



Pocket Genius

# HUMAN BODY



FACTS AT YOUR FINGERTIPS



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**FACTS AT YOUR FINGERTIPS**



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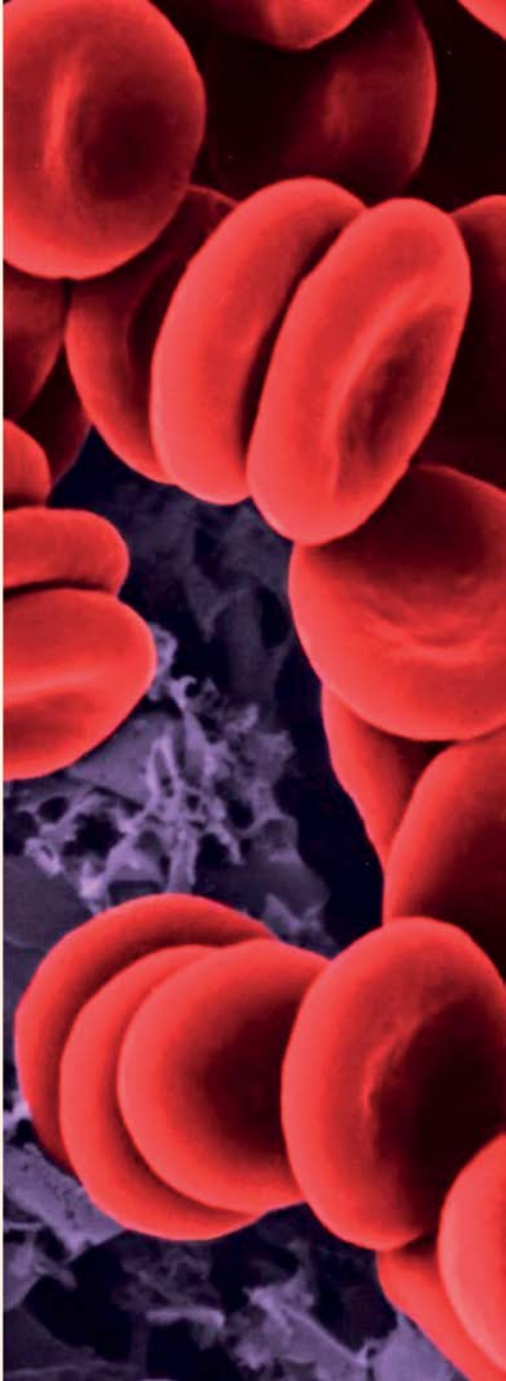
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# CONTENTS

- 4 Being human
- 6 Body builders
- 8 Types of cell
- 10 Dividing cells
- 12 From cells to systems
- 14 Looking inside

## 18 SHAPING THE BODY

- 20 Skin
- 22 Hair and nails
- 24 Keeping warm
- 26 Skeletal system
- 30 Inside bones
- 32 Bone types
- 34 Healing fractures
- 36 How joints work
- 38 Types of joint
- 40 Muscles and movement
- 42 Types of muscle
- 44 Inside a muscle
- 48 How muscles work

## 50 BLOOD AND LYMPH

- 52 Blood system
- 54 Blood vessels
- 58 The heart
- 60 Heartbeat
- 62 What's in blood?
- 64 Blood clotting
- 66 Fighting disease
- 70 The body's drain
- 72 Filtering blood
- 74 Getting rid of waste

## 76 LUNGS AND BREATHING

- 78 Breathing system
- 80 Breathe in, breathe out

- 82 Inside the lungs
- 84 Speech

## 86 THE DIGESTIVE SYSTEM

- 88 Feeding the body
- 90 Chew and swallow
- 92 Into the stomach
- 94 Small intestine
- 98 Large intestine
- 100 The liver

## 102 CONTROLLING THE BODY

- 104 Nervous system
- 106 The brain
- 110 Spinal cord
- 112 Seeing
- 116 Tasting
- 118 Smelling
- 120 Touching
- 122 Hearing
- 124 Balance
- 126 Chemical messengers
- 128 Hormones in action

## 130 REPRODUCTION AND GROWTH

- 132 Female and male
- 134 Fertilization
- 136 In the womb
- 140 Genes and DNA
- 142 Growing up
  
- 146 Your amazing body
- 150 Glossary
- 152 Index
- 156 Acknowledgments

# Being human

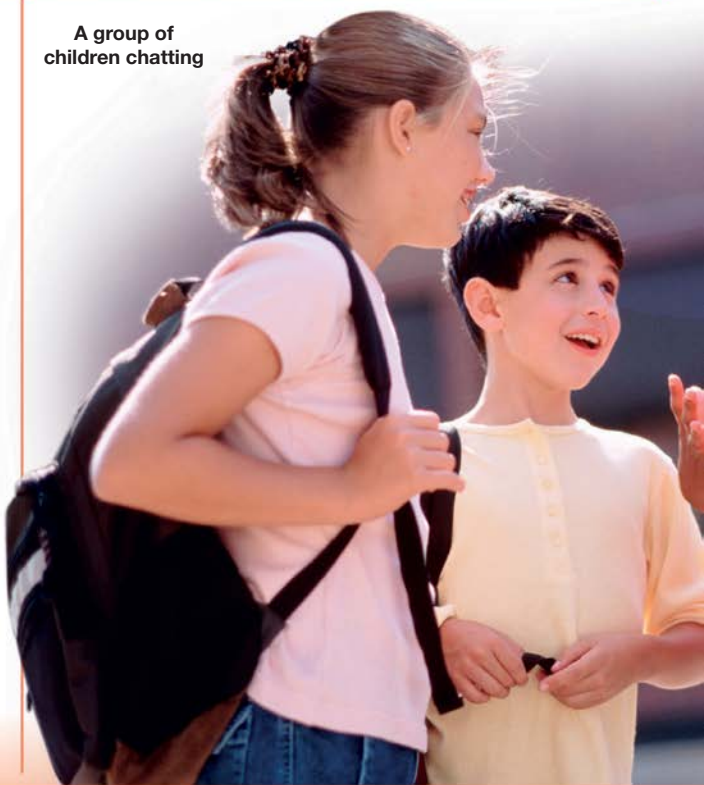
The human body has unique features that have enabled us to become the most successful animals on the Earth. We are the most intelligent and we have special ways of moving, communicating, and staying warm.



## On two legs

Humans stand on two legs, which allows us to walk or run long distances. Being upright raises the head, letting us see farther, and leaves the hands free for tasks such as using tools.

A group of children chatting



## In touch

Being able to talk to people using spoken language is unique to humans. It helps us to make and maintain social relationships. Other animals do this with calls and body language but not with words.



## Skillful hands

Human hands are incredibly flexible and can perform a wide range of movements. The thumbs and fingers can grip precisely for delicate tasks such as painting, or grip powerfully to pull a heavy weight.



## Keeping warm

Humans are the only animals that wear clothes. This way of keeping warm allowed early humans to migrate from tropical Africa, where they first appeared, to colder climates, including the Arctic.



# Body builders

The human body is made up of trillions of microscopic cells. Each cell is a living unit with a complex structure. Inside each cell are even smaller structures called organelles that control, produce, and move materials, release energy, and work together to keep the cell alive.

## Inside a cell

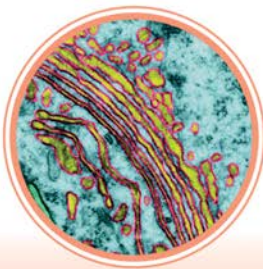
Although cells come in many shapes and sizes, they all share the same basic structure. Each cell has a membrane, or outer layer, that surrounds the cell. Inside the membrane is a liquid, called cytoplasm, which supports all the different organelles.

**Lysosomes** recycle worn-out organelles

The **nucleus** is the cell's control center

**Cytoplasm** is a jellylike fluid that contains organelles

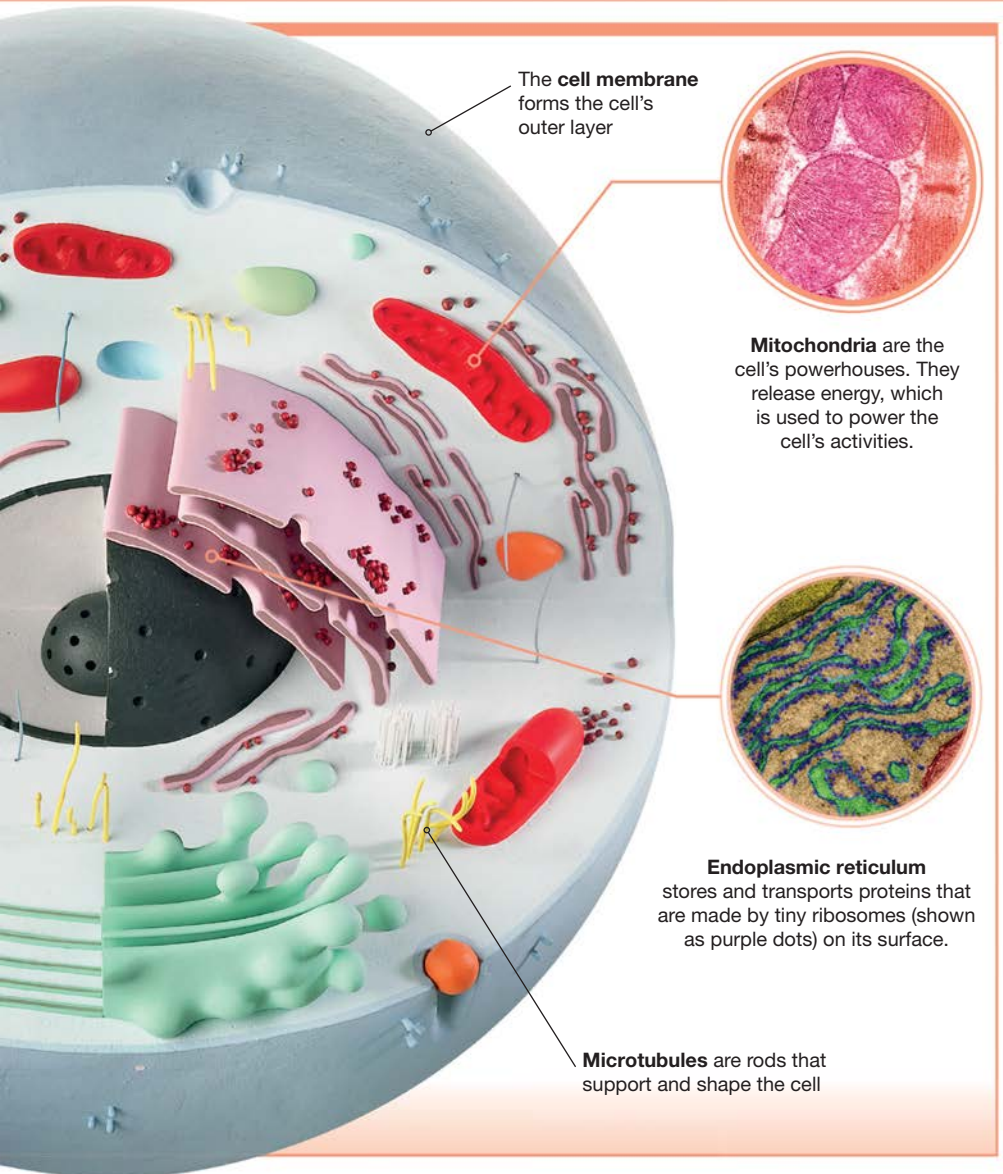
An organelle called the **Golgi complex** prepares proteins for use inside and outside the cell.



Structure of a typical cell, showing organelles





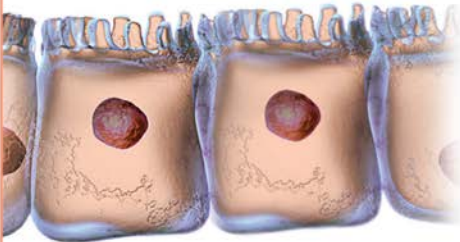


# Types of cell

There are around 200 different types of cell in a human body, each with its own job to do. Cells of the same type work together in groups called tissues. The size and shape of cells are linked to the specific roles they perform.

## Cell variety

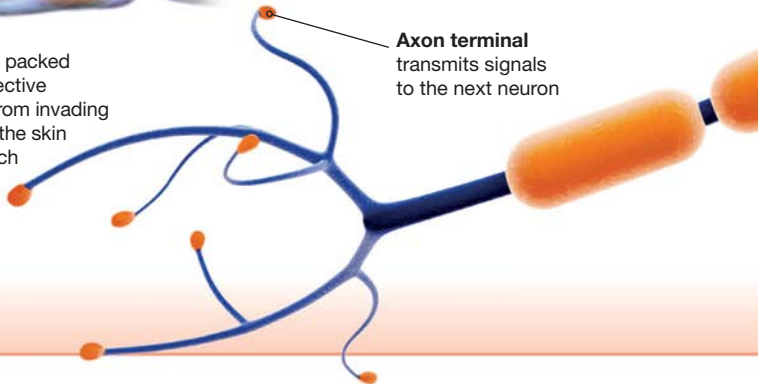
The six types of body cell shown here all have very different shapes and roles. For example, thin nerve cells carry signals over long distances, allowing the brain to communicate with other parts of the body, while round adipose cells store fuel.



**Epithelial cells** are tightly packed together and form a protective barrier that stops germs from invading body tissues. They cover the skin and line hollow organs such as the mouth and lungs.



**Red blood cells** travel around the body in the blood. They are small and, unlike other cells, do not have a nucleus. They give blood its red color and carry oxygen from the lungs to all other cells.

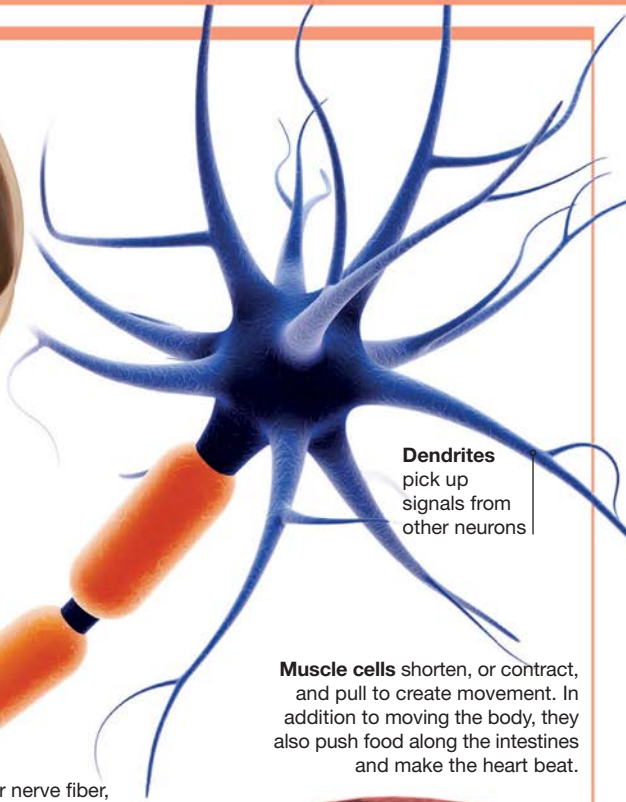


**Axon terminal**  
transmits signals  
to the next neuron



**Adipose cells**

contain a large droplet of fat—one of the body’s sources of energy. These cells also help insulate the body.



**Dendrites**

pick up signals from other neurons

**Nerve cells**, or neurons, carry electrical signals and make up the brain, the nerves, and the rest of the nervous system—the body’s control network.

**Axon**, or nerve fiber, carries signals

**Muscle cells** shorten, or contract, and pull to create movement. In addition to moving the body, they also push food along the intestines and make the heart beat.

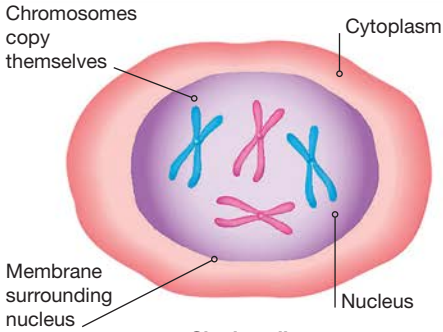


**Photoreceptor cells** are sensitive to light and are found inside the eye. When light hits these cells, they send signals to the brain that allow us to see.



# Dividing cells

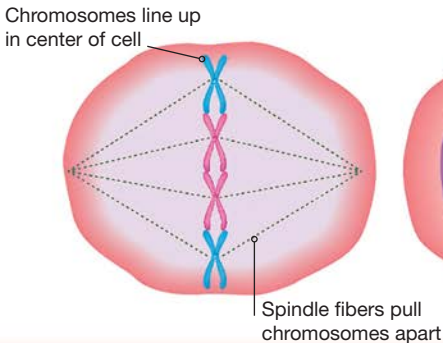
We all start life as a single cell. That cell divides again and again to produce the trillions of cells needed to build a body. Without cell division—or mitosis—the body would be unable to grow. It would also be unable to repair itself by replacing worn-out, damaged, or lost cells.



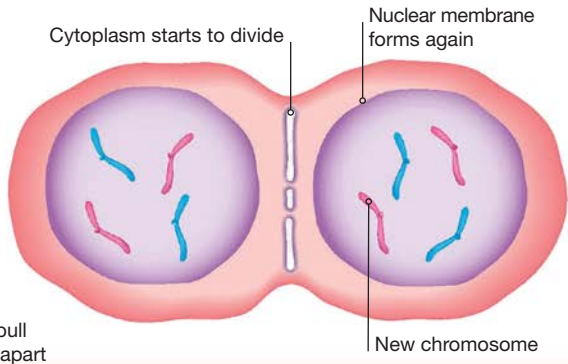
**Single cell**

## Identical offspring

In mitosis, a cell divides to produce two identical cells. Inside its nucleus, chromosomes hold the instructions to build and run the cell. First, each chromosome copies itself. Then, the two-stranded chromosomes line up. Next, the two strands are pulled apart to opposite ends of the cell. Finally, the cytoplasm divides to form two new, identical cells.



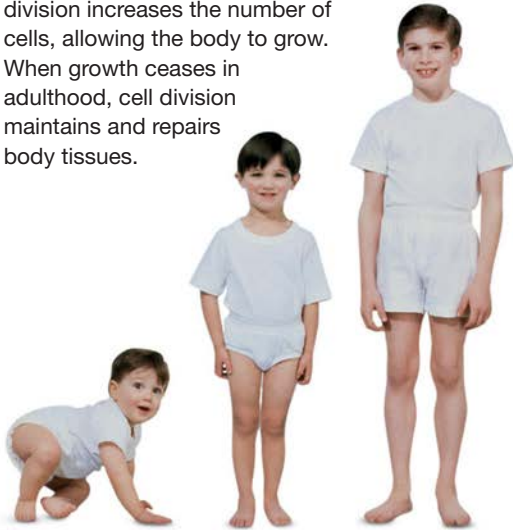
**Lining up**



**Separation**

## Getting bigger

Humans grow from birth to their late teens, mainly as a result of cell division. Controlled by the body's growth hormone, cell division increases the number of cells, allowing the body to grow. When growth ceases in adulthood, cell division maintains and repairs body tissues.

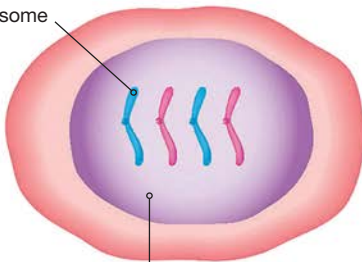


## HEALING

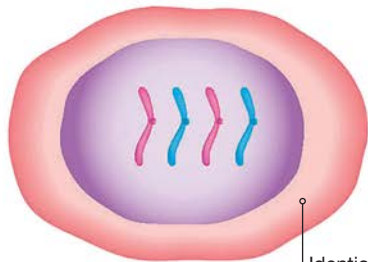


If the skin is cut or grazed, the damage is repaired automatically. Cell division is an important part of this repair process. At the wound site, cells divide to produce new skin cells to replace those that have died or been scraped away. Cell division also plays a key part in repairing damage inside the body.

Chromosome



Nucleus of offspring cell



Identical offspring cell

New cells

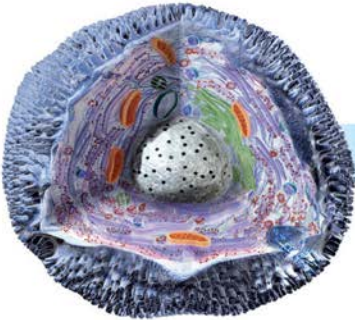
# From cells to systems

The 100 trillion cells that make up the body do not operate independently of each other. If they did, the body would be an uncoordinated, shapeless mass. Instead, they are precisely organized to form tissues, organs, and systems that work together to make a complete, functioning human body.

## Body organization

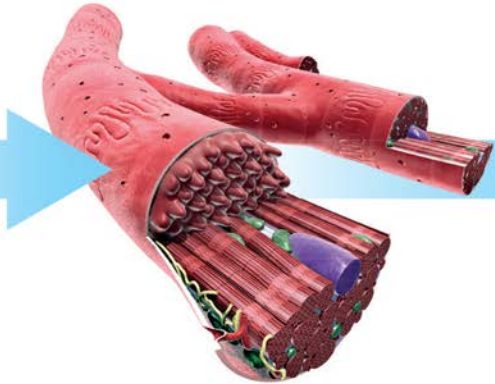
The body is organized as a series of different levels. At the lowest level are cells. Cells work together in groups called tissues. Different tissues are grouped together to produce organs, such as the heart. At the highest and most complex level, organs are linked together to form a system, such as the circulatory, or blood, system.

### CELL



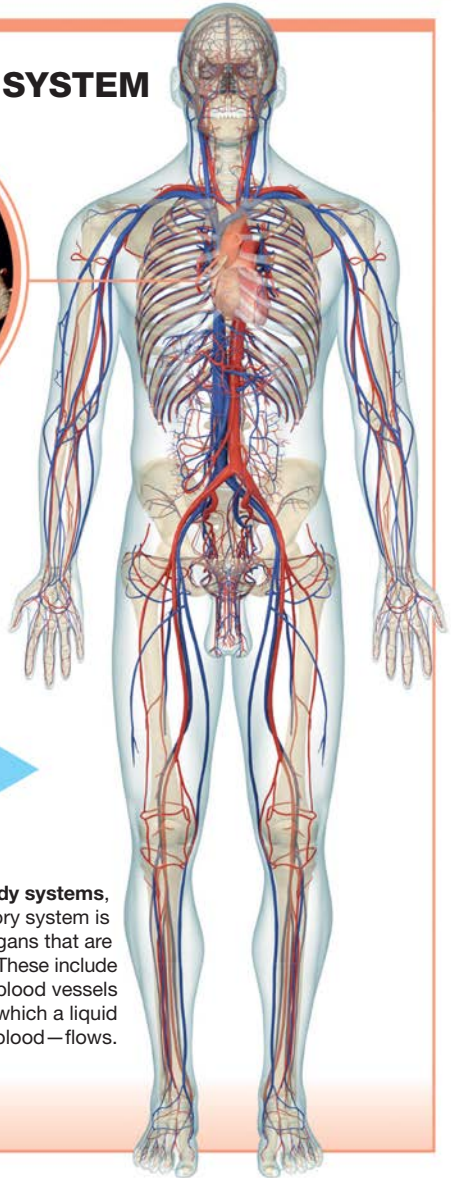
This typical **cell** shows the features that are common to all cells. Cardiac muscle cells, with these and other features, are found in the heart. They contract, or shorten, to make the heart beat.

### TISSUE



Cells of the same type work together in a group called a **tissue**. Cardiac muscle cells are linked together in a network to form cardiac muscle tissue.

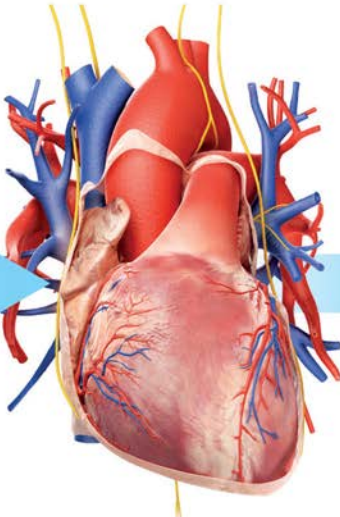
## SYSTEM



The heart is a **powerful pump** located in the chest. It pushes blood along a network of blood vessels to all parts of the body.



## ORGAN



**Organs**, such as the heart, are made of two or more types of tissue. In addition to muscle tissue, the heart also contains connective tissue, which holds it together.

Like other **body systems**, the circulatory system is made up of organs that are linked together. These include the heart and blood vessels through which a liquid tissue—blood—flows.

# Looking inside

Years ago, the only way doctors could look inside a living body was by cutting it open. Today, they can use many different techniques to produce images of body organs and tissues without causing any harm. Some of the most common methods include X-rays, CT scans, MRI scans, and ultrasound.



## X-ray

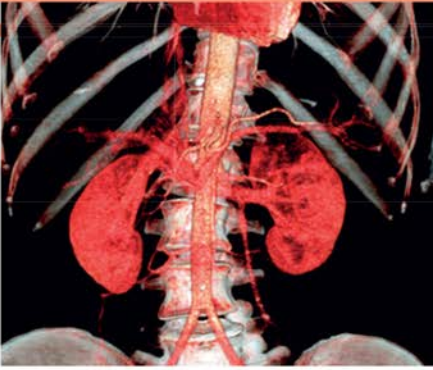
Discovered in 1895, X-rays are a form of high-energy radiation. These rays are beamed through the body onto a photographic film. Hard body parts, such as bones, absorb X-rays and show up clearly on film. X-rays pass through soft tissues, so these are less visible.

## MRI scan

The scan below shows a cross-section through the head and was produced by magnetic resonance imaging (MRI). A person lies inside a tunnel-like scanner and is exposed to powerful magnets. This causes body tissues to give off radio waves, which the scanner's computer turns into images.







## CT scan

A computed tomography (CT) scan is produced by sending beams of X-rays through the body and turning them into “slices” through organs and tissues on a computer. These slices can be built up to produce 3-D (three-dimensional) images, such as this one of the abdomen.

## Ultrasound

High-pitched sound waves are used to create ultrasound images, such as this one of a 20-week-old fetus (unborn baby). Sound waves bounce off the fetus, creating echoes that are turned into images by a computer.



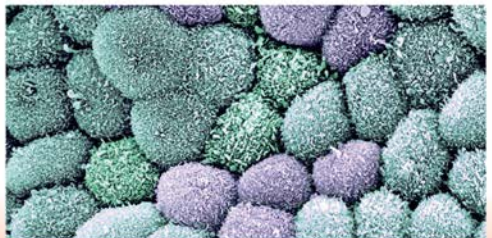
## Endoscopy

An endoscope is a thin, flexible tube with a camera at one end. This is inserted into the body so that doctors can see on screen what is happening.



## SEM

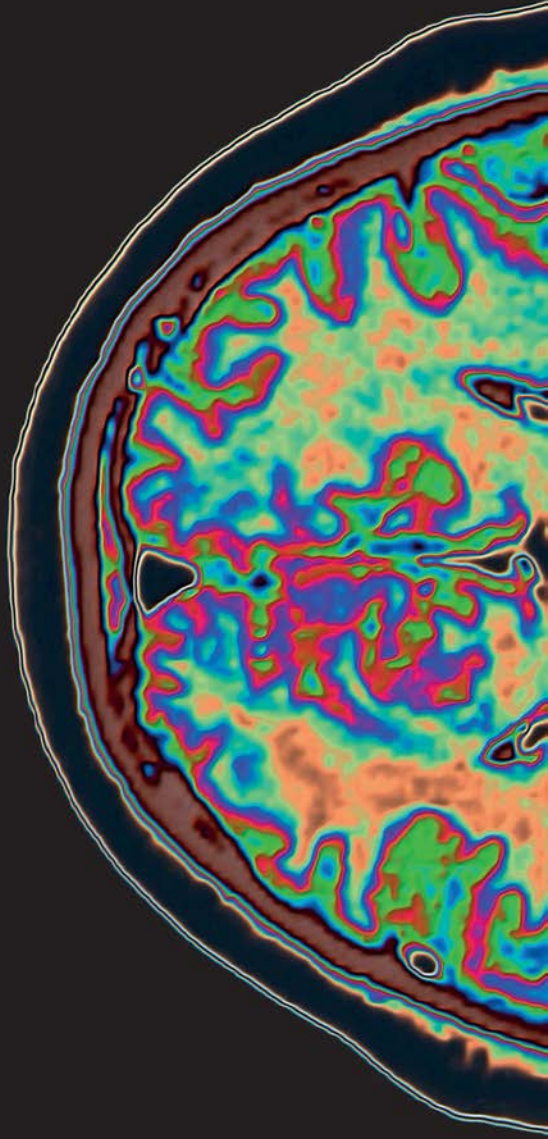
Using a special type of microscope, scanning electron microscopy (SEM) produces magnified, 3-D images of tissue samples taken from the body. This SEM image shows plump adipose cells taken from the layer of fat under the skin.

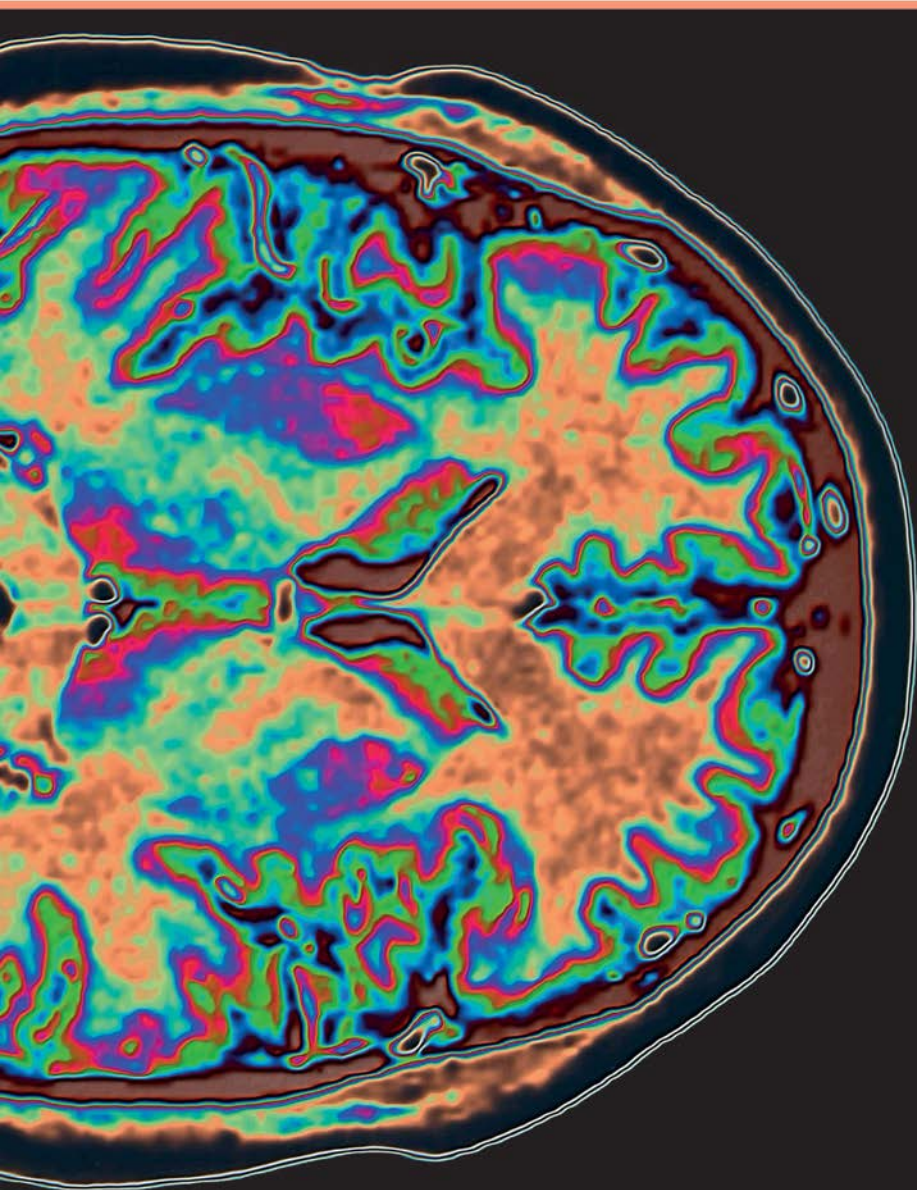


### **BRAIN SCAN**

This MRI scan shows a "slice" through the head, looking down on the brain and skull bones from above. Most of the scan's space is taken up by the cerebrum, the biggest part of the brain. The different colors show the different regions of the cerebrum.

**The human brain  
is about the size  
of a cauliflower,  
but weighs  
3 lb  
(1.4 kg)**







# Shaping the body

Together, the skeletal system, the muscular system, and the skin support, shape, move, and cover the body. The bones of the skeletal system form a structure that is strong enough to support the body's weight, but light and flexible enough to allow it to move. The muscular system works with the skeleton to shape the body, and, by pulling bones, makes the body move. Skin provides a protective overcoat around the whole structure.



## **SMALLEST BONES**

The three ossicles are the body's smallest bones. The tiniest ossicle is the size of a grain of rice. They are linked together and found in the ear, where they transmit sounds.

# Skin

The largest organ in the body, the skin forms a barrier between the body's insides and the outside world. Waterproof, germ-proof, and self-repairing, the skin also screens out harmful rays from the Sun and allows people to feel their surroundings.

## Skin-deep

The skin has two layers. The upper, protective epidermis consists mainly of flattened cells packed with keratin, a tough, waterproof protein. Below that, the thicker dermis contains blood vessels, nerves, sweat glands, and other structures.

### Sebaceous glands

release sebum, an oily substance that softens the skin

### Hair follicles

are narrow pouches from which hair grows

### Arteries

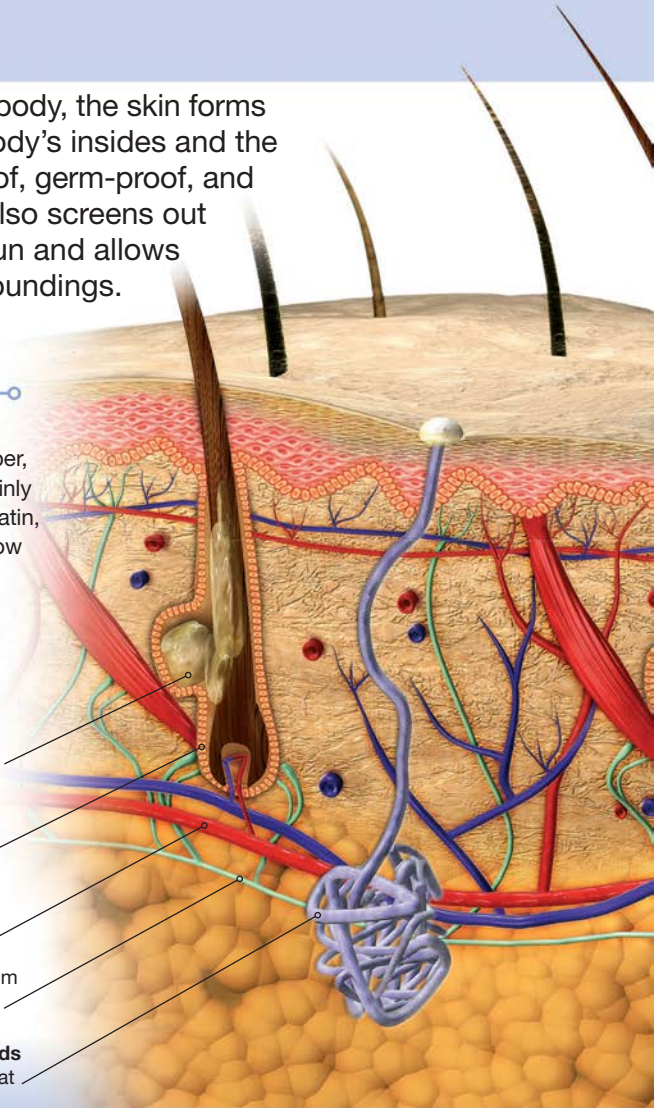
supply food and oxygen to skin cells

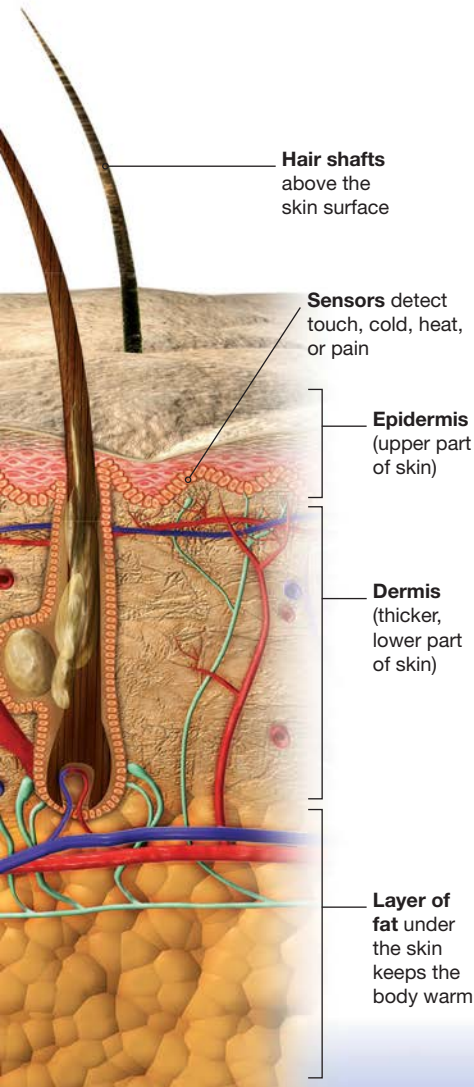
### Nerves

carry signals from the sensors to the brain

### Sweat glands

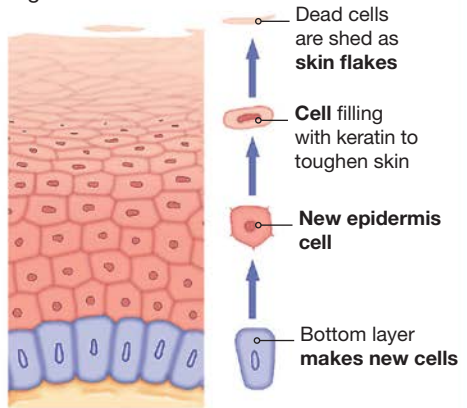
release sweat





## New skin

The epidermis is made up of different layers of cells. The top layer of dead cells is constantly worn away and replaced by new cells that move upward, flattening and dying as they do so. In this way, the skin regenerates itself.



## GRIPPING RIDGES



**Fingerprint**

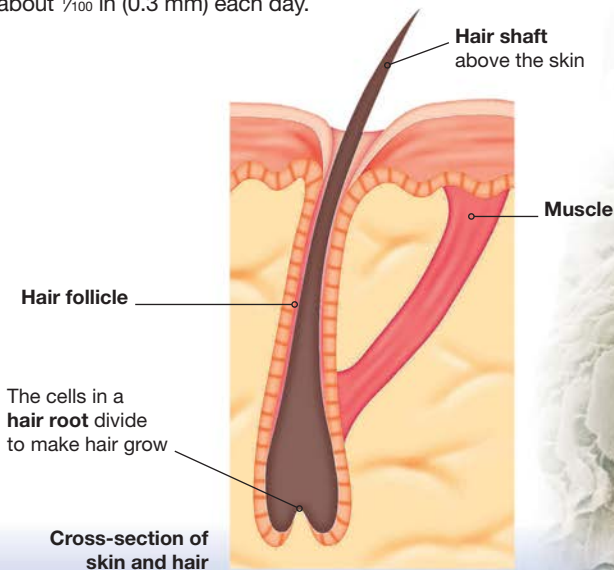
Tiny ridges at the end of each finger help the fingers grip objects. On hard surfaces, such as glass, these ridges leave behind sweaty patterns called fingerprints. Each person's fingerprint patterns are unique.

# Hair and nails

Both hair and nails grow from the skin. They are made from dead cells packed with tough keratin. Hair covers most parts of the body. Nails protect the sensitive tips of our fingers and toes and help us to grip small objects.

## Hair structure

Each flexible strand of hair grows out of a follicle. Hair consists of a shaft that appears above the skin's surface and a root below it. At the base of the root, new cells are produced that move upward and make the hair grow. The hair on your head grows about  $\frac{1}{100}$  in (0.3 mm) each day.



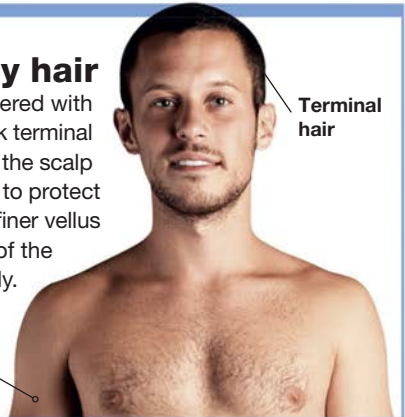


## Body hair

The body is covered with millions of hairs. Thick terminal hairs, such as those of the scalp and eyebrows, help to protect the body. Shorter, finer vellus hairs cover much of the rest of the body.

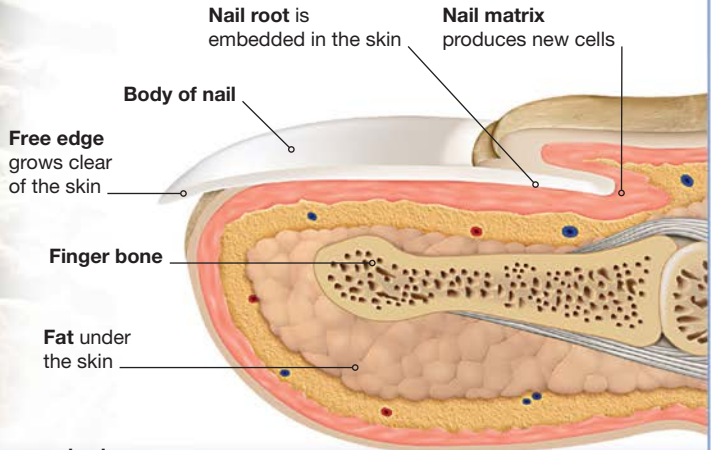
Terminal hair

Vellus hair



## Protective nails

Each nail has a root and a body, and ends in a free edge. In the nail matrix behind the root, living cells multiply and push the nail body forward to make the nail grow. Most nails grow about  $\frac{1}{100}$  in (0.3 mm) each week.



Microscopic view of hair shafts

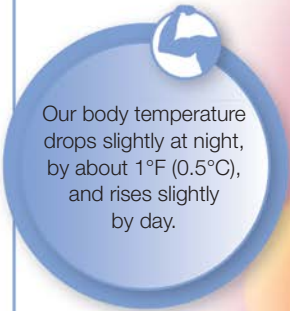
Cross-section of a finger and nail

# Keeping warm

Skin plays an important role in keeping the body temperature balanced at 98.6°F (37°C), no matter how hot or cold it is outside. This is the ideal temperature for the body's cells to work at their most efficient.

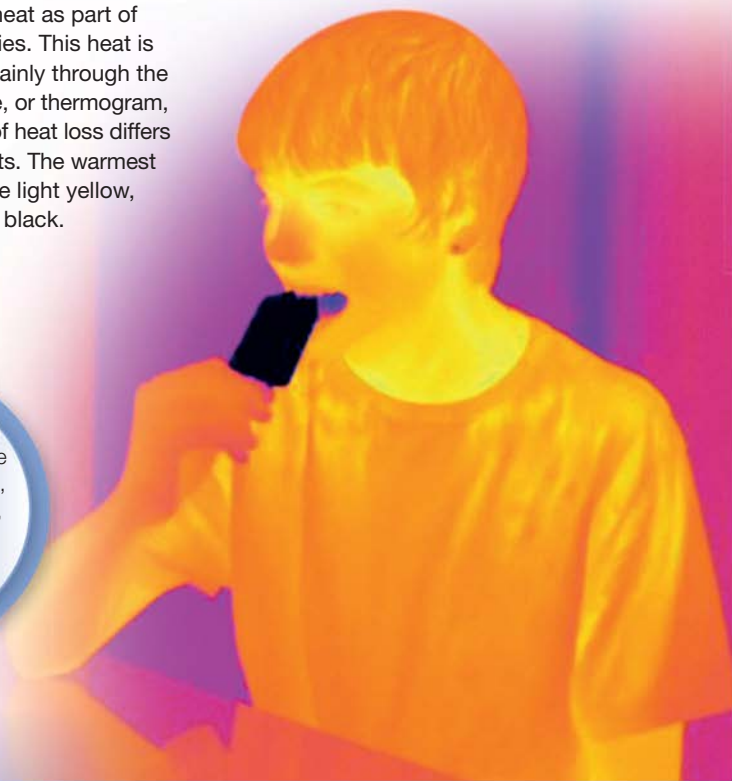
## Losing heat

Body cells produce heat as part of their everyday activities. This heat is lost from the body mainly through the skin. A thermal image, or thermogram, shows how the rate of heat loss differs for different body parts. The warmest parts of the image are light yellow, while the coldest are black.



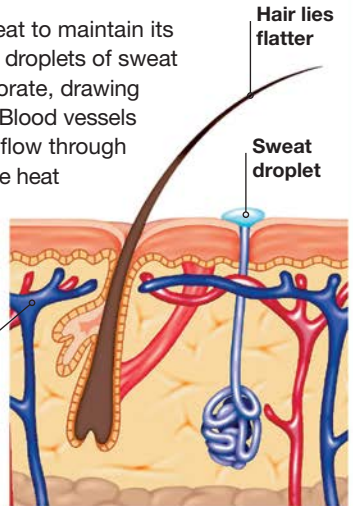
Our body temperature drops slightly at night, by about 1°F (0.5°C), and rises slightly by day.

**Thermal image  
of a boy eating  
an ice pop**



## Feeling hot

There are two ways the body loses heat to maintain its temperature in warm conditions. Tiny droplets of sweat released onto the skin's surface evaporate, drawing away heat and cooling the body. Blood vessels widen, increasing blood flow through the skin so that more heat escapes through the surface.

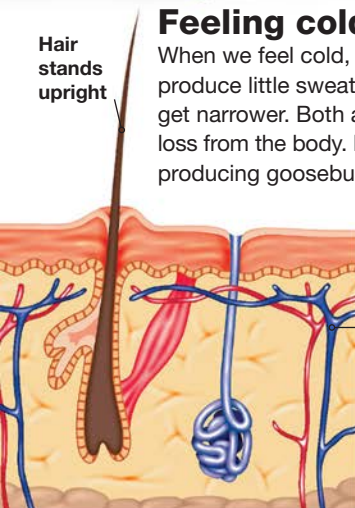


Blood vessels widen

Skin responds to hot conditions

## Feeling cold

When we feel cold, sweat glands produce little sweat and blood vessels get narrower. Both actions reduce heat loss from the body. Hairs are pulled upright, producing goosebumps on our skin.



Hair stands upright

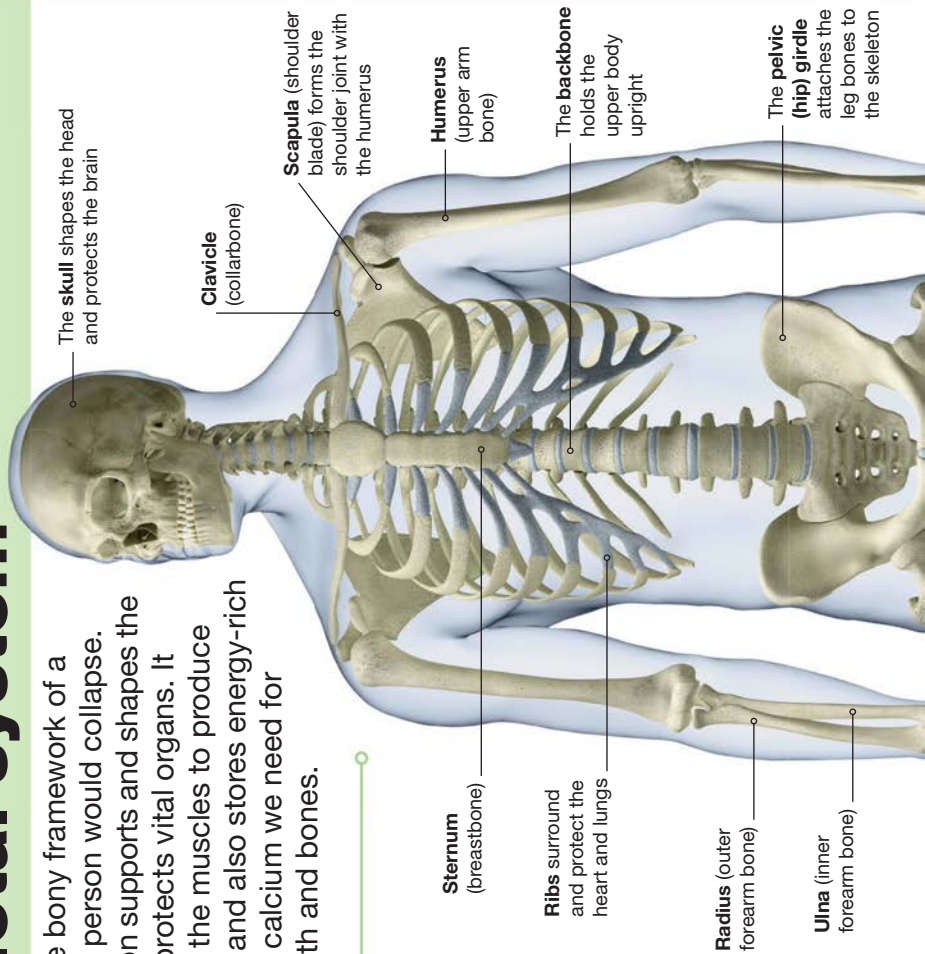
Blood vessels narrow

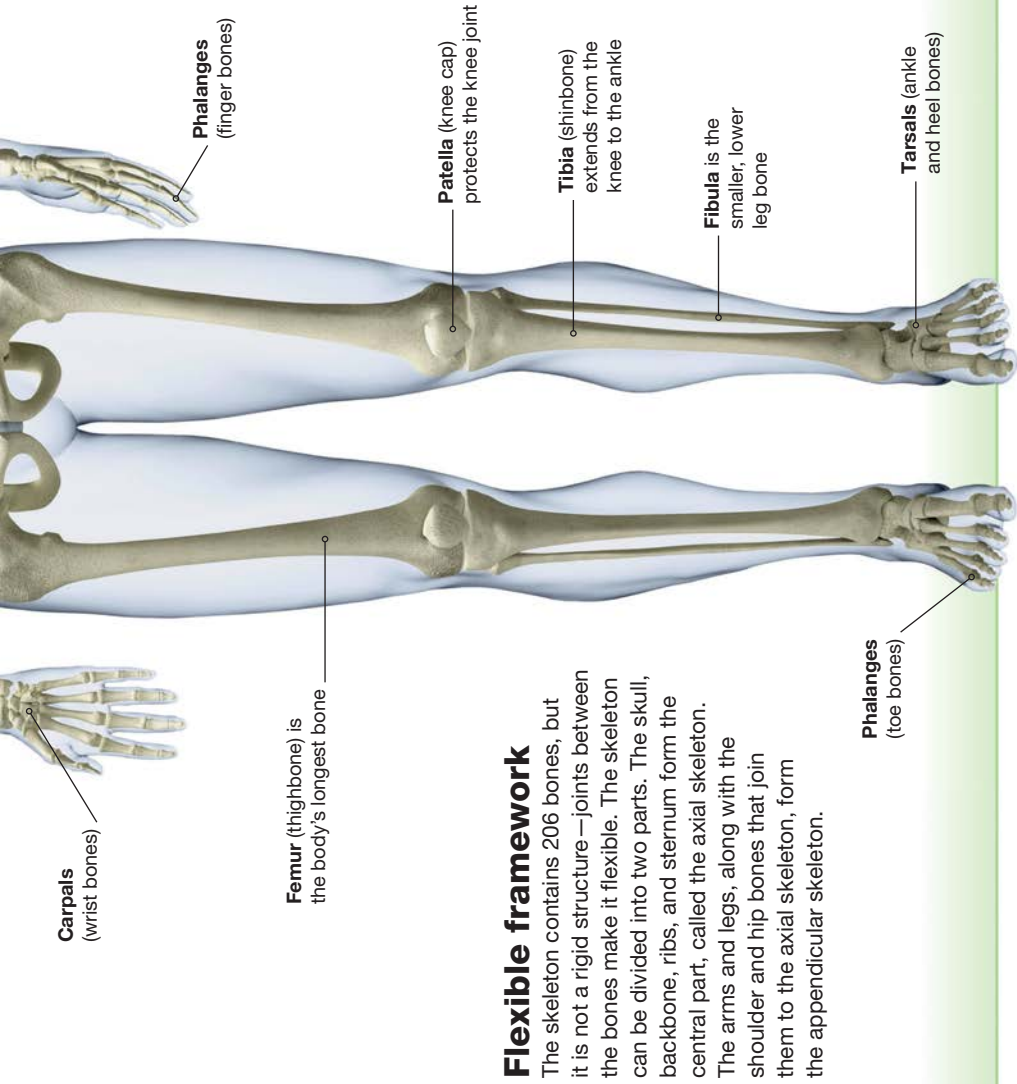
Skin responds to cold conditions



# Skeletal system

Without the bony framework of a skeleton, a person would collapse. The skeleton supports and shapes the body and protects vital organs. It works with the muscles to produce movement and also stores energy-rich fat and the calcium we need for healthy teeth and bones.





## Flexible framework

The skeleton contains 206 bones, but it is not a rigid structure—joints between the bones make it flexible. The skeleton can be divided into two parts. The skull, backbone, ribs, and sternum form the central part, called the axial skeleton. The arms and legs, along with the shoulder and hip bones that join them to the axial skeleton, form the appendicular skeleton.

Weight for  
weight, bone is  
**five times  
stronger**  
than steel



**BONE TISSUE**

This microscopic view inside some spongy bone shows a latticework of struts and spaces. This honeycomb structure makes the bone very light and incredibly strong.

# Inside bones

Bones are made up of different types of bone tissue. In the outer parts of the bone the tissue is dense, but in the inner parts it is lighter. This combination makes bones strong enough to support weight but not so heavy that the body cannot move.

## Structure of a bone

The view inside a bone shows its structure. The outer layer of hard, heavy, compact bone is made of tiny, bony tubes called osteons. It encloses lighter spongy bone. A central cavity contains yellow bone marrow.

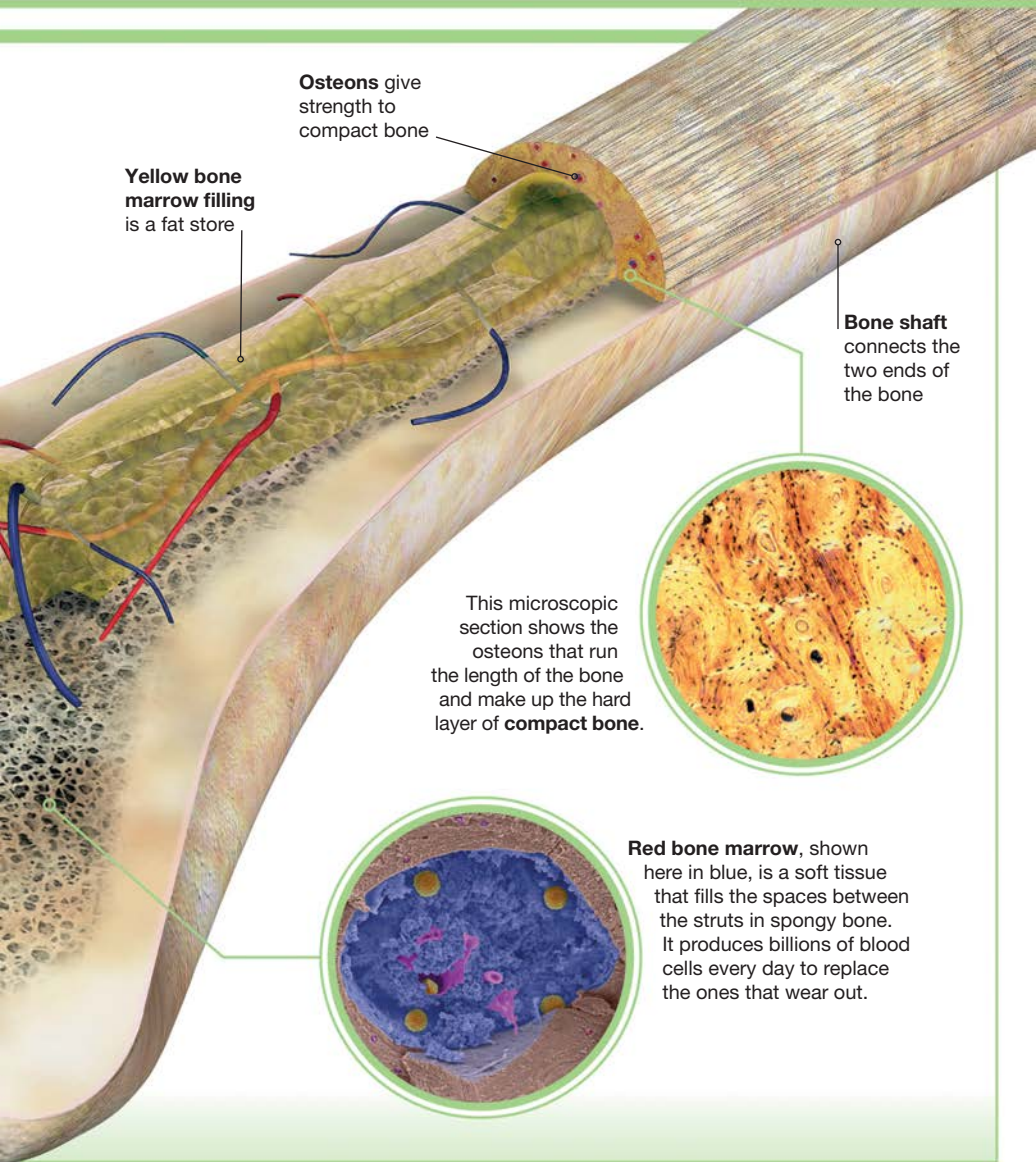
**Blood vessels** supply bone cells with nutrients and oxygen

**Epiphysis** is the rounded end of the bone

**Spongy bone** is not squishy, as its name may suggest. It consists of a network of bony struts that make it strong but light.







**Osteons** give strength to compact bone

**Yellow bone marrow filling** is a fat store

**Bone shaft** connects the two ends of the bone

This microscopic section shows the osteons that run the length of the bone and make up the hard layer of **compact bone**.

**Red bone marrow**, shown here in blue, is a soft tissue that fills the spaces between the struts in spongy bone. It produces billions of blood cells every day to replace the ones that wear out.

# Bone types

The shape and size of a bone depend on the functions it performs. Bones are divided into five different types, based on their shape—long, short, irregular, flat, or sesamoid.

## Long bones

These bones are so named because they are longer than they are wide. This group includes most arm and leg bones, such as the body's longest bone, the femur, as well as the much smaller phalanges—the toe and finger bones. Long bones support the body and allow it to move freely.

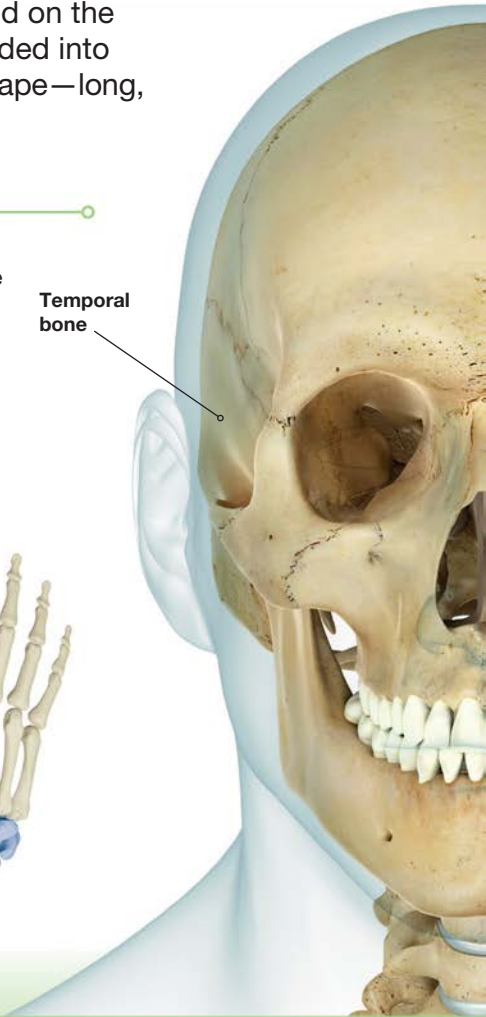
Femur

## Short bones

Shaped roughly like cubes, short bones are found in the wrists and ankles. They do not allow much movement, but do help to support the hands and feet.

Wrist bones

Temporal bone



Frontal  
bone

## Flat bones

Thin, flattened, and usually curved, flat bones protect the body's most important organs. For example, the skull's temporal, frontal, and other flat bones surround the brain. Other flat bones include the ribs, shoulder blades, breastbone, and hip bones.



## Irregular bones

These bones have complicated shapes. They include the 26 vertebrae that are stacked up to form the backbone or spine. In addition to supporting the upper body and allowing it to bend, the backbone also protects the spinal cord.

Backbone

Vertebra

Spinal  
cord



## SESAMOID BONES

These bones are shaped like sesame seeds. The patella (kneecap), which is a sesamoid bone, is found inside the tendon that attaches the thigh muscle to the shinbone. It increases the muscle's pulling power and protects the knee joint.



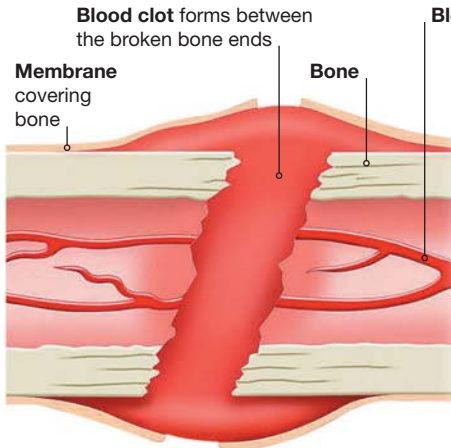
Patella

# Healing fractures

Bones are strong, but sometimes they fracture or break. When this happens, a self-repair mechanism springs into action. This process may need outside help from doctors to ensure that the bones—especially the arm and leg bones—are kept straight while they heal.

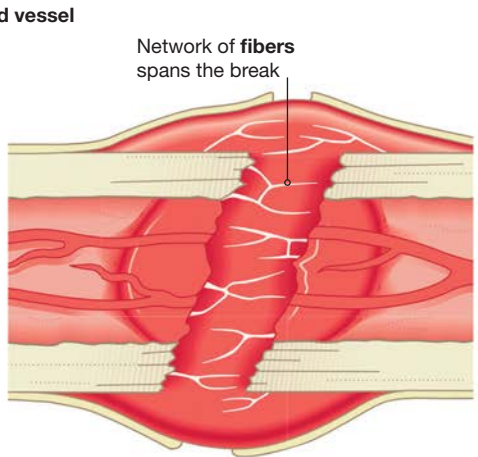
## Healing in progress

This step-by-step sequence shows how a long bone heals. When a bone fractures, the body's immediate response is to stop bleeding from the bone's blood vessels. In the days and weeks that follow, new tissues are laid down that reconnect the broken bone ends. A broken bone can take months to heal completely.



### IMMEDIATE RESPONSE

Blood leaking from torn blood vessels forms a jellylike clot. This seals off the vessels and stops blood from pouring into the wound.



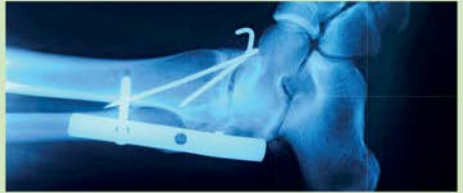
### THREE DAYS LATER

Repair cells called fibroblasts move to the fracture and produce fibers made of collagen (a protein that works as a building material). These fibers connect the broken bone ends.

## OUTSIDE HELP

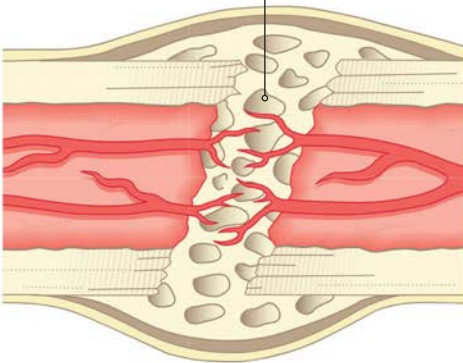


Broken bone ends are usually held together in the right position to make sure they heal correctly. This is often done using a rigid **plaster cast**.



For more severe fractures, **pins** are used to keep the bones lined up. This X-ray shows pinned leg bones just above the ankle.

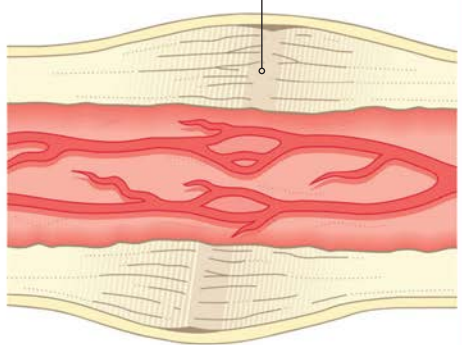
**Spongy bone** forms between the bone ends



### THREE WEEKS LATER

Bone-building cells are now active. They weave a mesh of spongy bone that provides a bond between the bone ends. But the bone is still weak and would be set in a plaster cast.

**Hard compact bone** replaces the spongy bone



### THREE MONTHS LATER

Blood vessels reconnect across the break. The healed bone shaft, made of compact bone, is almost the same shape as it was before the fracture.

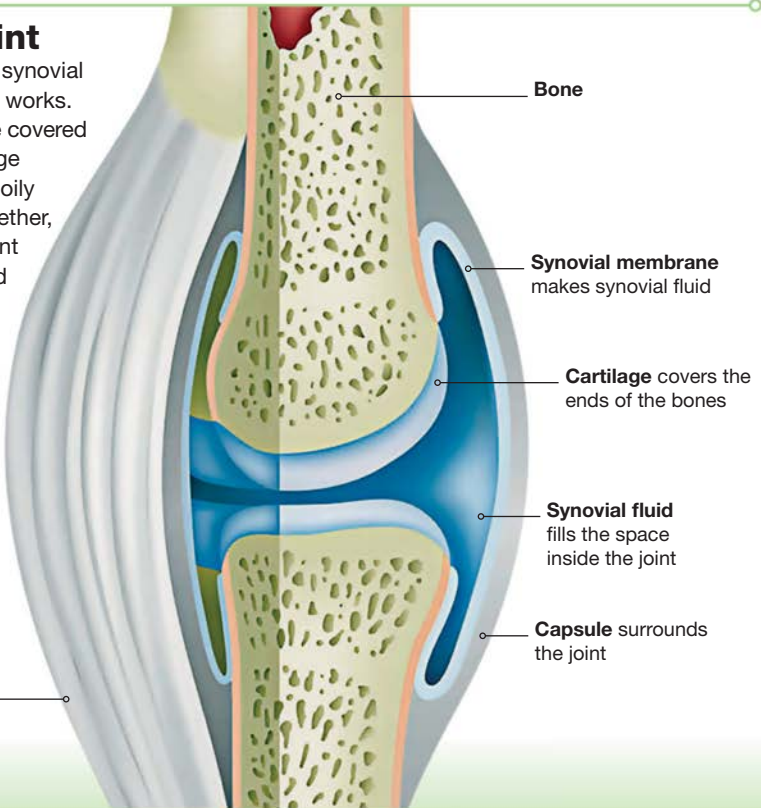
# How joints work

A joint is formed wherever two or more bones meet. Most joints, such as those in the fingers, are synovial joints. These allow the bones to move freely and give the skeleton its flexibility. Other joints, such as the semimovable and fixed joints, provide stability to the skeleton.

## Flexible joint

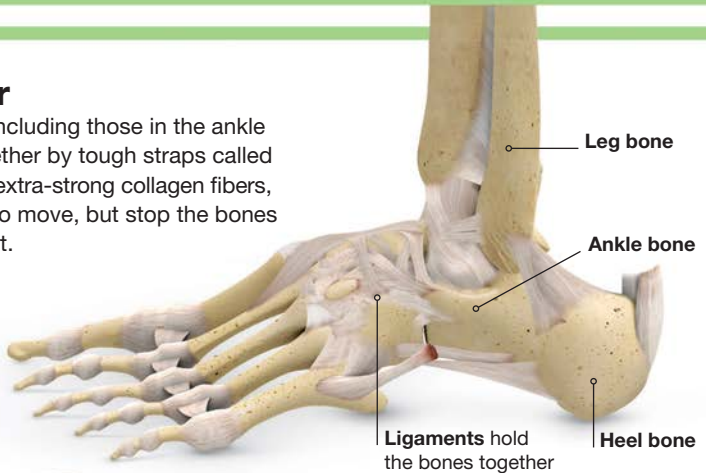
This view inside a synovial joint shows how it works. The bone ends are covered by slippery cartilage and separated by oily synovial fluid. Together, these allow the joint to move easily and smoothly. A tough capsule holds the joint in place.

**Ligaments** help the capsule to hold the joint together



## Held together

Many synovial joints, including those in the ankle and foot, are held together by tough straps called ligaments. Made from extra-strong collagen fibers, these allow the joints to move, but stop the bones from being pulled apart.



## Out of joint

This X-ray shows how two finger bones, forming a knuckle joint, have been pulled apart. This is known as dislocation and occurs when a sudden blow or pull forces the bones out of line. Doctors treat dislocations by moving the bones back into their correct positions.

# Types of joint

There are more than 400 joints in a human skeleton. Most of these are the synovial (movable) joints that allow us to run or shake our head. Others are fixed, or permit only limited movements.

## Movable joints

There are six types of movable joint in the body. Each type allows a different range of movement, shown here by arrows. Which way the bones can move depends on how their ends fit together in the joint. For example, the ball-and-socket joint in the hip allows the leg to swing in most directions.

## OTHER TYPES

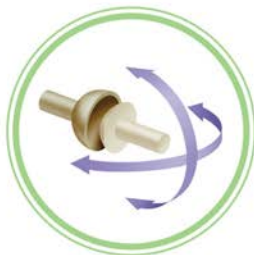


All 22 skull bones, except one in the jaw, are locked together by **fixed joints**.



**Semimovable joints**, such as those between the vertebrae in the backbone and between the hip bones shown here, allow limited movement.

**Saddle joint** allows the thumb to move freely and touch the other fingers.



**Ellipsoidal joint** in the knuckles and wrists allows up-and-down and side-to-side movements.







**Pivot joint**  
at the top of the  
backbone allows  
the head to turn  
from side to side.



**Ball-and-socket joint** in  
the hips and shoulders  
allows movement in  
most directions.



**Hinge joint** in  
the knees and  
elbows lets the  
legs and arms  
bend and  
straighten.



**Plane joint** between  
short bones with flat ends,  
such as the ankle and wrist  
bones, only allows small  
gliding movements.

# Muscles and movement

Without the body's muscles, we would not be able to move. The cells that make up the muscles have a unique ability to contract (get shorter) and pull. Skeletal muscles, for example, pull the bones of the skeleton to produce an incredible range of movement, from kicking a ball to scratching an itch.

## Skeletal muscles

Layered over the skeleton, skeletal muscles contract when they receive instructions from the brain. Some skeletal muscles are large and powerful—the bulkiest is the gluteus maximus, which pulls the thigh back as we walk, run, and jump. Others, such as the finger muscles, are built for small, precise movements such as turning a page. Skeletal muscles not only move the body, they also hold it upright.

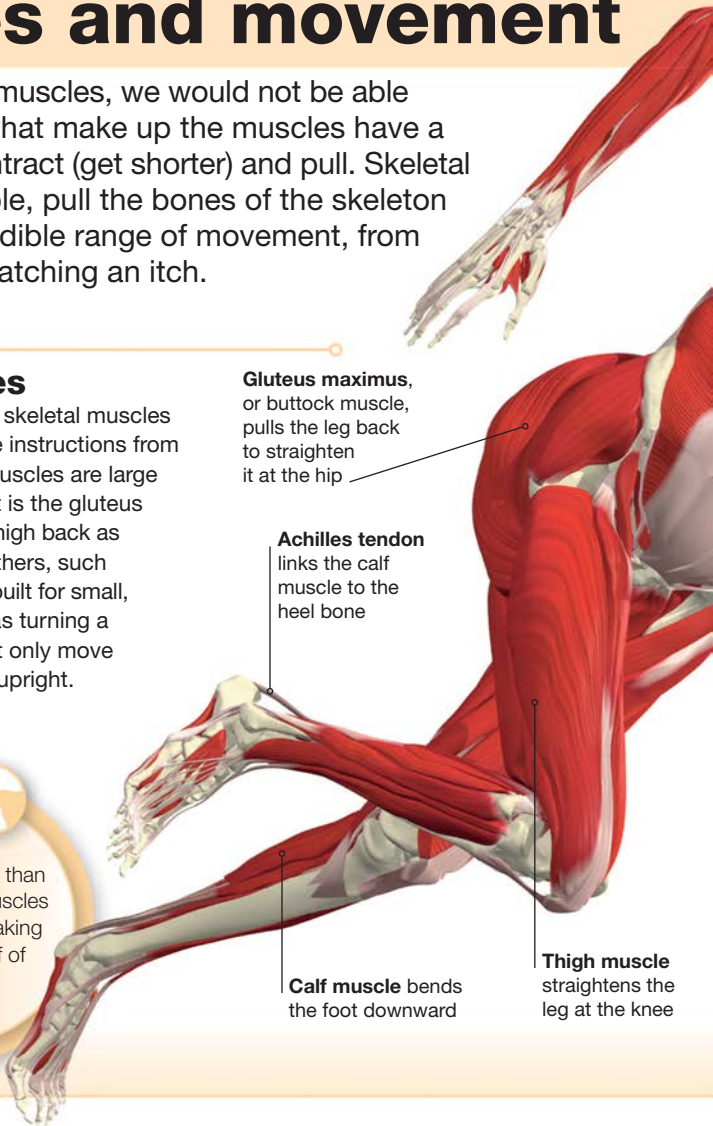
There are more than 640 skeletal muscles in the body, making up nearly half of its weight.

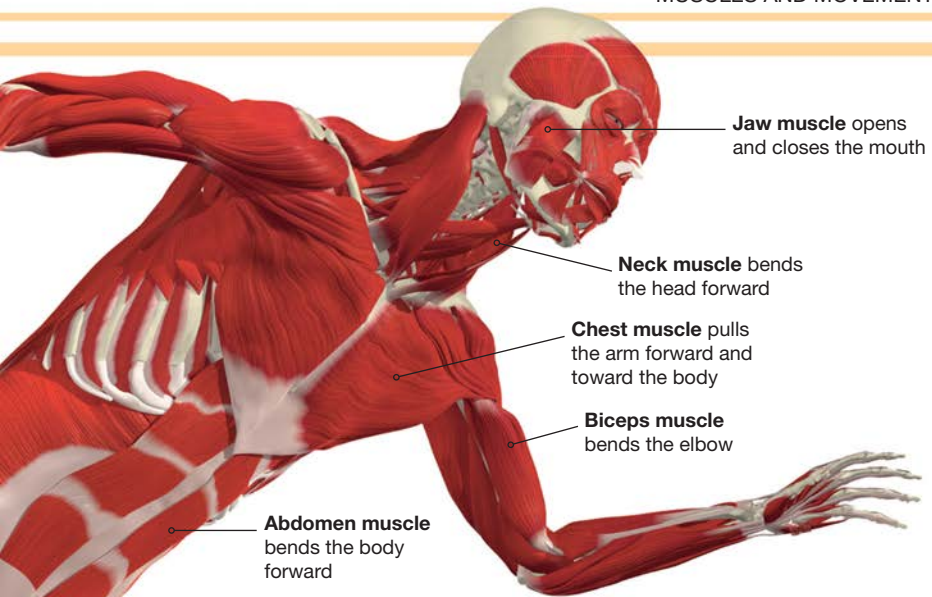
**Gluteus maximus**, or buttock muscle, pulls the leg back to straighten it at the hip

**Achilles tendon** links the calf muscle to the heel bone

**Calf muscle** bends the foot downward

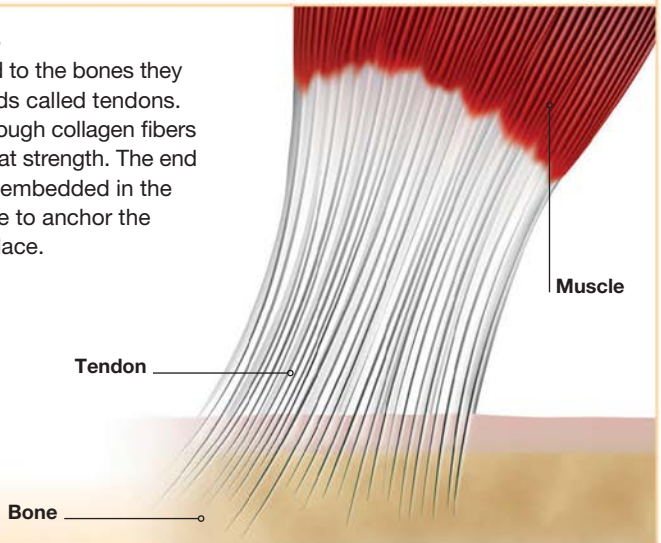
**Thigh muscle** straightens the leg at the knee





## Bone links

Muscles are linked to the bones they pull by strong cords called tendons. Tendons contain tough collagen fibers that give them great strength. The end of each tendon is embedded in the outer layer of bone to anchor the muscle firmly in place.

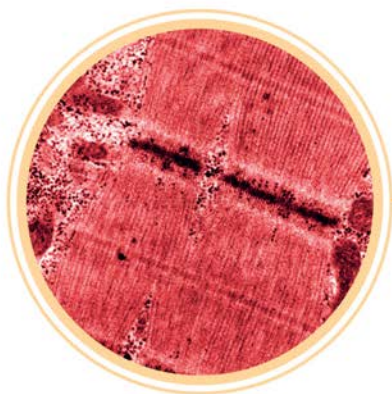


# Types of muscle

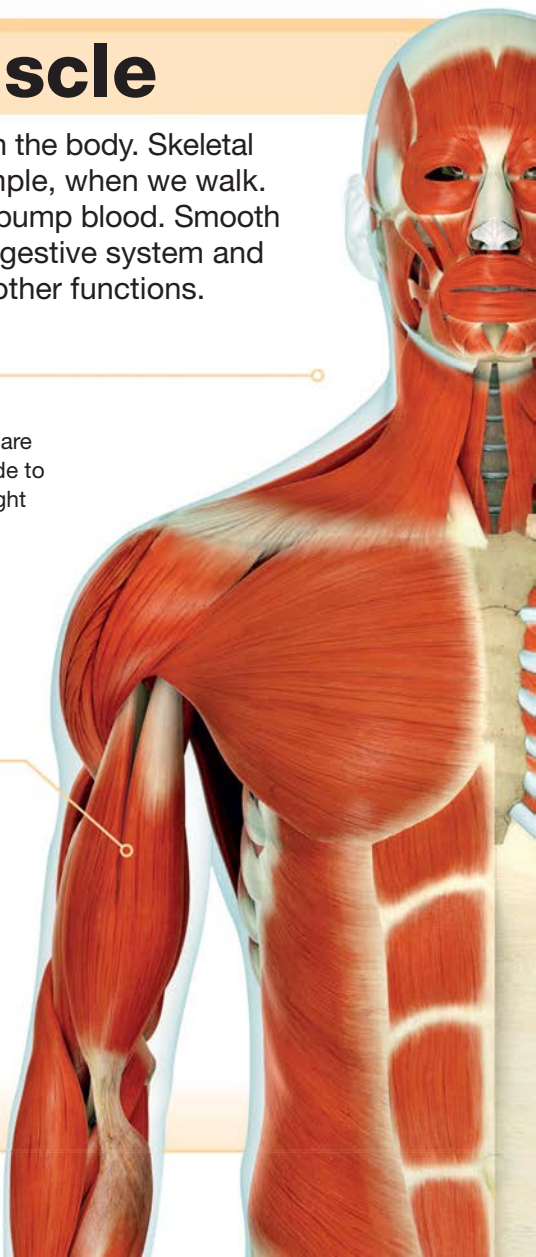
There are three types of muscle in the body. Skeletal muscle pulls the bones, for example, when we walk. Cardiac muscle makes the heart pump blood. Smooth muscle pushes food along the digestive system and urine out of the bladder, among other functions.

## Body movers

The skeletal muscles attached to our bones are under our conscious control. When we decide to make a movement, our brain instructs the right muscles to contract, or shorten.



**Skeletal muscle** fibers look striped under the microscope. Their overlapping filaments, or strands, work together to make a muscle contract.

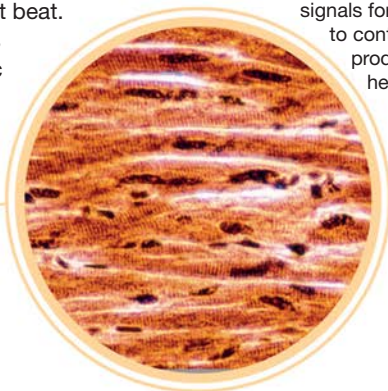


## Heart beater

Cardiac muscle is found in the wall of the heart. It contracts automatically thousands of times a day to make the heart beat.

Without us being aware, signals from the brain speed up cardiac muscle contraction when we exercise and slow it down when we rest.

**Cardiac muscle** is made up of a branching network of interlocking fibers. This passes on the signals for the fibers to contract and produce a heartbeat.

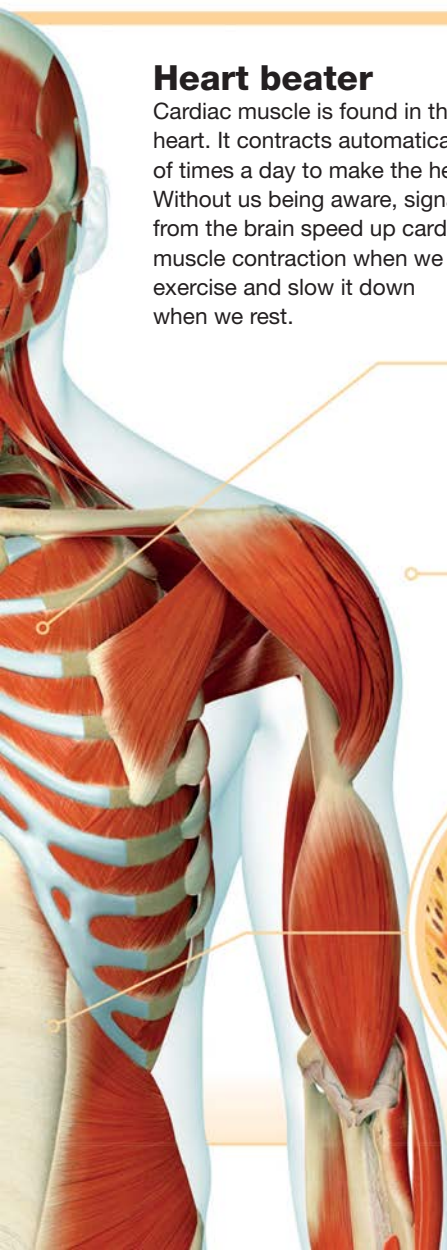
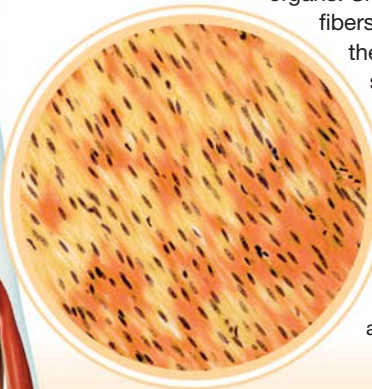


## Organ squeezers

Smooth muscle works automatically in the walls of hollow organs, such as the stomach and bladder. When it contracts, it squeezes those organs. Smooth muscle

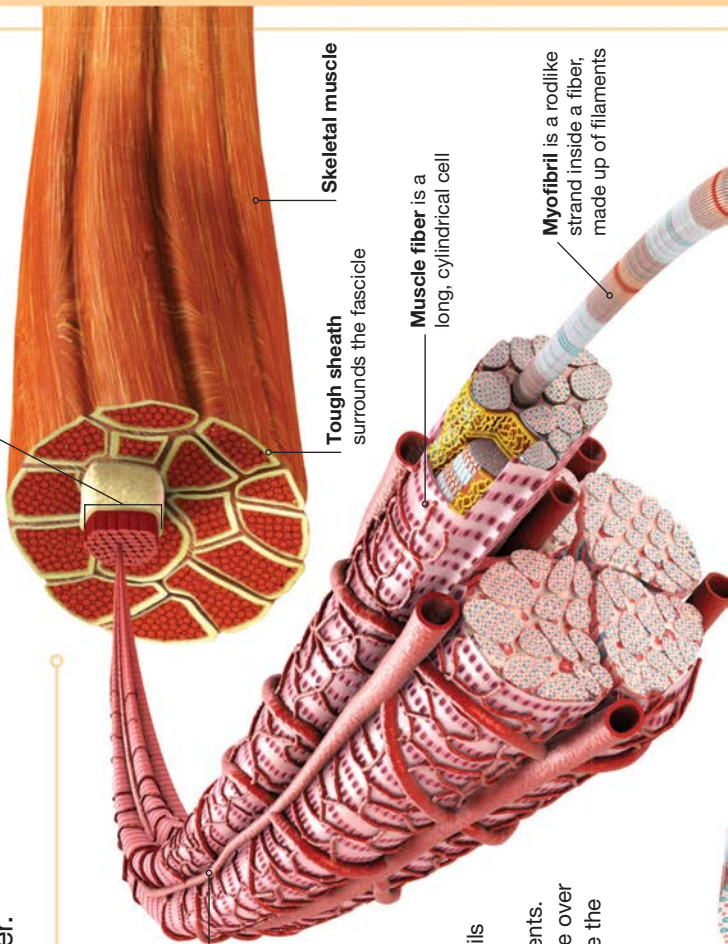
fibers in the irises of the eyes control the size of the pupils.

**Smooth muscle** has sheets of short fibers that wrap around hollow organs. Under a microscope, the fibers' nuclei appear as dark specks.



# Inside a muscle

Each skeletal muscle has a highly ordered structure, as shown by this “exploded” view. When instructed by the brain, each fiber of a skeletal muscle contracts to give the muscle its pulling power.



**Blood vessels** supply fuel and oxygen to the muscle fibers

## Muscle structure

Every muscle has bundles of fibers running along its length. Each fiber is packed with myofibrils that contain protein strands called filaments. These filaments slide over one another to make the muscle contract.

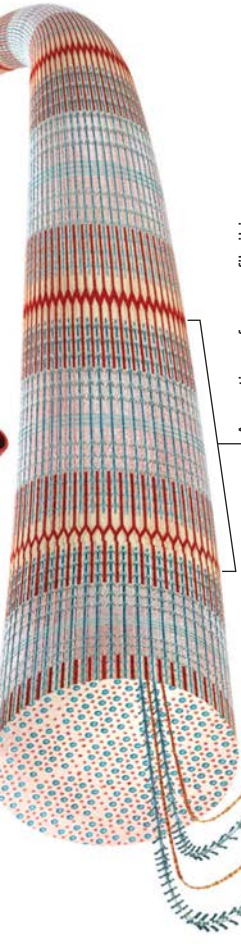
**Skeletal muscle**

Each bundle of muscle fibers is called a **fascicle**

**Tough sheath** surrounds the fascicle

**Muscle fiber** is a long, cylindrical cell

**Myofibril** is a rodlike strand inside a fiber, made up of filaments

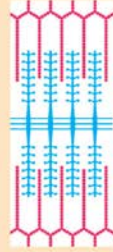


A section of a myofibril is called a **sarcomere**. It is made up of overlapping filaments.

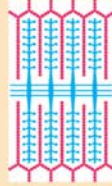
**Thin filament**  
mainly made up  
of the protein actin

**Thick filament**  
mainly made up of  
the protein myosin

## HOW MUSCLES CONTRACT



Relaxed muscle

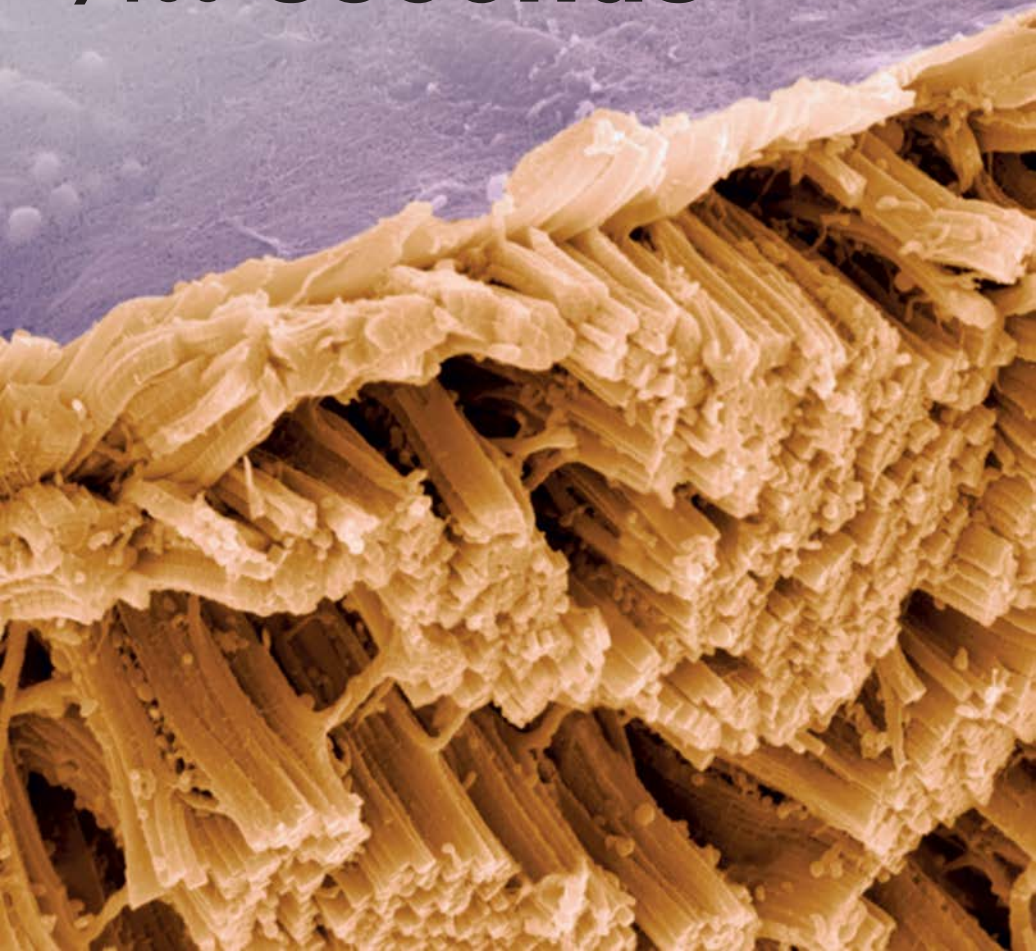


Contracted muscle

When the brain sends a signal to the muscles, overlapping thin filaments (shown here in red) slide over thick filaments (shown in blue). This makes muscle fibers shorter, causing the muscle to contract.

**The muscles that move the eyeballs  
react faster than any other body  
muscle, contracting in just**

**$\frac{1}{100}$  seconds**





**SKELETAL MUSCLE**

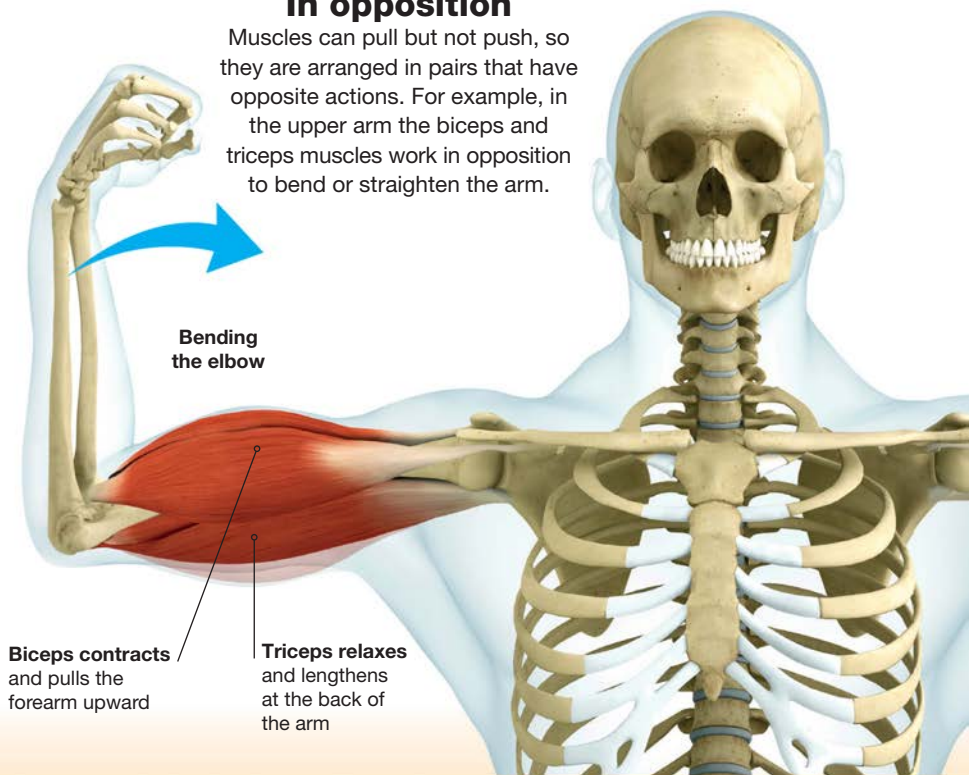
This SEM image shows a muscle fiber—one of the cells that make up skeletal muscle—that has been cut in two. It is packed with strands called filaments (shown in brown), which move to make the muscle contract.

# How muscles work

When skeletal muscles get instructions from the brain, they use energy to contract (shorten) and pull bones. Once the movement is complete, they relax and lengthen. Facial muscles tug at the skin of the face to produce different expressions.

## In opposition

Muscles can pull but not push, so they are arranged in pairs that have opposite actions. For example, in the upper arm the biceps and triceps muscles work in opposition to bend or straighten the arm.



**Bending  
the elbow**

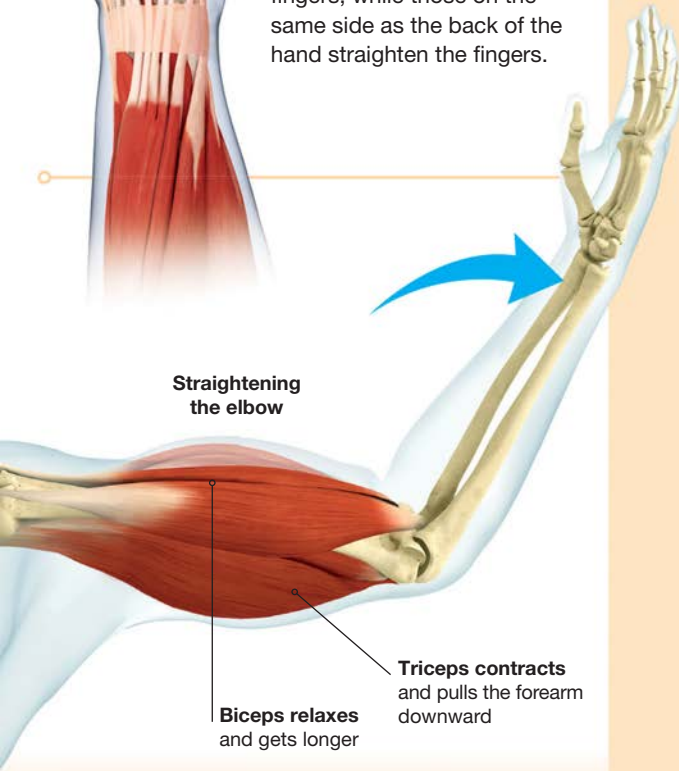
**Biceps contracts**  
and pulls the  
forearm upward

**Triceps relaxes**  
and lengthens  
at the back of  
the arm



## Finger pullers

The muscles that move the fingers are found mostly in the forearm. They are attached to the finger bones by long tendons that cross the wrist. Forearm muscles on the same side as the palm bend the fingers, while those on the same side as the back of the hand straighten the fingers.



Straightening  
the elbow

**Biceps relaxes**  
and gets longer

**Triceps contracts**  
and pulls the forearm  
downward

## FACE SHAPERS

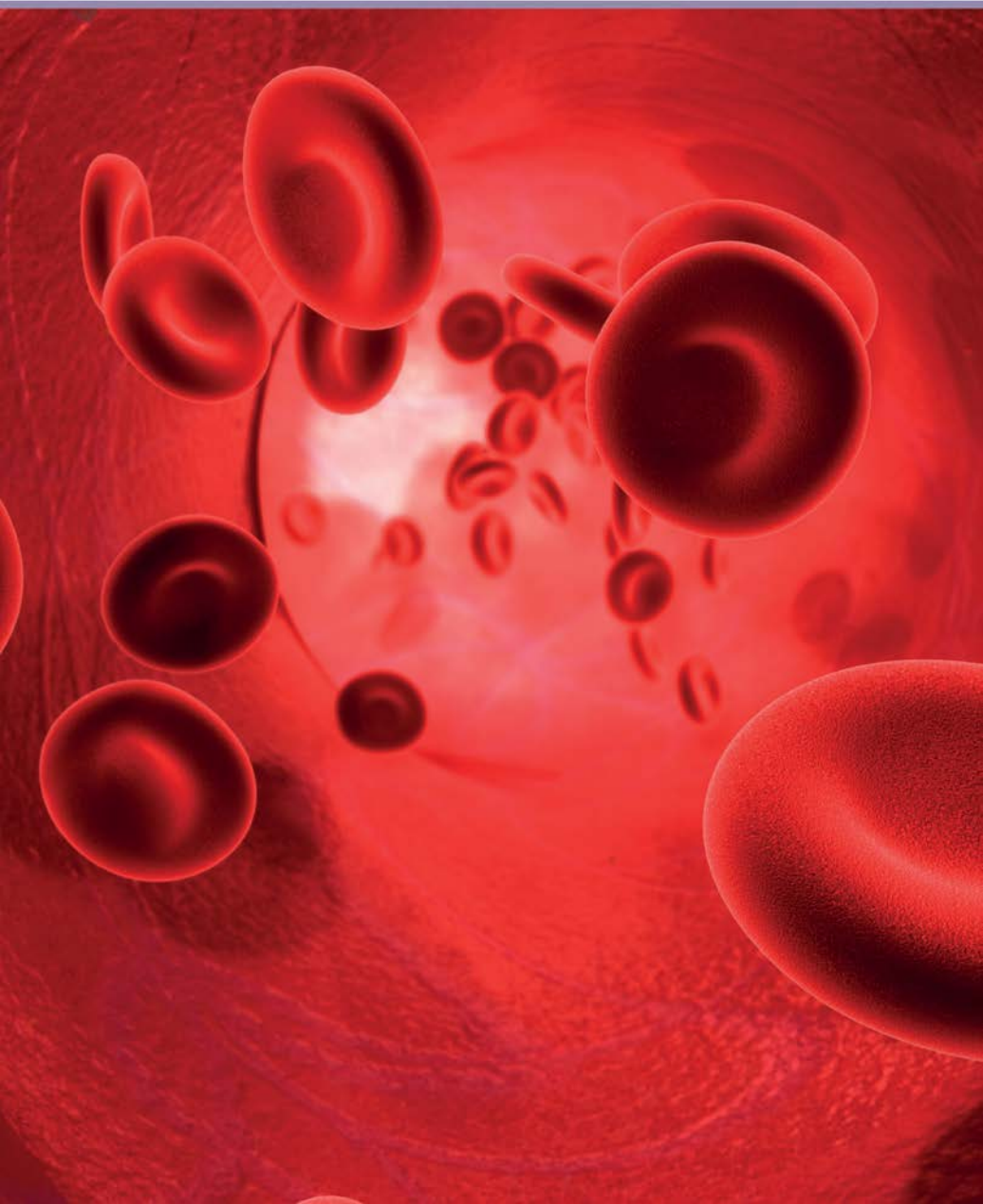
Facial expressions are created by more than 30 small muscles that pull the skin.



Muscles pull the corners of the mouth upward and outward and lift the top lip when a person **smiles**.

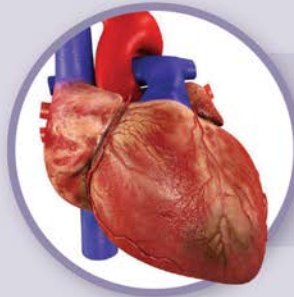


If a person is **sad**, the corners of the mouth are pulled downward and the eyebrows are wrinkled.



# Blood and lymph

To work at their best, cells must have stable surroundings. Three body systems make this happen. The blood system delivers food and oxygen to cells, removes their waste matter, and keeps them warm. The lymph system drains surplus fluid from tissues and works with the blood system to kill germs. The urinary system removes waste from the blood and disposes of it in urine.



## THE HEART

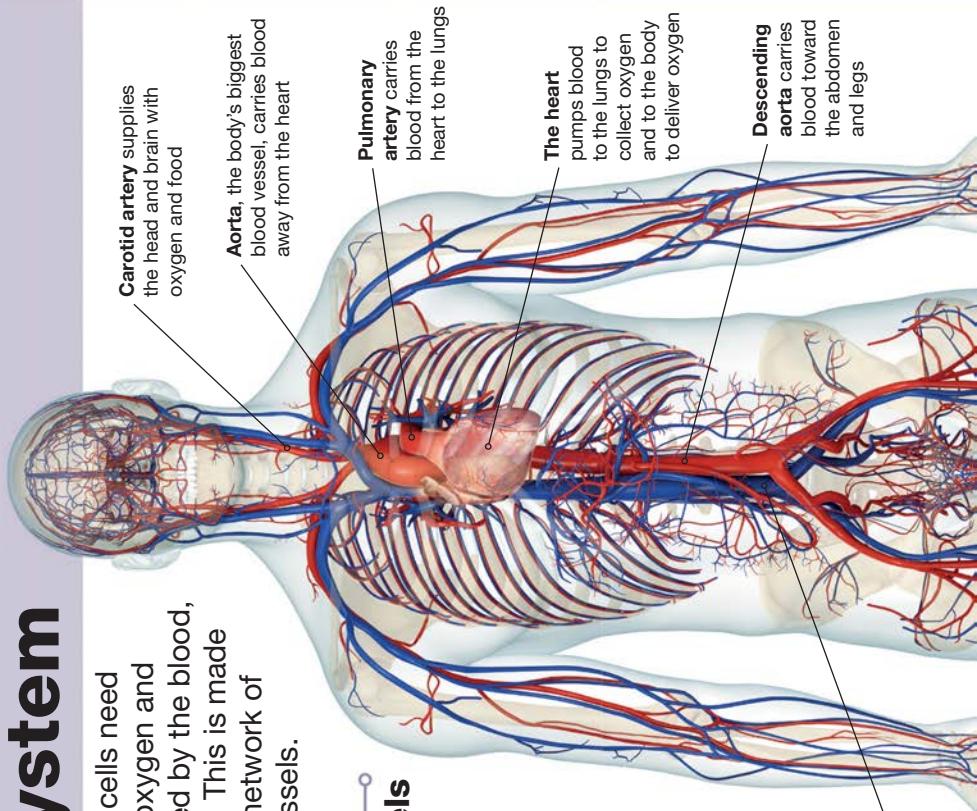
The heart beats 100,000 times each day to pump blood along a vast network of blood vessels. Stretched out, these would wrap around the world three times.

# Blood system

The body's trillions of cells need a constant supply of oxygen and food, which is provided by the blood, or circulatory, system. This is made up of the heart and a network of tubes called blood vessels.

## Network of vessels

Blood vessels carry blood to every part of the body, from head to toe. Arteries (shown in red) carry blood away from the heart. Veins (shown in blue) carry blood back to the heart. They are linked by tiny capillaries that are too small to be seen here.



**Carotid artery** supplies the head and brain with oxygen and food

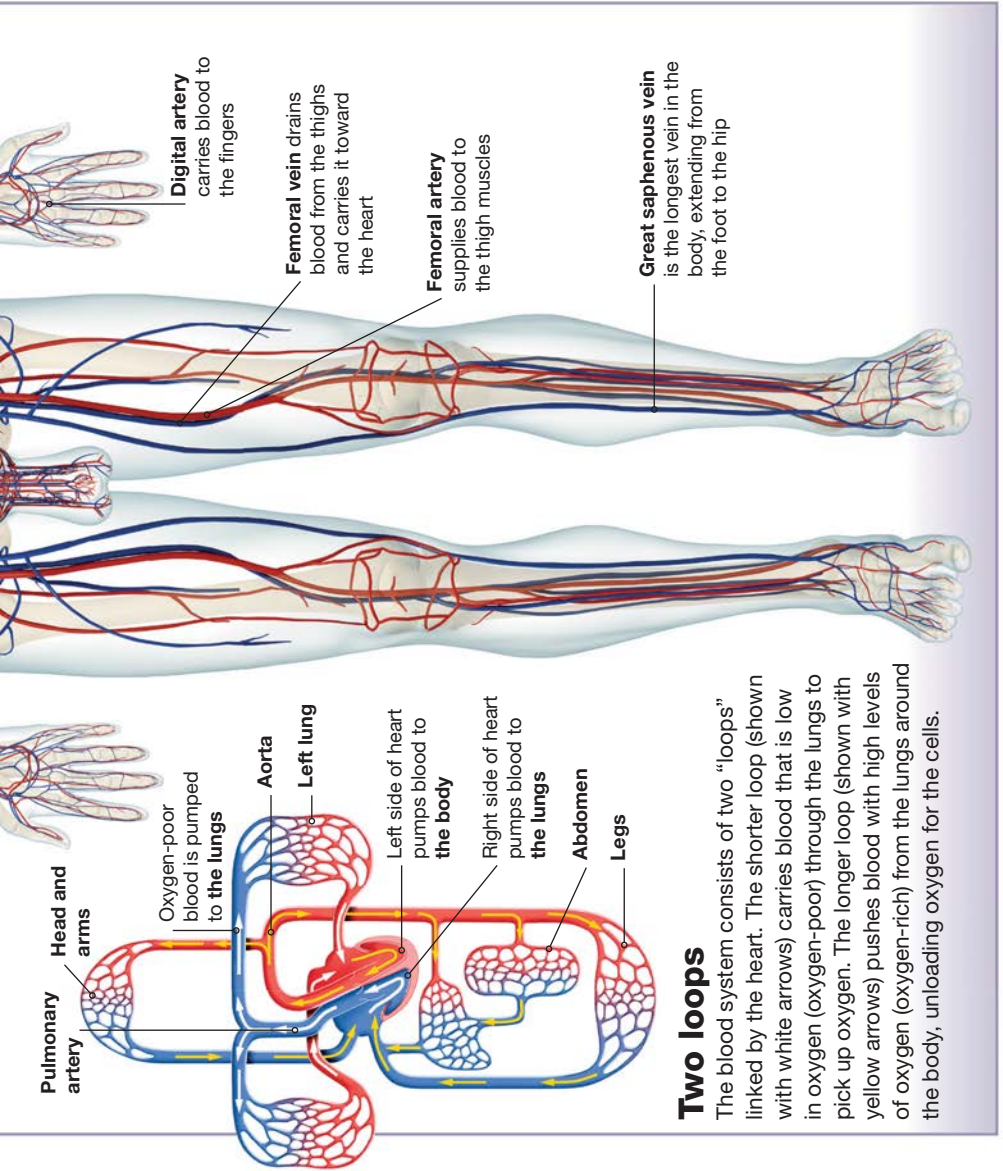
**Aorta**, the body's biggest blood vessel, carries blood away from the heart

**Pulmonary artery** carries blood from the heart to the lungs

**The heart** pumps blood to the lungs to collect oxygen and to the body to deliver oxygen

**Descending aorta** carries blood toward the abdomen and legs

**Inferior vena cava** carries blood from the abdomen and legs to the heart

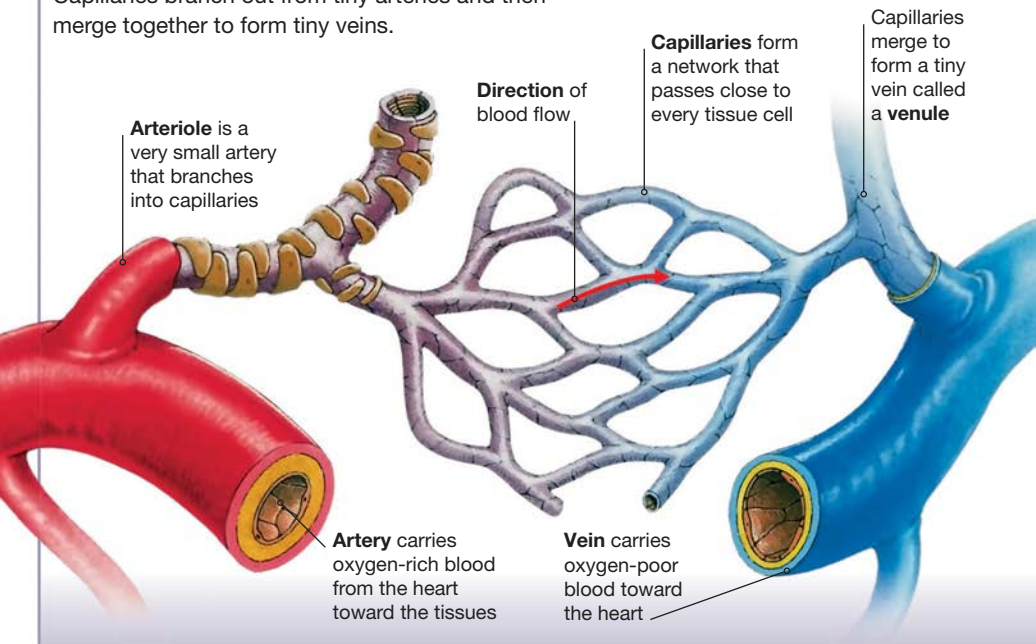


# Blood vessels

Three types of blood vessel carry blood around the body. Arteries transport blood away from the heart, veins carry blood toward the heart, and tiny capillaries carry blood through tissues and link arteries to veins. Altogether, the body's blood vessels extend over 60,000 miles (100,000 km).

## Capillary network

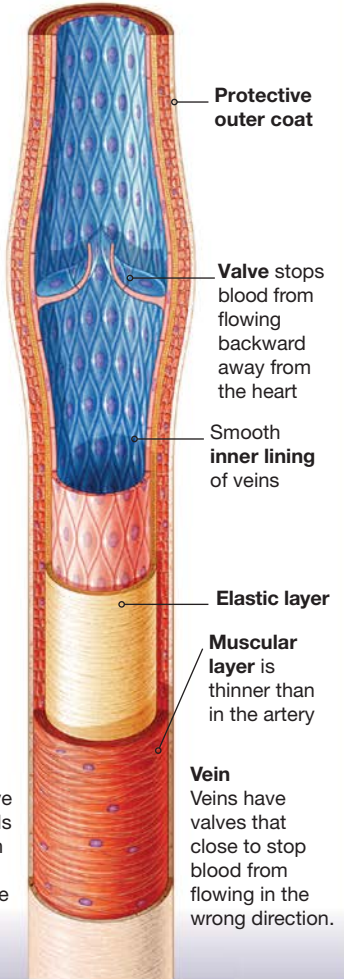
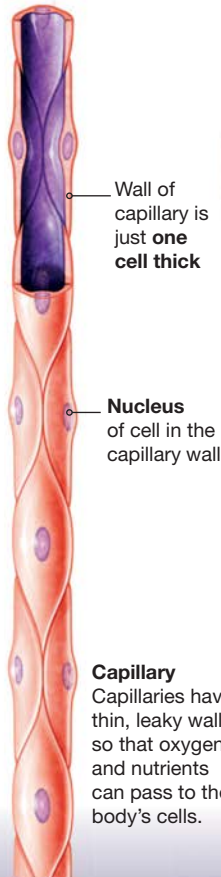
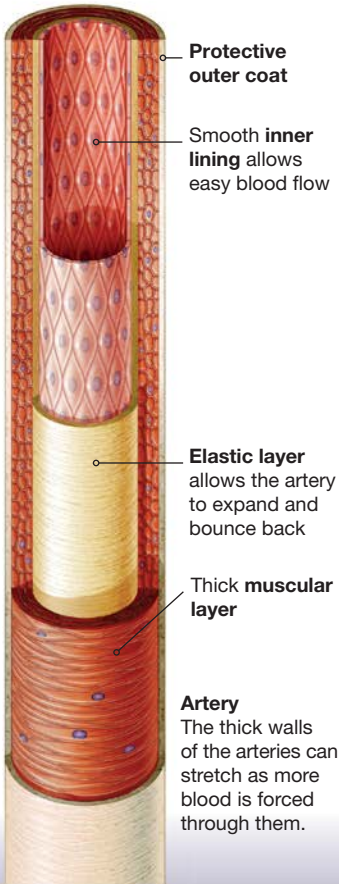
Vast networks of capillaries weave their way through body tissues to supply cells with food and oxygen. Capillaries branch out from tiny arteries and then merge together to form tiny veins.





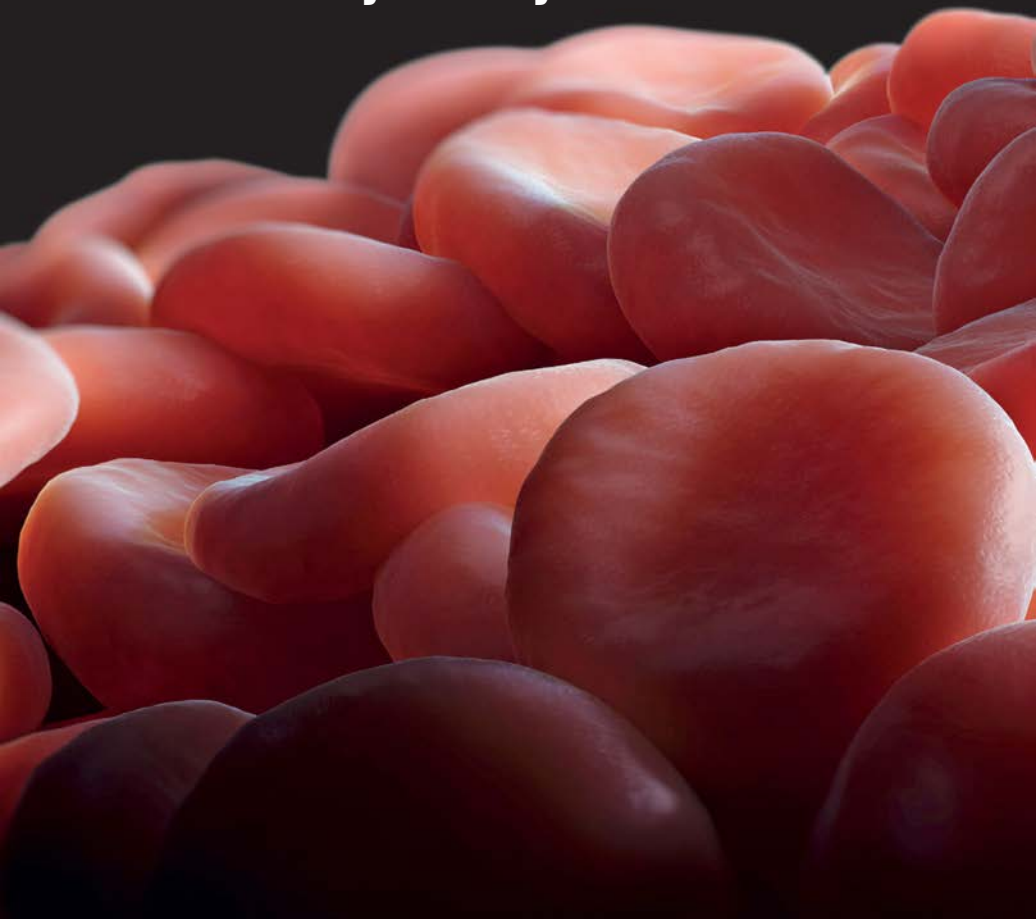
## Living tubes

Arteries have thick, muscular walls to cope with the high pressure created when the heart pumps blood. Microscopic capillaries make deliveries to individual cells. Thin-walled veins carry blood under low pressure back to the heart.



# Two million

**red blood cells are made and  
another two million worn-out  
cells are destroyed every second**



**RED BLOOD CELLS**

The flattened, dimpled shape of red blood cells is ideal for their role as oxygen carriers. It provides a large surface for both absorbing oxygen in the lungs and releasing oxygen in the tissues, making red blood cells incredibly efficient.

# The heart

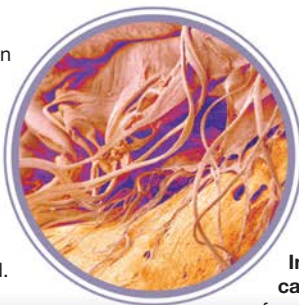
The heart is the powerhouse of the circulatory system. It beats around 70 times a minute to push blood around the body. The heart is made of cardiac muscle, which never tires.

## Inside the heart

The heart has a left and a right side, each with two chambers—the atrium and the ventricle. The right side of the heart pumps blood to the lungs, while the left side pumps blood to the body. Valves stop the blood from flowing in the wrong direction.

**Heart strings** are thin cords attached to the valve between each atrium and ventricle.

When the heart beats, these strings stop the valve from turning inside out like an umbrella in a strong wind.



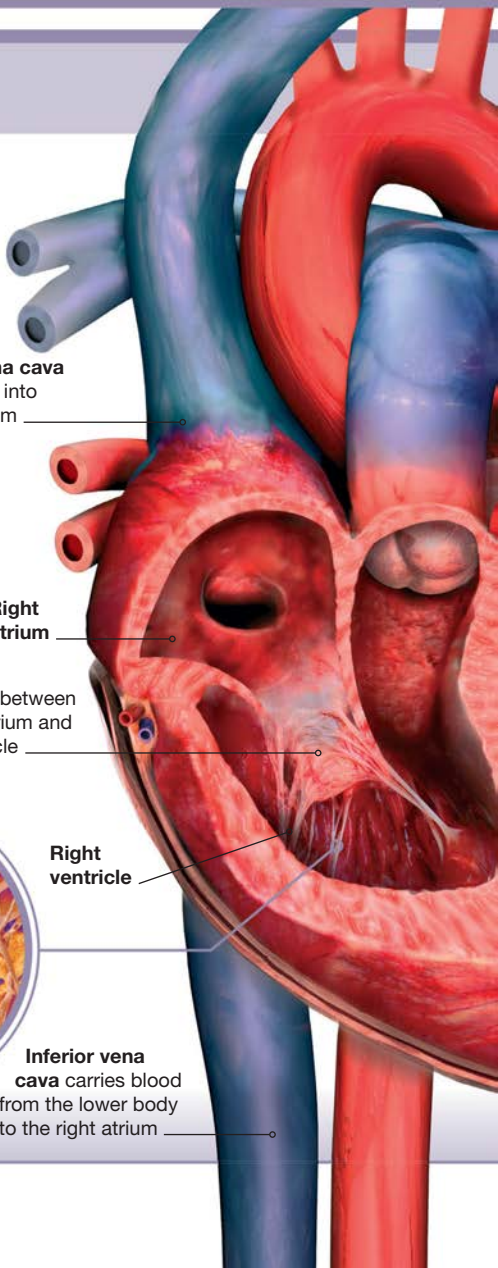
**Superior vena cava** carries blood into the right atrium

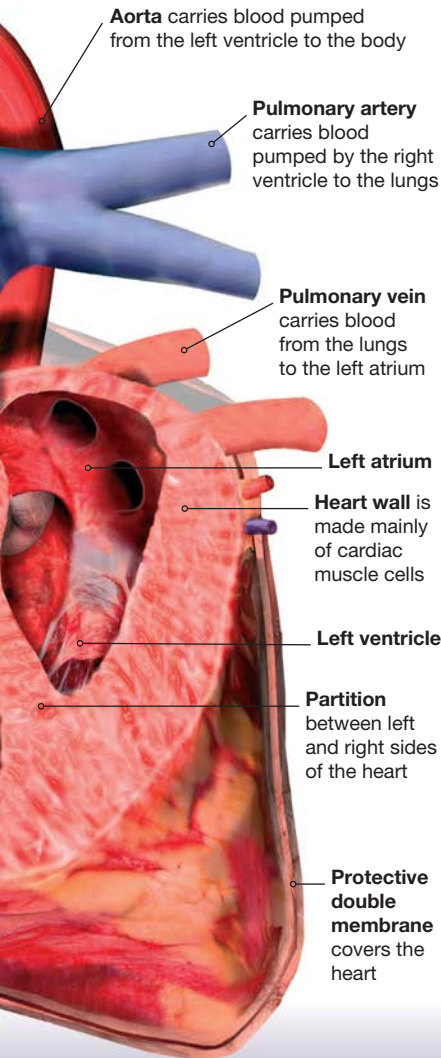
**Right atrium**

**Valve between the atrium and ventricle**

**Right ventricle**

**Inferior vena cava** carries blood from the lower body to the right atrium

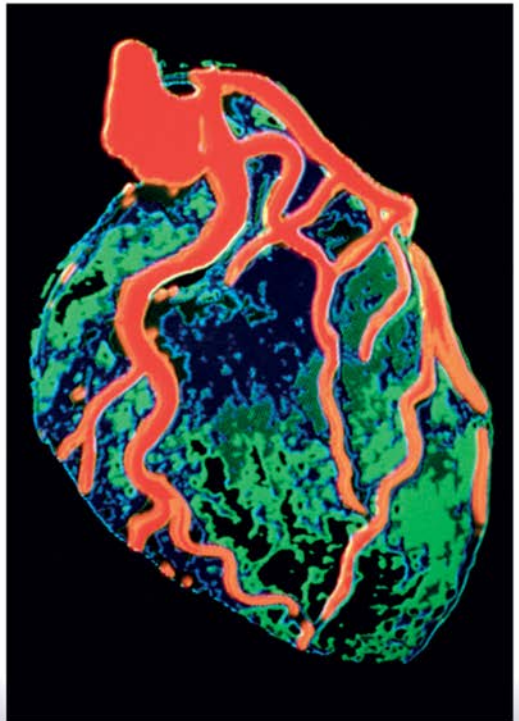




## Feeding the heart

Cardiac muscle cells in the wall of the heart need a constant supply of food and oxygen to give them the energy to contract and keep the heart beating. Deliveries are made to cardiac muscle cells through a network of arteries, called coronary arteries, that run through the wall of the heart.

Specialized X-ray of the heart, showing arteries in red



# Heartbeat

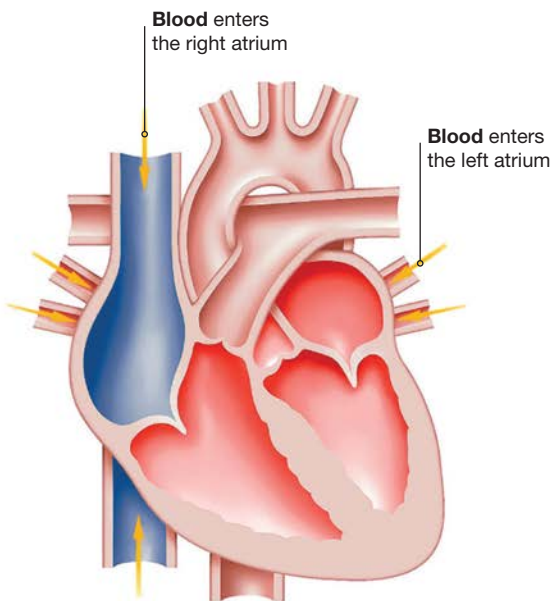
The fist-sized heart is an amazing double pump. Its right and left sides beat together to push blood to the lungs and body. In an average lifetime, the heart beats around 2.5 billion times without taking a break.

## Beating heart

Every heartbeat is made up of three stages. In the first stage, blood is drawn into the atria—the heart’s upper chambers. In the second, blood is pushed into the ventricles below. In the final stage, blood is pushed out of the heart. Valves in the heart keep the blood flowing in one direction.



A baby’s heart beats for the first time during the fourth week of pregnancy, when the baby is the size of a fingernail.



The **heart relaxes** and oxygen-poor blood flows into the right atrium, while oxygen-rich blood flows into the left atrium.

## Hearing heartbeats

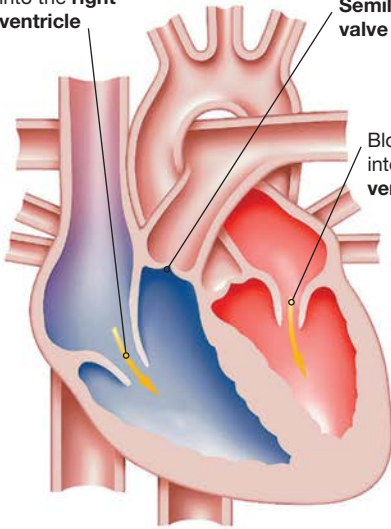
A doctor uses a stethoscope to listen to a person's heart and check if the heart valves are working properly. When the valves between the atria and the ventricles close, they make a loud “lub” sound, and when the semilunar valves slam shut, they make a shorter, sharper “dup” sound.



Blood flows into the **right ventricle**

**Semilunar valve closed**

Blood flows into the **left ventricle**



The **two atria contract** at the same time, pushing blood through open valves into the ventricles. The semilunar valves remain closed to stop blood from flowing backward.

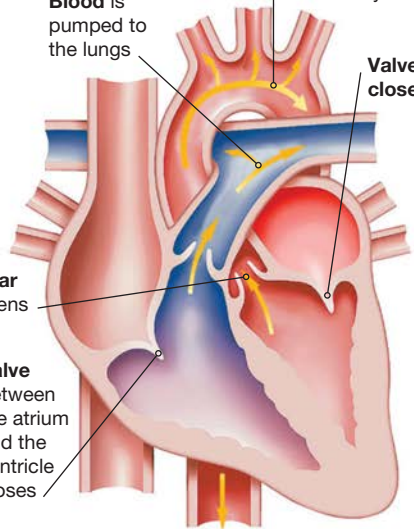
Blood is pumped to the lungs

Blood is pumped to the body

**Valve closes**

**Semilunar valve opens**

**Valve between the atrium and the ventricle closes**



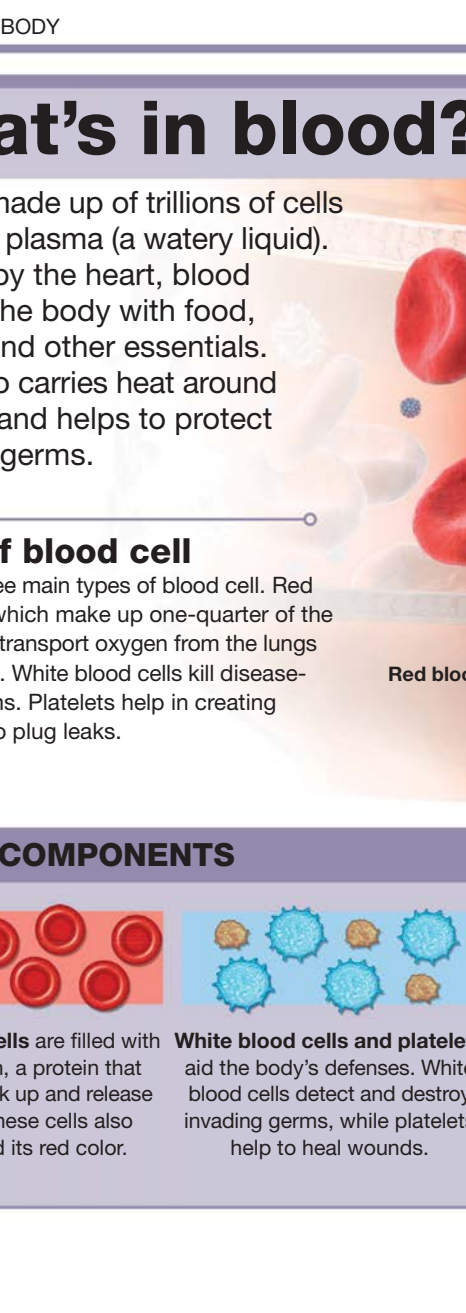
The **ventricles contract**, forcing blood out of the heart through the open semilunar valves. Valves between the atria and ventricles close to prevent backflow.

# What's in blood?

Blood is made up of trillions of cells floating in plasma (a watery liquid). Pumped by the heart, blood supplies the body with food, oxygen, and other essentials. Blood also carries heat around the body and helps to protect it against germs.

## Types of blood cell

There are three main types of blood cell. Red blood cells, which make up one-quarter of the body's cells, transport oxygen from the lungs to the tissues. White blood cells kill disease-causing germs. Platelets help in creating blood clots to plug leaks.



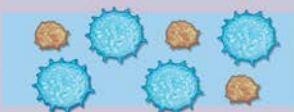
Red blood cell

White blood cell

## BLOOD COMPONENTS



**Red blood cells** are filled with hemoglobin, a protein that is able to pick up and release oxygen. These cells also give blood its red color.

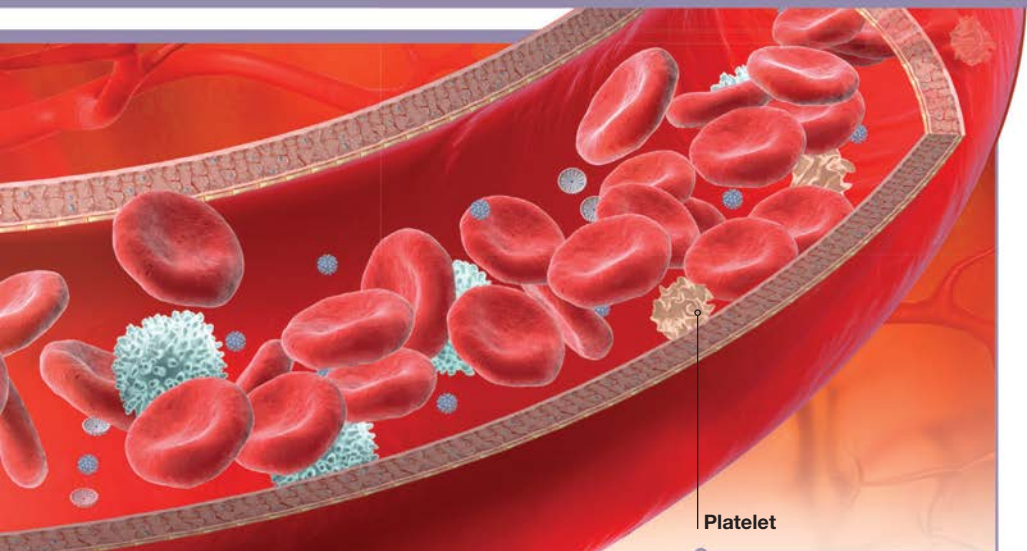


**White blood cells and platelets** aid the body's defenses. White blood cells detect and destroy invading germs, while platelets help to heal wounds.



**Plasma** is 90 percent water. The remaining 10 percent is made up of about 100 dissolved substances including nutrients, waste matter, and hormones.





Platelet

Wall of the  
blood vessel

## In the mix

Plasma makes up the greatest part of blood, followed by red blood cells and then white blood cells and platelets. A single pinhead-sized drop of blood contains about 2.5 million red blood cells, 3,750 white blood cells, and 160,000 platelets.



Plasma is a straw-colored liquid that makes up **55 percent** of blood

White blood cells and platelets make up **1 percent** of blood

Red blood cells make up the remaining **44 percent** of blood

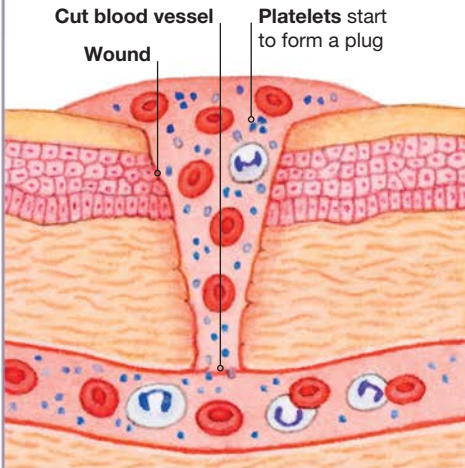
# Blood clotting

Damage to a blood vessel automatically triggers a chain of events to repair the wound. The blood becomes sticky to block the leak and prevent harmful germs from entering the body. Then the blood clots to seal the wound and allow the damage to be repaired.

## Healing the wound

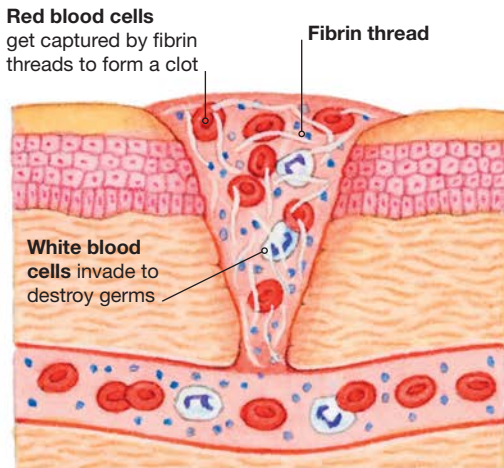
When an injury happens, such as a cut to the skin, the damage could be dangerous. To stop the loss of blood and avoid infection, all three types of blood cell take action.

### INJURY

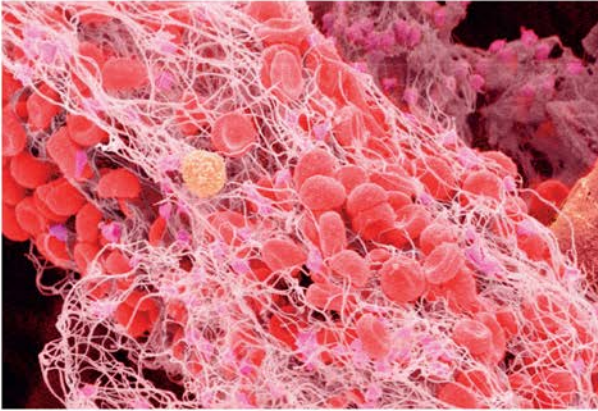


A **cut** in the skin damages blood vessels. The body reacts to stop the bleeding and destroy germs.

### PLUG



A **plug** is formed when platelets at the wound site stick together. They also trigger the formation of a clot.

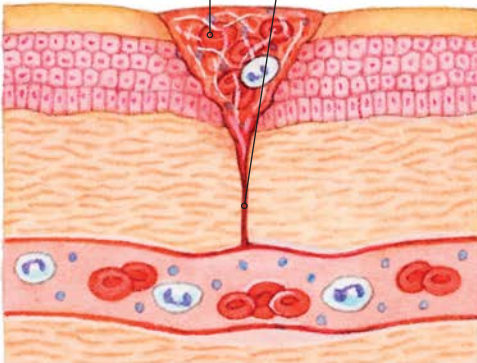


## Fibrin threads

Taken using a scanning electron microscope, this image shows a magnified view of a blood clot shortly after it formed. The red blood cells are trapped in a tight mesh of fibrin threads that looks like a fishing net.

## CLOT

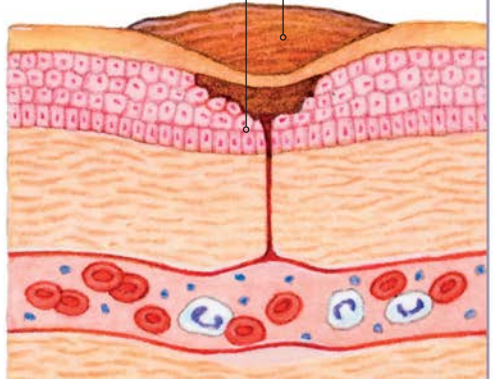
Contracted clot  
Wound sealed



**Fibrin threads** inside the clot contract and pull the edges of the wound together to prevent leakage.

## SCAB

Repaired tissue  
Hard scab



A **scab** is formed on the surface of the clot. The hard scab protects the wound site as tissues are repaired.

# Fighting disease

The body is constantly under threat from microscopic, disease-causing organisms such as bacteria and viruses (known more commonly as germs). Outer barriers, such as the skin, and an internal immune system stop germs from getting into and multiplying inside the body.

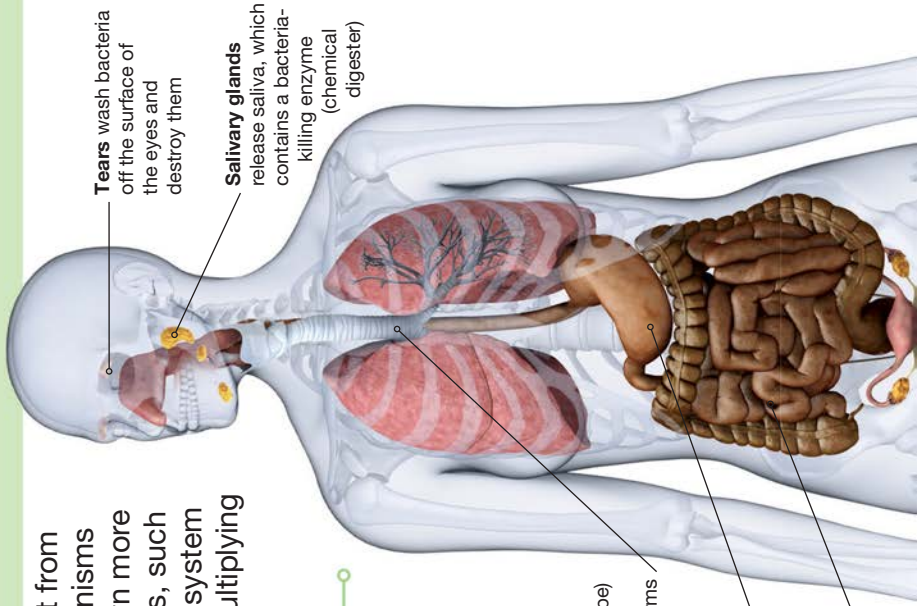
## Body barriers

The body has a number of physical defenses to stop infection. Cells lining hollow organs are packed together tightly to stop germs from reaching the tissues beneath them. Special protective fluids, such as mucus, saliva, and gastric juice, help to trap and kill germs.

The **trachea** (windpipe) is lined with sticky mucus that traps germs

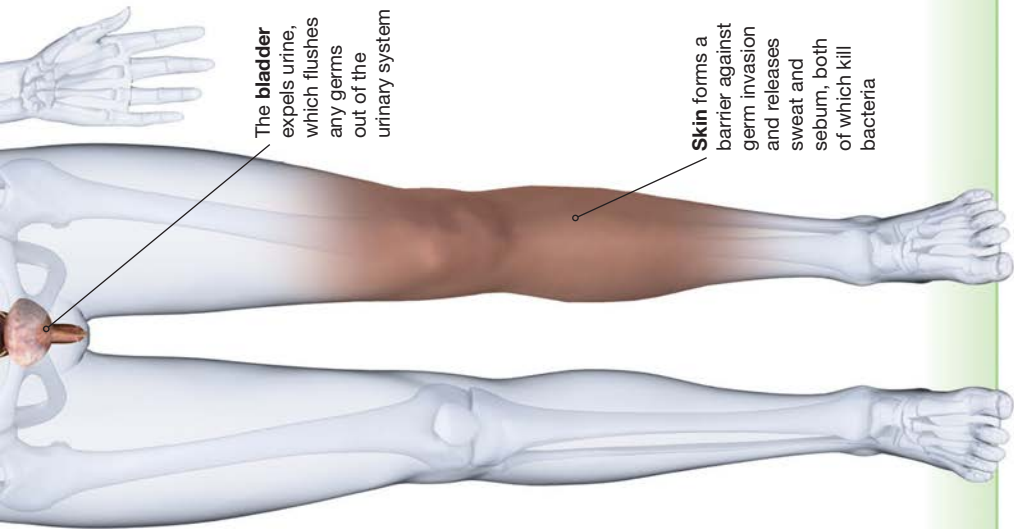
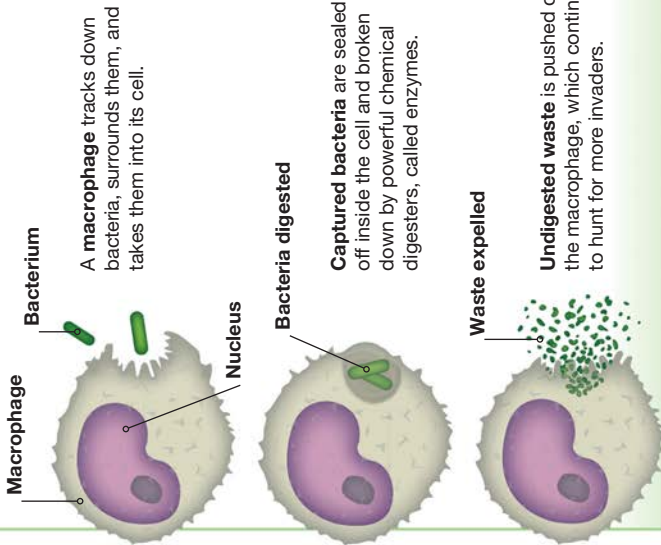
The **stomach** releases acidic gastric juice that kills germs in swallowed food

**Small intestine enzymes** (chemical digesters) destroy bacteria that escape stomach acid



## Germ eater

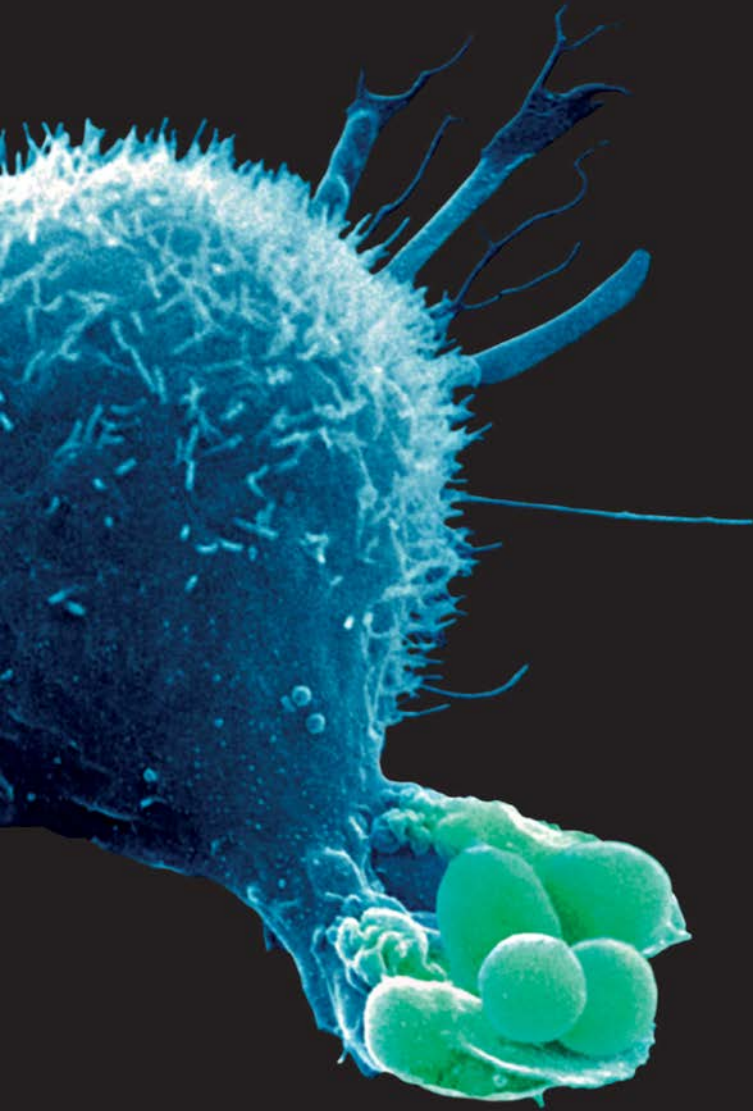
If germs do enter the tissues, the immune system defends the body. White blood cells, such as macrophages, track down invading germs, especially bacteria. Having identified germs as foreign, these cells surround and destroy them.



# Laughing

every day makes the  
immune system more  
efficient at defending  
the body



**GERM KILLER**

The word "macrophage" means "big eater." This germ-killing macrophage (shown in blue) has tracked down invading bacteria (shown in green) and is stretching out to capture them. It will then digest the bacteria and display markers that identify the bacteria for other defense cells.

# The body's drain

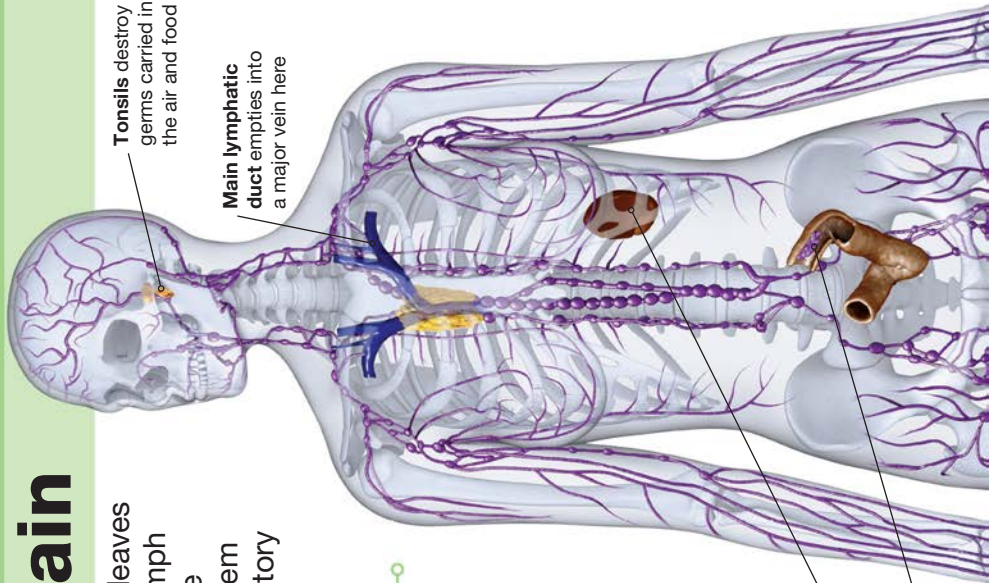
As blood circulates through tissues it leaves behind fluid. The fluid is known as lymph when it drains from the tissue into the lymphatic system. This one-way system of vessels returns lymph to the circulatory system. Along the way, lymph is also filtered to remove germs.

## Lymphatic system

Lymph vessels (shown in purple) extend to all parts of the body. Tiny lymph capillaries drain fluid from tissues and then merge to form larger lymph vessels. Two main tubes, or ducts, in the chest empty into the bloodstream. The system also contains swellings called lymph nodes and several organs, such as the tonsils and spleen. These contain immune system cells that kill germs.

**Spleen**, the largest lymphoid organ, contains immune system cells that destroy germs

**Lymph tissue** in the small intestine kills germs in food



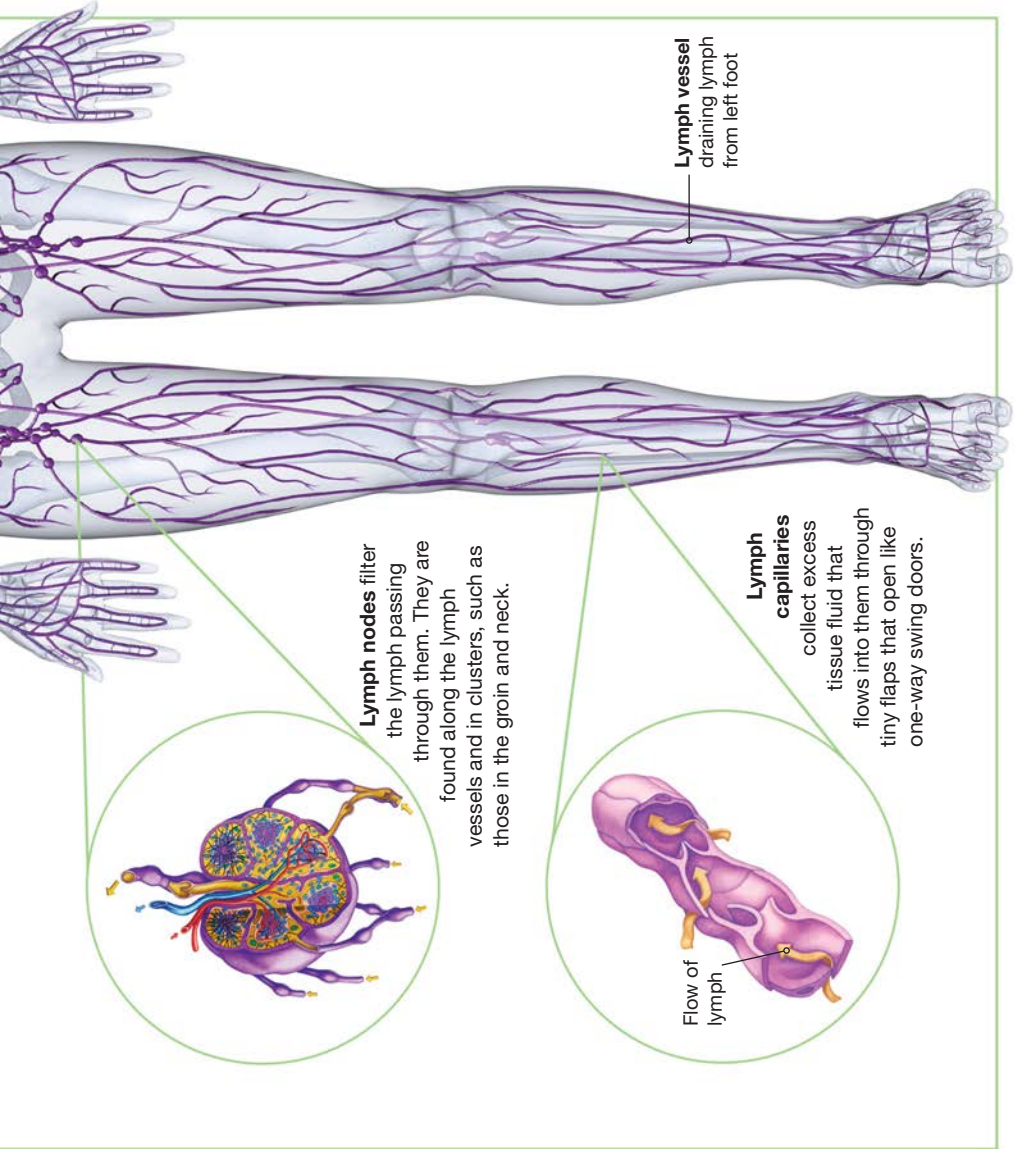
**Tonsils** destroy germs carried in the air and food

**Main lymphatic duct** empties into a major vein here

**Spleen**, the largest lymphoid organ, contains immune system cells that destroy germs

**Lymph tissue** in the small intestine kills germs in food





**Lymph nodes** filter the lymph passing through them. They are found along the lymph vessels and in clusters, such as those in the groin and neck.

**Lymph capillaries** collect excess tissue fluid that flows into them through tiny flaps that open like one-way swing doors.

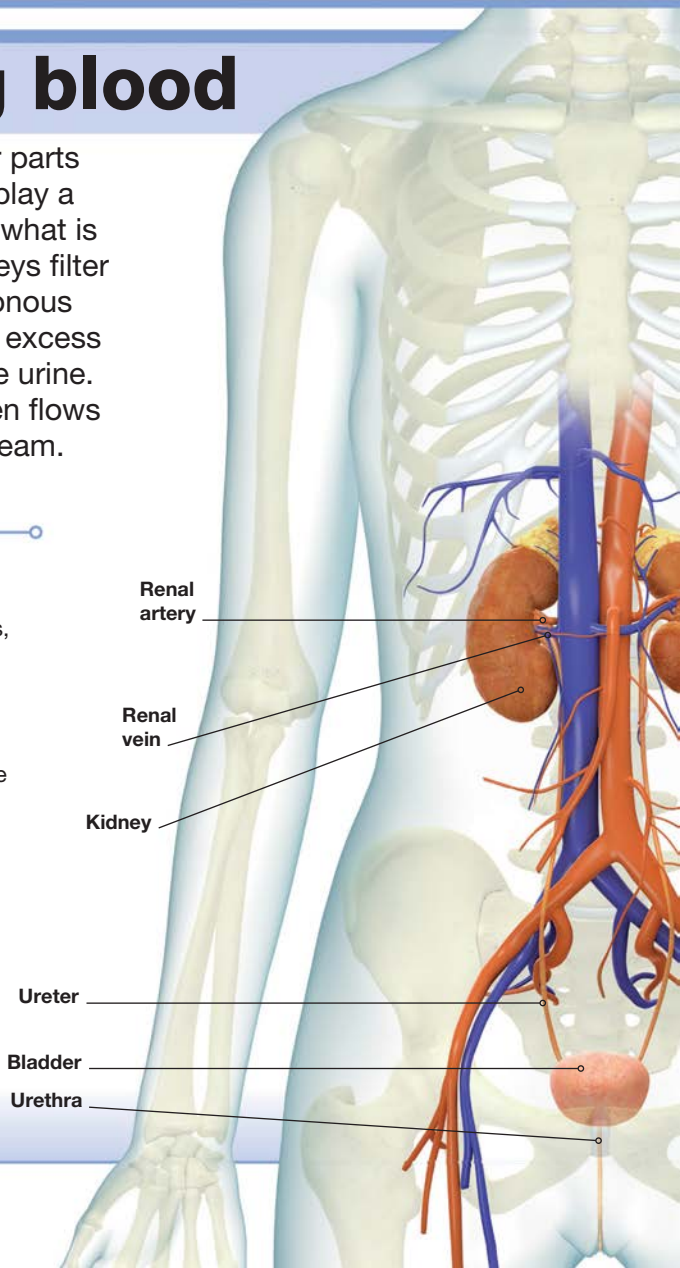
Flow of lymph

# Filtering blood

The kidneys and other parts of the urinary system play a key part in controlling what is in the blood. The kidneys filter blood to remove poisonous substances as well as excess water and salt to make urine. The cleaned blood then flows back into the bloodstream. The cleaned blood then flows back into the bloodstream.

## Urinary system

The urinary system is made up of two kidneys, two ureters, a bladder, and a urethra. The kidneys produce urine, which is pushed down the ureters to the bladder. It is stored here before being released from the body through the urethra.



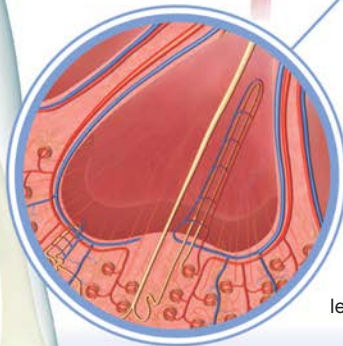
## Inside a kidney

A kidney contains about a million urine-making units called nephrons. Blood from the renal artery passes into the nephrons, where urine is collected. The urine empties out into a ureter and the clean blood flows back into the rest of the body.

Renal artery

Renal vein

Ureter



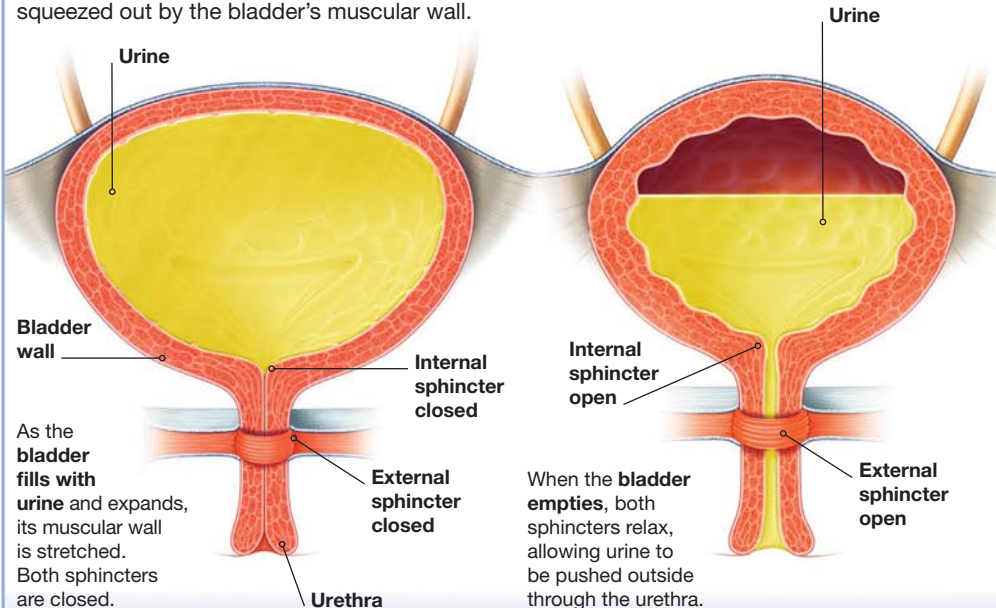
To make urine, each **nephron** filters fluids from the body. As this fluid passes along the nephron's long, thin tubule (shown in yellow), nutrients and most water are absorbed into the blood. The water and waste left behind form urine.

# Getting rid of waste

The kidneys release a constant dribble of urine at all times of the day. This urine passes into a stretchy muscular bag—the bladder—where it is stored until we feel the need to release it. Water lost from the body in urine is replaced by the water in food and drink.

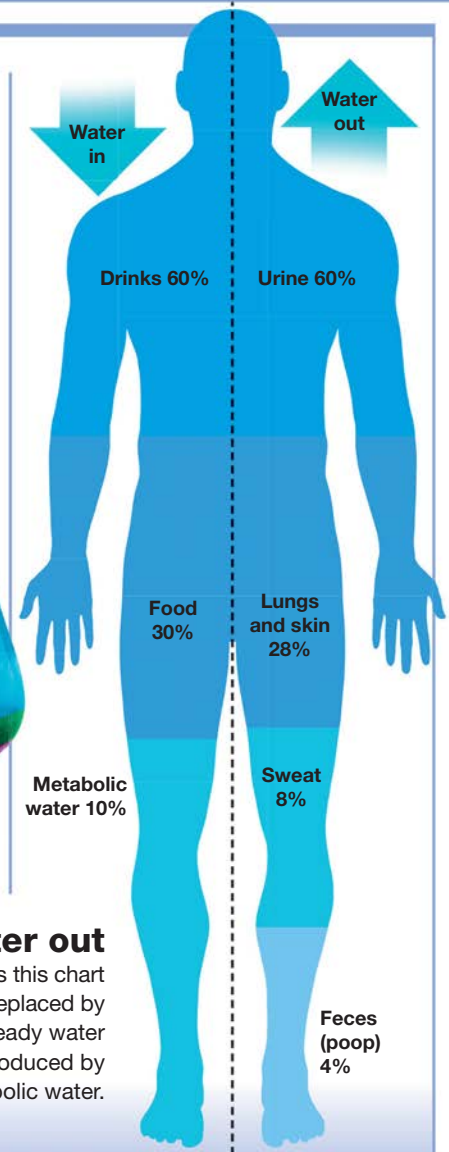
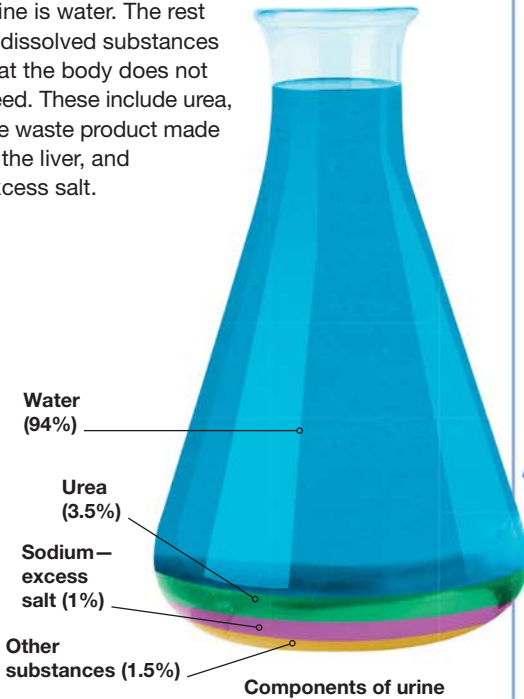
## Filling and emptying

The bladder's exit is normally closed by two rings of muscle called sphincters. As the bladder fills up, a person will feel the need to urinate (go to the bathroom). The sphincters relax and urine is squeezed out by the bladder's muscular wall.



## What's in urine?

About 94 percent of urine is water. The rest is dissolved substances that the body does not need. These include urea, the waste product made in the liver, and excess salt.



## Water in, water out

Around half of the body's weight is water. As this chart shows, water lost from the body has to be replaced by water taken in for the body to maintain a steady water balance. This includes water that is produced by chemical reactions in cells, known as metabolic water.



# Lungs and breathing

The human body cannot survive without a nonstop supply of oxygen from the air. The trillions of body cells need constant deliveries of oxygen to release the energy that powers their activities. This process also generates the waste gas carbon dioxide. To get oxygen into the body and to remove carbon dioxide, air is breathed into and out of the lungs.



## **MISTY BREATH**

The air we breathe out, or exhale, contains droplets of water from the lungs. On cold days, these water droplets show up as a fine mist in the air.

# Breathing system

Also called the respiratory system, the breathing system is made up of two lungs and the tubes, or airways, that carry air into and out of the body. Inside the lungs, those airways divide over and over again to form smaller and smaller branches.

The **nasal cavity** is a space behind the nose where the air we breathe is cleaned. Mucus traps dirt and germs and tiny hairlike cilia sweep the mucus to the throat.

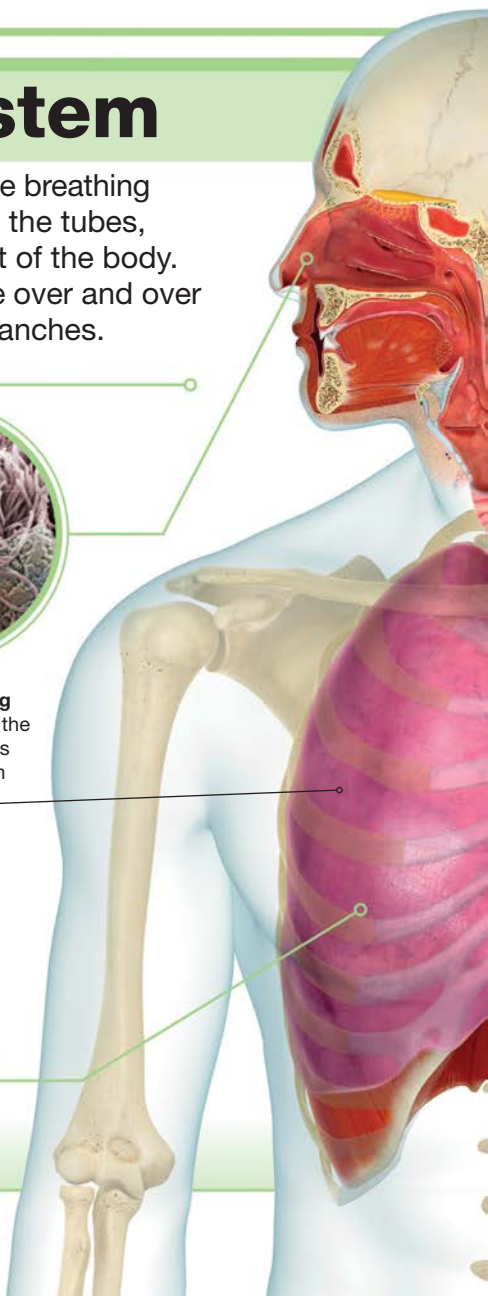
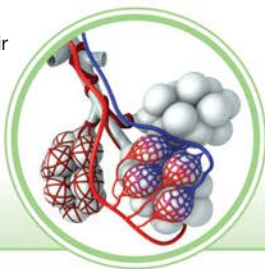


## Branching airways

Air travels through the nasal cavity and along the windpipe, or trachea. At its base, the trachea splits into two smaller tubes, called bronchi (each one is called a bronchus), which go into the lungs. These go into narrower and narrower bronchi and bronchioles.

The **right lung** is larger than the left, which has to make room for the heart

**Alveoli** are tiny air bags found at the ends of the bronchioles. Oxygen passes into the bloodstream through the walls of the alveoli.





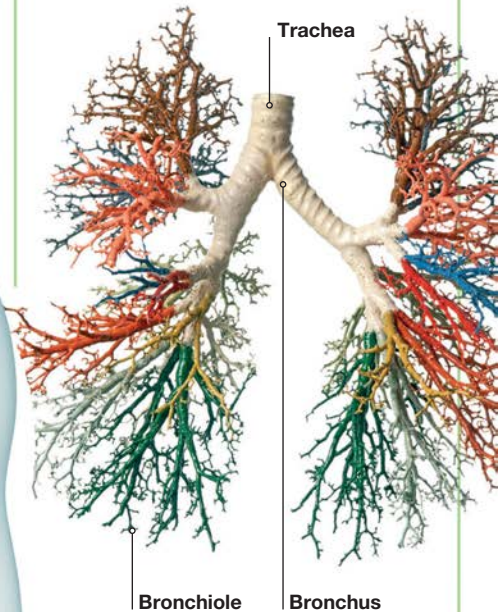
The **trachea** is lined with sticky mucus to trap dust particles.



**Bronchus** divides into smaller bronchi

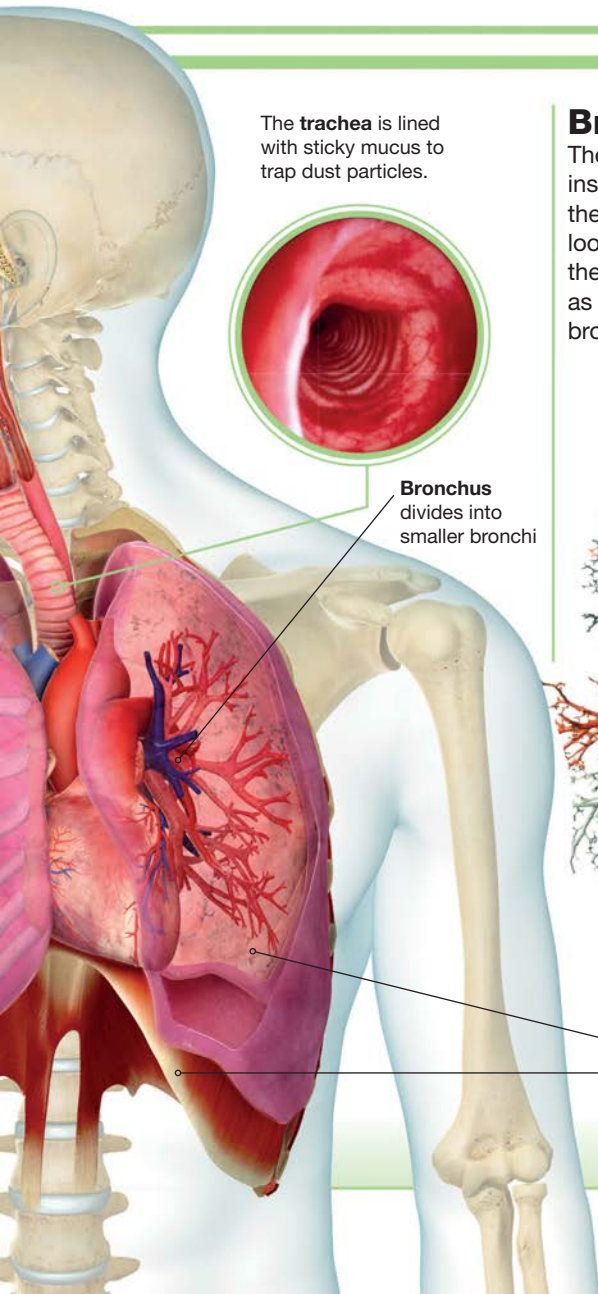
## Bronchial tree

The branching network of airways inside the lungs is sometimes called the bronchial tree. This is because it looks like an upside-down tree with the trachea as its trunk, the bronchi as its branches, and the tiny bronchioles as its twigs.



**Left lung**

**Diaphragm**, a sheet of muscle below the lungs



# Breathe in, breathe out

Breathing in and out brings oxygen into the lungs and removes the harmful waste gas, carbon dioxide. The process involves the diaphragm and the intercostal muscles, which are found between the ribs.

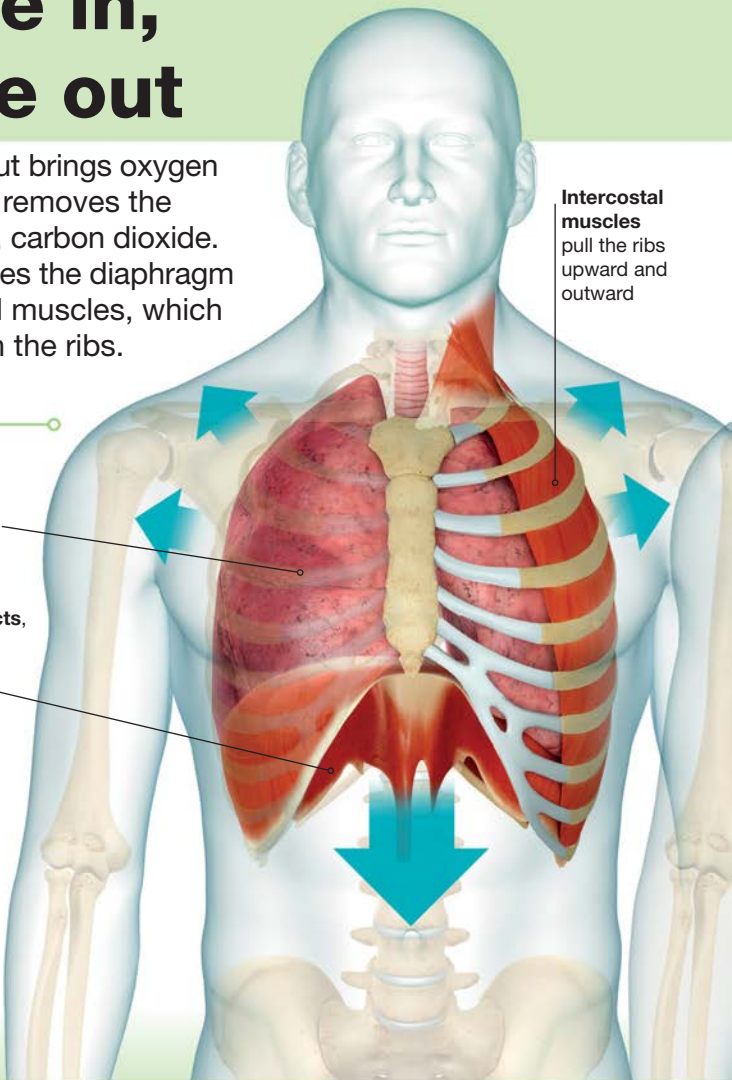
**Intercostal muscles** pull the ribs upward and outward

**Lungs expand** as the chest gets bigger

**Diaphragm contracts,** flattens, and pushes downward

## Air in...

The diaphragm and intercostal muscles contract (tighten) to increase the size of the space inside the chest. As this happens, the lungs expand and fresh air enters from outside.



Air passes out through the nose and mouth

Lungs shrink as the chest gets smaller

## IN CONTROL

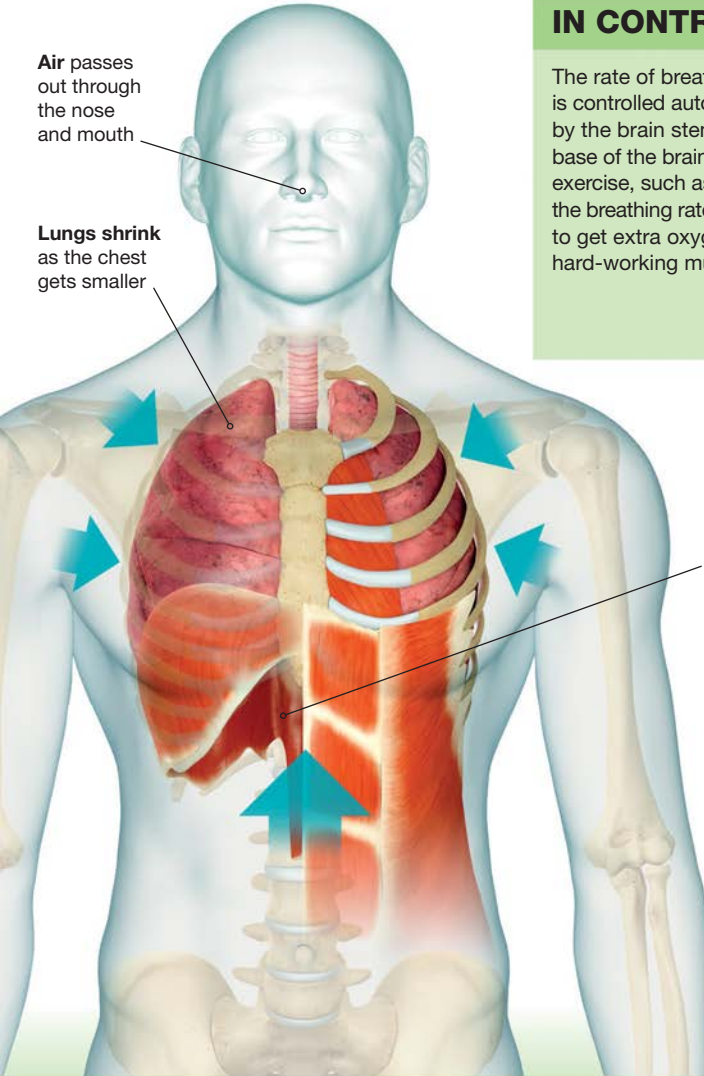
The rate of breathing is controlled automatically by the brain stem at the base of the brain. During exercise, such as running, the breathing rate increases to get extra oxygen to the hard-working muscles.



Diaphragm relaxes and is pushed upward into a dome shape by organs below

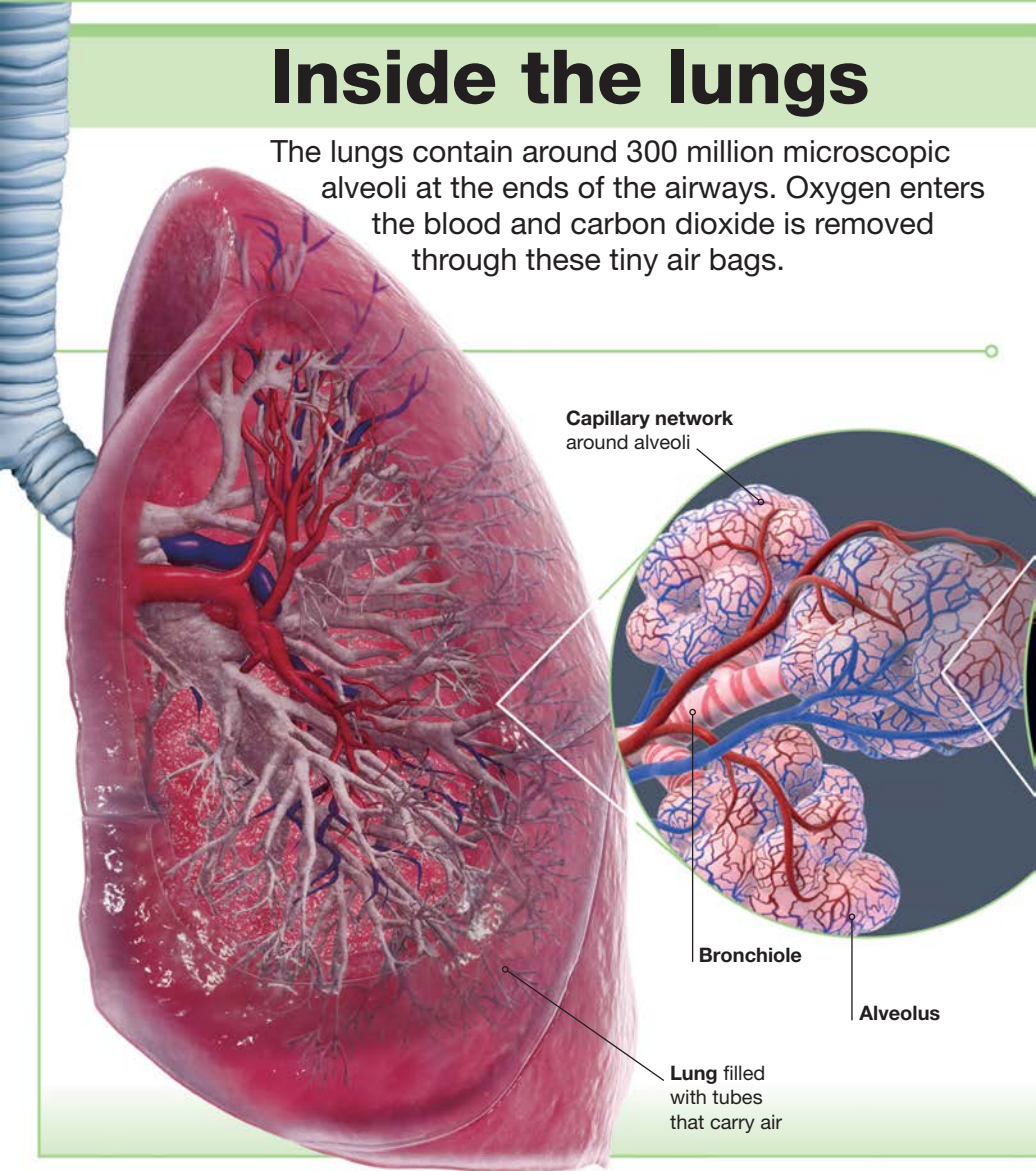
## ... Air out

The diaphragm and intercostal muscles relax so that the ribs move downward and inward. This squeezes the lungs, pushing air out of the body.



# Inside the lungs

The lungs contain around 300 million microscopic alveoli at the ends of the airways. Oxygen enters the blood and carbon dioxide is removed through these tiny air bags.



Capillary network  
around alveoli

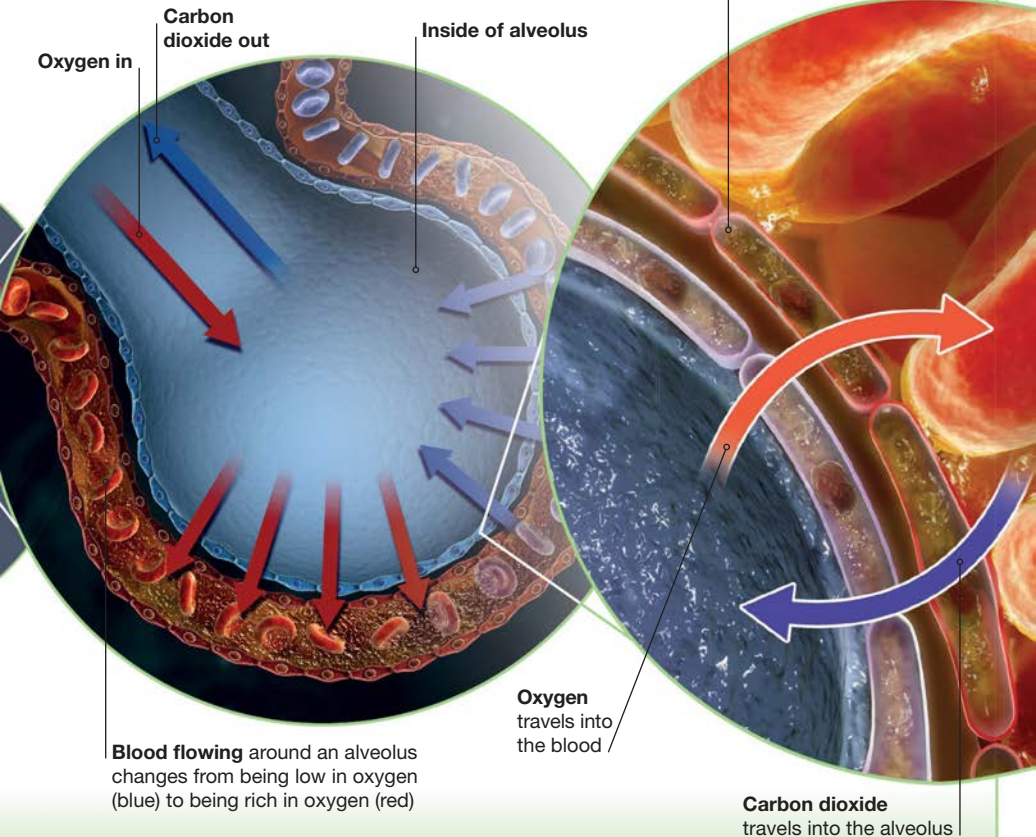
Bronchiole

Alveolus

Lung filled  
with tubes  
that carry air

## Exchanging gases

Blood flowing through the capillaries (tiny blood vessels) surrounding the alveoli constantly picks up oxygen and carries it to the body's cells. At the same time, it dumps carbon dioxide into the alveoli to be breathed out.



# Speech

People can communicate with each other using speech. The sounds we speak are produced by special breathing movements. These send bursts of air through the sound-creating vocal cords found in the throat.

## Making sounds

During normal breathing the vocal cords are pulled open to allow air to be breathed in and out. While we are speaking, muscles pull the vocal cords together. When air is pushed between the closed vocal cords, they vibrate and produce sounds.

The **larynx**, or voice box, links the throat to the trachea, or windpipe, and contains the vocal cords. It is made from pieces of cartilage.

Vocal cords stretch from the front to the back of the larynx

Rings of cartilage hold the trachea open

**Vocal cords** pulled closed

**Trachea** carries air to and from the lungs



## Shaping words

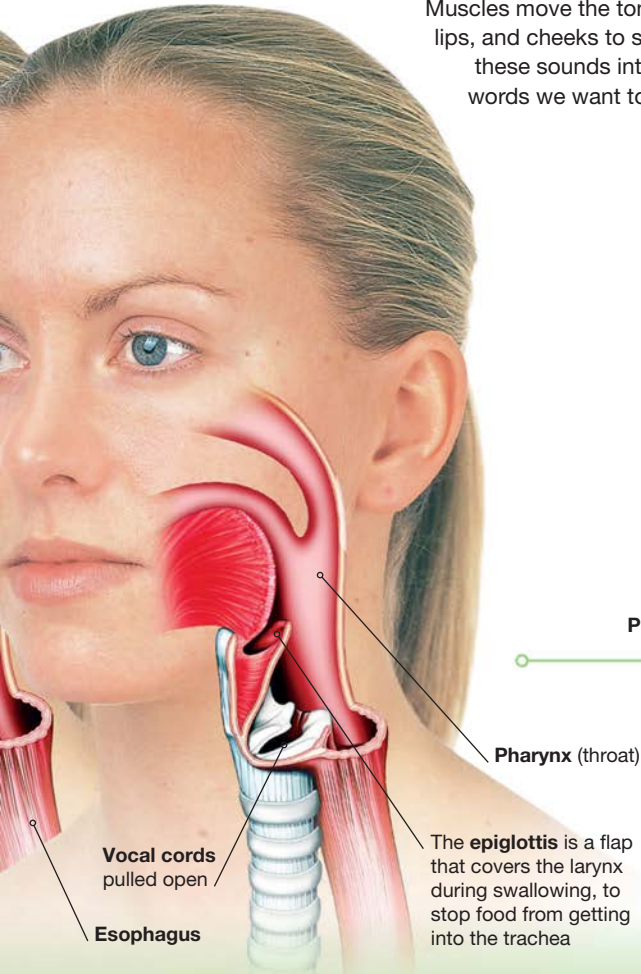
Vibrations of the vocal cords produce humming sounds. Muscles move the tongue, lips, and cheeks to shape these sounds into the words we want to say.



Open mouth forms an “ah” sound



Pursed open lips form an “oo” sound



About 6,900 languages are spoken across the world. The most common are Mandarin Chinese, English, Spanish, Hindi, and Russian.





# The digestive system

An average person eats about 20 tons of food in a lifetime. The digestive system transforms this mountain of meals into substances that the body can use. The system breaks food down into simple nutrients that supply energy to body cells and provide the chemicals needed to make the body grow, maintain, and repair itself.



## **FRIENDLY BACTERIA**

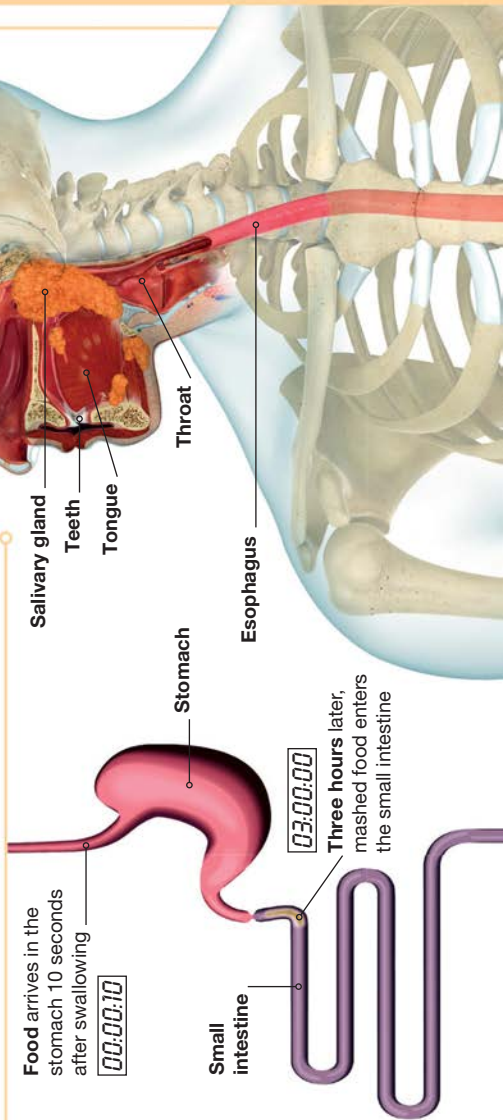
Inside the intestines are trillions of “friendly” bacteria, such as *Lactobacillus fermentum*. They release extra nutrients from food for the body to use.

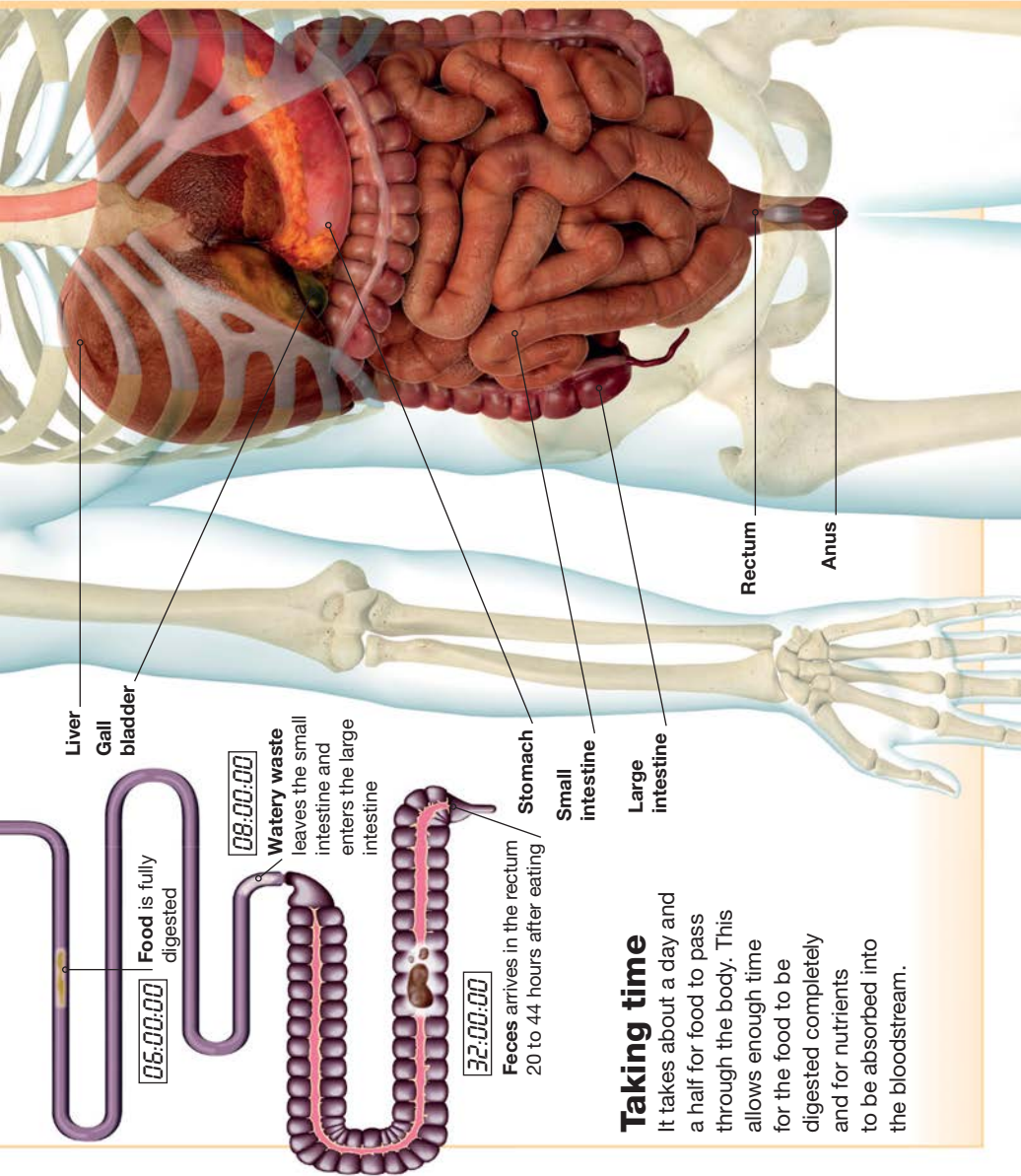
# Feeding the body

Before we can use the food we eat, it must be broken down, or digested, into simple nutrients. These nutrients are then absorbed into the bloodstream and carried to the body's cells.

## Digestive system

The digestive tract is a tube that runs from the mouth to the anus. Each part of the tract plays its own part in digestion. Other organs, such as the teeth, salivary glands, and liver, also help with digestion.





Liver  
Gall  
bladder

05:00:00  
Food is fully  
digested

08:00:00

Watery waste  
leaves the small  
intestine and  
enters the large  
intestine

32:00:00

Feces arrives in the rectum  
20 to 44 hours after eating

Stomach

Small  
intestine

Large  
intestine

Rectum

Anus

## Taking time

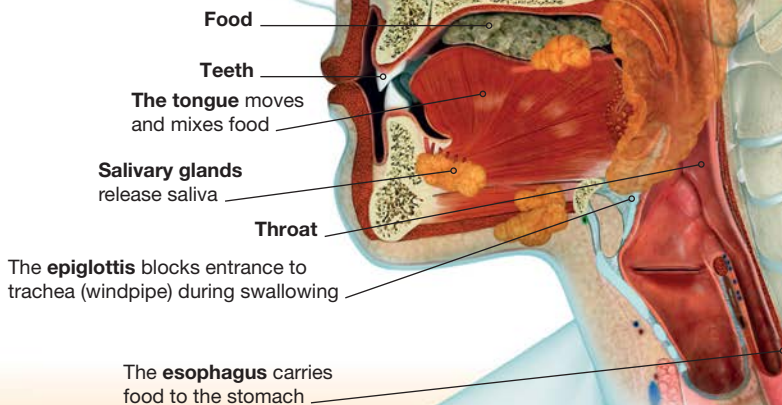
It takes about a day and a half for food to pass through the body. This allows enough time for the food to be digested completely and for nutrients to be absorbed into the bloodstream.

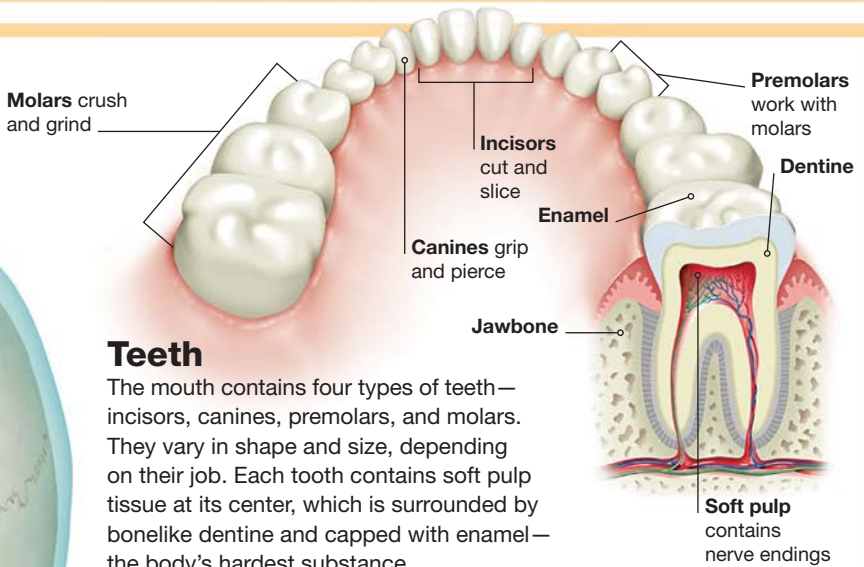
# Chew and swallow

The mouth is the first part of the digestive tract. Here, chunks of food are chewed and crushed by the teeth into pieces small enough to be pushed into the throat by the tongue, and swallowed.

## Mouth and throat

The mouth contains the teeth and tongue. During chewing, the tongue mixes the food with slimy saliva released by salivary glands. The resulting slippery ball of food is then swallowed.

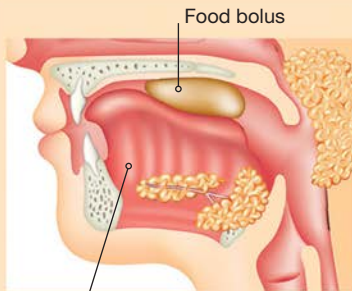




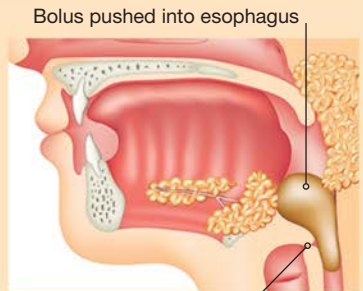
## Teeth

The mouth contains four types of teeth—incisors, canines, premolars, and molars. They vary in shape and size, depending on their job. Each tooth contains soft pulp tissue at its center, which is surrounded by bonelike dentine and capped with enamel—the body’s hardest substance.

## SWALLOWING



The tongue shapes the chewed food and saliva into a ball, called a bolus, and pushes it toward the throat.



When the food touches the back of the throat a reflex action squeezes the bolus into the esophagus.

# Into the stomach

The stomach mixes chewed food with gastric juice, a liquid that contains an enzyme (chemical digester) that breaks down proteins. The stomach also stores food, releasing it slowly so that the small intestine has time to digest it.

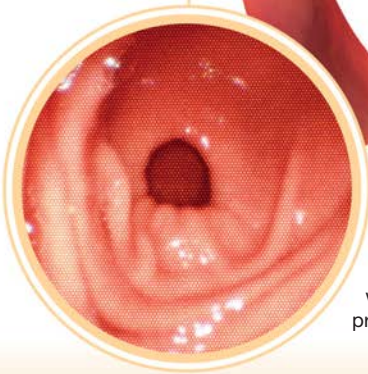
The **esophagus** delivers food from the mouth

## Muscular bag

The baglike stomach has a stretchy wall so that it can expand during a meal. The wall has three layers of muscles that contract to squash and squeeze the food, churning it up and mixing it with the gastric juice.

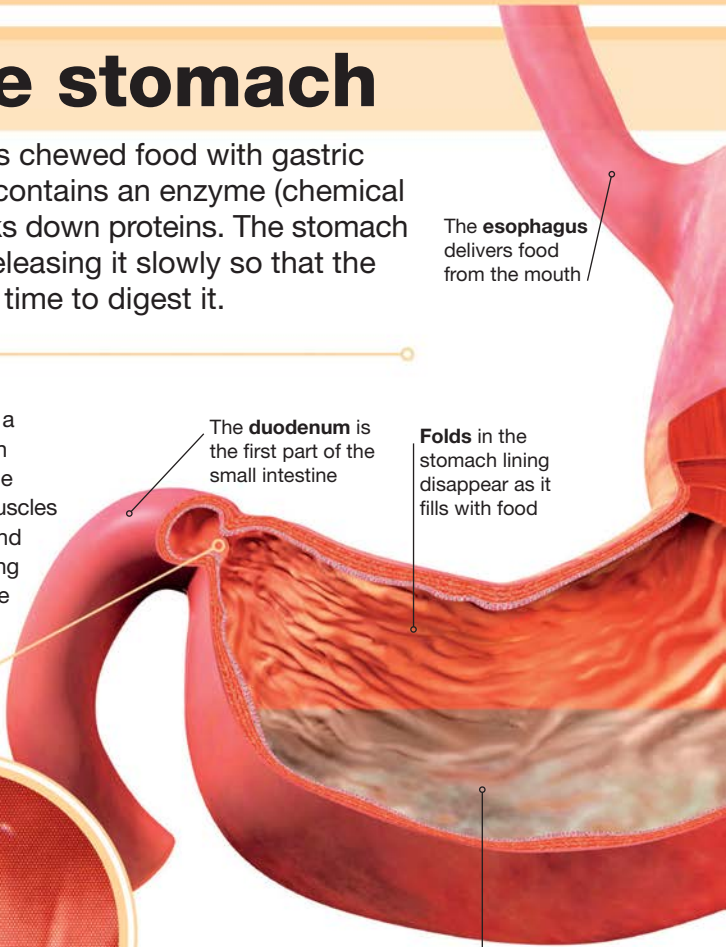
The **duodenum** is the first part of the small intestine

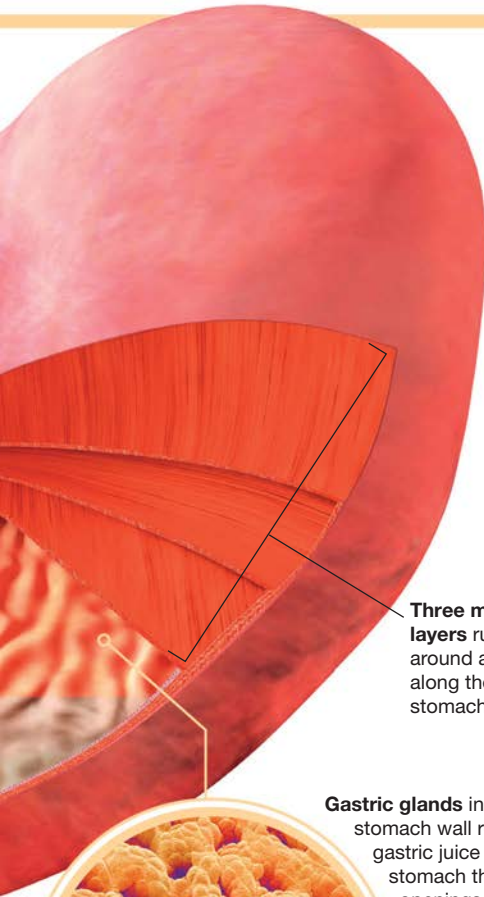
**Folds** in the stomach lining disappear as it fills with food



The **pyloric sphincter** is a ring of muscle that remains tightly closed when the stomach processes food.

**Chyme** is a mixture of part-digested food and gastric juice





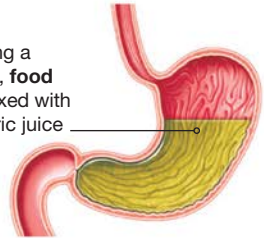
**Three muscle layers** run around and along the stomach

**Gastric glands** in the stomach wall release gastric juice into the stomach through openings called gastric pits.

## Filling and emptying

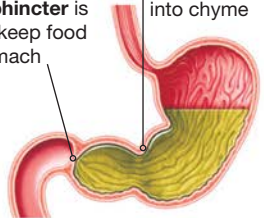
The process of filling and emptying the stomach takes at least three hours. During this time, the food is partially digested and churned into a creamy liquid called chyme. The semidigested, liquid food is then released into the duodenum through the open pyloric sphincter.

During a meal, **food** is mixed with gastric juice

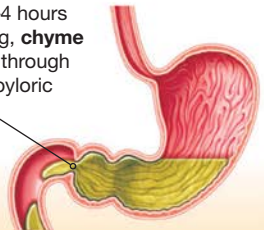


About 1–2 hours after eating, the **pyloric sphincter** is closed to keep food in the stomach

**Stomach wall** contracts to churn food into chyme



Around 3–4 hours after eating, **chyme** is pushed through the open pyloric sphincter



# Small intestine

With help from the gall bladder and pancreas, the small intestine completes digestion, using enzymes. These chemical digesters break down the proteins, carbohydrates, and fats in foods into simple nutrients that are absorbed into the bloodstream.

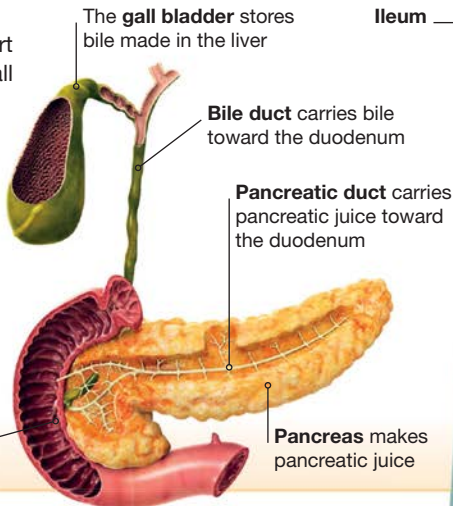
## Small intestine

The small intestine is nearly 23 ft (7 m) long and has three sections. The shortest is the duodenum. The middle jejunum and final ileum are where most digestion and absorption take place.

## Extra help

Two liquids kick-start digestion in the small intestine. Bile turns fats into tiny droplets that are easier to break down. Pancreatic juice contains enzymes that digest proteins and carbohydrates.

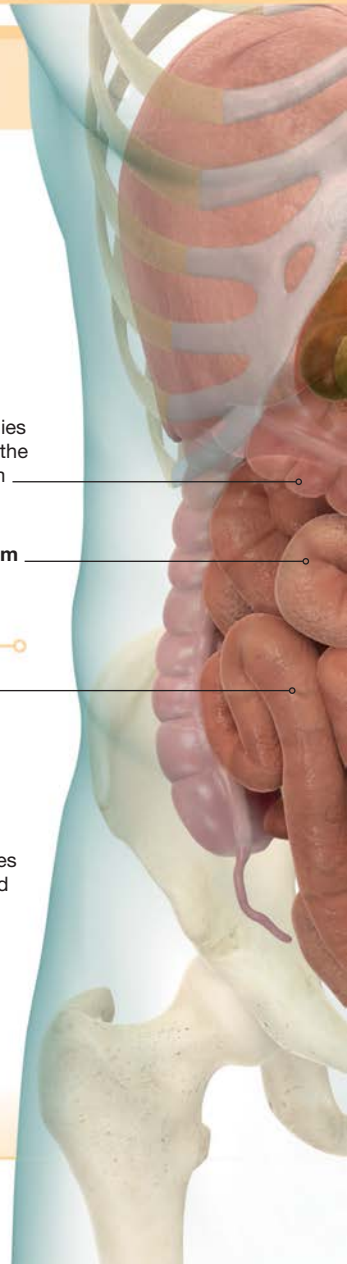
**Opening** of bile and pancreatic ducts into the duodenum



The **large intestine** lies in front of the duodenum

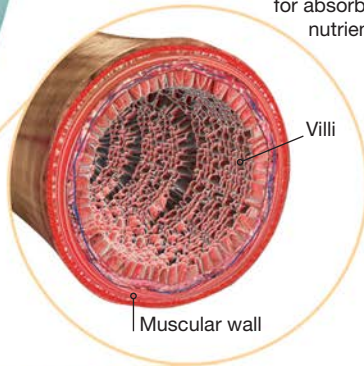
**Jejunum**

**Ileum**



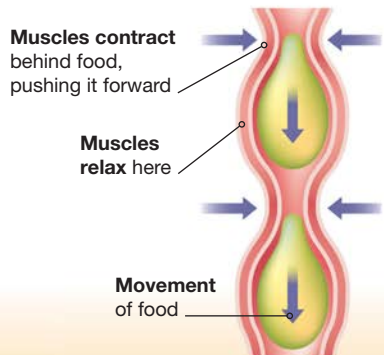


Lining the wall of the small intestine are millions of fingerlike **villi**. These provide a huge surface area for absorbing nutrients.



## Peristalsis

Muscles contract and relax in waves to push food along the small intestine and other parts of the digestive tract. This is called peristalsis.





**VILLI**

The inside of the small intestine is lined with tiny fingerlike projections called villi, which are about 0.04 in (1 mm) long. Together they cover an area of 2,800 sq ft (260 sq m). Villi give the inside of the intestine a velvety texture, just like a soft towel. They transfer nutrients into the bloodstream.

**Spread out, the lining of the inside  
of the small intestine would cover a**

**tennis court**



# Large intestine

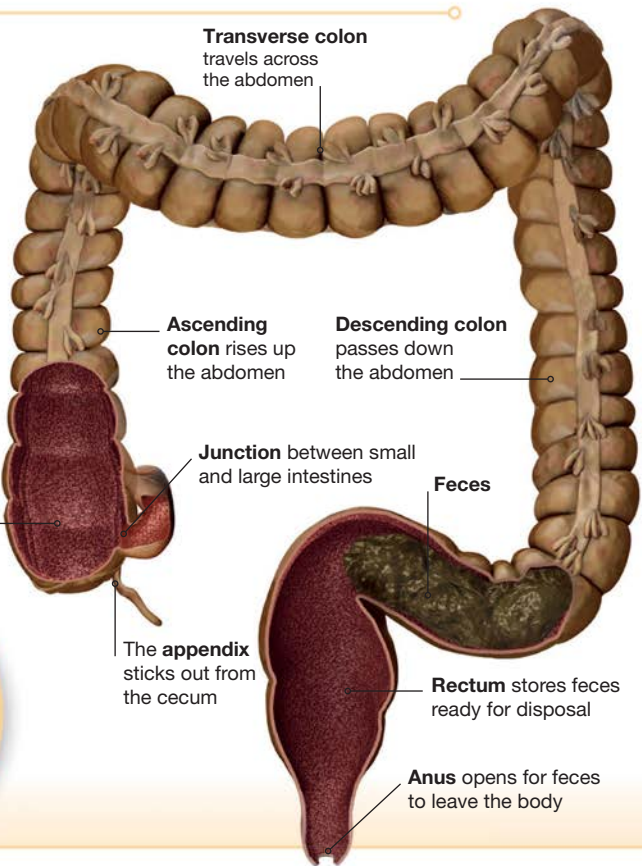
The large intestine is about a quarter of the length of the small intestine, but twice its width. It receives watery waste from the small intestine and turns it into semisolid feces (poop).

## Three parts

The cecum, colon, and rectum make up the large intestine. The longest section, the colon, travels up, across, and down the abdomen. It turns watery, undigested waste into feces by absorbing water back into the bloodstream.

The **cecum** is the first, short section of the large intestine

Each day, the average person passes enough wind (gas from the large intestine) to fill a party balloon.

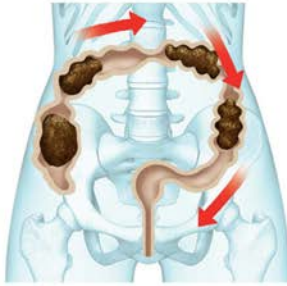


## Colon movements

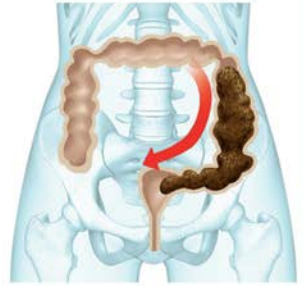
Three types of muscular movement push waste along the colon as it is turned into feces. These slow movements are made by smooth muscles that run along and around the walls of the large intestine.



**Segmentation** movements are produced by a series of short contractions all along the colon that mix and churn feces but do not move them.



**Peristalsis** movements involve small contractions that pass along the colon in waves and push feces toward the rectum.

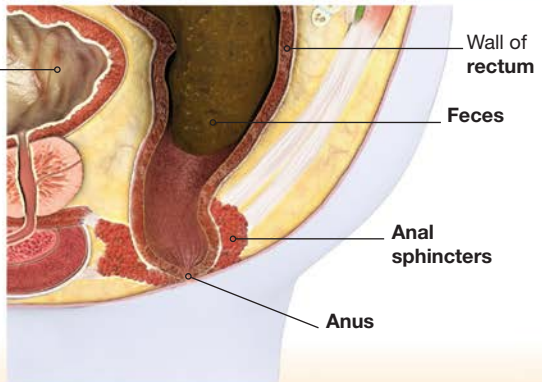


**Mass** movements are extra-strong contractions that happen three or four times a day after eating and push feces into the rectum.

Bladder stores urine

## Pushed outside

As feces is pushed into the rectum, it stretches the rectum wall. This triggers the need to go to the bathroom. The anal sphincter wall contracts to push the feces out through the anus.



# The liver

The liver is the body's largest internal organ, and all of our blood flows through it. The liver cells remove and add substances to help clean the blood. This helps to keep conditions stable inside the body.



**Liver**

**The gall bladder stores bile**

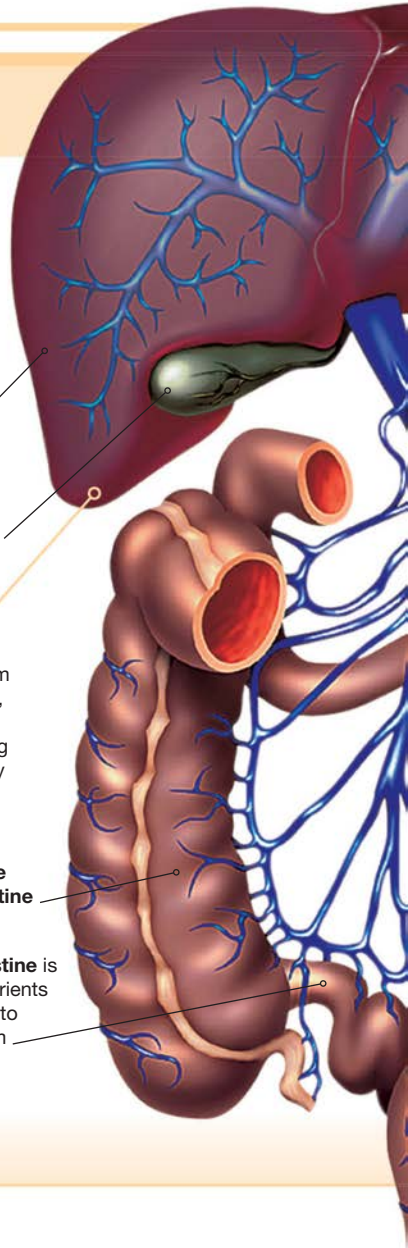
**Liver cells** perform over 500 functions, including storing nutrients and removing poisons from blood. They also make bile, which is used to help digest fats.

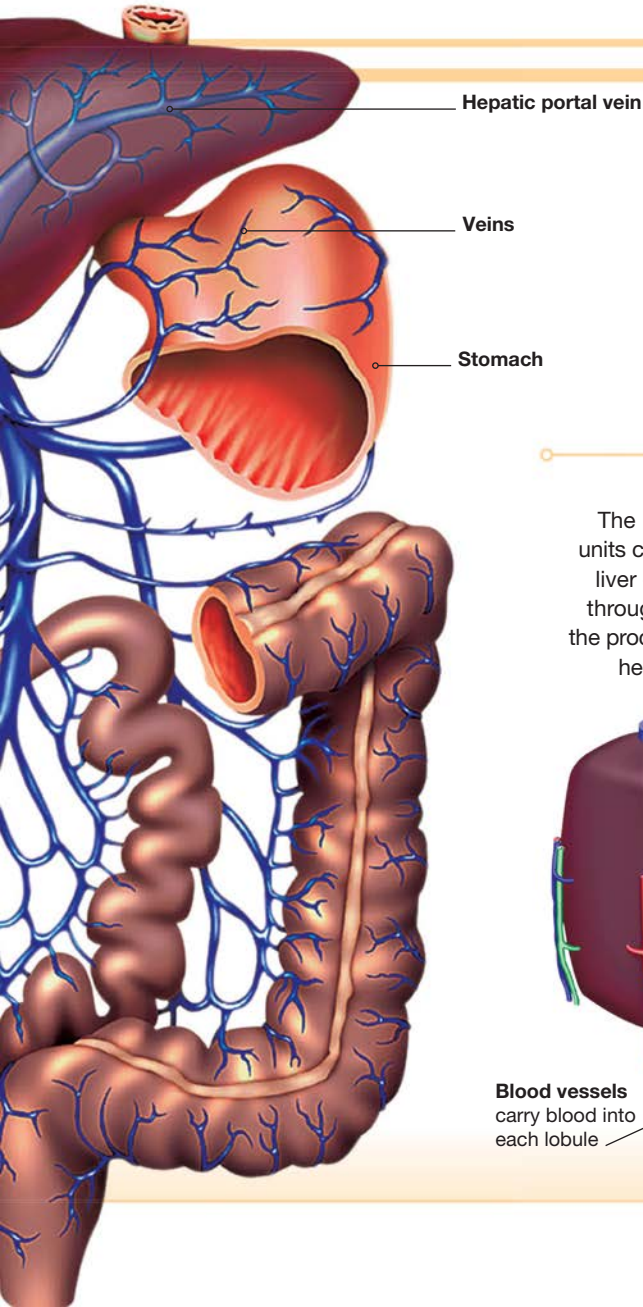
## Blood supply

The liver receives 80 percent of its blood from the hepatic portal vein. Veins carry the blood from the digestive organs to the hepatic portal vein, which then enters the liver. This blood is rich in nutrients, which the liver processes in its cells.

**Large intestine**

The **small intestine** is where most nutrients are absorbed into the bloodstream

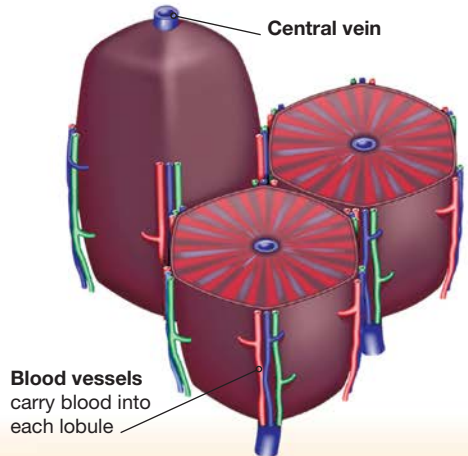




The liver stores glucose—the body's fuel—when there's too much of it in the blood and releases it when there is too little.

## Inside the liver

The liver contains a million processing units called lobules. Inside these lobules, liver cells process the blood that flows through the liver. A central vein collects the processed blood to be returned to the heart and pumped around the body.







# Controlling the body

Running throughout the body is a network called the nervous system, which is made up of long, thin nerve cells. This network carries tiny electrical signals from sensors all around the body to the body's control center—the brain. These signals tell the brain what is happening in the world around it and carry messages from the brain to the body, telling it to perform a range of activities, from breathing to balancing on tiptoe.



## **TOUCH**

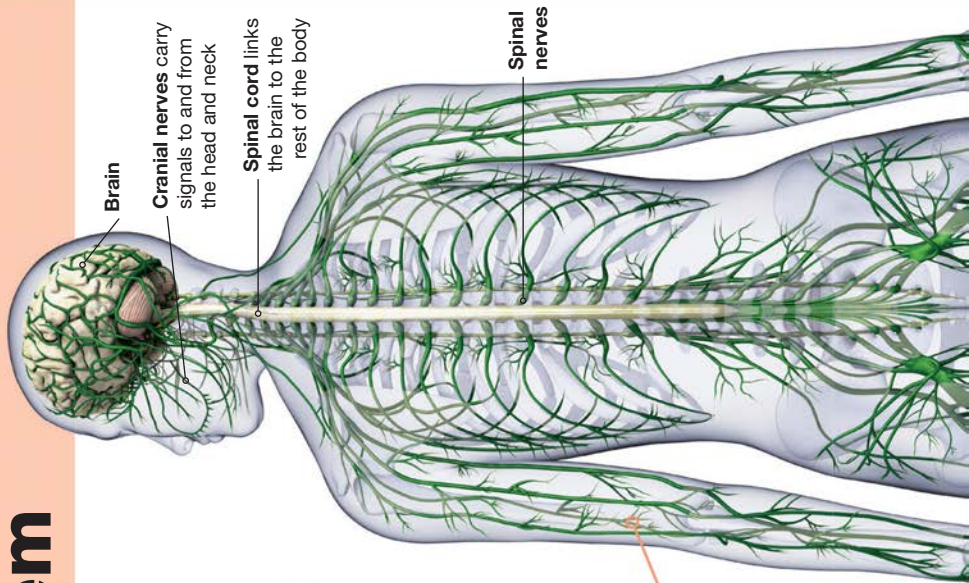
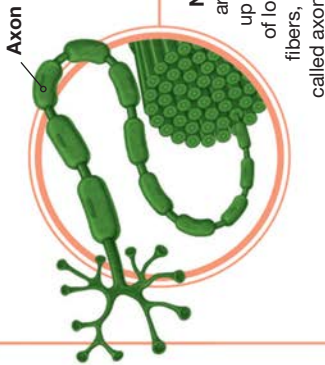
Our fingertips are very sensitive. Sensors in the skin send signals to the brain, allowing us to feel even the lightest touch.

# Nervous system

Everything we do is controlled by the nervous system. This is made up of billions of neurons — interconnected cells that carry high-speed electrical signals.

## Control network

Most neurons are packed into the brain and the spinal cord. Together, these make up the central nervous system and control the body's activities, communicating with the rest of the body through nerves.



## Signal carriers

Each neuron is made up of a cell body, with a long filament called an axon that carries nerve signals to other neurons. Shorter filaments called dendrites receive signals from other neurons.



Axon's protective covering

A synapse is a junction

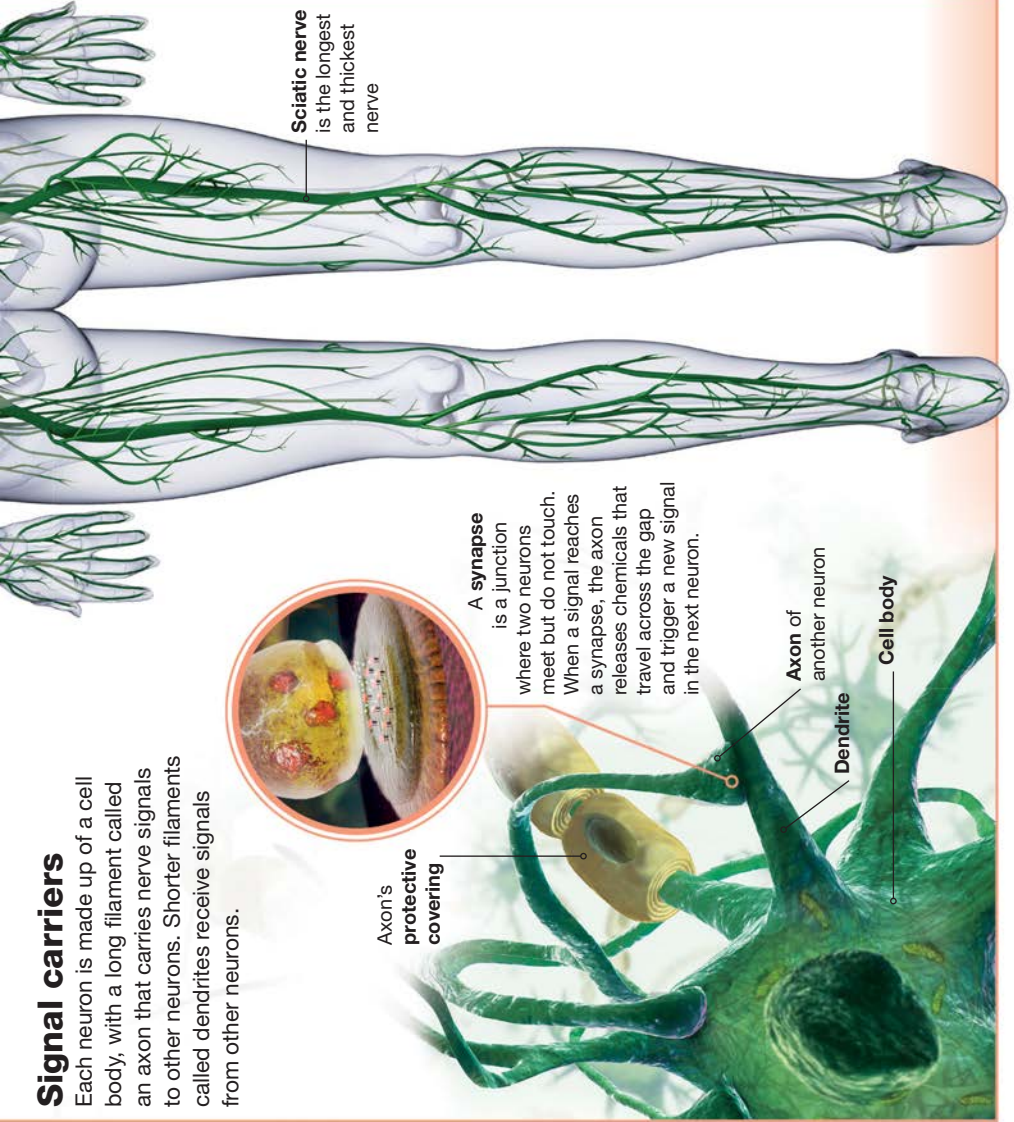
where two neurons meet but do not touch. When a signal reaches a synapse, the axon releases chemicals that travel across the gap and trigger a new signal in the next neuron.

Axon of another neuron

Dendrite

Cell body

Sciatic nerve is the longest and thickest nerve

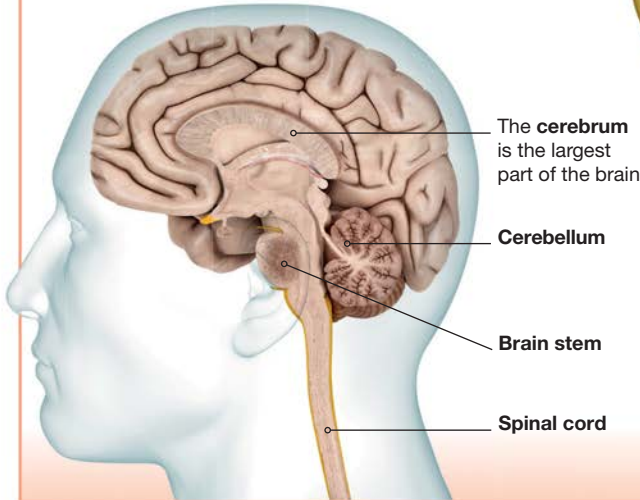


# The brain

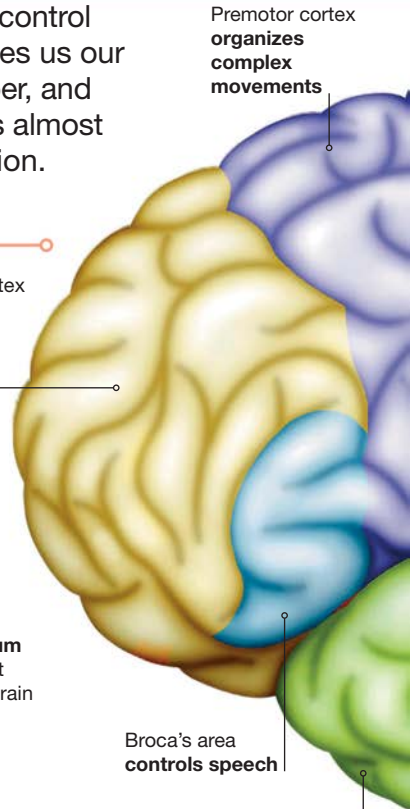
The 100 billion neurons in the brain form a control network of incredible power. The brain gives us our personality and allows us to think, remember, and sense our surroundings. It also coordinates almost all bodily activities, from running to digestion.

## Inside the brain

This cross-section through the brain shows its three parts. The cerebrum lets us think, feel, and move. The cerebellum organizes movement and balance. The brain stem controls vital functions such as our heartbeat and breathing rate.



Prefrontal cortex is the area involved with **thinking and personality**



**Broca's area controls speech**

Auditory association cortex **identifies sounds**

Motor cortex **sends signals to the muscles**

Sensory cortex **receives information about touch**

## Brain map

The thin outer layer of the cerebrum is called the cerebral cortex. Packed with neurons, it receives and processes incoming signals and sends out instructions. Different areas of the cerebral cortex are responsible for specific jobs.

Sensory association cortex **identifies skin sensations**

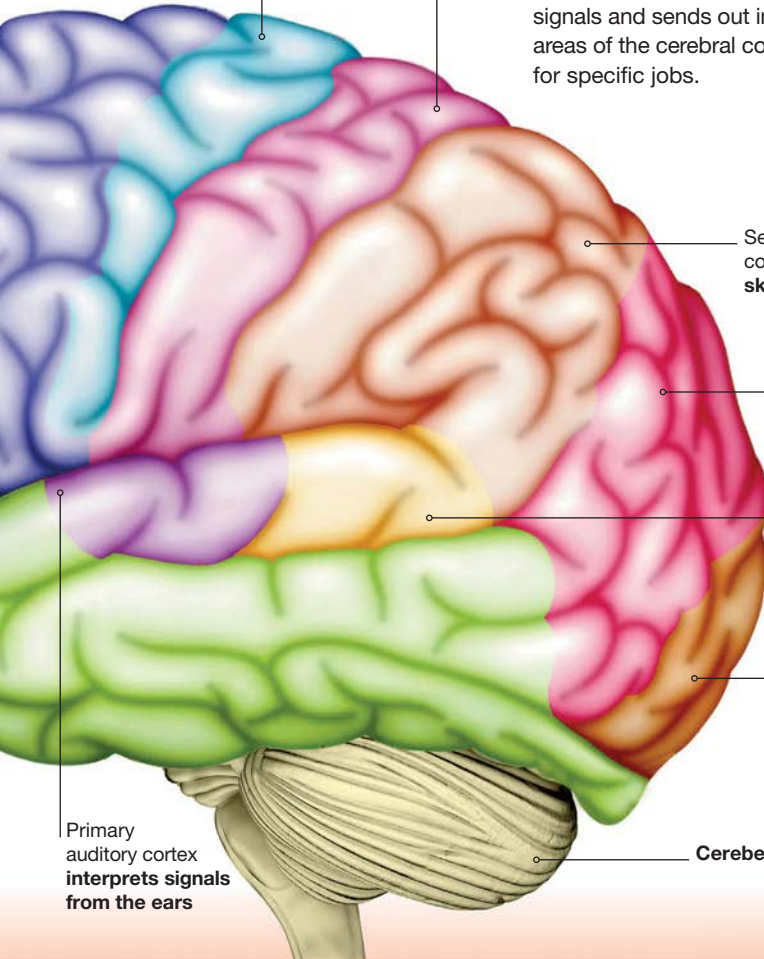
Visual association cortex **turns visual signals into images**

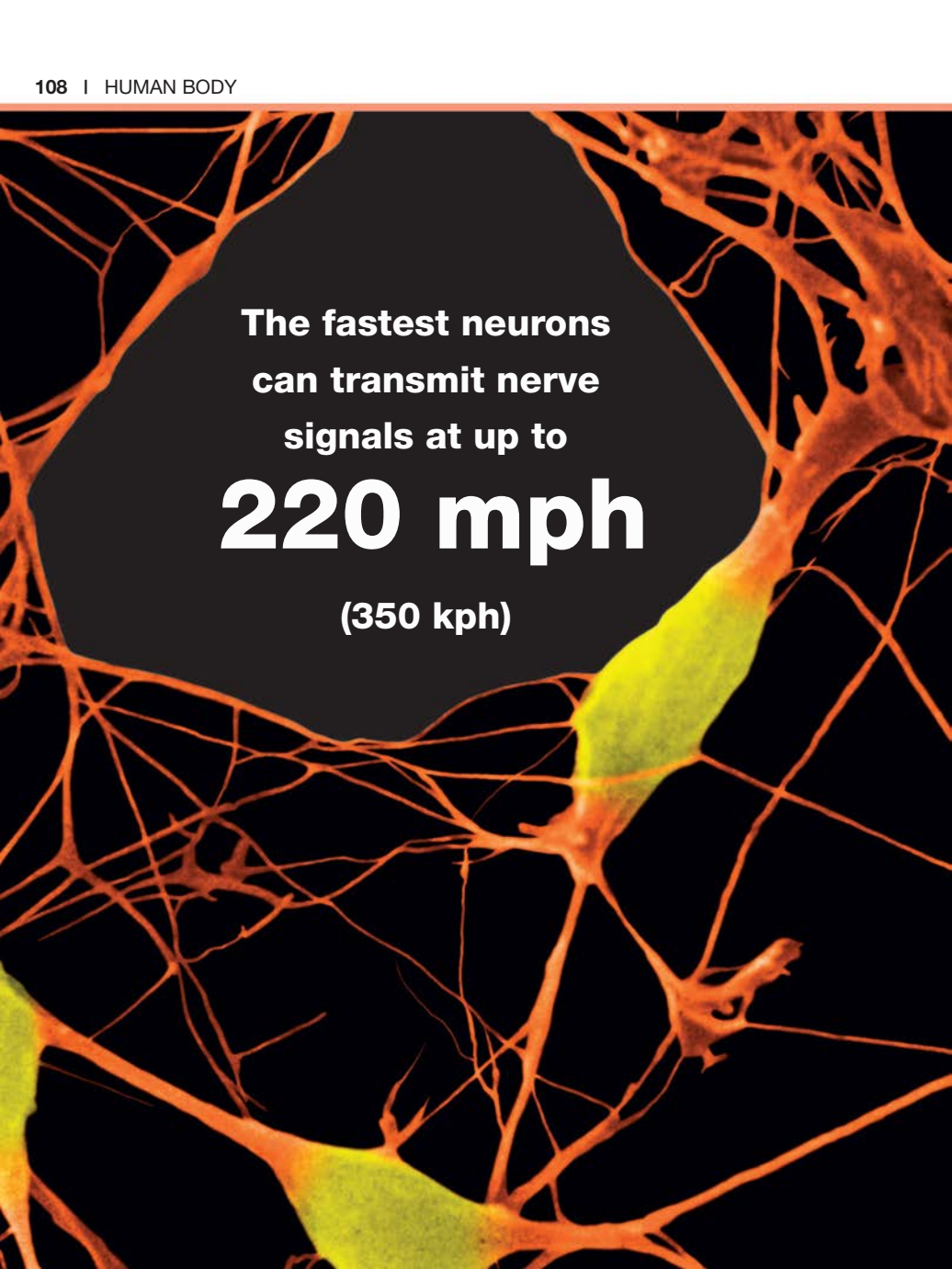
Wernicke's area **understands words**

Primary visual cortex **receives signals from the eyes**

Primary auditory cortex **interprets signals from the ears**

Cerebellum





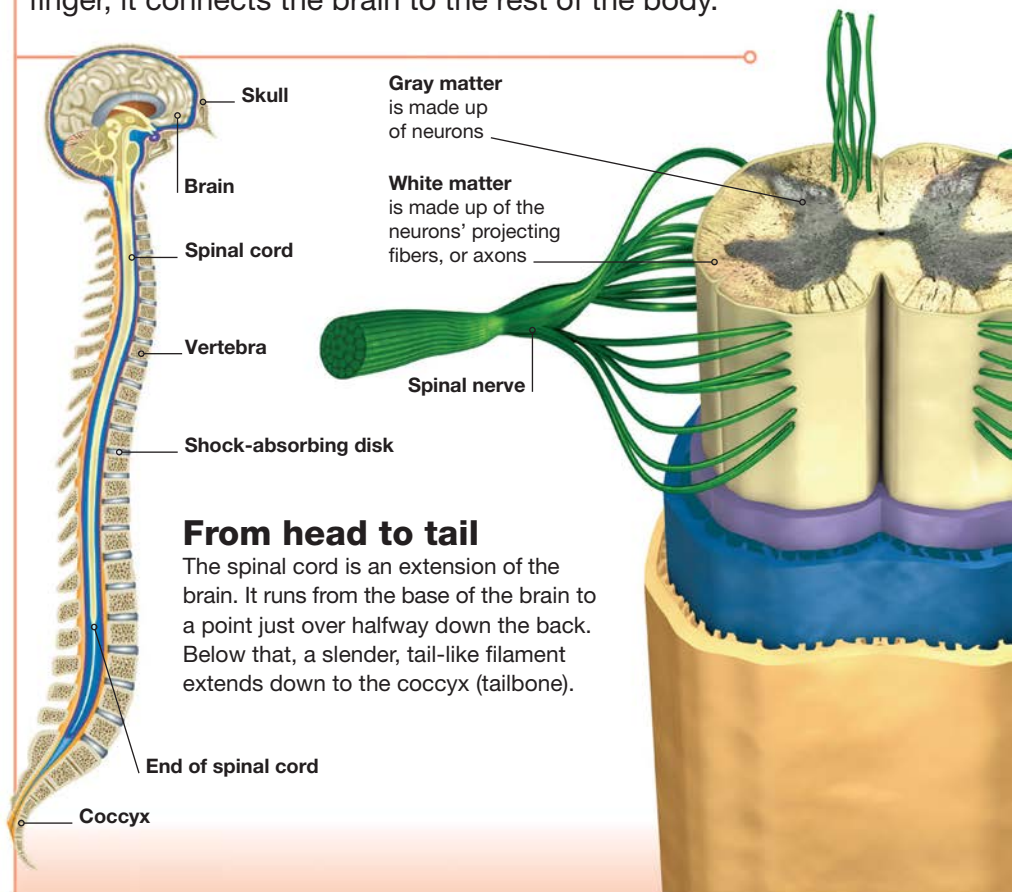
The fastest neurons  
can transmit nerve  
signals at up to  
**220 mph**  
(350 kph)

**BRAIN CELLS**

This microscopic view of brain neurons—nerve cells—shows the links between them. Each neuron makes up to 10,000 connections with other neurons, creating a network that allows the brain to process millions of pieces of information at the same time.

# Spinal cord

The spinal cord carries the signals that help control the body. It is a bundle of billions of neurons that stretches down the back from the brain. About the width of a finger, it connects the brain to the rest of the body.



## From head to tail

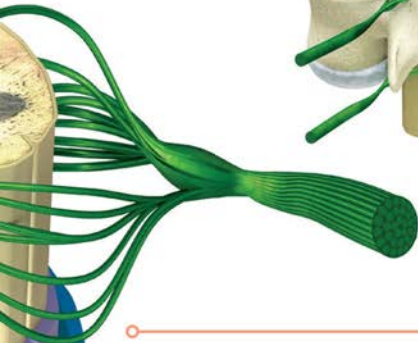
The spinal cord is an extension of the brain. It runs from the base of the brain to a point just over halfway down the back. Below that, a slender, tail-like filament extends down to the coccyx (tailbone).



## Protecting the spinal cord

The bundle of neurons that forms the spinal cord is made of soft tissue. This is protected by a tunnel of bone formed by the vertebrae that make up the backbone.

These vertebrae are separated by thick disks of cartilage.



## Information highway

A cross-section through the spinal cord shows butterfly-shaped gray matter in the center. The gray matter transmits signals across the cord. These signals are received from, and passed to, spinal nerves, which provide the link to the rest of the body. The white matter relays signals to and from the brain.

## WITHOUT THINKING

Reflexes are automatic actions that happen without our being aware of them. Many reflexes, such as this withdrawal reflex, protect the body from danger and are controlled by the spinal cord. Reflex actions happen quickly because nerve signals travel through the spinal cord without going to the brain.



### Danger

Pain receptors detect the burning heat of the flame and send signals to the spinal cord.



### Withdrawal

The spinal cord sends signals to an arm muscle that pulls the hand away from the candle.



### Pain

A message is now sent up the spinal cord to the brain and the person feels pain.

# Seeing

Our most important sense, sight, depends on our two eyes detecting light from our surroundings. Like a digital camera, each eye automatically adjusts its focus to give us clear, sharp images.

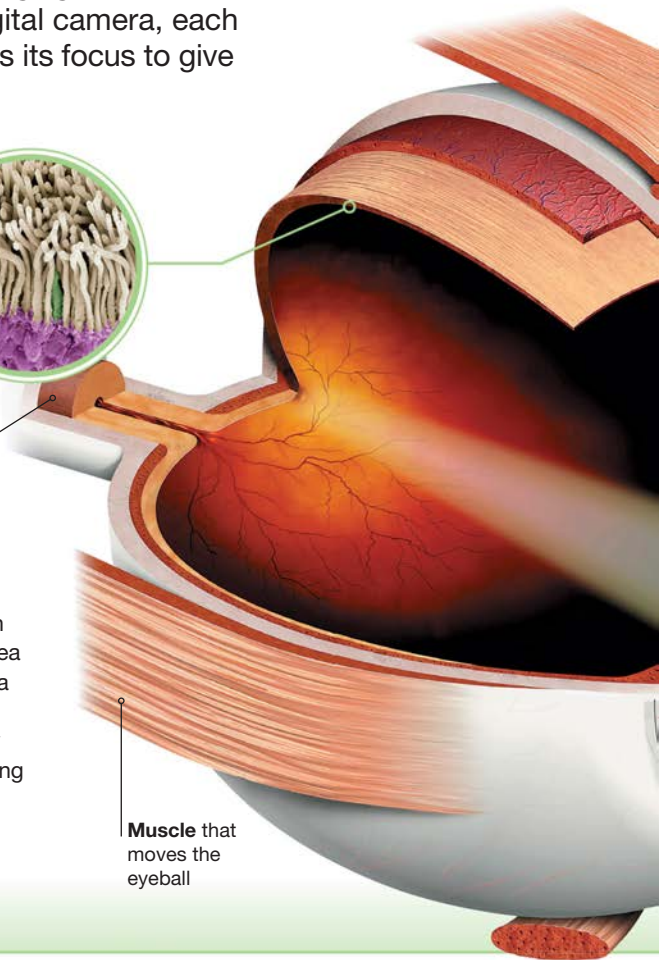
The **retina** contains light detectors called rods (white) and cones (green). Cones detect color and detail and work best in strong light, while rods work best in dim light.

**Optic nerve** carries signals to the brain

## Inside the eye

Light enters the eye through the cornea and then passes through the pupil and the lens. The cornea and lens focus the light to form a sharp image on the retina at the back of the eyeball. When hit by light, the retina sends signals along the optic nerve to the brain.

**Muscle** that moves the eyeball



## Pupil size

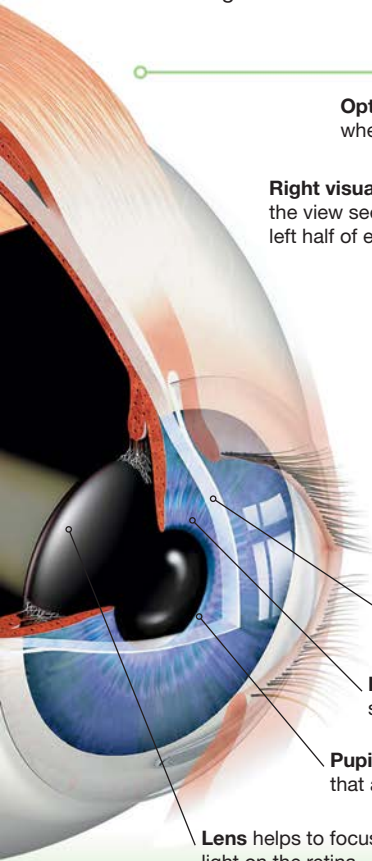
In bright light, pupils narrow to stop too much light from entering the eyes and dazzling us. In dim light, they widen to let in extra light so that we can see.



Narrow pupil



Wide pupil



**Optic nerve** carries a signal when light hits the retina

**Right visual field** is the view seen by the left half of each retina



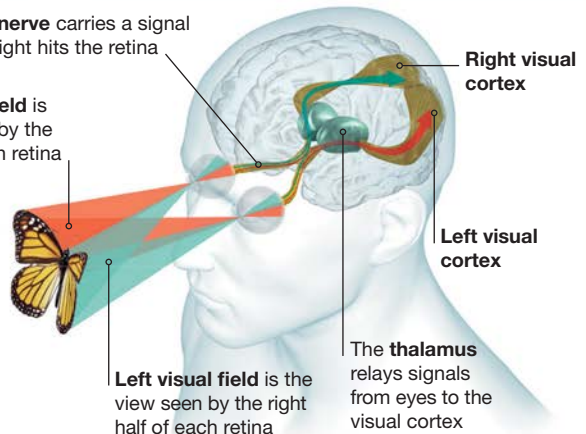
**Left visual field** is the view seen by the right half of each retina

**Cornea** is the clear front of the eyeball

**Iris** controls the size of the pupil

**Pupil** is a hole that allows light in

**Lens** helps to focus light on the retina



The **thalamus** relays signals from eyes to the visual cortex


## Brain connection

Signals from the eye are turned into images that we can “see” by the visual cortex at the back of the brain. Each eye sees a slightly different view, called a visual field. By comparing these, the brain can judge distances and create 3-D images of the world around us.



**IRIS**

People often have the same eye color but the patterns created by the fibers in the iris are unique to every person and can be used to identify them. This image shows a magnified view of a blue iris surrounding the pupil.



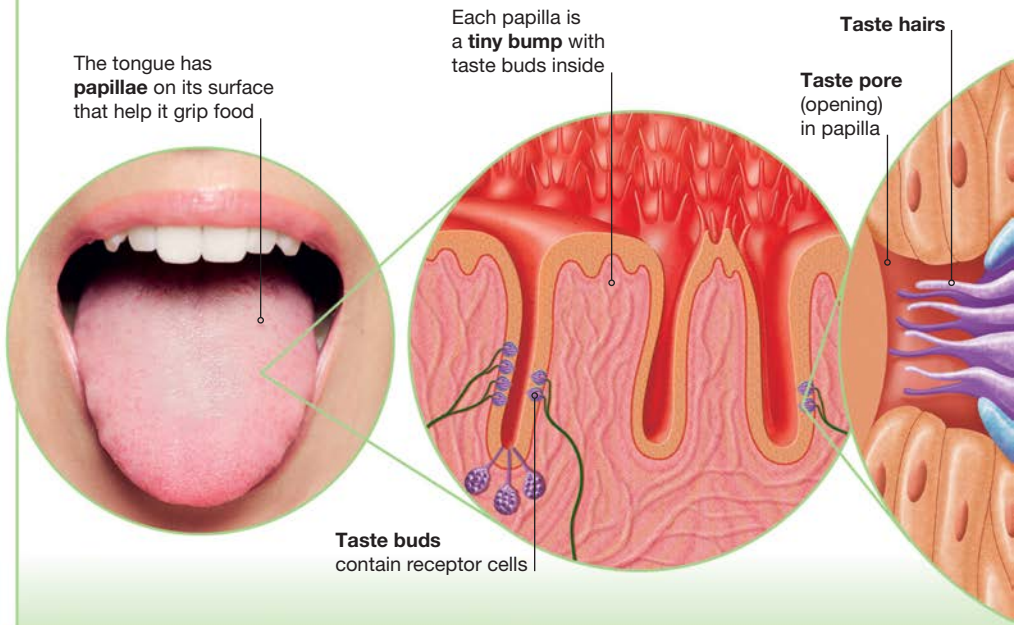
The human eye can  
distinguish up to  
**10 million**  
different colors

# Tasting

Being able to taste food increases our enjoyment of eating. It also warns us not to eat food that may be harmful. Sensors in the tongue can detect five tastes—sweet, sour, salty, bitter, and umami (savory).

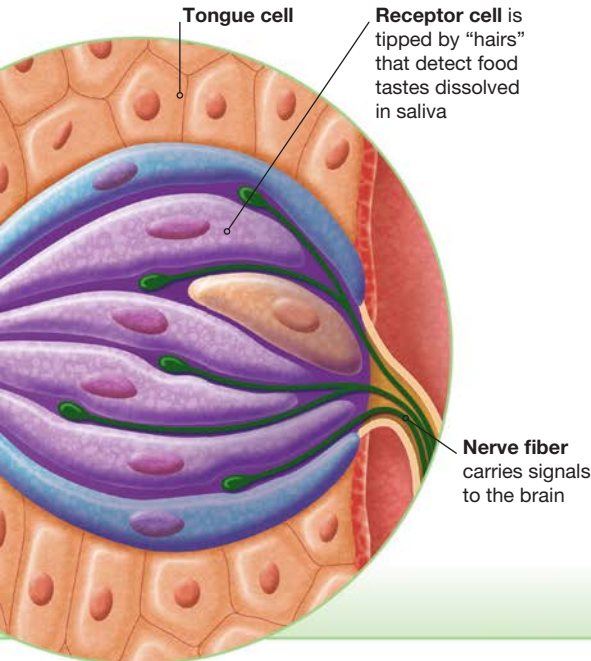
## Tongue and taste buds

When food enters the mouth, the muscular tongue moves the food around and mixes it with saliva. At the same time, 10,000 taste buds in the tongue's upper surface detect the tastes in the food and send that information to the brain.



## Enjoying flavors

Our senses of taste and smell work together and allow us to enjoy flavors. The pleasure we get from different flavors encourages us to eat and provide fuel for the body.



## FIVE TASTES



**Sweet** foods, such as cakes and fruits, are packed with energy.



**Sour** foods, such as citrus fruits, have a sharp, acid taste.



**Salt** occurs naturally in food—adding a lot more is bad for our health.



**Bitter** foods such as coffee often taste unpleasant to children.

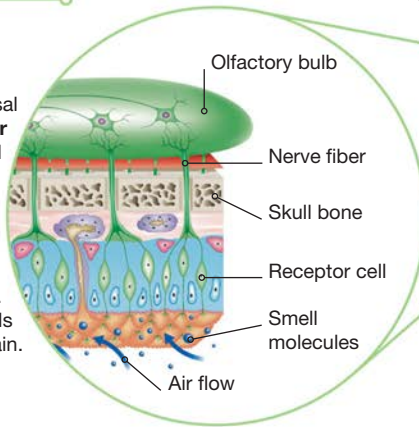


**Umami** is the savory taste found in grilled meats and cheese.

# Smelling

The nose has tiny detectors that pick up a vast range of smells, from freshly baked bread to the stink of rotten eggs. The smell detectors in the nose work closely with the tongue's taste sensors to allow us to appreciate flavors, too.

In the roof of the nasal cavity, **odor receptor cells** detect smell molecules dissolved in watery mucus. Nerve fibers carry signals from the receptors to the olfactory bulb at the front of the brain. From there, the signals are sent to the brain.



The **olfactory bulb** carries signals to the brain

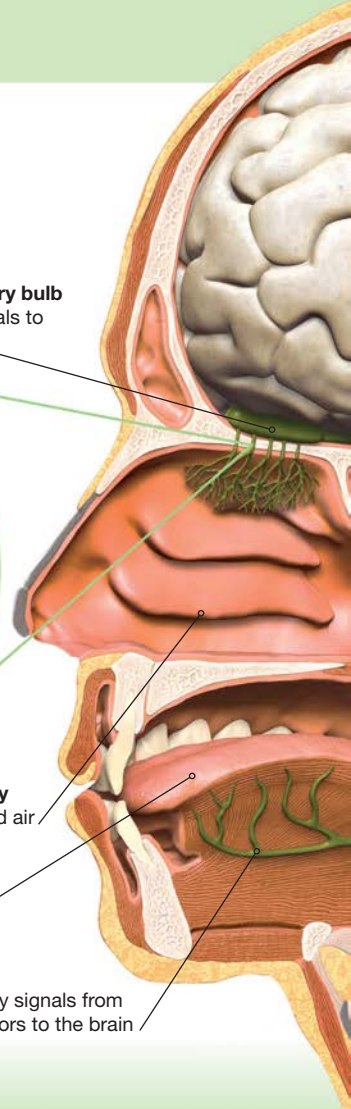
## Detecting smells

Air breathed in through the nose carries smell molecules. These are detected by odor receptors located at the top of the nasal cavity—the space that links the nostrils to the throat. The receptors send signals to the brain, which identifies each smell.

The **nasal cavity** channels inhaled air

The **tongue** houses taste receptors

**Nerves** carry signals from taste receptors to the brain







The nose contains 1,000 types of odor receptor that can detect 20,000 different smells.

### **Unpleasant smells**

Some unpleasant smells warn us of danger. The smell of smoke might mean a building is on fire. Food that smells odd may be rotten or poisonous. When milk smells sour, it is a sign that it is not safe to drink.

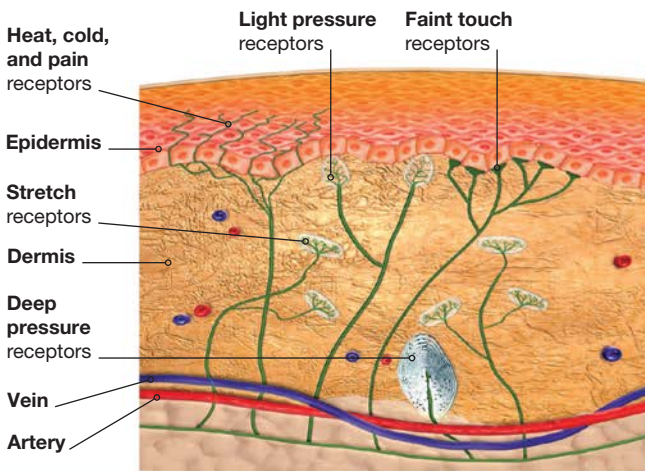


# Touching

The skin contains touch sensors that allow us to experience the softness of an animal's fur, the iciness of a cold swim, and much more. These skin sensors send signals to the brain, which gives us a “touch picture” of our surroundings.

## Skin receptors

This cross-section through the skin shows the different types of touch sensor. Most are found in the dermis, the skin's lower layer. The nerve endings that detect heat, cold, and pain may extend into the epidermis, the skin's outer layer.



## TYPES OF TOUCH

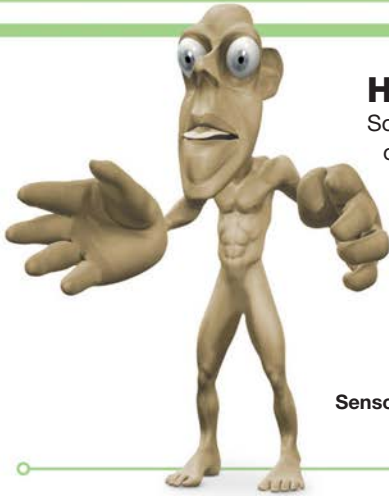
These images show the different types of touch sensation that are detected by the skin. There is also a sixth type—pain.



Cold and heat



Light pressure



## How sensitive?

Some parts of the skin are more touch-sensitive than others. This model is called a sensory homunculus (Latin for “little man”) and it exaggerates the sensitive parts of the body. The more sensitive the body part, the larger it is. That is why the fingers and lips look so huge.

Sensory homunculus

## Reading by touch

Our fingertips are so sensitive that they can pick up the slightest differences in the feel of an object. A visually impaired person can use touch to read, by feeling the patterns of writing printed in braille, where each letter is represented by raised dots.



Hands feel deep pressure  
from a tight grip



Faint touch



Stretching

# Hearing

Our ears detect sound waves that pass through the air. The sense of hearing allows us to recognize a vast range of sounds and to communicate using speech.

## Inside the ear

The ear has three parts. The outer ear collects sound waves. In the middle ear, the sound travels as vibrations along tiny bones called ossicles. The inner ear contains a coiled cochlea that detects the vibrations and sends signals to the brain.

**Ear flap** directs sound into the ear canal

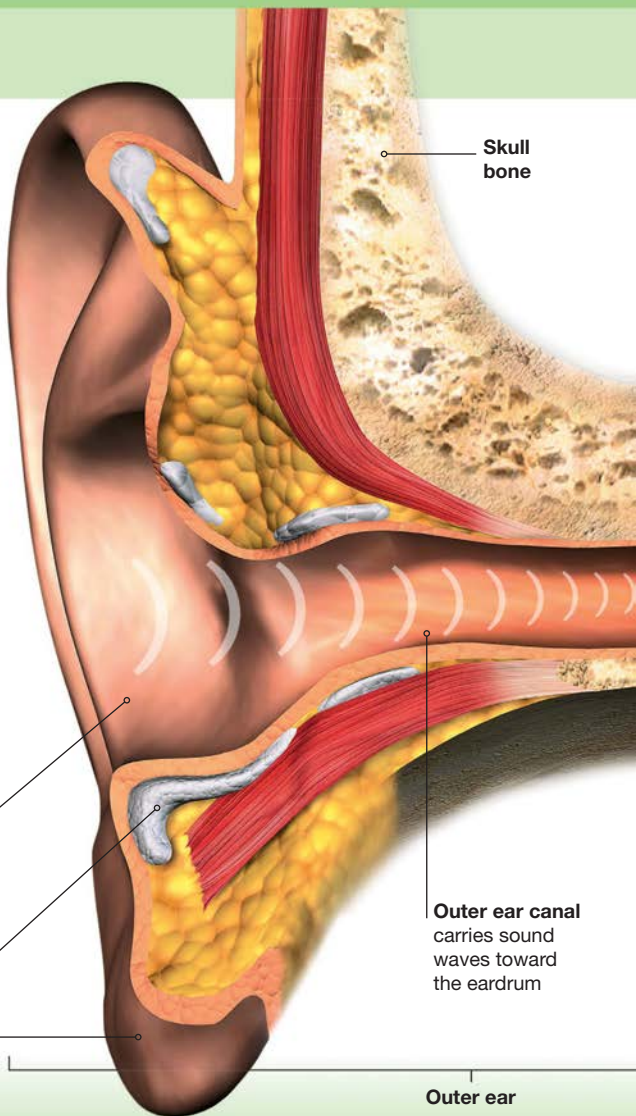
**Cartilage** provides support to the ear flap

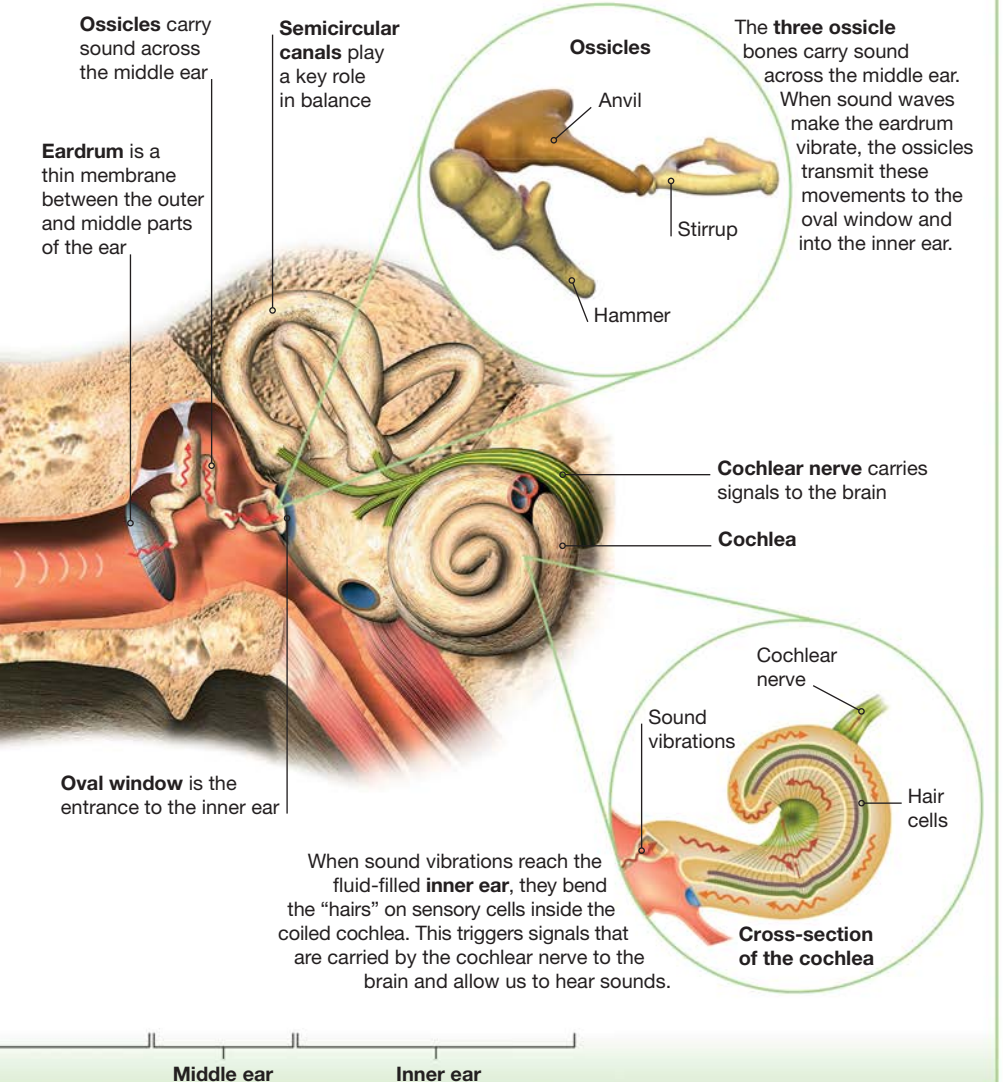
**Ear lobe** is filled with fatty tissue

**Skull bone**

**Outer ear canal** carries sound waves toward the eardrum

**Outer ear**



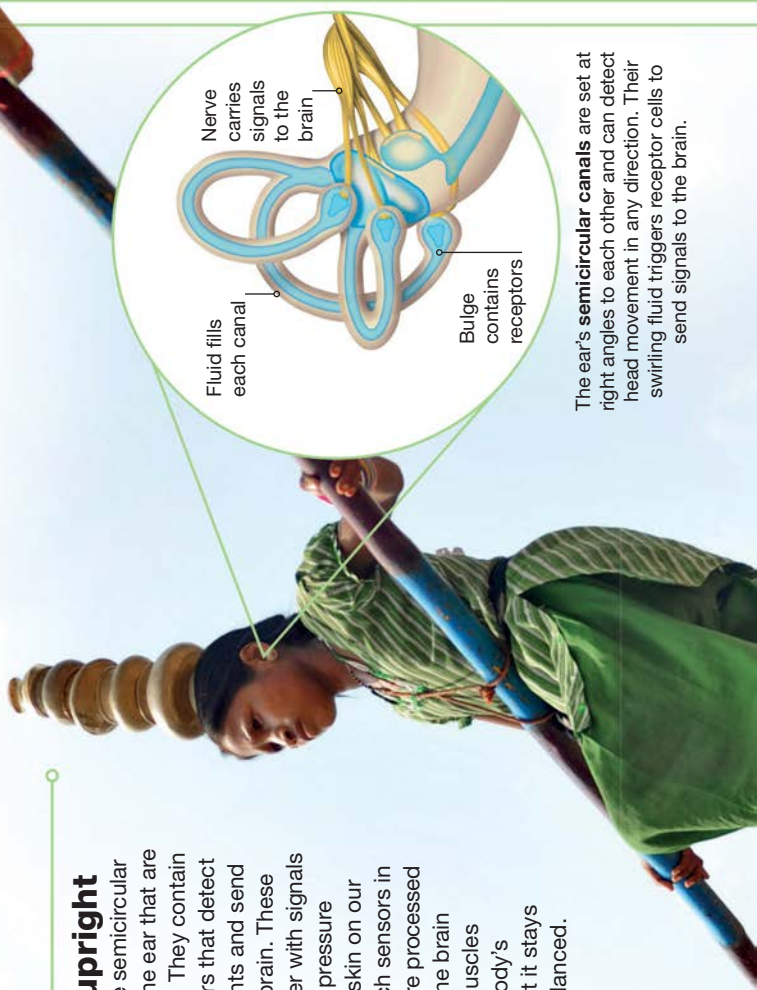


# Balance

Our sense of balance allows us to stand, walk, or run without falling over. Special sensors in the inner part of each ear keep the brain updated about how upright we are and what movements the head is making.

## Staying upright

There are three semicircular canals inside the ear that are filled with fluid. They contain balance sensors that detect body movements and send signals to the brain. These signals, together with signals from our eyes, pressure sensors in the skin on our feet, and stretch sensors in our muscles, are processed by the brain. The brain instructs the muscles to adjust the body's position so that it stays upright and balanced.



The ear's **semicircular canals** are set at right angles to each other and can detect head movement in any direction. Their swirling fluid triggers receptor cells to send signals to the brain.

An acrobat  
balances as she  
moves across  
a tightrope

When you are  
in an elevator, your ear  
sensors tell your brain  
whether you are going  
up or down.

## Feeling dizzy

Spinning around, such as on a amusement park ride, makes people feel dizzy. That is because sensors in the ears' semicircular canals send confusing information to the brain. This confusion can also cause motion sickness during a bumpy ride in a car, plane, or boat.



# Chemical messengers

In addition to the nervous system, the body has a second control system—the endocrine system. This releases hormones into the bloodstream.

Hormones are chemical messengers that target specific body tissues and change the way they act. They control growth, reproduction, and many other processes.

## Making hormones

This body map shows some of the endocrine glands that release hormones and make up the endocrine system. Some, such as the pituitary, thyroid, and adrenal glands, only release hormones. Some also have other functions—for example, the kidneys also filter the blood and make urine.

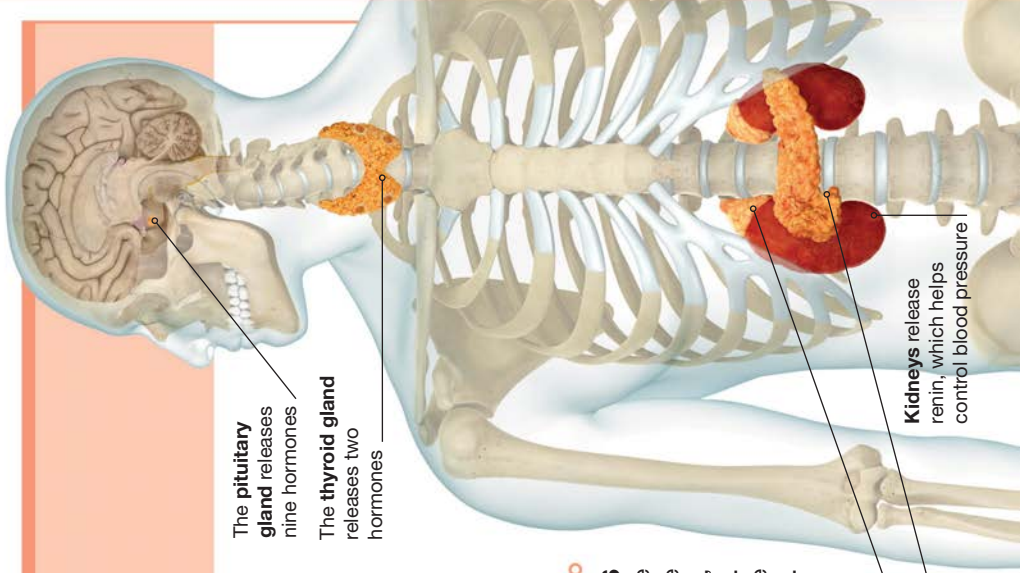
The **adrenal gland** releases epinephrine, which prepares the body to deal with danger.

The **pancreas** releases two hormones that control blood sugar levels.

The **pituitary gland** releases nine hormones.

The **thyroid gland** releases two hormones.

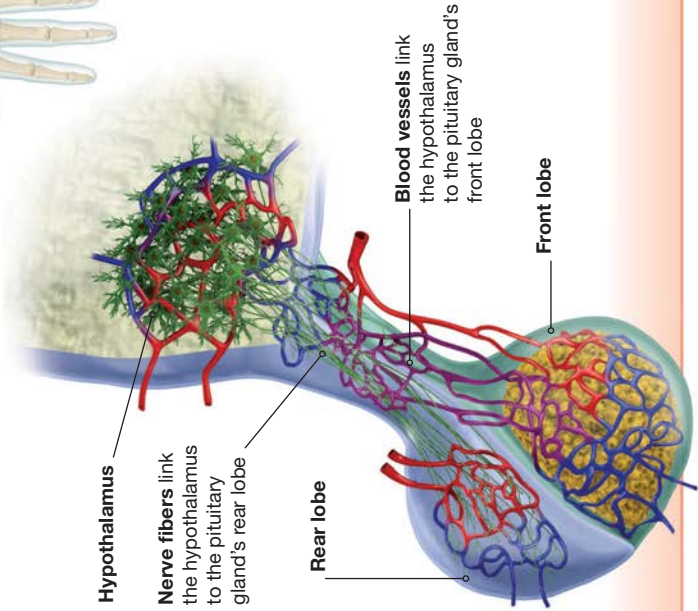
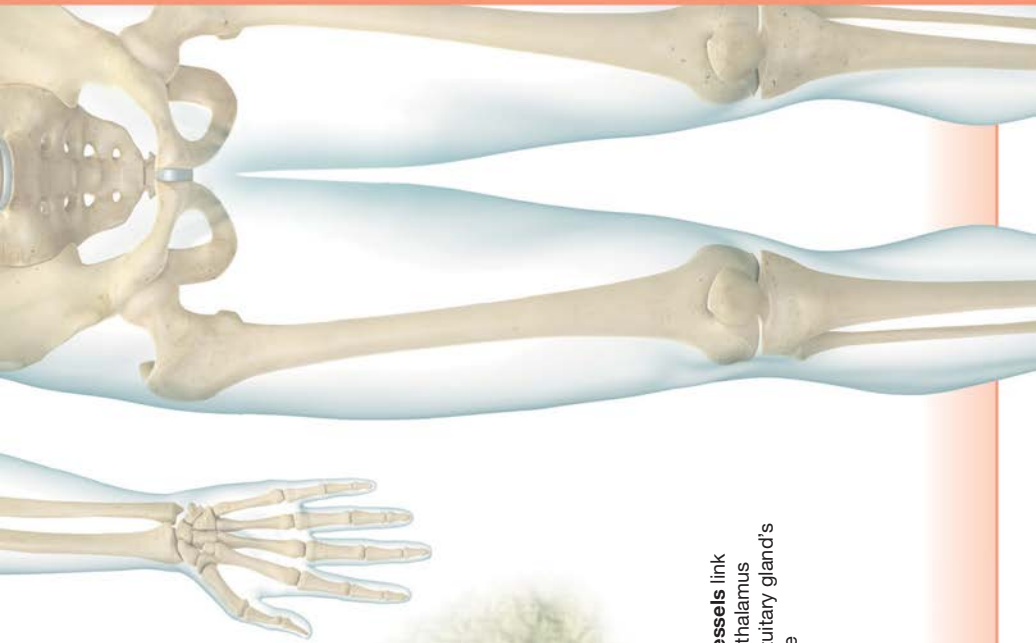
**Kidneys** release renin, which helps control blood pressure.





## In charge

Attached to the base of the brain, the pea-sized pituitary gland is controlled by a part of the brain called the hypothalamus. The pituitary gland releases nine hormones, and many of them control other endocrine glands.



# Hormones in action

There are more than 50 hormones in the body. Each controls a different activity, such as reacting to danger, triggering growth, and managing fuel supplies for energy.

## Hormone rush

The hormone epinephrine is released to help people face or flee from danger. This fast-acting hormone increases the heart and breathing rates, fuel supply, and blood flow to the muscles.



## Growing up

Released by the pituitary gland, growth hormone (GH) makes a child's bones grow longer. Growth happens when new bone tissue is added at the ends of bones. Bones stop growing in adults.



X-ray showing a child's hand bones



X-ray showing an adult's hand bones

Free-fall skydiving is exciting but scary and causes a rush of epinephrine



Epinephrine makes our pupils wider so we can see more clearly where danger threatens.

## Glucose control

The hormone insulin controls the level of glucose—the body's fuel—in the blood. People with diabetes produce very little insulin themselves and have to inject the hormone to keep their glucose levels normal.

Injecting insulin



# Reproduction and growth

Every child grows from a fertilized egg that contains body-building instructions inherited from both parents. This egg divides to produce trillions of cells that make up a baby growing inside its mother's body, like the one shown here. After it is born, the baby passes through a series of life stages that take it to adulthood and, eventually, old age.



## **DNA**

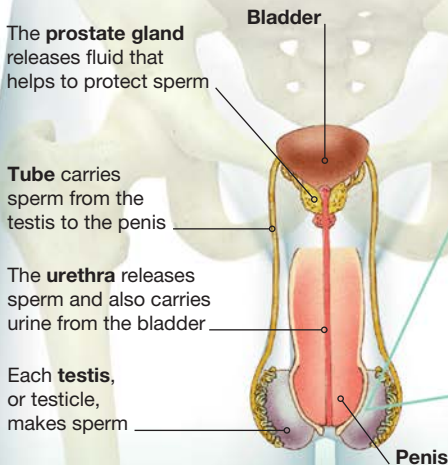
Our cells contain DNA—two spiral strands twisted around each other. This substance holds the instructions for creating a human being.

# Female and male

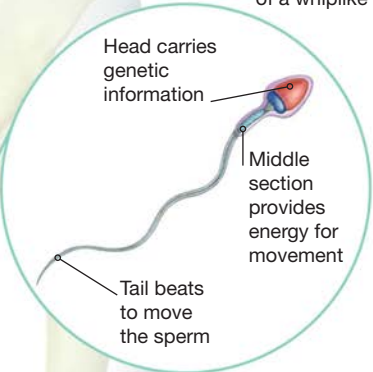
The reproductive system is the only body system that is different for males and females. From the teenage years onward, the male and female systems each release special sex cells—sperm in males and eggs in females—that join together to make a baby.

## Male reproductive system

The male sex organs are made up of two testes and the penis on the outside of the body, and the tubes and glands that link them inside. Millions of sperm are made in the testes, carried through the tubes, and released through the penis.



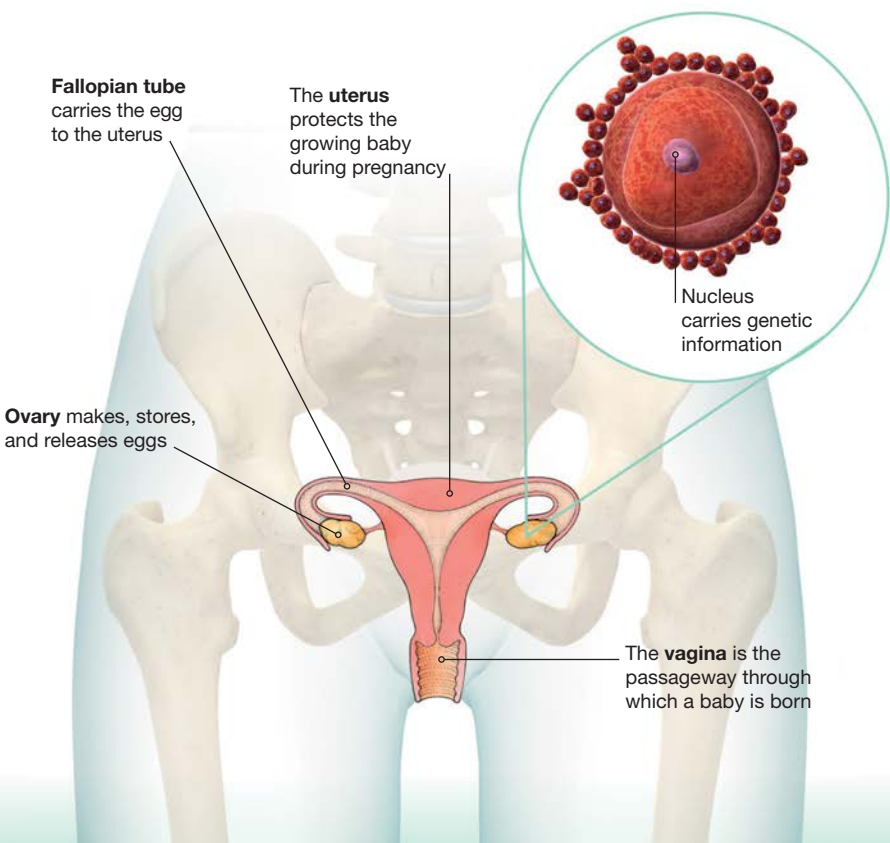
A **sperm cell** is about 0.002 in (0.05 mm) long, but most of this is made up of a whiplike tail.



## Female reproductive system

The female sex organs are made up of the two ovaries and fallopian tubes, the uterus, and the vagina. An egg is released from one of the ovaries every month. If the egg is fertilized by a sperm, it will travel to the uterus, or womb, and develop into a baby.

An **egg, or ovum**, is the body's widest cell—0.004 in (0.1 mm) across, which is 50 times wider than the head of a sperm.

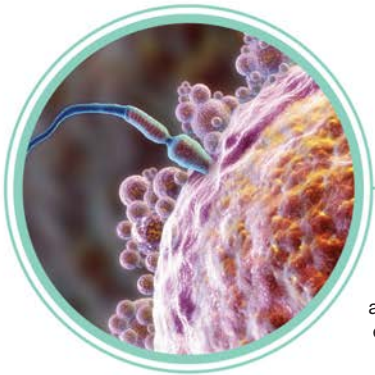


# Fertilization

To make a baby, an egg must be fertilized by a sperm within 24 hours of being released from the ovary. Genetic information in the sperm and egg combine to form the full set of instructions needed to build a new human being.

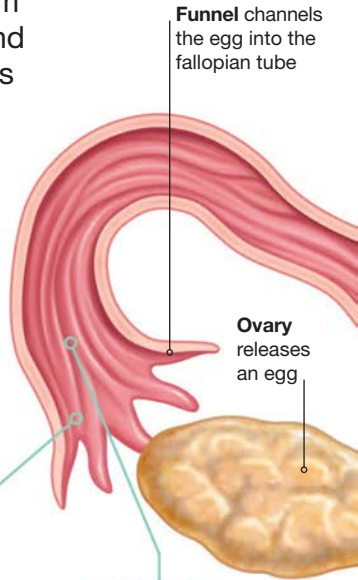
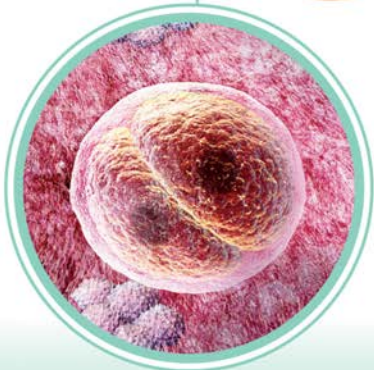
## Building cells

The fertilized egg travels to the uterus along a fallopian tube. As it does, the egg divides again and again. First, the single cell divides into two cells, then those two cells both divide, and so on. Eventually, the tiny ball of cells reaches the uterus, or womb, and settles in its lining.



**Fertilization** happens when a sperm penetrates the egg's outer layer (above), loses its tail, and fuses with the egg's nucleus.

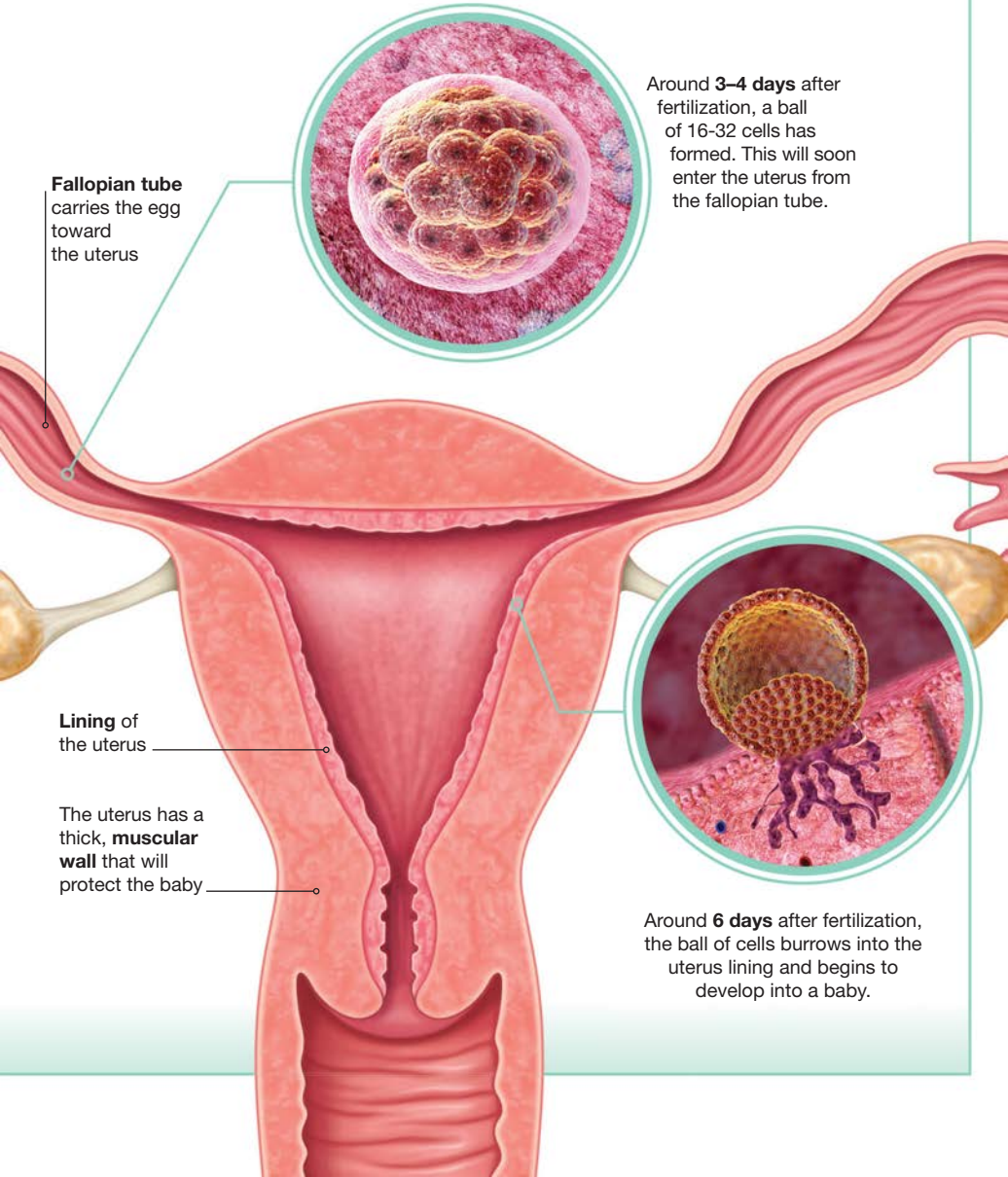
About **36 hours** after fertilization, the egg divides to form two new cells. These continue to divide every 12 hours.



**Funnel** channels the egg into the fallopian tube

**Ovary** releases an egg





Fallopian tube carries the egg toward the uterus

Around **3–4 days** after fertilization, a ball of 16-32 cells has formed. This will soon enter the uterus from the fallopian tube.

Lining of the uterus

The uterus has a thick, **muscular wall** that will protect the baby

Around **6 days** after fertilization, the ball of cells burrows into the uterus lining and begins to develop into a baby.

# In the womb

A baby grows, protected and cared for, within its mother's uterus, or womb. Over a period of nine months, known as pregnancy, a tiny ball of cells develops into a human being ready to be born.

## From embryo to fetus

For the first eight weeks, the developing baby is called an embryo, and after that it is a fetus. It is protected in a bag of fluid and receives food and oxygen through the umbilical cord and placenta.

The **umbilical cord** links the baby to the placenta

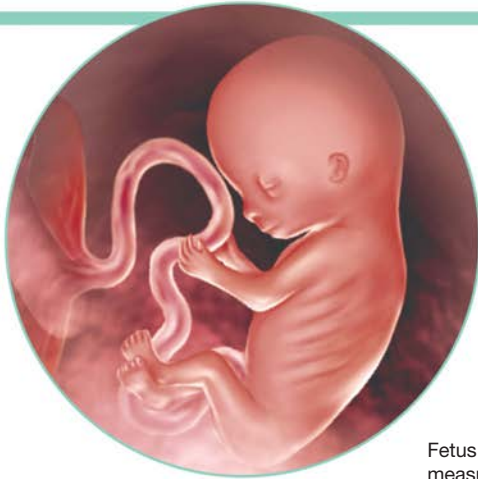


At **5 weeks**, the bean-sized embryo's heart is beating and other organs are developing. Budlike limbs are starting to grow.

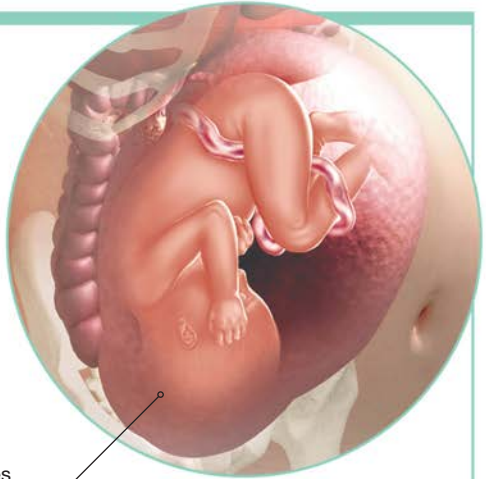


The **placenta** links the umbilical cord to the mother's blood supply

At **8 weeks**, the strawberry-sized fetus has a recognizable face. Its head and brain grow rapidly, and bones start to form.



At **11 weeks**, the lemon-sized fetus is active and uses its muscles to move its limbs. All internal organs are in place.



Fetus  
measures  
**18 in (46 cm)**

At **35 weeks**, a layer of fat under the skin makes the fetus plumper. It responds to sounds and light and turns head-down, ready for birth.

At **38–40 weeks**, the baby is fully developed and ready to take its first breath when it is born.





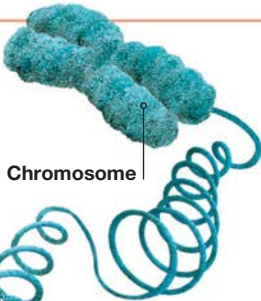
**Growing babies start to  
dream about 12 weeks  
before they  
are born**

**IN THE WOMB**

With its fingers curled into a fist, this 30-week-old fetus is nearing full development as it grows inside its mother's womb. This 3-D ultrasound scan clearly shows an eye, nose, lips, and other features of the face.

# Genes and DNA

Every cell in your body contains the instructions needed to build and run the body. These instructions, which are inherited from your mother and father, are called genes. The 23,000 genes in each cell are made from a substance called DNA.



## Set of instructions

Inside a cell's nucleus, there are 46 X-shaped structures called chromosomes, each made from coiled-up DNA. DNA is made up of two strands linked by pairs of chemicals called bases. These are the "letters" that spell out the instructions in genes.



If the DNA in your cells were put end-to-end it would reach to the Sun and back around 600 times.

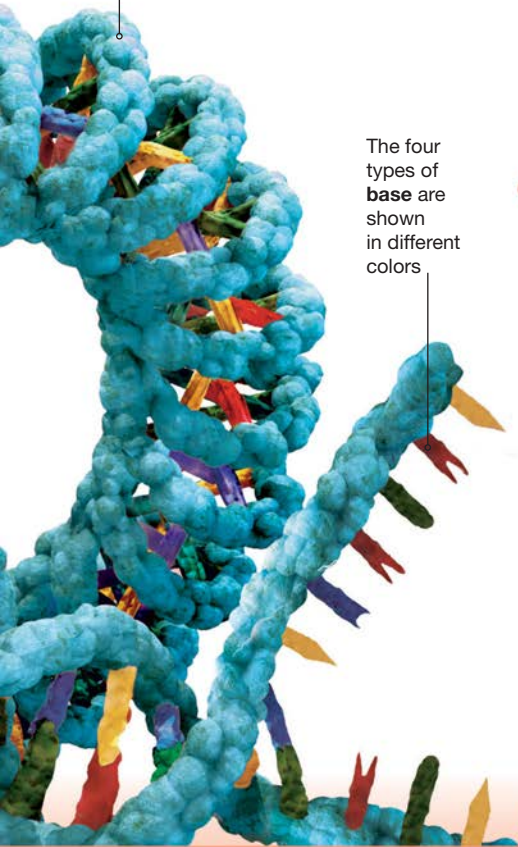
**Bases** link the strands, like rungs on a ladder.



## Passing on genes

The genes that are passed on from parents to their children control the children's features, such as the color of their eyes. Like most genes, eye-color genes have different versions. This explains why there are different eye colors.

One of the two **strands** that make up DNA



The four types of **base** are shown in different colors



## Identical genes

Identical twins look the same because they share identical genes. This happens when a single fertilized egg splits inside the mother's womb, creating two separate cells that develop into two identical babies.



# Growing up

Throughout life, everyone goes through the same stages of growth and development. The biggest changes happen between birth and the late teens—from a baby totally reliant on its parents to an independent young adult.

## Early years

Infancy, childhood, and adolescence are years of great change. During this time, the brain develops very quickly, making new connections that enable us to communicate, move, and behave in more sophisticated ways. The body also changes in appearance, eventually taking on the shape and size of an adult body.

The first year of life is called **infancy**. An infant grows rapidly and progresses from lying to sitting to crawling, then standing up, and finally walking. Infants grasp objects and interact with people using sounds and facial expressions.



During **childhood**, between the ages of one and 10, the proportions of a child's body change, with limbs growing longer. The brain develops rapidly and children learn to speak and read, run and jump, and pick up life skills.







The change from a child to an adult, called **adolescence**, happens during our teenage years. In addition to the physical changes of puberty, this phase includes changes in behavior, emotions, and attitudes. These are triggered by changes in the hormones and in the brain.

## PUBERTY

The first part of adolescence is puberty. The body grows rapidly and changes shape, and the reproductive system becomes active. Because puberty starts earlier in girls (age 10 to 12) than boys (age 12 to 14), girls initially grow faster than boys.

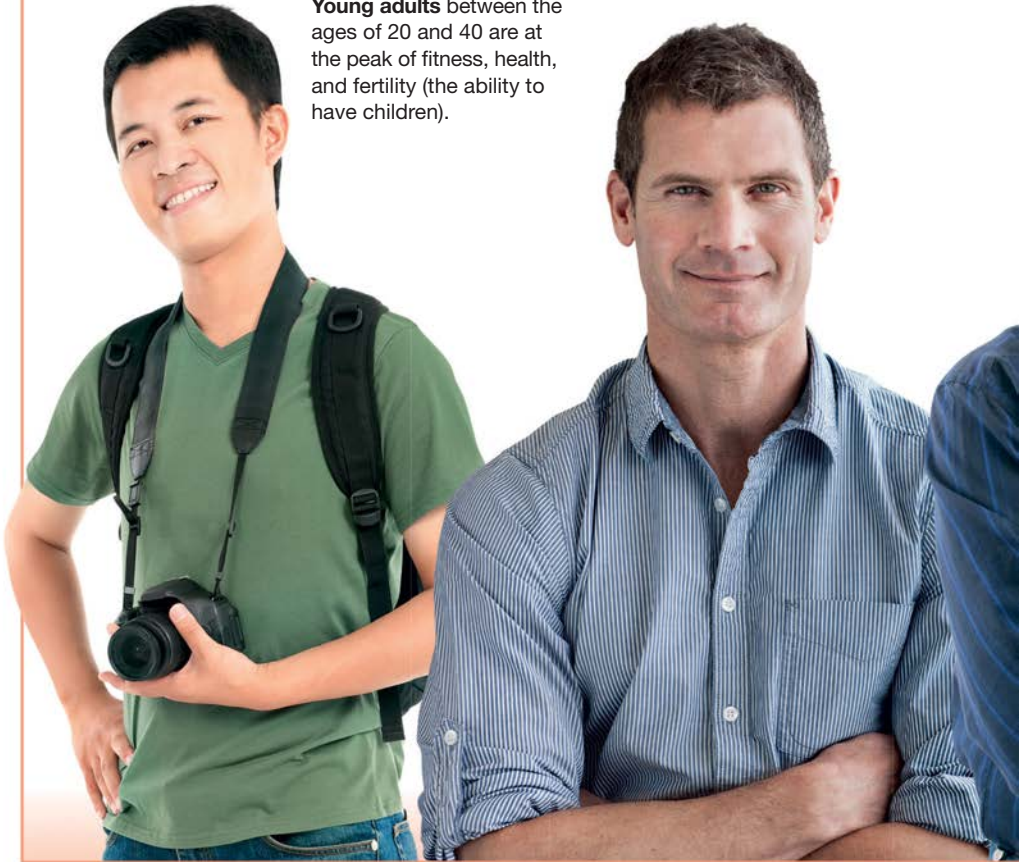


## Adulthood and old age

At about the age of 20, the body stops growing and we enter adulthood. But the adult body continues to change, and gradually signs of aging begin to appear.

**Young adults** between the ages of 20 and 40 are at the peak of fitness, health, and fertility (the ability to have children).

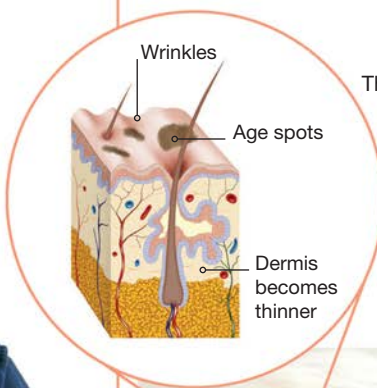
In **middle age**, between the ages of 40 and 60, the first signs of aging appear. Many organs become less efficient, including bones that are weaker and muscles that are less powerful. The brain, however, often works better than ever.



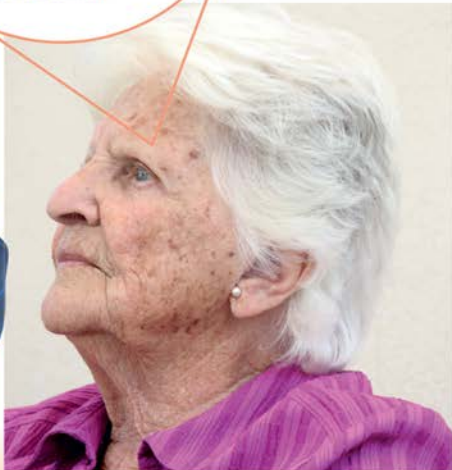
**Old age**, from 60 onward, is when signs of aging become more obvious. Hair thins and turns gray, sight and hearing become less efficient, muscles weaken and joints stiffen, and bones break more easily.

## Aging skin

The most obvious visible sign of aging is wrinkled skin, often with brown age spots. With age, the skin's dermis (the layer under the surface) becomes thinner and looser, with deeper creases.



This cross-section of the **skin** of an older person shows the effects of aging. Age spots occur where skin is exposed to the Sun.



# Your amazing body

## CELLS

- ★ The body's biggest cells—female egg cells—are  $\frac{1}{1000}$  in (**0.1 mm**) **across** and visible to the naked eye.
- ★ Lined up in a row, **40 average-sized cells** would stretch across a period.
- ★ **300 million body cells** die and are replaced every minute.
- ★ Liver cells last for about **18 months**.
- ★ Red blood cells can last for up to **120 days**.
- ★ Small intestine cells last for just **36 hours** before they are worn away by the passage of food.

## SKIN, NAILS, AND HAIR

- The outer layer of the skin, the upper epidermis, is replaced **every month**.
- About **50,000 skin flakes** drop off the skin's surface every minute. That amounts to about 40 lb (20 kg) of skin flakes in a lifetime, which is about the weight of a young child.

- Skin varies in thickness, from  $\frac{3}{100}$  in (**0.5 mm**) on the eyelids to  $\frac{1}{4}$  in (6 mm) on the soles of the feet.
- The skin is the body's heaviest organ, weighing about **11 lb (5 kg)** in an adult.
- Skin color depends on the amount of pigment or **melanin** that the skin produces. Small amounts of melanin result in light skin, while large amounts result in dark skin.
- Each human being has around **2.5 million sweat pores**. Sweat empties through the pores onto the skin's surface.
- Fingernails **grow four times faster** than toenails, and faster in summer than in winter.
- **About 120 head hairs** (out of 100,000 in total) are lost and replaced daily.
- Head hair normally grows  $\frac{1}{2}$  in (**12 mm**) a month. It usually stops growing when it is 2 ft (60 cm) long, falls out, and is replaced. Some people, however, can grow their hair to 13 ft (4 m) long.
- Nearly everyone has **eyelash mites** (harmless, sausage-shaped animals) that live in the hair follicles of humans.

## BONES AND MUSCLES

◆ A newborn baby has more than 300 bones, but as the baby grows some bones fuse together to form larger bones. An adult's skeleton is made up of **206 bones**.

◆ The skeleton makes up around **20 percent of an adult's body weight**.

◆ The body's longest bone—the femur (thighbone)—is **150 times longer** than the smallest—the stirrup bone inside the ear.

◆ The hands contain more than **one-quarter of the body's bones**.

◆ Bones may seem to be dry but are actually **22 percent water**.

◆ We use at least **12 face muscles** while smiling and 11 for frowning.

◆ An average person walks about **80,000 miles (128,000 km)** in a lifetime—the same distance as walking around the world three times.

◆ The bulkiest muscle in the body is the **gluteus maximus** in each buttock, used for powerful actions such as climbing stairs.

## HEART AND BLOOD

★ Blood makes up about **8 percent of our body weight**.

★ The heart pumps around **10½ pints (5 liters)** of blood around the body every minute. Each day it pumps enough blood to fill 170 bathtubs.

★ The average length of a capillary is  **$\frac{1}{100}$  in (1 mm)**.

★ Spread out flat, the enormous network of capillaries—which deliver oxygen to body cells—would cover an **area the size of 19 tennis courts**.



More than 10 billion white blood cells are produced daily to destroy invading bacteria.

## URINARY SYSTEM

• In an average lifetime, the urinary system makes and releases around **70,000 pints (40,000 liters) of urine**—enough to fill a small swimming pool.

• Every day, around **380 pints (180 liters)** of fluid are filtered from blood by the kidneys, but only 3 pints (1.5 liters) of waste leave the body as urine.

• The kidneys make up just **1 percent of the body's weight** but consume 25 percent of its energy.

## BREATHING

- ◆ On average, we breathe in and out around **30,000 times a day**—exhaling enough air to inflate 3,750 party balloons.
- ◆ **Inhaled air** contains 20.8 percent oxygen, 0.04 percent carbon dioxide, and 79.16 percent nitrogen. Exhaled air contains 15.6 percent oxygen, 4 percent carbon dioxide, 79.16 percent nitrogen, and 1.24 percent water vapor.
- ◆ Every day, we swallow a large glassful of **slimy mucus**, which is produced by the airways, pushed up to the throat, and swallowed back into the esophagus.

## DIGESTION

- ★ The salivary glands release around **4.2 pints (2 liters) of saliva** into the mouth every day.
- ★ The **gastric juice** released by the stomach is so acidic that it can strip paint.
- ★ **Tooth enamel** contains no living cells. If it is damaged, it cannot be replaced, except by fillings.
- ★ We have **two sets of teeth in a lifetime**: 20 baby (deciduous) teeth in childhood, which are replaced by up to 32 permanent adult teeth.

## BRAIN

- The brain is about **90 percent water**.
- A new-born baby's brain weighs about  **$\frac{8}{10}$  lb (375 g)** but triples in size and weight to 2.2 lb (1 kg) by the infant's first birthday.
- The brain makes up **2 percent of the body's weight** but receives 20 percent of the body's blood supply.
- Spread out, the **cerebral cortex**—the thin outer layer of the cerebrum which forms the “thinking” part of the brain—would cover the same area as a large pillow case.
- The **right side** of the brain controls the left side of the body and the left side of the brain controls the right side of the body.
- Over **250 million nerve fibers** link the left and right sides of the brain.
- Every day, adults between the ages of 20 and 60 lose about **12,000 brain neurons** that are never replaced.
- Brain neurons can last for up to **100 years**—a whole lifetime for most people.

## NERVES AND NEURONS

◆ A nerve impulse (signal) takes just **one hundredth of a second** to travel from the spinal cord to your big toe.

◆ The longest neurons—between spinal cord and big toes—are **3¼ ft (1 m) long**. They are also the longest cells in the body. The shortest neurons are  $\frac{1}{100}$  in (1 mm) long.

◆ A neuron can transmit **1,000 nerve impulses** every second.

◆ The widest nerve, the sciatic, is **¾ in (2 cm) wide**. It extends from the lower back to the foot.

◆ A withdrawal reflex—when a nerve signal passes through the spinal cord, not the brain—can pull the hand away from a dangerously hot object in just **30 thousandths of a second (30 milliseconds)**. If the signal went via the brain it would take 800 milliseconds.

◆ Stretched out, the body's nerves would extend for more than **93,000 miles (150,000 km)**—more than the distance covered by flying between London and New York 25 times.

## SENSES

★ Our **hearing range decreases with age**, which is why young people hear higher-pitched sounds than older people.

★ The tongue's **taste buds** are replaced every week, but the nose's smell receptors last for a month.

★ Chiles “taste” hot because they contain a substance that triggers the **tongue's pain receptors**.

★ Fingers are among the **most sensitive areas** of the body. Each fingertip has about 100 touch receptors.

★ The eyes contain **70 percent of the body's sensory receptors**, making sight our most important sense.

★ Eyelids blink about **9,400 times** a day, helping to keep our eyes clean.

## GENES

• Humans have **46 gene-carrying chromosomes** inside the nucleus of each body cell.

• Stretched out, the DNA in one human cell would extend over **6½ ft (2 m)**.



The farthest object that we see without a telescope is the Andromeda galaxy, which is 2.5 million light-years away.

# Glossary

**Artery** A thick-walled blood vessel that carries blood from the heart to the tissues.

**Axon** A long fiber that extends from the cell body of a neuron and carries signals to other nerve cells.

**Bacteria** A group of small, single-celled microorganisms, some of which cause disease in humans.

**Bone marrow** A soft tissue found in the spaces within bones.

**Calcium** A mineral used by the body to build bones and teeth.

**Capillary** A microscopic blood vessel that links the smallest arteries to the smallest veins, and delivers blood to tissue cells.

**Carbohydrate** A group of substances found in food and inside the body. It includes sugars, such as glucose—the body's store of energy.

**Carbon dioxide** A gas that is the waste product of energy release inside cells.

**Cardiac** Of or relating to the heart.

**Cartilage** A tough, flexible tissue that helps support the body and covers the ends of bones in joints.

**Cell** One of the trillions of microscopic living units that make up the body.

**Chromosome** One of 46 packages of DNA found in the nucleus of each cell.

**Chyme** A creamy liquid that is produced by the part-digestion of food in the stomach.

**Cilia** Tiny hairlike structures found on some tissue. They wave to move things, such as mucus, across their surface.

**Collagen** A tough protein that makes up the fibers that strengthen tendons, ligaments, and cartilage.

**CT (computed tomography) scan** A method of producing 2-D and 3-D images of body tissues and organs.

**Cytoplasm** The jellylike fluid found between the membrane and nucleus of a cell.

**Dendrite** A short fiber that carries incoming signals from other nerve cells to the cell body of a neuron.

**Dermis** The deeper, thicker layer of skin, below the epidermis. It contains sensory receptors and blood vessels.

**Digestion** The process by which food is broken down into simple nutrients that can be absorbed into the bloodstream and used by the body.

**Digestive enzyme** A substance that speeds up the breakdown of food molecules.

**DNA (deoxyribonucleic acid)** A long molecule found inside the nucleus of body cells. It contains the coded instructions needed to build and run a body.

**Embryo** A developing baby between the time it arrives in the uterus and eight weeks after fertilization.

**Energy** The fuel that comes from eating food. It is essential for keeping the body's cells working and alive.

**Enzyme** A protein that speeds up chemical reactions inside the body.

**Epidermis** The thin protective layer of the skin.

**Fat** A group of substances found in food and inside the body. Fat stores energy and insulates the body.

**Fertilization** The joining together of a male sperm and a female egg to make a new human being.

**Fetus** The name given to a developing baby from the ninth week after fertilization until birth.

**Gastric** Of or relating to the stomach.

**Gene** One of 23,000 coded instructions stored in the DNA that makes up the chromosomes inside a cell's nucleus.

**Germ** A common name given to microorganisms that cause disease.

**Gland** A group of cells that make and release specific substances such as hormones and enzymes.

**Glucose** A type of sugar found in the bloodstream that is the main source of energy for body cells.

**Hemoglobin** A red, oxygen-carrying protein found inside red blood cells.

**Hepatic** Of or relating to the liver.



**Hormone** A chemical messenger released by the endocrine glands into the bloodstream. It alters the activities of specific tissues.

**Immune system**

A collection of cells, including macrophages and lymphocytes, that protect the body from disease by destroying germs such as bacteria.

**Joint** The place where two or more bones meet. Most joints are movable.

**Keratin** A tough, waterproof protein found in nails, hair, and the upper layer of the skin's epidermis.

**Ligament** A tough strap that holds bones together at the joints.

**Lymph** A liquid that is drained from the body's tissues along the vessels of the lymphatic system.

**Mammal** An animal, such as a rabbit or human, that is warm-blooded, hairy, and feeds its young with milk.

**Metabolism** All the chemical processes that take place inside every one of the body's cells.

**Mitochondria** The tiny structures inside cells that release energy from glucose.

**Mitosis** The division of a body cell into two new, identical offspring cells.

**MRI (magnetic resonance imaging)**

**scan** A way of using magnetism, radio waves, and computers to produce images of body tissues and organs.

**Mucus** A slimy substance released by glands, such as those lining the esophagus that leads from the throat to the stomach.

**Muscle fiber** One of the cells that makes up a muscle.

**Neuron** A type of nerve cell that carries signals.

**Nucleus** The control center of the cell that contains chromosomes.

**Nutrient** A substance found in food that is needed by the body to function normally.

**Organ** A body part, such as the heart or kidney, that is made of two or more types of tissue and has specific roles.

**Organelle** One of the tiny working structures, such as mitochondria, found floating in the cytoplasm of cells.

**Oxygen** A gas that is used by body cells to release energy from glucose.

**Protein** A group of substances found in food and inside the body. Proteins build and run the body's cells.

**Puberty** The period of rapid growth, usually in the early teens, when the reproductive systems start working.

**Pulse** The rhythmic throbbing of an artery as it expands when blood is pumped through it by the heart. The pulse is the same as the rate the heart beats.

**Reflex** A rapid, automatic action, such as pulling the hand away from a hot object, that happens without our thinking about it.

**Renal** Of or relating to the kidney.

**Saliva** A liquid found in the mouth. It aids digestion by providing the lubrication needed for chewing and swallowing.

**SEM (scanning electron microscopy)** A way of using a special microscope to produce magnified 3-D images of body tissue.

**Sphincter** A ring of muscle around an opening that controls the flow of materials through it.

**Sweat** A watery liquid produced by glands in the skin.

**Synapse** The junction between two neurons that are separated by a tiny gap.

**Synovial joint** A free-moving joint, such as the elbow or knee.

**System** A group of linked organs that work together, such as the organs that make up the digestive system

**Tendon** A tough cord that links a muscle to a bone.

**Tissue** A group of cells of the same type—such as muscle cells—that work together to perform a particular function.

**Vein** A thin-walled blood vessel that returns blood to the heart from the tissues.

**Virus** A disease-causing particle that invades the body's cells and multiplies inside them, causing infections, such as colds and measles.

**X-ray** An imaging technique that uses radiation to reveal bones.

# Index

## A

abdomen muscle 41  
 Achilles tendon 40  
 adipose cells 8, 9, 15  
 adolescence 143  
 adrenal gland 126, 127  
 adulthood 131, 144  
 aging 144–5  
 alveoli 78, 82–3  
 anus 88, 89, 98, 99  
 aorta 52, 53, 58  
 appendicular skeleton 27  
 appendix 98  
 arteries 20, 52–3, 54–5, 150  
 arterioles 54  
 atrium (atria) 58–61  
 axial skeleton 27  
 axons 8–9, 104, 105, 150

## B

babies 131, 134–9,  
 141, 142  
 backbone 26, 33, 110, 111  
 bacteria 66–7, 69, 87, 150  
 balance 124–5  
 ball-and-socket joints 38, 39  
 biceps 41, 48, 49  
 bile 94, 100  
 bladder 32, 43, 67, 72, 74  
 blood cells 31, 62–3  
   *see also* red blood cells  
   and white blood cells  
 blood system 12, 13, 51–65, 147  
 cleaning the blood 72–73, 100  
 clotting 34, 62, 64–5  
 composition of blood 62–3  
 exchanging gases 83  
 filtering blood 72–3

nutrients 88, 89, 94, 96  
 two loops 53  
 blood vessels 25, 34, 35, 44,  
 51–5, 64, 101  
 bone-building cells 35  
 bones 19, 26–39, 147  
   growth 128  
   healing fractures 34–5  
   inside 30–1  
   joints 36–9  
   marrow 30–31, 150  
   muscles 41, 48–9  
   skeletal system 26–7  
   strength 28–9, 30  
   tissue 28–9, 30  
   types 32–3  
 braille 121  
 brain 106–9, 148  
   muscle contraction 45  
   nervous system 103, 104  
   scan 16–17  
   senses 112–25  
   spinal cord 110–11  
 brain stem 81, 106  
 breathing 76–85, 148  
   lungs 82–3  
   in and out 80–1  
   speech 84–5  
 bronchi 78–9  
 bronchioles 78–9, 82

## C

calcium 26, 150  
 calf muscle 40  
 canals, ear 122–5  
 canine teeth 91  
 capillaries 52, 54–5, 83,  
 147, 150  
 carbohydrates 94

carbon dioxide 77, 80,  
 82–3, 148, 150  
 cardiac muscle 12, 42, 43,  
 58, 59  
 carotid artery 52  
 carpals 27, 32  
 cartilage 36, 111, 150  
 cecum 98  
 cells 6–13, 146, 150  
   defense 69  
   dividing 10–11, 134  
   energy for 87, 88  
   fibroblasts 34  
   genes and DNA 140–1  
   inside 6–7  
   stable surroundings 51  
   temperature 24  
   tissues, organs, and systems  
   12–13  
   types of 8–9  
   *see also* specific cells  
 cerebellum 106, 107  
 cerebral cortex 106–7, 148  
 cerebrum 106, 107, 116  
 cheeks 85  
 chest muscle 41  
 chewing 90–1  
 childhood 142  
 chromosomes 10, 140, 149, 150  
 chyme 92, 93, 150  
 cilia 78, 150  
 circulatory system *see*  
   blood system  
 clavicle 26  
 clots 64–5  
 coccyx 110  
 cochlea 122, 123  
 cold, feeling 25  
 collagen fibers 37, 41, 150  
 colon 98–9  
 communication 4, 5, 84–5, 122  
 cones 112  
 cornea 112, 113

coronary arteries 59  
 cranial nerves 104  
 CT (computed tomography)  
   scans 15, 150  
 cytoplasm 6, 10

## D

dendrite 9, 105  
 dentine 91  
 dermis 20–1, 120, 145, 146, 150  
 descending aorta 52  
 diabetes 129  
 diaphragm 79, 80–1  
 digestive system 42, 86–101,  
   148, 150  
   chewing and swallowing 90–1  
   feeding the body 88–9  
   intestines 94–9  
   liver 100–1  
   stomach 92–3  
 digestive tract 88–9, 90  
 digital artery 53  
 disease, fighting 66–7  
 dislocations 37  
 dizziness 125  
 DNA 131, 140–1, 149, 150  
 duodenum 92, 93, 94

## E

ear 19, 122–3, 124–5  
 eardrum 123  
 eggs 131–4, 141, 146  
 ellipsoidal joints 38  
 embryo 136, 150  
 enamel 91, 148  
 endocrine system 126–9  
 endoplasmic reticulum 7  
 endoscopy 15  
 enzymes 66, 92, 94  
 epidermis 20–1, 120, 146  
 epiglottis 85, 90, 91

epithelial cells 8  
 esophagus 85, 88, 90, 91, 92  
 exercise 81  
 expressions, facial 49  
 eyelashes 146  
 eyes 46–7, 112–15, 141, 149

## F

facial muscles 48–9, 147  
 fallopian tubes 133, 134–5  
 fat 9, 21, 26, 94, 100, 150  
 feces 89, 98–9  
 female reproductive system 133  
 femoral artery 53  
 femoral vein 53  
 femur 27, 32, 147  
 fertilization 133, 134–5, 150  
 fetus 15, 136–9, 150  
 fibrin threads 64–5  
 fibroblasts 34  
 fibula 27  
 filaments 44, 45, 47  
 fingerprints 21  
 fingers 5, 49, 121, 149  
 fixed joints 38  
 flat bones 33  
 fluid 51, 70–5  
 food  
   blood 51, 52, 59, 62  
   digestion 87–93  
   taste 116–17  
 fractures 34–5

## G

gall bladder 89, 94, 100  
 gastric glands 93  
 gastric juice 66, 92, 148  
 genes 132–4, 140–1, 149, 150  
 germs 62, 64, 66–7, 69, 70, 150  
 glands 20, 93, 126–9  
 glucose 101, 129, 150

gluteus maximus 40, 147  
 Golgi complex 6  
 gray matter 110–11  
 great saphenous vein 53  
 grip 21, 22  
 growth 10–11, 126, 127, 131,  
   142–5

## H

hair 20–3, 25, 146  
 hands 5, 128, 147  
 healing 10, 11, 62, 64–5  
 hearing 19, 106–7, 122–3, 149  
 heart 12–13, 51–61, 147  
   beating 43, 51, 60–1, 151  
   inside 58–9  
   listening to 61  
 heart strings 58  
 heartbeat 43, 51, 60–1  
 heat 24–5, 51, 62  
   losing 24–5  
 hemoglobin 62, 150  
 hepatic portal vein 100, 101  
 hinge joints 39  
 hormones 11, 126–9, 143, 151  
 hot, feeling 25  
 humerus 26  
 hypothalamus 127

## IJK

ileum 94  
 imaging techniques 14–15  
 immune system 66–9  
 incisors 91  
 infancy 142  
 infection 64, 66–7  
 inferior vena cava 52, 58  
 inner ear 122, 123  
 insulin 129  
 intelligence 4  
 intercostal muscles 80–1

intestines 87, 88, 89, 94–9  
 iris 113, 114–15  
 irregular bones 33  
 jaw muscle 41  
 jejunum 94  
 joints 27, 36–9, 151  
 keratin 21, 22, 151  
 kidneys 72–3, 74, 126, 147

## L

language 5, 85, 106, 107  
 large intestine 66, 70, 88,  
 89, 98–9  
 larynx 84  
 laughter 68  
 lens 112, 113  
 ligaments 36, 37, 151  
 lips 85  
 liver 89, 100–1, 146  
 lobules 101  
 long bones 32  
 lungs 53, 76–83  
 inside 82–3  
 lymph 70, 71  
 lymphatic system 51, 70–1  
 lysosomes 6

## M

macrophages 67, 68–9  
 male reproductive system 132  
 melanin 146  
 membranes, cell 6–7  
 metabolism 75, 151  
 middle ear 122, 123  
 mitochondria 7, 151  
 mitosis 10, 151  
 molar teeth 91  
 mouth 81, 85, 90–1  
 movable joints 38–9  
 movement 4, 40–1, 147  
 brain 106–7

colon 99  
 joints 36–9  
 muscles 40–1, 42, 48–9  
 reflexes 111

MRI (magnetic resonance  
 imaging) scans 14, 16–17, 151  
 mucus 66, 78, 79, 148, 151  
 muscle cells 9, 12, 40  
 muscles 19, 26, 40–9  
 contraction 42, 45, 48–9  
 fibers 42, 43, 44, 46–7, 151  
 movement 40–1  
 structure 44–5  
 tissues 12–13  
 types of 42–3  
 working of 48–9  
 see also specific muscles

## NO

nails 22–3, 146  
 nasal cavity 78, 118  
 neck muscle 41  
 nephrons 73  
 nerve cells 8, 9, 103, 105  
 nervous system 20, 102–29,  
 148–9  
 brain 106–7  
 senses 112–25  
 spinal cord 110–11  
 neurons 8, 9, 104–11, 148–9, 151  
 nose 78, 81, 118–19  
 nucleus 6, 10, 133, 134, 151  
 nutrients 87, 88–9, 94,  
 97, 100, 151  
 old age 131, 144–5  
 optic nerve 112, 113  
 organelles 6, 151  
 organs 12, 13, 151  
 ossicles 19, 122, 123  
 osteons 30, 31  
 outer ear 122  
 ovaries 133, 134

oxygen 51–7, 59, 77–83, 151  
 blood 51, 52, 53, 59, 62, 67  
 breathing 77, 78, 80–3, 148

## P

pain 111  
 pancreas 94  
 papillae 116  
 patella 27, 33  
 pelvic girdle 26, 33, 38  
 penis 132  
 peristalsis 95, 99  
 personality 106  
 pharynx 85  
 photoreceptor cells 9  
 pituitary gland 126, 127, 128  
 pivot joints 39  
 placenta 136  
 plane joints 39  
 plasma 62–3  
 plaster casts 35  
 platelets 62–4  
 plugs 64  
 pregnancy 136–7  
 premolar teeth 91  
 prostate gland 132  
 protein 44, 45, 92, 94, 151  
 puberty 143, 151  
 pulmonary artery 52, 53, 59  
 pulmonary vein 59  
 pulse 151  
 pupil 113–15, 129  
 pyloric sphincter 92, 93

## R

radius 26  
 receptor cells 117, 118, 119, 124  
 rectum 89, 98, 99  
 red blood cells 8, 62–7, 83, 146  
 reflexes 111, 149, 151  
 renal artery 73

renal vein 73  
 repairs 10, 11, 64–5  
 reproduction 126, 130–41,  
 143  
 respiration *see* breathing  
 retina 112  
 ribs 26, 33, 80  
 rods 112

## S

saddle joints 38  
 saliva 66, 88, 90, 116, 148, 151  
 scabs 65  
 scapula 26, 33  
 sciatic nerve 105  
 seeing 9, 107, 112–13, 149  
 SEM (scanning electron  
 microscopy) 15, 46–7, 65, 151  
 semimovable joints 38  
 senses 112–23, 149  
 sensors 103, 118, 120, 123–5  
 sesamoid bones 33  
 sex cells 132  
 shape 18–49, 142–3  
 short bones 32  
 skeletal muscles 40, 42, 44–9  
 skeletal system 19, 26–7, 147  
 skin 19, 20–1, 146  
 aging 145  
 as barrier 66–7  
 hair and nails 22–3  
 healing 11, 64–5  
 keeping warm 24–5  
 sensations 107  
 touch 120–1  
 skin cells 21  
 skin flakes 21, 146  
 skull 26, 33, 38  
 small intestine 66, 70, 88, 89,  
 92, 94–7, 100, 146  
 smelling 117, 118–19  
 smooth muscles 42, 43

sounds 84–5, 122  
 speech 5, 84–5, 106, 122  
 sperm 132, 133, 134  
 sphincters 74, 92, 93, 99, 151  
 spinal cord 33, 104,  
 106, 149  
 spinal nerves 104, 110  
 spine 26, 33, 110  
 spleen 70  
 spongy bone 30  
 sternum 26, 33  
 stethoscopes 61  
 stomach 66, 88, 89, 92–3  
 superior vena cava 58  
 swallowing 85, 90–1  
 sweat 20, 25, 146, 151  
 synapses 105  
 synovial joints 36–7, 38, 151  
 systems 12, 13, 151

## T

taste buds 116, 149  
 tasting 116–17  
 tears 66  
 teeth 88, 90, 91, 148  
 temperature, body 24–5  
 tendons 40, 41, 49, 151  
 testes 132  
 thalamus 113  
 thinking 106  
 throat 88, 90–1  
 thumbs 5  
 thyroid gland 126  
 tibia 27  
 tissues 8, 12–13, 151  
 drainage 51, 70–1  
 repairs 11  
 tongue 85, 88, 90, 91,  
 116–18, 149  
 tonsils 70  
 touch 103, 107,  
 120–1, 149

trachea 66, 78–9, 84  
 triceps 48, 49  
 twins 141

## UV

ulna 26  
 ultrasound 15, 138–9  
 umbilical cord 136  
 upright stance 4, 124  
 urea 75  
 ureter 72, 73  
 urethra 72, 74, 132  
 urinary system 51, 67,  
 72–5, 147  
 filtering blood 72–3  
 waste disposal 74–5  
 urine 42, 51, 72, 74–5  
 uterus 133, 134–9  
 vagina 133  
 valves 55, 58, 60–1  
 veins 52–5, 100–1, 151  
 ventricles 58–61  
 vertebrae 33, 38, 110,  
 111  
 villi 95–7  
 viruses 66, 151  
 visual cortex 107, 113  
 vocal cords 84–5

## WX

warm, keeping 4, 5, 24–5  
 waste 51, 67, 74–5, 77, 82–3,  
 89, 98–9  
 water 72, 73, 75  
 white blood cells 62–4, 67  
 white matter 110–11  
 windpipe *see* trachea  
 withdrawal reflex 111, 149  
 words 85, 107  
 wounds 11, 62, 64–5  
 X-rays 14, 35, 37, 151

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