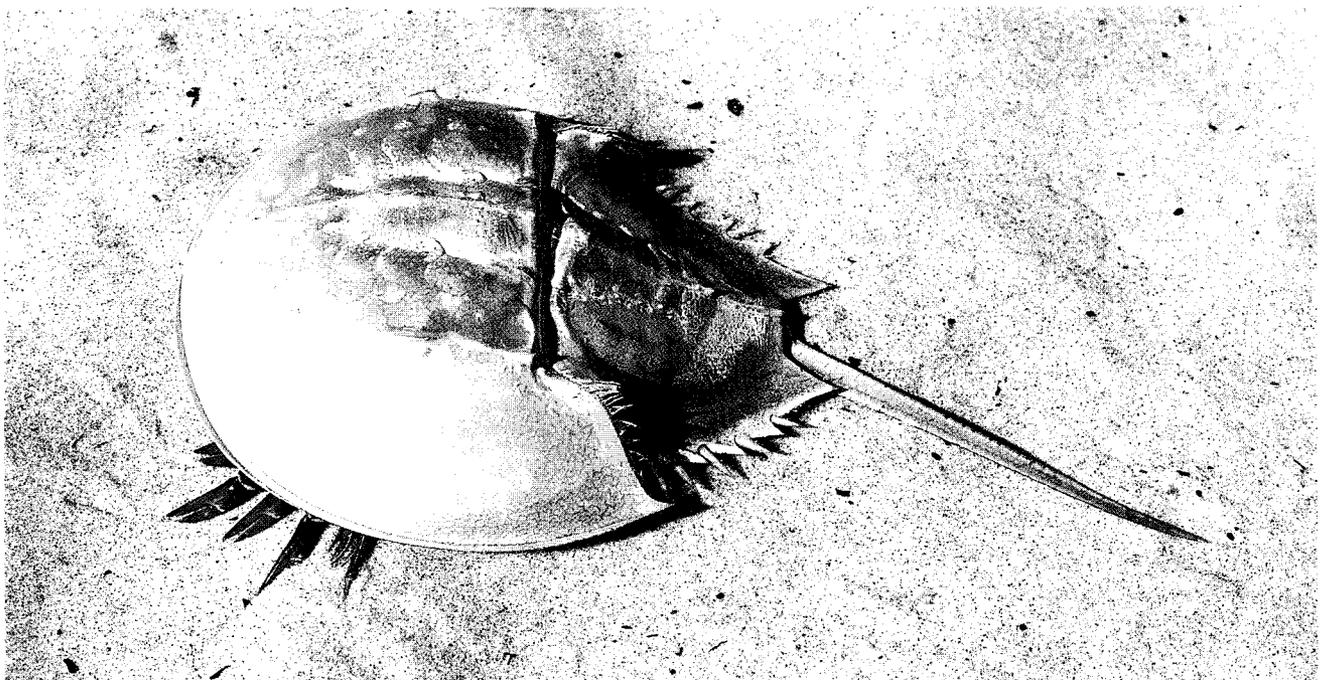
HORSETAIL

Horsetail stems (right) contain gritty particles of silica. They were once used for cleaning pots and pans. For this reason, the plant was sometimes known as scouring rush.



HORSESHOE CRAB

The horseshoe crab, or king crab (below), is the only surviving species of a group of arthropods that were common in the oceans millions of years ago.



Horsetails do not produce flowers. Instead, they produce reproductive stalks with conelike structures containing spores.

Horsetails are the sole survivors of an important group of plants of the Carboniferous period, when some horsetail species grew as large as trees. Their remains form an important part of coal.

See also CARBONIFEROUS PERIOD; PLANT KINGDOM.

HORTICULTURE Horticulture is a branch of agriculture that specializes in increasing the quality and quantity of fruits, vegetables, flowers, grasses, trees, and shrubs. The word *horticulture* comes from the Latin word *hortus*, which means garden. Horticulturalists try to determine the best growing conditions for plants—including types of soil, types and amounts of fertilizers, methods of cultivation, and methods of insect, weed, and disease control.

Horticulture has led to the development of stronger and more productive varieties of plants. Such plants have made it possible for farmers to produce more high-quality food on less land. Careers in horticulture include landscape architect (a person who designs and plans land-development projects, including arrangements of trees, flowers, and so on); greenhouse, orchard, or nursery (place where young plants are raised) operator; and horticultural researcher.

See also AGRICULTURE; BOTANY.

HOUSEFLY The housefly is one of the most widely distributed of all insects. It has a dull gray, bristled body that is about 0.3 in. [7 mm] long. It has large, reddish compound eyes (see EYE AND VISION). Its mouth, which consists of a spongy pad, cannot bite. The housefly eats by oozing saliva and digestive juices over food and then sponging up the resulting solution. In this way, houseflies contaminate large amounts of food. Houseflies often carry one or more disease-causing microorganisms in their saliva or on their bodies and legs (see MICROORGANISM).

Houseflies usually live and breed in or near garbage or organic wastes (such as feces). The female lays about one hundred eggs at a time and

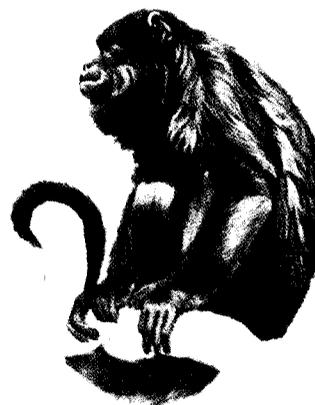
as many as one thousand during her lifetime. The eggs hatch into larvae (plural of *larva*), or maggots, in twelve to thirty hours. The maggots molt several times before becoming pupae (plural of *pupa*) (see METAMORPHOSIS; MOLTING). Within a few days, the pupae become adults, and the cycle begins again. Most adult houseflies live for about thirty days in the summer, and longer when the weather is cooler. Cold weather usually kills off the adults, but larvae and pupae are able to survive the winter.

See also FLY.

HOWLER MONKEY The howler monkey is any of five species of monkeys belonging to genus *Alouatta* of the family Cebidae. Howler monkeys are the largest in this family, often growing to a length of 2 ft. [60 cm] with tails at least that long. They weigh about 17.5 lb. [7.9 kg] and have red, black, or brown fur. Howler monkeys live in tropical forests in South America.

The howler monkey gets its name from its deafening, howling roar. Its howl is so loud that it can be heard more than 1.8 mi. [3 km] away. The sounds are amplified in a large, bony resonating chamber in the throat. This chamber produces an obvious swelling under the chin. Howler monkeys live in trees, sometimes hanging by their tails while feeding on leaves and fruits. They usually travel in family groups of fifteen to twenty.

See also MONKEY; RESONANCE.



HOWLER MONKEY

The howler monkey gets its name from its loud cry that can be heard more than 1.8 mi. [3 km] away.

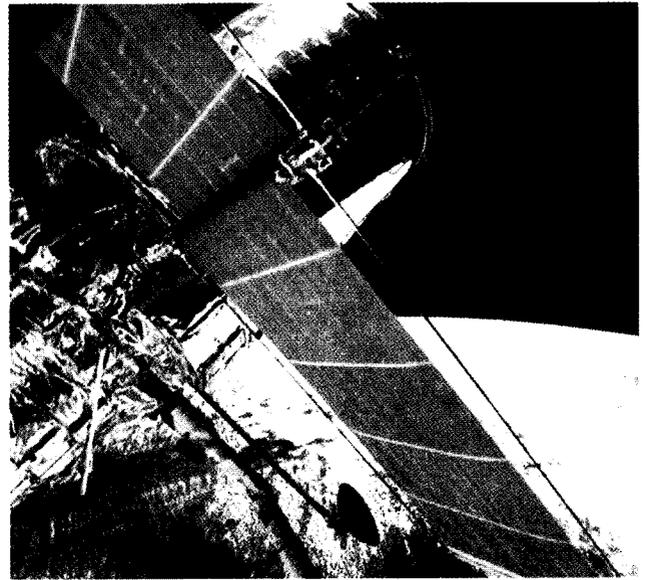
HUBBLE, EDWIN POWELL (1889–1953)
 Edwin Hubble was a famous American astronomer. He was interested in nebulae and galaxies (see GALAXY; NEBULA).

He worked at the Mount Wilson Observatory in California, with its famous 100-inch [254-cm] telescope (the largest in the world at that time). He used this telescope to find stars outside our galaxy and to help show that there are other galaxies outside our own. In 1929, he showed that a characteristic of the light received from these galaxies could mean that the universe is expanding (see RED SHIFT).

Some scientists believe that all the matter of the stars was once concentrated in one very dense lump. The lump exploded, and the fragments became the stars. The stars are moving apart like bits of an exploding bomb. Hubble calculated that this explosion occurred about 10 billion years ago. The ratio of the speed at which the galaxies are moving to their distance from Earth is called the Hubble constant. The Hubble Space Telescope,

launched into orbit by the United States in 1990, was named for Edwin Hubble.

See also COSMOLOGY; TELESCOPE.

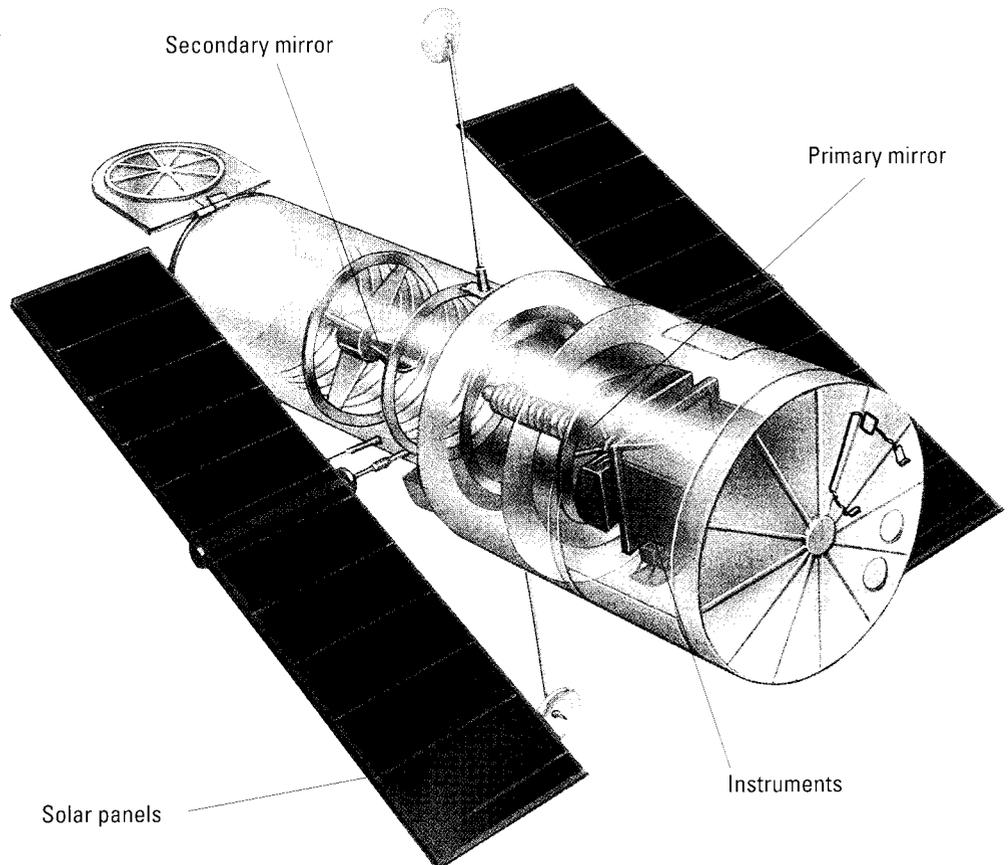


HUBBLE SPACE TELESCOPE—In orbit

The Hubble Space Telescope, launched into orbit by the United States in 1990, was named for Edwin Hubble.

HUBBLE SPACE TELESCOPE—How it works

The Hubble Space Telescope has a primary mirror 8 ft. [2.4 m] across, with a 13-in. [33-cm] secondary mirror. Its instruments include cameras to photograph heavenly bodies such as planets and stars and a photometer to measure their brightness. It is powered by solar panels.



HUMAN BEING

Human beings are unique among the creatures that inhabit the earth. The features that human beings share—and that make us different from other animals—include a large brain, the ability to walk upright on two legs, the ability to speak and write language, a dependence on learned behavior for adaptation and survival (including the making and using of tools), and self-consciousness. Because of our large, highly developed brain, human beings have the ability to think, work out problems, and form ideas. A combination of this unique brain and a highly developed voice enables us to speak. We therefore can communicate our ideas to others. The skill with which we human beings can use our hands is also unique. With this skill, we can use tools, write, and create art—again allowing us to communicate ideas and to record them. All art, religion, science, literature, and other aspects of culture and civilization are the results of such abilities.

Human beings are the only creatures to study ourselves and our achievements. Anthropology is the study of humankind, including common human ancestry and characteristics as well as the differences among various human groups. Anatomy studies the structure of the human body. Physiology is the study of how the body works.

Through psychology, the human mind is explored. Sociology is the study of how people behave in groups. Human beings study the nature and workings of the world around us through many branches of science, such as astronomy, biology, chemistry, geology, and physics. These studies, and many more, help us understand ourselves and plan for the future. Such studies have enabled people to survive in various surroundings. By developing agriculture, engineering, and medicine, we have been able to use and control many aspects of the environment to our advantage. On the other hand, human beings are the most destructive of creatures. Besides the capacity to destroy ourselves and all other life, we have the ability to change the balance of nature. Among other things, humans create pollution that kills plant and animal life.

Scientific classification Human beings belong to the animal kingdom. Within the animal kingdom, scientists place human beings in the phylum Chordata, and the human backbone puts human beings in the subphylum Vertebrata. Vertebrates form several classes, among them Mammalia, to which the human being belongs. Nearly all mammals give birth to live young and nurse them with milk (see ANIMAL KINGDOM; CHORDATA;



HARSH ENVIRONMENT

Human beings can survive in extremely harsh environments. They can live in scorching hot deserts or in the freezing cold of the Antarctic (left).

CLASSIFICATION OF LIVING ORGANISMS; MAMMAL; VERTEBRATE).

The more than four thousand species of mammals make up nineteen orders. Scientists place human beings, apes, monkeys, lemurs, and tarsiers in the order Primates. Primates have well-developed control over their fingers and toes and can grasp objects easily. Most primates have excellent eyesight and stereoscopic vision. Stereoscopic vision allows primates to judge depth. Human beings, monkeys, and apes make up the suborder Anthropoidea (see ANTHROPOID; PRIMATE). People and apes alone form the superfamily Hominoidea. The family of human beings, the Hominidae, includes human beings of prehistoric times as well as all modern human races. Some scientists divide this family into two groups, genus *Australopithecus* and genus *Homo*. Other scientists divide the family Hominidae into several different species. Scientists agree that all living human beings today are genus *Homo*, species *sapiens* (see HOMINID; HOMO SAPIENS). *Homo sapiens* are Latin words that mean "wise man."

The development of the human being

Human beings and the apes have developed from the same primate ancestor. This ancestor is now extinct. The most important differences between apes and human beings are brain size and the ability to walk upright. *Ramapithecus*, an ape that lived about 8 million years ago, showed some human



HUMAN ANCESTOR

Ramapithecus, an ape that lived in Africa, Europe, and Asia about 8 million years ago, had some human characteristics.

characteristics. However, true humanlike creatures did not occur until much later. More than 4 million years ago, a more advanced humanlike creature, which anthropologists call *Australopithecus*, appeared in Africa. In 1961, Louis Leakey discovered a fossil skull in Tanzania. This skull had a much larger brain than *Australopithecus*. This fossil is about 2 million years old. Anthropologists refer to it as *Homo habilis* and consider it the first human being partly because of its association with tools and culture (see LEAKEY FAMILY).

More recent fossils show definite relationships to human beings. Fossils dating from 1.5 million to 200,000 years ago are classified as *Homo erectus* (see HOMO ERECTUS). Examples are the Java man and Peking man. From this creature, several types of human beings seem to have developed. One was the Neanderthal. The Neanderthal had a thick, stocky body and enlarged eyebrow ridges. However, the Neanderthal possessed a large brain. The Neanderthals also used various stone tools and buried their dead. They lived in Europe from about 200,000 to 60,000 years ago (see NEANDERTHAL). Although Neanderthals are classified as *Homo sapiens*, today's humans probably are not descended from the Neanderthals. The modern human being probably evolved separately, directly from *Homo erectus*. Some of the earliest known remains of *Homo sapiens*, such as the Steinheim man and the Swanscombe man, are 275,000 years old. Among the most famous prehistoric humans are those found in France at Cro-Magnon and elsewhere. They lived in caves. The caves were decorated with drawings (see CRO-MAGNON).

Races of human beings All modern human beings are placed in the same biological species, *Homo sapiens*. Many people have suggested that human beings be divided into five main races. They are Caucasoid, Negroid, Mongoloid, Australoid, and Capoid. Other anthropologists, people who study human groups, reject racial classifications. However, anthropologists nevertheless study the relationships among groups living in various parts of the world.

See also ANTHROPOLOGY.

HUMBOLDT, BARON ALEXANDER VON (1769–1859) Baron Alexander von Humboldt was a German scientist and explorer. He is famous for his travels in South America, Europe, and Asia. He used the information that he collected on his travels to add to knowledge in many fields. Humboldt drew the first isothermal map. This showed the different climates of different places (see ISOBAR AND ISOTHERM). He also linked this information with the types of plants that grew in different places. He studied volcanoes and sea currents. The cold current that flows north from the west coast of South America is named after him, as is the university in Berlin.

Humboldt turned his five-year journey around South America (1799–1804) into a book. The book took twenty years to write. It was full of new information about biology, astronomy, and geology. His last book was called *Kosmos*. In this book, Humboldt tried to show the way everything in the universe fits together.

HUMERUS (hyŭō' mār əs) The humerus is a large bone in the upper half of the arm of a human being. The humerus is between the shoulder and the elbow. The upper part of the bone has a ball-

shaped head. This head fits into a cup-shaped hollow, called a socket, in a large bone in the back called the shoulder blade. The head of the humerus can move around quite freely in its socket. This allows the arm to move in many directions.

HUMIDITY Humidity is the amount of water vapor in the air. Absolute humidity measures the amount of water vapor in a given volume of air (see VAPOR).

The warmer the air is, the more water vapor it can hold. However, at any given temperature, the air can only hold a certain amount of water vapor. If the air is holding as much water vapor as it possibly can, the air is said to be saturated. When this happens, the temperature is equal to the dew point, and some of the water vapor condenses out of the air in the form of dew, mist, or fog (see CONDENSATION; DEW POINT).

Relative humidity is the amount of water vapor in the air compared with the amount needed for saturation. When the air is saturated, the relative humidity equals 100 percent. If the air is holding half as much water vapor as it possibly can, the relative humidity equals 50 percent.

Meteorologists measure relative humidity with an

HUMIDITY

In tropical regions the humidity can be very high and the air becomes saturated with water vapor. Some of the water vapor condenses out of the air and forms mist. For this reason, the vegetation is known as cloud forest.



instrument called a hygrometer (see HYGROMETER). Humidity has a significant effect on comfort, especially on hot days. On a hot day with high humidity, most people feel sticky because perspiration does not evaporate off their bodies (see EVAPORATION). The very low humidity associated with bitter cold winter weather gives people a biting sensation in the winter air.

See also METEOROLOGY; WEATHER.

 PROJECT 23, 53



HUMMINGBIRD

Hummingbirds feed mainly on the nectar of flowers. The birds hover and plunge their long beaks and tongues into the blossoms. This action often fertilizes the flowers.

HUMMINGBIRD A hummingbird is a very small bird that belongs to the family Trochilidae. There are fifteen species found in North America. Fourteen species are found only in the western and southwestern part of North America. Only the ruby-throated hummingbird is found east of the Mississippi River. Hummingbirds are the smallest of all North American birds.

The smallest hummingbird is the bee hummingbird of Cuba at 2 in. [5 cm] long. The largest is the giant hummingbird of the Andes at 8 in. [20.3 cm] long. Most species are about 3 in. [6.8 cm] long. Hummingbirds are so named because their wings beat very fast, creating a humming sound. They can hover in midair and even fly

backwards. Hummingbirds have a high rate of metabolism (see METABOLISM). They require large amounts of food to survive. The birds eat sugar-rich nectar, which they suck out of flowers with their long, slender bills and tongues. They also eat small insects.

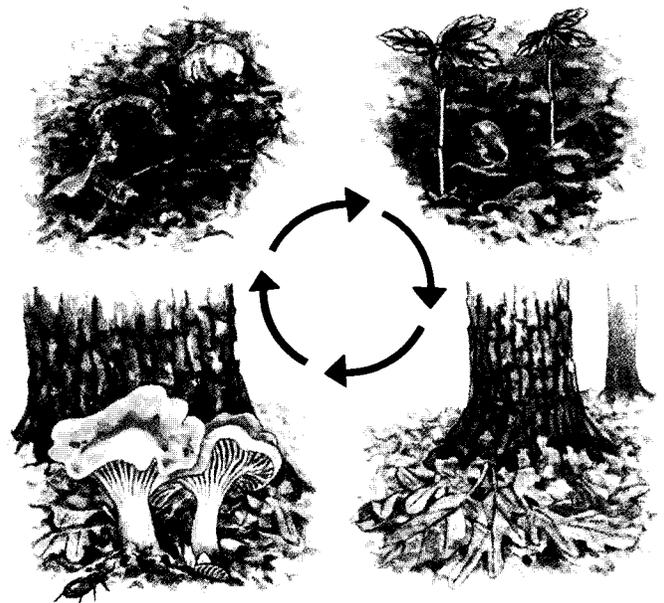
See also BIRD.

HUMUS (hyoo' mas) Humus is the dark, rich part of soil. It comes from dead plants and animals. The plants and animals die, fall to the ground, and slowly decay and are mixed into the soil. This process returns nutrients (nourishing substances) back to the soil from which they came. A sandy beach has no humus. The soil in a forest has a great deal of humus. The leaves from the trees that die and fall to the ground help build up humus.

Humus is important to agriculture because it binds the soil particles together and helps the soil to hold water. It also provides crops with some nutrients. If the humus in soil is depleted, the soil may lose its ability to grow healthy crops.

See also SOIL.

 PROJECT 20, 21



HUMUS

Humus forms from the decaying bodies of dead plants and animals. Nutrients formed in the decay process feed new plants, which grow and eventually die and decay. As a result, over a period of time, the formation and use of humus is a cyclic process.

HURRICANE

A hurricane is a violent tropical cyclone, with winds of at least 74 m.p.h. [119 kph] (see CYCLONE). Tropical cyclones are named according to where they form. A hurricane forms over the West Indies or the eastern Pacific Ocean. A typhoon forms over the western Pacific Ocean.

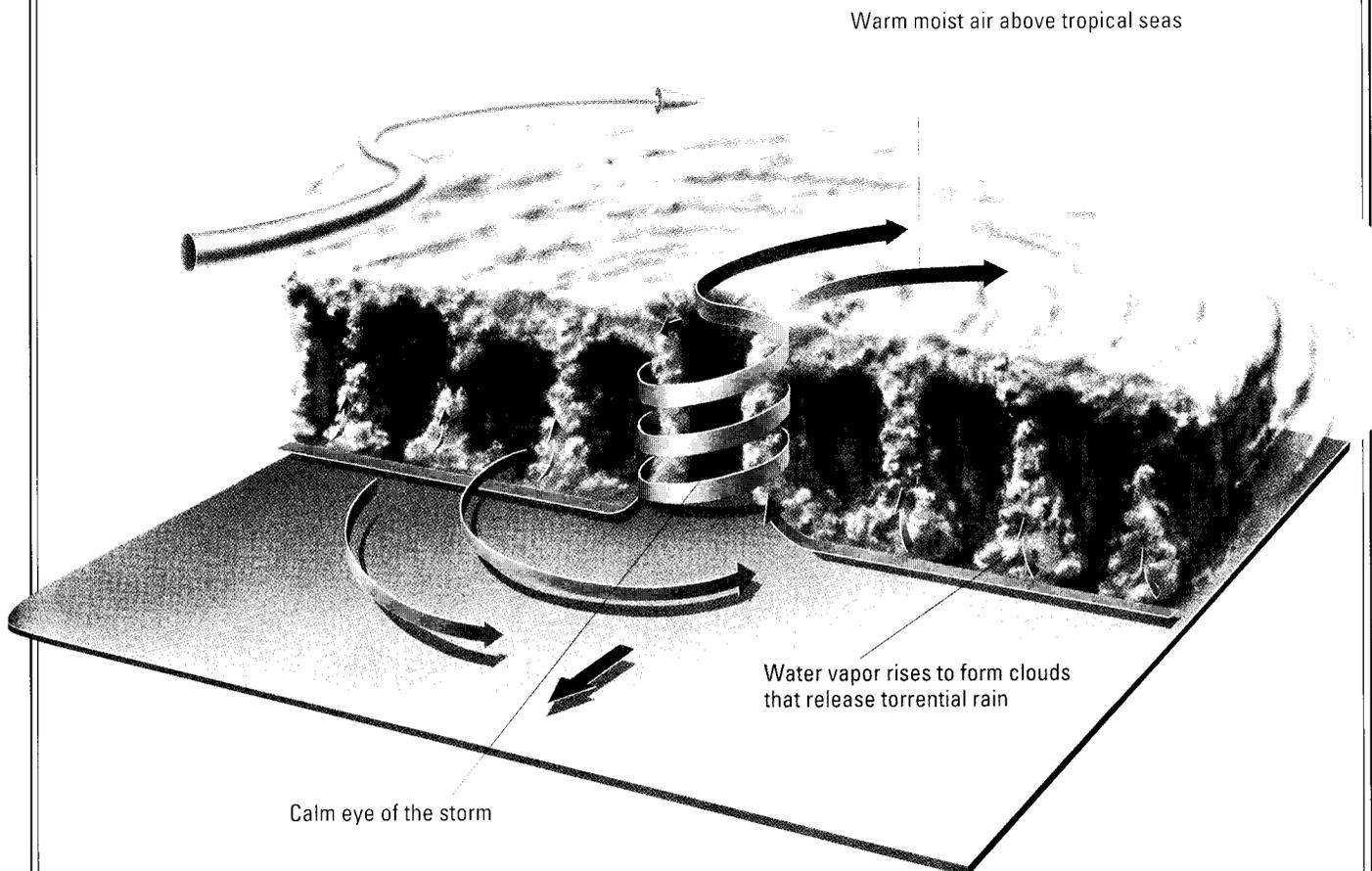
Hurricane formation There are several requirements for hurricane formation. Hurricanes can only develop over ocean waters of at least 80°F [27°C]. The area of formation must be at least 5° latitude away from the equator. At the equator, there is no Coriolis effect (see CORIOLIS EFFECT). The Coriolis effect is needed to produce cyclonic

wind circulation. Cyclonic winds are counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. If the first two requirements for creating a hurricane are met, a large mass of thunderstorms can combine to form a common updraft, thus creating an area of low atmospheric pressure (see ATMOSPHERE). Winds begin to revolve in a cyclonic direction around the low-pressure area. At the same time, water is being evaporated and condensed, pumping energy into the system.

There are three stages in the formation of a hurricane. Tropical depression is the stage in which the storm is rather undefined but appears to be strengthening. When the depression gains more power, it is called a tropical storm. When the wind speed reaches 74 m.p.h. [119 kph], it is called a hurricane.

STRUCTURE OF A HURRICANE

The swirling winds near the center of a hurricane often reach speeds of more than 74 m.p.h. [119 kph]. But in the very center, called the eye of the storm, it is calm with hardly any wind.



Hurricane structure The center of the hurricane is a calm area called the eye. This area of lowest atmospheric pressure measures about 3 to 5 mi. [5 to 15 km] in diameter. In the eye, the weather is calm, and the skies may be clear. Surrounding the eye is a doughnut-shaped area called the anulus. In the anulus exists the most violent weather of the hurricane. Huge cumulonimbus clouds form a wall around the eye (see CLOUD). Severe thunderstorms and winds of 130 to 150 m.p.h. [209 to 241 kph] have been recorded in the anulus of a hurricane. Surrounding the anulus is a large, spiral-shaped area of rain and scattered thunderstorms. The full diameter of a mature hurricane is usually from 300 to 600 mi. [480 to 960 km], and sometimes larger. The clouds may reach 18,000 ft. [5.5 km] into the atmosphere.

Hurricane movement and destruction

Hurricanes usually move westward at first, but then shift to north or northeast. In the United States, this movement makes the coasts of the Gulf of Mexico and the Atlantic Ocean particularly vulnerable to a hurricane.

Hurricanes are usually preceded by a storm surge. Storm surges are great waves that may cause extensive damage to coastal areas. As the hurricane moves over land, strong winds and rain increase in intensity until the eye arrives. There may be an hour of calm winds and no precipitation. However, when the eye moves on, the full fury of the storm returns.

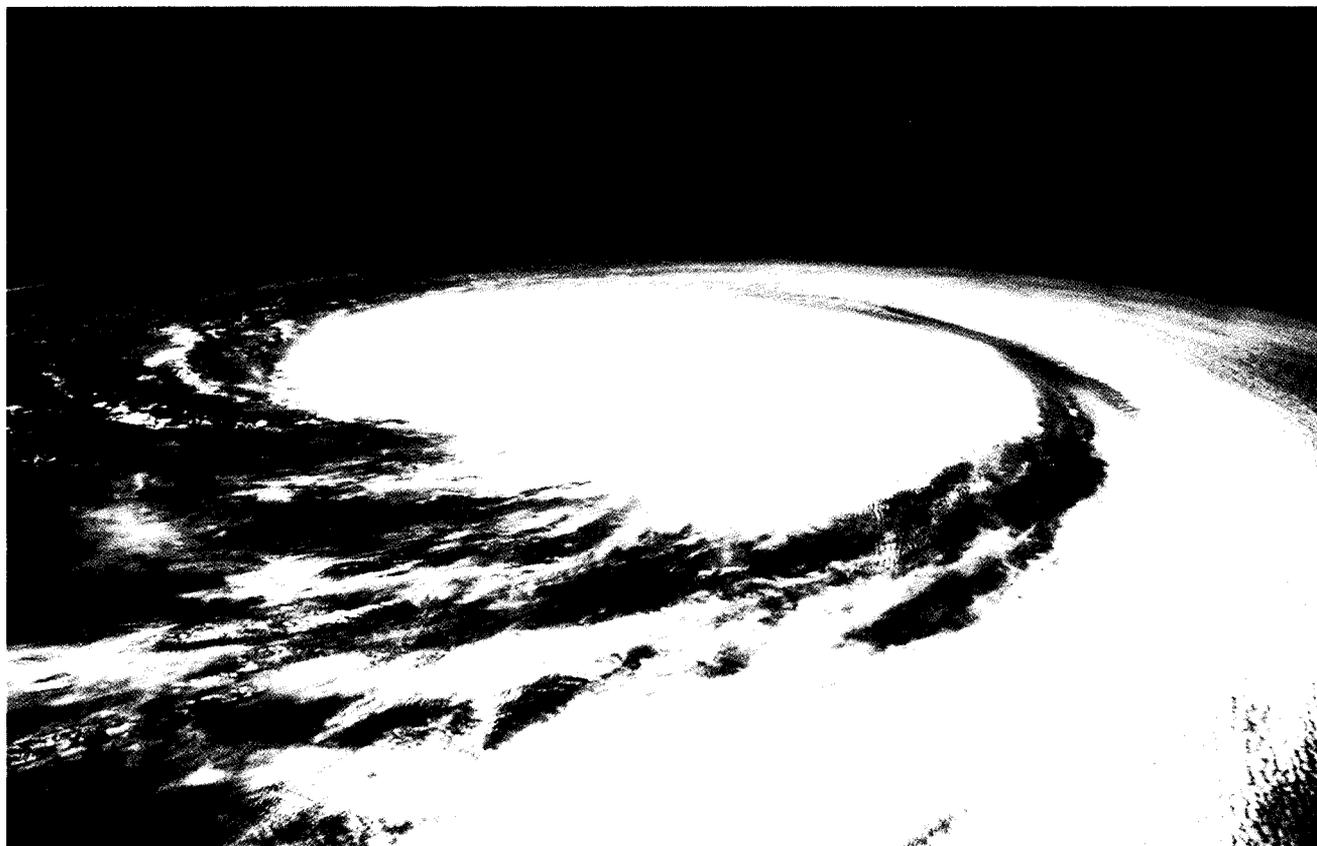
Hurricanes rapidly lose energy after they reach land. This happens because the moisture source is cut off and because of friction between the storm and the land. If a hurricane travels far enough north, it may cross a front and be transformed into a regular storm (see FRONT).

The National Weather Service watches all hurricane activity and informs the public of any important developments. If a hurricane threatens a land area, a hurricane warning is issued. This means that the population of that area must take the necessary precautions to avoid damage and casualties.

See also METEOROLOGY; WEATHER.

AERIAL VIEW

This view of hurricane Fefa was photographed over the Pacific Ocean on August 3, 1991.



HYACINTH The hyacinth is a spring flower of the lily family Liliaceae (see LILY FAMILY). The hyacinth's sweetly scented, bell-shaped flowers of blue, pink, white, yellow, or purple bloom in March and April on stalks that grow from 6 to 18 in. [15 to 46 cm] high. Hyacinths grow from bulbs in open beds, hothouses, and in the home.

The hyacinth originated in western Asia and north Africa and was brought to Europe in the early 1800s. Today, it is a popular plant in many parts of the world. The soil and climate of the Netherlands provide a particularly favorable place for growing hyacinths. The Dutch plant a large number every year near Haarlem. They ship the bulbs to many parts of the world, including the United States.

Hyacinths raised in open beds need rich, well-drained soil. The bulbs are planted between September and November, and flowers appear in the early spring. Gardeners usually tie the stems to



HYACINTH

These hyacinths have large, heavily scented, cream-colored flowers. The smaller blue flower is called grape hyacinth for the shape of its flowers, which resemble bunches of grapes.

stakes for added support. In summer, after the leaves have withered, the bulbs are dug up and stored for replanting.

HYATT, JOHN WESLEY (1837–1920) John Hyatt was an American printer who invented many different things. He developed a filter that made it possible to purify a large amount of water. He also invented a roller bearing that is still used in modern machinery. His most important work was in the use of cellulose. He read that a prize was to be given for the best idea for making a synthetic billiard ball. Billiard balls then were made of ivory, which was rare and expensive. Hyatt made a mixture of nitrocellulose, camphor, and alcohol in 1868. This could be molded under pressure when it was gently warmed. He won the prize and patented his invention, which he called celluloid. He also developed a way of making thin sheets of celluloid suitable for use in photography. Hyatt's work with cellulose made him a pioneer of plastics. *See also* CELLULOSE; PLASTIC.

HYBRID A hybrid is the offspring of parents of two different species or of two different breeds of the same species. Hybrids between different species are quite rare because the genes and chromosomes of the two species do not react correctly, but hybrids can be produced if the parent species are closely related. The term *hybrid* can refer to both plants and animals. An example of a hybrid animal is the mule. Its parents are a jackass (male donkey) and a mare (female horse) (see MULE). Most hybrids between different species produce few offspring or are unable to produce any offspring at all, but hybrids between different races of the same species are often very fertile.

Hybrids can occur naturally or be created by humans. Each parent of a hybrid has a different set of genes. These genes are passed on to the offspring during reproduction (see GENE). Sometimes, new races are created that are better able to handle their surroundings than their parents. They may be hardier, produce a higher yield, or be more resistant to disease than their parents. For example, some hybrid tomatoes contain more vitamins than either

**HYBRID**

This purple orchid is a hybrid between two other species, the spotted orchid and the fragrant orchid.

parent. Hybrid corn produces higher yields and is more resistant to disease and drought (long periods of little rain) than its parents.

See also BREEDING.

HYDRA The hydra is one of the simplest multicellular animals and is one of the very few members of the phylum Cnidaria that lives in fresh water (see CNIDARIA). The largest hydras are only about 0.6 in. [15 mm] long. The body of the hydra is called a polyp. Polyps are tube-shaped and sessile, meaning they usually stay in one place. The hydra attaches to rocks and underwater plants by means of a tiny pedal disk. It sometimes moves by sliding along on this pedal disk or by somersaulting through the water.

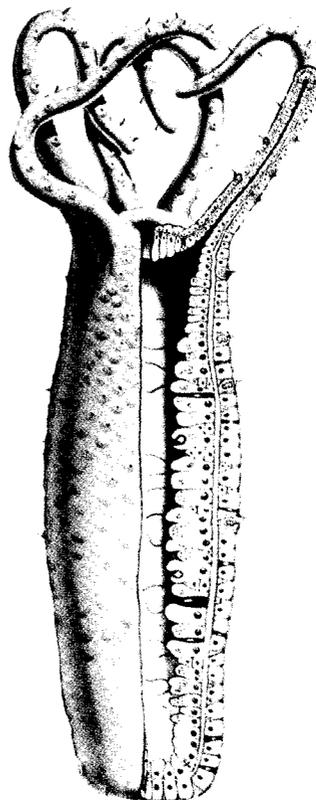
The hydra has a mouth opening at the unattached end of its body. The mouth is surrounded by five or six arms called tentacles, which are used

to capture insect larvae and other tiny water animals. Prey are paralyzed by a poison injected through nematocysts, tiny stinging threads in the tentacles. The hydra is said to have an incomplete digestive system because food enters and wastes leave through the same opening.

Hydras usually reproduce by budding, each bud becoming a new organism (see ASEXUAL REPRODUCTION; BUDDING). In cool weather, however, hydras reproduce sexually. The hydra forms sperm and eggs, which join within its body to form embryos (see HERMAPHRODITE; REPRODUCTION). These embryos develop tough coats, which protect them from drying or temperature changes. This is probably an adaptation to allow hydras to survive in areas where their habitat (ponds or lakes) dries up for part of the year. Hydras can regenerate lost parts and, in fact, regenerate all their body cells every few weeks (see REGENERATION).

The most common hydras are the green hydra and the brown hydra. They get their color from algae, which live symbiotically within the inner layer of cells of the hydras.

See also SYMBIOSIS.

**HYDRA**

The hydra is a simple animal, looking more like a plant than an animal. Its body consists of only two layers of cells.

HYDRANGEA

Hydrangeas are grown for their large, showy flowers. The color of the flowers may depend on whether the soil is slightly alkaline (pink flowers) or slightly acid (blue flowers).



HYDRANGEA *Hydrangea* is a genus of flowering shrubs in the family Saxifragaceae. One species grows 30 ft. [9 m] high. The flowers are white, pink, or bluish and grow in large, showy clusters. Each individual flower has four or five petals. Hydrangeas grow best in rich, slightly moist soil and in partially shaded areas. They bloom from late summer until fall. Hydrangeas grow wild in North and South America and in eastern Asia.

Pink hydrangeas produce blue flowers when grown in soil treated with aluminum sulfate, or alum. Lime added to the soil makes blue hydrangeas produce pink flowers. Hydrangeas are grown by planting either cuttings or seeds.

HYDRATE A hydrate is a compound (chemical substance composed of two or more elements) that forms crystals containing water. The water molecules are linked to the molecules of the compound. The water is called water of crystallization. The number of molecules of water can be shown in the chemical formula. For example, the formula for sodium carbonate is Na_2CO_3 . When it forms a

hydrate, it takes up ten molecules of water. The formula is now $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$.

The salts of some metals form more than one hydrate. Copper sulfate forms at least three. They can be written $\text{CuSO}_4 \cdot \text{H}_2\text{O}$, $\text{CuSO}_4 \cdot 3\text{H}_2\text{O}$, and $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$. Copper sulfate in the form of its hydrate makes deep blue crystals. If it is heated, the water of crystallization evaporates. The blue color disappears. White powder is left, containing no water. This is copper sulfate in its anhydrous state. *Anhydrous* means "without water." When water is added, the blue color returns (see COPPER SULFATE).

Cobalt chloride shows a color change when it gains water. When it is a hydrate, it forms pink crystals. It is blue when it is anhydrous. It can be used to show whether there is moisture inside a container or not. The blue crystals become pink if moisture is present.

Some hydrates lose their water without heating. When the air is dry, their crystals become white and powdery. This is called efflorescence.

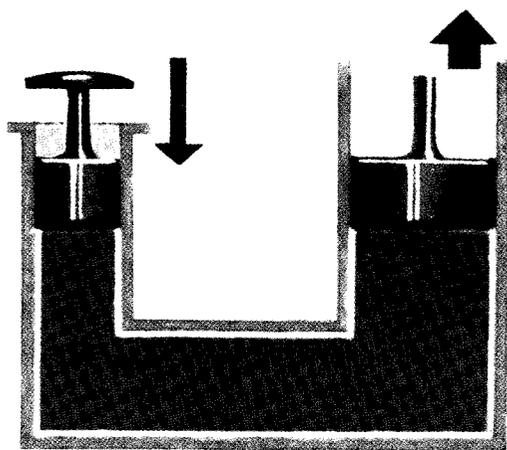
See also EFFLORESCENCE.

HYDRAULICS

Hydraulics is a branch of physics with several subdivisions. It is the study of the characteristics and behavior of liquids at rest and in motion. Practical applications of hydraulics include civil engineering (control of rivers, irrigation systems, and water supply systems) and mechanical engineering (machine design, such as water turbines, hydraulic jacks and presses, and pumps).

Some laws of hydraulics apply to all fluids—gases as well as liquids. However, they apply only under certain conditions. This article will focus on liquids. The basic difference between a liquid and a gas is that a liquid cannot be compressed. This characteristic of liquids makes them very useful for some kinds of work. The molecules of liquids can move about easily but cannot be squeezed any closer together. When pressure is applied to liquid in a sealed container, the liquid instantly transfers the pressure equally in every direction.

Hydrostatics and hydrokinetics The study of liquids at rest (hydrostatics) considers such things as buoyancy and pressure (see BUOYANCY; PRESSURE). The behavior of liquids at rest is described by the laws of hydrostatics (see HYDROSTATIC). One such law is that the pressure exerted by the weight of a column of liquid is determined



PRINCIPLE

This diagram shows the principle of the hydraulic press. Pressure applied to the smaller piston (left) is transmitted by the hydraulic fluid to the larger piston (right), where it exerts a much greater force.

by the height of the column. Another is that an object placed in a liquid will seem to lose as much weight as the weight of the liquid it displaces. These two laws explain why some objects will float while others will sink in a given liquid.

The study of liquids in motion (hydrokinetics or hydrodynamics) deals with such things as friction and velocity of water as it moves through pipes, valves, and nozzles (see FRICTION; VELOCITY). It deals also with hydraulic pressure in machines. One of the laws of hydrokinetics is that the velocity (speed in a certain direction) of a fluid moving through a pipe will decrease if the area of the pipe increases, and vice versa. For example, the velocity of water moving under pressure through a garden hose is less than its velocity when moving through the smaller nozzle.

Hydraulic machines Water and other liquids can be used to perform work by means of their motion or pressure. The waterwheel is a simple example of work performed by the motion of a liquid. The pressure can be simply that of the weight of the liquid, or it can be applied by an external force. Machines that make use of liquid motion or pressure are often called hydraulic engines or machines.

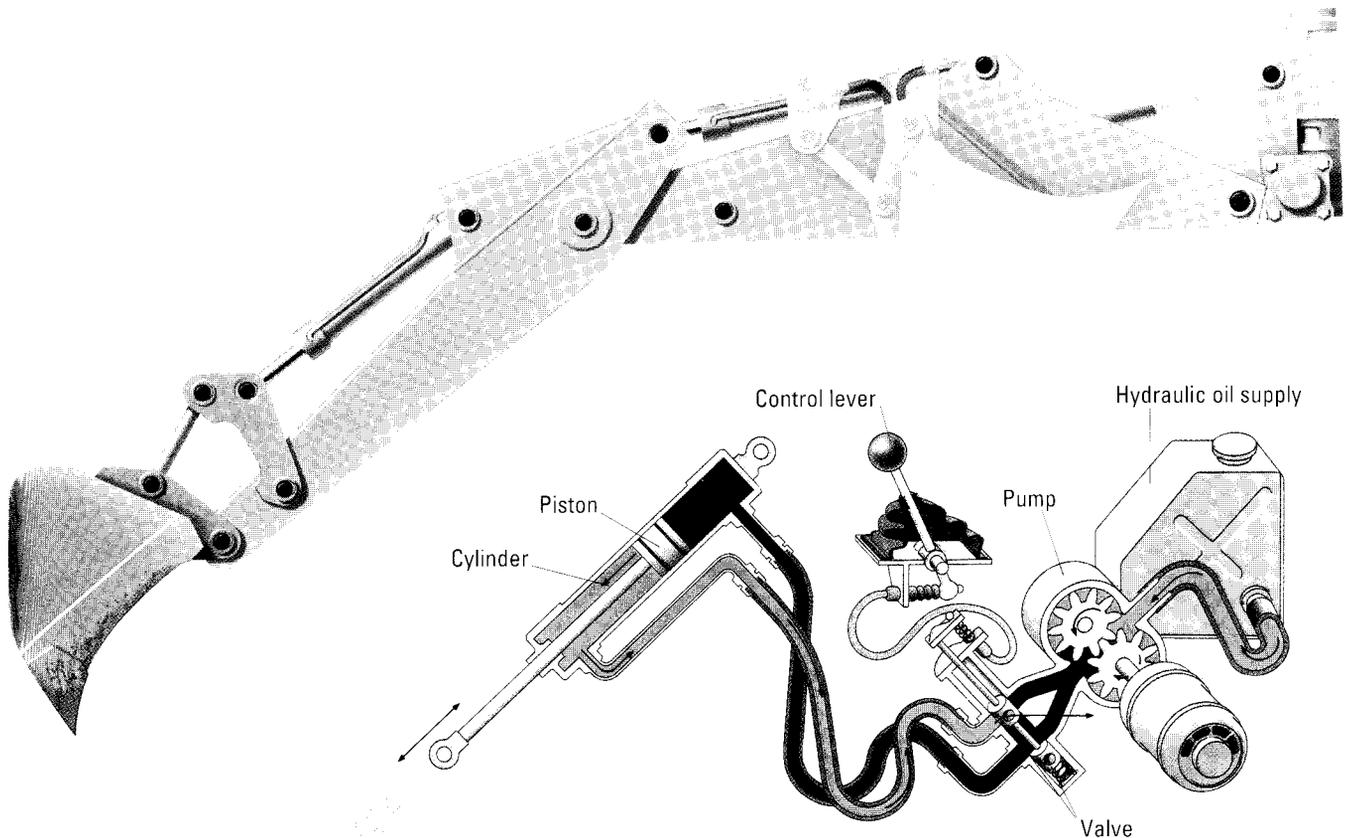
The turbine is an example of a rotary engine that uses a continuous stream of liquid to turn a shaft (usually at high speeds) to operate machines or perform other work. Water turbines are commonly used to operate electric generators. Water flowing over a dam provides a constant source of natural energy that can be used to turn a turbine engine (see HYDROELECTRIC POWER; TURBINE).

Water or other liquids placed under pressure can perform many kinds of work. Most hydraulic machines use a liquid that will not readily freeze, such as oil or silicone. Automobiles, tractors, bulldozers, dump trucks, aircraft, industrial robots, car-wash equipment, and many other kinds of machines make use of hydraulic mechanisms.

In an automobile, foot-pressure on a pedal is transferred to a liquid and multiplied many times

APPLICATION

Many modern machines make use of hydraulics. This mechanical excavator has two hydraulic systems—one to bend the arm and one to swivel the bucket. In this hydraulic system, the fluid is an oil. It is put under pressure by a pump.



to operate the braking mechanism in each wheel. It takes relatively light pressure on the pedal to bring a moving automobile to a halt because of the law of hydraulic pressure. Pressure applied to a small piston by movement of the brake pedal is increased by being applied, via a tube filled with liquid, to a larger piston. If the diameter of the larger piston is five times that of the smaller piston, five times as much pressure is applied to the larger piston.

The use of pistons and valves in a hydraulic press or jack is the most common application of hydrokinetics. In some machines, the pressure is mechan-

ically applied. In others, a reservoir of oil or other liquid is placed under pressure by a pump, and the pressure is applied to the desired piston by a system of valves.

Examples of mechanisms operated by a hydraulic press or jack are the flight-control surfaces of aircraft (ailerons, flaps, elevators, rudders, landing gear), barbers' and dentists' chairs, and some automobile jacks. On a bulldozer, excavator, or snowplow, a hydraulic mechanism positions the blade. Scrap-metal dealers use metal compactors operated by large, powerful hydraulic presses.

See also LIQUID; MECHANICS.

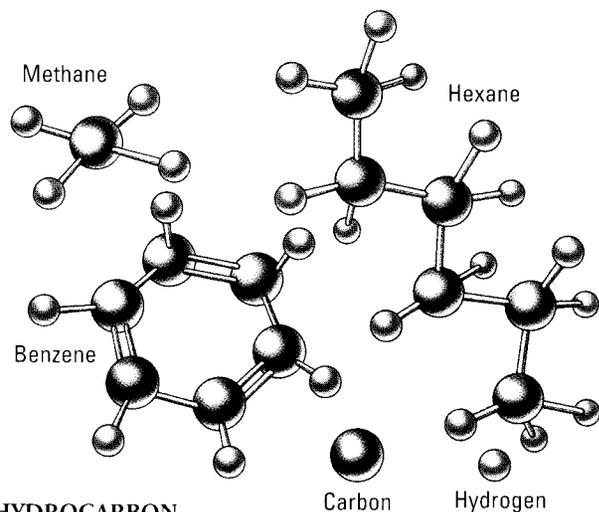
 PROJECT 58

HYDRAZINE Hydrazine (N_2H_4) is a colorless liquid with an odor resembling that of ammonia. It is flammable and is used as a fuel in rocket and jet engines. Hydrazine is sometimes added to water in boilers. It helps prevent rust formation on the inside of the boiler. Hydrazine boils at $236.3^\circ F$ [$113.5^\circ C$] and freezes at $34.5^\circ F$ [$1.4^\circ C$].

HYDROCARBON Hydrocarbons are compounds that contain only the elements hydrogen and carbon (see CARBON; COMPOUND; HYDROGEN). Because hydrocarbons contain carbon, they are called organic compounds (see ORGANIC CHEMISTRY). Many hydrocarbons occur naturally in coal, natural gas, and petroleum (oil). Hydrocarbons are used in industry to make many different products, such as dye, glue, gasoline, plastic, and wax.

There are two basic groups of hydrocarbons—aliphatics and aromatics. In aliphatic hydrocarbons, the carbon atoms are usually linked in chains. The hydrogen atoms are then linked to these chains of carbon atoms (see ATOM). Methane is an example of an aliphatic hydrocarbon (see METHANE). Its chemical formula is CH_4 . Some scientists classify alicyclics, in which the carbon atoms are linked in rings, as a type of aliphatic hydrocarbon. In alicyclics, the carbon atoms are usually linked by single or double bonds but may be linked by triple bonds.

Aromatic hydrocarbons are also made up of rings. The ring structure that characterizes aromatics is



HYDROCARBON

Methane (CH_4) is the simplest hydrocarbon. Like hexane (C_6H_{14}), it is an aliphatic hydrocarbon. Benzene (C_6H_6) is the simplest aromatic hydrocarbon.

called a benzene ring (see BENZENE). A benzene ring includes six carbon atoms, with three of the bonds linking the carbon atoms being double bonds. These three atoms with double bonds are what distinguish the rings of aromatic hydrocarbons from the rings of alicyclic hydrocarbons. The hydrogen atoms are linked to the carbon atoms. Toluene is an example of an aromatic hydrocarbon (see TOLUENE). It belongs to the benzene series. Toluene's chemical formula is $C_6H_5CH_3$.

HYDROCHLORIC ACID (*hī' drə klôr' ik äs'íd*) Hydrochloric acid is a strong acid (see ACID). It is made by dissolving hydrogen chloride gas in water. Its formula is HCl . Concentrated hydrochloric acid contains 39 percent hydrogen chloride. It is a colorless liquid when it is absolutely pure. It usually has a yellowish color when there are impurities. The acid is very poisonous and dangerous. It is extremely corrosive (see CORROSION). It burns holes in clothes and eats into metal. It gives off fumes in moist air. It must be handled very carefully.

When hydrochloric acid reacts with many metals, bubbles are given off. Hydrogen gas is produced. At the same time, the salt of the acid is formed. The salts of hydrochloric acid are called chlorides. Chlorides are also formed when hydrochloric acid reacts with bases (see BASE; CHLORIDE).

Hydrochloric acid can be manufactured by bubbling hydrogen chloride gas through water. Another method is to add concentrated sulfuric acid to sodium chloride (common salt). Chlorine gas also produces hydrochloric acid when it reacts with certain hydrocarbons (compounds of carbon and oxygen) (see HYDROCARBON).

Hydrochloric acid is used to produce other chemicals. It is used to make dyes and to produce textiles and leather goods. It is also used in the manufacture of glues and glucose. In many industries it is used to clean metal surfaces. In the automobile industry, it is used to remove rust and dirt before automobile parts are plated or painted. This is called pickling the metal. Hydrochlorides are organic salts of hydrochloric acid. They are formed when the acid reacts with an organic (carbon-containing) base. Many drugs are hydrochlorides.

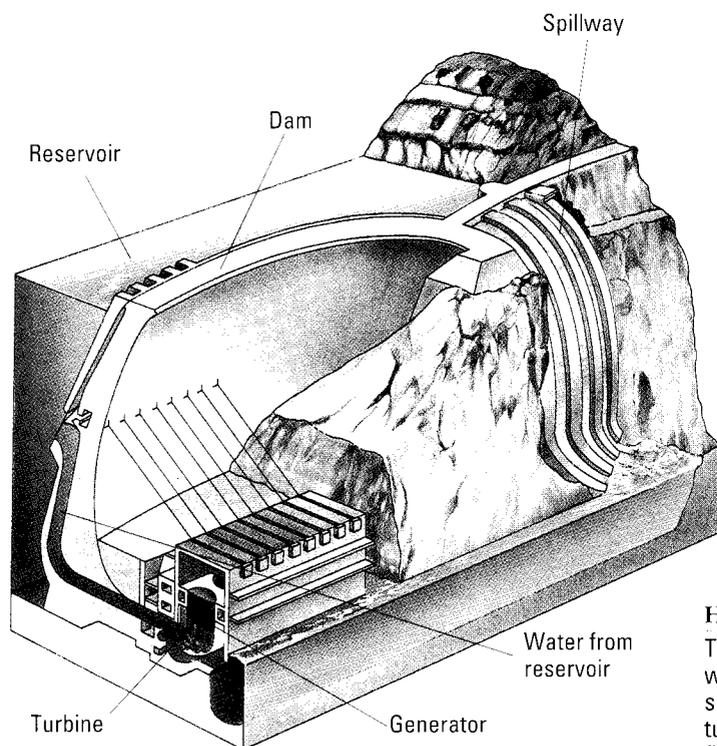
HYDROELECTRIC POWER Hydroelectric power is power that is obtained from the energy of flowing water. In a hydroelectric power plant, flowing water is made to turn the blades of a turbine. The turbine drives a generator, which produces electricity (see **ELECTRICITY**; **ENERGY**; **GENERATOR**, **ELECTRICAL**; **POWER**; **TURBINE**).

Most hydroelectric power comes from water that falls a great distance. This water has high potential energy (see **POTENTIAL ENERGY**). This potential energy is tapped when the water falls to a lower level. In a slow-moving river, the water may fall only a few inches over many miles. This would not supply much power. In a waterfall, however, water may fall a very long way. Waterfalls are an excellent source of hydroelectric power. However, there are not enough natural waterfalls to meet the world's hydroelectric power needs.

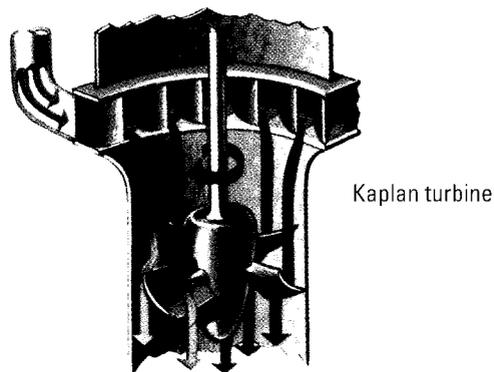
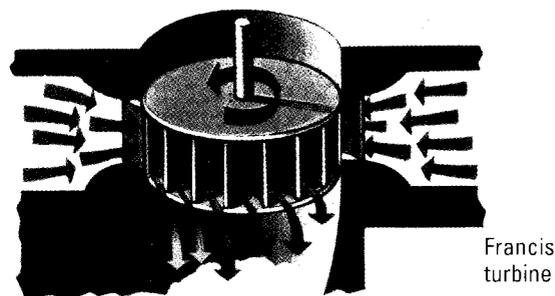
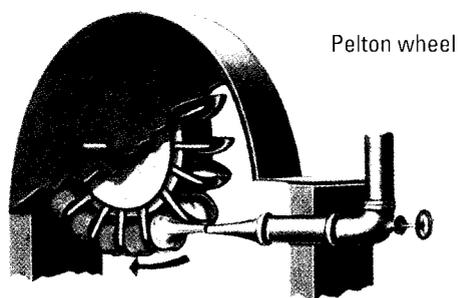
Artificial waterfalls must be made (see **WATERFALL AND RAPID**). Artificial waterfalls can be created through the use of dams (see **DAM**). The dam and other devices needed to convert the flow of water

HYDROELECTRIC POWER—Station

The turbines of a hydroelectric power station are below a dam. Water flows down large pipes from the reservoir behind the dam. The fast-moving water turns the blades of turbines. The spinning turbines drive electric generators.



into energy are called the hydroelectric scheme. One part of the hydroelectric scheme is the reservoir. The reservoir is the area where the water from a river builds up behind the dam (see **RESERVOIR**). A gatelike device called a sluice regulates the flow of water through the dam. Pipes called penstocks carry water from the dam to the power plant. There, different turbines are used for different size heads. The head is the distance the water falls before it hits the turbine. There are two basic turbines—impulse and reaction. In an impulse turbine, a jet of water is directed onto the turbine blades. In reaction turbines, water flows past blades that are submerged in water. The Pelton wheel is an impulse turbine that is used with heads of more



HYDROELECTRIC POWER—Types of turbines

There are three main types of water turbines. The Pelton wheel is an impulse turbine in which a jet of water strikes a series of spoon-shaped baffles. The Francis and Kaplan turbines are reaction types, in which the direction of water flow changes.

than 1,000 ft. [300 m]. Its blades consist of cup-shaped devices. The Francis turbine is a reaction turbine that is used with heads that are between 40 ft. [12 m] and 1,000 ft. [300 m]. The Kaplan turbine is a reaction turbine that is used with heads of less than 100 ft. [30 m]. The Kaplan turbine has fewer blades than a Francis turbine but works in a similar way. Both reaction and impulse turbines in turn drive a generator. A transformer adjusts the voltage of the electricity produced by the generator (see TRANSFORMER; VOLT). The power plant is often built at the foot of the dam. However, it may be located a distance from the dam. If the power plant is a great distance away, the water from the dam first passes through an aqueduct (channel) to an area called a forebay. Penstocks carry the water from the forebay to the power plant (see AQUEDUCT).

Demand for the electricity from hydroelectric plants goes up and down. Hydroelectric power plants called pumped-storage hydroelectric plants can adjust to this demand. When demand is low, the turbines act as pumps, forcing the water back up to the reservoir. Extra water in the reservoir means extra power when the demand for electricity is highest.

The largest hydroelectric plants in the world include that at the Grand Coulee Dam, which is located on the Columbia River near Spokane, Washington, and the plant at Krasnoyarsk along the Yenisey River in Russia. Both plants can produce more than six million megawatts per year (see WATT). Other large plants are located in Venezuela and Brazil.

Hydroelectric power plants have several advantages over other means of producing power. They use a renewable natural resource instead of a non-renewable natural resource, such as fossil fuel. By not burning a fuel, hydroelectric power plants release no pollution. In addition, the turbines and other equipment are fairly simple and require few repairs (see FOSSIL FUEL; POLLUTION).

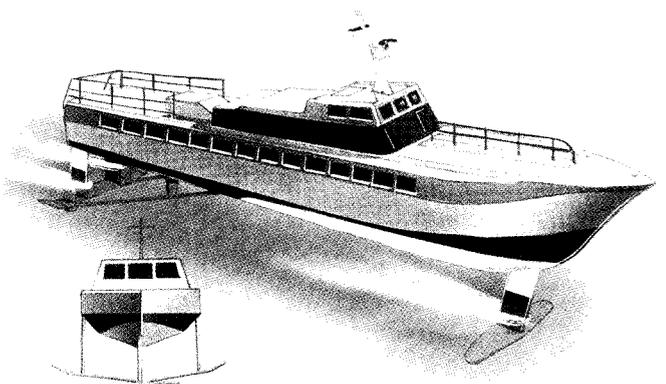
Hydroelectric plants do have disadvantages, however. These disadvantages are due to the fact that dams interfere with the natural flow of a river. This may cause an area to be flooded or interfere with

the movement of fish. In the 1960s, the Egyptians built the huge Aswan High Dam on the Nile River. The dam provides hydroelectric power and holds back rising water that occurs during the annual flood. Holding back the floodwaters, however, keeps the silt that was naturally deposited by the floodwaters from reaching farmers' fields downstream from the dam. The farmers now have to add costly fertilizers to their fields (see FERTILIZER). In addition, holding back the floodwaters means that a particular kind of snail is not killed each year. A tiny worm that breeds in the snails also is not killed. The worm carries the disease schistosomiasis. Scientists blame the dam for an increase in the spread of this disease in Egypt (see SCHISTOSOMIASIS).

 **PROJECT 59**

HYDROFOIL A hydrofoil is a structure on a boat that is designed to lift the boat out of the water as it gains speed. The hydrofoil's purpose is to counteract the fact that, by its nature, a boat uses most of its power overcoming the drag (resistance) of the water on its hull. As a result, the boat does not travel as fast as a land or air vehicle might.

Hydrofoils are of such a shape that the flow of the water over them causes lift (see AERODYNAMICS). As the boat's speed increases, the hull lifts farther and farther out of the water until it is clear. The only parts then in contact with the water are the hydrofoils and supporting struts and the propeller shaft (see PROPELLER). As a result, hydrofoil boats can travel very fast.



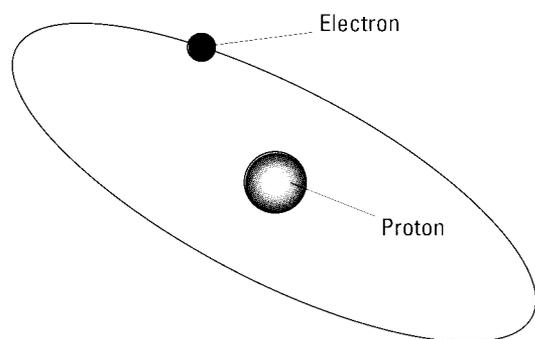
HYDROFOIL

A hydrofoil has underwater "wings" that lift its hull nearly out of the water as the craft speeds along.

HYDROGEN

Hydrogen is a colorless, odorless, tasteless gas. It is the first and simplest of all the elements. Its atomic number is 1, and it has the chemical symbol H (see ELEMENT; GAS).

Hydrogen is the most abundant element in the universe. The sun and other stars are made mostly of hydrogen. The gas is also spread very thinly throughout space. On Earth, very little hydrogen gas is found. This is because the element is so reactive. That is, it readily forms compounds with other elements. The most plentiful compound of hydrogen on Earth is water. Each water molecule contains two hydrogen atoms linked to an oxygen atom. The formula for water is H_2O . Some hydrogen gas is found in natural gas. Hydrogen gas is also found in the upper atmosphere.



HYDROGEN ATOM

Hydrogen has the simplest atom. Its central nucleus contains a single positively charged proton. A single negatively charged electron orbits around the nucleus.

All living things contain compounds of hydrogen. Hydrogen is found in carbohydrates, proteins, fats, and oils. Coal, petroleum, and natural gas all contain hydrogen compounds. These compounds are mainly in the form of hydrocarbons. They were formed from the fossilized remains of plants that grew many millions of years ago (see HYDRO-CARBON).

Hydrogen gas can easily be made in the laboratory. Bubbles of the gas are formed when a metal such as zinc, sodium, or aluminum is added to dilute hydrochloric or sulfuric acid.

Large amounts of hydrogen are produced for industry. The gas can be produced by treating natural gas or gases from petroleum refining with steam. The hydrocarbons are turned into hydrogen and carbon monoxide. Another method of production is the Bosch process. In this process, a mixture of steam and carbon monoxide is passed over a catalyst. Hydrogen and carbon dioxide are formed (see CATALYST).

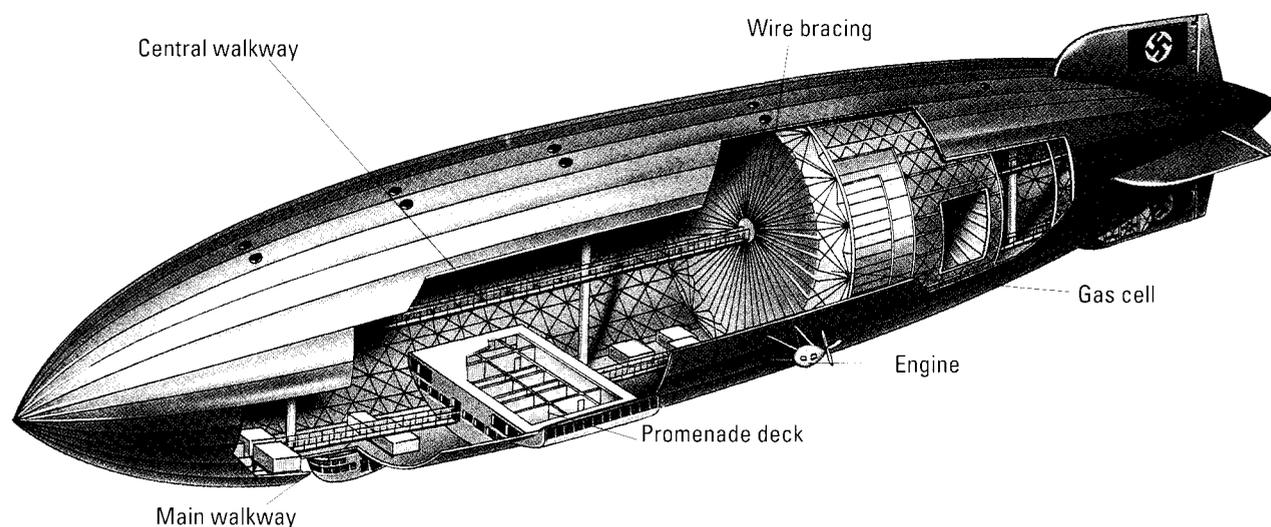
Very pure hydrogen can be produced by electrolysis. When an electric current is passed through water, the water splits up into the gases hydrogen and oxygen. Pure water will not conduct electricity. A little acid or base is added to it so that a current will pass through it (see ELECTROLYSIS).

Two-thirds of the hydrogen made in industry is used to make the gas ammonia. Ammonia is a compound of nitrogen and hydrogen. Its formula is NH_3 . The process used to make ammonia is called the Haber process. A large amount of hydrogen is also used to produce methanol, a kind of alcohol.



HYDROGEN IN STARS

All stars, including our sun (above), are made mostly of hydrogen. Atoms of hydrogen join and give off vast amounts of heat and light energy.



AIRSHIP

The *Hindenburg* was a German airship. Its aluminum framework contained large gas cells, each containing hydrogen gas.

Different kinds of fuel can be made by treating coal, heavy oils, tar, and pitch with hydrogen. This process is called hydrogenation. It can also be used to change liquid vegetable oils into solid fats. This is known as the hardening of oils. Margarine is made in this way.

Hydrogen is extremely flammable. When it is mixed with oxygen, it forms an explosive mixture. The mixture is easily ignited. When hydrogen burns, great heat is produced. The gas is used in oxyhydrogen blowtorches to cut through and weld metal. Hydrogen can be used as a fuel. It makes a good fuel because burning it does not cause pollution. When hydrogen burns in air, only water is formed. Hydrogen and oxygen are used in the rocket engines of spacecraft. They also are used in fuel cells (see FUEL CELL).

Hydrogen has a relative atomic mass of 1.00797. It is the lightest element because its atoms are the simplest. The nucleus of a hydrogen atom is simply a proton, with a positive charge. In orbit around the nucleus is one electron, with a negative charge. If the electron is removed, the result is a hydrogen ion (H^+). All acids, when dissolved in water, release hydrogen ions (see ACID; ATOM; IONS AND IONIZATION).

Two hydrogen atoms come together to form a

hydrogen molecule. They share their electrons between them. A hydrogen molecule is written H_2 .

Hydrogen has two other isotopes (different forms of the same element). They are called deuterium and tritium. In deuterium, there is a neutron as well as a proton in the nucleus. A little deuterium is found mixed with ordinary hydrogen. If deuterium replaces the ordinary hydrogen in water, the result is heavy water. Its molecules are heavier than those of ordinary water because of the extra neutrons (see HEAVY WATER). Tritium contains three particles in its nucleus. There are one proton and two neutrons. Tritium is radioactive. A tiny amount occurs naturally, but it is usually made artificially. The normal form of hydrogen is sometimes called the protium isotope of hydrogen.

The sun and other stars produce vast amounts of energy from hydrogen. Atoms of hydrogen join together to form atoms of heavier elements. This is called fusion. During fusion, nuclear energy is released. For fusion to take place, the temperature must be very high. All the plants and animals on the earth rely on the fusion of hydrogen in the sun for the heat and light that keep them alive (see FUSION).

At very low temperatures, hydrogen becomes a solid. Solid hydrogen melts into a liquid at $-434.5^\circ F$ [$-259.2^\circ C$]. At $-423^\circ F$ [$-252.8^\circ C$], liquid hydrogen boils and becomes hydrogen gas. Hydrogen has a valence of 1 in all its compounds. See also VALENCE.

HYDROGEN PEROXIDE Hydrogen peroxide is a colorless, syrupy liquid. Each molecule contains two atoms of hydrogen and two atoms of oxygen. It has the formula H_2O_2 . Hydrogen peroxide is unstable. Sunlight and heat make it break up into water and oxygen.

Because it yields oxygen so readily, hydrogen peroxide is a strong oxidizing agent (see **OXIDATION AND REDUCTION**). It may set fire to some substances. Pure hydrogen peroxide causes blisters on the skin. It is sometimes used as a rocket propellant.

For most uses, hydrogen peroxide is diluted with water. A 6 percent solution is called 20-volume peroxide because it can give up twenty times its own volume of oxygen gas. The solution is used as a bleach and as a disinfectant. A 3 percent solution (10-volume peroxide) is often used as a mouthwash.

Hydrogen peroxide is produced by the action of sulfuric acid on barium peroxide. It can also be produced by electrolysis of ammonium sulfate solution or concentrated sulfuric acid (see **ELECTROLYSIS**). Hydrogen peroxide's boiling point is $302^\circ F$ [$150.2^\circ C$], and it freezes at $31.2^\circ F$ [$-0.43^\circ C$].

HYDROGEN SULFIDE Hydrogen sulfide is a colorless, poisonous gas. It has the formula H_2S .

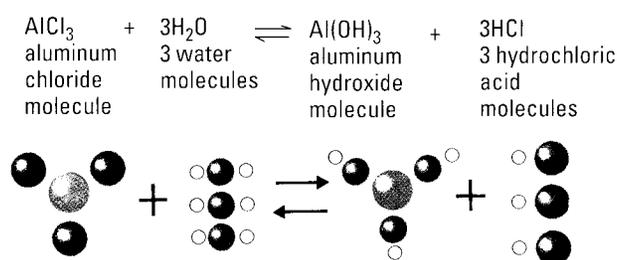
The gas has a strong odor of rotten eggs. This is because eggs and other animal and vegetable matter contain sulfur compounds (chemical substances made up of two or more elements). Hydrogen sulfide gas is formed from these compounds as they decay. The gas is also found in the mineral water from sulfur springs, in the gases from volcanoes, and in some oil wells. Hydrogen sulfide in the air turns silver coins and other silver objects black. A layer of black silver sulfide forms over them.

Hydrogen sulfide can be made by treating ferrous sulfide with hydrochloric or sulfuric acid. In the laboratory, the gas can be used to identify and separate substances (see **CHEMICAL ANALYSIS**). Hydrogen sulfide solidifies at $121.9^\circ F$ [$-85.5^\circ C$] and boils at $-77.3^\circ F$ [$-60.7^\circ C$].

HYDROLOGY Hydrology is the study of the surface and underground water found on the

continents. Hydrologists are scientists who study water. They study what chemicals are found in water, the characteristics of water, and how water flows—for example, in rivers and in underground streams. By studying these things, the hydrologist can help engineers build canals, sewers, and roads that will not wash out during floods or heavy rains. The hydrologist also helps towns and cities locate underground sources of water for domestic use. Hydrologists have learned a great deal about floods. They have helped design and build many flood-control dams. By making measurements and using mathematical formulas, they can determine how much water is held behind a dam and how much water is able to spill over the top. By studying the water cycle, hydrologists can learn where water comes from and where it goes (see **WATER CYCLE**). They also try to save water and prevent soil erosion. See also **HYDRAULICS**; **HYDROELECTRIC POWER**; **WATER**; **WATER SUPPLY**.

HYDROLYSIS Hydrolysis is a chemical reaction in which a substance is broken down by the action of water. During the reaction, the water itself divides into hydrogen ions (H^+) and hydroxyl ions (OH^-). The ions link up with different parts of the substance and form new compounds (see **COMPOUND**; **IONS AND IONIZATION**).



HYDROLYSIS

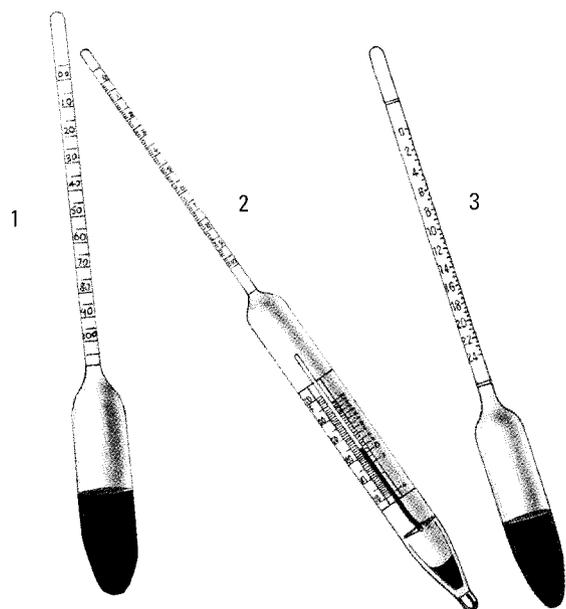
The hydrolysis of aluminum chloride into aluminum hydroxide and hydrochloric acid is illustrated above. As shown by the double arrows, the action is reversible.

Salts can be hydrolyzed. They form two new compounds. One is an acid, and the other is a base. Sodium carbonate, for example, forms carbonic acid and sodium hydroxide. Carbonic acid is only a weak acid, but sodium hydroxide is a strong base. The solution that forms will therefore be more basic than acidic (see **ACID**; **BASE**).

In organic chemistry, esters can be hydrolyzed to form organic (carbon-containing) acids and alcohols (see **ESTER**). Acids or bases may have to be added to make hydrolysis take place. When an ester is hydrolyzed by boiling with a base, it forms an alcohol and a salt of the organic acid. Soaps are made in this way. The process is called saponification.

Hydrolysis also occurs in the digestion of foods. Enzymes help bring about the hydrolysis of food into simple compounds that the body can use. *See also* **DIGESTION**; **ENZYME**.

HYDROMETER A hydrometer is an instrument that is used to make measurements of the relative density of liquids (see **RELATIVE DENSITY**). It is a glass tube with a weight on one end and numbers printed on the side. When the tube is set in liquid, the bottom of it sinks into the liquid to a certain depth, depending upon the relative density of the liquid. The surface of the liquid reaches one of the numbers on the side. That number indicates the relative density of the liquid. If the tube sinks deeply, the liquid's surface reaches a number near



HYDROMETER

Hydrometers come in various shapes and weights, to suit the relative density of the liquids they are used to measure. Shown here are (1) a general-purpose hydrometer; (2) a saccharometer, for measuring the relative density of sugar solutions; and (3) a general-purpose hydrometer for testing liquids that are denser than water.

the top of the tube, indicating a low relative density. If the tube sinks only a little, the liquid's surface reaches only the numbers at the bottom of the tube, indicating a high relative density. A hydrometer works on the principle that a floating body displaces its own weight in a liquid (see **ARCHIMEDES**). Hydrometers are used to tell if many different liquids are pure.

 **PROJECT 3**

HYDROPONICS Hydroponics is the science of growing plants without soil. Instead of receiving nutrients from the soil, plants are fed on water that has had nutrients added to it. There are two main methods of hydroponics. The first is growing plants in gravel or coarse sand through which nutrient-rich water is pumped. Another method is to grow plants in tanks of nutrient-rich water. The plants are suspended by a device, such as a wire mesh. Air is pumped into the water to replace the air used by the plant roots. Hydroponics is also called nutriculture, soilless agriculture, and chemical culture.

Hydroponics has been practiced for thousands of years. Ancient peoples, such as the Aztecs, the Babylonians, and the Egyptians, practiced hydroponics. However, modern hydroponic methods were not developed until after the 1930s.

A hydroponic method developed in the 1970s, called nutrient film technique (NFT), uses thick plastic mats that are laid out in troughs. The plants are suspended over the plastic by a wire mesh. A film of water containing chemical nutrients is continuously pumped into the troughs over the plastic. The troughs are sloped, so that gravity keeps the water flowing downward. The water that collects at the bottom of the troughs is pumped back up to the top of the slope. NFT has several advantages over growing plants in soil. Plants grown by NFT require only 10 percent of the water that plants grown in soil require. Also, because the flow of water is carefully controlled, there is no runoff of nutrients. This method is very popular with commercial growers. More recent developments include the flood and drain technique in which a pump is used to flood the plant roots with water and nutrients at regular intervals.

Hydroponics is useful in extending the growing season in areas where the climate limits outdoor growing of crops. Scientists also hope to use hydroponics in places such as Alaska or the Middle East where the temperatures are too extreme or the rainfall too minimal to otherwise grow crops outdoors. In the United States, hydroponics is mostly practiced as a hobby. However, certain vegetables, such as cucumbers, peppers, lettuce, and tomatoes, are grown hydroponically for sale.

When the water-culture method of hydroponics was introduced in the 1930s, some farmers predicted it would become widespread. However, the specialized equipment and knowledge needed to practice hydroponics has prevented that from occurring. Also, studies have shown that higher crop yields can be achieved using soil. Hydroponics may someday be used on ships at sea or in orbiting space stations.

See also AGRICULTURE.



HYDROPONICS

The tomato plants in the foreground are being grown hydroponically. Their roots are in plastic tanks of water containing fertilizer. There is no soil.

HYDROSPHERE The hydrosphere is all the water that lies on, or in, the earth, or floats above it in the air. The hydrosphere includes the oceans and seas, the rivers and lakes, the ponds and swamps, and the vast masses of ice locked up in glaciers and ice sheets. It also includes the steam from volcanoes

and geysers, the water vapor in the air, the clouds, and the rain, hail, and snow that are produced as the hydrosphere circulates. The oceans, for example, cover 71 percent of the earth's surface—a total of 40 million sq. mi. [361 million sq. km]. The total volume of water in the oceans is more than 322 million cubic mi. [1,347 million cubic km]. All the water in the oceans and seas is salty. About 90 percent of the world's fresh water is frozen in the Antarctic ice cap.

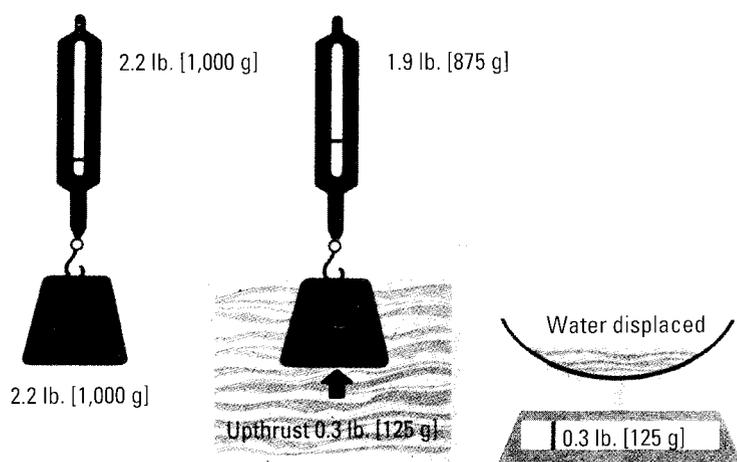
See also GLACIER; LAKES AND PONDS; OCEAN; RIVER; WATER.

HYDROSTATICS Hydrostatics is one of the subdivisions of the branch of physics known as hydraulics (see HYDRAULICS). Hydraulics is the study of the characteristics of liquids at rest and in motion. Hydrostatics is the study of liquids at rest. For example, hydrostatics might deal with water in a glass tank, including the way the water presses against the sides of the tank and the way anything floating in the tank behaves. In hydrostatics, there are three important principles, or laws, that were discovered many years ago.

The first law The first law of hydrostatics deals with objects that are floating or immersed in liquids. It is also called Archimedes' principle. Archimedes was a Greek scientist who discovered the principle over 2,200 years ago. The law states that a body floating or submerged in a liquid is pushed up in the liquid by a force equal to the weight of the liquid that the object displaces (pushes out of the way). Thus, the object will seem to lose as much weight as the weight of the liquid it displaces (see ARCHIMEDES).

It is easy for us to tell that we "lose weight" when we are in water. It is also easy to see that we displace water. If a person climbs into an absolutely full bathtub, then a great deal of water will spill over.

The principle is important in ships. When a ship has no cargo, it floats high in the water. It displaces only a little water. When it is heavily loaded with cargo, it sinks much lower in the water. It displaces a greater amount of water. If the weight of the ship and the cargo becomes greater than the weight of



HYDROSTATICS

The first law of hydrostatics—Archimedes' principle—states that a floating or submerged object experiences an upthrust equal to the weight of the liquid it displaces. On the left, a weight is hung from a scale. When immersed in water, the weight appears to weigh less, by an amount equal to the weight of the water displaced.

water the ship can displace, then the ship will sink (see BUOYANCY).

The second law The second law of hydrostatics was stated in 1586 by the Dutch mathematician Simon Stevin. This law says that the pressure on a given point of a submerged object is equal to the weight of fluid directly above that point. A fluid may be a liquid, a gas, or a mixture of gases, such as the atmosphere. This means that at the surface of the earth, the weight of several miles of atmosphere is pressing down upon us. High in the mountains, or higher still in airplanes, the pressure of the atmosphere is reduced.

At the deepest points in the ocean, the pressure is extremely great. Here there is the pressure of hundreds of yards of salt water as well as the atmospheric pressure on top of that. The pressure may be several tons per square inch.

The third law The third law of hydrostatics is also called Pascal's law. It was named for the French scientist Blaise Pascal, who discovered the law in 1648 (see PASCAL, BLAISE). The law states that pressures applied to a contained liquid are transmitted equally throughout the liquid, in every direction.

The last two laws of hydrostatics are very important in engineering. Marine engineers, for example, must determine how strong to make the hulls of submarines to withstand underwater pressures. Dam builders must be able to calculate how thick to build their dams.

HYDROXIDE A hydroxide is any inorganic chemical compound containing one or more hydroxyl (OH) groups. A hydroxyl group is a negatively charged ion made up of a hydrogen atom and an oxygen atom (see IONS AND IONIZATION). Its chemical formula is OH^- . The hydroxide ion combines with metals and certain nonmetals to form various hydroxide compounds.

Many, but not all, hydroxides are bases (see BASE). Solutions of sodium and potassium hydroxides are very strong bases. The molecules split up in the water to produce hydroxide ions. Bases that dissolve in water are called alkalis. The most important alkali is sodium hydroxide. Other names for it are caustic soda and soda lye. Another important alkali is potassium hydroxide, or caustic potash (see ALKALI).

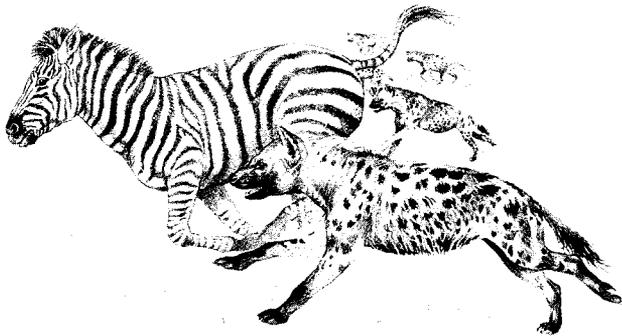
A solution of calcium hydroxide is called lime-water. It is used to detect carbon dioxide gas. When carbon dioxide is bubbled through it, the solution becomes milky. This is because white particles of calcium carbonate are formed.

The hydroxides of certain metals may be produced by adding soluble (dissolvable) hydroxides, such as sodium hydroxide, to soluble salts of the metal (see SALTS). For example, zinc hydroxide may be made by adding sodium hydroxide to zinc sulfate solution.

Soluble hydroxides may be made by electrolyzing solutions of salts (see ELECTROLYSIS). For example, sodium hydroxide forms during the electrolysis of sodium chloride (common salt) solution.

HYENA Hyenas are doglike nocturnal carnivores that belong to the family Hyaenidae (see **CARNIVORE**; **NOCTURNAL BEHAVIOR**). Hyenas feed on the remains of dead animals. They also hunt animals for food. Hyenas have strong jaws and teeth, enabling them to crush and eat even large bones.

The spotted hyena lives in Africa. Its fur is yellowish gray with black spots. It is known for its strange howl that sounds like a hysterical human laugh. The striped hyena lives in northern Africa and parts of Asia. Smaller than the spotted hyena, the striped hyena has a grayish coat. Narrow black stripes run across its body and legs. The brown hyena lives mainly in southern Africa. It has long hair on its back and stripes only on its legs. Frequently poisoned and shot by farmers, the brown hyenas are now endangered (see **ENDANGERED SPECIES**).



HYENA

In Africa, packs of spotted hyenas will chase and kill animals as large as a zebra.

HYGIENE Hygiene is the branch of science and medicine that has to do with maintaining a healthy body. If a body is generally fit and healthy, it is much more able to withstand disease or to recover quickly from an illness or accident.

To keep healthy, the body has many needs. Among the most important are fresh air, light, warmth, cleanliness, and a balanced diet. The diet should consist of the right kinds of food and drink (see **DIET**). Supplies of food and water must be fresh and clean, and therefore not contaminated with toxins (poisons) or pathogens (disease-causing organisms). Regular washing, adequate sleep, and regular exercise also aid in personal health.

Although a person can do much to guard his or her health, some threats to health can be prevented by the action of communities. For example, governments enforce laws to control pollution of the air and water. Laws are also passed to protect workers in factories or other places from various hazards. Clean water supplies and the disposal of garbage and sewage are usually the responsibility of public utilities or authorities. Governmental bodies, such as the United States Food and Drug Administration, make sure hygienic standards are kept in food processing industries. At the international level, the World Health Organization develops programs to fight disease and prevent its spread.



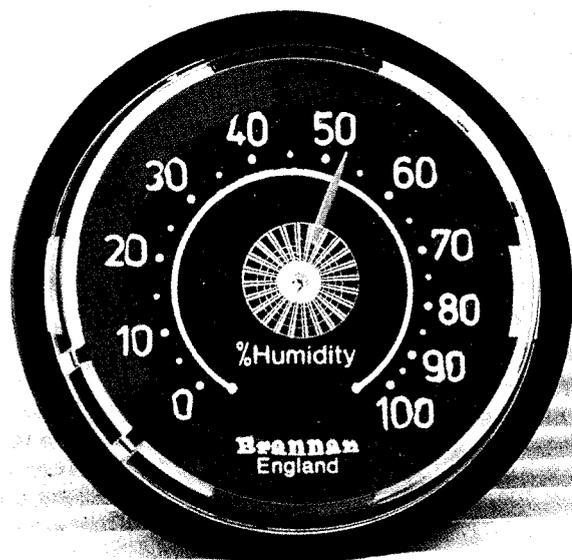
HYGIENE

Hygiene is of utmost importance in an operating room. All instruments and equipment are sterilized to make sure that no disease-causing organisms infect the patient.

HYGROMETER A hygrometer is an instrument that measures the water vapor content of the air. It is used by meteorologists to determine relative humidity. There are two main types of hygrometers: the psychrometer and the hair hygrometer.

A psychrometer, also called a wet- and dry-bulb hygrometer, consists of two thermometers. One thermometer gives the actual temperature. The bulb of the other thermometer is wrapped in muslin and kept moist with water. In order to determine the humidity, the psychrometer is spun at about 9 m.p.h. [14 kph]. Water evaporates from the wet-bulb thermometer, thus lowering its temperature reading (see EVAPORATION). If the humidity is high, less water will evaporate.

The wet-bulb thermometer reading is always less than the dry-bulb reading, unless there is 100 percent relative humidity. The difference between the thermometer readings is called the wet-bulb depression. Using this information, the relative humidity can be determined by referring to special tables.



HYGROMETER

A hygrometer measures humidity, which is the percentage of water vapor in the air. The type shown is designed for use in a greenhouse, where the correct humidity must be maintained for plants to grow well.

A hair hygrometer uses human hair to determine the humidity. The hair absorbs moisture from the air, becoming longer if the humidity is high. A lever moves according to the change in hair length, indicating the relative humidity.

See also HUMIDITY.

 **PROJECT 23, 25**

HYPNOSIS Hypnosis is a state in which the mind becomes less aware of the surrounding world. The subject (person under hypnosis) may seem to be asleep but is capable of complex thinking and responding to outside events. Easily influenced by suggestion, the subject can control many body functions that are normally automatic. For example, a hypnotized person may be insensitive to pain if told that he or she feels nothing.

A person is generally put into a state of hypnosis by another person, called a hypnotist. However, hypnosis can also be brought about by the subject himself or herself. This is called self-hypnosis or autohypnosis.

There are many methods a hypnotist may use to induce (bring about) hypnosis. One such method consists of the hypnotist's talking to the subject slowly, repeating the words over and over again. Eventually, the subject becomes completely relaxed and goes into a trance (a hypnotic state).

Not everyone can be hypnotized. People cannot be hypnotized against their will. Also, subjects do not do anything under hypnosis that is against their ideas or principles. However, hypnosis is not a game. It can be extremely dangerous when performed by an untrained person.

Hypnosis may be used in place of an anesthetic during surgery or childbirth. The patient feels nothing but can cooperate with the doctor. Hallucinations can also be induced under hypnosis (see HALLUCINATION). A hypnotized person may be able to recall forgotten events in his or her early life. This ability has been used by psychiatrists to treat certain mental illnesses.

See also PSYCHIATRY; PSYCHOANALYSIS.

HYPOTHERMIA (hī'pō thū'mē ə) Hypothermia is a drop in body temperature below 95°F [35°C]. If maintained long enough, hypothermia

causes drowsiness, lowering of the breathing rate and heart rate, and eventually unconsciousness and death. Most serious cases of hypothermia are in sick, elderly people living in poorly heated homes. Babies are also at risk from hypothermia because they lose heat rapidly. Anyone can develop hypothermia if they are exposed to cold conditions without adequate protection. Swimming in cold water is especially dangerous because heat loss can be rapid, and increases the risk of drowning.

Hypothermia is a medical emergency, and first aid is very important. Follow these steps:

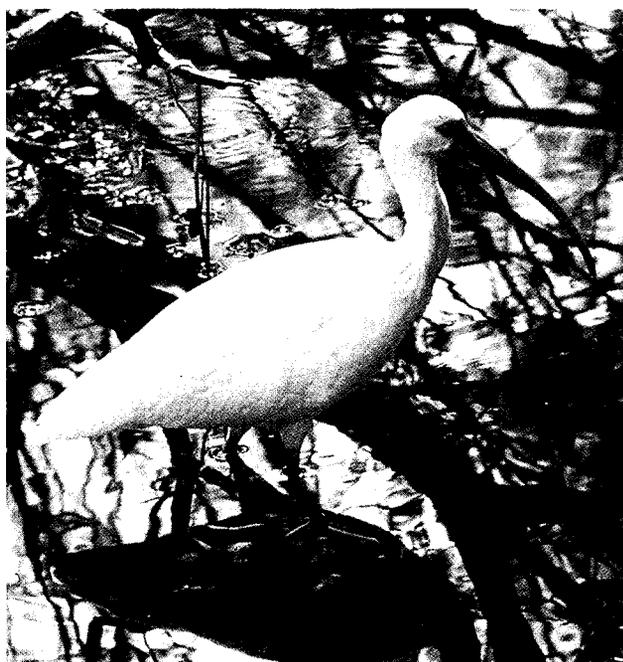
- Call for medical help immediately.
- Move the victim to a warm place.
- Replace wet clothing with dry clothing and wrap the person in blankets.
- Warm an elderly victim gradually with layers of blankets.
- Treat mild cases by giving the person a hot drink and covering with warm clothes.

Hypothermia has been used in surgery. By lowering the temperature of heart muscles during heart surgery, the damage caused to them from lack of oxygen is also lessened.

HYPOTHESIS (hī pōth' ĩ sīs) A hypothesis is a statement that is generally believed to be true but has not been proved. In science, hypotheses (plural of *hypothesis*) are based on existing information and help explain, order, or unify related facts. Experiments are then used to test the hypothesis to see whether any new information comes to light that either confirms the hypothesis or refutes it (calls it into doubt). If the evidence in support of a hypothesis is strong enough, it may then be called a scientific law. The planet Neptune was discovered as a result of a hypothesis. In the nineteenth century, Uranus was the most distant planet known. Astronomers noticed that Uranus was not always in the position that the known laws of gravity said it should be. A hypothesis was formed that the changes in its orbit were being caused by another, undiscovered planet. Astronomers looked for another planet where the hypothesis said there should be one, and found Neptune.

I

IBIS Ibises are tall birds that belong to the family Threskiornithidae. They are closely related to spoonbills (see SPOONBILL). Ibises have long necks and legs, and down-curved bills. They wade in shallow water and catch small fish, reptiles, and amphibians. There are four species of ibises in North America. Three species are found only in the southeastern part of the United States and in parts of Mexico. The fourth species, the whitefaced ibis, is found in the west-central part of the United States and in Mexico.



IBIS

The white ibis is an African species.

ICE Ice is the solid form of water. When water is cooled, it contracts (shrinks) until its temperature drops to 39°F [4°C]. It then expands until the temperature drops to 32°F [0°C], the freezing point of water. The density of ice is slightly less than the density of water. This is why ice cubes float in a glass of water (see DENSITY).

When ice freezes, hydrogen bonds form a rigid structure of six-sided crystals. The type of crystal structure depends on how the water is frozen. Forms of ice include snow, sleet, frost, and hail.

See also CRYSTAL; WATER.

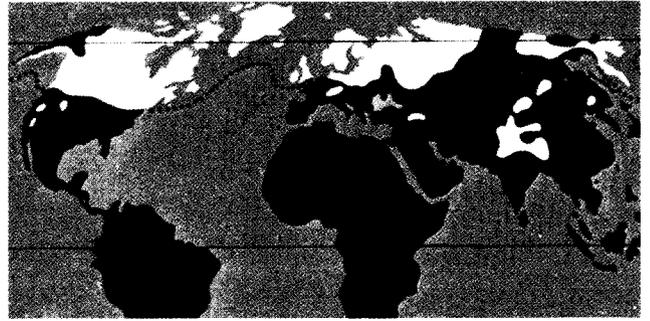
 PROJECT 11, 12

ICE AGE

An ice age is a period of the earth's history when large areas of the globe are covered by glaciers (see **GLACIATION**; **GLACIER**). The most recent ice age occurred during the Pleistocene epoch, which ended about 10,000 years ago. An ice age also took place during Precambrian times, about 600 million years ago. Several ice ages took place in the Precambrian, there was one in the Ordovician, and an important one in the late Carboniferous and early Permian (see **GEOLOGICAL TIME SCALE**).

During the ice age of the Pleistocene epoch, beginning about 1,640,000 years ago, the ice advanced southward during several periods called glacial ages. These glacial ages were separated by interglacial ages, when the ice retreated. The main glacial ages in North America, from oldest to most recent, are called the Nebraskan, the Kansan, the Illinoian, and the Wisconsin. The interglacial ages are called the Aftonian, the Yarmouth, and the Sangamon. Evidence from sea sediments suggests that there may have been about 20 glacial-interglacial cycles. Geologists have suggested that the earth may now be in an interglacial age.

Scientists have learned a great deal about the ice ages by studying fossils and other evidence from the Pleistocene epoch (see **FOSSIL**). Geologists believe that great ice sheets were centered near Hudson Bay in North America and on the Scandinavian peninsula in Europe. The ice became thick and flowed out from these centers. All of Canada and the northern one-third of the United States, as far south as present-day New York City and the Missouri River valley, were covered by ice. In places, the ice was 8,000 to 10,000 ft. [2,400 to 3,000 m] thick. In Europe, ice covered all of northern Europe, the British Isles, and part of northern Russia. At times during the Pleistocene epoch, more than 30 percent of the earth's surface was covered with ice. The Pleistocene glaciations had a profound effect on the landscape of the areas covered by ice and also those directly south of the glaciers. Plants and animals were forced to live in more restricted environments. Fjords, moraines, and drumlins were created by the retreating ice. Many



ICE AGE MAP

The white areas on the map show the parts of the earth that were covered by glaciers during the last ice age.

lakes, including the Great Lakes, were formed during the last ice age.

Different theories have been proposed to explain what caused the ice ages. Some scientists think that changes in oceanic circulation patterns caused by continental drift had worldwide cooling effects that encouraged growth of glaciers (see **CONTINENTAL**



WOOLLY RHINOCEROS

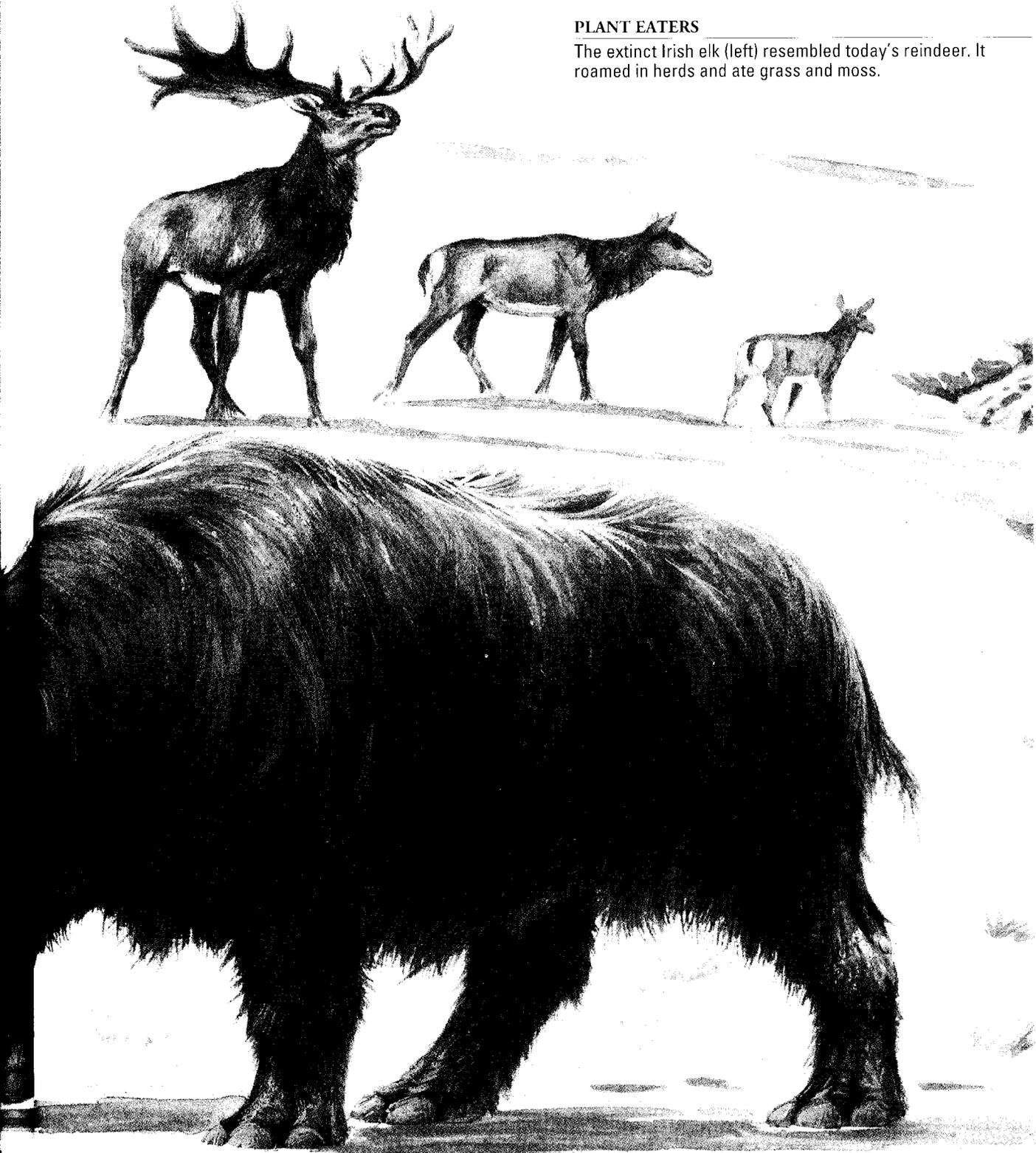
Many large mammals of the ice age had long hair to keep out the cold. They included the woolly rhinoceros (above), which was probably hunted to extinction by early humans.

DRIFT). Others think in the 300 million years it takes for the solar system to make a complete rotation of the galaxy, there are two phases 150 million years apart, in which the galactic environment

has a cooling influence. Other astronomers have found evidence that cyclic variations in the earth's orbit can produce cooling effects strong enough to start an ice age.

PLANT EATERS

The extinct Irish elk (left) resembled today's reindeer. It roamed in herds and ate grass and moss.



ICEBERG An iceberg is a large, floating mass of ice. Icebergs break away, or calve, from the glaciers along the coasts of Alaska, Greenland, and Antarctica (see **GLACIER**). They sometimes present a major hazard to shipping.

A glacier often extends offshore into the sea. Eventually, cracks form in the ice of the glacier, and pieces of the glacier break off. Greenland is the source of most North Atlantic icebergs. These icebergs may be taller than 300 ft. [90 m]. Antarctic icebergs are often very large but are usually flat-topped, formed from parts of the ice cap that have broken away. In 1995 an Antarctic iceberg almost as big as Rhode Island broke away from James Ross Island, suggesting that the Antarctic climate is becoming warmer.

Usually, only one-ninth of an iceberg is visible above water. As an iceberg floats, some of the ice melts, and pieces break off. Eventually, the iceberg completely disappears.

In 1912, the British ocean liner *Titanic* hit an iceberg and sank in the North Atlantic. More than 1,500 people died. Since then, the United States and other countries have formed an International Ice Patrol. The patrol, operated by the United States Coast Guard, uses ships, planes, and radar to locate icebergs.

 **PROJECT 12**



ICEBERG—Shipping hazard

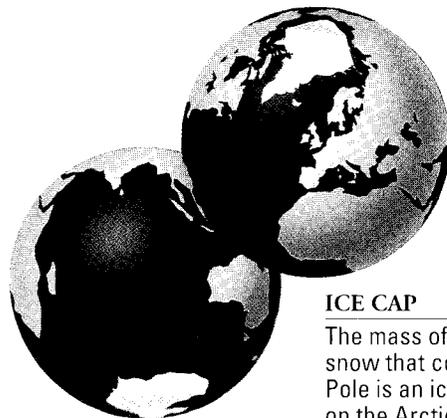
Only one-ninth of an iceberg can be seen above the water. The submerged part of the iceberg may have jagged edges below the surface. These cannot be seen and are a danger to ships (left).



ICEBERG—Ice islands

Icebergs are large, floating masses of ice that have broken away from ice caps or glaciers. Icebergs are most often found along the coasts of Alaska, Greenland, and Antarctica.

ICE CAP An ice cap is a mass of ice that spreads outwards from its center. An ice cap differs from a glacier in that a glacier flows only in one direction, like a river (see **GLACIER**). An ice cap is fed by snow that falls on its surface. If this snow does not melt, it becomes compacted into ice. The weight of new snow falling on top of this ice squeezes the ice out at the side, producing the outward movement. Some glaciologists—scientists who study ice—call the mass of ice that covers the North Pole and spreads out over the sea an ice cap. Others restrict the term to a mass of ice that forms and spreads out over land, such as that covering most of Iceland.



ICE CAP

The mass of compressed snow that covers the North Pole is an ice cap that floats on the Arctic Ocean (top). The southern ice cap (bottom) covers most of the land mass of Antarctica.

ICHNEUMON FLY Ichneumon flies are common, widely distributed insects belonging to the same group as bees and wasps (order Hymenoptera). Ichneumon flies are not true flies. Ichneumon flies have four wings, while true flies have only two wings. Some ichneumon are about the size of a small ant. Others grow to 2.3 in. [6 cm] in length. Ichneumon flies do not sting people.

The body of a female ichneumon fly ends in a pointed egg-laying structure called an ovipositor. The ovipositor may be up to twice the length of the insect's body. The three threadlike parts of the ovipositor form a tube. With the ovipositor, the insect places eggs in or on the bodies of caterpillars or other insect larvae and pupae. The eggs hatch into grubs which feed on the caterpillars or other hosts and eventually kill them (see **PARASITE**).

Ichneumon flies are important to farmers. These insects often feed on other insects that destroy crops.

ICHTHYOLOGY (ik' thē ōl' ə jē) The study of fishes is called ichthyology. It includes the study of the bodies of fishes, their evolution, how and where fishes live, and their relationships to other animals.

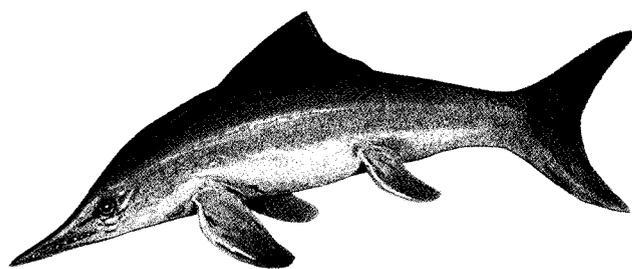
Ichthyologists, or scientists who study fishes, do many different things. Some ichthyologists study only the fish itself. They cut open the body, examine the organs, and learn how various organs work.

Other ichthyologists travel all over the world, studying where the thousands of different kinds of fishes live. They may also search for and study fossils of fishes that have become extinct (see FOSSIL). Besides learning about the fishes, these ichthyologists learn a great deal about the history of the earth. Still other ichthyologists study the number of fishes that live in particular places. They may start programs to help increase the numbers of various species of fishes. They also supply information to fishers to help them catch more fish. These scientists may determine how many fish can be caught without endangering the whole population of fishes.

See also CONSERVATION; FISH.

ICHTHYOSAUR (ik' thē ə sōr') Ichthyosaurs were fishlike reptiles that lived during the Mesozoic era (see MESOZOIC ERA). Ichthyosaurs resembled dolphins of today, having a streamlined body and paddles for limbs. Some ichthyosaurs had a long snout and sharp teeth, some had a sword like a swordfish, and some were toothless. Many were quite small, but some were the size of whales. Like dolphins, ichthyosaurs also gave birth to live young, instead of laying eggs as modern reptiles do.

See also DOLPHIN; FISH; FOSSIL; REPTILE.



ICHTHYOSAUR

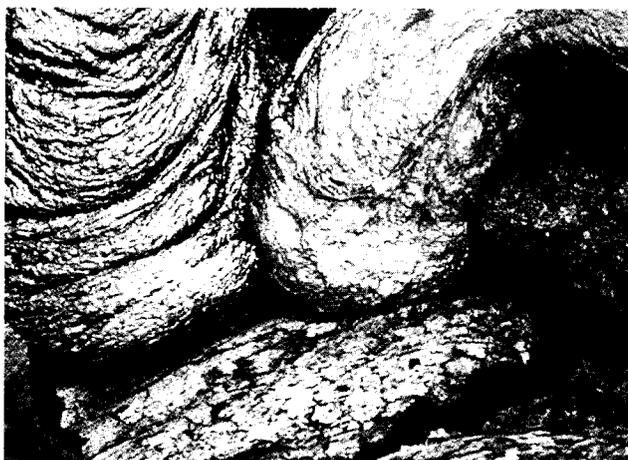
This marine species of extinct reptiles resembles the dolphins of today.

ICONOSCOPE An iconoscope is a type of cathode-ray tube that was used in the first television cameras. The iconoscope was invented in 1923 by Vladimir K. Zworykin, a Russian physicist. The iconoscope is shaped like a light bulb, but it is usually much larger. This device made the first television transmissions possible.

In a television camera with an iconoscope, light enters the lens and is focused on a photoelectric surface inside the iconoscope. This surface is made up of tiny metal particles. These particles give off electrons when light hits them (see PHOTOELECTRIC EFFECT). Highly lit areas of the surface give off more electrons than dimly lit areas. A device called an electron gun, which is in the neck of the iconoscope, shoots electrons at the photoelectric surface of the iconoscope. Different areas of the surface absorb different amounts of electrons from the electron gun. The areas that have given off many electrons absorb more electrons from the electron gun than the areas that have given off fewer electrons. The absorption of electrons creates a signal that varies in strength in proportion with the pattern of light hitting the photoelectric surface. This signal is transmitted through the air and picked up by television antennas. It gets reconverted into the pattern of light that appears on the television screen.

The image orthicon, a device that is much smaller and more sensitive to light, replaced the iconoscope between the 1940s and mid-1960s. In modern color television cameras, a more sensitive tube called a vidicon replaces the image orthicon. In high-quality color cameras, three vidicon tubes are used to create a separate video signal for each of the three primary colors.

IGNEOUS ROCK Igneous rock forms from the cooling and crystallization of a hot, molten material called magma. Magma is rock that has been subjected to great temperature and pressure beneath the earth's surface. Igneous rocks contain a variety of minerals, including quartz, mica, and feldspar. There are two main types of igneous rock: extrusive and intrusive. Extrusive igneous rock is magma forced from the earth's interior through a volcano or a crack in the earth's surface. This



IGNEOUS ROCK

Hot, molten lava (above) cools after it reaches the earth's surface. The rock that forms is called extrusive igneous rock.

magma, called lava when it reaches the earth's surface, quickly cools when it is exposed to air. Because of the rapid cooling, extrusive rock contains small crystals and is fine-textured. Extrusive igneous rocks include basalt, obsidian, and pumice.

Intrusive igneous rock forms when magma cools below the surface of the earth. The magma sometimes cools in large masses called batholiths. It may also cool in vertical bands called dikes or in horizontal bands called sills. Because intrusive rock cools and hardens slowly, it contains large crystals and is coarse-textured. Granite is an intrusive igneous rock.

See also CRYSTAL; MAGMA; MINERAL; ROCK.

IGUANA An iguana is a large lizard that belongs to the family Iguanidae. There are many different species of iguanas in the world. Most of them live in South America and on islands in the Pacific Ocean. They are all basically vegetarian and they eat a lot of fruit. The best-known species of iguana is the marine iguana, which lives on the Galápagos Islands, off the coast of Ecuador. The marine iguana may reach a length of 5 ft. [1.5 m]. This iguana is the only marine lizard in the world. It feeds on seaweeds.

See also GALAPAGOS ISLANDS; LIZARD; REPTILE.

ILLUMINATION Illumination is the creation of artificial light. The earliest means of illumination were open fires and burning torches. Candles,

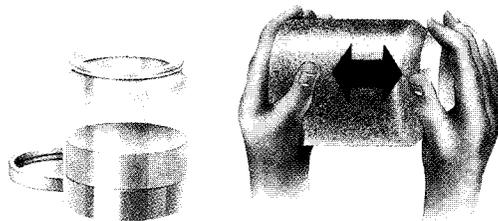
kerosene lamps and lanterns, and gas lamps were developed later. Incandescent electric lights were introduced in 1879 by Thomas Alva Edison. Most modern illumination is accomplished with incandescent lights (see EDISON, THOMAS ALVA; INCANDESCENCE; LIGHT).

The neon light, developed in 1910 by French physicist Georges Claude, is used largely to illuminate commercial signs and displays. Fluorescent light is a more recent development in illumination. It produces a brighter light than an incandescent bulb but uses less electricity. Fluorescent bulb tubes are straight or curved. They are often used to light office buildings and other commercial and public structures. Fluorescent tubes are also used in low-energy light bulbs (see FLUORESCENCE). Sodium vapor lamps and mercury vapor lamps are used to illuminate highways and other outdoor public areas.

See also ELECTRIC LIGHT.

IMMISCIBLE LIQUID Two liquids are immiscible if they cannot be mixed together. A common example of immiscible liquids are oil and water. If you try to mix them together, a boundary forms between the two. The lighter liquid, usually the oil, lies above the heavier liquid. Certain liquids, such as ethyl alcohol and water, can be mixed together. These liquids are said to be miscible. Whether two liquids mix or not depends on their chemical properties. If they resemble each other

ACTIVITY *Testing immiscible liquids*



Take a jar with a lid. Fill it one quarter with cooking oil. Then add water to fill it halfway up. Screw the lid on the jar. Shake it vigorously. Put the jar down, and watch what happens. What happens to the oil and water?

chemically, they are usually miscible. For example, the molecules of both water and alcohol are similar and have an $-OH$ group. Because of this, they are miscible. On the other hand, water and oil are very different chemically and so are immiscible.

See also LIQUID.

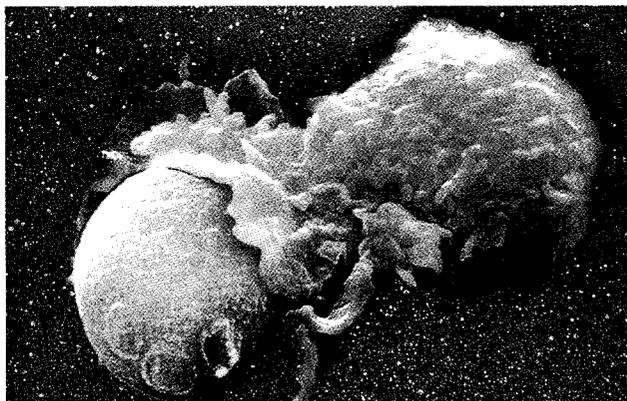
IMMUNITY Immunity is the ability of the body to prevent pathogens (disease-causing organisms) that enter the body from causing disease. The human body has natural immunity to many bacteria and viruses that cause disease in other animals. For some disease, humans must acquire immunity. This means that the pathogens that cause these diseases must be present for a person to become immune to such diseases. During the body's fight to overcome these diseases, permanent defenses against the disease may be developed by the immune system. Then, the pathogens that cause these diseases cannot attack that body again for a long period. In some cases, the immunity lasts for the rest of a person's life (see BACTERIA; DISEASE; PATHOGEN; VIRUS).

Through a medical procedure called immunization, a person can be given immunity to many diseases without first catching the disease. Immunization is any medical procedure that makes a person able to develop immunity to specific pathogens (see VACCINATION). The job of fighting pathogens is chiefly carried out by the lymphocytes. Lymphocytes are a type of white blood cell (see BLOOD; LEUCOCYTE). There are two kinds of lymphocytes. Both kinds are produced in the bone marrow (see BONE MARROW). One kind stays and matures in the bone marrow. These cells are called B cells. The other kind leaves the bone marrow and travels in the bloodstream to the thymus. The thymus is an organ involved with immunity, located high in the chest cavity. There, the cells from the marrow mature into T cells. There are several kinds of T cells. One kind is called a helper T cell.

Lymphocytes are specific. In other words, each lymphocyte can fight only a certain type of pathogen or a few types that are very closely related. This is why catching chicken pox does not give immunity to smallpox. However, catching cowpox

does give immunity to smallpox. The viruses that cause cowpox and smallpox are very similar (see CHICKEN POX; SMALLPOX).

The body also has other defenses that are not so specific. These defenses involve the other white blood cells—monocytes and neutrophils. Together, lymphocytes, monocytes, and neutrophils are called leucocytes. Monocytes and neutrophils consume bacteria. Monocytes also work with lymphocytes. The action of lymphocytes depends on their ability to tell that invading pathogens are foreign substances in the body. These foreign substances are called antigens or immunogens. The reaction of the lymphocytes to pathogens is called the immune response.



IMMUNITY

White blood cells called lymphocytes play an important part in immunity because they fight disease-causing pathogens. This electron microscope photograph shows a human lymphocyte (right) attacking and engulfing a yeast cell.

During an immune response, the B cells produce substances called antibodies (see ANTIBODY). Antibodies attack and kill antigens. The T cells regulate the production of antibodies. Some pathogens produce poisons called toxins. In order to neutralize these toxins, the lymphocytes produce a kind of antibody called an antitoxin (see ANTITOXIN).

The production of antibodies usually is too slow to stop invading pathogens the first time they enter the body. Therefore, the first time a person is exposed to a pathogen, he or she will probably develop the disease that the pathogen causes. After the person has recovered, however, the antibodies may continue to circulate in the blood, ready to react immediately if the pathogens invade again. The body may also be able to make the particular

kind of antibody much more quickly when faced with the pathogen a second time. The circulating antibodies or the ability to make the antibodies quickly gives the person immunity to the disease. This type of immunity, which is acquired through exposure to a specific disease, is called active immunity. The body has actively produced its own antibodies. People who have developed childhood diseases such as measles, mumps, and chicken pox usually gain active immunity against these diseases. That is why people rarely develop these diseases more than once in their lives (see MEASLES; MUMPS).

Immunity can also be passive. In passive immunity, the body acquires ready-made antibodies. Babies acquire antibodies to many diseases through their mother's bloodstream before birth and from her milk afterward. Such passive immunity, however, is short-lived.

Artificial immunity through vaccination may also be active or passive. Active immunity can be acquired by injecting dead pathogens into the body, or by injecting a type of the living pathogen that causes only a slight reaction (see INJECTION). In some cases, a toxoid is used. A toxoid is a bacterial poison that has been made harmless. Each of these methods may stimulate the body to make antibodies or antitoxins.

Passive immunity is given by injecting a solution of pre-formed antibodies. This solution is made from the blood of an infected person or animal that has produced the right antibodies.

In the case of most diseases caused by viruses, vaccination remains medicine's basic weapon. Diseases caused by viruses range from the common cold to smallpox and polio. These viruses are unaffected by antibiotics, powerful drugs that fight bacterial diseases (see ANTIBIOTIC). However, in 1957, it was discovered that the body has a second type of immune response to viruses, apart from that involving antibodies.

It was found that certain helper T cells produce substances called interferons whenever viruses are present in the body (see INTERFERON). Interferons stop a virus from reproducing, stimulate certain cells that consume viruses, or create a condition called viral immunity. Viral immunity means that

while a person is infected with one virus, related viruses or stronger strains of the same virus are prevented from reproducing.

Immunologists (scientists who study immunity) have been able to make animals produce more interferon by injecting a form of nucleic acid into their bodies (see NUCLEIC ACID). This meant the animals had an improved ability to fight viruses. Scientists have been able to make human cells produce interferon by adding certain foreign substances to them. Also, scientists used cloning techniques to produce interferon in the laboratory (see CLONE).

Immunologists have also been able to produce specific antibodies by cloning. To produce antibodies by cloning, immunologists join lymphocytes with cancer cells. The combined cells are called hybridomas. The lymphocyte genes enable the hybridoma to produce antibodies. The cancer genes enable the hybridoma to multiply indefinitely. Hybridomas are used for research and may someday be used for immunizations.

The body's immune response to foreign protein is not always of help to a patient. For example, the same mechanism that causes immunity is responsible for rejecting tissue transplanted from another person's body into a patient (see TRANSPLANTATION). The lymphocytes attack a transplanted heart or kidney in the same way they attack invading bacteria. In quite another way, if the body becomes oversensitive to foreign proteins, the immune system may become overactive. The result may be an allergy, such as asthma or hay fever (see ALLERGY).

Some diseases occur because of deficiencies in the body's immune system, called immunodeficiencies. These include AIDS (see AIDS). Most scientists believe that a newborn child does not have the ability to reject foreign tissues. Its body learns this in the first year or two of life. At the same time, it learns not to attack its own tissues. If the body's ability to recognize its own tissues is somehow disrupted, an autoimmune disease may result. In an autoimmune disease, such as multiple sclerosis, the immune system begins to attack the body's own tissues. Drugs called steroids can be used to treat some autoimmune diseases.

See also STEROID.