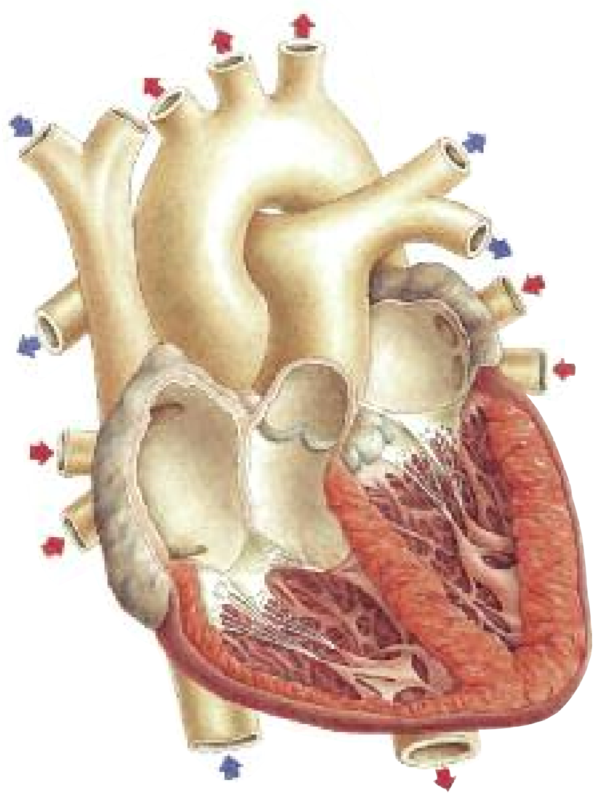
children's illustrated encyclopedia

The Human Body



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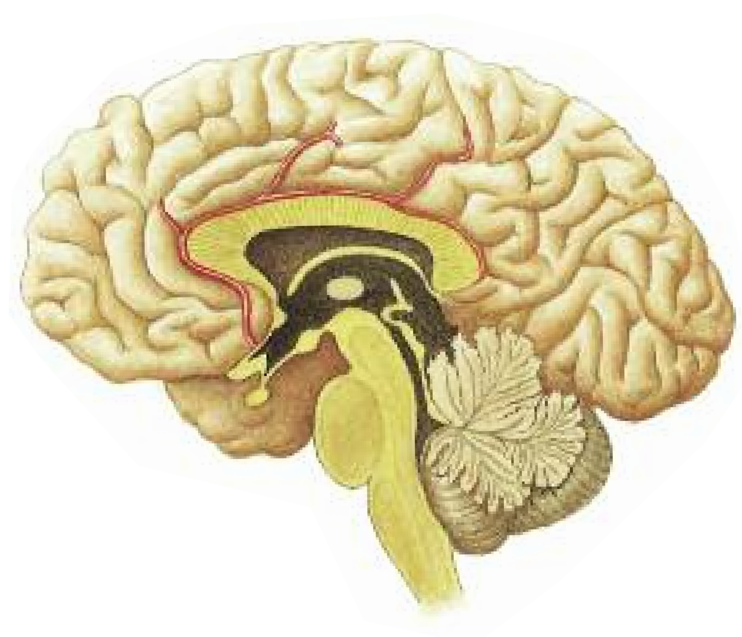


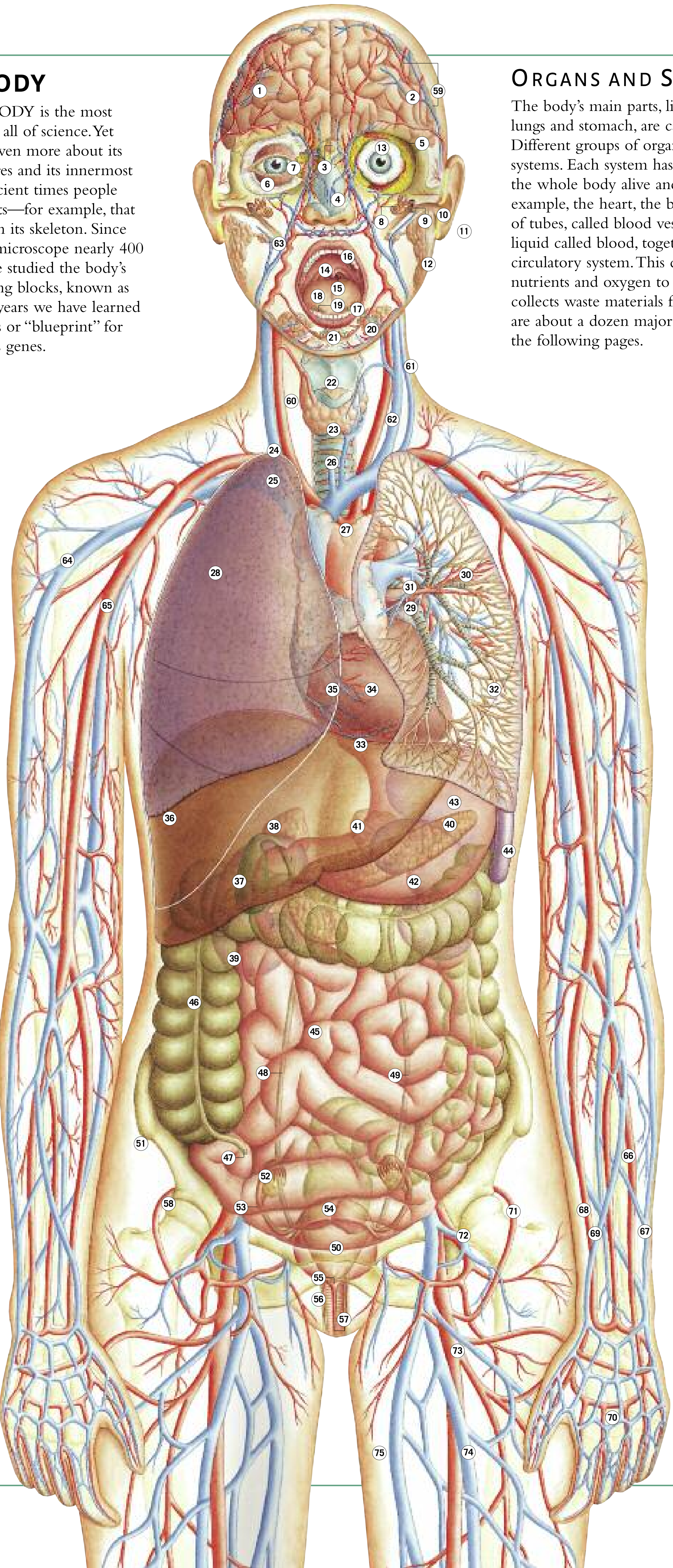
Contents

Human Body

THE HUMAN BODY is the most studied object in all of science. Yet every year we learn even more about its most detailed structures and its innermost workings. Even in ancient times people have known basic facts—for example, that there are 206 bones in its skeleton. Since the invention of the microscope nearly 400 years ago, people have studied the body's billions of tiny building blocks, known as cells. In more recent years we have learned about the instructions or "blueprint" for making the body—its genes.

Organs and Systems

The body's main parts, like the brain, heart, lungs and stomach, are called organs. Different groups of organs work together as systems. Each system has a vital job to keep the whole body alive and healthy. For example, the heart, the body-wide network of tubes, called blood vessels, and the red liquid called blood, together form the circulatory system. This carries essential nutrients and oxygen to all body parts and collects waste materials for disposal. There are about a dozen major systems, shown on the following pages.



KEY

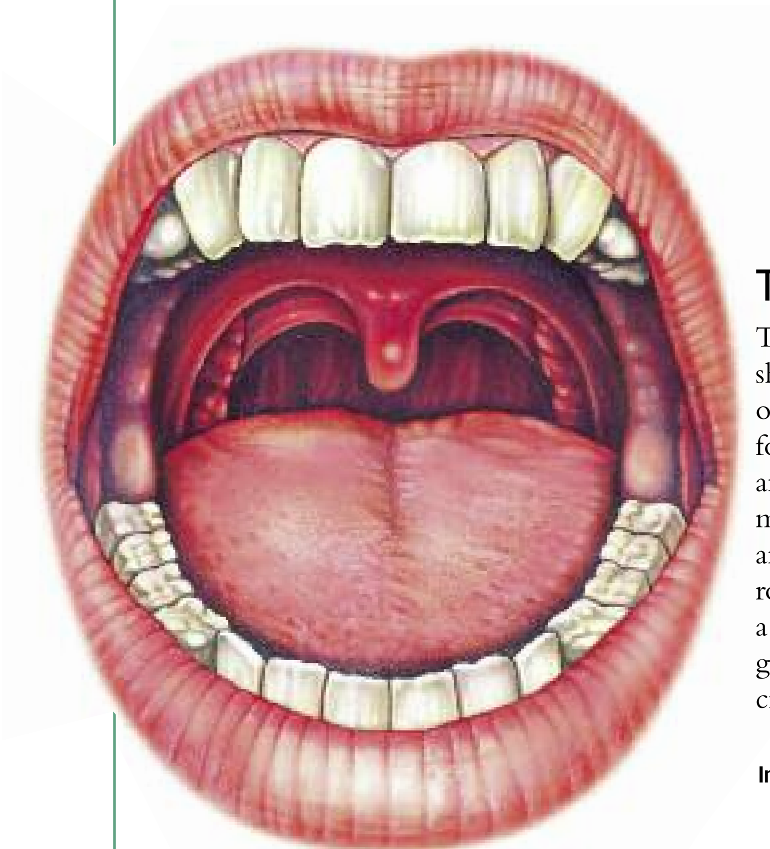
1 *Right cerebral hemisphere of brain*
2 *Left cerebral hemisphere of brain*
3 *Pituitary gland*
4 *Nose cartilage*
5 *Tear gland*
6 *Eyelid muscle*
7 *Eye orbit (socket)*
8 *Inner ear*
9 *Eardrum*
10 *Outer ear canal*
11 *Outer ear*
12 *Parotid salivary gland*
13 *Eyeball muscles*
14 *Tonsils*
15 *Uvula*
16 *Upper teeth*
17 *Lower teeth*
18 *Tongue*
19 *Sublingual salivary gland*
20 *Submandibular salivary gland*
21 *Hyoid bone*
22 *Larynx (voice box)*
23 *Thyroid gland*
24 *Apex of lung*
25 *Lung surface*
26 *Trachea (windpipe)*
27 *Thymus gland*
28 *Right lung*
29 *Bronchus (main airway) of left lung*
30 *Pulmonary arteries to left lung*
31 *Pulmonary veins from left lung*
32 *Bronchioles of left lung*
33 *Diaphragm*
34 *Heart*
35 *Coronary blood vessels of heart*

KEY *continued*

36 *Liver*
37 *Gall bladder*
38 *Right adrenal gland*
39 *Right kidney*
40 *Pancreas*
41 *Left adrenal gland*
42 *Left kidney*
43 *Stomach*
44 *Spleen*
45 *Small intestine*
46 *Large intestine*
47 *Appendix*
48 *Right ureter*
49 *Left ureter*
50 *Bladder*
51 *Hip bone (pelvis)*
52 *Ovary*
53 *Oviduct or egg duct (fallopian tube)*
54 *Womb (uterus)*
55 *Cervix (neck of womb)*
56 *Vagina*
57 *Urethra*
58 *Hip joint*
59 *Cerebral arteries and veins*
60 *Carotid artery*
61 *Internal jugular vein*
62 *External jugular vein*
63 *Facial arteries and veins*
64 *Cephalic vein*
65 *Brachial artery and vein*
66 *Ulnar artery*
67 *Ulnar vein*
68 *Radial artery*
69 *Radial vein*
70 *Palmar arteries and veins*
71 *Iliac artery*
72 *Iliac vein*
73 *Femoral artery*
74 *Femoral vein*
75 *Great saphenous vein*

DIGESTION I

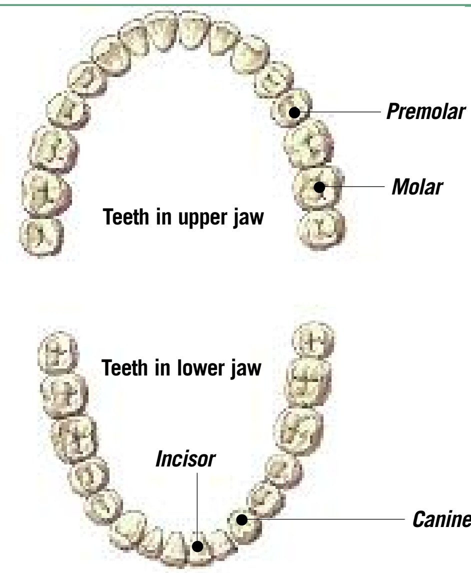
THE BODY NEEDS energy to power its chemical life processes. It also needs raw materials for maintenance, growth and repair. The energy and raw materials are in our food. Digestion is the process of taking in, or eating, food and breaking it down into tiny pieces, small enough to pass into the blood and be carried all around the body. The parts that take in and break down food are known as the digestive system.



The mouth is the entrance to the digestive system. Here, food is chewed and moistened.

INSIDE THE MOUTH

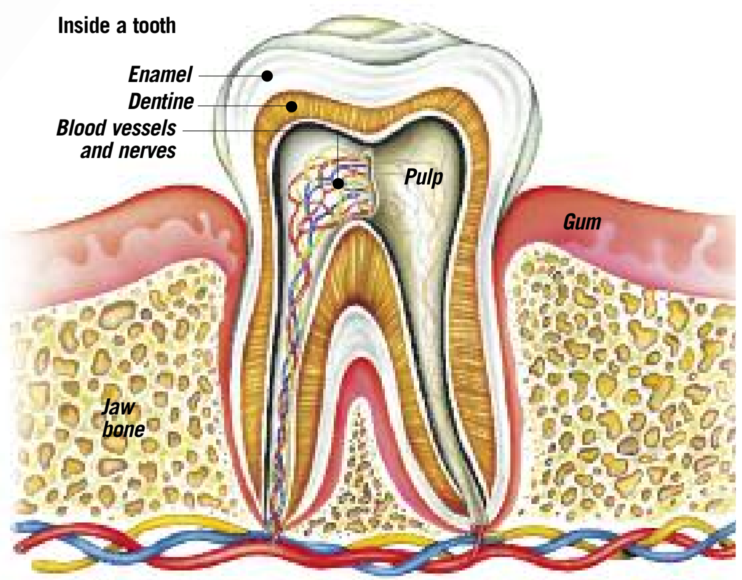
The teeth cut off and chew pieces of food into a soft pulp. Saliva (spit) makes the food moist and slippery, for easy swallowing. The tongue tastes the food, to make sure it is not bad or rotten, and moves it around in the mouth, for thorough chewing. The lips seal at the front of the mouth to stop food and drink dribbling out during chewing.

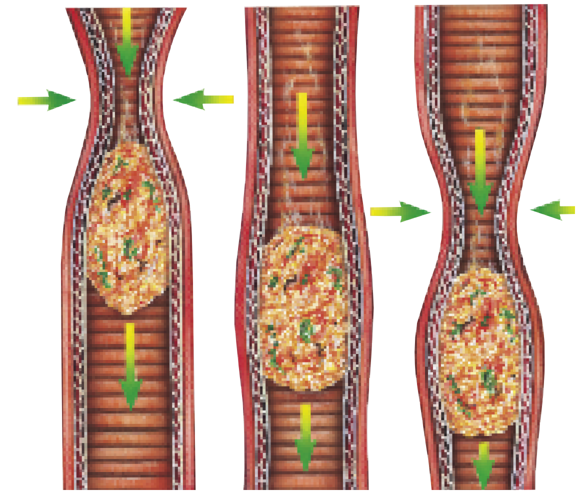


An adult person has 32 teeth. There are four incisors at the front of each jaw. Behind these on each side are one canine, two premolars and three molars.

TEETH

There are four main kinds of teeth. The sharp-edged, chisel-like incisors at the front of the mouth slice and cut pieces from large food items. The taller, pointed canines tear and rip tough food. The premolars and molars at the back of the mouth squeeze and crush the food. Each tooth has a long root that fixes it firmly in the jaw bone, and a crown that sticks up above the soft, pink gum. The whitish enamel covering the crown is the hardest substance in the body.

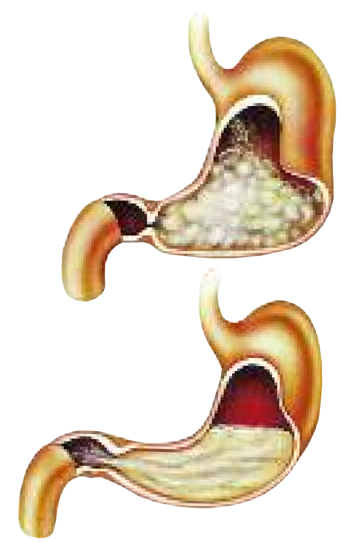




Food is pushed down the oesophagus and through the stomach and intestines by waves of muscular squeezing (peristalsis).

OESOPHAGUS AND STOMACH

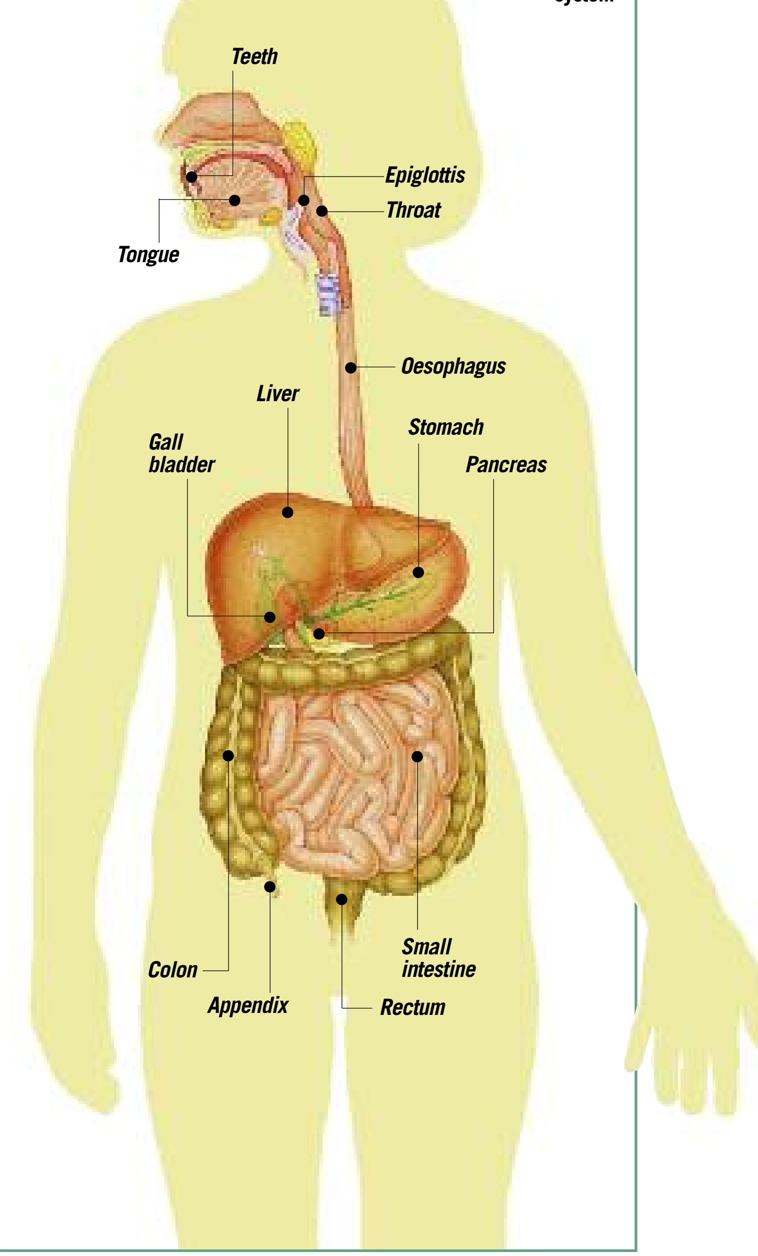
Swallowed food is squeezed down the oesophagus by wave-like muscular contractions of its wall, called peristalsis. The food enters the stomach, a J-shaped muscular bag. This expands like a balloon to hold about three litres of food and drink. It churns up the food, mixing in its strong digestive juices to break it into smaller and smaller particles. An average meal takes between three and six hours to be digested in the stomach. If the food is bad or unsuitable in some way, peristalsis works in reverse and pushes it up and out of the mouth, a process called vomiting.

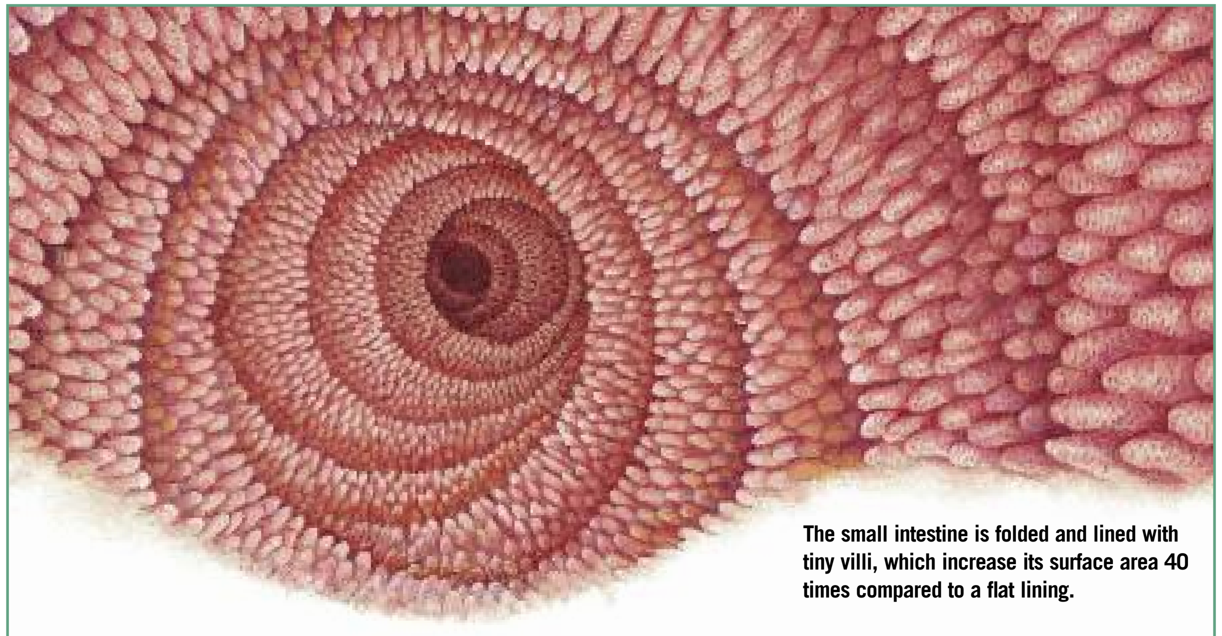


The stomach stretches as it fills with food, then digests the food by physical and chemical processes. The muscular walls of the stomach writhe and squirm to squash and pulverize the food physically. Also, the lining of the stomach makes powerful digestive juices, including acids and enzymes. These pour on to the food and mix with it, to dissolve it chemically. The result is a creamy soup called chyme. This oozes slowly into the next part of the digestive system, the small intestine.

Two large organs aid the process of digestion. The pancreas gland is wedge-shaped and lies behind the stomach on the left. It makes strong digestive juices that flow along a tube, the pancreatic duct, into the small intestine. These juices dissolve the food further. The other organ is the liver *(see page 8)*, in front of the stomach on the right. It makes a yellow-green liquid, bile. This is stored in the gall bladder and then added to the food in the small intestine, to help digest fatty foods.

The main parts of the digestive system

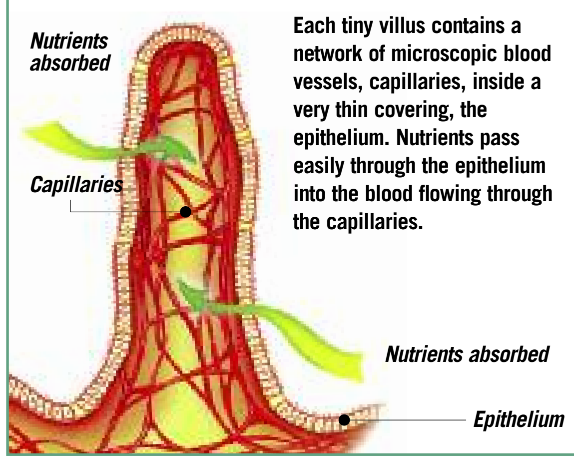




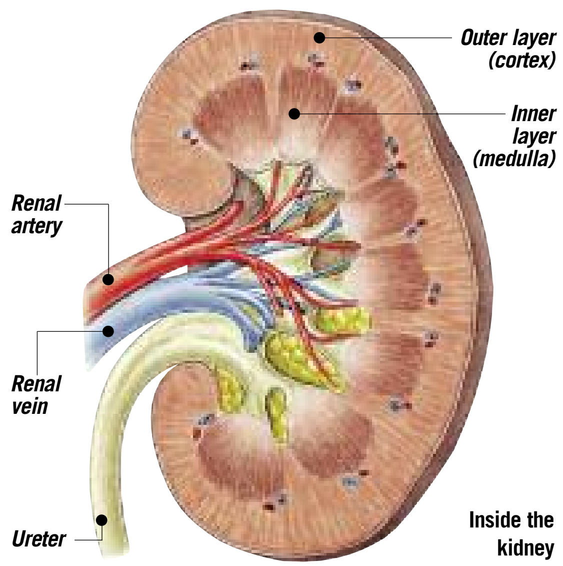
The small intestine is folded and lined with tiny villi, which increase its surface area 40 times compared to a flat lining.

Digestion II

THE ENTIRE digestive system, from the mouth to the anus, is about nine metres long. Looped and coiled into the lower abdomen *(see page 7),* the **small intestine** makes up two-thirds of this length. Digestive juices from the small intestine's lining are added to the food to complete its chemical breakdown. The resulting nutrients are so small that they can pass through the lining into the blood, to be carried away to the **liver.** The liver acts as a kind of food processor, making new chemicals from the nutrients it receives and storing them until they are required. Those substances the body does not need, including impurities in the blood, it sends on to the kidneys.



Each tiny villus contains a network of microscopic blood vessels, capillaries, inside a very thin covering, the epithelium. Nutrients pass easily through the epithelium into the blood flowing through the capillaries.



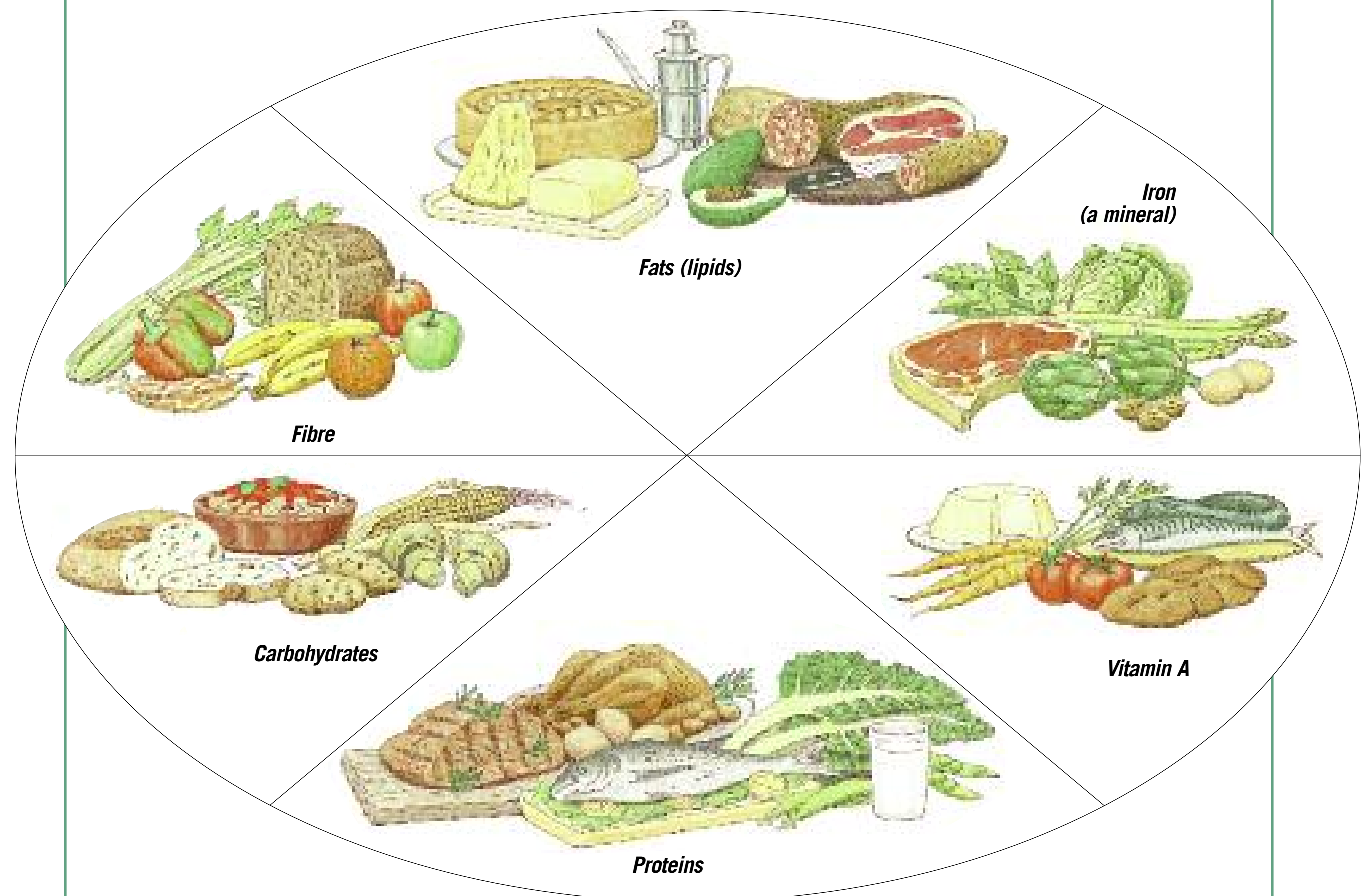
Inside the kidney

The Kidneys

The two kidneys receive a very large flow of blood—more than one litre per minute. It passes through about one million microscopic filtering units, called nephrons, packed into the outer layer of each kidney. The nephrons remove waste substances and excess water from the blood. These flow through the kidney's inner layer, where some water is taken back into the blood according to the body's needs. The resulting liquid waste is called urine. It dribbles down a tube, the ureter, to a stretchy bag in the lower abdomen, the bladder. It is stored here until it can be passed to the outside.

Nutrients

THE BODY NEEDS a wide range of nutrients to stay healthy. There are six main groups of nutrients—proteins, fats, carbohydrates, vitamins, minerals and fibre. Different kinds of foods are rich in different groups *(see illustration below)*. Proteins are found in meat, poultry, fish, milk, beans and green vegetables. They help to build and maintain muscles and other body parts, so they are important for growth. Fats (lipids) are found in meat, dairy products, pies, and some oily fruits and vegetables like avocado, olive and sunflower seeds. Small amounts are needed to build the walls around the body's microscopic cells, and also for healthy nerves. Carbohydrates such as starches and sugars are found in bread, pasta, rice and other grains, and potatoes. They are the main source of energy for movement, digestion and other life processes.



Vitamins and Minerals

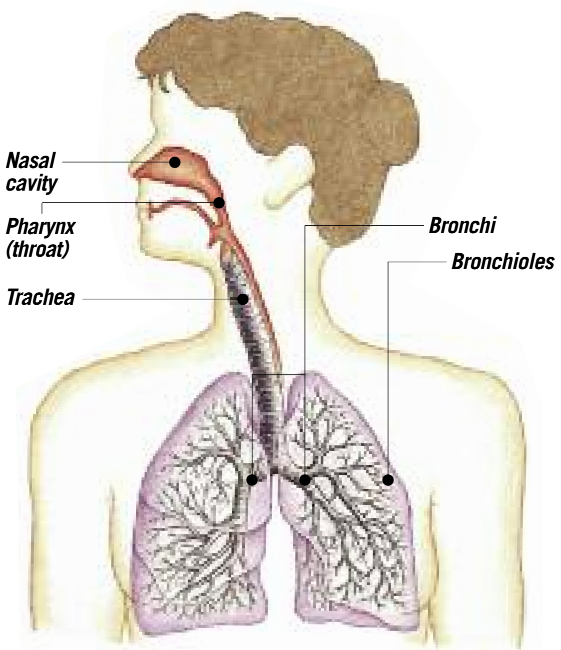
Many vitamins and minerals are needed for good health, but usually in small amounts. Vitamins have letters such as A, B and C. Lack of a vitamin may cause illness. For example, lack of vitamin A from tomatoes, carrots, cheese, fish and liver may result in poor eyesight. Minerals include calcium and iron. Iron is found in meat, green vegetables and nuts. It is needed for healthy blood. Its lack causes a type of anaemia.

Fibre

Fibre is found only in plant foods, chiefly in breads, pastas and other products made from wholemeal grains or cereals, and also in many fresh fruits and vegetables. Fibre is not actually digested and absorbed by the body, but it helps the digestive system to work effectively and stay healthy. It adds bulk to the food so that the stomach and intestines can grip and squeeze the food along.

Breathing

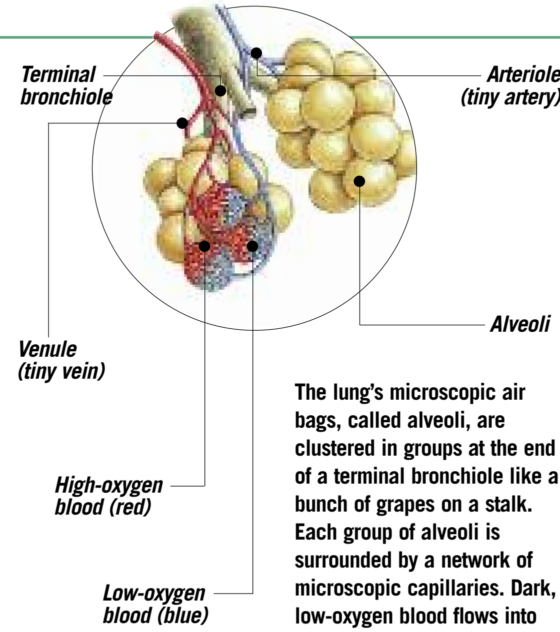
THE BODY needs continual supplies of oxygen. This invisible gas makes up about one-fifth of the air around us. It is needed for chemical processes inside the body's cells *(see page 24)* that release energy from food. Breathing draws air into the body so that oxygen can be absorbed.



The two lungs almost fill the chest. Air passes into them along the trachea. This divides at its base into two tubes, the primary bronchi, one to each lung.

Respiratory System

The respiratory system draws fresh air into the body, absorbs the vital oxygen from it into the blood, and then passes the stale air out again. The main parts of the system where oxygen is absorbed are the **lungs.** Breathing muscles stretch the lungs to make them larger and suck in air. These muscles are the diaphragm below the lungs, and the intercostal muscles between the ribs (*right*). Fresh air passes in through the nose and mouth, down the pharynx (throat) and trachea (windpipe), into the lungs. The lung airways, called bronchi, divide many times and become thinner, ending in terminal bronchioles, narrower than human hairs.

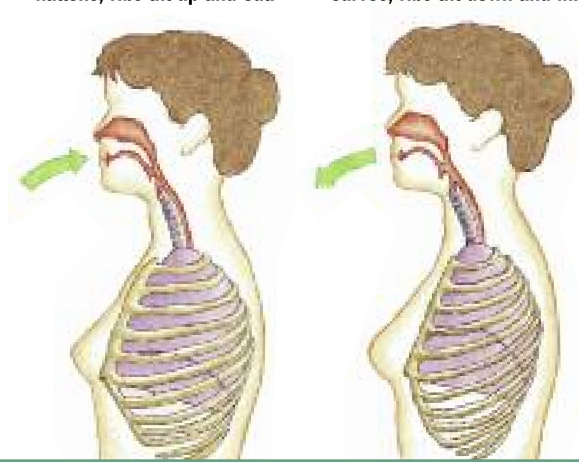


The lung's microscopic air bags, called alveoli, are clustered in groups at the end of a terminal bronchiole like a bunch of grapes on a stalk. Each group of alveoli is surrounded by a network of microscopic capillaries. Dark, low-oxygen blood flows into the capillaries. It takes in oxygen from the air inside the alveoli, and becomes bright red, high-oxygen blood.

Each terminal bronchiole ends in a cluster of microscopic air bubbles, called alveoli. There are about 300 million **alveoli** in each lung, giving the whole lung a spongy texture. Besides fresh air, the lungs also receive low-oxygen blood from the heart along the pulmonary arteries. These divide and form networks of microscopic blood vessels (capillaries) around the alveoli. Oxygen from the air inside the alveoli passes easily through the thin walls of the alveoli and capillaries into the blood. This high-oxygen blood returns along pulmonary veins to the heart.

Breathing in—diaphragm flattens, ribs tilt up and out.

Breathing out—diaphragm curves, ribs tilt down and in.



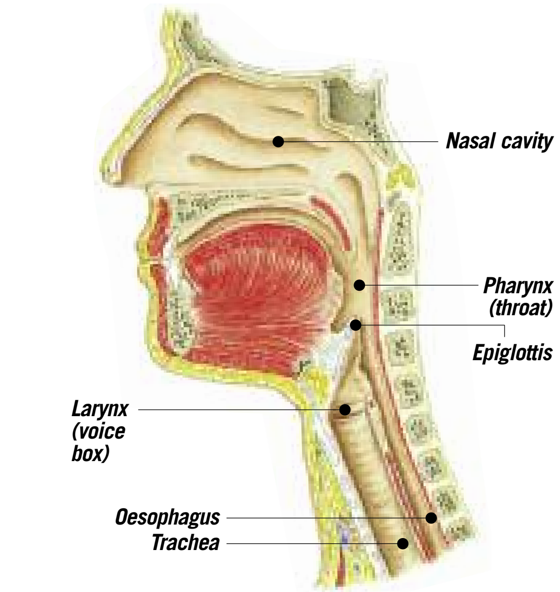
Breathing Rate

As oxygen passes from the air in the alveoli into the blood, the waste substance carbon dioxide passes the opposite way, from the blood into the air. This stale air is then pushed out of the lungs when the breathing muscles relax and the stretched lungs spring back to their smaller size. At rest, an adult person breathes in and out about 12 times each minute. Each breath is around half a litre of air. After running a race, a person may breathe 60 times each minute and take in more than two litres of air each time, to obtain extra oxygen for the active muscles.

Unlike fish, people cannot breathe under water. Scuba divers carry their own air supply. The air in the tanks is compressed so that a lot fits into a small space.

Cleaning the Lungs

The lungs are delicate and easily damaged. Hairs in the nose filter bits of floating dust and other particles from air as it is breathed in. The airways are lined by sticky mucus which traps dirt and dust. Microscopic hairs, called cilia, line the smaller airways. They sweep mucus and trapped dirt into the throat, where it can be swallowed.

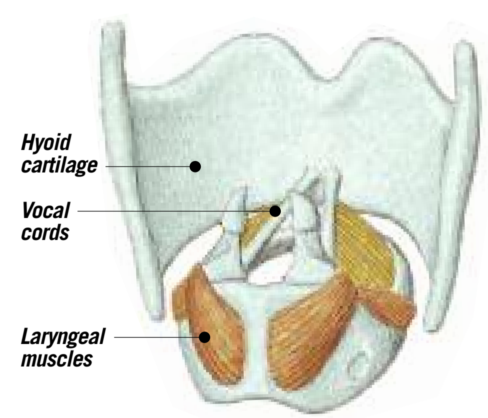


The voice box is at the top of the trachea, where it joins the lower throat. It is a box shape made of plates of cartilage (gristle).

Speech

Air emerging from the lungs not only carries waste carbon dioxide. It has another use—speech. At the top of the trachea is the **larynx** (voice box). This has a shelf-like fold of cartilage projecting from each side, known as the vocal cords. To speak, muscles pull the vocal cords together so that there is only a very narrow slit between them. Air rushing through the slit makes the cords shake or vibrate, which produces sounds. These sounds are shaped into clear words by movements of the mouth, cheeks, teeth, tongue and lips.

Muscles stretch the vocal cords longer and tighter to make higher-pitched sounds.



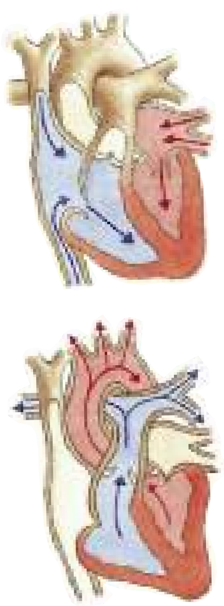
HEART

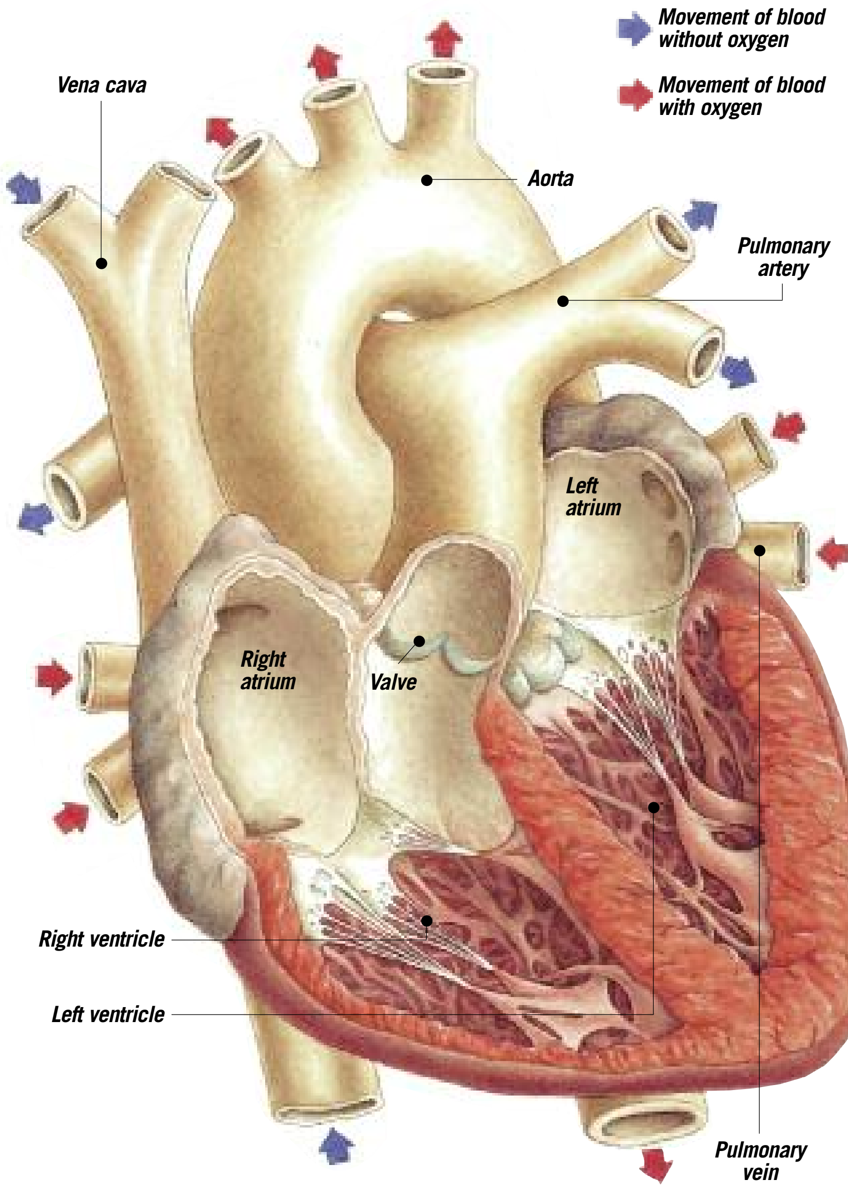
ALL THE MUSCLES and tissues that make up the body must be continually supplied with food and oxygen. This job is carried out by the blood circulatory system.

The heart lies at the centre of the circulatory system and pumps the blood around the body. About the size of your fist, it is an incredibly strong organ, made entirely of muscle. It beats more than two billion times during the average life span of a person and pumps about 340 litres of blood every hour—enough to fill a car's petrol tank every seven minutes.

Blood containing fresh oxygen travels from the lungs to the heart through the pulmonary veins. At the same time, blood with very little oxygen left in it returns to the heart along veins from the muscles and tissues. The heart pumps the fresh blood to the rest of the body and the exhausted blood to the lungs. It pumps the blood at high pressure so that it can travel upwards to the head—against gravity—as well as downwards. You can feel this pumping action by placing your fingers on the inside of your wrist or the side of your neck, both points where a main artery lies close to the surface of your skin.

The heart has four chambers (left and right atria, left and right ventricles). Flaps, called valves, slam shut to prevent blood leaking back once it has entered each chamber (this is the heartbeat you can hear in someone's chest). Blood arrives in the heart through the pulmonary veins from the lungs *(shown in red in the diagrams below)*, and through the vena cava from the rest of the body *(shown in blue)*. The heart then squeezes inwards and the blood is pushed out. Some travels along the pulmonary arteries to the lungs; the rest passes through the aorta to the body.

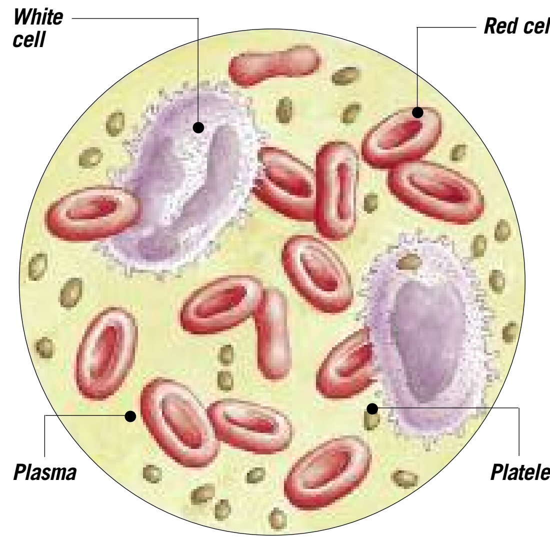




BLOOD

PUMPED by the heart, blood collects oxygen from the lungs and dissolved food from the liver and delivers it to all parts of the body. It also clears away waste, helps cool the body when it overheats, clots when the skin is damaged and protects against invading bacteria and viruses.

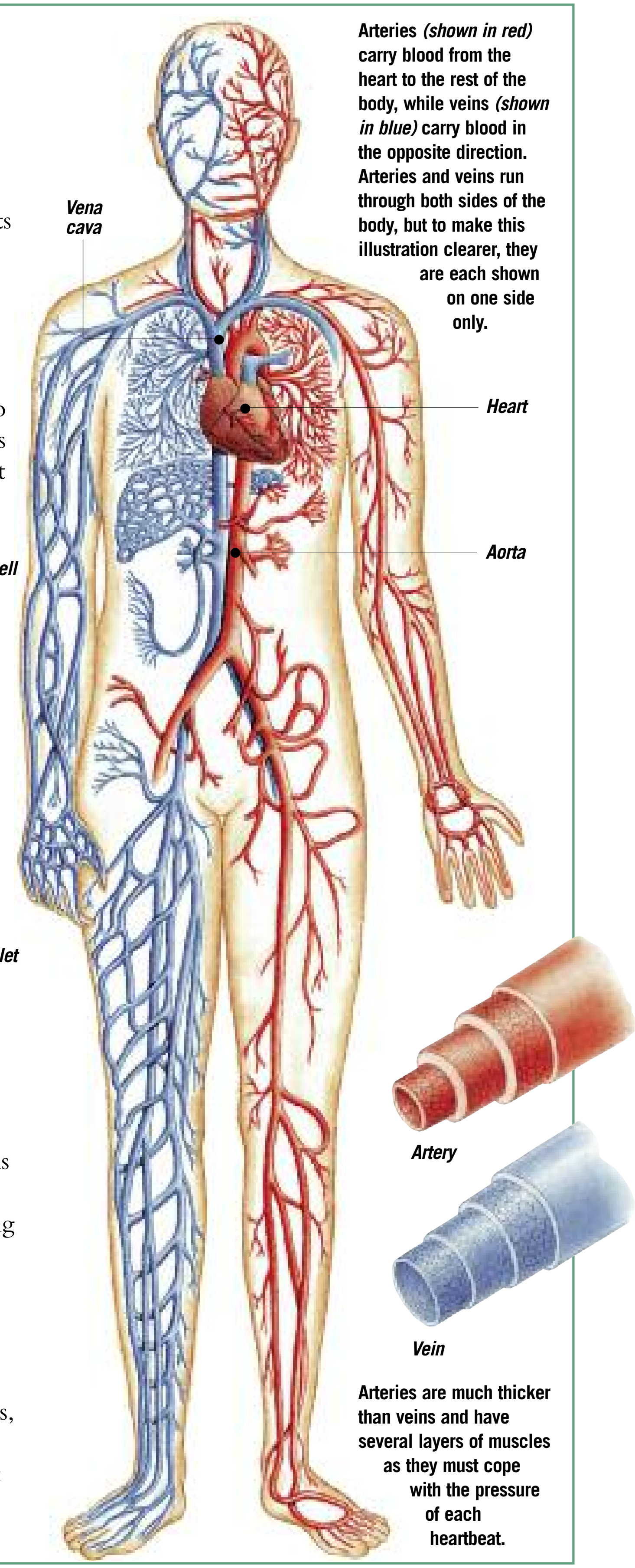
The **veins** and **arteries** in your body look like a page in a road atlas. There are motorways, the main blood-carrying tubes or vessels, which lead out from the heart to the limbs and the head. There are also lanes and tracks, tiny vessels called capillaries that reach all the cells in the body.



Seen under a very powerful microscope, blood is made up of a number of cells. A drop of blood the size of a pinhead would contain about 5 million red cells.

Blood is made up of millions of tiny cells floating in a yellowish, watery fluid called plasma. There are red cells, used for carrying oxygen, white cells, which fight any infection by invading bacteria or viruses, and platelets, which make the blood clot when a vessel is damaged, so sealing the wound. Different kinds of white cell work together to protect you from disease: T-cells, which identify invaders; B-cells, which make deadly proteins called antibodies that surround the invaders; and macrophages, which swallow them up and destroy them.

Arteries *(shown in red)* carry blood from the heart to the rest of the body, while veins *(shown in blue)* carry blood in the opposite direction. Arteries and veins run through both sides of the body, but to make this illustration clearer, they are each shown on one side only.



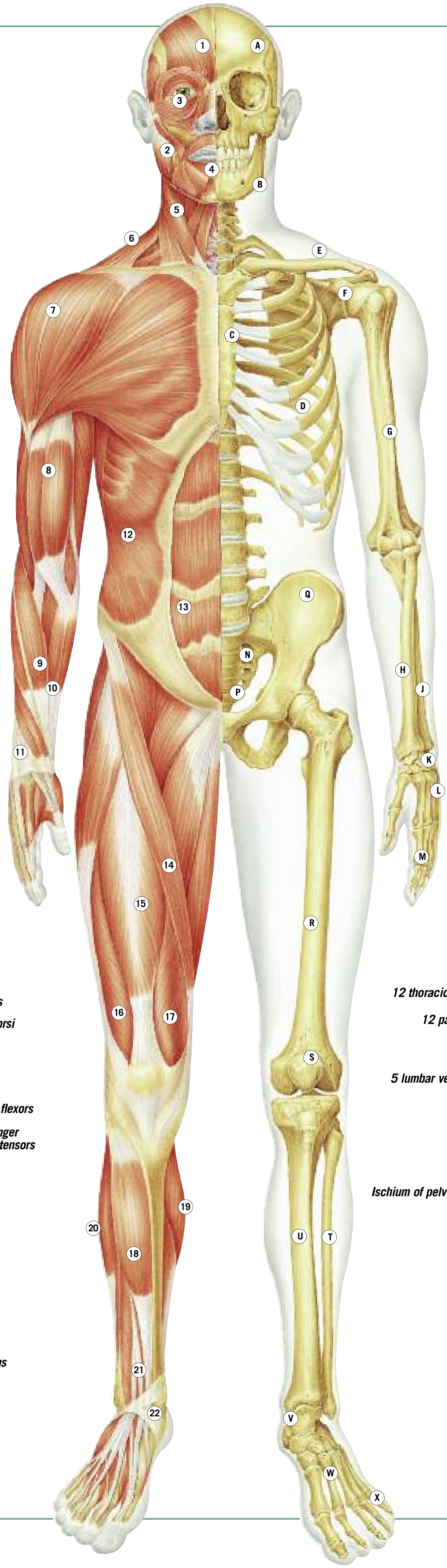
Arteries are much thicker than veins and have several layers of muscles as they must cope with the pressure of each heartbeat.

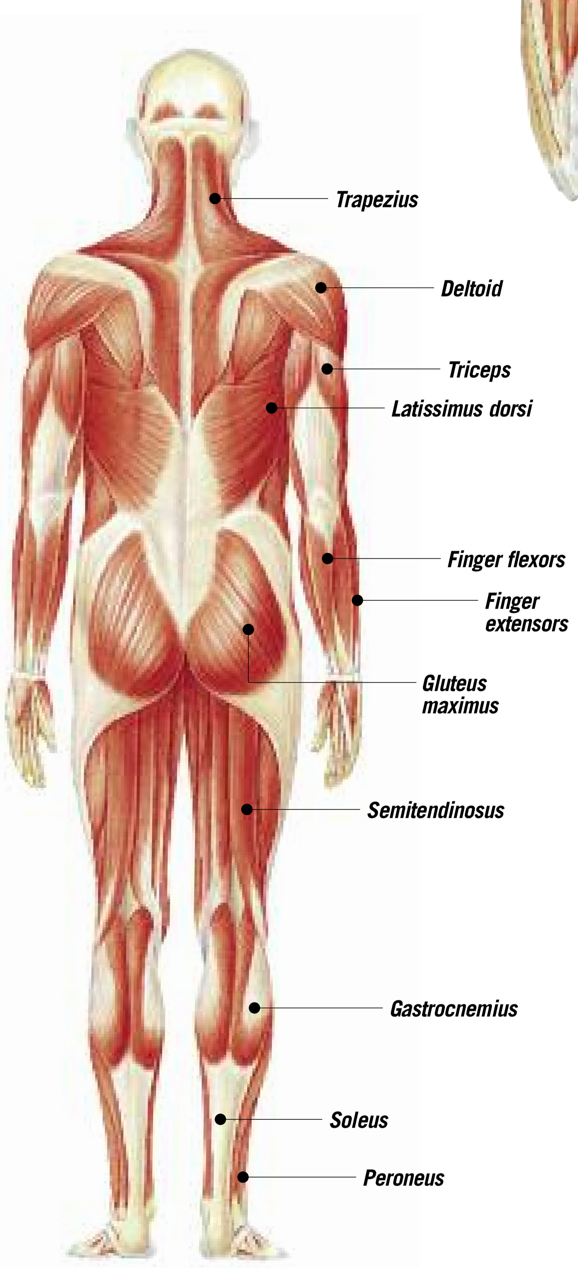
Muscles

ABOUT TWO-FIFTHS of the body's weight is made up by its muscles—some 640 of them. Most are attached to the bones of the skeleton and pull on them to make the body move. In each part of the body the muscles are in two main layers. There are superficial muscles just under the skin and deep muscles lying below them next to the bones.

MUSCLE KEY

1 *Frontalis*
2 *Masseter*
3 *Orbicularis oculi*
4 *Orbicularis oris*
5 *Sternocleido-mastoid*
6 *Trapezius*
7 *Deltoid*
8 *Biceps brachii*
9 *Brachio-radialis*
10 *Finger flexors*
11 *Carpal sheath*
12 *External oblique*
13 *Rectus abdominis*
14 *Sartorius*
15 *Rectus femoris*
16 *Vastus lateralis*
17 *Vastus medialis*
18 *Tibialis anterior*
19 *Gastroc-nemius*
20 *Peroneus longus*
21 *Toe extensors*
22 *Tarsal sheath*



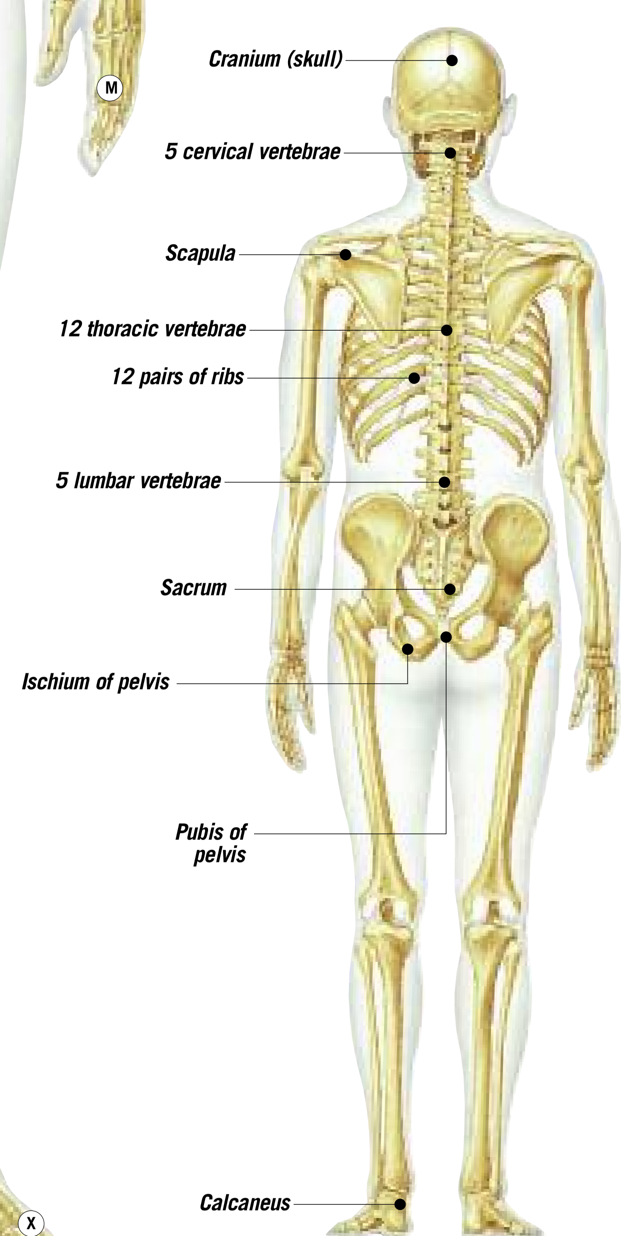


Skeleton

THE 206 BONES of the skeleton form a strong inner framework for the rest of the body, which is soft and floppy. Different parts of the skeleton work in different ways. The skull is a domed protective case for the brain. The backbones, or vertebrae, are a strong yet flexible central support. The long bones of the limbs work like levers.

SKELETON KEY

A *Cranium (skull)*
B *Mandible (lower jaw)*
C *Sternum (breastbone)*
D *Ribs*
E *Clavicle (collar bone)*
F *Scapula (shoulder blade)*
G *Humerus*
H *Radius*
J *Ulna*
K *Carpals (wrist bones)*
L *Metacarpals*
M *Phalanges of fingers*
N *Sacrum*
P *Coccyx*
Q *Pelvis (hip bone)*
R *Femur*
S *Patella (knee cap)*
T *Fibula*
U *Tibia*
V *Tarsals (ankle bones)*
W *Metatarsals*
X *Phalanges of toes*

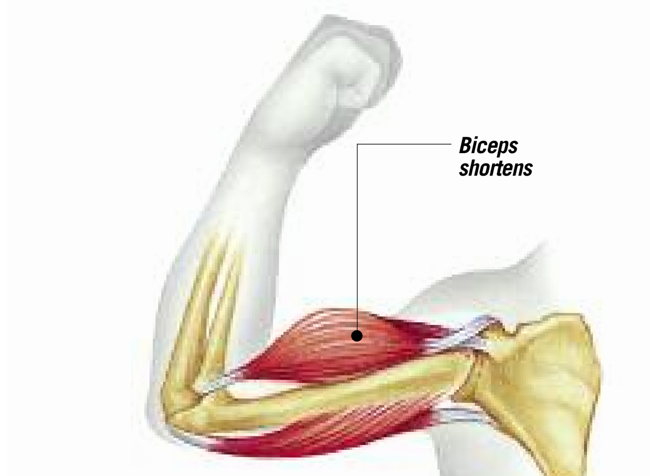


HUMAN BODY

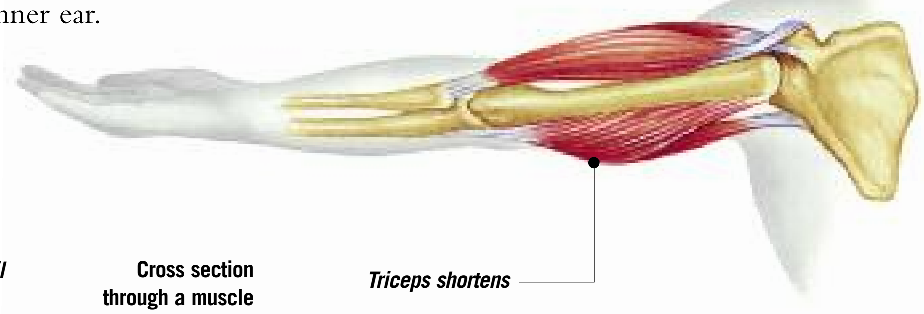
Muscles

EVERY MOVEMENT that the body makes is powered by muscles. A muscle is a body part designed to get shorter or contract *(see page 14)*. Most muscles are long and slim. They taper at each end into a rope-like tendon which is attached firmly to a bone of the skeleton. As the muscle contracts, it becomes thicker and pulls on the bone, moving that part of the body.

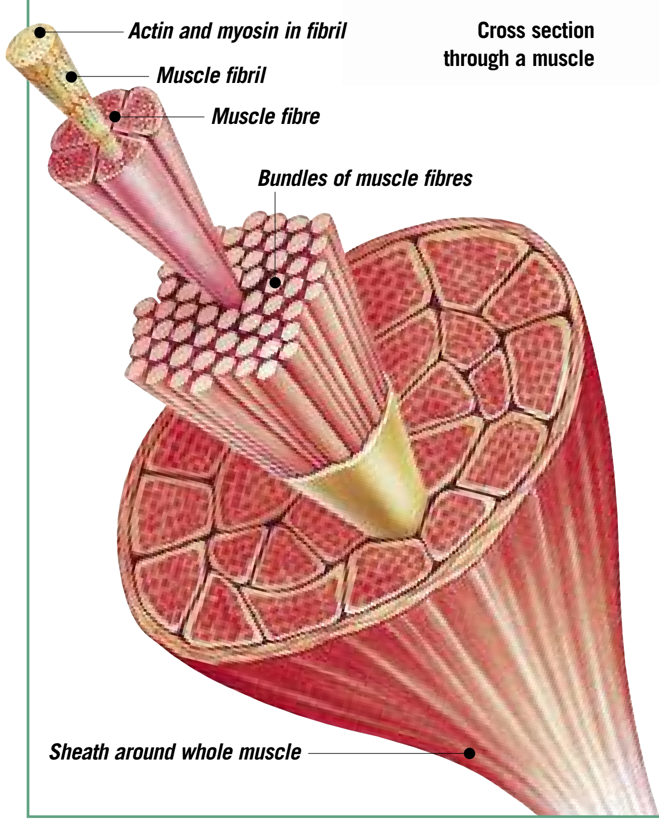
The largest muscle is the gluteus maximus in the buttock. It pulls the thigh bone backwards at the hip when you walk, and with greater speed and power when you run and jump. The smallest muscle is the stapedius, deep inside the ear. It is just a few millimetres long and thinner than cotton thread. It pulls on a tiny ear bone, the stirrup, to prevent very loud noises from damaging the delicate inner ear.



A muscle can only pull on a bone, not push it. So most muscles have opposing partners, like the biceps and triceps in the upper arm. The biceps shortens and pulls the lower arm to bend the elbow. The triceps shortens and pulls to straighten the elbow, as the biceps relaxes.



A muscle contains many bundles of fibres. In turn, each fibre is made of even thinner fibrils.



Cross section through a muscle

How Muscles Work

Each muscle is linked by nerves to the brain. The muscle itself is made up of bundles of hair-thin muscle fibres, which contain even thinner microscopic fibrils. In turn, each muscle fibril contains bundles of long, chain-like substances. These are muscle proteins, called actin and myosin.

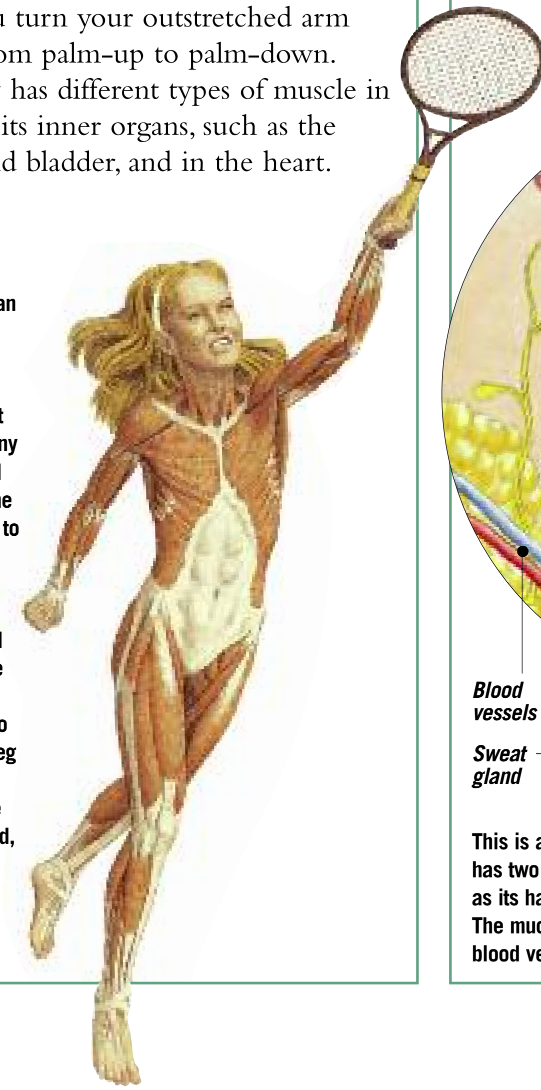
When you want to contract a muscle, the brain sends signals along the nerve to the muscle. The signals make the actin and myosin proteins slide past each other, rather like people pulling hand-over-hand on a rope. Each protein slides together only a fraction of a millimetre. But these tiny movements build up in the thousands of fibrils contained inside the hundreds of fibres. Most muscles can shorten to about two-thirds of their relaxed length.

Muscles in Action

Blinking your eye involves the movement of just one muscle, called the orbicularis oculi, an O-shaped muscle inside the eyelid. It is attached not to bones, but to other muscles and soft tissues. When it shortens, the two sides of the O move together and close the gap between them. The lip muscle, the orbicularis oris, works in the same way. Several other muscles in the face are not attached to bones. They pull on each other. This is how we make our huge range of facial expressions.

Most muscles are attached to bones. They rarely work alone. They pull in pairs or teams, to make a bone move in a precise way. One bone may have 20 or 30 muscles attached to it, each in a different place and pulling in a different direction. This means different combinations of muscles can tilt and twist the bone in almost any direction, as when you turn your outstretched arm and hand from palm-up to palm-down.

The body has different types of muscle in the walls of its inner organs, such as the intestines and bladder, and in the heart.

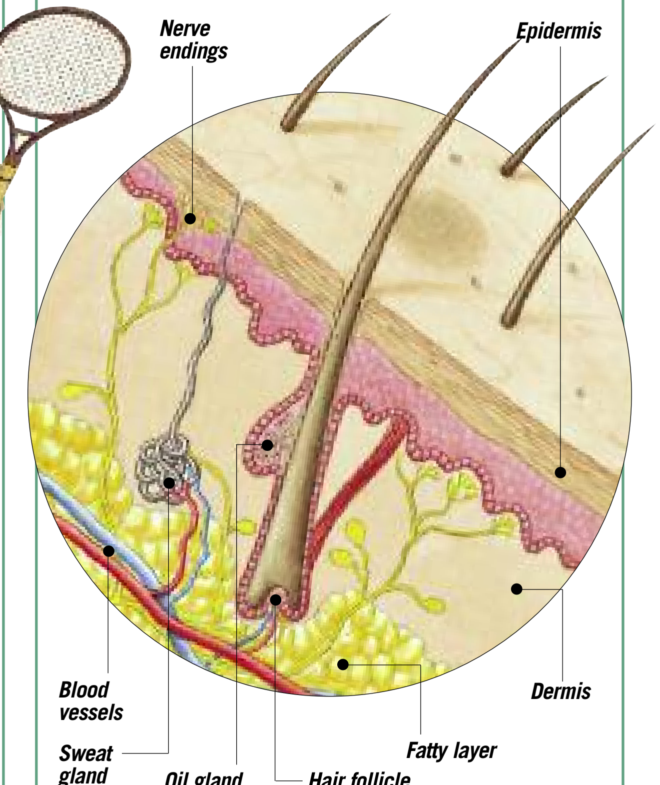


When you hit a tennis ball, this involves more than one hundred muscles in your shoulder, arm, wrist and hand. It also involves many other muscles all over the body. The other arm moves to keep you balanced. The middle of your body tilts forward to give the stroke extra power. The feet move up onto tip-toe and one leg steps forward as you complete the stroke. By the end, almost every muscle has been used.

Skin

THE LARGEST part of the human body is its outer covering—the skin. This is like a flexible, all-over coat that protects the body from knocks and keeps out dirt and germs. It also keeps the delicate inner parts of the body moist and shields them from the harmful rays of the sun. Skin is at its thickest, five millimetres or more, on the soles of the feet. The thinnest skin, about half a millimetre, is on the eyelids.

Skin gives the body its sense of touch. Millions of microscopic nerve endings just under the surface detect light touch, heavy pressure, heat, cold and pain. The skin grows hairs from tiny pits called follicles. There are about 120,000 large hairs on the head, and four million tiny hairs over the rest of the body. Skin also sweats and increases the amount of blood flowing through it, to keep the body cool in hot conditions.

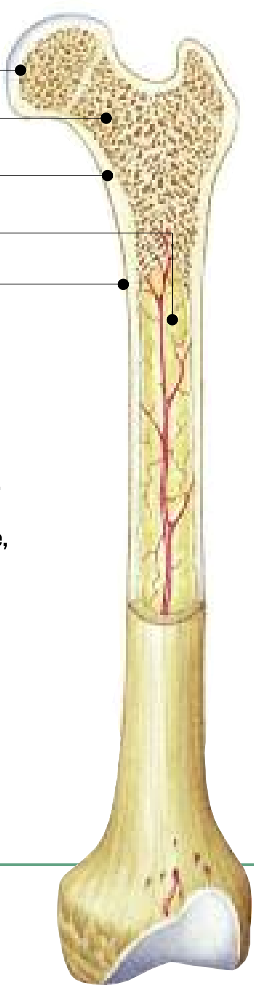


This is a cross-section through skin, greatly enlarged. Skin has two layers. The upper epidermis continually renews itself as its hard, dead outer surface is worn away by daily activity. The much thicker lower layer, the dermis, contains nerves, blood vessels, sweat glands and hair follicles.

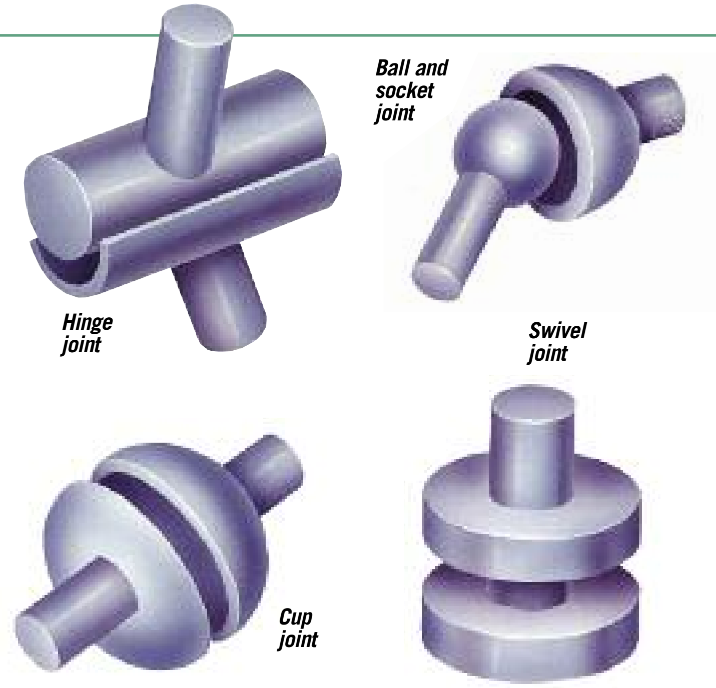
Bones and Joints

THE 206 BONES of the body make up its skeleton *(see page 14)*. Each bone forms a hard, rigid inner support for its part of the body, and anchorage points for muscles to pull as the body moves. The old bones of a museum skeleton are dry, brittle and crumbly. But inside the body, a bone is a very active, living part. It is not dry—it contains about one-fifth water. It is not brittle—it is slightly bendy because it contains fibres of a flexible substance, the body protein called collagen. Bone is also very tough because it contains hard crystals of minerals such as calcium phosphate. And like any other body part, a bone has a supply of blood vessels and nerves.

Most bones are not solid. They are hollow, with a cavity inside. This contains a soft, jelly-like substance called bone marrow. The marrow makes new microscopic red and white cells for the blood at the rate of two million every second, to replace the old, dead blood cells.



Some bones are long and slim, like the femur or thigh bone shown here. Its ball-shaped head fits into the socket in the hip bone. Its lower knuckle-like end is in the knee joint. Between the two ends is the long, tubular shaft. The outer layer of bone, known as compact bone tissue, is hard, dense and strong. The inner layer of bone tissue, where strength is less important, has a honeycomb structure to save weight. It is known as spongy bone. In the centre of the bone is the jelly-like marrow.

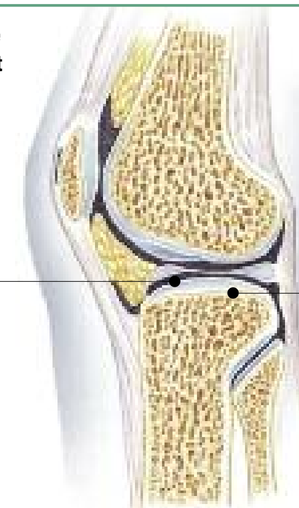


Types of Joints

Bones are linked together at joints. In some joints the bones are fixed or cemented firmly to each other and cannot move, as with the small bones of the face. These are known as suture joints. In other joints the bones can move in relation to each other. The body has many different kinds of moveable joints, depending on the shapes of the bone ends and how they fit together. They resemble the joints used in machines to give a certain kind of movement *(see above)*. For example, the knee is a hinge joint and moves only backwards and forwards. The hip is a ball-and-socket joint and can move in any direction.

The knee joint

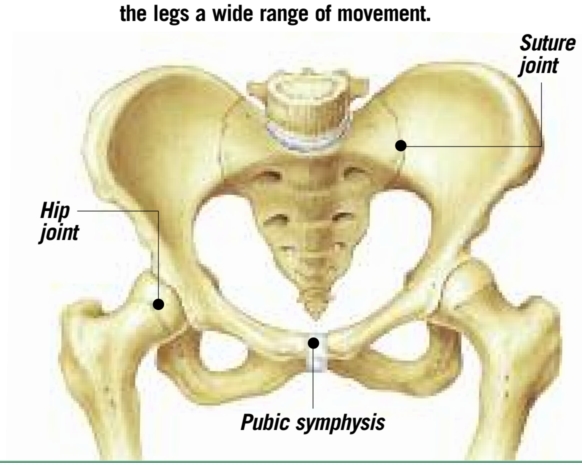
Inside the knee joint



Inside a Joint

In a moveable joint the ends of the bones are covered with a smooth, shiny, slippery, slightly soft substance called **cartilage.** This prevents the bone ends rubbing against each other and wearing away. The cartilage surfaces slip over each other with hardly any wear. A flexible bag, the synovial capsule, wraps around the bone ends. This makes an oily fluid which fills the bag and lubricates the joint, like the oil in a machine. The two bones are linked by flexible, strap-like **ligaments** around the synovial capsule. These stop the bones coming apart and prevent the joint bending too much.

The hip region has both fixed and moveable joints. The hip bone is, in fact, six separate bones joined firmly together and to the sacrum at the base of the spine. The joint at the front, the pubic symphysis, has cartilage between the bones and can bend slightly. Ball-and-socket joints allow the legs a wide range of movement.



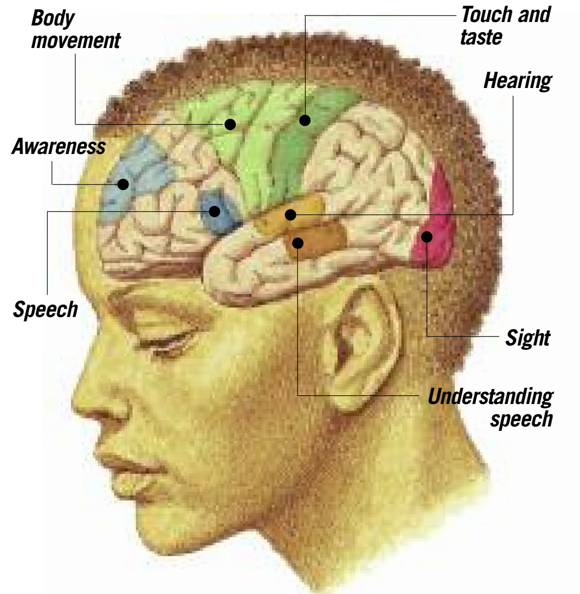
Fractures

Bones are strong but sometimes they cannot withstand the stress put on them, especially in an accident. A bone may crack or snap. This is known as a fracture. In a compound fracture, the broken ends protrude through the skin *(above)*. Part of the bone shatters into small parts in a comminuted fracture. The parts of the bone ram into each other in an impacted fracture.

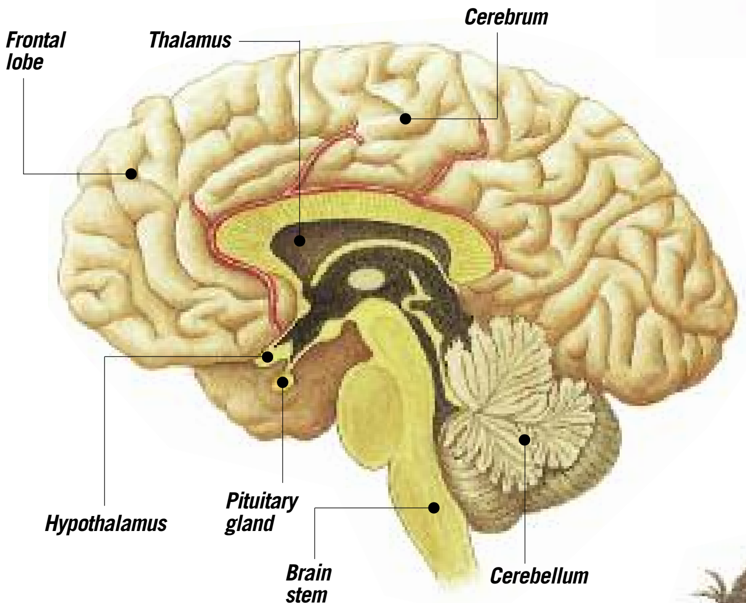
The backbone or spinal column (spine) is made of 26 separate bones called the vertebrae. Each is linked to bones above and below by a simple ring-like joint, except at the top where specialized joints with the skull allow the head to nod and twist. A pad of cartilage between each pair of vertebrae, known as the intervertebral disc, provides a flexible cushion so that the vertebrae can twist and tilt slightly against each other. Over the whole backbone, these limited movements add up so that the spine can bend into a U-shape.

The Brain

Every thought and idea, every wish and want, every emotion and feeling, happens inside the brain. The brain fills the top half of the head, well protected within the domed skull bone. It looks like a large, wrinkled lump of pink-grey jelly. It contains some 50 billion nerve cells, or neurones *(see opposite)*. Each nerve cell is linked to many thousands of others. Tiny electrical nerve signals pass through this vast network, representing your thoughts and memories. Nerve signals also come into the brain from nerves all over the body, and go out to the muscles.

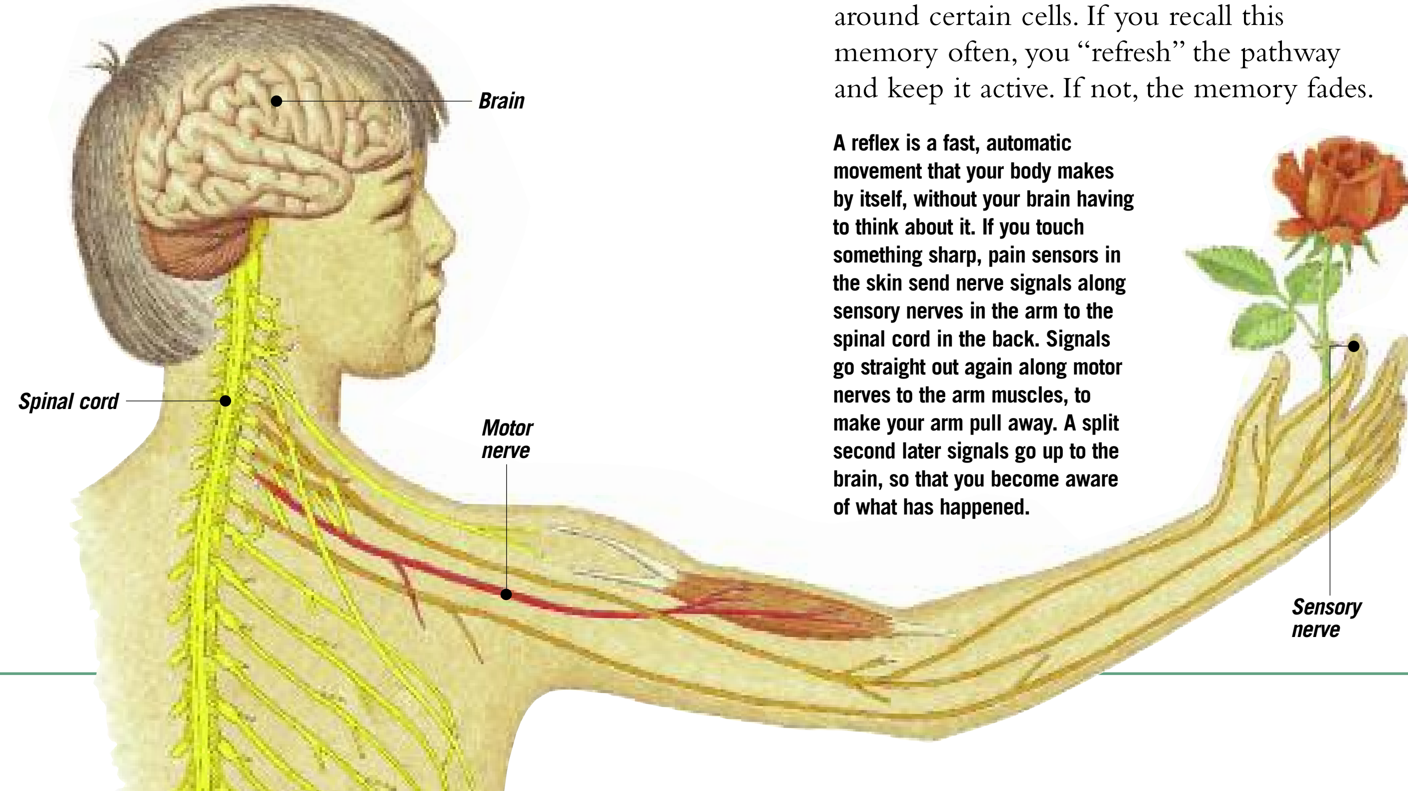


The large, wrinkled cerebrum makes up four-fifths of the brain's bulk. Its outer layer, about 3 to 5 millimetres thick, is called the cerebral cortex. This is where most thoughts and ideas occur. The cortex has different areas called centres that deal with nerve signals coming from and going to different body parts *(above)*. For example, signals from the eyes are sorted and analysed in the sight centre at the lower rear of the brain. A slice through the brain shows its inner parts *(left)*. The hypothalamus monitors conditions within the body, such as the level of oxygen in the blood. It sends signals to the pituitary gland just below it, which controls the body's hormone system *(see page 23)*.



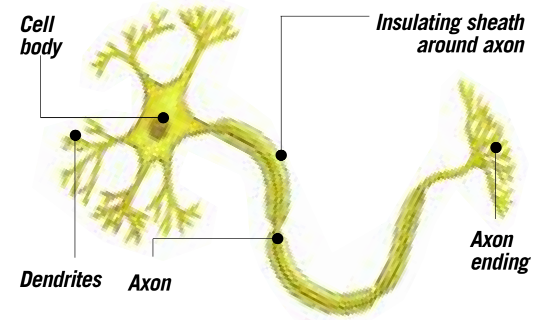
Inside the Brain

The brain has four main parts. The brain stem at the base tapers into the spinal cord *(see opposite)*. It controls automatic bodily activities such as heartbeat, breathing and digestion. The mid-brain just above has close links with the hormone system *(see page 23)*. One of its parts, the thalamus, controls the level of awareness, from wide awake and alert to drowsy or asleep. The third part is the cerebellum, a wrinkled lump at the rear. It deals with muscle control to make movements smooth and coordinated. The fourth part is the cerebrum, where thinking happens.



Nerve Cells and Signals

A nerve signal is a tiny pulse of electricity that travels very fast, almost 100 metres per second, along a nerve cell. A nerve cell *(below)* has a normal-shaped cell body surrounded by thin, spidery parts called dendrites. It also has a very long, thin part like a wire, called the axon. Dendrites collect nerve signals from other nerve cells and pass them on, via the axon, to other nerve cells. Nerves contain bundles of hundreds or thousands of nerve cells.

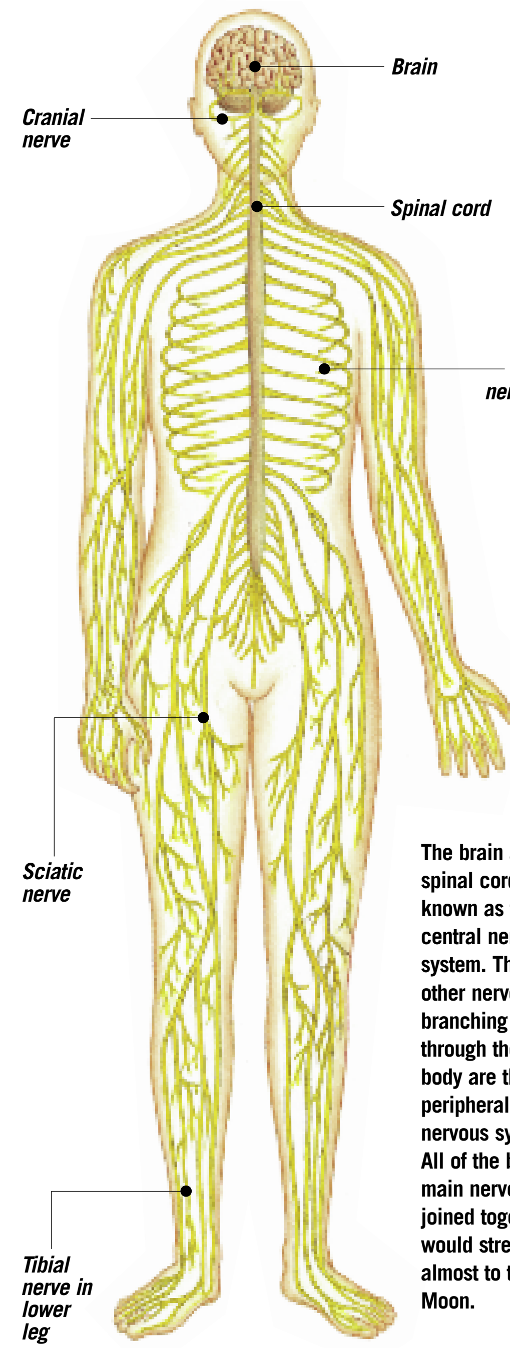


The brain's thoughts, ideas and memories consist of nerve signals flashing to and fro around the unimaginably vast network of billions of nerve cells. New connections between nerve cells are constantly being made as old ones are lost. A new memory may form as a new pathway or route around certain cells. If you recall this memory often, you "refresh" the pathway and keep it active. If not, the memory fades.

A reflex is a fast, automatic movement that your body makes by itself, without your brain having to think about it. If you touch something sharp, pain sensors in the skin send nerve signals along sensory nerves in the arm to the spinal cord in the back. Signals go straight out again along motor nerves to the arm muscles, to make your arm pull away. A split second later signals go up to the brain, so that you become aware of what has happened.

The Nervous System

The base of the brain merges into the **spinal cord.** The cord has nerve branches that reach out to every body part, down to the fingertips and toes. The spinal cord carries nerve signals to and fro between the brain and all of these body parts. In addition, there are nerves that branch directly from the brain, into the head, face, neck and chest. These are cranial nerves.



The brain and spinal cord are known as the central nervous system. The other nerves branching through the body are the peripheral nervous system. All of the body's main nerves joined together would stretch almost to the Moon.

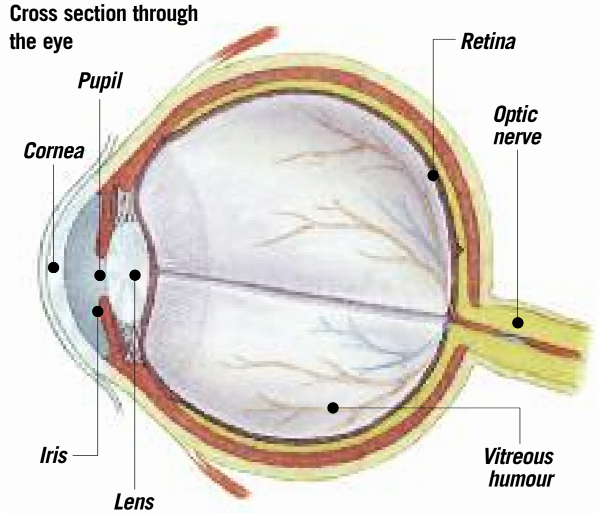
The Senses

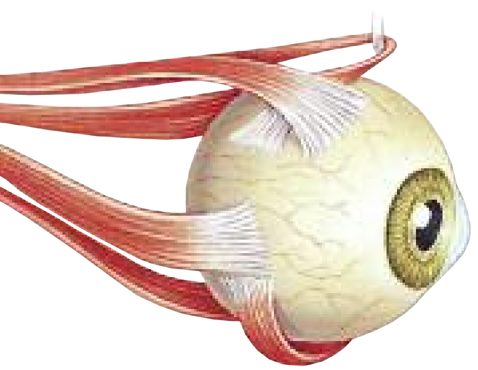
The body has five main senses that detect what is happening in the outside world. Four are shown here. The fifth is touch, sensed by the skin *(see page 17)*.

Sight

Each eyeball is about 25 millimetres across and well protected in a socket, called the orbit, inside the skull bone. Light rays enter the eye through its transparent domed front, the cornea. They pass into the eye through the pupil, a hole in a ring of muscle known as the iris. The iris makes the pupil smaller in bright conditions, to prevent too much light damaging the eye's delicate interior. The rays are bent or focused by the lens, and shine a clear image on to the retina, which lines the rear of the eyeball. When light hits the retina, its 130 million microscopic cells make nerve signals, which pass along the optic nerve to the brain.

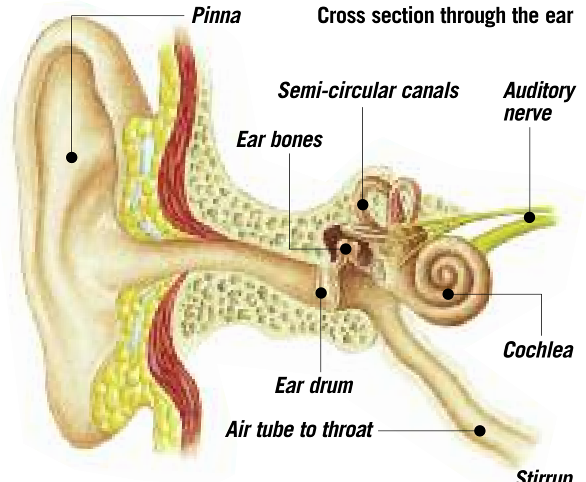
Cross section through the eye



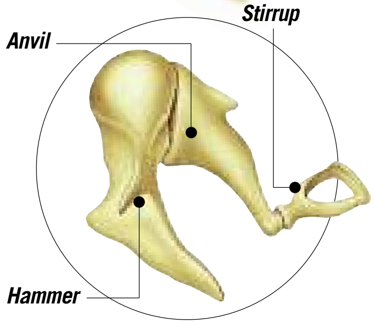


Most of the eye's interior is filled with a see-though jelly called the vitreous humour *(above)*. Light shines through this on to the retina. Six small strap-shaped muscles attach the eyeball to the rear of the eye socket *(left)*. They work together to make the eye look up, down and sideways.

Cross section through the ear

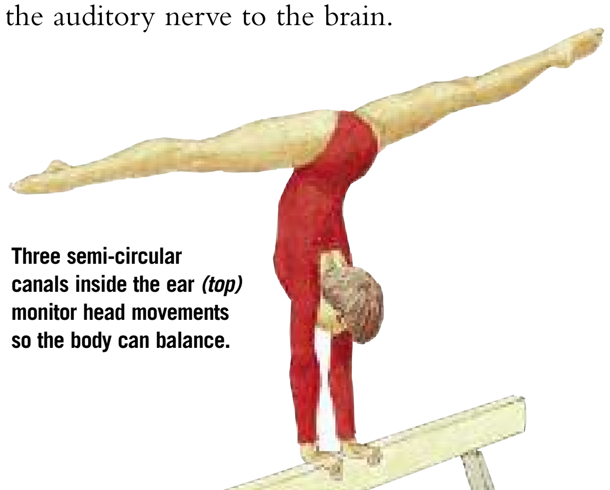


The delicate working parts of the ear are behind the ear flap, or pinna. They are encased and protected within the skull bone *(above)*. The three tiny ear bones, or auditory ossicles, are the smallest bones in the body *(right)*.



Hearing

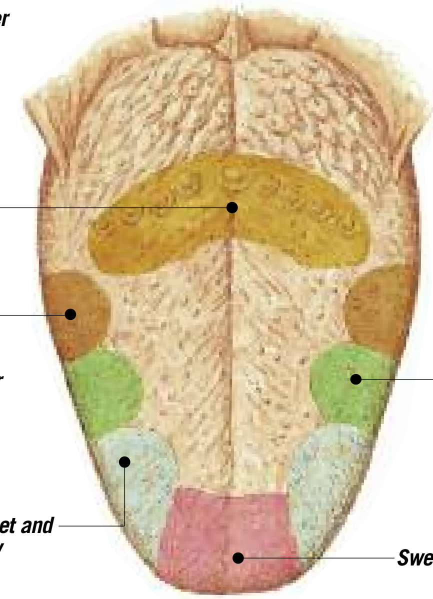
The curly flap of skin and gristle on the side of the head, which we call the ear, is simply a funnel shape for collecting sound waves from the air around. The waves travel along a slightly curved tube, the ear canal, and strike the ear drum, a small, thin piece of skin, which vibrates. The vibrations pass along a row of three tiny bones, the hammer, anvil and stirrup. The stirrup sends the vibrations into a snail-shaped part filled with fluid, known as the cochlea. The vibrations ripple through the fluid and shake microscopic hairs sticking out of nerve cells. When the hairs shake, the cells produce nerve signals, which travel along the auditory nerve to the brain.



Three semi-circular canals inside the ear *(top)* monitor head movements so the body can balance.

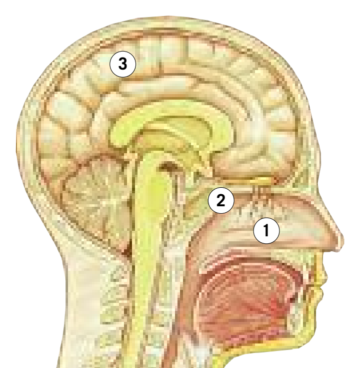
Taste

The tongue's upper surface is covered with many pimple-like lumps, known as papillae. These grip food to move it around while chewing. Scattered between the papillae are about 8000 taste buds. Each one has some 30 microscopic taste cells and looks like a tiny onion set into the tongue's surface. When substances of a certain flavour in foods touch micro-hairs sticking up from the taste cells, the cells generate nerve signals which pass to the brain. Different tongue areas respond to different flavours.



Smell

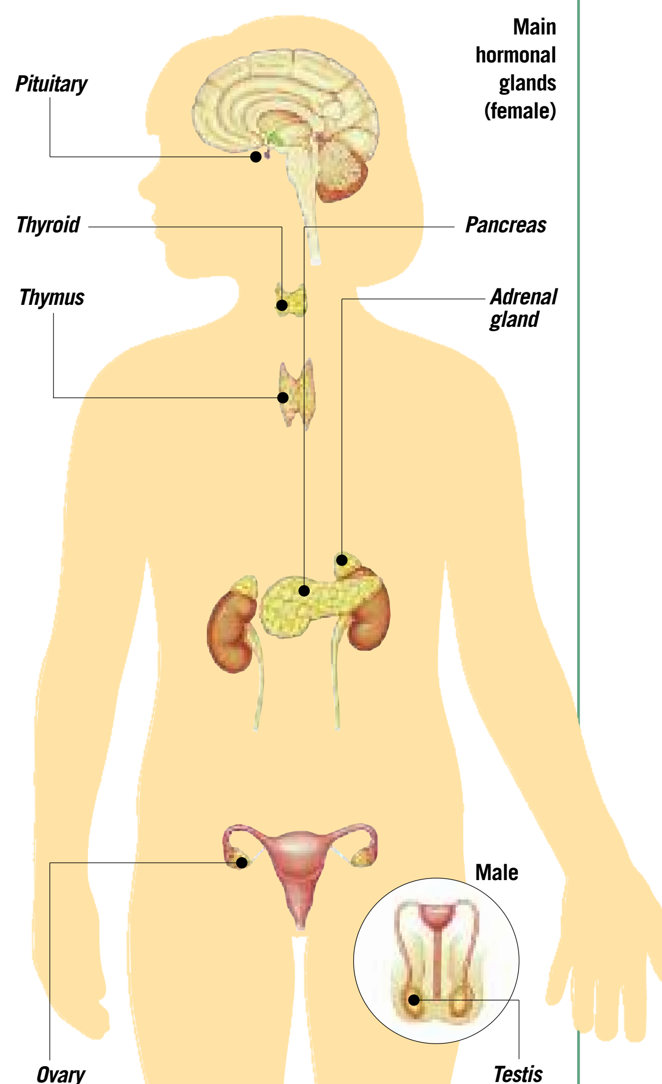
In each side of the nose is an air chamber about as large as a thumb. Lining the roof of the chamber is a patch of 25 million smell cells. Each has more than 20 tiny hairs sticking from it. When certain odour substances touch the hairs, their cells send nerve signals to the brain. The nose can detect 10,000 different scents and smells.



The olfactory (smell) area lies at the top of the nasal cavity (1). To smell, we sniff the air into this area, where olfactory nerves (2) send signals to the brain (3).

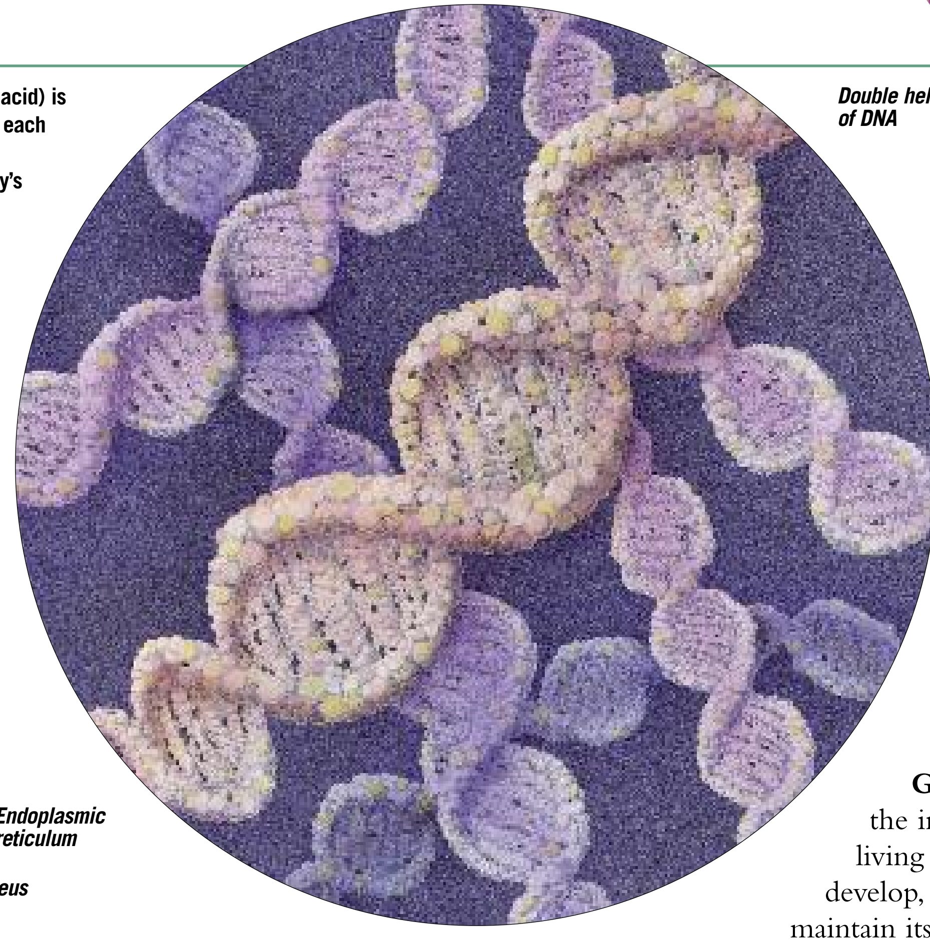
Hormones

Two systems help the body's parts and organs work together. One is the nervous system *(see page 21)*. The other is the hormonal or endocrine system, based on body chemicals called hormones. There are more than 50 different hormones. Each is made in a gland. Hormones flow around the bloodstream and affect certain cells, tissues and organs. They may cause them to work faster or slower, or release their products. For example, adrenaline from the adrenal gland makes the heart beat faster and more blood flow to the muscles, so the body is ready for action. The pituitary gland near the brain makes hormones that control other hormonal glands *(see also page 26)*.

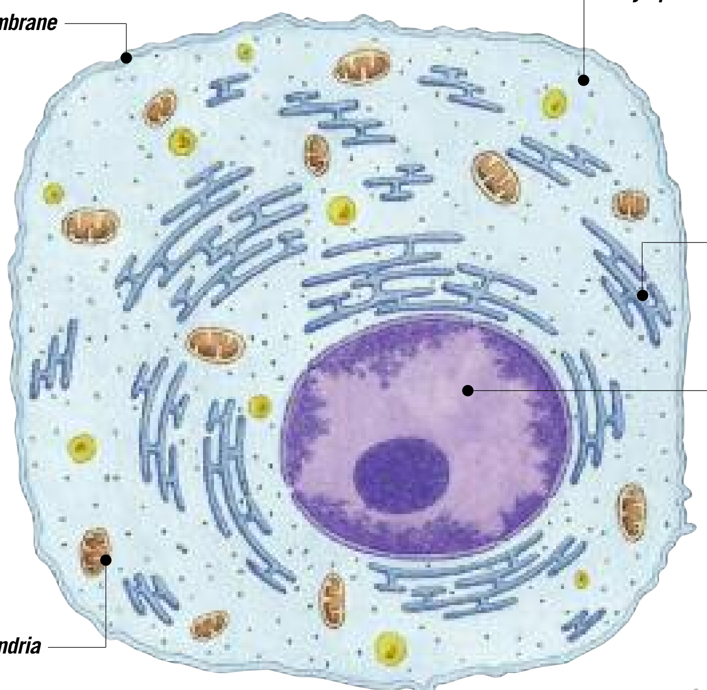


CELLS AND GENES

THE BASIC "building bricks" of the body are cells. There are over 200 different types, such as blood cells, nerve cells and muscle fibre cells. They vary greatly in size and shape, although most cells are far too small to see except through a powerful microscope. About 30 typical cells placed in a row would stretch only one millimetre. The whole body contains more than 50 million million cells. Most are in the blood and the brain.



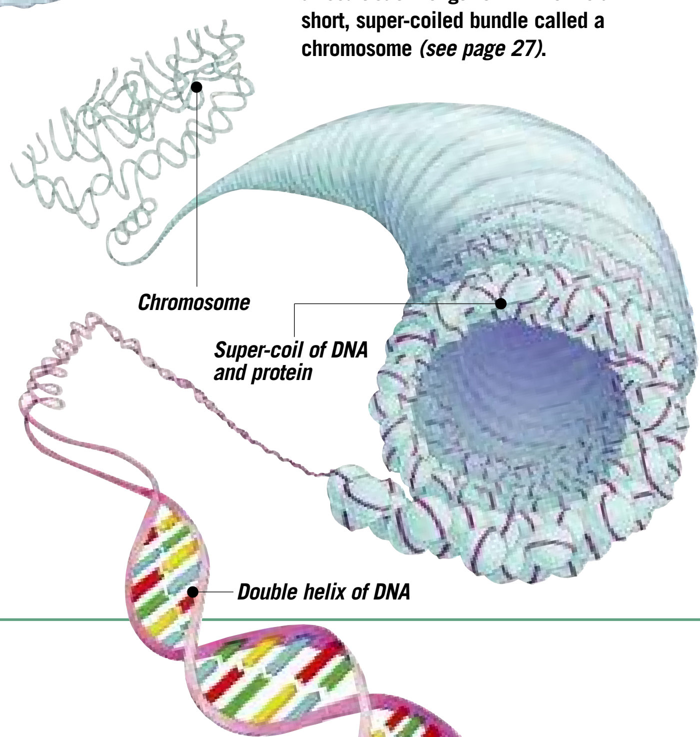
DNA (deoxyribonucleic acid) is found in the nucleus of each cell. It is the chemical which contains the body's genes. A piece or molecule of DNA is enormously long and thin, like a rope ladder twisted into a corkscrew shape. All the DNA in one cell nucleus joined together would stretch nearly two metres.

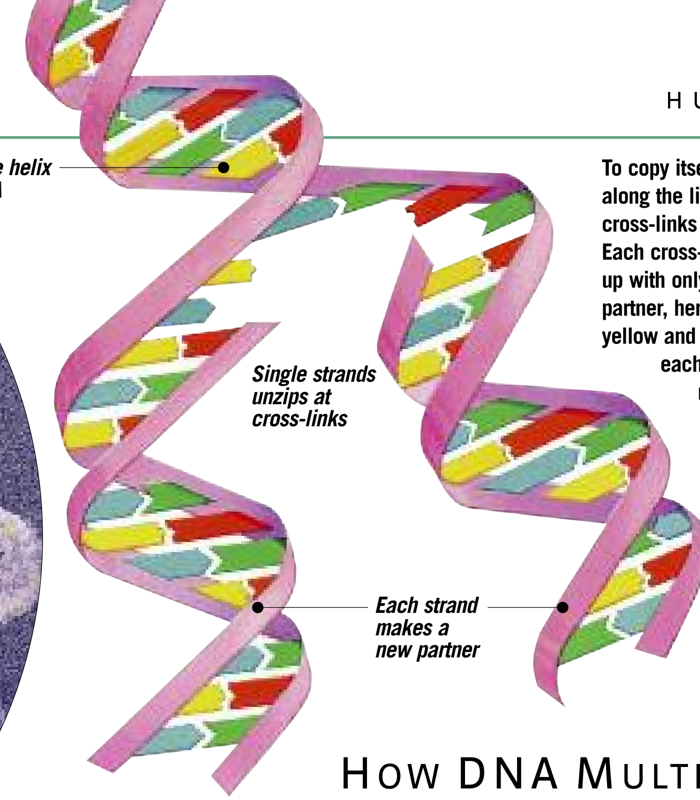


INSIDE A CELL

A typical cell is a bag of jelly, or cytoplasm, containing even smaller parts called organelles *(above)*. Mitochondria are small and sausage-shaped. They break up substances such as sugar (glucose) to release energy for use in the cell. The cell's skin-like covering, the cell membrane, allows only certain substances to pass in and out. The cell's factory for making various substances and products is called the endoplasmic reticulum. The biggest organelle is usually the nucleus, a dark lump near the cell's centre. It contains genes in the form of DNA.

There are 46 main pieces of DNA inside the nucleus of one cell. Usually each piece is spread out like an unwound length of rope. But when the cell is about to divide and form two cells, each length of DNA twists itself into a tight coil. In turn, this coil twists itself into a super-coil and combines with protein. As a result each length of DNA forms a short, super-coiled bundle called a chromosome *(see page 27).*





To copy itself, DNA unzips along the line where the two cross-links join each other. Each cross-link can then pair up with only one kind of new partner, here shown as red with yellow and blue with green. So each single strand makes a new partner which is an exact copy of its old partner.

Genes contain all the information a living thing needs to develop, grow and maintain itself through life. A tiny worm has a few hundred genes. The human body has more than 100,000 genes. They determine whether you have dark hair, long legs, a tendency to develop certain diseases, and so on.

Genes are encoded like an "instruction manual" in DNA. The twisted-ladder shape of DNA is called a double helix. The rungs or cross-links are made of chemical sub-units, known as nucleotides. There are four: A, T, G and C (adenine, thymine, guanine and cytosine). A always forms a cross-link with T, and G with C. The order of sub-units A, T, G and C along the DNA is the genetic code, containing information for the genes in chemical form. Every body cell has a full set of DNA including all genes. But each cell uses only a tiny part of the DNA for its own life processes.

If two bodies have the same genes, they look the same. This happens with identical twins *(right)*. They both develop from the same fertilized egg cell which splits in two *(see next page)*. Non-identical twins are produced when two eggs are both fertilized. Identical twins will always be of the same sex and have the same eye colour.

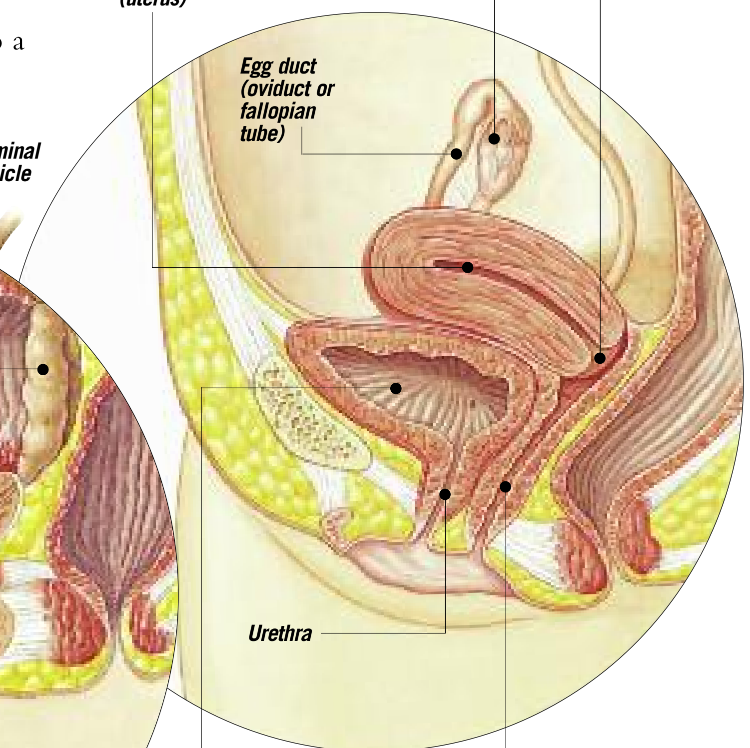
HOW DNA MULTIPLIES

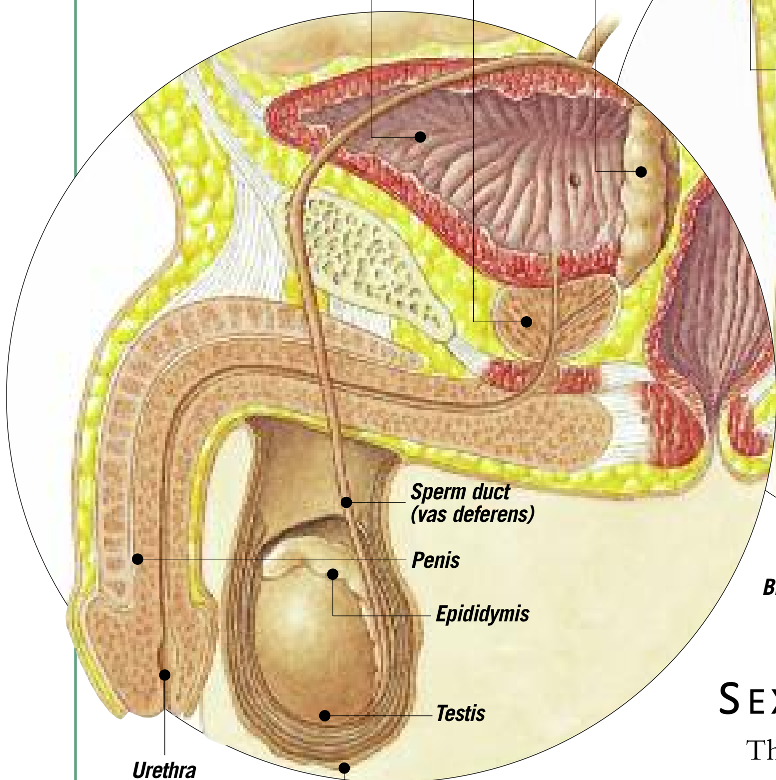
Cells do not live for ever. Every minute the body makes about 3000 million new cells to replace those which naturally wear out and die. Also, reproduction involves making new cells *(see page 26)*. When a cell divides to make two new cells, its set of DNA is copied to make a duplicate set. Then each of the two new cells has a full DNA set with all the genes. DNA duplicates (copies) itself by breaking the cross-links that hold together its two strands. Each nucleotide sub-unit then joins to a new partner of its usual kind—A with T, and G with C. The row of new sub-units forms its own new strand. The result is two lengths of DNA, each identical to the other.

REPRODUCTION

THE KEY FEATURE of all living things is that they can make more of their kind. This is called reproduction. The human body reproduces in much the same way as animals such as cats, dogs, horses and tigers. A female and male come together and have sexual intercourse. A microscopic tadpole-shaped cell from the male joins with, or fertilizes, an egg cell from the female. This fertilized egg grows and develops in the womb of the female, into a baby ready to be born.

The main parts of the female reproductive system are the two ovaries and the womb. They are in the lower body, the pear-shaped womb positioned just behind the bladder. Once each month during the menstrual cycle (the female reproductive cycle), one ovary releases a pinhead-sized egg cell. This passes into the egg duct, where it may join with a sperm. The menstrual cycle is controlled by hormones.

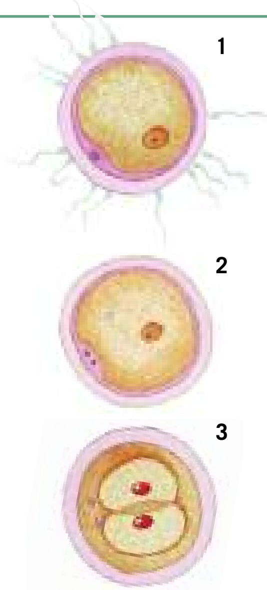




The main parts of the male reproductive system are the two testes. They make millions of tiny sperm cells each day. The sperm are stored in a long coiled tube, the epididymis. During sex they pass along the sperm duct, mix with fluid from the seminal vesicle and prostate gland, and travel along the urethra. They pass out of the end of the penis, into the woman's body.

SEX ORGANS

The parts of the body involved in reproduction are called the sex organs *(above and above left)*. They are present at birth, but they develop rapidly and start to work from the ages of about 11–14 years in girls and 13–16 years in boys. This time of rapid growth and changes in bodily features is known as puberty. A girl develops a more rounded body outline and her breasts enlarge. A boy grows facial hair and his voice breaks. These changes are controlled by hormones *(see page 23)*.



During sexual intercourse, a man releases many millions of sperm cells, which are much smaller than the egg cell. Each sperm has a round head and swims by lashing its long tail. The sperm move along the egg tube towards the egg. Several manage to reach it (1), but only one sperm cell joins, or fertilizes, the egg. The others are kept out as a thick barrier develops around the egg (2). The genes in the sperm and egg combine to form a single cell, the fertilized egg. Almost at once this divides by the process of cell division to form two cells (3).

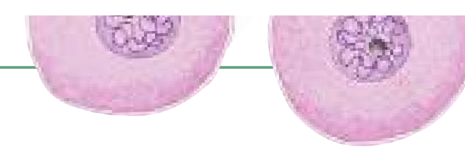
A few hours after the fertilized egg divides into two cells, each of these cells also divides to make four cells (4). A few hours later the same happens to give eight cells, and so on. The result is a ball-shaped clump called a morula (5). About five days after fertilization, the morula has become a hollow ball known as a blastocyst with hundreds of cells (6). By this time it has passed along the egg tube into the womb. It has been living on nutrients stored in the original huge egg cell. Now it absorbs nutrients from the womb lining, so it can begin to grow.

THE FIRST WEEK OF LIFE

The egg cell (ovum) contains a set of genetic material from the mother. The sperm cell (spermatozoon) has a set from the father. When sperm and egg join, the fertilized egg contains the normal double-set of genetic material found in all body cells. The fertilized egg is larger than most cells, almost one-tenth of one millimetre across. But it divides many times *(above)* by the process of cell division *(below)*, so the cells reduce back to normal size. During this time the ball of cells passes along the egg duct to the womb.

The womb lining has become thickened and rich with blood and nutrients, as part of the menstrual cycle. When the ball of cells reaches the inside of the womb, it burrows into the lining. The cells in the ball continue to multiply and the ball becomes hollow. A flatter, disc-shaped part appears in the middle of the hollow ball. As the cells multiply into many thousands and begin to move about, the disc changes shape into a tiny, tadpole-like object. This is a very young baby, called an embryo. It is hardly larger than a grain of rice, but its heart is already beating. *(Continued on next page.)*

Cell division happens all over the body as cells wear away or die and need replacing. The genetic material, DNA, usually lies in long lengths inside the cell's nucleus (1). As division starts, the DNA coils into thicker, shorter objects called chromosomes (2). There are two of each chromosome. They line up across the middle of the cell (3) and are pulled by micro-threads to opposite ends (4). A new nucleus forms around each set of chromosomes (5). Finally the original cell pinches into two new cells (6). The DNA in the chromosomes is copied and the cells grow larger before the next cell division *(see page 25)*.



A BABY GROWS

IT TAKES nine months for the fertilized egg to grow and develop in the mother's womb, then become a baby ready to be born. This time is known as pregnancy. For the first eight weeks the developing baby is called an **embryo.** During this period, all of the main body parts and organs, such as the brain, heart, eyes, ears, and even the fingers and toes, form. At the end of eight weeks, the embryo is only about the size of a thumb-tip. But the main phase of development is complete and the baby looks like a miniature human being.

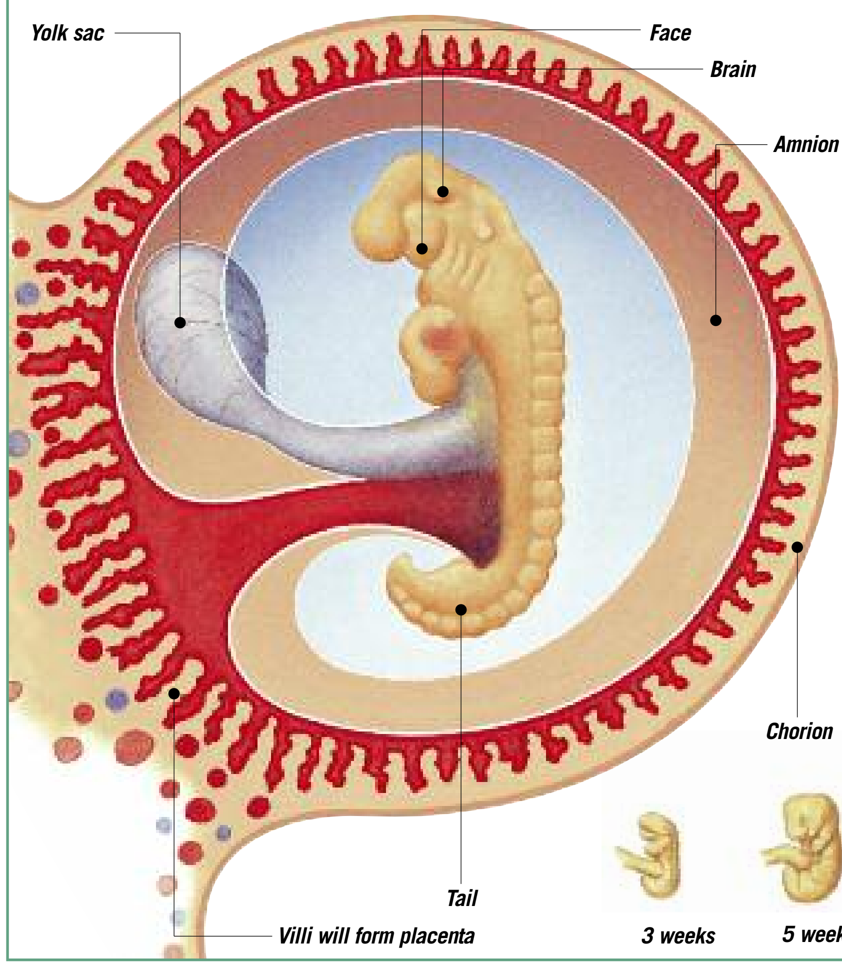
For the next seven months the main change is in size. The baby grows at a faster rate than it will ever grow in the rest of its life. Finishing touches are added to the body, such as fingernails, toenails and eyelashes. During this growth phase the baby is known as a **foetus.**

EARLY DEVELOPMENT

The part of the baby that develops fastest is the head, followed by the main body and then the limbs. In the early stages, the brain and spinal cord are by far the largest part of the body *(see below)*. During the fourth week, the main body begins to develop. The heart pumps blood through a simple system of tubes and the lungs begin to grow.

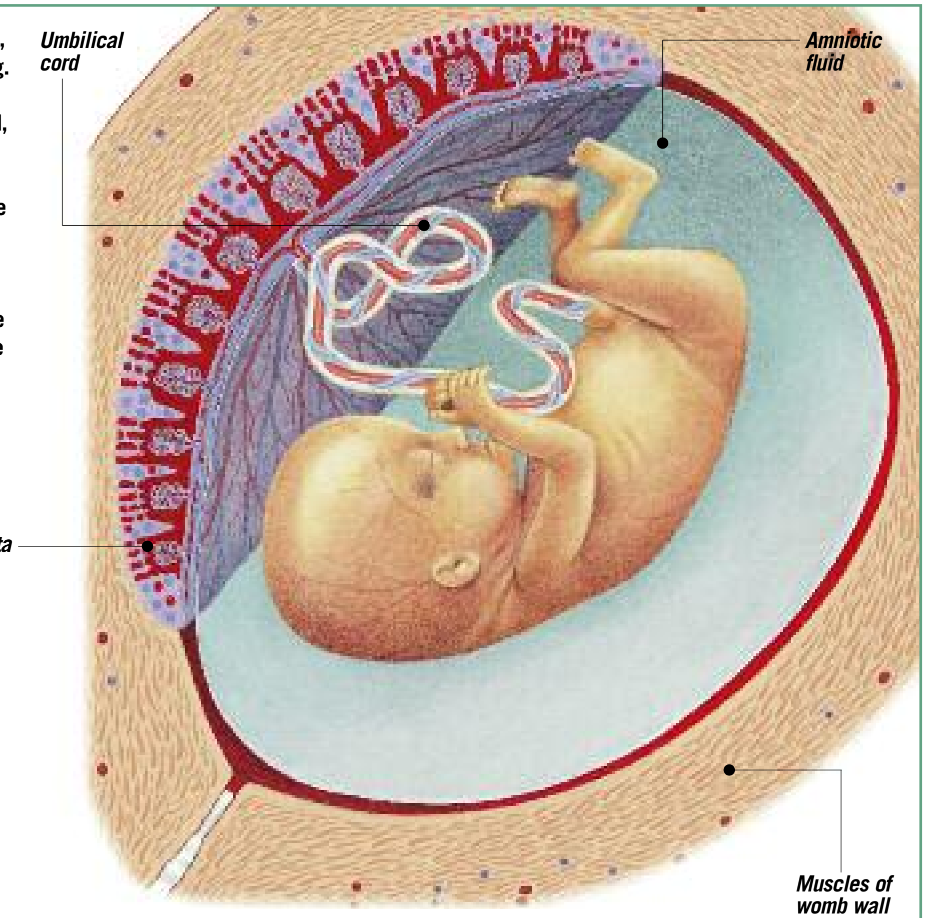
Towards the end of the fourth week, the lower body organs, such as the intestine, liver and pancreas, form. The arms and then the legs also start to develop. At first they are tiny bumps on the body called limb buds, but they soon lengthen and the fingers and toes take shape *(right)*.

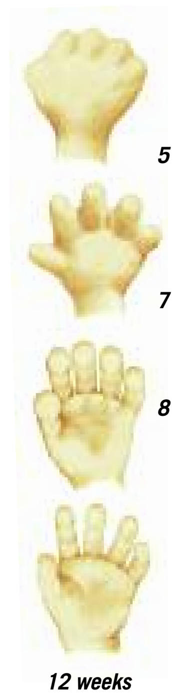
During the fifth week, the ears, eyes and nose take on more recognizable shapes. Main nerves begin to grow out from the brain and spinal cord. The kidneys and stomach also develop.



About three weeks after fertilization, the growing human embryo *(left)* looks much like the embryo of a dog, cat or chicken at a similar stage. It even has a "tail", but this gradually shrinks away as growth continues. The largest part of the body is the brain and other developing areas of the head. The ridges along the back will eventually form the backbones (vertebrae), but proper bones do not start to develop until the third month. The embryo floats in fluid within skin-like outer membranes, the chorion and amnion. At this early stage it receives nutrients from the yolk sac. But parts of the outer membranes, called villi, are growing into the womb lining. They will form the placenta which provides nourishment *(above right)*. The stages of growth are shown life-sized *(below)*.

Three months after fertilization, the baby is 65 millimetres long. Its ears are formed and can hear. The eyes are also formed, but the eyelids stay shut until nearer birth. The muscles are now starting to develop and the baby can twist and turn. The umbilical cord carries the baby's blood to the placenta where it flows very close to the mother's blood. In this way, the baby's blood collects nourishment and oxygen from the mother, while getting rid of its wastes to her blood.



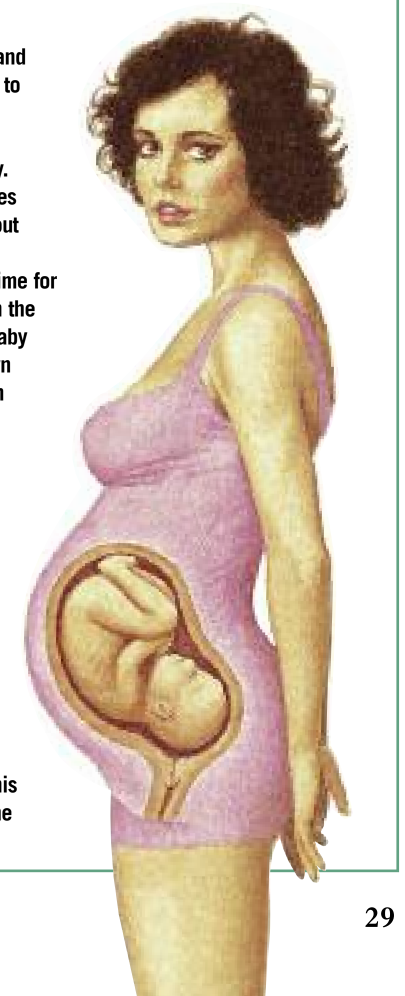


The fingers start to appear in the seventh week after fertilization. By the twelfth week they are fully formed and developing their fingernails. The toes grow in a similar way but lag a few days behind the fingers.

LIFE IN THE WOMB

Inside the womb, the baby floats in a pool of amniotic fluid. The fluid cushions and protects it from bumps and jolts. The baby cannot breathe or eat in its watery surroundings. So it receives oxygen and nutrients from the mother through the placenta (also called the afterbirth). The baby can hear sounds such as its mother's heartbeat. Loud noises from outside also pass into the womb and may startle the baby and make it jump. At first the baby has room to move and even turn somersaults. But as it grows larger it becomes more cramped, even though the womb stretches.

As the baby grows and the womb stretches to hold it, a "bump" appears on the mother's lower body. This usually becomes noticeable from about the fourth month of pregnancy. As the time for birth comes near, in the eighth month, the baby rests in a head-down position. When birth starts, the strong muscles in the womb wall push hard and squeeze the baby through the neck of the womb and along the birth canal. The baby emerges head-first. It is still attached by its umbilical cord to the placenta, and this emerges a short time later.



MEDICINE

OCCASIONALLY the body is ill or suffers injury. From ancient times people have used many different methods—not always successfully—to help the sick and injured. Modern medicine is based on scientific tests and treatments rather than superstition or magic.

The common cold is a disease caused by a variety of viruses. Symptoms include a runny nose, sore throat, headache, sneezing and coughing. Healthy people can carry cold-producing viruses for long periods.

Two main types of treatment are medical and surgical. Medical help involves chemicals or drugs. These may be obtained from natural substances such as plants, animals or microbes, or made in the laboratory (for example, chemotherapy, used to fight cancer). Surgery involves physical treatment, for example, cutting open the body during an operation, to remove a diseased part or mend a broken bone.

Some diseases are carried in genes *(see page 25)* and inherited by later generations. Queen Victoria *(inset, top left)* passed on to several of her grandchildren, including the son of Nicholas II, Tsar of Russia *(above)*, a disease called haemophilia, a condition where blood will not clot after injury.

CLEAN CONDITIONS

Before the invention of the microscope, no one could see germs. These are microscopic life-forms such as bacteria and viruses that invade the body and cause the illnesses known as infections. Since people did not know about germs, they did not understand the importance of keeping wounds clean. Surgeons never bothered to wash their hands or their instruments. Many more people died after operations than got better.

In vaccinations, dead or disabled versions of germs are injected into the body. The germs cannot cause harm, but the body's defence system fights and kills them. It will then recognize the germs again quickly in the future. If real germs were to try to enter the body, they would be killed before they could cause illness. Protecting the body in this way is called immunization. It was first tried in a scientific form in 1796 by English doctor Edward Jenner (1749-1823) and soon became widespread. By 1980 the disease smallpox had been wiped out due to a worldwide campaign of vaccination.

DOCTORS AND HOSPITALS

A doctor is qualified to examine and treat people using drugs and surgery. A person who is ill usually goes to the family doctor or general practitioner (GP). The GP has a wide knowledge of medicine and can diagnose (identify) and treat most illnesses.

If the cause of the problem is not clear, the person may be sent, or referred, to a hospital doctor or consultant. The consultant is an expert in a certain type of medicine. For example, a neurologist deals with problems of the brain and nerves and a cardiologist with diseases of the heart.

Emergency case

Operating theatre

EMERGENCY MEDICINE

Some of the greatest advances in recent years have been in emergency medicine. When a person is badly injured in a road accident or suffers a heart attack, every second may count. The ambulance crew are specially trained and equipped to give life-saving first aid and to care for the victim or patient on the way to hospital.

At hospital the patient is taken to A&E (the Accident & Emergency department) where specialist doctors quickly decide on treatment. If an emergency operation is needed, the surgeon and team go to the operating room or theatre and begin straight away. After surgery, the patient is looked after in IC (the Intensive Care unit). Machines and monitors check the patient's heartbeat, breathing, blood pressure and other body processes. If all goes well, the patient begins to recover and can leave IC for the general ward. Nurses carry out daily care and check on progress until the patient is well enough to go home.

Intensive care

General ward

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