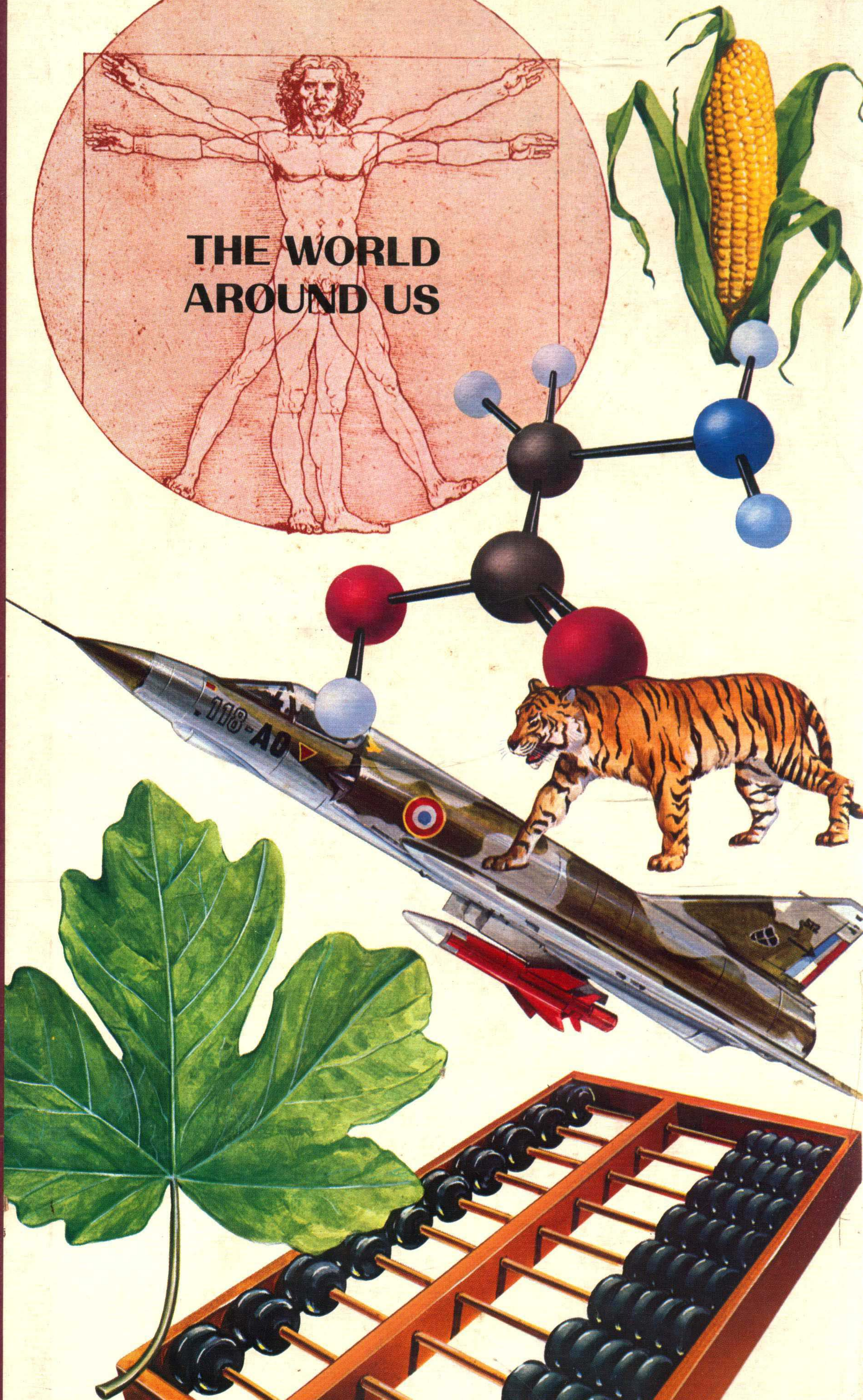
SCIENCE AND TECHNOLOGY ILLUSTRATED

THE WORLD AROUND US



Science and Technology Illustrated

The World Around Us

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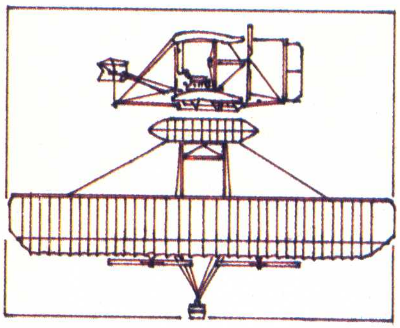

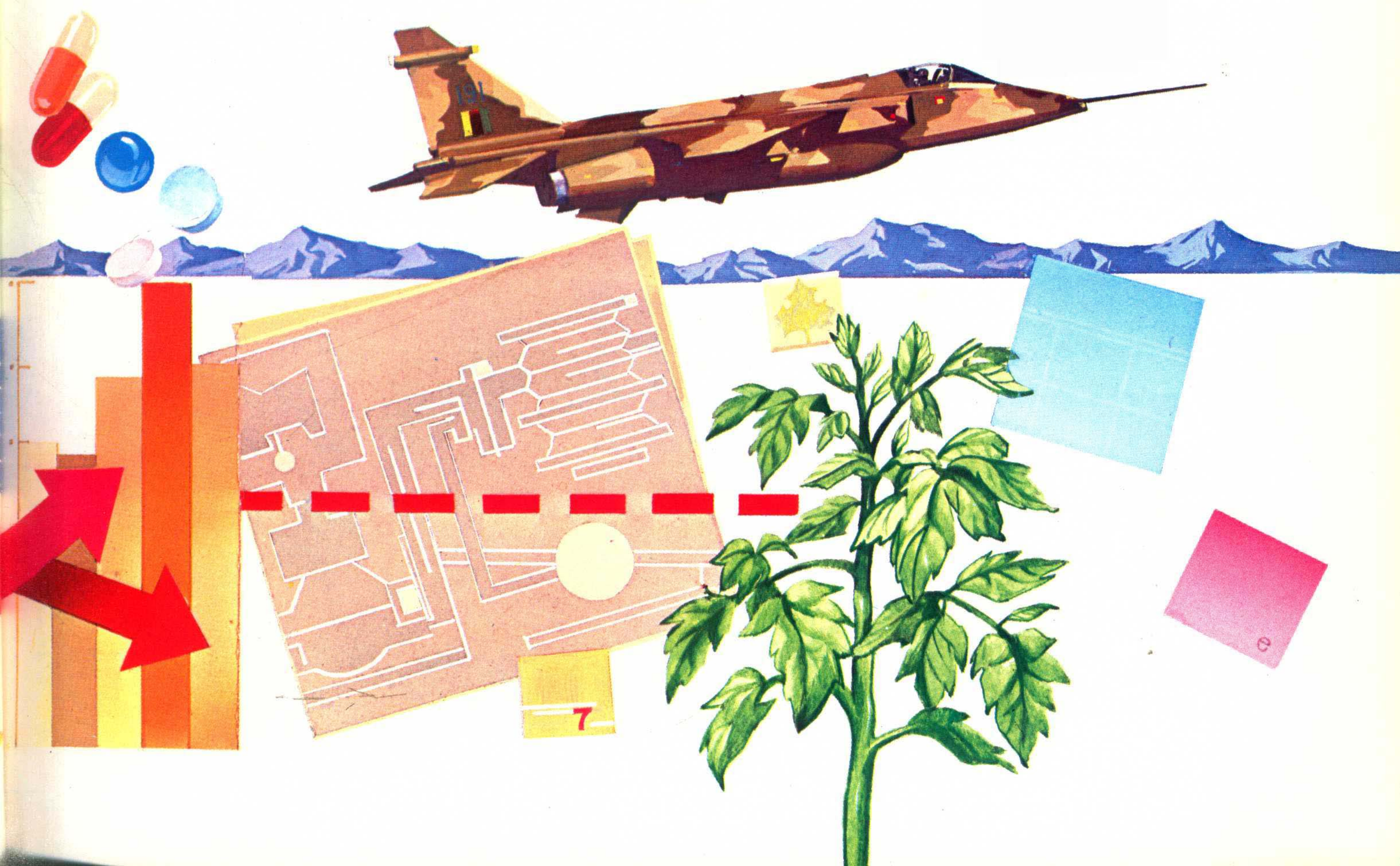
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Testosterone

What really "separates the men from the boys?" Sometime around the age of 12, a boy's body begins to change, internally and externally, and develops into an adult male body. Many of those changes are initiated and regulated by a hormone called testosterone, which is produced in the male gonads, or testes.

Function

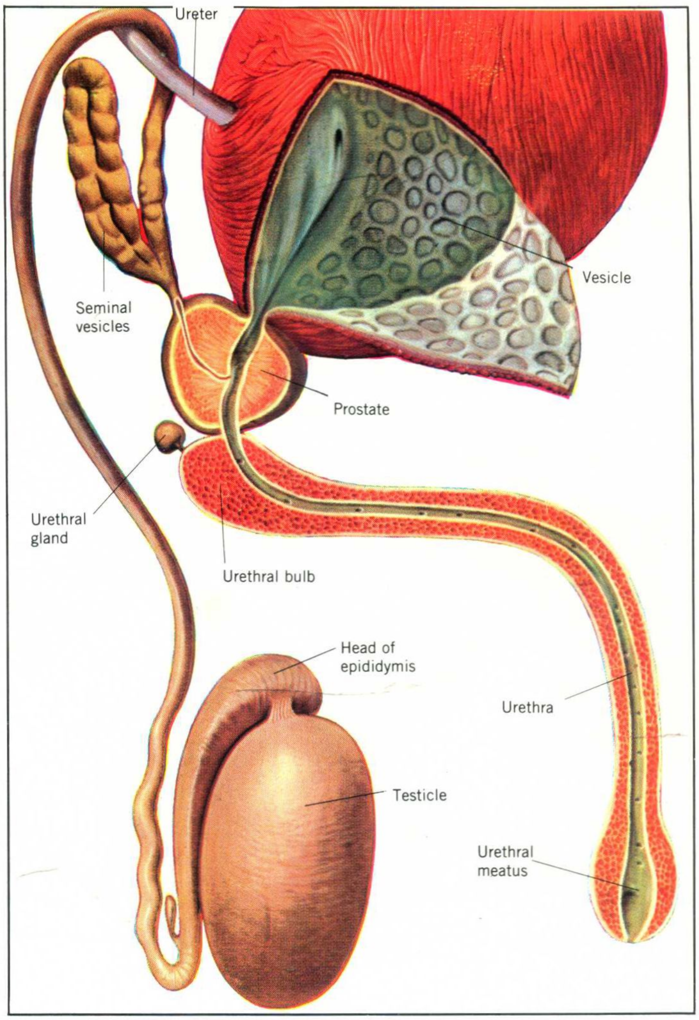
Testosterone is one of the male sex hormones, or androgens; it is the most abundant androgen and the main masculinizing hormone. Testosterone helps change a boy into a man by developing the male secondary sex characteristics; it lowers voice pitch, regulates the distribution and growth of hair, and affects behavior by increasing the sex drive. Testosterone also stimulates an increase in height and weight, but because this androgen causes closure of the ends of the long bones after stimulating skeletal development, it is instrumental in stopping as well as starting growth. Thus, at puberty, the increased production of testosterone is responsible for rapid growth and for completing skeletal development before full reproductive activity starts. This is important, because growth and reproduction both make heavy demands on the body; testosterone helps prevent competition for bodily resources between the two processes.

Testosterone promotes growth of the penis, the spermatic tubules (the tubes in the testes that produce sperm cells), and the seminal vesicles and prostrate gland (organs that produce the fluid in which sperm is ejaculated). The hormone is anti-estrogenic; that is, it suppresses the action of the small amount of estrogen (a main female sex hormone) produced by the testes, so that estrogen cannot induce the development of female secondary sex characteristics. Testosterone also stimulates the production of red blood cells (red-cell count is generally higher in men than in women).

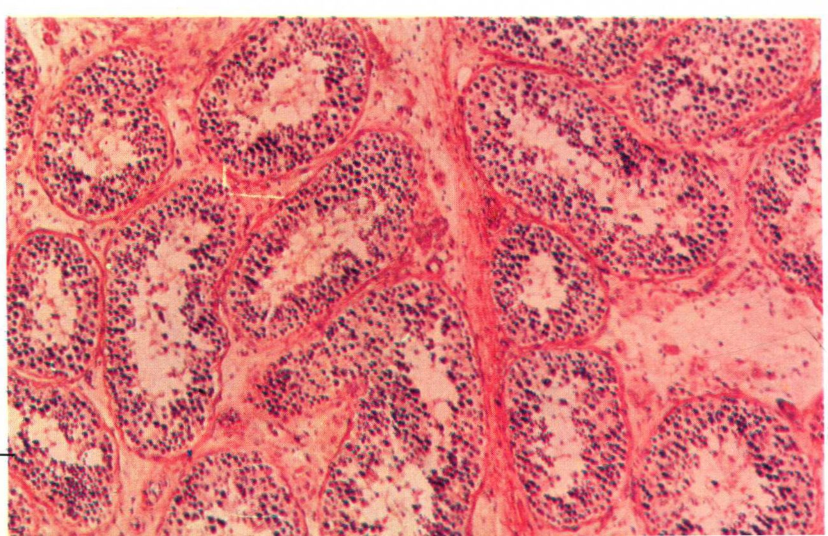
Production

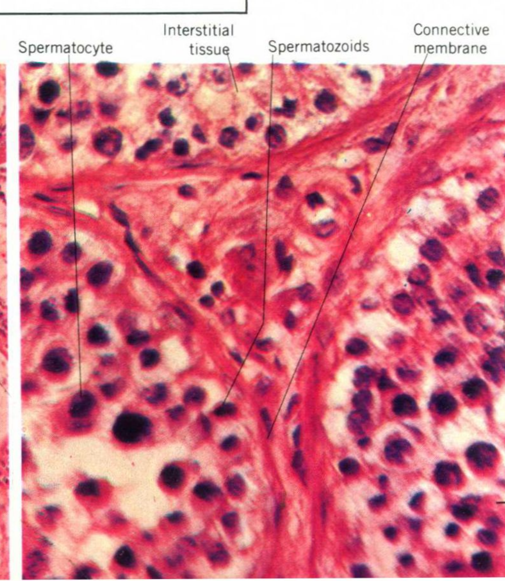
Testosterone is only one hormone in the body's endocrine system. This system produces many different kinds of hormones—chemical substances responsible for directing, regulating, and coordinating bodily processes. Various endocrine glands secrete hormones directly into the bloodstream, through which they travel to the "target" organs—those whose processes they direct. The endocrine system also regulates itself; that is, hormone production is regulated by other hormones.

The pituitary gland is an endocrine gland that produces several kinds of hormones, including FSH (follicle-stimulating hormone) and LH (luteinizing hormone). These hormones are called gonadotropins because they act on the gonads—the sex glands—producing reproductive cells and sex hormones. FSH not only stimulates the development of the



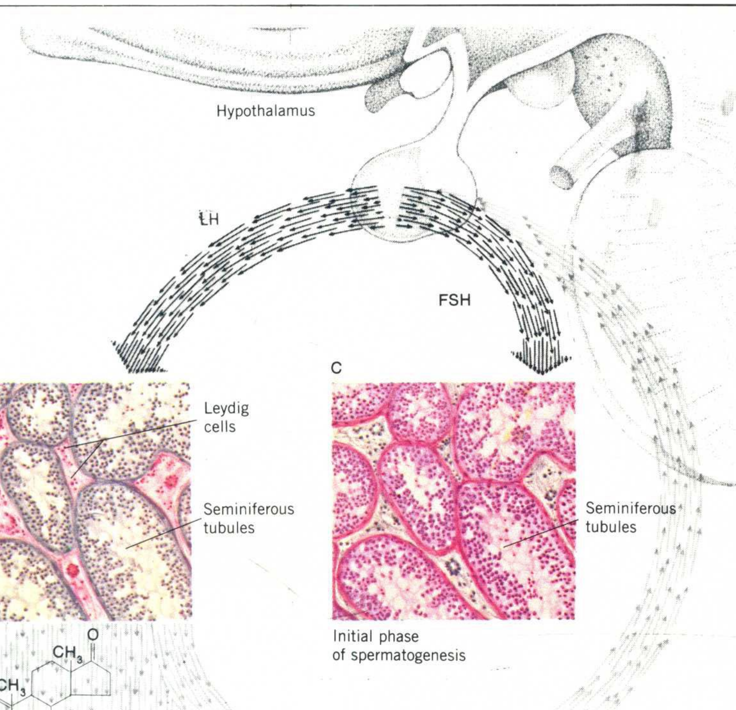
Left: Male genital system. The testicles, surrounded by a fibrous membrane, are divided into 200-300 lobules, each one containing from 1-3 seminiferous tubules. Between the tubules there is an interstitial connective tissue (seen below in 2 magnified views) containing the Leydig cells, which produce testosterone.

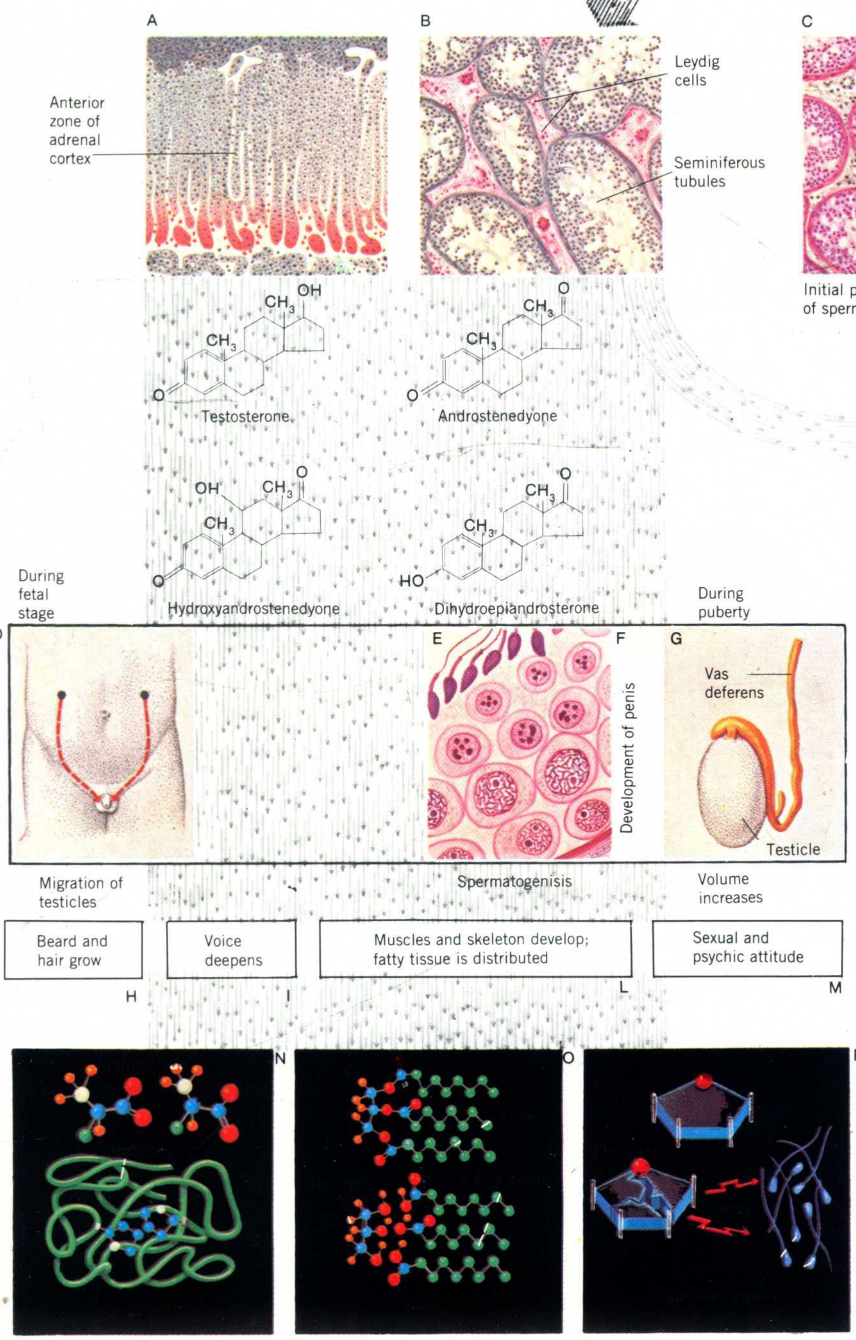




tubules in the testes that form sperm cells, it also regulates sperm growth. LH is also called ICSH (interstitial-cell-stimulating hormone). Interstitial cells (also called Leydig cells) make up the connective tissue that supports the tubules of the testes. The Leydig cells produce testosterone when stimulated by ICSH. They also produce small amounts of estrogen.

The pituitary gland increases testosterone production in the sex glands and regulates it throughout life. The pituitary itself is regulated by a part of the brain, the hypothalamus. At puberty, the hypothalamus secretes a hormone called gonadotropin-releasing factor (GRF), which increases production of the gonadotropins.





Above: Diagram shows, at top, secretion of testosterone and, below, effects of this hormone on the body. Testosterone is produced by Leydig cells (B) reacting to triggering hormones released by tissues of the adrenal cortex (A). In the body, testosterone triggers the development of male secondary sexual characteristics; the distribution of body hair, deepening voice, etc., during puberty, and also has an important metabolic role in breaking down fats and generating energy.

Disorders

Most disorders of the testes are associated with too little testosterone production. Hypogonadism involves a decrease of testicular secretion of testosterone due to testicular disease or pituitary failure. The result is impaired growth and underdeveloped secondary sex characteristics.

Testicular feminizing syndrome is an inherited disorder; afflicted men with functioning testes and male chromosomes may appear to be normally developed females. Evidence shows their bodies' cells may resist the effects of testosterone even though the hormone is being produced. Excessive masculinization is especially apparent when it occurs in young boys (and is then called precocious puberty).

Chemical Structure

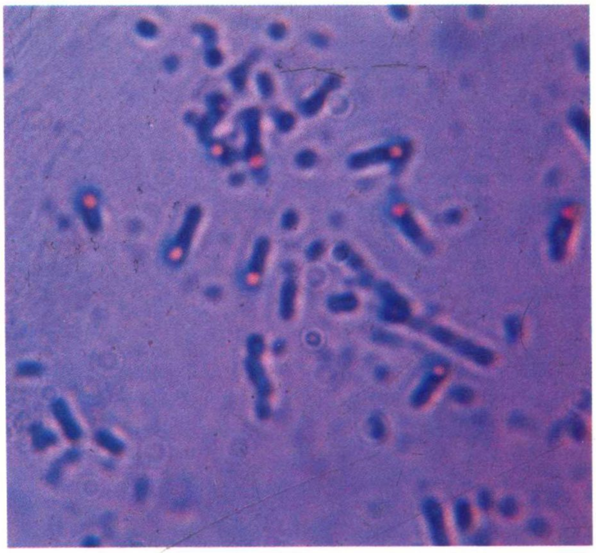
The molecular formula for testosterone is $C_{19}H_{28}O_2$. It is a steroid hormone; that is, it is derived from a particular nucleus configuration (a cyclopentanoperhydrophenanthrene nucleus). Testosterone is formed in the body from cholesterol, or can be created artificially either by modifying a similar, more abundant steroid or by total synthesis. Synthetic testosterone is used to offset hormone deficiencies in men, to suppress milk production in women, and to treat breast cancer.

See also PITUITARY GLAND; PUBERTY AND ADOLESCENCE.

Tetanus

For a disease that is relatively uncommon in many parts of the world, tetanus is fairly well known simply because of its more popular and suggestive name—lockjaw. This term indicates the devastating muscle spasms associated with tetanus. In severe cases, the muscles of the jaw contract tightly, locking the face of the victim into a pained, joyless grin.

Tetanus is an acute bacterial infection that usually results from a deep laceration or puncture wound. The invading bacteria produce toxins (poisons) that stimulate the body's nerve-transmission centers, which then mistakenly signal muscles to become rigid or, occasionally, cause convulsions. Death usually results from respiratory failure or cardiac arrest, although a great many other complications can arise from tetanus. The disease is highly lethal. Between 40 and 50 percent of all tetanus victims die, although the best treatment centers can reduce this figure to 20 percent. Approximately a million people worldwide are afflicted with tetanus each year, with over 400,000 deaths, most of which occur in underdeveloped countries.



Right: Tetanus bacilli seen under an optical microscope.

Below: Single bacillus shown greatly magnified in an electron-microscope image. In the body, these bacteria produce toxins that interfere with functions of the nervous system.

Invading the Body

Tetanus is caused by a thin, rod-shaped bacillus, *Clostridium tetani*. Spores of this bacteria occur widely in nature and can be found in particular profusion in topsoil. These spores normally enter the body through wounds. Since *C. tetani* is an anaerobic bacteria (it can thrive only in an oxygen-deprived environment), the spores are most likely to take hold if the wound is deep and not exposed to air.

After an incubation period ranging anywhere from 2 days to 3 months, the spores develop into full-fledged bacilli. As a by-product of their ordinary metabolism, these bacteria produce an extremely lethal poison (or toxin) called tetanospasmin (1 milligram of the toxin can kill as many as 20 million white mice). It is this toxin that technically causes the disease symptoms.

Toxin in the Blood

Tetanospasmin spreads through the body in the bloodstream and also along nerve trunks and the spinal cord. The bloodstream seems to be the most important route from the site of production to the central nervous system. The exact biochemical interaction between tetanospasmin and the nerve ending is unknown; it is believed, however, that the toxin spurs production of acetylcholine, a substance that stimulates the central nervous system.

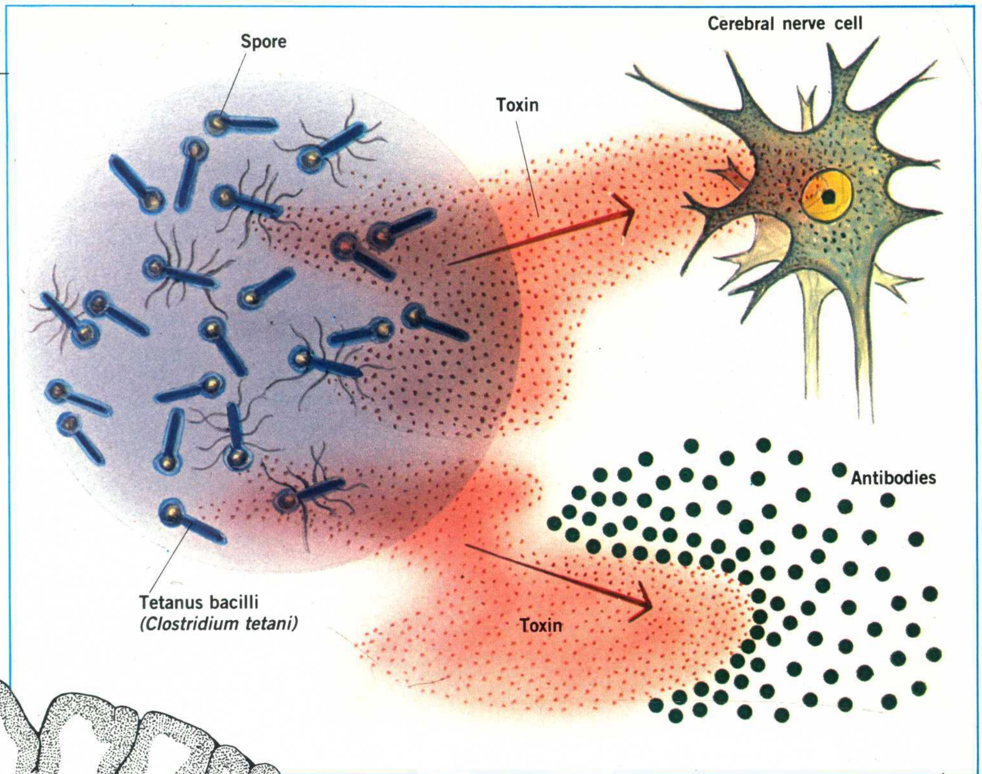
This stimulation takes the form of provoking a more or less constant rigidity in the body's muscles, particularly those that resist the force of gravity—the limbs, the neck, and the jaw, to name the major ones. The rigidity is interrupted only by unpredictable attacks of muscular spasms.

Treatment of Tetanus

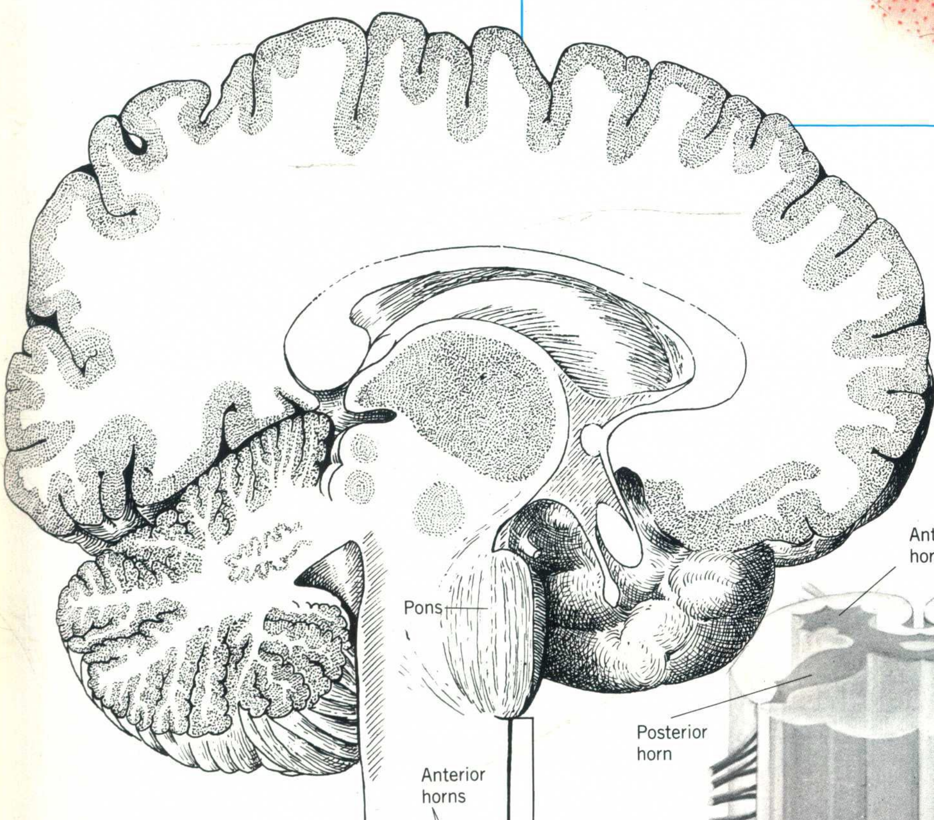
In general, a brief incubation period means a more serious tetanus attack. Treatment is usually based on the use of antibiotic drugs (penicillin or tetracyclines) to eliminate the *C. tetani* bacilli. Once the toxin is in the bloodstream, sedatives and muscle relaxants are often used to counteract the effect of tetanospasmin on the central nervous system. Tetanus antitoxin is administered intravenously to inactivate toxins in the bloodstream.

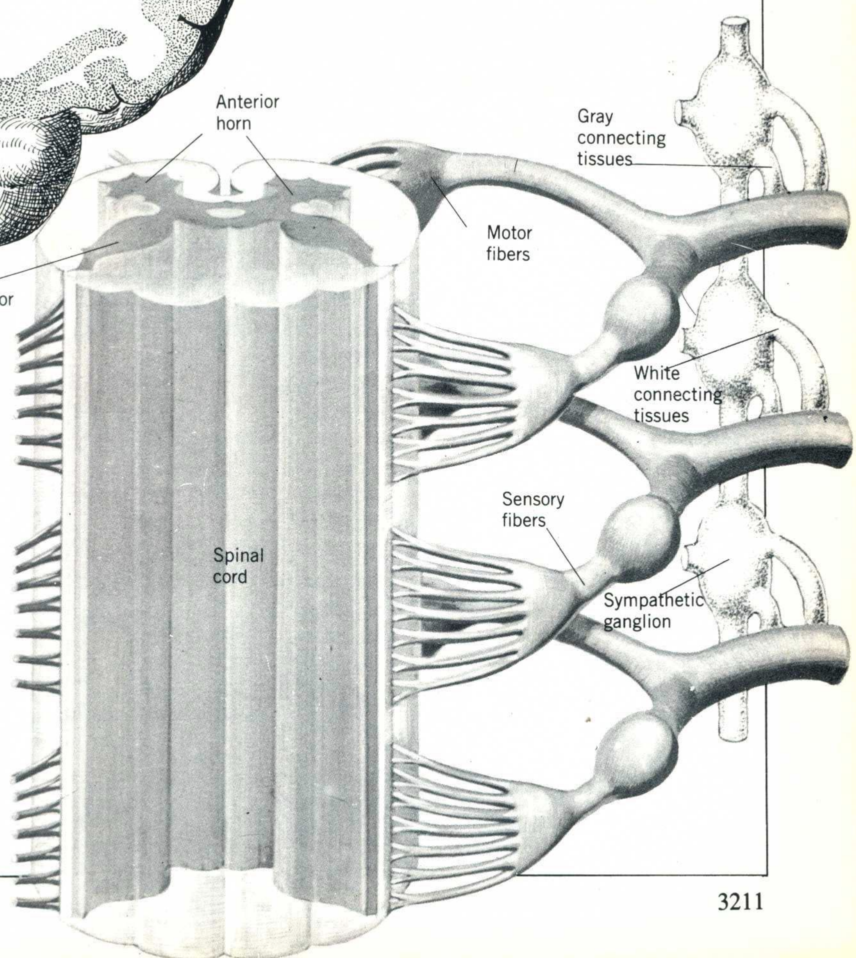
In any case where a wound might conceivably be infected by clostridial bacteria, an injection of tetanus antitoxin is usually advisable—this usually prevents the appearance of symptoms. Tetanus toxoid, also injected, provides active immunization for a limited period of time. The first 4 days are considered the most critical in tetanus cases. If the patient survives this period, chances for complete recovery are good.

The best program for tetanus is prophylactic immunization with tetanus toxoid. The American Academy of Pediatrics recommends three injections 1 month apart for infants, followed by boosters at 1 year and 5 years of age. This program should confer immunity that lasts 10 years. Thereafter, a toxoid booster is recommended every 10 years. This program has reduced the incidence of tetanus in American children under 10 to 3.8 per million, an extremely low number.



Above: As tetanus spores mature within the body and become bacilli, they begin to produce deadly nerve toxins. These toxins tend to concentrate in the pons and in the anterior horns of the medulla, as shown at left and below, causing pain, loss of muscular control, and eventual death from respiratory failure or cardiac arrest.





Textile

The word "textile" comes from the Latin *texere,* meaning "to weave." Today, we use the term to cover not only weaving but all the processes used to convert plant, animal, and synthetic materials into yarn and cloth, dyeing, printing, and finishing treatments that make fabrics suitable for consumer needs, as well as actually making the products themselves.

Raw Materials into Thread

The first step in making cloth is to convert raw fiber into thread. Fibers must first be separated according to length, as long fibers make better cloth. In the case of cotton, for example, the fibers are separated (or "carded") and combed mechanically; this step can be skipped, though, in the case of silk, as the silkworm secretes individual liquid filaments that dry when exposed to air. Synthetic fabrics are made from polymer solutions that are forced through a spinneret, an instrument resembling a showerhead in that it consists of a nozzle with many small holes. The polymer solution, much like the liquefied filament of the silkworm, is drawn out and then dried into a solid strand.

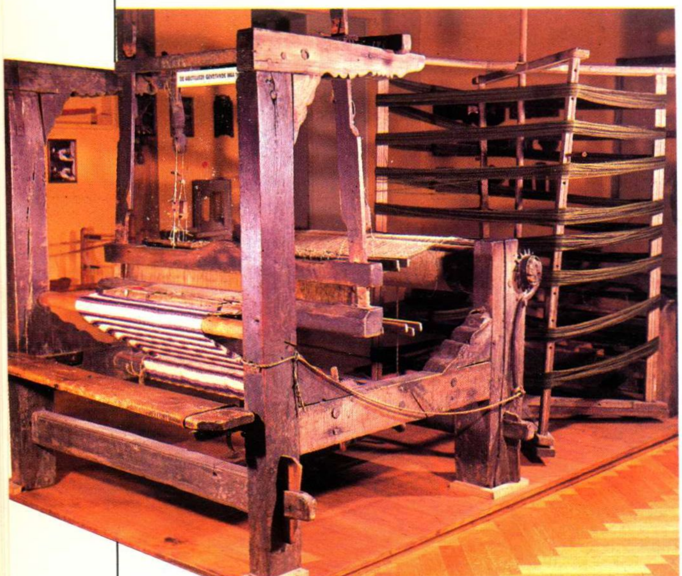
The next step is to "spin"—twist several filaments into one length of thread. (Even the most delicate sewing thread is a twine of several strands.) Spinning is an ancient activity; the earliest spinning utensils consisted simply of a spindle and a distaff. The distaff, a stick of about a foot (30 cm) in length, held loose fibers, which the spinner wound around it. The spindle, which was notched and weighted and attached at one end to the filler, twirled slowly to the floor, twisting the fibers in its descent. With the Industrial Revolution came mechanized spinning machines. Today, industrial spindles can turn 45,000 revolutions per minute.

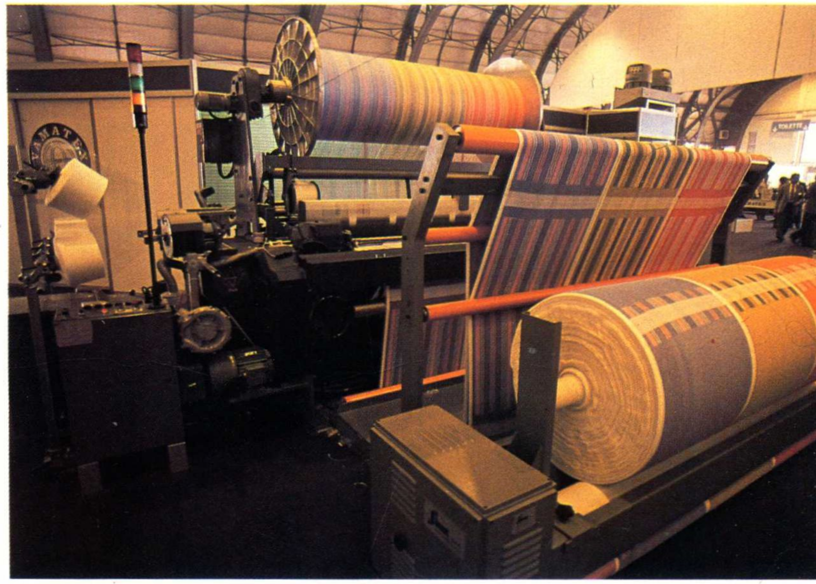
Thread into Cloth

Spun natural fibers are then woven or knitted into fabrics. Weaving is the perpendicular interlacing of fibers. In ancient times, the weaver probably hung the fibers lengthwise from a tree and then ran fibers crosswise between them by hand. Today this process is mechanized for mass-market purposes, though the basic principle remains unchanged. Weaving on hand looms is preferred by artisans, whose work is often considered fine art.

Knitting entails intermeshing a single yarn or set of yarns by means of interlocking loops. In hand knitting, which is done either on two straight needles or on one circular needle, the rows of loops ("stitches") are done in horizontal series, stitch by stitch; in machine knitting, complete rows of loops are made at one time.

Most synthetic fabrics fall into the category of nonwovens, since they are neither woven nor knitted. Nonwovens are produced by three methods. In the dry-lay process, the fibers are entangled, either randomly or according to a design, to form a web. In synthetics with good fiber integ-



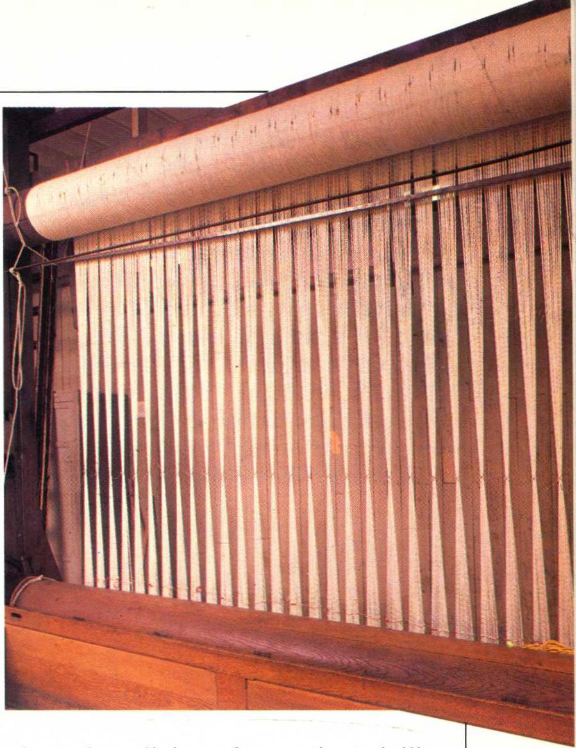


Above: At left, hand loom from the early 1800s. Except for weaving art fabrics, such looms have been made obsolete by automatic power looms like the one shown above at right.

Spinning has been automated as well. A modern spinning mill is shown at top left facing page.

Above: Sun-drying of dyed wool according to the artisan tradition at Sabadell, Spain.

Right: Microphotograph of dyed textile fibers.



rity, this is sufficient to make a strong cloth. In synthetics with weaker fiber integrity, the wet-lay process is preferred. After the fibers are entangled, as in the first process, a chemical binder is introduced. The third way to make nonwoven fabric is by spin-binding, which entails forcing liquid fiber through spinnerets. It is the distribution of holes on the spinnerets that determines the configuration of fibers within the cloth.

Fabric can be dyed at almost any stage of manufacture. Vegetable dyes were the earliest known dyes and are still used today; most commercial and industrial plants, though, use synthetic coal-tar dyes. In addition to obtaining the proper hue, dye considerations include fastness to light and reactions to washing, rubbing, and the normal stress of wear.

Fabrics are "finished," or treated with chemical solutions, heat, and pressing treatments in order to make them wrinkle-free (for wash-and-wear items) and resistant to soil, static, mildew, moths, water, fire, and heat.

Textile Products

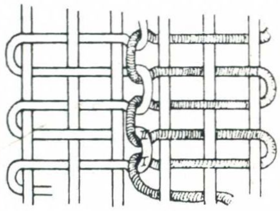
Ancient Egyptian and pre-Columbian burial sites have provided us with the earliest known examples of textiles. Burial shrouds, clothing, and ceremonial robes are among the most common finds. Today, apparel is only part of the enormous market for products made of fabric. Other uses for textiles include home and office furnishings, such as draperies, upholstery, and wall coverings; medical products, such as dressings, bandages, and certain orthopedic supports; and industrial products, such as machine parts.

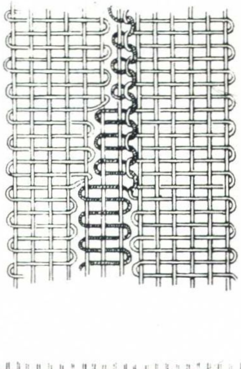
The development of synthetic fibers revolutionized textiles, enabling fibers to be developed in response to scientific, industrial, and consumer demand. Aramid, for example, a type of nylon notable for its nonflammability, was developed for high-speed machine accessories, filter media, military and protective garments, and outerwear for astronauts.

The designs woven into pre-Columbian textiles are our best source of information about the religion of an extinct civilization. The textiles of today are not only an important part of our daily lives but will also be part of the higher technologies of the future.

See also COTTON; SILK; SPINNING; SYNTHETIC FIBERS AND FABRICS; WOOL.

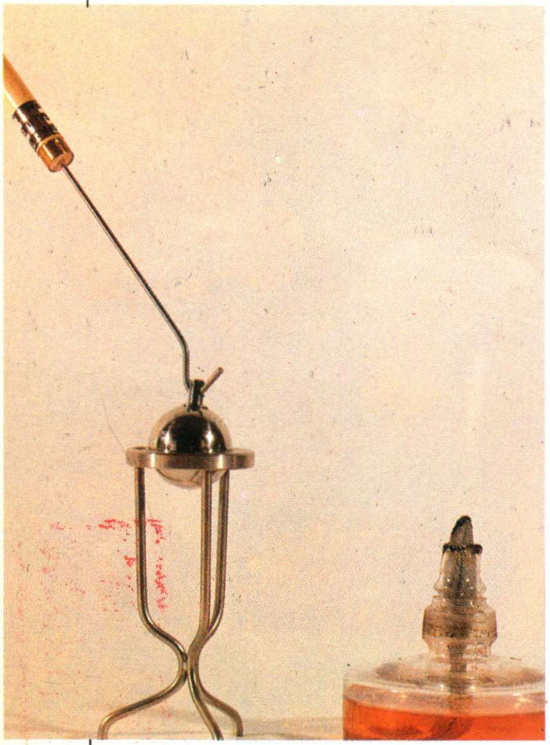
Tapestries are a special form of handwoven art fabric. Since the colored designs are tied in from the back, the tapestry maker uses a mirror system to follow the progress of the work. *Top right:* Heddle of a vertical tapestry loom. *Below:* At left, tapestry knots; at right, partially completed tapestry on its loom.





Thermal Expansion

Mercury, when it rises in a thermometer, exhibits the process called thermal expansion. Liquids, gases, and solids all increase in volume as their temperature increases. When heat is applied to a body, the vibrations and distances between the molecules increase, so the entire volume of the body increases. The degree to which different substances expand depends on the strength of the forces that hold their particles together. These forces are stronger in solids than in liquids or gases, and because of this, solids expand less. Also, while the thermal expansion of liquids and especially gases is affected by the pressure of the surrounding environment, this is not a factor for solids.



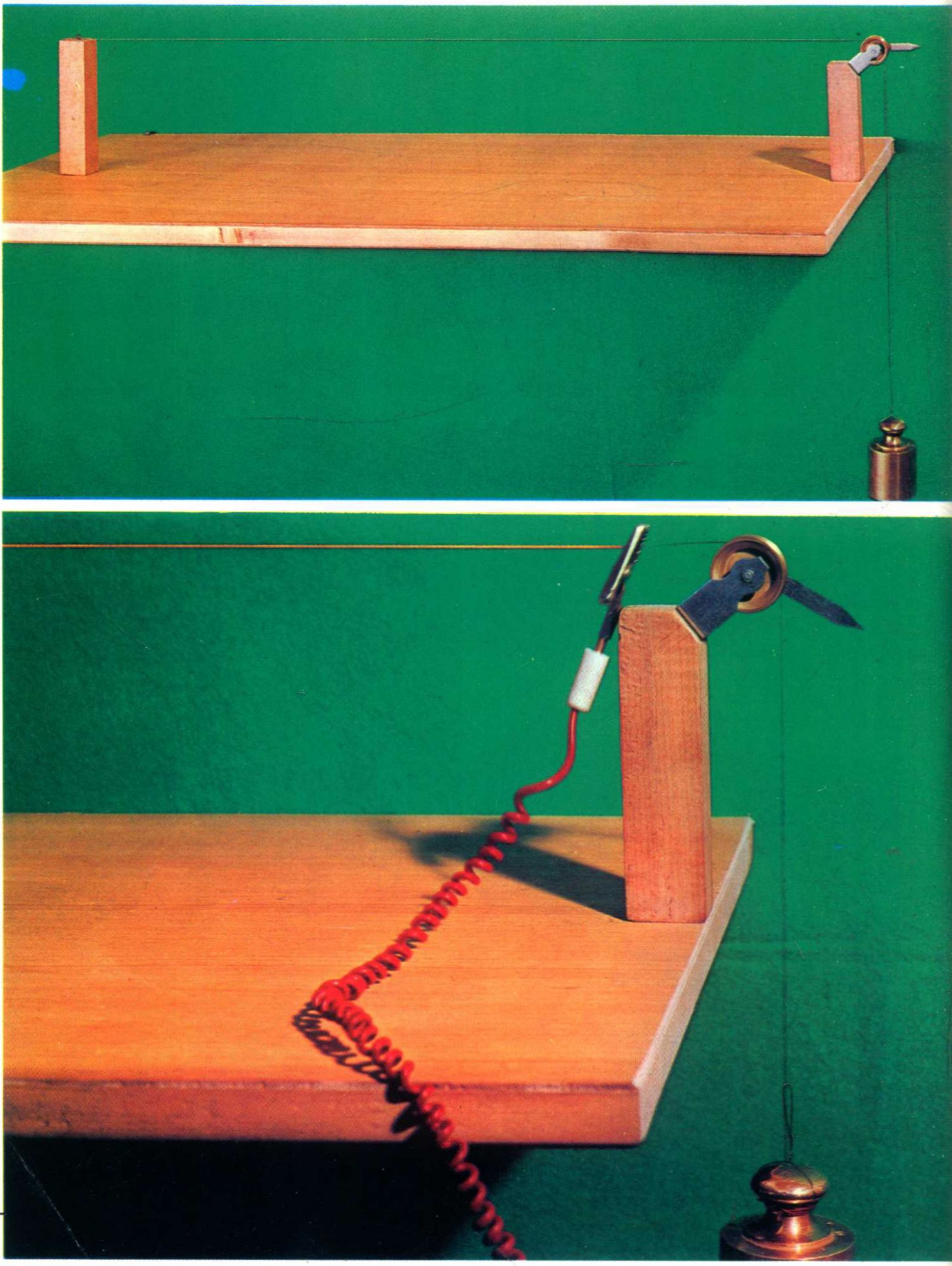
Expansion of Solids

The rate at which solids expand depends entirely on the strength of the forces bonding the solid's molecules. The expansion is usually expressed by a measure called the coefficient of linear expansion. This coefficient represents the fractional change in length of a solid per degree of change in temperature. It is very low for all solids. A 1° C. temperature increase in aluminum, for example, will increase its length by 24 millionths. For another solid, diamond, the hardest of natural substances, the coefficient of linear expansion is even less: 1×10^{-6} (1 millionth). Invar, a metal alloy at 122° F. (50° C.) has 0 as its coefficient of linear expansion. Because invar does not expand at most common temperatures, it is often used in scales and measuring tapes.

The sensing device in the household thermostat is generally made of two metals with different coefficients of linear expansion. The two strips of metal, chosen because they expand at different rates, are bonded together. Because half of the strip expands more rapidly than the other half, as the temperature increases, the strip begins to curve. In the "cool" position, the strip touches electrical contacts, which start the heater. As the strip begins to warm and curve, contact is broken. The thermostat is adjusted by hand to the temperature at which contact is broken.

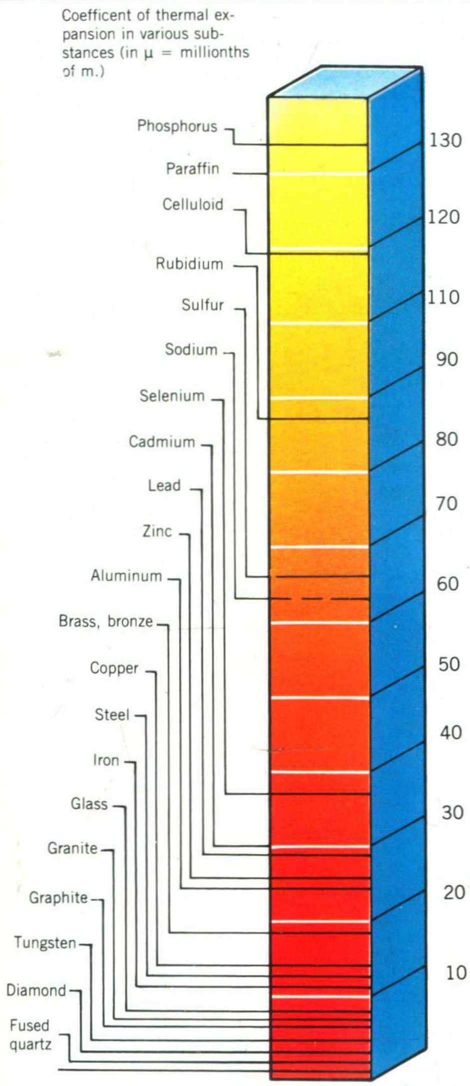
Left: A cold metal ball will pass through the ring, but on heating, the ball expands and can no longer pass.

Below: Simple experiment to measure thermal expansion in a piece of wire. Heated by a flow of electric current, the wire lengthens, and the indicator needle moves downward.



Expansion of Gases

A gas is made up of moving atoms or molecules that are no longer bonded together as in the liquid or solid state. The speed at which the gas particles move increases with additional heat, and so the gas tends to expand, increasing its volume. However, this expansion is controlled by the outside pressure. If the outside pressure (often air pressure) is greater than that of the gas, it will force the gas to contract. If the outside pressure is less than that of the gas, the gas will expand. The fractional increase in volume for each degree increase of temperature—the volumetric coefficient—is the same if the outside pressure is kept constant. At constant pressure and at 0° C., most gases increase their volume by 1/273 (0.0037) per 1° C. of temperature increase.

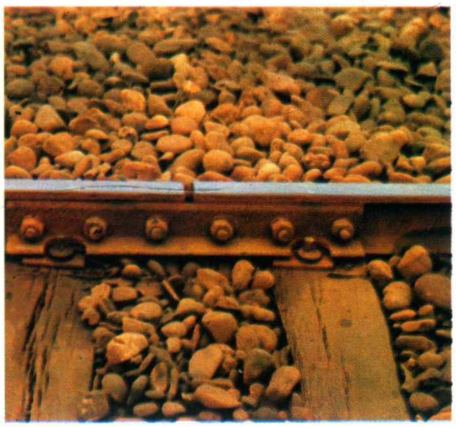


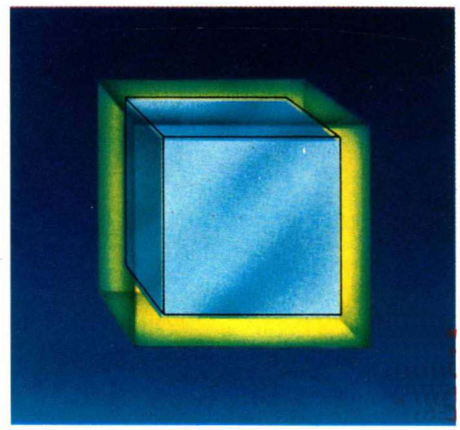
Expansion of Liquids

In general, most liquids expand with an increase in temperature. The expansion of mercury, a liquid metal, is so reliable that it is used as the sensing medium in thermometers. The expansion of liquids is somewhat affected by the pressure of the outside environment, but not as strongly as in the case of gases.

Liquids tend to expand more than solids because their molecules are generally not as strongly bonded. Water from 32° F. (0° C.) to 39° F. (4° C.) is an exception. As water's temperature increases in that range, the water contracts rather than expands. This can be explained by the fact that 32° F. (0° C.) is the freezing point of water, and ice, surprisingly, is more "expanded" than water. It has a lower density (mass per volume) than water, and for this reason, ice floats on water. Water has a greater density than ice because, in the nonstructured liquid form, a type of bonding is possible that is called hydrogen bonding, which is not possible in the crystalline structure of ice. As ice liquefies, hydrogen bonding between the water molecules begins, causing the water to contract. However, from 39° F. (4° C.) up, water expands with increased temperature, as expected.

See also WATER.





Top left: Comparison of the coefficients of thermal expansion of various substances.

Above: Steel rails mounted with a gap to take up expansion of the metal in hot weather; cube at right is a reminder that thermal expansion is an increase in volume, not just in length.

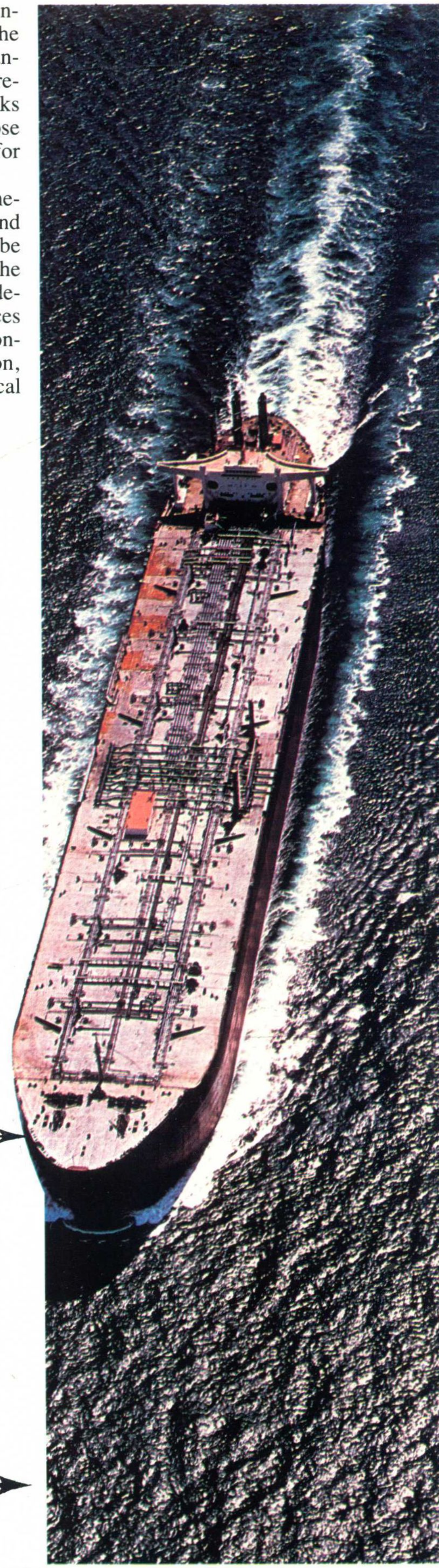
Left: Column of paraffin supports a convex lens that shows Newton's ring. The ring pattern changes as the column expands with heating.

Thermodynamics

Around 75 A.D., the Greek scientist Hero of Alexandria took a hollow metal globe, suspended it above a stove on a horizontal axis in such a way that it could revolve freely, and inserted two L-shaped, hollow tubes on opposite sides of the globe. When Hero added water to the globe and kindled a fire in the stove, the steam from the boiling water began to shoot out the pipe segments in opposite directions. The globe began to spin, first slowly, then rapidly. Hero called the device an *aeolipile* ("wind vent"). Although it is not known whether a use was found for the aeolipile, the device shows that heat is a form of energy, which can be used to create mechanical motion.

Hero probably had little scientific understanding of the relation between the energy of heat and the energy of mechanical motion. Today, we have a very precise understanding of this relation, thanks to the science of thermodynamics, whose name derives from the Greek words for "heat" and "power."

Thermodynamics studies heat and mechanical motion as forms of energy and the conditions under which one may be converted into the other. The fruit of the science of thermodynamics was the development of many processes and devices that perform useful tasks through the conversion of heat into mechanical motion, or through the conversion of mechanical



Below: Diagram and graphs illustrating conversion of heat into mechanical energy. In a closed system (a, at top), the energy level is constant as shown in b. If heat is added to the system (c, below), the gas in the chamber expands, and the piston is forced upward. Diagram d shows input of thermal energy (red line), output of mechanical energy (green line), and total energy change (black line). The relationship may be described by the equation E (total energy) = Q (heat) + W (work).
Right: Petroleum tanker powered by thermodynamic conversion of heat to mechanical energy.