Course Companion

IGCSE Biology

Every topic handout in one volume

全部专题讲义合集

exercises.lol

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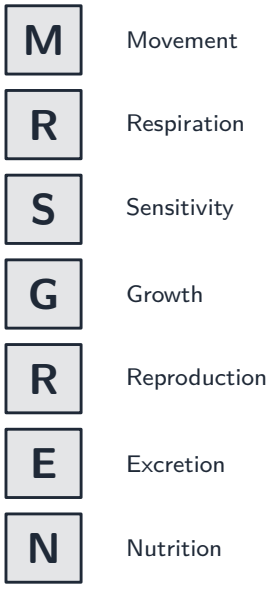
Characteristics and classification of living organisms

IGCSE Biology

The seven characteristics of living organisms

Every living thing shares the same seven **characteristics** 特征 — seven **life processes** 生命过程 that all **organisms** 生物体 carry out. You can remember them with the letters **MRS GREN**. The examiner gives marks for the exact wording, so learn each definition.



The seven life processes spell MRS GREN

- **Movement** 运动 — an action by an organism, or part of an organism, that changes its position or place.
- **Respiration** 呼吸作用 — the chemical reactions in **cells** 细胞 that break down **nutrient molecules** 营养物质 and release **energy** 能量 for **metabolism** 新陈代谢.
- **Sensitivity** 应激性 — the ability to detect and respond to changes in the internal or external **environment** 环境.
- **Growth** 生长 — a permanent increase in size and **dry mass** 干重.
- **Reproduction** 生殖 — the processes that make more of the same kind of organism.

- **Excretion** 排泄 — the removal of the **waste products** 废物 of metabolism, and of substances the body has in excess (more than it needs).
- **Nutrition** 营养 — the taking in of materials for energy, growth and development.

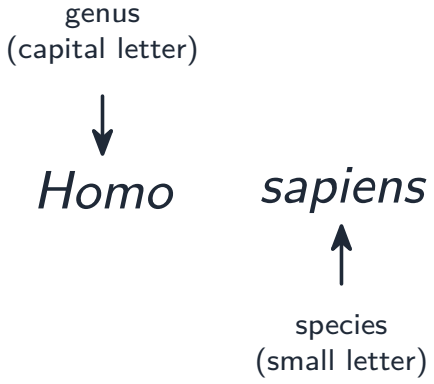
Metabolism means all the chemical reactions that happen inside an organism's cells.

Classification: sorting living things into groups

There are millions of kinds of living thing. To study them, scientists **classify** 分类 them — they sort them into groups by the features they share. Organisms in the same group share more features with each other than with organisms in other groups.

Species and the binomial system

The smallest common group is the **species** 物种. A species is a group of organisms that can reproduce to make **fertile offspring** 可育后代 ("fertile" means the offspring can themselves go on to have young).



A scientific name: a capital-letter genus and a small-letter species

Each species has a two-part **scientific name** 学名. This way of naming is the **binomial system** 双名法 — a system agreed all over the world, so every scientist uses the same name.

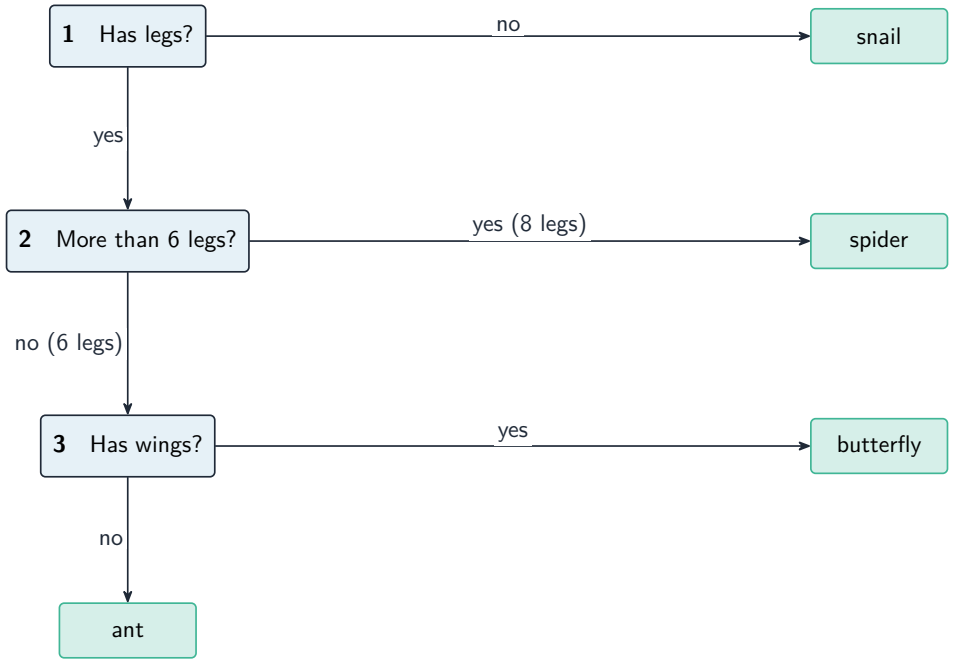
- The **first** part is the **genus** 属 (a larger group that the species belongs to). It starts with a capital letter.
- The **second** part is the species. It starts with a small letter.

The whole name is written in italics, for example *Homo sapiens* (humans). Two rats

named *Rattus norvegicus* and *Rattus rattus* belong to the same genus but are different species.

Dichotomous keys

A **dichotomous key** 二歧检索表 is a tool that helps you identify an unknown organism. "Dichotomous" means "splitting into two". At each step the key gives you **two** choices about a feature. You pick the one that fits your organism, and that choice sends you on to the next pair of choices. You repeat this until you reach the organism's name.



A dichotomous key: each step gives two choices until you reach the organism

When you build a key, choose clear features you can see — for example "has wings / has no wings" — not features that change, such as size.

Worked example. A key reads: step **1**, has wings, go to **2**; no wings, go to **3**. Step **2**, one pair of wings, it is a housefly; two pairs of wings, it is a butterfly. An unknown insect has two pairs of wings. Step **1** only asks "wings or no wings?", so having wings sends you to step **2**. At step **2**, "two pairs" gives **butterfly**. Follow the route the key gives you, one step at a time - never jump straight to the name that looks right.

Classification and DNA (Supplement)

Modern classification tries to show **evolutionary relationships** 进化关系 — how closely different organisms are related. Organisms that are more closely related share a more recent **ancestor** 祖先.

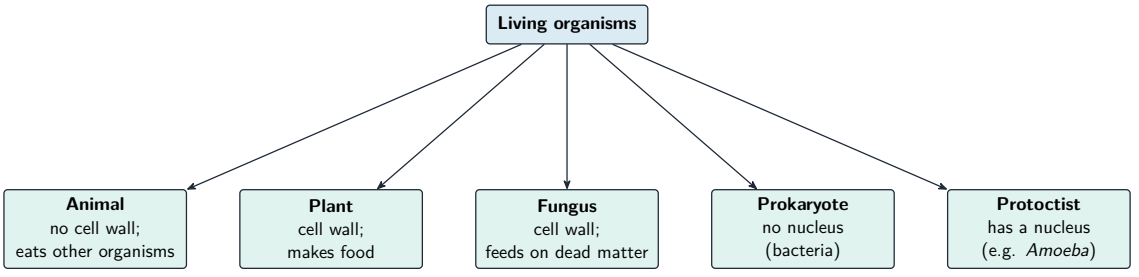
To measure this, scientists compare the **base sequence** 碱基序列 of DNA (the order of the chemical "letters" that make up an organism's **genes** 基因). The rule is simple:

- Organisms that share a **more recent** ancestor (more closely related) have **more similar** DNA base sequences.
- Organisms that share only a **distant** ancestor have **less similar** base sequences.

So a DNA base sequence can be used both to classify organisms and to work out how closely two species are related.

Kingdoms

The biggest groups that organisms are sorted into are called **kingdoms** 界. At Core level you place organisms into the first two kingdoms below; for Supplement you need all **five kingdoms**. You decide where an organism belongs by looking at its main features.

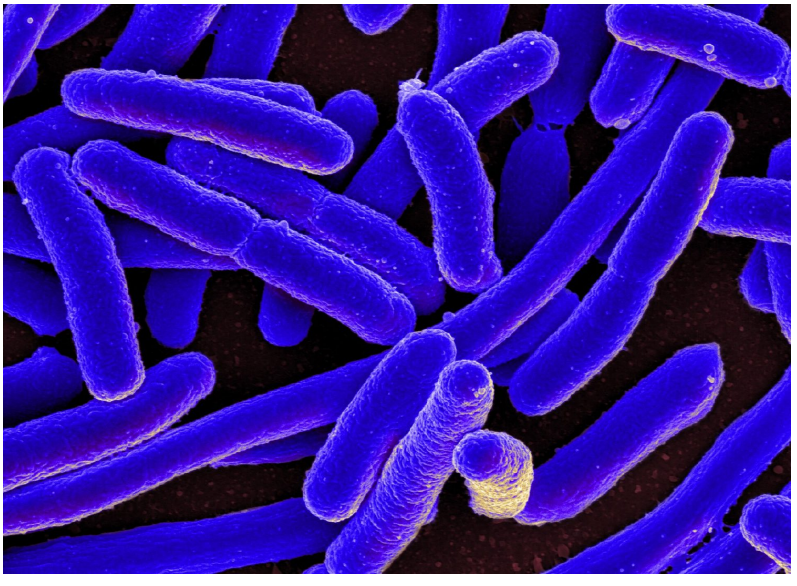


Living organisms are sorted into five kingdoms by their main features

Kingdom	Main features
Animal 动物	made of many cells; cells have no **cell wall** 细胞壁; cannot make their own food, so they feed on other organisms; most can move their whole body
Plant 植物	made of many cells; cells have a cell wall; make their own food by **photosynthesis** 光合作用, so many cells contain **chloroplasts** 叶绿体
Fungus 真菌	for example **moulds** 霉菌, **mushrooms** 蘑菇 and **yeast** 酵母; have cell walls; cannot photosynthesise; feed on dead or living matter
Prokaryote 原核生物	for example **bacteria** 细菌; **single-celled** 单细胞; cells have no **nucleus** 细胞核
Protoctist 原生生物	for example *Amoeba* and **algae** 藻类; usually single-celled; cells do have a nucleus

The fungus, prokaryote and protoctist kingdoms are Supplement only.

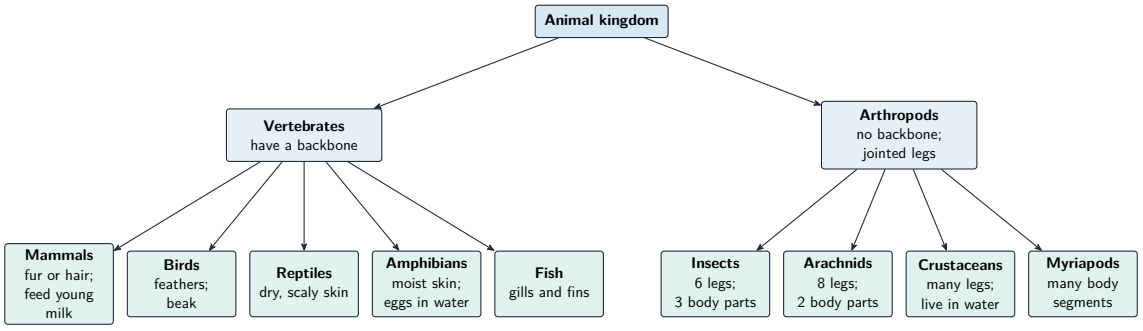
A fungus: the fly agaric, a mushroom



A prokaryote (bacterium): E. coli seen under an electron microscope

Grouping the animal kingdom

The animal kingdom is split first into two: animals with a backbone and animals without one.



The animal kingdom splits into vertebrates (with a backbone) and arthropods (no backbone), each with its main groups

Vertebrates 脊椎动物 are animals with a **backbone** 脊柱. There are five main groups.

Group	Main features
Mammals 哺乳动物	have **fur** 毛发 or hair; feed their young on milk
Birds 鸟类	have **feathers** 羽毛 and a **beak** 喙; lay eggs with hard shells
Reptiles 爬行动物	have dry skin covered with **scales** 鳞片; lay eggs with leathery shells on land
Amphibians 两栖动物	have moist skin; lay eggs in water; the young live in water
Fish 鱼类	have wet scales and **fins** 鳍; breathe using **gills** 鳃; lay eggs in water

Arthropods 节肢动物 are animals with no backbone. They have a hard outer skeleton (an **exoskeleton** 外骨骼) and legs that bend at **joints** 关节. There are four main groups.

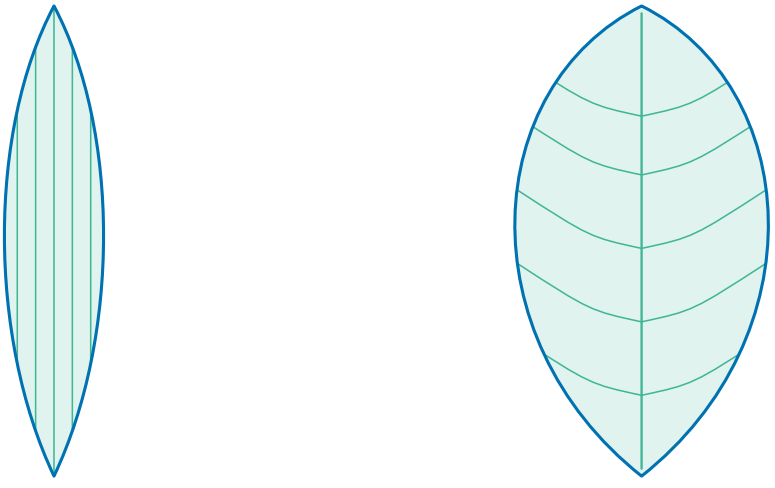
Group	Main features
Insects 昆虫	body in 3 parts; 3 pairs of legs; usually 2 pairs of wings; 1 pair of **antennae** 触角
Arachnids 蛛形类	body in 2 parts; 4 pairs of legs; no wings; no antennae
Crustaceans 甲壳类	many pairs of legs; 2 pairs of antennae; most live in water
Myriapods 多足类	long body made of many **segments** 体节; one or two pairs of legs on each segment

Grouping the plant kingdom (Supplement)

Plants are placed into groups too. You need two of them.

- **Ferns** 蕨类植物 — have roots, stems and leaves, but make **no** flowers or seeds. They reproduce using tiny **spores** 孢子.
- **Flowering plants** 开花植物 — make flowers, and form **seeds** 种子 inside the flower. They split into two groups by their seed-leaves (the first leaves inside a seed, called **cotyledons** 子叶):

Group	Features
Monocotyledons 单子叶植物	seed has **one** cotyledon; long narrow leaves; **veins** 叶脉 run side by side (parallel)
Dicotyledons 双子叶植物	seed has **two** cotyledons; broad leaves; veins form a branching net

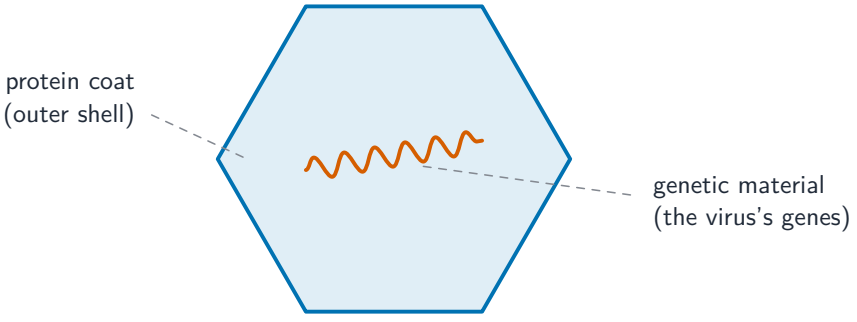


Monocot leaves have parallel veins; dicot leaves have a net of branching veins

Viruses (Supplement)

Viruses 病毒 are not placed in any kingdom. They are not made of cells, so many scientists do not count them as living. A virus is very simple, with only two parts:

- an outer **protein coat** 蛋白质外壳, and
- **genetic material** 遗传物质 (its genes) inside.



A virus is just a protein coat around its genetic material

A virus cannot carry out the life processes on its own. It can only reproduce inside the living cells of a **host** 宿主 — the organism it infects.

Exam tips

- Learn the **seven characteristics** by heart, with their exact definitions. Write them as clear, full sentences.
- **Digestion** 消化 is *not* one of the seven characteristics — it is just one part of nutrition. "Breathing" is not one of the seven either.
- In a scientific name, the genus starts with a capital letter and the species with a small letter, and both are in italics.
- To use a dichotomous key, start at the first pair of choices and follow the route step by step. Do not jump ahead.
- More similar DNA base sequence → the organisms are more closely related (they share a more recent ancestor).

Organisation of the organism

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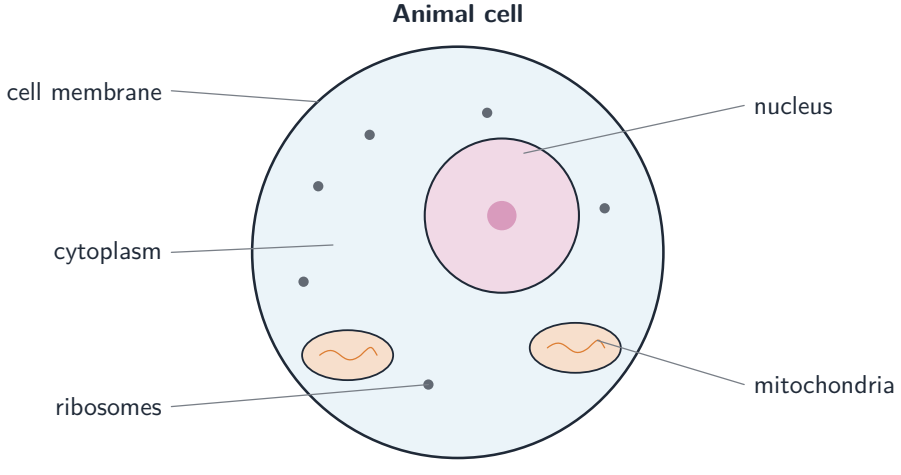
Cells: the building blocks of life

Every living thing is made of **cells** 细胞. A cell is the smallest part that can carry out the life processes. In this topic you compare a **plant** 植物 cell, an **animal** 动物 cell and the cell of a **bacterium** 细菌. All new cells are made by the **division** 分裂 of cells that already exist.

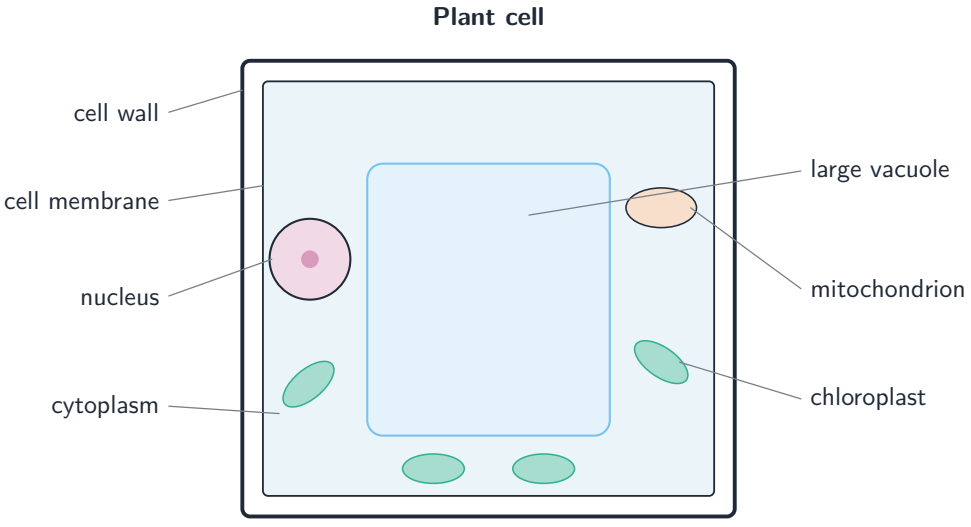
Which structures are in each cell?

Structure	Animal cell	Plant cell	Bacterial cell
cell membrane 细胞膜	yes	yes	yes
cytoplasm 细胞质	yes	yes	yes
ribosomes 核糖体	yes	yes	yes
nucleus 细胞核	yes	yes	no — has a loop of DNA instead
mitochondria 线粒体	yes	yes	no
cell wall 细胞壁	no	yes	yes (different material)
chloroplasts 叶绿体	no	yes (only in green parts)	no
large **vacuole** 液泡	no	yes	no
plasmids	no	no	yes

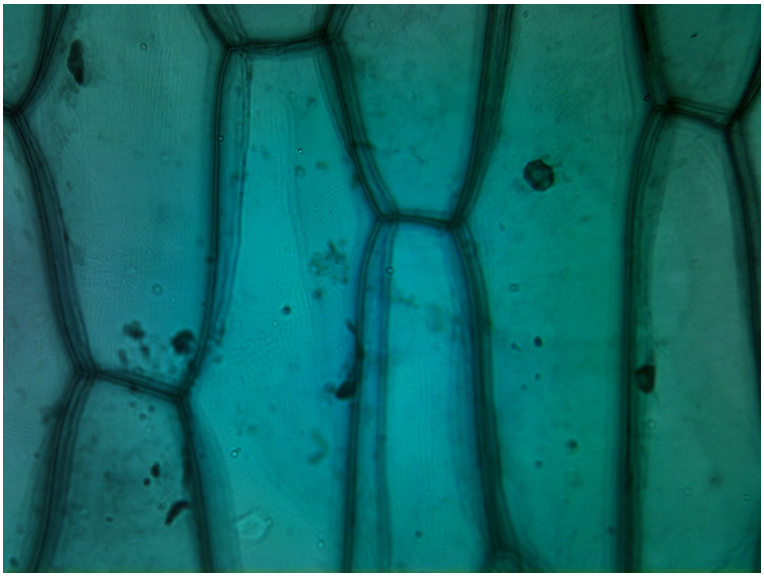
So plant and animal cells share five structures: cell membrane, cytoplasm, ribosomes, nucleus and mitochondria. A plant cell has three extra structures: a cell wall, a large vacuole and (in green parts) chloroplasts.



An animal cell: membrane, cytoplasm, nucleus, mitochondria and ribosomes



A plant cell also has a cell wall, a large vacuole and chloroplasts



Onion epidermis cells under a light microscope — each cell has a clear cell wall

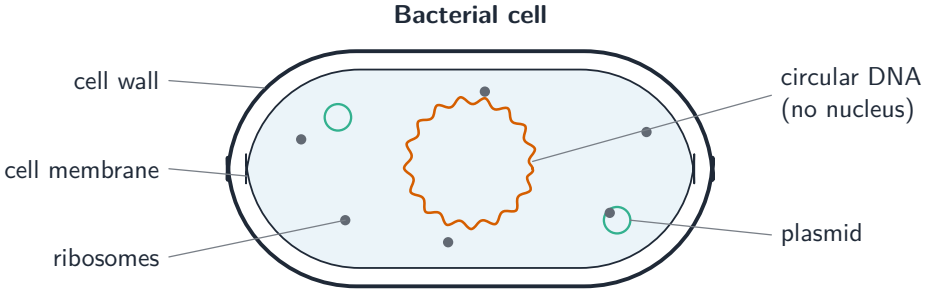
What each structure does

- **Cell membrane** — controls which substances enter and leave the cell.
- **Cytoplasm** — a jelly-like liquid where many chemical reactions happen.
- **Nucleus** — controls the cell's activities and holds the **genetic material** 遗传物质.
- **Ribosomes** — where **proteins** 蛋白质 are made.
- **Mitochondria** — where **respiration** 呼吸作用 happens to release **energy** 能量.

- **Cell wall** — made of **cellulose** 纤维素; it gives a plant cell strength and a fixed shape.
- **Chloroplasts** — contain **chlorophyll** 叶绿素, a green substance that traps light for **photosynthesis** 光合作用.
- **Large vacuole** — filled with **cell sap** 细胞液; it helps keep the plant cell firm.

Bacterial cells

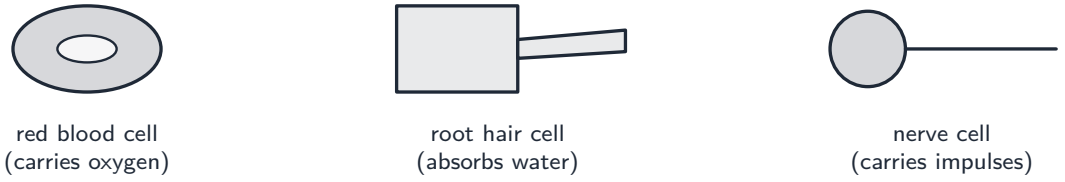
A **bacterium** is a **prokaryote** 原核生物 — its cell has **no** nucleus. Instead its DNA is a single loop (a ring), loose in the cytoplasm. Bacteria also have small extra rings of DNA called **plasmids** 质粒. A bacterial cell has a cell wall and cell membrane, cytoplasm and ribosomes, but no mitochondria and no chloroplasts.



A bacterial cell has no nucleus — its DNA is a single loop, plus small plasmids

Specialised cells

Most cells are **specialised cells** 特化细胞 — their shape and parts suit one special job.



Specialised cells have shapes that suit their jobs

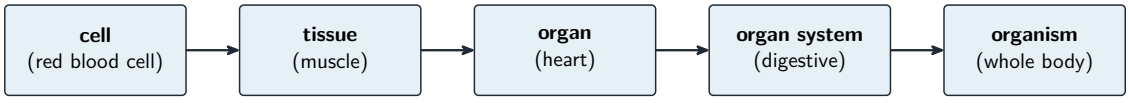
Cell	Job	How its shape helps
ciliated cells 纤毛细胞	move **mucus** 黏液 along the **trachea** 气管 and **bronchi** 支气管	tiny hairs (cilia) on top sweep the mucus along
root hair cells 根毛细胞	**absorption** 吸收 of water and minerals from the soil	a long, thin "hair" gives a large surface
palisade mesophyll cells 栅栏叶肉细胞	photosynthesis	packed with chloroplasts, near the top of the leaf
neurones 神经元	carry **electrical impulses** 电脉冲	very long, to reach far across the body
red blood cells 红细胞	transport **oxygen** 氧气	no nucleus and a dish shape, to carry more oxygen
sperm 精子 and **egg cells** 卵细胞	reproduction	the sperm can swim; the egg cell stores food

Sperm and egg cells are the sex cells, called **gametes** 配子.

Levels of organisation

An **organism** 生物体 made of many cells is built up in levels, from small to large:

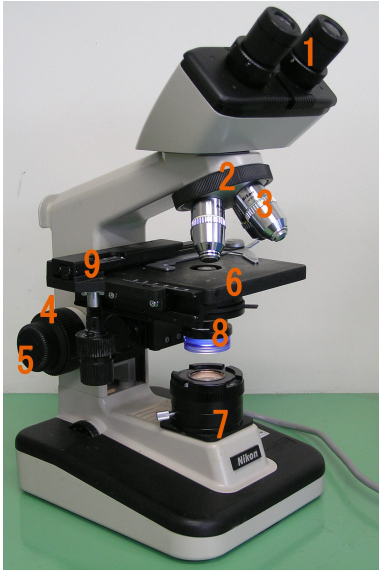
- **cell** — the smallest unit of life (for example a red blood cell).
- **tissue** 组织 — a group of similar cells that work together (for example **muscle** 肌肉).
- **organ** 器官 — several different tissues that work together to do a job (for example the heart, or a leaf).
- **organ system** 器官系统 — several organs that work together (for example the **digestive system** 消化系统, which breaks down food).
- **organism** — all the organ systems together make one whole living thing.



From a single cell up to the whole organism

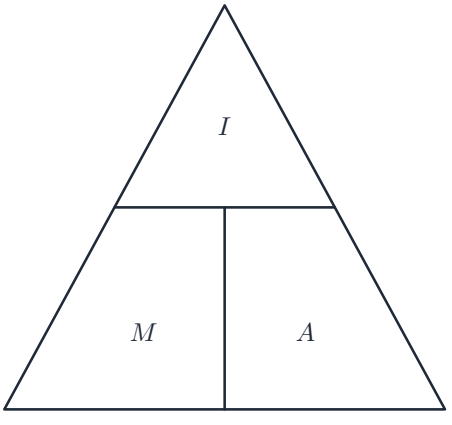
The size of cells: magnification

Cells are tiny, so you look at them under a **microscope** 显微镜, which makes them appear much larger. How many times larger the image is, is called the **magnification** 放大倍数.



A light microscope, used to look at cells

$$\text{magnification} = \frac{\text{image size}}{\text{actual size}}$$



I = image size
M = magnification
A = actual size

$$M = \frac{I}{A}$$

cover a letter to get its formula

Cover the quantity you want in the triangle to read off its formula

- **image size** = the size in the drawing or photo.
- **actual size** = the real size of the **specimen** 标本.

Magnification has **no unit** — it is just a number, for example ×250. You can rearrange the formula:

$$\text{actual size} = \frac{\text{image size}}{\text{magnification}}, \qquad \text{image size} = \text{actual size} \times \text{magnification}$$

Worked example. A structure is shown at a magnification of 250. Its image size is 5.00 mm. So the actual size = 5.00 ÷ 250 = 0.02 mm. Always put both sizes in the **same unit** before you divide.

Changing units (Supplement)

Cells are often measured in **micrometres** 微米 (μm), which are smaller than millimetres (mm):

$$1 \text{ mm} = 1000 \ \mu\text{m}, \qquad 1 \ \mu\text{m} = 0.001 \text{ mm}$$

So 0.02 mm = 20 μm. To change mm into μm, multiply by 1000. To change μm into mm, divide by 1000.

Worked example. A cell is drawn 60 mm wide, and its real width is 30 μm. Find the magnification. First make the units match: image size = 60 mm = 60 × 1000 = 60,000 μm. Then magnification = image ÷ actual = 60,000 ÷ 30 = ×2000. If you forget to convert and divide 60 ÷ 30, you get ×2 — a thousand times too small. This is the most common mistake in the whole topic.

Exam tips

- A plant cell has a cell wall, a large vacuole and chloroplasts; an animal cell has none of these. Both have a nucleus, cytoplasm, cell membrane, mitochondria and ribosomes.
- A cell with **no nucleus** but with plasmids and a loop of DNA is a bacterium.
- For magnification, cover the quantity you want: magnification = image ÷ actual; actual = image ÷ magnification.
- Always convert to the same unit before you calculate. Remember 1 mm = 1000 μm.
- For a specialised cell, link its job to the one feature that suits it (for example a red blood cell has no nucleus, so it can hold more oxygen).

Movement into and out of cells

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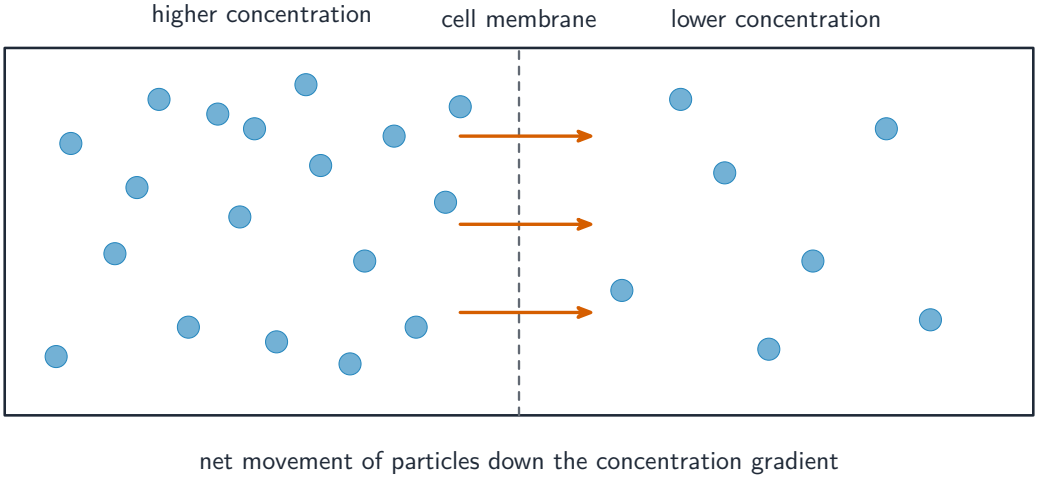
Diffusion

Diffusion 扩散 is the **net movement** 净移动 of **particles** 粒子 from a region of their higher **concentration** 浓度 to a region of their lower concentration. We say the particles move **down a concentration gradient** 浓度梯度.

The particles spread out because of their own **random movement** 随机运动. The **energy** 能量 for diffusion comes from the **kinetic energy** 动能 of the random movement of **molecules** 分子 and **ions** 离子 — so diffusion needs **no** extra energy.

Some substances pass into and out of cells by diffusion through the **cell membrane** 细胞膜.



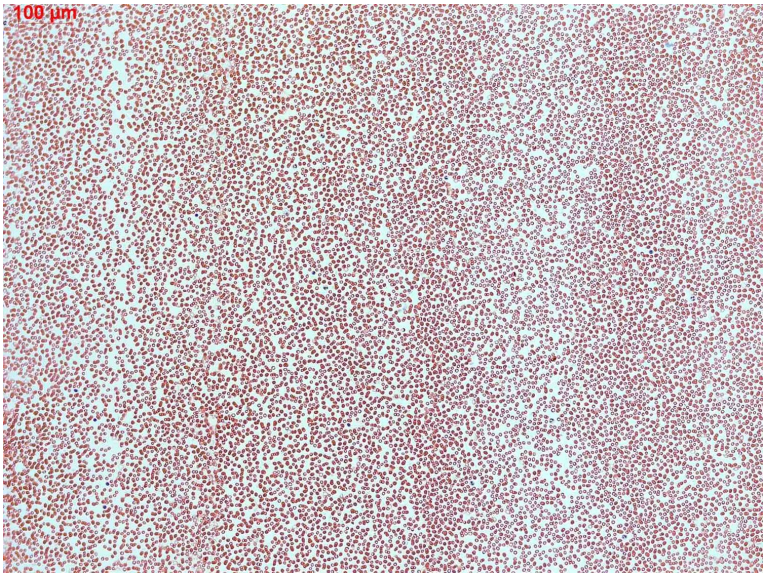
Diffusion: particles move from higher to lower concentration, down the gradient

Why diffusion matters. Many **gases** 气体 and dissolved substances (**solutes** 溶质) move by diffusion in living things. For example, **oxygen** 氧气 diffuses into cells for respiration, and **carbon dioxide** 二氧化碳 diffuses out.

The rate of diffusion changes with four factors:

Factor	Diffusion is faster when...
surface area 表面积	the surface is larger
temperature 温度	it is hotter (particles move faster)
concentration gradient	the difference in concentration is bigger
distance	the distance to travel is shorter (a thinner barrier)

Osmosis



Red blood cells: water moves in and out of cells by osmosis.

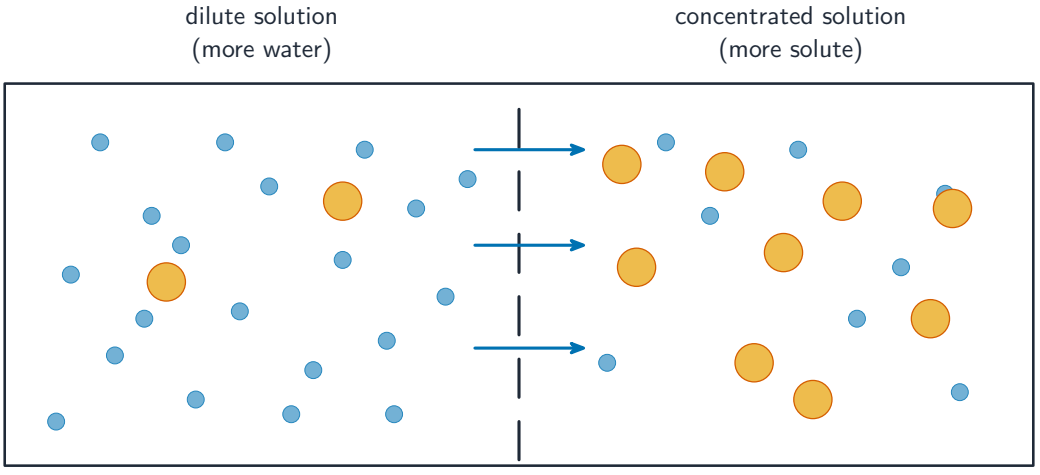
Water as a solvent

Water is a very good **solvent** 溶剂 — many substances **dissolve** 溶解 in it to make a **solution** 溶液. This matters for **digestion** 消化 (food must dissolve before it can be used), **excretion** 排泄 (wastes are carried away dissolved in water) and **transport** 运输 (substances travel around the body dissolved in blood and sap).

What osmosis is

Osmosis 渗透 is a special kind of diffusion: the net movement of water across a **partially permeable membrane** 半透膜. This kind of membrane has tiny holes that let small water molecules through but hold back larger solute particles. Water moves into and out of cells by osmosis through the cell membrane.

A **concentrated** solution has a lot of dissolved solute and little water. A **dilute** solution has little solute and a lot of water.



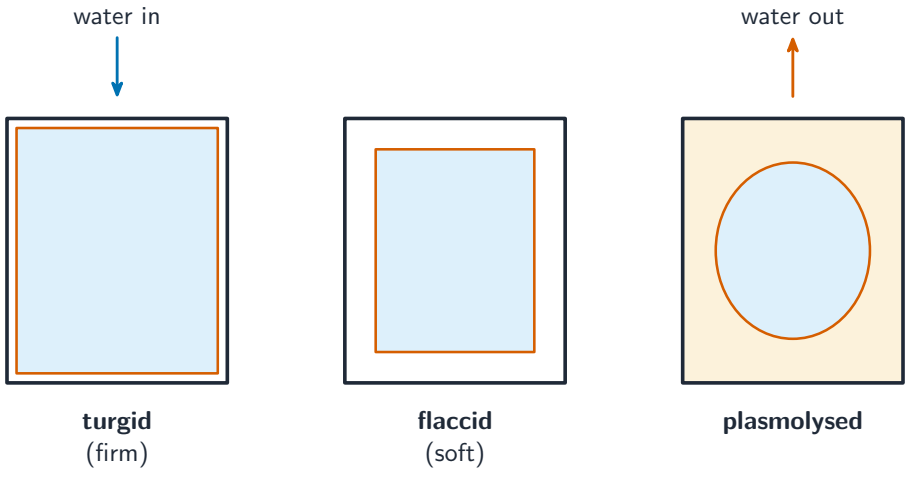
Osmosis: water crosses the partially permeable membrane; the solute cannot

(Supplement) Osmosis is the net movement of water molecules from a region of **higher water potential** 水势 (a dilute solution — more water) to a region of lower water potential (a concentrated solution — less water), through a partially permeable membrane.

Osmosis and plant cells

When you put plant tissue into different solutions, water moves by osmosis:

- In **pure water or a dilute solution**, water moves **into** the cells. The cells swell and become firm, or **turgid** 膨胀. The water presses outward on the cell wall; this outward push is the **turgor pressure** 膨压. Turgid cells make a plant stand up straight — this is how plants are supported.
- In a **concentrated solution**, water moves **out** of the cells. The cells lose their firmness and become soft, or **flaccid** 松软.
- **(Supplement)** If even more water leaves, the cell membrane pulls away from the cell wall. This is **plasmolysis** 质壁分离.



Water entering or leaving a plant cell makes it turgid, flaccid or plasmolysed

Plasmolysed red onion cells: the purple contents have pulled away from the cell walls

You can investigate osmosis using **dialysis tubing** 透析管 (an artificial partially permeable membrane), or using cylinders cut from a potato. Measure their length or mass before and after soaking. Cylinders in pure water or a dilute solution gain length and mass; cylinders in a concentrated solution lose length and mass; in a solution of equal concentration there is no change.

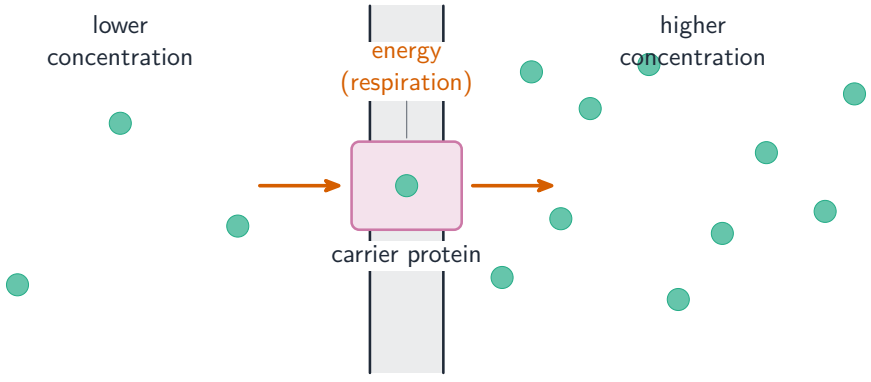
Worked example. A potato cylinder has a mass of 5.0 g before soaking and 5.6 g after soaking in a dilute solution. Find the percentage change in mass.

- change in mass = 5.6 - 5.0 = 0.6 g (a gain).
- percentage change = change ÷ starting mass × 100 = 0.6 ÷ 5.0 × 100 = +12%.

A positive answer means the cylinder gained water, so the solution was more dilute than the cell contents. Always work out the *percentage* change, not just the change in grams — it lets you compare cylinders that started at different masses fairly.

Active transport

Active transport 主动运输 is the movement of particles through a cell membrane from a region of **lower** concentration to a region of **higher** concentration — that is, **against** the concentration gradient. Because this is "uphill", it needs energy from **respiration** 呼吸作用.



Active transport uses energy and a carrier protein to move particles against the gradient

(Supplement) Active transport lets a cell take in useful molecules or ions even when they are already more concentrated inside the cell. For example, **root hairs** 根毛 take up mineral ions from the soil by active transport. **Protein carriers** 载体蛋白 in the membrane pick up the molecules or ions and carry them across, using energy.

Comparing the three processes

Process	Direction	Energy from respiration?	What moves
diffusion	high → low concentration	no	particles, gases, solutes
osmosis	high → low water potential	no	water only
active transport	low → high concentration (against the gradient)	yes	molecules and ions

Exam tips

- Always write **net** movement: particles move both ways, but the overall flow is down the gradient (for diffusion and osmosis).
- Osmosis moves **water only**, and **only** through a partially permeable membrane. Diffusion can move many kinds of particle.
- Only **active transport** uses energy from respiration, and only it goes **against** the gradient.
- For the potato or plant experiment: water in → turgid, longer and heavier; water out → flaccid, shorter and lighter; equal concentration → no change.
- A larger surface area, higher temperature, steeper concentration gradient and shorter distance all make diffusion faster.

Biological molecules

IGCSE Biology

The chemical elements in food

Bread is rich in carbohydrates, one of the main food groups.

carbohydrates and fats
C H O

proteins
C H O N

Carbohydrates and fats contain C, H and O; proteins also contain nitrogen

Living things are built from a few kinds of **molecule** 分子. The most important are carbohydrates, fats and proteins. Each is made from a small number of chemical **elements** 元素.

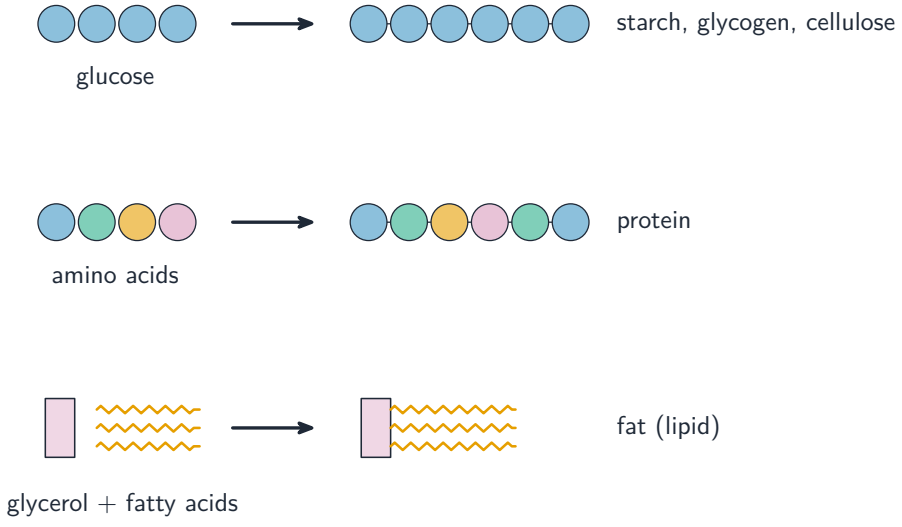
- **Carbohydrates** 碳水化合物 and **fats** 脂肪 contain three elements: **carbon** 碳 (C), **hydrogen** 氢 (H) and oxygen (O).
- **Proteins** 蛋白质 contain carbon, hydrogen and oxygen too, plus **nitrogen** 氮 (N). (Some proteins also contain sulfur, S.)

Building large molecules from small ones

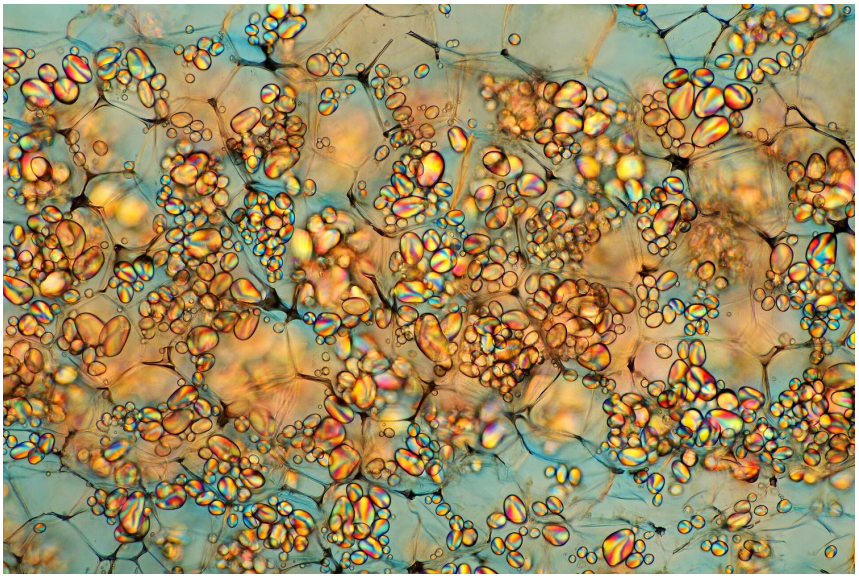
Large molecules are made by joining many small molecules together, like beads on a string.

Large molecule	Built from
starch 淀粉, **glycogen** 糖原 and **cellulose** 纤维素	many **glucose** 葡萄糖 units
proteins	**amino acids** 氨基酸
fats and oils	**fatty acids** 脂肪酸 and **glycerol** 甘油

Starch and glycogen are energy stores; cellulose makes plant cell walls. Proteins are built from about 20 different kinds of amino acid joined in a chain. One fat molecule is made from three fatty acids joined to one glycerol.



Large molecules are built by joining many small units, like beads on a string



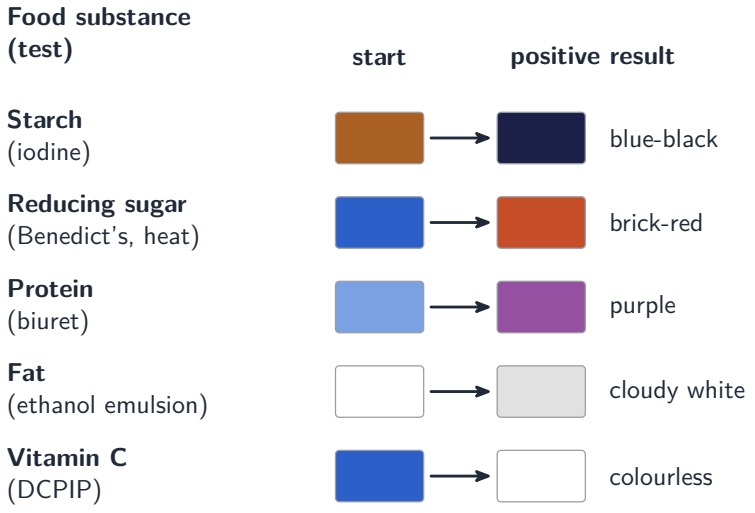
Starch grains from a potato, seen under a microscope — each grain is built from many glucose units

Food tests

You can test a piece of food to find out which substances it contains. Add the test chemical and watch for a colour change.

Food substance	Test	Positive result
starch	add **iodine solution** 碘液	orange-brown → blue-black
reducing sugars 还原糖 (such as glucose)	add **Benedict's solution** 本尼迪特试剂 and heat	blue → brick-red / orange
protein	add **biuret** 双缩脲 solution	blue → purple
fats and oils	**ethanol** 乙醇 **emulsion** 乳浊液 test	a cloudy white layer forms
vitamin 维生素 C	add to blue DCPIP	blue → colourless

Two things to remember: only the Benedict's test needs **heat**; and DCPIP loses its colour (goes colourless), while the other tests gain a new colour.



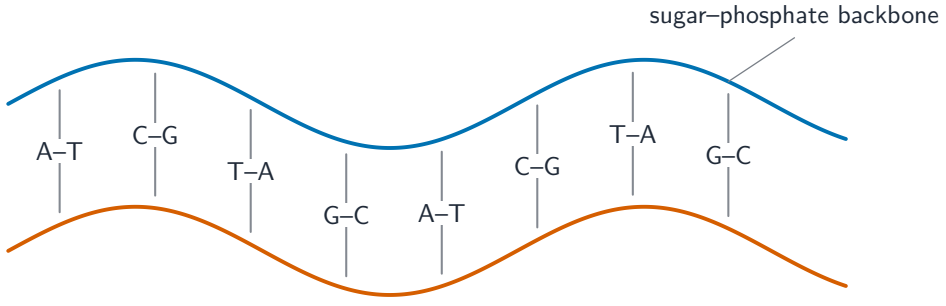
Each food test gives its own colour change for a positive result

Worked example. A student tests an unknown food. Iodine solution stays orange-brown. Benedict's solution, after heating, turns brick-red. Biuret solution turns purple. What does the food contain? Iodine staying orange-brown is a **negative** result, so there is no starch. Brick-red is a **positive** Benedict's result, so reducing sugar is present. Purple is a **positive** biuret result, so protein is present. The food contains reducing sugar and protein, but no starch. "No colour change" is a real result - it tells you the substance is **absent**.

The structure of DNA (Supplement)

DNA is the **genetic material** 遗传物质 — it carries the instructions for building and running an organism. Its structure has four key points:

- two **strands** 链 are coiled together to form a **double helix** 双螺旋 (like a twisted ladder).
- each strand carries chemicals called **bases** 碱基.
- **bonds** 化学键 between pairs of bases hold the two strands together.
- the bases always pair in the same way: **A with T**, and **C with G**.



two strands form a double helix; bases pair A–T and C–G

DNA is a double helix; the bases always pair A–T and C–G

Exam tips

- Carbohydrates and fats are made of C, H and O. Proteins also contain N (nitrogen).
- Learn each food test and its colour change. For reducing sugars you must **heat** the Benedict's solution.
- DCPIP goes from blue to **colourless**; the other four tests each give a **new** colour.
- In DNA, the bases pair only A–T and C–G. So if you know the bases on one strand, you can work out the other.

Enzymes

IGCSE Biology

What enzymes are

Biological washing powders contain enzymes that break down stains.

A **catalyst** 催化剂 is a substance that speeds up the **rate** 速率 of a **chemical reaction** 化学反应 but is **not** used up or changed by the reaction. The same catalyst can be used again and again.

Enzymes 酶 are biological catalysts — catalysts made by living cells. They are **proteins** 蛋白质. Enzymes take part in all the reactions of **metabolism** 新陈代谢, so they control almost every chemical reaction in a living thing.

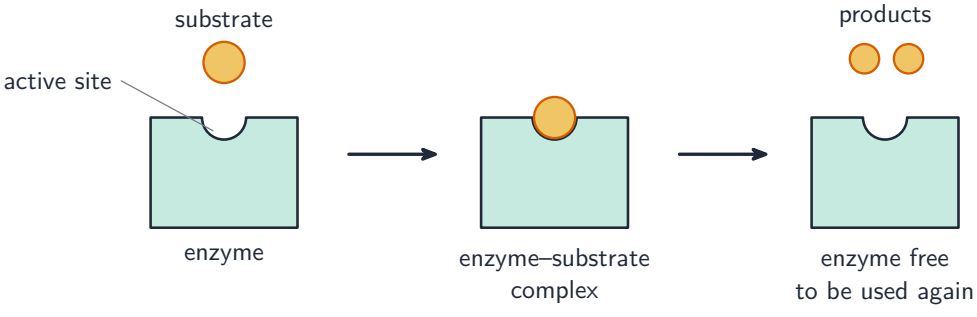
Enzymes are vital. Without them, the reactions that keep you alive would be far too slow. Enzymes raise the reaction rate enough to keep the organism alive.

How an enzyme works

Kiwi fruit contains a protease enzyme that breaks down protein.

Each enzyme has a special pocket called its **active site** 活性位点. The **molecule** 分子 it works on is called the **substrate** 底物.

- The shape of the active site is **complementary** 互补 to the shape of the substrate — they fit together like a key in a lock.
- The substrate slots into the active site. **(Supplement)** This makes an **enzyme-substrate complex** 酶底物复合物.
- The reaction takes place, and the substrate is changed into one or more **products** 产物.
- The products leave the active site, which is then free to be used again.



The substrate fits the active site like a key in a lock, then leaves as products

Why enzymes are specific (Supplement)

Each enzyme is **specific** 专一 — it works on only one kind of substrate. This is because only that substrate has the right shape to fit the active site. A substrate of a different shape will not fit, just as the wrong key will not open a lock.

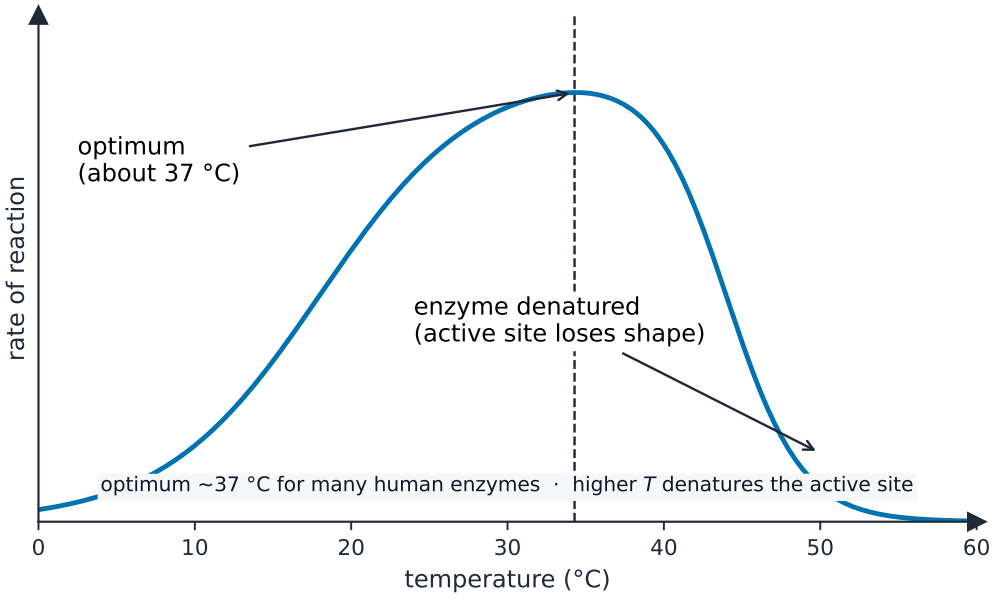
Only the matching substrate fits the active site

The effect of temperature and pH

The activity of an enzyme depends on **temperature** 温度 and pH. You can investigate this by measuring how fast the reaction goes at different temperatures or pH values.

Temperature

- As the temperature rises from cold, enzyme activity speeds up. The enzyme and substrate molecules have more **kinetic energy** 动能, so they move faster and meet more often. **(Supplement)** There are more useful **collisions** 碰撞 each second.
- Activity is highest at the **optimum temperature** 最适温度 (about 37 °C in the human body).
- Above the optimum, activity falls fast. The heat changes the shape of the active site, so the substrate no longer fits. The enzyme is **denatured** 变性. Denaturation is permanent — the enzyme cannot recover.

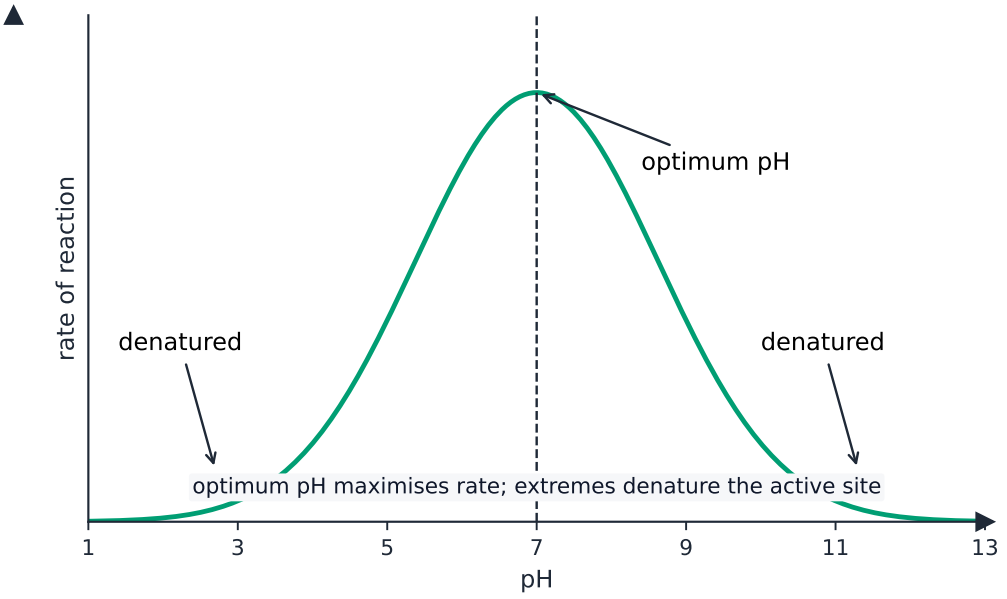


Activity peaks at the optimum temperature, then falls sharply as the enzyme denatures

Worked example. A reaction finishes in 50 s at 20 °C, and in 20 s at 37 °C. Which temperature is faster, and by how much? A **shorter** time means a **faster** rate, so work out a rate with rate = 1000 ÷ time. At 20 °C the rate is 1000 ÷ 50 = 20 units; at 37 °C it is 1000 ÷ 20 = 50 units. So 37 °C is 50 ÷ 20 = **2.5 times faster**. Do not say the rate "went up by 30 s" - a time is not a rate. Turn the time into a rate first, and remember the bigger rate always goes with the smaller time.

pH

- Each enzyme works best at one particular pH.
- If the pH is too high or too low, the shape of the active site changes, the substrate stops fitting, and the enzyme is denatured.



Each enzyme has one optimum pH; far from it the enzyme is denatured

Exam tips

- An enzyme is both a **protein** and a biological catalyst: it speeds up a reaction and is **not** used up.
- Describe the shape: the active site is **complementary** to the substrate (the lock-and-key idea). Each enzyme is **specific** to one substrate.
- Low temperature → slow (too little kinetic energy). Optimum → fastest. Too hot → **denatured** (the active site loses its shape, permanently).
- The wrong pH also **denatures** the enzyme by changing the shape of the active site.
- "Denatured" does **not** mean "killed" — enzymes are not alive. Say that the shape of the active site has changed so the substrate no longer fits.

Plant nutrition

IGCSE Biology

Photosynthesis

Green leaves capture sunlight for photosynthesis.

Photosynthesis 光合作用 is the process by which plants make **carbohydrates** 碳水化合物 from simple **raw materials** 原料, using **energy** 能量 from light. It is how plants feed themselves.

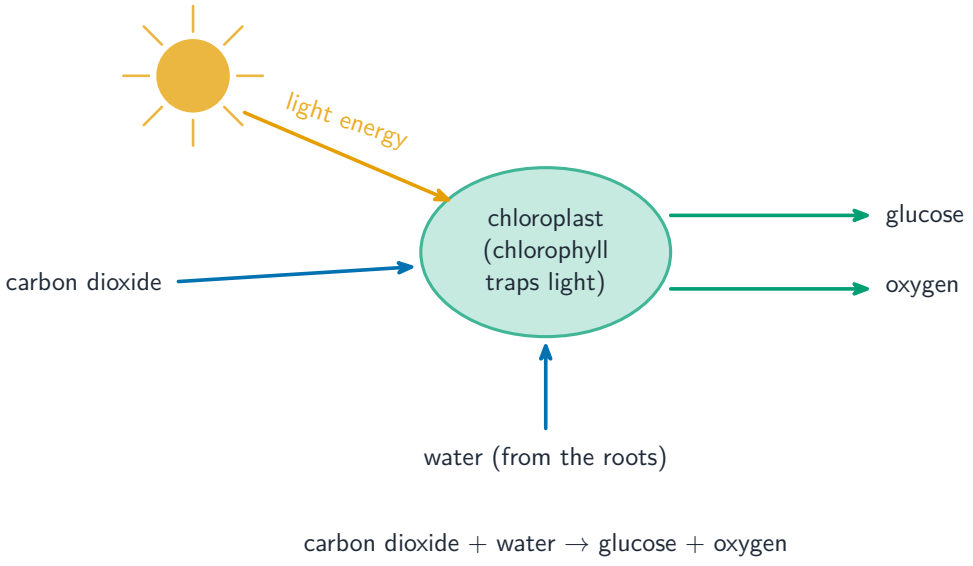
The word equation

$$\text{carbon dioxide} + \text{water} \rightarrow \text{glucose} + \text{oxygen}$$

In words: plants take in **carbon dioxide** 二氧化碳 and water, and make **glucose** 葡萄糖 and **oxygen** 氧气. This reaction can only happen in the light, and only where there is **chlorophyll** 叶绿素.

(Supplement) The balanced chemical equation is:

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$



carbon dioxide + water → glucose + oxygen

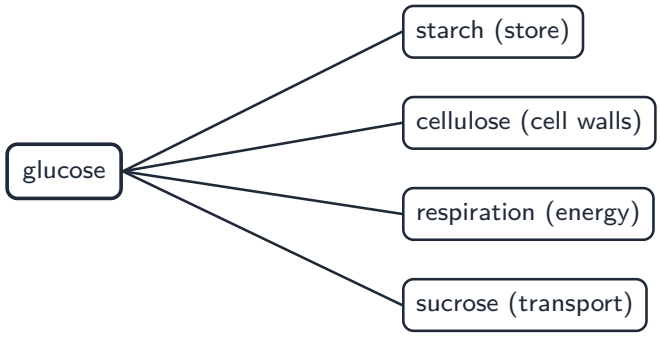
Photosynthesis takes in carbon dioxide and water and makes glucose and oxygen, using light

What chlorophyll does

Chlorophyll is a green **pigment** 色素 found in the **chloroplasts** 叶绿体. It traps light and transfers the energy from light into energy stored in chemicals. That chemical energy is then used to build carbohydrates.

What the plant does with the glucose

Use	What happens
store	changed to **starch** 淀粉, an energy store that does not dissolve
build	made into **cellulose** 纤维素 to build **cell walls** 细胞壁
release energy	broken down in **respiration** 呼吸作用 to release energy
transport	changed to **sucrose** 蔗糖 and moved around the plant in the **phloem** 韧皮部
attract animals	made into **nectar** 花蜜 to attract **insects** 昆虫 for **pollination** 传粉



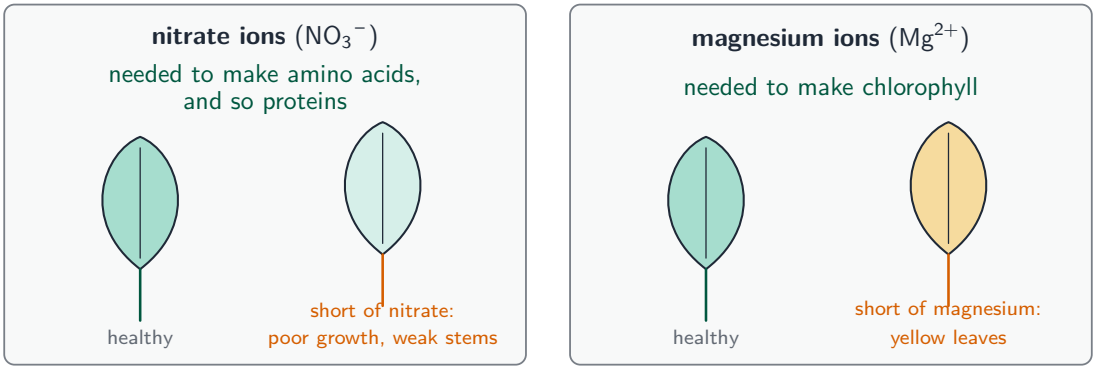
What a plant does with the glucose it makes

Minerals from the soil

Plants also take up mineral **ions** 离子 from the soil through their roots:

- **nitrate ions** 硝酸根离子 — needed to make **amino acids** 氨基酸 (and so proteins).
- **magnesium ions** 镁离子 — needed to make chlorophyll.

A plant short of nitrate grows poorly with weak stems; a plant short of magnesium has yellow leaves (it cannot make enough chlorophyll).



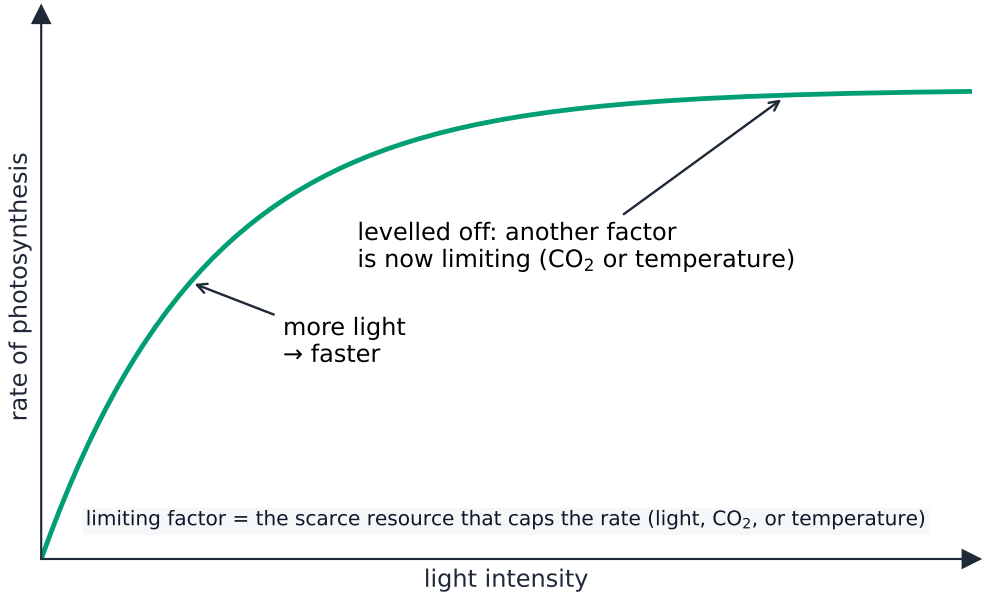
A plant short of nitrate grows poorly; a plant short of magnesium has yellow leaves

The rate of photosynthesis

The **rate** 速率 of photosynthesis depends on three things:

- **light intensity** 光照强度 — more light gives a faster rate, up to a point.
- carbon dioxide **concentration** 浓度 — more carbon dioxide gives a faster rate.
- **temperature** 温度 — a warmer temperature is faster, until it gets so hot that the enzymes are denatured.

(Supplement) At any moment, the one factor that is in shortest supply holds back the rate. This is called the **limiting factor** 限制因素. For example, on a dull day light intensity is usually the limiting factor; on a bright day carbon dioxide may be.



More light speeds up photosynthesis until another factor becomes limiting

Worked example. On a graph of rate against light intensity, the line rises steeply at first and then levels off flat. Which factor is limiting on each part? On the **rising** part, adding light raises the rate, so **light intensity** is the limiting factor there. On the **flat** part, adding more light changes nothing, so light is no longer limiting - something else is, usually carbon dioxide concentration or temperature. The test is always the same: if adding more of a factor speeds the reaction up, that factor was the one holding it back.

Investigating photosynthesis

To show that a plant needs light, chlorophyll and carbon dioxide, you test a leaf for starch after taking one of them away. A **control** 对照 keeps every other condition the same, so the test is fair. (First leave the plant in the dark to use up its starch.) A leaf with green and white parts shows starch only in the green parts, which have chlorophyll.

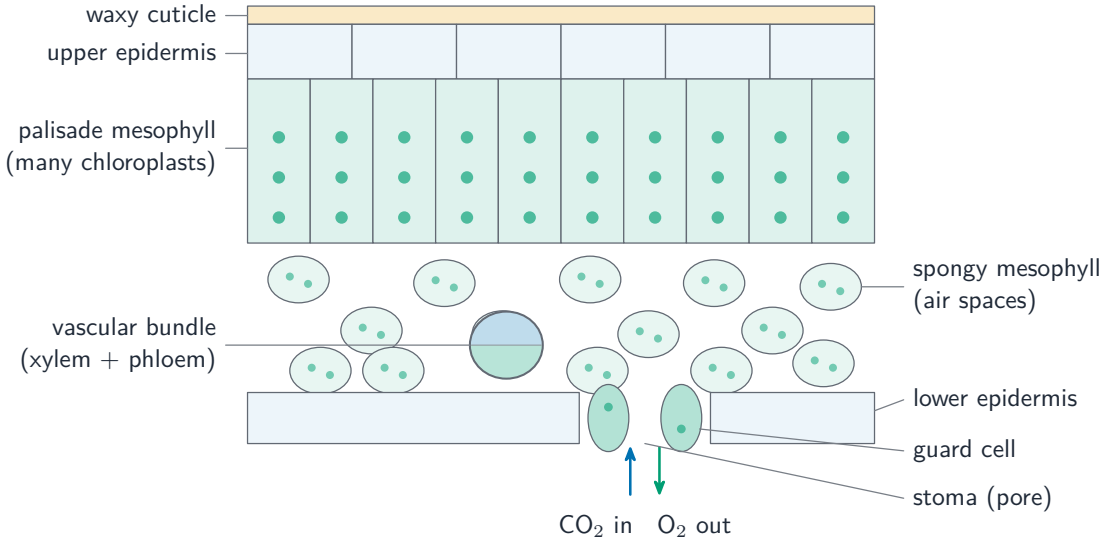
You can also watch **gas exchange** 气体交换 in a water plant using hydrogencarbonate **indicator** 指示剂, which changes colour as the carbon dioxide level changes. In the light the plant takes in carbon dioxide for photosynthesis; in the dark it gives out carbon dioxide from respiration.

Leaf structure

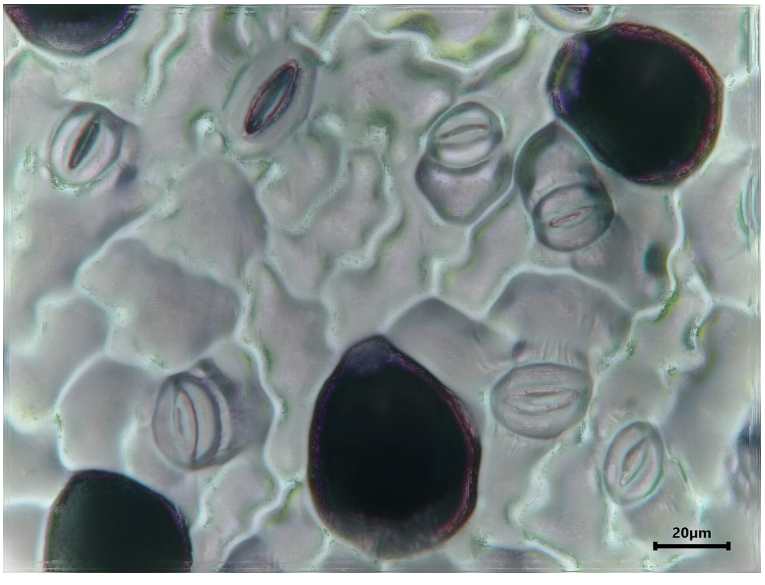
A leaf is well **adapted** 适应 for photosynthesis. Most leaves are broad, with a large **surface area** 表面积 to catch plenty of light, and thin, so that gases and light quickly reach all the cells.

The middle of the leaf, the **mesophyll** 叶肉, is where most photosynthesis happens. These are the main parts of a leaf:

Structure	Job / how it helps photosynthesis
cuticle 角质层	a clear waxy layer on top; it reduces water loss but still lets light through
upper **epidermis** 表皮	a clear layer of cells with no chloroplasts; it lets light pass to the cells below
palisade mesophyll 栅栏叶肉	tall, column-shaped cells packed with chloroplasts, near the top; they do most of the photosynthesis
spongy mesophyll 海绵叶肉	rounded cells with **air spaces** 气腔 between them, so gases can move easily
stomata 气孔	tiny holes, mostly on the lower surface, that let carbon dioxide in and oxygen out
guard cells 保卫细胞	a pair of cells around each stoma; they open and close it
lower epidermis	a thin layer that holds the stomata
vascular bundles 维管束	contain **xylem** 木质部 (brings water to the leaf) and phloem (carries sugars away)



A leaf in cross-section: each tissue is adapted for photosynthesis and gas exchange



Real stomata in the lower surface of a leaf — each pore has two guard cells (scale bar 20 µm)

Exam tips

- Learn the word equation exactly: carbon dioxide + water → glucose + oxygen (in light, with chlorophyll).
- Chlorophyll is in the chloroplasts; it does not get used up — it transfers light energy.

- Link each factor to the rate: more light, more carbon dioxide, warmer (but not too hot) → faster, until a **limiting factor** stops further increase.
- For leaf structure, always link the part to its job: broad and thin to catch light; palisade cells full of chloroplasts; stomata and air spaces for gas exchange.
- Nitrate ions → amino acids; magnesium ions → chlorophyll.

Human nutrition

IGCSE Biology

A balanced diet

A balanced diet includes plenty of fruit and vegetables.

A **balanced diet** 均衡饮食 gives you all the substances you need, in the right amounts. There are seven parts.

a balanced diet: seven parts

carbohydrates main energy source	**fats and oils** energy store, warmth	**proteins** growth and repair	**vitamins** C: skin & gums; D: calcium

mineral ions calcium: bones, teeth; iron: red blood cells	**fibre** keeps the gut moving	**water** most reactions happen in it

the right **amounts** matter too - too much or too little each brings its own problems

The seven parts of a balanced diet and the job each one does

Part of diet	Good sources	Why you need it
carbohydrates 碳水化合物	rice, bread, potatoes	the main source of **energy** 能量
fats 脂肪 and oils	butter, oil, nuts	an energy store; help keep you warm
proteins 蛋白质	meat, fish, eggs, beans	growth and repair of cells
vitamin 维生素 C	fresh fruit, vegetables	keeps skin and gums healthy
vitamin D	sunlight, oily fish, eggs	helps the body take in **calcium** 钙
mineral ions 矿物质离子 — calcium	milk, cheese	strong bones and teeth
mineral ions — **iron** 铁	red meat, leafy greens	needed to make **haemoglobin** 血红蛋白, the red pigment in red blood cells that carries oxygen
fibre 膳食纤维 (roughage)	vegetables, whole grains	keeps food moving through the gut
water	drinks and food	needed for all reactions; most of the body is water

Two diseases come from missing a vitamin:

- too little vitamin C → **scurvy** 坏血病 (bleeding gums, slow healing).
- too little vitamin D → **rickets** 佝偻病 (soft, bent bones), because the body cannot take in enough calcium.

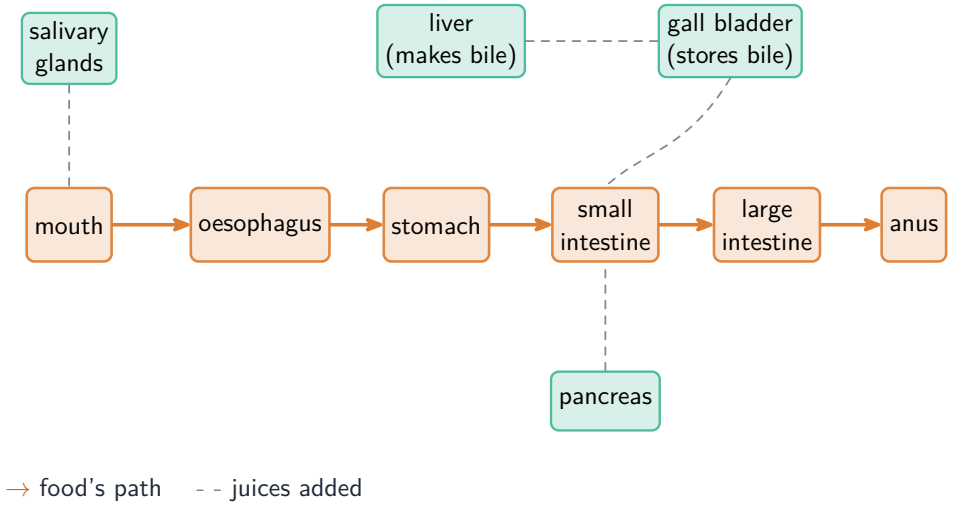
Worked example. A child eats almost no fresh fruit or vegetables. Their gums bleed and small cuts heal slowly. Which part of the diet is missing, and why does that explain the symptoms? Fresh fruit and vegetables are the main source of **vitamin C**, and too little vitamin C causes **scurvy** - whose signs are exactly bleeding gums and slow healing. So the missing part is vitamin C. Name the **substance** and the **disease** separately: an answer that says only "a vitamin deficiency" does not earn the mark.

The digestive system

The **digestive system** 消化系统 breaks food down. Food passes along one long tube, the **alimentary canal** 消化道:

mouth → **oesophagus** 食道 → **stomach** 胃 → **small intestine** 小肠 (the **duodenum** 十二指肠 then the **ileum** 回肠) → **large intestine** 大肠 (the **colon** 结肠, **rectum** 直肠 and **anus** 肛门).

Some organs help with digestion but food does not pass through them: the **salivary glands** 唾液腺 in the mouth, the **pancreas** 胰腺, the **liver** 肝脏 and the **gall bladder** 胆囊.



The alimentary canal that food passes through, plus the organs that add digestive juices

Five things happen to food, in order:

Process	What it means
ingestion 摄入	taking food and drink into the body through the mouth
digestion 消化	breaking food down into small molecules
absorption 吸收	**nutrients** 营养物质 move from the intestine into the blood
assimilation 同化	cells take in and use the nutrients
egestion 排遗	undigested food leaves the body as **faeces** 粪便

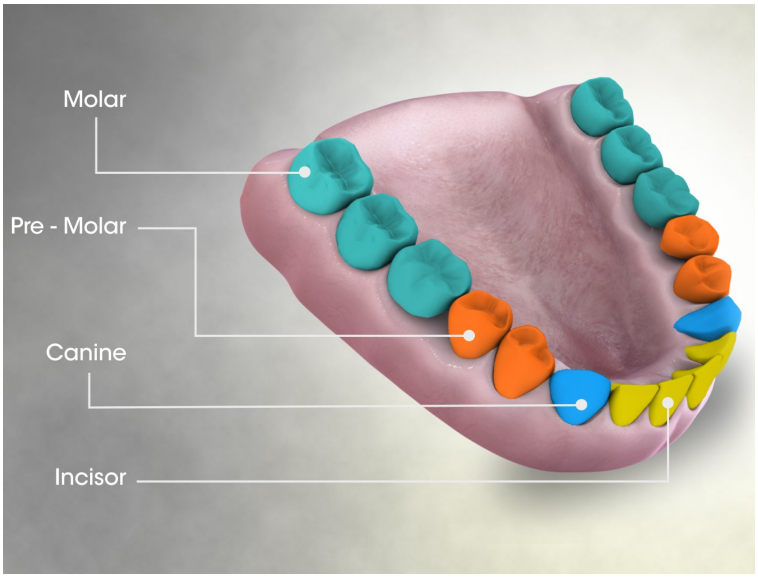
Physical digestion

Physical digestion breaks food into smaller pieces **without** changing the food molecules. This gives a larger **surface area** 表面积 for the **enzymes** 酶 to act on later.

Teeth

You have four kinds of **teeth** 牙齿:

Tooth	Job
incisors 门齿	sharp front teeth for biting and cutting
canines 犬齿	pointed teeth for tearing
premolars 前臼齿	flat teeth for chewing and grinding
molars 臼齿	flat back teeth for chewing and grinding

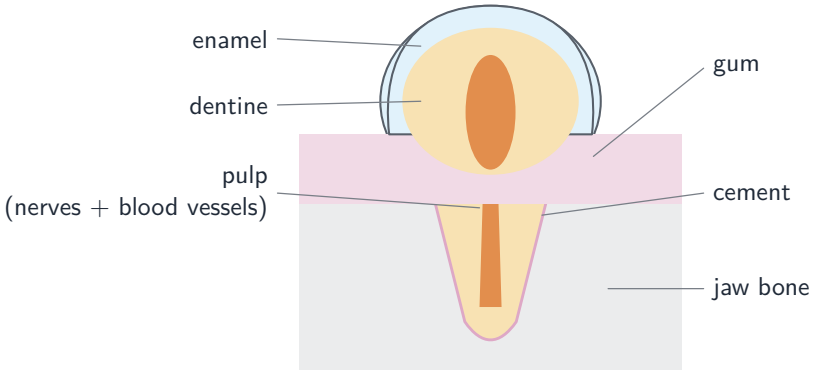


The four kinds of teeth: incisors and canines at the front, premolars and molars at the back

A tooth is built from these parts:

Part	Description
enamel 牙釉质	hard white outer layer; the hardest material in the body
dentine 牙本质	softer, bone-like layer under the enamel
pulp 牙髓	soft centre with **nerves** 神经 and **blood vessels** 血管
cement 牙骨质	fixes the root into the jaw

Teeth are set into the bone of the jaw and held firm by the **gums** 牙龈.



A tooth in section: hard enamel over dentine, a soft pulp, and a root set in the jaw

The stomach

The wall of the stomach is made of **muscle** 肌肉 that squeezes and mixes the food, breaking it into smaller pieces.

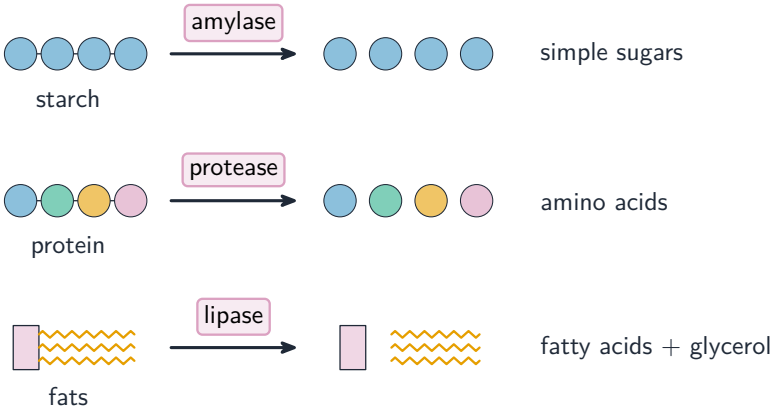
Bile (Supplement)

Bile 胆汁 is made in the liver and stored in the gall bladder. It **emulsifies** 乳化 fats and oils — it breaks large drops of fat into many tiny droplets. This gives a much larger surface area for the enzyme **lipase** 脂肪酶 to digest the fat. Bile itself contains no enzymes.

Chemical digestion

Chemical digestion breaks large **insoluble** 不溶性 molecules into small **soluble** 可溶性 molecules. Only small soluble molecules can be absorbed into the blood. Enzymes carry out this work.

Enzyme	Breaks down	Into	Made in
amylase 淀粉酶	**starch** 淀粉	**reducing sugars** 还原糖	salivary glands, pancreas
protease 蛋白酶	protein	**amino acids** 氨基酸	stomach, pancreas
lipase	fats and oils	**fatty acids** 脂肪酸 and **glycerol** 甘油	pancreas



Digestive enzymes break large insoluble molecules into small soluble ones

Acid in the stomach

The stomach makes **hydrochloric acid** 盐酸, which is part of the **gastric juice** 胃液. This acid:

- kills harmful **microorganisms** 微生物 in the food, and
- gives an **acidic** 酸性 pH, the best pH for the stomach's protease to work.

Digesting starch and protein (Supplement)

Starch is digested in two steps:

- amylase breaks starch into **maltose** 麦芽糖.
- **maltase** 麦芽糖酶, on the membranes of the **epithelium** 上皮 lining the small intestine, breaks maltose into **glucose** 葡萄糖.

Protein is digested by two proteases:

- **pepsin** 胃蛋白酶 breaks protein down in the acidic stomach.
- **trypsin** 胰蛋白酶 breaks protein down in the **alkaline** 碱性 small intestine.

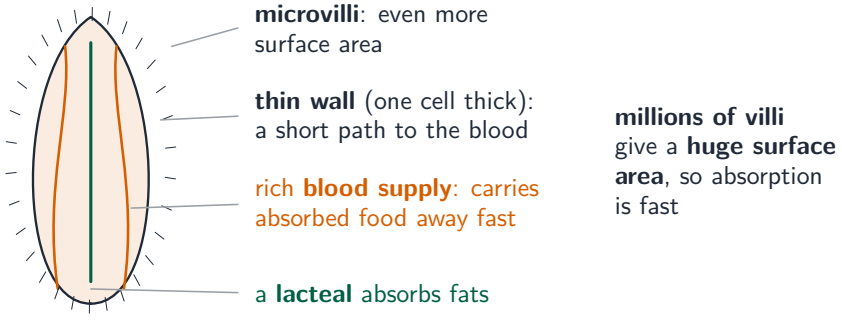
Bile is alkaline. It **neutralises** 中和 the acidic food and gastric juice as they enter the duodenum, giving a suitable pH for the enzymes there.

Absorption

Digested nutrients are absorbed into the blood in the small intestine. Most water is absorbed here too; the colon absorbs the rest, leaving solid faeces.

Villi (Supplement)

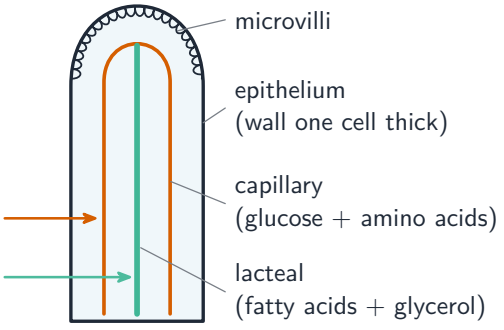
The inside of the small intestine is covered with millions of tiny finger-shaped **villi** 绒毛. Each villus is itself covered in much smaller **microvilli** 微绒毛. Together these give a huge surface area, so absorption is fast.



A villus is adapted for fast absorption: microvilli, a thin wall, a rich blood supply and a lacteal

A single villus has:

- a wall just one cell thick, so molecules have only a short distance to travel.
- a network of **capillaries** 毛细血管 that carry away absorbed glucose and amino acids.
- a **lacteal** 乳糜管 in the centre that carries away absorbed fatty acids and glycerol.



a villus (huge surface area for absorption)

A villus has a thin wall, a capillary network and a lacteal, for fast absorption

Exam tips

- A balanced diet has the right amount of each part. Learn one source and one use for each.
- Vitamin C ↔ scurvy; vitamin D ↔ rickets.
- The five processes in order: ingestion → digestion → absorption → assimilation → egestion. Egestion (faeces) is **not** excretion.
- Physical digestion makes pieces smaller (more surface area); chemical digestion uses enzymes to make molecules smaller and soluble.
- amylase → sugars, protease → amino acids, lipase → fatty acids + glycerol. Stomach acid kills microorganisms and sets a low pH.
- Villi and microvilli give a large surface area, and a thin wall gives a short distance — both make absorption faster.

Transport in plants

IGCSE Biology

Xylem and phloem

A tree moves water up from its roots through xylem vessels.

Plants have two transport tissues that run through the roots, stems and leaves:

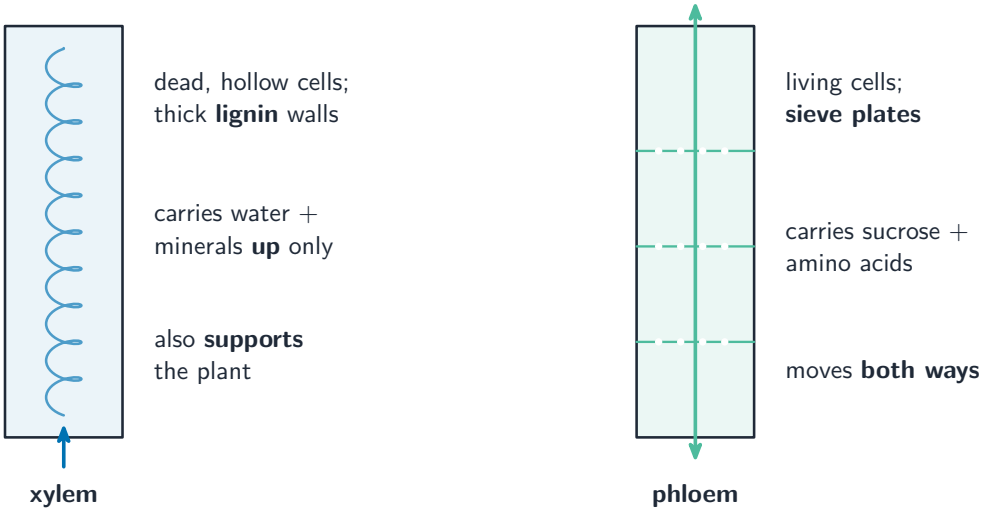
- **xylem** 木质部 — carries water and **mineral ions** 矿物质离子 up from the roots, and gives the plant **support** 支撑.
- **phloem** 韧皮部 — carries **sucrose** 蔗糖 and **amino acids** 氨基酸 to wherever they are needed.

In a root, stem or leaf, the xylem and phloem lie side by side in **vascular bundles** 维管束.

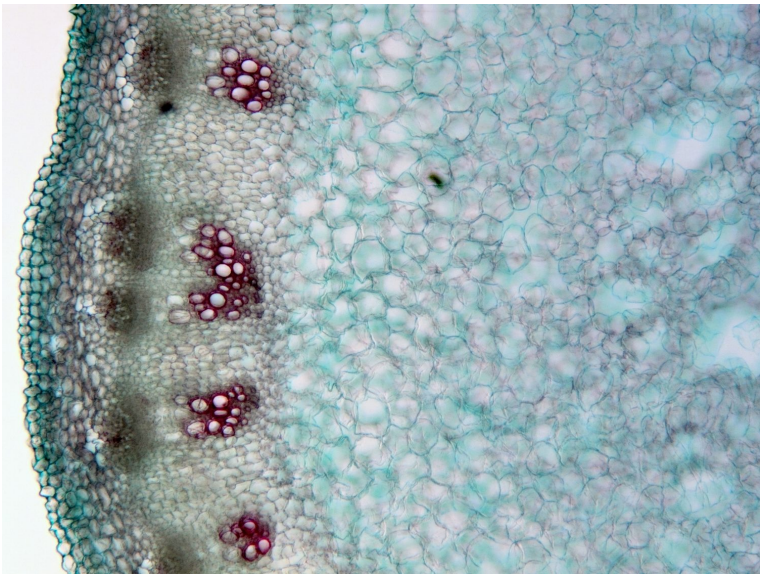
Xylem structure (Supplement)

Xylem is made of long tubes called **vessels** 导管, well suited to carrying water:

- their walls are thick and strengthened with **lignin** 木质素, which also helps support the plant.
- the cells are dead and empty (they have no cell contents), so water flows through freely.
- the cells are joined end to end with no walls across the tube, making one long, continuous pipe.



Xylem carries water up in dead lignified tubes; phloem carries sucrose in living cells



A stem in cross-section: the red-stained xylem sits in vascular bundles near the edge

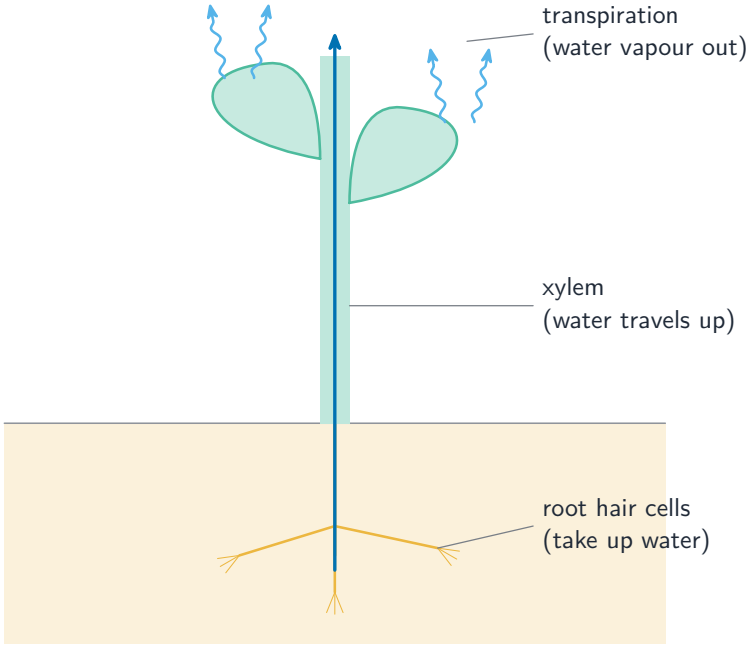
Water uptake

Water and mineral ions enter the plant through **root hair cells** 根毛细胞. The huge number of **root hairs** 根毛 gives a very large **surface area** 表面积, which speeds up the uptake of water and mineral ions.

The water then follows this pathway:

root hair cells → root **cortex** 皮层 cells → xylem → **mesophyll** 叶肉 cells in the leaf.

You can show this pathway by standing a plant or a white flower in water that contains a coloured **stain** 染色剂. The stain is carried up the xylem and colours the veins.

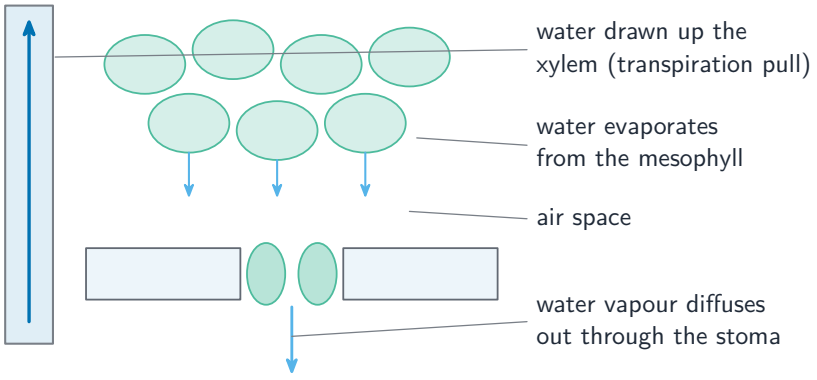


Water is taken up by root hairs, carried up the xylem, and lost from the leaves

Transpiration

Transpiration 蒸腾作用 is the loss of **water vapour** 水蒸气 from the leaves.

- Water **evaporates** 蒸发 from the wet surfaces of the mesophyll cells into the **air spaces** 气腔 inside the leaf.
- The water vapour then **diffuses** 扩散 out of the leaf through the **stomata** 气孔.



Water evaporates from the mesophyll and diffuses out of the stomata as water vapour

What changes the rate of transpiration

Factor	Transpiration is faster when...	Why
temperature 温度	it is hotter	water evaporates faster
wind speed 风速	it is windier	wind carries the water vapour away
humidity 湿度 (Supplement)	the air is drier	a bigger difference makes water diffuse out faster

Worked example. In a potometer the air bubble moves 60 mm in 5 minutes. Find the rate of water uptake, and say what happens when a fan is switched on. Rate = distance ÷ time = 60 ÷ 5 = **12 mm per minute**. Always give a rate its full unit, "mm per minute", not just "12". A fan raises the wind speed, which carries water vapour away from the leaf, so transpiration speeds up and the bubble moves further in the same 5 minutes.

How water rises up the xylem (Supplement)

As water vapour leaves the leaf, it pulls more water up behind it. This pull is called the **transpiration pull** 蒸腾拉力. The water molecules stick to one another by **forces of attraction** 吸引力, so they are drawn up the xylem together as one long **column** 水柱 of water.

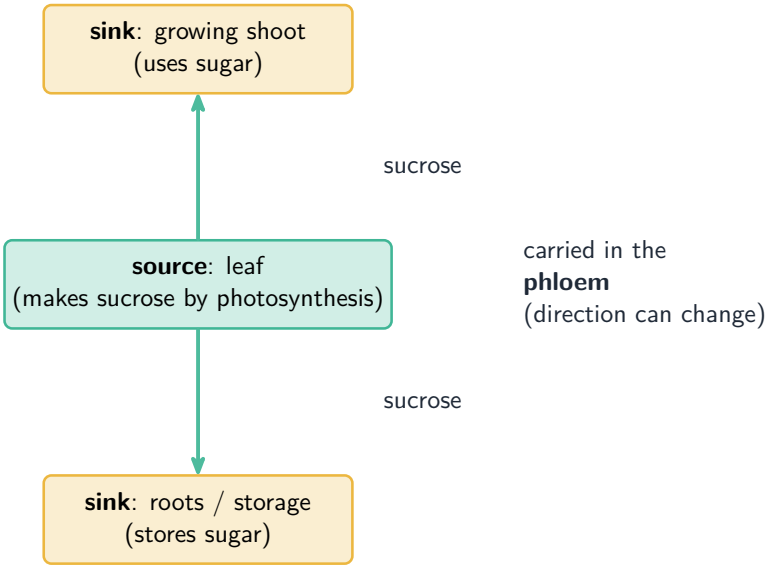
Wilting (Supplement)

If a plant loses water faster than it can take it up, its cells become soft and the plant **wilts** 萎蔫 — the leaves and stem droop. This often happens on a hot, dry, windy day.

Translocation (Supplement)

Translocation 转运 is the movement of sucrose and amino acids in the phloem, from **sources** 源 to **sinks** 库.

- sources are the parts that **release** sucrose or amino acids — for example the leaves, which make sugar by photosynthesis.
- sinks are the parts that **use or store** them — for example growing roots, or a storage organ.



The phloem moves sucrose from a source to a sink; the direction can change

Exam tips

- Xylem: water and mineral ions, upward only, plus support — its cells are dead, with thick lignin walls. Phloem: sucrose and amino acids, in living cells.
- Learn the water pathway: root hair cell → cortex → xylem → mesophyll.
- Transpiration = evaporation from the mesophyll, then diffusion out of the stomata. It is faster when hotter, windier or drier.

- Water rises by the **transpiration pull**; the water molecules hold together as a column.
- Translocation goes from a **source** (where sugar is made or stored) to a **sink** (where it is used). The direction can change with the season.

Transport in animals

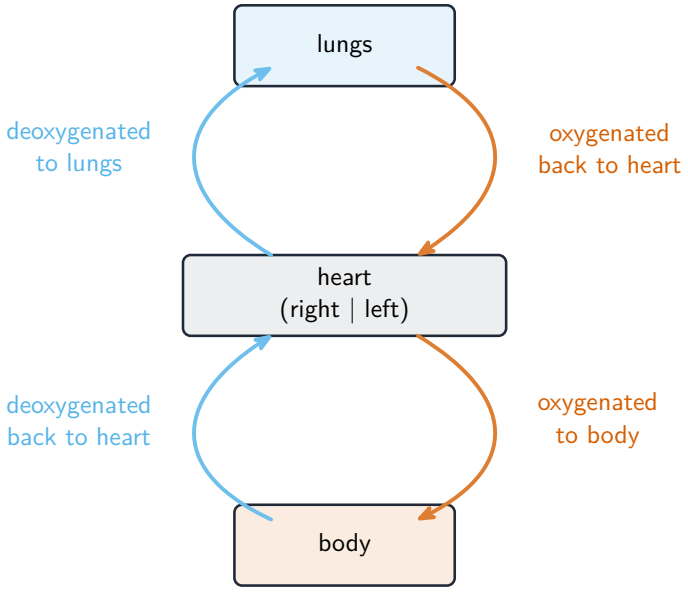
IGCSE Biology

The circulatory system

The **circulatory system** 循环系统 carries blood around the body. It has three parts: a **pump** 泵 (the **heart** 心脏), a network of **blood vessels** 血管, and **valves** 瓣膜 that keep the blood flowing one way only.

Single and double circulation (Supplement)

- A fish has a **single circulation** 单循环: the blood passes through the heart **once** on each trip around the body.
- A **mammal** 哺乳动物 has a **double circulation** 双循环: the blood passes through the heart **twice** on each full trip — once on the way to the lungs, and once on the way to the rest of the body.
- The advantage of a double circulation: the blood can be pumped again at **high pressure** 压力 before going to the body, so it travels faster and delivers **oxygen** 氧气 quickly.



In a double circulation, blood passes through the heart twice on each trip round the body

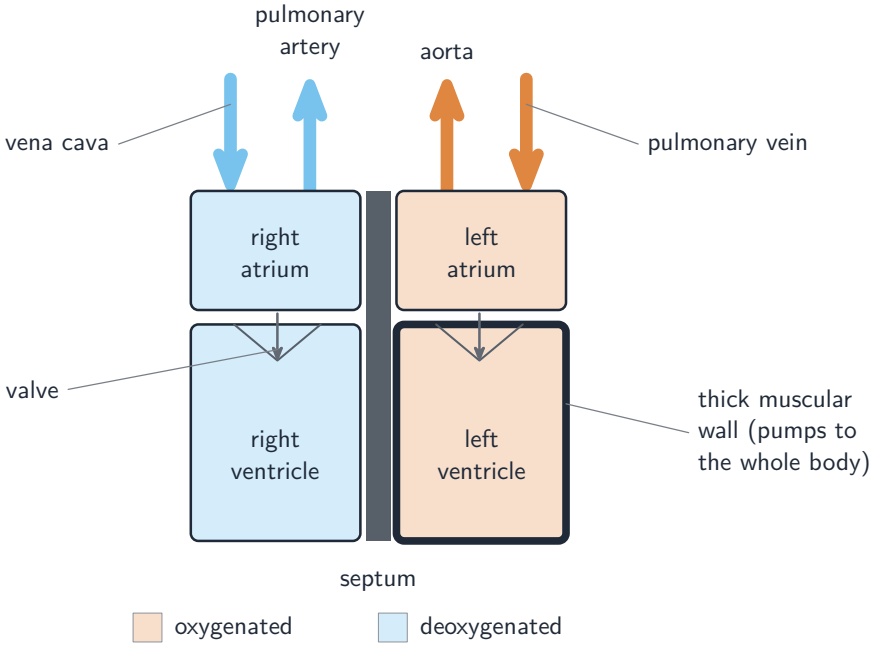
The heart

The heart is made of **muscle** 肌肉. A wall called the **septum** 隔膜 divides it into a left side and a right side. On each side there is an upper chamber, the **atrium** 心房, and a lower chamber, the **ventricle** 心室. Valves between the chambers stop the blood flowing backwards. The heart muscle is fed with blood by the **coronary arteries** 冠状动脉.

(Supplement) The wall of the left ventricle is thicker than the right, because it must pump blood all the way around the body; the right side only pumps blood to the nearby lungs. The atria have thin walls, as they only push blood into the ventricles just below them.

The septum keeps **oxygenated blood** 含氧血 on the left side apart from **deoxygenated blood** 缺氧血 on the right side, so the two never mix.

(Supplement) The valves between each atrium and ventricle are the **atrioventricular valves** 房室瓣. The valves at the exit of each ventricle are the **semilunar valves** 半月瓣.



The heart's four chambers; the left ventricle has the thickest wall, to pump to the whole body

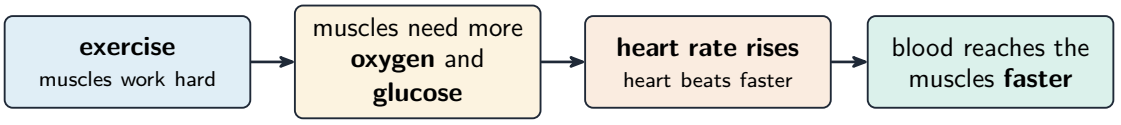
How the heart beats (Supplement)

1. The atria **contract** 收缩 and push blood down into the ventricles.
2. The ventricles contract and force blood out into the arteries; the valves snap shut so blood cannot flow back.
3. The muscle relaxes and the heart fills with blood again.

Blood is pumped away from the heart in arteries and returns to the heart in veins.

Heart rate and exercise

You can check the heart's activity with an **ECG**, by feeling the **pulse** 脉搏 in an artery, or by listening to the valves closing. During exercise the **heart rate** 心率 goes up, so blood reaches the muscles faster, bringing the extra oxygen and glucose they need.



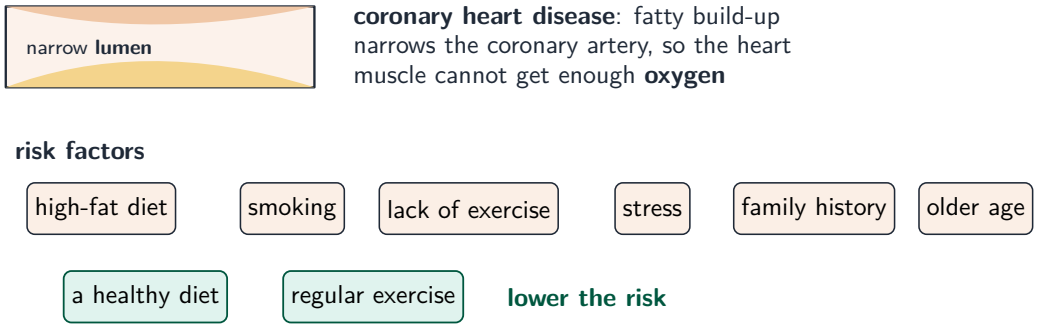
check the heart's activity by feeling the **pulse**, listening to the valves, or with an **ECG**

During exercise the heart rate rises so blood reaches the muscles faster

Worked example. A student counts 18 pulse beats in 15 seconds at rest, and 33 beats in 15 seconds straight after exercise. Give both heart rates in beats per minute. A minute holds $60 \div 15 = 4$ lots of 15 seconds, so multiply by 4. At rest: $18 \times 4 =$ **72 beats per minute**. After exercise: $33 \times 4 =$ **132 beats per minute**. The rise delivers more oxygen and glucose to the muscles. Writing the 15-second count straight down as the heart rate is the commonest mistake - always scale it up to a full minute.

Coronary heart disease

Coronary heart disease 冠心病 happens when the coronary arteries become narrow or blocked, so the heart muscle cannot get enough oxygen. **Risk factors** 风险因素 include a diet high in fat, lack of exercise, stress, smoking, family history (genetics), older age, and being male. A healthy diet and regular exercise lower the risk.



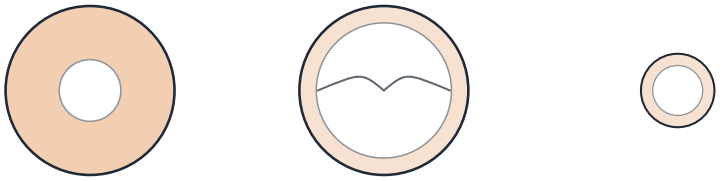
Coronary heart disease narrows the artery; several risk factors raise it and a healthy lifestyle lowers it

Blood vessels

There are three kinds of blood vessel. The space inside a vessel is its **lumen** 管腔.

Vessel	Wall	Lumen	Valves?	Job
arteries 动脉	thick, muscular, elastic	narrow	no	carry blood **away** from the heart, at high pressure
veins 静脉	thin	wide	yes	carry blood **back** to the heart, at low pressure
capillaries 毛细血管	one cell thick	very narrow	no	let **oxygen**, glucose and wastes pass between blood and cells

(Supplement) Arteries have thick elastic walls to cope with the high pressure from the heart. Veins have valves because their blood is at low pressure and could otherwise flow backwards. Capillaries are very thin (one cell thick) and very narrow, giving a large **surface area** 表面积 and a short distance for fast exchange.



artery
thick muscular, elastic wall; narrow lumen; high pressure

vein
thin wall; wide lumen; has **valves**; low pressure

capillary
wall one cell thick; lets substances be exchanged

Arteries, veins and capillaries are each built for their job

Main blood vessels

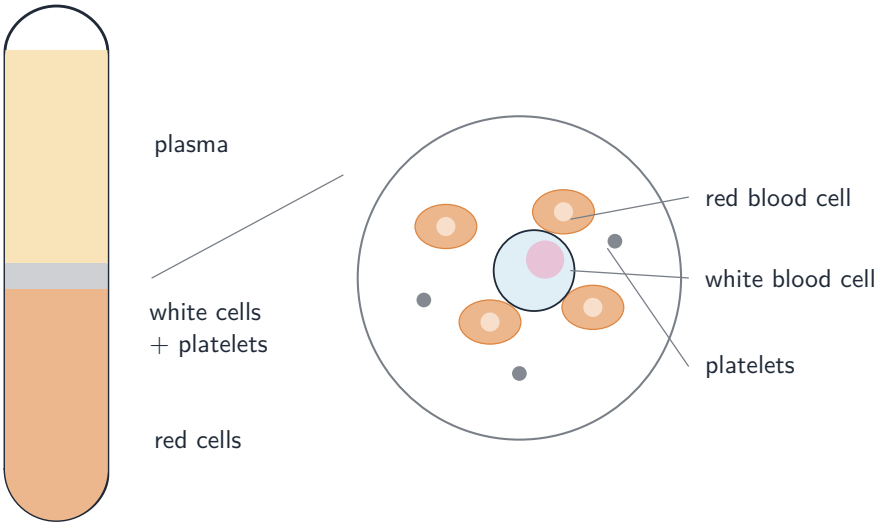
Connects	Artery (carries blood out)	Vein (carries blood in)
heart ↔ body	**aorta** 主动脉	**vena cava** 腔静脉
heart ↔ lungs	**pulmonary artery** 肺动脉	**pulmonary vein** 肺静脉
↔ kidney	**renal artery** 肾动脉	**renal vein** 肾静脉

(Supplement) The liver is served by the **hepatic artery** 肝动脉, the **hepatic vein** 肝静脉, and the **hepatic portal vein** 肝门静脉, which brings blood from the gut to the liver.

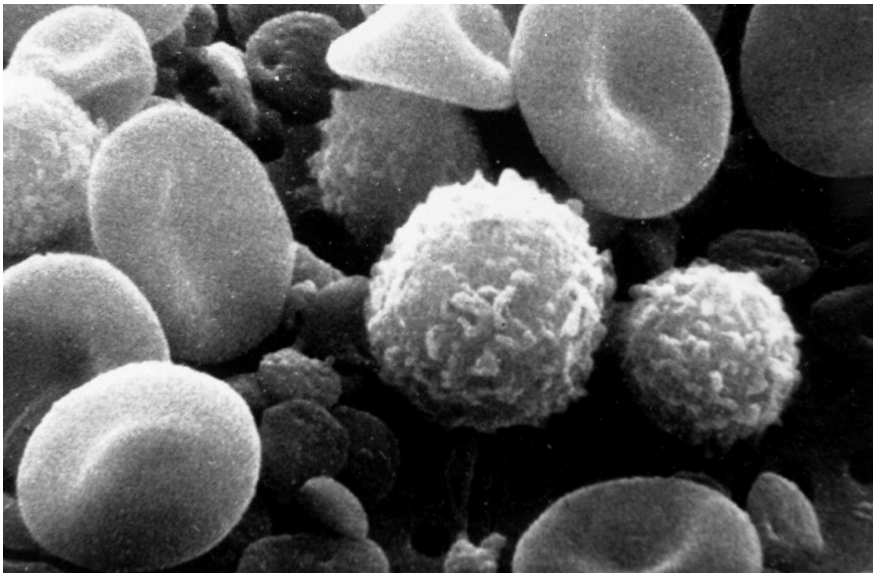
Blood

Blood has four parts:

Part	Function
red blood cells 红细胞	carry oxygen, using the red **pigment** 色素 **haemoglobin** 血红蛋白
white blood cells 白细胞	defend the body against disease
platelets 血小板	help the blood to **clot** 凝血
plasma 血浆	a liquid that carries blood cells, **ions** 离子, **nutrients** 营养物质, **urea** 尿素, **hormones** 激素 and **carbon dioxide** 二氧化碳



Blood is red cells, white cells and platelets carried in liquid plasma



Real blood cells under an electron microscope: red cells (discs), white cells and platelets

Defending the body, and clotting

White blood cells fight **pathogens** 病原体 (the microbes that cause disease) in two ways:

- **phagocytes** 吞噬细胞 carry out **phagocytosis** 吞噬作用 — they surround and digest the pathogens.
- **lymphocytes** 淋巴细胞 make **antibodies** 抗体, which stick to the pathogens and destroy them.

When you cut yourself, the blood **clots** to seal the wound. This stops blood loss and stops pathogens getting in. **(Supplement)** During clotting, a soluble protein called **fibrinogen** 纤维蛋白原 is changed into threads of **fibrin** 纤维蛋白. The threads form a net that traps blood cells and makes a solid clot.

Exam tips

- Circulatory system = pump (heart) + vessels + valves for one-way flow.
- Double circulation (mammals): blood passes through the heart twice. The left ventricle wall is thickest because it pumps to the whole body.
- Arteries carry blood **away** (thick, high pressure); veins carry it **back** (valves, low pressure); capillaries are for exchange (one cell thick).
- Blood = red cells (oxygen, haemoglobin) + white cells (defence) + platelets (clotting) + plasma (transport).
- Phagocytes engulf pathogens; lymphocytes make antibodies.

Diseases and immunity

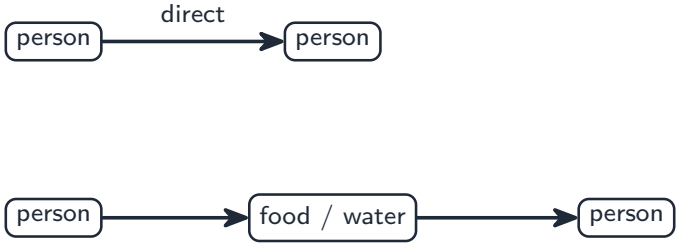
IGCSE Biology

Pathogens and disease

A **pathogen** 病原体 is an organism that causes **disease** 疾病. A **transmissible disease** 传染病 is one in which the pathogen can pass from one **host** 宿主 to another.

How pathogens spread

A mosquito can spread pathogens from person to person when it bites.



Pathogens spread by direct contact or indirectly

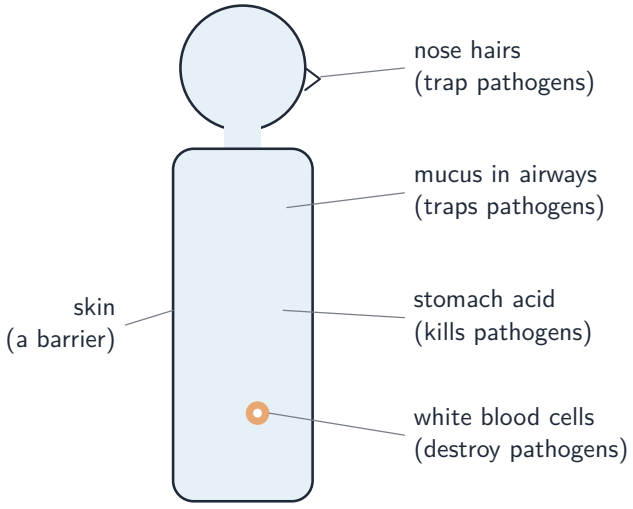
A pathogen is **transmitted** 传播 in two main ways:

- by **direct contact** 直接接触 — for example through blood and other **body fluids** 体液.
- indirectly — for example from **contaminated** 污染 surfaces, food, animals, or the air.

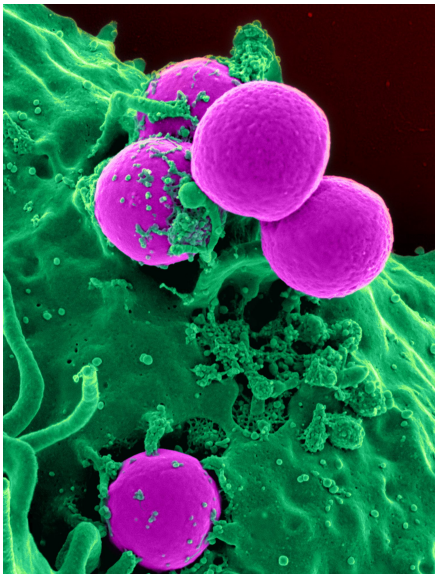
The body's defences

Your body has several **defences** 防御 that keep pathogens out or destroy them:

- **skin** — a barrier that covers and protects the body.
- **hairs in the nose** — trap dust and pathogens in the air you breathe in.
- **mucus** 黏液 — sticky liquid in the airways that traps pathogens.
- **stomach acid** 胃酸 — kills most pathogens in your food.
- **white blood cells** 白细胞 — find and destroy any pathogens that get inside.



The body keeps most pathogens out; white blood cells deal with any that get in



A white blood cell (green) engulfing round bacteria (purple), a key body defence

Controlling the spread of disease

Good public health stops disease spreading:

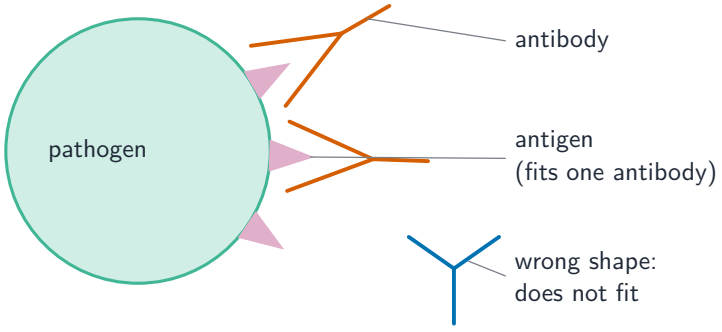
- a clean water supply, so drinking water carries no pathogens.
- **hygienic** 卫生 food preparation and good personal hygiene, such as washing your hands.
- proper waste disposal and **sewage treatment** 污水处理, so waste does not contaminate water or food.

Immunity (Supplement)

Antigens and antibodies

Every pathogen carries **antigens** 抗原 on its surface, and each kind of antigen has its own special shape.

Antibodies 抗体 are **proteins** 蛋白质 made by **lymphocytes** 淋巴细胞 (a kind of white blood cell). An antibody has a shape that is **complementary** 互补 to one antigen, so it fits only that antigen. When antibodies bind to a pathogen's antigens, they either destroy the pathogen directly or mark it so that **phagocytes** 吞噬细胞 destroy it.



An antibody's shape is complementary to one antigen, so it fits only that pathogen

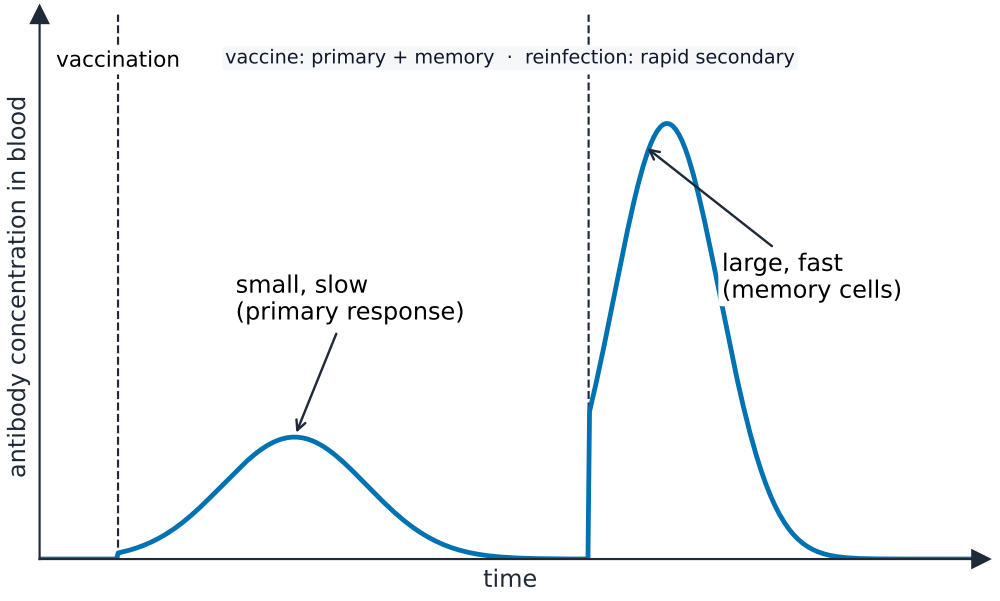
Active immunity and vaccination

Active immunity 主动免疫 is protection made by your **own** body producing antibodies. You gain it after an infection, or after **vaccination** 疫苗接种.

Vaccination works like this:

1. weakened pathogens, or just their antigens, are put into the body; they cannot make you ill.
2. the antigens make your lymphocytes produce antibodies.
3. the body also makes **memory cells** 记忆细胞 that stay for years.

If the real pathogen enters later, the memory cells make antibodies very fast, so you do not become ill. This gives long-term protection. If most people in a group are vaccinated, the disease cannot spread easily.



After vaccination, memory cells give a fast, large response if the real pathogen arrives

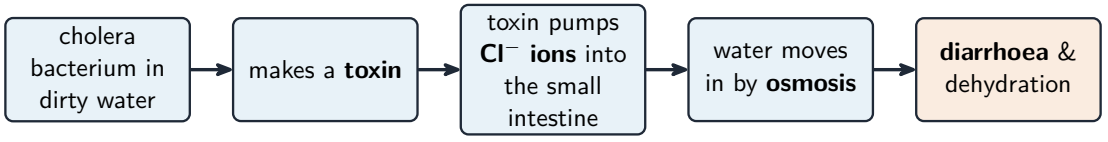
Worked example. After a first dose of a vaccine, antibody levels rise slowly and stay low. After a second dose of the same vaccine, they rise faster and reach a much higher level. Explain. At the first dose the body has no memory cells for that antigen, so time is lost while the right lymphocyte is found and multiplies - the response is slow and small. The second dose meets the memory cells left over from the first, which recognise the antigen at once, so antibodies are made sooner and in far greater numbers. The marks are for **memory cells**: "the body is used to it" earns nothing.

Passive immunity

Passive immunity 被动免疫 is protection from antibodies made by **another** body, not your own. For example, a baby receives antibodies from its mother across the **placenta** 胎盘 and in **breast milk** 母乳. This is why **breast-feeding** 母乳喂养 helps protect **infants** 婴儿. Passive immunity is only short-term, because **no** memory cells are made.

Cholera (Supplement)

Cholera 霍乱 is a disease caused by a **bacterium** 细菌 that spreads in contaminated water. The cholera bacterium makes a **toxin** 毒素. This toxin causes **chloride ions** 氯离子 to be pumped into the **small intestine** 小肠. Water then moves into the intestine by **osmosis** 渗透. The result is **diarrhoea** 腹泻, **dehydration** 脱水 (loss of water) and a loss of **ions** 离子 from the blood.



Cholera toxin pulls water into the gut by osmosis, causing diarrhoea and dehydration

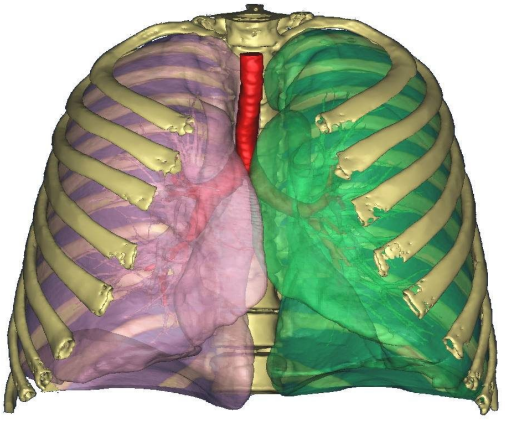
Exam tips

- Pathogen = organism that causes disease. Transmissible = can pass between hosts, by direct contact or indirectly.
- Learn the five body defences: skin, nose hairs, mucus, stomach acid, white blood cells.
- An antibody's shape is **complementary** to one antigen (like an enzyme and its substrate).
- Active immunity (from infection or vaccination) makes **memory cells** → long-term. Passive immunity (placenta, breast milk) makes **no** memory cells → short-term.
- Cholera: toxin → chloride ions into the gut → water in by osmosis → diarrhoea and dehydration.

Gas exchange in humans

IGCSE Biology

Gas exchange surfaces

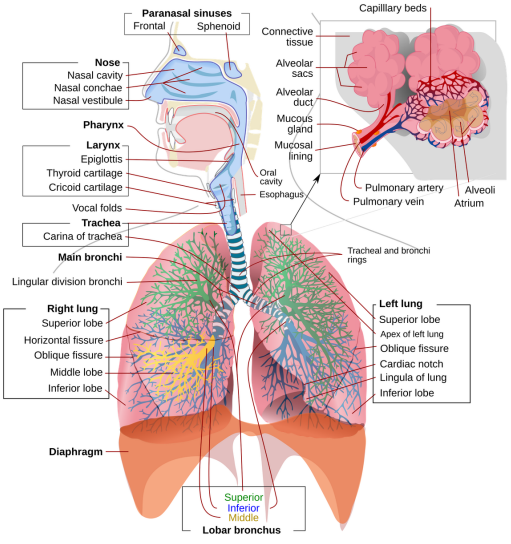


Gas exchange happens across the huge surface of the lungs.

Gas exchange 气体交换 is how **oxygen** 氧气 gets into the blood and **carbon dioxide** 二氧化碳 gets out, by **diffusion** 扩散. A good gas exchange surface has four features:

- a large **surface area** 表面积 — so more gas can cross at once.
- a **thin** surface — so gases have only a short distance to diffuse.
- a good **blood supply** — to keep a steep difference in concentration.
- good **ventilation** 通气 with air — fresh air keeps the difference steep.

The breathing system

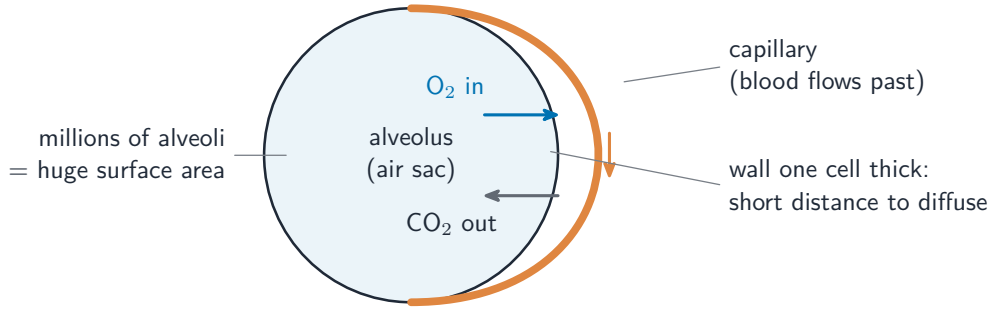


The lungs are the gas-exchange organs of the human body.

Air travels in and out through these parts:

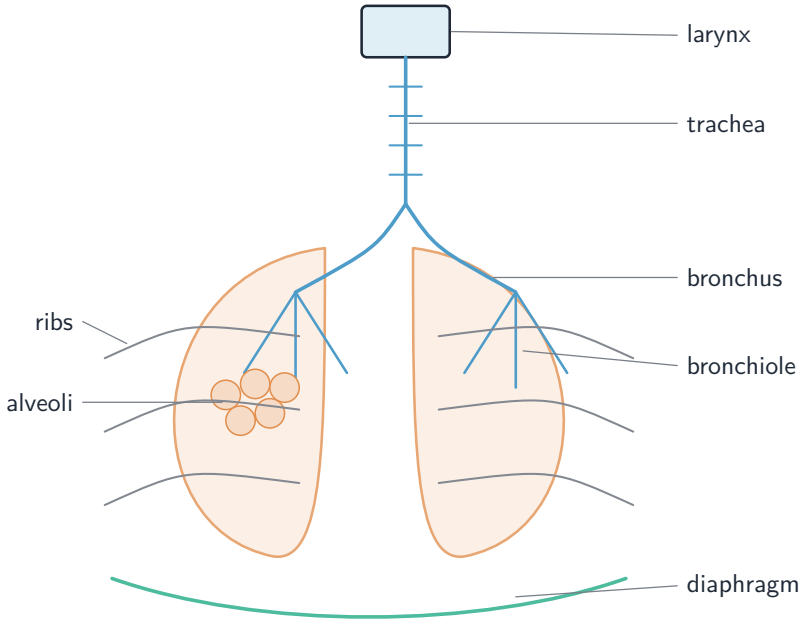
Part	Job
larynx 喉	the voice box, at the top of the windpipe
trachea 气管	the windpipe; carries air towards the lungs
bronchi 支气管	two tubes, one going to each lung
bronchioles 细支气管	smaller branching tubes inside the lungs
alveoli 肺泡	tiny air sacs where gas exchange happens; each is wrapped in **capillaries** 毛细血管

The alveoli make excellent gas exchange surfaces: there are millions of them (a huge surface area), each has a wall only one cell thick (a short distance), and each is surrounded by capillaries (a good blood supply).



At an alveolus, oxygen diffuses into the blood and carbon dioxide diffuses out

The lungs sit in the chest, protected by the **ribs** 肋骨. Below them is a sheet of muscle, the **diaphragm** 膈肌. Between the ribs are the **intercostal muscles** 肋间肌. **(Supplement)** The trachea is held open by rings of **cartilage** 软骨, so it cannot collapse when you breathe in.



Air travels from the trachea through the bronchi and bronchioles to the alveoli

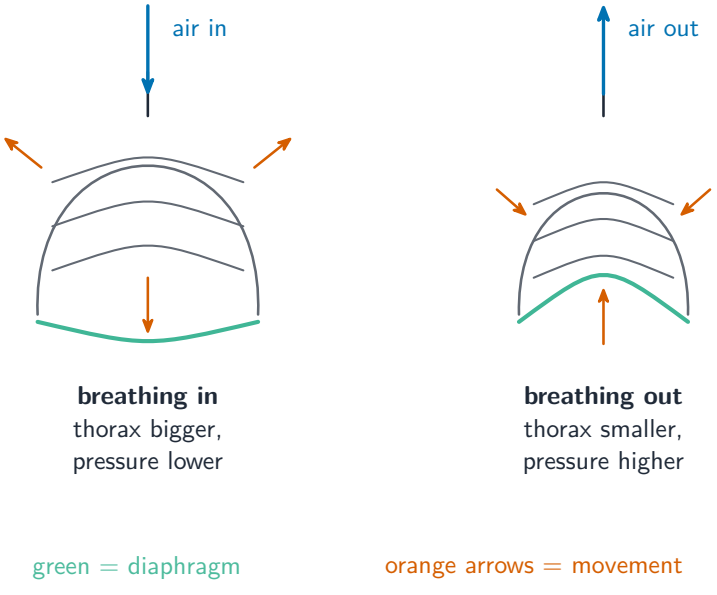
How you breathe (Supplement)

Breathing changes the volume and **pressure** 压力 inside the chest (the **thorax** 胸腔).

Breathing in (**inhaling** 吸气):

- the external intercostal muscles contract, pulling the ribs up and out.
- the diaphragm contracts and flattens (moves down).
- the thorax becomes bigger, so the pressure inside drops below the outside air pressure.
- air is pushed in.

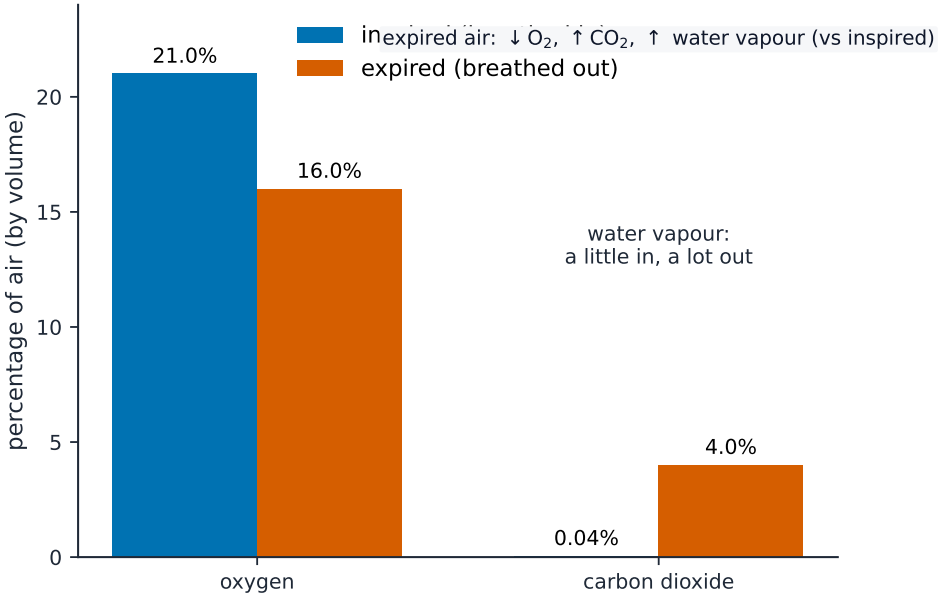
Breathing out (**exhaling** 呼气) is the opposite: the muscles relax (and the internal intercostal muscles may contract), the thorax becomes smaller, the pressure rises, and air is pushed out.



Breathing in makes the thorax bigger (lower pressure); breathing out makes it smaller

Inspired and expired air

Gas	Inspired air (breathed in)	Expired air (breathed out)
oxygen	about 21%	about 16% (less)
carbon dioxide	about 0.04%	about 4% (more)
water vapour 水蒸气	a little	a lot (more)



Expired air has less oxygen and much more carbon dioxide than inspired air

You can test for carbon dioxide with **limewater** 石灰水, which turns cloudy. Expired air turns limewater cloudy much faster than inspired air, showing it contains more carbon dioxide.

Breathing and exercise

During exercise your muscles respire faster and make more carbon dioxide. This raises the **concentration** 浓度 of carbon dioxide in the blood. **(Supplement)** Your **brain** 大脑 detects the rise and makes you breathe at a faster **rate** 速率 and a greater depth. This brings in more oxygen and removes the extra carbon dioxide quickly.

Worked example. At rest a person takes 12 breaths per minute, moving 500 cm^3 of air per breath. During exercise this becomes 20 breaths per minute at 900 cm^3 per breath. How much air passes through the lungs each minute in each case? Multiply the rate by the depth. At rest: $12 \times 500 =$ **6000 cm^3 per minute**. During exercise: $20 \times 900 =$ **18 000 cm^3 per minute**, three times as much. Exercise raises **both** the

rate and the depth of breathing - an answer that changes only the rate throws away half the marks.

Keeping the airways clean (Supplement)

The airways are lined with two kinds of cell that trap and remove dirt:

- **goblet cells** 杯状细胞 make **mucus** 黏液, which traps **pathogens** 病原体 and dust **particles** 粒子.
- **ciliated cells** 纤毛细胞 have tiny hairs that sweep the mucus, with the trapped dirt, up to the throat, where it is swallowed.

Exam tips

- A gas exchange surface is large, thin, with a good blood supply and good ventilation.
- Air path: larynx → trachea → bronchi → bronchioles → alveoli.
- Breathing in: external intercostal muscles and diaphragm contract → thorax bigger → pressure lower → air in. Breathing out is the opposite.
- Expired air has **less** oxygen, **more** carbon dioxide and **more** water vapour. Limewater tests for carbon dioxide.
- Exercise → more carbon dioxide in the blood → brain → faster, deeper breathing.

Respiration

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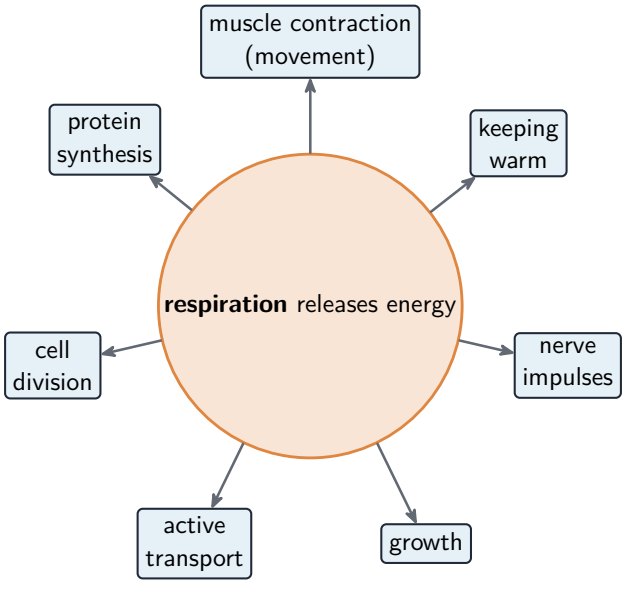
Respiration and energy

Respiration 呼吸作用 is the release of **energy** 能量 from food, and it happens in every living cell, all the time. (It is **not** the same as breathing.) Cells use this energy for many jobs:

- **muscle** 肌肉 contraction (movement).
- **protein synthesis** 蛋白质合成 (building proteins).
- cell **division** 分裂 (making new cells).
- **active transport** 主动运输.
- growth.
- the passage of **nerve impulses** 神经冲动.
- keeping a constant body **temperature** 温度.



Cells use the energy from respiration for many different jobs

You can investigate respiration in **yeast** 酵母: warmer yeast respires faster (up to its best temperature), giving off bubbles of **carbon dioxide** 二氧化碳.

Aerobic respiration

Aerobic respiration releases energy steadily for sustained exercise.

Aerobic respiration 有氧呼吸 uses **oxygen** 氧气 to break down **nutrient molecules** 营养物质 (mainly **glucose** 葡萄糖) and release energy.

Word equation:

$$\text{glucose} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water}$$

(Supplement) Balanced chemical equation:

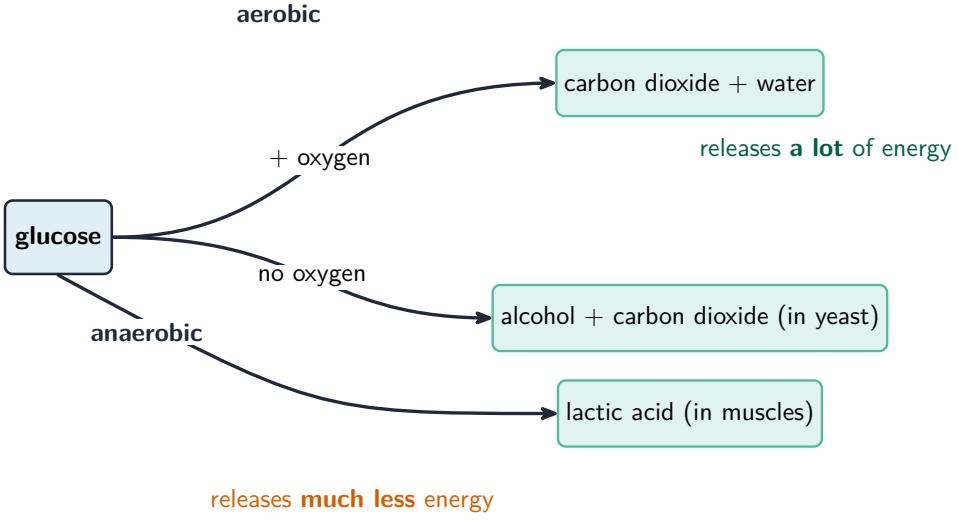
$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

Aerobic respiration releases a **lot** of energy from each glucose molecule.

Anaerobic respiration

A hard sprint relies on anaerobic respiration, building up lactic acid.

Anaerobic respiration 无氧呼吸 breaks down glucose to release energy **without** oxygen. It releases **much less** energy from each glucose molecule than aerobic respiration, because the glucose is not fully broken down.



Aerobic respiration needs oxygen and gives a lot of energy; anaerobic gives much less

In yeast

$$\text{glucose} \rightarrow \text{alcohol} + \text{carbon dioxide}$$

The **alcohol** 酒精 made by yeast is used to make bread rise and to brew drinks.

In muscles (Supplement)

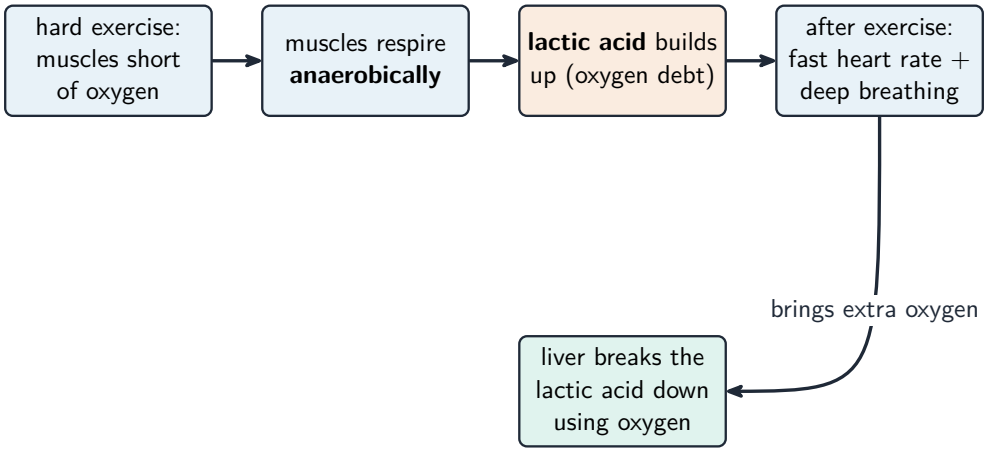
During hard exercise your muscles cannot get enough oxygen, so they respire anaerobically:

$$\text{glucose} \rightarrow \text{lactic acid}$$

The **lactic acid** 乳酸 builds up in the muscles and the blood. This creates an **oxygen debt** 氧债 — the extra oxygen the body will need later to break that lactic acid down.

After you stop exercising, the oxygen debt is repaid:

- your **heart rate** 心率 stays high, carrying the lactic acid in the blood from the muscles to the **liver** 肝脏.
- you keep breathing deeply and quickly, taking in extra oxygen.
- the liver uses this oxygen to break the lactic acid down by aerobic respiration.



Lactic acid from anaerobic respiration is broken down later, using extra oxygen

Worked example. A runner sprints hard for 20 seconds, then breathes deeply for several minutes after stopping. Explain why. During the sprint the muscles cannot get oxygen fast enough, so they respire **anaerobically** and lactic acid builds up, creating an **oxygen debt**. The deep breathing afterwards takes in the extra oxygen the liver needs to break that lactic acid down by aerobic respiration, while a high heart rate

carries the acid from the muscles to the liver. The breathing repays a debt built up **during** the sprint - it is not simply "because the muscles are still working".

Exam tips

- Respiration releases energy in **all** living cells, all the time — it is not breathing.
- Aerobic: glucose + oxygen → carbon dioxide + water, and it gives **a lot** of energy. Learn the balanced equation too.
- Anaerobic (no oxygen) gives **much less** energy. In yeast: glucose → alcohol + carbon dioxide. In muscles: glucose → lactic acid.
- Lactic acid causes an **oxygen debt**, repaid by a fast heart rate and deep breathing, with the liver breaking the lactic acid down.

Excretion in humans

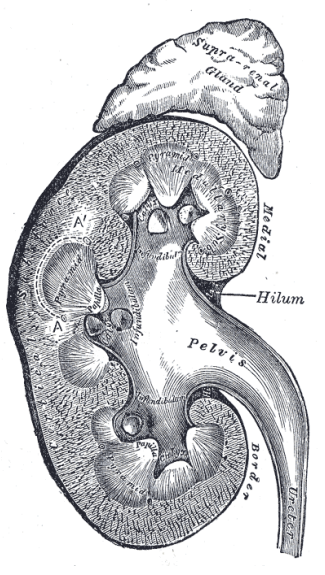
IGCSE Biology

Excretion

Excretion 排泄 is the removal of the waste products of metabolism, and of substances the body has in excess. Two main wastes are removed:

- **carbon dioxide** 二氧化碳 — made during respiration, and breathed out through the lungs.
- **urea** 尿素 — made in the **liver** 肝脏, and removed by the kidneys together with excess water and **ions** 离子.

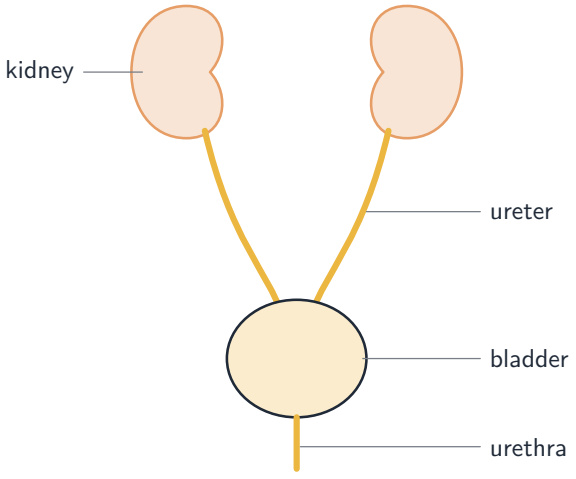
The urinary system



The kidneys filter the blood and make urine.

The **kidneys** 肾脏 clean the blood and make **urine** 尿液. The urine then passes through:

- the **ureters** 输尿管 — tubes from the kidneys to the bladder.
- the **bladder** 膀胱 — stores the urine.
- the **urethra** 尿道 — carries the urine out of the body.



The kidneys make urine, which flows down the ureters to the bladder and out of the urethra

If the kidneys stop working, a **dialysis** 透析 machine can do their job. The patient's blood flows through the machine, where waste and excess water pass out across a thin membrane, and the clean blood returns to the body.

A dialysis machine cleans the blood when the kidneys stop working

Inside the kidney (Supplement)

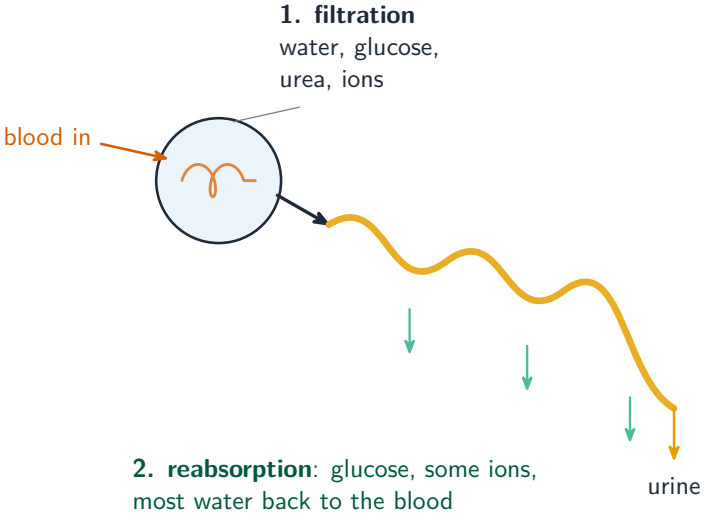
A kidney has two regions: an outer **cortex** 皮质 and an inner **medulla** 髓质.

The nephron

Each kidney holds millions of tiny tubes called **nephrons** 肾单位. A nephron cleans the blood in two steps:

1. **Filtration** 过滤: at the **glomerulus** 肾小球 (a knot of capillaries), high pressure forces water, **glucose** 葡萄糖, urea and ions out of the blood and into the nephron.
2. **Reabsorption** 重吸收: as the liquid flows along the nephron, the blood takes back **all** of the glucose, **some** of the ions, and **most** of the water.

What is left behind — urea, excess water and excess ions — becomes the urine.



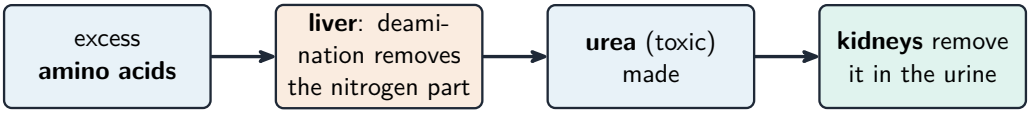
A nephron filters the blood, then reabsorbs the useful substances; what is left is urine

Worked example. A healthy person's urine contains urea and ions but **no** glucose, even though glucose is forced out of the blood at the glomerulus. Explain. Filtration does not choose: high pressure pushes water, glucose, urea and ions into the nephron together. The choosing happens at the next step - during **reabsorption** the blood takes back **all** of the glucose, so none is left to reach the urine. Glucose does appear in the urine of someone with untreated diabetes, because there is more of it than the nephron can reabsorb. Filtration removes; reabsorption selects.

The liver, amino acids and urea (Supplement)

The liver carries out the **assimilation** 同化 of **amino acids** 氨基酸: it joins them together into the **proteins** 蛋白质 that the body needs.

The body cannot store extra amino acids. The liver breaks the excess down by **deamination** 脱氨基作用 — it removes the **nitrogen** 氮-containing part of each amino acid. This part is then turned into urea.



The liver makes urea from excess amino acids; the kidneys excrete it

Urea must be excreted because it is **toxic** 有毒 (poisonous) if it is allowed to build up in the blood.

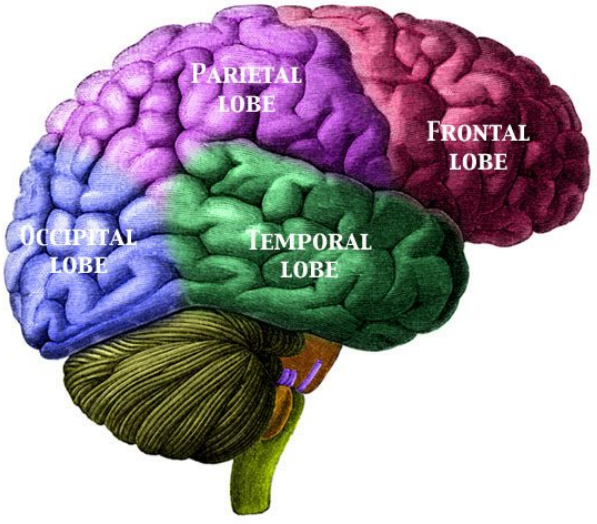
Exam tips

- Excretion removes metabolic wastes. Carbon dioxide leaves through the lungs; urea, excess water and excess ions leave through the kidneys.
- Urine path: kidney → ureter → bladder → urethra.
- Nephron: the glomerulus **filters** the blood; the nephron **reabsorbs** all the glucose, some ions and most of the water. What is left is urine.
- Urea is made in the **liver** from excess amino acids by **deamination**.
- We must excrete urea because it is **toxic** to the body.

Coordination and response

IGCSE Biology

The nervous system



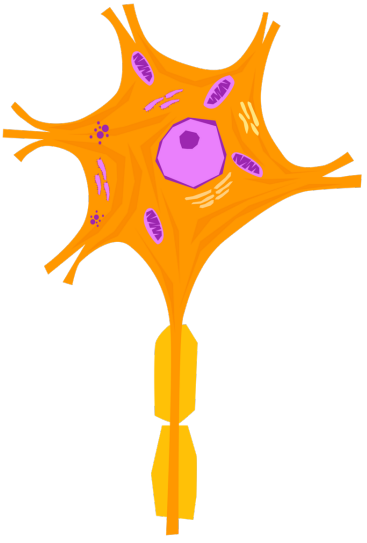
The brain coordinates the body through the nervous system.

Your body must **coordinate** 协调 all its parts and react to changes. The **nervous system** 神经系统 does this using fast **electrical impulses** 电脉冲 that travel along **neurones** 神经元 (nerve cells). It has two parts:

- the **central nervous system** 中枢神经系统 (CNS) — the **brain** 大脑 and the **spinal cord** 脊髓.
- the **peripheral nervous system** 周围神经系统 (PNS) — all the nerves outside the brain and spinal cord.

The nervous system coordinates and **regulates** 调节 the body's functions.

Neurones and the reflex arc



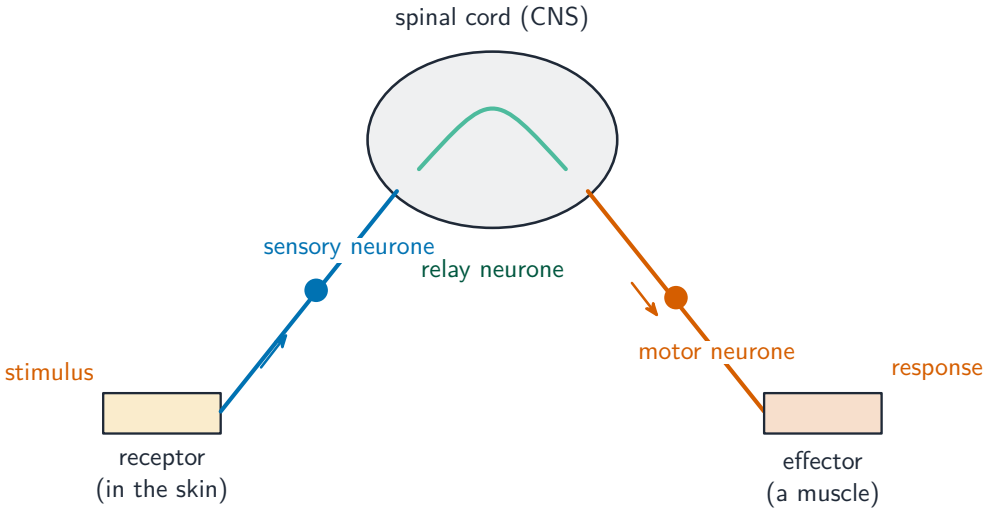
A neurone (nerve cell) carries electrical impulses around the body.

There are three kinds of neurone:

- **sensory neurones** 感觉神经元 — carry impulses from receptors to the CNS.
- **relay neurones** 中间神经元 — pass impulses on inside the CNS.
- **motor neurones** 运动神经元 — carry impulses from the CNS to effectors.

A **reflex** 反射 action is a fast, automatic **response** 反应 to a **stimulus** 刺激 (a change). It follows a fixed path, the **reflex arc** 反射弧:

receptor 感受器 → sensory neurone → relay neurone → motor neurone → **effector** 效应器 (a **muscle** 肌肉 or **gland** 腺体)



In a reflex arc the impulse passes from receptor → sensory → relay → motor neurone → effector

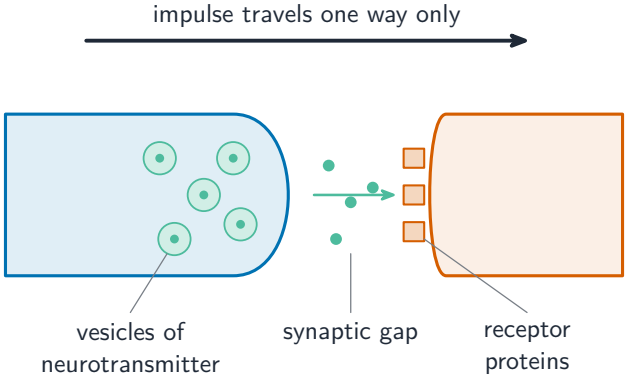
Synapses (Supplement)

A **synapse** 突触 is a junction (a tiny gap) between two neurones. At the end of one neurone are **vesicles** 囊泡 holding **neurotransmitter** 神经递质 molecules. Across the **synaptic gap** 突触间隙, the next neurone has **receptor proteins** 受体蛋白.

Events at a synapse:

1. an impulse arrives and makes the vesicles release neurotransmitter into the synaptic gap.
2. the neurotransmitter molecules **diffuse** 扩散 across the gap.
3. they bind to the receptor proteins on the next neurone.
4. this starts a new impulse in the next neurone.

Synapses make impulses travel in **one direction only**.



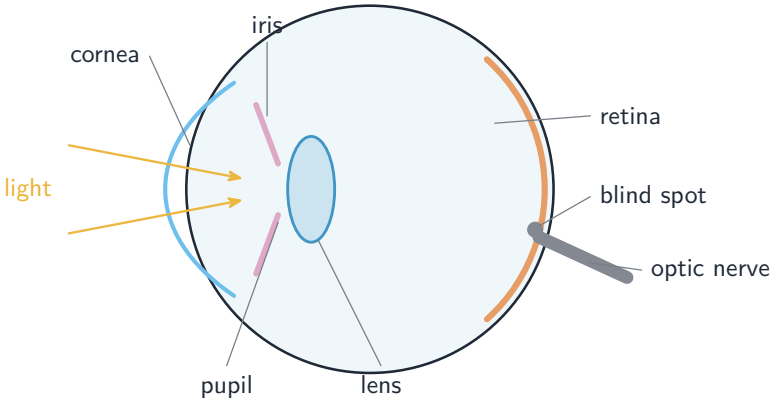
At a synapse, neurotransmitter diffuses across the gap, so impulses travel one way only

Sense organs and the eye

Sense organs 感觉器官 are groups of receptor cells that respond to one kind of stimulus — light, sound, touch, temperature or chemicals. The eye responds to light.

Parts of the eye

Part	Function
cornea 角膜	**refracts** 折射 (bends) the light as it enters
iris 虹膜	controls how much light enters the **pupil** 瞳孔
lens 晶状体	focuses the light onto the retina
retina 视网膜	contains light receptors, some sensitive to different colours
optic nerve 视神经	carries the impulses to the brain
blind spot 盲点	where the optic nerve leaves the eye; it has no receptors



Light is focused by the cornea and lens onto the retina; impulses leave by the optic nerve

The front of a real eye: the black pupil is the hole that lets light in, and the coloured iris around it controls how wide the pupil opens

The pupil reflex

In bright light the pupil gets **smaller**, to protect the retina. In dim light it gets **wider**, to let more light in. **(Supplement)** This is done by two sets of **antagonistic** 拮抗 muscles in the iris: the **circular muscles** 环肌 and the **radial muscles** 辐射肌. In bright light the circular muscles contract and the pupil narrows; in dim light the radial muscles contract and the pupil widens.

Accommodation (Supplement)

Accommodation 视觉调节 is changing the shape of the lens to focus on near or far objects, using the **ciliary muscles** 睫状肌 and the **suspensory ligaments** 悬韧带:

- near object: the ciliary muscles contract, the ligaments slacken, and the lens becomes fatter — more refraction.
- far object: the ciliary muscles relax, the ligaments pull tight, and the lens becomes thinner — less refraction.

Rods and cones (Supplement)

The retina has two kinds of light receptor:

- **rods** 视杆细胞 — very sensitive, good for **vision** 视觉 in dim light (night vision); they do not detect colour.
- **cones** 视锥细胞 — three kinds, each absorbing a different colour, giving colour vision; they work best in bright light.

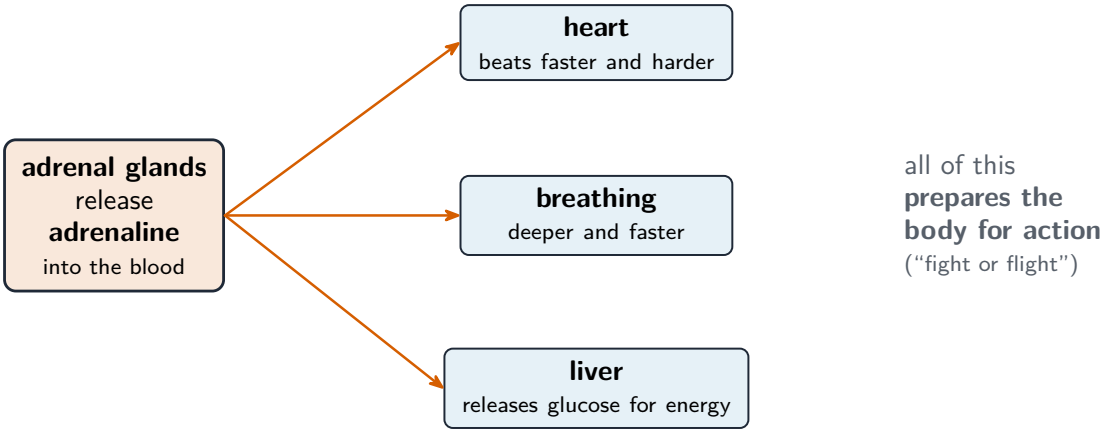
Cones are packed most densely at the **fovea** 中央凹, the part of the retina that gives the sharpest image.

Hormones

A **hormone** 激素 is a chemical, made by a gland and carried in the blood, that changes the activity of one or more **target organs** 靶器官. Hormones are made by **endocrine glands** 内分泌腺, which release them straight into the blood.

Gland	Hormone	Main effect
adrenal glands 肾上腺	**adrenaline** 肾上腺素	prepares the body for action
pancreas 胰腺	**insulin** 胰岛素 (and **glucagon** 胰高血糖素)	control blood **glucose** 葡萄糖
testes 睾丸	**testosterone** 睾酮	male development
ovaries 卵巢	**oestrogen** 雌激素	female development

Adrenaline is released in 'fight or flight' situations, such as fear or danger. It increases the breathing rate, the **heart rate** 心率, the blood glucose **concentration** 浓度 and the pupil diameter, getting the body ready to act.



Adrenaline prepares the body for action by acting on several target organs

Nervous control vs hormonal control

	Nervous control	Hormonal control
speed	very fast	slower
duration 持续时间	short-lived	longer-lasting
how it travels	electrical impulses along neurones	chemicals in the blood

	nervous control	hormonal control
how it travels	electrical impulses along **neurones**	**chemicals** in the blood
speed	very fast	slower
duration	short-lived	longer-lasting

fast but brief, versus slow but lasting

Nervous control is fast but brief; hormonal control is slower but longer-lasting

Homeostasis

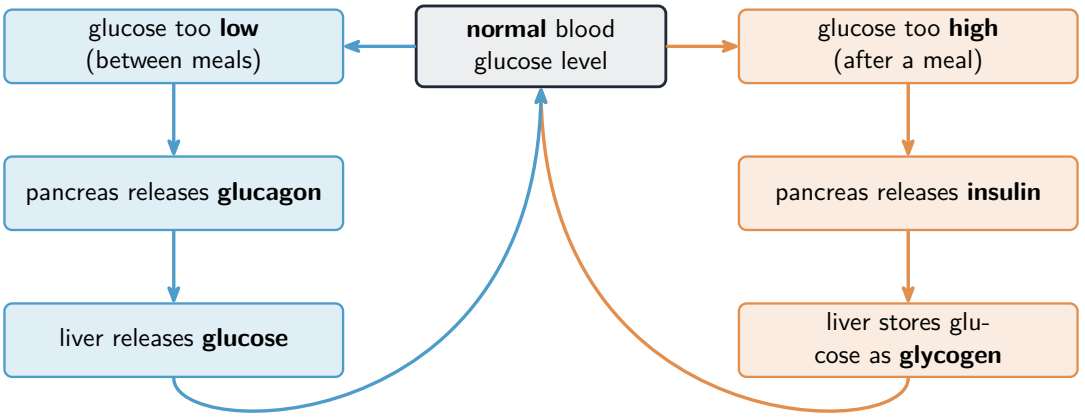
Homeostasis 稳态 is keeping a constant internal **environment** 环境 inside the body — for example a steady temperature and a steady blood glucose level.

(Supplement) Homeostasis works by **negative feedback** 负反馈: when a value moves away from its **set point** 设定点, the body acts to bring it back. The change itself triggers the correction.

Controlling blood glucose

The **liver** 肝脏 and the pancreas keep blood glucose steady:

- **insulin** lowers blood glucose after a meal — the liver stores the glucose as **glycogen** 糖原.
- **(Supplement) glucagon** raises blood glucose between meals — the liver releases glucose.



Insulin lowers blood glucose and glucagon raises it, keeping it near a normal level

In **Type 1 diabetes** 糖尿病 the pancreas cannot make insulin, so blood glucose rises too high. It is treated with insulin injections and a carefully planned diet.

Worked example. Blood glucose rises sharply after a meal, then falls back to normal over the next two hours. Name the organs and the hormone involved, and say what they do. The **pancreas** detects the rise and releases **insulin**. Insulin makes the **liver** take glucose out of the blood and store it as **glycogen**, so the level falls back to normal. Between meals the opposite loop runs: the pancreas releases glucagon and the liver releases glucose again. Keep the two words apart - insulin is the **hormone**, glycogen is the **store**. Swapping them is the classic error.

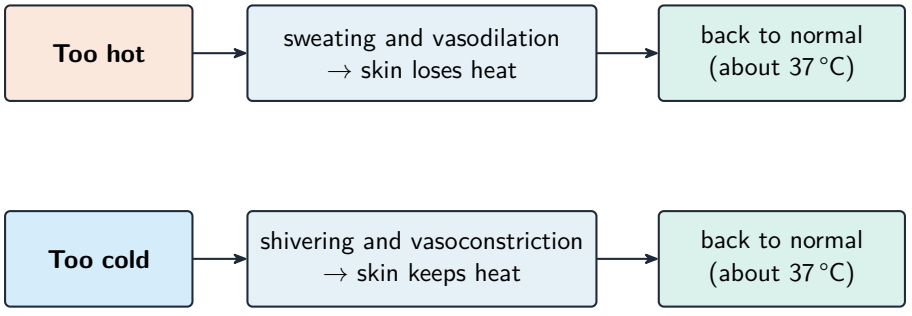
Controlling body temperature (Supplement)

The brain detects the body **temperature** 温度 and keeps it steady. The skin helps:

Structure	Role
sweat glands 汗腺	make sweat; as it evaporates it cools the skin (**sweating** 出汗)
hair erector muscles 立毛肌	raise the hairs to trap a layer of air
blood vessels 血管	change how much blood flows near the skin surface
fatty tissue 脂肪组织	gives **insulation** 隔热 to reduce heat loss

When you are **too hot**: you sweat, and the **arterioles** 小动脉 widen (**vasodilation** 血管舒张) so more blood flows to the skin **capillaries** 毛细血管 and loses heat.

When you are **too cold**: you **shiver** 颤抖 (the muscles make heat), and the arterioles narrow (**vasoconstriction** 血管收缩) so less blood reaches the surface, keeping heat in.



Negative feedback: a change away from about 37 °C triggers the response that reverses it, bringing the body back to normal.

Tropisms

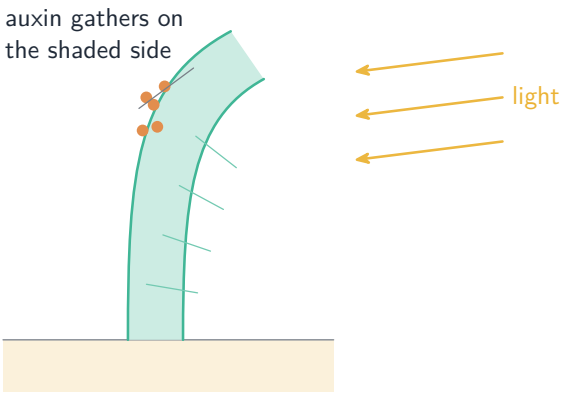
A **tropism** 向性 is a plant's growth response to a direction:

- **gravitropism** 向地性 — growth in response to **gravity** 重力 (roots grow down, shoots grow up).
- **phototropism** 向光性 — growth in response to the direction of light (shoots grow towards the light).

(Supplement) These responses are controlled by a chemical called **auxin** 生长素:

- auxin is made in the **shoot** 嫩枝 tip.
- it diffuses down through the plant.
- light or gravity makes the auxin spread unequally to one side.

- auxin makes cells **elongate** 伸长 (grow longer). The side with more auxin grows faster, so the shoot bends.



cells on the shaded side grow longer, so the shoot bends towards the light

Auxin gathers on the shaded side and makes those cells grow longer, bending the shoot to the light

Exam tips

- Nervous system: CNS (brain + spinal cord) and PNS (the nerves). Impulses travel along neurones.
- Learn the reflex arc in order: receptor → sensory → relay → motor → effector.
- At a synapse, neurotransmitter diffuses across the gap — this makes impulses go one way only.
- Eye: cornea and lens refract light; the lens changes shape (accommodation); rods for dim light, cones for colour.
- Hormones are slower but longer-lasting than nerves. Insulin lowers blood glucose; glucagon raises it.
- Too hot → sweating and vasodilation; too cold → shivering and vasoconstriction.
- Auxin from the shoot tip controls phototropism and gravitropism by making cells elongate.

Drugs

IGCSE Biology

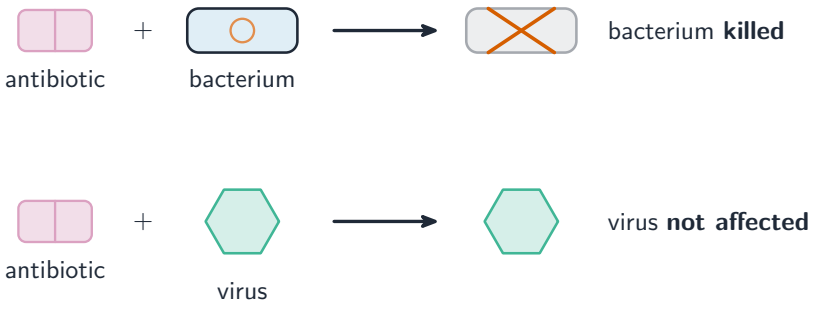
What a drug is

Cigarettes contain nicotine, an addictive drug.

A **drug** 药物 is any substance taken into the body that changes or affects the **chemical reactions** 化学反应 in the body. Many drugs are medicines that help to treat illness.

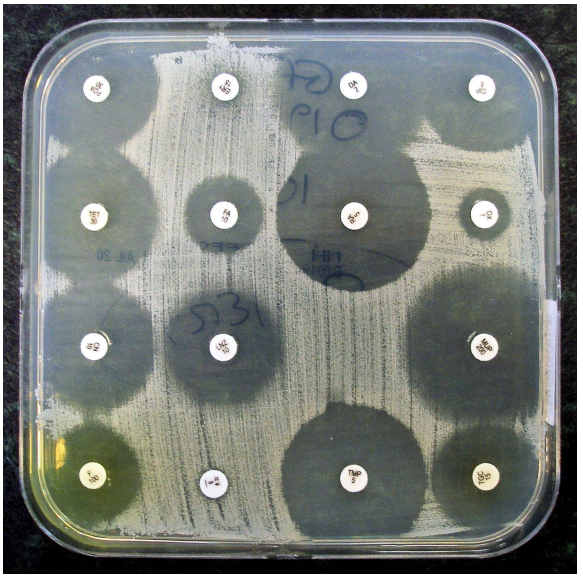
Antibiotics

Antibiotics 抗生素 are drugs used to treat bacterial **infections** 感染. They **kill bacteria** 细菌, or stop them growing, but they do **not** affect **viruses** 病毒. This is why antibiotics cannot cure a cold or the flu, which are caused by viruses.



Antibiotics kill bacteria but have no effect on viruses

To test which antibiotic works best, small paper discs soaked in different antibiotics are placed on a plate covered with bacteria. Where an antibiotic kills the bacteria, a clear ring with no growth appears around the disc. A bigger ring means the antibiotic is more effective.

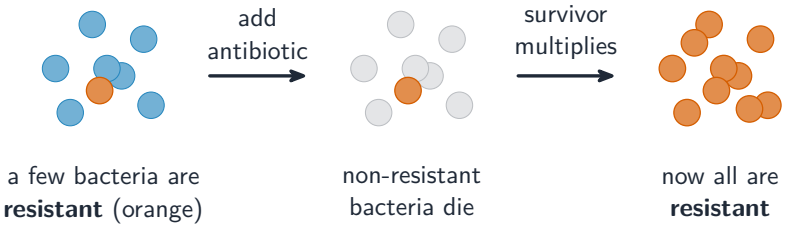


Clear rings show where antibiotics have killed the bacteria on the plate

Antibiotic resistance

Some bacteria are **resistant** 耐药 to an antibiotic — the antibiotic no longer kills them. These bacteria survive and multiply, so the antibiotic slowly becomes less effective for everyone.

(Supplement) To slow this down, antibiotics should be used **only when they are really needed**, and the full course should always be finished. Using antibiotics too often lets resistant bacteria, such as **MRSA**, spread.



Resistant bacteria survive the antibiotic and multiply, so the population becomes resistant

Worked example. A patient stops taking their antibiotic as soon as they feel better, and the infection comes back worse. Explain using resistance. In the starting population a few bacteria are **already resistant**, by chance. The antibiotic kills the non-resistant ones, so those few survive, multiply, and come to make up most of the population - and the antibiotic no longer works on it. Stopping early leaves behind exactly the bacteria that are hardest to kill. Say the resistant bacteria **already existed** and survived: writing that the antibiotic "made them resistant" is wrong and loses every mark.

Exam tips

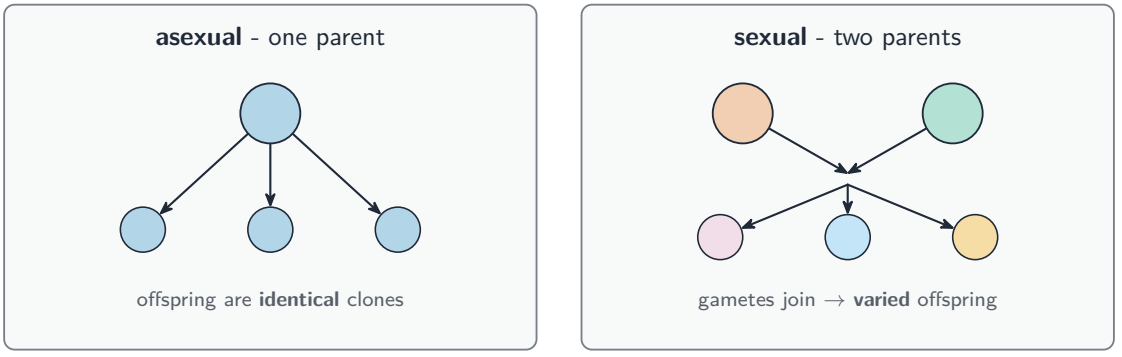
- A drug is **any** substance that changes the body's chemical reactions — not only illegal drugs.
- Antibiotics kill **bacteria** only; they do **not** work on **viruses** (so they are useless against colds and flu).
- Overusing antibiotics leads to **resistant** bacteria like MRSA. Use them only when needed, and finish the whole course.

Reproduction

IGCSE Biology

Two kinds of reproduction

Reproduction 生殖 makes new organisms of the same kind. There are two types.

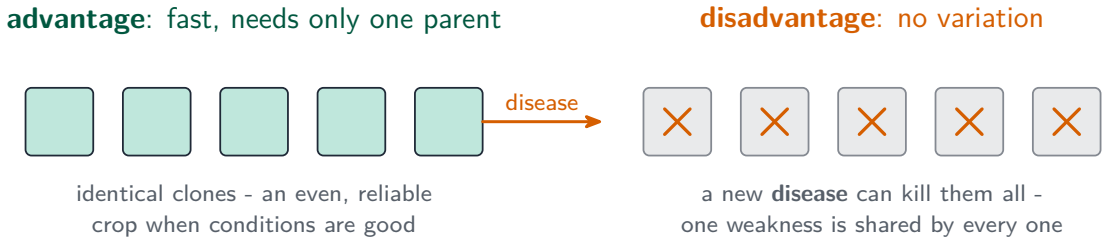


Asexual reproduction needs one parent and gives identical clones; sexual reproduction needs two and gives varied offspring

Asexual reproduction

Asexual reproduction 无性生殖 needs only **one parent** 亲本. The **offspring** 后代 have exactly the same **genes** 基因 as the parent — they are genetically identical (clones).

- **Advantage**: it is fast and needs only one parent — useful when conditions are good and stable.
- **Disadvantage**: all the offspring are identical, so if the **environment** 环境 changes (for example a new disease) they may all die. (In crops, identical plants give an even harvest, but one disease can wipe out the whole crop.)



Asexual reproduction is fast but gives no variation, so one disease can kill every identical offspring

Sexual reproduction

Sexual reproduction 有性生殖 needs **two** parents. It involves the **fusion** 融合 (joining) of the **nuclei** 细胞核 of two **gametes** 配子 (sex cells) to make a **zygote** 合子. This joining is called **fertilisation** 受精. The offspring get a mix of genes from both parents, so they show **variation** 变异 (they are genetically different).

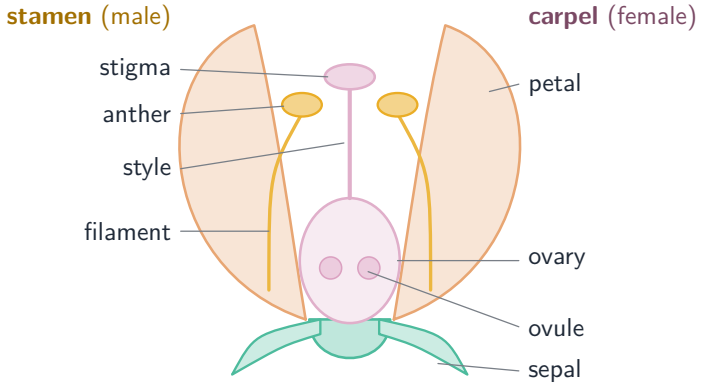
- **Advantage**: variation means some offspring may survive if the environment changes.
- **Disadvantage**: it is slower and needs two parents.

(Supplement) The nuclei of gametes are **haploid** 单倍体 (one set of **chromosomes** 染色体); the nucleus of the zygote is **diploid** 二倍体 (two sets).

Sexual reproduction in plants

Parts of an insect-pollinated flower

Part	Function
sepals 萼片	protect the flower bud before it opens
petals 花瓣	large and colourful, to attract **insects** 昆虫
stamens 雄蕊	the male parts; each is a **filament** 花丝 holding up an **anther** 花药
anther	makes **pollen grains** 花粉粒
carpel 雌蕊	the female part; made of a **stigma** 柱头, a **style** 花柱 and an **ovary** 子房
stigma	catches pollen grains
ovary	holds the **ovules** 胚珠, which become seeds



An insect-pollinated flower: the male stamens and the female carpel

A real lily: the long stamens make pollen and the central stigma receives it

Pollination

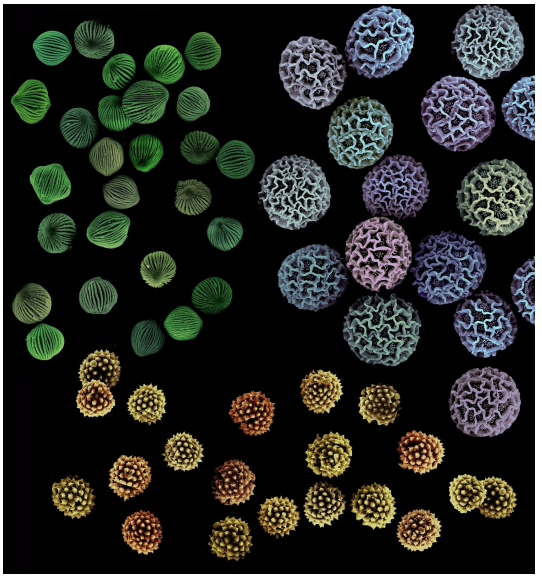
Pollination 传粉 is the transfer of pollen grains from an anther to a stigma.

- **insect-pollinated** flowers have bright petals, scent and nectar, and sticky or spiky pollen, to attract insects and stick to them.
- **wind-pollinated** flowers have small dull petals, anthers and stigmas that hang outside, and light, smooth pollen that blows in the wind.

insect-pollinated
bright petals, scent + nectar;
sticky, spiky pollen

wind-pollinated
small dull petals; anthers &
stigma hang out; light pollen

Insect-pollinated flowers are showy; wind-pollinated flowers are small with parts hanging out



Pollen grains seen under an electron microscope (colour added); each plant has its own pattern

(Supplement) Self-pollination 自花传粉 is pollen landing on the stigma of the same flower (or another flower on the same plant). **Cross-pollination** 异花传粉 is pollen carried to a flower on a **different** plant of the same species. Cross-pollination gives more **variation**, helping the population cope with change, but it relies on **pollinators** 传粉者 or wind. Self-pollination is more reliable but gives less variation.

Fertilisation and germination

Fertilisation happens when a pollen nucleus fuses with a nucleus in an ovule. **(Supplement)** First a **pollen tube** 花粉管 grows down the style into the ovary, carrying the pollen nucleus to the ovule.

A **seed** 种子 will only **germinate** 萌发 (begin to grow) when it has water, **oxygen** 氧气 and a suitable **temperature** 温度.

Sexual reproduction in humans

The male reproductive system

Part	Function
testes 睾丸	make **sperm** 精子 and **testosterone** 睾酮
scrotum 阴囊	holds the testes outside the body, kept slightly cool
sperm ducts 输精管	carry sperm away from the testes
prostate gland 前列腺	adds fluid to make semen
urethra 尿道	carries semen (and urine) out through the penis
penis 阴茎	passes sperm into the female

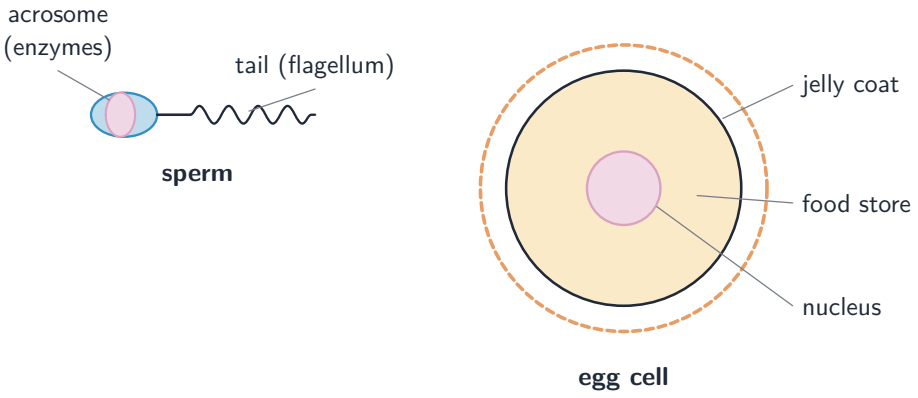
The female reproductive system

Part	Function
ovaries 卵巢	make **egg cells** 卵细胞 and **oestrogen** 雌激素
oviducts 输卵管	carry the egg towards the uterus; fertilisation happens here
uterus 子宫	where the baby develops
cervix 子宫颈	the ring of muscle at the base of the uterus
vagina 阴道	receives the penis; also the birth canal

Gametes and fertilisation

Fertilisation is the fusion of the nuclei of a male gamete (sperm) and a female gamete (egg cell). The two gametes are adapted to their jobs:

	Sperm	**Egg cell**
size	very small	large
number	millions	few (about one a month)
can it move?	yes — swims with a **flagellum** 鞭毛	no — it is carried along
special features	many **mitochondria** 线粒体 for energy; **enzymes** 酶 in the **acrosome** 顶体 to break into the egg	a store of food; a **jelly coat** 胶质层 that changes after fertilisation to keep other sperm out



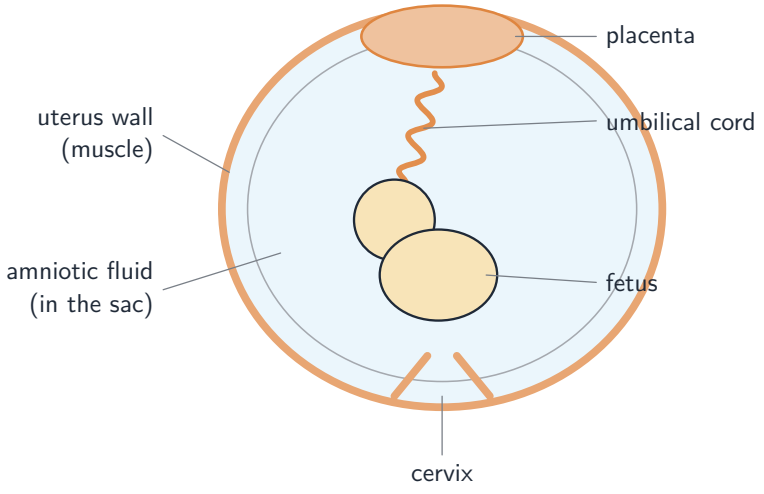
sperm: small, millions, swims | egg: large, few, carried

The sperm is small and swims; the egg cell is large and stores food

Pregnancy and the fetus

After fertilisation the zygote divides to form an **embryo** 胚胎 — a ball of cells that **implants** 植入 into the lining of the uterus. As it grows it becomes a **fetus** 胎儿. These structures support it:

- the **placenta** 胎盘 — where dissolved nutrients, gases and wastes are exchanged between the mother's blood and the fetus's blood (the two never mix).
- the **umbilical cord** 脐带 — joins the fetus to the placenta.
- the **amniotic sac** 羊膜囊 — a bag around the fetus, filled with **amniotic fluid** 羊水 that cushions it.



The fetus develops in the uterus, supported by the placenta, cord and amniotic sac

(Supplement) Some **pathogens** 病原体 and **toxins** 毒素 can cross the placenta and harm the fetus.

Sex hormones

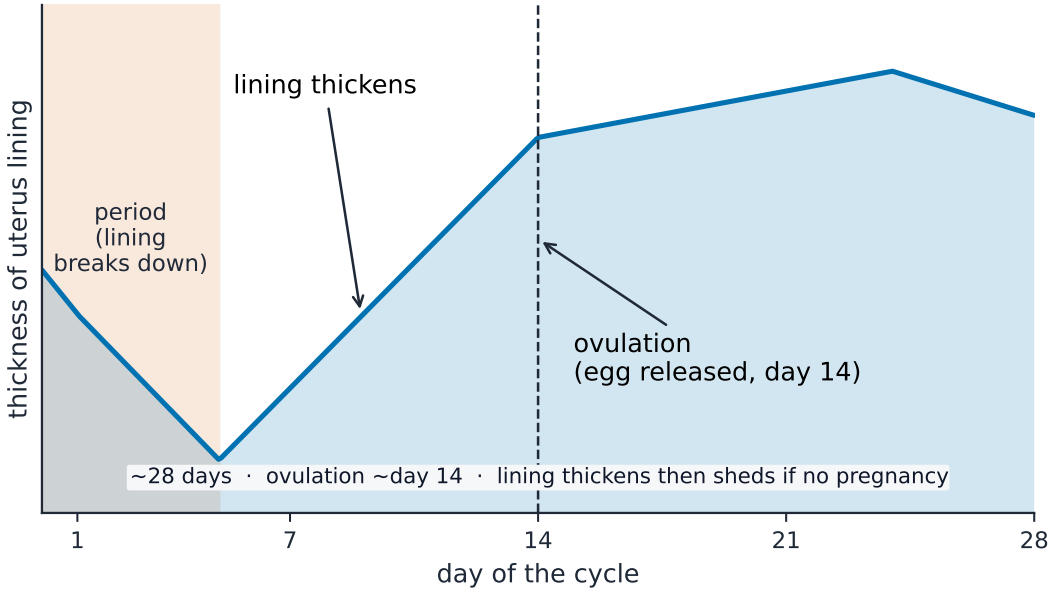
Puberty

At **puberty** 青春期, sex **hormones** 激素 make the body develop **secondary sexual characteristics** 第二性征 — such as body hair, a deeper voice in boys, and breasts in girls. **Testosterone** does this in boys; **oestrogen** does it in girls.

The menstrual cycle

The **menstrual cycle** 月经周期 (about 28 days) prepares the uterus for a possible pregnancy:

- the lining of the uterus thickens.
- around day 14 an ovary releases an egg (**ovulation** 排卵).
- if the egg is not fertilised, the lining breaks down and leaves the body (a period), and the cycle starts again.



The lining thickens, an egg is released at day 14, and a period follows if there is no pregnancy

(Supplement) Four hormones control the cycle: **FSH** (makes an egg mature and the ovary release oestrogen), **LH** (triggers ovulation), **oestrogen** (repairs and thickens the lining), and **progesterone** 孕酮 (keeps the lining thick). Oestrogen and progesterone are made in the ovaries; during **pregnancy** 怀孕, progesterone keeps the lining in place.

Worked example. A woman has a regular 28-day cycle, and her period starts on the 1st of the month. On roughly which date is she most likely to conceive? Ovulation happens about **day 14**, so counting 14 days on from the start of the period points to about the **14th**, and the days either side of it are the most fertile. Day 1 is the day the period **starts**, not the day it ends - counting from the wrong day is what makes most cycle questions go wrong.

Sexually transmitted infections

A **sexually transmitted infection** 性传播感染 (STI) is an **infection** 感染 spread through sexual contact.

HIV is a **virus** 病毒 that causes an STI, and it can lead to **AIDS**, in which the immune system stops working properly. HIV is passed on in infected body fluids — for example by sharing needles, during sex, or from mother to baby (across the placenta or in breast milk).

The spread of STIs is controlled by using condoms, having fewer partners, testing and treating infected people, and not sharing needles.

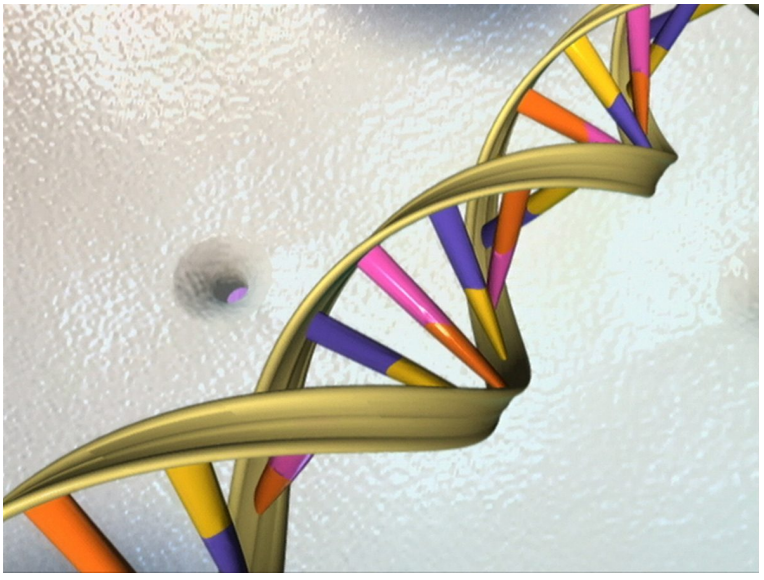
Exam tips

- Asexual: one parent, identical offspring (no variation). Sexual: two parents, gametes fuse, offspring show variation.
- Fertilisation = fusion of two gamete nuclei → zygote. (Supplement: gametes haploid, zygote diploid.)
- Learn the flower parts and which are male (stamen) and female (carpel). Compare insect- and wind-pollinated flowers.
- Sperm: small, many, moving (flagellum). Egg: large, few, with a food store.
- Menstrual cycle: lining thickens → ovulation (day 14) → period if no fertilisation. (Supplement: FSH, LH, oestrogen, progesterone.)
- HIV is a virus that causes an STI and can lead to AIDS; it spreads through body fluids.

Inheritance

IGCSE Biology

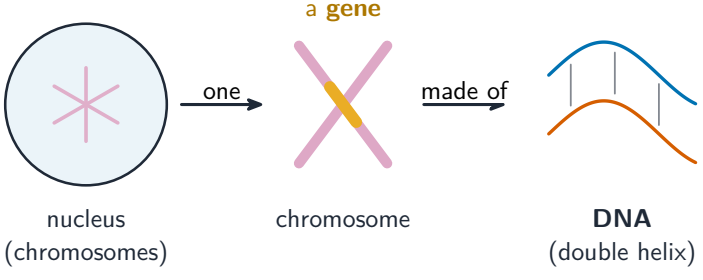
Chromosomes, genes and DNA



DNA carries inherited information in its double-helix structure.

Chromosomes 染色体 are made of **DNA**, which carries the genetic information in units called **genes** 基因.

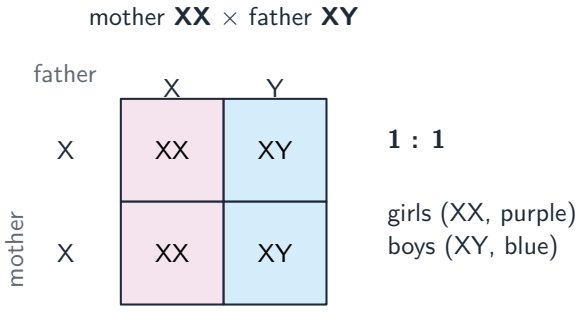
- A **gene** is a length of DNA that **codes** 编码 for one **protein** 蛋白质.
- An **allele** 等位基因 is an alternative form of a gene. For example, a gene for eye colour may have a brown allele and a blue allele.



A chromosome is made of DNA and carries genes; a gene is a length of the DNA

Sex chromosomes

Sex is inherited through the **sex chromosomes** 性染色体. Females are **XX** and males are **XY**. An egg always carries an X; a sperm carries either an X or a Y, so the sperm decides the baby's sex. This gives a 1:1 **ratio** 比例 of girls to boys.



XX × XY gives a 1:1 ratio of girls to boys; the sperm decides the sex

How DNA controls the cell (Supplement)

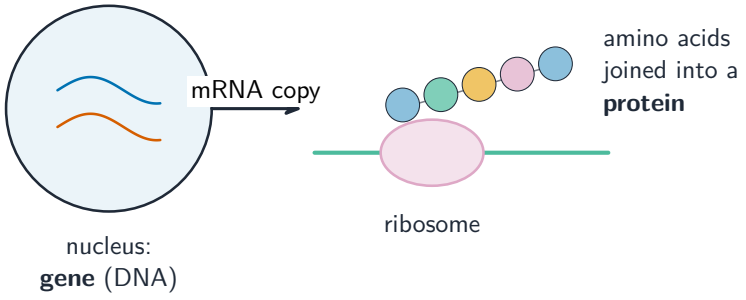
The **base sequence** 碱基序列 of a gene sets the order of **amino acids** 氨基酸 in a protein. A different order of amino acids folds the protein into a different shape, and the shape decides its job. So DNA controls the cell by controlling which proteins are made — including **enzymes** 酶, membrane carriers and **receptor proteins** 受体蛋白 for **neurotransmitters** 神经递质.

Most body cells hold the **same** genes, but each cell only **expresses** 表达 (switches on) the genes it needs, so it makes only the proteins for its own job.

Making a protein (Supplement)

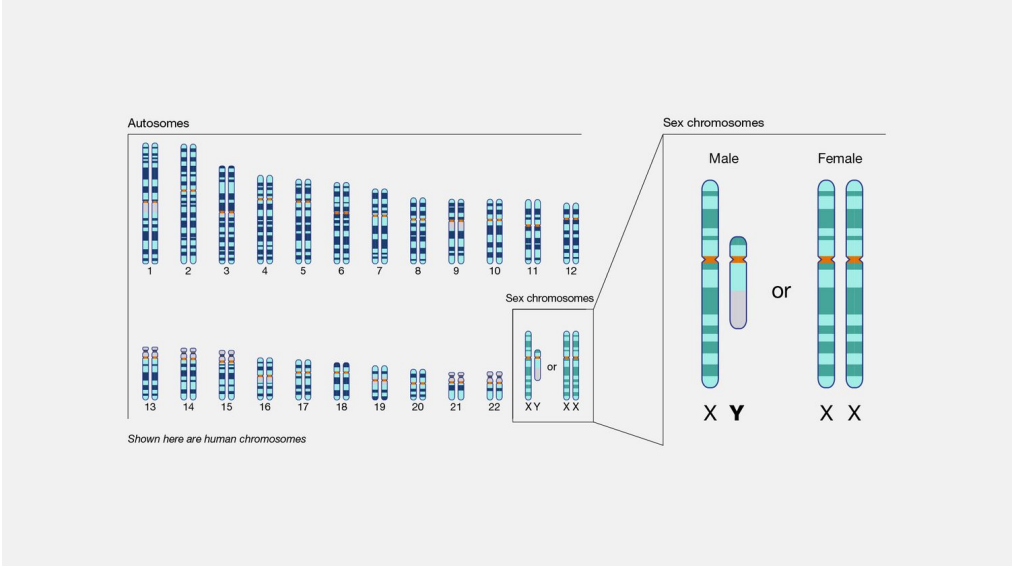
A gene stays in the **nucleus** 细胞核, but proteins are made in the **cytoplasm** 细胞质. The link between them is **messenger** 信使 RNA (mRNA):

1. mRNA is made in the nucleus as a copy of the gene.
2. the mRNA moves out into the cytoplasm and passes through a **ribosome** 核糖体.
3. the ribosome reads the mRNA's **bases** 碱基 and joins amino acids in the matching order to build the protein.



mRNA copies a gene, then a ribosome reads it to build a protein from amino acids

Cell division (Supplement)



A karyotype shows the full set of chromosomes in a human cell.

Body cells are **diploid** 二倍体 (two sets of chromosomes; humans have 23 pairs).

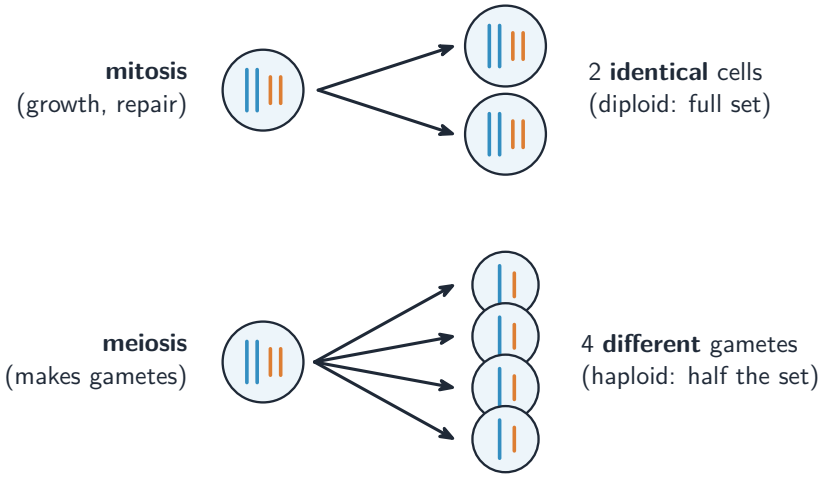
Gametes are **haploid** 单倍体 (one set). Cells make new cells by nuclear **division** 分裂, of two kinds.

Mitosis 有丝分裂:

- makes two cells that are genetically **identical** to the parent cell.
- the chromosomes are copied exactly (**replication** 复制) before division, so each **daughter cell** 子细胞 keeps the full chromosome number.
- it is used for growth, repair of tissues, replacing old cells, and **asexual reproduction** 无性生殖.
- **stem cells** 干细胞 are unspecialised cells that divide by mitosis; their daughter cells can then become specialised.

Meiosis 减数分裂:

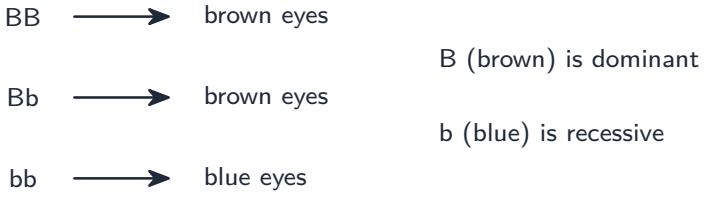
- makes **gametes** 配子.
- it is a **reduction division**: the chromosome number is halved, from diploid to haploid.
- the cells it makes are genetically **different** from one another.



Mitosis makes two identical diploid cells; meiosis makes four different haploid gametes

Inheritance: key words

Inheritance 遗传 is the passing of genetic information from one generation to the next. Learn these words:



A dominant allele shows with one copy; a recessive needs two

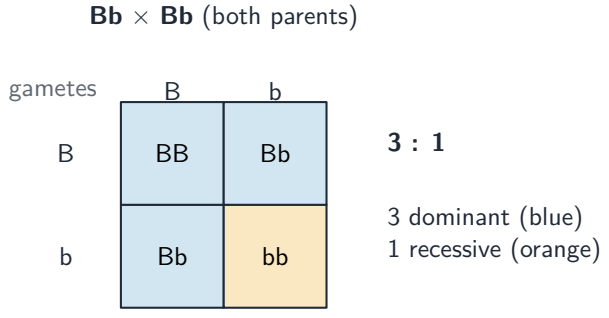
Word	Meaning
genotype 基因型	the alleles an organism has (its genetic make-up)
phenotype 表现型	the features you can observe
dominant 显性 allele	shown in the phenotype even if only one copy is present (written as a capital letter, e.g. B)
recessive 隐性 allele	shown only when **no** dominant allele is present (small letter, e.g. b)
homozygous 纯合子	two **identical** alleles (BB or bb); these breed true, or **pure-breeding** 纯种
heterozygous 杂合子	two **different** alleles (Bb); not pure-breeding

Monohybrid crosses

To predict the offspring of a **cross** 杂交 involving one gene, use a genetic diagram or a **Punnett square** 庞纳特方格:

- write each parent's genotype, then the gametes (each gamete carries one allele).
- combine them in a grid to find the possible offspring genotypes and phenotypes.

Two heterozygous parents (Bb × Bb) give a **3:1** ratio of dominant to recessive. A heterozygous crossed with a homozygous recessive (Bb × bb) gives a **1:1** ratio. You can also read a **pedigree diagram** 系谱图 (a family tree) to follow a feature and work out genotypes.



A Punnett square for Bb × Bb gives a 3:1 ratio of dominant to recessive

(Supplement) A **test cross** 测交 finds an unknown genotype: cross the unknown with a homozygous recessive. If any offspring show the recessive feature, the unknown must have been heterozygous.

Worked example. Brown eyes (B) are dominant to blue (b). Two brown-eyed parents have a blue-eyed child. Give the parents' genotypes, and the chance that their next child has blue eyes. Start from the child: blue is recessive, so the child must be **bb**, and it got one b from each parent. So each parent carries a b. But both parents show brown eyes, so each must also carry a B: both parents are **Bb**. The Punnett square for Bb × Bb gives BB, Bb, Bb and bb, so the chance of a blue-eyed child is **1 in 4 (25%)**. Always work backwards from the recessive individual - a recessive phenotype pins a genotype exactly, and the rest follows. The 25% applies to **each** child on its own: three brown-eyed children do not make the fourth blue.

Codominance and blood groups (Supplement)

In **codominance** 共显性, **both** alleles in a heterozygous organism show in the phenotype.

The ABO **blood groups** 血型 are an example. The alleles are I^A, I^B and I^o. The alleles I^A and I^B are codominant, while I^o is recessive:

- I^AI^A or $I^AI^o \rightarrow$ group A
- I^BI^B or $I^BI^o \rightarrow$ group B
- $I^AI^B \rightarrow$ group AB (both alleles shown)
- $I^oI^o \rightarrow$ group O

Sex linkage (Supplement)

A **sex-linked** 伴性遗传 characteristic is controlled by a gene on a sex chromosome (usually the X). Because males have only one X chromosome, a recessive allele on it always shows in males, so the feature is more common in males than in females.

Red-green colour blindness 色盲 is an example: the recessive allele is on the X chromosome, so it is much more common in boys than in girls.

Exam tips

- Gene = a length of DNA coding for a protein. Allele = one form of a gene.
- Genotype = the alleles present; phenotype = what you see. Homozygous = two same; heterozygous = two different.
- Dominant shows with one copy; recessive needs two copies.
- Learn to draw a Punnett square. Bb × Bb → 3:1; Bb × bb → 1:1.
- (Supplement) Codominance: both alleles show (blood group AB). Sex linkage: a gene on the X, more common in boys (colour blindness).

Variation and selection

IGCSE Biology

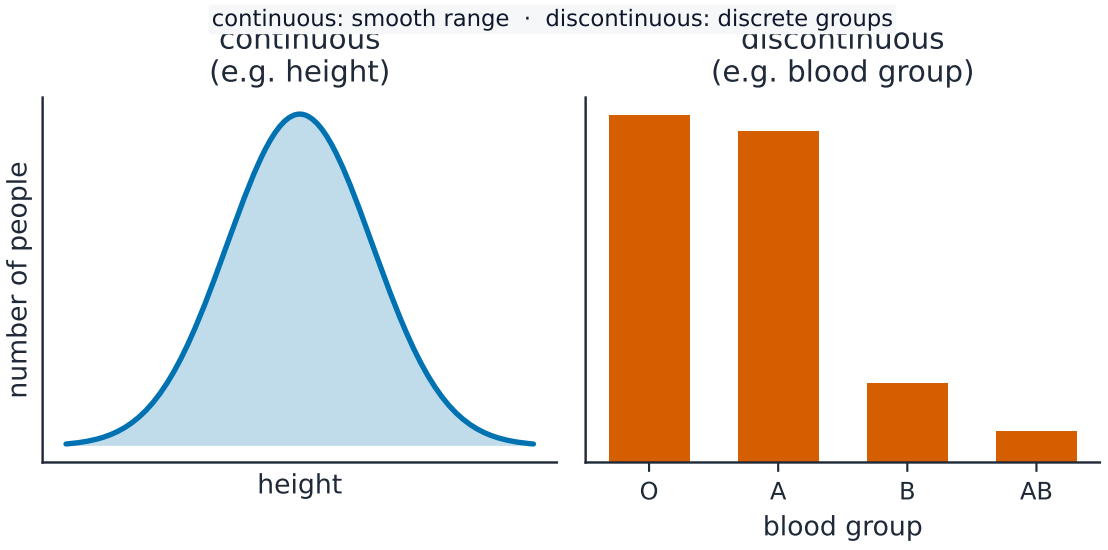
Variation

People show wide variation in many inherited features.

Variation 变异 means the differences between individuals of the same **species** 物种. There are two types:

- **continuous variation** 连续变异 — a smooth range of **phenotypes** 表现型 between two extremes (for example body length and body mass).
- **discontinuous variation** 不连续变异 — a few separate phenotypes with nothing in between (for example **ABO blood groups** 血型, or seed shape in peas).

Discontinuous variation is usually caused by **genes** 基因 only. Continuous variation is caused by **both** genes and the **environment** 环境 — for example, your height depends on your genes and also on your diet.



Continuous variation is a smooth range; discontinuous variation falls into separate groups

Mutation

A **mutation** 突变 is a genetic change. Mutations are the way **new alleles** 等位基因 are made, so they are the original source of all variation. **(Supplement)** A **gene mutation** 基因突变 is a random change in the **base sequence** 碱基序列 of DNA.

A mutation changes the DNA bases, making a new allele

Ionising radiation 电离辐射 (such as X-rays) and some chemicals raise the **rate** 速率 of mutation. **(Supplement)** Other sources of genetic variation are **meiosis** 减数分裂, random mating and random **fertilisation** 受精.

Adaptive features

An **adaptive feature** 适应特征 is an **inherited** 遗传 feature that helps an organism to **survive** 生存 and **reproduce** 生殖 in its **environment**.

A camel is adapted to desert life: it stores fat in its humps and can survive a long time without water

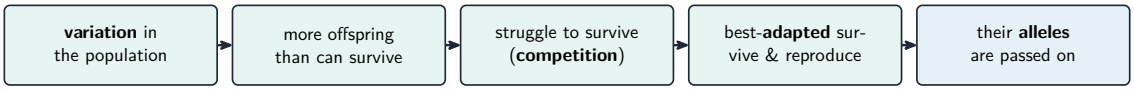
(Supplement)

- **hydrophytes** 水生植物 (water plants) have features such as air spaces to help them float, and stomata on the upper leaf surface.
- **xerophytes** 旱生植物 (desert plants) have features such as a thick waxy cuticle, few small stomata, and the ability to store water — all to reduce water loss.

Natural selection

Natural selection 自然选择 explains how a species becomes better suited to its environment:

1. there is genetic variation in a population (caused by mutation).
2. organisms produce **many offspring** 后代 — more than can survive.
3. there is a struggle to survive, with **competition** 竞争 for **resources** 资源 such as food and space.
4. the individuals that are better **adapted** 适应 are more likely to survive and reproduce.
5. they pass on their alleles, so the helpful alleles become more common in the next generation.



Natural selection: the best-adapted survive, reproduce and pass on their alleles

The dark (melanic) form of the peppered moth — the form favoured on soot-darkened bark

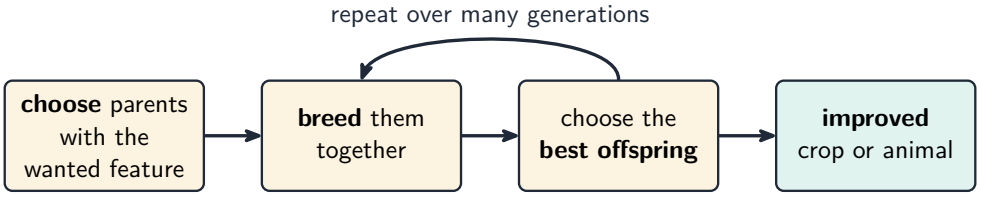
(Supplement) Over many generations this makes the population more suited to its environment; this process is called adaptation. A clear example is **antibiotic** 抗生素-resistant **bacteria** 细菌: a few bacteria carry a **resistant** 耐药 allele and survive the antibiotic, then multiply, until the whole population is resistant.

Worked example. A moth species is mostly pale. Soot darkens the tree trunks the moths rest on, and within a few decades most of the moths are dark. Explain by natural selection. **Variation** is already there: a few dark moths exist by chance, caused by **mutation**. On sooty bark the dark moths are better camouflaged, so birds eat fewer of them and they are more likely to **survive**. The survivors **reproduce** and pass the allele for dark colour to their offspring, so it becomes more common each generation until most moths are dark. Follow the chain: variation, survival, reproduction, the allele becomes more common. The moths did not turn dark in order to hide - the dark ones simply survived more often.

Selective breeding

In **selective breeding** 选择育种 (also called **artificial selection** 人工选择), humans choose which organisms breed:

1. choose the individuals that have the features you want.
2. cross them to produce the next generation.
3. choose the offspring that show those features, and repeat over many generations.



humans choose which breed (not the environment)

In selective breeding, humans choose which organisms breed, over many generations

This is used to improve **crops** 农作物 (for example a higher yield) and farm animals (for example cows that give more milk).

(Supplement) The key difference: in natural selection the **environment** decides which individuals survive; in artificial selection **humans** decide.

Exam tips

- Continuous variation = a range (genes + environment); discontinuous = separate groups (genes only).
- Mutation makes new alleles — the source of all variation. Radiation and some chemicals raise the mutation rate.
- Natural selection: variation → too many offspring → struggle and competition → the best-adapted survive and reproduce → they pass on their alleles.
- Antibiotic resistance in bacteria is natural selection in action.
- Selective breeding (artificial selection): humans pick the parents; in natural selection, the environment "picks".

Organisms and their environment

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Energy flow

The **Sun** is the main source of **energy** 能量 for almost all life. Plants capture light energy by **photosynthesis** 光合作用 and store it as chemical energy in food. This energy then passes from organism to organism as they feed. At every step, some energy is lost (mostly as heat from **respiration** 呼吸作用) to the **environment** 环境. Energy flows **one way** — it is not recycled.

Food chains and food webs

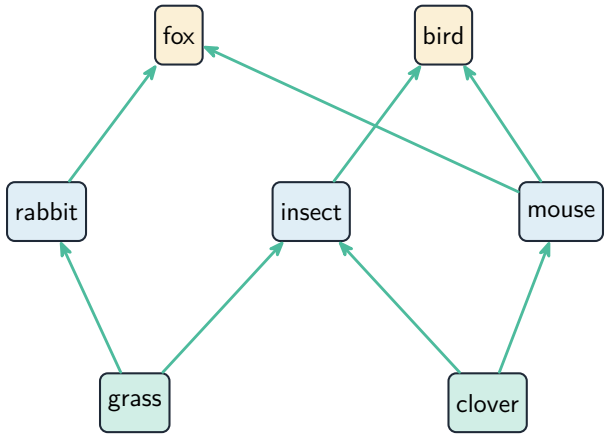
A savanna ecosystem: organisms linked by feeding relationships.

A **food chain** 食物链 shows the transfer of energy from one organism to the next, starting with a producer. Each arrow points in the direction the energy flows:

grass → rabbit → fox

A food chain: arrows show energy passing from producer to consumers

A **food web** 食物网 is many food chains linked together.



A food web is several food chains linked together

Producers, consumers and decomposers

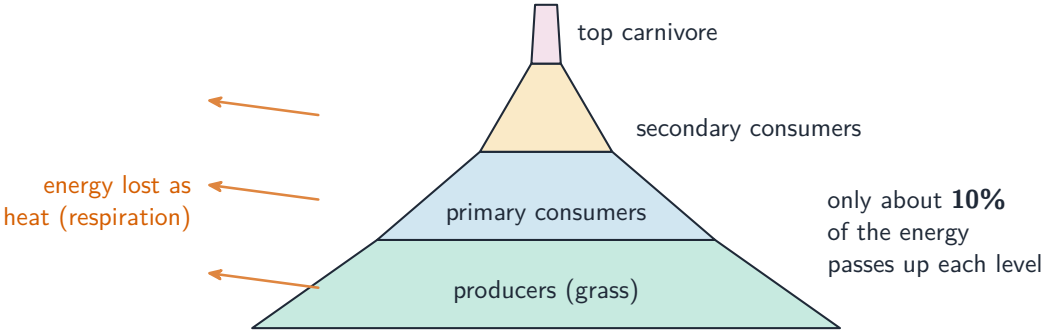
Type	Meaning
producer 生产者	makes its own food (organic **nutrients** 营养物质), usually by photosynthesis
consumer 消费者	gets its energy by feeding on other organisms
herbivore 食草动物	a consumer that eats plants
carnivore 食肉动物	a consumer that eats other animals
decomposer 分解者	gets its energy from dead or waste material, causing **decomposition** 分解

Consumers are named by their position: a **primary** consumer eats the producer; a **secondary** consumer eats the primary consumer; then come **tertiary** and **quaternary** consumers.

Trophic levels and pyramids

A **trophic level** 营养级 is the position of an organism in a food chain (producers first, then primary consumers, and so on). You can show a food chain as a **pyramid** 金字塔:

- a **pyramid of numbers** counts the organisms at each level.
- a **pyramid of biomass** 生物量 shows the total mass at each level — usually a better picture, because it does not depend on how big the organisms are.
- **(Supplement)** a **pyramid of energy** shows the energy at each level — the most useful picture of all.



Only about 10% of energy passes up each level, so the levels get smaller

Energy loss along a chain (Supplement)

Only about 10% of the energy at one trophic level passes to the next. The rest is lost as heat (from respiration), in movement, and in waste. Because so much energy is lost, food chains usually have **fewer than five** trophic levels. It is more energy-efficient for people to eat **crop plants** 农作物 directly than to eat animals that were fed on those crops, because each extra level wastes energy.

Worked example. The producers in a field trap 40 000 kJ of energy. Roughly how much reaches a secondary consumer, and why do food chains stay short? About 10% passes on at each step. Primary consumers receive 10% of 40 000 = **4000 kJ**. Secondary consumers receive 10% of 4000 = **400 kJ** - only 1% of what the plants trapped. After a few levels too little energy is left to support another one, which is why chains rarely pass five levels. Apply the 10% **again at every step**, not once for the whole chain.

Human impact

Humans can damage food webs by:

- **overharvesting** 过度捕捞 — taking too many of one species (such as overfishing), so its numbers crash.
- introducing a **foreign species** 外来物种 — a new species may have no predators and may crowd out native species.

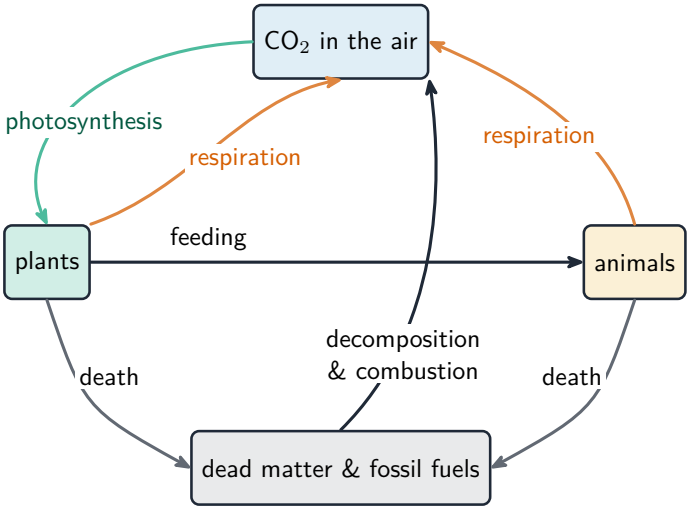
Nutrient cycles

Unlike energy, nutrients are **recycled** — used again and again.

The carbon cycle

In the **carbon cycle** 碳循环:

- photosynthesis removes **carbon dioxide** 二氧化碳 from the air.
- respiration and **combustion** 燃烧 (burning) return carbon dioxide to the air.
- feeding passes carbon from one organism to the next.
- decomposition returns carbon to the air and soil.
- over millions of years, dead organisms can form **fossil fuels** 化石燃料 (coal and oil), which release carbon dioxide when they are burned.



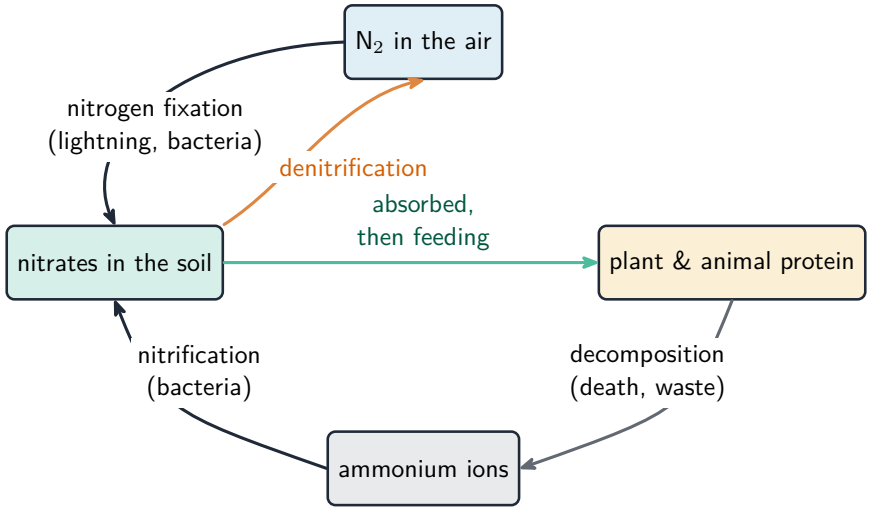
The carbon cycle: photosynthesis removes CO_2; respiration, combustion and decay return it

The nitrogen cycle (Supplement)

The **nitrogen cycle** 氮循环 recycles nitrogen for making **proteins** 蛋白质. **Microorganisms** 微生物 do most of the work:

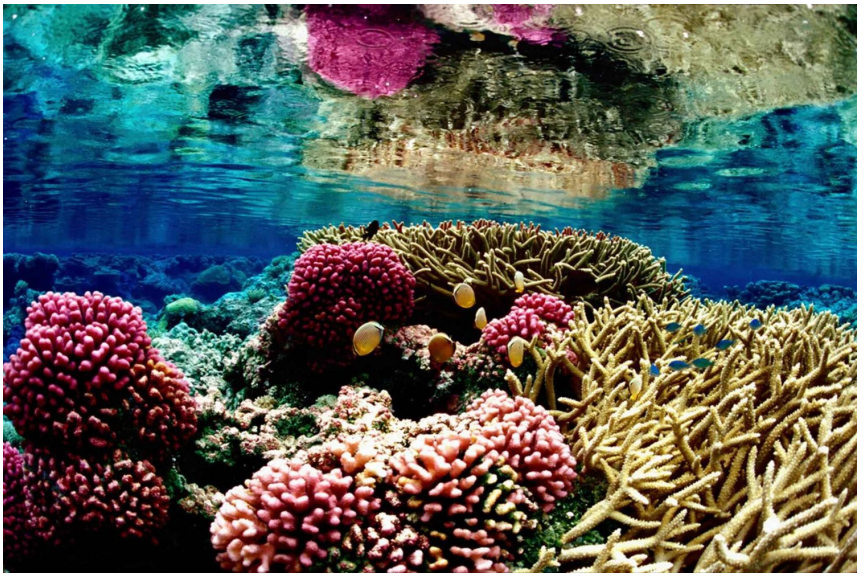
- **decomposition**: decomposers break dead protein down into **ammonium ions** 铵离子.
- **nitrification** 硝化作用: bacteria change ammonium ions into **nitrate ions** 硝酸根离子.

- **nitrogen fixation** 固氮作用: lightning and some **bacteria** 细菌 turn nitrogen gas into compounds that plants can use.
- plants absorb nitrate ions to make **amino acids** 氨基酸 and proteins; animals get them by feeding and **digestion** 消化.
- **deamination** 脱氨基作用 (in the liver) and decomposition release nitrogen compounds again.
- **denitrification** 反硝化作用: some bacteria turn nitrate ions back into nitrogen gas.



The nitrogen cycle: microorganisms move nitrogen between the air, soil and living things

Populations



A coral reef is a rich ecosystem supporting many interdependent species.

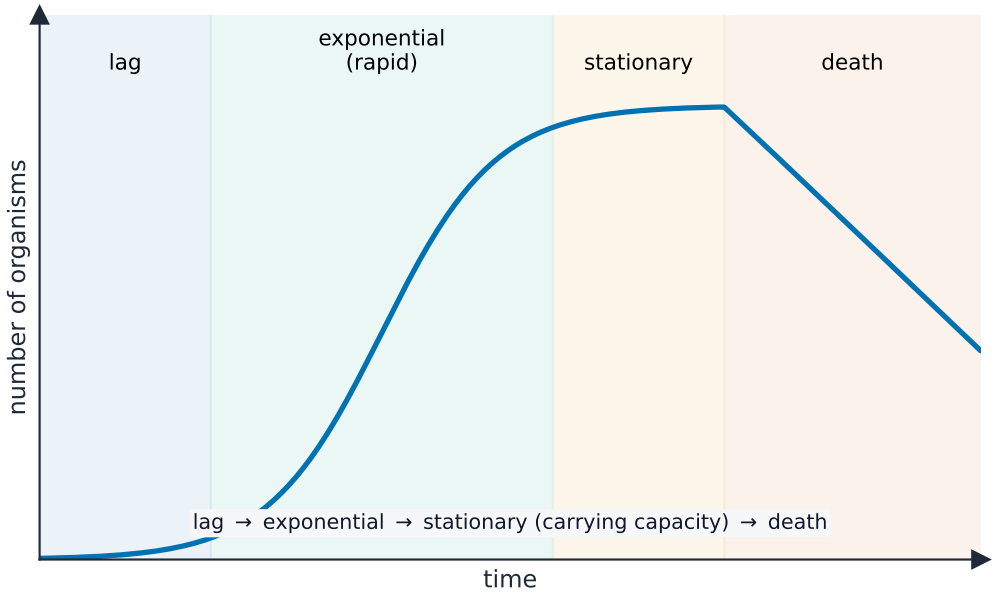
- a **population** 种群 is a group of organisms of one **species** 物种, living in the same area at the same time.
- a **community** 群落 is all the populations of different species in one place.
- an **ecosystem** 生态系统 is the community together with its **environment**, all interacting.

Population growth

The growth of a population depends on the food supply, **competition** 竞争, **predation** 捕食 (being eaten) and disease.

When a population grows in a place with limited **resources** 资源, its growth follows an S-shaped curve with four phases:

Phase	What happens
lag phase 延迟期	slow growth at first, while numbers are still small
exponential phase 对数期	very fast growth, with plenty of food and space
stationary phase 稳定期	growth stops; births ≈ deaths (a **limiting factor** 限制因素 such as food holds it back)
death phase 衰亡期	numbers fall as food runs out, wastes build up, or disease spreads



A population in a limited space grows in four phases: lag, exponential, stationary, death

Exam tips

- Energy enters from the Sun, flows one way along the chain, and is lost as heat at each step. Nutrients are recycled.
- Food chain starts with a producer; arrows show energy flow. Learn producer, consumer, herbivore, carnivore, decomposer.
- Only ~10% of energy passes up each trophic level, so chains are short and eating plants is more efficient.
- Carbon cycle: photosynthesis ↔ respiration and combustion; nitrogen cycle (Supplement): fixation, nitrification, denitrification by microorganisms.

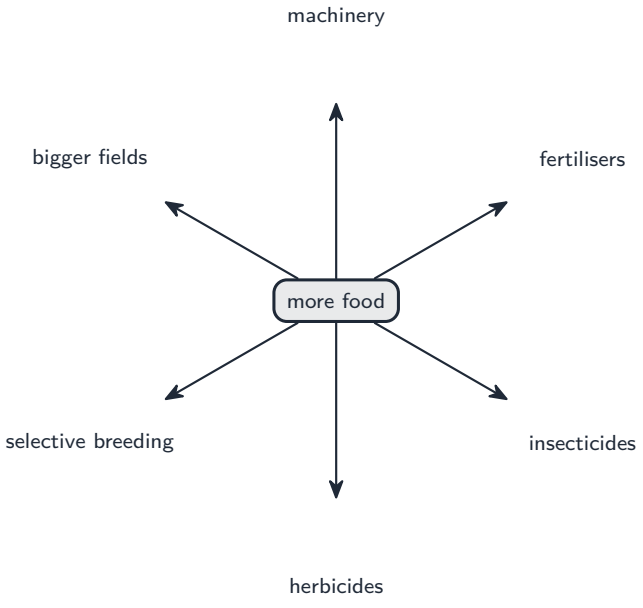
- Population: one species, one area, one time. Learn the four phases of the S-shaped growth curve.

Human influences on ecosystems

IGCSE Biology

Increasing food supply

To grow more food, humans use:



Ways farmers increase food production

- **agricultural machinery** to farm larger areas of land quickly.
- chemical **fertilisers** 化肥 to improve **yields** 产量.
- **insecticides** 杀虫剂 to kill insect pests.
- **herbicides** 除草剂 to kill **weeds** 杂草 that compete with the crops.
- **selective breeding** 选择育种 to improve **crop plants** 农作物 and **livestock** 牲畜.

A **monoculture** 单一栽培 (growing one crop over a large area) gives a big, easy harvest, but one pest or disease can destroy the whole crop, and it lowers **biodiversity** 生物多样性. Intensive livestock farming (many animals in a small space) gives cheap meat, but raises worries about animal welfare and the spread of disease.

Habitat destruction

Clearing forest destroys habitats and reduces biodiversity.

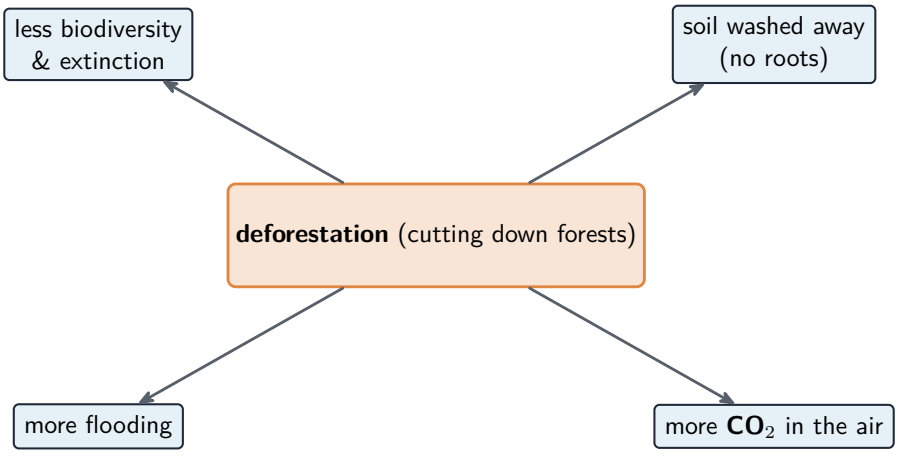
Biodiversity is the number of different **species** 物种 living in an area. Humans destroy **habitats** 栖息地 (the places where organisms live) by:

- clearing land for housing, crops and livestock.
- extracting natural **resources** 资源, such as by mining.
- **pollution** 污染 of fresh water and the sea.

By changing **food webs** 食物网 and **food chains** 食物链, humans harm habitats.

Deforestation 森林砍伐 (cutting down forests) is a major example. It causes:

- lower biodiversity and the **extinction** 灭绝 of species.
- loss of soil (no roots to hold it, so it washes away).
- more flooding.
- more **carbon dioxide** 二氧化碳 in the air, because there are fewer trees to take it in.



Deforestation lowers biodiversity, washes away soil, causes flooding and adds CO_2

Pollution

Plastic pollution is a major human impact on ecosystems.

Water pollution

Untreated **sewage** 污水 and excess fertiliser washed into rivers and lakes damage water **ecosystems** 生态系统.

(Supplement) Excess fertiliser causes **eutrophication** 富营养化:

1. the fertiliser adds **nitrate ions** 硝酸根离子 and other ions to the water.

2. **producers** 生产者 such as algae grow very fast.
3. they soon die, and **decomposition** 分解 increases.
4. **decomposers** 分解者 use up the **oxygen** 氧气 in **aerobic respiration** 有氧呼吸.
5. the dissolved oxygen falls, so fish and other organisms die.

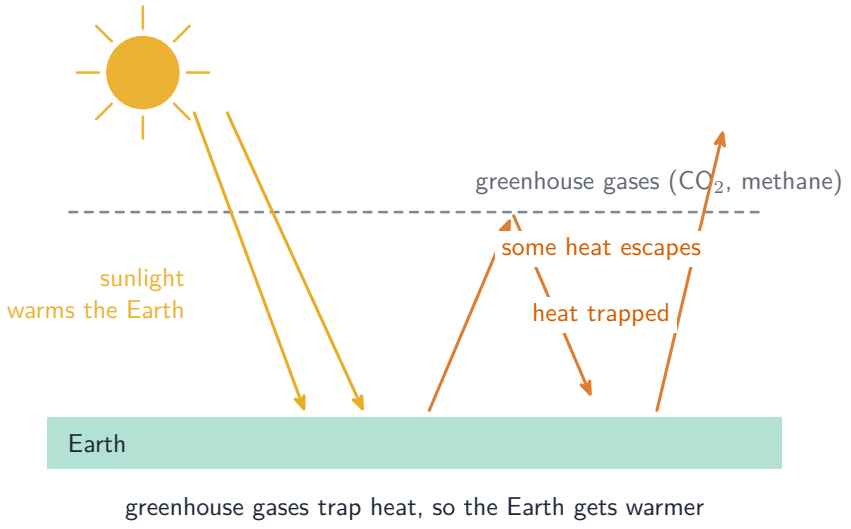
Eutrophication: extra fertiliser makes algae bloom, then the water loses its oxygen and fish die

Worked example. A farmer spreads fertiliser on a field; weeks later the fish in a nearby river die. Put the steps in order and explain. Rain washes **nitrate ions** off the field into the river. The extra nitrate makes algae grow very fast and cover the surface. The algae block the light, so the plants below die. **Decomposers** multiply as they feed on the dead algae and plants, and their **aerobic respiration** uses up the oxygen dissolved in the water. With too little oxygen left, the fish die. The fish are **not** poisoned by the fertiliser - they suffocate, and it is the decomposers that actually remove the oxygen.

Plastics and air pollution

Non-biodegradable 不可降解 **plastics** 塑料 do not rot away. They build up in the sea and on land, harming wildlife — animals may eat them or get trapped.

Methane 甲烷 and carbon dioxide are greenhouse gases. Too much of them strengthens the **greenhouse effect** 温室效应 (the enhanced greenhouse effect), which causes **climate change** 气候变化.



Greenhouse gases trap heat leaving the Earth, so the Earth gets warmer

Conservation

Sustainable resources

A **sustainable** 可持续 resource is produced as fast as it is used up, so it never runs out. Forests and **fish** 鱼类 stocks can both be managed in this way.

(Supplement) Forests are **conserved** 保护 by education, protected areas, **quotas** 配额 (limits on how much is taken) and replanting. Fish stocks are conserved by **closed seasons** 禁渔期, protected areas, controlled net mesh sizes (so young fish can escape), quotas and monitoring.

Saving endangered species

A species becomes **endangered** 濒危 or extinct when its numbers fall, because of climate change, habitat destruction, **hunting** 狩猎, **overharvesting** 过度捕捞, pollution and **introduced species** 外来物种.

Endangered species can be saved by:

- monitoring and protecting the species and its habitat.
- education.
- **captive breeding** 圈养繁殖 programmes, which breed animals in zoos. **(Supplement)** These may use **artificial insemination** 人工授精 (AI) or **in vitro fertilisation** 体外受精 (IVF).
- **seed banks** 种子库, which store seeds safely.

The giant panda was once endangered; protected habitats and captive-breeding programmes have helped its numbers recover

(Supplement) We conserve nature to keep up biodiversity, reduce extinction, protect ecosystems, and keep ecosystem functions going — such as recycling nutrients and providing food, **drugs** 药物, fuel and useful **genes** 基因. If a population becomes too small, it loses **genetic variation** 变异, which makes it harder for the species to survive future change.

Exam tips

- More food: machinery, fertilisers, insecticides, herbicides, selective breeding. Monocultures and intensive farming each have advantages and disadvantages.

- Deforestation: less biodiversity, extinction, soil loss, flooding, more carbon dioxide.
- Eutrophication (Supplement): fertiliser → more producers → more decomposers → less dissolved oxygen → organisms die.
- Greenhouse gases (carbon dioxide, methane) → enhanced greenhouse effect → climate change.
- Conservation: sustainable use, protected areas, quotas, captive breeding and seed banks. Small populations lose genetic variation.

Biotechnology and genetic modification

IGCSE Biology

Why bacteria are useful

Biotechnology 生物技术 uses living things (or their **enzymes** 酶) to make useful products. **Bacteria** 细菌 are especially useful because:

- they reproduce very fast (a high **rate** 速率 of reproduction).
- they can make complex **molecules** 分子.
- **(Supplement)** there are few **ethical** 伦理 concerns about growing them, and they contain **plasmids** 质粒 (small DNA rings that are easy to work with).

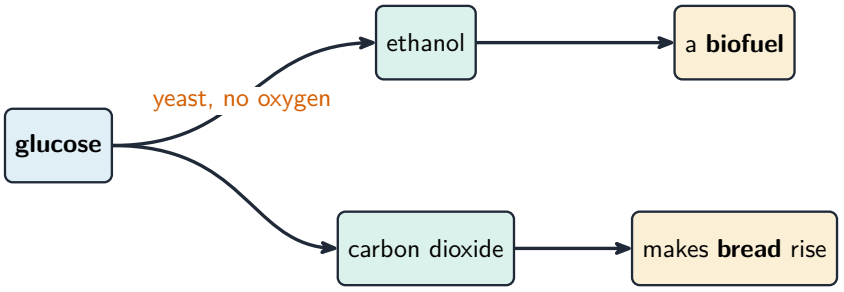
Biotechnology in action

Fermentation tanks: microbes are grown at scale in biotechnology.

Yeast: biofuels and bread

Yeast 酵母 carries out **anaerobic respiration** 无氧呼吸 (without oxygen), making **ethanol** 乙醇 and carbon dioxide.

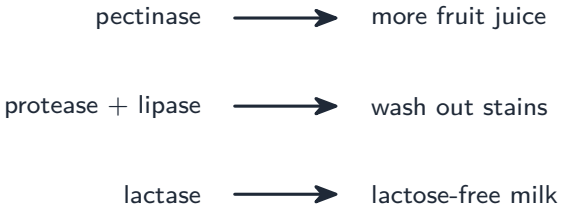
- the ethanol can be used as a **biofuel** 生物燃料.
- in bread-making, the carbon dioxide makes the dough rise.



Yeast makes ethanol (a biofuel) and carbon dioxide (which makes bread rise)

Enzymes in industry

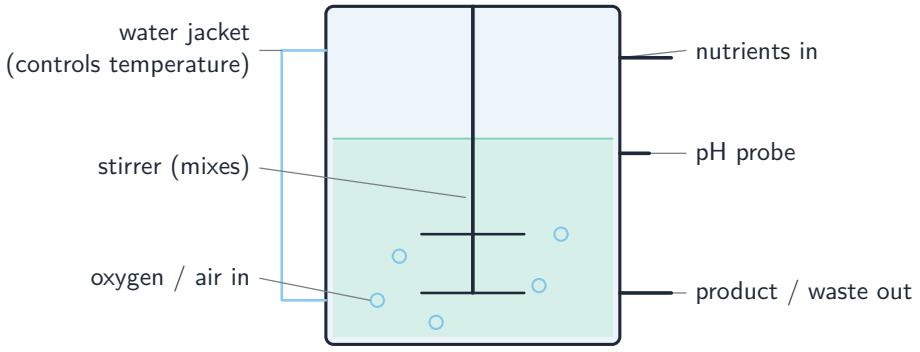
- **pectinase** 果胶酶 breaks down cell walls to release more juice from fruit, giving more and clearer juice.
- biological **washing powders** 洗衣粉 contain enzymes (such as proteases and lipases) that digest stains, even at lower temperatures.
- **(Supplement) lactase** 乳糖酶 breaks down **lactose** 乳糖 to make lactose-free milk, for people who cannot digest lactose.



Enzymes used in industry

Fermenters (Supplement)

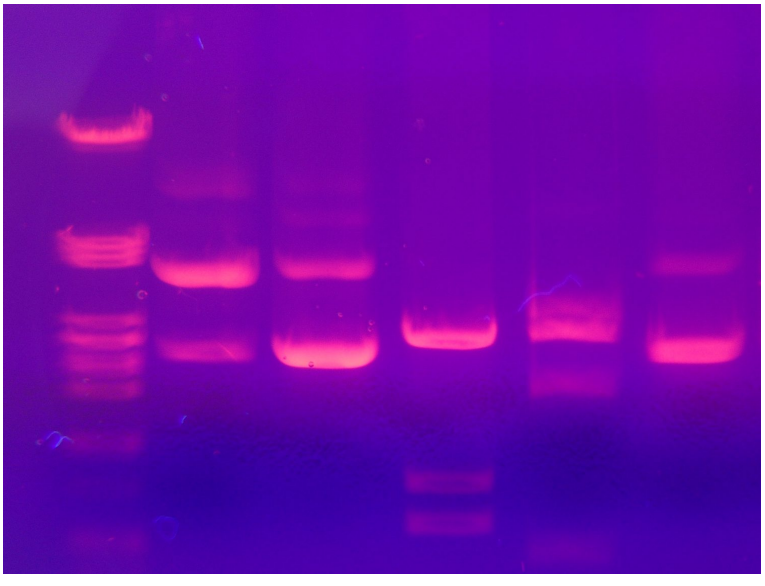
A **fermenter** 发酵罐 is a large tank used to grow bacteria or fungi to make useful products, such as **insulin** 胰岛素, **penicillin** 青霉素 and **mycoprotein** 真菌蛋白. The conditions inside must be carefully controlled: **temperature** 温度, pH, **oxygen** 氧气, the supply of nutrients, and the removal of waste products.



A fermenter grows microbes with the temperature, pH, oxygen and nutrients all controlled

Genetic modification

Genetic modification 基因改造 means changing an organism's **genetic material** 遗传物质 by removing, changing or inserting individual **genes** 基因.

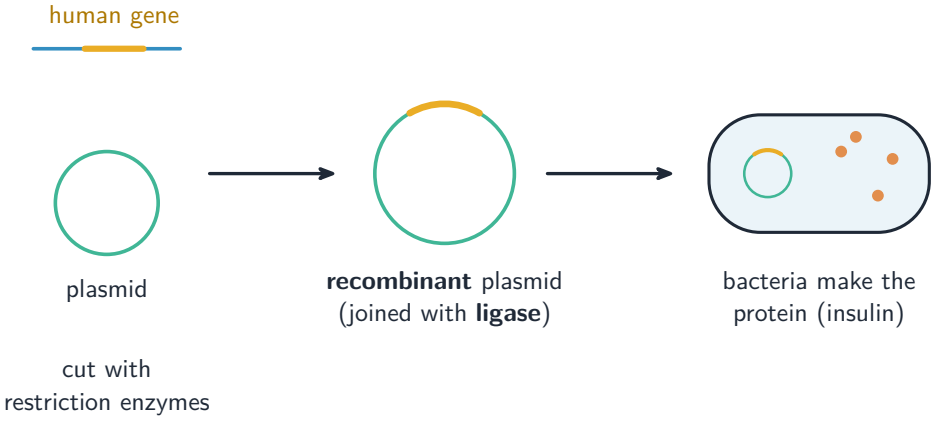


DNA fragments separated by gel electrophoresis appear as glowing bands

Making a human protein in bacteria (Supplement)

For example, to make a human **protein** 蛋白质 (such as insulin) in bacteria:

1. cut the human gene out of human DNA using **restriction enzymes** 限制酶, which leave **sticky ends** 黏性末端.
2. cut open a bacterial plasmid with the **same** restriction enzymes, giving matching sticky ends.
3. join the human gene into the plasmid using DNA **ligase** 连接酶, making a **recombinant plasmid** 重组质粒.
4. put the recombinant plasmid into a bacterium.
5. the bacteria multiply and **express** 表达 the human gene, making the human protein.



A human gene is joined into a plasmid, then bacteria make the human protein

Worked example. Put the steps of making human insulin in bacteria in order. **Restriction enzymes** cut the human insulin gene out of human DNA, leaving sticky ends. The **same** restriction enzyme cuts open a bacterial plasmid, so its sticky ends match the gene's. **Ligase** joins the gene into the plasmid, making a recombinant plasmid. The plasmid is put into a bacterium, and the bacteria multiply in a fermenter, each one expressing the gene and making human insulin. Two marks hang on precision: the **same** enzyme must cut both the gene and the plasmid, which is what makes the sticky ends fit; and ligase **joins** - it does not cut.

Examples of genetic modification

Genetic modification is used to:

- put human genes into bacteria to make human proteins (such as insulin).
- put genes into **crop plants** 农作物 to give **resistance** 抗性 to **herbicides** 除草剂.
- put genes into crops to give resistance to insect pests.
- put genes into crops to improve their food value.

(Supplement) GM crops such as soya, maize and rice can give higher yields and better nutrition, but some people worry about effects on health, on wild species, and about the cost of GM seeds.

Exam tips

- Bacteria are used because they reproduce fast, make complex molecules, and contain plasmids.
- Yeast (anaerobic respiration) → ethanol (biofuel) and carbon dioxide (bread). Enzymes: pectinase (fruit juice), proteases and lipases (washing powders), lactase (lactose-free milk).
- Fermenters make insulin, penicillin and mycoprotein; control temperature, pH, oxygen, nutrients and waste.
- Genetic modification: cut a gene with restriction enzymes (sticky ends) → join it into a plasmid with ligase (a recombinant plasmid) → put into bacteria → express the gene to make the protein.
- GM crops can resist herbicides or insect pests, or have better nutrition.