

Course Companion

AQA · GCSE · Biology

Every topic handout in one volume

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Contents

1. 1 · Cell biology	2
2. 2 · Organisation	16
3. 3 · Infection and response	28
4. 4 · Bioenergetics	37
5. 5 · Homeostasis and response	46
6. 6 · Inheritance, variation and evolution	71
7. 7 · Ecology	80

1 · Cell biology

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Cell biology: the unit of life

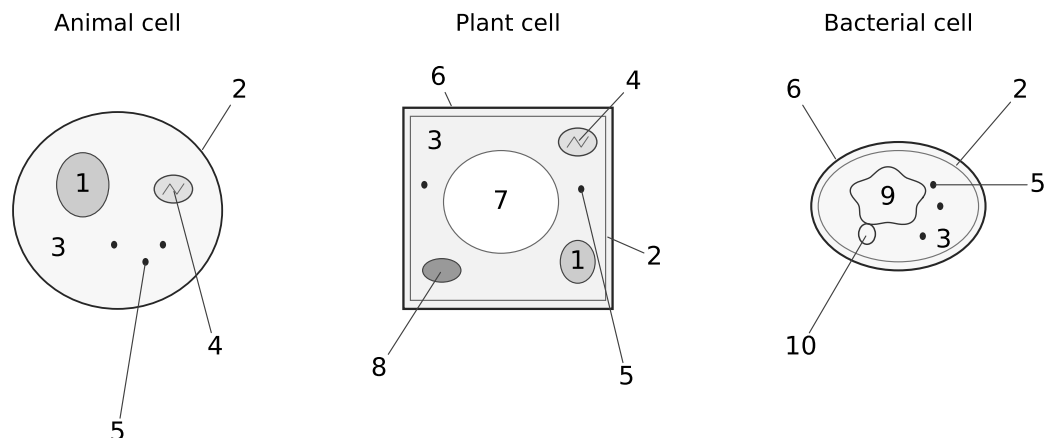
Every living thing is built from cells, and the differences between them decide what each can do. This reference covers **AQA GCSE Biology 8461, topic 4.1 Cell biology**.

How the exam treats this topic:

- Paper 1 (4.1–4.4) carries Cell biology. Required practicals: RP1 (light microscope), RP2 (antiseptics/antibiotics on agar, biology only) and RP3 (osmosis in plant tissue).
- Culturing microorganisms is **biology only**; standard-form answers for bacterial numbers are **HT only**.
- Calculations the exam demands: magnification ($\text{image} \div \text{real}$), real size from image and magnification, area by πr^2 , percentage change in mass, surface-area-to-volume ratio, bacterial division counts.

Cell structure: eukaryotes and prokaryotes

Teacher models – not to scale. Numbers match the structure key. The plant model represents a photosynthetic cell; many root cells do not have chloroplasts. The bacterial model includes a plasmid, but not every bacterium has plasmids.

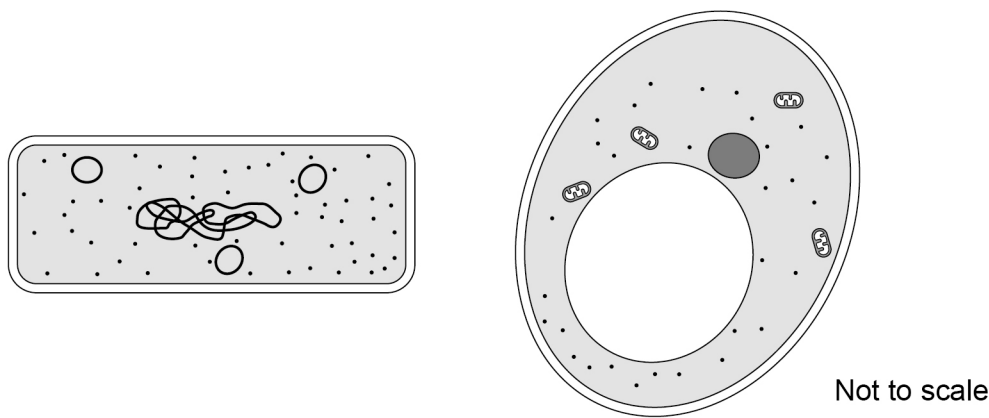


Eukaryotic cells include plant, animal and yeast cells; their genetic material is enclosed in a nucleus. **Prokaryotic** bacterial cells have no nucleus: the main DNA is a single loop and there may be plasmids. Bacteria have a membrane, cytoplasm, ribosomes and a wall; they do not have mitochondria or chloroplasts. Their

wall is not made of cellulose. Cell wall alone does not distinguish a bacterium from a yeast cell. Do not claim that all plant cells have chloroplasts or that bacteria lack ribosomes.

Key	Structure	Function
1	nucleus	DNA; controls cell activities
2	cell membrane	regulates entry and exit
3	cytoplasm	site of many reactions
4	mitochondrion	aerobic respiration
5	ribosome	protein synthesis
6	cell wall	support; cellulose in plants
7	permanent vacuole	cell sap; maintains firmness
8	chloroplast	photosynthesis
9	DNA loop	bacterial genetic material
10	plasmid	small DNA ring carrying genes

Figure 10



Original 2025 Q08.1 [1]: bacteria are prokaryotic; yeast is eukaryotic. **Q08.2 [2]:** any two visible yeast features not found in bacteria include nucleus, vacuole and mitochondria. Name the structures; “more complicated” is not a labelled comparison. Do not use this not-to-scale drawing to calculate their relative real sizes.

Cell specialisation, differentiation and microscopy

Specialised cells have structures suited to their functions. Explain the feature and the resulting advantage, rather than only listing structures.

Cell	Feature	Link to function
sperm	tail; many mitochondria	swimming; energy for movement
nerve	long axon; insulation	impulses over a distance
muscle	contractile fibres; mitochondria	contraction; energy released
root hair	long projection, large surface	water and ion uptake
xylem	hollow; lignified wall	water flow; strength
phloem sieve tube	sieve plates	dissolved sugars can flow

Sheet 1.1 Q2.2 [2]: one feature plus its advantage earns the pair: a tail propels the sperm towards the egg; alternatively many mitochondria release energy through aerobic respiration for swimming. Do not replace the explanation with a second unrelated feature. **Q3.1 [4]:** mitochondria carry out aerobic respiration, releasing energy for contraction; ribosomes synthesise proteins, including the contractile fibres needed by the cell.

Differentiation means acquiring different sub-cellular structures to become specialised. Most animal cell types differentiate early; many plant cells retain this ability throughout life. Division in mature animals is mainly for repair/replacement. Differentiation changes cell type/function; division increases cell number.

■ Microscopy, scale and calculations

Magnification is how many times larger the image is than the real object. **Resolving power** concerns distinguishing close structures as separate. Enlarging a blurred image increases its size without necessarily revealing more detail. Electron microscopes have higher magnification and resolution than light microscopes, allowing finer sub-cellular detail.

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

Here M is magnification, I image size and L real size. Use the same length units for I and L; M has no unit. Rearranging gives $L = I/M$. Prefixes: centi = 10^{-2} , milli = 10^{-3} , micro = 10^{-6} , nano = 10^{-9} . Thus 1 cm = 10 000 μm ; 1 mm = 1000 μm = 1 000 000 nm.

Worked example: image 4.8 cm at $\times 1200$. Convert 4.8 cm = 48 000 μm .

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

$$L = \frac{48\,000\ \mu\text{m}}{1200} = 40\ \mu\text{m}$$

For sheet Q2.3, $2.4 \text{ mm} = 2400 \text{ }\mu\text{m}$ and $L = 2400 \text{ }\mu\text{m}/800 = \mathbf{3.0 \text{ }\mu\text{m}}$.

Original AQA 2024 Q08.3 [6]: a cylindrical structure has volume $24\,500\,000 \text{ nm}^3$ and radius 125 nm . Its image is 4 mm long. Use $\pi = 3.14$. The question provides the cylinder-length equation; find the real length before magnification.

$$L = \frac{V}{\pi r^2}$$

$$L = \frac{24\,500\,000 \text{ nm}^3}{3.14 \times (125 \text{ nm})^2} = 499.363 \dots \text{ nm}$$

Convert $I = 4 \text{ mm} = 4\,000\,000 \text{ nm}$, then:

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

$$M = \frac{4\,000\,000 \text{ nm}}{499.363 \dots \text{ nm}} = 8010.204 \dots \approx 8010$$

Report $\times \mathbf{8010}$, without a length unit. The official scheme rejects a magnification answer with a unit. Preserve intermediate precision and distinguish the provided radius from a diameter. Use the stated 4 mm image length rather than measuring a resized PDF.

RP1: prepare/observe the selection of plant and animal cells under a light microscope, find and focus the specimen, then draw clear outlines and accurate labels. Start with low magnification to locate the specimen before moving higher. Include a magnification scale. Draw the structures actually observed; the teacher model is not proof that every organelle will be visible with the classroom microscope. A printed magnification is tied to image size. If the image is resized, that printed value changes; an embedded scale bar resized with the image retains the correspondence between bar and object.

Culturing microorganisms (biology only)

Bacteria multiply by **binary fission**. With enough nutrients and a suitable temperature they may divide as often as every 20 minutes; this is not a fixed rate for every species or condition. They can grow in nutrient broth or as colonies on agar. For a stated constant division time:

$$\text{number of divisions} = \frac{\text{elapsed time}}{\text{division time}}$$

$$\text{final population} = \text{initial population} \times 2^{\text{number of divisions}}$$

Worked example: one bacterium, 20-minute divisions, 3 hours. Elapsed time = 180 minutes; divisions = $180/20 = 9$; population = $1 \times 2^9 = 512$. Sheet 1.1 Q3.3 instead uses 2 hours: six divisions, **64** cells. Standard form 6.4×10^1 is the HT extension for this population calculation. These predictions assume the stated division rate continues; nutrient shortage or changed conditions can invalidate it.

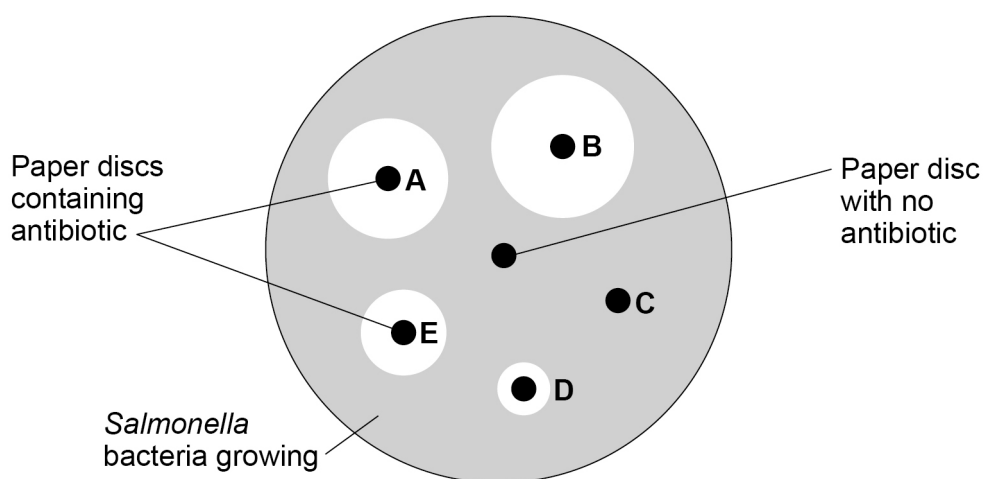
■ Aseptic technique and the reason for each action

Aseptic technique aims to prevent contamination by unwanted microorganisms. Sterilise Petri dishes and culture media before use; sterilise the inoculating loop before transfer. Briefly lifting/tilting the lid reduces contact with air, and adhesive tape secures it. Store inverted to reduce condensation dripping onto the agar. These actions have different purposes: in original 2023 Q03.3 [2], inversion alone is ignored as an aseptic answer. Name the item/action; “sterilise equipment” alone is too vague for that scheme.

Original 2023 Q03.4 [3]: 37°C is human body temperature, where the investigated *Salmonella* grows better. Schools use a maximum of 25°C to reduce growth of organisms harmful to humans. This reduces risk; it does **not** guarantee that every organism present is non-pathogenic. School work still requires aseptic precautions. Do not copy a specialist laboratory’s conditions into a school method merely because growth is faster there.

■ RP2: controls, measurements and conclusions

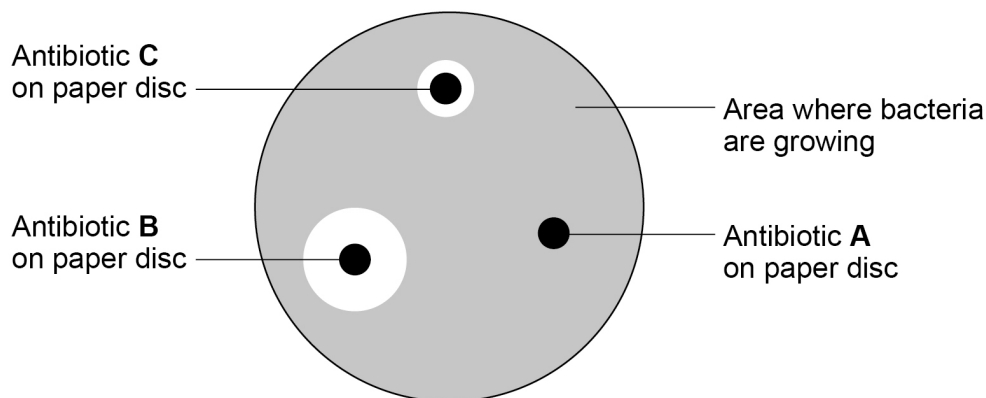
Figure 4



Original Q03.5 [1]: the disc with no antibiotic is a **control**, allowing comparison to check that inhibition is due to the antibiotic rather than the paper disc. It is not a “control variable”. **Q03.6–Q03.7 [1 + 1]:** A and B have the largest zones of inhibition for the tested bacterium. Measure each diameter/radius, or calculate each area, to

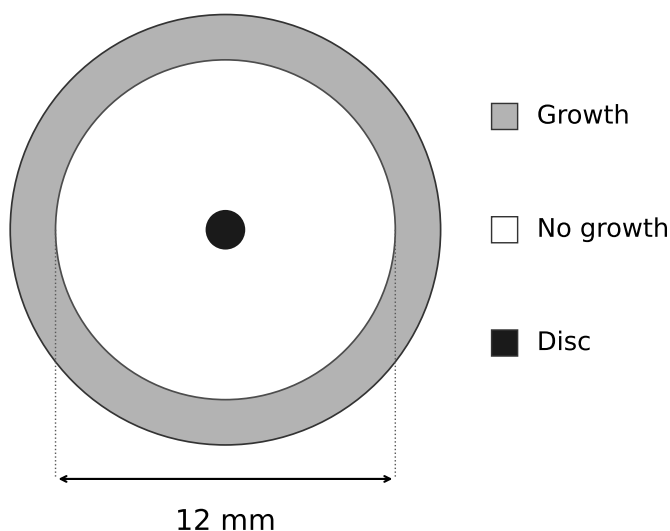
compare quantitatively. In a fair investigation keep bacterial type, agar, disc size, amounts/concentrations, incubation time and temperature consistent as appropriate; repeat measurements/cultures and compare means. A zone is evidence about the tested organism under the tested conditions, not proof of identical effects in every infection.

Figure 5



Original 2024 Q06.2 [2]: the claim that this bacterium is resistant to C is contradicted by a zone of inhibition. If it were resistant in this test, growth would reach the disc edge and no zone would appear. A **small** zone is still a zone; it is not the same as no inhibition. Describe bacteria being killed or their growth being prevented, rather than only saying “white area”.

Teacher schematic for the worksheet’s stated diameter – not measured exam data.



Sheet 1.1 Q3.2(c) [2]: diameter 12 mm, so radius is half the diameter.

$$r = \frac{d}{2} = \frac{12 \text{ mm}}{2} = 6 \text{ mm}$$

$$A = \pi r^2$$

$$A = \pi \times (6 \text{ mm})^2 = 113.097 \dots \text{ mm}^2 \approx 113 \text{ mm}^2$$

Using 12 mm as the radius gives four times the correct area. The question supplies the clear-zone diameter and does not ask for an annular area excluding the disc. If a different question asks for an area excluding the disc, use its stated dimensions and subtract the disc area. Measure several diameters for an irregular zone where appropriate; use a consistent measurement rule across samples.

Cell division: chromosomes, mitosis and the cell cycle

The nucleus contains **chromosomes** made of DNA. Each carries many **genes**, sections of DNA; body-cell chromosomes normally occur in pairs. For human body cells, 23 pairs means 46 chromosomes, not 23 chromosomes. This paired arrangement is different from the two copies produced when DNA replicates.

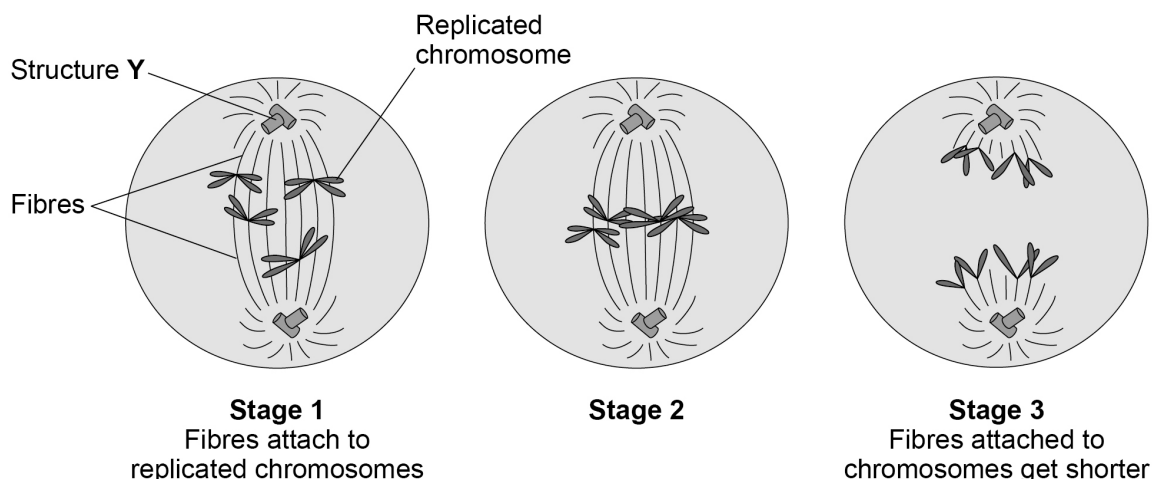
Overall stage	What happens
Preparation	Growth; more ribosomes/mitochondria; DNA copied
Mitosis	One chromosome set to each end; nucleus divides
Final division	Cytoplasm/membrane divide; two identical cells

Growth and DNA replication both prepare the cell for division; do not present replication as a separate stage before growth. Replication makes two copies of each chromosome. **Mitosis** distributes the copied genetic material: it does not halve the chromosome set in each daughter cell. The three overall stages above are sufficient here; the named phases within mitosis are not required.

Original 2024 Q08.1 [1]: DNA replication is already given. Another preparatory change is cell growth or an increase in ribosomes/mitochondria. Repeating DNA replication does not answer “one other change”.

Original 2023 Q05.6 [3] / sheet 1.2 Q3.1: after DNA replication, one set of chromosomes is pulled to each end of the cell (1); the nucleus divides (1); cytoplasm or cell membrane divides to form two cells (1). Keep these three points distinct. DNA copying is preparation; it does not replace one of these division points.

Figure 9



Original Figure 9 shows some stages within division, not the three overall cell-cycle stages in the table. Its stage numbers belong to that figure.

Original 2024 Q08.4 [2]: drug X prevents fibres attaching to replicated chromosomes. Therefore chromosomes cannot be pulled to each end (1), so the nucleus cannot divide / two genetically identical cells cannot form (1). “The cell cannot divide” simply repeats the question; describe the mechanism. **Q08.5 [1]:** stopping division stops tumour growth/spread. Mitosis also supports normal growth, development and repair. Blocking division in living hair-follicle cells can cause hair loss; slowing division in repair tissue can delay healing. The dead hair shaft is not dividing.

Stem cells

A **stem cell** is undifferentiated: it can make more cells of its own type and can differentiate into other cell types. Division increases cell number; differentiation provides specialised structures/functions.

Source	Differentiation potential
Embryo	Most human cell types
Adult bone marrow	Many types, including blood cells; narrower range
Plant meristem	Any plant cell type throughout plant life

Original 2025 Q07.1 [1]: embryonic stem cells can differentiate into liver cells, giving the relevant property for liver treatment. “Can divide” alone does not explain production of the required specialised cells. The question explicitly says donor cells can be rejected: do not transfer the patient-matched therapeutic-cloning claim to all donated stem cells.

Therapeutic cloning: an embryo with the patient’s genes provides matching stem cells, which the syllabus describes as not rejected. This is an immune-compatibility

benefit, not a guarantee against every risk. Stem-cell treatment has potential uses in diabetes and paralysis; possible viral transfer remains a risk. Details of the cloning technique are outside this specification.

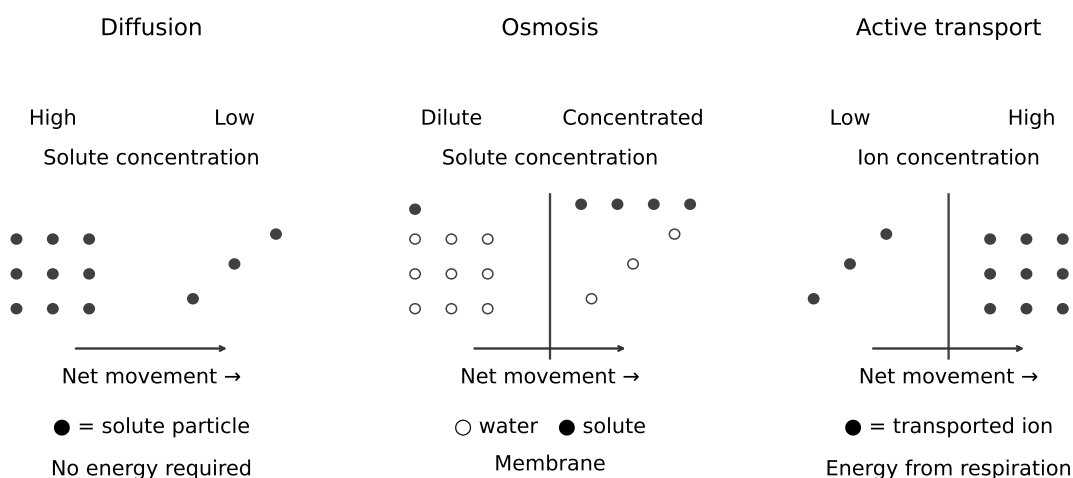
Original 2025 Q07.2 [1]: an ethical objection needs a reason: embryo destruction, inability of an embryo to consent, or conflict with specified personal/religious beliefs. “Religion” alone is insufficient in this scheme. Viral transfer is a biological risk, not an ethical explanation.

Teacher comparison model, not an official six-mark scheme: embryonic cells have a wider differentiation range; bone-marrow cells have a narrower range including blood cells. Using embryos raises objections about embryo destruction; adult marrow avoids that particular objection. Both sources still require safety assessment. A benefit should be linked to a possible treatment and a risk/objection should be explained, then weighed in context; do not claim the source alone guarantees a cure.

Original 2023 Q01.2 [1]: the plant stem-cell tissue is **meristem**. Meristem cells retain differentiation potential throughout life. Cloning can preserve rare plants and rapidly/economically produce identical crops with useful traits such as disease resistance. These are separate purposes: preserving a rare species does not automatically make it disease-resistant.

Transport in cells

Teacher particle models: filled circles represent solute particles (transported ions in the third panel); open circles represent water. The arrows show **net movement**, not the motion of every particle. The osmosis panel’s concentration labels refer to **solute**, and water crosses a partially permeable membrane. Active transport moves the named substance against its own concentration gradient.



Process	Net direction	Energy from respiration
Diffusion	Substance: high $\rightarrow$ low concentration	Not required
Osmosis	Water: dilute $\rightarrow$ concentrated solution	Not required
Active transport	Substance: low $\rightarrow$ high concentration	Required

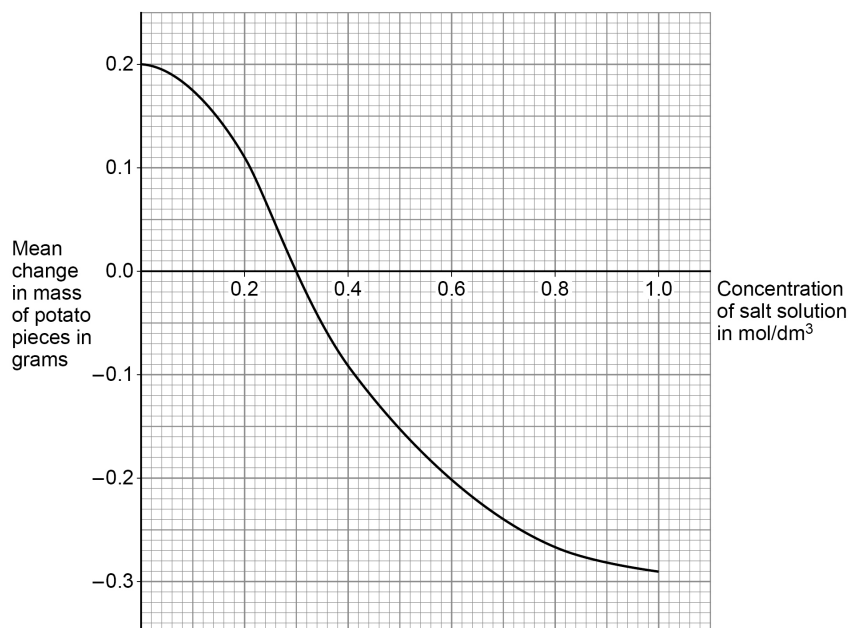
Diffusion is the net movement of particles from higher to lower concentration. Particles still move both ways; the overall transfer is down the gradient. Examples: oxygen/carbon dioxide in gas exchange and urea from cells to blood plasma. Original 2025 Q06.1 [1] needs the net high-to-low direction; sheet Q2.1 [2] also identifies particles in a gas or solution.

Rate: a steeper concentration gradient gives greater net movement; higher temperature increases particle motion; greater membrane surface area allows more transfer at once. A thin exchange barrier shortens the diffusion path. Blood flow and ventilation help maintain gradients rather than supplying energy for diffusion.

Active transport: root hairs can absorb a mineral ion when its concentration is lower in the soil than in the cell. It moves low $\rightarrow$ high for that ion, using energy from respiration. Glucose uptake from gut to blood is another example. Original 2025 Q03.3 [1]: energy requirement, movement against a gradient, or transport of ions/glucose rather than water distinguishes it from osmosis.

Osmosis: net water movement from a dilute solution to a more concentrated solution through a partially permeable membrane. Original 2025 Q03.2: potato cell solution is more concentrated than distilled water, so net water entry increases mass. With more concentrated solution outside, water leaves and mass falls. At no mass change, there is **no net water movement**, not an absence of molecular movement.

Figure 4



Original Figure 4: the vertical axis is **mean change in mass in grams**, not percentage. Its zero crossing is approximately 0.30 mol/dm³, an estimate of the matching external concentration under these conditions. Original Q05.2 [3]: at 0.6 mol/dm³ mass decreases because water leaves; the cell solution is less concentrated than outside; water moves by osmosis. Q05.3 [2]: 1.0 mol/dm³ gives a steeper concentration gradient and more water loss than 0.6 mol/dm³. The graph does not give an exact universal concentration for all potatoes.

■ Percentage change and RP3

Known initial and final masses must be distinguished. Subtract initial from final, then divide by the **initial** mass. Percentage change permits comparison when starting masses differ; preserve a negative sign for loss.

$$\Delta m = m_{\text{final}} - m_{\text{initial}}$$

$$p = \frac{\Delta m}{m_{\text{initial}}} \times 100\%$$

Teacher example: initial mass 2.5 g, final mass 2.9 g.

$$\Delta m = 2.9 \text{ g} - 2.5 \text{ g} = +0.4 \text{ g}$$

$$p = \frac{+0.4 \text{ g}}{2.5 \text{ g}} \times 100\% = +16\%$$

Sheet Q2.2: the 3.0 g piece loses 0.45 g, so the signed change is -0.45 g.

$$p = \frac{-0.45 \text{ g}}{3.0 \text{ g}} \times 100\% = -15\%$$

RP3 sequence: cut equal-sized peeled pieces from the same potato; blot consistently and record initial masses; immerse in measured concentrations with equal solution volume, time and temperature; remove, blot and record final masses; calculate change/percentage change; repeat at each concentration, calculate means and plot the appropriate dependent variable. The original 2024 graph requires **mean mass change in grams**; a percentage-change graph needs that additional calculation and a different vertical-axis label.

Original 2025 Q03.1 [6], evaluation: recording before/after mass and using several concentrations are strengths. “Cubes” alone does not specify equal size. Blot before weighing to remove surface liquid; specify equal dimensions, time, temperature and volume to control competing effects; repeat at each concentration and calculate means to reduce random variation; use percentage change if starting masses differ. A high-level answer includes a strength, explained improvements and a supported judgement, not an unlinked checklist. More concentrations improve the detail of the response curve but do not replace repeats.

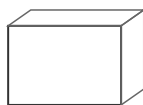
One workable teacher setup: 1 cm peeled cubes; $0.0\text{--}1.0$ mol/dm³ salt solutions in 0.2 steps; equal 30 mL volumes fully covering the cubes; 20 minutes at 20°C; three pieces per concentration. These are stated design choices, not values supplied by the original method.

Original 2024 Q05.1 [6], planning: a logical method must produce the displayed mean mass-change graph: before/after weighing, stated concentrations, controlled time/size/temperature, consistent blotting, repeats and means. “Evaluate” examines an existing method; “plan” supplies a reproducible sequence. A list of control-variable names alone is not either complete answer.

■ Surface area, volume and exchange

Teacher cubes: drawn side lengths are proportional; use the stated dimensions, not a ruler on a resized PDF. For a cube, six square faces give surface area; three dimensions give volume.

Side length: 2 mm

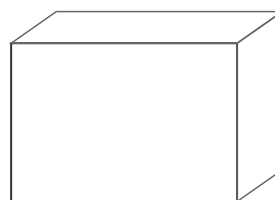


Surface area = 24 mm²

Volume = 8 mm³

SA:V = 3:1

Side length: 4 mm



Surface area = 96 mm²

Volume = 64 mm³

SA:V = 1.5:1

$$SA = 6a^2 \quad V = a^3 \quad R = \frac{SA}{V}$$

For side length a = 2 mm:

$$SA = 6(2 \text{ mm})^2 = 24 \text{ mm}^2$$

$$V = (2 \text{ mm})^3 = 8 \text{ mm}^3$$

$$R = \frac{24 \text{ mm}^2}{8 \text{ mm}^3} = 3 \text{ mm}^{-1}$$

For a = 4 mm, SA = 96 mm² and V = 64 mm³, so R = 1.5 mm⁻¹. The classroom shorthand SA:V is 3:1 versus 1.5:1 when numerical values use matching millimetre units. Doubling length multiplies area by four and volume by eight, halving SA per unit volume. The larger cube has **more total surface area**, but a **smaller ratio**.

A small single-celled organism can exchange enough through its cell surface. Large multicellular organisms have less surface area per unit volume and longer internal diffusion paths, so specialised exchange surfaces and transport systems meet demand. The cell surface is still an exchange surface: “no specialised organ” does not mean “no exchange”.

Adaptation	Effect
Large area	More exchange at once
Thin barrier	Short diffusion path
Blood supply	Maintains gradients; carries substances
Ventilation	Replaces air/water; maintains gas gradients

Examples: lungs and small intestine in mammals, fish gills, plant roots and leaves. Sheet Q3.3: numerous alveoli provide area; thin walls shorten the path; capillaries maintain gradients. Halving working alveoli reduces gas-exchange area and oxygen transfer rate; supply may fail to meet demand, prompting faster breathing. This does not mean each breath contains half the oxygen.

Checklist before you call this topic done

- Label animal, plant and bacterial cells; match every structure to its function.
- Specialised cells: one structural feature linked to one function each.
- Magnification, real size and image size – convert units before dividing.
- Aseptic technique whys; binary-fission counts; πr^2 zones (RP2).
- Cell cycle stages and where mitosis occurs; stem cell sources with benefits and risks.
- Diffusion, osmosis, active transport: direction, energy, examples; the three rate factors.
- SA:V calculations; four exchange-surface features; percentage change in mass (RP3).

2 · Organisation

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Organisation: from cells to systems

Cells form tissues, tissues form organs, organs form systems – and the digestive system, blood and plants each show the pattern. This reference covers **AQA GCSE Biology 8461, topic 4.2 Organisation**.

How the exam treats this topic:

- Paper 1 carries Organisation. Required practicals: RP4 (food tests) and RP5 (pH and amylase rate).
- You must **evaluate** heart-disease treatments and lifestyle risk data, and interpret graphs and tables of risk factors.
- Recall exactly: the enzymes table, the heart's vessels, blood components, plant tissues, transpiration factors.

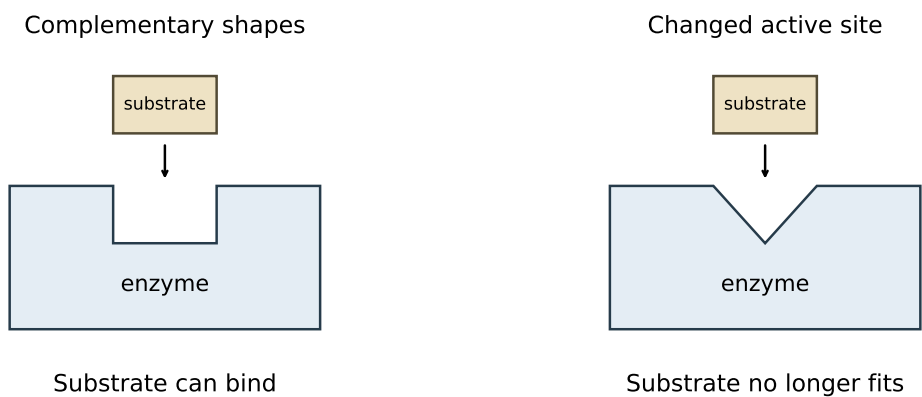
Principles of organisation

Cells → tissues → organs → organ systems → organism. A **tissue** contains cells with similar structure and function. An **organ** contains different tissues working together. **Organ systems** contain organs working together.

Digestive example: a muscle cell belongs to muscular tissue; the stomach also contains glandular tissue (secretes digestive juice) and epithelial tissue (covers surfaces). These tissues together form the stomach. The stomach, intestines and other digestive organs work together in the digestive system. Calling the stomach a tissue misses its several tissue types.

The human digestive system (4.2.2.1)

Enzymes are protein biological catalysts: they speed reactions without being used up. In the simplified **lock-and-key model**, a substrate fits a complementary **active site**. Products leave and the enzyme can act again. This is a shape model, not a drawing of real molecules.



Cold versus denatured: at low temperature, particles move more slowly, so there are fewer successful enzyme–substrate collisions; warming can increase the rate again. High temperature can change the enzyme’s shape permanently (**denaturation**), so the substrate no longer fits. pH changes can reduce activity by affecting the active site; do not claim every small move away from optimum causes permanent denaturation.

Enzyme	Production sites	Substrate → products
Amylase	Salivary glands; pancreas; small intestine	Starch → simple sugars
Protease	Stomach; pancreas; small intestine	Protein → amino acids
Lipase	Pancreas; small intestine	Lipids → glycerol + fatty acids

Amylase breaks starch into **simple sugars**; it does not directly turn starch into glucose. Digestive enzymes make small soluble products that cross the small-intestine wall into blood. Digestion is breakdown; absorption is movement into blood. Digestion products can build new carbohydrates, lipids and proteins, and glucose is used in respiration.

Bile is made in the **liver** and stored in the **gall bladder**. It is alkaline: neutralising stomach acid provides suitable conditions for lipase in the small intestine. It also **emulsifies** large fat globules into smaller droplets, increasing surface area for lipase. Bile is not an enzyme; emulsification does not itself make glycerol and fatty acids.

RP4: use separate portions of a prepared food sample for each test. Record reagent, treatment and observed colour; use known positive and negative controls to check the procedure.

Substance	Reagent / treatment	Positive result
Reducing sugar	Benedict's; hot water bath	Green/yellow/orange/brick-red
Starch	Iodine solution	Blue-black
Protein	Biuret reagent	Purple/lilac
Lipid	Sudan III; mix, allow to separate	Red-stained oil layer

Benedict's starts blue; iodine starts yellow-brown; Biuret starts blue. A negative result means **not detected by this test**, not proof that none is present. Benedict's does not test for every kind of sugar. Heating supplies energy for the Benedict's reaction; brick-red is not the only positive colour. Wear eye protection; use a water bath, not a flame under the food-test tube. Follow school handling instructions for reagents.

RP5: pH and amylase rate. Change pH with buffers; measure time for the starch endpoint, then compare relative rates. Use a water bath to control temperature and sample onto iodine **every 30 s**, as specified by AQA.

Reproducible sequence: place separate drops of iodine in a spotting tile. Equilibrate measured starch, amylase and buffer in the same water bath. Mix at the chosen pH and start the timer immediately. Every 30 s, transfer a fresh small sample of reaction mixture to a new iodine drop, using clean equipment so iodine is not carried into the reaction tube. Record the first sample that stays yellow-brown. Repeat the sequence with fresh reactants at each pH.

Keep temperature, enzyme/starch concentrations and volumes, buffer volume, total volume and sampling interval constant. Repeat each pH at least three times and calculate a mean. Choose pH values that span the possible peak; investigate smaller pH steps around the fastest tested condition. Shortest time identifies the fastest **tested** pH, not an exact universal optimum.

Teacher example (invented data, not a past-paper table): mean endpoint times at pH 5, 6, 7 and 8 are 180, 90, 60 and 120 s. The same initial starch quantity and endpoint make reciprocal time a useful relative-rate measure.

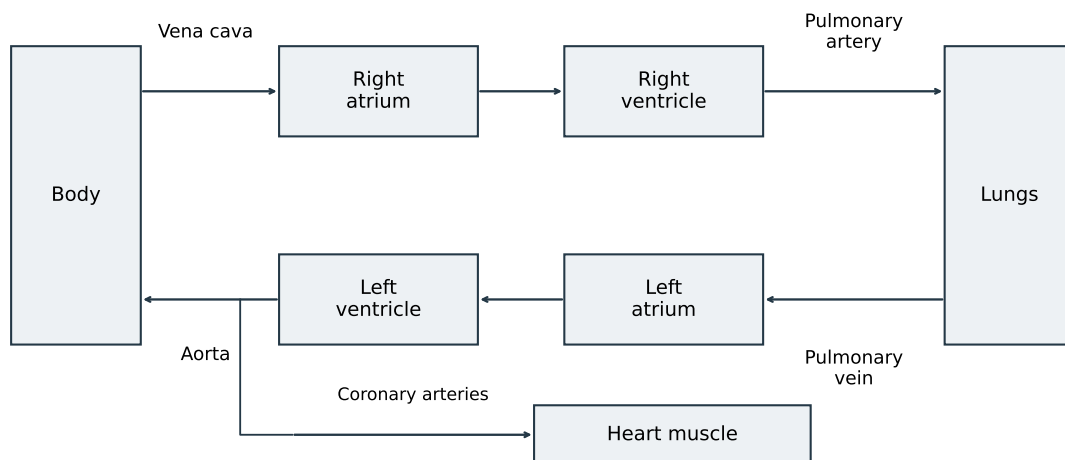
$$r = \frac{1}{t}$$

$$r = \frac{1}{60 \text{ s}} = 0.0167 \text{ s}^{-1}$$

At pH 6, $r = 1/(90 \text{ s}) = 0.0111 \text{ s}^{-1}$. The pH 7 reaction is 1.5 times as fast by this measure. Plot pH horizontally and relative rate (s^{-1}) vertically; a time graph instead has its **minimum** at the fastest tested pH. If starch still remains when observation ends, report "endpoint not reached"; do not invent an endpoint or use zero time. The 30 s sampling interval limits time resolution.

Original exam application, AQA June 2025 Paper 1H Q02.5 [4]: after 5 min the iodine stayed yellow-brown at 30 °C but became blue-black at 90 °C. At 30 °C no starch remained because amylase had broken it down; at 90 °C starch remained because amylase had denatured. Q02.6 [1] asks for a more precise best temperature: test additional temperatures between 10 and 60 °C. The four tested temperatures do not establish exactly 30 °C as the optimum.

The heart, blood vessels and blood (4.2.2.2–4.2.2.3)



Teacher flow model, not an anatomical layout: follow the arrows, not the position on this page. Body → vena cava → right atrium → right ventricle → pulmonary artery → lungs → pulmonary vein → left atrium → left ventricle → aorta → body. **Coronary arteries** branch from the aorta to supply heart muscle itself. Blood in the chambers does not directly supply all the muscle.

Double circulation: in one complete body–lung circuit blood passes through the heart twice. The right ventricle pumps to the lungs; the left pumps around the body at higher pressure and has a thicker muscular wall. Pressure/resistance, rather than “distance” alone, explains the difference. Valves prevent backflow; atria receive returning blood and ventricles pump blood out.

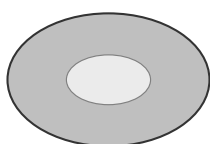
Arteries carry blood **away from** the heart; veins carry it **towards** the heart. The pulmonary artery carries deoxygenated blood; the pulmonary vein carries oxygenated blood, so oxygen content does not define an artery or vein. Cells in the **right atrium** form the natural pacemaker; an artificial pacemaker corrects an irregular rhythm.

Vessel	Structure → function
Artery	Thick muscular/elastic wall withstands high pressure; elastic recoil helps maintain flow
Vein	Wider lumen, thinner wall; valves reduce backflow at low pressure
Capillary	Wall one cell thick gives a short exchange path

Original AQA 2025 Q05.5 [1] needs “thick muscle/elastic layer”; “thick wall” alone is not enough for that mark. **2023 Q02.4 [2]** asks for two comparisons: thicker muscle and elastic layers, narrower lumen or absence of valves compared with veins. The narrower lumen is a structural comparison, not a complete explanation that it creates the heart’s pressure.

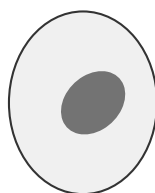
Lungs: air passes through trachea and bronchi to **alveoli**. Numerous alveoli provide large surface area; thin alveolar/capillary walls shorten the diffusion path; blood flow and ventilation maintain oxygen/carbon-dioxide gradients. Oxygen diffuses into blood; carbon dioxide diffuses into alveolar air.

Red blood cell



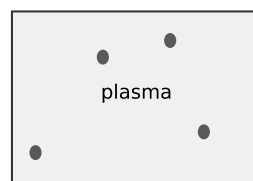
No nucleus
Biconcave shape
Binds oxygen

White blood cell



Has a nucleus
Defends against
pathogens

Plasma and platelets



Dots: platelets
Clotting limits
blood loss

Teacher cell models, not to scale. The red cell’s pale centre represents a depression, not a nucleus. **Blood** is a tissue: **plasma** carries dissolved glucose, amino acids, CO₂, urea and hormones, and distributes heat. **Red blood cells** have haemoglobin to bind oxygen, no nucleus (more room for haemoglobin) and a biconcave shape (large surface area for rapid exchange). **White blood cells** have nuclei; some engulf pathogens and others produce antibodies. **Platelets** are cell fragments involved in clotting, reducing blood loss and pathogen entry.

Coronary heart disease (4.2.2.4) and treatments

CHD: fatty material narrows the coronary arteries → reduced flow to heart muscle → reduced oxygen/glucose supply → less aerobic respiration and energy release → weaker contraction / fatigue. Exercise raises demand; restricted supply can contribute to chest pain. A percentage blockage does not imply the same percentage fall in flow.

Treatment	Benefit	Limitation / risk
Stent	Holds narrowed artery open; improves flow	Procedure risks; does not prevent new deposits
Statin	Lowers cholesterol; slows fatty deposits	Long-term medication; possible side effects
Replacement valve	Restores effective one-way flow	Surgery; mechanical valves need anticoagulants
Heart transplant	Replaces a failing heart	Donor shortage; rejection; immunosuppression
Artificial heart	Maintains pumping while awaiting transplant	Infection/clotting risk; device limitations

A faulty valve may not open fully (restricting flow) or may leak (allowing backflow). A stent treats a narrowed artery; a replacement valve treats valve disease. Transplant/artificial heart address severe pump failure, not every narrowed artery. Bypass surgery diverts flow around a blockage (accepted in the original 2023 Q02.9 scheme).

Worked evaluation, sheet Q3.2 [4]: a stent can restore flow promptly by holding the artery open, but its procedure has risks and it does not prevent future fatty deposits. Statins reduce cholesterol and slow further deposits, but need continued use and may cause side effects. The two act differently and may be used together. Choice depends on severity, urgency and patient circumstances; the question supplies no basis for claiming one is always best.

Original 2024 Q01.4–Q01.5 [1 + 2]: identify statins for reducing cholesterol; explain that a stent opens/holds open the artery, allowing more blood and oxygen/glucose to the heart muscle. “Unblocks it” alone misses the mechanism.

Original 2023 Q02.5 data: blockage 0, 10, 20, 50, 80%; flow 100, 64, 42, 8, 2 cm³/min. Describe a decreasing trend; these data are not a direct percentage-loss rule or a mathematical inverse-proportion law. **Q02.8 [6]** needs linked reasons from reduced supply through respiration/energy to contraction or symptoms. A list of separate symptoms is insufficient.

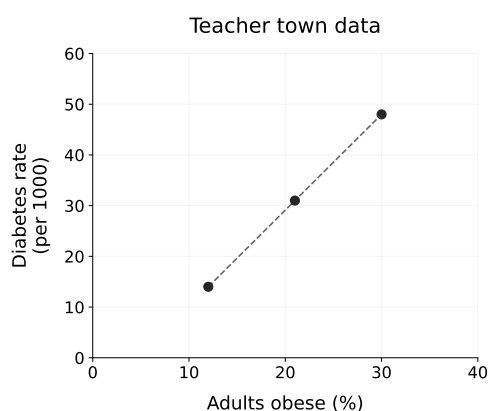
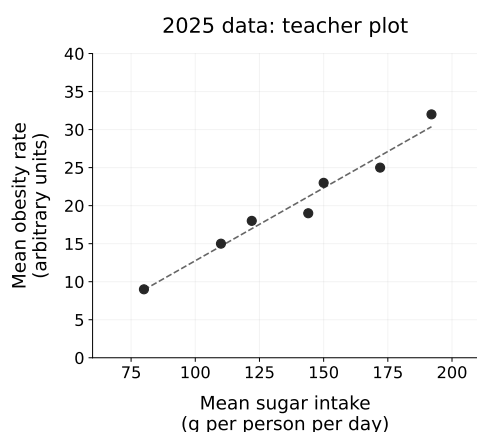
Health, lifestyle and cancer (4.2.2.5–4.2.2.7)

Health is physical and mental well-being. Communicable and non-communicable diseases, diet, stress and life situations can affect both. Disease interactions include immune defects increasing infection risk, some viruses triggering cancers, immune reactions following infection triggering allergies, and severe physical illness contributing to depression.

A **risk factor** is linked to an increased disease rate. It may be lifestyle or a substance in the body/environment. Increased risk does not mean every exposed person develops the disease.

Factor	Established risk / effect
Diet, smoking, exercise patterns	Cardiovascular disease
Obesity	Type 2 diabetes
Alcohol	Liver damage; brain effects
Smoking	Lung disease; lung cancer
Smoking / alcohol during pregnancy	Harm to unborn babies
Carcinogens, including ionising radiation	Cancer

Correlation and cause: a scatter plot shows an association, not its cause. An established causal risk factor such as obesity can contribute to Type 2 diabetes, but one three-town association does not isolate that effect from age, diet, activity, sampling or chance. Prior scientific evidence and the particular dataset are different sources of evidence. A known mechanism does not make every observed association causal.



Teacher redraw, not the original exam figure: left uses the exact AQA June 2025 Q02.2 table; right uses the teacher-authored sheet Q3.2 data. Dashed lines show fitted trends, not measured paths or proof of cause. The seven-country vertical axis is in **arbitrary units**, not percentages; the three-town diabetes axis is **per 1000**, not percent.

Reading a scatter plot: identify each axis and unit; use one point per paired observation; describe the direction with both variable names. A line of best fit represents the overall pattern and need not pass through every point or the origin. Original 2025 Q02.2 [4] requires a suitable vertical scale/label, five additional correct plots and a line of best fit. Q02.1 [1] accepts **Type 2 diabetes** as an obesity-related disease; do not give Type 1.

Worked teacher-town data (sheet Q3.2): A = 12% obese / 14 per 1000 diabetes; B = 21% / 31; C = 30% / 48. As the percentage obese rises, diabetes rate rises: positive correlation. Support the trend with two values using units.

$$R = \frac{d_C}{d_A}$$

$$R = \frac{48 \text{ per } 1000}{14 \text{ per } 1000} = 3.43$$

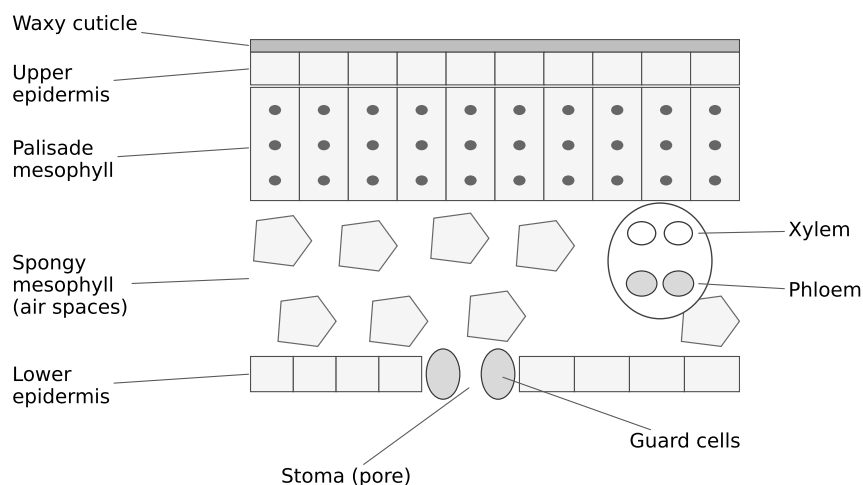
The rate is about **3.4 times** as high, not “roughly double”. The absolute increase is 34 cases per 1000, not 34 percentage points. Obesity is an established causal risk factor for Type 2 diabetes, but these three towns alone cannot prove that obesity caused the difference in their rates. Other factors and sampling must be considered.

Checking a survey claim (sheet Q3.3): compare similar groups and account for smoking, diet, exercise and age; these may affect both exposure and disease. Check sample size, selection and representativeness so a small/biased group does not stand for everyone. Check whether exposure preceded disease and whether findings repeat. Seek a plausible tested mechanism and independent review, but neither plausibility nor peer review alone proves causation. Each answer needs a check **and its reason**.

Cancer results from cell changes leading to uncontrolled growth and division. **Benign** tumours remain in one area, usually within a membrane, and do not invade other tissues. **Malignant** tumour cells invade nearby tissues and spread in blood to form secondary tumours. Compare containment/invasion and spread as separate features; size alone does not identify malignancy.

Smoking mechanism (sheet Q3.1): tobacco smoke contains **carcinogens**. These can damage/mutate DNA in lung cells; changes affecting division control can lead to uncontrolled division and malignant tumours. This explains increased risk, not certainty for every smoker or every mutation. Some cancers also have inherited genetic risk factors.

Plant tissues and transport (4.2.3)



Teacher model, not to scale: palisade dots represent chloroplasts. The leaf is an organ containing several tissues. Upper/lower epidermis protects; the waxy cuticle reduces water loss. Palisade mesophyll has many chloroplasts for photosynthesis; spongy mesophyll has air spaces for gas movement. **Guard cells** control **stomata**, balancing gas exchange and water loss. **Meristems** at growing root/shoot tips produce cells that can differentiate throughout plant life.

Original 2024 Q04.1–Q04.3: name palisade mesophyll, spongy mesophyll and meristem tissue in that order; lignin strengthens xylem; **translocation** is sugar transport. “Active transport” alone is not the name for movement through the phloem.

Feature	Xylem	Phloem
Cells	Dead; hollow, no cytoplasm	Living sieve tubes; some cytoplasm
Walls	Lignin-strengthened tubes	Perforated end walls (sieve plates)
Load	Water and mineral ions	Dissolved sugars
Direction	Roots → stems/leaves	Sources → growing/storage regions; can be up or down
Process	Transpiration stream	Translocation

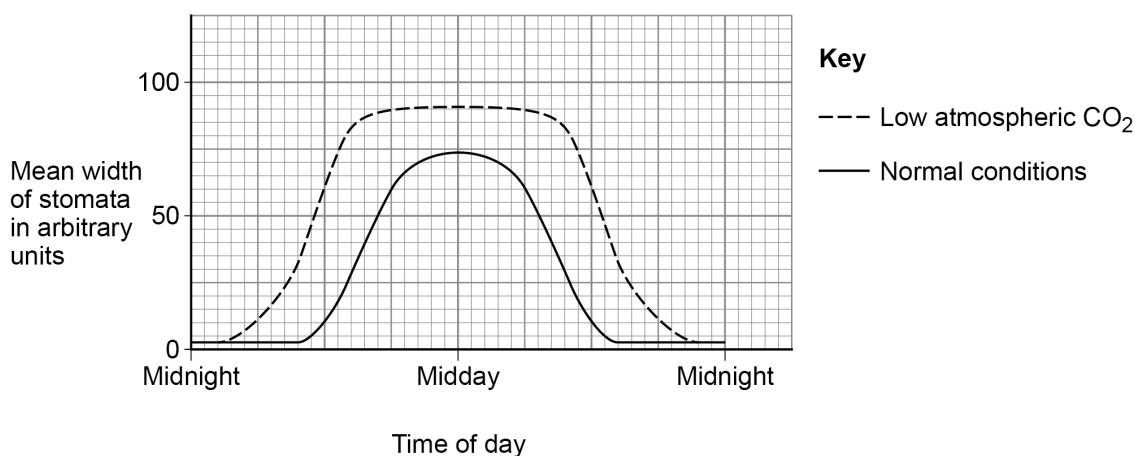
Worked comparison (sheet Q3.1 / original 2021 Q06.6 [6]): both are transport tissues with tube-like cells. Compare dead hollow lignified xylem with living phloem and sieve plates; then compare water/mineral transport upwards with dissolved-sugar transport to growing/storage tissues in either direction. A high-level original answer needs **both structure and function**, not six disconnected facts about only one tissue. “Both directions” describes transport in the tissue, not simultaneous opposite flow in every individual tube.

Root hairs: a large surface area supports uptake; water enters by osmosis through a partially permeable membrane. Mineral-ion uptake against its concentration gradient needs active transport and respiration energy. Original 2024 Q04.5 [5] extends the same logic to sugar loading: mitochondria → aerobic respiration → energy released → sugar moved low-to-high → active transport. This is a text-based teacher explanation; the paper’s referenced photograph is absent from the supplied PDF, so no identification of its missing label is inferred.

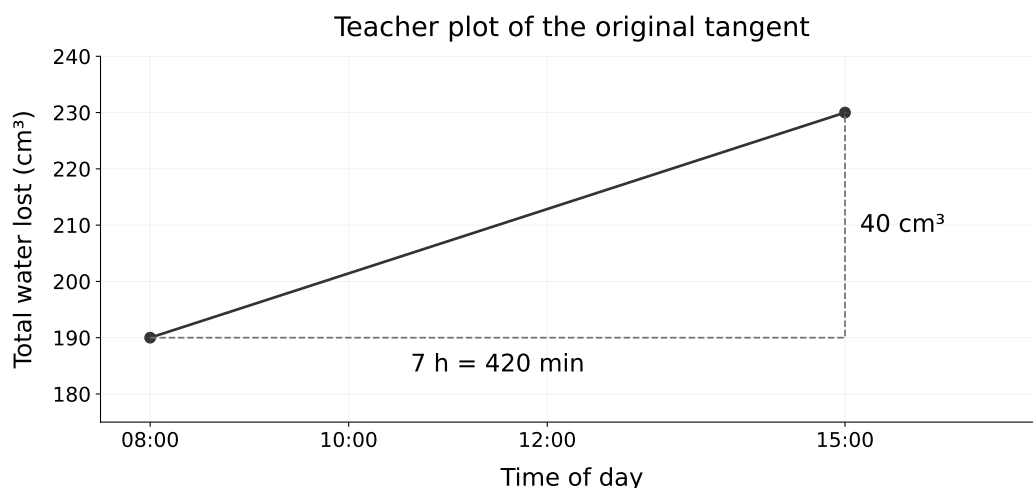
Transpiration : water evaporates from moist mesophyll cell walls into leaf air spaces, then water vapour diffuses through stomata into outside air. Water loss draws more liquid water through xylem in the transpiration stream. Roots, stem and leaves cooperate as a transport system. Keep evaporation (liquid → vapour) distinct from diffusion (vapour moving down its gradient).

Change	Usual effect, with other conditions controlled
Higher temperature	Faster evaporation / particle motion; rate rises
More air movement	Removes humid boundary air; steeper vapour gradient
More light	Stomata usually open more; rate rises
Higher humidity	Smaller vapour gradient; rate falls

These are expected effects under suitable water supply, not guarantees for every stressed plant. Original 2022 Q05.3: greatest rate in **warm, low-humidity** conditions. Sheet Q3.2: moving air removes humid air → maintains the water-vapour gradient → faster diffusion out. Sheet Q3.3: fewer upper-surface stomata can limit water loss from a more exposed surface while lower stomata still permit CO₂ uptake. This is a suggested advantage for the stated plant, not a law for every leaf orientation or species.



Original Figure 7 shows mean stomatal width in arbitrary units, not water-loss rate. Solid line = normal conditions; dashed = low atmospheric CO₂. Q05.4 [4]: near-closed stomata at night reduce water loss when little/no light is available for photosynthesis; wide opening around midday allows more CO₂ uptake for photosynthesis when light is greatest. Q05.5 [2]: in low CO₂, stomata are wider and open longer, allowing greater CO₂ entry for photosynthesis. Do not claim that low atmospheric CO₂ increases the concentration outside the leaf.



Teacher tangent plot: reproduces the given straight-line tangent's readings, not the original measured curve. Original 2021 Figure 10 plots **total water lost (cm³)** against clock time. Its height is cumulative volume; its gradient is rate. Q06.7 [4] asks for the tangent slope **at 12:00**, in cm³/min and standard form. Take two well-separated points on the tangent, even away from the contact point; do not use two points on the curved results line.

Known tangent readings: 08:00 / 190 cm³ and 15:00 / 230 cm³ (the latter is a point on the extended tangent, not a new measured result). Use $\Delta V = V_2 - V_1$ and $\Delta t = t_2 - t_1$ to calculate the changes:

$$\Delta V = 230 \text{ cm}^3 - 190 \text{ cm}^3 = 40 \text{ cm}^3$$

$$\Delta t = 15 \text{ h} - 8 \text{ h} = 7 \text{ h}$$

$$\Delta t = 7 \text{ h} \times 60 \text{ min/h} = 420 \text{ min}$$

$$r = \frac{\Delta V}{\Delta t}$$

$$r = \frac{40 \text{ cm}^3}{420 \text{ min}} = 0.0952 \text{ cm}^3/\text{min}$$

$$r = 9.52 \times 10^{-2} \text{ cm}^3/\text{min}$$

The official scheme uses 40/7 h or 40/420 min, allowing consistent tangent readings. Dividing the total volume by the clock time does not give the requested gradient. Q06.8

[2]: lower nighttime rate links mostly closed stomata to less light/lower temperature; it does not mean cumulative water loss falls overnight.

Potometer reasoning: bubble movement measures water uptake, a proxy for water loss, not an exact direct transpiration measurement (some water is retained/used). Use a water-filled sealed apparatus, avoid air entering the cut stem, allow acclimatisation, change one factor and control leaf area, time and the other environmental factors; repeat. Distance/time compares uptake rates in the same capillary; volume/time additionally needs its cross-sectional area. Do not claim every absorbed drop is immediately transpired.

Checklist before you call this topic done

- Order cells → tissues → organs → systems with one example each.
- Enzyme table: name, site, substrate, products; lock and key; denaturing.
- Bile: two functions with reasons; RP4 tests and colours; RP5 method.
- Label the heart with all five named vessels; double circulation; pacemaker.
- Artery/vein/capillary structure ↔ function; four blood components with adaptations.
- CHD: cause + each treatment's benefit and risk.
- Risk factors with causal mechanisms; benign vs malignant tumours.
- Plant tissues and their jobs; xylem vs phloem; four transpiration factors.

3 · Infection and response

AQA · GCSE · Biology

Infection and response: the war inside

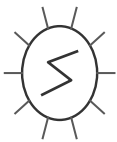
Pathogens invade, defences respond, and medicine arms the fight. This reference covers **AQA GCSE Biology 8461, topic 4.3 Infection and response**.

How the exam treats this topic:

- Paper 1 carries this topic; RP2 (antibiotics/antiseptics on agar) links from topic 1.
- **Monoclonal antibodies** (4.3.2) and **plant disease** (4.3.3) are **biology only**, and monoclonals plus plant-disease detection are **HT only**.
- Recall exactly: each named disease → pathogen type, symptoms and spread; the defence systems; the drug-testing stages.

Communicable diseases and pathogens (4.3.1.1)

Virus



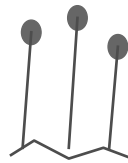
Reproduces
inside host
cells

Bacterium



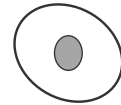
Some bacteria
release toxins

Fungus



Black spot:
spores spread

Protist



Malaria protist:
mosquito vector

Pathogens are microorganisms causing infectious disease: **viruses, bacteria, protists, fungi**. They infect plants or animals and spread by **direct contact, water or air**. Bacteria may produce **toxins** that damage tissues; viruses live and reproduce inside cells.

Reducing spread: hygiene (hand washing), sterilising wounds, clean water, sewage treatment, using condoms, vector control (mosquito nets, draining water).

Named diseases (4.3.1.2–4.3.1.5)

Disease	Pathogen	Spread	Symptoms/signs	Control
measles	virus	droplet inhalation (sneezes, coughs)	fever, red skin rash; can be fatal	vaccination of young children
HIV	virus	sexual contact, exchange of body fluids (shared needles)	flu-like illness; attacks immune cells → late-stage AIDS	antiretroviral drugs; safe sex; clean needles
TMV (tobacco mosaic virus)	virus (plants)	contact between plants	mosaic discolouration of leaves; reduced photosynthesis and growth	resistant varieties; hygiene
Salmonella	bacterium	food ingested in unhygienic conditions	fever, cramps, vomiting, diarrhoea (bacteria + toxins)	poultry vaccinated (UK); hygienic food prep
gonorrhoea	bacterium	sexual contact	thick yellow/green discharge, pain urinating	antibiotics (resistance rising); condoms
rose black spot	fungus (plants)	spores in water/air	black spots on leaves; leaves yellow and drop	removing/burning leaves; fungicide
malaria	protist	mosquito vector	recurrent fever; can be fatal	nets; stopping mosquito breeding

From knowledge to exam answers:

Pathogen means a microorganism causing infectious disease: viruses, bacteria, protists or fungi. A **vector** carries a pathogen; malaria's mosquito is the vector and its protist is the pathogen. The teacher drawings above are schematic examples, not to scale. Virus shapes and genetic material vary.

Choose controls by transmission route: reduce inhalation of infected droplets; use hygiene to prevent food contamination; use clean water; reduce exchange of infected body fluids; avoid vector bites and breeding. Bacteria may release toxins that damage tissue. Viruses reproduce inside host cells, causing damage.

Measles precision (2025 Q01.1/.2/.4): virus; inhaled cough/sneeze droplets; fever or red rash. **Malaria terminology (2023 Q05.1):** mosquito = vector, protist =

pathogen. Match each prevention to the transmission route.

Worked symptom mechanism (original 2023 Q03.1 [1]): *Salmonella bacteria release toxins*. The scheme ignores “toxins” alone: state who produces them.

Worked spread/control (sheet Q3.1 [4], teacher rubric): bacteria are swallowed in contaminated food; poor food hygiene permits contamination; UK poultry are vaccinated; fewer infected animals mean fewer bacteria reach human food. Symptoms alone do not explain spread or control. Original 2023 Q03.2 [4] additionally requires specific antibodies/rapid secondary response in the animal and a link to less contaminated human food; see the immunity section.

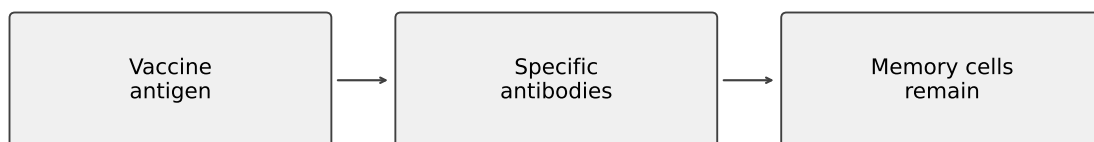
Worked growth chain (sheet Q3.2 [3]): TMV reduces functioning chlorophyll-containing leaf area → less photosynthesis → less glucose for respiration and making biomass → less growth. Black spot also reduces photosynthesis when leaves are damaged or lost.

Worked resistance (sheet Q3.3 [4]): random mutation produces resistant variants → penicillin kills susceptible bacteria → survivors reproduce/pass on resistance → repeated selection raises the resistant proportion. Bacteria do not learn resistance or mutate because they need it.

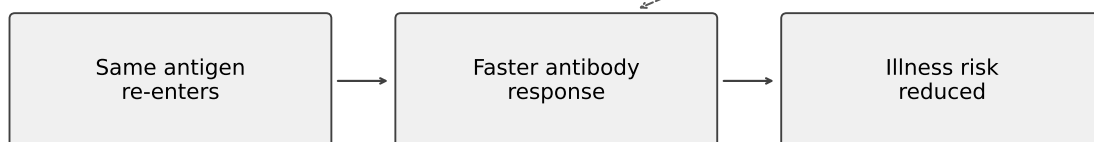
Worked vector control (sheet Q1.3): mosquito is the vector [1]; nets or preventing mosquito breeding is a suitable control [1]. Teacher explanation: nets reduce infectious bites; fewer breeding sites reduce the number of vectors.

Human defence systems and immunity (4.3.1.6–4.3.1.7)

Vaccination



Later re-exposure



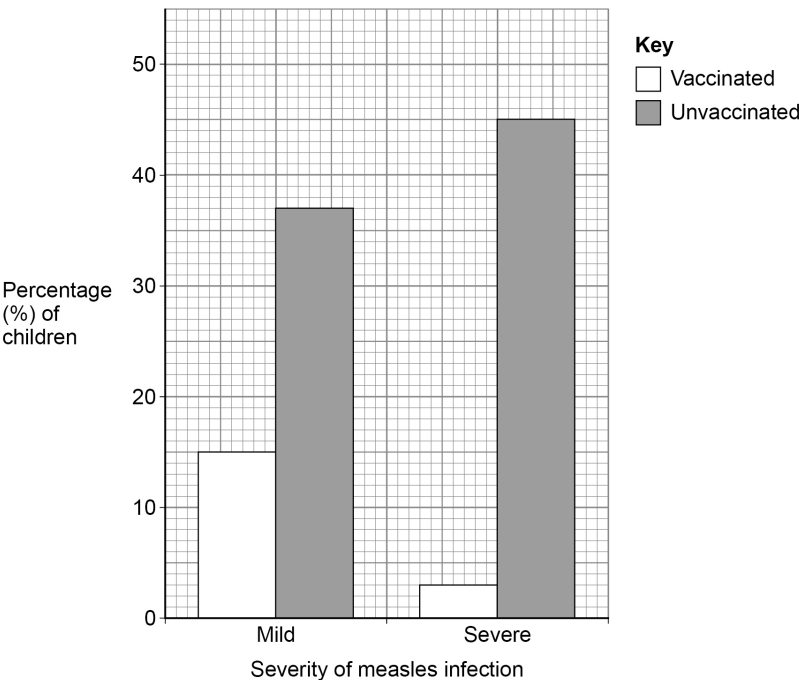
Teacher sequence model, not measured response data.

Non-specific defences: skin forms a physical barrier; scabs seal wounds. Nose hairs/mucus trap inhaled pathogens. Airway mucus traps pathogens; cilia move it towards the throat to be swallowed. Stomach hydrochloric acid kills many swallowed pathogens.

White blood cells defend by **phagocytosis** (engulf/digest), **antibody production** (antibodies complementary to a specific antigen), and **antitoxin production** (neutralising toxins). An antigen is the target recognised by an antibody; antitoxins are not antibiotics.

Worked vaccination (sheet Q3.1 [4]): small amounts of dead/inactive pathogen supply antigens → white cells make specific antibodies → memory cells remain → later exposure produces correct antibodies quickly, reducing illness risk. This is the syllabus vaccine model, not a claim that every vaccine has the same manufacture or guarantees zero infection.

Population protection (original 2025 Q01.5 [2]; sheet Q3.2 [3]): fewer susceptible/infected hosts → fewer opportunities to pass on the pathogen → unvaccinated people are less likely to encounter it. “Herd immunity” alone does not supply the mechanism. Vaccination reduces infection and transmission risk; protection is not absolute.



Original AQA June 2025 Figure 1; percentages of all surveyed children.

Original 2025 Figure 1: percentages refer to the entire surveyed sample, not to the vaccinated or unvaccinated group alone.

Severity	Vaccinated	Unvaccinated
Mild	15%	37%
Severe	3%	45%

Worked number (Q01.6 [3]): 240 surveyed children; severe/unvaccinated bar = 45%.

$$N = \frac{p}{100} \times N_{\text{total}}$$

$$N = \frac{45}{100} \times 240 \text{ children}$$

$$N = 108 \text{ children}$$

Evidence (Q01.7 [2]): severe cases represent 3% vaccinated versus 45% unvaccinated in the whole sample. This supports reduced severity; vaccinated infected children are still present. Do not silently change the denominator or label these raw percentages as vaccine efficacy.

Animal-to-human chain (2023 Q03.2 [4]): specific antibodies in vaccinated animals → rapid response to later Salmonella infection → fewer bacteria in animal products → fewer bacteria ingested by humans, reducing infection/toxin production. The original level-two requirement links the animal immune response to human food poisoning.

Antibiotics, painkillers and drug development (4.3.1.8–4.3.1.9)

Antibiotics kill susceptible infective bacteria; they do not kill viruses. The cold is viral, so antibiotics do not cure it (sheet Q1.3 [2]). **Painkillers** relieve symptoms without killing pathogens. Viruses reproduce in host cells, making antiviral development difficult; this does not mean antiviral treatment is impossible.

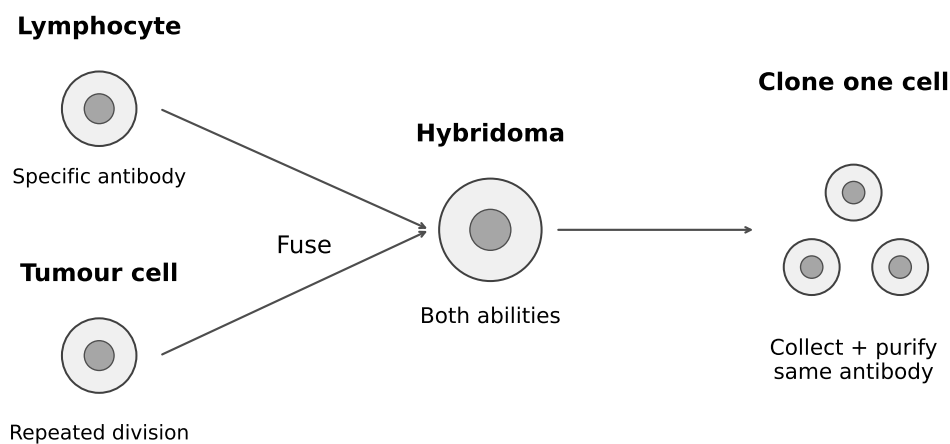
Sources: digitalis–foxglove (heart); aspirin–willow (painkiller; 2025 Q01.3); penicillin–Penicillium mould (Fleming). Modern synthesis can start from plant chemicals.

Testing questions (2023 Q01.7 [2]): toxicity (harm/side effects), efficacy (does it work?), dose (how much?). Choose distinct reasons.

Worked testing sequence (sheet Q3.3 [5]): preclinical cells/tissues/live animals investigate toxicity and potential efficacy → healthy volunteers start at very low dose for safety → patients test efficacy/optimum dose → appropriate controlled double-blind comparison → peer review scrutinises methods/results. Original 2024 Q08.6 [1] identifies testing live tissues in a laboratory as preclinical; volunteers/patients are clinical.

Placebo and blinding: placebo lacks the active drug and helps account for expectation effects. In a double-blind comparison neither participants nor outcome assessors know allocation, reducing bias. Comparator choice depends on the trial; not every trial uses placebo. Peer review is scrutiny, not a guarantee of success. Original 2023 Q01.8 [1]: company financial gain or competitor loss can motivate bias; Q01.9 [1]: peer review scrutinises claims.

Monoclonal antibodies (biology only, HT)



Teacher schematic, not to scale; clone one antibody-producing cell.

Monoclonal antibodies come from one clone and bind one site on one protein antigen. Complementary shape means a binding fit, not identical shape.

Production (sheet Q1.1/Q3.1): stimulate mouse lymphocytes with the relevant antigen → fuse an antibody-producing lymphocyte with a repeatedly dividing tumour cell → **hybridoma** combines both abilities → clone a single suitable hybridoma → collect and purify its identical antibody. Activated lymphocytes can divide; the culture-production issue is sustained division, not “lymphocytes cannot divide”. Original 2025 Q07.4 requires the relevant liver antigen/cells, not an unspecified pathogen.

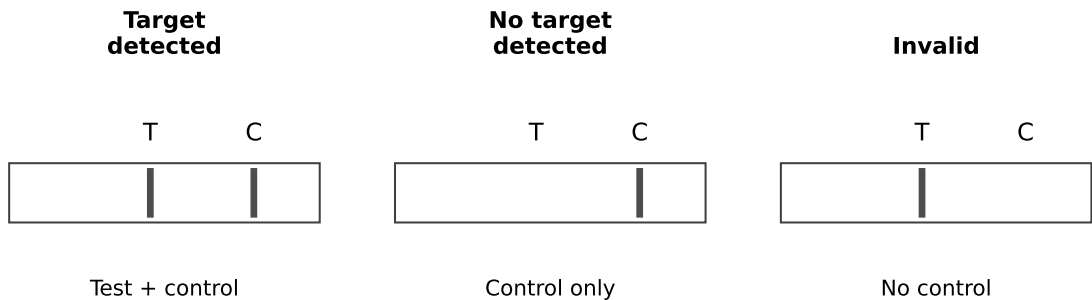
After fusion (original 2023 Q04.5 [3]): clone → many identical cells → same antibody → collect/purify. The original question starts from the hybridoma, so naming it alone is not enough.

Use	How binding is useful
Diagnosis / laboratory	detect hCG, a pathogen antigen or another chemical; measure hormone levels
Research	a fluorescent label locates a specific molecule
Targeted treatment	an attached toxic/radioactive agent or growth-inhibitor is delivered towards target cells

Cancer model (sheet Q3.2 [3]): assume the target antigen is confined to cancer cells. Antibody binds that antigen; attached agent is delivered to the target cells, reducing exposure elsewhere. “Without harming other cells” describes this ideal model, not guaranteed real treatment safety. Side effects can occur and must be evaluated.

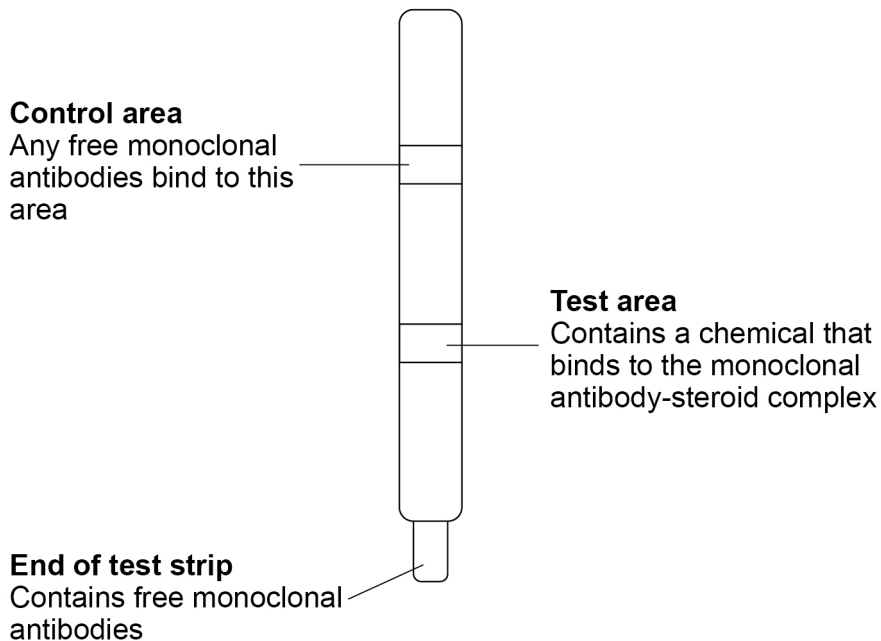
Transplant model (original 2025 Q07.5 [3]): the supplied drug antibody binds

liver antigens because it is complementary in shape → recipient antibodies cannot bind the occupied sites → recognition/attack is reduced. Specificity alone is insufficient for the three-mark explanation; do not substitute the cancer-payload mechanism.

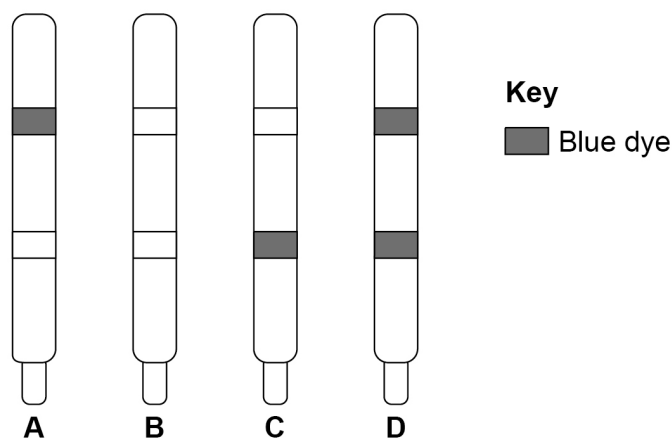


Teacher sandwich-test model: T = test; C = control. Other assays must be read using their supplied mechanism.

Positive hCG model (sheet Q3.3 [3]): urine hCG binds mobile labelled antibody → complex moves and is captured by fixed antibody at the test zone → accumulated label forms a line. The control shows the process worked. Control only = no target detected under these conditions; no control = invalid, even if the test line appears. A negative-looking invalid result does not prove target absence.



Original AQA 2023 Figure 5: test captures complex; control captures free antibody.



Original Figure 6; the grey key denotes blue dye.

Original 2023 Q04.7–.9: Figure 5 states test area captures antibody–steroid complex; control captures free antibody; binding changes the dye colour. Figure 6: A has control only; B neither line; C test without control; D both. B is invalid because its control has no dye; possible failure is no sample/antibody movement or missing antibody. D is the valid positive. Do not call C positive without checking control.

Plant disease (biology only)

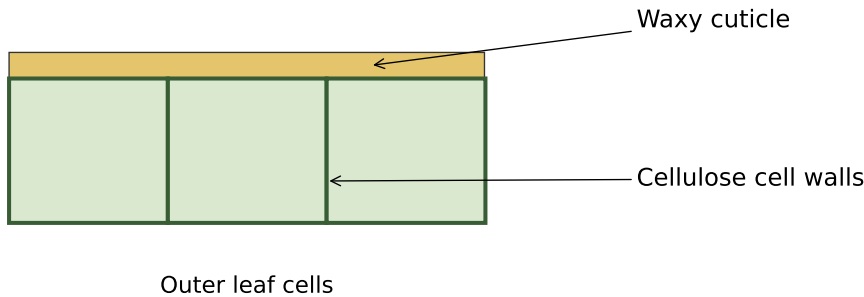
Detection and identification (HT). Signs include stunted growth, spots, decay, growths, malformed stems/leaves, discolouration and visible pests. A sign alerts us to a problem; it does not uniquely identify its cause. Compare the pattern with a **gardening manual/website**, send an affected plant/sample to a **laboratory**, or use a suitable **monoclonal-antibody kit** to detect a specific pathogen antigen. Follow the kit instructions and check its control; failure to detect one target does not exclude every disease.

Named problems: **TMV** (virus, mosaic discolouration), **rose black spot** (fungus, purple/black spots and leaf loss), **aphids** (insect pests).

Deficiency	Mechanism and effect
nitrate ions	less amino-acid/protein synthesis → reduced growth
magnesium ions	less chlorophyll → chlorosis (yellow leaves), less light absorbed → reduced photosynthesis

Worked evidence (2025 Q04.7–.8). Purple spots with leaf loss suggest rose black spot. Yellow leaves without spots **may** result from magnesium shortage: magnesium is needed to make chlorophyll. Lack of light is another accepted explanation. Yellowing alone does not prove a deficiency or rule out infection; 2023 Q01.6 also accepts several plausible causes. Use identification evidence before asserting a diagnosis.

Leaf surface: barriers to pathogen entry



Defences: physical – cellulose cell walls and waxy cuticle resist pathogen entry; bark/dead outer layers protect stems and can fall off. Chemical – antibacterial chemicals act against bacteria; poisons deter herbivores. Mechanical – thorns/hairs deter feeding, touch-induced drooping/curling can discourage herbivores, and mimicry can deter them. Explain the function of the named feature, rather than saying only “protects the plant”.

Growth chain: less chlorophyll → less photosynthesis → less glucose for biomass and respiration; respiration releases energy for growth. Nitrate shortage acts through reduced protein synthesis, not by being a fuel for respiration.

Checklist before you call this topic done

- Four pathogen types; three routes of spread; two ways to reduce each named disease's spread.
- Recite the disease table: pathogen, spread, symptoms, control.
- Four non-specific defences; three white-blood-cell actions.
- Vaccination mechanism + population effect; antibiotic vs painkiller; why antibiotics fail on viruses.
- Drug sources (foxglove, willow, Penicillium) and the preclinical/clinical stages with placebo and double-blind.
- (HT, biology) Hybridoma production sequence and four monoclonal uses.
- (Biology) Plant disease signs, identification methods, nitrate/magnesium deficiencies, three defence classes.

4 · Bioenergetics

AQA · GCSE · Biology

Bioenergetics: photosynthesis and respiration

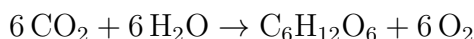
Plants capture light energy; respiration transfers energy for living processes in plant and animal cells. This reference covers **AQA GCSE Biology 8461, topic 4.4 Bioenergetics**.

How the exam treats this topic:

- Paper 1 carries Bioenergetics. RP6: light intensity and the rate of photosynthesis using pondweed.
- Limiting-factor graphs with two or three factors, the **inverse square law** and greenhouse economics are **HT only**.
- Equations are word equations – know the symbol forms too (CO_2 , H_2O , O_2 , $\text{C}_6\text{H}_{12}\text{O}_6$).

Photosynthesis (4.4.1.1)

carbon dioxide + water $\xrightarrow{\text{light}}$ glucose + oxygen

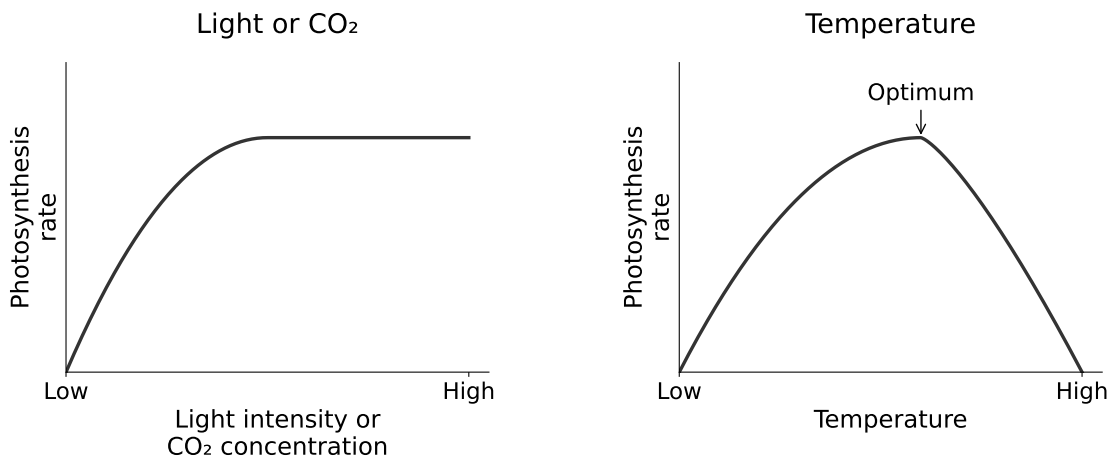


Photosynthesis is an **endothermic** reaction: energy is transferred **from the environment to the chloroplasts by light**. Chlorophyll absorbs light; carbon dioxide and water are the reactants, glucose and oxygen the products. Light is an energy input, not a chemical reactant. The coefficients balance the atoms: 6 carbon, 12 hydrogen and 18 oxygen on each side.

Worked evidence (2024 Q07.1): black paper blocks light; sealed transparent plastic prevents carbon dioxide entering; an uncovered leaf has both. In the supplied results, covered leaves have no starch and the uncovered leaf does. Explain the chain: restricted photosynthesis $\rightarrow$ no new glucose $\rightarrow$ no conversion of that glucose to starch. Do not claim photosynthesis directly makes starch.

Rate of photosynthesis and limiting factors (4.4.1.2)

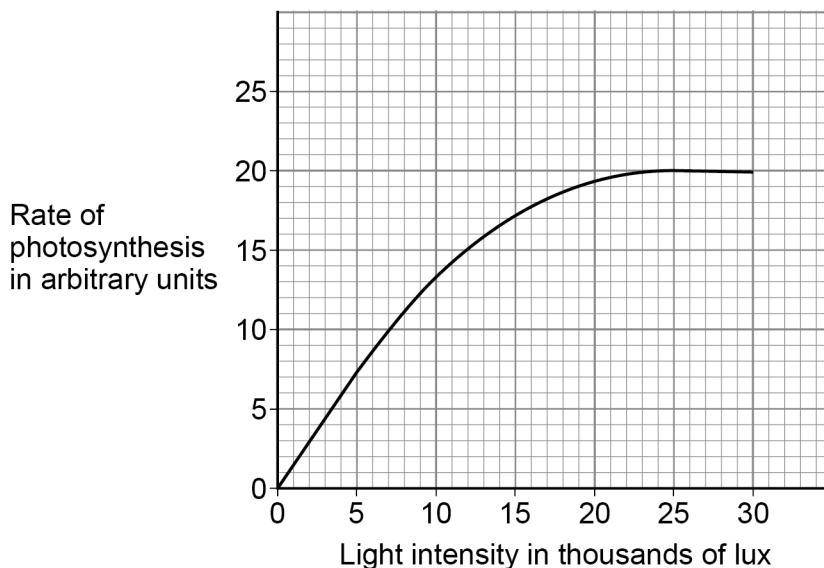
Factor	Why changing it can affect rate
light intensity	supplies energy absorbed by chlorophyll
CO_2 concentration	supplies a reactant
temperature	affects enzyme-controlled reaction rate
chlorophyll amount	affects how much light can be absorbed

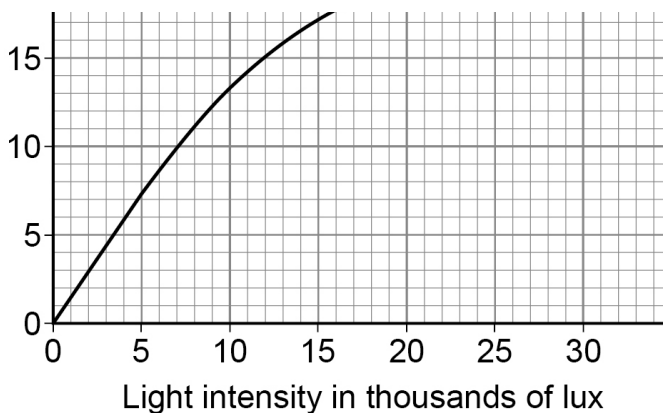


Light/CO₂ curves level off when another factor limits. The temperature curve falls above its optimum as enzymes denature; the optimum is not a universal fixed temperature.

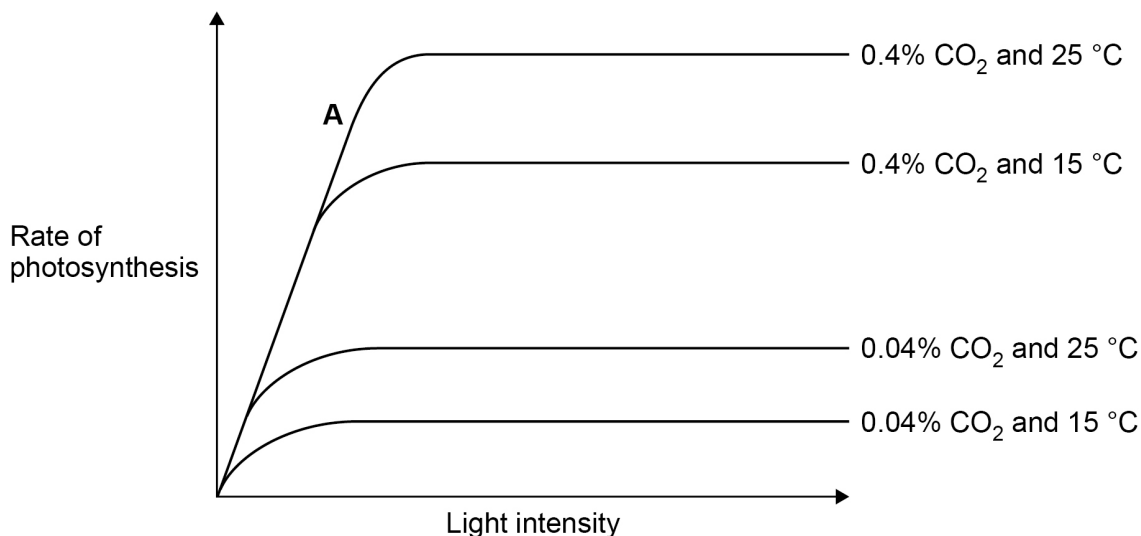
A **limiting factor** prevents the rate increasing under the current conditions; increasing that factor can increase rate. For temperature, this means an increase towards an appropriate optimum, not unlimited heating. (HT) Interacting factors require comparing curves at the same light intensity with just one other condition changed.

Figure 8





2023 Q06.2: the straight section from 0 to 5 000 lux can be represented by $y = mx + c$. The x-axis is in **thousands of lux**: a reading of 5 means 5 000 lux. A changing gradient is not one straight-line relationship; the plateau shows further light does not raise the rate under these conditions.



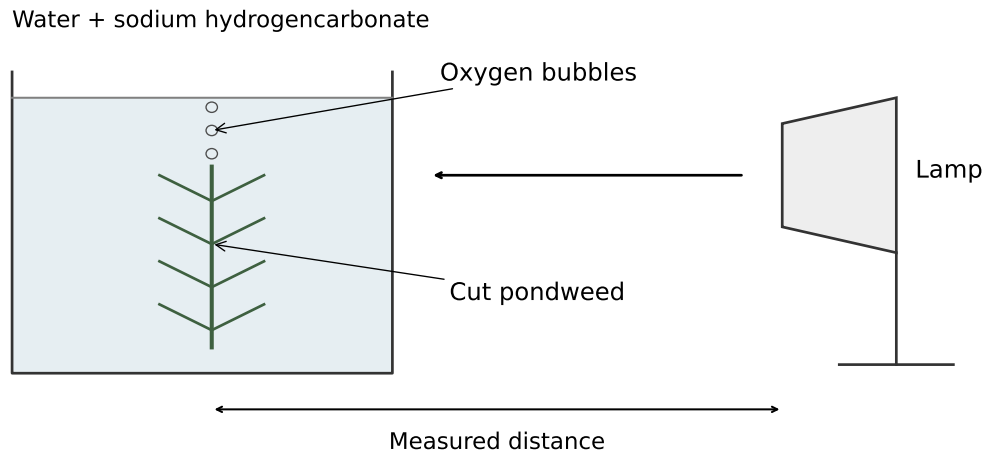
(HT) 2024 Q07.7–.8: at A, more light increases rate. Compare 15→25°C while CO₂ stays 0.4%: higher rate, through faster particle movement/enzyme activity. Compare 0.04→0.4% CO₂ at the same temperature: more reactant increases rate. On each high-light plateau, a different factor limits; light is not the limiting factor there. These comparisons do not justify an unlimited-temperature rule.

(HT) Inverse square law: light intensity is proportional to $1/\text{distance}^2$. For the same source, $I_2/I_1 = (d_1/d_2)^2$. Sheet 4.1 Q3.2: $d_2/d_1 = 45 \text{ cm}/15 \text{ cm} = 3$; $I_2/I_1 = (15 \text{ cm}/45 \text{ cm})^2 = 1/9$. The new intensity is one ninth of the old. A photosynthesis-rate prediction additionally needs light to limit in an approximately proportional region and other conditions to stay suitable; the law itself predicts intensity.

(HT) Greenhouse economics: identify the limiting factor, estimate the

yield/revenue gain, and compare it with the added cost. Lighting supplies energy; added CO₂ supplies reactant; heating towards the optimum can speed enzyme-controlled reactions. Each may fail to pay if another factor limits or the cost exceeds extra crop revenue. Heating alone is not automatically CO₂ addition.

RP6: changing light intensity



Use pondweed in sodium hydrogencarbonate solution (CO₂ supply). Set several measured lamp distances, allow adjustment at each, then count oxygen bubbles in a fixed time. Maintain temperature with a water bath and monitor with a thermometer; keep CO₂ concentration constant; keep pondweed size and timing comparable. Repeat at each distance and calculate a mean. Rate = bubble count/time, with units such as bubbles/s. Alternatively measure collected oxygen volume/time. A gas syringe or **inverted** measuring cylinder must actually collect/measure oxygen; naming apparatus alone is not a method. Unequal bubble size limits volume accuracy, and gas collection measures volume more directly. Repeats reduce random variation; they do not fix unequal bubble volumes.

2025 temperature investigation: the independent variable is temperature; the measured dependent variable is **time for ten bubbles**, not the calculated rate. Five tubes were placed in different-temperature baths and left two minutes before timing. All times below are exact original Table 4 values.

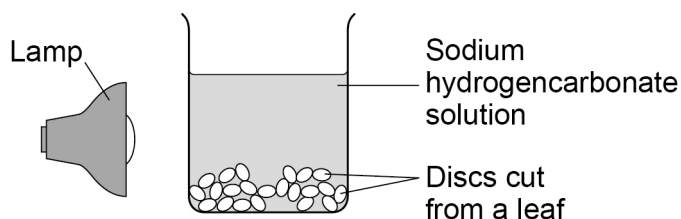
Temperature / °C	Time for 10 bubbles / s
10	84
20	43
30	27
40	25
50	33

Worked rate (2025 Q04.2, four marks): rate = bubble count/time; rate = 10 bubbles/43 s = 0.232558... bubbles/s; rate = **0.233 bubbles/s** (3 significant figures).

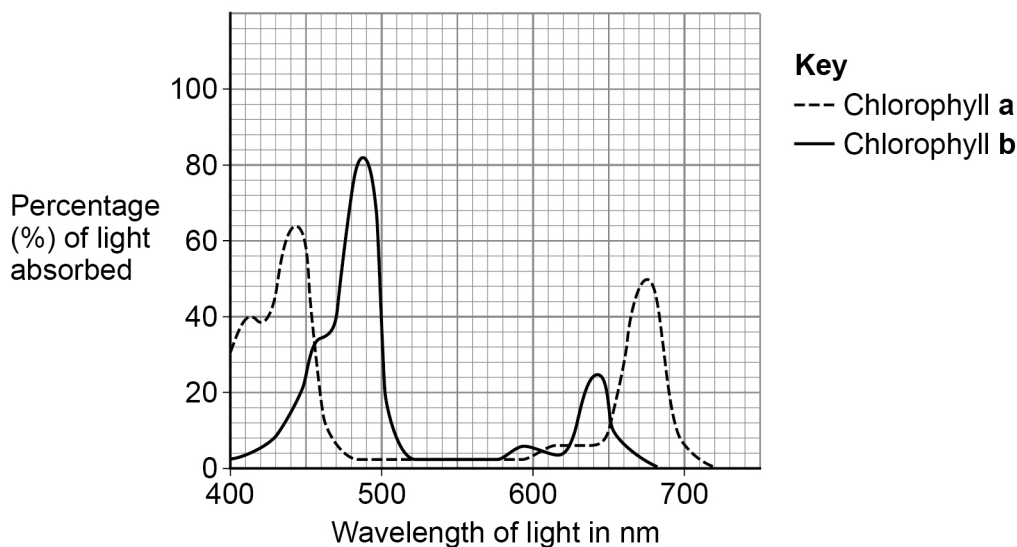
A smaller time for the same output means a higher rate. At 40°C versus 10°C, the rate is higher; particles have more kinetic energy and collide more frequently. The lower measured rate at 50°C does not change that comparison or prove an exact universal optimum.

Leaf-disc application (2023 Q06.3–.7)

Figure 9



Change light colour using coloured LEDs/bulbs or transparent filters. Independent variable: light colour/wavelength. Dependent variable: time for ten discs to reach the surface. Remove initial air so discs sink and rising gas comes from photosynthesis. Sodium hydrogencarbonate supplies CO_2 used in photosynthesis. Oxygen produced becomes trapped in/around the discs, reducing their average density so they rise. Do not claim CO_2 is the gas making them rise.



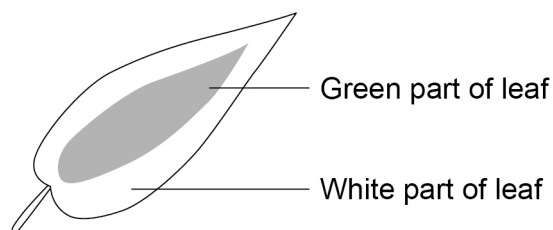
2023 Q06.8–.9: two chlorophyll types allow more wavelengths to be used, not all wavelengths. Original Table 6 ranges: violet 380–435, blue 450–499, green 500–570, yellow 571–590, red 620–720 nm. Table 5 times for ten discs: blue 115 s, green 831 s, red 397 s. Near 490 nm (blue), chlorophyll b absorbs about 80%; green wavelengths are absorbed very little. Thus blue discs rise sooner because photosynthesis/oxygen production is faster; green discs take longer. Use spectral absorption data and colour ranges, not times alone, in the four-mark explanation.

Uses of glucose (4.4.1.3)

Glucose from photosynthesis is used for:

- **respiration**;
- converted to **insoluble starch** for storage (it does not dissolve to form a concentrated cell solution);
- **fat or oil** for storage;
- **cellulose** for cell walls;
- **amino acids** for protein – this also needs **nitrate ions from the soil**.

Figure 6

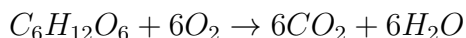


Worked evidence (2024 Q07.2–.3): after the supplied 48-hour light treatment, predict starch in the green region and no starch in the white region. Green tissue has chlorophyll and absorbs light for photosynthesis; glucose made there can form starch. White tissue lacks chlorophyll. A positive iodine test is blue-black; a negative result remains yellow/orange/brown. This is a prediction for the supplied investigation, not a guarantee that every green leaf always contains starch.

Respiration (4.4.2.1)

Respiration is an **exothermic** reaction occurring **continuously in living cells**, transferring energy for movement, keeping warm and reactions that build larger molecules. Plants respire in light and darkness. Breathing moves air; cellular respiration is a chemical process. Energy is transferred or released, not created.

Aerobic word equation: glucose + oxygen → carbon dioxide + water.



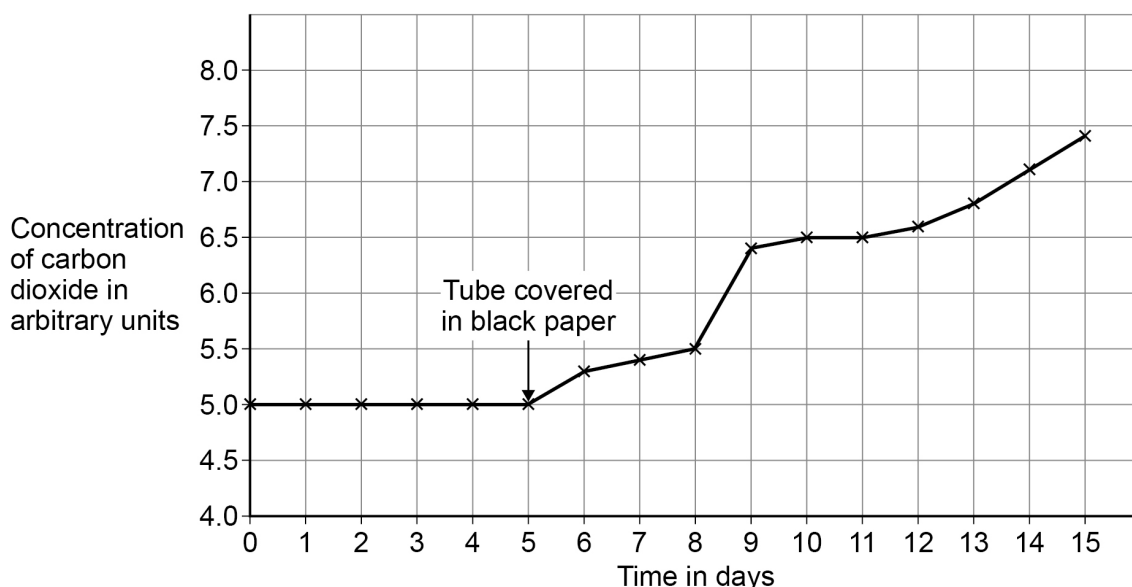
Both sides have 6 carbon, 12 hydrogen and 18 oxygen atoms. In human cells, mitochondria are the main site of aerobic respiration; its stages occur in the cytoplasm and mitochondria. Anaerobic respiration occurs in the cytoplasm.

Pathway	Products from glucose	Energy per glucose
Aerobic, using oxygen	Carbon dioxide + water	Much more transferred
Anaerobic, human muscle	Lactic acid	Much less transferred
Anaerobic, plant / yeast	Ethanol + carbon dioxide	Much less transferred

Anaerobic word equations: **muscle:** glucose $\rightarrow$ lactic acid; **plant/yeast:** glucose $\rightarrow$ ethanol + carbon dioxide. Anaerobic respiration incompletely oxidises glucose, so transfers less energy per glucose molecule; it still transfers energy.

Anaerobic respiration in yeast is **fermentation**. With little oxygen in dough, yeast uses sugar and releases ethanol and carbon dioxide; trapped gas bubbles make the dough rise. Ethanol is also important in alcoholic drinks. Yeast can respire aerobically when oxygen is available; excessive heat does not keep improving fermentation.

Worked evidence: two processes at once (2021 Q04.6–.8). A tube contains pondweed and a snail, with a carbon dioxide probe. It is well lit until day 5, then completely covered with black paper. The snail dies on day 10. The local file is catalogued November 2021; the original paper is printed Jun21.

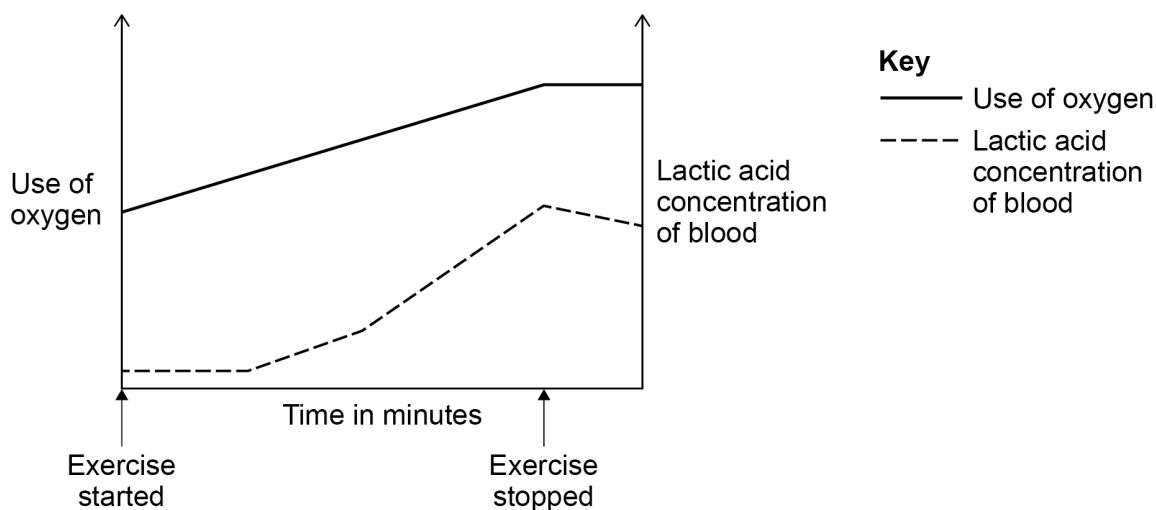


- **Days 0–5:** pondweed takes in carbon dioxide for photosynthesis; both pondweed and snail respire, releasing it. Uptake balances release, so concentration stays constant. A flat line does not mean both processes stopped.
- **Days 5–10:** darkness prevents photosynthesis, while both organisms continue respiring. Carbon dioxide accumulates.
- **After day 10:** decomposers such as bacteria break down the dead snail. These living microorganisms respire and release carbon dioxide; the dead snail is not continuing to respire.

Response to exercise (4.4.2.2)

Heart rate, breathing rate and breath volume **increase** during exercise to supply muscles with more oxygenated blood for aerobic respiration. Breathing rate counts breaths per minute; breath volume is air moved per breath. If oxygen supply cannot meet demand, **anaerobic respiration contributes alongside aerobic respiration**, and **lactic acid** accumulates. In the AQA GCSE model, this causes muscle fatigue and less efficient contractions.

(HT) Blood transports lactic acid to the **liver**, which converts it back into glucose. Separately, **oxygen debt** is the extra oxygen needed after exercise to react with and remove accumulated lactic acid. Do not describe extra oxygen as a reactant in the conversion back to glucose in the liver: the 2025 Q05.7 scheme ignores that claim.



Worked recovery explanation [2]: lactic acid has accumulated / an oxygen debt exists (1); extra oxygen is needed to react with and remove it (1). The solid and dashed lines use different, unnumbered vertical axes: compare changes within each curve, not their absolute heights against each other.

Explaining two effects [4] (2023 Q04.1): pair each effect with a reason. Muscles become fatigued (1) because lactic acid builds up (1). Heavy/deep breathing continues after exercise (1) because extra oxygen is needed to remove accumulated lactic acid / repay oxygen debt (1).

Worked investigation plan (2023 Q04.2 [6]): use the same suitable athletes for at least two exercise types. Before each trial, allow recovery to resting heart rate and measure that baseline. Exercise for the same duration; measure heart rate promptly afterwards with the same method and delay. Keep relevant conditions such as prior activity and caffeine intake similar. Calculate each athlete's increase, then compare mean increases for each exercise type. Randomise exercise order to reduce order effects. A logical method giving a valid comparison earns the higher levels; six disconnected facts do not guarantee six marks.

Teacher data, beats per minute: exercise A changes are 40, 50 and 30; B changes are 60, 70 and 50. $\text{Change} = \text{after-exercise heart rate} - \text{resting heart rate}$. $\text{Mean change} = \text{sum of changes} \div \text{number of athletes}$. Mean change for A = $(40 + 50 + 30) \div 3 = \mathbf{40 \text{ beats per minute}}$. Mean change for B = $(60 + 70 + 50) \div 3 = \mathbf{60 \text{ beats per minute}}$. B gives a mean increase **20 beats per minute** greater in this sample. These are authored examples, not original exam results.

Connect to circulation (2025 Q05.8 [2]): more red blood cells provide more haemoglobin to carry oxygen (1); this supports more aerobic respiration and energy transfer in muscles (1). **Supplied exam application (2023 Q04.3 [2]):** increased muscle mass can allow more/stronger contractions (1), improving speed, strength or stamina (1). The original question states anabolic steroids are banned in competitive sport; the task is to explain its supplied relationship.

Metabolism (4.4.2.3)

Metabolism is the sum of all reactions in a cell or body. Energy transferred by respiration supports continual enzyme-controlled processes that build new molecules. Recognise building and breakdown reactions:

- glucose $\rightarrow$ **starch, glycogen or cellulose**;
- **one glycerol + three fatty acids** $\rightarrow$ a lipid molecule;
- in plants, glucose + **nitrate ions** $\rightarrow$ amino acids $\rightarrow$ **proteins**;
- **respiration**, which breaks down glucose and transfers energy;
- breakdown of **excess proteins** to form **urea** for excretion.

Urea is not a protein building block. Protein synthesis and formation of urea are not a direct reversible pair. Sugars, amino acids, fatty acids and glycerol supply different materials for synthesis and breakdown.

Checklist before you call this topic done

- Write the photosynthesis word and symbol equations; say endothermic + light $\rightarrow$ chloroplasts.
- Explain the four rate factors; read flattening single-factor graphs; (HT) inverse square law and greenhouse economics.
- Describe RP6 with its controls and the rate calculation.
- List five uses of glucose (with nitrate for protein).
- Compare aerobic with both anaerobic equations; name fermentation's two products and uses.
- Exercise: three increases; lactic acid and oxygen debt; (HT) the liver's role.
- Define metabolism with its five strands.

5 · Homeostasis and response

AQA · GCSE · Biology

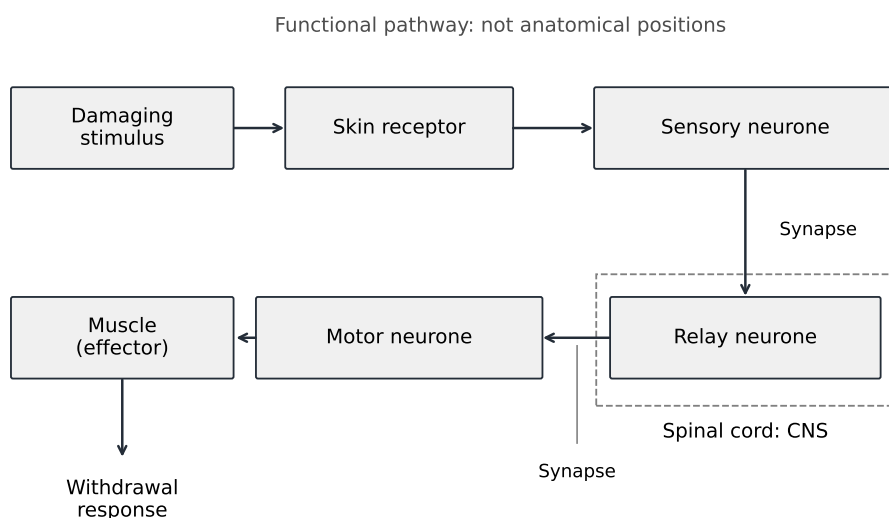
Homeostasis and response: keeping conditions steady

- **Homeostasis** is the regulation of the internal conditions of a cell or organism, to maintain **optimum conditions for enzyme action** and all cell functions, in response to internal and external changes.
- The body controls **blood glucose concentration**, **body temperature** and **water levels**.
- Every automatic control system has: **receptors** (detect stimuli), **coordination centres** (brain, spinal cord, pancreas – receive and process information) and **effectors** (muscles or glands – bring about the response that restores optimum levels).
- Nervous responses are generally rapid and short-lived; hormonal effects are usually slower and longer-lasting. Compare the signalling route as well: impulses along neurones versus hormones carried in blood.

Homeostasis and the nervous system (4.5.1–4.5.2.1, RP7)

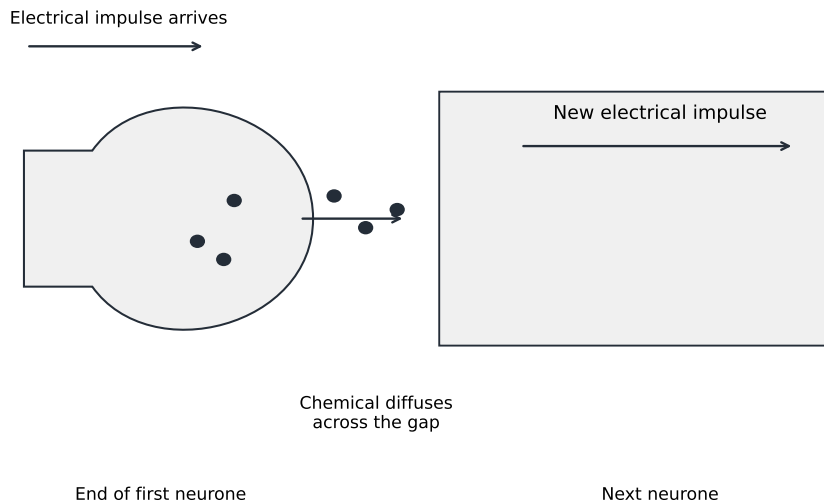
The pathway: stimulus → receptor → coordinator (CNS: brain + spinal cord) → effector (muscle contracts / gland secretes) → response.

Information passes along cells called **neurones** as **electrical impulses**. The CNS coordinates the response of effectors.

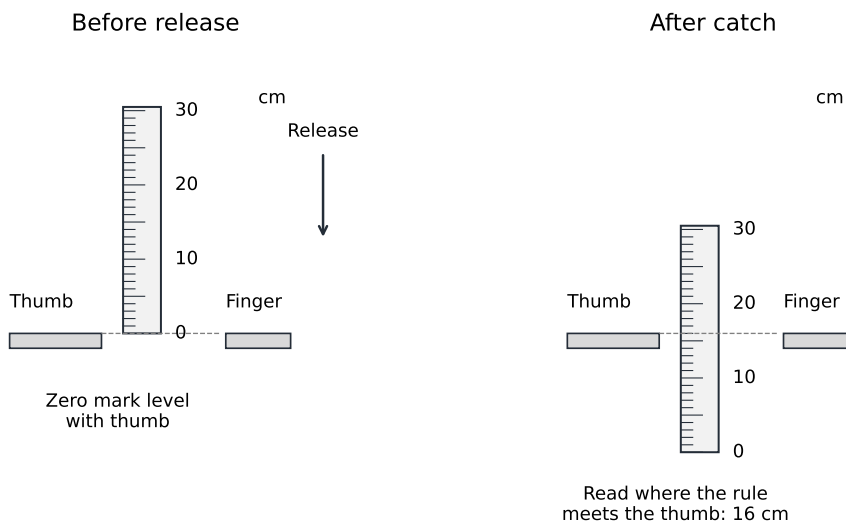


The reflex arc – automatic and rapid protection that does **not** involve the conscious part of the brain:

stimulus → receptor → **sensory neurone** → **synapse** → **relay neurone** (in CNS)
 → synapse → **motor neurone** → effector → response.



At a **synapse** the electrical impulse arrives at the end of a neurone and a chemical is released; it diffuses across the gap and triggers an electrical impulse in the next neurone.



RP7 – reaction time: Use listening to music versus silence as a factor. Support the same person's arm; hold the ruler vertically with its zero mark level with the top of the thumb and the same gap between finger and thumb. Release after a variable delay

without a countdown, and record catch distance. Repeat trials, keep the same hand, ruler and starting position, and keep the music condition fixed. Give practice trials first and vary/counterbalance condition order to reduce learning and order effects; these controls do not eliminate them. Convert readings using the supplied table or equation, then process the results as the task directs. For paired conditions, compare mean reaction times and state the limits of the conclusion.

■ Distinguish a withdrawal reflex from a visual reaction

For a withdrawal reflex, a receptor detects a damaging stimulus → a sensory neurone carries impulses to a relay neurone in the spinal cord → a motor neurone carries impulses to a muscle → contraction withdraws the limb. The rapid response does not wait for conscious decision; information can still reach the brain and become conscious afterwards. Do not claim that all reflexes exclude the brain: the pupil reflex is coordinated in the brain without conscious decision.

For catching a falling ruler, the stimulus is **movement detected by receptors in the retina**. Impulses travel along the optic nerve to the **brain**, pass through synapses and motor neurones, and reach the hand muscles, which contract. This is the pathway required by AQA June 2025 8461/2H Q07.4; a generic spinal reflex answer misses its context.

■ Worked reaction-time data

AQA June 2025 8461/2H Q07.1–07.2 gives catch distances of **18, 15, 12, 16, 14, 23, 14 cm**. In order these are **12, 14, 14, 15, 16, 18, 23 cm**: the fourth value is the **median**, 15 cm. The mean distance is $\bar{d} = 112/7 = 16$ cm.

The question supplies the following equation, with the numerical value of d in **cm** and t in **seconds**; use its given mean distance.

$$t = \sqrt{\frac{2d}{980}}$$

$$t = \sqrt{\frac{2d}{980}} = \sqrt{\frac{2 \times 16}{980}} = 0.18070 \dots \text{ s}$$

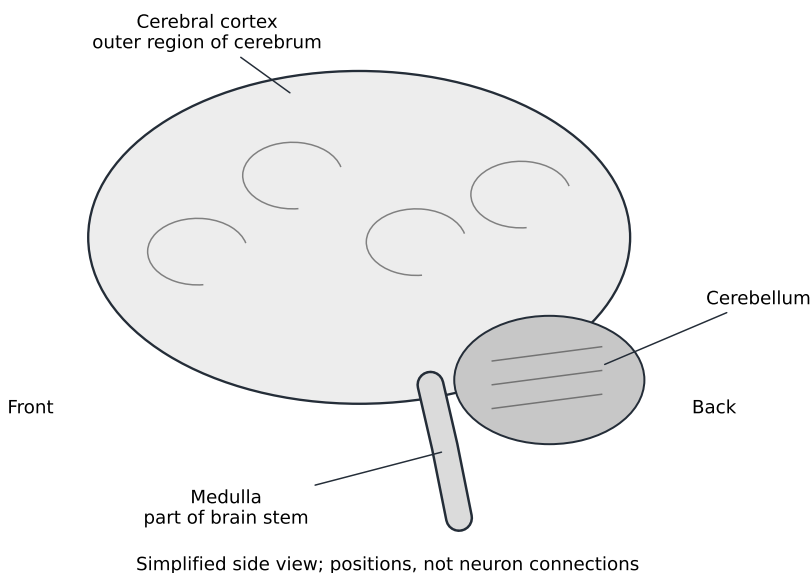
$$t_{\text{ms}} = 1000t = 1000 \times 0.18070 \dots = 180.70 \dots \text{ ms}$$

The final answer is **181 ms**, to 3 significant figures. Do not round to 0.18 s before converting. The official question defines its mean-time estimate through mean distance; this is not a general rule that converting an average always equals averaging converted readings. Do not discard the 23 cm result just because it is largest.

The brain, the eye and temperature – biology only (4.5.2.2–4.5.2.4)

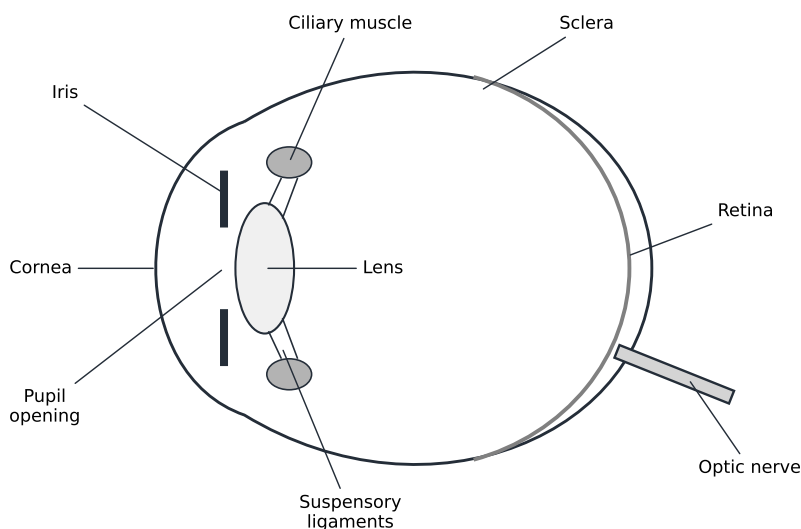
■ The brain

The brain contains billions of interconnected neurones. Identify the **cerebral cortex** (consciousness, memory and language), **cerebellum** (balance and coordination) and **medulla** (automatic heartbeat and breathing). These structures and functions are common-tier Biology knowledge.



Investigating the brain (HT). Damage associated with loss of a function helps map that function, but an injury may affect several connected areas. Electrical stimulation can reveal a response when a region is activated. MRI gives images that help locate structures or damage; an image alone does not prove that a region causes a particular behaviour. Brain tissue is complex, delicate and easily damaged. Evaluate a proposed procedure using its expected benefit, evidence, possible permanent harm and alternatives; do not conclude that all procedures are too risky.

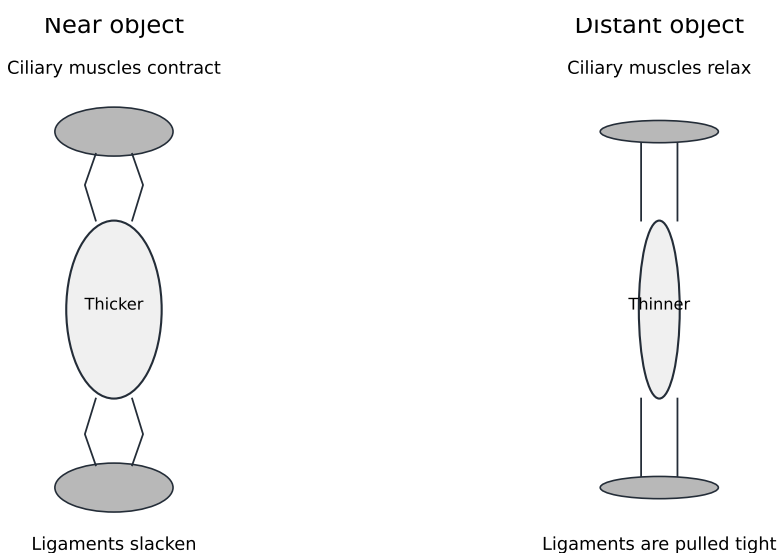
■ The eye



Retina : light-sensitive receptor cells detect intensity and colour. The **optic nerve** carries impulses to the brain. The **sclera** protects the eye; the transparent **cornea** refracts incoming light. The **pupil** is an opening, not a muscle or a black solid structure.

Iris and light level. In bright light, circular iris muscles contract and radial muscles relax; the pupil becomes smaller and less light reaches the retina. In dim light, radial muscles contract and circular muscles relax; the pupil widens and admits more light. This reflex is coordinated in the brain without conscious decision. The iris controls light entry; ciliary muscles change focus.

Accommodation changes lens shape so the image focuses on the retina.



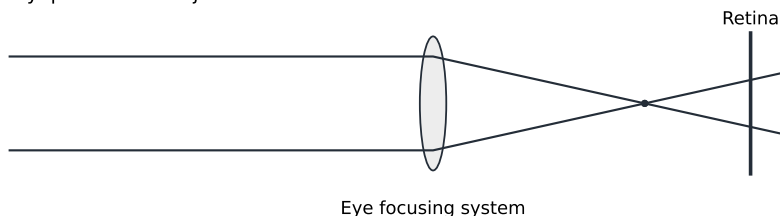
Mechanism model: ligament tension changes lens shape; not pupil size

Object	Ciliary muscles	Ligaments	Lens
Near	contract	slacken	thicker
Distant	relax	pulled tight	thinner

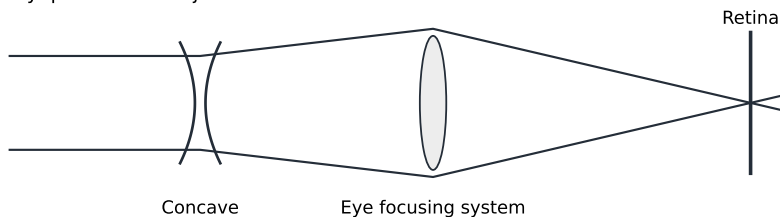
A thicker lens refracts rays more strongly; a thinner lens refracts them less strongly. A thin lens still refracts light. Ligaments transmit tension: they do not actively contract.

Myopia : rays from distant objects focus in front of the retina, for example if the eyeball is too long or focusing is too strong. A **concave** lens diverges incoming rays so the eye focuses them on the retina.

Myopia: distant object — uncorrected



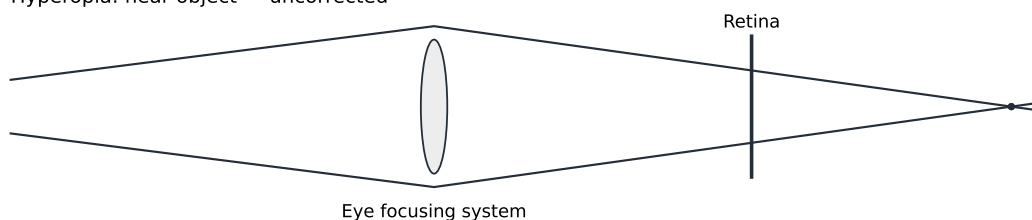
Myopia: distant object — corrected



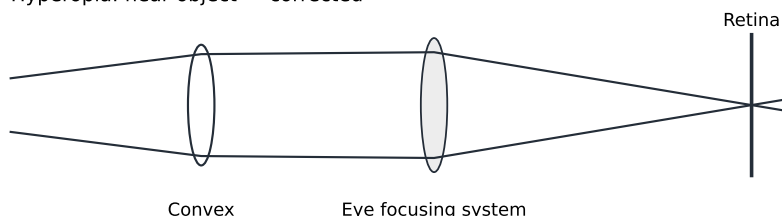
Simplified optical model: cornea and eye lens act together; distances not to scale

Hyperopia : rays from near objects would focus behind the retina, for example if the eyeball is too short or focusing is insufficient. A **convex** lens provides extra convergence so the image focuses on the retina. The ray models combine the cornea and eye lens; they are not anatomical sections.

Hyperopia: near object — uncorrected



Hyperopia: near object — corrected



Simplified optical model: cornea and eye lens act together; distances not to scale

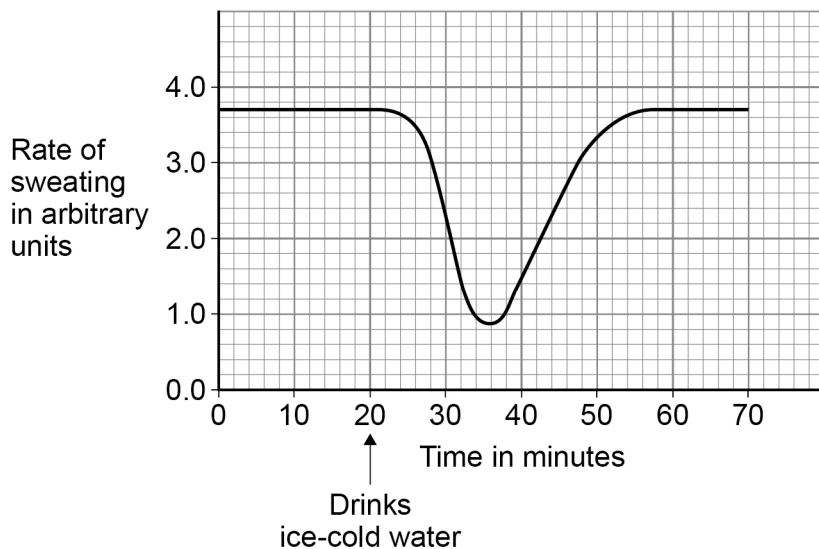
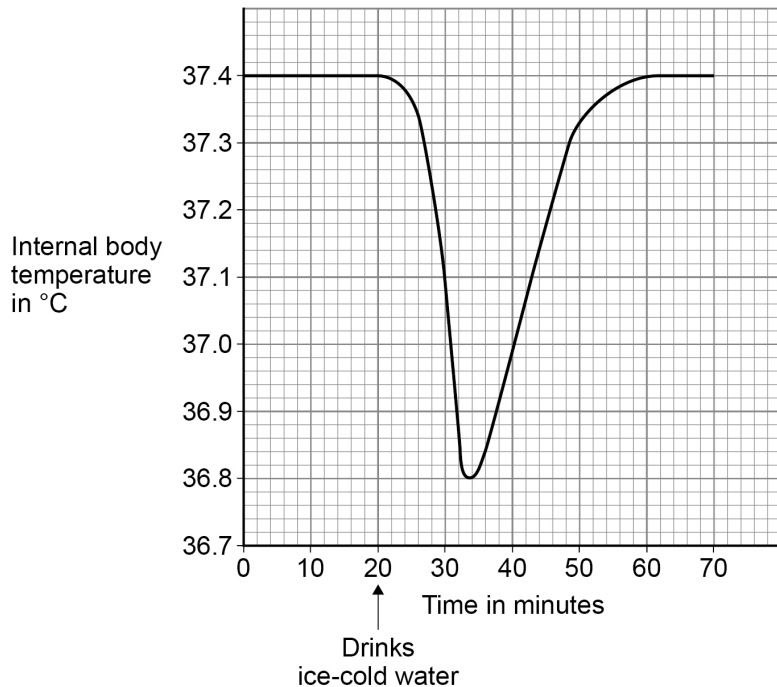
Treatment choices. Spectacles or contact lenses change the rays before they enter the eye. Laser surgery changes the cornea's shape; a replacement lens changes focusing inside the eye. Suitability depends on the defect and the individual. Use supplied evidence to compare benefits, risks, care requirements and reversibility; no treatment is best for everyone.

■ Control of body temperature

The **thermoregulatory centre** in the brain monitors blood temperature. Skin temperature receptors send nervous impulses to it. It coordinates responses by muscles and sweat glands.

Condition	Response	Effect (HT explanation)
Too hot	skin arterioles dilate	more blood near surface
Too hot	more sweat	evaporation transfers energy away
Too cold	skin arterioles constrict	less blood near surface
Too cold	less sweating	less evaporative cooling
Too cold	shivering	more energy from respiration

Vasodilation and **vasoconstriction** change blood flow through skin capillaries; capillaries themselves do not actively widen and narrow. When the surroundings are cooler than the skin, more surface blood flow increases energy transfer to the surroundings; reduced flow reduces this transfer. Sweating cools when **sweat** evaporates, not merely when it is secreted. Shivering is involuntary skeletal-muscle contraction; increased respiration transfers energy that warms the body. These responses oppose the initial change: negative feedback.

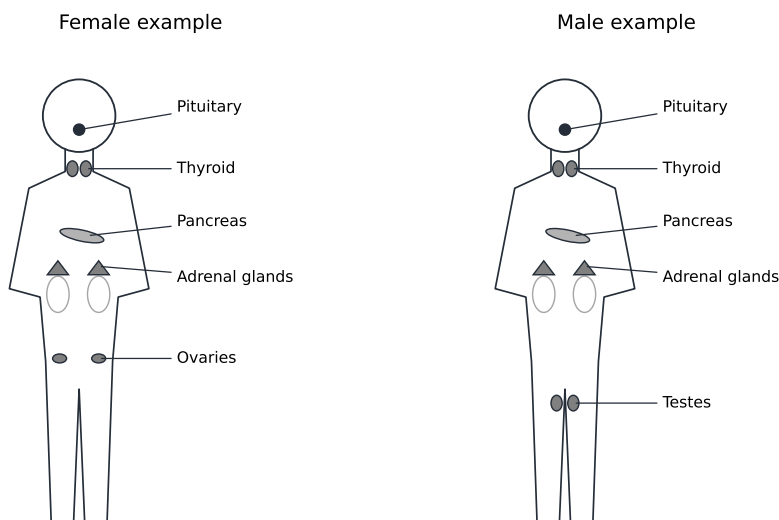


Worked evidence (HT). AQA 8461/2H 2021 Q03 uses a person drinking ice-cold water after 20 minutes. Its graph gives this person's initial temperature as **37.4 °C**: read the graph rather than automatically writing 37 °C. Cooled blood travels from the mouth/stomach to the brain. Nervous impulses coordinate a reduction in sweating. Less sweat evaporates, so less energy is transferred away; this helps restore temperature. The 24–36 minute interval shows **less sweating**, not no sweating. Holding the person still controls extra energy release from movement. This explains supplied evidence; it is not a classroom instruction to administer ice-cold water.

Hormonal coordination in humans (4.5.3)

■ Glands, hormones and target organs

The **endocrine system** contains glands that release **hormones** directly into the blood. Blood transports them to **target organs**, where they produce an effect. Compared with nervous signalling, hormonal responses are usually slower and last longer. This is a general comparison, not a claim that every hormone acts slowly.



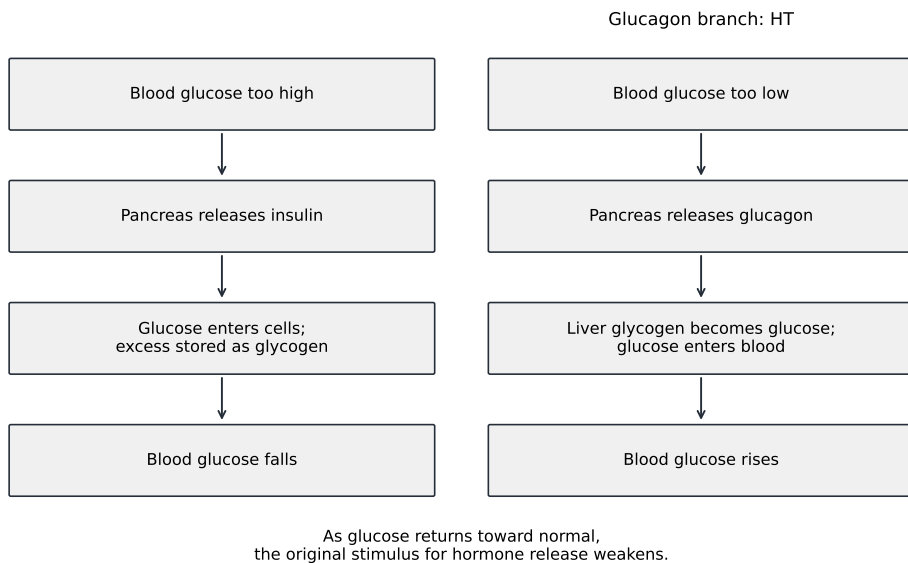
Schematic positions; the two gonad arrangements are alternatives

Identify the **pituitary gland** at the base of the brain, **thyroid** in the neck, **adrenal glands** above the kidneys, **pancreas** in the upper abdomen, **ovaries** in the female pelvis and **testes** in the scrotum. The pituitary releases several hormones that influence other glands; this is why it is called a 'master gland'. It does not directly control every endocrine response: the pancreas itself monitors blood glucose.

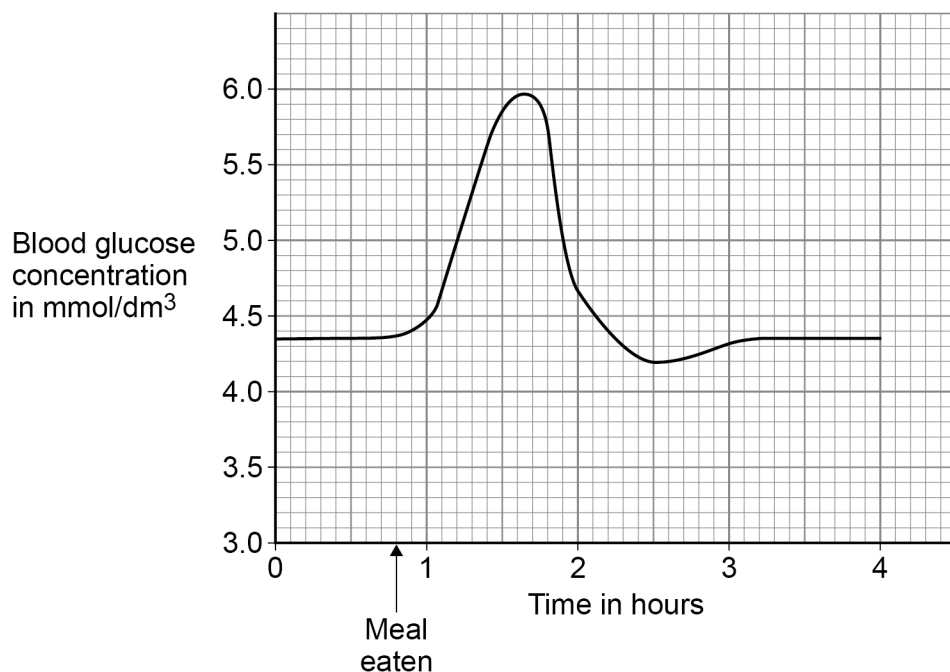
■ Blood glucose and negative feedback

The pancreas monitors blood glucose. When it rises too high, the pancreas releases **insulin**. Glucose moves from the blood into cells, where it can be used in respiration. Excess glucose is converted to **glycogen** for storage in the liver and muscles; blood glucose falls.

(HT) When blood glucose is too low, the pancreas releases **glucagon**. In the **liver**, stored glycogen is converted to glucose and released into the blood; blood glucose rises. Insulin and glucagon oppose changes away from the normal range. As the original stimulus decreases, the drive to release the responding hormone decreases. This is **negative feedback**; it does not mean both hormones are permanently switched off or glucose stays at an exactly constant value.



Worked graph reading. AQA June 2022 8461/2H Q03.1 asks when insulin would be high. Read the time axis and the high-glucose part of the curve. **1.5 hours** is a valid answer; the official accepted range is 1.1–2.0 hours. This is a glucose graph, not a measured insulin graph: insulin release is inferred from the control mechanism. For Q03.2, explain that insulin lowers blood glucose by glucose uptake/use or conversion to glycogen in cells, liver or muscles.

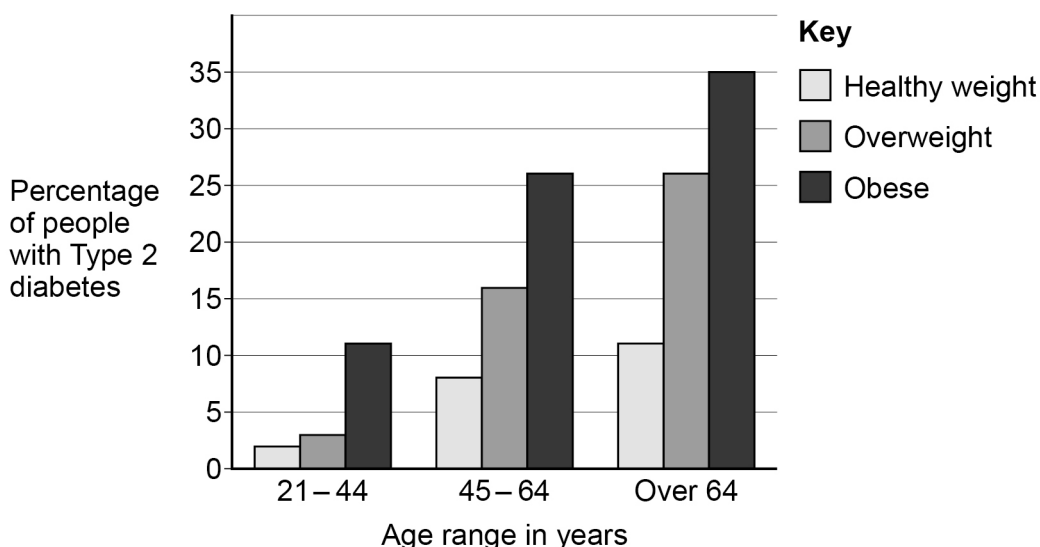


■ Diabetes: compare the mechanisms and the evidence

Type 1 diabetes: the pancreas does not produce sufficient insulin; blood glucose can remain too high. Insulin injections are a usual treatment. **Type 2 diabetes:** body cells have a reduced response to insulin; insulin may still be present at high levels. A carbohydrate-controlled diet and exercise are common treatments; medicines are also used, as the 2025 paper illustrates. Obesity is a risk factor, not a guarantee that an individual has Type 2 diabetes.

Worked comparison, AQA 2022 Q03.5. Person C has blood glucose **9.56 mmol/dm³**, compared with **4.51 mmol/dm³** for the mean without diabetes. Insulin is **24.32 arbitrary units**, compared with **14.83**. Both are higher: state the comparison, not just two isolated values. High insulin alongside high glucose is consistent with reduced cellular response. These supplied results support “might have Type 2 diabetes”; they do not establish a diagnosis by themselves. The scheme rejects higher cholesterol as one of the two requested indicators.

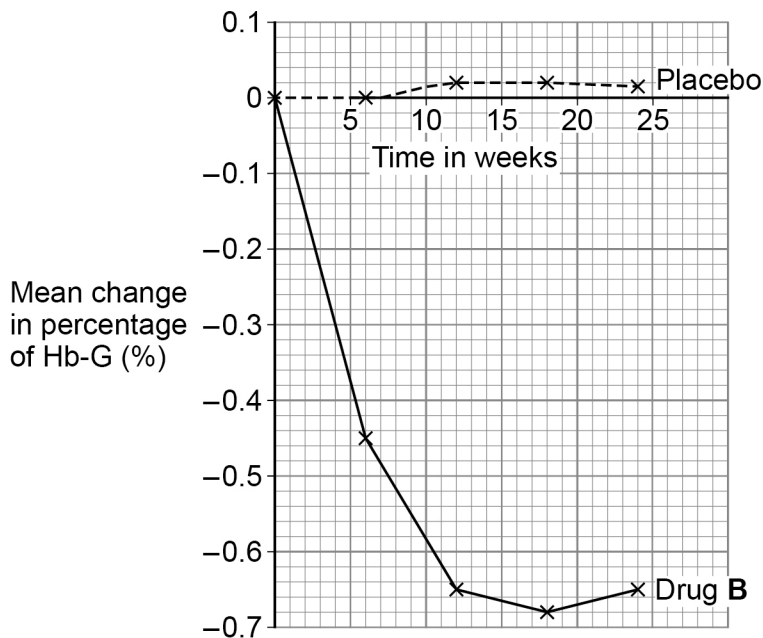
Population evidence, AQA 2025 Q09.1. Compare age groups within the same weight category, and weight categories within the same age group. The percentage with Type 2 diabetes increases with age and with heavier weight category in these results. A group-level association does not show that every person will develop the condition or prove a single cause.



Reading a treatment graph, AQA 2025 Q09.2–Q09.3. Hb-G is the percentage of haemoglobin with glucose attached; the question uses it as an indicator of longer-term blood-glucose control. Figure 11 plots the **change**, not the final Hb-G percentage. Drug B starts at 8.3%; at 12 weeks the change is -0.65 percentage points.

$$H_{12} = H_0 + \Delta H$$
$$H_{12} = 8.3\% + (-0.65\%) = 7.65\%$$

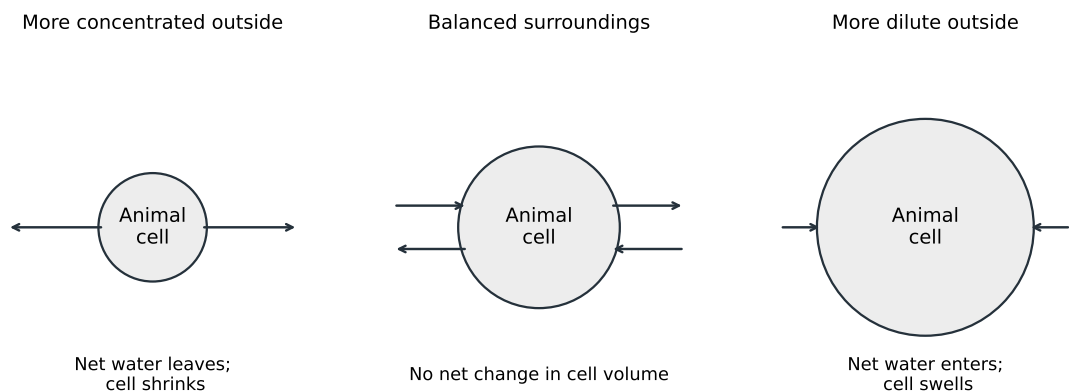
The result is not 0.65%, and the graph is not an instantaneous glucose concentration in mmol/dm^3 .



Evaluate the two trials. Drug A: 175 patients, daily injection, 12 weeks, Hb-G 9.2%→7.6%. Drug B: 631 patients, daily tablet, 24 weeks; 630 placebo patients; readings every 6 weeks; initial Hb-G 8.3%. Both treatments lower Hb-G, but neither reaches the question's acceptable value of **less than 7%**. Drug A has the larger observed decrease (1.6 percentage points versus 0.65 at 12 weeks), but unequal starting levels, sample sizes, durations and methods prevent a secure "A is the better drug" conclusion. The placebo and repeated measurements strengthen interpretation of trial B. Side effects and doses are not supplied. Do not invent randomisation or double-blinding. Give a judgment linked to both the methods and the outcomes, as the six-mark scheme requires.

■ Water and nitrogen balance – biology only

Why water balance matters. Water moves by osmosis through cell membranes from a more dilute solution towards a more concentrated solution. In more concentrated body fluid, animal cells lose water and shrink; in more dilute fluid they gain water and swell. Too much change prevents efficient cell function. In balanced surroundings water still moves both ways, with no net change in cell volume. Compare the fluid outside the cell with the fluid inside it.

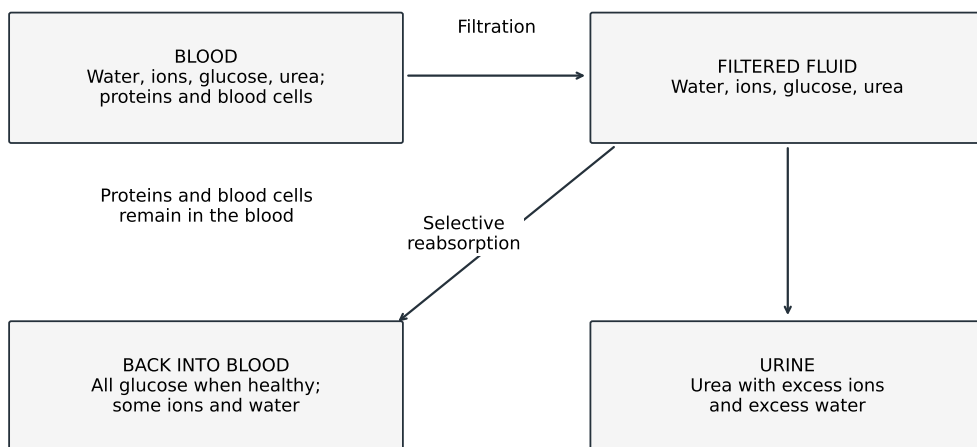


Arrows show net movement, except the balanced case: water moves both ways.

Different exit routes. Water leaves in exhaled air; sweat loses water, ions and some urea. Kidneys cannot recover material already lost through skin or lungs; they adjust urine to maintain balance. Sweating is still controlled for temperature regulation. Urine removes excess water and ions with urea. **Excretion** removes metabolic waste; it is not the same as passing undigested food out of the gut.

(HT) Where urea comes from. Digestion releases amino acids from proteins. Excess amino acids are deaminated in the **liver**: the amino group is removed, forming toxic ammonia, which is immediately converted to less toxic **urea**. Blood carries urea to the kidneys for excretion. Do not say that kidneys make urea or that all amino acids are waste: many are used to build proteins.

Filtration and selective reabsorption are different steps. Small substances leave the blood during filtration. Useful substances are then taken back into the blood by selective reabsorption. In healthy kidneys, all filtered glucose is reabsorbed; some ions and water are reabsorbed according to need. Large proteins and blood cells stay in the blood. Urea is filtered and mostly remains in the fluid that becomes urine. This is a functional account; kidney and nephron anatomy are not required here.



Functional process, not anatomy.

Worked explanation, AQA 2024 Q08.2 [4]. Glucose and urea are filtered out of the blood (1); protein is not filtered out (1); all glucose is reabsorbed into the blood in healthy kidneys (1); urea is mostly not reabsorbed and passes out in urine (1). “Glucose is useful” alone does not describe its journey. Filtration is not selective reabsorption, and filtered fluid is not yet the final urine.

(HT) ADH controls water reabsorption. When blood becomes too concentrated, the **pituitary releases ADH** into blood. ADH makes kidney tubules more permeable to water. More water returns to blood, leaving a smaller volume of more concentrated urine. As blood concentration returns towards normal, the original stimulus for ADH release weakens: negative feedback. With less ADH, tubules are less permeable, less water is reabsorbed, and a larger volume of more dilute urine is produced. ADH changes water movement; it does not add urea to urine.

Worked response, sheet 5.3 Q3.3 [4]. Dehydration makes blood more concentrated and receptors detect the change (1); the pituitary releases more ADH (1); tubules become more permeable and more water is reabsorbed into blood (1); less, more concentrated urine is produced (1). AQA 2024 Q08.3 instead starts with ADH: name permeability/reabsorption, the tubules, increased urine concentration and decreased urine volume. Match the starting point of the question.

Table 2

Concentration of ADH in the blood in nanograms/dm³	Concentration of dissolved substances in urine in arbitrary units	Rate of urine production in cm³/minute
0.0	50	20.0
1.25	700	8.8
2.50	980	3.9
3.75	1110	1.8
5.00	1170	0.9

Worked data explanation, AQA 2023 Q05.3 [4]. ADH falls from 3.75 to 1.25 nanograms/dm³. Tubules become less permeable to water (1), so less water is reabsorbed into blood (1). More water remains in urine, increasing production from 1.8 to 8.8 cm³/minute (1) and diluting dissolved substances from 1110 to 700 arbitrary units (1). Values support the answer; they do not replace the causal explanation. A production rate is volume per time, not a total collected volume.

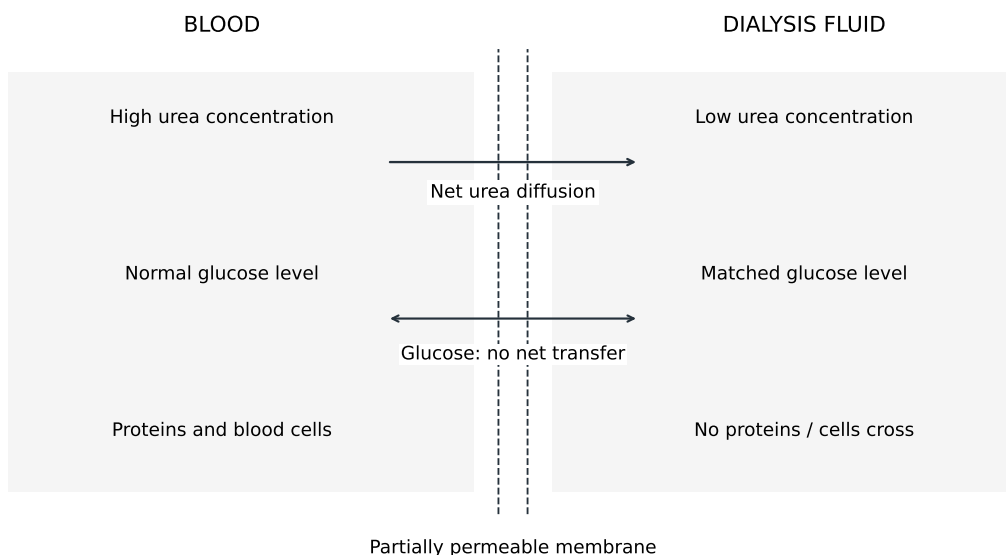
Teacher-written extension using those rates. If the rate remains 8.8 cm³/minute for 10 minutes, find the volume collected. Known: rate and duration; use volume = rate × time because rate is volume per minute.

$$V = rt$$

$$V = (8.8 \text{ cm}^3/\text{min}) \times (10 \text{ min}) = 88 \text{ cm}^3$$

The time assumption is supplied by this extension, not by the original paper. For the same 10 minutes at 1.8 cm³/minute, $V = rt = (1.8 \text{ cm}^3/\text{min}) \times (10 \text{ min}) = 18 \text{ cm}^3$.

Kidney failure: explain dialysis using a gradient. In **dialysis**, blood and dialysis fluid are separated by a partially permeable membrane. Urea can cross and diffuses from its higher concentration in blood towards the initially low concentration in the fluid. Replacing the fluid maintains that gradient. Dialysis fluid has a suitable glucose concentration matched to normal blood, so there is no net glucose loss when concentrations match. Proteins and blood cells are too large to cross. Glucose molecules can cross; no net loss is explained by concentration, not by an impermeable glucose barrier.



Evaluate dialysis and transplant. Dialysis can treat someone while a suitable donor is unavailable and avoids transplant surgery; repeated lengthy sessions restrict daily life and diet/fluid intake may need control. A successful **transplant** can give continuous kidney function and greater freedom, but requires a suitable donor and surgery. Rejection is a risk; immunosuppressant medicines reduce rejection risk but increase susceptibility to infection. Neither option is a guaranteed cure for every patient.

Teacher-written judgment. A patient has no suitable donor now and needs waste removal. Dialysis is a practical current treatment. If a suitable donor becomes available, transplant may reduce the burden of repeated sessions, but donor compatibility, surgery, rejection and infection risks must be weighed. State a decision linked to the supplied circumstances; a list of advantages alone is not an evaluation.

■ Hormones in human reproduction

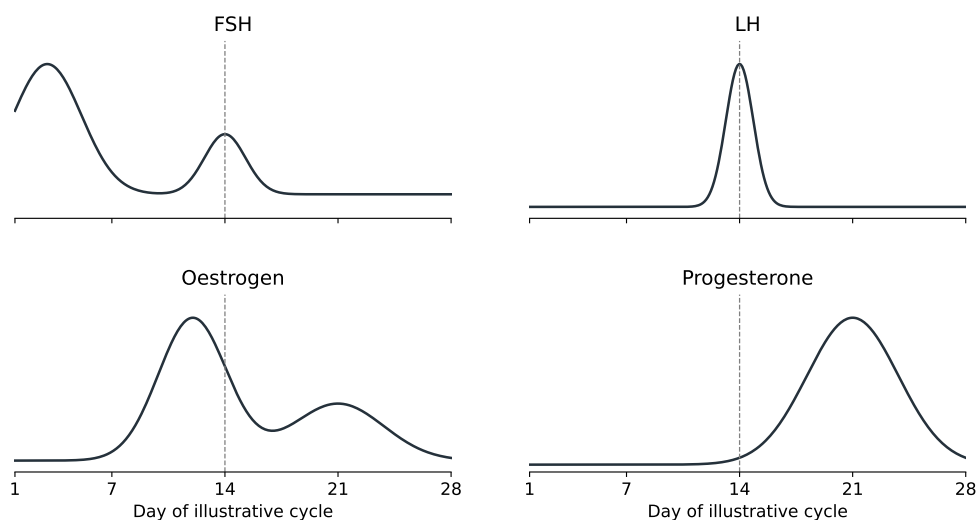
Puberty and reproductive hormones. **Oestrogen** is produced by the ovaries and helps female secondary sexual characteristics develop; **testosterone** is produced by the testes and stimulates sperm production. Eggs begin to mature at puberty. **Ovulation** is release of an egg from an ovary, not fertilisation by a sperm. A cycle of about 28 days is an illustrative pattern; timing varies.

The basic roles are common-tier. Explaining interactions and interpreting hormone graphs are HT.

Hormone	Source	Basic role
FSH	pituitary	causes an egg to mature in an ovarian follicle
LH	pituitary	stimulates ovulation
Oestrogen	ovary	helps build and maintain the uterus lining
Progesterone	ovary	maintains the uterus lining

(HT) Link the stages. FSH stimulates follicle development and oestrogen production. Oestrogen inhibits FSH; high oestrogen near ovulation promotes an LH surge. LH stimulates egg release. Progesterone then maintains the uterus lining and inhibits FSH and LH. If pregnancy does not occur, progesterone falls, the lining breaks down and a new cycle begins. Do not say that LH fertilises the egg or that menstruation is egg release.

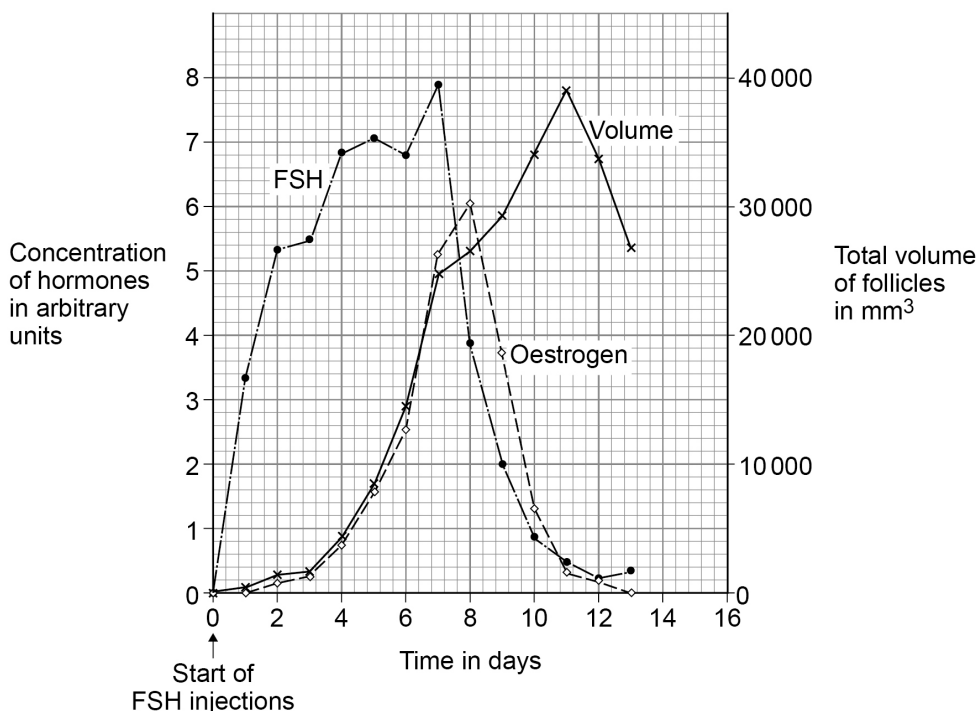
Schematic trends: each hormone has its own relative scale



Illustrative ovulation: day 14; cycle timing varies.

Read the schematic honestly. Use the order of events: oestrogen rises before the LH surge, then progesterone rises after ovulation. Each panel has its own relative scale; it does not compare absolute concentrations of different hormones. The curves are an author-drawn teaching model, not patient measurements or diagnostic cut-offs.

Actual treatment evidence, AQA 2023 Q07.1–Q07.3. A woman with no detectable FSH received daily FSH injections for seven days. Figure12 shows hormone concentration on the **left axis** in arbitrary units and total follicle volume on the **right axis** in mm³. Use the axis for the quantity being read. The original graph below retains its data, labels, units and injection-start marker.



Worked evidence, Q07.1 [1]. For roughly the first seven or eight days, increasing follicle volume is associated with increasing oestrogen concentration. This supports follicles releasing oestrogen. The relationship does not continue throughout the whole graph, and association alone does not prove that oestrogen causes follicle growth. The official scheme rejects that reversed causal claim.

Worked calculation, Q07.2 [5]. The mean follicle diameter on day11 is 22mm. Assume spherical follicles, using the supplied $\pi = 3.14$. First find radius, because the sphere formula uses radius rather than diameter:

$$r = \frac{d}{2}$$

$$r = \frac{22 \text{ mm}}{2} = 11 \text{ mm}$$

For one follicle:

$$V_{\text{one}} = \frac{4}{3}\pi r^3$$

$$V_{\text{one}} = \frac{4}{3} \times 3.14 \times (11 \text{ mm})^3 = 5572.45 \text{ mm}^3$$

Read the **total** follicle volume at day11 from the right axis: $V_{\text{total}} = 39000 \text{ mm}^3$. The number is total volume divided by the modelled volume of one follicle:

$$N = \frac{V_{\text{total}}}{V_{\text{one}}}$$

$$N = \frac{39000 \text{ mm}^3}{5572.45 \text{ mm}^3} = 6.9987 \dots \approx 7$$

Answer **7 follicles**, to the nearest whole number, not 7.0. Keep extra digits until the final division. The calculation uses the paper's common-size/sphere approximation, not a claim that all real follicles are identical.

Worked mechanism, Q07.3 [2]. Lack of FSH means little follicle development/oestrogen production (1); development of female secondary sexual characteristics depends on oestrogen (1). FSH acts through the ovary; do not replace that link with "FSH directly causes breast growth". The inheritance questions later in this paper belong to the genetics topic.

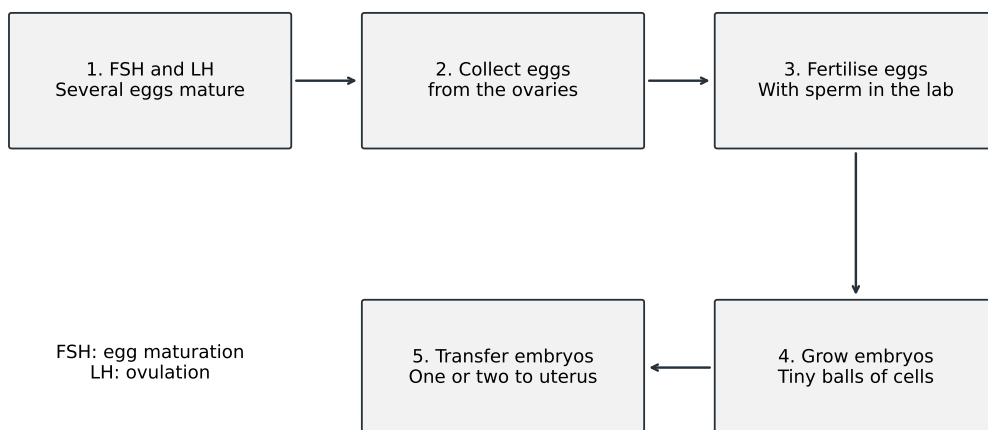
■ Controlling fertility: reduce or increase the chance of pregnancy

Hormonal contraception. In the GCSE model, contraceptive hormones inhibit FSH so an egg does not mature; inhibition of LH prevents ovulation. Without a released egg there is no egg for sperm to fertilise. Giving contraceptive hormones is therefore different from giving FSH/LH to stimulate fertility. Examples include oral pills and hormonal injections, implants and patches. The hormones and duration depend on the method: a combined patch releases oestrogen and progestogen (a progesterone-like hormone), so do not describe every method as progesterone-only or as lasting years.

Non-hormonal methods and devices. Condoms and diaphragms form barriers preventing sperm reaching an egg. Spermicides kill or disable sperm. Avoiding intercourse when an egg may be present depends on estimating timing; the illustrative day14 is not a guaranteed safe/unsafe timetable. Sterilisation surgically prevents sperm and egg meeting and is intended to be permanent. Intrauterine devices act within the uterus: copper IUDs primarily prevent fertilisation; hormonal intrauterine systems release progestogen. Do not assume every coil releases a hormone. **Implantation** is an embryo attaching to the uterus lining, a different event from fertilisation.

Evaluate using a supplied case. Compare effectiveness evidence, correct use, reversibility, hormone use, duration, practical access and the person's stated preferences. A teacher-written case asks for a reversible method without hormones and accepts use at each intercourse: a barrier method meets those conditions, whereas sterilisation conflicts with reversibility. Science can explain mechanisms and provide evidence, but personal, social and ethical values also affect a choice. No single method is automatically best for every case.

(HT) Fertility drugs and IVF. FSH stimulates eggs to mature; LH stimulates ovulation. Fertility drugs may allow pregnancy through intercourse, without laboratory fertilisation. **IVF** adds collection of eggs, fertilisation with sperm in a laboratory and embryo transfer. Hormone treatment alone is not the whole IVF process.



Fertilisation happens in the laboratory; embryos are transferred.

Worked, sheet5.3 Q3.4 [5]. Give FSH/LH to stimulate several eggs to mature (1); collect eggs and fertilise with sperm in the laboratory (1); let embryos develop into tiny balls of cells, then transfer one or two to the uterus (1). Concerns include emotional/physical stress (1), limited success and risk of multiple births to mother/babies (1). Do not transfer unfertilised eggs and call them embryos. Chance of success is not a promise of pregnancy.

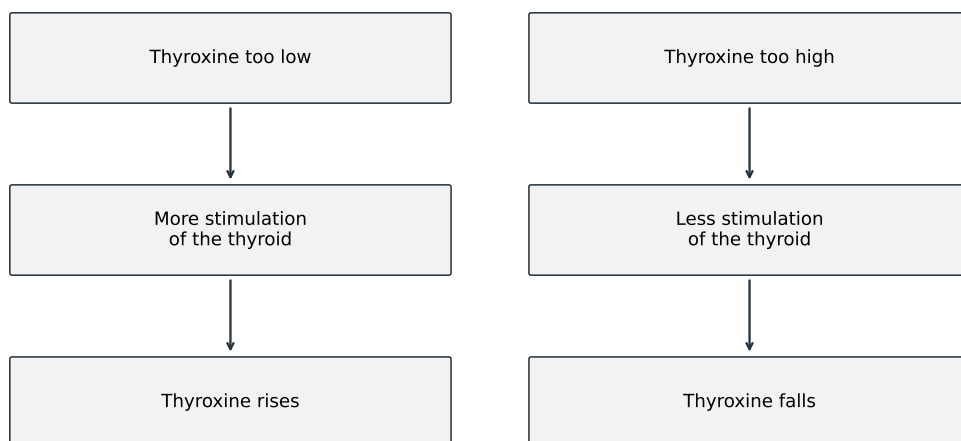
Capstone, AQA 2024 Q05.6 [6]. Explain **both** uses of hormones. For contraception, link contraceptive hormones → inhibited FSH/LH → reduced egg maturation/ovulation → no egg to fertilise. For infertility, link FSH → egg maturation and LH → ovulation, then explain collection, laboratory fertilisation and embryo transfer if using IVF. Progesterone may support the uterus lining. The top level requires detailed causal links and both contraception and infertility treatment; listing six hormone names does not earn six marks.

■ Adrenaline, thyroxine and negative feedback (HT)

Adrenaline is released by the adrenal glands in fear or stress. Heart rate rises, increasing delivery of oxygen and glucose to brain and muscles for respiration and action. AQA 2024 Q05.5 [2] accepts two distinct effects, for example increased heart rate and increased oxygen delivery. “Fight or flight” names the overall response but does not replace two specified effects. Hormones are carried in blood; adrenaline can act rapidly, so “hormones always act slowly” is not a rule.

Thyroxine from the thyroid increases the **basal metabolic rate**, and is important in growth and development. **Worked, AQA 2023 Q05.2 [2].** In the given cold-body context, increased thyroxine increases metabolic rate/respiration (1); respiration releases energy, including thermal energy (1), increasing body temperature. Energy is released, not created. This is distinct from the earlier nervous control of skin blood

flow, sweating and shivering.



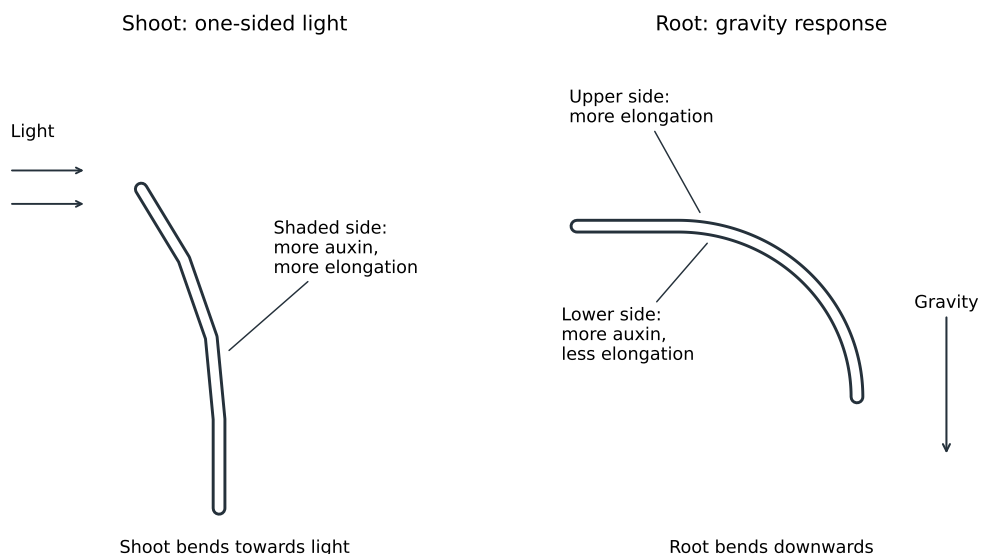
Responses oppose the change and move the level towards normal.

Read negative feedback in either direction. When thyroxine is below normal, increased stimulation of the thyroid helps raise it; when it is above normal, reduced stimulation helps lower it. As levels return towards normal, the original stimulus weakens. Negative feedback means opposing the original deviation, not always reducing every hormone. The model describes function; naming additional signalling hormones is unnecessary here.

Plant hormones – biology only (4.5.4)

Tropisms are growth responses to the direction of a stimulus. Phototropism responds to light; **gravitropism** (geotropism) responds to gravity. A positive response is towards the stimulus, a negative response away from it. Shoots commonly grow towards light and against gravity; roots grow with gravity. AQA 2025 Q03.1 [2] requires both **growth response** and **gravity**, not just “downwards”. A plant does not move its whole body like a walking animal.

Unequal auxin distribution produces unequal growth. In a shoot receiving one-sided light, more **auxin** accumulates on the shaded side. Those cells elongate more, so the shoot bends towards the light. Do not teach that light simply destroys auxin. In a horizontal root, more auxin accumulates on the lower side, where it inhibits elongation; the upper side grows more and the root bends down. The effect depends on the organ and conditions: do not apply a shoot’s elongation rule to a root.

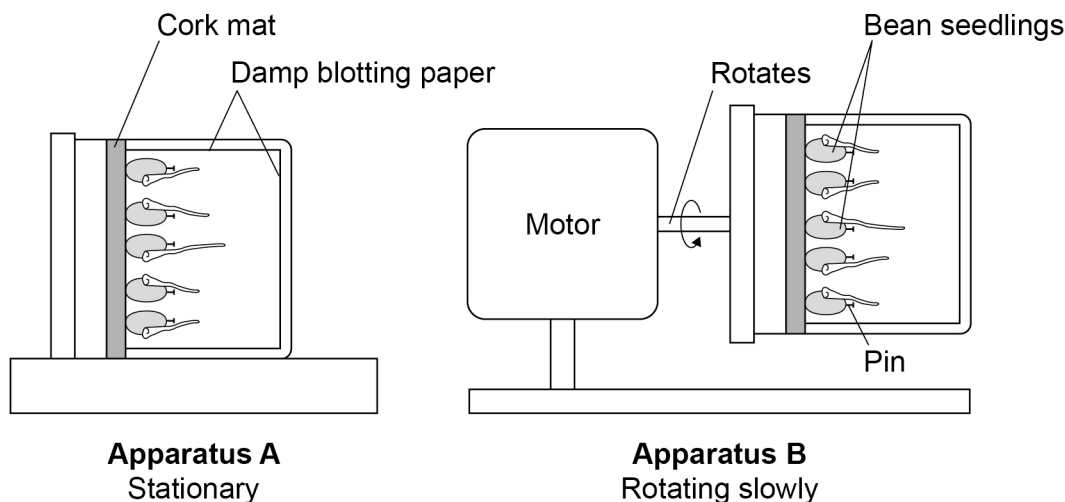


Worked, sheet 5.4 Q3.1 [3]. More auxin on the shaded side (1) → greater elongation there than on the lit side (1) → shoot bends towards light (1). **Worked, AQA 2024 Q04.6 [2].** Uneven auxin distribution, with more on the lower side (1) → upper-side root growth exceeds lower-side growth (1), causing a downward bend. Explain the comparison between sides, not just “auxin makes it grow”.

■ RP8: investigate direction and growth

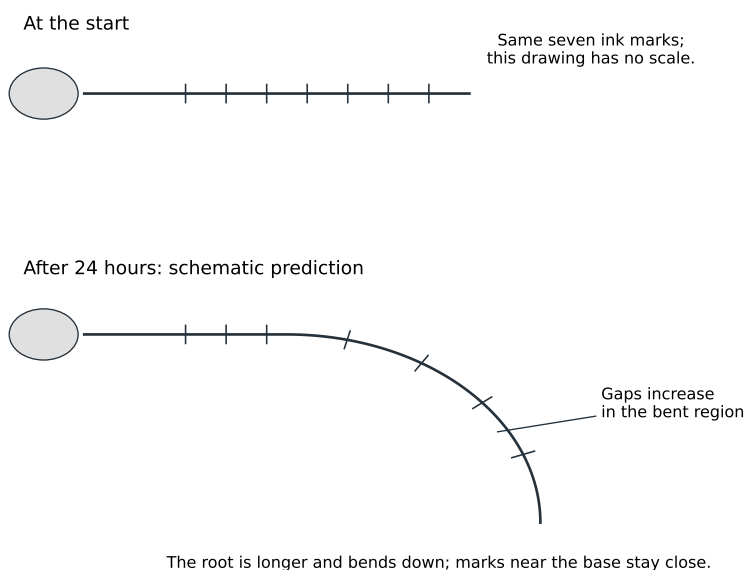
Original gravity experiment, AQA 2024 Q04.1–Q04.6. Apparatus A is stationary; apparatus B rotates slowly. Both are left in darkness for 24 hours and surrounded with damp blotting paper. The original apparatus drawing is reproduced below.

Figure 6



Explain each control. Darkness prevents directional light affecting the root response (Q04.1 [1]). Damp paper supplies water for growth and reduces an unequal water supply influencing direction (Q04.2 [2]); it is not primarily a source of mineral ions. The rotating apparatus provides comparison and prevents gravity acting consistently on the same side of the root (Q04.3 [2]). Rotation does **not** remove gravity. In B, the root grows approximately straight/horizontally, unlike the downward bend in A (Q04.5 [1]).

Predict the drawing, Q04.4 [3]. The stationary root becomes longer (1), bends down (1), and the ink marks become further apart in the bent growth region (1). Do not spread the marks equally along the old base: that does not show the location of elongation. The author-drawn example below preserves seven marks and illustrates the pattern; it is not measured experimental data or an original exam answer image.



Plan light-direction RP8, AQA 2025 Q03.2 [6]. Use newly germinated seedlings of the same species and age with similar starting lengths. Compare light entering through a slit on one side with all-round light; keep temperature, water, growth medium and duration alike, and use comparable light intensity where possible. Darkness is another allowed exam comparison, but changes light availability as well as its direction. Record initial and final shoot lengths over the same interval. A curved shoot needs non-stretch thread laid along its curve then measured against a ruler; vertical height alone is not its length. Use several seedlings per condition, calculate mean growth and compare directions as well as lengths. Record careful **labelled biological drawings** of the results; a photo alone does not satisfy the specified drawing record.

Teacher-written measurement example. Three shoots in one condition start at 20 mm and finish at 32, 34 and 33 mm. Use final minus initial for each shoot, then calculate the mean increase. These are illustrative classroom values, not results from

the 2025 paper.

$$\Delta L = L_{\text{final}} - L_{\text{initial}}$$

$$\Delta L_1 = 32 \text{ mm} - 20 \text{ mm} = 12 \text{ mm}$$

$$\Delta L_2 = 34 \text{ mm} - 20 \text{ mm} = 14 \text{ mm}$$

$$\Delta L_3 = 33 \text{ mm} - 20 \text{ mm} = 13 \text{ mm}$$

$$\overline{\Delta L} = \frac{\sum \Delta L}{n}$$

$$\overline{\Delta L} = \frac{12 + 14 + 13}{3} \text{ mm} = 13 \text{ mm}$$

Compare that mean with the other condition and examine the recorded bends. One condition alone cannot establish the effect of light direction. A mean does not replace repeat measurements or drawings.

■ Applying plant hormones (HT)

Auxins are used in rooting powders, to promote growth in tissue culture, and as weed killers. Rooting powder stimulates root formation at the cut end so a cutting can establish and grow as a clone; this is not a claim that more auxin always speeds elongation in existing roots. Some auxin-like weed killers disrupt growth of susceptible plants. Not every herbicide is an auxin-like hormone. Killing non-target plants can reduce plant diversity and food/habitat for other organisms, so weigh the agricultural benefit against biodiversity effects.

Ethene controls cell division and fruit ripening; it is used to control ripening during storage and transport. **Gibberellins** initiate germination and are used to end seed dormancy, promote flowering and increase fruit size. Their biochemical mechanisms are not required.

Worked applications, AQA 2024 Q04.7–Q04.8 [2+2]. Two distinct auxin uses could be rooting powders and growth in tissue culture. For a sprayed apple tree, promoting flowering and increasing fruit size are relevant gibberellin uses. Ending seed dormancy is a valid general use but does not answer why an already-growing apple tree was sprayed. Select the application for the object and context in the question.

Checklist before you call this topic done

- Define homeostasis; receptor–coordination centre–effector said in order; reflex arc drawn with synapse.
- Eye parts and accommodation table cold; myopia vs hyperopia with corrections.
- Temperature: vasodilation/sweat vs vasoconstriction/shivering, in context (HT).
- Insulin and (HT) glucagon with negative feedback; Type 1 vs Type 2 treatments.
- (Bio) kidney filtration + selective reabsorption; (HT) ADH; dialysis vs transplant.
- Reproductive hormone roles and contraception; (HT) cycle interactions/graphs, IVF, adrenaline and thyroxine.
- (Bio) tropisms with auxin; RP8; (HT) the three hormone uses.

6 · Inheritance, variation and evolution

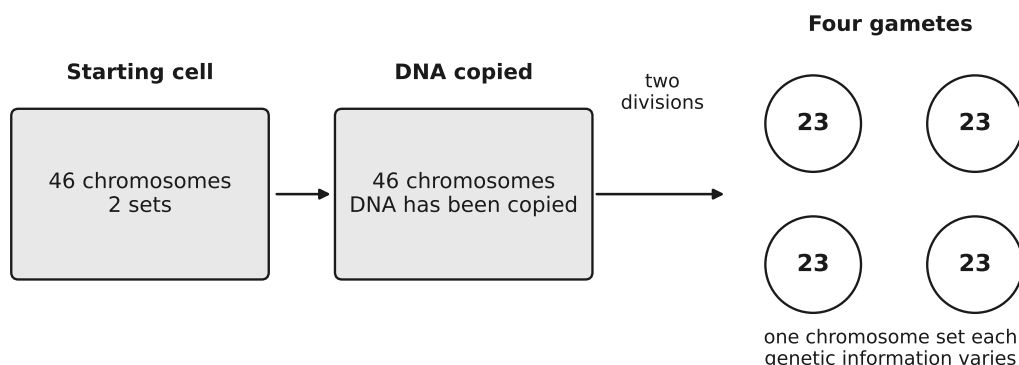
AQA · GCSE · Biology

Inheritance, variation and evolution: passing it on

- Sexual reproduction mixes genetic information; asexual reproduction clones it. Meiosis halves chromosomes for gametes; fertilisation restores them.
- DNA → genes → alleles → phenotype: the Punnett square turns this into probabilities.
- Natural selection changes inherited characteristics across generations. Selective breeding, genetic engineering and cloning (biology only) use different mechanisms. Fossils and resistant bacteria provide evolutionary evidence; classification uses evidence of relationships.

Reproduction, DNA and genomes (4.6.1.1–4.6.1.5)

Sexual reproduction – fusion of male and female gametes (sperm + egg in animals; pollen + egg in flowering plants). Meiosis forms gametes; mixing of genetic information gives **variety** in offspring. **Asexual reproduction** – one parent, no fusion, mitosis only: genetically identical offspring (**clones**).



Human chromosome-number model. Fertilisation: $23 + 23 = 46$; mitosis then increases cell number.

Meiosis : in reproductive organs, copies of the genetic information are made first, then the cell divides **twice** to form **four gametes**, each with a **single set** of chromosomes – all genetically different. **Fertilisation** restores the normal number; the new cell divides by **mitosis** and cells differentiate as the embryo develops.

(Bio) Sexual vs asexual: sexual gives variation – a survival advantage if the environment changes, and the variation selective breeding uses; asexual needs no mate (time and energy efficient), is faster, and produces many identical offspring when conditions are favourable. Malarial parasites: asexual in the human host, sexual in the

mosquito; many fungi: asexual spores + sexual; strawberry plants: sexual seeds + asexual runners; daffodils: bulb division.

DNA and the genome: DNA is a **polymer** of two strands forming a **double helix**, held in the nucleus as **chromosomes**. A **gene** is a small section of DNA that codes for a sequence of amino acids → a specific protein. The **genome** is the entire genetic material of the organism. Importance of the human genome: searching for genes linked to disease; understanding and treating inherited disorders; tracing human migration patterns from the past.

(Bio) DNA structure: a polymer of four different **nucleotides** – common sugar + phosphate group + one of four bases – **A**, **C**, **G**, **T**; alternating sugar–phosphate backbone; **a sequence of three bases codes for one amino acid**, and the base order controls the amino-acid order of the protein.

(HT Bio) Protein synthesis: on **ribosomes**, from a template; **carrier molecules** bring specific amino acids in the correct order; the chain folds into a unique shape that lets the protein work as an enzyme, hormone or structural protein (e.g. collagen). In complementary strands **C pairs with G, T with A**. Mutations change the base sequence: a mutation may leave the protein unchanged, alter it slightly, or change its shape so an enzyme no longer fits its substrate or a structural protein loses strength. Variants in **non-coding DNA** can switch genes on and off, changing how genes are expressed.

■ Apply the reproduction and DNA knowledge

Try first – strawberries. Seeds form after fertilisation; runners form without gamete fusion. Identify the two routes and explain which may help a population survive a new disease.

Worked reasoning. Seeds result from sexual reproduction: meiosis makes gametes and fertilisation mixes genetic information. Variation means some offspring may resist the disease. Runners form by mitosis from one parent: clones, apart from mutation. Asexual reproduction needs no mate and is fast in favourable conditions; neither route guarantees survival.

Try first – chromosome number. A human cell has 46 chromosomes before meiosis. Predict the number of gametes, their chromosome number, the number after fertilisation and the division growing the embryo.

Worked reasoning. DNA is copied before two divisions form four gametes, each with 23 chromosomes (one set). DNA copying does not change the count to 92 chromosomes at that point. Fertilisation combines $23 + 23 = 46$; mitosis increases embryo cell number and cells differentiate. The diagram models chromosome numbers, not the stages of meiosis.

Try first – scale and code. Distinguish a gene, chromosome and genome. (HT Bio) Write the bases complementary to A C G T and explain whether a mutation must stop an enzyme working.

Worked reasoning. A gene is a DNA section coding an amino-acid sequence for a protein; a chromosome contains a long DNA molecule and many genes; a genome is all the organism's genetic material. Complementary bases are T G C A. At ribosomes, a template and carrier molecules determine the amino-acid order; the chain folds. A mutation may leave the protein unchanged or change its shape and function. Non-coding variants can change whether genes are expressed.

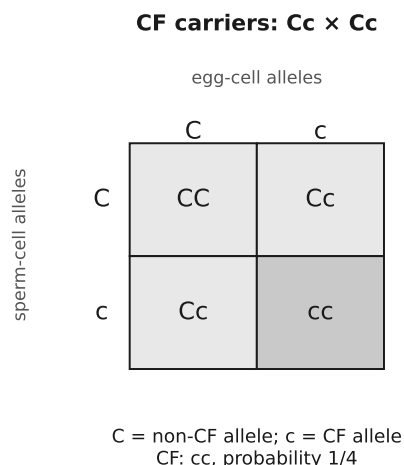
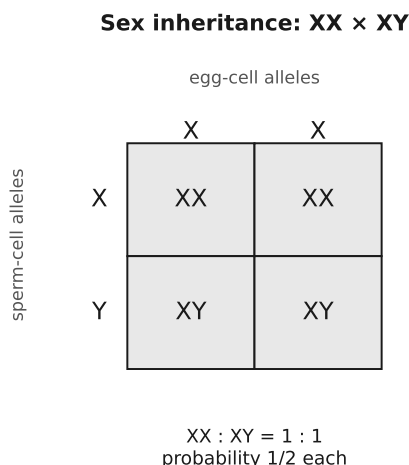
Genetic inheritance, disorders and sex determination (4.6.1.6–4.6.1.8)

Learn the terms: **gamete** (sex cell), **chromosome** (DNA structure), **gene** (section coding a protein), **allele** (a form of a gene), **dominant** (expressed with one copy), **recessive** (expressed only with two), **homozygous** (two same alleles), **heterozygous** (two different), **genotype** (alleles present), **phenotype** (characteristics expressed).

Single-gene examples: fur colour in mice; red-green colour blindness. Most characteristics result from **multiple genes interacting**.

Punnett squares and crosses: complete a Punnett square, extract ratios (e.g. 3:1, 1:1) and probabilities from genetic crosses and family trees. (HT) Construct a cross from parent genotypes and predict outcomes with probability.

Inherited disorders: polydactyly (extra fingers or toes) – **dominant** allele; **cystic fibrosis** (a disorder of cell membranes) – **recessive** allele. Make informed judgements about the economic, social and ethical issues of **embryo screening**.



Sex determination: body cells have **23 pairs** of chromosomes; 22 pairs control characteristics, one pair carries the sex genes – **female XX**, **male XY**. A sex cross ($X \times X$, $X \times Y$) gives a 1:1 ratio, 50 % chance each.

■ From terms to family inference and probabilities

Try first – terminology. D causes dominant polydactyly; d does not. Classify Dd and predict its phenotype and gamete alleles.

Worked reasoning. Dd is heterozygous (two different alleles); DD and dd are homozygous. Genotype means the alleles present; phenotype means the characteristics expressed. Dd is affected because one D is expressed. “Dominant” does not mean stronger or more common. Gametes contain D or d, not Dd.

Guided family inference – adapted from AQA June 2024 Paper 2H Q06.2.

An affected father and unaffected mother have an unaffected son. Deduce the father’s genotype before reading the answer.

Worked reasoning. The mother and son are dd. The father passed d to his son, but must also carry D because he is affected. Therefore he is Dd. The child’s genotype supplies evidence that the father’s phenotype alone cannot provide.

Construct a cross (HT). Two unaffected CF carriers are Cc and Cc. Each produces gametes C or c. Combining them gives CC, Cc, Cc, cc: probability of CF = $1/4$; probability of being a carrier = $1/2$. Carriers do not have CF in this recessive model. The separate XX × XY cross gives XX, XX, XY, XY: probability $1/2$ each in the GCSE sex-determination model.

Exam transfer – adapted from AQA June 2024 Paper 2H Q06.3. An affected mother Dd and unaffected father dd have three unaffected sons. Construct a cross and predict whether the fourth child will be affected.

Worked reasoning. Egg alleles D/d combine with sperm alleles d/d to give Dd, dd, Dd, dd. Two of four equally likely combinations are affected: probability = $2/4 = 1/2$. Earlier births do not change this probability. The four boxes describe possible combinations, not four promised children.

Evaluate – teacher-written screening scenario. Screening can identify embryos with the CF genotype, but treatment is costly and some embryos may not be used. A biological benefit is identifying cc embryos to inform the couple’s decisions. Cost can limit access and creates funding choices. Some families object to selecting or not using embryos; others prioritise reducing inherited disease. An informed judgement uses the stated evidence and recognises different values.

Variation, selective breeding, genetic engineering and cloning (4.6.2)

Variation – differences between individuals in a population – comes from **genes inherited** (genetic), **conditions of development** (environmental), or **a combination**. There is usually extensive genetic variation within a population; all genetic variants arise from **mutations** – most have no effect on the phenotype, some influence it, very few determine it. A rare mutation giving a **new phenotype** suited to an environmental change can change the species rapidly.

Evolution: a change in the inherited characteristics of a population over time, through **natural selection**, which may result in a new species. All species evolved from simple life forms that first developed over three billion years ago. Natural selection: variation → the phenotype best suited to the environment survives and breeds → those characteristics are passed on. If two populations become so different they cannot interbreed to produce **fertile offspring**, two new species have formed.

Selective breeding (artificial selection): choose parents with the desired characteristic from a mixed population → breed → choose the best offspring → repeat over many generations. Uses: disease resistance in food crops; animals with more meat or milk; dogs with gentle natures; large or unusual flowers. Risk: **inbreeding** – breeds prone to disease or inherited defects.

Genetic engineering: modifying the genome by introducing a gene from another organism to give a desired characteristic – GM crops resistant to insect attack or herbicides (increased yields); bacteria engineered to make **human insulin**. (HT) Steps: **enzymes isolate the required gene** → inserted into a **vector** (bacterial plasmid or virus) → vector inserts the gene into the required cells → transferred early in development so the organism develops with the desired characteristic. Weigh benefits (medicine, agriculture) against risks (wild-flower and insect populations, unexplored health effects) and ethical objections.

(Bio) Cloning: **tissue culture** – small groups of plant cells grown into identical new plants (preserving rare species; nurseries); **cuttings** – simple, older gardeners' method; **embryo transplants** – splitting unspecialised cells of a developing animal embryo into identical embryos placed in host mothers; **adult cell cloning** – nucleus removed from an unfertilised egg cell → nucleus from an adult body cell inserted → **electric shock** makes it divide into an embryo → ball of cells placed in the womb.

■ Apply variation, selection and biotechnology

Start with variation – teacher-written seedling case. Seedlings differ in inherited disease resistance. Genetically identical plants grow to different heights under different light conditions. Identify genetic and environmental variation, then explain what may happen during a disease outbreak.

Worked reasoning. Resistance alleles provide genetic variation; light conditions can cause environmental differences in height. Phenotype often depends on both. Resistant plants may survive the disease and reproduce more successfully, passing favourable alleles to offspring. Over generations, resistance alleles can become more common. Mutations change DNA; they do not occur because an organism needs a particular change.

Exam transfer – adapted from AQA June 2024 Paper 2H Q01.2. Describe natural selection using insects that already vary in inherited insecticide resistance.

Worked reasoning. The insecticide is a selection pressure: more susceptible insects die. Resistant survivors reproduce and pass resistance alleles to offspring. The population's inherited characteristics change across generations; an individual does not

evolve just by being sprayed. Speciation requires populations to become unable to interbreed to produce fertile offspring.

Compare mechanisms – teacher-written crop case. A grower wants inherited disease resistance without transferring a gene. Select resistant parents from a mixed population, breed them, select resistant offspring and repeat over many generations. This is selective breeding, not natural selection or genetic engineering. Repeatedly breeding close relatives risks inherited defects and reduced genetic variation.

Linked exam explanation – adapted from AQA June 2024 Paper 2H Q09.1. GM soya plants resist glyphosate. Explain how spraying the field can increase yield.

Worked reasoning. Glyphosate kills weeds but the resistant crop survives. Less competition gives the crop more light, water and mineral ions. More light and water can support photosynthesis, producing glucose for respiration and building biomass. Nitrate ions support amino-acid and protein synthesis. Link resources to growth and harvested yield; “GM means higher yield” omits the mechanism. These are authored explanation points checked against the scheme, not an official model or a guaranteed score.

HT – follow a gene. Enzymes isolate a required gene (for example, human insulin). Insert it into a vector such as a bacterial plasmid; use the vector to introduce it into the required cells. The modified cells express the gene and produce the substance. For a developing animal or plant, introduce the gene early so the organism develops with the desired characteristic.

Evaluate – teacher-written GM scenario. An insect-resistant crop suffers less target-pest damage, but a study reports fewer nearby non-target insects without establishing why. Reduced damage may improve harvest. The insect decline raises a food-web concern; compare modified and unmodified fields while accounting for habitat and pesticide use. Association alone does not prove the inserted gene caused the decline. Judge the particular modification and evidence.

Biology – choose and order cloning methods. A nursery can use tissue culture to grow plants from small groups of cells, or cuttings from a parent plant. Embryo transplants split cells before they specialise and place identical embryos into host mothers. Adult cell cloning removes an unfertilised egg’s nucleus, inserts an adult body-cell nucleus, stimulates division with an electric shock, and transfers the ball of cells to a womb. The adult body-cell donor supplies the nuclear genetic information. Environmental differences can still affect a clone’s phenotype.

Evolution, genetics and evidence (4.6.3, biology only)

(Bio) Darwin’s theory: wide **variation** within a species; individuals best suited to the environment **survive to breed**; the useful characteristics are **passed on**. Published in *On the Origin of Species* (1859). Accepted only gradually: it challenged the idea that God made all living things; **insufficient evidence** at publication; the mechanism of inheritance was unknown for another 50 years. **Lamarck’s** rival theory

– that changes acquired during an organism’s lifetime are inherited – is now known to be wrong in almost all cases.

(Bio) Wallace: independently proposed evolution by natural selection; joint 1858 publications with Darwin prompted Darwin to publish; best known for **warning colouration** and pioneering work on **speciation** – the steps by which new species arise.

(Bio) Mendel and the growth of genetics: mid-19th-century breeding experiments showed each characteristic is inherited through ‘units’ passed unchanged to descendants; late 19th century – chromosomes observed in cell division; early 20th century – the units behave like chromosomes → **genes on chromosomes**; mid-20th century – DNA structure determined and gene function worked out. Mendel’s work was unrecognised in his lifetime.

(Bio) Evidence for evolution: genes show characteristics pass to offspring; **fossils**; **antibiotic resistance** in bacteria.

(Bio) Fossils form when parts do not decay (a decay condition is absent), when parts are replaced by **minerals** as they decay, or as **preserved traces** (footprints, burrows, rootlet traces). Early soft-bodied life left few traces, mostly destroyed by geological activity – so science cannot be certain how life began. Extinction means no individuals of a species remain – causes include new diseases, new predators, competition, environmental change, catastrophic events. **Evolutionary trees** use current classification data and fossil data.

(Bio) Resistant bacteria: mutations produce genetic variants; some are resistant to a particular antibiotic. Susceptible bacteria are killed, while resistant survivors reproduce quickly and pass on resistance genes. The resistant strain becomes more common and can spread (for example, MRSA). This population change is evidence for evolution. Resistance can make infection harder to treat; it does not mean every antibiotic is ineffective or that people have no immune defence. Reducing inappropriate prescribing and unnecessary agricultural antibiotic use reduces avoidable selection pressure. Developing new antibiotics takes time and resources.

Try first – resistance explanation. A population contains susceptible and resistant variants before antibiotic exposure. Explain why resistant bacteria become more common, and correct “the antibiotic makes every bacterium mutate because it needs resistance”.

Worked reasoning. Genetic variation already exists; mutations are not directed by need. Antibiotic exposure selects survivors. Resistant bacteria reproduce and pass resistance genes to offspring, increasing their share of the population. Selection and inheritance explain the change without claiming that every individual becomes resistant.

■ Use historical and fossil evidence

Explain the history (Biology). Darwin and Wallace independently proposed natural selection; their joint writings appeared in 1858 and Darwin published his book in 1859. Acceptance was gradual: the theory challenged prevailing creation beliefs, some scientists found the evidence insufficient, and inheritance mechanisms were unknown. Mendel's plant breeding suggested inherited units. His work's importance was recognised after his death; later chromosome behaviour, genes on chromosomes and DNA structure connected these units to physical mechanisms.

Apply speciation – teacher-written case. A barrier separates a population into different habitats. Different selection pressures favour different variants; survivors reproduce and pass favourable alleles to offspring. Mutations supply genetic variants. Over many generations the populations may diverge. Separation alone does not prove a new species: inability to interbreed to produce fertile offspring is the stated species criterion.

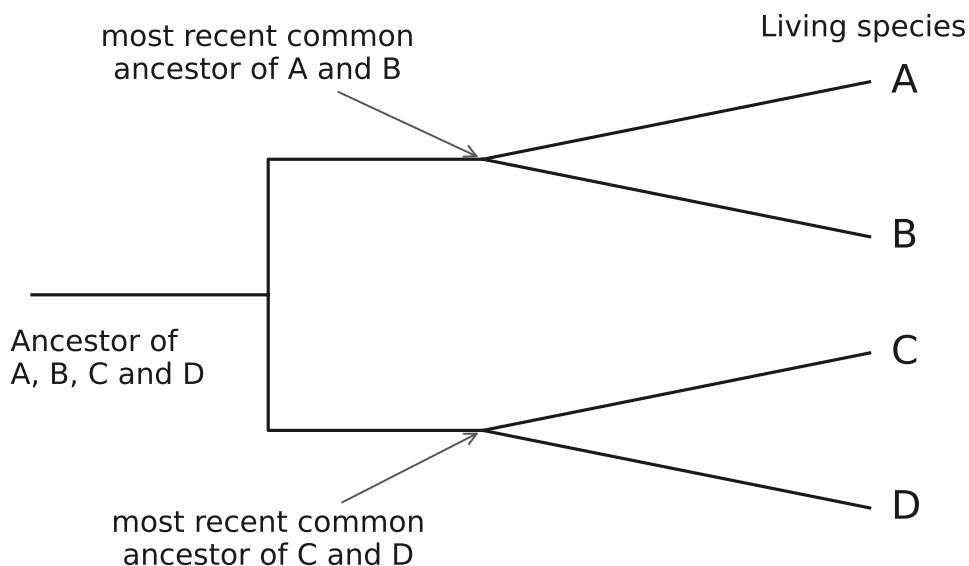
Interpret evidence – teacher-written fossil case. A footprint preserved in rock is a trace fossil; a shell replaced by minerals illustrates mineral replacement. Conditions that prevent decay can also preserve remains. Soft-bodied organisms may leave no trace, and geological activity destroys fossils. An incomplete record still supplies evidence of past organisms and change. A species missing from one site is not necessarily extinct: extinction means no living individuals remain anywhere.

Read the diagram. Trace A and B back to their first shared fork: this is their most recent common ancestor. A and C share the older ancestor of all four species, so A and B are more closely related. This is a schematic without a time scale; do not infer dates from branch lengths or relationships from vertical spacing. Trees use classification and fossil evidence.

Classification of living organisms (4.6.4)

Linnaeus: classification by structure and characteristics into **kingdom, phylum, class, order, family, genus, species**; organisms named by the **binomial** system (genus + species).

Three-domain system (Carl Woese), from chemical-analysis evidence: **archaea** (a distinct domain of prokaryotes, including many organisms from extreme environments), **bacteria** (true bacteria), **eukaryota** (protists, fungi, plants, animals). Improvements in microscopes and biochemistry drove the new models.



Evolutionary trees show how scientists believe organisms are related – interpret them using classification and fossil data.

Apply classification. In *Panthera leo* and *Panthera tigris*, *Panthera* identifies the shared genus; the second word distinguishes the species within it. The ranks are kingdom → phylum → class → order → family → genus → species. New microscopy and chemical-analysis evidence can reveal relationships that external appearance does not show, leading to revised classification. Woese's three domains are archaea, bacteria and eukaryota.

Final retrieval. Without the answers, explain (1) how 23-chromosome gametes restore 46 at fertilisation; (2) the next affected-child probability for $Dd \times dd$ after three unaffected births; (3) how antibiotic exposure changes a bacterial population. Check: two gamete sets combine; the cross gives a $1/2$ probability independently at each birth; resistant survivors reproduce and pass on resistance genes. Then use the earlier worked examples to retrieve gene transfer, cloning order and common ancestry.

Checklist before you call this topic done

- Meiosis (four gametes, halved number) vs mitosis; sexual vs asexual advantages with named organisms.
- All ten genetics terms; Punnett squares with ratios; polydactyly vs cystic fibrosis; XX/XY cross 1:1.
- (Bio) DNA nucleotides and bases; (HT) protein synthesis and mutations.
- Variation three sources; natural selection sequence; selective breeding steps and inbreeding risk; (HT) genetic engineering steps; (Bio) four cloning methods.
- (Bio) Darwin/Wallace/Mendel history, fossil formation and why the record is incomplete, MRSA story, Linnaeus ranks and the three domains.

7 • Ecology

AQA • GCSE • Biology

Ecology: communities, cycles and human impacts

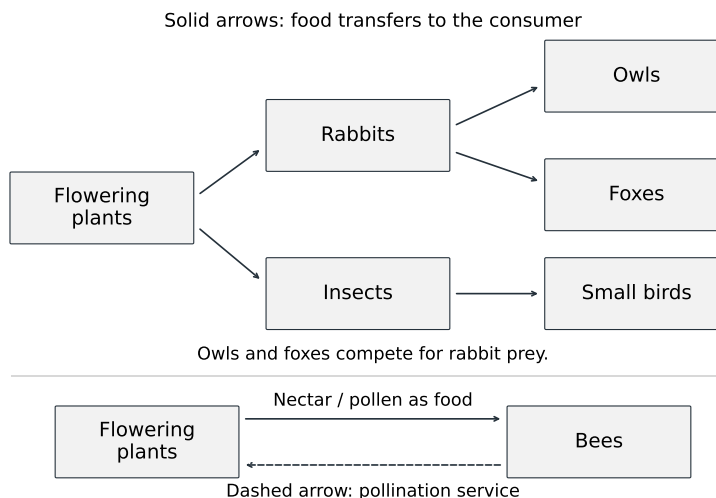
- The Sun's energy passes through ecosystems; carbon and water cycle between the living and non-living world.
- Communities compete and depend on each other; adaptations fit organisms to their conditions.
- Human activity – waste, land use, deforestation, global warming – threatens biodiversity, and trophic-level biology (bio only) explains why food chains are short.

Adaptations, interdependence and competition (4.7.1)

■ Levels, resources and interdependence

An **ecosystem** includes the interaction between a **community** of living organisms and the non-living parts of its environment. An individual is one organism; a population is organisms of one species in an area; a community includes the populations of different species there. **Worked, AQA 2023 Q01.1 [1]:** all organisms in the same habitat form a community. Add their interactions with soil, water, temperature and other abiotic surroundings to describe the ecosystem (sheet 7.1 Q2.1 [2]).

Competition occurs when organisms require the same limited resource. Plants compete for light, space, water and mineral ions. Animals compete for food, mates and territory. Two predator species can compete for the same prey; competition for mates usually concerns members of the same species. **Interdependence** includes food, shelter, pollination and seed dispersal. A removal can affect several populations; the size of the effect depends on the other available resources and relationships.



Worked, sheet 7.1 Q3.1 [4]. In the model, flowering plants provide food for bees and bees pollinate flowers. If bee numbers fall, bee-dependent flowers may receive less pollination, produce fewer seeds/fruits, and reproduce less successfully. Consumers may then have less plant food. This gives a named, linked explanation; it does not mean every plant depends on bees or every removal must destroy a community.

Worked, sheet 7.1 Q3.2 [4]. Suppose a new predator eats rabbits. More rabbits are eaten, so fewer survive and their population may fall (effect plus cause: 2). Existing rabbit predators face greater competition for the same prey, so less food may reduce their survival/reproduction (effect plus cause: 2). Alternatively, explain how fewer rabbits grazing could allow their food plants to increase. Give two developed effects, not four unexplained names.

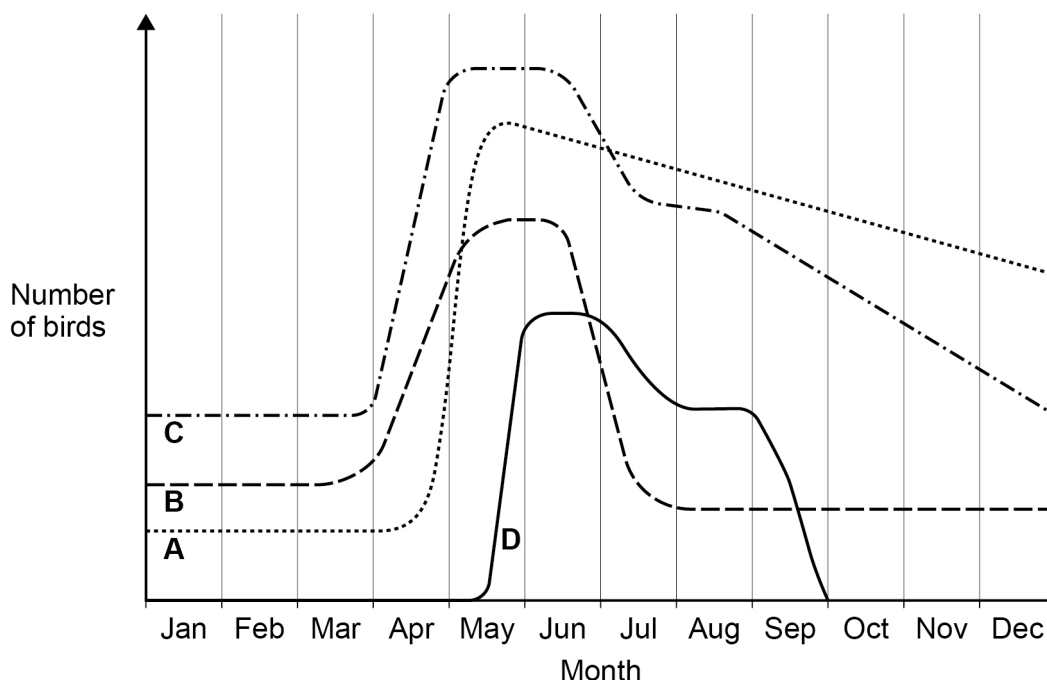
■ Abiotic and biotic factors in context

Abiotic factors are non-living conditions: light intensity, temperature, moisture, soil pH/mineral content, wind intensity/direction, carbon dioxide for plants and dissolved oxygen for aquatic animals. **Biotic factors** include food availability, new predators, pathogens and competition. Classify the factor, then explain its effect using the organism and conditions in the question.

Worked, AQA 2025 Q02.5 [3]. Daisies were more abundant further from a tree; the question asks for three abiotic factors other than soil water. Light intensity, soil pH and soil mineral-ion content are three accepted answers. Temperature, soil type, wind and soil oxygen are also accepted. Do not repeat water. Although carbon dioxide is a general syllabus example, the scheme ignores it here; “space” and vague “nutrients” are also ignored. Choose context-relevant factors rather than reproducing a memorised list.

Teacher-written causal example. Nitrate ions supply nitrogen for amino acids and proteins. Less nitrate can reduce protein synthesis and plant growth. Magnesium ions have a different role in chlorophyll. Do not say every mineral ion makes amino acids. Differing success in obtaining a limited resource can change the relative sizes of plant populations.

■ Reading community data



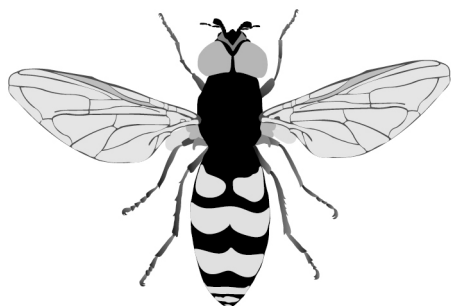
Worked, AQA 2023 Q01.4 [3]. Read the dotted A line: numbers are constant from January to March/early April; increase during April towards May; then decrease from May/June towards December. Name time intervals with each trend. The original vertical axis has no numbers, so exact counts and percentage decreases cannot be calculated from it.

Worked, Q01.5–.6 [1+1]. The question supplies a disease outbreak in June/July: B has the lowest resistance in that context. D is the migrating species because it is present for only part of the year, around May to September/October. The graph alone does not identify every cause of population change; use the supplied disease and migration information. “The line goes down” without the species/time context is inadequate.

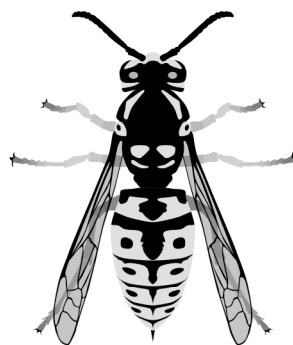
■ Adaptations and extreme environments

Adaptations enable survival in normal conditions. Structural features concern the body, such as insulating blubber; behavioural features are actions, such as migration; functional features are internal processes, such as venom production. Explain how a feature helps in the stated environment. A thick insulating layer reduces heat transfer in cold conditions; migration changes the conditions encountered; producing venom can help capture prey. An organism does not deliberately acquire a new inherited feature simply because it needs one.

Figure 1



Hoverfly



Wasp

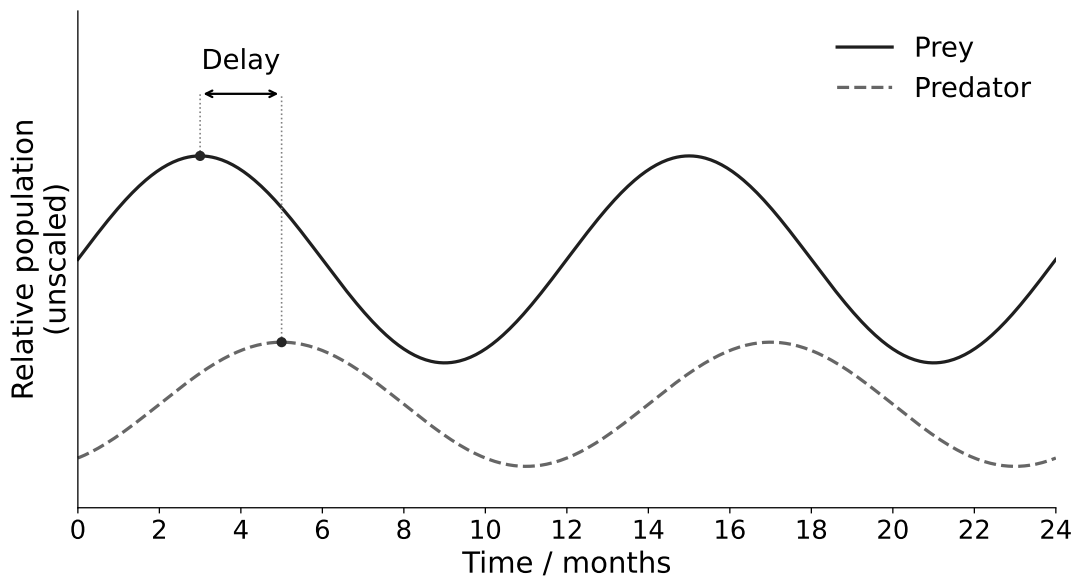
Worked adaptation, AQA 2024 Q01.4 [3]. Both insects have yellow/black markings and share a habitat; the wasp has a sting, the hoverfly does not. The hoverfly resembles the wasp (1); predators avoid wasps to avoid being stung (1); so predators are less likely to attack/eat the hoverfly (1). Similar appearance is the structural feature; the survival benefit needs the predator-response explanation. Do not just say a predator “thinks it is a wasp”.

Extremophiles live in conditions extreme for most organisms, such as very high temperature, pressure or salt concentration. Deep-sea vent bacteria are the named syllabus example. **Sheet 7.1 Q3.3 extension:** darkness prevents photosynthesis using sunlight, but some vent bacteria use energy released by chemical reactions to make organic food (chemosynthesis). This explains a possible energy source, not all bacteria’s metabolism. Chemosynthesis is supplied enrichment for this authored question, beyond the named extremophile knowledge required in 4.7.1.4.

Organisation of an ecosystem and material cycles (4.7.2, RP9/RP10)

■ Food chains and population cycles

A **producer** (green plant or alga) makes glucose by photosynthesis and builds biomass. A teacher-written chain is grass → rabbit → fox: the arrows show food transfer to the consumer, not the direction in which an animal moves. The rabbit is a primary consumer ; the fox is a secondary consumer in this chain.



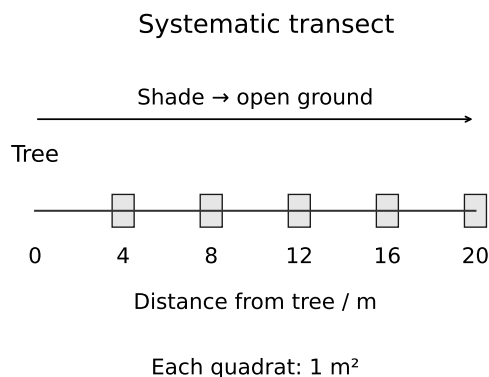
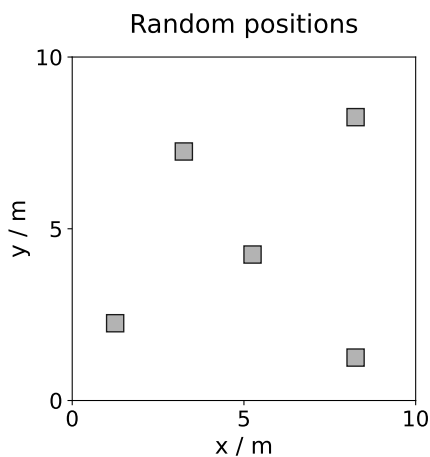
More prey can support predator survival and reproduction. More predators eat more prey; as prey decline, food becomes scarce and predator numbers fall. With fewer predators, prey can recover. The predator response takes time. Real populations are also affected by other factors, so do not assume every supplied graph is a perfect cycle.

Worked model reading: the first prey peak is at month 3; the corresponding predator peak is at month 5.

$$\text{peak delay} = t_{\text{predator}} - t_{\text{prey}}$$

$$\text{peak delay} = 5 \text{ months} - 3 \text{ months} = 2 \text{ months}$$

■ RP9: choose a sampling method



For a **population estimate**, use random coordinates over the defined area, not convenient or plant-rich positions. Keep quadrat size and counting rules consistent, sample sufficiently and calculate a mean. For **distribution along a gradient**, lay a transect from shade to open ground; sample at regular distances, count the species (or estimate cover) and measure light intensity at each position. Repeat transects and calculate means at comparable positions. A quadrat measures a local sample; a transect arranges those samples along a line. Record units and plot the measured factor against abundance using suitable labelled scales.

Worked teacher extension to sheet Q2.2: counts 4, 6, 6, 8, 11; assume random 0.25 m² quadrats in a 100 m² field. The ordered middle value and most frequent value are both 6.

$$\text{mean count} = \frac{\text{sum of counts}}{\text{number of quadrats}}$$

$$\text{mean count} = \frac{4 + 6 + 6 + 8 + 11}{5} = 7 \text{ plants per quadrat}$$

$$\text{density} = \frac{\text{mean count}}{\text{quadrat area}}$$

$$\text{density} = \frac{7 \text{ plants}}{0.25 \text{ m}^2} = 28 \text{ plants m}^{-2}$$

$$\text{estimated population} = \text{density} \times \text{total area}$$

$$\text{estimated population} = 28 \text{ plants m}^{-2} \times 100 \text{ m}^2 = 2800 \text{ plants}$$

This estimate assumes a representative sample. Do not treat one shaded-to-open transect as a random sample of the whole field.

■ **RP9: interpret original exam evidence**

Table 2

	Distance from the tree in metres				
	4	8	12	16	20
Mass of fresh soil in grams	250	266	260	248	252
Mass of dried soil in grams	225	234	209	184	181
Mass of water lost from soil in grams	25	32	51	64	71
Percentage of water in soil	10	12	20	26	X
Number of daisies per m ²	0	7	15	28	32

2025 Q02.1–Q02.4: students dried soil at 100°C, cooled and reweighed, repeating until mass stopped changing. Constant mass helps ensure **all water has been removed**. Subtract container mass if it is included in a weighing; this table already gives soil masses. At 20 m, fresh soil = 252 g and dry soil = 181 g.

$$\text{water mass} = \text{fresh soil mass} - \text{dry soil mass}$$

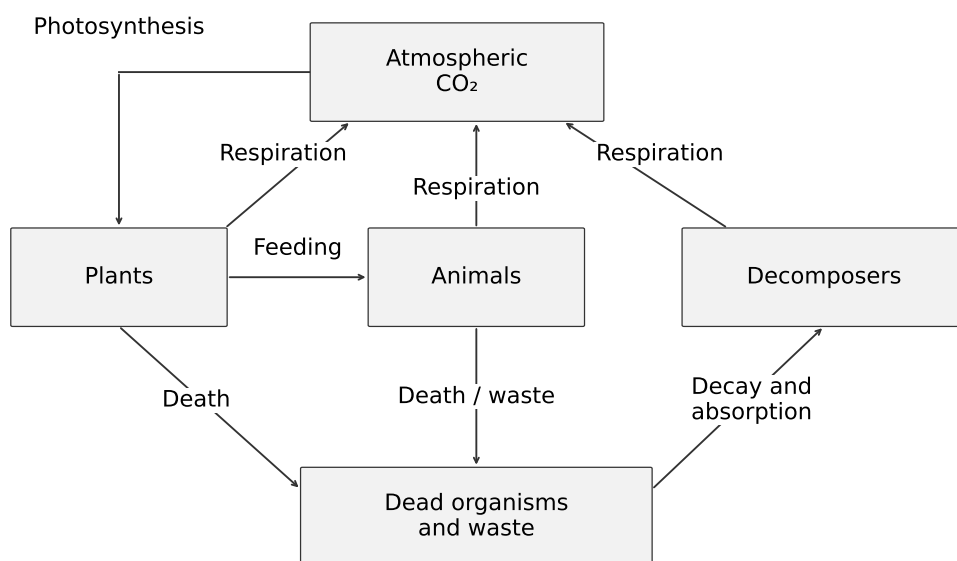
$$\text{water mass} = 252 \text{ g} - 181 \text{ g} = 71 \text{ g}$$

$$\text{water percentage} = \frac{\text{water mass}}{\text{fresh soil mass}} \times 100$$

$$\text{water percentage} = \frac{71 \text{ g}}{252 \text{ g}} \times 100 = 28.1746 \dots \% = 28\% \text{ (nearest whole number)}$$

Between 4 and 16 m, water percentage increases with distance (10% to 26%); this is not direct proportionality. To improve the conclusion about water and daisies, repeat at each distance and calculate means; sample more trees or directions, or add intermediate distances. Light and other factors may vary too: association alone does not establish that water caused the change.

■ Carbon, water and mineral recycling



Photosynthesis uses atmospheric CO₂ to make glucose. **Feeding** transfers carbon compounds; **respiration** by plants, animals and decomposers releases CO₂. Microorganisms secrete enzymes that break down large molecules in dead material; small soluble products are absorbed. Their respiration returns carbon to the atmosphere. **Combustion** of biomass or fossil fuels also releases CO₂: this is a separate process from respiration. Material is recycled; energy is transferred and eventually dissipated.

Water cycle: evaporation from water surfaces and transpiration from plants put water vapour into air. Cooling causes condensation into droplets; precipitation returns water to land and sea. Run-off and drainage return water to the sea. Evaporation leaves dissolved salts behind, helping provide fresh water over land.

Original 2023 Q04.1 [6] – response plan: decomposer bacteria/fungi use enzymes to break down fallen leaves. Respiration releases CO₂ into air; it enters leaves through stomata and is used in photosynthesis to make glucose and other plant material. Nitrogen in the leaves is recycled into soil nitrate ions; roots absorb these, including by active transport, and use nitrogen to make amino acids/proteins. Link breakdown to reuse for **both** carbon and nitrogen. The detailed nitrogen cycle is not required.

■ Decay, compost and biogas – Biology

During **decomposition**, bacteria and fungi use enzymes to break down dead material. Warmth towards the enzyme optimum increases activity; temperatures above the optimum can denature enzymes. Moisture supports microbial activity, but a waterlogged heap can lack oxygen. Turning compost adds oxygen for aerobic respiration. Compost is decomposed organic material used as a natural fertiliser. Anaerobic decay produces methane; a biogas generator collects this gas, which can then be burned for

heating or electricity generation. Gas production and combustion are different stages.

■ **RP10: milk decay and temperature**

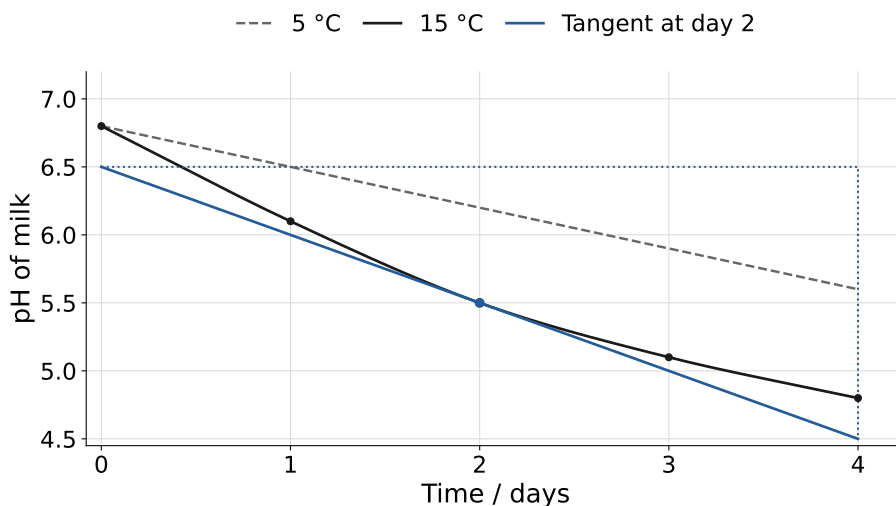
Original 2023 Q 04.2–Q 04.5: students used 25 cm³ fresh milk at 5°C, 15°C and 25°C, recording pH daily for four days. Keep volume/type of milk and measurement timing consistent; maintain the set temperatures. Repeat at each temperature and calculate means, or measure pH more frequently. These are improvements to a comparison, not evidence that all possible temperatures were tested.

Table 1

Time in days	pH of milk		
	5 °C	15 °C	25 °C
0	6.8	6.8	6.8
1	6.5	6.1	5.3
2	6.2	5.5	4.9
3	5.9	5.1	4.8
4	5.6	4.8	4.8

Q 04.3 [3]: plot all five 25°C points: (0,6.8), (1,5.3), (2,4.9), (3,4.8), (4,4.8). Draw a smooth curved best-fit line; one straight line is not suitable. The official scheme awards points for days 1–3 and the curve, but incorrect endpoint plots can still invalidate marks. Read labelled scales before plotting.

Teacher redraw: the following graph uses Table 1 data and an illustrative tangent matching the official example. It is not the original Figure 7.



Q 04.4 [4]: draw a tangent to the 15°C curve at day 2, then use well-separated points on that tangent. This measures the instantaneous rate; an endpoint-to-endpoint gradient on the curve is an average. The official example tangent uses pH 6.5 at day 0 and pH 4.5 at day 4.

$$\text{gradient} = \frac{\Delta \text{pH}}{\Delta t}$$

$$\text{gradient} = \frac{4.5 - 6.5}{4 \text{ days} - 0 \text{ days}} = -0.5 \text{ pH units per day}$$

The pH decreases; the rate of decrease has magnitude 0.5 pH units per day. The given rate at 5°C is 0.3 pH units per day.

$$\text{rate ratio} = \frac{\text{rate at } 15^\circ\text{C}}{\text{rate at } 5^\circ\text{C}}$$

$$\text{rate ratio} = \frac{0.5 \text{ pH units per day}}{0.3 \text{ pH units per day}} = 1.666 \dots \approx 1.67$$

The ratio is dimensionless: the 15°C rate is about 1.67 times as fast. A student's accepted tangent may give a slightly different gradient; use that tangent consistently.

Q 04.5 [3]: within the tested range, enzymes are more active at the higher temperature; lipids are broken down more quickly; fatty acids are produced faster, so pH falls faster. Do not write amino acids as lipid breakdown products. The 25°C curve levels off near pH 4.8; the graph alone does not show that all bacteria died, or that heating further would always speed decay.

(HT Bio) Environmental change: temperature, water availability, atmospheric-gas composition – changes may be **seasonal, geographic or human-caused** – shift the distribution of species.

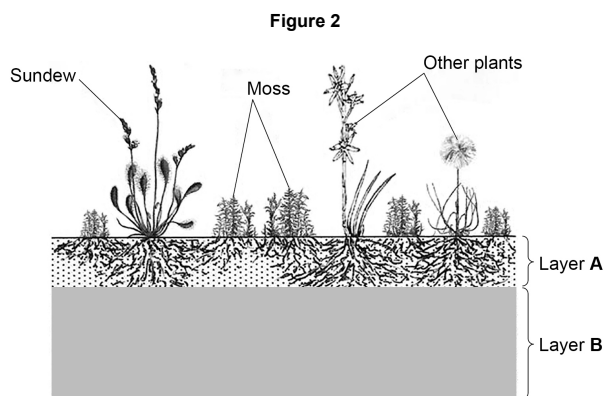
Biodiversity and human interactions (4.7.3)

■ Variety, stability and human pressures

Biodiversity means the variety of different species on Earth or within an ecosystem, not the number of individual organisms. A field with many plants of one crop can still have low species variety. Greater variety can reduce dependence on one particular species for food, shelter or maintaining the physical environment. This supports stability; it does not guarantee that disturbance has no effect. Human survival depends on maintaining biodiversity.

Population growth and rising living standards increase resource use and waste. If not properly managed, waste causes **pollution** : sewage, fertiliser and toxic chemicals in water; smoke and acidic gases in air; landfill and toxic chemicals on land. Pollution can kill organisms and reduce species variety. Building, quarrying, farming and waste disposal also remove habitat. Tropical forests are cleared for cattle, rice fields and biofuel crops: habitats are lost, fewer trees remove carbon dioxide by photosynthesis, and burning or decay releases carbon dioxide. Rising carbon dioxide and methane contribute to global warming. Changed temperature, rainfall or sea level can alter habitats, species distributions and migration, with possible species loss.

■ Peat: distinguish local loss from global effects



Layer **A** contains a lot of air.

Layer **B**:

- contains the dead remains of plants
- has a low pH
- contains very little oxygen
- contains carbon dioxide and methane.

Original 2024 Q02.1 [3]. Little oxygen in layer B limits aerobic respiration, so less energy is released for decomposer activity and decay is slow. Low pH can also reduce enzyme activity. Do not explain respiration of the dead plants themselves.

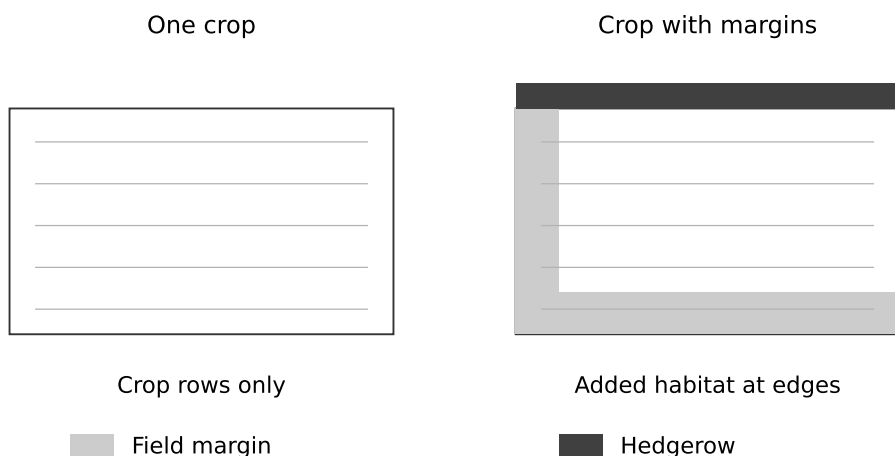
Original 2024 Q02.5 [4]. Removing peat can release trapped carbon dioxide and methane. Burning peat produces carbon dioxide; exposed peat can decay, with decomposer respiration releasing carbon dioxide. These gases trap heat, raising atmospheric temperature. In this question the scheme ignores methane attributed to burning/decay: name the stored methane released from the bog. Anaerobic decay producing methane is biologically valid and appears in the 2025 scheme; keep the process and question context clear.

Worked extended answer – original 2025 Q05.3 [6]. Locally, destroying a bog removes specialised habitat, food and shelter. Populations may die or migrate, reducing local biodiversity; loss of a local population does not automatically mean worldwide extinction. Globally, peat removal releases trapped greenhouse gases, while burning and decay release further gases. Increased warming changes rainfall, temperature or sea level, so habitats and food availability change elsewhere. Some species migrate; others may become extinct if they cannot survive the changed conditions. The level-based scheme requires explained local **and** global effects for Level 2, and detailed linked explanations at both scales for Level 3. Six disconnected facts are not a complete explanation.

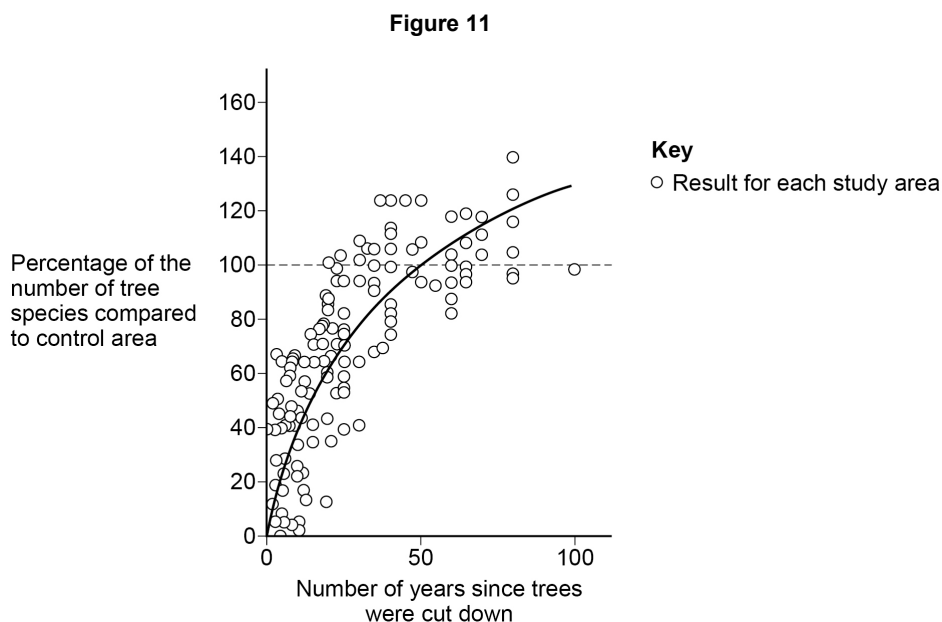
■ Maintain biodiversity and judge evidence

Programmes include: **breeding programmes** for endangered species; protection and **regeneration of rare habitats**; reintroducing **field margins and hedgerows** into single-crop farmland; reducing **deforestation and carbon dioxide emissions**; and **recycling** rather than landfill. Match the intervention to the threat and explain its mechanism.

Teacher schematic – not measured species counts.



Margins and hedgerows can supply different foods, shelter and nesting sites. Connected hedgerows can allow movement between habitats. More plant species may support a wider variety of animals; the outcome depends on establishment and management. Do not promise a particular numerical increase or guaranteed pest control from this schematic.



Original 2023 Q06.3–Q06.5. Percentages allow comparison because the areas began with different numbers of tree **species**, not necessarily different numbers of trees. Recovery is initially faster, then slower; results also vary between areas at similar times. Reaching 100% of the control’s species count does not establish recovery of the original species composition. Greater tree diversity can provide more **types** of food and habitat for animals; merely saying “more food” misses the variety required. Evaluate conflicting pressures using given evidence: habitat protection can compete with food production, housing or income. State a justified choice and its limitation rather than assuming every intervention has no cost.

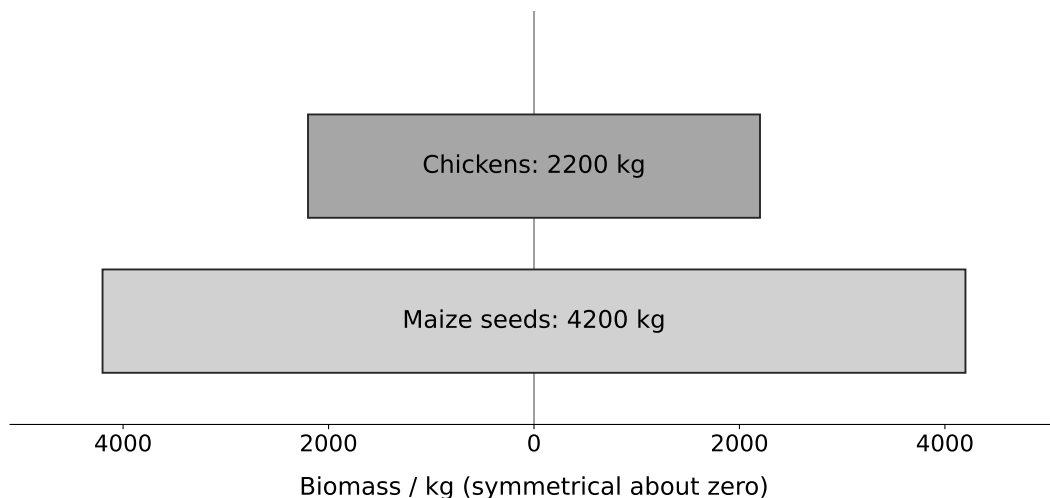
Trophic levels and food security – biology only (4.7.4–4.7.5)

Trophic levels are numbered from the producer: 1 plants/algae; 2 primary consumers (herbivores); 3 secondary consumers (carnivores eating herbivores); 4 tertiary consumers (carnivores eating carnivores). Apex predators have no predators. Decomposers secrete enzymes onto dead material; small soluble molecules diffuse into the microorganisms. They act on material from different levels, rather than forming a compulsory final link in every food chain.

■ Construct and calculate from biomass data

Put the producer at the bottom of a **pyramid of biomass** and use bar widths proportional to the supplied masses. Do not force every dataset to fit an exact 10% transfer.

Teacher answer drawing from original AQA 2024 Q07.2; not the original Figure 11.



Original Q07.2 [3]: 4200 kg maize seeds feed 1000 chickens of mean mass 2.2 kg. Total chicken biomass = $1000 \times 2.2 = \mathbf{2200 \text{ kg}}$. Use a suitable scale symmetrical around zero, label the horizontal axis **biomass / kg**, label both bars and plot 4200 and 2200 accurately. Bar height is not assessed; the relative width carries the biomass information.

Original Q07.3 [2]: chicken : maize = $2200 : 4200 = \mathbf{11 : 21}$. This is about 0.524 : 1; do not reverse the requested order. The percentage for these supplied masses is about 52.4%, not exactly 10%. The approximately 10% syllabus statement is a broad description, not a replacement for calculation with given data.

$$\text{transfer efficiency} = \frac{\text{biomass transferred}}{\text{biomass available}} \times 100\%$$

Worked example [2], authored: 200 kg of producers supports 18 kg of herbivores. Efficiency = $18/200 \times 100\% = \mathbf{9\%}$. One mark is for the method and one for the value; an extra explanation is not needed to earn the calculation marks. Sheet 7.4 Q2.2 uses $40/500 \times 100\% = \mathbf{8\%}$.

Producers transfer about 1% of incident light energy for photosynthesis. This is an **energy** percentage, distinct from biomass transfer between feeding levels. Much ingested material is not absorbed and is **egested as faeces**. Absorbed material can leave as carbon dioxide/water from respiration or water/urea in urine; glucose is used

in respiration. Only part becomes biomass available to the next level, so progressively less remains to support populations higher in the chain. In original 2024 Q07.4 [1], 80% is already available for respiration/growth: the remaining 20% is lost as **faeces**, not respiration, urine or heat. Identify which part of the budget the question asks about.

Original Q02.2 [1]: for moss producing $340 \text{ g/m}^2/\text{year}$, an approximate 10% transfer gives $340 \times 0.10 = \mathbf{34 \text{ g/m}^2/\text{year}}$. Preserve the rate units.

■ Food security and efficient production

Food security means enough food for a population. Pressures include increasing birth rate and demand; changing diets and transport of scarce food; new pests/pathogens damaging crops or animals; failed rains/environmental change reducing production; agricultural input costs; and conflict disrupting water or food availability. Explain how the named pressure changes supply or demand, rather than listing six words.

Restricting animal movement reduces muscle activity and associated energy transfer. Keeping surroundings at a suitable temperature reduces the need for extra respiration to maintain body temperature; it does **not** stop respiration. More of the food resource can contribute to growth. High-protein feed supplies material for growth. Evaluate production benefits against animal-welfare concerns, costs and the evidence provided.

Original 2024 Q07.1 [5], worked: 1000 chickens each require 46 MJ; maize supplies 16 MJ/kg and 80% is usable. One hectare produces 16.4 tonnes = 16 400 kg.

$$\text{required energy} = 1000 \times 46 = 46\,000 \text{ MJ}$$

$$\text{usable energy per hectare} = 16\,400 \times 16 \times 0.80 = 209\,920 \text{ MJ/ha}$$

$$\text{area} = \frac{46\,000}{209\,920} \times 10\,000 = 2191.3\dots \text{ m}^2 \approx 2190 \text{ m}^2 \text{ (3 s.f.)}$$

Apply the usable fraction before calculating land area. Keep intermediate values unrounded.

■ Fisheries and biotechnology

Larger **mesh** openings let young fish escape and potentially breed before capture. **Fishing quotas** limit catches, helping leave breeding adults. These measures aim to maintain stocks where breeding continues; recovery depends on appropriate limits and enforcement.

Fusarium is a fungus grown on glucose syrup in aerobic conditions. Its biomass is harvested and purified to produce mycoprotein, a protein-rich vegetarian food. GM crops can increase food supply or improve nutritional value; golden rice is a nutritional example, not a guarantee that all GM crops have higher yields. GM

bacteria produce human insulin, which is harvested/purified to treat diabetes. Insulin is a biotechnology example addressing health, **not a food or a direct solution to hunger**. The farming, fisheries and biotechnology sections here are Biology content for both tiers; the old worksheet's HT-only labels were incorrect.

Checklist before you call this topic done

- Definitions chain: ecosystem, community, abiotic/biotic factors with examples.
- Plant vs animal competition; interdependence consequences; three adaptation types + extremophiles.
- Food-chain vocabulary; predator–prey cycle read off a graph; RP9 sampling with mean/mode/median.
- Carbon and water cycles with decomposers' role; (bio) decay factors + biogas + RP10.
- Four human threats + five biodiversity programmes named.
- (Bio) Trophic levels, pyramid shape, 10 % rule with efficiency calculation.
- (Bio) Six food-security threats; efficiency farming, net size and quotas, mycoprotein, golden rice.