●●●●○ Level 4 · Science S4.5

Nerves, hormones and balance

How the body and plants send messages and keep conditions steady.

Follow a message along nerves from a receptor to the brain and out to a muscle, and see why a reflex is faster than a decision. Learn how the eye focuses, how hormones work more slowly through the blood, and how the body holds blood sugar, temperature and water steady. Then see how hormones control the menstrual cycle, and how plants respond to light and gravity.

YOU ARE READY FOR THIS BOOK IF

You can describe what happens to your pulse and breathing when you run.

One step up	S5.4 Physiology
This book	**S4.5 Nerves, hormones and balance**
One step down	S3.4 Growing up: puberty and reproduction

Contents

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S4.5.5 Blood sugar and diabetes

S4.5.6 Temperature and water balance

S4.5.7 Hormones and the menstrual cycle

S4.5.8 Plant responses

Key words, A to Z

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S4.5.1 CHAPTER 1

The nervous system

> **You touch something hot. How does the news get to your brain, and how does your hand get the order to move?**

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** The news travels in the blood from the finger to the brain, and the order comes back the same way.
- ☐ **B** Nerve cells carry the news to the brain, and other nerve cells carry the order to a muscle.
- ☐ **C** The finger decides by itself and the brain is not needed for any feeling.

IF THIS FEELS HARD, READ THIS FIRST

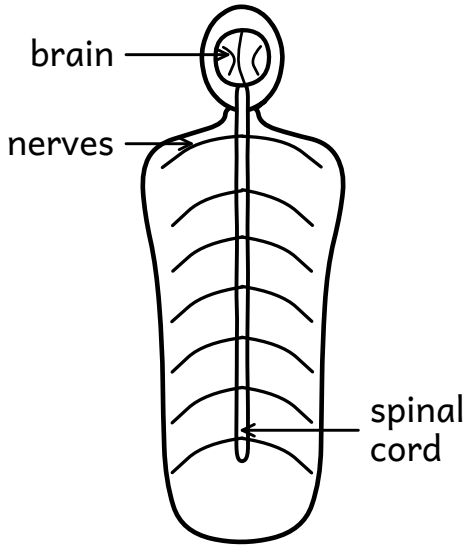
- Level 3, Cells, S3.1.5. It shows how a nerve cell is long and thin so that it can carry messages.
- Level 3, Body systems, S3.3.1. It names the body systems and shows how they work together.
- Level 1, My body, my senses, keeping well, S1.3.2, coming soon. It names the five senses and the part of the body for each one.

BY THE END YOU CAN

- Trace a message from a receptor through the brain to a muscle
- Name the main parts of the brain and their jobs

Put a finger on this page. At once you know that it is smooth, or rough, or cool. The nervous system does this. It senses what is around you, sends the news to a control centre, and sends orders back to your muscles. The control centre is the **central**

nervous system: the brain and the spinal cord. Nerves join it to the rest of the body.



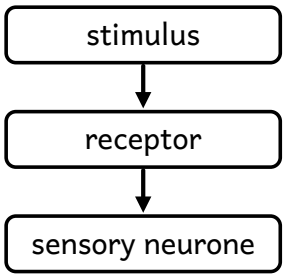
The brain and the spinal cord make up the central nervous system. Nerves run from them to every part of the body.

A change around you, such as heat, light or pressure, is a stimulus. A **receptor** is a cell that detects a stimulus. Receptors are in your skin, your eyes, your ears, your tongue and your nose.

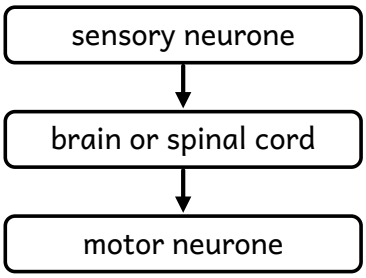
A receptor starts an impulse. An impulse is a tiny electrical signal that runs along a nerve cell. Nerve cells carry it to the central nervous system. There the brain or the spinal cord decides what to do, and an impulse goes out to a muscle or a gland. A muscle or a gland that does the job is an **effector**.

DRAW IT FIRST

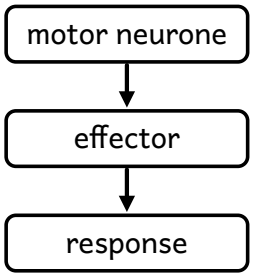
The path of a message in three steps



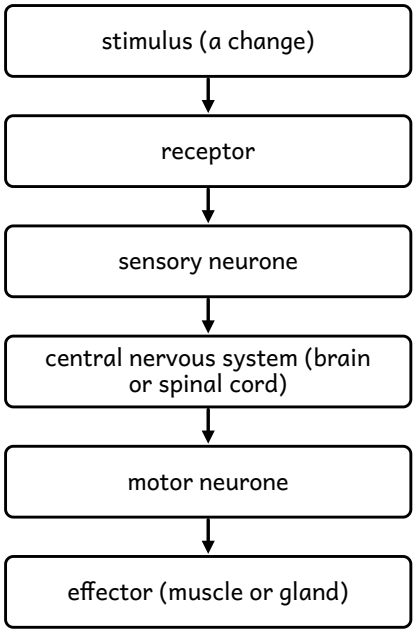
1 A stimulus acts on a receptor. The receptor starts an impulse in a sensory neurone.



2 The sensory neurone carries the impulse to the brain or spinal cord. There it passes to a motor neurone.



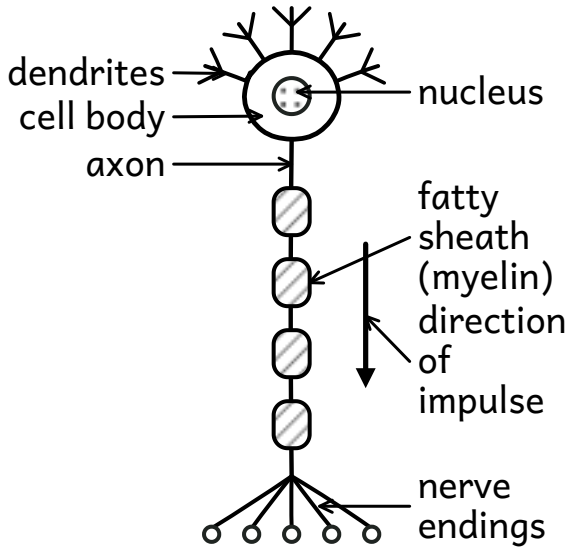
3 The motor neurone carries the impulse to an effector, which makes a response.



The whole path in one picture. The response of a muscle is to move. The response of a gland is to release a fluid, such as sweat.

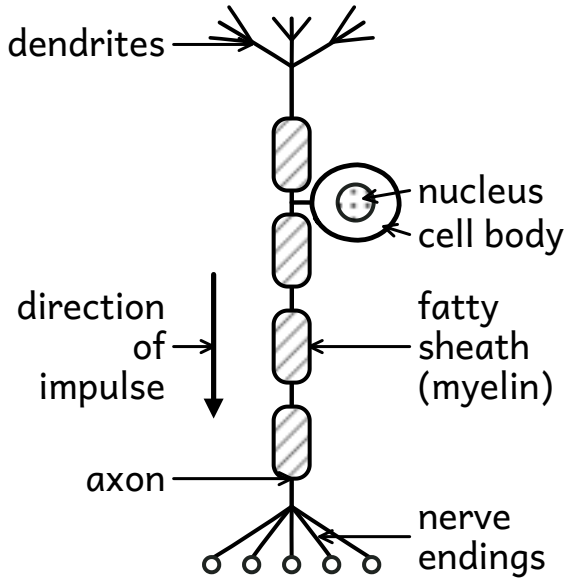
A **neurone** is a nerve cell. Neurones are the longest cells in the body. One can reach from your spine to your toe. A nerve is a bundle of many long neurone fibres, held together like wires in a cable.

Look at a motor neurone. The dendrites at the top receive the impulse. The cell body holds the nucleus. The axon is a long thin fibre that carries the impulse away. Fatty sheaths wrap the axon in pieces. They work like the plastic round a wire, and they let an impulse travel much faster. At the end, nerve endings pass the impulse on.

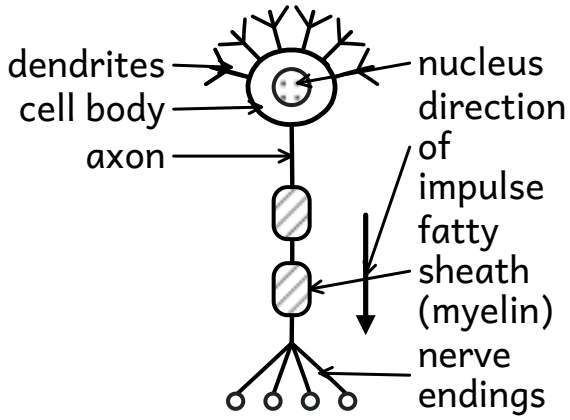


A motor neurone. The cell body is at the end where the impulse starts. The impulse runs down the long axon to the nerve endings.

The body has three kinds of neurone. A sensory neurone carries impulses from a receptor to the central nervous system. A relay neurone is short. It joins neurones inside the brain or spinal cord. A motor neurone carries impulses from the central nervous system to an effector.



A sensory neurone. Its cell body sits on a short branch to one side. The impulse passes it and goes on along the fibre towards the spinal cord.



A relay neurone is short. It lies inside the spinal cord or brain and joins a sensory neurone to a motor neurone.

How much does the fatty sheath matter? Suppose a message must travel 1.2 m. Look at the table, then work out the time for the neurone with the sheath. The speeds are round numbers. Real speeds differ between neurones.

Fibre	Speed	Length
sheath	100 m/s	1.2 m
no sheath	1 m/s	1.2 m

Two fibres of the same length. The one with a fatty sheath carries the impulse much faster.

WORKED EXAMPLE

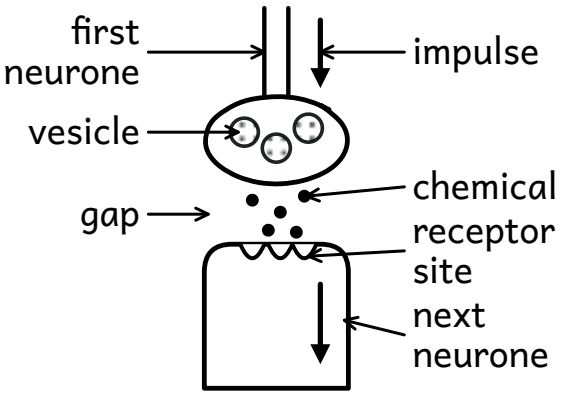
How long does an impulse take to travel 1.2 m along a fibre with a fatty sheath, at 100 m/s?

1. Time = distance ÷ speed.
2. Distance is 1.2 m and speed is 100 m/s, so time = 1.2 ÷ 100 = 0.012 s.
3. One second is 1 000 ms, so 0.012 s = 12 ms.

Answer: 12 ms

Two neurones in a row do not touch. A tiny gap lies between them, called a ***synapse***. An impulse cannot cross the gap as electricity. Instead the first neurone releases a chemical from small bags called vesicles. The chemical spreads across the

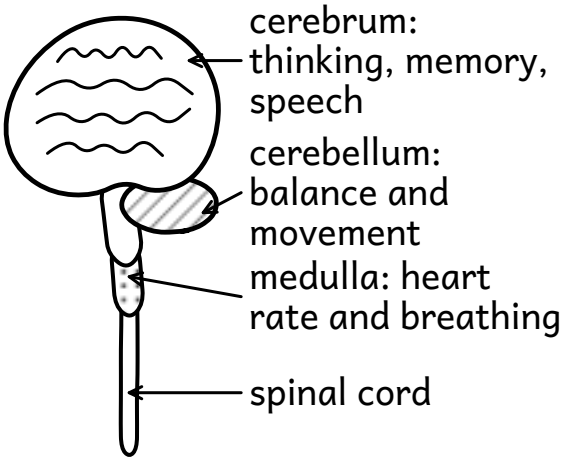
gap and fits receptor sites on the next neurone. These are tiny parts of the cell's surface, not the receptor cells of the senses. That starts a new impulse.



A synapse. Small bags called vesicles hold the chemical. The gap is drawn far wider than the real one, which is too narrow to see with a school microscope. The chemical crosses it in a tiny fraction of a second.

The chemical is released on one side only, and only the next neurone has receptor sites for it. So a message at a synapse can move in one direction. This keeps the path in order: receptor, then brain, then muscle.

Now the brain. It has three parts that you should know. The **cerebrum** is the large, folded top part. It is used for thinking, memory and speech, and it receives what the senses report. The **cerebellum** is at the back, below the cerebrum. It helps with balance and with smooth movement. The **medulla** joins the brain to the spinal cord. It controls the heart rate and breathing, which carry on without your thinking about them.



The brain from the side. These are three main parts. The brain has more parts than this, and they work together.

TRY IT

Which parts of the skin have the most receptors?

You need: two pencils with blunt ends, or two blunt sticks, a ruler marked in millimetres, a friend, paper and a pencil to record results.

Be safe: Use blunt ends and touch lightly. Never use a pin or anything sharp.

1. Close your eyes. Your friend touches your fingertip lightly with one pencil point, or with two points 50 mm apart. They choose one or two at random. You say "one" or "two".
2. Try again with the points 40 mm apart, then 30, 20, 10, 5, 3 and 2 mm. Mix in single touches. Write down the smallest gap at which you were right every time.
3. Repeat on your palm and on the back of your forearm.
4. Swap places, so that your friend is tested too. Make a table of your results.

What you will see: On the fingertip you can feel two points even when they are very close. On the forearm the points must be much further apart, or you feel only one. The fingertip has many more touch receptors in each square millimetre. The numbers in the picture are an example. Yours will differ.

If you cannot try it, this is what happens.

Where	Smallest gap
fingertip	3 mm
palm	10 mm
forearm	40 mm

A WRONG IDEA MANY PEOPLE HAVE

~~**A nerve is a tube with a liquid in it, like a blood vessel.**~~

Why it feels right: Nerves look like thin white threads, a little like blood vessels, and we say that a message "flows" along them.

The test that breaks it: A nerve is a bundle of many long neurone fibres. Each neurone carries a tiny electrical impulse, not a liquid. In a fibre with a fatty sheath the impulse runs at about 100 m/s, far faster than blood moves.

What is true: A nerve is a bundle of neurones. Each one carries an electrical impulse along its axon. At a synapse a chemical carries the message across the gap.

KEY WORDS

central nervous system
the brain and the spinal cord, where messages are sorted and orders are sent.

receptor
a cell that detects a stimulus, such as light, heat or pressure.

effector
a muscle or a gland that makes a response.

neurone
a nerve cell. It carries impulses.

synapse
the gap between two neurones, which a chemical crosses.

cerebrum
the large top part of the brain, used for thinking, memory and speech.

cerebellum
the part of the brain at the back that helps with balance and smooth movement.

medulla
the part of the brain that controls heart rate and breathing.

BACK TO YOUR GUESS

The answer is B: Nerve cells carry the news to the brain, and other nerve cells carry the order to a muscle.

A receptor in the skin starts a tiny electrical signal in a nerve cell. Nerve cells carry it to the brain or spinal cord. Other nerve cells carry the order to a muscle. Blood is far too slow for this.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. Which list shows the path of a message from a touched finger to a muscle, in the right order?

   A receptor, motor neurone, brain or spinal cord, sensory neurone, effector

   B receptor, sensory neurone, brain or spinal cord, motor neurone, effector

   C effector, sensory neurone, brain or spinal cord, motor neurone, receptor

   Answer at the back of the book.

2. Which part of a neurone is wrapped in fatty sheaths that make an impulse travel faster?

   A The dendrites

   B The cell body

   C The axon

   D The nerve endings

   Answer at the back of the book.

3. Which kind of neurone is short, lies inside the spinal cord, and joins a sensory neurone to a motor neurone?

   A A relay neurone

   B A motor neurone

   C A sensory neurone

   Answer at the back of the book.

4. How does a message cross the gap between two neurones?

    A The impulse jumps across the gap as a spark.

    B The two neurones touch for a moment and join.

    C A chemical crosses the gap and sets off a new impulse.

    Answer at the back of the book.

5. Which part of the brain controls heart rate and breathing?

    A The medulla

    B The cerebrum

    C The cerebellum

    Answer at the back of the book.

6. A cyclist stays upright on a bike and moves smoothly. Which part of the brain helps most with this?

    A The medulla

    B The cerebellum

    C The spinal cord

    Answer at the back of the book.

7. An impulse travels 1.5 m along a fibre with a fatty sheath at 100 m/s. How long does it take, in milliseconds?

    Answer at the back of the book.

8. A fibre with a fatty sheath carries impulses at 100 m/s. A fibre without one carries them at 1 m/s. How many times faster is the fibre with the sheath?

    Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Stimulus, receptor, sensory neurone, brain or spinal cord, motor neurone, effector, response. A chemical crosses each synapse. Cerebrum thinks, cerebellum balances, medulla keeps heart and breathing going.

Draw: The six boxes of the path with arrows, and a small side view of the brain with three parts named.

S4.5.2 CHAPTER 2

Reflexes

Why do you pull your hand away from a hot pan before you even feel the pain?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** The impulse goes to the spinal cord, which sends the order to the muscle without waiting for the brain to decide.
- ☐ **B** The brain decides very quickly, so the hand moves at once.
- ☐ **C** The muscle feels the heat by itself and moves with no message at all.

IF THIS FEELS HARD, READ THIS FIRST

- Level 3, Cells, S3.1.5. It shows how a nerve cell is built to carry messages.
- Level 2, Bones, muscles, teeth and food, S2.3.3. It shows how a muscle pulls on a bone when it gets shorter.
- Level 2, Forces: friction, falling and floating, S2.5.5. It says that gravity pulls things down, which is why the ruler falls.

BY THE END YOU CAN

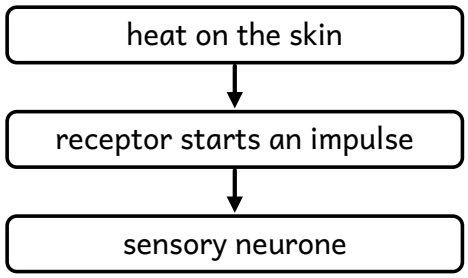
- Draw a reflex arc with sensory, relay and motor neurones
- Measure your reaction time with a falling ruler

Your hand touches a hot pan. It is away before you feel anything. This is a **reflex**: a quick, automatic response to a stimulus. You do not choose it, and you do not need to think about it. It protects you.

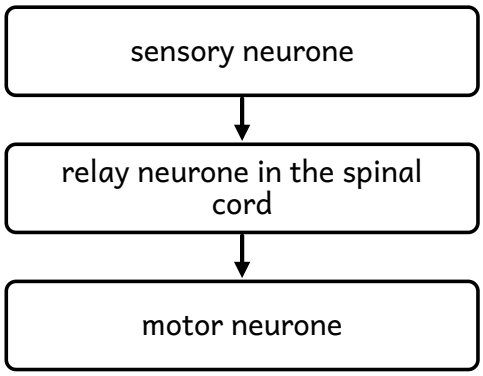
The path of a reflex is called the **reflex arc**. It uses the same kinds of neurone you met in the last chapter. The difference is the short route. The impulse does not wait for the thinking part of the brain.

DRAW IT FIRST

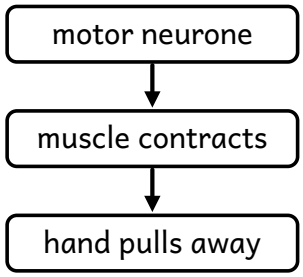
A reflex in three steps



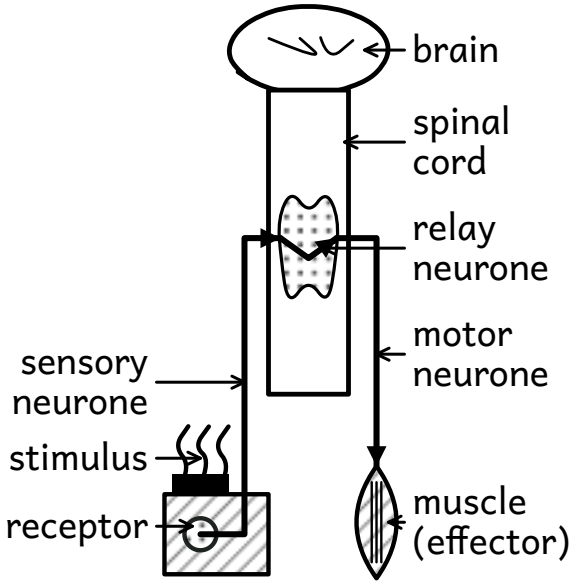
1 Heat acts on a receptor in the skin. The receptor starts an impulse in a sensory neurone.



2 The sensory neurone carries the impulse to the spinal cord. A relay neurone there passes it on to a motor neurone.



3 The motor neurone carries the impulse to a muscle in the arm. The muscle contracts and pulls the hand away.



The reflex arc for a hot object. The brain is drawn, but the path does not go through it. The dotted shape is the central part of the cord, where the relay neurone lies.

Look at the picture. The sensory neurone enters the spinal cord. The relay neurone joins it to the motor neurone. The picture does not show them, but at each join between two neurones there is a synapse. Many reflex arcs have a relay neurone. A few do not. In the knee jerk, the sensory neurone passes the impulse straight to the motor neurone.

The spinal cord is not the only place for a reflex. Blinking and the pupil reflex pass through parts of the brain that you do not control. What they share is the short path. No conscious decision is needed, and the action is over before you could decide.

Action	Reflex
hand off a flame	yes
kicking a ball	no
blinking at dust	yes
writing a word	no
pupil in light	yes

Some actions are reflexes and some are decisions. A reflex is quick, automatic and protective.

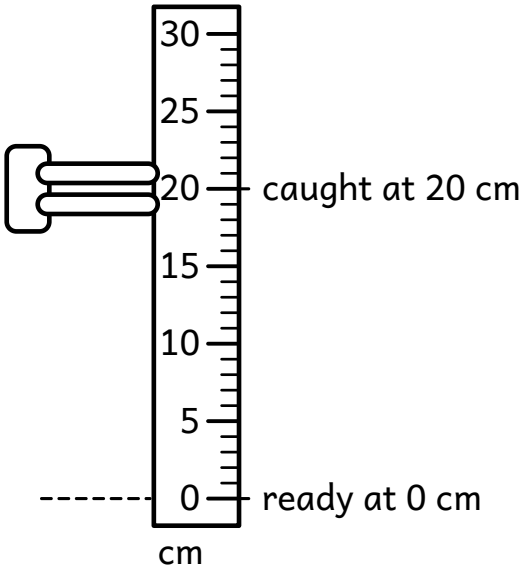
At the same moment, other impulses run up the spinal cord to the brain. The brain then tells you about the heat. That is a longer path, so you feel the pain after your hand has already moved. Now you can decide what to do next, such as running cold water over the hand.

Reflex	Decision
spinal cord	brain
very fast	slower
automatic	you choose
protects you	any job

A reflex and a decision compared. A decision uses the brain, with more neurones and more synapses, so it takes longer.

How much longer? You can measure it. Your **reaction time** is the time from a stimulus to your response. A person drops a ruler without warning, and you catch it. The further it falls before you catch it, the longer your reaction time.

Gravity makes the ruler speed up as it falls. Starting from rest, it falls a distance d in a time $t = \sqrt{(2d \div g)}$. Here $g = 9.8\ m/s^2$ and d is in metres. Look at the picture, then work out the time.



The fingers wait level with 0 cm. The ruler falls, and the fingers catch it at the mark shown. That mark is the distance fallen.

WORKED EXAMPLE

A ruler is caught at 20 cm. What was the reaction time, in milliseconds?

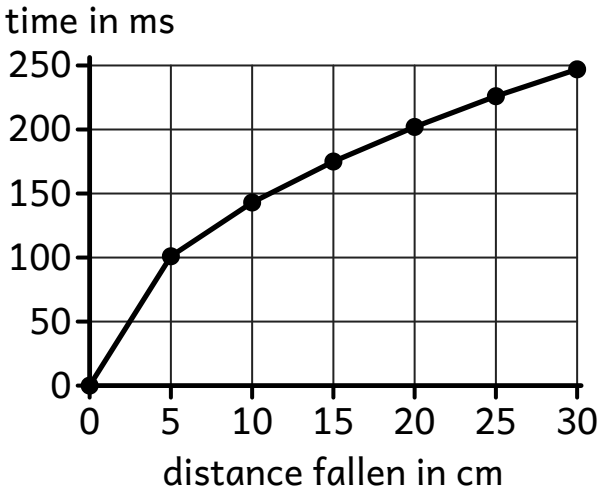
1. The ruler fell 20 cm, which is 0.20 m.
2. Use $t = \sqrt{(2d \div g)}$, with $g = 9.8\ m/s^2$.
3. $t = \sqrt{(2 \times 0.20 \div 9.8)} = \sqrt{0.0408} = 0.202$ s.
4. One second is 1 000 ms, so 0.202 s = 202 ms.

Answer: 202 ms

You do not have to work out the square root each time. Here is a table of the same sum for other distances, and the same results drawn as a graph. The line bends, because the ruler speeds up as it falls.

Fell	Time
5 cm	101 ms
10 cm	143 ms
15 cm	175 ms
20 cm	202 ms
25 cm	226 ms
30 cm	247 ms

Time of fall for a ruler that falls 5 cm to 30 cm, to the nearest millisecond.



The time of the fall against the distance fallen. A ruler that falls twice as far takes less than twice as long.

SEE IT THREE WAYS

As a picture

Caught at	Reaction time
5 cm	101 ms
10 cm	143 ms
20 cm	202 ms

In words

The farther the ruler falls before you catch it, the longer your reaction time. Twice the distance does not mean twice the time, because the ruler keeps speeding up.

In symbols

$t = \sqrt{(2d \div g)}$, with d in metres and g = 9.8 m/s^2. For d = 0.20 m, $t = \sqrt{(0.40 \div 9.8)} = 0.202$ s, which is 202 ms.

One catch is not enough. You may be ready or you may be distracted. So take several catches and find the mean. Here are five catches from one learner. Find the time for each, then the mean.

Try	Caught at
1	18 cm
2	22 cm
3	20 cm
4	16 cm
5	24 cm

Five catches from one learner. Each is the distance the ruler fell.

WORKED EXAMPLE

A learner caught the ruler at 18, 22, 20, 16 and 24 cm. What is the mean reaction time, to the nearest millisecond?

1. Find the time for each catch. The five times are 192 ms, 212 ms, 202 ms, 181 ms and 221 ms.
2. Add the five times: 192 + 212 + 202 + 181 + 221 = 1 008 ms.
3. Divide by 5: 1 008 ÷ 5 = 201.6, which is 202 ms to the nearest millisecond.

Answer: 202 ms

TRY IT

Measure your reaction time

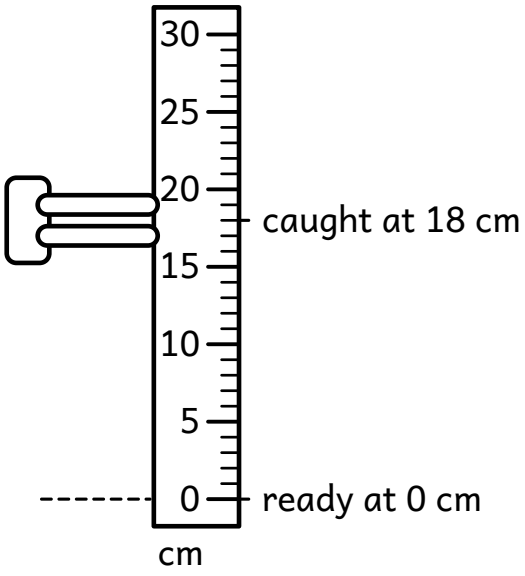
You need: a 30 cm ruler, plastic or wood, a friend, a table or chair, and a clear floor, paper and a pencil.

Be safe: Sit down and keep the floor clear. Hold the ruler low, over a table. Never drop it near anyone's face, and never stand on a chair.

1. Sit with your forearm resting on a table and your hand over the edge. Your friend holds the ruler by its top end, hanging between your open thumb and finger. The 0 cm end is level with the top of your finger.
2. Your friend lets go without warning, at a time of their own choosing. Catch the ruler as fast as you can.
3. Read the mark level with the top of your finger. This is the distance in cm that the ruler fell. Write it down.
4. Do this five times. Use the table or the formula to turn each distance into a time. Then find the mean.
5. Swap places. Or try again when you are tired, or while someone talks to you, and compare.

What you will see: Most people get a time between about 150 ms and 250 ms. If the ruler falls right through your fingers, count that go as a miss and try again. Your time changes from one go to the next. It is usually longer when you are tired or distracted. A reflex, such as pulling your hand from heat, takes far less time, because no decision is needed.

If you cannot try it, this is what happens.



A WRONG IDEA MANY PEOPLE HAVE

~~When your hand pulls away from something hot, your brain decides to move it, very fast.~~

Why it feels right: The movement is quick, and we think the brain controls everything we do.

The test that breaks it: The hand moves before you feel the pain. The pain is felt in the brain. If the brain had decided first, you would feel it first.

What is true: In a reflex, the order to the muscle comes from the spinal cord. The brain is told at about the same time, but the movement does not wait for it.

KEY WORDS

reflex
a quick, automatic response that you do not decide.

reflex arc
the path of a reflex: receptor, sensory neurone, relay neurone, motor neurone, effector.

reaction time

the time from a stimulus to your response.

BACK TO YOUR GUESS

The answer is A: The impulse goes to the spinal cord, which sends the order to the muscle without waiting for the brain to decide.

In a reflex the spinal cord passes the impulse straight from a sensory neurone to a motor neurone. The hand moves first. A second message goes up to the brain, so you feel the pain a moment later.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. What is a reflex?

   A A response that the brain plans carefully before the muscle moves.

   B A movement that the muscle makes with no nerve message at all.

   C A quick, automatic response to a stimulus that you do not decide.

   Answer at the back of the book.

2. Which list shows the parts of a basic reflex arc in the right order?

   A receptor, sensory neurone, relay neurone, motor neurone, effector

   B receptor, sensory neurone, brain, motor neurone, effector

   C receptor, relay neurone, sensory neurone, motor neurone, effector

   Answer at the back of the book.

3. Why is a reflex faster than a decision that you think about?

   A The impulses travel much faster along the neurones of a reflex.

   B The path is shorter, with fewer synapses, and no decision is needed.

   C The muscle contracts faster in a reflex than in a decision.

   Answer at the back of the book.

4. Sipho touches a hot pan and pulls his hand away. A moment later he feels pain. Why does the pain come after the movement?

   A The muscle makes the pain when it contracts.

   B Other impulses must travel all the way up to the brain, which takes longer than the reflex.

   C The brain switches off pain for a short time on purpose.

   Answer at the back of the book.

5. Which of these is not a reflex?

   A Catching a ball that someone throws to you

   B Blinking when something flies towards your eye

   C The pupil getting smaller in bright light

   Answer at the back of the book.

6. In the falling ruler test, Mei catches the ruler at a longer distance than Hana. What does this show?

   A Mei has a faster reflex.

   B Mei has a shorter reaction time.

   C Mei has a longer reaction time.

   Answer at the back of the book.

7. **From an earlier chapter**

   A message crosses a synapse in the reflex arc. What carries it across the gap?

   A A spark of electricity

   B A drop of blood

   C A chemical

   D The neurones touch and join

   Answer at the back of the book.

8. A ruler is caught at 25 cm. What is the reaction time in milliseconds?

   Answer at the back of the book.

9. Suppose a pulling away reflex takes 50 ms. Kofi's reaction time in the ruler test is 200 ms. How many times as long as the reflex is his reaction time?

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

A reflex is quick, automatic and protective. Its path is receptor, sensory neurone, relay neurone, motor neurone, effector. The brain is told later. Reaction time is longer, because the brain decides.

Draw: The reflex arc as a loop through the spinal cord, with the brain drawn to one side.

S4.5.3 CHAPTER 3

The eye

> **How does your eye let in the right amount of light, and how does it see near things and far things clearly?**

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** The pupil gets smaller, so that more light can get in.
- ☐ **B** The pupil stays the same size, and only the brain adjusts what you see.
- ☐ **C** The pupil gets wider, so that more light can get in.

IF THIS FEELS HARD, READ THIS FIRST

- Level 3, Light, colour and sound, S3.9.3. It shows how a lens makes an image and how glasses help people to see clearly.
- Level 3, Light, colour and sound, S3.9.2. It explains why light bends when it goes into glass or water.
- Level 2, Light and shadows, S2.6.3. It says that we see things when light from them enters our eyes.

BY THE END YOU CAN

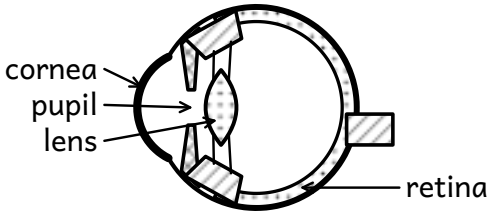
- Label the eye and give the job of each part
- Explain how the pupil changes in bright and dim light
- Explain how the lens focuses on near and far objects

You see an object when light from it enters your eye. The eye makes a small picture of the object on a layer at the back. That layer sends impulses to the brain, and the brain makes sense of them. The picture on the back of the eye is upside down. The brain turns it the right way up.

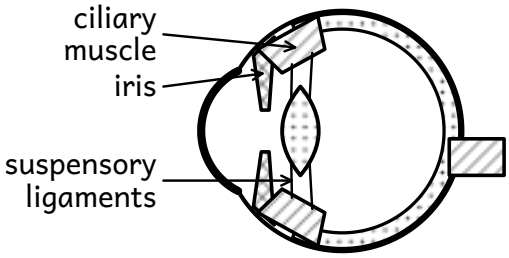
Be safe. Never look straight at the Sun, even for a moment. Do not look at it through glass, a tube, cloth or a mirror. The light can damage the back of the eye for good. Never shine a torch or a lamp into anyone's eyes.

DRAW IT FIRST

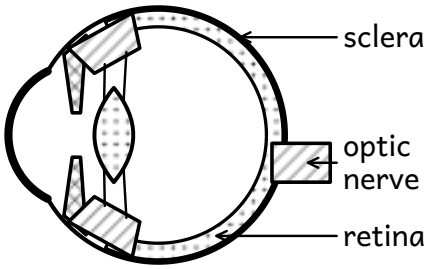
What the parts of the eye do



1 Light enters through the cornea and the pupil. The cornea and the lens bend it so that it makes an image on the retina.



2 The iris changes the size of the pupil. The ciliary muscle and the suspensory ligaments change the shape of the lens.



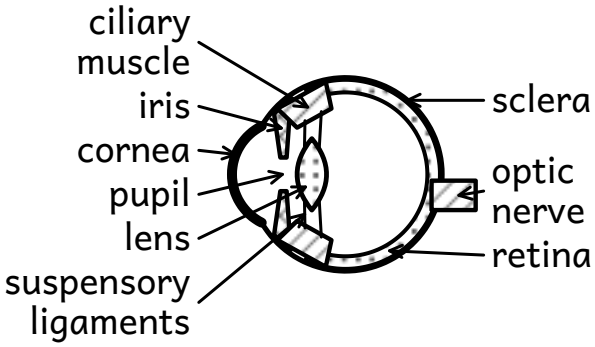
3 The retina turns light into impulses. The optic nerve carries them to the brain. The sclera is the tough outer wall.

Now each part and its job. The **cornea** is the clear window at the front. It bends light more than any other part. The **iris** is the coloured ring. It has muscles that

change the size of the **pupil**, the hole in the middle. The pupil looks black because the light that goes in is not sent back out.

Behind the pupil is the **lens**. It bends the light a little more, and it can change its shape to give a sharp image. The **ciliary muscle** is a ring of muscle round the lens. **Suspensory ligaments** are fibres that join the muscle to the lens. They hold the lens in place.

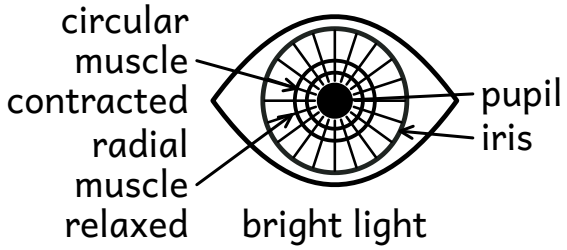
The **retina** lines the back of the eye. It holds the receptors for light. Rods work in dim light and do not see colour. Cones need bright light and see colour. The **optic nerve** carries impulses from the retina to the brain. The tough white wall of the eye is the sclera.



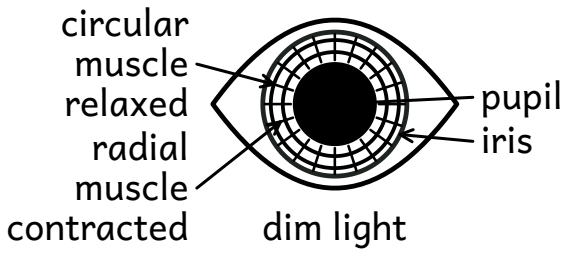
The eye cut across, with the front on the left. The picture is a model. A real eye also holds clear jelly and fluid that keep its shape.

Now the pupil. Too much light can harm the retina, and too little gives a poor picture. The iris has two sets of muscles. Circular muscles go round the pupil like the rings of a target. Radial muscles run outwards like the spokes of a wheel.

In bright light, the circular muscles contract and the radial muscles relax. The pupil becomes smaller, so less light gets in. In dim light, it is the other way round. The radial muscles contract and the circular muscles relax, so the pupil becomes wider.



Bright light. The circular muscles are contracted, so the pupil is small.



Dim light. The radial muscles are contracted, so the pupil is wide.

This is a reflex. Receptors in the retina sense the light. Impulses go along the optic nerve to the brain, and motor neurones carry the answer back to the muscles of the iris. They are the effectors. You cannot decide to do it.

How much difference does it make? Look at the typical sizes in the table. The amount of light that gets in depends on the area of the pupil. The area of a circle is π × r × r, where r is the radius, half the width.

Part	Width
iris	12 mm
pupil, bright	3 mm
pupil, dim	7 mm

Typical widths. They differ a little from person to person.

WORKED EXAMPLE

What is the area of a pupil that is 3 mm wide, in bright light?

1. The radius is half the width: 3 ÷ 2 = 1.5 mm.
2. Area = π × 1.5 × 1.5 = 7.07 mm^2.

Answer: 7.07 mm^2

WORKED EXAMPLE

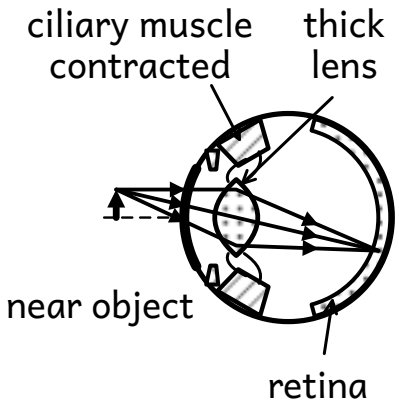
A pupil is 3 mm wide in bright light and 7 mm wide in dim light. How many times bigger is the area in dim light?

1. In dim light the radius is 7 ÷ 2 = 3.5 mm.
2. Its area is π × 3.5 × 3.5 = 38.48 mm^2.
3. In bright light the area is 7.07 mm^2, from the last example.
4. Divide: 38.48 ÷ 7.07 = 5.44, so the area is about 5.4 times bigger.

Answer: 5.4 times

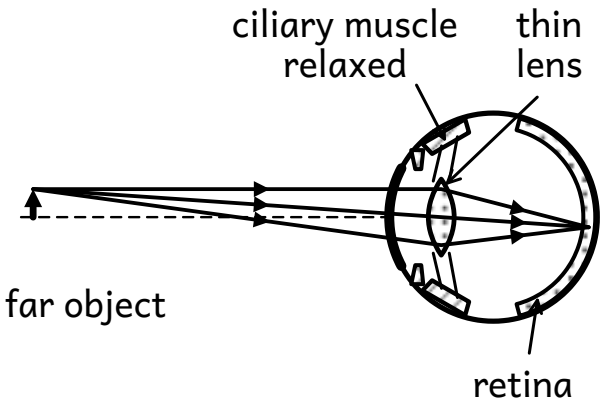
Now focus. Light from an object must meet at one point on the retina, or the picture is blurred. The cornea bends light most. The lens does the fine work, and it can change its shape. A fatter lens bends light more. A thinner lens bends it less.

Light from a near object spreads out more as it enters the eye. It needs more bending, so the lens must be fat. The ciliary muscle contracts, and its ring gets smaller. The suspensory ligaments slacken. The lens is elastic, so it springs into a fatter shape.



A near object. The ciliary muscle is contracted and the lens is thick. The rays meet on the retina. The distances are drawn closer than real ones, to fit the page.

Light from a far object is almost parallel when it enters the eye. It needs less bending. The ciliary muscle relaxes and its ring gets larger. The suspensory ligaments pull tight and stretch the lens thin.



A far object. The ciliary muscle is relaxed and the lens is thin. The rays meet on the retina again.

Part	Near	Far
muscle	contracts	relaxes
ligament	slack	tight
lens	fat	thin

Focusing in one table. The muscle is the ciliary muscle. The ligament is the set of suspensory ligaments.

Some eyes cannot focus well. In short sight, far things look blurred and near things are clear. The eyeball is too long, or the lens is too strong, so light from far things meets in front of the retina. In long sight, near things look blurred and far things are clear. The eyeball is too short, or the lens too weak, so light from near things would meet behind the retina.

Sight	Blurred	Lens
short	far things	spreads
long	near things	bends

Short and long sight. Glasses put a lens in front of the eye, so that the image falls on the retina. The lens that spreads light helps short sight. The lens that bends light inwards helps long sight.

Anyone who sees badly, or who has pain in the eye, should see a health worker or an eye specialist. They can test the eyes and say which glasses are right.

TRY IT

Watch a pupil change size

You need: a friend, a mirror, if you work alone, a room with ordinary daylight or room light, a clock or a way of counting seconds.

Be safe: Use only the ordinary light of the room. Never look at the Sun. Never shine a torch or a lamp at anyone's eyes.

1. Sit in an ordinary lit room, not in direct sunlight. Your friend sits facing you.
2. Cover your eyes with your palms for 30 seconds. Do not press on them. This makes the pupils wide.
3. Take your hands away. Your friend watches your pupils for the next few seconds. Or look in a mirror.
4. Write down what you see. Then swap places.

What you will see: Straight after you uncover your eyes, the pupils are wide. Within a second or two they get smaller. The muscles of the iris do this as a reflex, in answer to the light that enters.

If you cannot try it, this is what happens.

When	Pupil
hands just off	wide
seconds later	smaller

A WRONG IDEA MANY PEOPLE HAVE

~~In people, the eye focuses by moving the lens towards or away from the retina, like a camera.~~

Why it feels right: A camera focuses by moving its lens, and the eye is often compared with a camera.

The test that breaks it: The lens of the eye is held in place by the suspensory ligaments. What changes is its shape. The ciliary muscle makes it fatter, and the ligaments make it thinner.

What is true: The lens does not move. The ciliary muscle and the ligaments change its shape, so that it bends light more or less.

KEY WORDS

cornea
the clear window at the front of the eye. It bends light most.

iris
the coloured ring with muscles that change the size of the pupil.

pupil
the hole in the middle of the iris, where light goes in.

lens
the part behind the pupil that changes shape to focus light.

retina
the layer at the back of the eye with receptors for light.

optic nerve
the nerve that carries impulses from the retina to the brain.

ciliary muscle
a ring of muscle round the lens that changes the shape of the lens.

suspensory ligaments
fibres that join the ciliary muscle to the lens and hold it in place.

BACK TO YOUR GUESS

The answer is C: The pupil gets wider, so that more light can get in.

In dim light the muscles of the iris make the pupil wider, so more light reaches the retina. In bright light they make it smaller, which protects the retina.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. Which part of the eye has receptors that detect light?

   A The retina

   B The cornea

   C The iris

   D The lens

   Answer at the back of the book.

2. Ana walks out into bright light. What happens in her iris?

   A The radial muscles contract and the pupil gets wider.

   B The circular muscles contract and the pupil gets smaller.

   C The circular muscles contract and the pupil gets wider.

   D The radial muscles contract and the pupil gets smaller.

   Answer at the back of the book.

3. Why does the pupil get wider in dim light?

   A To protect the retina from damage

   B To make the lens thicker

   C To let more light reach the retina

   Answer at the back of the book.

4. Yusuf has been looking at a far hill. Now he looks at a book held close to his face. What happens in his eye?

   A The ciliary muscle contracts, the ligaments slacken and the lens gets fatter.

   B The ciliary muscle contracts, the ligaments tighten and the lens gets thinner.

   C The ciliary muscle relaxes, the ligaments tighten and the lens gets thinner.

   Answer at the back of the book.

5. Leila looks up at a tree on a far hill. What do the suspensory ligaments do?

   A They slacken, and the lens gets fatter.

   B They pull tight, and the lens gets thinner.

   C They move the lens away from the retina.

   Answer at the back of the book.

6. Ravi can read a book clearly. The writing on the board at the front of the class is blurred. What is this called?

   A Long sight

   B A damaged optic nerve

   C Short sight

   Answer at the back of the book.

7. **From an earlier chapter**

   The pupil gets smaller in bright light. This is a reflex. Which part is the effector?

   A The retina

   B The optic nerve

   C The muscles of the iris

   Answer at the back of the book.

8. A pupil is 4 mm wide. What is its area in mm^2, to 1 decimal place? Use $A = \pi \times r \times r$.

   Answer at the back of the book.

9. A pupil widens from 2 mm to 6 mm. How many times bigger is its area?

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Light goes in through the cornea and pupil, and the lens focuses it on the retina. Bright light: pupil small. Dim light: pupil wide. Near: ciliary muscle contracts, lens fatter. Far: muscle relaxes, lens thinner.

Draw: The eye cut across, with the cornea, pupil, lens, retina and optic nerve named.

S4.5.4 CHAPTER 4

Hormones

> **Your heart pounds when you get a fright, and you still feel shaky a minute later. What is carrying that message?**

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** A chemical in the blood, which reaches the heart and other organs.
- ☐ **B** Nerve impulses only, which stop as soon as the danger has gone.
- ☐ **C** The heart itself, which keeps beating fast until it calms down.

IF THIS FEELS HARD, READ THIS FIRST

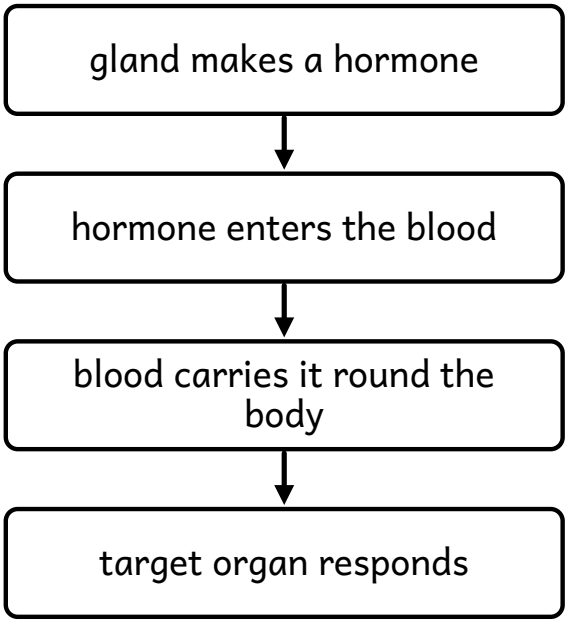
- Level 3, Body systems, S3.3.6. It shows that blood travels round the whole body and carries substances with it.
- Level 3, Growing up: puberty and reproduction, S3.4.2. It describes the changes of puberty, which hormones cause.
- Level 3, Growing up: puberty and reproduction, S3.4.4. It names the ovaries and testes and says what they do.

BY THE END YOU CAN

- Compare nerves and hormones by speed and how long effects last
- Name the main glands and the hormones they make

Nerves are fast, but their messages are short. Many jobs in the body need a slower message that lasts longer. Growing, changing in puberty and keeping the blood sugar steady are examples. The body sends these messages with hormones.

A **hormone** is a chemical messenger. It is made by a **gland**, an organ that makes chemicals and releases them. The hormone goes into the blood and is carried all round the body. It acts on a **target organ**, an organ that has receptor sites for it.



The path of a hormone. Unlike a nerve impulse, it travels in the blood.

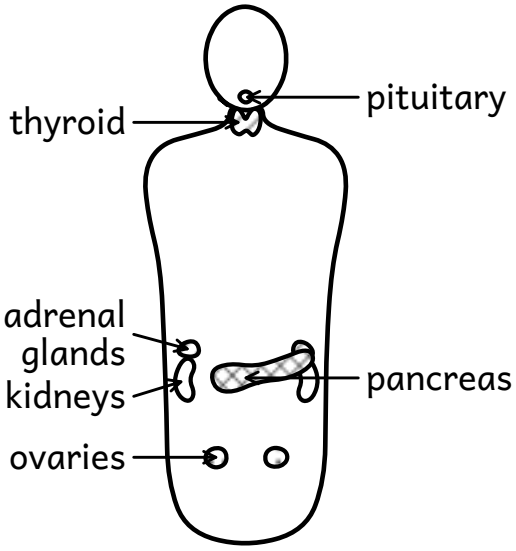
The blood reaches every organ, but a hormone acts only on its target organs. Only the cells of a target organ have receptor sites that fit that hormone, as a key fits one lock. These are tiny parts of the cell's surface. The other cells do not react to it.

Nerves and hormones do different jobs. An impulse goes along a neurone to one place. It acts in a fraction of a second and soon stops. A hormone must be made, released and carried in the blood. It takes longer to arrive, but its effect can last for minutes, hours or years.

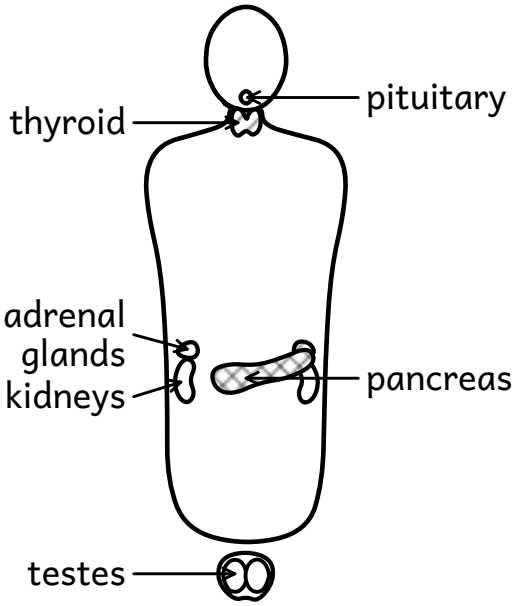
Feature	Nerves	Hormones
signal	impulse	chemical
route	neurones	blood
speed	fast	slower
effect	short	long

Nerves and hormones compared. The body needs both.

A gland that sends its hormone into the blood is called an endocrine gland. The body has several. Look at where they lie. The first picture is a female body and the second is a male body. The glands in the neck and the trunk are the same in both. Only the last gland differs.



The glands in a female body. The ovaries are low in the trunk. The pancreas lies in front of the kidney and adrenal gland on one side, so their outlines overlap in the drawing.



The glands in a male body. The testes hang outside the trunk. The other glands are in the same places. The pancreas again overlaps the kidney and adrenal gland on one side.

The **pituitary gland** is a small gland under the brain. It releases several hormones. Growth hormone makes children grow. ADH controls the water in the body. FSH and LH act on the ovaries or the testes. Some of its hormones make other glands work, so it controls other glands.

The **thyroid gland** is in the neck. It makes thyroxine, which sets the rate of the chemical reactions in the body. The thyroid needs iodine to make it. Too little iodine in food can make the thyroid swell.

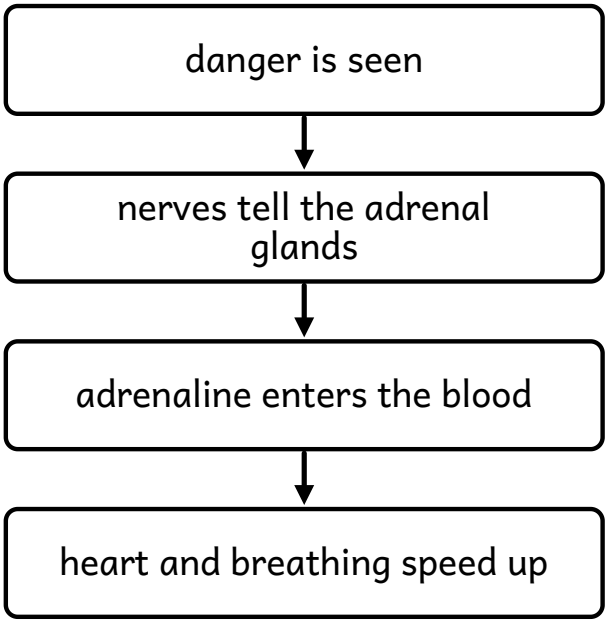
The two **adrenal glands** lie on top of the kidneys. They make **adrenaline**. The **pancreas** lies behind the stomach and makes insulin and glucagon, which control blood sugar. You will study them in the next chapter.

The ovaries make oestrogen and progesterone. The testes make testosterone. These hormones bring about the changes of puberty and control the making of eggs and sperm. Puberty starts when the pituitary releases more FSH and LH.

Gland	Hormone
pituitary	growth hormone
pituitary	ADH
pituitary	FSH and LH
thyroid	thyroxine
adrenal	adrenaline
pancreas	insulin
pancreas	glucagon
ovaries	oestrogen
ovaries	progesterone
testes	testosterone

The main glands and some of the hormones they release. The adrenal row stands for the adrenal glands.

Adrenaline shows nerves and hormones working together. You see a danger. Nerves quickly tell the adrenal glands to release adrenaline. The blood carries it round the body. Your heart beats faster, your breathing quickens, and your liver releases glucose, so that your muscles get more energy and oxygen. Your pupils widen.



A fright. Nerves start the response, and a hormone keeps it going. You may feel shaky for a few minutes after the danger has passed. Adrenaline is still in the blood.

How much slower is a hormone? Here are two round numbers. A nerve impulse takes about 20 ms to cross the body. Blood takes about 60 s to make a full trip round it. A hormone must make that trip, so it needs about that time to reach every part.

WORKED EXAMPLE

Suppose an impulse takes 20 ms to cross the body, and a hormone takes 60 s. How many times longer does the hormone take?

1. Put both times in the same unit. 60 s = 60 × 1 000 = 60 000 ms.
2. Divide the longer time by the shorter time: 60 000 ÷ 20 = 3 000.

Answer: 3 000 times

TRY IT

Two ways to send a message

You need: at least five people, standing in a line, a clock or phone timer showing seconds, a small piece of paper, paper and a pencil to record times.

Be safe: Walk, never run. Keep the floor clear of bags and shoes.

1. Stand in a line, with a gap of about one arm between people. The first person is the receptor. The last person is the target organ.
2. Nerve message. The first person squeezes the hand of the next person. Each person squeezes the next as soon as they feel a squeeze. Time how long the squeeze takes to reach the last person.
3. Hormone message. Write a message on the piece of paper. The first person walks it along the line and hands it to the last person. Time how long it takes.
4. Repeat each way three times and write down the times. Compare them.

What you will see: The squeeze message is fast, but it is passed from one person to the next, like an impulse along neurones. The walking message is slower. It is carried by one person and goes to the target, like a hormone in the blood. The times in the picture are an example. Yours will differ.

If you cannot try it, this is what happens.

Message	Time
squeeze	2 s
walk with paper	7 s

A WRONG IDEA MANY PEOPLE HAVE

~~Hormones are only about puberty and having babies.~~

Why it feels right: Hormones are often talked about with puberty, so it seems that is all they do.

The test that breaks it: Look at the table of glands. Adrenaline prepares you for danger. Insulin and glucagon control blood sugar. ADH controls water in the body. Thyroxine sets the rate of chemical reactions. None of these is about puberty.

What is true: Hormones control many things in every body, at every stage of life. The hormones of puberty are only some of them.

KEY WORDS

hormone
a chemical messenger that is made by a gland and carried in the blood.

gland
an organ that makes a chemical and releases it.

target organ
an organ with receptor sites for a hormone, which responds to it.

pituitary gland
a small gland under the brain that releases hormones, some of which control other glands.

thyroid gland
a gland in the neck that makes thyroxine.

adrenal glands
two glands on top of the kidneys that make adrenaline.

adrenaline
a hormone that gets the body ready for danger.

pancreas
a gland behind the stomach that makes insulin and glucagon.

BACK TO YOUR GUESS

The answer is A: A chemical in the blood, which reaches the heart and other organs.

Nerves start the response very quickly. But a gland also releases adrenaline into the blood. The blood carries it to the heart and to other organs, and it keeps working for a few minutes.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. How does a hormone get from a gland to its target organ?

    A It is carried in the blood.

    B It runs along a neurone as an impulse.

    C It crosses a synapse from one neurone to the next.

    Answer at the back of the book.

2. Which is true of hormones, compared with nerve impulses?

    A They are faster, and their effects are shorter.

    B They are about as fast, and last as long.

    C They are slower, and their effects last longer.

    Answer at the back of the book.

3. Blood carries a hormone to every organ, yet only some respond. Why?

    A The blood takes the hormone only to the target organs.

    B Only the target organs have receptor sites that fit the hormone.

    C The hormone breaks down at once in all the other organs.

    Answer at the back of the book.

4. Which gland releases adrenaline?

   A The thyroid gland

   B The pituitary gland

   C The pancreas

   D The adrenal glands

   Answer at the back of the book.

5. Which gland releases hormones that control other glands?

   A The pituitary gland

   B The thyroid gland

   C The pancreas

   Answer at the back of the book.

6. What does the hormone thyroxine control?

   A The level of sugar in the blood

   B The rate of the chemical reactions in the body

   C The amount of water that leaves in urine

   Answer at the back of the book.

7. **From an earlier chapter**

   Which kind of neurone carries impulses from the brain or spinal cord to a muscle or a gland?

   A A sensory neurone

   B A relay neurone

   C A motor neurone

   Answer at the back of the book.

8. Suppose a nerve impulse takes 20 ms and a hormone takes 60 s. How many times longer does the hormone take?

   Answer at the back of the book.

9. A nerve impulse takes 40 ms to reach a muscle. How many seconds is that?

Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Hormones are chemicals made by glands, carried in the blood to target organs. Slower than nerves, but they last longer. Pituitary controls other glands. Thyroid: thyroxine. Adrenal glands: adrenaline. Pancreas: insulin and glucagon.

Draw: A body outline with the pituitary, thyroid, adrenal glands and pancreas marked and named.

S4.5.5 CHAPTER 5

Blood sugar and diabetes

> **You eat a sweet meal one hour and nothing the next. Why does the sugar in your blood stay about the same?**

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** The pancreas releases glucagon, and glucagon lowers the sugar in the blood.
- ☐ **B** The pancreas releases insulin, and insulin makes cells and the liver take glucose out of the blood.
- ☐ **C** The level falls by itself, and no hormone has anything to do with it.

IF THIS FEELS HARD, READ THIS FIRST

- Level 3, Body systems, S3.3.2. It shows how food is broken into small pieces, such as glucose, that pass into the blood.
- Level 3, Body systems, S3.3.3. It says what carbohydrates do in the body.
- Level 4, Cells, photosynthesis and respiration, S4.1.8. It shows how cells use glucose to release energy.

BY THE END YOU CAN

- Explain how insulin controls blood sugar
- Compare type 1 and type 2 diabetes and how each is managed

Every cell uses glucose as fuel. Glucose comes from the carbohydrate in food, and the blood carries it to the cells. The amount in the blood is called the blood sugar level, or blood glucose. It must stay steady. Too little starves the cells, and too much harms the body.

Between meals the level of glucose in blood is about 0.7 to 1.0 g/L. In an adult the blood holds only about 4 or 5 g of glucose in all. Keeping it steady is called **homeostasis**. The body keeps many things steady in this way.

The pancreas does the main work. It lies behind the stomach and has cells that sense the glucose in the blood. They release two hormones: insulin and glucagon. They have opposite jobs.

DRAW IT FIRST

After a meal

a meal is eaten → glucose enters the blood → blood glucose rises

1 You eat. The carbohydrate is digested to glucose, which passes into the blood. The blood glucose rises.

blood glucose rises → pancreas releases insulin → cells take in glucose

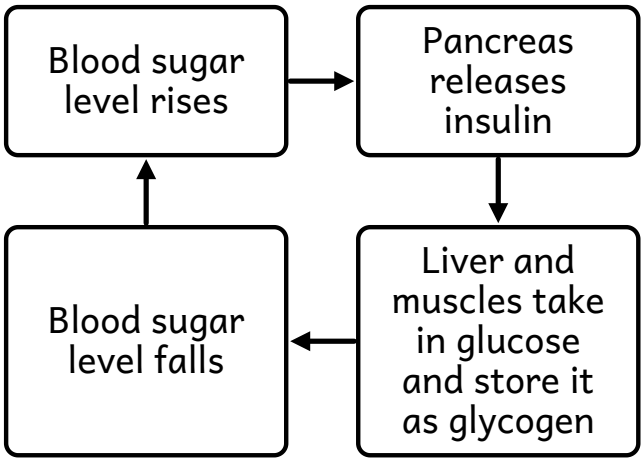
2 The pancreas senses the rise and releases **insulin** into the blood. The blood carries it to the liver and the muscles. Cells there take in glucose.

liver stores glycogen → blood glucose falls → level back to normal

3 The liver turns glucose into **glycogen**, a store. The glucose in the blood falls back to normal.

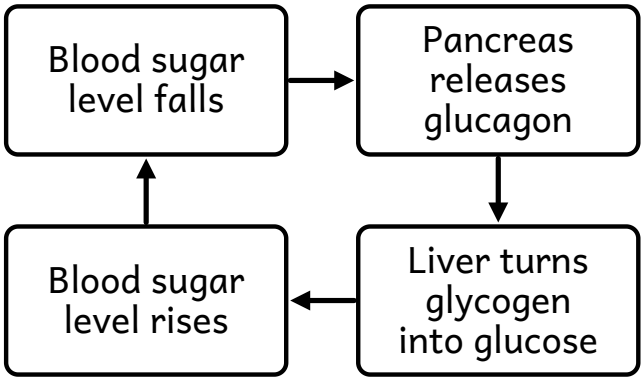
Insulin lowers blood glucose. It makes liver and muscle cells take glucose in. The liver joins the glucose into long chains of glycogen and keeps them as a store.

Muscle cells use glucose, or store glycogen too.



The insulin loop. A high level starts a response that lowers it.

Between meals, or during hard exercise, the level can fall. Then the pancreas releases **glucagon**. Glucagon makes the liver turn glycogen back into glucose and release it into the blood. The level rises again.



The glucagon loop. A low level starts a response that raises it.

In both loops the last step undoes the first. A rise leads to a fall, and a fall leads to a rise. This is **negative feedback**. It keeps the level close to the same value, rising and falling a little around it.

How much glucose is in all your blood? The amount is the volume times the concentration. Look at the table, then work it out for 5 L of blood.

Blood	Amount
volume	5 L
glucose	0.9 g/L

An example. Real values differ from person to person.

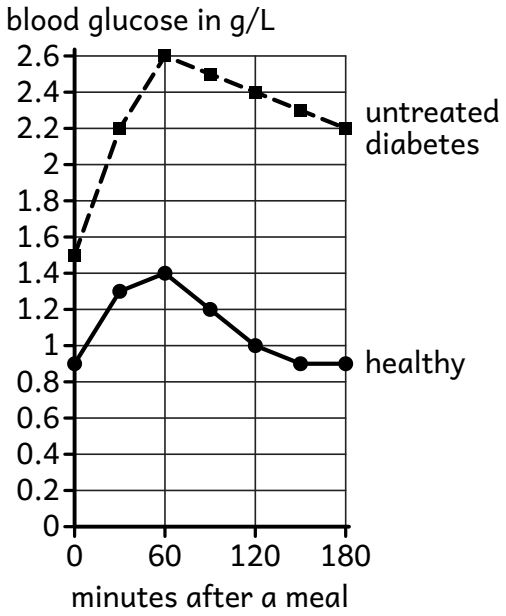
WORKED EXAMPLE

An adult has 5 L of blood, with 0.9 g of glucose in each litre. How much glucose is in all the blood?

1. Multiply the volume by the amount in each litre.
2. 5 × 0.9 = 4.5 g.

Answer: 4.5 g

That is about one teaspoon of sugar in all the blood. A meal can add far more glucose than that. So the control must work fast. Look at the graph of a healthy person after a meal. The level rises, but only a little, and it soon returns.



Example blood glucose after a meal. These numbers show the shape. Real values differ between people, and they are written in other units in some places.

WORKED EXAMPLE

At 120 minutes, how much higher is the glucose of the person with untreated diabetes than that of the healthy person?

1. Read the line for untreated diabetes at 120. It is at 2.4 g/L.
2. Read the healthy line at 120. It is at 1.0 g/L.
3. Subtract: 2.4 − 1.0 = 1.4 g/L.

Answer: 1.4 g/L

Diabetes is a condition in which the body cannot keep blood glucose steady. The level goes too high and stays high. A health worker can test for it with a drop of blood. Over the years a high level damages blood vessels, nerves, eyes and kidneys. Early care prevents much of this harm.

In **type 1 diabetes** the pancreas makes too little insulin. The body's own defences destroy the cells that make it. It often starts in children and young people, but it can start later in life. Eating sugar does not cause it. A person with type 1 diabetes needs insulin from a health worker, with care over food and exercise. Insulin is a protein, so it would be digested if it were swallowed. A health worker shows how it is given.

In **type 2 diabetes** the cells stop responding well to insulin. The pancreas may also make too little. It is the more common kind. It is linked to body mass, to little exercise, to family history and to growing older. A healthy diet, more exercise and a healthy body mass help. A health worker may also give medicines. Some people need insulin later.

Type 1	Type 2
low insulin	weak response
defences	body mass
insulin	diet, exercise

The two main kinds. Row one is the problem, row two is what it is linked to, and row three is the main care. In type 1 the defences of the body attack the cells that make insulin. Type 1 also needs care over food and exercise. Both kinds need a health worker.

Someone with very high glucose may be very thirsty, pass a lot of urine and feel tired. Someone whose glucose falls too low may feel shaky, confused or faint. Both need a health worker. If a person with diabetes is confused or faint, get help at once. Diabetes is not catching. You cannot get it from another person.

TRY IT

A model of the control

You need: two bowls, a cup, water, a piece of tape or a pen mark on the inside of one bowl, two or three people, a tray or a place where spills do not matter.

Be safe: Work on a tray or outside, and wipe up any spills so that no one slips. Use only water.

1. Fill bowl A, the blood, with water up to the mark. Bowl B, the liver store, has a little water in it.
2. One person is the food. At times of their choice they pour a cup of water into bowl A.
3. One person is the pancreas. If the water in bowl A is above the mark, they say "insulin". The liver, the third person, moves a cup of water from bowl A to bowl B.
4. If the water is below the mark, the pancreas says "glucagon". The liver moves a cup from bowl B back to bowl A. Play ten rounds and notice the level.
5. Now play again with no pancreas. Nobody says "insulin" or "glucagon", and the liver does nothing. Watch what the level does.

What you will see: With the pancreas, the level stays close to the mark. Without it, every cup of food pushes the level up and it stays high. This is a model of type 1 diabetes, where too little insulin is made. The model is basic, and the real body is far more detailed.

If you cannot try it, this is what happens.

Case	Level
pancreas	near mark
no pancreas	keeps rising

A WRONG IDEA MANY PEOPLE HAVE

~~Diabetes is caused by eating too much sugar.~~

Why it feels right: A person with diabetes has to take care over sugar, and sweet food does raise blood glucose.

The test that breaks it: In type 1 diabetes the pancreas makes too little insulin, and food does not cause this. Type 2 is linked to body mass, to little exercise, to family history and to age. Many people eat a lot of sugar and do not have diabetes.

What is true: Sugar on its own does not cause diabetes. Diabetes means the body cannot control its blood glucose. There is too little insulin, or the cells do not respond to it well.

KEY WORDS

homeostasis
keeping conditions inside the body steady.

insulin
a hormone from the pancreas that lowers blood glucose.

glycogen
a store of glucose, kept in the liver and the muscles.

glucagon
a hormone from the pancreas that raises blood glucose.

negative feedback
a change that sets off a response which reverses the change.

diabetes
a condition in which the body cannot keep blood glucose steady.

type 1 diabetes
diabetes in which the pancreas makes too little insulin.

type 2 diabetes
diabetes in which the cells respond badly to insulin.

BACK TO YOUR GUESS

The answer is B: The pancreas releases insulin, and insulin makes cells and the liver take glucose out of the blood.

After a meal the pancreas releases insulin. Insulin makes the liver and muscle cells take glucose out of the blood, and the liver stores it as glycogen. Glucagon does the opposite job, when the level is low.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. What does insulin do?

   A It makes the liver release glucose into the blood.

   B It breaks down food in the stomach.

   C It makes liver and muscle cells take glucose out of the blood.

   Answer at the back of the book.

2. Between meals, a person's blood glucose starts to fall. What happens next?

   A The pancreas releases glucagon, and the liver turns glycogen into glucose.

   B The pancreas releases more insulin, to hold the level steady.

   C The liver releases insulin into the blood.

   Answer at the back of the book.

3. Why is the control of blood glucose called negative feedback?

   A The response makes the change bigger.

   B The response reverses the change that started it.

   C There is no response to a change.

   Answer at the back of the book.

4. What is the main problem in type 1 diabetes?

   A The cells ignore insulin because the person ate too much sugar.

   B The liver makes too much glucagon.

   C The pancreas cannot sense the glucose.

   D The pancreas makes too little insulin.

   Answer at the back of the book.

5. Which is a main way to manage type 2 diabetes?

   A Staying away from other people, in case it spreads

   B Insulin only, because diet and exercise make no difference

   C A healthy diet and more exercise, with medicines from a health worker if needed

   Answer at the back of the book.

6. Which statement about diabetes is true?

   A Eating sugar on its own always causes diabetes.

   B You cannot catch diabetes from someone who has it.

   C Type 1 diabetes is caused by too little exercise.

   Answer at the back of the book.

7. **From an earlier chapter**

   Which hormone does the thyroid gland make?

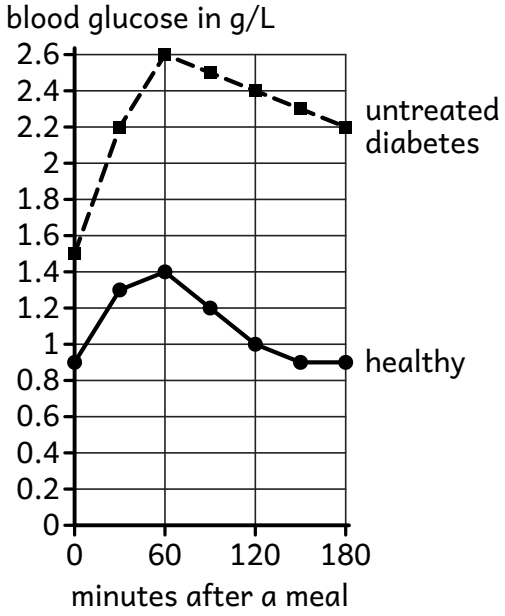
   A Insulin

   B Thyroxine

   C Adrenaline

   Answer at the back of the book.

8. Look at the graph. How much higher is the highest glucose of the untreated diabetes line than the highest glucose of the healthy line, in g/L?



Answer at the back of the book.

9. A child has 3 L of blood with 0.9 g of glucose in each litre. How much glucose is in all the blood?

Answer at the back of the book.

10. At 60 minutes after a meal, one person's blood glucose is 1.8 g/L and another person's is 1.2 g/L. How much higher is the first?

Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Glucose high: pancreas releases insulin, cells and liver take in glucose, liver stores glycogen. Glucose low: glucagon, liver releases glucose. Type 1: too little insulin. Type 2: cells respond badly. See a health worker.

Draw: Two loops side by side: glucose rises, insulin, glucose falls; and glucose falls, glucagon, glucose rises.

S4.5.6 CHAPTER 6

Temperature and water balance

> **You sweat when it is hot, shiver when it is cold, and pass dark urine when you have drunk little. On a hot day, which of these cools your body?**

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** Blood vessels near the skin get narrower, so less blood reaches the skin.
- ☐ **B** The hairs on the skin stand up to trap air.
- ☐ **C** Sweat evaporates from the skin and takes heat away from the body.

IF THIS FEELS HARD, READ THIS FIRST

- Level 3, Energy stores and transfers, S3.8.4. It explains the difference between heat and temperature and shows how to read a thermometer.
- Level 3, Energy stores and transfers, S3.8.6. It shows how a wet clay pot keeps water cool, which is how sweat works.
- Level 4, Cells, photosynthesis and respiration, S4.1.5. It shows how temperature changes the way an enzyme works.
- Level 4, Cells, photosynthesis and respiration, S4.1.3. It shows how water moves into and out of cells.

BY THE END YOU CAN

- Explain how sweating and shivering keep body temperature steady
- Explain how the kidneys control the water in the body

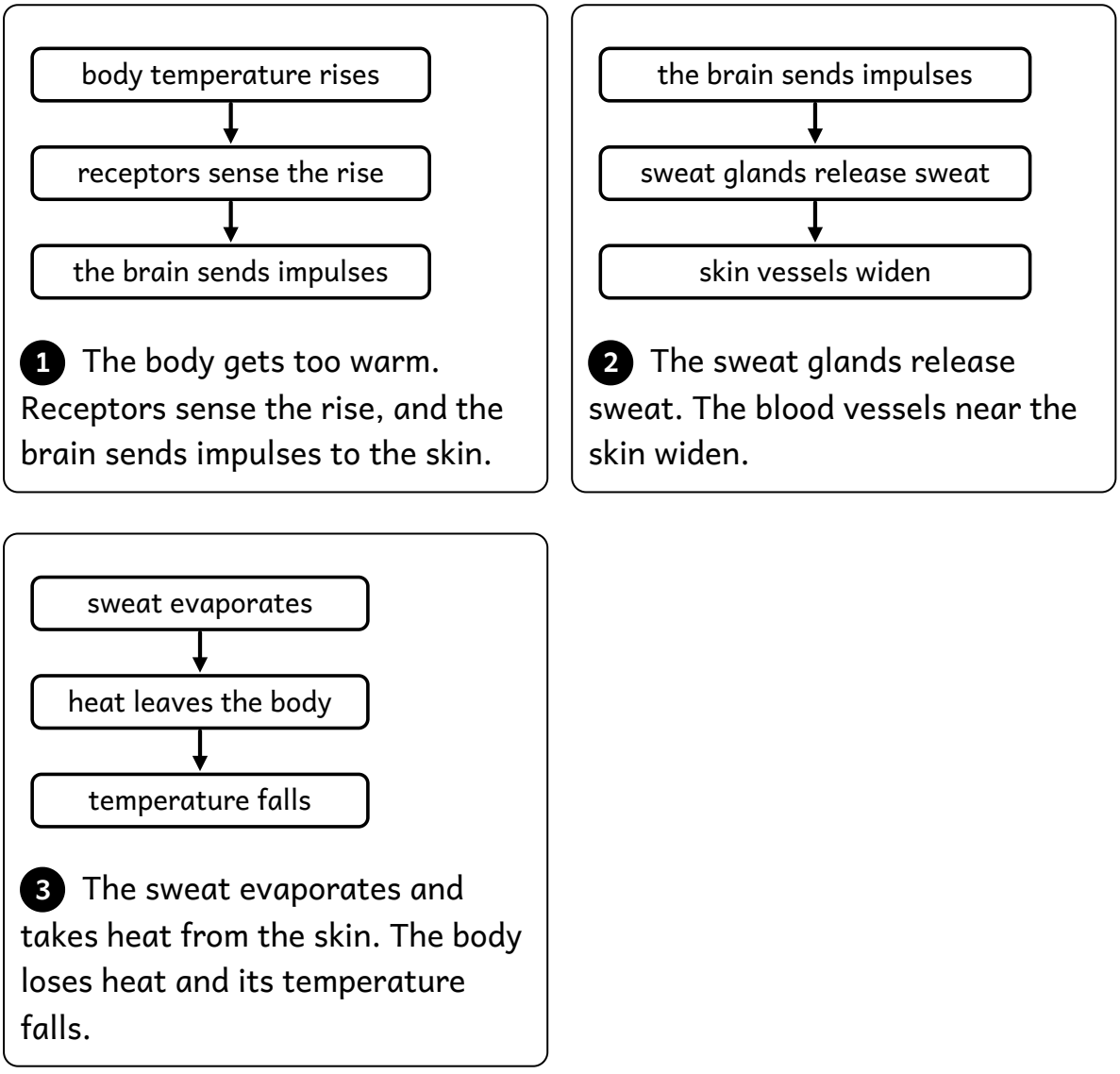
The inside of your body stays at about 37 °C, whether the air is hot or cold. A healthy body varies by a degree or so between people and through the day. This

steady temperature matters because the enzymes in your cells work best near it. Much hotter or colder, they work badly.

A part of the brain called the hypothalamus checks the temperature of the blood that passes through it. Receptors in the skin also send impulses to it. If the temperature drifts, the brain sends impulses to make the body respond. This is negative feedback, as in the control of blood glucose.

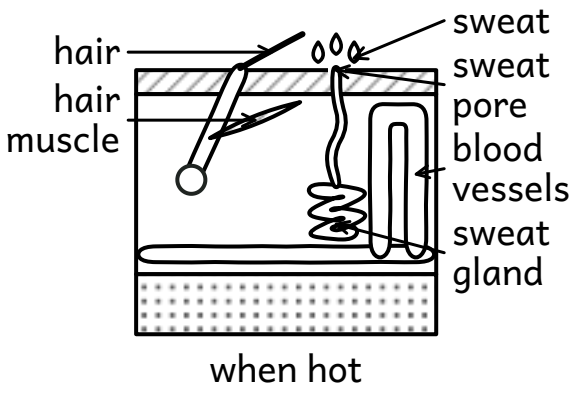
DRAW IT FIRST

When the body is too hot



Look at a cut through the skin. It has a sweat gland, a hair with a small muscle, and blood vessels near the surface. When you are hot, the sweat gland releases sweat

through a pore onto the skin. The vessels near the skin widen, so more warm blood flows close to the surface and more heat leaves. The hair lies flat.



The skin when hot. The vessels are wide, sweat lies on the surface and the hair lies flat. The long tube at the bottom is a deeper blood vessel, and the dotted layer is fat.

Why does sweat cool you? Sweat is mostly water. **Evaporation** is when a liquid turns into a gas at its surface. The particles with most energy escape first, and the ones that are left are cooler. So the skin loses heat. Sweat that only drips off does not cool you. Sweat that evaporates does.

Evaporation takes a lot of heat. About 2.4 kJ is needed to evaporate 1 g of water. Look at the table, then work out the heat taken by a larger amount of sweat.

Sweat	Heat
1 g	2.4 kJ
10 g	24 kJ

The heat taken when sweat evaporates.

WORKED EXAMPLE

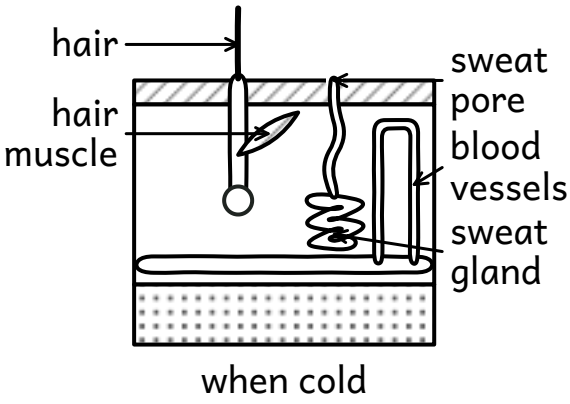
On a hot day, a person sweats 500 g in an hour and all of it evaporates. How much heat does it take from the body?

1. Each gram that evaporates takes 2.4 kJ.
2. 500 × 2.4 = 1 200 kJ.

Answer: 1 200 kJ

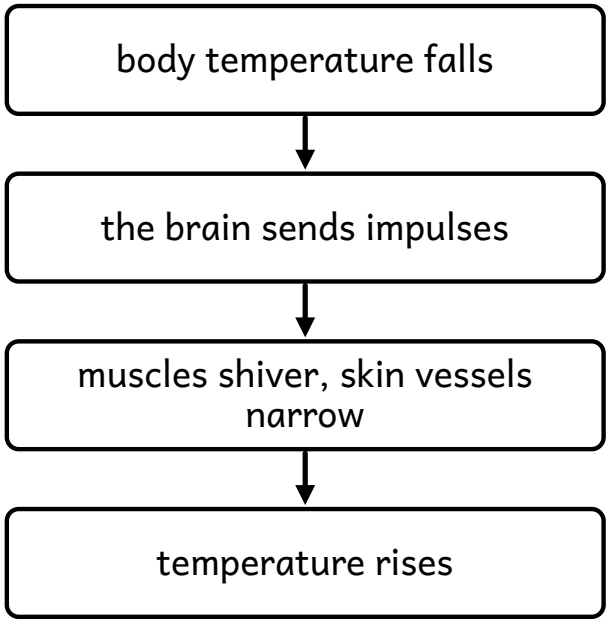
When the air is very damp, sweat evaporates slowly, so it cools you less. That is why a hot, damp day feels worse than a hot, dry one. A person who is very hot, confused and no longer sweating needs urgent help from a health worker.

In the cold, the body does the opposite. The vessels near the skin narrow, so less blood flows close to the surface and less heat is lost. The sweat glands stop. The hair stands up and traps a layer of air. In people this does little, and in furry animals it helps a lot.



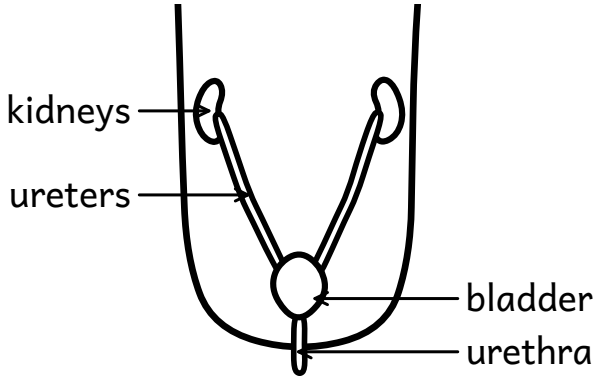
The skin when cold. The vessels are narrow, there is no sweat and the hair stands up. The long tube at the bottom is a deeper blood vessel, and the dotted layer is fat.

Shivering is rapid shaking of the muscles. The muscles contract and relax again and again. Their cells use more energy, and respiration in them releases heat. This warms the blood. You also put on warm clothes and move to shelter.



The body in the cold. As in the hot loop, the last step undoes the first.

Now water. You lose water every day in sweat, in breath and in urine, and you gain it in drink and in food. The body must keep the amount of water steady. The organs that do this are the **kidneys**. You have two, at the back of the trunk. A tube from each, the ureter, takes urine to the bladder. It leaves the body through the urethra.

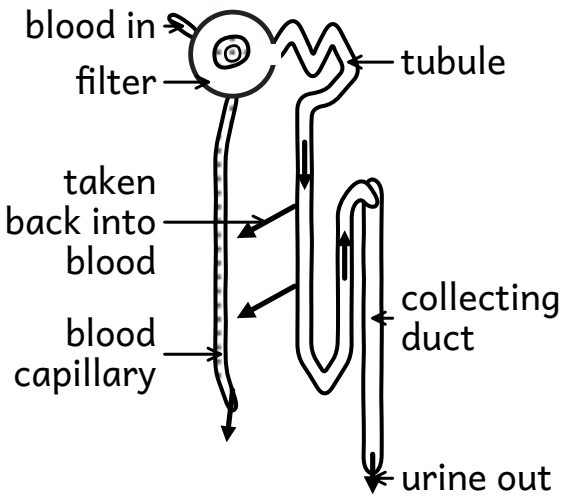


The kidneys, ureters, bladder and urethra, from the front, with the other organs left out. The kidneys lie against the back wall of the trunk, partly under the lowest ribs.

Each kidney holds about a million tiny filters called **nephrons**. Blood comes to the filter. Water, salts, glucose and **urea** pass out of the blood. Urea is a waste made in the liver from the breakdown of protein. Blood cells and big molecules stay in the blood.

The liquid then runs along a tubule. Here the body takes back what it needs. All the glucose goes back into the blood, and so does most of the water. The rest, with the

urea and the extra salts and water, goes down the collecting duct and out as urine.



One nephron. A real nephron has more parts. The loop in the tubule is drawn but not named.

The numbers are large. In a day, the kidneys filter about 180 L of liquid out of the blood. A person makes only about 1.5 L of urine. The rest goes back into the blood.

In a day	Litres
filtered	180 L
urine	1.5 L

Typical amounts for one day. They differ between people.

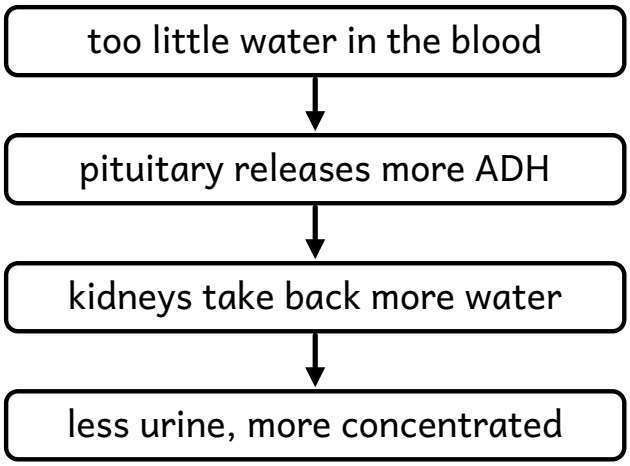
WORKED EXAMPLE

The kidneys filter 180 L in a day and a person makes 1.5 L of urine. What percentage of the filtered water goes back into the blood, to the nearest whole number?

1. The water taken back is 180 − 1.5 = 178.5 L.
2. As a fraction of the water filtered, 178.5 ÷ 180 = 0.99.
3. As a percentage, 0.99 × 100 = 99%.

Answer: 99%

How does the body control how much water leaves? The brain checks the water in the blood. If there is too little, the pituitary gland releases more **ADH** into the blood. ADH makes the kidney tubules take back more water. Less water is left, so the person makes less urine, and it is more concentrated.



When the body is short of water. When there is plenty of water, the pituitary releases less ADH. The kidneys take back less water, so more urine, and a paler one, leaves the body.

You can see the effect. When you drink little, or sweat a lot, your urine is small in amount and dark. When you drink a lot, it is large in amount and pale. Dark urine can mean that you need more water. In untreated diabetes, glucose can also appear in the urine, because the tubule cannot take back so much.

Drink	ADH	Urine
little	more	small, dark
a lot	less	large, pale

The control of water in one table.

TRY IT

Why sweat cools the skin

You need: a bowl of water at room temperature, a towel, a clock or a way of counting a minute.

Be safe: Use water at room temperature only. Never use hot water.

1. Dip the fingers and back of one hand in the water. Shake off the drops. Keep the other hand dry.
2. Hold both hands up in the air for one minute. Do not touch anything with them.
3. Compare how the two hands feel. Does one feel cooler?
4. Now blow gently on the wet hand, then on the dry hand. Compare again. Dry your hand on the towel.

What you will see: The wet hand feels cooler. When you blow on it, it feels cooler still, because moving air carries the water vapour away and the water evaporates faster. This is how sweat cools your skin. In very damp air the water evaporates slowly, so the cooling is smaller.

If you cannot try it, this is what happens.

Hand	Feels
wet	cooler
dry	same

A WRONG IDEA MANY PEOPLE HAVE

~~When you are hot, the blood vessels move closer to the skin to lose heat.~~

Why it feels right: Textbook pictures often show the vessels near the skin, and the skin looks redder when we are hot.

The test that breaks it: Blood vessels are fixed in place, and they cannot move. What changes is their width. When you are hot, the vessels near the skin widen, and more blood flows through them.

What is true: The vessels widen when you are hot and narrow when you are cold. They do not move. More blood near the surface means more heat leaves.

KEY WORDS

evaporation
a liquid turning into a gas at its surface, which takes heat from what is left.

shivering
rapid shaking of the muscles that releases heat.

kidneys
two organs that filter the blood and make urine.

nephrons
the tiny filters in the kidneys.

urea
a waste made in the liver from the breakdown of protein, which leaves in urine.

ADH
a hormone from the pituitary gland that makes the kidneys take back more water.

BACK TO YOUR GUESS

The answer is C: Sweat evaporates from the skin and takes heat away from the body.

Sweat takes heat from the skin when it evaporates. The blood vessels near the skin also widen, so that more heat can leave. Narrow vessels and raised hairs

happen in the cold.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. Why does the body keep its temperature steady, near the same value all the time?

   A The body can make heat only at that temperature.

   B The enzymes in the cells work best near that temperature.

   C Blood can flow only at that temperature.

   Answer at the back of the book.

2. Lucía is hot after running. Which describes what happens in her skin?

   A The blood vessels near the skin narrow and the hairs stand up.

   B The blood vessels near the skin widen and she shivers.

   C The blood vessels move closer to the skin and sweating stops.

   D The blood vessels near the skin widen and the sweat glands release sweat.

   Answer at the back of the book.

3. Why does a person shiver in the cold?

   A To make more sweat

   B To make the skin vessels widen

   C The muscles contract quickly and release heat.

   Answer at the back of the book.

4. How does sweat cool the body?

   A It evaporates and takes heat from the skin.

   B It is cold when it leaves the sweat gland.

   C It blocks the heat of the air from reaching the skin.

   Answer at the back of the book.

5. What do the kidneys do with the blood that reaches them?

   A They store it until the body needs it.

   B They turn all the water in it into urine.

   C They take back all the urea and let the water out.

   D They filter it, take back what the body needs and pass the rest out as urine.

   Answer at the back of the book.

6. Kofi sweats a lot on a hot day and drinks little. What happens to the ADH in his blood and to his urine?

   A There is less ADH, and his urine is large in amount and pale.

   B There is more ADH, and his urine is small in amount and dark.

   C There is more ADH, and his urine is large in amount and pale.

   Answer at the back of the book.

7. **From an earlier chapter**

   Which gland releases ADH into the blood?

   A The adrenal glands

   B The pituitary gland

   C The pancreas

   Answer at the back of the book.

8. A person sweats 300 g and all of it evaporates. Each gram takes 2.4 kJ of heat from the body. How much heat is taken, in kJ?

   Answer at the back of the book.

9. In a day the kidneys filter 170 L of liquid and a person makes 1.5 L of urine. How many litres go back into the blood?

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Hot: sweat evaporates, skin vessels widen. Cold: vessels narrow, shivering. Kidneys filter blood, take back what is needed. ADH from the pituitary makes them take back more water.

Draw: A nephron with blood in, the filter, the tubule, water taken back and urine out.

S4.5.7 CHAPTER 7

Hormones and the menstrual cycle

How does the body know when to release an egg, and when to start a period?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** Nerves carry signals from the brain to the uterus.
- ☐ **B** Hormones in the blood, from the pituitary gland and the ovaries, switch each other on and off.
- ☐ **C** The uterus keeps its own count of the days.

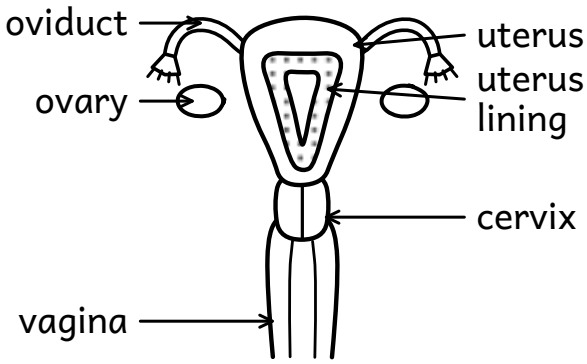
IF THIS FEELS HARD, READ THIS FIRST

- Level 3, Growing up: puberty and reproduction, S3.4.4. It names the ovaries, oviducts, uterus, cervix and vagina.
- Level 3, Growing up: puberty and reproduction, S3.4.5. It shows what a period is and how to stay clean and comfortable.
- Level 3, Growing up: puberty and reproduction, S3.4.6. It shows how a sperm and an egg join and how a pregnancy starts.

BY THE END YOU CAN

- Explain how hormones control the menstrual cycle
- Explain how hormones are used in contraception and fertility treatment

From puberty until periods stop later in life, the female body goes through a cycle about once a month. It is the menstrual cycle. Its job is to release an egg and get the uterus ready, in case a pregnancy starts.



The two ovaries hold the eggs. The lining of the uterus, drawn dotted, builds up and breaks down in each cycle.

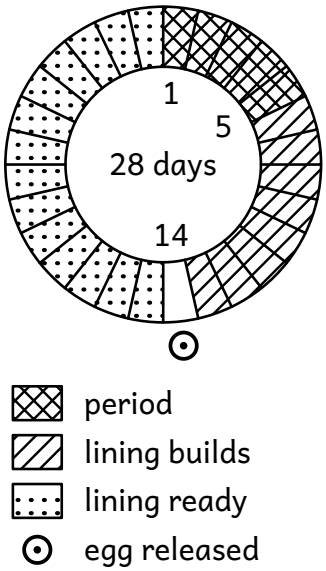
A cycle is about 28 days long on average. Anything from about 21 to 35 days is common. Cycles differ between people, and from one month to the next. In the first years after periods start, they are often irregular.

Day 1 of a cycle is the first day of bleeding. The lining of the uterus breaks down and leaves through the vagina as blood. This is **menstruation**, also called a period. Most periods last about 2 to 7 days.

After the period, the lining builds up again. Around day 14 of a 28 day cycle, one ovary releases an egg. This is **ovulation**. The egg moves along the oviduct toward the uterus.

If the egg is not fertilised, it dies within about a day. The lining is kept for about two more weeks, then it breaks down. That is the next period, and a new cycle starts.

If the egg is fertilised and settles into the lining, a pregnancy starts. The lining is kept, so there are no periods during the pregnancy.



A 28 day cycle. The period here is days 1 to 5, and the egg is released about day 14.

Ovulation comes about 14 days before the next period starts. So in a longer cycle, ovulation comes later, and in a shorter cycle it comes sooner.

WORKED EXAMPLE

Amina's cycles are about 26 days long. About which day of her cycle is ovulation?

1. Ovulation comes about 14 days before the next period starts.
2. 26 − 14 = 12.

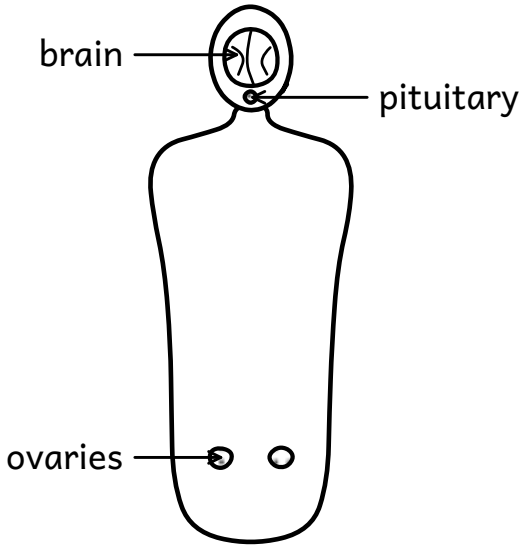
Answer: About day 12

part of cycle	days
whole cycle	26 days
second half	14 days
ovulation	about day 12

Amina's 26 day cycle. The egg is released about day 12, still about 14 days before the next period.

These days are averages. The real day of ovulation can move by several days, even in the same person. So counting days alone cannot say for sure when an egg is released.

What controls all this? Four hormones. Two are made by the pituitary gland, a small gland under the brain. Two are made by the ovaries. All four travel in the blood.



The glands that control the cycle. Hormones from the pituitary gland reach the ovaries in the blood. Hormones from the ovaries reach the pituitary gland the same way.

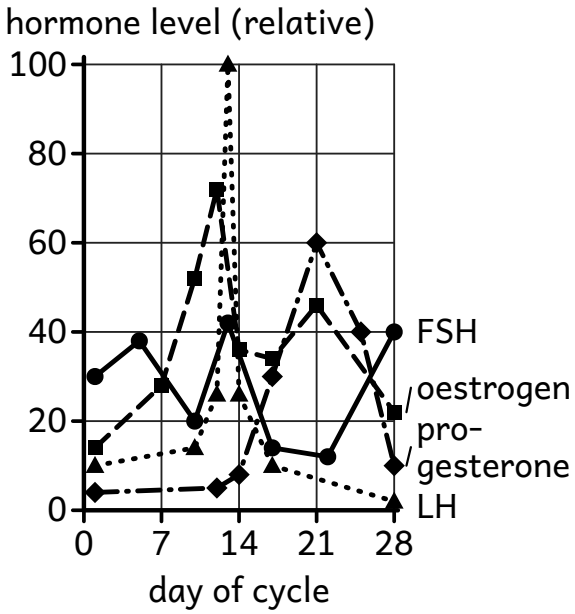
FSH (follicle stimulating hormone) is made by the pituitary gland. It makes an egg mature inside the ovary. It also makes the ovary produce oestrogen.

Oestrogen is made by the ovaries. It makes the lining of the uterus build up again after a period. As it rises, it holds back FSH, so no more eggs start to mature.

When oestrogen is high, it makes the pituitary gland release a sudden burst of **LH** (luteinising hormone). This burst is the LH surge. It causes ovulation.

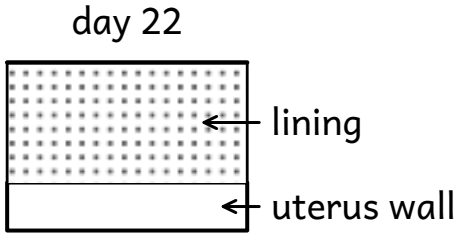
After ovulation, the part of the ovary that held the egg makes **progesterone**, and some oestrogen. Progesterone keeps the lining thick and ready. It also holds back FSH and LH, so no new egg matures.

If no pregnancy starts, progesterone falls near the end of the cycle. Without it, the lining breaks down and the period starts. FSH is no longer held back, so it rises and a new cycle begins.

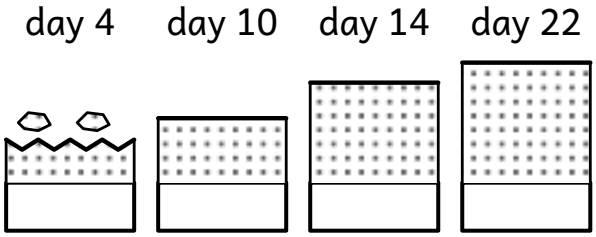


Each hormone is drawn on its own scale, so the graph has no unit. Compare the shapes and the timing, not the heights. Real levels differ between people.

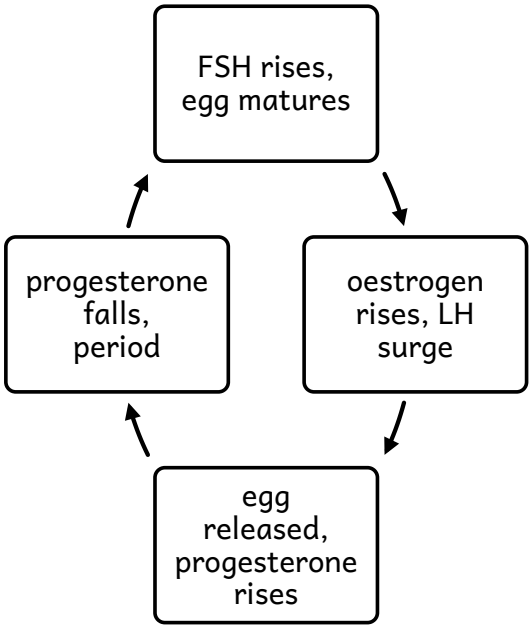
Read the graph from left to right. FSH is high early on. Oestrogen peaks just before the LH surge. The LH surge peaks just before day 14, and ovulation follows. Progesterone is high in the second half.



The lining on day 22, thick and ready, held there by progesterone.



The lining is shed during the period, built up by oestrogen, then kept thick by progesterone.



Each hormone switches the next one on or holds another back. That is why the cycle repeats.

TRY IT

Draw two made-up cycles on paper

You need: paper, a pencil, a ruler.

1. Draw a row of 28 boxes and number them 1 to 28. This is a made-up 28 day cycle.
2. Shade boxes 1 to 5 for the bleeding. Write "lining builds" over boxes 6 to 13. Draw a small egg in box 14.
3. From the graph in this chapter, write oestrogen over box 12, LH over box 13 and progesterone over box 21. Each is highest there.
4. Draw a second row of 32 boxes. The egg goes in box 18, because 32 − 14 = 18. Count the boxes after the egg in each row.

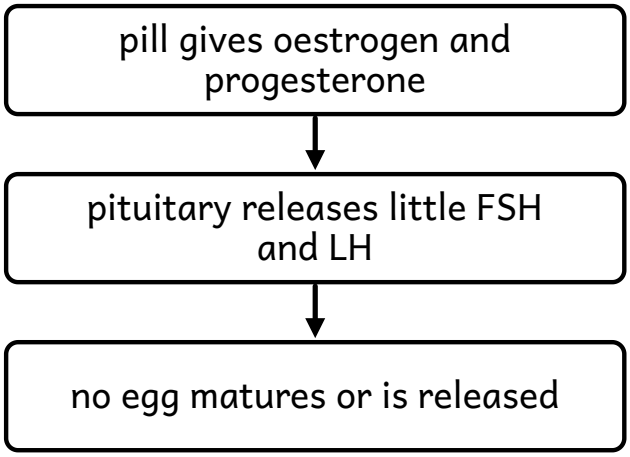
What you will see: Both rows have 14 boxes after the egg. In the longer cycle the first half is longer, but the second half stays about 14 days.

If you cannot try it, this is what happens.

cycle length	ovulation
28 days	about day 14
32 days	about day 18

Contraception means ways to prevent pregnancy. Some ways use hormones. The hormones in them are made to work like the body's own oestrogen and progesterone.

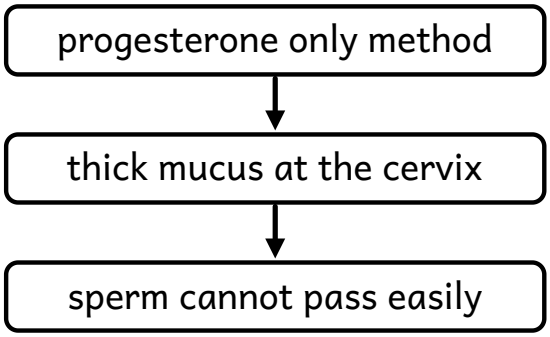
The combined pill contains oestrogen and progesterone. Taken as a health worker explains, these hormones hold back FSH and LH. So no egg matures, and none is released. The pill also thickens the mucus at the cervix.



How the combined pill stops ovulation. It uses the same holding back the body's own hormones do in every cycle.

Progesterone only methods include a pill, an injection, a small implant under the skin of the arm, and a hormonal coil. A health worker places the coil in the uterus.

All of them thicken the mucus at the cervix, so sperm cannot easily get through. Some also stop ovulation, and the hormonal coil keeps the lining thin.



Every progesterone only method does this. The injection, the implant and some pills also stop ovulation.

Used correctly every time, hormone methods are very effective. A missed or late pill makes the pill less reliable. An implant, an injection or a coil does not need remembering each day, so it fails less often.

Hormone methods can have side effects, such as changes in bleeding, headaches or changes in mood. These differ between people. Rarely, combined methods cause blood clots, so a health worker checks health first. A health worker can help choose a method that suits.

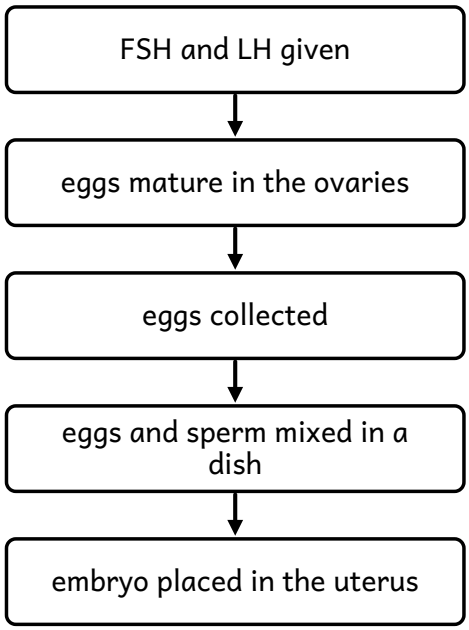
No hormone method protects against sexually transmitted infections. Only condoms also give that protection.

Some people find it hard to become pregnant. One cause is that eggs do not mature, or are not released. Hormones can help with this.

In fertility treatment, a health worker can give FSH and LH. FSH helps eggs mature, and LH helps them be released. Several eggs may mature at once, so twins are more likely.

IVF (in vitro fertilisation) goes further. First FSH and LH are given, so several eggs mature. The eggs are collected from the ovaries with a fine needle.

In a dish in a laboratory, the eggs are mixed with sperm. Some are fertilised and grow for a few days into small balls of cells, called embryos. One embryo, or sometimes two, is placed in the uterus.



The steps of IVF. Fertilisation happens in the dish, outside the body.

Fertility treatment does not always work. Many tries do not lead to a pregnancy. It can be hard on the body and on the feelings, and the hormones can have side effects.

Periods are a normal, healthy part of life. They are not dirt, and they are not an illness.

Pads, cloths, tampons and cups, and how to use each safely, are in the Growing up chapter "The menstrual cycle". Some pain low in the belly is common.

Be safe. Tell an adult you trust or a health worker if bleeding is very heavy. Very heavy means soaking a pad in an hour or two. Tell one if periods are

very painful. Tell one about bleeding between periods, or a period of more than 7 days. Tell one if periods stop for 3 months and pregnancy is not the reason. Tell one if anything about periods worries you.

Nobody may touch your body without your yes. That is true for everyone, every time. If anyone does, it is not your fault. Tell an adult you trust or a health worker.

A WRONG IDEA MANY PEOPLE HAVE

~~A person cannot get pregnant during a period.~~

Why it feels right: Ovulation usually comes in the middle of the cycle, far from the period.

The test that breaks it: Sperm can live in the body for up to about 5 days. In a short cycle, ovulation can come soon after a period ends, while sperm are still alive.

What is true: Pregnancy is less likely during a period, but it can happen. Counting days alone is a less reliable way to avoid pregnancy.

KEY WORDS

menstruation
the lining of the uterus breaking down and leaving the body as blood; a period.

ovulation
an ovary releasing an egg, about 14 days before the next period.

FSH
a hormone from the pituitary gland that makes an egg mature.

oestrogen
a hormone from the ovaries that builds up the lining of the uterus.

LH
a hormone from the pituitary gland whose surge causes ovulation.

progesterone
a hormone from the ovaries that keeps the lining thick.

contraception
ways to prevent pregnancy.

IVF
fertility treatment in which eggs are fertilised with sperm in a dish.

Where to get help: a nurse, a doctor, a health worker at a clinic or a pharmacist. Each of them can answer questions about periods, contraception and fertility. An adult you trust can help you reach one. Health workers hear these questions every day.

BACK TO YOUR GUESS

The answer is B: Hormones in the blood, from the pituitary gland and the ovaries, switch each other on and off.

Four hormones control the cycle. Two come from the pituitary gland and two from the ovaries. They travel in the blood and switch each other on and off, so the cycle repeats.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. Which gland makes FSH and LH?

   A The ovaries

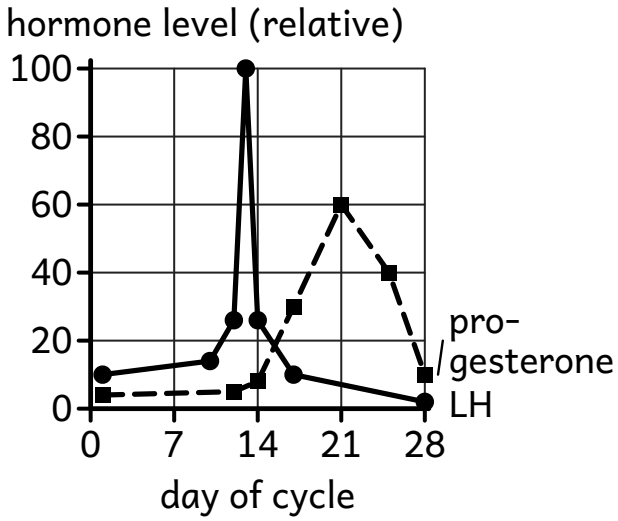
   B The pituitary gland

   C The pancreas

   D The uterus

   Answer at the back of the book.

2. The graph shows LH and progesterone in one 28 day cycle. On about which day does LH reach its peak?



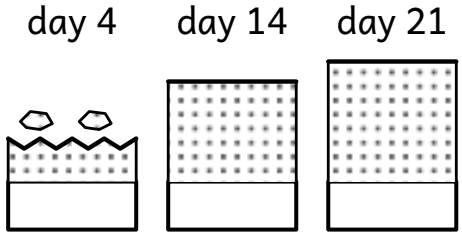
A Day 28

B Day 13

C Day 21

Answer at the back of the book.

3. The strips show the lining of the uterus on days 4, 14 and 21, all to one scale. On which day is the lining thickest?



A Day 4

B Day 14

C Day 21

Answer at the back of the book.

4. No egg is fertilised in a cycle. What makes the lining of the uterus break down at the end of the cycle?

   A A fall in progesterone

   B A surge of LH

   C A rise in oestrogen

   Answer at the back of the book.

5. Which sentence about the combined pill is true?

   A Its hormones hold back FSH and LH, so no egg is released.

   B It kills sperm inside the body.

   C It also protects against sexually transmitted infections.

   D It works just as well when pills are missed.

   Answer at the back of the book.

6. Which sentence about pregnancy and periods is true?

   A A person cannot get pregnant during a period.

   B Pregnancy can only start if sex happens on day 14 exactly.

   C Pregnancy is less likely during a period, but it can happen.

   Answer at the back of the book.

7. In fertility treatment, why might a health worker give FSH?

   A To stop ovulation

   B To help eggs mature in the ovaries

   C To thicken the mucus at the cervix

   Answer at the back of the book.

8. In IVF, where are the eggs and sperm joined?

   A In the oviduct, as without treatment

   B In the uterus, after the eggs are placed there

   C In a dish in a laboratory

   Answer at the back of the book.

9. Ovulation comes about 14 days before the next period starts. Leila's cycles are about 30 days long. About which day of her cycle is ovulation?

   Answer at the back of the book.

10. In one cycle, ovulation is about day 19. Ovulation comes about 14 days before the next period starts. About how long is the cycle?

    Answer at the back of the book.

11. **From an earlier chapter**

    How do FSH and LH travel from the pituitary gland to the ovaries?

    A In the blood

    B Along nerves

    C Through the oviducts

    Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

FSH from the pituitary matures an egg. Oestrogen builds the lining and sets off LH. LH releases the egg. Progesterone keeps the lining thick; when it falls, a period starts. The pill holds back FSH and LH.

Draw: Draw the 28 day hormone graph with FSH, oestrogen, LH and progesterone, and mark the LH surge just before day 14.

S4.5.8 CHAPTER 8

Plant responses

Seedlings grow in a closed box with one hole in its side. Which way will their shoots grow?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** Away from the hole, into the dark.
- ☐ **B** Towards the hole, where the light comes in.
- ☐ **C** Straight up, because a plant always grows upwards.

IF THIS FEELS HARD, READ THIS FIRST

- Level 2, How plants grow, S2.1.4. It compares plants grown with and without light.
- Level 2, How plants grow, S2.1.1. It names the root and the shoot and gives the jobs of each.
- Level 4, Cells, photosynthesis and respiration, S4.1.6. It shows why leaves need light.
- Level 2, Forces: friction, falling and floating, S2.5.5. It says that gravity pulls things towards the centre of the Earth.

BY THE END YOU CAN

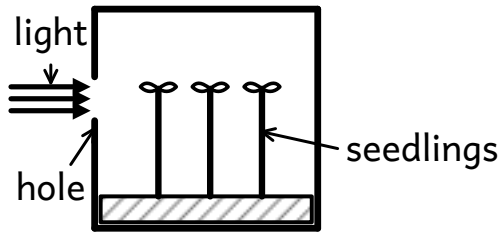
- Explain how auxin makes shoots grow towards light
- Show seedlings bending towards light in a box with one hole

A plant on a windowsill leans towards the window, and its roots grow down. A plant cannot run from danger or walk to food. It responds by growing. The way a plant grows is set by what acts on it. Growth in a direction set by a stimulus is a **tropism**. The two you will study are light and gravity.

Take seedlings in a closed box. The box has one hole in one side, so light comes from that side only. Look at the seedlings at the start, and again after a few days.

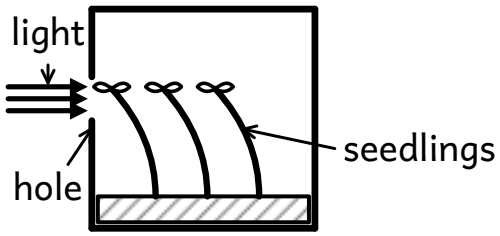
DRAW IT FIRST

Seedlings in a box with one hole



at the start

1 At the start, the shoots stand straight up. Light comes in through the hole.



a few days later

2 A few days later, every shoot has bent so that its tip points at the hole.

This is **phototropism**: growth in a direction set by light. A shoot grows towards the light. This helps the plant, because its leaves then get more light for photosynthesis.

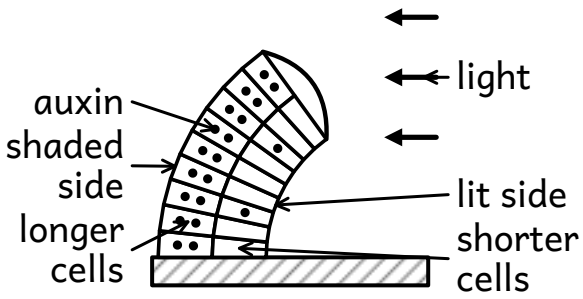
How does the shoot know where the light is? In the 1880s Charles Darwin and his son Francis tested young grass shoots with light from one side. A shoot with its tip covered by a small cap did not bend. A shoot with its base covered still did. So the tip is what senses the light.

Test	Result
tip uncovered	bends
tip covered	no bend
tip cut off	no bend
base covered	bends

Shoots with light from one side. The tip senses the light.

The tip makes a plant hormone, **auxin**. Auxin moves down the shoot to the cells behind the tip, and it makes them grow longer. Cells grow longer by taking in water and stretching. A plant has no blood, so auxin passes from cell to cell.

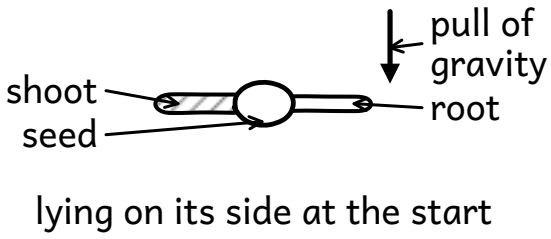
When light comes from one side, auxin moves to the shaded side. There is more auxin on the shaded side, so the cells there grow longer than the cells on the lit side. The shaded side becomes longer, and the shoot bends towards the light.



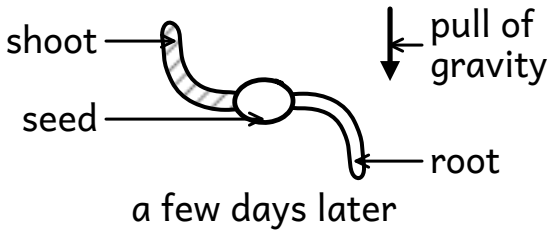
A model of a shoot tip. The dots show auxin. The cells on the shaded side are longer. The longer side is on the outside of the bend.

Gravity acts on plants too. **Gravitropism** is growth in a direction set by gravity. A shoot grows up, away from the pull of gravity. A root grows down, in the direction of the pull. Even a seed that is planted upside down sends its root down and its shoot up.

Lay a seedling on its side. Auxin collects on the lower side of both the shoot and the root. In a shoot, more auxin makes the cells grow longer. So the lower side grows faster, and the shoot turns up. In a root, a lot of auxin slows growth. So the lower side grows more slowly, and the root turns down.



A seedling on its side at the start. The shoot and the root both point sideways.



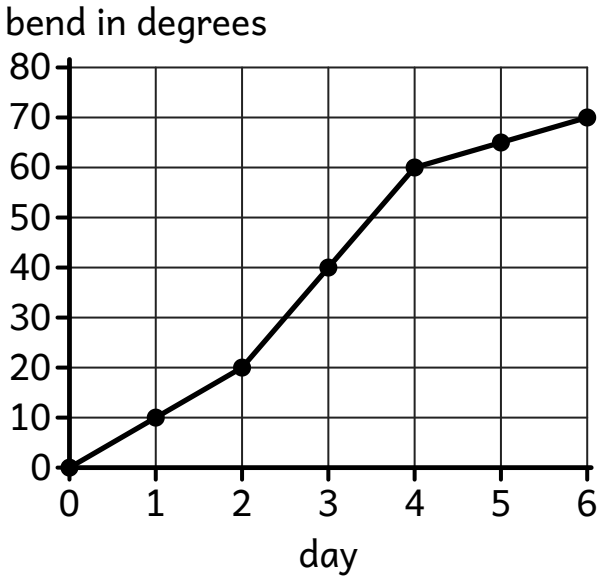
A few days later. The shoot has turned up and the root has turned down. This happens in the dark too, so it is not a response to light.

Part	Grows	Auxin below
shoot	up	speeds growth
root	down	slows growth

On a seedling lying on its side, auxin collects on the lower side. It speeds growth in a shoot and slows it in a root.

Plants respond to other things too. Roots grow towards water. The tendrils of a pea or a vine curl round whatever they touch. Each response helps the plant to find what it needs. A plant that grows towards light and its roots towards water has more to live on.

Now some numbers. A learner grew a seedling in a box with a hole. Each day they measured the bend of its shoot, as an angle from straight up. The graph shows example results. Read it, then work out how fast the shoot bent.



Example data. The bend of a shoot, in degrees from upright, each day. Real seedlings differ.

WORKED EXAMPLE

What was the mean rate of bending from day 2 to day 4, in degrees per day?

1. Read the graph. On day 2 the bend is 20 degrees. On day 4 it is 60 degrees.
2. The bend grew by 60 − 20 = 40 degrees in 4 − 2 = 2 days.
3. Divide: 40 ÷ 2 = 20 degrees per day.

Answer: 20 degrees per day

WORKED EXAMPLE

What was the mean rate of bending over all six days, to 1 decimal place?

1. Read the graph. On day 0 the bend is 0 degrees. On day 6 it is 70 degrees.
2. The bend grew by 70 − 0 = 70 degrees in 6 days.
3. Divide: 70 ÷ 6 = 11.7 degrees per day.

Answer: 11.7 degrees per day

TRY IT

Seedlings in a box with one hole

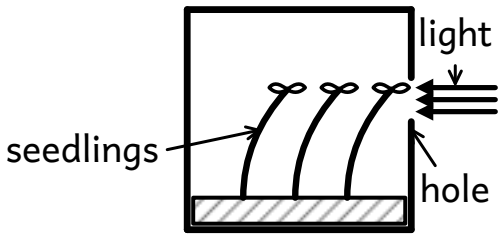
You need: a cardboard box, such as a shoebox, with a lid, two cups or tins with damp soil, or damp cotton wool or cloth, six beans or other seeds, water, a bright window or a bright place, a pencil and paper.

Be safe: Do not eat the seeds or the seedlings. Some raw seeds, such as beans, can make people ill. Ask an adult to cut the hole, or tear thin card. Do not use a knife yourself.

1. Soak the seeds in water for a night. Put three in the damp soil or cotton wool in each cup, and keep both cups damp.
2. Put one cup in the box, at the end opposite the hole. Ask an adult to cut a hole the size of a coin in one side wall. Or tear a hole in thin card. Put the lid on.
3. Stand the box with the hole facing a bright window. Do not move it. Give the seedlings a little water each day, and open the box for a moment to check them.
4. Put the second cup in the open, in the same room, with no box. Look at both after a few days.
5. Draw the seedlings in the box and write down which way the shoots point.

What you will see: In the box the shoots bend towards the hole, where the light comes in. In the open the shoots grow straight up. The time it takes depends on the seeds and on how warm it is. It is often three to seven days. The picture shows an example, with the hole on the other side.

If you cannot try it, this is what happens.



a few days later

A WRONG IDEA MANY PEOPLE HAVE

~~A shoot bends towards light because the cells on the lit side grow more.~~

Why it feels right: Light helps a plant, so it seems that the side with the light should grow more.

The test that breaks it: Auxin moves to the shaded side. The cells there grow longer than the cells on the lit side. In the model picture, the longer cells are on the outside of the bend, on the side away from the light.

What is true: The shaded side grows more, not the lit side. Because the shaded side gets longer, the shoot curves round towards the light.

KEY WORDS

tropism
growth in a direction that is set by a stimulus.

phototropism
growth in a direction set by light. A shoot grows towards light.

gravitropism
growth in a direction set by gravity. A shoot grows up and a root grows down.

auxin
a plant hormone made in the shoot tip that makes cells grow longer.

BACK TO YOUR GUESS

The answer is B: Towards the hole, where the light comes in.

The shoots bend towards the hole. A plant hormone called auxin gathers on the shaded side of the shoot, and the cells there grow longer. That bends the shoot towards the light.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. What is phototropism?

    A Growth in a direction that is set by the direction of light

    B The making of food by a plant, using light

    C The folding of leaves when you touch them

    Answer at the back of the book.

2. Where is auxin made in a shoot?

    A In the roots

    B In the leaves only

    C In the shoot tip

    Answer at the back of the book.

3. Light shines on a shoot from the right. What happens?

    A Auxin gathers on the right, and the cells there grow longer, so the shoot bends left.

    B Auxin gathers on the left, and the cells there stop growing, so the shoot bends left.

    C Auxin stays spread out evenly, and the shoot grows straight up.

    D Auxin gathers on the left, and the cells there grow longer, so the shoot bends right.

    Answer at the back of the book.

4. A bean seedling is laid on its side in the dark. A few days later, what has the root done?

    A It has turned up.

    B It has turned down.

    C It has kept growing sideways.

    D It has stopped growing.

    Answer at the back of the book.

5. How does it help a plant when its shoot grows towards light?

   A The roots can then get light too.

   B The shoot keeps cooler.

   C The leaves get more light for photosynthesis.

   Answer at the back of the book.

6. In the box experiment, why does the box have only one hole?

   A So that light reaches the seedlings from one side only

   B So that the seedlings get no light at all

   C So that the air cannot reach the seedlings

   Answer at the back of the book.

7. **From an earlier chapter**

   Which statement is true of both auxin and a hormone such as insulin?

   A Both are chemical messengers.

   B Both are carried in the blood.

   C Both are made by glands.

   Answer at the back of the book.

8. A shoot bent from 20 degrees on day 2 to 60 degrees on day 4. What was the mean rate of bending, in degrees per day?

   Answer at the back of the book.

9. A shoot bends at a steady 12 degrees per day. How many degrees has it bent after 5 days?

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Light from one side: auxin moves to the shaded side, the cells there grow longer, the shoot bends towards the light. Gravity: shoots grow up, roots grow down.

Draw: A shoot bending towards a light, with dots of auxin on the shaded side.

Key words, A to Z

Every key word in this book, what it means, and the chapter that teaches it.

ADH
a hormone from the pituitary gland that makes the kidneys take back more water. S4.5.6

adrenal glands
two glands on top of the kidneys that make adrenaline. S4.5.4

adrenaline
a hormone that gets the body ready for danger. S4.5.4

auxin
a plant hormone made in the shoot tip that makes cells grow longer. S4.5.8

central nervous system
the brain and the spinal cord, where messages are sorted and orders are sent. S4.5.1

cerebellum
the part of the brain at the back that helps with balance and smooth movement. S4.5.1

cerebrum
the large top part of the brain, used for thinking, memory and speech. S4.5.1

ciliary muscle
a ring of muscle round the lens that changes the shape of the lens. S4.5.3

contraception
ways to prevent pregnancy. S4.5.7

cornea
the clear window at the front of the eye. It bends light most. S4.5.3

diabetes
a condition in which the body cannot keep blood glucose steady. S4.5.5

effector
a muscle or a gland that makes a response. S4.5.1

evaporation
a liquid turning into a gas at its surface, which takes heat from what is left. S4.5.6

FSH

a hormone from the pituitary gland that makes an egg mature. S4.5.7

gland
an organ that makes a chemical and releases it. S4.5.4

glucagon
a hormone from the pancreas that raises blood glucose. S4.5.5

glycogen
a store of glucose, kept in the liver and the muscles. S4.5.5

gravitropism
growth in a direction set by gravity. A shoot grows up and a root grows down. S4.5.8

homeostasis
keeping conditions inside the body steady. S4.5.5

hormone
a chemical messenger that is made by a gland and carried in the blood. S4.5.4

insulin
a hormone from the pancreas that lowers blood glucose. S4.5.5

iris
the coloured ring with muscles that change the size of the pupil. S4.5.3

IVF
fertility treatment in which eggs are fertilised with sperm in a dish. S4.5.7

kidneys
two organs that filter the blood and make urine. S4.5.6

lens
the part behind the pupil that changes shape to focus light. S4.5.3

LH
a hormone from the pituitary gland whose surge causes ovulation. S4.5.7

medulla
the part of the brain that controls heart rate and breathing. S4.5.1

menstruation
the lining of the uterus breaking down and leaving the body as blood; a period. S4.5.7

negative feedback
a change that sets off a response which reverses the change. S4.5.5

nephrons

the tiny filters in the kidneys. S4.5.6

neurone
a nerve cell. It carries impulses. S4.5.1

oestrogen
a hormone from the ovaries that builds up the lining of the uterus. S4.5.7

optic nerve
the nerve that carries impulses from the retina to the brain. S4.5.3

ovulation
an ovary releasing an egg, about 14 days before the next period. S4.5.7

pancreas
a gland behind the stomach that makes insulin and glucagon. S4.5.4

phototropism
growth in a direction set by light. A shoot grows towards light. S4.5.8

pituitary gland
a small gland under the brain that releases hormones, some of which control other glands. S4.5.4

progesterone
a hormone from the ovaries that keeps the lining thick. S4.5.7

pupil
the hole in the middle of the iris, where light goes in. S4.5.3

reaction time
the time from a stimulus to your response. S4.5.2

receptor
a cell that detects a stimulus, such as light, heat or pressure. S4.5.1

reflex
a quick, automatic response that you do not decide. S4.5.2

reflex arc
the path of a reflex: receptor, sensory neurone, relay neurone, motor neurone, effector. S4.5.2

retina
the layer at the back of the eye with receptors for light. S4.5.3

shivering
rapid shaking of the muscles that releases heat. S4.5.6

suspensory ligaments

fibres that join the ciliary muscle to the lens and hold it in place. S4.5.3

synapse
the gap between two neurones, which a chemical crosses. S4.5.1

target organ
an organ with receptor sites for a hormone, which responds to it. S4.5.4

thyroid gland
a gland in the neck that makes thyroxine. S4.5.4

tropism
growth in a direction that is set by a stimulus. S4.5.8

type 1 diabetes
diabetes in which the pancreas makes too little insulin. S4.5.5

type 2 diabetes
diabetes in which the cells respond badly to insulin. S4.5.5

urea
a waste made in the liver from the breakdown of protein, which leaves in urine. S4.5.6

Answers

S4.5.1. The nervous system

1. **receptor, sensory neurone, brain or spinal cord, motor neurone, effector**

   The receptor detects the stimulus. A sensory neurone takes the impulse in. The brain or spinal cord sorts it. A motor neurone takes the order out to the effector.

   - **If you chose A:** The two kinds of neurone are the wrong way round. A sensory neurone carries the message in. A motor neurone carries the order out.
   - **If you chose C:** This path runs backwards. A message starts at a receptor and ends at an effector.

2. **The axon**

   The fatty sheaths wrap the axon in pieces. An impulse jumps along the gaps between the pieces, which is much faster than running along bare fibre.

   - **If you chose A:** Dendrites are the branched ends that receive impulses. They have no sheath.
   - **If you chose B:** The cell body holds the nucleus. The sheaths are along the long fibre, not on the body.
   - **If you chose D:** The nerve endings pass the impulse on at the synapse. The sheaths are along the axon.

3. **A relay neurone**

   A relay neurone stays inside the brain or spinal cord. It receives the impulse from a sensory neurone and passes it on to a motor neurone.

   - **If you chose B:** A motor neurone carries orders from the central nervous system out to a muscle or gland. It is a long neurone.
   - **If you chose C:** A sensory neurone carries impulses in from a receptor. It is long, and it runs from the skin or an organ to the spinal cord.

4. **A chemical crosses the gap and sets off a new impulse.**

   The first neurone releases a chemical. It spreads across the synapse and fits receptor sites on the next neurone, which starts a new impulse.

   - **If you chose A:** The impulse stops at the end of the first neurone. It cannot cross a gap as a spark.
   - **If you chose B:** They stay separate. There is always a gap between them.

5. **The medulla**

   The medulla joins the brain to the spinal cord. It keeps the heart beating and the lungs breathing without any thought.

   - **If you chose B:** The cerebrum is for thinking, memory and speech. Your heart and breathing carry on even when you sleep and do not think.
   - **If you chose C:** The cerebellum helps with balance and smooth movement, not with heart rate and breathing.

6. **The cerebellum**

   The cerebellum takes reports about position and movement and helps the muscles work smoothly together to keep balance.

   - **If you chose A:** The medulla controls heart rate and breathing. It does not do balance.
   - **If you chose C:** The spinal cord carries impulses between the brain and the body. The balance is worked out in the cerebellum, in the brain.

7. **15 ms**

   Time = distance ÷ speed = 1.5 ÷ 100 = 0.015 s. One second is 1 000 ms, so 0.015 s is 15 ms.

8. **100 times**

   100 ÷ 1 = 100, so the fibre with the sheath is 100 times as fast.

S4.5.2. Reflexes

1. **A quick, automatic response to a stimulus that you do not decide.**

   A reflex is fast and automatic. It uses a short path of neurones, and it often protects you from harm.

   - **If you chose A:** That describes a decision. A reflex is automatic, and it does not wait for you to plan.
   - **If you chose B:** A reflex still uses nerve impulses. They follow a short path called the reflex arc.

2. **receptor, sensory neurone, relay neurone, motor neurone, effector**

   The receptor starts the impulse. The sensory neurone carries it to the spinal cord. The relay neurone passes it to the motor neurone, which carries it to the effector.

   - **If you chose B:** In a reflex the impulse does not wait for the brain. A relay neurone in the spinal cord passes it from the sensory to the motor neurone.
   - **If you chose C:** The neurones are in the wrong order. The sensory neurone comes first, because it carries the impulse in from the receptor. Go to S4.5.1.

3. **The path is shorter, with fewer synapses, and no decision is needed.**

   A reflex uses only a few neurones and two synapses. A decision uses the brain, with many more neurones and synapses, so it takes longer.

   - **If you chose A:** Impulses travel at much the same speed along similar neurones. The reflex is faster because its path is shorter.
   - **If you chose C:** The muscle works at the same speed. The time saved is in the nerve path, before the muscle starts.

4. **Other impulses must travel all the way up to the brain, which takes longer than the reflex.**

   The reflex arc is short. The impulses to the brain have a longer path, so the brain tells him about the heat after the hand has moved.

   - **If you chose A:** The pain starts in the receptors of the skin, not in the muscle. The muscle moves because of the reflex.
   - **If you chose C:** The brain does not switch it off. The pain message simply takes a longer path than the reflex does.

5. **Catching a ball that someone throws to you**

   You decide to catch a ball, and you can learn to do it better. A reflex is automatic, and you do not choose it.

   - **If you chose B:** This is a reflex. It protects the eye and happens without a decision.
   - **If you chose C:** This is a reflex. It protects the eye from too much light, and you cannot decide it.

6. **Mei has a longer reaction time.**

   The ruler speeds up as it falls, so a longer fall means more time has passed. Mei took longer to respond than Hana.

   - **If you chose A:** The test does not measure a reflex. It measures the time for a decision and a response.
   - **If you chose B:** The further the ruler falls, the more time has passed. Mei took longer to catch it.

7. **A chemical**

   The first neurone releases a chemical. It crosses the synapse and sets off an impulse in the next neurone.

   - **If you chose A:** The impulse does not cross the gap as a spark.
   - **If you chose B:** Blood does not carry the message across a synapse.
   - **If you chose D:** The neurones stay apart, with a gap between them.

8. **226 ms**

   The ruler fell 0.25 m. $t = \sqrt{(2 \times 0.25 \div 9.8)} = \sqrt{0.051} = 0.226$ s, which is 226 ms.

9. **4 times**

   200 ÷ 50 = 4, so his reaction time is 4 times as long as the reflex.

S4.5.3. The eye

1. **The retina**

   The retina lines the back of the eye. Its receptors, the rods and cones, detect the light and start impulses in the optic nerve.

   - **If you chose B:** The cornea is the clear window at the front of the eye. It bends light, but it has no receptors.
   - **If you chose C:** The iris is the coloured ring. Its muscles change the size of the pupil.
   - **If you chose D:** The lens bends light and changes shape to focus. The receptors are in the retina, at the back.

2. **The circular muscles contract and the pupil gets smaller.**

   In bright light the circular muscles contract and the radial muscles relax. The pupil gets smaller and protects the retina.

   - **If you chose A:** Radial muscles contract in dim light, and that widens the pupil. In bright light the pupil gets smaller.
   - **If you chose C:** When the circular muscles contract, they pull the pupil smaller, not wider.
   - **If you chose D:** The radial muscles run outwards like spokes. When they contract they pull the pupil wider.

3. **To let more light reach the retina**

   A wider pupil has a larger area, so more light enters. This helps the retina to work in dim light.

   - **If you chose A:** The pupil gets smaller to protect the retina in bright light. In dim light the pupil must let in all the light it can.
   - **If you chose B:** The size of the pupil does not change the lens. The ciliary muscle changes the lens.

4. **The ciliary muscle contracts, the ligaments slacken and the lens gets fatter.**

   Light from a near object needs more bending. The lens must be fatter. The contracted ciliary muscle lets the ligaments go slack, and the elastic lens becomes fatter.

   - **If you chose B:** When the ciliary muscle contracts, the ligaments slacken, not tighten. Then the lens springs fatter.
   - **If you chose C:** That is what happens when you look at something far away. A near object needs a fatter lens.

5. **They pull tight, and the lens gets thinner.**

   For a far object the ciliary muscle relaxes, so the ligaments pull tight and stretch the lens thin. A thin lens bends light less, which suits light from far away.

   - **If you chose A:** The ligaments slacken for near objects. For a far object they pull tight.
   - **If you chose C:** The lens does not move. The ligaments change its shape.

6. **Short sight**

   In short sight, light from far things meets in front of the retina, so far things look blurred. Near things are clear. Glasses with the right lens can fix this.

   - **If you chose A:** Long sight is the other way round. Near things are blurred and far things are clear.
   - **If you chose B:** A damaged nerve would affect the whole picture, not only far things. Blurred far sight with a clear near sight is short sight.

7. **The muscles of the iris**

   An effector is a muscle or a gland that makes the response. The muscles of the iris change the size of the pupil.

   - **If you chose A:** The retina holds the receptors. They sense the light and start the impulse. Go to S4.5.2.
   - **If you chose B:** The optic nerve carries the impulses from the retina to the brain. It is a sensory path.

8. **12.6 mm^2**

   The radius is 2 mm. $A = \pi \times 2 \times 2 = 12.6\ mm^2$.

9. **9 times**

   The width is 3 times as big, and area goes with the width squared: $3 \times 3 = 9$. Check: $\pi \times 3 \times 3 = 28.3$ and $\pi \times 1 \times 1 = 3.14$, and $28.3 \div 3.14 = 9$.

S4.5.4. Hormones

1. **It is carried in the blood.**

   A gland releases the hormone into the blood. The blood carries it all round the body to the target organs.

   - **If you chose B:** Nerve impulses run along neurones. A hormone is a chemical, and the blood carries it. Go to S4.5.1.
   - **If you chose C:** A chemical crosses a synapse between neurones. A hormone goes in the blood, far beyond a synapse.

2. **They are slower, and their effects last longer.**

   A hormone has to be made, released and carried in the blood, so it arrives later. Its effect can last for minutes, hours or years.

   - **If you chose A:** It is the other way round. A hormone has to be carried in the blood, so it is slower.
   - **If you chose B:** Nerve impulses act in a fraction of a second. Hormones are slower, and last far longer.

3. **Only the target organs have receptor sites that fit the hormone.**

   A hormone fits only the receptor sites of its target cells, as a key fits one lock. The cells of other organs have no such sites.

   - **If you chose A:** Blood reaches every organ. The target organs are the ones that respond.
   - **If you chose C:** The hormone is not destroyed in other organs. They simply have no receptor sites for it, so they do not respond.

4. **The adrenal glands**

   The two adrenal glands lie on top of the kidneys. They release adrenaline, which gets the body ready for danger.

   - **If you chose A:** The thyroid makes thyroxine. It sets the rate of the chemical reactions in the body.
   - **If you chose B:** The pituitary releases growth hormone, ADH, FSH and LH and others. It does not release adrenaline.
   - **If you chose C:** The pancreas makes insulin and glucagon. They control blood sugar.

5. **The pituitary gland**

   The pituitary lies under the brain. Some of its hormones, such as FSH and LH, make other glands release their own hormones.

   - **If you chose B:** The thyroid makes thyroxine. It is controlled by a hormone from the pituitary.
   - **If you chose C:** The pancreas makes insulin and glucagon. Insulin and glucagon act mainly on the liver and muscles. They do not make other glands release hormones.

6. **The rate of the chemical reactions in the body**

   Thyroxine from the thyroid sets how fast the body's chemical reactions go.

   - **If you chose A:** Insulin and glucagon from the pancreas control blood sugar.
   - **If you chose C:** ADH from the pituitary controls the water in urine.

7. **A motor neurone**

   A motor neurone carries impulses out from the central nervous system to an effector, which is a muscle or a gland.

   - **If you chose A:** A sensory neurone carries impulses in, from a receptor. Go to S4.5.1.
   - **If you chose B:** A relay neurone is short and stays inside the brain or spinal cord.

8. **3 000 times**

   60 s is 60 000 ms. 60 000 ÷ 20 = 3 000.

9. **0.04 s**

   One second is 1 000 ms. 40 ÷ 1 000 = 0.04 s.

S4.5.5. Blood sugar and diabetes

1. **It makes liver and muscle cells take glucose out of the blood.**

   Insulin lowers blood glucose. The liver stores the glucose it takes in as glycogen.

   - **If you chose A:** That is the job of glucagon. Insulin does the opposite.
   - **If you chose B:** Food is broken down by enzymes in the digestive system. Insulin is a hormone, and it acts after the glucose is in the blood. Go to S3.3.2.

2. **The pancreas releases glucagon, and the liver turns glycogen into glucose.**

   Glucagon makes the liver break down glycogen to glucose. The glucose enters the blood, and the level rises.

   - **If you chose B:** More insulin would lower the level further. When the level is low, the pancreas releases glucagon.
   - **If you chose C:** Insulin comes from the pancreas, not the liver. The liver releases glucose when glucagon tells it to.

3. **The response reverses the change that started it.**

   A rise in glucose leads to insulin, which lowers it. A fall leads to glucagon, which raises it. The response reverses the change, so the level stays near the same value.

   - **If you chose A:** That would be positive feedback. Here the response undoes the change.
   - **If you chose C:** There is a response. Insulin or glucagon is released.

4. **The pancreas makes too little insulin.**

   In type 1 diabetes the body's own defences destroy the cells that make insulin. Without insulin, glucose stays high in the blood.

   - **If you chose A:** That mixes up two things. In type 1 the problem is too little insulin, and eating sugar does not cause it.
   - **If you chose B:** Glucagon comes from the pancreas, not the liver. In type 1 the problem is that the pancreas makes too little insulin.
   - **If you chose C:** Sensing is not the main problem. The cells that make insulin have been destroyed, so little insulin is released, however high the level goes.

5. **A healthy diet and more exercise, with medicines from a health worker if needed**

   In type 2 diabetes the cells respond badly to insulin. A healthy diet, more exercise and a healthy body mass help them respond better. A health worker may also give medicines.

   - **If you chose A:** Diabetes is not catching. You cannot get it from another person.
   - **If you chose B:** Diet and exercise do matter in type 2. A health worker may also give medicines.

6. **You cannot catch diabetes from someone who has it.**

   Diabetes is not an infection. It cannot pass from one person to another.

   - **If you chose A:** Sugar on its own does not cause it. Type 1 is not caused by diet, and type 2 has many linked causes.
   - **If you chose C:** Little exercise is linked to type 2. Type 1 happens when the cells that make insulin are destroyed.

7. **Thyroxine**

   The thyroid gland in the neck makes thyroxine, which sets the rate of the chemical reactions in the body.

   - **If you chose A:** Insulin comes from the pancreas, and it lowers blood glucose. Go to S4.5.4.
   - **If you chose C:** Adrenaline comes from the adrenal glands. Go to S4.5.4.

8. **1.2 g/L**

   The highest healthy value is 1.4 g/L. The highest untreated value is 2.6 g/L. 2.6 − 1.4 = 1.2 g/L.

9. **2.7 g**

   3 × 0.9 = 2.7 g.

10. **0.6 g/L**

    1.8 − 1.2 = 0.6 g/L.

S4.5.6. Temperature and water balance

1. **The enzymes in the cells work best near that temperature.**

   Enzymes speed up the reactions in cells. They work best near the body temperature. Much hotter or colder, they work badly.

   - **If you chose A:** The body makes heat all the time, in respiration. What changes is how much heat it keeps or loses.
   - **If you chose C:** Blood flows at many temperatures. It is the enzymes in the cells that work best in a small range. Go to S4.1.5.

2. **The blood vessels near the skin widen and the sweat glands release sweat.**

   Wide vessels bring more warm blood near the surface, so more heat leaves. Sweat evaporates and takes more heat with it.

   - **If you chose A:** That is what happens in the cold. When you are hot, the vessels widen.
   - **If you chose B:** Shivering happens when you are cold. A hot body sweats.
   - **If you chose C:** Vessels cannot move, and sweating does not stop when you are hot. The vessels widen and the sweat glands release sweat.

3. **The muscles contract quickly and release heat.**

   Shivering is rapid contracting and relaxing of the muscles. Respiration in the muscle cells releases heat, which warms the blood.

   - **If you chose A:** There is no sweat in the cold. The sweat glands stop.
   - **If you chose B:** In the cold the skin vessels narrow, and shivering does not widen them.

4. **It evaporates and takes heat from the skin.**

   When sweat evaporates, the particles with most energy leave the skin. This takes heat from it, and the skin cools.

   - **If you chose B:** Sweat is released at about body temperature. It cools because it evaporates.
   - **If you chose C:** Sweat does not block heat. It cools the skin as it evaporates.

5. **They filter it, take back what the body needs and pass the rest out as urine.**

   The nephron filters the blood. The tubule takes back all the glucose and as much water and salt as the body needs. What is left leaves as urine.

   - **If you chose A:** The kidneys do not store blood. The blood flows through them and returns.
   - **If you chose B:** Most of the filtered water goes back into the blood. Only a small part leaves as urine.
   - **If you chose C:** It is the other way round. Urea is a waste and leaves in the urine. The water the body needs is taken back.

6. **There is more ADH, and his urine is small in amount and dark.**

   Too little water in the blood makes the pituitary release more ADH. The kidneys take back more water. Less water is left, so the urine is small in amount and concentrated.

   - **If you chose A:** That happens when you drink a lot. When water is short, there is more ADH, not less.
   - **If you chose C:** More ADH makes the kidney take back more water, so there is less urine, not more.

7. **The pituitary gland**

   The pituitary gland under the brain releases ADH. It makes the kidneys take back more water.

   - **If you chose A:** The adrenal glands release adrenaline. Go to S4.5.4.
   - **If you chose C:** The pancreas releases insulin and glucagon. Go to S4.5.4.

8. **720 kJ**

   300 × 2.4 = 720 kJ.

9. **168.5 L**

   170 − 1.5 = 168.5 L go back into the blood.

S4.5.7. Hormones and the menstrual cycle

1. **The pituitary gland**

   The pituitary gland, under the brain, makes FSH and LH. They travel in the blood to the ovaries.

   - **If you chose A:** The ovaries make the other two hormones of the cycle, oestrogen and progesterone. FSH and LH come from the pituitary gland. Go to S4.5.4.
   - **If you chose C:** The pancreas makes insulin, which controls blood sugar. It does not make the hormones of the cycle. Go to S4.5.5.
   - **If you chose D:** The uterus responds to the hormones. Its lining builds up and breaks down, but it does not make FSH or LH. Go to S3.4.4.

2. **Day 13**

   The LH line is low most of the time, with one tall peak at day 13. This surge causes ovulation about day 14.

   - **If you chose A:** Day 28 is where the name LH is written, at the end of the line. The peak is the highest point of the line.
   - **If you chose C:** That is the peak of the other line, progesterone. Check which name is at the end of each line.

3. **Day 21**

   After ovulation, progesterone keeps the lining thick and ready for a fertilised egg. Of these three days, it is thickest on day 21.

   - **If you chose A:** On day 4 the lining is being shed during the period, so it is thin.
   - **If you chose B:** At ovulation the lining is thick, but progesterone keeps it growing a little after that.

4. **A fall in progesterone**

   Progesterone keeps the lining thick. When no pregnancy starts, progesterone falls, and the lining breaks down as the period.

   - **If you chose B:** The LH surge comes in the middle of the cycle and causes ovulation. It does not make the lining break down.
   - **If you chose C:** Rising oestrogen builds the lining up after a period. It does not break it down.

5. **Its hormones hold back FSH and LH, so no egg is released.**

   The oestrogen and progesterone in the pill hold back FSH and LH from the pituitary gland. Oestrogen and progesterone do the same in every cycle.

   - **If you chose B:** The pill does not kill sperm. Its hormones stop ovulation and thicken the mucus at the cervix.
   - **If you chose C:** Hormones do not stop infections passing from one person to another. Only condoms also give that protection. Go to S4.4.8.
   - **If you chose D:** Missed or late pills let FSH and LH rise, so an egg may be released. The pill is very effective only when used correctly.

6. **Pregnancy is less likely during a period, but it can happen.**

   Ovulation usually comes in the middle of the cycle, but its day varies, and sperm can live for several days. So no day of the cycle is certain to be safe.

   - **If you chose A:** Many people believe this. But sperm can live in the body for up to about 5 days. In a short cycle, ovulation can come soon after a period.
   - **If you chose B:** Day 14 is only an average for a 28 day cycle. Ovulation moves between people and from month to month, and sperm can wait for days.

7. **To help eggs mature in the ovaries**

   FSH makes eggs mature. Giving it can help when the body makes too little, and LH can then help an egg be released.

   - **If you chose A:** Stopping ovulation is how the combined pill works, by holding FSH back. Fertility treatment gives FSH to do the opposite.
   - **If you chose C:** Thick mucus keeps sperm out. That is how progesterone only methods work, not fertility treatment.

8. **In a dish in a laboratory**

   In IVF the eggs are collected and mixed with sperm in a dish. An embryo is then placed in the uterus.

   - **If you chose A:** Without treatment, an egg is usually fertilised in the oviduct. In IVF it happens outside the body. Go to S3.4.6.
   - **If you chose B:** The eggs are not placed in the uterus. An embryo is placed there, after fertilisation in the dish.

9. **About day 16**

   30 − 14 = 16. So ovulation is about day 16, though the real day can vary.

10. **About 33 days**

    The next period starts about 14 days after ovulation. 19 + 14 = 33.

11. **In the blood**

    Every hormone is carried in the blood from the gland that makes it to the organ it acts on.

    - **If you chose B:** Nerves carry fast electrical messages. Hormones are chemicals carried in the blood, which is slower. Go to S4.5.4.
    - **If you chose C:** The oviducts carry eggs from the ovaries to the uterus. They do not reach the pituitary gland. Go to S3.4.4.

S4.5.8. Plant responses

1. **Growth in a direction that is set by the direction of light**

   A tropism is growth in a direction set by a stimulus. In phototropism the stimulus is light.

   - **If you chose B:** That is photosynthesis. Phototropism is about the direction of growth. Go to S4.1.6.
   - **If you chose C:** That is a quick response to touch. Phototropism is slow growth that is set by light.

2. **In the shoot tip**

   The tip makes auxin. It moves down to the cells behind the tip, and it makes them grow longer.

   - **If you chose A:** The roots do not make the auxin that bends a shoot. It is made in the tip of the shoot.
   - **If you chose B:** Auxin is made at the tip of the shoot, not only in the leaves.

3. **Auxin gathers on the left, and the cells there grow longer, so the shoot bends right.**

   Light from the right leaves the left side shaded. Auxin gathers there, and the cells grow longer. The longer left side makes the shoot bend to the right, towards the light.

   - **If you chose A:** Auxin gathers on the shaded side, which is the left. The lit side is the right.
   - **If you chose B:** Auxin makes the cells grow longer. They do not stop. It is the longer cells on the shaded side that bend the shoot.
   - **If you chose C:** Auxin does not stay even. Light from one side makes it move to the shaded side.

4. **It has turned down.**

   Gravity makes auxin collect on the lower side of a root. A lot of auxin slows growth there, so the root curves down.

   - **If you chose A:** A root grows in the direction of gravity, which is down. The shoot turns up.
   - **If you chose C:** A root responds to gravity, even in the dark. It turns down.
   - **If you chose D:** A root does not stop. Auxin collects on its lower side and slows growth there, so the root curves down.

5. **The leaves get more light for photosynthesis.**

   The leaves use light to make glucose. A shoot that bends towards light puts its leaves where there is more of it.

   - **If you chose A:** Roots do not need light. It is the leaves that use light.
   - **If you chose B:** Cooling is not the reason. Light is what the leaves need for photosynthesis.

6. **So that light reaches the seedlings from one side only**

   A single hole makes the light come from one direction. Then you can see which way the shoots bend.

   - **If you chose B:** Some light comes in through the hole. The seedlings need it, and they grow towards it.
   - **If you chose C:** Air can get in. The hole is there to let the light in from one side.

7. **Both are chemical messengers.**

   A hormone is a chemical messenger. Auxin is a chemical messenger in plants, and insulin is one in animals. They differ in how they travel.

   - **If you chose B:** A plant has no blood. Auxin passes from cell to cell. Go to S4.5.4.
   - **If you chose C:** Insulin is made by a gland, the pancreas. A plant has no glands like this, and the shoot tip makes auxin. Go to S4.5.4.

8. **20 degrees per day**

   The bend grew by 60 − 20 = 40 degrees in 2 days. 40 ÷ 2 = 20 degrees per day.

9. **60 degrees**

   12 × 5 = 60 degrees.

About this book

For learners who can follow a written argument and have met the body, the senses and plants in earlier books. In many schools this fits learners of about 14 to 16, and older learners can use it as a reference. Each chapter takes two or three short sessions. A learner can work alone: every exercise has its answer and the reason for it. The Try it activities use a ruler, a cup of water, a window or lamp in a dim room, a cardboard box and a few beans or other seeds. Nobody should look at the Sun, and seeds are not eaten. The chapters on diabetes and on the menstrual cycle give established science

only. They name no medicine and no dose, and they send a reader with a health question to a health worker.

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