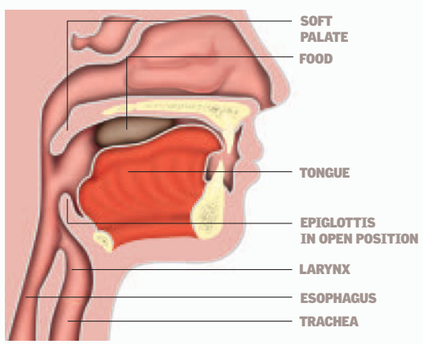
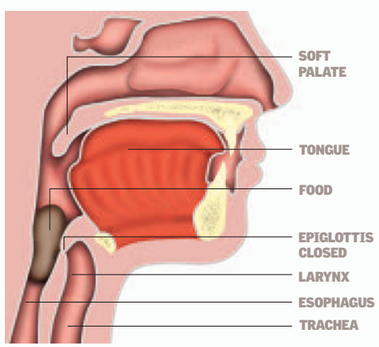
Stomach

The part of the digestive tract that is a continuation of the esophagus. It is sometimes thought of as an expansion of the esophagus. It is the first section of the digestive system that is located in the abdomen. It has the shape of an empty bag that is curved somewhat like a bagpipe, the handle of an umbrella, or the letter "J." In the stomach, gastric juices and enzymes subject the swallowed food to intense chemical reactions while mixing it completely. The stomach connects with the duodenum through the pylorus. Peristalsis, or the muscular contractions of the alimentary canal, moves the food from the stomach to the duodenum, the next station in the progress of the alimentary bolus.

How We Swallow

Although swallowing is a simple act, it does require the coordination of multiple parts. The soft palate moves backward when the alimentary bolus passes through the esophagus. The epiglottis moves downward to close the trachea and prevent the food from entering the respiratory pathways. The alimentary bolus is advanced by the muscular motions of peristalsis.





X-ray of the Stomach

The stomach is the best known of the internal body organs, but it is also the most misunderstood. This J-shaped sac stretches to fill up with food, but it does not absorb any of the nutrients. Its work consists of starting the digestion process, storing semi-digested food, and releasing the food slowly and continuously. Internal gastric juices make it possible for the enzymes to decompose the proteins, while muscular contractions mix the food.

ESOPHAGUS
carries chewed food to the stomach.

INFERIOR ESOPHAGEAL SPHINCTER
closes the junction between the esophagus and the stomach to prevent reflux of the stomach contents.

PYLORUS
A muscular ring that opens and closes the pyloric sphincter to allow (or prevent) passage of liquefied food from the stomach on its way to the intestine

STOMACH WALL
A covering of three muscular layers that contract in different directions to mash the food. It contains millions of microscopic glands that secrete gastric juices.

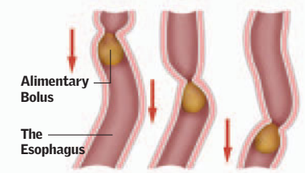
WRINKLES OR FOLDS
are formed when the stomach is empty, but they stretch out as the stomach fills and increases its size.

DUODENUM
The initial section of the small intestine

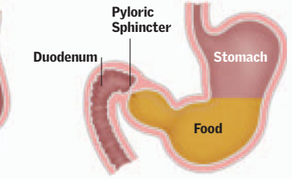
20 times
THE STOMACH INCREASES UP TO 20 TIMES ITS ORIGINAL SIZE AFTER A PERSON EATS.

Peristalsis: Muscles in Action

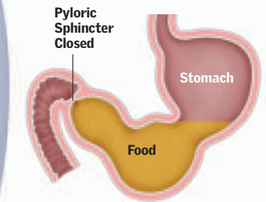
Peristalsis is the group of muscular actions that moves the food toward the stomach and, once the digestive stage has been completed, moves it on to the small intestine. The sphincters are stationary, ring-shaped muscular structures whose opening and closing regulates the passage of the bolus.



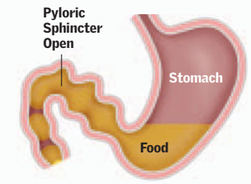
Food is sent toward the stomach, pumped by the muscular contractions of the esophageal walls. Gravity helps accomplish this downward journey.



Full stomach. Food enters. The pyloric sphincter remains closed. The gastric juices kill bacteria and are mixed with the food through muscular motions.



The stomach in full digestive action. The peristaltic muscles mix the food until it becomes a creamy, viscous liquid (chyme).



The stomach is being emptied. The pyloric sphincter relaxes, the muscles move the food, and small quantities of food exit toward the duodenum.

Stomach Wall

The structure of the wall accounts for the two important functions of the stomach: the muscular layers and the activity of the gastric glands guarantee that digestion will run its course.

GASTRIC MUCOSA
contains the gastric glands, which produce 3 quarts (2.8 l) of gastric juice per day.

MUSCULAR LAYERS OF THE MUCOSA
Two fine layers of muscular fibers extend under the mucosa.

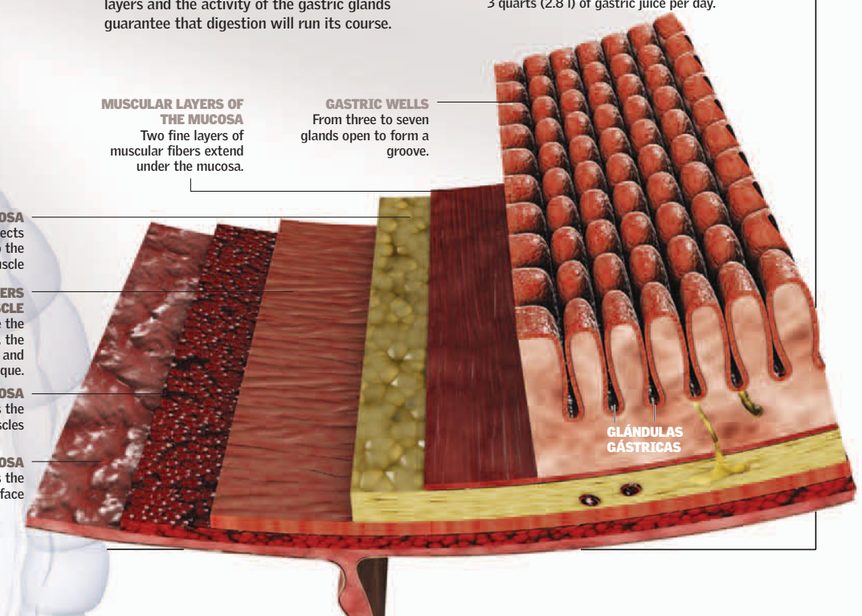
GASTRIC WELLS
From three to seven glands open to form a groove.

SUBMUCOSA
Tissue that connects the mucosa to the layers of muscle

THREE LAYERS OF MUSCLE
They are the circular, the longitudinal, and the oblique.

SUBSEROSA
Layer that connects the serosa to the muscles

SEROSA
Layer that covers the outer surface

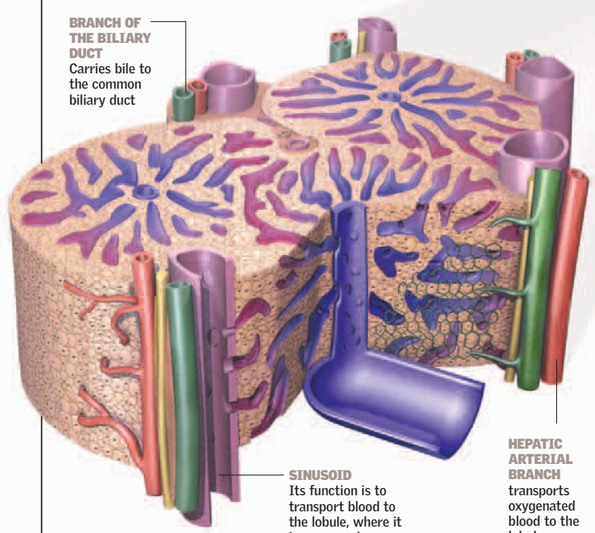


Liver, Pancreas, Bile

The liver is the largest gland of the human body and the second largest organ (the skin is the largest). It has numerous functions, and a large part of the body's general equilibrium depends on it. The liver produces bile, a yellowish-green fluid that helps in the digestion of fats. The liver is the great regulator of the glucose level of the blood, which it stores in the form of glycogen. Glycogen can be released when the organism requires more sugar for activity. The liver regulates the metabolism of proteins. Proteins are the essential chemical compounds that make up the cells of animals and plants. The liver is also a large blood filter and a storage site for vitamins A, D, E, and K. The pancreas is a gland that assists in digestion, secreting pancreatic juice.

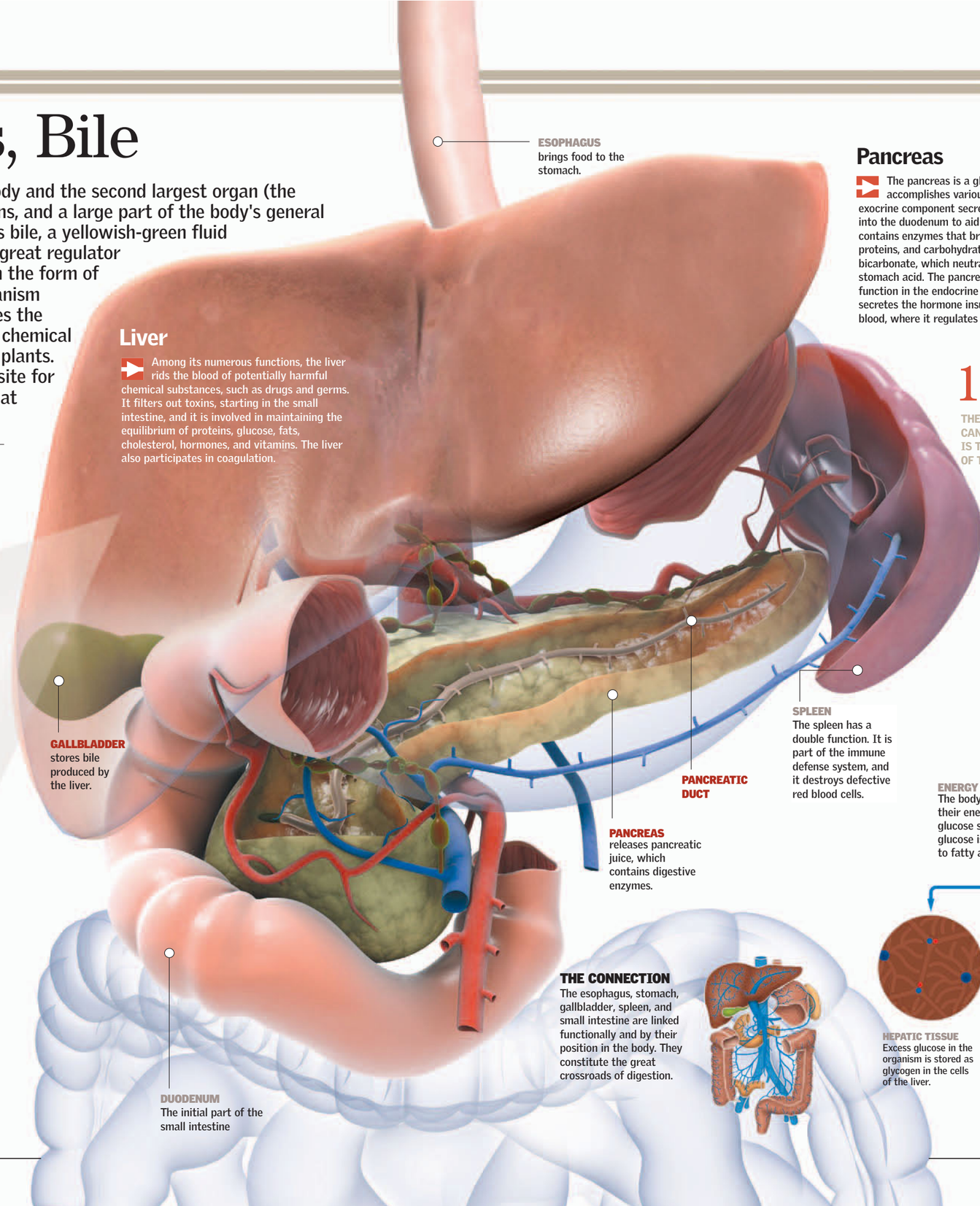
Lobules

Among its other functions, the liver processes nutrients to maintain an adequate level of glucose in the blood. This task requires hundreds of chemical processes that are carried out by the hepatocytes, or liver cells. These are arranged in columns, forming structures called lobules. They produce bile and a sterol (a solid steroid alcohol) called cholesterol. They also eliminate toxins that might be present in food.



Vesicle and Bile

The biliary system stores bile that is produced by the hepatocytes in a specialized pouch called the gallbladder. The path the bile takes from the liver to the gallbladder leads through little canals, biliary ducts, and hepatic ducts, whose diameter increases as the bile moves along. When the body ingests fat, the bile is sent from the gallbladder to the small intestine to accomplish its main function: emulsifying fats to help promote their later absorption.



Liver

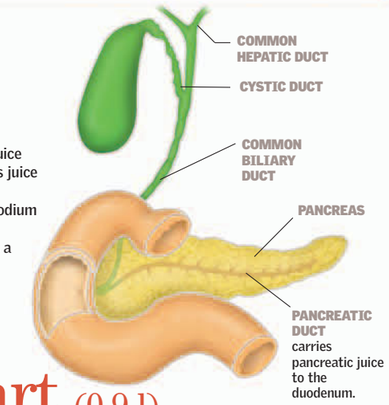
Among its numerous functions, the liver rids the blood of potentially harmful chemical substances, such as drugs and germs. It filters out toxins, starting in the small intestine, and it is involved in maintaining the equilibrium of proteins, glucose, fats, cholesterol, hormones, and vitamins. The liver also participates in coagulation.

THE CONNECTION

The esophagus, stomach, gallbladder, spleen, and small intestine are linked functionally and by their position in the body. They constitute the great crossroads of digestion.

Pancreas

The pancreas is a gland that accomplishes various functions. Its exocrine component secretes pancreatic juice into the duodenum to aid in digestion. This juice contains enzymes that break down fats, proteins, and carbohydrates. It contains sodium bicarbonate, which neutralizes the strong stomach acid. The pancreas also performs a function in the endocrine system: it secretes the hormone insulin into the blood, where it regulates glucose levels.

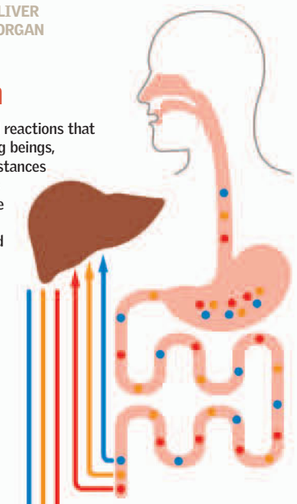


1 quart (0.9 l)

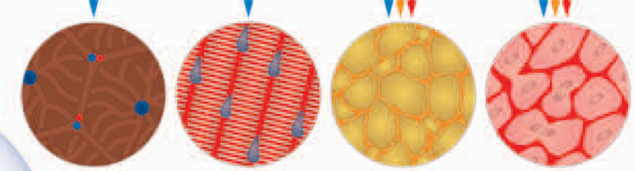
THE AMOUNT OF BILE THE LIVER CAN PRODUCE IN A DAY. THE LIVER IS THE HEAVIEST INTERNAL ORGAN OF THE BODY.

Metabolism

The complex of chemical reactions that occur in the cells of living beings, transforming simple substances into complex substances and vice versa. When the nutrients are absorbed into the bloodstream and passed to the liver, the liver breaks down proteins into amino acids, fats into fatty acids and glycerol, and carbohydrates into smaller components. A normal diet includes carbohydrates, proteins, fats, vitamins, and minerals.



ENERGY
The body's cells basically obtain their energy from the breakdown of glucose stored in the liver. When no glucose is available, the body turns to fatty acids for energy.



HEPATIC TISSUE
Excess glucose in the organism is stored as glycogen in the cells of the liver.

MUSCULAR FIBER
Muscle cells in the liver together with the hepatic cells store glycogen.

ADIPOSE CELLS
are cells in which the organism stores excess fatty acids in the form of fat.

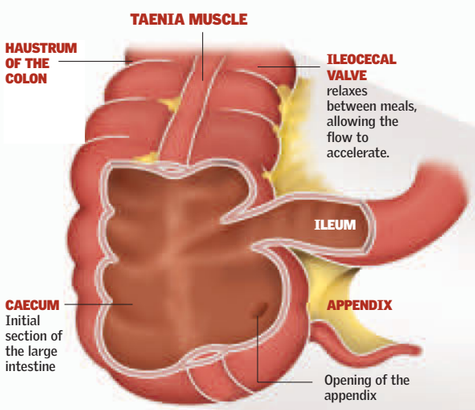
CELLULAR GROWTH AND REPAIR
Amino acids are converted into proteins by a process called anabolism. Proteins are fundamental for mitosis, cellular regeneration, and enzyme production.

Large and Small Intestine

The longest part of the digestive tract. It is about 26 to 30 feet (8 to 9 m) long and runs from the stomach to the anus. The small intestine receives the food from the stomach. Digestion continues through enzyme activity, which completes the chemical breakdown of the food. Then the definitive process of selection begins: the walls of the small intestine absorb the nutrients derived from the chemical transformation of the food. The nutrients then pass into the bloodstream. Waste substances, on the other hand, will go to the large intestine. There the final stage of the digestive process will occur: the formation of the feces to be excreted.

The Union of Both

The small and large intestines join at the section called the ileum (which is the final section of the small intestine; the duodenum and jejunum come before the ileum). The iliac valve acts as a door between the small intestine and large intestine, or colon. The ileum terminates in the caecum (of the large intestine). The ileum measures approximately 13 feet (4 m) in length. Its primary function is the absorption of vitamin B12 and biliary salts. The primary function of the large intestine is the absorption of water and electrolytes that arrive from the ileum.



WATER THAT ENTERS THE ALIMENTARY CANAL

In fluid ounces

Saliva	34 (1 l)
Water from Drinking	77 (2.3 l)
Bile	34 (1 l)
Pancreatic Juice	68 (2 l)
Gastric Juice	68 (2 l)
Intestinal Juice	34 (1 l)
Total	**313 (9.3 l)**

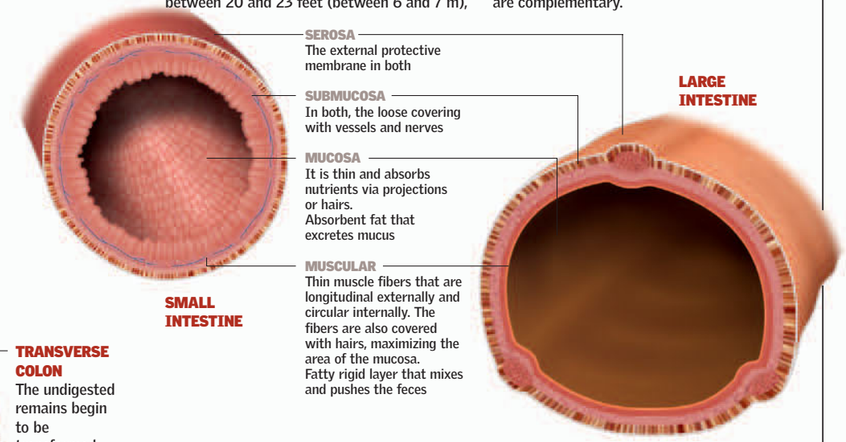
WATER REABSORBED BY THE ALIMENTARY CANAL

In fluid ounces

Small Intestine	280 (8.3 l)
Large Intestine	30 (0.9 l)
Subtotal	310 (9.2 l)
Water Lost in the Feces	3 (0.1 l)
Total	**313 (9.3 l)**

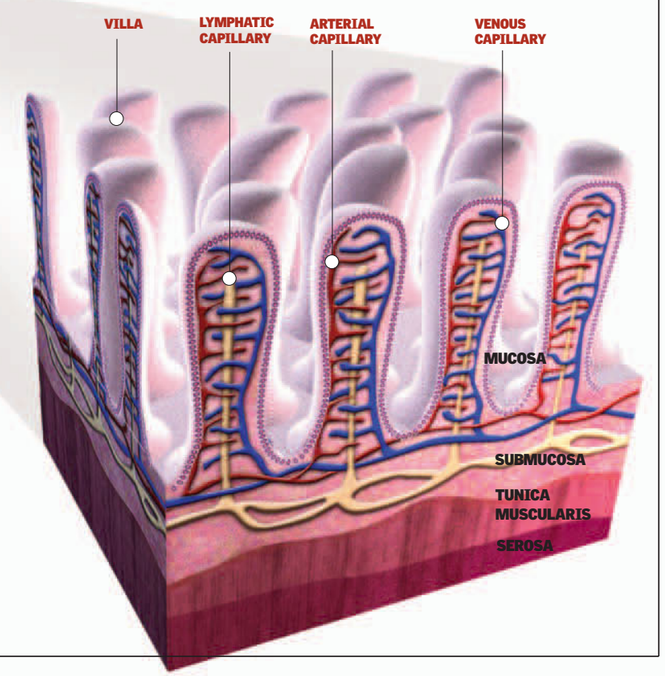
Differences and Similarities

The small intestine is longer than the large intestine. The length of the small intestine is between 20 and 23 feet (between 6 and 7 m), and the large intestine averages 5 feet (1.5 m). Their respective composition and functions are complementary.



Villa

The internal wall of the small intestine is covered with millions of hairlike structures called villi. Each one has a lymphatic vessel and a network of vessels that deliver nutrients to it. Each villus is covered by a cellular layer that absorbs nutrients. Together with epithelial cells, the villi function to increase the surface area of the intestine and optimize the absorption of nutrients.



Urinary System

Its basic organs are the kidneys (2), the ureters (2), the bladder, and the urethra. Its function is to regulate homeostasis, maintaining the equilibrium between the water and the chemicals in the body. The first phase of this objective is accomplished when the kidneys produce and secrete urine, a liquid that is eliminated from the body. Urine is essentially harmless, only containing about 2 percent urea, and is sterile: it is composed primarily of water and salts, and it normally does not contain bacteria, viruses, or fungi. The ureters are channels that carry the urine through the body. The bladder is a sac that stores the urine until it is passed to the urethra, a duct through which it will be expelled from the body.

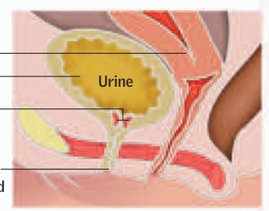
The Urinary Tract

The glomerulus is a grouping of vessels located in the cortex of the kidneys. Most of the filtering that takes place in the nephron is performed in the glomerulus. Wide arterioles carry blood to the glomerulus. Other, thinner arterioles exit from the glomerulus, carrying away blood. So much pressure is generated inside the kidney that the fluid exits from the blood via the porous capillary walls.

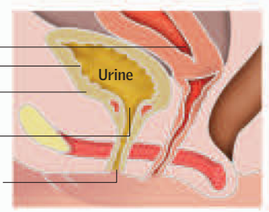
The Bladder in Action

The bladder is continually filled with urine and then emptied periodically. When full, the bladder stretches to increase its capacity. When the muscle of the internal sphincter is relaxed, the muscles of the wall contract, and the urine exits through the urethra. In adults this occurs voluntarily in response to an order issued by the nervous system. In infants, on the other hand, this evacuation occurs spontaneously, as soon as the bladder is filled.

FILLING



EMPTYING



Legend

1. BLOOD FILTERING
The blood enters the kidney via the renal artery.

2. TRANSFER
The artery carries the blood into the kidney, where it is filtered by the kidney's functional units, the nephrons.

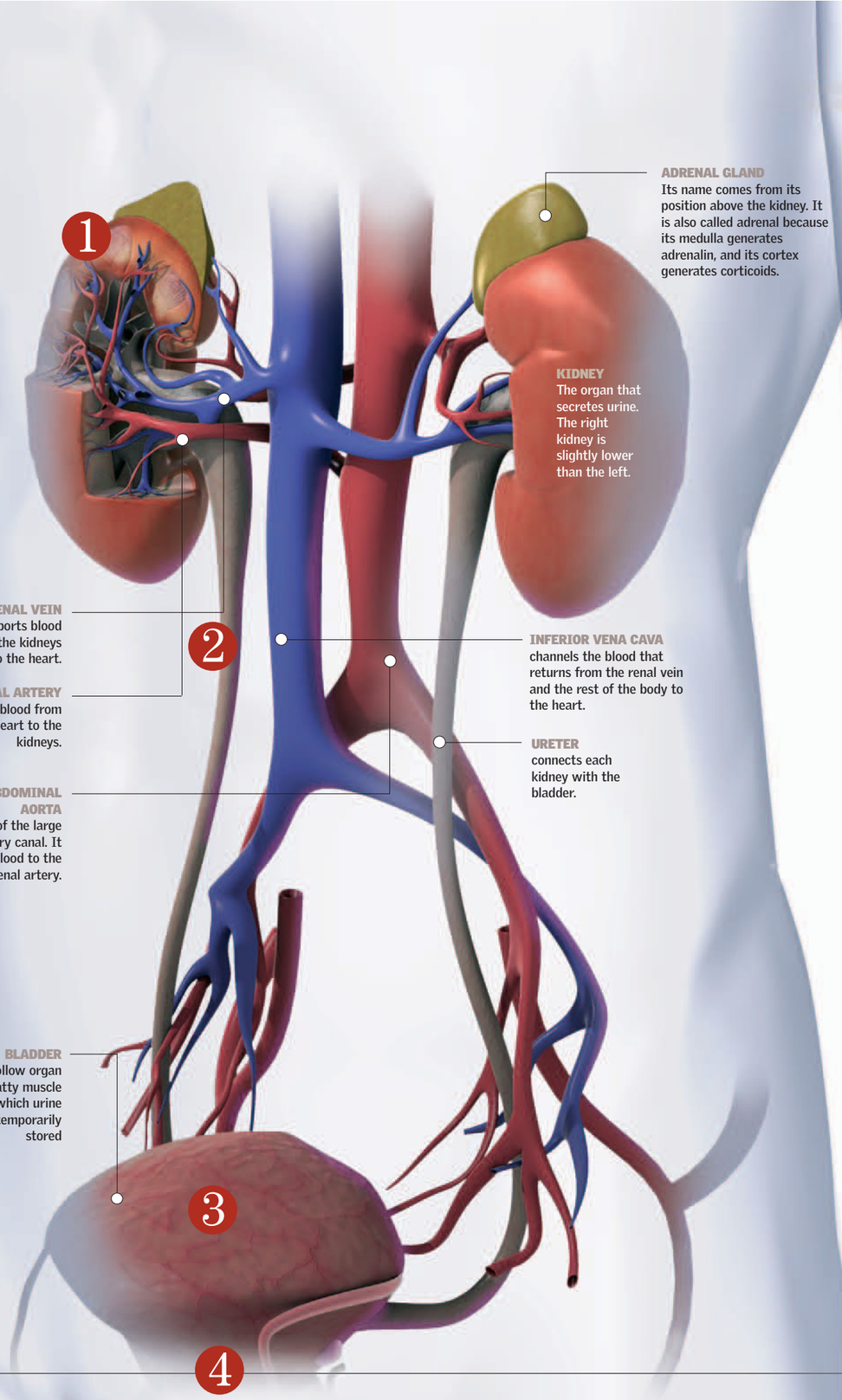
3. STORAGE
A certain amount of urine is obtained from the filtrate in the nephrons, and that urine is sent to the renal pelvis.

4. ELIMINATION
The urine passes from the renal pelvis to the ureter and then to the bladder, where it accumulates until it is eliminated through the tube-shaped urethra.

15 minutes
IT TAKES 15 MINUTES FOR LIQUIDS TO CIRCULATE THROUGH THE NEPHRONS.

COMPONENTS OF URINE

95%	**Water**
2%	**Urea,** a toxic substance
2%	**Chloride salts,** sulfates, phosphates of potassium and magnesium
1%	**Uric acid**



ADRENAL GLAND
Its name comes from its position above the kidney. It is also called adrenal because its medulla generates adrenalin, and its cortex generates corticoids.

KIDNEY
The organ that secretes urine. The right kidney is slightly lower than the left.

RENAL VEIN
transports blood filtered by the kidneys to the heart.

RENAL ARTERY
brings the blood from the heart to the kidneys.

ABDOMINAL AORTA
A section of the large circulatory canal. It provides blood to the renal artery.

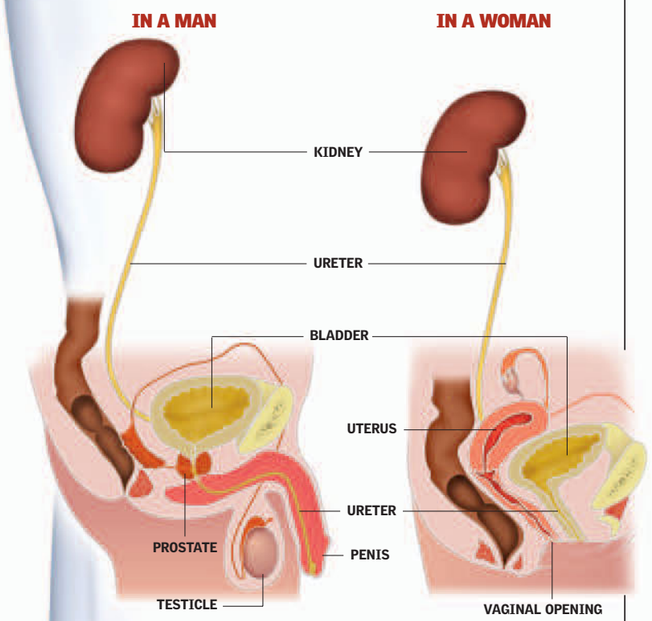
BLADDER
A hollow organ with a fatty muscle wall in which urine is temporarily stored

INFERIOR VENA CAVA
channels the blood that returns from the renal vein and the rest of the body to the heart.

URETER
connects each kidney with the bladder.

Differences by Sex

The urinary system has a double relationship to the reproductive system. The two systems are linked by their close physical proximity, but they are also linked functionally. For example, the ureter is a vehicle for secretions produced by the glands of both systems. The urinary systems in men and women are different. A man's bladder is larger, and the male ureter is also larger than a woman's, because in a man the ureter extends to the end of the penis, for a total length of about 6 inches (20 cm); in a woman, on the other hand, the bladder is located at the front of the uterus, and the length of the ureter is approximately 1.5 inches (4 cm).



Fluid Exchange

The volume of urine that a person expels every day is related to the person's consumption of liquids. Three quarts (2.5 l) a day would be excessive, but a significant decrease in the production of urine can indicate a problem. The table details the relationship between the consumption of liquid and its expulsion by the different glands of the human body.

CONSUMPTION OF WATER

Drinking	**60%**
50 fluid ounces (1,500 ml)	
Food	**30%**
25 fluid ounces (750 ml)	
Metabolic water	**10%**
16 fluid ounces (250 ml)	
3 quarts (2,500 ml) TOTAL	

EXPULSIÓN DE AGUA

Urine	**60%**
50 fluid ounces (1,500 ml)	
Losses through the lungs and the skin	**28%**
25 fluid ounces (700 ml)	
Sweat	**8%**
16 fluid ounces (200 ml)	
Feces	**4%**
3 fluid ounces (100 ml)	
3 quarts (2,500 ml) TOTAL	

Kidneys

Located on either side of the spinal column, the kidneys are the fundamental organs of the urinary system. They regulate the amount of water and minerals in the blood by producing urine that carries away the waste the kidneys discard. They keep the composition of the bodily fluids constant, regulate the pressure of the arteries, and produce important substances such as the precursor of vitamin D and erythropoietin. Every day they process 500 gallons (1,750 l) of blood and produce 2 quarts (1.5 l) of urine. The kidneys measure approximately 5 inches (12 cm) long and 3 inches (6 cm) wide. Their weight is only 1 percent of the total body weight, but they consume 25 percent of its energy. If one kidney ceases to function, the body is able to survive with the activity of the other.

The Renal Circuit

Urine is produced in the nephrons in each kidney; there are thought to be a million nephrons in each kidney. From the nephrons the urine flows into the proximal convoluted tubule, where all the nutrients, such as glucose, amino acids, and most of the water and salts, are reabsorbed into the blood. After passing through the nephron the urine is filtered, and it arrives at the common collecting duct where only the residues and excess water are retained.

1. ENTRY OF BLOOD
The blood enters the kidney via the renal artery.

2. FILTRATION
The blood is filtered in the nephrons, the functional units of the kidneys.

3. URINE IS OBTAINED
A certain amount of urine is obtained from the filtrate in the nephrons, and it is sent to the renal pelvis. The filtered blood, free from waste, is sent to the renal vein and reenters the bloodstream.

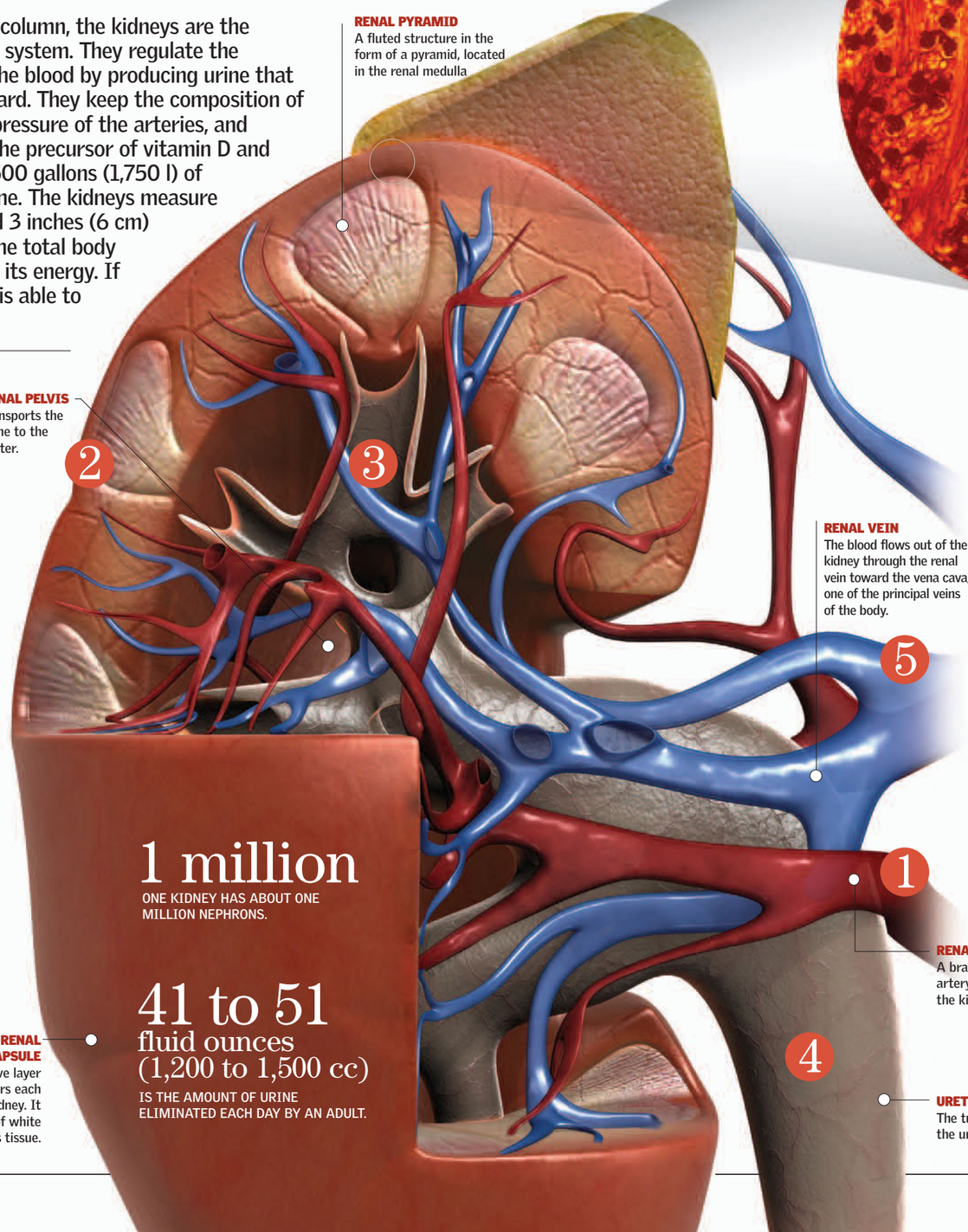
4. URINE
The urine passes through the renal pelvis to the ureter and from there to the bladder, where it accumulates until it is eliminated through the tube-shaped urethra.

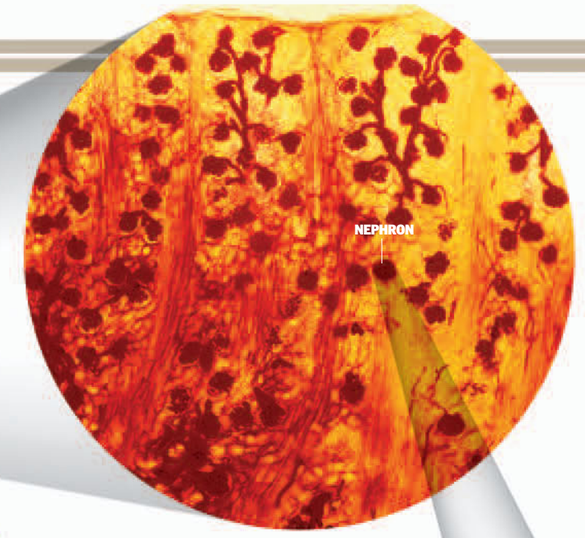
5. CLEAN BLOOD
The clean blood exits the kidney via the renal vein, which is connected to the vena cava. The blood then returns to the heart.

45 minutes

THE FRENCH PHYSIOLOGIST CLAUDE BERNARD (1813-78) WAS THE FIRST TO NOTE THE IMPORTANCE OF THE KIDNEYS.

At that time it was not known that the kidneys filter all the water content of the blood in the body every 45 minutes and that, even so, it is possible to survive with only one kidney (or none, in the case of dialysis).



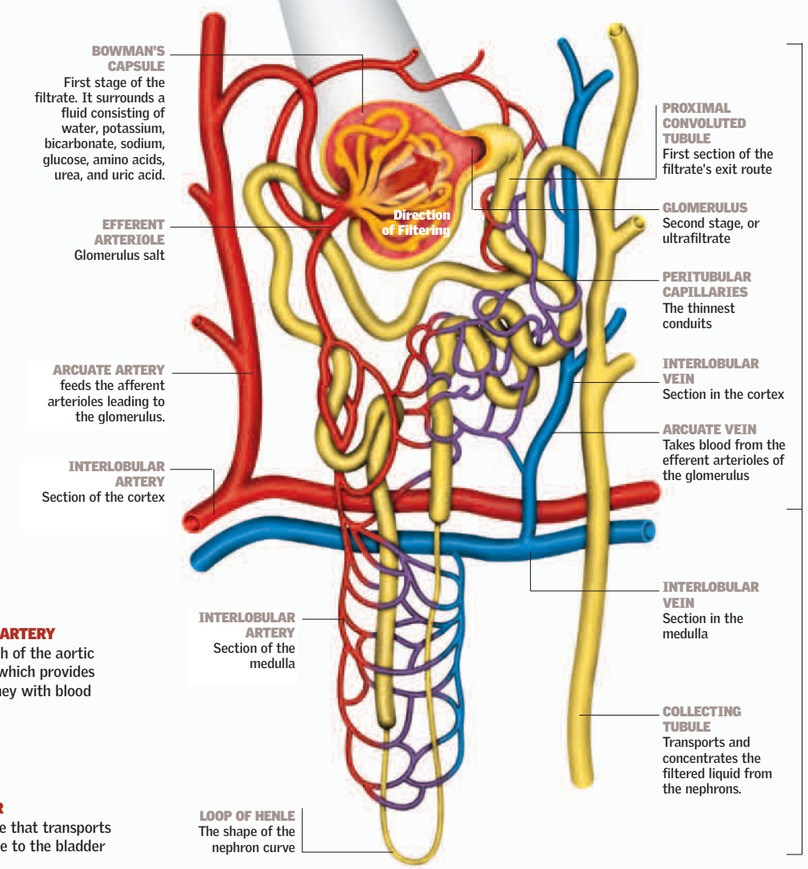


Glomerulus

A grouping of vessels and capillaries in the kidney's cortex, or sheath. Most of the filtering done by the nephrons takes place there. The wide, afferent arterioles bring blood to the glomerulus. Other, narrower, efferent arterioles lead out of the glomerulus, transporting blood. Inside the glomerulus so much pressure is generated that substances in the blood pass out through the porous capillary walls.

Nephrons

The functional units of the kidney that filter the blood and produce urine. The basic structure of the nephron consists of two parts: (1) the renal or Malpighian corpuscle, where filtration occurs, including the glomerulus and Bowman's capsule that envelops it; and (2) the renal tubule, a tube that collects the filtered liquid (urine) that is to be eliminated from the body.



Endocrine System

Consists of the glands inside the body that secrete approximately 50 specific substances called hormones into the blood. The hormones activate or stimulate various organs and control reproduction, development, and metabolism. These chemicals control many of the body's processes and even meddle in our love lives.

The Hormonal Message

The endocrine system is made up of the so-called endocrine glands. This complex, controlled by the pituitary (hypophysis), or master, gland, includes the thyroid, parathyroid, pancreas, ovaries, testicles, adrenals, pineal, and hypothalamus. The role of these glands is to secrete the many hormones needed for body functions. The word "hormone" comes from the Greek *hormon*, which means to excite or incite. The term was suggested in 1905 by the British physiologist Ernest Starling, who in 1902 assisted in the isolation of the first hormone, secretin, which stimulates intestinal activity. Hormones control such functions as reproduction, metabolism (digestion and elimination of food), and the body's growth and development. However, by controlling an organism's energy and nutritional levels, they also affect its responses to the environment.

Pituitary Hormones

ACTH Adrenocorticotropin hormone. It goes to the adrenal gland.

TSH A hormone that stimulates the thyroid to produce the thyroid hormones, which influence metabolism, energy, and the nervous system.

GH Growth hormone

FSH Follicle-stimulating hormone

LH Luteinizing hormone; testosterone and estrogen

MSH Hormone that stimulates the melanocyte of the skin.

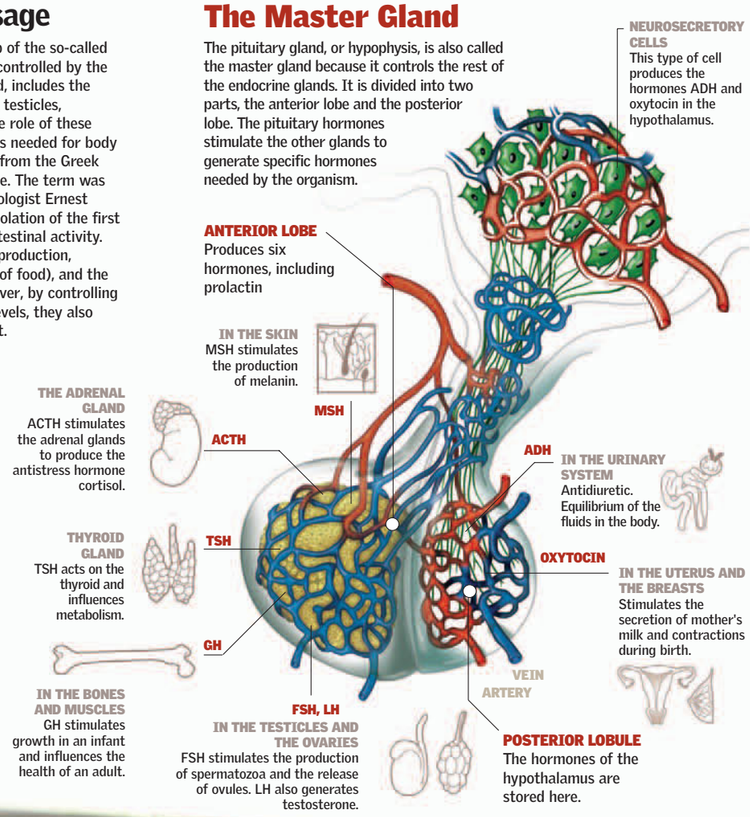
ADH Antidiuretic hormone

PRL Prolactin; stimulates milk production by the mother.

OXYTOCIN Stimulates the release of milk by the mother, as well as the contractions needed during labor.

The Master Gland

The pituitary gland, or hypophysis, is also called the master gland because it controls the rest of the endocrine glands. It is divided into two parts, the anterior lobe and the posterior lobe. The pituitary hormones stimulate the other glands to generate specific hormones needed by the organism.



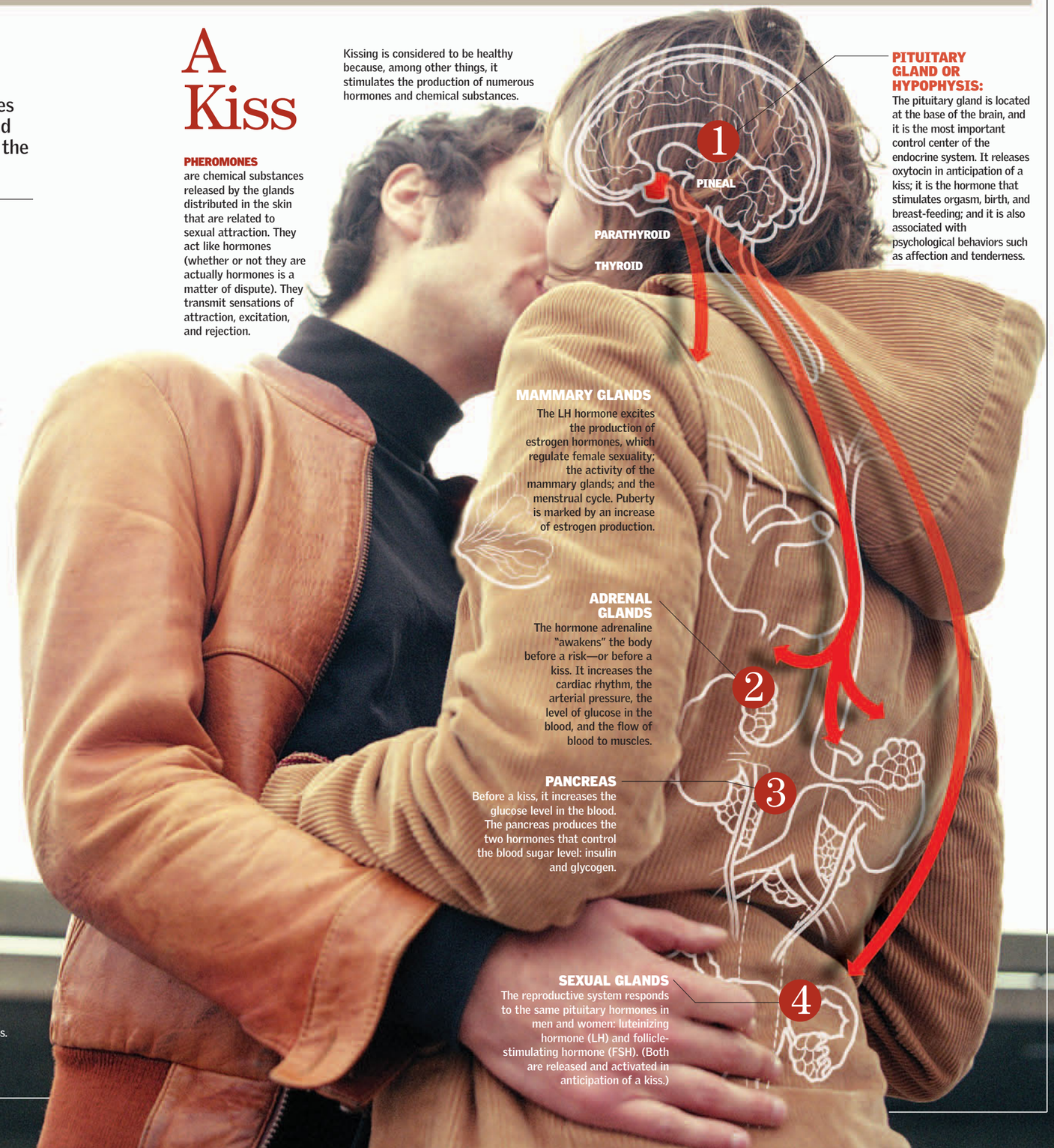
The Confidence Hormone

Oxytocin, the hormone that influences basic functions, such as being in love, orgasm, birth, and breast-feeding, is associated with affection and tenderness. It is a hormone that stimulates the formation of bonds of affection.

A Kiss

Kissing is considered to be healthy because, among other things, it stimulates the production of numerous hormones and chemical substances.

PHEROMONES are chemical substances released by the glands distributed in the skin that are related to sexual attraction. They act like hormones (whether or not they are actually hormones is a matter of dispute). They transmit sensations of attraction, excitation, and rejection.



PITUITARY GLAND OR HYPOPHYSIS: The pituitary gland is located at the base of the brain, and it is the most important control center of the endocrine system. It releases oxytocin in anticipation of a kiss; it is the hormone that stimulates orgasm, birth, and breast-feeding; and it is also associated with psychological behaviors such as affection and tenderness.

MAMMARY GLANDS The LH hormone excites the production of estrogen hormones, which regulate female sexuality; the activity of the mammary glands; and the menstrual cycle. Puberty is marked by an increase of estrogen production.

ADRENAL GLANDS The hormone adrenaline "awakens" the body before a risk—or before a kiss. It increases the cardiac rhythm, the arterial pressure, the level of glucose in the blood, and the flow of blood to muscles.

PANCREAS Before a kiss, it increases the glucose level in the blood. The pancreas produces the two hormones that control the blood sugar level: insulin and glycogen.

SEXUAL GLANDS The reproductive system responds to the same pituitary hormones in men and women: luteinizing hormone (LH) and follicle-stimulating hormone (FSH). (Both are released and activated in anticipation of a kiss.)

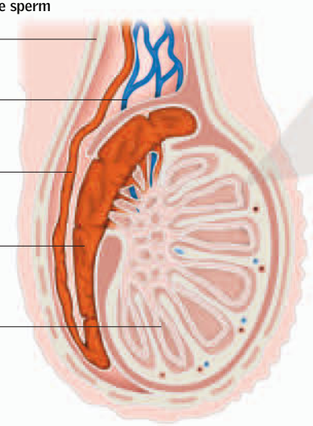
Male Reproductive System

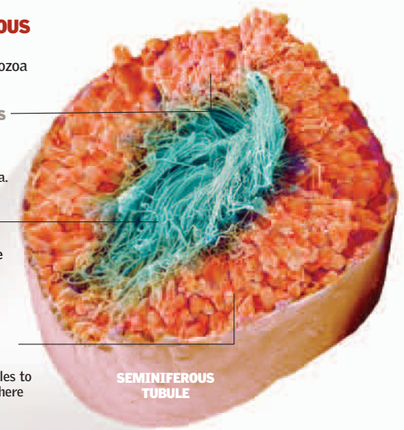
The male reproductive system is the complex of organs that leads to a man's production of one of two types of cells necessary for the creation of a new being. The principal organs are the two testicles, or male gonads, and the penis. The testicles serve as a factory for the production of millions of cells called spermatozoa, which are minute messengers of conception bearing the genetic information for the fertilization of the ovum. The penis is linked to the urinary apparatus, but for reproduction it is the organ that functions as a vehicle for semen, a liquid through which the spermatozoa can reach their destination. The word "semen" comes from Greek and means "seed."

Testicles and Spermatozoa

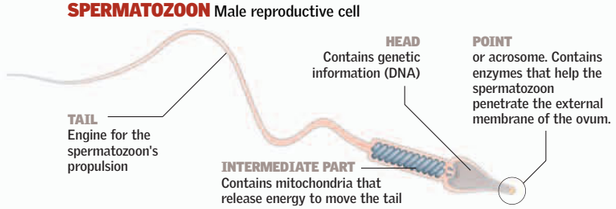
The seminiferous tubes in the testicles are covered with spermatogenic cells. By a process of successive cellular divisions called meiosis, the spermatogenic cells are transformed into spermatozoa, the term for the gametes, or male sexual cells, the bearers of half of the genetic information of a new individual. The spermatozoa fertilize the ovum, or female gamete, which contains the other half of the genetic information. The number of chromosomes is kept constant because the spermatozoa and the ovum are both haploid cells (cells that possess half of the genetic information of other cells). When the two haploid cells unite, the fertilized egg, or zygote, is a diploid cell (which contains a total of 46 chromosomes).

THE TESTICLES
The sexual organs that produce sperm





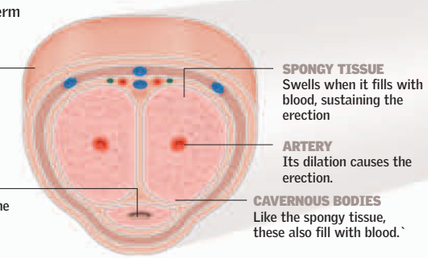
SPERMATOZOON Male reproductive cell



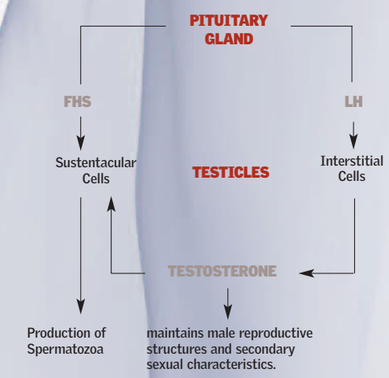
Internal Structure of the Penis

The most characteristic organ of a man's body, the penis has a cylindrical form with a double function for the urinary system and the reproductive system. In its normal, or relaxed, state the penis carries urine from the body via the urethra during urination. In its erect state its rigidity permits it to be introduced into the female vagina and to release sperm through ejaculation. The penis consists of spongy tissue supplied with blood vessels. The circulatory system supplies abundant blood to these vessels during sexual arousal so that the spongy tissue becomes swollen because of the filled blood vessels. This produces an erection, which makes copulation possible. The body of the penis surrounds the urethra and is connected to the pubic bone. The prepuce covers the head (glans) of the penis, which is located above the scrotum.

THE PENIS
transfers the sperm to the woman.



THE GLANDS



Prostate and Epididymis

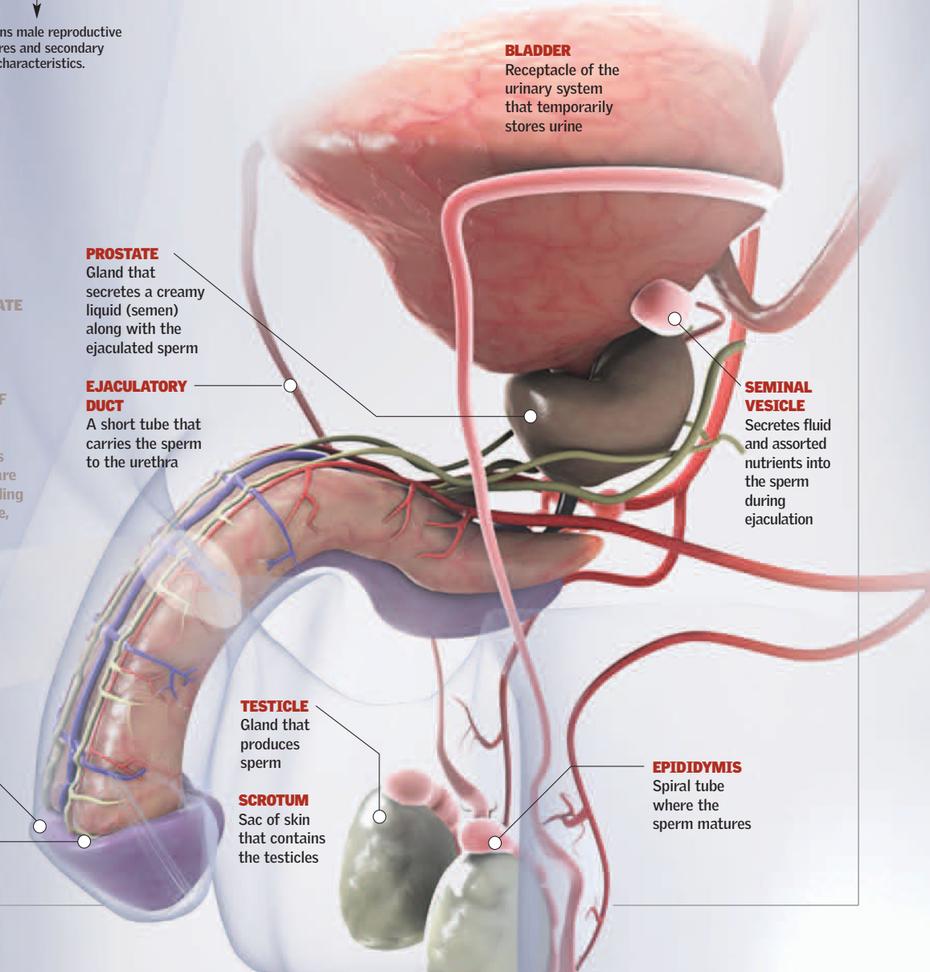
The prostate is a gland located in front of the rectum and below the bladder. It is the size of a walnut, and it surrounds the urethra, a tube that carries urine from the bladder. The prostate produces the liquid for the semen, which carries the spermatozoa. During orgasm, muscular contractions occur that send the liquid from the prostate out through the urethra. The epididymis is a duct that, when stretched out to its full length, is approximately 20 feet (5 m) long. In the male body it is extremely coiled and lies on the back surface of the testicles, where it is connected with the corresponding vas deferens. The vas deferens stores spermatozoa and provides them with an exit route. The seminal vesicles are two membranous receptacles that connect to both sides of the vas deferens and form the ejaculatory duct.

150 million

THE NUMBER OF SPERMATOZOA THAT EACH 0.06 CUBIC INCH (1 ML) OF SEMEN CAN CONTAIN

93° F (34° C)

IS THE IDEAL APPROXIMATE TEMPERATURE REQUIRED BY THE TESTICLES TO PRODUCE SEMEN.
It is lower than the normal body temperature of 98.6° F (37° C) because that temperature would be too warm for this function. This explains why the testicles are outside of the body. Depending on the ambient temperature, they extend or retract.



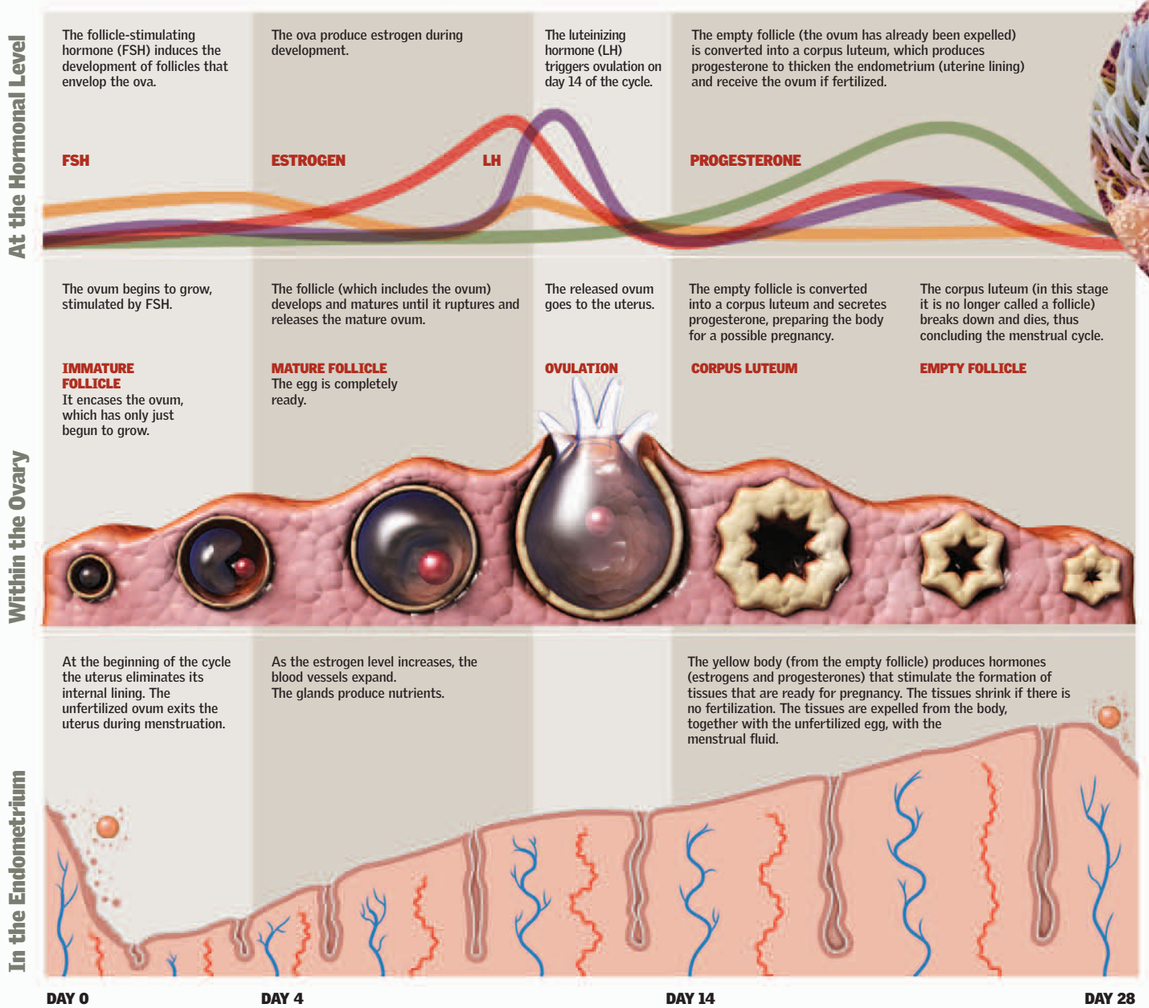
Female Reproductive System

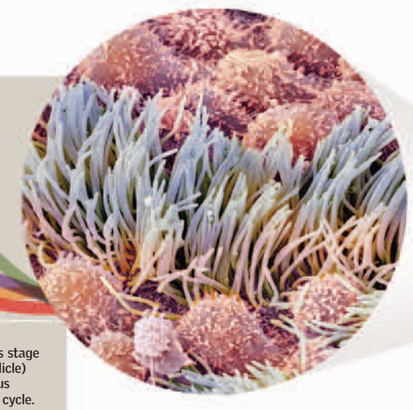
Its primary function is the production of ova, and its organs are arranged so as to allow the fertilization of the ovum by a spermatozoon of the male reproductive system and from that moment to facilitate a series of processes known collectively as pregnancy for the creation of a new being. The internal organs of the female reproductive system are the vagina, the uterus, the ovaries, and the fallopian tubes. The external genitalia, generally referred to as the vulva, are relatively hidden and include the labia majora and minora, the clitoris, the urinary meatus, Bartholin's glands, and the vaginal orifice that leads to the vagina. The menstrual cycle governs the system's function.

2 million

IS THE APPROXIMATE NUMBER OF OVA THAT AN INFANT GIRL HAS IN HER BODY AT BIRTH. BETWEEN THE AGES OF 10 AND 14, ABOUT 300,000 TO 400,000 OVA REMAIN, OF WHICH ONLY 400 WILL MATURE COMPLETELY OVER HER LIFETIME.

The 28 Days of the Menstrual Cycle

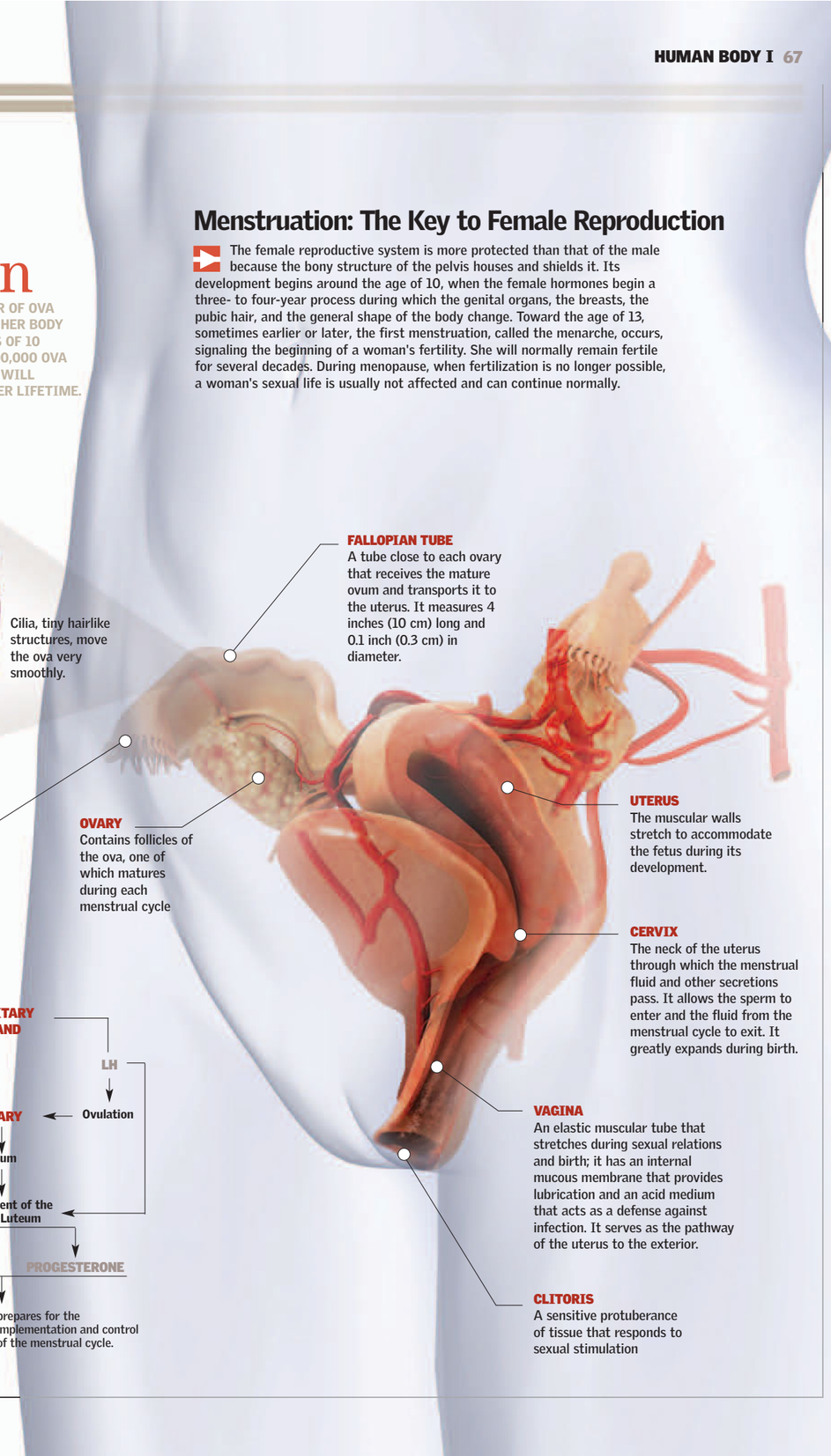




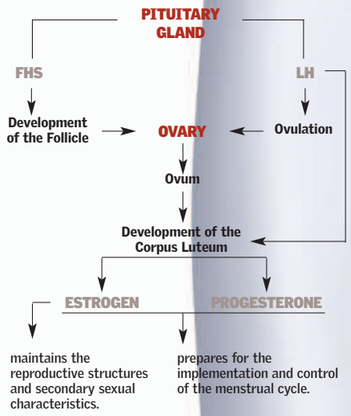
Cilia, tiny hairlike structures, move the ova very smoothly.

Menstruation: The Key to Female Reproduction

The female reproductive system is more protected than that of the male because the bony structure of the pelvis houses and shields it. Its development begins around the age of 10, when the female hormones begin a three- to four-year process during which the genital organs, the breasts, the pubic hair, and the general shape of the body change. Toward the age of 13, sometimes earlier or later, the first menstruation, called the menarche, occurs, signaling the beginning of a woman's fertility. She will normally remain fertile for several decades. During menopause, when fertilization is no longer possible, a woman's sexual life is usually not affected and can continue normally.



THE GLANDS



The Senses and Speech

HEALTHY AND SHINY SKIN
The health of the skin depends upon a diet that provides the organism with a sufficient amount of proteins and minerals.

Everything we know about the world comes to us through the senses. Traditionally it was thought that we had only five: vision, hearing, touch, smell, and taste. However, for some time now we have known that we have many additional classes of sensations—such as pain, pressure, temperature, muscular sensation, and a sense of motion—that are generally included in the sense of touch. The areas of the brain involved are called somatosensory areas. Although we often take our senses for granted, each one of them is delicate and irreplaceable. Without them it is nearly impossible to understand our surroundings. They are a bridge between us and everything alive on the Earth. ●

Smell and Taste

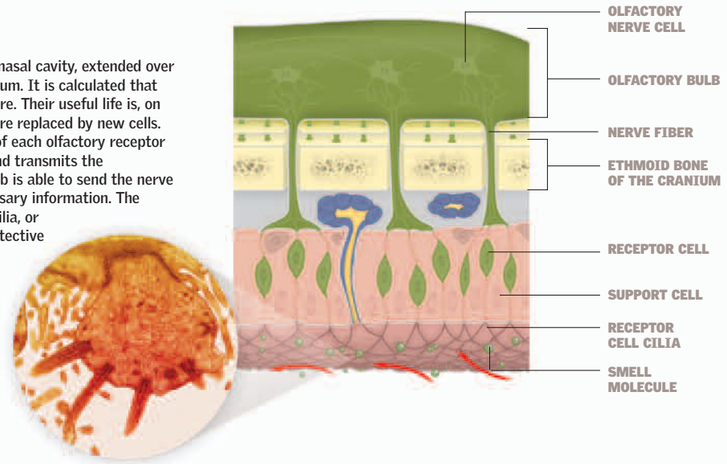
These two senses of the body function as powerful allies of the digestive system. Taste involves the perception of dissolved chemical substances arriving, for example, in the form of food. Taste sensation is principally seated on the upper surface of the tongue, and saliva is a fundamental ingredient for dissolving and tasting. Smell involves the perception of these chemicals when they take the form of dispersed aromas. The sense of smell operates at a greater distance than that of taste and can capture substances floating in the environment. It is thought that smell is some 10,000 times more sensitive than any of our other senses.

Olfactory Cells

These are located deep in the nasal cavity, extended over the so-called olfactory epithelium. It is calculated that some 25 million cells are located there. Their useful life is, on average, 30 days, after which they are replaced by new cells. They have a dual function. One end of each olfactory receptor is connected to the olfactory bulb and transmits the sensations it records, so that the bulb is able to send the nerve impulses to the brain with the necessary information. The other end terminates in a group of cilia, or microscopic hairs, which serve a protective function within the mucosa.

10,000

THE NUMBER OF ODORS THE SENSE OF SMELL CAN DISTINGUISH



Gustatory Papillae

The tongue is the principal seat of the sense of taste. It has great mobility at the bottom of the mouth and contains between 5,000 and 12,000 gustatory papillae. Each of these papillae has approximately 50 sensory cells, which have an average life span of 10 days. The salivary glands are activated by the ingestion of food or just before ingestion. They generate an alkaline liquid called saliva, a chemical solvent that, together with the tongue, breaks down the substances of which food is composed and makes it possible to differentiate between them by taste. The tongue takes charge of perceiving these tastes via the fungiform papillae, which give the tongue its rough appearance.

4 Flavors

THE SURFACE OF THE TONGUE CAN DISTINGUISH: SWEET, SALTY, SOUR, AND BITTER.

Touch and the Skin

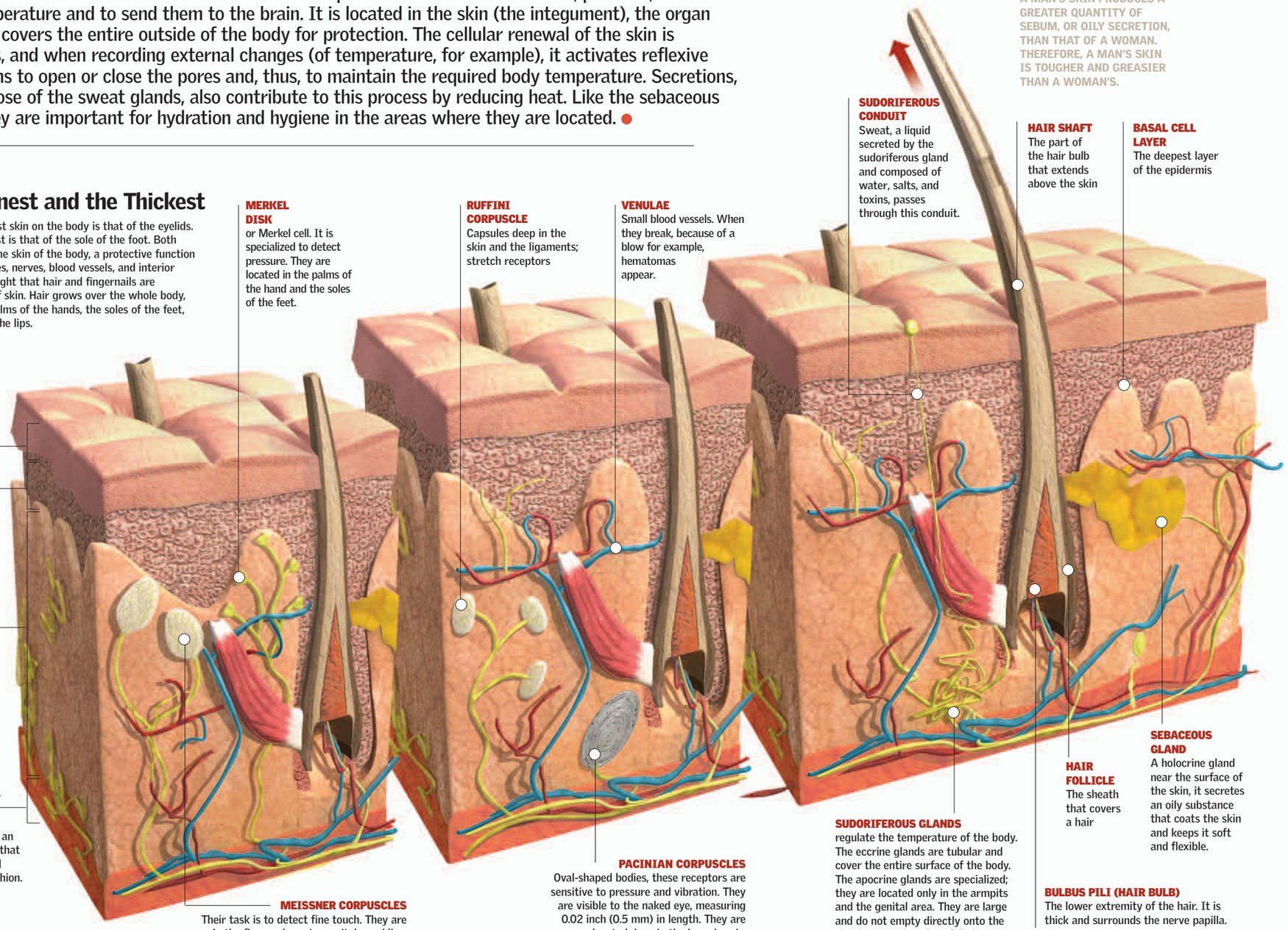
Touch is one of the five senses. Its function is to perceive sensations of contact, pressure, and temperature and to send them to the brain. It is located in the skin (the integument), the organ that covers the entire outside of the body for protection. The cellular renewal of the skin is continuous, and when recording external changes (of temperature, for example), it activates reflexive mechanisms to open or close the pores and, thus, to maintain the required body temperature. Secretions, such as those of the sweat glands, also contribute to this process by reducing heat. Like the sebaceous glands, they are important for hydration and hygiene in the areas where they are located.

The Thinnest and the Thickest

The thinnest skin on the body is that of the eyelids. The thickest is that of the sole of the foot. Both provide, like all the skin of the body, a protective function for muscles, bones, nerves, blood vessels, and interior organs. It is thought that hair and fingernails are modified types of skin. Hair grows over the whole body, except for the palms of the hands, the soles of the feet, the eyelids, and the lips.

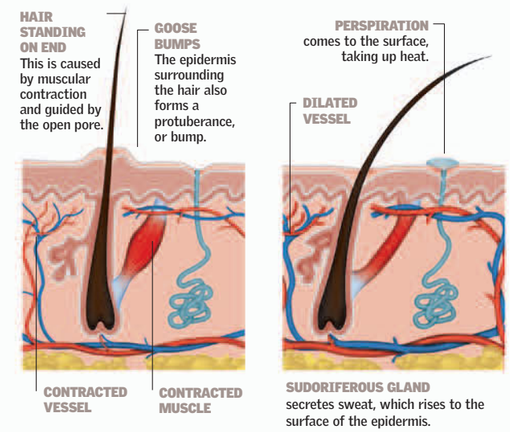
Skin

A MAN'S SKIN PRODUCES A GREATER QUANTITY OF SEBUM, OR OILY SECRETION, THAN THAT OF A WOMAN. THEREFORE, A MAN'S SKIN IS TOUGHER AND GREASIER THAN A WOMAN'S.



Responding to Temperature

When the skin perceives the sensation of cold, the blood vessels and the muscles contract. The purpose of this is to prevent the escape of heat; as a consequence, the hairs stand on end, resulting in what is commonly called goose bumps. The opposite happens in response to heat: the blood vessels dilate because the skin has received instructions from the brain to dissipate heat, and the vessels emit heat as if they were radiators. The sudoriferous glands exude sweat onto the surface of the skin. The evaporation of sweat removes heat from the skin.



A COLD
As with fear, cold puts a person's hair on end—literally! The contraction of both the blood vessels and the muscles causes the hair on the skin to stand on end.

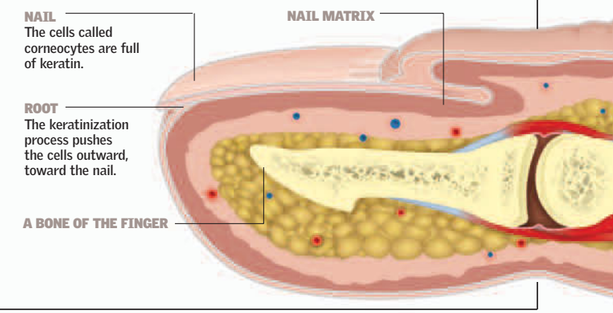
B HEAT
causes the secretion of sweat, which increases as the temperature rises. Cooling is caused by the evaporation of the sweat, which carries heat away from the body.

Nails

They are hard and hornlike. Their principal component is keratin, a protein that is also present in the skin and the hair. Their function is to cover and protect the ends of the fingers and toes. Their cells arise from the proliferative matrix and advance longitudinally. Once outside the body, they die. That is why there is no pain when you cut them.

A SHIELD FOR THE FINGERS AND TOES

The fingernail can be seen with the unaided eye, but the protective structure of the fingers and toes also includes their matrix and bone structure.

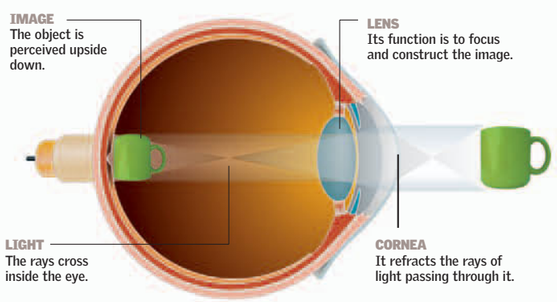


Anatomy of the Eye

Almost all the information that comes from the world into the brain depends on vision. The eye, one of the most complex organs of the body, allows us to judge the size and texture of an object even before we touch it or to know how far away it is. More than 100 million cells are activated instantaneously in the presence of light, converting the image perceived into nerve impulses that are transmitted to the brain. For this reason 70 percent of all the body's sensory receptors are concentrated in the eyes. It is vital that the brain receive information in a correct form: otherwise, things would appear to be distorted.

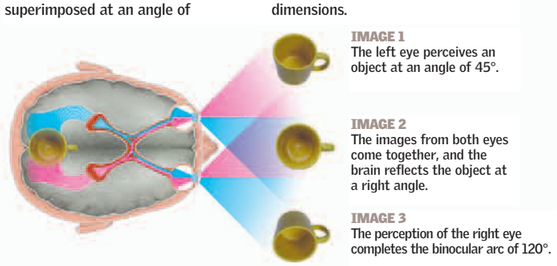
How Does the Eye See?

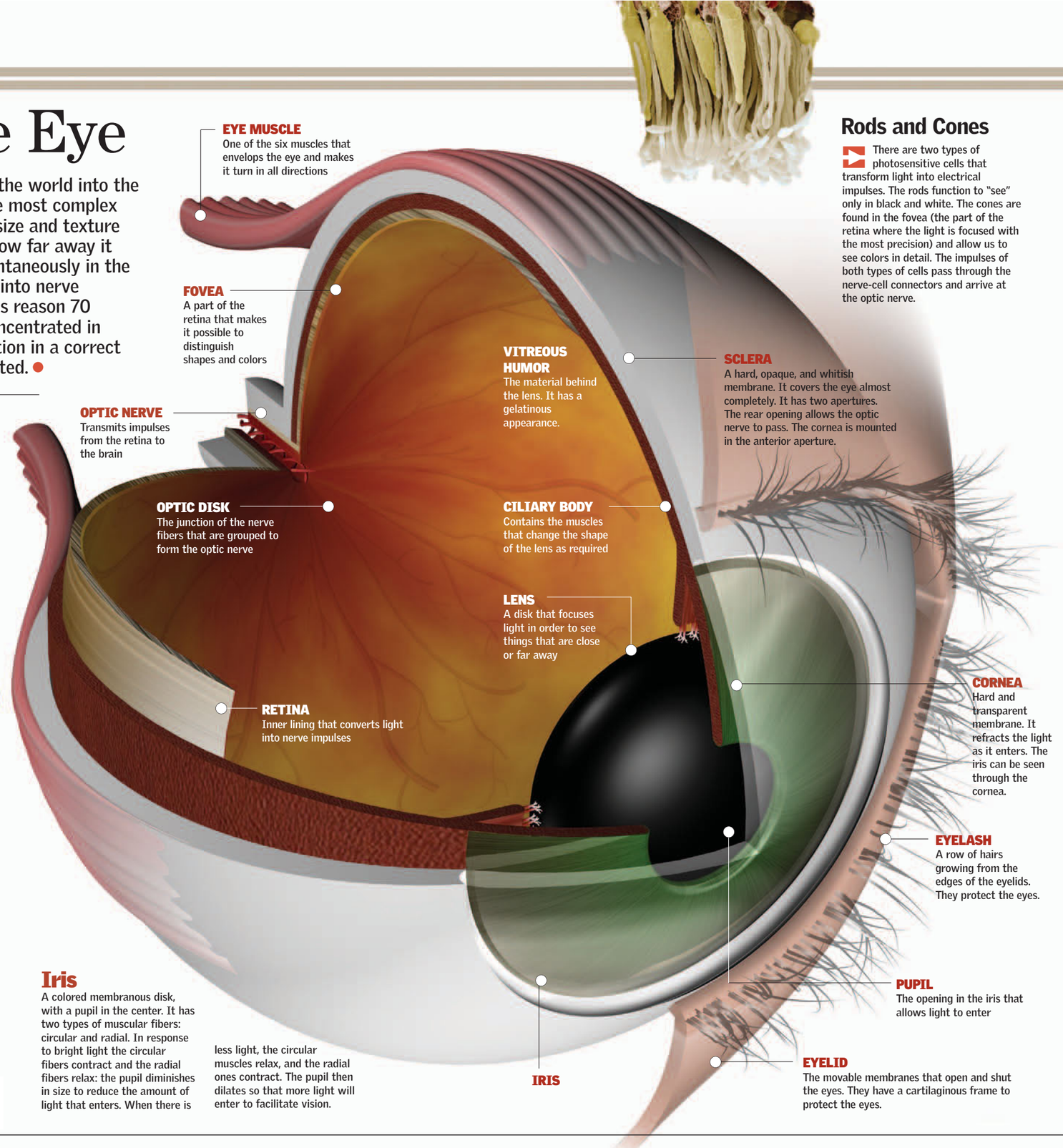
An object reflects light in all directions. The light is partially focused by the cornea, which refracts the entering rays. The lens focuses the rays of light, changing its shape to give the light the focus it needs. The rays cross the inside of the eye. The light arrives at the retina, and the rays perceived produce an inverted image of the object. The retina sends this information to the brain, which processes it and constructs a correct image of the object. Thanks to the fovea the eye can perceive details such as the shape and color of objects.



Seeing in Three Dimensions

When the eyes look ahead, the field of vision is binocular because both eyes see at the same time, each one from a different perspective. The images are superimposed at an angle of approximately 120°. This allows stereoscopic vision (two images of the same object from different angles, without deformation). The brain perceives the image in three dimensions.





Iris

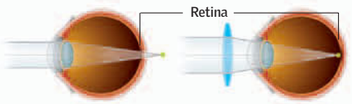
A colored membranous disk, with a pupil in the center. It has two types of muscular fibers: circular and radial. In response to bright light the circular fibers contract and the radial fibers relax: the pupil diminishes in size to reduce the amount of light that enters. When there is less light, the circular muscles relax, and the radial ones contract. The pupil then dilates so that more light will enter to facilitate vision.

Rods and Cones

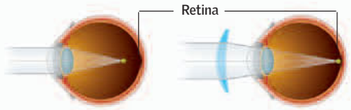
There are two types of photosensitive cells that transform light into electrical impulses. The rods function to "see" only in black and white. The cones are found in the fovea (the part of the retina where the light is focused with the most precision) and allow us to see colors in detail. The impulses of both types of cells pass through the nerve-cell connectors and arrive at the optic nerve.

VISION PROBLEMS

The most common problems involve seeing things out of focus. These are hypermetropia and myopia. Both can be corrected by the use of lenses. A hereditary condition called color blindness, or Daltonism, is less frequent.



A HYPEROPIA (FARSIGHTEDNESS)
This condition makes it difficult to see objects that are close to us. It happens when the image is focused behind the retina. It can be corrected by convex (converging) lenses, which make the rays of light strike the retina properly.

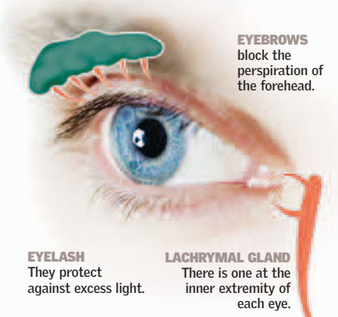


B MYOPIA (NEARSIGHTEDNESS)
Here the image is formed in front of the retina. This usually occurs when the ocular sphere is longer than normal. The myopic person has difficulty seeing distant objects. Myopia is corrected with concave (diverging) lenses or by an operation using a laser.

C COLOR BLINDNESS
Persons who are color blind have problems distinguishing between certain colors. It is a hereditary illness caused by the absence of the types of cone cells that are sensitive to yellow, green, or blue.

Protection

THE EYELIDS PROTECT THE EYES FROM BRIGHT LIGHT AND DUST. THE EYELASHES REDUCE EXCESS LIGHT. THE EYEBROWS KEEP SWEAT OUT OF THE EYES. THE NASOLACHRYMAL DUCT TAKES THE TEARS FROM THE NASAL CAVITY TO THE LACHRYMAL DUCTS—THE OPENINGS AT THE EXTREMITIES OF THE EYES—WHERE THEY ARE SECRETED.



Mechanics of Hearing

The ear is the sense responsible for hearing and maintaining equilibrium. When the ear perceives sounds, it registers its characteristics—volume, tone, and timbre—as well as the direction from which it comes. A group of nerve terminals receives information about the body's motion and transmits this to the brain in order to maintain dynamic and static equilibrium. The ear is important for communication by means of speech or other means, such as music. The ear is capable of distinguishing a great range of volumes, from the buzzing of a mosquito to the roar of an airplane. The ear contains the smallest bones of the body.

Frequencies

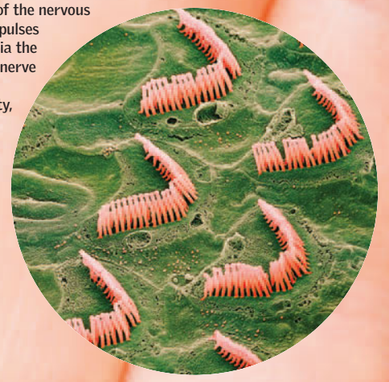
The frequency of a sound is the speed at which the sound makes the air vibrate. It is measured in units called hertz (Hz): one hertz corresponds to one vibration per second. High frequencies correspond to high sounds, and low frequencies to low sounds. The human ear can hear sounds between 20 and 20,000 vibrations per second.

FREQUENCIES AUDIBLE TO HUMANS AND ANIMALS

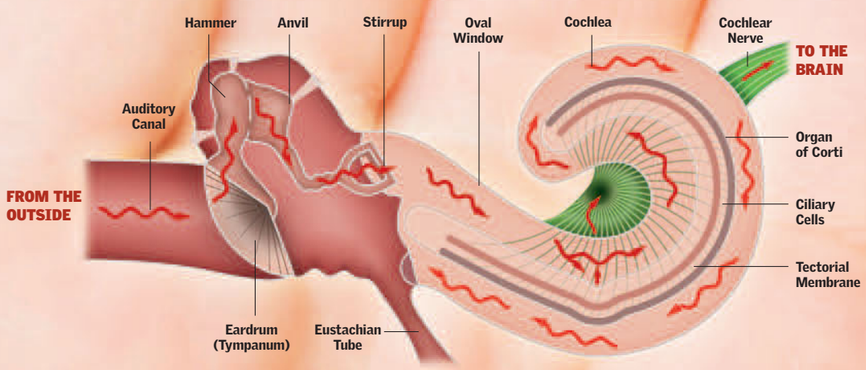
SUBJECT	MINIMUM	MAXIMUM
Person 10 years old	20 Hz	20,000 Hz
Person 60 years old	20 Hz	12,000 Hz
Dog	60 Hz	45,000 Hz
Frog	100 Hz	3,000 Hz
Bat	1,000 Hz	120,000 Hz
Cat	60 Hz	65,000 Hz

Organ of Corti

Contains ciliary cells that collect vibrations and transform mechanical energy into energy of the nervous system. Next the impulses arrive at the brain via the cochlear nerve. The nerve cells do not have a regenerative capacity, so if they are lost hearing will be lost along with them.



THE PROCESSING OF SOUND



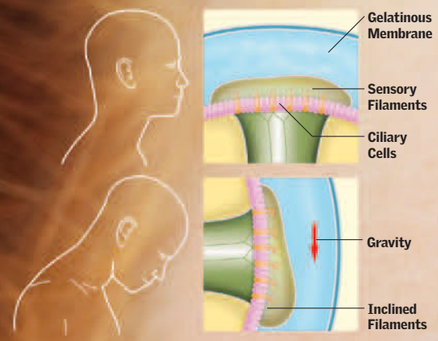
1 ENTRANCE
The sound wave is captured by the ear and enters via the auditory canal.

2 VIBRATION
The tympanum registers the intensity of the wave.

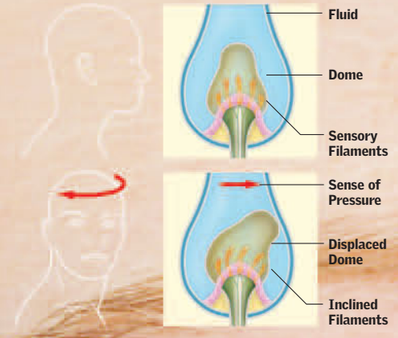
3 TRANSMISSION
The vibration of the eardrum is transmitted to the hammer, from the hammer to the anvil, from the anvil to the stirrup, from the stirrup to the oval window, from there to the cochlea, and from there to the cochlear nerve, whose electrical impulses are transmitted to the brain.

Equilibrium

Dynamic and static equilibrium are maintained by the inner ear. Above the cochlea there are three semicircular canals, which are spiral-shaped conduits. Inside the canals are a gelatinous membrane and thousands of cilia, or hairlike structures, traversed by a cranial nerve that connects them to the brain. When the head moves, this gelatinous membrane is displaced, and the tiny cilia send the brain information about the velocity and the direction of this displacement. On that basis the body can move as required to maintain equilibrium. Excessive motion produces seasickness, because the cilia continue to move even when the motion stops.

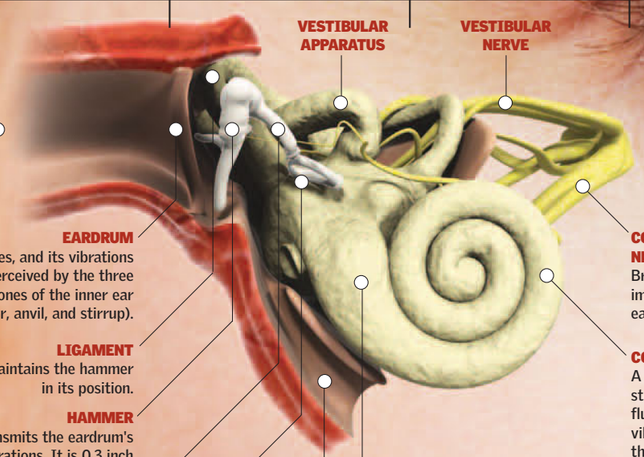


LINEAR MOTION
The displacement of the gelatinous membrane, caused by a difference in height, changes the structure of the auditory cilia.



ROTATIONAL MOTION
The gelatinous membrane takes on the shape of a dome so that lateral motion will also disturb its equilibrium.

EXTERNAL EAR / MIDDLE EAR / INNER EAR



AURICULAR PAVILION
or pavilion of the ear. The only visible part of the ear. It consists of cartilage and skin. It captures the sound vibrations and redirects them into the ear, preventing echo.

EXTERNAL AUDITORY CANAL
It is on average 1 inch (2.5 cm) long.

EARDRUM
It vibrates, and its vibrations are perceived by the three bones of the inner ear (hammer, anvil, and stirrup).

LIGAMENT
Maintains the hammer in its position.

HAMMER
Transmits the eardrum's vibrations. It is 0.3 inch (8 mm) long.

ANVIL
Receives the hammer's vibrations

STIRRUP
Transmits vibrations to the oval window. It is 0.15 inch (4 mm) long.

EUSTACHIAN TUBE
Connects the middle ear with the back of the nose and the pharynx. It controls the air pressure in the ear, at times through yawning.

VESTIBULE
Oval window or labyrinth. Encased in the temporal bone, one conduit goes to the cochlea (for hearing), and two go to the semicircular canals (for equilibrium).

COCHLEAR NERVE
Brings the nerve impulses of the inner ear to the brain

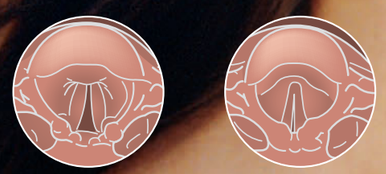
COCHLEA
A tubular, spiral structure filled with fluid that receives vibrations, which are then transmitted to the brain by the organ of Corti. These vibrations produce waves in the fluid, which stimulate the cilia of the organ of Corti. The cochlea allows differences in volume to be identified.

Speech and Nonverbal Language

Speaking is the verbal expression of a language and includes articulation, which is the manner in which words are formed. However, one can make oneself understood by means other than the spoken word, such as with signs, facial expressions, or gestures. These are examples of what is called nonverbal communication, whereby even silence can be expressive.

Language and Speech

Linguists explain that the organs of speech necessary to express language in sounds, which constitute the fundamental elements of speech, are just as independent of language as a telegraph apparatus is of the Morse code it transmits. Linguists also compare language (the verbal system of communication that is almost always written) with a symphony whose score exists independently of the musicians who play it.
The vocal cords behave like instruments. They are folds of muscle that open and close to produce sounds. When they are not producing vocal sounds, normal breathing occurs. Under the control of the brain, the vocal cords produce sounds that are modified by the lips and the tongue to create speech.



A **Passage of Air** The vocal cords relax and open to allow air to pass to and from the lungs. No sound is produced because the vocal cords do not vibrate, which is the basis for sound.

B **Sound Is Produced.** The vocal cords stretch horizontally above the larynx. They tighten when air flows past them. Sound is the vibration of the vocal cords.

NASAL CAVITY Adds resonance to speech

ORAL CAVITY Acts like a resonance chamber

TONGUE By changing its shape and position, the tongue varies the sounds produced.

ESOPHAGUS In its respiratory function it brings in air, which is pushed by the diaphragm.

LIPS modify sounds by changing their shape.

LARYNX Contains the vocal cords

TRACHEA Influences speech because the air passes through it

Language of Gesture

The expressivity of the human face is the result of more than 30 muscles that tense small areas of the skin when they contract. Most of them operate in pairs. Their use is reflexive in most cases, as in the gestures, facial expressions, and grimaces that often accompany the spoken word and are silent expressions in certain situations. In other cases, however, such as the art of acting, their use and mastery can be studied and practiced. The usual example of this is the art of mimes, who can stage complete dramas that are transmitted very effectively with no recourse to the spoken word or use of the voice.

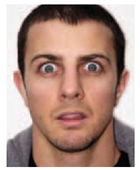
Broca Controls the articulation of speech.

Visual Receives and analyzes the nerve impulses from the eye.

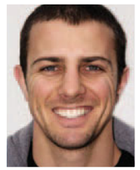
Wernicke Controls the comprehension of language.

FACIAL EXPRESSIONS The muscles of the face also serve to communicate feelings.

FROWNING Action of the corrugator muscles on the eyebrows



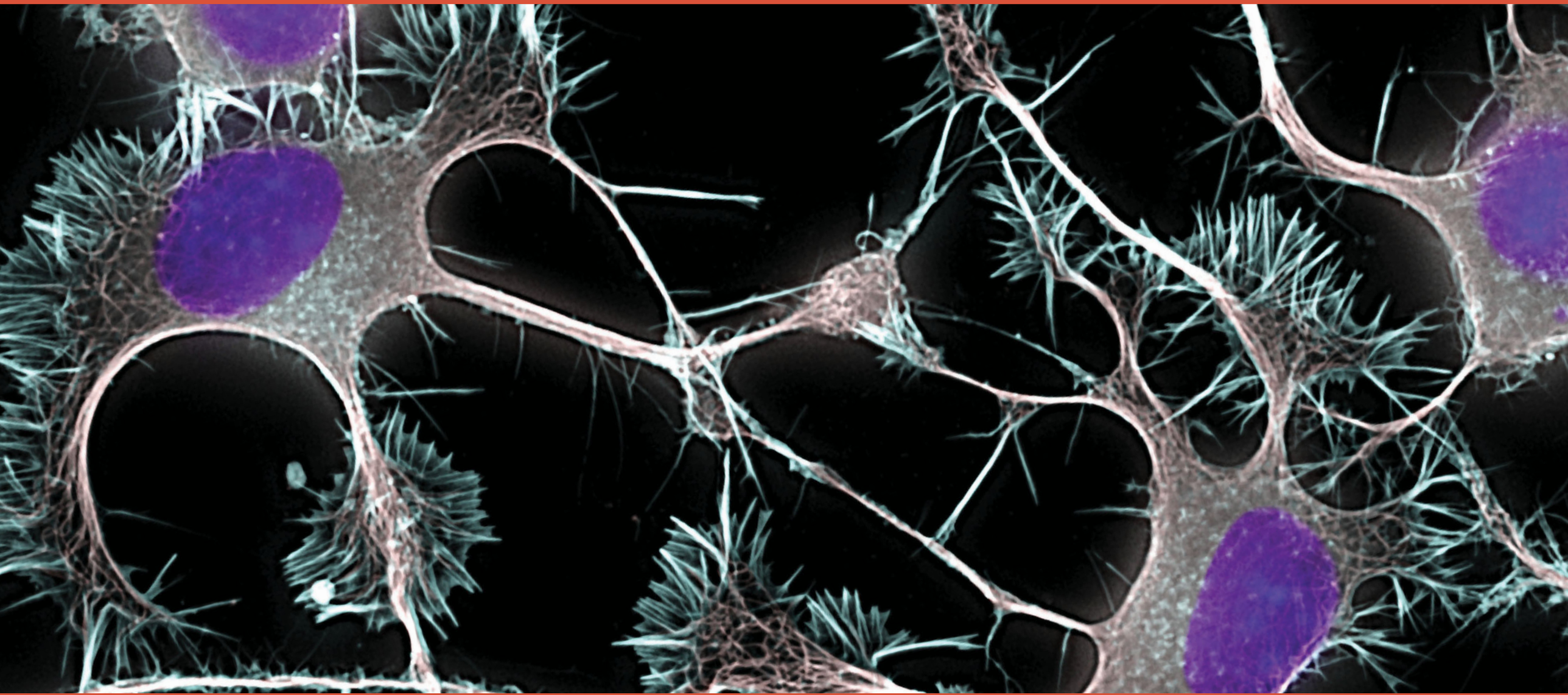
SURPRISE The muscles of the forehead are contracted.



SMILE Action of the smile muscles and the zygomaticus major

Control Centers

NERVE CELLS
Microscope photograph of a group of neurons



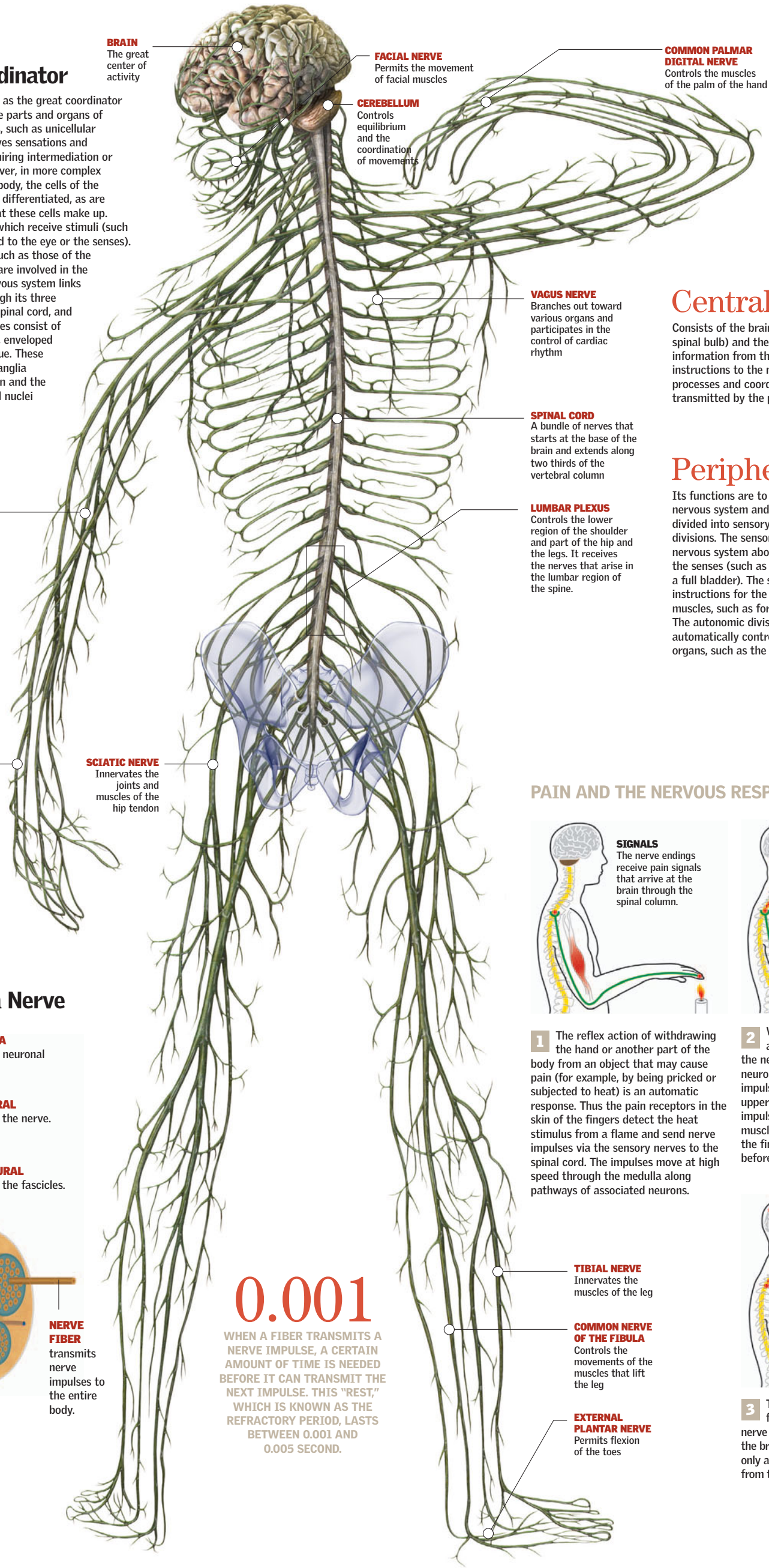
Brain tissue consists of thousands of millions of neurons that continually send each other signals through connections called synapses. Thanks to this network the brain can remember, calculate, decide, think, dream, create, and express emotions. We invite you to understand the secrets about how these activities of the brain are accomplished. What determines the formation of synapses and neuronal networks? Where are intelligence and memory located? Is it possible to stimulate brain cells? What happens during a dream? What are nerves, and how are they formed? What functions are carried out by each region of the brain? You will find all this and much more in this chapter, including incredible images.

Nervous System

The body's most complex system, many of whose characteristics and potentialities are still unknown. Together with the endocrine system, the brain has the job of controlling the organism. Its specific functions are rapid and intellectual activities, such as memory, emotions, and will. The brain is divided into three portions: the central (the brain and the spinal cord), the peripheral (nerves of the spinal cord and cranium), and the vegetative (or autonomic function).

The Great Coordinator

The nervous system acts as the great coordinator of the functions of all the parts and organs of the body. In simpler organisms, such as unicellular organisms, the same cell receives sensations and responds to them without requiring intermediation or specialized coordination. However, in more complex organisms such as the human body, the cells of the different parts of the body are differentiated, as are the functions of the organs that these cells make up. Thus there are receptor cells, which receive stimuli (such as the cells of the organs linked to the eye or the senses). There are also effector cells (such as those of the muscles or the glands), which are involved in the organism's responses. The nervous system links these functions together through its three principal parts: the brain, the spinal cord, and the nerves in general. The nerves consist of numerous axons and dendrites, enveloped by a sheath of conjunctive tissue. These groups of neurons are called ganglia when they are outside the brain and the spinal cord, and they are called nuclei when they are inside.



300 feet (90 m) per second

THE SPEED AT WHICH IT IS CALCULATED THAT A NERVE IMPULSE TRAVELS IN A NERVE WITH A MYELINATED SHEATH

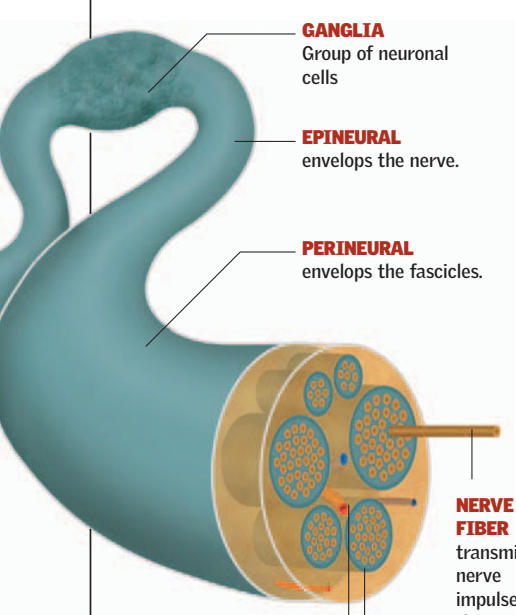
Central

Consists of the brain (cerebrum, cerebellum, and spinal bulb) and the spinal column. It receives information from the sense organs and sends instructions to the muscles and other organs. It also processes and coordinates the nervous signals transmitted by the peripheral system.

Peripheral

Its functions are to provide information to the central nervous system and to coordinate movements. It is divided into sensory, somatic, and autonomic divisions. The sensory division informs the central nervous system about external changes detected by the senses (such as pain) or internal changes (such as a full bladder). The somatic division sends instructions for the conscious movement of different muscles, such as for shaking hands or kicking a ball. The autonomic division (vegetative nervous system) automatically controls the functioning of the internal organs, such as the heart.

Structure of a Nerve

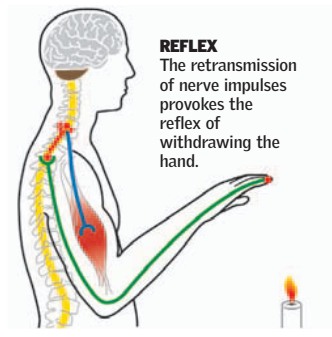


0.001

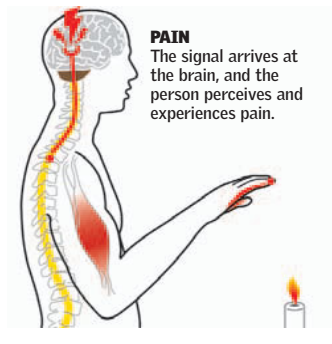
WHEN A FIBER TRANSMITS A NERVE IMPULSE, A CERTAIN AMOUNT OF TIME IS NEEDED BEFORE IT CAN TRANSMIT THE NEXT IMPULSE. THIS "REST," WHICH IS KNOWN AS THE REFRACTORY PERIOD, LASTS BETWEEN 0.001 AND 0.005 SECOND.

PAIN AND THE NERVOUS RESPONSE

1 The reflex action of withdrawing the hand or another part of the body from an object that may cause pain (for example, by being pricked or subjected to heat) is an automatic response. Thus the pain receptors in the skin of the fingers detect the heat stimulus from a flame and send nerve impulses via the sensory nerves to the spinal cord. The impulses move at high speed through the medulla along pathways of associated neurons.



2 Within thousandths of a second after detecting the pain stimulus, the nerve impulses reach the motor neurons. These neurons transmit the impulses to the flexor muscles in the upper part of the arm. Once the impulses have been received, the muscles contract, the arm bends, and the fingers move away from the flame before any pain is consciously felt.



3 The pain is felt when the nerve fibers in the spinal cord bring the nerve impulses to the sensory areas of the brain. The sensation of pain is felt only after the hand has been withdrawn from the fire by reflex action.

Neurons

Neurons are cells that make up the nervous system. Their function is to transmit impulses in the form of electrical signals carrying information to the brain and from there to the periphery. The neurons provide the basis for the system's activities and form a highly complex communication network. They are surrounded and protected by other nerve cells that are not excitable, called glial cells, which constitute more than half of all an organism's nerve cells.

Plasticity

Each neuron is essentially made up of a body, an axon, and many dendrites. The communication that is established among neurons resembles a conversation, or a continuous ongoing exchange of information. Until recently it was thought that neurons, unlike other tissue, could not be regenerated once lost. Today not only is it known that this is not so, but it is also known that the capabilities of the brain and the nervous system are more a function of the circuits and connections that are established among the neurons than of the number of neurons per se. These connections are activated, deactivated, and modified by very diverse factors (such as learning, food, habits, exercise, the effects of drugs and accidents). Some neurons can regenerate if they have been damaged.

SYNAPTIC NODE
The terminal point of the axon branch, it contains chemicals that transmit nerve impulses.

MYELIN SHEATH
A fatty layer that insulates the axons of some neurons in order to accelerate nerve impulse transmission. In the peripheral nervous system, this sheath consists of Schwann cells.

RANVIER'S NODE
An opening in the myelin sheath that aids in the transmission of nerve impulses

MITOCHONDRIA
provide energy to the cell.

AXON
Nerve fiber that transmits impulses

NUCLEUS
Contains the neuron's genetic material

SCHWANN CELL
A glial cell that surrounds an axon

CELL BODY
Generates the vital processes of the neuron cell

DENDRITE
Protuberance that captures signals from other neurons. A neuron can have about 200 dendrites; the number of dendrites varies from cell to cell.

500 million

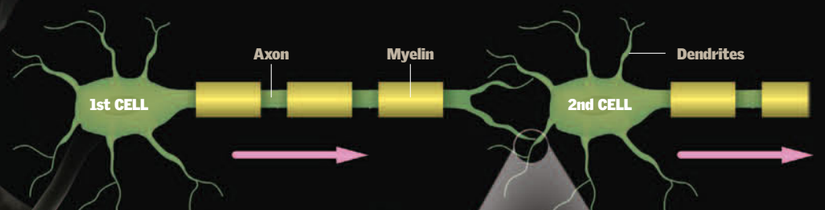
IS THE NUMBER OF SYNAPSES (CONNECTIONS AMONG NEURONS) FORMED IN 0.06 CUBIC INCH (1 CU MM) OF A BRAIN'S NERVE TISSUE. OVERALL, THE BRAIN HAS 1 QUADRILLION SYNAPSES.

100 billion

THE NUMBER OF INTERCONNECTED NEURONS IN A HUMAN BEING

Transmission and Synapses

The synapse is the point of communication between neurons. It comprises a synaptic cleft, a synaptic knob, and a target to which the nerve signal is directed. In order for a neuron to be activated, there must be a stimulus that converts the electrical charge inside the membrane of the cell from negative to positive. The nerve impulse travels via the axon toward the synaptic knob and brings about the release of chemical substances called neurotransmitters. These in turn can elicit a response from the target to which the stimulus is directed.

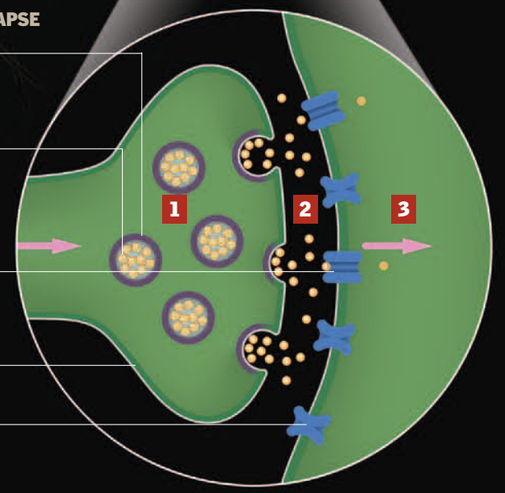


FIRST IMPULSE
Received by the dendrites that transmit it to the axon

SYNAPSE

SECOND IMPULSE
The sequence repeats, maintaining its shape.

COMPONENTS OF THE SYNAPSE



SYNAPTIC VESICLES
Sacs that contain neurotransmitter molecules brought to the synaptic cleft via calcium ions

NEUROTRANSMITTERS
Chemical molecules released by the synaptic vesicles toward the synaptic cleft. From there they influence the transmission of the impulse.

POINT OF RECEPTION
The neurotransmitter combines with protein receptors at the point of neuronal communication.

CELL MEMBRANE
The charge inside the cell membrane is negative.

MICROTUBULES
Structures that help transport neurotransmitter molecules to the synaptic membrane.

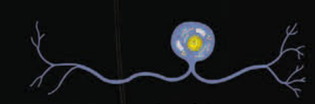
TRANSMISSION OF NERVE IMPULSES

1 Without Information
When the neuron is at rest, the sodium ions inside it are uniformly distributed so that the electrical charge inside the cell membrane is permanently negative.

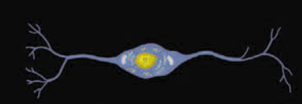
2 The Impulse Arrives
The arrival of the neurotransmissions at the dendrites causes a reversal of the charge, which becomes positive in this area, giving it a tendency to move in the direction of the negatively charged part of the cell.

3 Transmission of Information
The positive charge travels toward the negatively charged axon until it reaches the synapse and thus the other cell. The areas it has left return to their stable (negative) state.

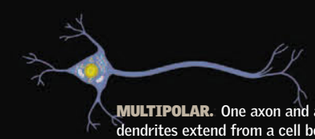
TYPES OF NEURONS ACCORDING TO THEIR COMPLEXITY



UNIPOLAR. Two branches of the same axon extend from one cell body.



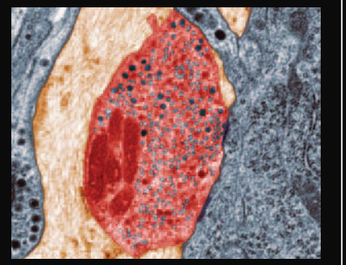
BIPOLAR. Two separate axons extend from each end of a cell body.



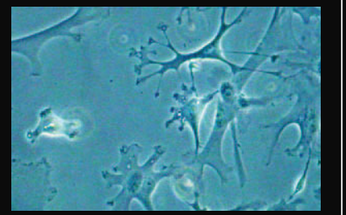
MULTIPOLAR. One axon and a number of dendrites extend from a cell body.

Neuromuscular Union

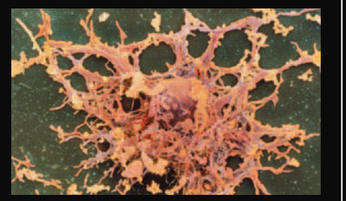
This is a special kind of synapse between the neurons and the skeletal muscle fibers that causes voluntary contraction of the muscles.



The axon of a neuron links itself with a muscle fiber. At the point of contact a chemical synapse is produced between the neuron and an effector, a muscle with electrically excitable tissue, and movement results.



ASTROCYTES are cells located in cerebral tissue, where they exceed neurons in number. Astrocytes have some delicate protuberances that are linked to the blood vessels and that regulate the flow of nutrients and waste between neurons and blood.



OLIGODENDROCYTES are the cells that form the myelin sheath around the nerve fibers of the brain and the spinal column. Their function is similar to that of Schwann cells in the peripheral nervous system

The Brain

The brain is the body's control center. Underneath its folds more than 100 billion neurons organize and examine incoming information and act as a guide for the organism. In spite of amounting to only 2 percent of the total weight of a human body, the brain alone uses one fifth of the oxygen inhaled. It is one of the most fragile parts of the body and, therefore, one of the most protected. Along with the spinal cord, the brain forms the central nervous system, which gives instructions to the peripheral nervous system.

3 pounds (1.4 kg)

AVERAGE WEIGHT OF AN ADULT BRAIN. AT BIRTH THE BRAIN WEIGHS BETWEEN 12 AND 14 OUNCES (350 AND 400 G).

CEREBRAL CORTEX
Gray matter. It is between 0.08 and 0.24 inch (2 and 6 mm) thick. The white matter is underneath.

Parietal Lobe
In Latin parietal means "wall." Located on the sides, this area receives sensory information and influences spatial orientation.

Frontal Lobe
Contains neurons that govern the production of speech, the elaboration of thought and emotion, and the performance of complex movements

CALLUS BODY
A bundle of nerve fibers that connect the two cerebral hemispheres

Occipital Lobe
Detects and interprets visual images

Temporal Lobe
Where sound and its pitch and volume are recognized. The temporal lobe plays an important role in the storage of memories.

THALAMUS
Retransmits nerve signals to the cerebral cortex

HYPOTHALAMUS
Controls the endocrine system (produces hormones)

Cerebellum
Associated with controlling the body's equilibrium

MAP OF THE BRAIN

PRIMARY SENSORY CORTEX
Receives signals from the sensory receptors in the skin

MOTOR CORTEX
Sends instructions to the muscles telling them to contract

PRE-MOTOR CORTEX
Coordinates complex movements of the muscle motor area

SENSORY ASSOCIATION CORTEX
Areas of the cortex that do not process sensory or motor information

PRE-FRONTAL CORTEX
Promotes the development of reasoning and planning (area of association and analysis of information)

BROCA'S AREA
Speech production. It is a motor area that commands the phonation muscles.

VISUAL ASSOCIATION CORTEX
Forms images by association and analysis of information

PRIMARY AUDITORY CORTEX
A sensory area. It receives information from the sensory receptors of the eyes.

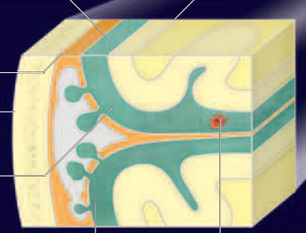
PRIMARY VISUAL CORTEX
Receives sensory information sent by the eyes

WERNICKE'S AREA
Linguistic area for auditory decoding

ASSOCIATIVE AUDITORY CORTEX
Area for association and analysis of sounds

MENINGES

Protective membranes covering the brain



PIAMATER

BRAIN

DURA MATER

CRANIAL BONE

CEPHALO-SPINAL LIQUID

ARACHNOIDS

BLOOD VESSEL

Meninges

There are three membranes, called meninges, that cover the brain. The outermost one covers the inside of the cranium, and it contains veins and arteries that feed blood to the cranial bones. It is called dura mater. The middle membrane is known as the arachnoid and consists of netlike elastic connective tissue. The piamater, the thinnest of the three, is the closest to the surface of the cerebral cortex. Its functions are primarily protective.

On one hand it acts as a filter to prevent the entry of harmful substances and microorganisms into the nervous system. On the other hand, as the covering of the most important organ of the body, it acts like an elastic helmet (remember that death takes place when the brain ceases to function). The cephalo-spinal liquid, a transparent fluid that acts like a shock absorber, circulates within the meninges.

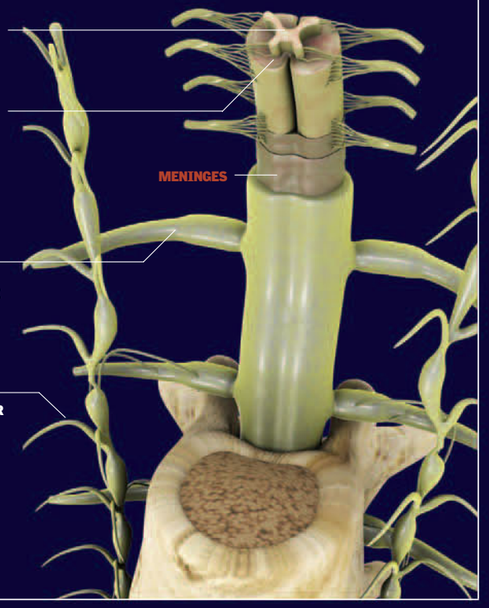
Gray and White Matter

The so-called gray matter, located in the cerebral cortex and in the spinal column, consists of groups of neuronal cells. White matter, on the other hand, consists primarily of myelin-sheathed axons or nerves that extend from the neuron cell bodies. The fatty layers of myelin allow for an increase in the transmission speed of nerve impulses.

Spinal Medulla

The spinal medulla is the spinal cord, which goes from the cephalic trunk to the lumbar region. Together with the brain it forms the central nervous system. It can reach a length of 18 inches (45 cm). It is composed of gray and white matter. The gray matter is located in its core, in tissue consisting essentially of neurons.

Surrounding the gray matter is white matter that contains the nerve fibers that transmit signals to and from the brain. The spinal nerves extend outward from the medulla to the body and its extremities. Paralysis in one or more parts of the body can result if the spinal cord is damaged.



GRAY MATTER

WHITE MATTER

MENINGES

SENSORY ROOT OF THE NERVE

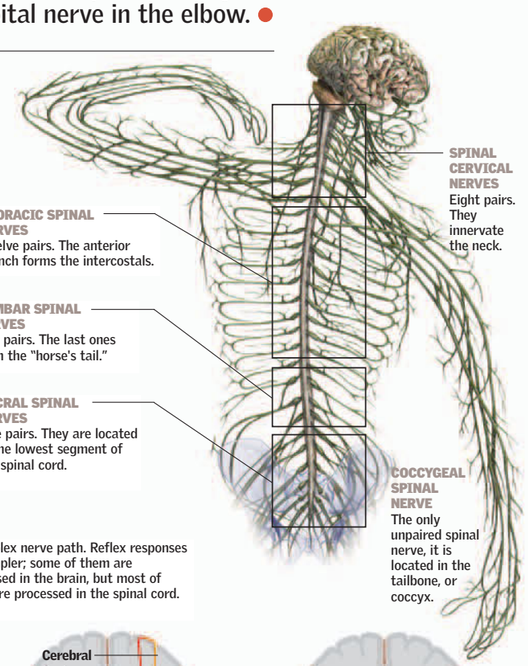
ROOT OF THE MOTOR NERVE

Peripheral Nerves

The peripheral nerves have the task of bringing information to and from the brain and spinal column. Depending on their location, they may be cranial or spinal nerves. The sensory fibers in the peripheral nerves receive information from the outside world, the skin, and the internal organs and transmit it to the central nervous system; the motor fibers begin to contract the skeletal muscles and transmit signals in the opposite direction from the sensors. The nerves are located deep in the body, with some exceptions, such as the cubital nerve in the elbow.

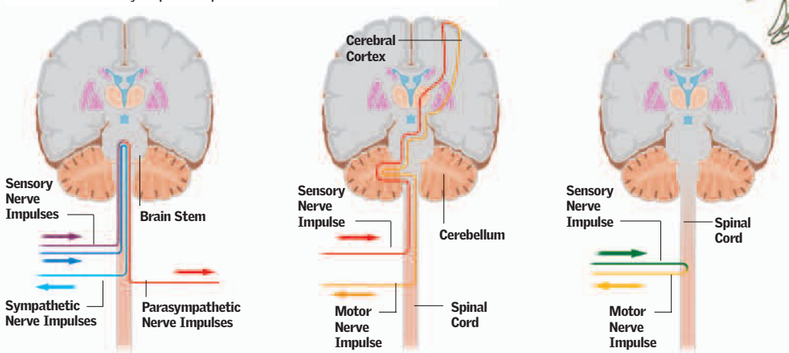
Spinal Nerves

There are 31 pairs of spinal nerves that begin at the spinal cord and extend through the spaces between the vertebrae. Each nerve is divided into numerous branches. These nerves control most of the body's skeletal muscles, as well as the smooth muscles and the glands. The cervical nerves serve the muscles of the chest and shoulders. The lumbar nerves serve the abdomen and part of the legs, and the sacral nerves control the rest of the legs and the feet.



THE THREE RESPONSES

The nerve receptors gather information that goes to the cerebral cortex and to the spinal cord. The response can be automatic, ordering dilation or contraction. Voluntary response implies a complex nerve path. Reflex responses are simpler; some of them are processed in the brain, but most of them are processed in the spinal cord.



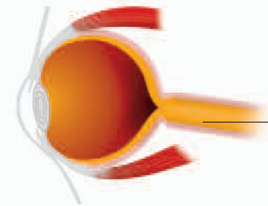
A AUTOMATIC RESPONSE
The impulses, or sympathetic (dilation) or parasympathetic (contraction) response signals, travel over separate pathways.

B VOLUNTARY RESPONSE
The sensory impulses that activate voluntary responses occur in various areas of the brain. The nerve path is complex.

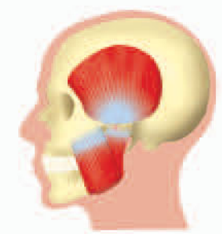
C REFLEXES
Some are processed in the brain, but most of them are processed in the spinal cord, where the impulse is processed and the reply is sent.

Cranial Nerves

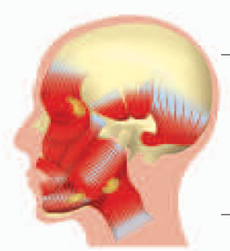
The 12 pairs of cranial nerves extend from the lower part of the brain, as can be seen in the main illustration. Except for the vagus nerve, the cranial nerves control the muscles of the head in the neck region or bring nerve impulses from sense organs, such as the eyes, to the brain. In the case of nerve impulses that come from the eyes, it is the pair of optical nerves that record the sensations from the retina of the eye. The olfactory nerve works the same way for the nose.



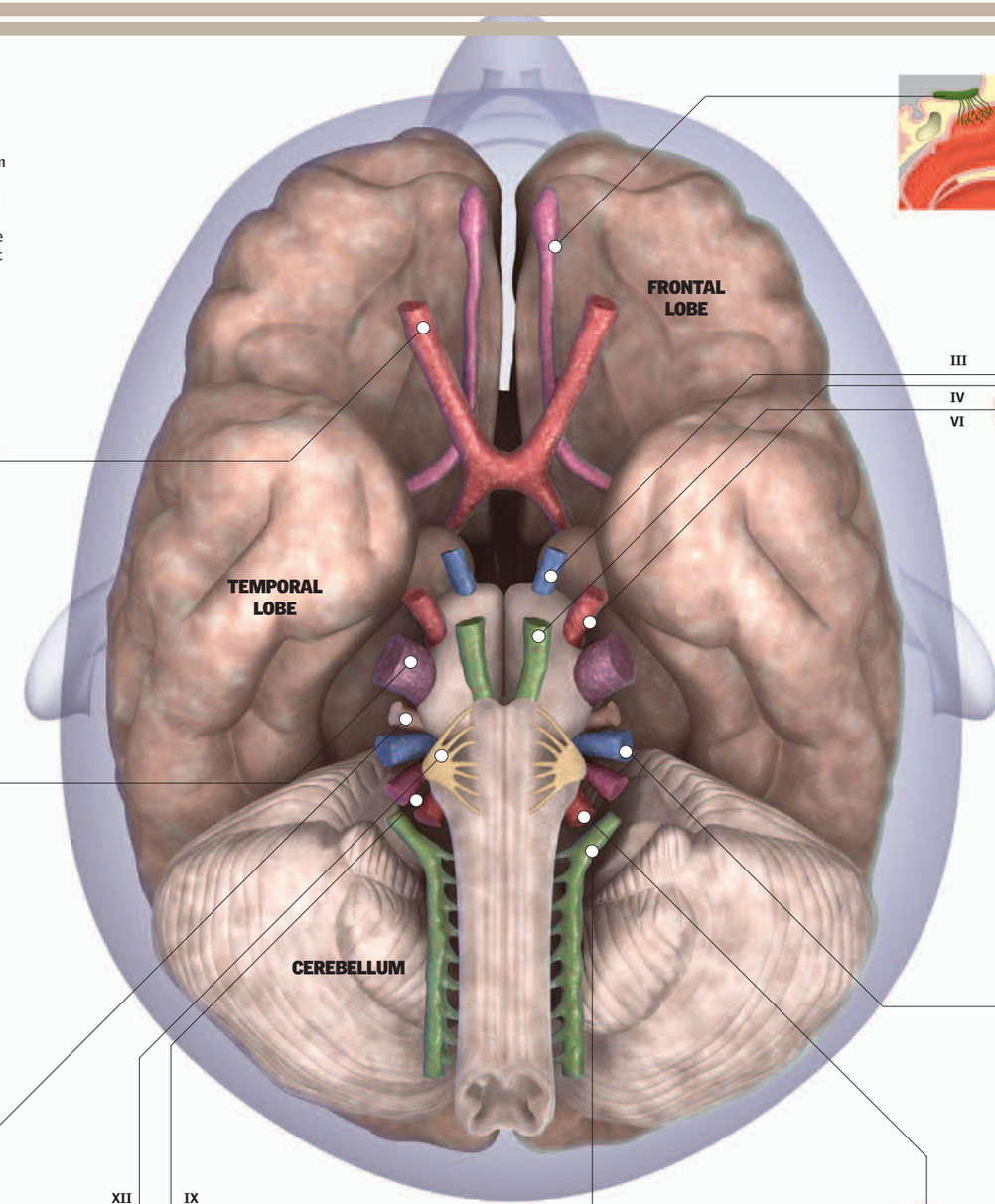
PAIR II
Optic nerve. Supplies the retina. Transmits signals, from the photo receptors, perceived as vision.

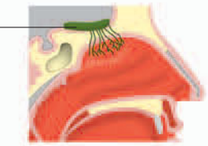


PAIR V
Trigeminal nerve. Controls the muscles involved in chewing and transmits sensory information from the eyes, the teeth, and the side of the face.

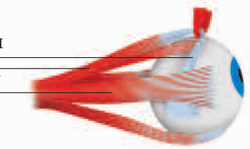


PAIR VII
Facial nerve. Controls the muscles of facial expressions and the salivary and tear glands. Transmits sensory information from the taste buds.





PAIR I
Olfactory nerve. Innervates the internal and upper region of the nose and transmits signals from the olfactory cells that are perceived as the sense of smell.

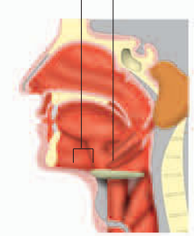


PAIR III
Oculomotor nerve. Controls the movements of the eye and the eyelid. It changes the shape of the pupil and the lens.

PAIR IV
Trochlear nerve. Controls the oblique muscle above the eye.

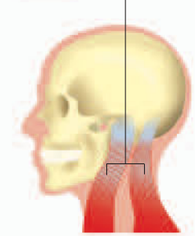
PAIR VI
Abducens nerve. The nerve that moves the external lateral rectus muscle of the eye.

PAIR VIII
The cochlear vestibular nerve. Transmits sensory signals from the inner ear, which are perceived as sound; enables equilibrium.

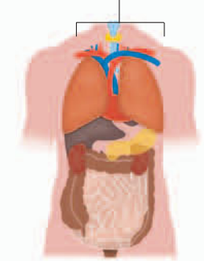


PAIR IX
Glossopharyngeal nerve. Controls the salivary glands and transmits sensory signals from the tongue and the pharynx.

PAIR XII
Hypoglossal nerve. Controls the movements of the tongue.



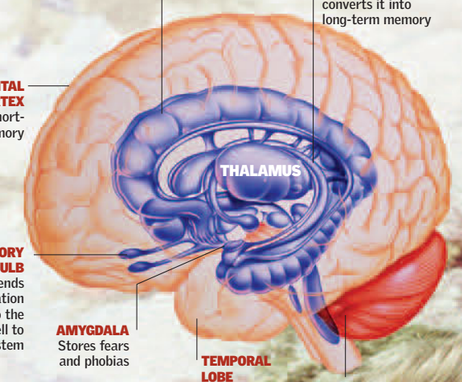
PAIR XI
Accessory nerve. Its function is to control the muscles involved in swallowing and moving the head.



PAIR X
Vagus nerve. Also called the 10th cranial nerve. Among its other functions, it controls the muscles and glands of various internal organs, such as the heart, the lungs, and the stomach.

Dream and Memory

To be able to process the information gathered during the day, the brain takes advantage of periodic dream states. During a dream the brain reduces its activities, and its patterns of thought are disconnected from the external world. The passage from consciousness to dreaming (and from dreaming to consciousness) is the task of neurotransmitters, chemical substances that are manufactured and released from the reticular activator system, a regulator in the cephalic talus, which lies in the brain stem.

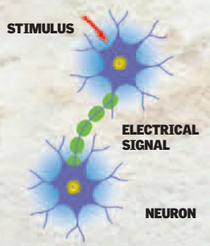


Limbic System

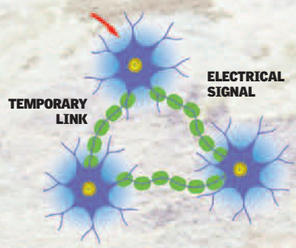
Consists of a complex of structures that wrap around the upper part of the brain stem. These structures control emotions such as annoyance and happiness. They protect us from danger and play an important role in memory formation. For example, the amygdala produces fear when processing danger. The hippocampus permits us to store and remember short-term memories that are brought to the cortex. When the hippocampus is damaged, new memories cannot be incorporated.

Formation of Memory

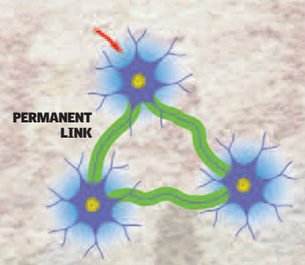
Memory is a set of processes in which unconscious associations are capable of retaining and recording highly varied information. This information can be perceived consciously or unconsciously and ranges from ideas and concepts to sensations that were previously experienced or processed. Memory has many forms, but the two basic ones are the long-term and short-term memory.



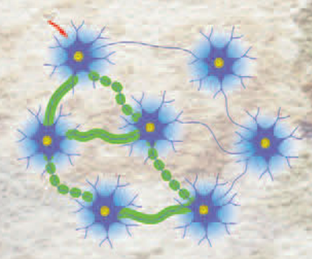
1 CONNECTION. An experience triggers a pattern (or model to be repeated), exciting two neutrons. To form long-term memory the template that was generated earlier by the short-term memory must be replicated. When a stimulus is received, the neuron reacts, sending an impulse to a neighboring neuron.



2 LINK FORMATION. The nerve impulses sent to the neighboring neurons generate a greater capacity for response from the cells that sent the impulses. A temporary union is formed among the cells. In the future, they will be more likely to trigger a nerve impulse together. A neuronal template is beginning to be created.



3 DEEPER LINKS. Every time an event is remembered, a nerve impulse is triggered. As a recollection is repeated, the neurons become more solidly connected. Then the neurons begin to send joint impulses, no matter which was excited first. The development of connections is strengthened with repetition or notable or stressful events.



4 EXPANDING NETWORK. With successive repetition, different groups of neurons begin to form a neuronal network that represents the long-term memory. The more complex the network, the more accessible and durable the memory will be. Each group of neuronal cells represents a different aspect through which one accesses the complete memory.

20 seconds

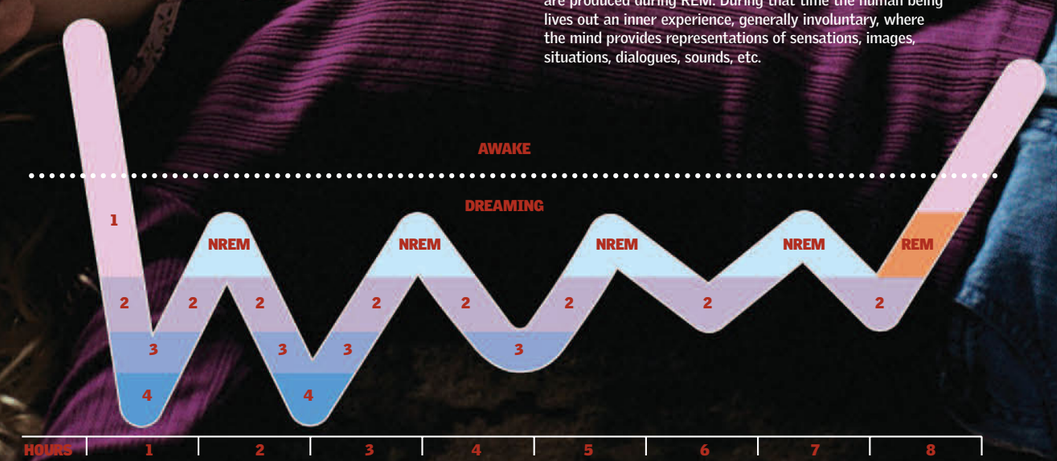
THE TIME AFTER WHICH SHORT-TERM MEMORY LOSES INFORMATION (SUCH AS A TELEPHONE NUMBER) THAT HAS NOT BEEN USED

REM

The acronym for Rapid Eye Movement. The eyes move, though the body is stationary.

Dream Patterns

A pattern is a model that serves as a template, or mold, to obtain the same format. During sleep the two great patterns are REM and NREM, with their four phases. REM sleep is the most enigmatic; it is thought that dreams are produced during REM. During that time the human being lives out an inner experience, generally involuntary, where the mind provides representations of sensations, images, situations, dialogues, sounds, etc.



PHASE 1
Transition between waking and sleeping. The electroencephalograph (EEG), a device that measures cerebral activity, registers alpha waves. The body is relaxed, but if someone disturbs the sleeping person then he or she will wake up.

PHASE 2
Second-phase NREM. The EEG pattern is more irregular. Waking up the person is more difficult.

PHASE 3
Delta waves appear. The vital signs decrease: respiration and the heartbeat slow down, and the body temperature falls.

PHASE 4
Now the dream phase or phase of deep sleep occurs. The delta waves are dominant, and the vital signs drop to minimal levels.

PHASE REM
Rapid Eye Movement. The vital signs increase. The skeletal muscles become inhibited. Dreams enter the scene.

Glossary

Acid
Substance that, in solution, increases the concentration of hydrogen ions and combines with bases to form salts.

Adrenaline
Hormone secreted primarily by the adrenal medulla of the adrenal glands. It constricts blood vessels and is used as a medicine.

Allele
Gene variant that encodes a trait. One diploid cell contains one allele of each parent for each characteristic.

Amino Acid
Organic chemical whose molecular composition includes an amino group (derived from ammonia) and a carboxyl group (a radical that characterizes organic acids).

Antigen
Substance that causes an immune response, such as the production of antibodies, when introduced into the body.

Aorta
Largest artery in the body, originating in the left ventricle of the heart. Down to the diaphragm it is called the thoracic aorta and then the abdominal or ventral aorta to the point where it branches.

Aortic Arch
Curve in the aortic artery near its origin at the heart. The arch has the shape of a shepherd's crook.

Apparatus
Complex of organs that fulfills one function. In the physiology of the human body it is also used as a synonym for system. For example, the digestive apparatus, reproductive apparatus, or respiratory apparatus.

Artery
Blood vessel that brings blood from the heart to the entire body.

Arthroscopy
Surgical procedure used by orthopedic surgeons to inspect, diagnose, and treat problems in the joints. It consists of making a small incision and inserting an arthroscope, an instrument the size of a pencil that contains a small lens and a lighting system to magnify and illuminate the interior. The light is transmitted via fiber optics to the end of the arthroscope, and the interior of the joint can be observed via a miniature television camera.

Articulation
Joint between two bones of the body.

ATP
Adenosine triphosphate. A molecule produced primarily by mitochondria that functions as the primary energy source for the cells.

Atrium
The name for each of the two chambers of the heart that receive blood from the veins.

Basal Metabolism
Activity level of the body functions during rest or while fasting.

Bones
Rigid structures, rich in calcium, that make up the skeleton.

Carpal
The structure of the wrist, composed of eight connected bones arranged in two rows. On the side toward the arm it joins with the cubital and radial bones, and on the side toward the hand it joins with the metacarpal bones.

Cartilage
Flexible skeletal tissue consisting of isolated groups of cells within a collagenous matrix.

Celiac Artery
Artery that brings blood from the heart to the stomach and the other organs of the abdomen.

Cellular Membrane
The flexible covering of all living cells, which contains the cytoplasm. It regulates the exchange of water and gases between the cell and its exterior.

Chromatin
Complex substance in the cell nucleus composed of nucleic acid and proteins.

Cilium
Tiny hairlike protuberance on a cell with a locomotive function in a liquid medium.

Coagulation
Organic process in which the blood turns from a liquid to a solid state and whose normal purpose is to stop bleeding.

Coccyx
Bone formed by the fusion of the last vertebrae. At its base it articulates with the sacral bone. In human beings and other vertebrates that do not have a tail, it is an actual bone.

Coronal
A name given to the frontal bone, located at the anterior and superior part of the cranium. At birth the frontal bone or coronal is divided into two halves, which fuse over time. In medicine this can also refer to a suture that joins the frontal bone with the two parietal bones.

Coronary Arteries
A pair of arteries, originating in the aortic artery, that branch out and supply blood to the heart.

Cortex
The gray material present in most areas of the brain. It is the largest part of the central nervous system. The majority of the most advanced functions occur in the cortex.

Corticoids
Hormonal steroids produced by the adrenal gland cortex. Corticoids can be produced artificially. They have a therapeutic application as anti-inflammatory drugs.

Cystoscope
Apparatus used to explore the inner surface of the bladder.

Cytoplasm
A compartment of eukaryotic cells, bounded by a cellular membrane and the membranes of the cell's organelles.

Diaphragm
Respiratory muscle between the thorax and the abdomen.

Digestion
The set of processes through which the digestive system converts food into substances that can be assimilated by the organism.

Diploid
A cell with two complete sets of chromosomes. It is denoted by the symbol 2n.

Dislocation
The displacement of any bone from its normal position in a joint.

DNA
Deoxyribonucleic acid. A double helix molecule containing encoded genetic information.

Ejaculation
The action of expelling semen.

Embryo
The result of the fertilization of an ovum by a sperm cell. It can develop to become a mature organism.

Emulgent Arteries
Arteries that bring blood from the heart to the kidneys, also called renal arteries.

Endocardium
Membrane that lines the walls of the heart. It consists of two layers: an exterior, consisting of connective tissue, and an interior, of endothelial tissue.

Endometrium
Mucous membrane covering the inner walls of the uterus.

Endoplasmatic Reticulum
Network of membranes in the cell that are interconnected through the cytoplasm and whose function is the synthesis and assembly of proteins.

Endothelial
Organic tissue that lines wall-like structures within the body, such as those of the pleura or of blood vessels.

Enzyme
Protein that helps regulate the chemical processes within a cell.

Erythropoiesis
The creation of red blood cells, stimulated by the action of a protein called erythropoietin.

Follicle
Inward fold of the epidermis in the form of a sac, which usually surrounds the base of a hair.

Gene
Unit of information of a chromosome; it is a sequence of nucleotides in a DNA molecule that fulfills a specific function.

Gland
Organ that has the function of producing secretions that can be expelled through the skin or mucous membranes (salivary glands or sweat glands, for example) or into the bloodstream (the thyroid, for example).

Haploid
From the Greek *haplous*, meaning single. A haploid cell has a single set of chromosomes, unlike the diploid cells. Gametes are haploid.

Hemostatic
Substance or agent that halts hemorrhaging.

Hippocampus
Part of the brain that governs the memory.

Holocrine
Gland with an exclusively secretory function or whose secretion consists of disintegrated cells of the gland itself, such as the sebaceous glands.

Homeostasis
Complex of self-regulatory phenomena that keep the composition and the properties of the body's internal environment constant. It is said that homeostasis is reached when the body's internal environment contains the optimum concentrations of gases, nutrients, ions, and water; when

its temperature is optimum; and when the volume of fluids is optimum for the life of the cells.

Hormone

The product of the glandular secretion whose function is to stimulate, inhibit, or regulate the action of other glands, systems, or organs of the body.

Innominate Bones

A pair of bones, one in each hip, which join the sacrum and the coccyx to form the pelvis. They consist of the fusion of the iliac, the ischium, and the pubic bones.

Lobes

Rounded protuberances of organs, such as the liver, the lungs, or the brain.

Lysosome

Protein that can break down the constituent substances of the walls of certain bacteria and is, hence, a potent antibacterial.

Meiosis

Type of cell division in which two successive divisions of the nucleus of a diploid cell create four haploid nuclei. As a result of this mechanism, gametes or spores are produced.

Meristem

Tissue with cells that produce other cells by cellular division.

Metabolism

Complex of chemical reactions that take place continuously within cells to synthesize complex substances from simpler substances or to degrade a substance into simpler substances. An example is the digestive process.

Metacarpal

Middle part of the skeletal structure of the hand, between the wrist (carpal bones) and the phalanges. It consists of five bones, which are the largest bones of the hand.

Metatarsal

Part of the skeletal structure of the foot, between the tarsus (posterior part of the foot) and the phalanges (toes). It consists of five bones and is usually called the sole of the foot.

Micturition

Act of urinating, or expelling urine.

Mitochondria

Organelle that has a double membrane. The final stage of the aerobic respiration process takes place in mitochondria, where ATP is obtained by breaking down sugars and other substances.

Mitosis

Nuclear division in a cell that forms daughter nuclei identical to the parent.

Mucous Membrane

Covering of body cavities that communicate with the exterior (such as the nose). A mucous membrane contains numerous single-celled glands that secrete mucus.

Muscles

Organs composed of fibers capable of contracting.

Myocardium

Muscular part of the heart, between the pericardium and the endocardium.

Nucleic Acid

Molecule that carries genetic information about the cell. There are two types: DNA and RNA.

Nucleus

The part of the cell that contains the DNA with its genetic information.

Organ

Any part of the body that accomplishes a function.

Osmosis

Movement of a liquid through a selectively permeable membrane.

Papillae

Conical protuberances, usually sensory, formed on the skin or mucous membranes (especially the tongue) by the branching of nerves and blood vessels.

Pericardium

Pair of membranes that surround the heart.

Phagocytes

Cells found in blood and tissue. They capture bacteria or any other kind of noxious particles and "phagocytize," or "eat," them, absorbing them into their cytoplasm and later digesting them.

Phalanges

Bones of the fingers and toes. They extend to the metacarpal bones in the hand and the metatarsals in the foot. Starting from the metacarpals and the metatarsals, they are sequentially numbered: first, second, and third phalanges (of each finger or toe). The word "phalanges" commonly designates the first phalanges, or each of the jointed parts of the fingers or toes.

Physiology

Study of the functions of the organism.

Polymer

Macromolecule consisting of repeated structural units, called monomers.

Popliteus

Section of the leg opposed to, or behind, the knee.

Protein

Substance that makes up the cells. It is a biopolymer consisting of one or several chains of amino acids, fundamental for the constitution and functioning of living material, such as enzymes, hormones, and antibodies.

Ranine Artery

Artery that branches out toward the front of the tongue.

Respiration

The act and effect of inhaling air, primarily through the nose, to take in the substances that the body requires, such as oxygen, and after processing them exhaling unneeded substances, such as carbon dioxide.

Ribosome

Organelle located in the cytoplasm that governs the formation of proteins based on information provided by the nucleic acids.

Ribs

Long and curved bones. They originate at the back of the body at the spinal column and curve forward. They are called "true" if they end at the sternum and "false" if they remain floating without completely enclosing the rib cage.

Schwann Cells

Cells that produce myelin, a fatty insulating substance that prevents electrical signals from losing strength as they move away from the body of the neuron.

Semen

The spermatozoa and fluids produced in the male genital organs. It is often called sperm.

Sensation

Physiological process of receiving and recognizing stimuli produced by vision, hearing, smell, taste, touch, or the body's spatial orientation.

Sleep

State of repose characterized by inactivity or suspension of the senses and voluntary motion. The cerebral activity called dreaming takes place during sleep.

Spinal

Relating to the spine.

Spinal Bulbar

Part of the cerebral trunk that goes from the annular protuberance to the cranium's occipital foramen.

Spine

The neuroskeletal axis that runs along the medial dorsal of the body and consists of a series of short bones called vertebrae, which are arranged in a column and jointed with each other.

Sternum

Bone of the anterior thorax, which joins the front of the ribs.

Striated Muscle

Muscle used for voluntary motion. Its muscle fibers show striations, or grooves.

Subclavian Arteries

Pair of arteries, one of which branches off from the brachiocephalic trunk (on the right side of the body) and the other from the aortic arc (on the left). They run toward the shoulder on each side and, after passing below the clavicle, become the axillary artery.

System

Complex of organs that participates in any of the principal functions of the body. A synonym of "apparatus."

Tarsal

The skeletal structure of the leg between the foot and the metatarsal. It consists of seven bones that constitute the posterior part of the foot.

Tissue

Group of identical cells that together accomplish a function.

Uterus

Hollow viscera of the female reproductive system. It is located inside a woman's pelvis. In the uterus, or womb, either menstrual fluid is produced or a fetus develops until it is born.

Veins

Blood vessels that bring blood from the entire body toward the heart.

Ventricles

Cavities of the heart that receive blood from their respective atrium (right or left) and pump it through the arteries.

Viscera

Organs located in the principal cavities of the body (such as the stomach or the liver within the abdominal cavity).

Vitamins

Organic substances present in food. The body ingests them to ensure the balance of various vital functions. There are different kinds of vitamins, designated with the letters A, B, C, etc.

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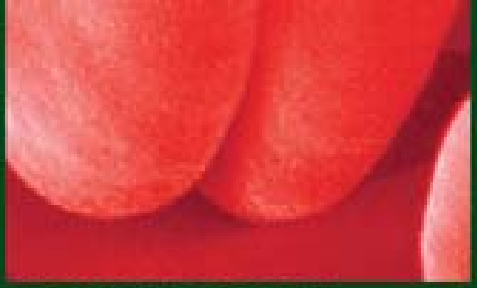

HUMAN BODY I

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