Course notes

AQA · GCSE · Biology

AQA GCSE · Biology: teaching notes

Version: 8461; Version 1.0 (21 April 2016); exams 2018 onwards

These notes cover selected topics of the course; they are not the whole specification.

Assessment and course boundaries

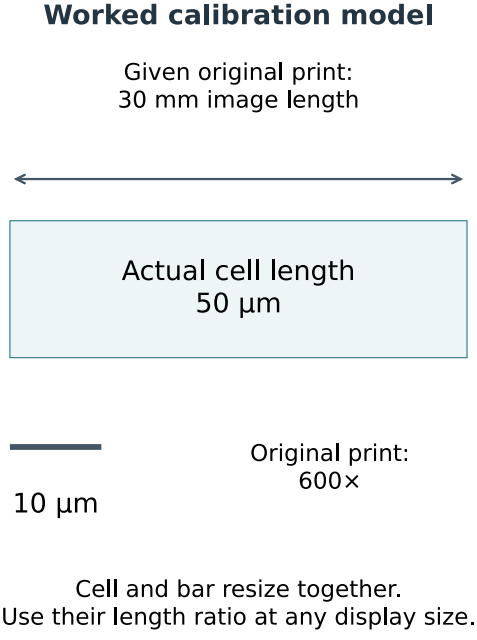
- Foundation and Higher are separate routes; use 8461 separate Biology rather than 8464 Combined Science.
- Paper 1: 4.1–4.4; Paper 2: 4.5–4.7. Each paper is 100 marks, 1 h 45 min, 50%.
- Required practicals are school laboratory experiences assessed through written questions; retain biology-only and HT labels.

Cell measurements and scale

Official-unit focus: 4.1 Cell biology

A cell can look larger on a screen without changing its real size. Two photographs at different zoom settings cannot be compared by eye alone.

Eukaryotic cells contain a nucleus. Prokaryotic cells have genetic material but no membrane-bound nucleus. A bacterial cell is a living cell; a virus depends on a host cell to reproduce.



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A scale bar provides a known real distance in the same image. Convert the image length and real length to the same unit before dividing. Magnification is a ratio and has no unit.

Focus a prepared slide at low power first. Move to a higher power and use fine focus. Make a clear line drawing, label structures with straight lines, and record the scale rather than shading the image.

■ Checked worked case

Known: a cell image is 30 mm long and represents a 50 micrometre cell. Use magnification = image size / actual size. Convert 30 mm to 30,000 micrometres. Magnification = 30,000 / 50 = 600. A separate 10 mm scale bar representing 20 micrometres gives 10,000 / 20 = 500, and that magnification applies to every object in its image.

■ Common error

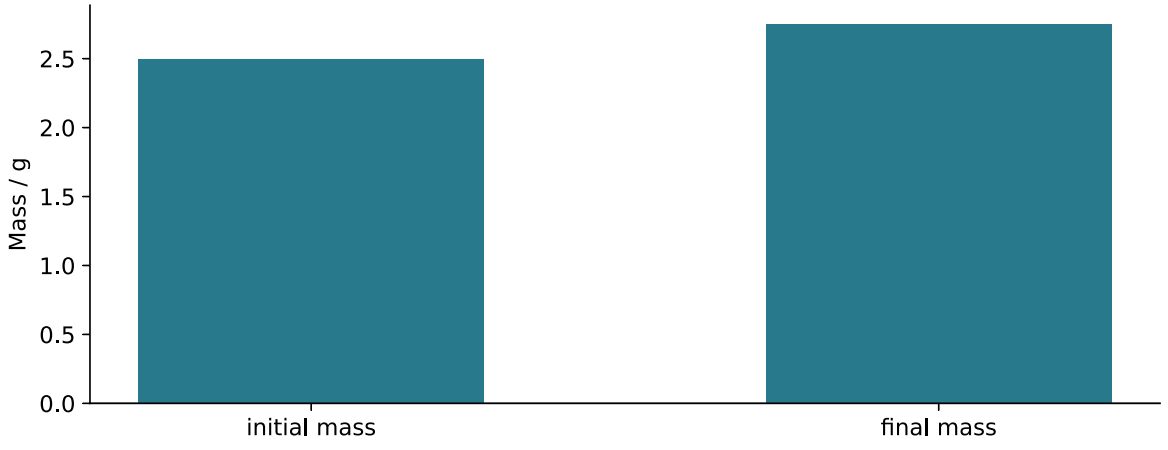
A nucleus is not the only cell structure. Do not claim bacteria have no DNA, or that more magnification always means better resolution.

Osmosis and a fair potato experiment

Official-unit focus: 4.1 Cell biology

A potato cylinder gains mass in one solution and loses mass in another. Its mass change provides evidence about movement of water, rather than movement of potato tissue.

Osmosis is the net movement of water through a partially permeable membrane from a more dilute solution to a more concentrated solution. Dissolved solutes can change the direction of net water movement.



Use percentage change to compare samples with different initial masses. A zero percentage change estimates a solution concentration with no net water movement. This is an estimate from a trend, not proof that water molecules stop moving.

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Use equal-length cylinders from similar tissue, fixed solution volume, temperature and immersion time. Blot each cylinder in the same way before weighing. Repeat each concentration and plot mean percentage change against concentration.

■ Checked worked case

Known: initial mass 2.50 g; final mass 2.75 g. Use percentage change = (final - initial) / initial × 100. Percentage change = (2.75 - 2.50) / 2.50 × 100 = +10%. A positive value means net water entry. Interpolate the concentration where the plotted trend crosses zero.

■ Common error

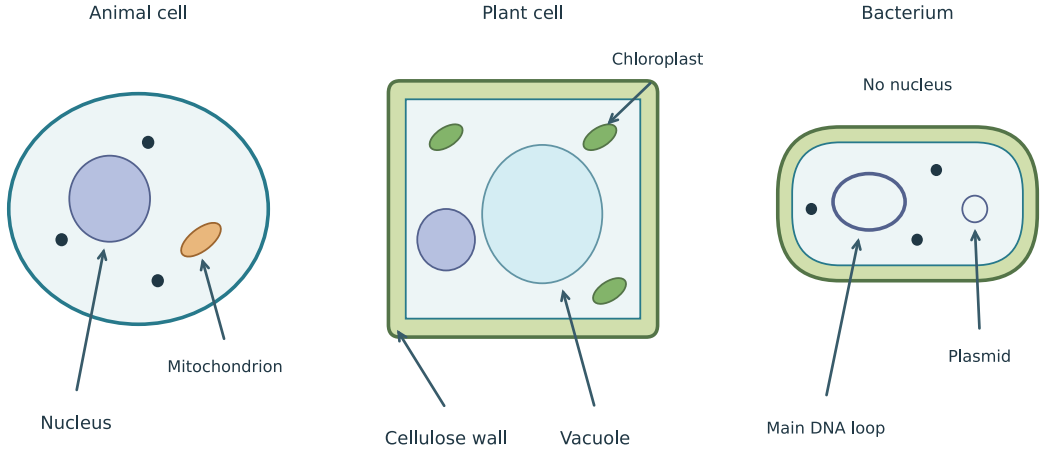
Blotting removes surface solution. Weighing a wet cylinder without blotting adds liquid that did not enter the cells. Repeats reduce random variation but do not correct a miscalibrated balance.

Eukaryotes and prokaryotes: location of genetic material

Official-unit focus: 4.1 Cell biology

A bacterium and a plant cell both contain DNA. Their genetic material is arranged differently, and a bacterium is usually much smaller.

Plant and animal cells are eukaryotic: their genetic material is enclosed in a nucleus. A bacterial cell is prokaryotic and has no nucleus. It contains cytoplasm, a cell membrane and a surrounding cell wall. Its main genetic material is a single DNA loop, and it may also contain small DNA rings called plasmids.



Schematic; sizes not to scale. Dark dots: ribosomes; teal boundary: membrane.

Use structures rather than size alone to identify a cell type. A plant cell has a cellulose cell wall, but a bacterial wall is not made of cellulose. Not every bacterium has a plasmid. A small cell image can be enlarged, so image size cannot by itself show real cell size.

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Inspect teacher-provided labelled images with scale bars. For a size comparison, convert both real dimensions into one unit before dividing. One millimetre is 1,000 micrometres; one micrometre is 1,000 nanometres. State whether the ratio concerns length, area or volume.

■ Checked worked case

Known: a bacterial cell is 2 micrometres long and a plant cell is 40 micrometres long. Length ratio = $40/2 = 20$. In metres these are 2×10^{-6} m and 4×10^{-5} m. The plant cell is twenty times longer in this example, not twenty times larger in every possible measure.

■ Common error

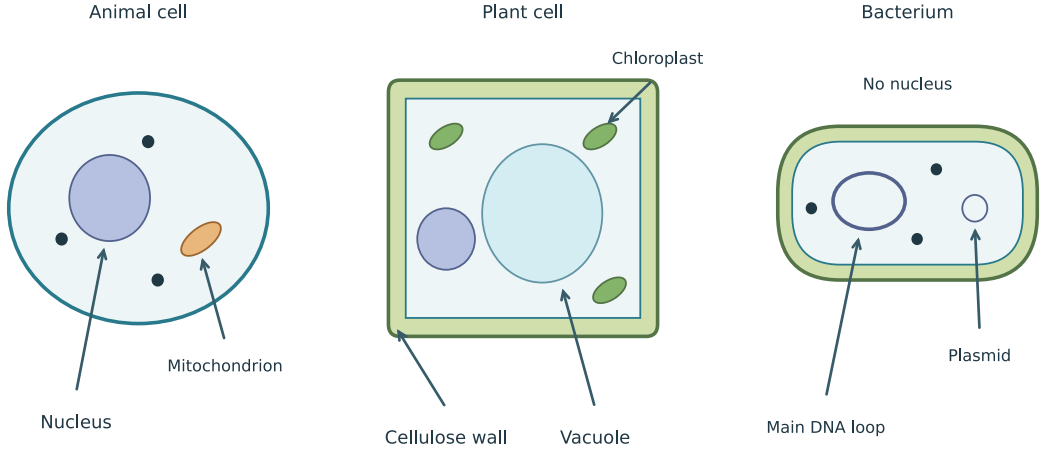
Prokaryotes have DNA even though they lack a nucleus. Magnification changes the displayed size; it does not turn one cell type into another. Order-of-magnitude estimates give a scale comparison rather than a precise identity test.

Cell structures: explain a function for every label

Official-unit focus: 4.1 Cell biology

An onion-storage cell may have no chloroplasts even though it is a plant cell. A useful cell diagram identifies structures present in the particular tissue.

The nucleus contains genetic material controlling cell activities. Cytoplasm is where many chemical reactions occur. The membrane controls movement into and out of the cell. Mitochondria are sites of aerobic respiration, while ribosomes make proteins. Plant cells often also have chloroplasts for photosynthesis and a permanent vacuole containing cell sap. A cellulose cell wall strengthens plant and algal cells.



Schematic; sizes not to scale. Dark dots: ribosomes; teal boundary: membrane.

Link structure to function: chloroplasts contain chlorophyll to absorb light; the vacuole helps support a turgid cell; the membrane is a selective boundary rather than a rigid

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support. Most animal cells have the five named structures, but specialized cells can differ. Not all structures can be resolved clearly with a school light microscope.

For required practical 1, use school-prepared plant and animal material and teacher-approved staining. Start with low power, focus safely, then use higher power with fine focus. Draw what is visible using clear lines and separate labels, record the scale or magnification, and do not invent structures that the image does not show.

■ Checked worked case

Known: a 20 mm drawing represents a cell 0.050 mm long. Magnification = image size/real size = 20/0.050 = 400. A 5 mm scale bar at this magnification represents 5/400 = 0.0125 mm, or 12.5 micrometres. Labelled structure and scale convey different kinds of evidence.

■ Common error

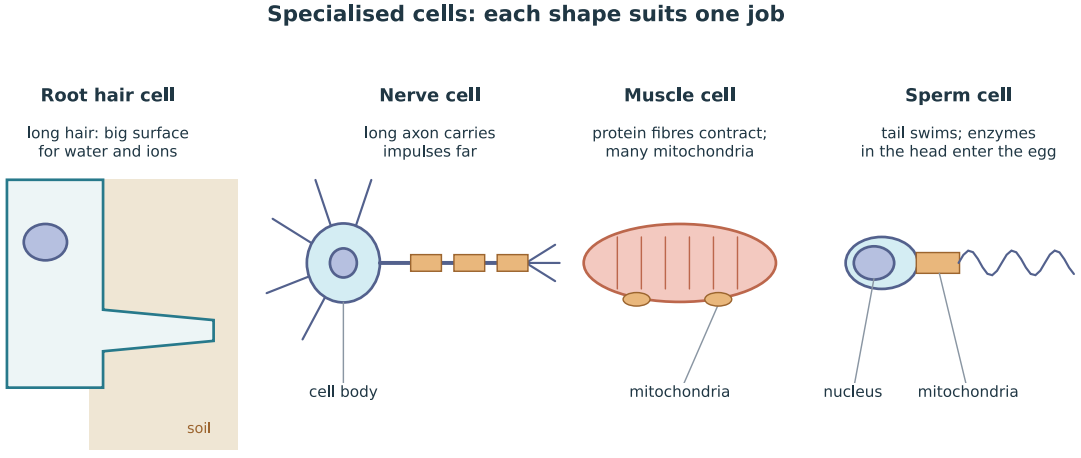
A cell wall is outside the membrane and does not replace it. Root and storage cells need not contain chloroplasts. A nucleus is not responsible for every reaction directly; many reactions occur in the cytoplasm and specialized structures.

Specialized cells: connect a feature to the task

Official-unit focus: 4.1 Cell biology

A long root hair increases contact with soil, while a long nerve cell can carry information over a distance. Shape is useful when its effect on function is explained.

A sperm cell has a tail for movement, mitochondria providing energy through respiration and an acrosome containing enzymes that help entry into an egg. A nerve cell has a long extension carrying impulses and branches connecting with other cells. Muscle cells contain contractile structures and many mitochondria for the energy demand of contraction.



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A root hair cell has a long projection increasing surface area for absorption. Xylem vessels are dead hollow cells joined into tubes, with strengthened lignified walls carrying water and supporting the plant. Phloem transports dissolved sugars through living tissue; its conducting cells work with companion cells. GCSE explanations should link each named feature to its role rather than give an unsupported list.

Compare labelled teacher-provided cell diagrams at stated scales. Use the pattern feature → effect → function. For unfamiliar cells, read the supplied information and reason from it; do not assume every specialized cell has lost its nucleus or contains a tail.

■ Checked worked case

Known: a model root hair has an absorbing surface of 1.8 square units instead of 0.6 for a rounded model cell. The surface ratio is $1.8/0.6 = 3$. This can increase exchange capacity under the same conditions, but transport also depends on concentration, membrane processes and available energy.

■ Common error

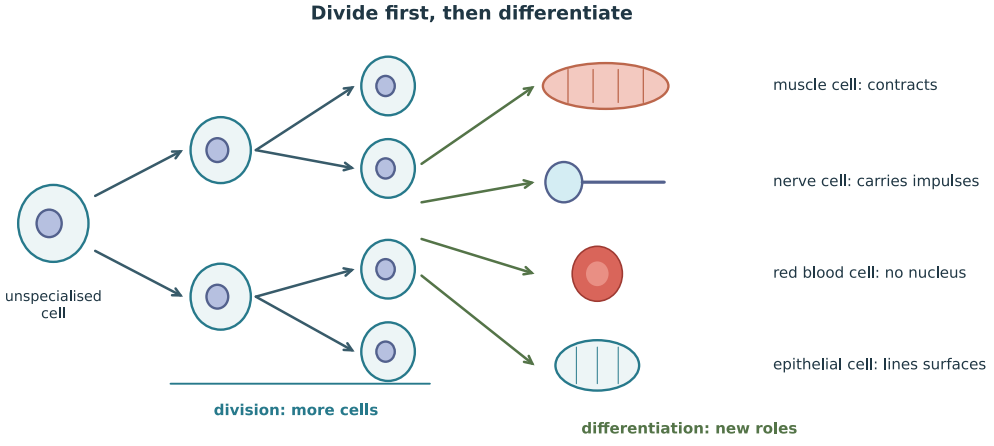
More mitochondria does not mean mitochondria themselves contract or propel the cell. Xylem and phloem are different tissues and do not carry the same substances by the same mechanism. A cell adaptation is explained in the context of its task.

Differentiation: a developing cell gains a particular role

Official-unit focus: 4.1 Cell biology

A developing organism needs cells with different tasks. Producing more cells is not the same as making those cells become specialized.

Differentiation is the process by which a cell becomes specialized. As it develops, the cell acquires particular sub-cellular structures suited to its function. Most types of animal cell differentiate early in development. Many plant cells retain the ability to differentiate throughout life.



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In a mature animal, cell division mainly supports repair and replacement. Differentiation and mitosis have different roles: division increases cell number, while differentiation changes the functional type. Cells in a growing root can continue producing new plant tissues because developing cells can still specialize.

Use a model lineage that distinguishes division arrows from differentiation arrows. Label an undifferentiated starting cell, the increase in number, and the later cell functions. Compare plants and animals without claiming that no adult animal cell can divide or that every adult cell can form every tissue.

■ Checked worked case

Known: one model precursor divides into two, then each divides once more, giving four cells. If two become one tissue type and two another, cell number remains four during the stated specialization step. Four cells were produced by division; the later differences are explained by differentiation.

■ Common error

Differentiation does not mean a cell simply gets larger, and it does not usually mean the cell receives a completely new genome. Mature animal repair still depends on some cells dividing, even though most differentiated cells have restricted roles.

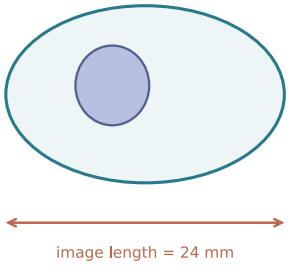
Microscopy: magnification and resolution answer different questions

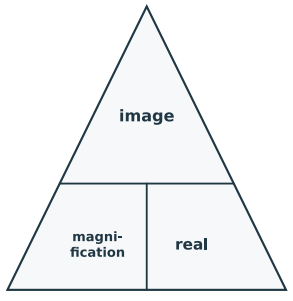
Official-unit focus: 4.1 Cell biology

Enlarging a blurred photograph gives a larger blur. A microscope must distinguish close structures as well as make the image larger.

Magnification is image size divided by real size. Resolution is the ability to distinguish two close points as separate. Electron microscopes have much higher magnification and resolving power than light microscopes, allowing finer cell structures to be investigated. This development increased biological understanding of sub-cellular detail.

Magnification = image size ÷ real size





real = image ÷ magnification

= 24 mm ÷ 6000

= 0.004 mm

= 4 µm (× 1000)

cover the one you want: the other two show how to work it out

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Choose the relation for the unknown: real size = image size/magnification, and image size = real size×magnification. Convert to the same length unit first. A stated scale bar continues to describe the particular image even if the displayed image is resized, provided the bar is resized with it.

Measure the image and its scale bar rather than assuming the screen magnification is a printed original value. Include units and use sensible precision. Compare a light and electron image for actual resolved detail; do not assume a darker or more colourful picture necessarily resolves more.

■ Checked worked case

Known: a structure measures 24 mm on an image magnified 6,000 times. Real size = 24/6,000 = 0.004 mm = 4 micrometres = 4×10^{-6} m. The division is valid because magnification is a dimensionless length ratio. Area would scale with the square of the length magnification.

■ Common error

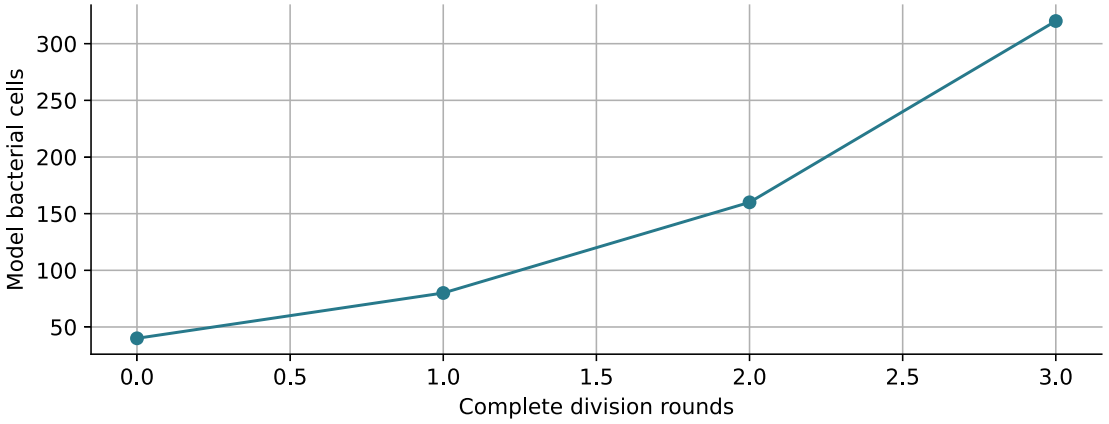
Resolution and magnification are not synonyms. A larger screen image does not change the real cell size. Misusing millimetres and micrometres gives a thousandfold error even if the calculator division is otherwise correct.

Culturing microorganisms: growth and contamination are separate

Official-unit focus: 4.1 Cell biology

An extra organism on an agar plate can change a test result. Aseptic technique reduces contamination so the effect of the tested substance can be interpreted.

Bacteria divide by binary fission. With enough nutrients and suitable temperature, some can divide every twenty minutes, but a supplied mean division time should be used for a particular calculation. They can grow in nutrient broth or form colonies on agar. An uncontaminated culture is needed to compare antibiotic or disinfectant effects.



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Sterilized dishes and media reduce unwanted microorganisms. Sterilizing an inoculating loop prevents it transferring contaminants. The lid is secured with small pieces of tape rather than sealed all around; the plate is stored upside down to reduce condensation falling onto the agar. School cultures are generally incubated at 25 °C to reduce the chance of growing harmful human pathogens.

Use only the school's approved non-pathogenic organism, apparatus and supervised protocol. Students explain the aseptic controls and record labelled plate observations; staff manage approved sterilization and disposal. Do not reopen incubated cultures. Keep organism, medium, temperature and exposure time the same in comparisons.

■ Checked worked case

Known: a model starts with 40 bacteria and has a mean division time of 30 min. After 90 min there are three complete divisions. Population = $40 \times 2^3 = 320$. This ideal model assumes every cell divides on schedule without death or nutrient limitation. In this specification, expressing this culture-growth result in standard form is a Higher-tier extension.

■ Common error

Twenty minutes is not a universal division time. An apparently clear plate is not proof of sterility, and a contaminated culture cannot be made a fair comparison by ignoring the extra colonies. Practical precautions protect people and the validity of the evidence.

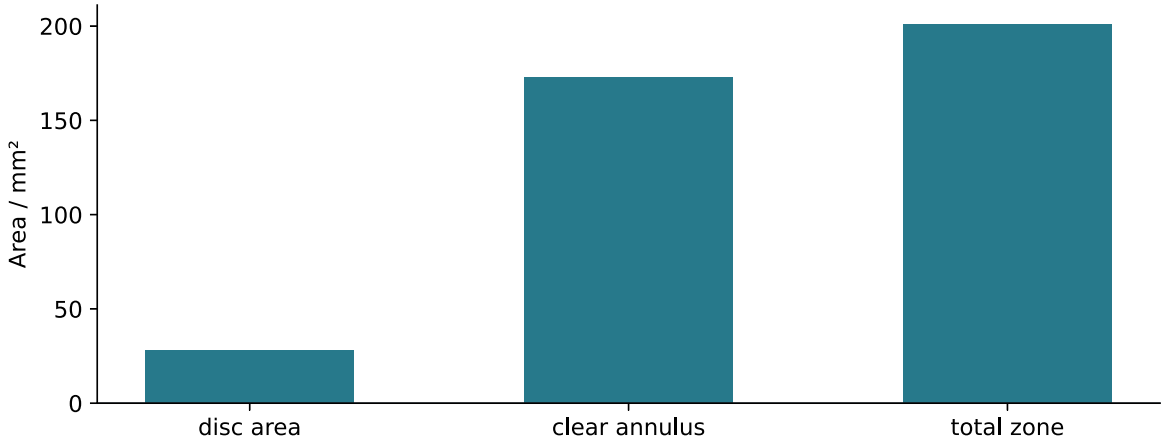
Zones of inhibition: measure radius and control the comparison

Official-unit focus: 4.1 Cell biology

A clear circle around a treated disc indicates inhibited growth in that plate. Comparing circle diameters is useful only if the culture and treatment conditions are matched.

An inhibition zone is an area where growth has been prevented or reduced around an applied substance. Its size can reflect the effect on the approved bacterium, but also diffusion through the agar and the dose used. Required practical 2 compares antiseptics or antibiotics using agar plates and measurements of these zones.

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For a circular region, area = πr^2. Radius is half the diameter. State whether the reported area includes the disc or subtracts its area: use the same convention for every treatment. A bigger zone does not on its own prove that the substance will treat a particular infection in a person.

Under the school's supervised microbiological protocol, use equal discs and applied amounts, the same approved organism and agar, matched incubation and a suitable control disc. Keep culture plates closed after incubation. Record repeated diameters through the centre if a zone is not perfectly circular, and explain the approximation.

■ Checked worked case

Known: a zone diameter is 16 mm, giving radius 8 mm. Total circular area = $\pi \times 8^2$ = 64π, approximately 201 mm^2. If the disc diameter is 6 mm, its area is 9π, and the clear annulus is 55π, approximately 173 mm^2. The answer depends on the stated area convention.

■ Common error

Do not put the diameter directly into πr^2. Matched incubation and a control are necessary for interpreting inhibition, and changing both substance and concentration prevents attributing the difference to one variable.

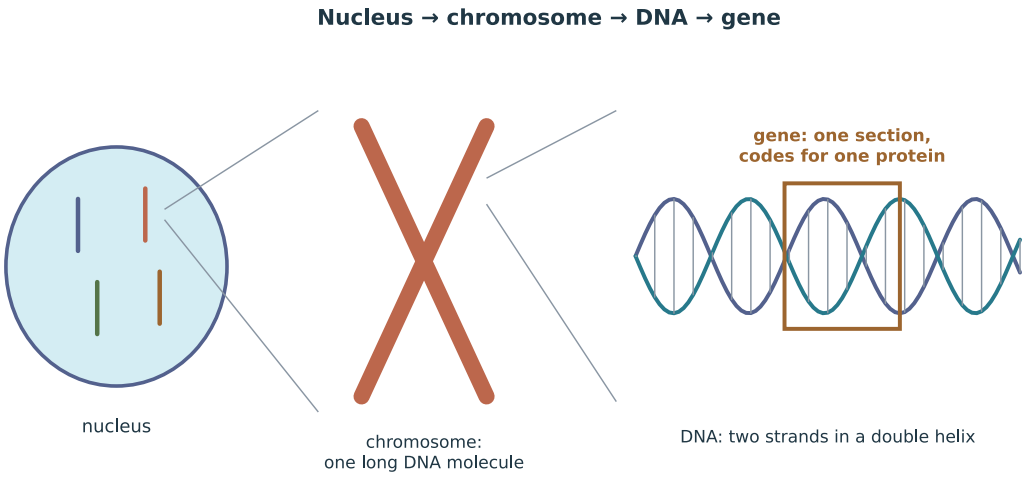
Chromosomes, genes and DNA: keep the levels distinct

Official-unit focus: 4.1 Cell biology

A chromosome is not one gene. A single chromosome carries many genes along its DNA molecule, and body cells normally contain chromosomes in pairs.

The nucleus contains chromosomes made of DNA molecules. A gene is a section of DNA, and each chromosome carries a large number of genes. Chromosome pairs contain corresponding types of genetic information; they are not two halves joined merely because the cell is large.

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Keep three levels separate: DNA is the chemical genetic material, a chromosome is an organized DNA-containing structure, and a gene is a section of DNA. A replicated chromosome has copied genetic material ready for division. Replication and the later distribution into daughter cells have different effects.

Use a labelled chromosome model and a short DNA segment. Identify the chromosome pair and mark several gene positions on each model rather than labelling an entire chromosome as a single gene. For counting exercises, state whether chromosomes are being counted in a body cell, a gamete or a daughter cell.

■ Checked worked case

Known: a model body cell has 12 chromosomes, organized as six pairs. The number of pairs is 12/2=6. After mitosis, each daughter cell normally has the same chromosome number, 12, rather than six. The halving associated with gamete production belongs to meiosis, studied separately.

■ Common error

DNA, gene and chromosome are not interchangeable terms. A chromosome count alone does not tell how many genes an organism has. Copying DNA before mitosis is not the same as permanently doubling the chromosome number of each daughter cell.

The cell cycle: prepare, divide the nucleus, divide the cell

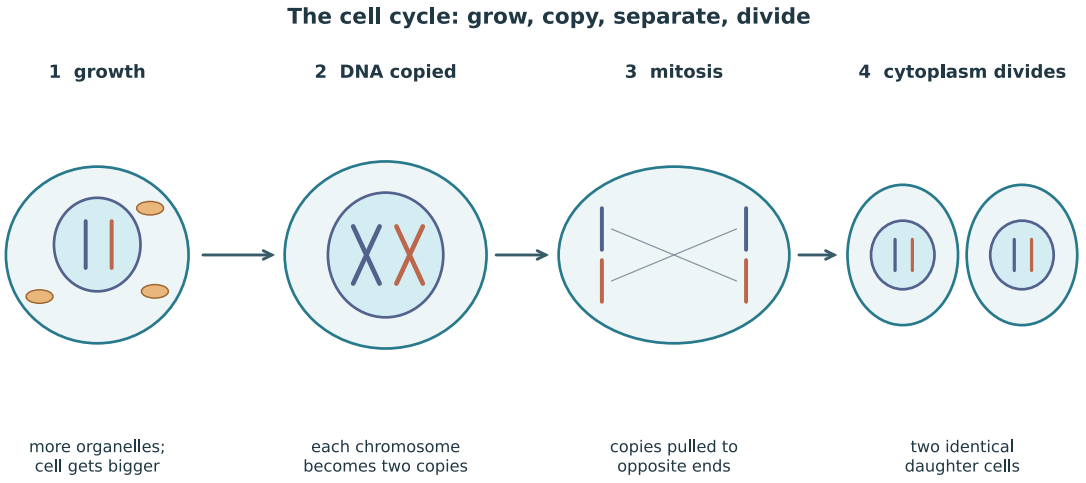
Official-unit focus: 4.1 Cell biology

A cell must copy genetic material before distributing it to two daughter cells. Growth alone cannot provide each daughter with a complete genetic set.

Before division, a cell grows and increases its sub-cellular structures, including ribosomes and mitochondria. Its DNA replicates to give two copies of each chromosome.

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During mitosis, one set is pulled to each end and the nucleus divides. Finally, cytoplasm and cell membranes divide, forming two genetically identical daughter cells under the normal model.



Use three overall stages: growth and DNA copying, mitosis, then cell division. AQA does not require the named phases within mitosis at this point. Mitosis supports growth and development in multicellular organisms and repair or replacement in mature animals; it does not produce genetically varied haploid gametes.

Observe school-prepared dividing-tissue images or use chromosome-copy models. Trace one copied chromosome through nuclear division and into each daughter. Identify whether an example describes more cells, specialized cell functions or gamete formation before naming its process.

■ Checked worked case

Known: a model cell has eight chromosomes before DNA replication. The copied genetic material is shared through mitosis so each daughter normally has eight chromosomes. If one starting cell completes four successive ideal division rounds with no loss, cell number is $2^4=16$. Each cell still has the model chromosome number eight.

■ Common error

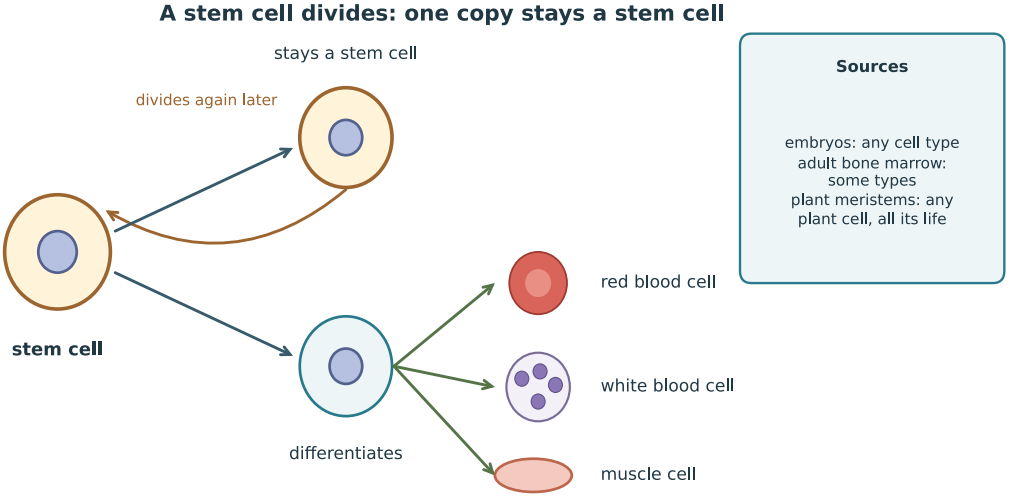
Mitosis divides a nucleus; the complete cell cycle includes preparation and division of the cell. “Identical” concerns the normal copied genetic information in this model, not a claim that every cell is physically the same size at every moment.

Stem cells: compare potential, matching and ethical choices

Official-unit focus: 4.1 Cell biology

A cell that can divide and specialize may help replace damaged tissue. The possible benefit depends on which cell types it can produce and on evidence about risks.

A stem cell is undifferentiated and can produce more stem cells and some differentiated cells. Human embryonic stem cells can differentiate into most human cell types. Adult bone-marrow stem cells can form several cell types, including blood cells. Plant meristems can form any plant cell type throughout life.



Therapeutic cloning produces an embryo with the patient's genes, so its stem cells offer a genetic match and reduced rejection in the specification's model. Potential applications include conditions such as diabetes or paralysis. These are potential benefits, not guaranteed cures. Viral transfer and ethical or religious objections must be considered with the evidence.

Evaluate a supplied fictional research proposal using benefit, evidence, risk and value judgement as separate headings. AQA does not require laboratory stem-cell techniques. For plants, compare rapid economical production of genetically identical disease-resistant crops with conserving rare plants and retaining genetic diversity.

■ Checked worked case

Known: an approved model nursery starts with five identical plant clones and each produces four new clones. New clones = 5×4=20. If the originals remain, total plants =25. The number increases, but cloning alone does not add genetic variety; a shared susceptibility could affect the whole group.

■ Common error

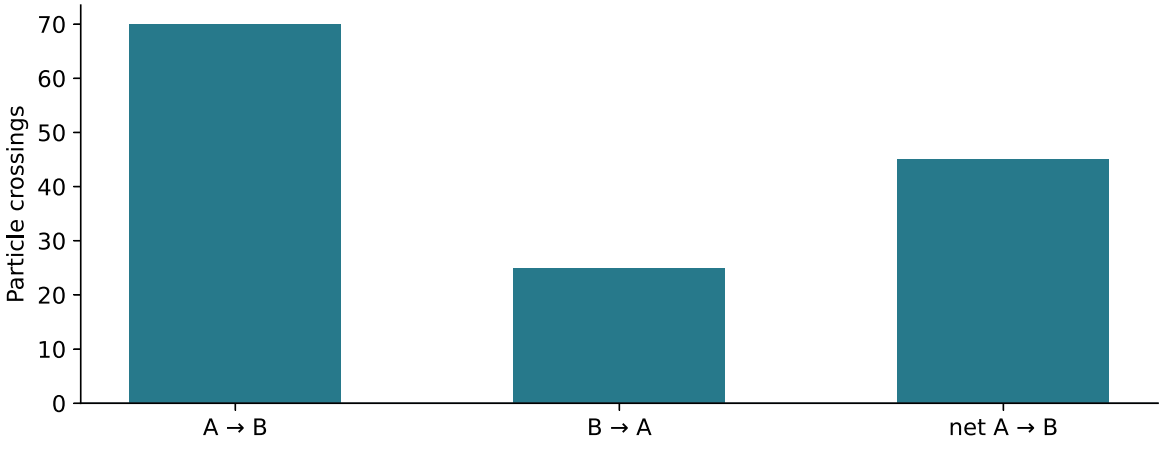
Adult bone-marrow stem cells are not assumed to form every body cell type. Genetic matching does not remove every medical risk. Cloning a rare species can increase its number, while habitat protection and genetic diversity still require attention.

Diffusion: random motion can give directional net transfer

Official-unit focus: 4.1 Cell biology

Oxygen enters a respiring cell while carbon dioxide can leave it. The direction of net diffusion depends on the concentration difference for each substance.

Diffusion is the spreading of particles in a solution or gas, giving net movement from higher concentration to lower concentration. Oxygen and carbon dioxide diffuse during gas exchange. Urea can diffuse from cells into blood plasma before excretion. Particles move in both directions, while the concentration difference determines the net result.



A larger concentration difference produces a greater net diffusion rate under comparable conditions. Higher temperature increases particle motion, and a larger membrane surface area allows more transfer at once. A thinner exchange surface provides a shorter route, as developed in the exchange-surface case.

Use a teacher-approved model or provided concentration data. State which substance is being tracked, identify its high and low concentration sides, and keep temperature, exposed area and time consistent when comparing one variable. Do not treat a coloured model substance as a direct measurement of every gas or solute.

■ Checked worked case

Known: in a model interval, 70 particles cross from A to B and 25 from B to A. Net transfer A→B $=70-25=45$ particles. If both directions later show 40 crossings, net transfer is zero, although 80 crossings occurred. This illustrates why zero net movement does not mean molecules stop moving.

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■ Common error

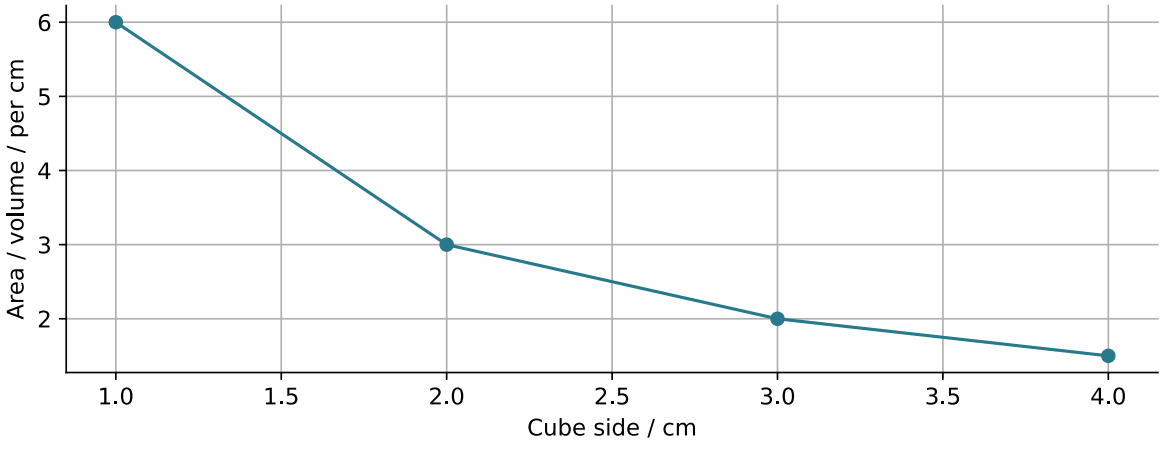
Diffusion does not require respiration to supply energy for the particles' net movement. A concentration gradient is specific to a substance; oxygen and carbon dioxide can have opposite gradients across the same surface.

Exchange surfaces: small size and thin barriers matter

Official-unit focus: 4.1 Cell biology

A large animal cannot rely on diffusion through its outer surface to supply every cell quickly. Size changes the area available relative to the volume needing materials.

A single-celled organism has a relatively large surface-area-to-volume ratio, allowing enough transport across its surface. Larger multicellular organisms need specialized exchange surfaces and transport systems. Large area, thin membranes, efficient blood supply and ventilation improve exchange when relevant to the organ.



Villi give the small intestine a large absorbing area. Lungs have many alveoli with thin surfaces, a blood supply and ventilation. Fish gills provide a large exchange surface supplied with blood. Root hairs increase plant absorbing area, while leaves provide a large gas-exchange surface and short paths through their tissues.

Compare cubes or labelled organ models using the same units. For a cube of side L, area=$6L^2$ and volume=L^3. Link each organ feature to how it increases transfer or maintains a concentration difference; do not simply list "large area" without naming the structure.

■ Checked worked case

Known: a cube of side 1 cm has area 6 cm^2, volume 1 cm^3 and ratio 6:1. At side 2 cm, area=24 cm^2 and volume=8 cm^3, giving 3:1. Length doubles, but area grows fourfold and volume eightfold. Less surface per unit volume helps explain the need for internal exchange systems.

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■ Common error

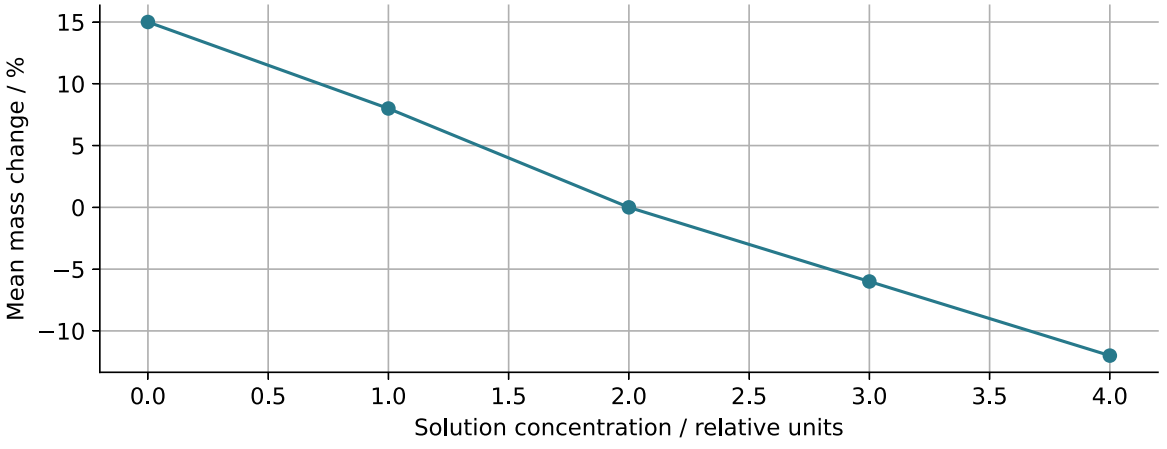
A bigger object has more total surface area but can have less surface per unit volume. Blood flow and ventilation maintain gradients rather than make molecules choose a direction. Plant roots and leaves do not use animal blood vessels.

Osmosis: mass changes and rates use different denominators

Official-unit focus: 4.1 Cell biology

Two plant samples can gain the same mass but show different percentage changes. Starting mass and exposure time both matter when comparing uptake.

Osmosis is net movement of water from a dilute solution to a more concentrated solution through a partially permeable membrane. Plant tissue can gain water in a more dilute surrounding solution and lose water in a more concentrated one. A zero net change suggests balanced water exchange under the measured conditions.



Percentage change = (final−initial)/initial×100. Mean water-uptake rate compares an estimated water amount with elapsed time. These are different quantities: percentage change adjusts for starting mass, while a rate describes change per unit time. Plot a concentration series and estimate where the trend crosses zero rather than expecting every individual repeat to lie on one line.

For required practical 3, use repeated equal-size pieces from comparable tissue in teacher-approved sugar or salt solutions. Keep solution volume, temperature and duration fixed; blot consistently before weighing. Record all raw masses and units. A range of concentrations allows a meaningful zero-change estimate and a check for anomalies.

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■ Checked worked case

Known: initial mass 3.00 g and final mass 3.30 g after 40 min. Gain=0.30 g. Percentage gain=0.30/3.00×100=10%. Mean gain rate=0.30/40=0.0075 g/min under the model that the mass change represents water. The two answers have different meanings and units.

■ Common error

Surface liquid adds mass without entering the cells, so blotting is essential. A negative percentage indicates loss. An estimated zero-change concentration does not mean water molecules stop moving or that every cell is undamaged and identical.

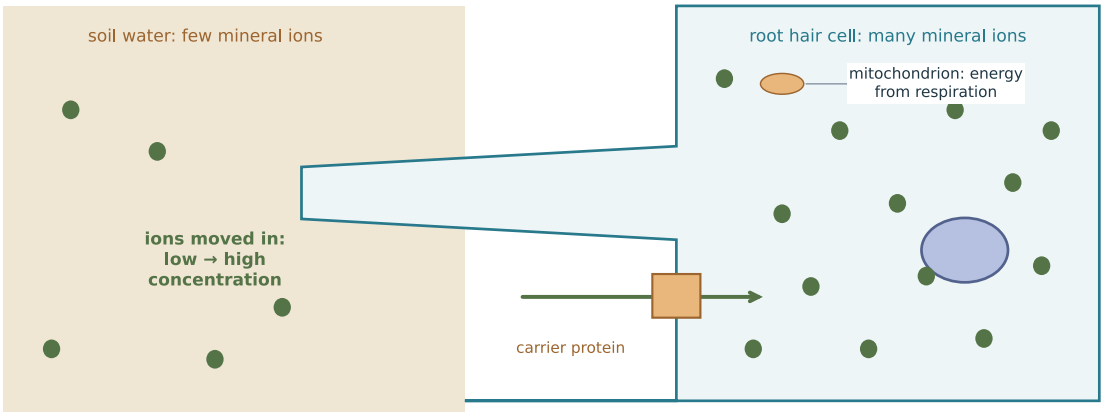
Active transport: uptake against the gradient needs energy

Official-unit focus: 4.1 Cell biology

A root can absorb mineral ions even when their concentration is lower in soil solution than inside its cells. Net diffusion alone would not explain this uptake.

Active transport moves substances from a more dilute region to a more concentrated one, against their concentration gradient. It requires energy from respiration. Root hair cells use it to absorb mineral ions needed for healthy growth from dilute soil solution. Sugar can also be absorbed from a lower concentration in the gut into blood with a higher sugar concentration.

Active transport: against the concentration gradient



Compare three processes. Diffusion gives net movement of particles down their gradient. Osmosis concerns water crossing a partially permeable membrane from dilute toward more concentrated solution. Active transport can move selected solutes against their gradient using respiratory energy. The same membrane can support more than one process for different substances.

Interpret a provided concentration diagram: label the substance and both concentra-

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tions before choosing the process. Use school-approved plant observations or model data to examine the effect of conditions limiting respiration. Control tissue condition and time; reduced uptake may have several causes and does not alone reveal a complete transport mechanism.

■ Checked worked case

Known: a model uptake observation transfers 0.24 milligrams of a mineral ion in 12 min. Mean uptake rate =0.24/12=0.020 mg/min. If uptake is into a cell already at higher mineral-ion concentration, its direction supports an active-transport explanation. Rate alone does not identify whether the gradient is favourable or unfavourable.

■ Common error

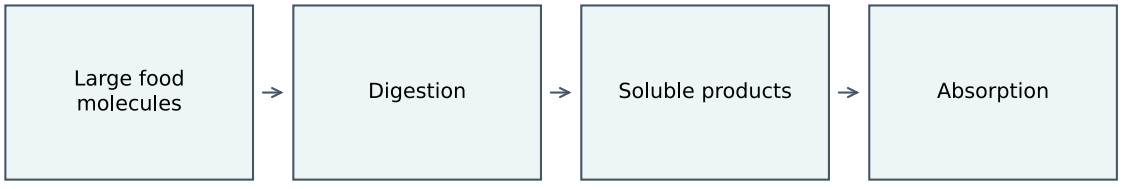
"Active" does not mean faster under every condition. Energy comes from respiration, not from the mineral ion automatically being nutritious. Water movement by osmosis is not defined as active transport of water against a gradient.

Digestion, transport and health evidence

Official-unit focus: 4.2 Organisation

Two foods can have the same mass but provide different nutrients. A health claim must distinguish the nutrient measured from the health outcome inferred.

Large insoluble food molecules are digested into smaller soluble molecules. Carbohydrases form sugars, proteases form amino acids, and lipases form fatty acids and glycerol. Bile emulsifies lipids and helps neutralize acidic stomach contents.



Absorption moves soluble products into blood or lymph. Thin exchange surfaces and a large surface area shorten diffusion paths and increase transfer. Enzyme activity and transport are different processes.

Use Benedict reagent with controlled heating for reducing sugars, iodine for starch, Biuret reagent for protein, and the ethanol emulsion test for lipids. Keep ethanol away

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from flames. Use positive and negative controls.

Checked worked case

Known: 6 of 24 study participants report a condition. Proportion = cases / total. Percentage = $6/24 \times 100 = 25\%$. The percentage describes this sample. It does not establish that one food caused the condition; confounders and how the sample was chosen matter.

Common error

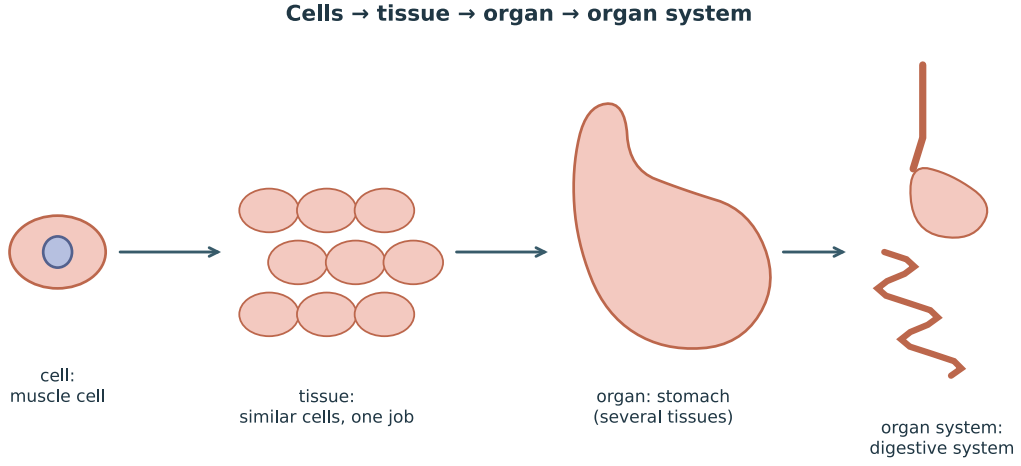
Bile is not an enzyme. A positive food test identifies a component under the test conditions; it does not show that a food is healthy or unhealthy in every diet.

Organisation: several tissues can form one organ

Official-unit focus: 4.2 Organisation

The stomach contains several tissue types working together. Calling it a tissue misses the way its different parts cooperate.

Cells are the basic building blocks of living organisms. A tissue is a group of cells with similar structure and function. An organ contains different tissues performing a specific function. Organs work together in organ systems, and those systems cooperate in the whole organism.



In the digestive system, organs including the stomach and small intestine work together to digest and absorb food. Within an organ, muscle tissue can move contents while glandular tissue releases substances. A list of levels becomes an explanation when each example is placed at the correct level.

Use a provided organ description to classify its components. Compare the scale of a cell image with an organ image using their own scale bars; do not compare raw displayed widths. Build a chain using the same organism and explain the role of each

level.

Checked worked case

Known: a model cell is 0.02 mm wide, while a tissue strip is 2 mm wide. Length ratio =2/0.02=100. This is a scale comparison, not a claim that the tissue contains exactly 100 cells: their arrangement and third dimension have not been specified.

Common error

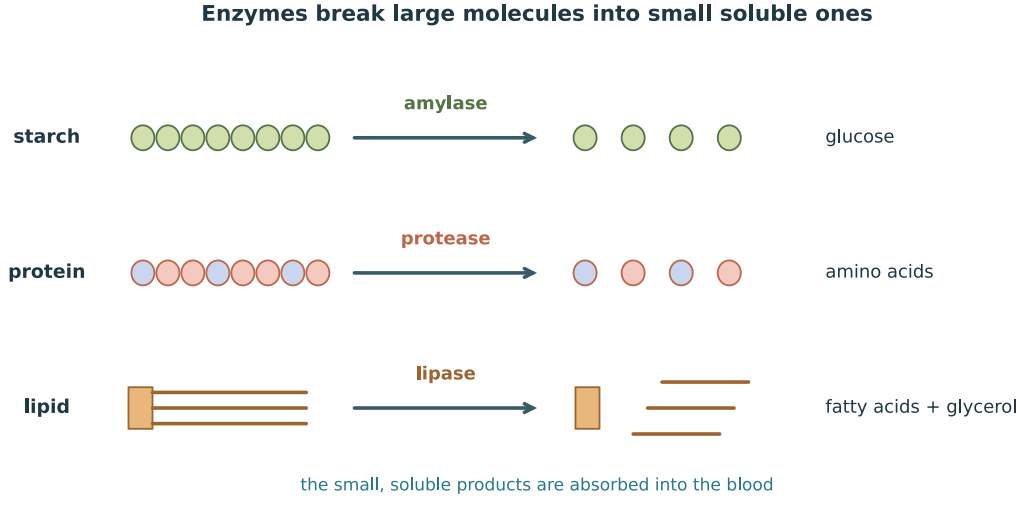
An organ is not necessarily made from one tissue type. A named blood vessel is an organ structure, while blood is a tissue. Real organ boundaries and cooperating systems can overlap in function without changing the meaning of the hierarchy.

Digestion: make soluble products, then absorb them

Official-unit focus: 4.2 Organisation

Chewing makes food pieces smaller, but digestive enzymes change large food molecules into soluble products. Mechanical breakdown and chemical digestion have different effects.

The mouth, oesophagus, stomach and intestines form a digestive pathway. Amylase from salivary glands, pancreas and small intestine breaks starch into sugars. Proteases produced in stomach, pancreas and small intestine digest proteins into amino acids. Lipases from pancreas and small intestine break lipids into glycerol and fatty acids. Small soluble products can be absorbed, mainly through the small intestine.



Bile is made in the liver and stored in the gall bladder. Its alkaline character helps neutralize stomach acid entering the small intestine. It emulsifies fat into small droplets, increasing surface area for lipase. Bile is not an enzyme. Digestion products can build new carbohydrates, proteins and lipids, and some glucose is used in respiration.

Trace one food molecule from a digestive site through a named enzyme to its products,

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then to absorption and use. Use simple word equations at GCSE: protein → amino acids, and lipid → glycerol + fatty acids. AQA does not require chemical symbol equations for these digestion reactions.

■ Checked worked case

Known: a model contains 12 identical fat droplets that are divided into 48 smaller droplets while total fat amount stays the same. Droplet count rises fourfold. The increased exposed area can increase lipase action under matched conditions, but counting droplets alone cannot calculate their total area without size information.

■ Common error

Absorption does not mean breaking the food molecule down. Bile helps lipase but does not itself digest lipid. The stomach is not the main site where every nutrient is absorbed, and digested food does not travel through the trachea.

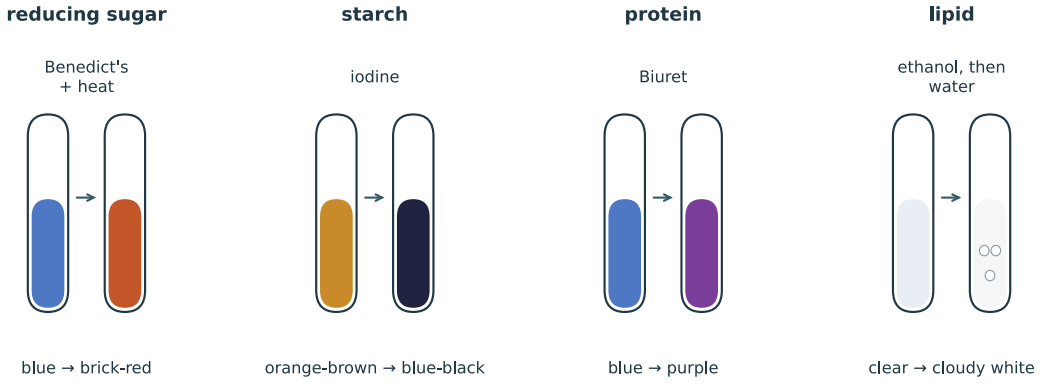
Food tests: identify the tested group and the observation

Official-unit focus: 4.2 Organisation

A colour change supports a particular chemical test result. It does not identify every nutrient in the sample or measure its full nutritional value.

Benedict's reagent, heated with a sample in an approved water bath, tests for reducing sugars: a positive result changes from blue toward green, yellow, orange or brick-red depending on conditions. Iodine solution changes from orange-brown to blue-black with starch. Biuret reagent changes from blue to purple with protein. A school-approved ethanol emulsion test gives a cloudy white emulsion when lipid is present.

Food tests: the colour change shows the nutrient



Keep the test and result paired. A negative iodine observation does not show that all carbohydrates are absent, because the test concerns starch. Qualitative colour observations can indicate presence under the test conditions; a precise concentration

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requires calibration and controlled measurements.

For required practical 4, prepare comparable sample extracts and use positive and negative controls. Use the school's approved reagents and volumes, eye protection and supervised heating. Keep ethanol away from flames. Use separate clean apparatus for tests so contamination does not transfer a positive result between samples.

■ Checked worked case

Known: four model samples each undergo the iodine test; three turn blue-black and one remains orange-brown. The observed fraction positive is 3/4=75%. This describes the tested samples, not the starch concentration or the percentage of starch in each food.

■ Common error

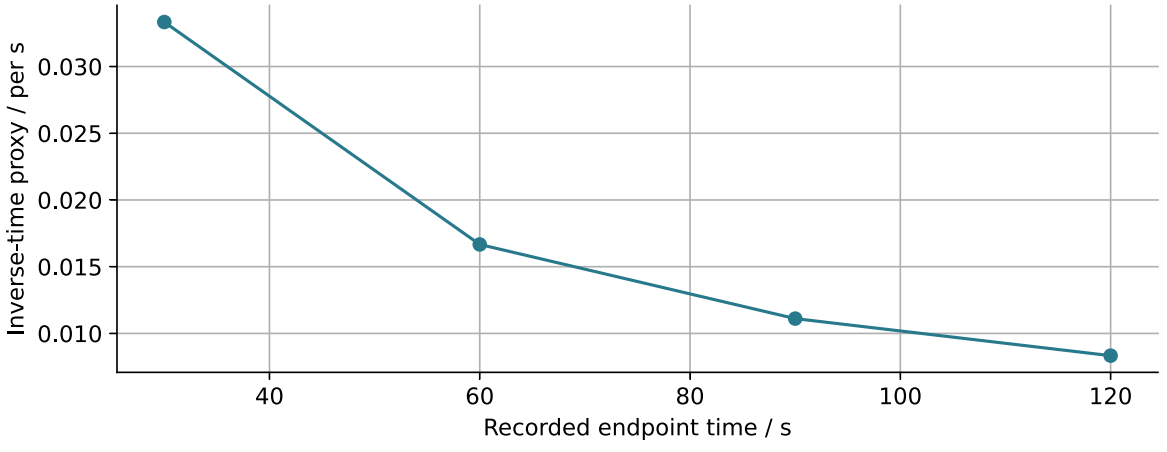
Heating is part of Benedict's test, not a reason to heat every reagent in the same way. A colour chart without matched time, temperature and amounts is not an exact sugar assay. A food can contain several tested groups at once.

Amylase and pH: define the endpoint before comparing rates

Official-unit focus: 4.2 Organisation

An amylase sample can digest starch quickly at one pH and slowly at another. A fair comparison needs the same starting amounts and a common endpoint.

Enzymes are protein molecules catalysing specific reactions in living organisms. The active site has a shape suited to the substrate; the lock-and-key model is a simplified explanation. Temperature and pH affect activity. Excessive heat or unsuitable pH can change the active site, reducing binding and catalysis.



Amylase breaks starch into sugars. In an iodine sampling method, the endpoint is reached when a sample no longer turns iodine blue-black. With a fixed starting amount and endpoint, 1/time gives a comparative rate proxy. This proxy is not an independently measured amount of product per second.

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For required practical 5, use buffers to set a range of pH values, equilibrate amylase and starch in a controlled water bath, and keep concentrations and volumes the same. After mixing, sample into fresh iodine spots every 30 s. Do not add iodine to the main reaction. Repeat and record the last positive and first negative sampling times.

■ Checked worked case

Known: the last positive iodine observation is at 60 s and the first negative at 90 s. The endpoint lies between them, so using 90 s gives a rate proxy of $1/90 = 0.0111$ per second with a sampling limitation. Sampling every 15 s could locate the endpoint more closely without pretending to remove all other uncertainty.

■ Common error

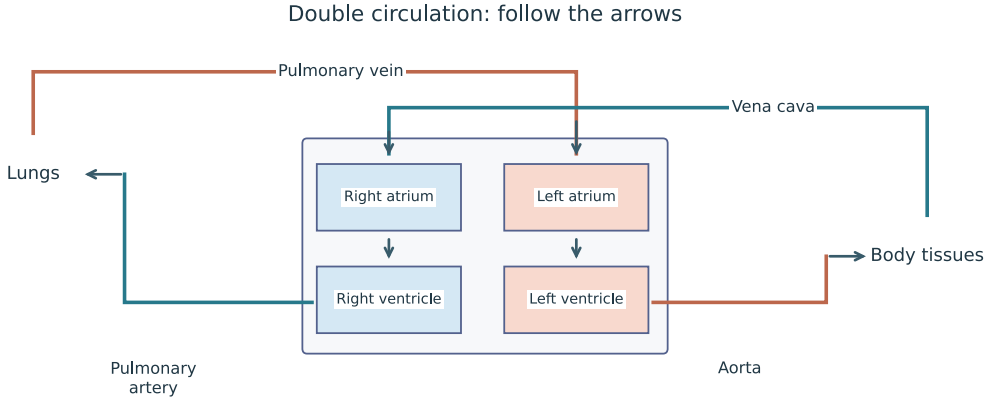
Low temperature usually slows activity rather than permanently denaturing the enzyme. A buffer controls pH, not temperature. An optimum observed with this amylase and setup cannot be assumed for every enzyme or every biological condition.

Double circulation: the heart pumps to lungs and body

Official-unit focus: 4.2 Organisation

Blood passes through the heart twice on one complete circuit through lungs and body. The two pumps serve different destinations.

The right ventricle pumps blood through the pulmonary artery to the lungs. Blood returns in the pulmonary vein, enters the left side of the heart and is pumped by the left ventricle into the aorta to the body. Blood returns through the vena cava to the right side. Coronary arteries supply the heart muscle itself. Valves prevent backflow; valve names are not required here.



Arteries leave the heart; veins return to it. Valves prevent backflow.

Blue: lower oxygen content Orange: higher oxygen content (schematic)

Air moves through trachea and bronchi to alveoli. Many alveoli provide a large area; thin walls, nearby capillaries and ventilation support gas exchange. Blood flow main-

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tains concentration differences for oxygen entering blood and carbon dioxide leaving it. The natural resting rate is controlled by pacemaker cells in the right atrium; an artificial electrical pacemaker can correct some rhythm irregularities.

Trace a labelled circulation model without confusing anatomical left/right with the viewer's sides. Mark destination and oxygen status separately: an artery carries blood away from the heart, and its name does not guarantee high oxygen content. Use provided flow data rather than personal diagnosis.

■ Checked worked case

Known: a model heart moves 4,800 cm^3 blood in 60 s. Mean flow=4,800/60=80 cm^3/s. A second observation of 6,000 cm^3 in 60 s gives 100 cm^3/s. This compares volume per time; it does not by itself separate the effects of beat frequency and volume per beat.

■ Common error

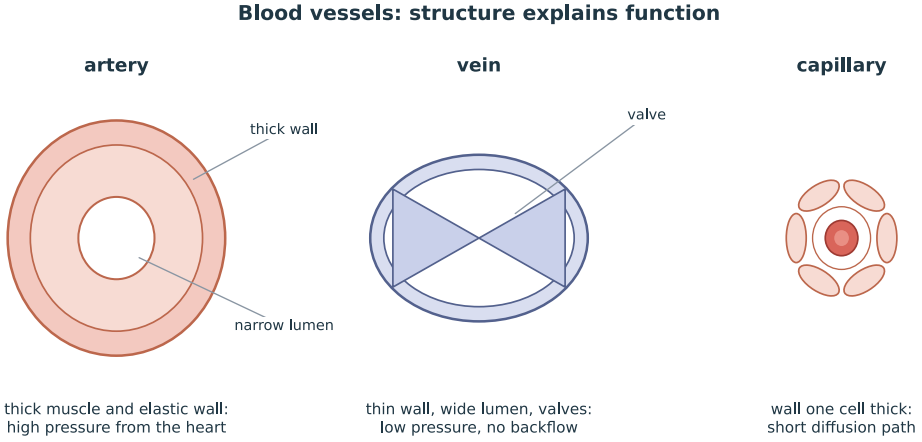
The pulmonary artery carries blood toward the lungs and has lower oxygen content than the pulmonary vein. Coronary arteries are not the route carrying all blood into the heart chambers. An artificial pacemaker concerns electrical rhythm, not removal of every artery blockage.

Blood vessels: structure fits pressure and exchange

Official-unit focus: 4.2 Organisation

A vessel supplying tissue under high pressure has a different structure from a vessel where exchange with cells occurs.

Arteries carry blood away from the heart and have thick muscular, elastic walls suited to higher pressure. Veins return blood toward the heart at lower pressure; they generally have a larger lumen and valves helping prevent backflow. Capillaries have very thin walls, allowing a short diffusion path between blood and tissues.



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Use structure → effect → function. A capillary wall only one cell thick reduces diffusion distance. Arterial muscle and elastic tissue cope with and modify blood flow under pressure. Venous valves aid one-way flow, particularly when pressure is low. Direction defines artery versus vein, while exchange defines the key capillary role.

Compare provided transverse vessel diagrams using their own scale information. Identify wall thickness and lumen, and distinguish a section image from the direction of flow. A collapsed specimen or schematic drawing should not be treated as a precise pressure measurement.

■ Checked worked case

Known: in a fictional diagram an artery lumen radius is 1 mm and a vein lumen radius is 2 mm. Circular areas are π and 4π mm^2, giving area ratio 4. Doubling radius gives four times the area; it does not alone specify actual flow or pressure because those depend on further conditions.

■ Common error

A vein does not necessarily carry oxygen-poor blood: the pulmonary vein returns oxygen-rich blood. Large lumen area is not by itself evidence that a vessel's flow rate is greater. Capillaries are small exchange vessels, not tiny versions with all arterial wall layers.

Blood: a tissue with several transport and defence roles

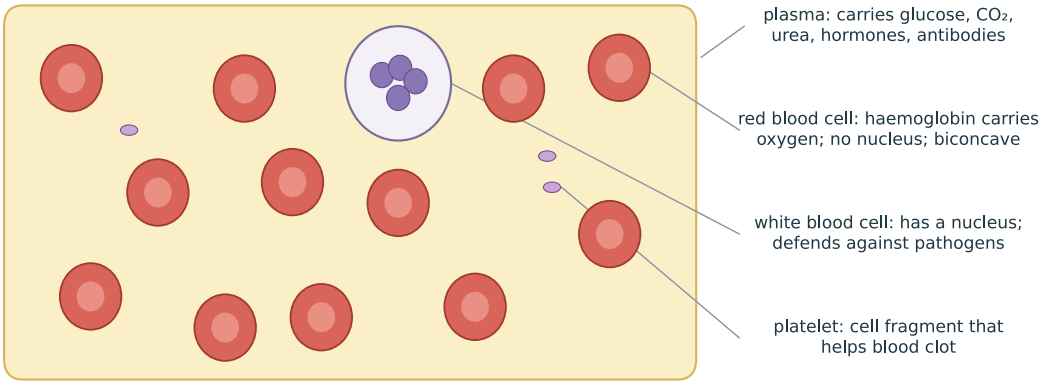
Official-unit focus: 4.2 Organisation

A blood image contains several components, not one cell type. Plasma transports dissolved substances while suspended components perform different tasks.

Blood consists of plasma with red blood cells, white blood cells and platelets suspended in it. Plasma transports dissolved substances such as carbon dioxide, urea and absorbed nutrients, and distributes heat. Red blood cells carry oxygen using haemoglobin; their biconcave shape increases area, and mature human red cells lack a nucleus, leaving space for haemoglobin. White cells support defence, while platelets contribute to clotting.

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Blood: plasma carries the cells and dissolved substances



A red-cell adaptation explains oxygen transport, not every blood function. White cells can engulf pathogens or produce antibodies and antitoxins, developed in infection teaching. Platelets are cell fragments involved in reducing blood loss through clots. Plasma and cells should be identified separately in an image or diagram.

Observe prepared images or school-approved slides, rather than collecting students' blood. Draw distinct components with scale information where available. Evaluate a fictional blood-product proposal using infection-screening evidence, matching and the benefit of replacement; the evaluation concerns supplied data, not personal treatment advice.

■ Checked worked case

Known: a model image field shows 48 red cells and 2 white cells. White cells are $2/(48+2)\times100=4\%$ of the counted cells. This small selected field is not a clinical blood count and excludes plasma and platelets from its denominator.

■ Common error

Platelets are not whole red blood cells, and plasma is not empty space. A picture count cannot diagnose health without a validated sampling and measurement system. Red cells transport oxygen; they do not manufacture it in the lungs.

Cardiovascular treatment: match the intervention to the problem

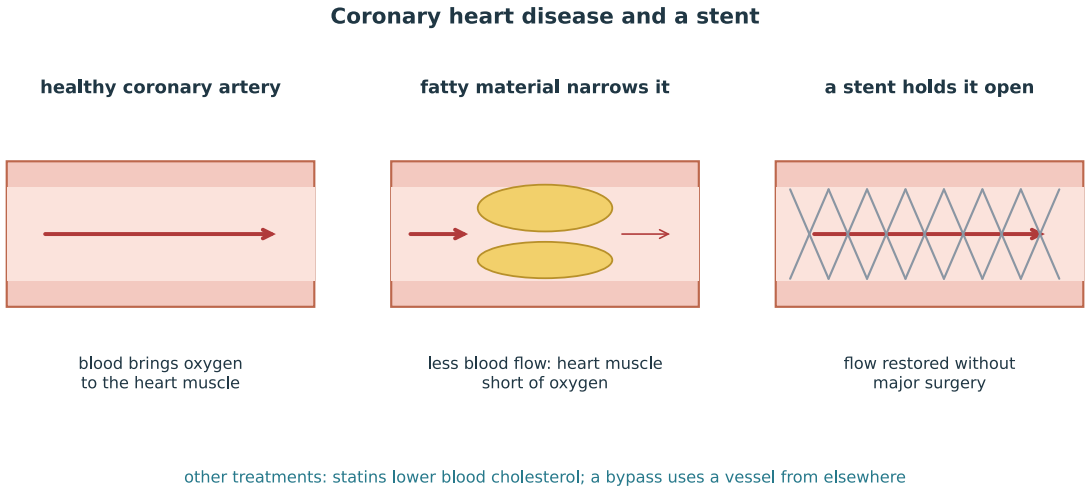
Official-unit focus: 4.2 Organisation

A blocked coronary artery, an irregular rhythm and a leaking valve are different problems. A treatment comparison needs the mechanism as well as the outcome.

Coronary heart disease involves fatty material accumulating inside coronary arteries, narrowing them and reducing blood flow and oxygen delivery to heart muscle. Stents

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hold narrowed arteries open. Statins reduce blood cholesterol and can slow fatty deposit formation. A faulty valve may not open fully or may allow backflow; biological or mechanical replacements can restore its function.



A donor heart, or heart and lungs, can be transplanted for severe failure. Artificial hearts are sometimes used while a donor is awaited or to let the heart rest. Evaluate benefit against procedural risk, infection, rejection or long-term management where relevant. A device treating one mechanism is not automatically a treatment for all cardiovascular disease.

Use a supplied fictional comparison table: identify the target problem, immediate and longer-term benefit, evidence quality and possible adverse effects. Include donor availability or required maintenance when the scenario provides it. Avoid converting a classroom option comparison into advice for a particular person.

■ Checked worked case

Known: a fictional study reports 18 complications among 300 recipients of a device. Recorded complication proportion=$18/300\times100=6\%$. A second group with 12 among 100 has 12%. These descriptive rates require comparable populations, follow-up and definitions before attributing the difference to the intervention.

■ Common error

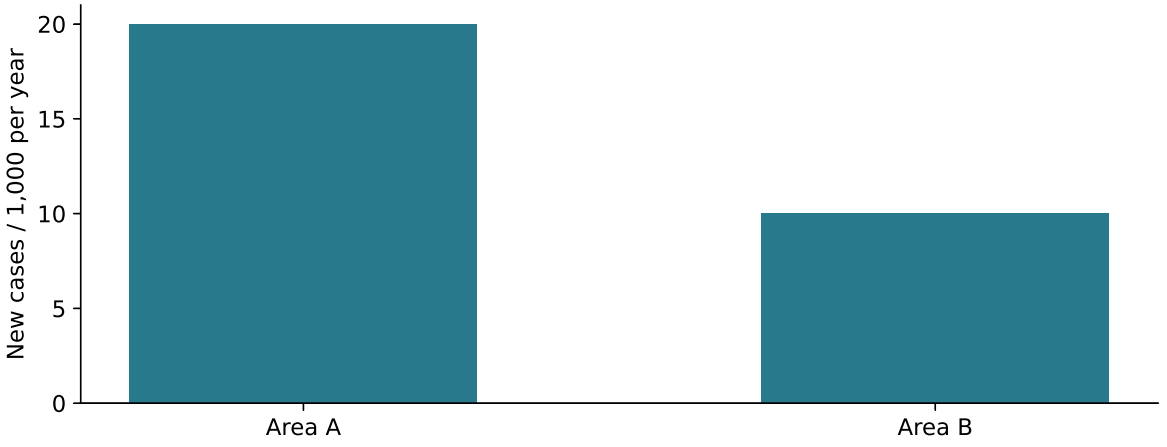
Statins do not mechanically prop open an artery, and a stent does not act as an artificial pacemaker. A lower recorded complication rate is not enough to prove that one option is best for every condition or person.

Health evidence: physical and mental well-being interact

Official-unit focus: 4.2 Organisation

A person can have no recorded infectious disease and still have poor health. Health includes physical and mental well-being and is affected by wider circumstances.

Both communicable and non-communicable diseases can reduce well-being. Diet, stress and life situations also affect health. Different conditions can interact: impaired immune defence can increase infections, some viruses can trigger cancers, an immune reaction initiated by a pathogen can trigger allergy, and severe physical illness can contribute to depression or other mental illness.



An incidence comparison needs a population denominator and time period. A scatter diagram can show an association between two variables, but an association alone does not establish direction or cause. Selection, access to diagnosis, age and other factors can change recorded rates.

Use anonymized fictional population tables, not students' private health information. Define a new case, the surveyed population and interval. Convert counts to comparable rates, choose a suitable chart and explain how the sampling method may miss groups. State what the evidence supports before discussing possible mechanisms.

■ Checked worked case

Known: area A records 30 new cases in 1,500 people during a year, or 20 per 1,000. Area B records 50 in 5,000, or 10 per 1,000. Area B has more counted cases but a smaller recorded rate. The comparison still needs consistent case definitions and observation periods.

■ Common error

Mental well-being is part of health, not merely an optional addition. Correlation does not prove that one factor is the only cause, and a self-selected sample may not represent the wider population.

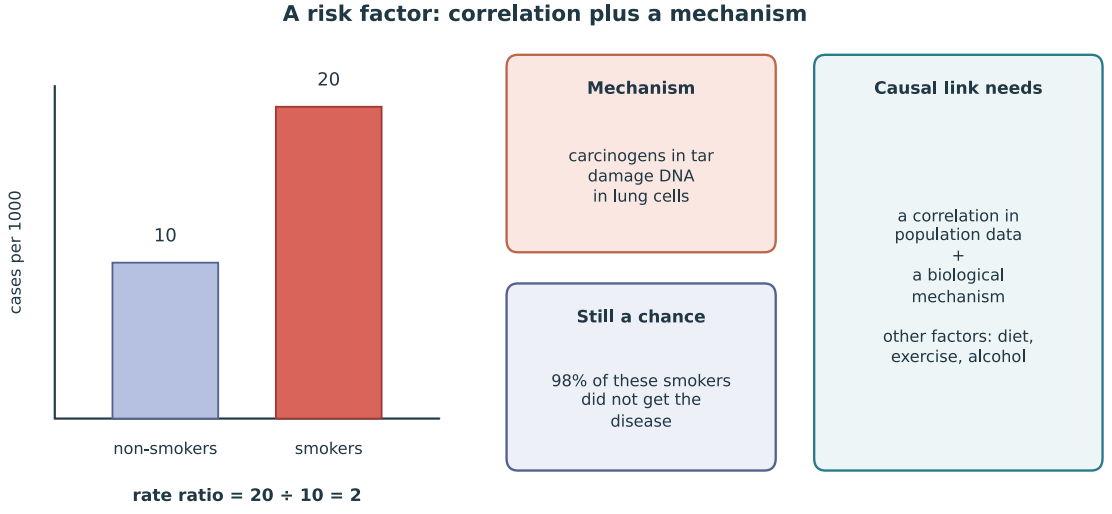
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Risk factors: a population association is not a prediction of certainty

Official-unit focus: 4.2 Organisation

Two people with similar habits can have different outcomes. A risk factor concerns increased probability in a population, not a guarantee for an individual.

Risk factors can involve lifestyle, substances in the body or environmental exposure. Diet, smoking and exercise influence cardiovascular risk; obesity is a risk factor for Type 2 diabetes. Alcohol can harm liver and brain function. Smoking is linked to lung disease and lung cancer; smoking and alcohol can affect unborn babies. Carcinogens, including ionising radiation, can increase cancer risk.



Many diseases involve several interacting factors, including genetic ones. A causal mechanism is established for some risks, while other associations remain less well explained. Population consequences include illness, reduced quality of life, care demands and financial costs for families, communities and health systems.

Interpret supplied fictional or attributed epidemiological evidence with matched definitions and intervals. Use rates rather than unequal raw counts, inspect confounders and explain sampling limits. Identify whether a claim rests on a proposed mechanism, observational association or controlled evidence. Students analyse evidence without disclosing personal habits or receiving a diagnosis.

■ Checked worked case

Known: a fictional dataset has 40 events among 2,000 people in one exposure group and 10 among 1,000 in another. Rates are 20 and 10 per 1,000, a rate ratio of 2. The association does not establish that exposure is the only difference between groups, nor that every exposed person will develop the condition.

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■ Common error

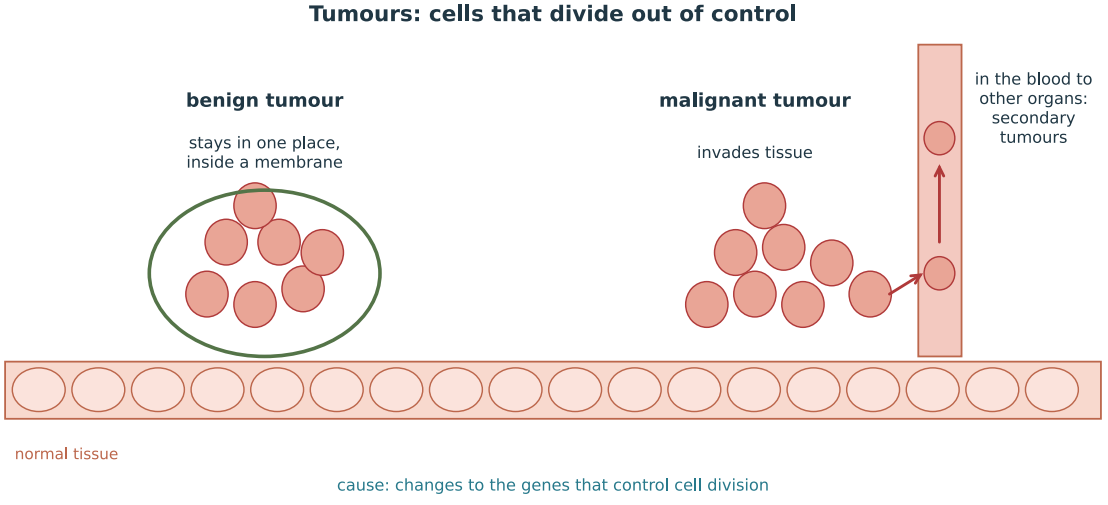
A risk factor is not a certain outcome. A scatter plot alone cannot eliminate confounding or show an established causal mechanism. Financial totals and event counts must be interpreted with their period, population and included costs stated.

Tumours: location and spread distinguish the models

Official-unit focus: 4.2 Organisation

An abnormal cell growth can remain contained or invade other tissues. The word tumour alone does not specify whether a growth is malignant.

Cancer results from cell changes leading to uncontrolled growth and division. A benign tumour is an abnormal growth contained in one area, usually within a membrane, and does not invade other parts of the body. Malignant tumour cells are cancerous: they invade neighbouring tissue and can spread in blood to form secondary tumours elsewhere.



Uncontrolled division is different from normal regulated growth, repair and replacement. Lifestyle risk factors and inherited genetic risk factors can contribute to cancer risk, often with several factors interacting. A diagram of spread is a model of a mechanism, not a clinical diagnosis from appearance.

Use a fictional sequence showing contained growth, invasion and movement to a distant site. Label a primary site and secondary growth without confusing the latter with a new unrelated origin. For data comparisons, state how cases were identified and which population and interval were observed.

■ Checked worked case

Known: a fictional image series records model abnormal-cell counts of 20, 40 and 80 at equal intervals. Each interval shows a twofold increase. The trend describes these counts, but neither rapid increase nor size alone tells whether cells invade neighbouring tissue; that requires separate evidence.

■ Common error

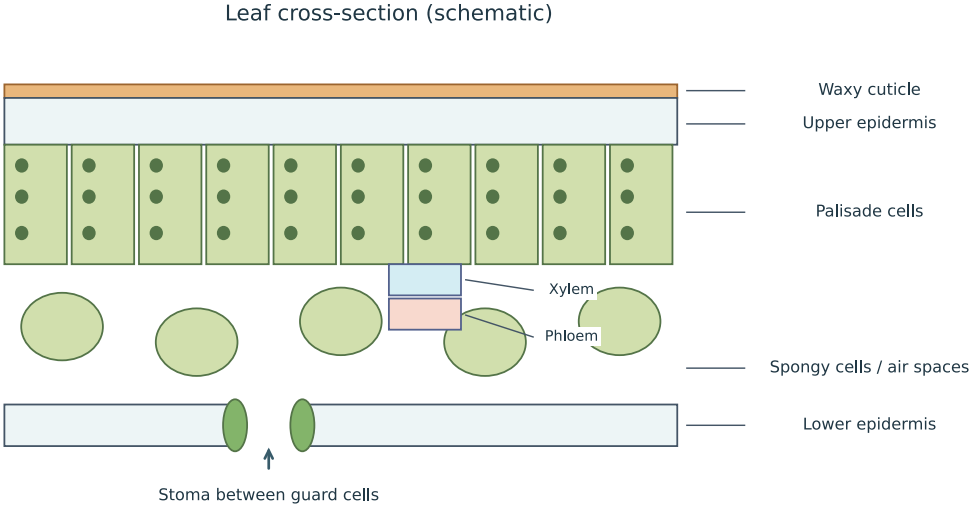
Benign does not mean a growth can never affect an organ, but it does not invade other body sites in this GCSE distinction. A single risk factor does not guarantee cancer, and a rapidly dividing normal tissue is not automatically malignant.

A leaf is an organ: tissue layers have different tasks

Official-unit focus: 4.2 Organisation

The upper leaf layer admits light while inner tissues exchange gases and photosynthesize. A leaf cross-section explains how several tissue types cooperate.

Epidermal tissue forms an outer covering. Palisade mesophyll has many chloroplasts and is suited to photosynthesis. Spongy mesophyll contains air spaces aiding gas movement. Xylem supplies water and mineral ions; phloem transports dissolved sugars. Guard cells surround stomata and change their opening. Meristems at growing shoot and root tips produce cells that can differentiate.



A tissue is defined by its cells and role, while the whole leaf is an organ. Light reaching palisade cells supports photosynthesis, and a short gas pathway through air spaces supports exchange. A vascular bundle contains distinct transport tissues; it is not one tube carrying every substance in the same way.

Observe a prepared transverse leaf section or attributed micrograph. Draw visible layers with clear labels and a scale. Identify palisade versus spongy tissue from orga-

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nization and spaces rather than colour alone. Include guard cells and stomata only where the actual section or supplied diagram shows them.

■ Checked worked case

Known: a fictional microscope field covers 0.50 mm^2 and contains 12 stomata. Recorded density=12/0.50=24 stomata/mm^2. Compare several fields selected by a defined sampling rule, rather than choosing the field with the most stomata.

■ Common error

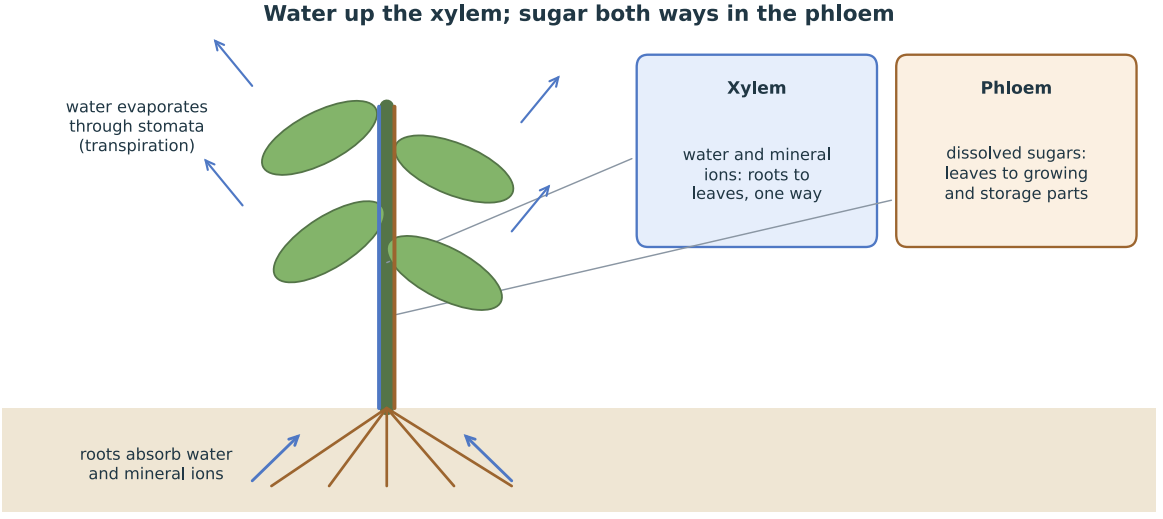
A stoma is the opening, while guard cells are the cells around it. Meristem is plant growth tissue, not a vessel moving sap. Every plant leaf need not have exactly the same arrangement as a standard schematic.

Plant transport: water loss draws water through xylem

Official-unit focus: 4.2 Organisation

A potometer bubble moves when a shoot takes up water. This is useful evidence about transpiration, but uptake and evaporation are not exactly the same quantity.

Roots, stem and leaves form a transport system. Root hairs absorb water and mineral ions. Xylem consists of hollow dead vessels strengthened by lignin and carries water and ions from roots toward leaves. Phloem uses living tissue to move dissolved sugars from producing or storing regions to where they are needed; this is translocation.



Transpiration is water loss by evaporation from leaf surfaces, mainly through stomata after water evaporates from moist internal tissues. Guard cells control stomatal opening. Higher temperature and greater air movement generally increase loss; greater humidity reduces the water-vapour gradient. More light usually opens stomata, increasing loss under comparable conditions.

Use a school-approved potometer or provided data with an airtight setup, an acclima-

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tized shoot and matched leaf area. Change one environmental factor at a time, repeat, and plot mean uptake against that factor. If calculating volume from tube distance, use cross-sectional area×distance. Some absorbed water is used or stored, so interpret uptake as an estimate of transpiration.

■ Checked worked case

Known: a bubble moves 18 mm in 6 min, giving 3 mm/min. If tube area is 0.50 mm^2, volume uptake=0.50×18=9.0 mm^3, and volume rate=9.0/6=1.5 mm^3/min. Distance rate and volume rate are different measures and must not be mixed.

■ Common error

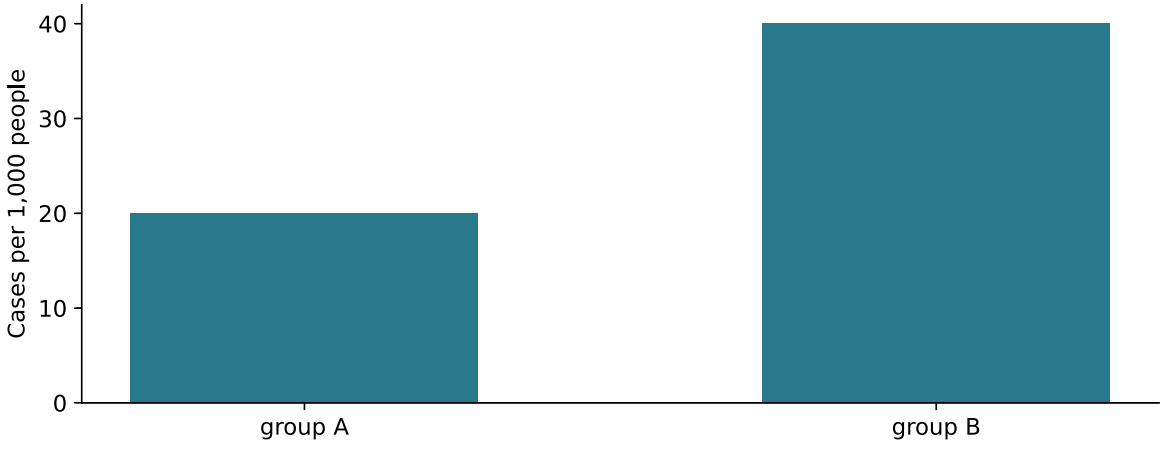
Phloem and xylem do not both carry only water upward. A faster bubble can reflect a leak or unmatched leaf area. Closing stomata conserves water but also affects carbon-dioxide entry and therefore photosynthesis.

Disease transmission and immune response

Official-unit focus: 4.3 Infection and response

An antibiotic may help against a bacterial infection but fail against a viral illness. Treatment depends on the causal organism and the evidence supporting diagnosis.

Pathogens cause infectious disease. Physical barriers, phagocytosis and specific immune responses reduce infection. Antibodies bind particular antigens. Vaccination exposes the immune system to antigen safely enough to develop memory.



After vaccination, memory cells can support a faster secondary response. Antibiotic resistance arises through heritable variation and selection; an individual bacterium does not choose to become resistant because it needs to survive.

Use published infection data to compare rates per equal population size. Distinguish prevalence at a time from new cases over a period. In school, use safe simulations or approved cultures rather than collecting unknown pathogens.

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■ Checked worked case

Known: 18 cases occur in 900 people. Rate per 1,000 = cases / population × 1,000. Rate = 18/900 × 1,000 = 20 cases per 1,000. A second group with 10 cases in 250 people has 40 per 1,000, even though it has fewer cases.

■ Common error

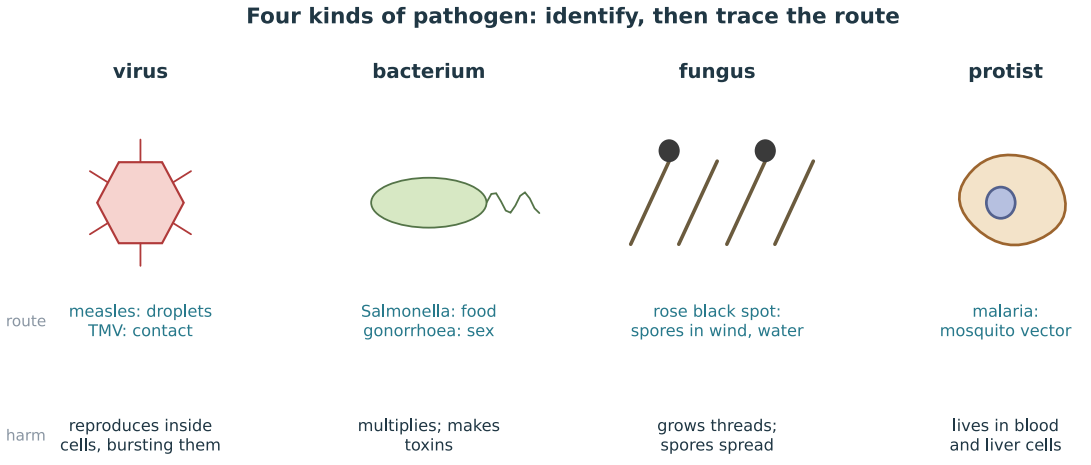
Antibiotics do not act on viruses in the same way they act on bacteria. A vaccine is not an immediate cure for an established infection.

Pathogens: distinguish spread from damage

Official-unit focus: 4.3 Infection and response

Two diseases can spread through the same route but damage a host in different ways. Identify both the pathogen and its route before proposing a control.

A pathogen causes infectious disease. The specification includes viruses, bacteria, fungi and protists. Bacteria can multiply rapidly in suitable host conditions and may release toxins that damage tissues. Viruses reproduce inside host cells, causing cell damage. Pathogens can pass by direct contact, contaminated water or air; a vector can carry a pathogen between hosts.



A prevention must interrupt the stated transmission route. Safe food and clean water reduce ingestion of pathogens; hygiene can reduce contact transmission. Ventilation and limiting exposure can reduce some airborne transmission. Controlling a vector interrupts a different route. These measures reduce risk rather than prove that every infection has been prevented.

Use fictional outbreak records without collecting classmates' medical information. Sort evidence into pathogen type, transmission route, host damage and proposed control. Explain each control using the route given, then identify evidence needed to test the

explanation. Never culture unknown samples from bodies or an outbreak.

Checked worked case

Known: a fictional school model records 18 cases among 300 people exposed to a stated source. The observed proportion is $18/300 \times 100 = 6\%$. A second group has 8 among 200, or 4%. Counts alone would hide the different denominators. These observations do not establish causation or diagnose an individual.

Common error

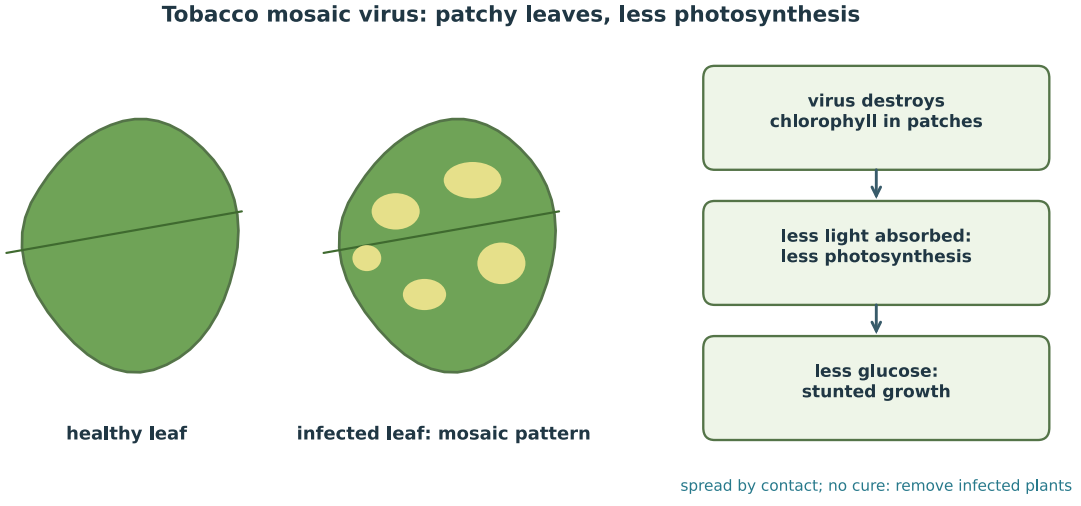
A toxin is not the same thing as a virus. An infectious disease can affect a plant as well as an animal. Not all microorganisms cause disease, and a high observed disease rate does not by itself identify the transmission route.

Measles, HIV and tobacco mosaic virus

Official-unit focus: 4.3 Infection and response

A red rash, a weakened immune system and a discoloured leaf are different outcomes of viral disease. Their transmission routes and effects must remain separate.

Measles causes fever and a red skin rash and can have serious, sometimes fatal complications. It spreads by inhaled droplets from coughs and sneezes; vaccination is the specified preventive measure. HIV can initially cause a flu-like illness. Without successful antiretroviral control it damages immune cells; late-stage infection, AIDS, leaves the body less able to deal with other infections or cancers.



HIV spreads through sexual contact or exchange of body fluids such as blood, including shared needles. Tobacco mosaic virus, TMV, causes a mosaic pattern of leaf discolouration. Less effective photosynthetic tissue means less glucose production, reducing plant growth. A symptom describes an effect; it is not itself the mechanism of transmission.

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Compare supplied disease fact cards in a table with host, symptoms, route and control. Use anonymized fictional data only. For a plant model, compare leaf photographs and stated photosynthesis measurements under the same light and temperature. Do not infer a medical diagnosis from a classroom image or symptom list.

■ Checked worked case

Known: a model healthy leaf produces 80 relative units of glucose in the stated interval and an infected leaf produces 52 under matched conditions. The decrease is 28 units; percentage decrease = $28/80 \times 100 = 35\%$. This supports lower photosynthetic output in that model, not a universal TMV reduction.

■ Common error

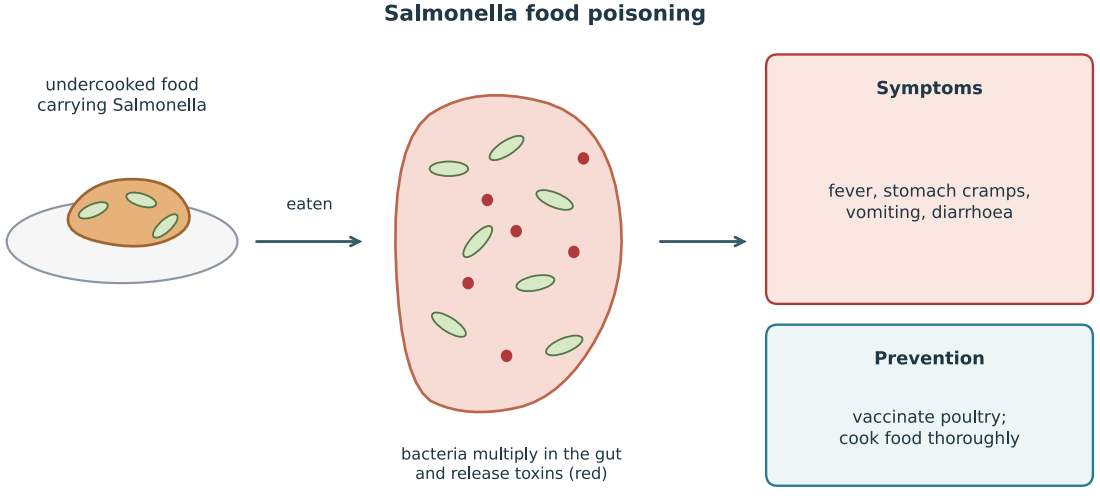
HIV infection and AIDS are not interchangeable labels for every stage. Antibiotics do not kill these viruses. TMV affects plants rather than causing the human symptoms described for measles or HIV. Classroom facts do not prescribe a treatment or vaccination schedule.

Salmonella and gonorrhoea: route-specific control

Official-unit focus: 4.3 Infection and response

Both named diseases are bacterial, but a food-handling control does not interrupt every route. Explain why the preventive measure fits the particular pathogen.

Salmonella food poisoning follows ingestion of bacteria in contaminated food, including food prepared unhygienically. Bacteria and their toxins can cause fever, abdominal cramps, vomiting and diarrhoea. The specification identifies vaccination of poultry in the UK as a control. Gonorrhoea is a sexually transmitted bacterial disease that can cause thick yellow or green discharge and pain when urinating.



Gonorrhoea spreads through sexual contact. Barrier contraception such as condoms

reduces transmission risk, while appropriate antibiotic treatment targets the bacteria. Some strains are resistant to antibiotics; the historical use of penicillin does not imply that it will now treat every strain. A named symptom alone cannot prove which organism caused it.

Analyse fictional food-chain and contact-route diagrams. Place each control at the point where it interrupts transmission: prevent contamination, prevent transfer or treat infection under professional care. Compare denominators when evaluating model control data. Do not use actual infected material or ask students to disclose sexual or medical histories.

■ Checked worked case

Known: fictional food models have 9 contaminated samples among 150 before a control and 3 among 150 after it. Rates are 6% and 2%; the decrease is 4 percentage points, or a 66.7% relative decrease. Matching counts and denominators helps comparison, but other changes could explain the result.

■ Common error

Resistance belongs to the bacterial population, not a person becoming resistant to a medicine. Food hygiene and barrier contraception address different routes. Treatment choices require current clinical guidance; this lesson teaches the specified mechanisms rather than recommending a particular drug.

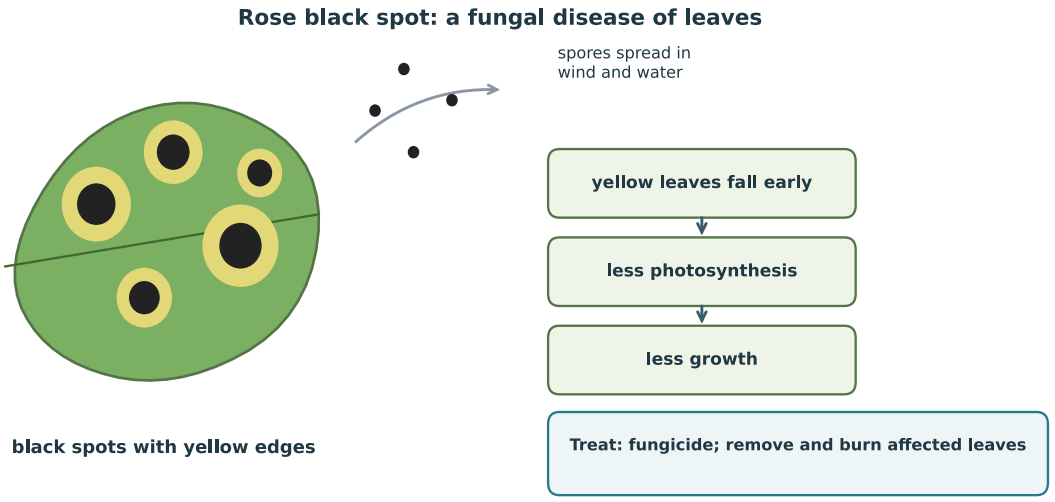
Rose black spot: loss of working leaf area

Official-unit focus: 4.3 Infection and response

A rose can lose growth without being eaten. Diseased leaves may yellow and fall before the plant has finished using them for photosynthesis.

Rose black spot is a fungal disease. Purple or black spots develop on leaves, which often turn yellow and fall early. The reduction in functioning leaves reduces photosynthesis, so less glucose is available for growth. The disease spreads in the environment through water or wind.

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Removing and destroying affected leaves can reduce infectious material. Appropriate fungicides are another specified control, but school work follows teacher-approved handling and disposal. A control aimed at a fungus is distinct from treating bacterial disease. The effect on growth is explained through leaf function rather than simply saying that spots look unhealthy.

Use supplied rose photographs and fictional growth data. Record the visible symptoms separately from an inferred cause, because spots alone can have other causes. Compare matched plants with the same variety, water, light and observation time. Do not spray chemicals or transfer diseased material without school supervision.

■ Checked worked case

Known: a model plant begins with 24 functioning leaves and loses 6 early. It retains 18, or $18/24 \times 100 = 75\%$ of the initial leaf count. Leaf count is only a rough indicator: leaves may have different areas, ages and levels of damage, so it cannot by itself give an exact photosynthesis rate.

■ Common error

Black spot is fungal, not the same pathogen as TMV. A fallen diseased leaf may still be a source of spread. A correlation between leaf loss and lower growth needs a mechanism and suitable comparison, and remaining leaf number is not a direct measure of glucose production.

Malaria: interrupt a vector's role

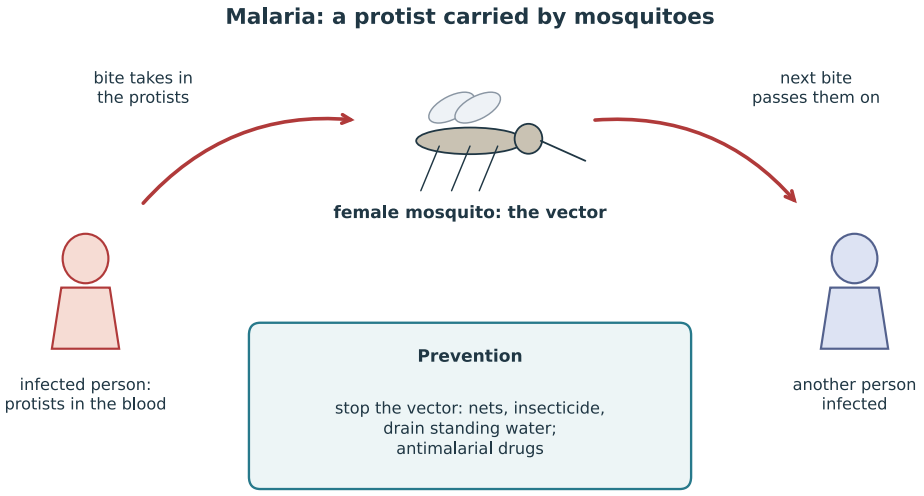
Official-unit focus: 4.3 Infection and response

A mosquito can carry a pathogen without being the pathogen itself. Malaria prevention must address the vector as well as the parasite.

Malaria is caused by a protist pathogen. A mosquito is a vector: it transfers the

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pathogen between hosts and is involved in its life cycle. Malaria causes recurrent episodes of fever and can be fatal. Preventing mosquito bites, for example with suitable nets, and reducing mosquito breeding are specified methods of control.



Distinguish organism roles carefully. The mosquito is an animal carrier, whereas the disease-causing organism is a protist. A net can reduce opportunities for a mosquito to bite a person; removing suitable breeding conditions can reduce the number of vectors. Neither measure should be described as directly killing every protist already inside an infected person.

Build a paper model connecting infected host, mosquito and another host. Mark which link each proposed control interrupts. Analyse supplied fictional trap counts rather than breeding or handling mosquitoes. School field observations require teacher approval and should avoid exposure to bites or potentially contaminated water.

■ Checked worked case

Known: fictional matched traps catch a mean of 40 mosquitoes before a breeding-site control and 26 after it. The decrease is 14; percentage decrease = $14/40 \times 100$ = 35%. Trap counts estimate vector abundance at those sites and times, not the number of human infections or an individual's risk.

■ Common error

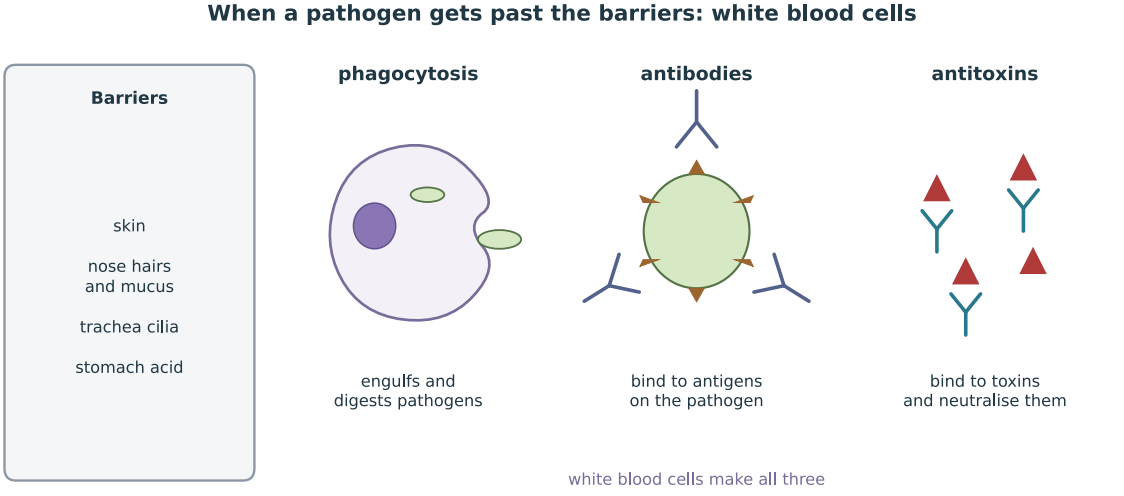
Malaria is not caused by the mosquito itself or by a bacterium. Fewer vectors can reduce transmission opportunities, but a trap result alone does not demonstrate that malaria has been eradicated. Do not infer a safe travel or treatment decision from classroom model data.

Barriers and white blood cells

Official-unit focus: 4.3 Infection and response

The body first tries to stop pathogens entering. Once pathogens cross a barrier, white blood cells can respond through several distinct mechanisms.

Skin forms a physical barrier; a clot helps seal a break. Nose hairs and mucus trap particles. Mucus in the trachea and bronchi traps pathogens, and cilia move it away from the lungs towards the throat. Stomach acid kills many swallowed pathogens. These defences are nonspecific because they do not target one particular antigen.



White blood cells defend against pathogens by phagocytosis, producing antibodies and producing antitoxins. In phagocytosis a cell engulfs and digests a pathogen. Antibodies bind to particular antigens associated with a pathogen; antitoxins neutralize toxins. Explain the target before choosing the mechanism: removing a bacterium and neutralizing its toxin are different actions.

Use labelled barrier diagrams and paper antigen–antibody models. Match a named defence to its location and effect. Then trace a pathogen that has crossed a barrier to a suitable immune response. This is a model exercise; do not test disinfectants on students' skin or collect body samples.

■ Checked worked case

Known: a fictional observation shows 80 particles entering a model airway and 62 trapped in mucus. The remaining count is 18 and the trapped proportion is $62/80 \times 100 = 77.5\%$. The model illustrates interception, but real defence depends on particle properties, ciliary function and many additional processes.

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■ Common error

Antibodies and antitoxins are not antibiotics. Red blood cells mainly transport oxygen and do not replace the white-cell roles here. A barrier lowers entry risk but is not an absolute guarantee that no pathogen will ever enter.

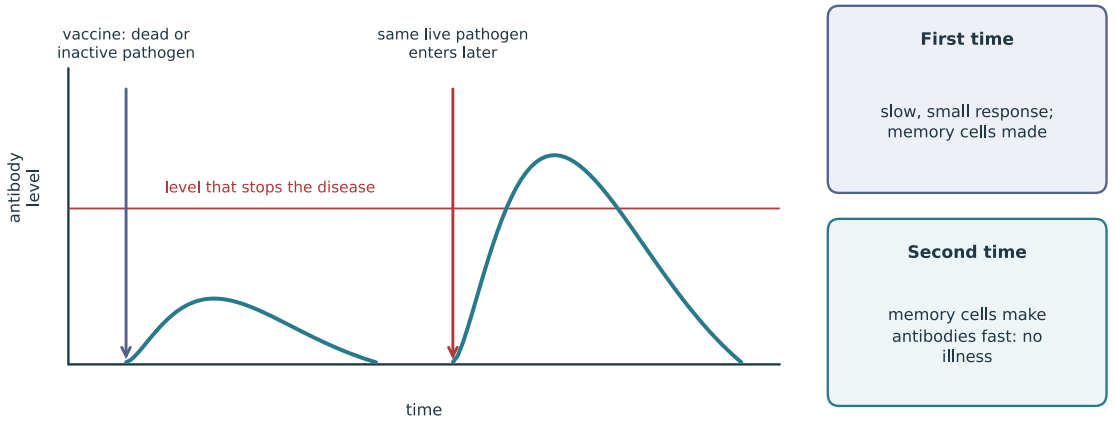
Vaccination: a faster specific response

Official-unit focus: 4.3 Infection and response

A vaccinated person's immune system has encountered relevant pathogen material before a later infection. The key comparison is the speed and specificity of the response.

Vaccination introduces a small amount of dead or inactive pathogen material in the model specified for this course. This stimulates white blood cells to produce antibodies. If the same pathogen enters later, the immune system can rapidly produce the correct antibodies, preventing illness or reducing its likelihood. The response is specific to the relevant pathogen antigens.

Vaccination: a faster, bigger second response



When many people are immune, a pathogen has fewer opportunities to pass to susceptible hosts. This can reduce spread through the population. Distinguish a vaccinated proportion from guaranteed protection: immunity, exposure and effectiveness vary, and a single percentage does not prove that transmission has stopped.

Use a classroom token network to model transmission, with tokens assigned immunity at random. Compare repeated runs and keep contact rules constant. Explain where the model simplifies real immune responses. Do not collect classmates' vaccination status, use real injections or present fictional thresholds as public-health advice.

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■ Checked worked case

Known: in a fictional group of 200, 150 are assigned immunity in a transmission model. Immune proportion = 150/200×100 = 75%; 50 remain susceptible. The percentage alone does not determine the number of cases because contact patterns and the model's transmission rule also matter.

■ Common error

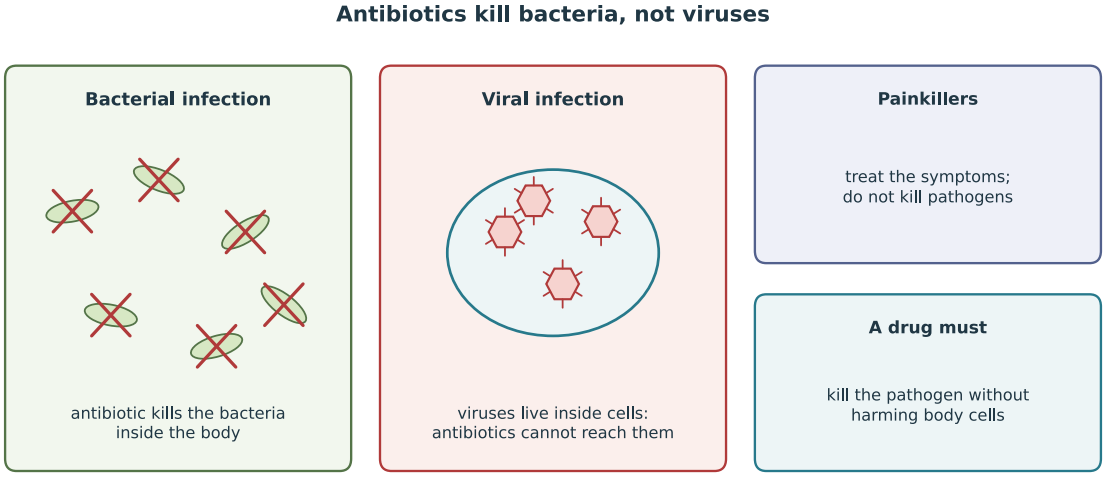
Vaccination does not mean antibiotics have been placed in the blood. A rapid response must produce the appropriate antibodies, not just any antibodies. The simplified dead/inactive-material description is the specified teaching model rather than a claim that every real vaccine uses the same technology.

Antibiotics and symptom relief have different targets

Official-unit focus: 4.3 Infection and response

A medicine can make someone feel better without killing the pathogen. Always state whether the intended target is a bacterium, a viral process or a symptom.

Antibiotics such as penicillin are medicines that kill or inhibit bacteria. Different antibiotics are effective against different bacteria; resistant strains can survive a medicine that affects susceptible bacteria. Antibiotics do not kill viruses. Painkillers relieve symptoms such as pain but do not necessarily kill the pathogen causing the disease.



Viruses reproduce inside host cells. A drug that interferes with reproduction must avoid unacceptable damage to the host's own cells and tissues, which makes development difficult. This does not imply that no antiviral medicines exist: antiretroviral control of HIV is one example already studied.

Interpret supplied laboratory summaries using an identified bacterium, antibiotic and stated conditions. Compare inhibition evidence without choosing a treatment for a

real person. School antimicrobial practicals use only approved strains, concentrations, closed cultures and supervised disposal; no trial on human participants is appropriate.

■ Checked worked case

Known: a fictional approved culture starts with 120 colonies in a control and shows 30 under a stated treatment condition. The reduction is 90, or 75% of the control count. The comparison measures this model's growth outcome; it does not by itself establish a safe human dose or prove complete bacterial killing.

■ Common error

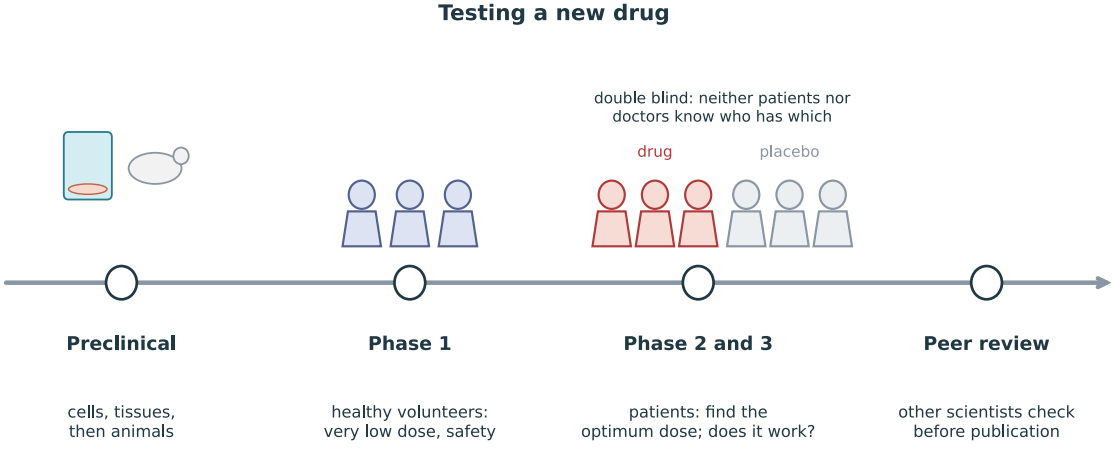
Antibiotic effectiveness is not the same as pain relief. A medicine that relieves fever does not demonstrate that it killed the virus. Resistant bacteria survive because of their characteristics; the person is not becoming genetically resistant to an antibiotic.

Discovering and testing medicines

Official-unit focus: 4.3 Infection and response

A substance that affects cells is not automatically a useful medicine. Evidence must establish whether it works, which dose is appropriate and what harm it can cause.

Traditional sources include digitalis from foxgloves and aspirin developed from a substance in willow. Alexander Fleming discovered penicillin from Penicillium mould. Most new medicines are synthesized by chemists, often starting from substances found in nature. Preclinical testing uses cells, tissues and live animals; clinical trials use healthy volunteers and patients.



Testing investigates toxicity, efficacy and dose. Initial clinical doses are low to check safety. Suitable patient comparisons can include a placebo; blinding helps prevent expectations affecting reported or assessed outcomes. Double-blind trials keep both participants and the relevant researchers unaware of allocation during measurement.

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Independent peer review examines the methods and evidence before conclusions are accepted.

Evaluate fictional trial summaries as a data exercise, identifying allocation, comparison groups, dose and measured outcome. Consider sample size and missing side-effect evidence. Never give a medicine, plant extract or placebo to classmates as an experiment. Real trials require professional ethical review and informed consent.

■ Checked worked case

Known: in a fictional summary, 48 of 80 treatment participants and 30 of 75 comparison participants meet a stated improvement criterion. Proportions are 60% and 40%, a difference of 20 percentage points. This outcome difference alone does not settle toxicity, optimum dose or whether allocation and assessment were unbiased.

■ Common error

Natural origin does not guarantee safety. A placebo comparison is not the same as leaving every patient without appropriate care. A larger improvement proportion must be interpreted alongside safety, fair comparison and uncertainty; a classroom calculation is not a medicine recommendation.

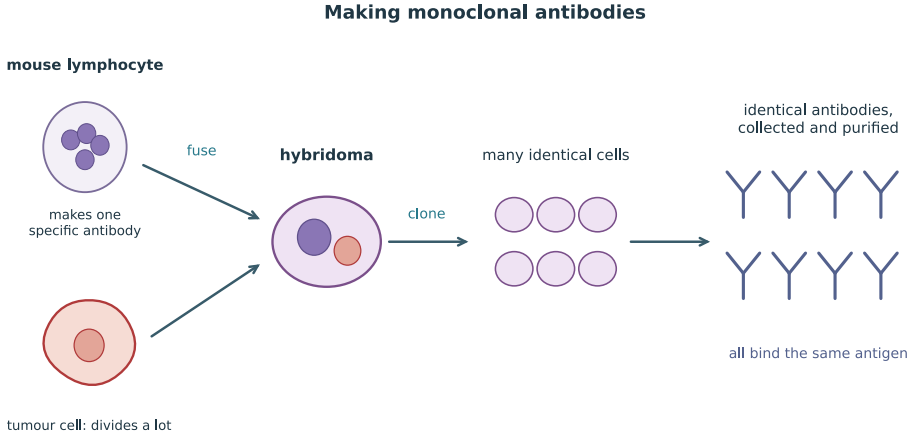
Monoclonal antibodies: one clone, one binding target

Higher Tier focus; see section scope notes.

Official-unit focus: 4.3 Infection and response

A laboratory needs many copies of one antibody. A lymphocyte supplies the antibody-making ability, while a tumour cell supplies sustained division.

Monoclonal antibodies are made by a single clone of cells. They bind to one particular binding site on a specific protein antigen. A mouse is stimulated to produce suitable lymphocytes. These are fused with tumour cells to form hybridoma cells, combining antibody production with repeated division. A selected hybridoma is cloned to make many identical antibody-producing cells.



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The hybridoma culture supplies antibodies that can be collected and purified. Explain the purpose of each stage: lymphocyte for a suitable antibody, tumour cell for division, selection for the desired binding specificity and cloning for consistent output. Specificity does not mean the antibody binds to every protein or always cures a disease.

Use cards to model cell fusion and selection, then distinguish growing a cell clone from collecting its protein product. This is a school modelling task, not a request to immunize animals or culture tumour cells. Actual production uses regulated laboratory procedures and raises animal-welfare and safety considerations.

■ Checked worked case

Known: a fictional selected hybridoma population starts with 3 cells and each divides once in each of four model rounds. Final count = $3 \times 2^4 = 48$ cells. This assumes no cell loss and equal division. It gives a cell count, not an antibody mass; protein yield needs separate measurement.

■ Common error

A hybridoma is a fused cell, not the antibody itself. Monoclonal describes origin from one clone and a consistent binding target. The tumour-cell component is used for division in the model; it does not mean the purified antibody is a tumour.

Antibody specificity in tests, research and treatment

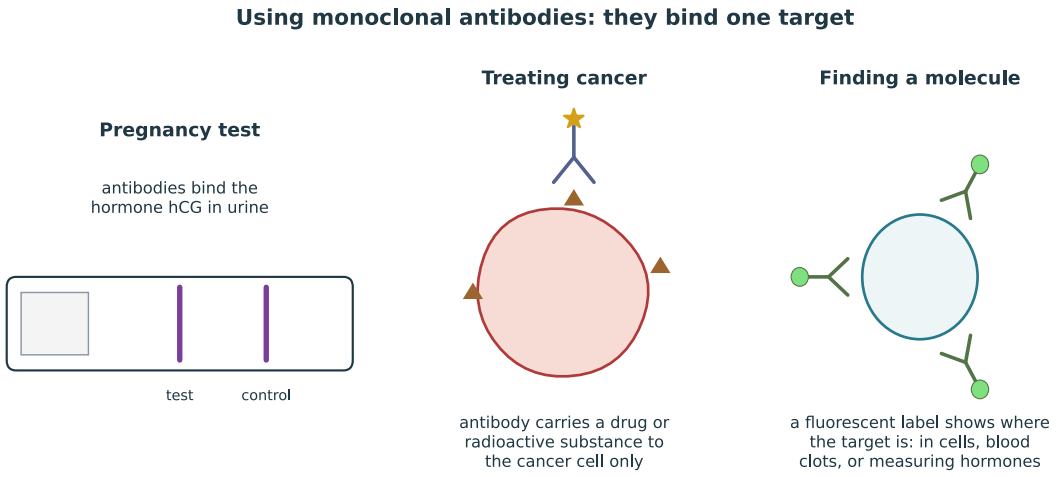
Higher Tier focus; see section scope notes.

Official-unit focus: 4.3 Infection and response

The same binding principle can create a test signal or carry a payload. Explain both what the antibody binds and what the attached signal or substance does.

Monoclonal antibodies are used in pregnancy tests, in laboratories to measure hormones and other chemicals or identify pathogens, and in research to locate particular molecules using fluorescent labels. A diagnostic antibody binds its target; a linked signal makes that binding detectable. A test therefore needs a target-specific part and a way to observe the result.

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In a supplied cancer-treatment model, antibodies bind an antigen on cancer cells and carry a radioactive substance, a toxic drug or a chemical that stops growth and division. Targeting can reduce effects on other cells, but side effects may still occur. Evaluate usefulness through specificity, measured effects, harm and practical or ethical constraints rather than claiming a guaranteed cure.

Interpret provided labelled test-strip or fluorescence diagrams. Compare a control signal with the target signal, and explain why a missing control makes interpretation unreliable. Use paper models or approved classroom materials only. Specific treatment names are not required by this section; explain an unfamiliar example from its supplied mechanism.

■ Checked worked case

Known: a fictional research image has 120 counted cells and 36 show the specified fluorescent signal. Signal-positive proportion = $36/120 \times 100 = 30\%$. This measures a stated labelled target in that image. Without validation and suitable controls it cannot show that every positive cell is cancerous or establish clinical test accuracy.

■ Common error

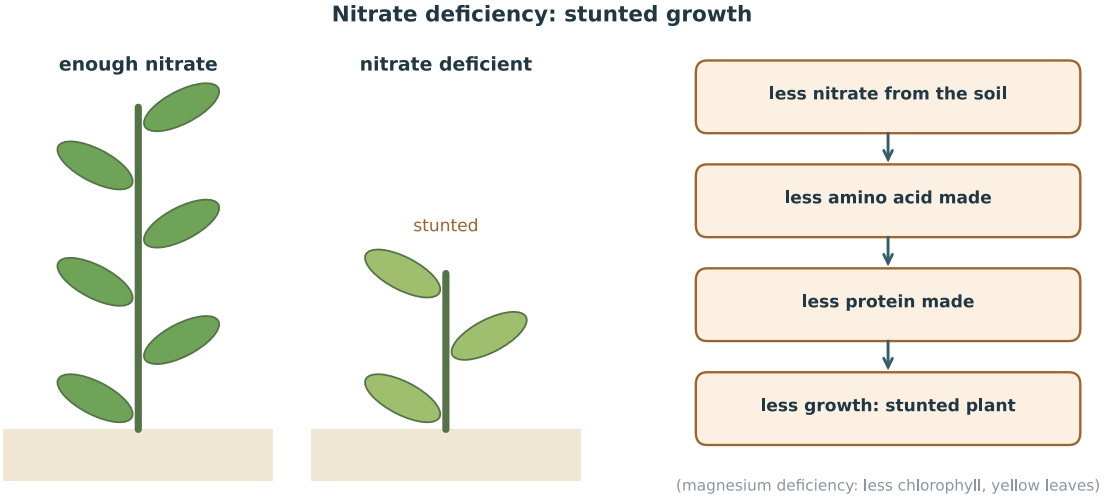
The antibody's binding target and attached payload have different roles. A diagnostic signal is evidence interpreted with controls, not an automatic diagnosis. Targeted delivery can still have unwanted effects, so the benefit must be balanced against measured risks.

Plant infection, pests and mineral deficiency

Official-unit focus: 4.3 Infection and response

A yellow leaf may reflect infection or a shortage of a mineral. A symptom is a starting observation, so compare possible explanations before naming a cause.

Plants can be damaged by pathogens such as TMV and rose black spot and by pests such as aphids. Aphids feed on plant material and can reduce growth. Mineral deficiency also damages a plant without being an infectious disease. Nitrate ions are needed to make amino acids and proteins; insufficient nitrate can cause stunted growth.



Magnesium is needed for chlorophyll production. A shortage can cause chlorosis, or yellowing, which reduces effective light absorption for photosynthesis. Distinguish a pest, a pathogen and a nutrient shortage: an insect is not a mineral deficiency, and adding nitrate does not directly eliminate a virus.

Compare supplied photographs and teacher-prepared mineral-growth records. Keep plant species, light, water and observation time matched when interpreting a mineral comparison. Record alternative causes and the limits of the evidence. Do not grow or release pests or transfer infected plants as an unsupervised task.

■ Checked worked case

Known: matched fictional seedlings grow 12 cm under a complete mineral treatment and 7.2 cm under a nitrate-limited treatment. Difference = 4.8 cm; decrease relative to the complete treatment = 40%. The mechanism links nitrate to protein production, but the numerical difference is specific to the stated model.

■ Common error

Chlorosis describes yellowing rather than proving a single cause. Nitrate supports protein synthesis, while magnesium supports chlorophyll production; swapping these explanations loses the mechanism. Higher-only disease-identification methods are taught separately from this both-tier plant content.

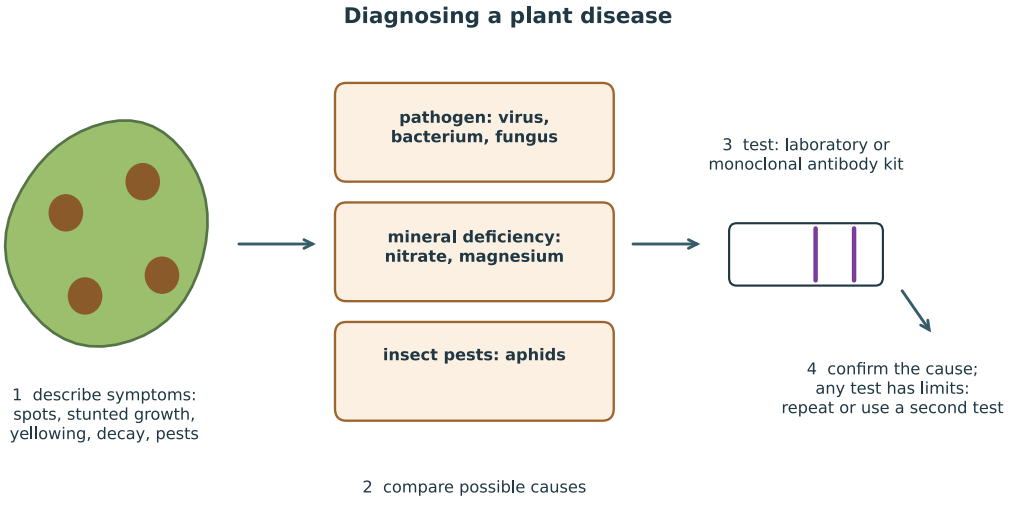
Plant diagnosis: symptoms need confirmation

Higher Tier focus; see section scope notes.

Official-unit focus: 4.3 Infection and response

A photograph can show a leaf spot clearly without revealing the organism responsible. Diagnosis uses observations plus a suitable reference or confirming test.

Possible plant disease signs include stunted growth, spots on leaves, areas of decay, growths, malformed stems or leaves, discolouration and the presence of pests. These observations can narrow an investigation but are not all specific to one pathogen. Mineral deficiency, for example, can also cause stunting or discolouration.



The specification identifies gardening manuals or websites, laboratory identification of pathogens and test kits containing monoclonal antibodies as methods of identification. A specific antibody binds an appropriate target associated with a pathogen. Interpretation still requires valid controls and attention to the kit's stated target and limitations.

Examine supplied images, describe the observations before naming a disease, and list plausible alternatives. Use a teacher-provided reliable reference or simulated test result to refine the identification. Record which evidence is direct and which is inferred. School work must not culture unknown plant pathogens or use a test outside its instructions.

■ Checked worked case

Known: a fictional set of 40 symptom photographs contains 26 independently confirmed pathogen cases and 14 other causes. Confirmed pathogen proportion = $26/40 \times 100 = 65\%$. This demonstrates why visible symptoms alone do not prove infection. It does not provide a sensitivity or specificity value for an unspecified test.

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■ Common error

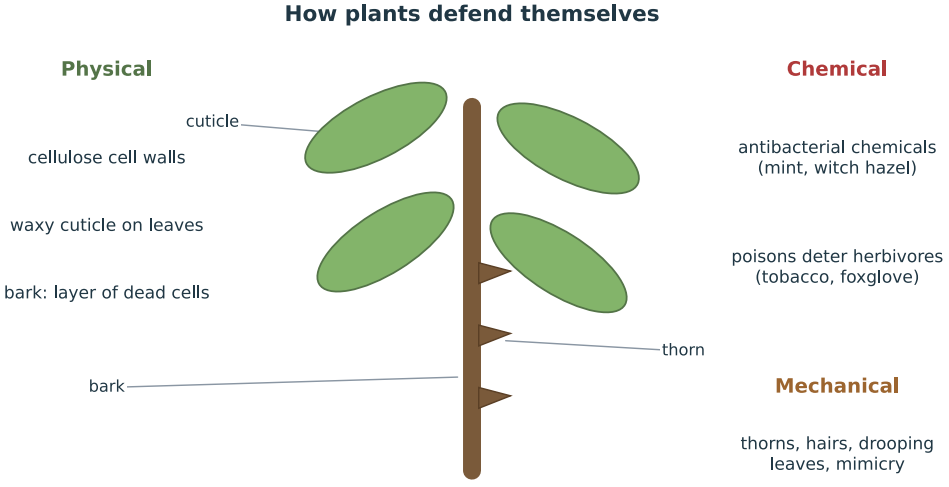
A symptom list is not a guaranteed diagnosis. A positive target test concerns the target named by that test; it does not identify every possible plant disease. Reliable references and laboratory evidence complement careful observation rather than replace it.

Plants defend themselves in several ways

Official-unit focus: 4.3 Infection and response

Plants cannot simply run away from a feeding animal. Their barriers, chemicals and mechanical responses reduce damage in different ways.

Physical defences include cellulose cell walls, a tough waxy cuticle on leaves and layers of dead cells around stems as bark. Bark can fall off, removing attached pathogens. These structures form barriers to entry or damage. Chemical defences include antibacterial substances and poisons that deter herbivores.



Mechanical adaptations include thorns and hairs that discourage feeding, leaves that droop or curl when touched, and mimicry that can deter animals. Explain the consequence of each feature: a thorn affects contact or feeding, while an antibacterial substance affects bacteria. No single defence protects a plant against every threat.

Observe teacher-approved plants or supplied images without touching unknown hairs, thorns, sap or berries. Classify each feature as physical, chemical or mechanical in the specification's grouping, then write a feature → effect → protection explanation. A paper model can compare exposed and protected surfaces without using a real poison or provoking animal feeding.

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■ Checked worked case

Known: a fictional protected-leaf model records 6 damaged patches among 50 compared with 15 among 50 in an unprotected model. Damage proportions are 12% and 30%, a difference of 18 percentage points. The comparison supports protection under those rules, not a universal reduction for every plant defence.

■ Common error

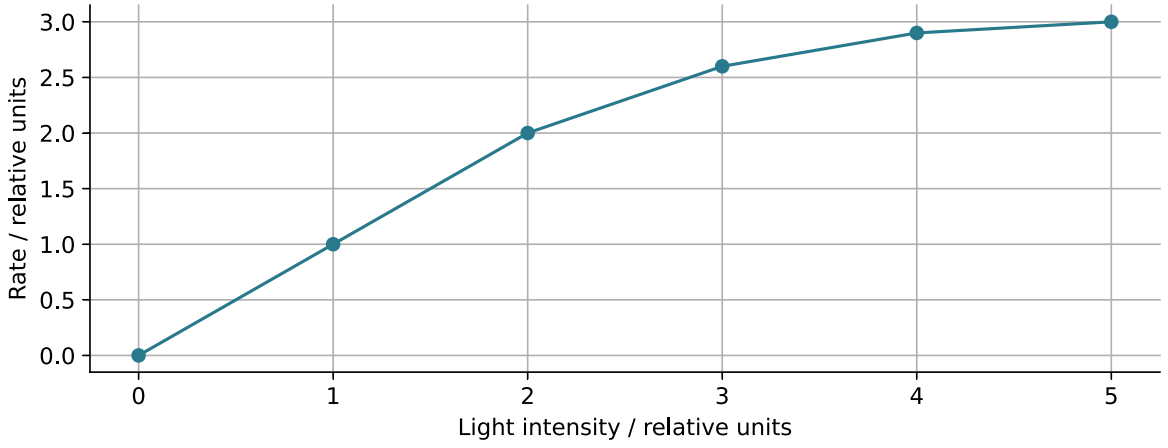
A waxy cuticle is a physical barrier and is not an antibody. Plants do not use the same white-blood-cell mechanisms as animals. A poisonous plant can harm people as well as herbivores, so classroom observation must not involve tasting or extracting its chemicals.

Photosynthesis and limiting factors

Official-unit focus: 4.4 Bioenergetics

A brighter lamp does not always produce more oxygen from pondweed. Another factor may limit the process when light is already sufficient.

Photosynthesis transfers energy from light into chemical stores. Carbon dioxide and water form carbohydrate, releasing oxygen. Chlorophyll absorbs light; light intensity, temperature and carbon dioxide supply can affect rate.



Change only one factor when testing a limiting factor. At low light, extra light may increase rate. At a plateau, the changed factor is no longer the main limit in that range; the graph alone does not identify which other factor is limiting.

Measure collected gas volume over a fixed time instead of assuming all bubbles have the same volume. Control temperature, plant size and carbon dioxide supply. Allow the plant to adjust before each reading and repeat.

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■ Checked worked case

Known: 6.0 cubic centimetres of gas are collected in 3.0 minutes. Use rate = volume/time. Rate = 6.0/3.0 = 2.0 cubic centimetres per minute. Bubble counts can be a rough proxy, but bubbles of different size make comparisons less reliable.

■ Common error

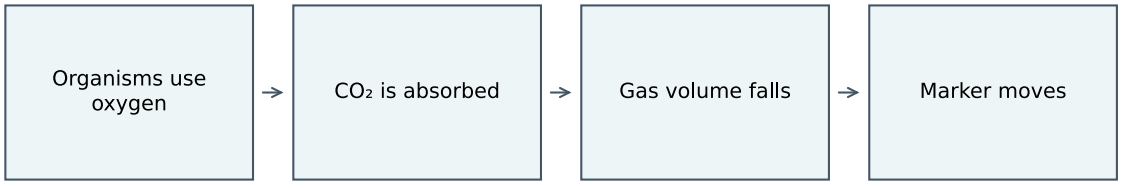
Moving a lamp changes light and may also change temperature. A photosynthesis experiment needs control of heating, not just a ruler.

Respiration, ATP and energy transfers

Official-unit focus: 4.4 Bioenergetics

A muscle can use oxygen while you exercise without producing a flame. Respiration transfers energy through a controlled series of reactions.

Aerobic respiration transfers energy from glucose using oxygen and produces carbon dioxide and water. Energy supports movement, temperature regulation and the synthesis of larger molecules.



Anaerobic respiration releases less energy per glucose than aerobic respiration. In human muscles it produces lactic acid; in yeast it produces ethanol and carbon dioxide. Breathing supplies oxygen but is not itself respiration.

A respirometer can measure oxygen uptake when carbon dioxide is absorbed. Control temperature with a water bath and use a comparison containing inert material. Keep absorbent separated from organisms and follow the school risk assessment.

■ Checked worked case

Known: oxygen uptake is 0.80 cubic centimetres in 4.0 minutes for 2.0 g of tissue. Rate per mass = volume / (time × mass). Rate = 0.80/(4.0 × 2.0) = 0.10 cubic centimetres per minute per gram. Normalizing allows a fairer comparison of samples of different mass.

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■ Common error

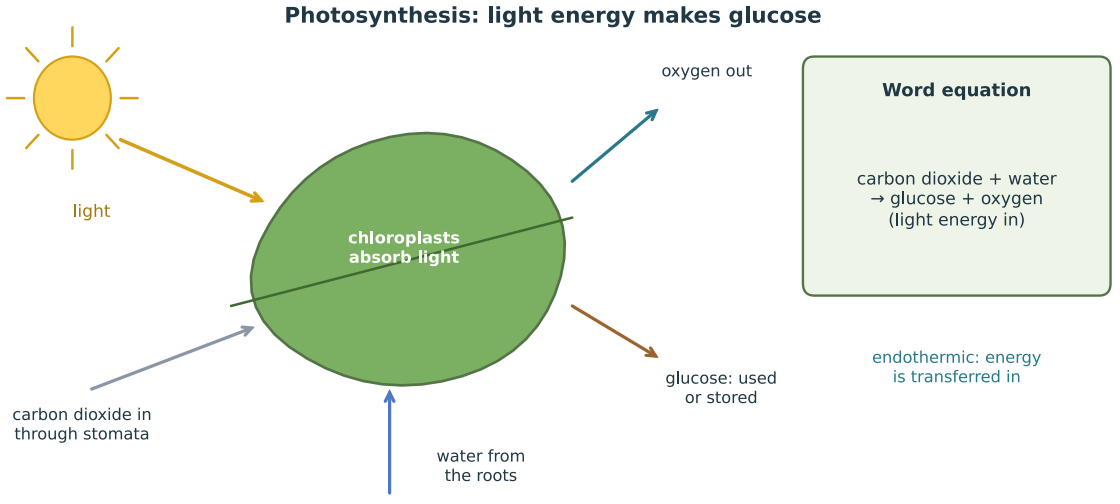
Breathing ventilates the lungs; respiration consists of chemical reactions in cells. A moving respirometer marker can also reflect temperature or pressure changes.

Photosynthesis: energy enters through light

Official-unit focus: 4.4 Bioenergetics

A growing plant gains material without eating another organism. It uses carbon dioxide and water to make glucose, with energy transferred by light.

Photosynthesis is represented by carbon dioxide + water → glucose + oxygen, in the presence of light. Carbon dioxide is CO_2, water is H_2O, glucose is $C_6H_{12}O_6$ and oxygen is O_2. Chloroplasts contain chlorophyll, which absorbs light. The reaction is endothermic: energy is transferred from the environment to the chloroplasts by light.



Light supplies energy rather than being a material reactant with a mass in the equation. Carbon dioxide supplies carbon for glucose; water is also required and oxygen is released. Photosynthesis and respiration are different processes. Plants respire continuously in living cells, even when no light is available for photosynthesis.

Use a labelled chloroplast model and equation cards to identify reactants, products and the energy input. If using the balanced extension $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$, count atoms to check conservation. Recognizing the required symbols does not require an invented mole calculation or an ATP yield.

■ Checked worked case

Known: the balanced model uses 6 carbon dioxide molecules for one glucose molecule. For 4 glucose molecules the model requires 24 carbon dioxide molecules and produces 24 oxygen molecules. This is a particle-ratio check of the equation, not a measurement of a real leaf's rate or a statement that light has six molecules.

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■ Common error

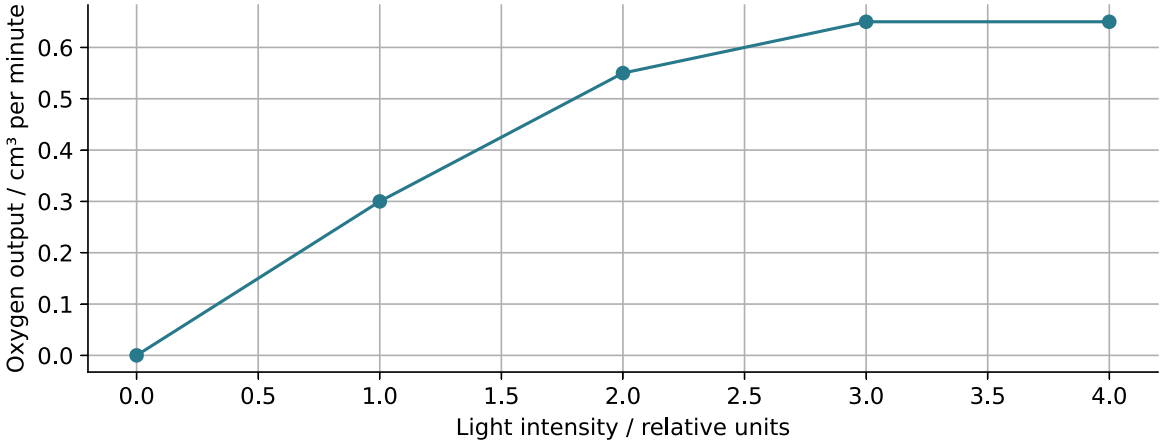
Photosynthesis takes in energy; it does not release usable energy from glucose in the way respiration does. Chlorophyll and chloroplast are not interchangeable: one is the light-absorbing pigment, the other the cell structure containing it.

Measure photosynthesis rate fairly

Official-unit focus: 4.4 Bioenergetics

Counting bubbles is convenient, but one large bubble can contain more gas than several small ones. Decide what the measurement really estimates.

Photosynthesis rate depends on light intensity, carbon dioxide concentration, temperature and the amount of chlorophyll. More light or carbon dioxide can increase rate over a suitable range. Enzyme-controlled reactions are slow at low temperatures; temperatures above a suitable range can damage enzyme function. Reduced chlorophyll can reduce light absorption.



In required practical 6, an aquatic organism such as pondweed supplies an observable oxygen-output estimate. Gas volume divided by time is usually a better measure than bubble count when bubble sizes vary. A graph needs the varied factor on the horizontal axis, rate on the vertical axis and a consistent scale with units. A plateau means the changed factor no longer increases rate under those conditions.

Use teacher-approved pondweed and equipment. Change lamp distance in a planned range, control water temperature and carbon dioxide supply, keep organism size and observation time comparable, and allow adjustment before measurements. Repeat readings and calculate a mean. Electrical equipment stays safely separated from water; observe school handling and disposal procedures.

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■ Checked worked case

Known: a model collects 2.4 cm^3 oxygen in 4 minutes. Mean output rate = 2.4/4 = 0.60 cm^3 per minute. A bubble count of 60 in that time would instead give 15 bubbles per minute; it is not 15 cm^3 per minute without measured bubble volumes. Net oxygen output also reflects concurrent respiration.

■ Common error

Do not claim that moving a lamp changes only light if it also heats the water. A measured output rate is an estimate under stated conditions. Multi-factor graphs, inverse-square calculations and greenhouse economics belong to the separate Higher Tier lesson.

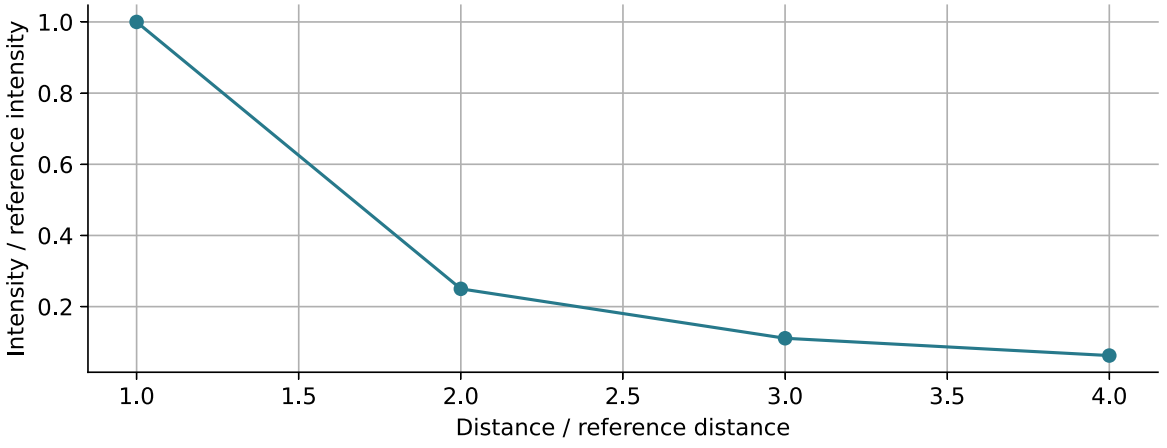
Higher Tier: interacting factors and greenhouse decisions

Higher Tier focus; see section scope notes.

Official-unit focus: 4.4 Bioenergetics

A greenhouse can spend more on lighting without growing more crop. A useful decision checks which factor limits the response and whether extra revenue exceeds extra cost.

Photosynthesis factors interact: light, carbon dioxide or temperature can limit rate under a particular set of conditions. Increasing a factor that is not currently limiting may produce no gain. On a graph, compare curves at the same value of the horizontal variable and use the stated changed condition to explain differences.



For the ideal point-source model, light intensity is proportional to 1/distance^2. Doubling distance makes intensity one quarter, not one half. Real lamp geometry and reflections can depart from this approximation. A greenhouse decision compares added revenue with added lighting, heating or carbon dioxide costs; maximum photosynthesis rate need not give maximum profit.

Inspect supplied curves with one controlled change between them. Identify evidence that a proposed limiting factor matters at a particular point. Calculate relative in-

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tensity using a stated reference distance, then evaluate a fictional greenhouse budget. These calculations extend RP6 interpretation but do not justify uncontrolled heating or added gases in a classroom.

■ Checked worked case

Known: intensity is 100 relative units at 20 cm. At 40 cm the ideal model predicts $100\times(20/40)^2 = 25$. Separately, a greenhouse change adds 180 revenue units but 120 cost units, so added profit is 60. A second change adding 40 revenue and 70 cost reduces profit by 30 even if photosynthesis increases.

■ Common error

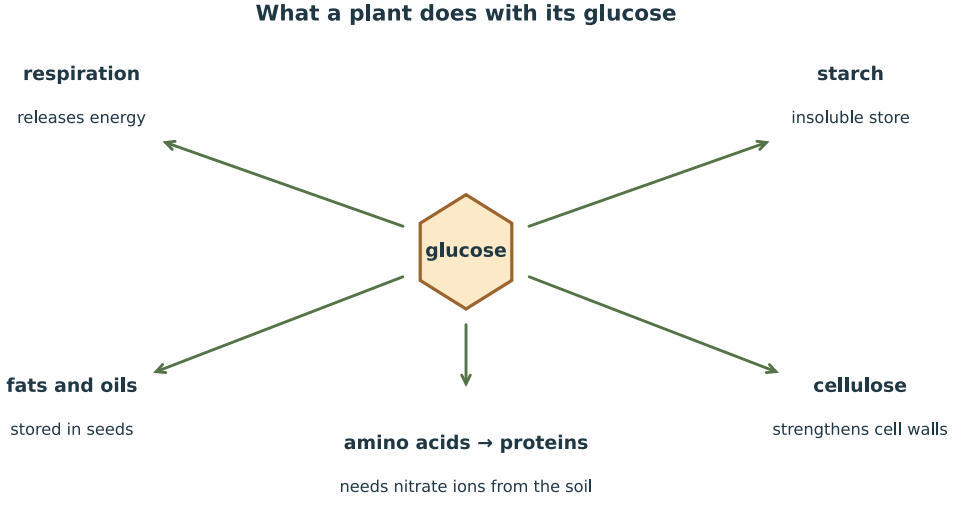
Inverse square applies to light intensity in the stated model, not automatically to photosynthesis rate across all conditions. A plateau can reflect another limiting factor. Profit uses both income and cost; comparing income alone is insufficient.

Where the glucose goes

Official-unit focus: 4.4 Bioenergetics

A leaf makes glucose, but a growing plant also needs strong walls, stored material and proteins. Glucose can supply carbon to several products with different functions.

Glucose made by photosynthesis can be used in respiration. It can be converted into insoluble starch for storage or into fat or oil for storage. It can also be used to make cellulose, which strengthens cell walls. Plants use glucose and nitrate ions absorbed from soil to form amino acids; these are used to synthesize proteins.



Storage, structure and energy transfer are separate roles. Starch is insoluble, so it can be stored without behaving like an equivalent amount of dissolved glucose. Cellulose is structural. Nitrate supplies needed nitrogen for amino acids; sunlight alone does not supply every element a growing plant needs.

Sort glucose-use cards by product and function. Link nitrate absorption by roots to protein production rather than to oxygen release. Interpret teacher-provided results of starch, glucose and protein tests with controls. Actual testing follows approved reagents, heating and disposal; a negative test concerns the stated sample and detection conditions.

■ Checked worked case

Known: a fictional allocation model has 100 carbon units from glucose. It assigns 35 to respiration, 25 to starch, 20 to cellulose and 10 to oils. The remaining 10 can be assigned to other products in this model. These are accounting units, not a fixed biological percentage or a balanced synthesis equation.

■ Common error

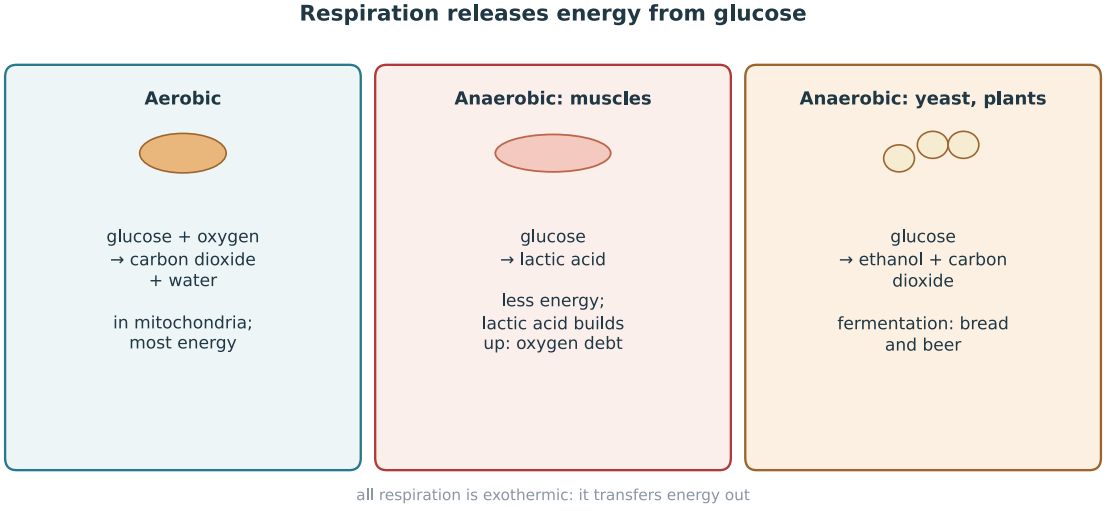
Photosynthesis makes glucose rather than directly making every protein. Plants need mineral nutrients as well as light, water and carbon dioxide. A glucose molecule cannot supply nitrogen that it does not contain; nitrate is relevant to amino acids and proteins.

Compare three respiration equations

Official-unit focus: 4.4 Bioenergetics

Muscle cells and yeast can both transfer energy without oxygen, but their products differ. Name the organism before selecting the anaerobic equation.

Cellular respiration is continuously occurring in living cells and is exothermic. It transfers energy needed for chemical reactions building larger molecules, movement and keeping warm. Aerobic respiration uses oxygen: glucose + oxygen → carbon dioxide + water. Required symbols are $C_6H_{12}O_6$, O_2, CO_2 and H_2O.



Anaerobic respiration in muscle is glucose → lactic acid. Oxidation is incomplete, so

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much less energy is transferred than in aerobic respiration. In plant and yeast cells, anaerobic respiration is glucose → ethanol + carbon dioxide. Yeast fermentation is economically useful: carbon dioxide helps bread dough rise, and ethanol is used in alcoholic-drink manufacture.

Build a comparison table with oxygen requirement, products and relative energy transfer. Use teacher-provided fermentation data or a supervised approved yeast practical; control temperature, substrate amount and observation time. Keep apparatus safely vented according to school instructions. Do not infer an energy yield from gas volume alone or introduce unrequired ATP counts.

■ Checked worked case

Known: an approved yeast model produces 18 cm^3 gas in 6 minutes, giving a mean rate of 3 cm^3 per minute. A matched condition produces 12 cm^3 in the same time, or 2 cm^3 per minute. This compares carbon dioxide output under the stated conditions; it is not a direct comparison of muscle lactic-acid production.

■ Common error

Respiration is a chemical process in cells, whereas breathing moves air. Plants also respire. Carbon dioxide is a product of the yeast anaerobic model but is not a product of the muscle equation here. Less energy transfer is not the same as no energy transfer.

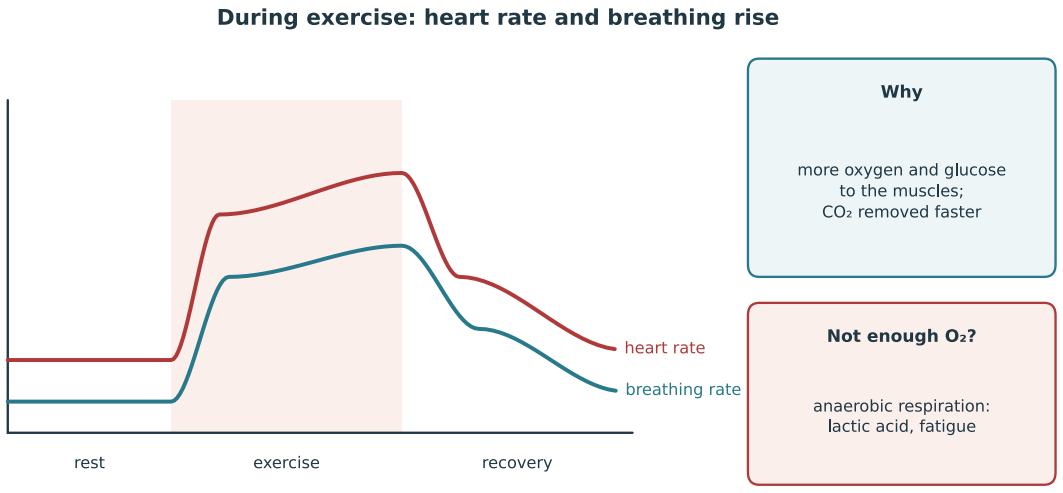
Exercise increases oxygen delivery demand

Official-unit focus: 4.4 Bioenergetics

During activity, working muscles need more energy. The body increases delivery of oxygenated blood, rather than producing oxygen in the heart.

Exercise increases the energy demand of muscle cells. Heart rate, breathing rate and breath volume increase, helping supply muscles with more oxygenated blood for aerobic respiration. If oxygen supply is insufficient for the demand, anaerobic respiration takes place in muscles. Incomplete oxidation of glucose causes lactic acid to build up and creates an oxygen debt.

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During long periods of vigorous activity muscles become fatigued and stop contracting efficiently. Breathing can remain elevated during recovery as extra oxygen is needed. Distinguish rate from volume: breaths per minute and volume per breath are separate quantities, so both can affect the volume of air moved per minute.

Use supplied fictional exercise-and-recovery records or a voluntary teacher-approved low-intensity observation. Participation needs consent and an alternative data task; do not test maximal effort, illness, medication or distress. Keep timing and measurement method consistent and protect personal information. Explain trends without treating classroom results as a health diagnosis.

■ Checked worked case

Known: a fictional record has 12 breaths per minute and 0.5 litres per breath at rest, giving 6 litres per minute. During the stated activity, 20 breaths per minute and 0.8 litres per breath give 16 litres per minute. This is air movement, not pure oxygen uptake; air contains other gases and exchange is not complete.

■ Common error

The heart moves blood and does not generate oxygen. Faster breathing does not mean every oxygen molecule in the air enters the blood. The detailed liver handling of lactic acid and quantitative definition of oxygen debt are Higher Tier content taught separately.

Higher Tier: lactic acid and recovery

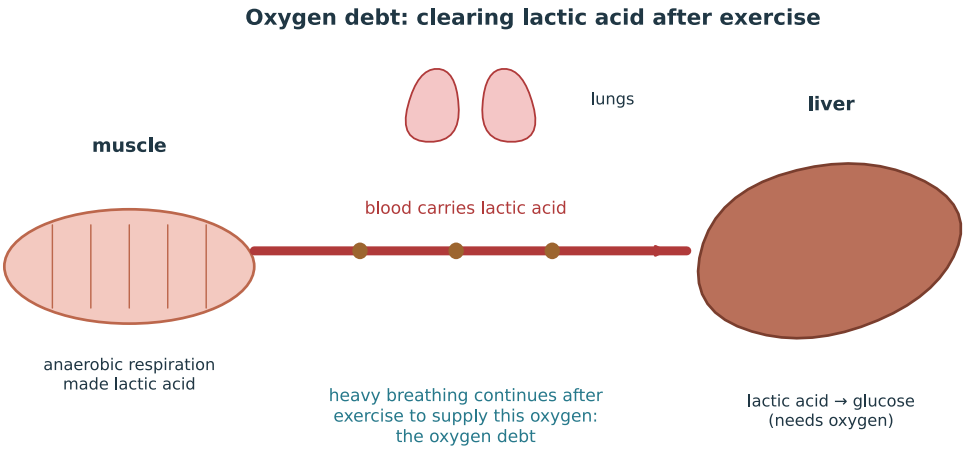
Higher Tier focus; see section scope notes.

Official-unit focus: 4.4 Bioenergetics

Stopping an activity does not immediately return oxygen demand to its resting level. Recovery includes handling substances accumulated during anaerobic respiration.

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When oxygen supply cannot meet vigorous muscle demand, incomplete glucose oxidation produces lactic acid. In the specified Higher Tier model, blood flowing through muscles transports lactic acid to the liver, where it is converted back into glucose. Oxygen debt is the extra oxygen the body needs after exercise to react with accumulated lactic acid and remove it from the cells.



Explain the sequence using location and transport: muscle production, blood movement, liver processing and continued oxygen demand. The examination model supports explaining raised breathing during recovery. It does not imply that all oxygen consumed during exercise was absent or that every recovery process is the same chemical reaction.

Interpret supplied recovery oxygen-use data against a stated resting baseline. For equal observation intervals, subtract the resting requirement from each interval and total the extra volumes. This is an evidence model, not an invitation to provoke oxygen debt or fatigue experimentally. Human observations stay voluntary, low-risk and supervised.

■ Checked worked case

Known: resting oxygen use in a fictional model is 0.30 L per minute. Recovery use over three one-minute intervals is 0.90, 0.60 and 0.45 L. Extra oxygen = $(0.90-0.30)+(0.60-0.30)+(0.45-0.30) = 1.05$ L. Adding total use without subtracting baseline would overestimate the extra amount.

■ Common error

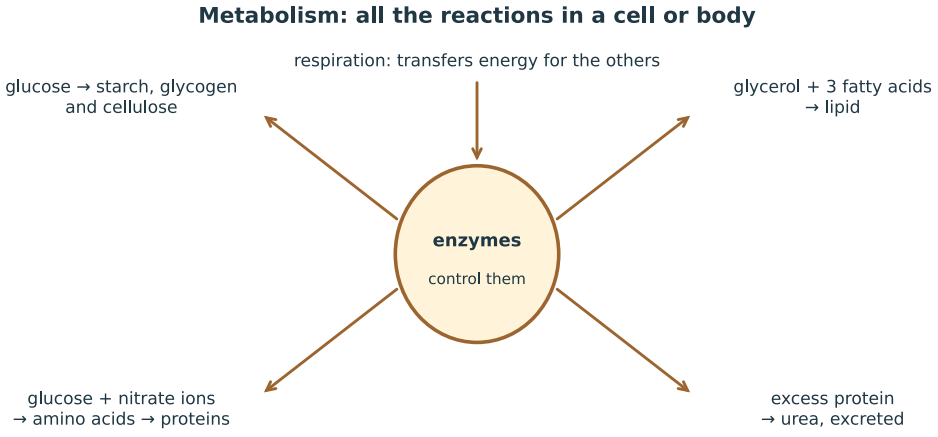
An oxygen debt is a quantity of extra oxygen, not a financial cost or simply the time taken to rest. Blood transports lactic acid; it does not mean the heart converts it into glucose. This finite supplied record estimates only the extra oxygen included in its stated intervals.

Metabolism links building and breaking down

Official-unit focus: 4.4 Bioenergetics

Digestion breaks some molecules down while cells build others. Metabolism includes both directions, linked by enzymes, available materials and energy transfer.

Metabolism is the sum of all reactions in a cell or body. Energy transferred by respiration supports continual enzyme-controlled processes that synthesize new molecules. It includes glucose conversion into starch, glycogen and cellulose; formation of a lipid from one glycerol molecule and three fatty-acid molecules; and amino acids joining to form proteins.



In plants, glucose and nitrate ions provide materials for amino-acid production. Metabolism also includes respiration and the breakdown of excess proteins to form urea for excretion. Match each molecule to its role rather than treating every metabolic reaction as digestion or every product as an energy store. Urea formation and urea excretion are related but distinct processes.

Build a concept map with reactants, products and functions. Use one arrow for a specified conversion and annotate any needed additional material, such as nitrate. Trace where a material comes from and where a waste goes. Do not add advanced reaction pathways or treat the lipid particle-ratio model as a complete biochemical mechanism.

■ Checked worked case

Known: the stated lipid-building model requires one glycerol and three fatty acids per lipid molecule. For 7 lipid molecules it needs 7 glycerol and 21 fatty-acid molecules. With 10 glycerol and 24 fatty acids, at most 8 lipid molecules can form in this model because fatty acids run out first, leaving 2 glycerol molecules unused.

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■ Common error

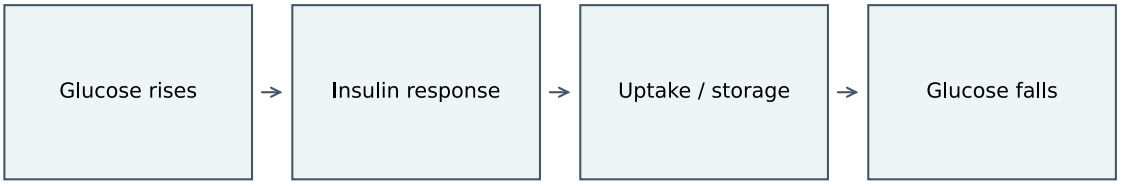
Metabolism includes synthesis and breakdown, not only reactions that release energy. Proteins are made from amino acids, while lipids use glycerol and fatty acids. Urea is a waste from excess protein breakdown and is not the same substance as glucose or lactic acid.

Feedback and internal conditions

Official-unit focus: 4.5 Homeostasis and response

Blood glucose rises after a meal, but usually does not keep rising indefinitely. A control system responds to the change in internal conditions.

Homeostasis maintains internal conditions within suitable limits. Receptors detect changes, coordination centres process information, and effectors respond. Negative feedback opposes the original change.



When blood glucose is high, insulin helps increase glucose uptake and storage as glycogen. When it is low, glucagon supports release of glucose from stores. These responses are coordinated, not identical effects of two hormones.

Interpret a time graph by identifying the initial disturbance, the response and the return toward the normal range. Mark the delay before a response. Do not assume a graph shows an instantaneous correction.

■ Checked worked case

Known: glucose changes from 5.0 to 7.0 arbitrary concentration units. Increase = final - initial. Increase = 7.0 - 5.0 = 2.0 units. Percentage increase = 2.0/5.0 × 100 = 40%. The numerical change is evidence of a disturbance, not a diagnosis on its own.

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■ Common error

Negative feedback does not mean the response is harmful or the measured value becomes negative. Diabetes has different mechanisms; do not treat every case as a failure to make insulin.

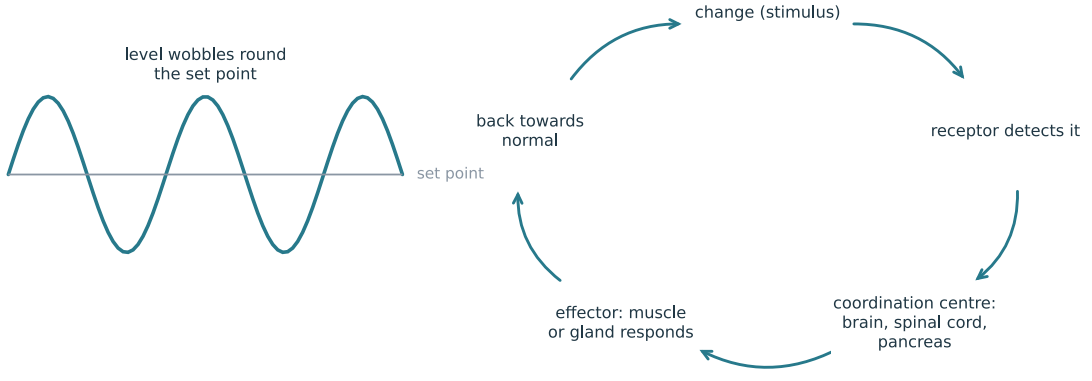
Homeostasis: detect a change and respond

Official-unit focus: 4.5 Homeostasis and response

The temperature outside can change while the body maintains a much narrower internal range. Control systems respond to change rather than keeping the outside environment constant.

Homeostasis regulates internal conditions of a cell or organism to maintain optimum conditions for function. It supports enzyme action and other cell functions. In humans the course examples are blood glucose concentration, body temperature and water levels. Control can involve nervous responses or chemical responses.

Homeostasis: negative feedback keeps conditions steady



Receptors detect stimuli, or changes. A coordination centre such as the brain, spinal cord or pancreas receives and processes information. Effectors are muscles or glands that produce a response restoring suitable levels. A receptor detects a change; it is not necessarily the structure producing the corrective action.

Use a paper control model with separate receptor, centre and effector cards. Present a stated change and follow the information and response arrows. Identify what the system measures and which internal condition it changes. The model must not claim that internal levels never fluctuate or that one organ alone performs every control function.

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■ Checked worked case

Known: a fictional temperature-control record has a reference of 37.0 °C and readings of 36.8, 37.2 and 37.0 °C. Deviations are −0.2, +0.2 and 0.0 °C. The range is 0.4 °C. Small variation can coexist with regulation; these model values are not diagnostic thresholds or a request to measure students' health.

■ Common error

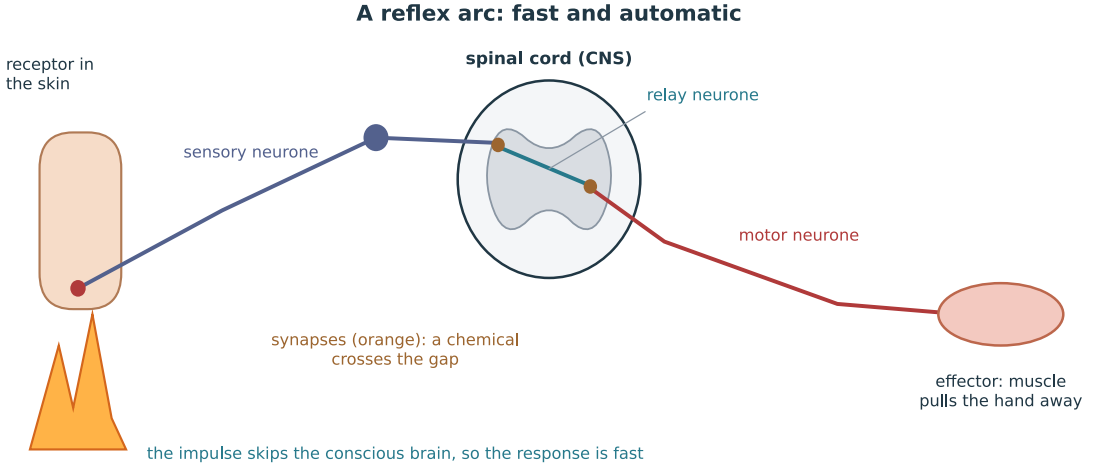
Homeostasis maintains suitable internal conditions rather than a perfectly constant outside world. Receptor, coordination centre and effector describe roles, not interchangeable labels. Nervous and chemical systems can both contribute; detailed hormone-specific feedback is taught in its own section.

A reflex arc: rapid automatic coordination

Official-unit focus: 4.5 Homeostasis and response

A hand can withdraw from a harmful stimulus before a person consciously decides to move it. The response follows a coordinated nerve pathway.

The nervous system enables responses to surroundings and coordinates behaviour. Receptors detect a stimulus and information travels as electrical impulses along neurones to the central nervous system, the brain and spinal cord. A response passes to an effector such as a muscle, which contracts, or a gland, which secretes.



A reflex pathway includes a sensory neurone carrying information from a receptor, a relay neurone in the CNS and a motor neurone carrying information to an effector. At a synapse a chemical messenger crosses the small junction between neurones and triggers a new electrical impulse in the next cell. Reflexes are automatic and rapid and do not involve the conscious part of the brain, helping protect the body from harm.

Arrange a labelled reflex-arc model in the correct order and explain the direction of

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information at each connection. Compare automatic reflexes with deliberate choices without testing pain or injury. Use supplied timing tables to interpret responses; do not claim that a stimulus physically travels as an object through the nerve.

■ Checked worked case

Known: fictional pathway stages take 8, 3 and 11 ms in a supplied model. Total model time = 8+3+11 = 22 ms, or 0.022 s. This sums the stated delays only. It is not a universal human reflex time and does not include any omitted receptor or muscle delay.

■ Common error

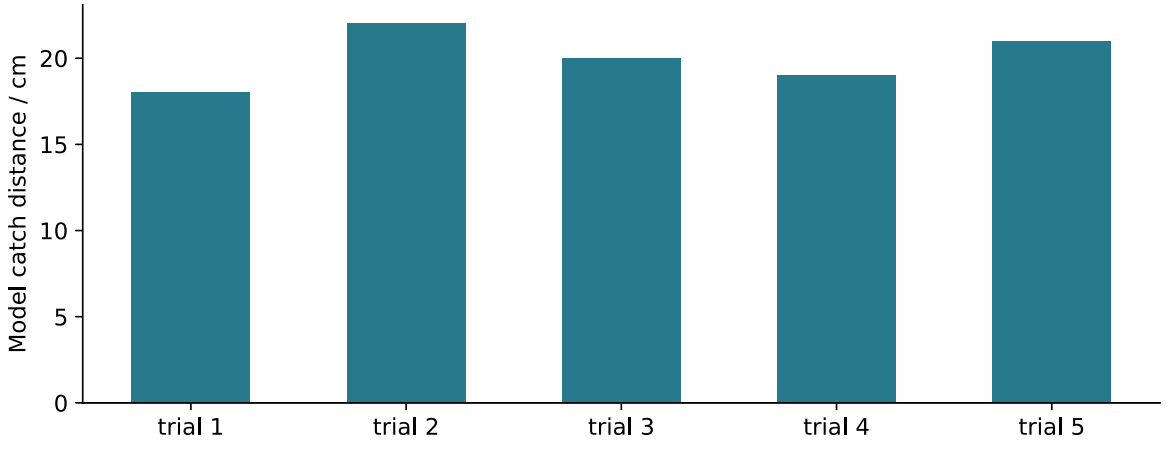
A reflex does involve the nervous system even though it is not a conscious choice. The sensory neurone leads towards the CNS; the motor neurone leads towards an effector. A synapse is a junction, not a whole sensory cell or a blood vessel.

Required practical 7: reaction time and fair comparison

Official-unit focus: 4.5 Homeostasis and response

A ruler-drop result can improve because someone learns when to expect the drop. A fair investigation must distinguish the chosen factor from practice and anticipation.

Reaction time is the interval between a stimulus and a response. In required practical 7 a suitable factor is investigated under school supervision. A ruler-drop method measures the distance fallen before a catch. Use a supplied conversion chart if time is required; distance in centimetres is not automatically time in seconds.



The chosen factor must change while other relevant conditions stay comparable. Keep the starting ruler position, hand position, catching method and instructions consistent. Avoid advance cues to the release. Repeated trials reduce the influence of random variation; a planned order can reduce practice or fatigue effects. A shorter drop distance generally indicates a quicker catch in the same method.

Use informed, voluntary participation and an alternative supplied-data task. Choose

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a low-risk factor such as a stated distraction under teacher guidance, not sleep deprivation, stimulants, illness, distress or strenuous exertion. Repeat enough trials, record all results and use a mean or justified treatment of an anomalous result. Do not rank students' ability or infer medical conditions.

■ Checked worked case

Known: model catch distances are 18, 22, 20, 19 and 21 cm. Mean = 100/5 = 20 cm. A second condition averaging 25 cm suggests slower catching under the same method. Without repeats, order control and comparable starting positions, the difference cannot confidently be assigned to the chosen factor.

■ Common error

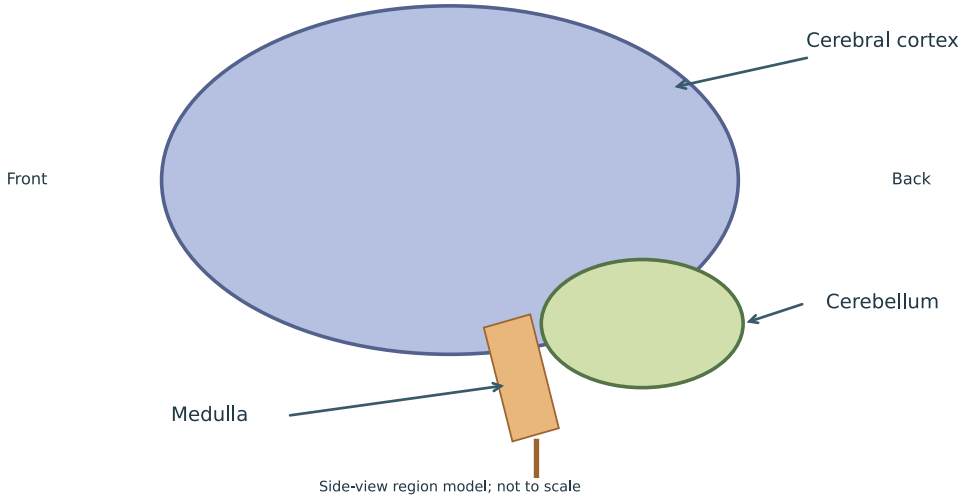
A result is a measurement under particular conditions, not a permanent personal characteristic. Never silently discard the largest value just to improve the mean. A distance-to-time conversion must use the specified model or table rather than relabelling centimetres as milliseconds.

Brain regions have different functions

Official-unit focus: 4.5 Homeostasis and response

Different brain regions contribute to different tasks, yet they work through interconnected neurones. A labelled location is useful only when its function is also explained.

The brain controls complex behaviour and contains billions of interconnected neurones. The cerebral cortex supports functions including consciousness, intelligence, memory and language. The cerebellum coordinates muscle movement and balance. The medulla controls unconscious functions such as breathing and heart rate.



Use a diagram's orientation to locate a region rather than assuming every picture has the same left/right view. The large outer cerebral region, the smaller cerebellum

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towards the back and the medulla linking to the spinal cord are distinct. A function can involve connections between regions; naming a region does not imply that it acts in isolation.

Identify these three regions on teacher-provided side-view diagrams and connect each label to an example function. Compare a deliberate spoken answer, coordinated movement and automatic breathing. This is an observation/model task; school learners should not attempt electrical stimulation, injury-based experiments or tests of neurological disease.

■ Checked worked case

Known: a supplied learning model groups 36 function cards equally among the three named regions. Each group has 12 cards. This is only an organizational classroom calculation, not a measure of brain size, neurone number or the proportion of behaviour controlled by a region. The actual region–function links need biological reasoning.

■ Common error

The medulla and cerebellum are not alternate names for the cerebral cortex. A brain schematic is not to scale and cannot diagnose damage. The separate Higher Tier lesson discusses the evidence and difficulty of mapping brain function; its procedures are not classroom experiments.

Higher Tier: evidence about brain function

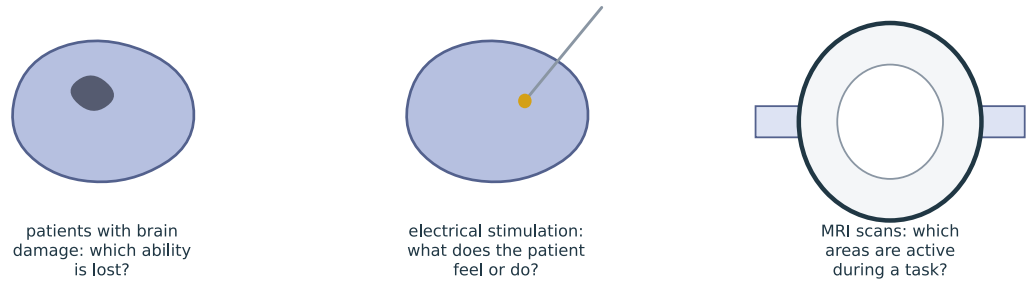
Higher Tier focus; see section scope notes.

Official-unit focus: 4.5 Homeostasis and response

A scan can show a pattern related to a task, but a correlation is not automatically proof that one region alone causes the whole behaviour.

Neuroscientists map brain regions using evidence from patients with brain damage, electrical stimulation of particular areas and MRI scanning. Damage associated with a lost function provides evidence about a region's role. Stimulation can produce a response, and scanning can supply structural or task-related information interpreted using the stated technique.

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The brain is complex and delicate. Regions are interconnected, damage may affect more than one pathway and invasive procedures can cause harm. Evaluating a procedure weighs the expected information or treatment benefit against risks, uncertainty and ethical constraints. Agreement between different kinds of evidence can strengthen a conclusion without eliminating every limitation.

Compare supplied fictional case summaries, a stimulation map and a described scan result. State what each actually measures and distinguish association from direct intervention. Real procedures require professional oversight and appropriate consent. The school task is evidence analysis, never an instruction to stimulate brains, imitate a clinical scan or provoke damage.

■ Checked worked case

Known: a fictional evidence set reports a stated response in 18 of 24 recorded stimulation cases, or 75%. Six cases differ. The proportion summarizes those records but does not prove a universal region–function relationship; location, procedure, patient differences and the definition of a response need review.

■ Common error

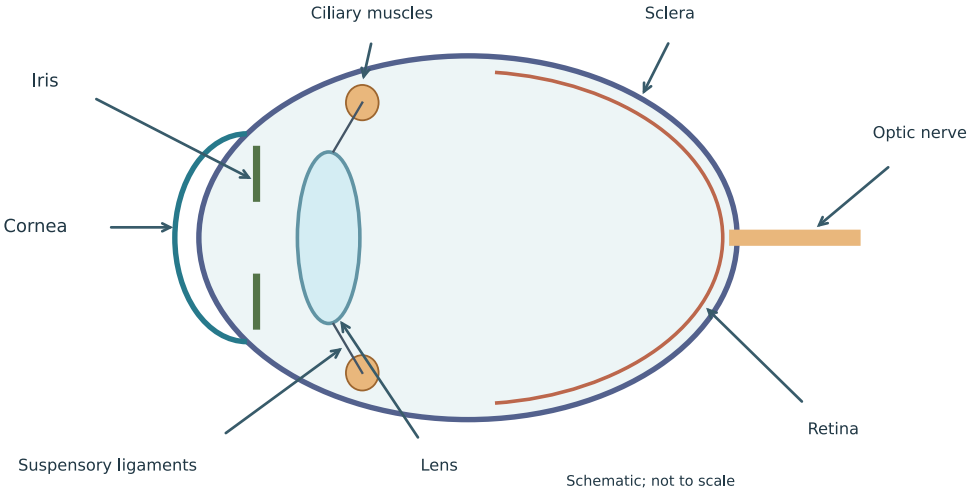
MRI is a technique rather than a single universal readout of every thought. A damaged region may affect connected systems, so a lost function cannot always be localized to one isolated cell group. Higher Tier evaluation must give a specific benefit and risk rather than a generic claim that technology is good.

The eye detects light and controls its entry

Official-unit focus: 4.5 Homeostasis and response

In dim light the eye can admit more light by changing its pupil size. The pupil is an opening, not the structure that detects the image.

The retina contains receptors sensitive to light intensity and colour. The optic nerve carries information from the eye towards the brain. The sclera is a tough outer layer; the transparent cornea admits and refracts light. The iris controls the diameter of the pupil. The lens refracts light to focus an image on the retina.



In dim light the iris allows a larger pupil, admitting more light; in bright light it reduces the opening. This is different from accommodation, which changes lens shape for focusing. Ciliary muscles and suspensory ligaments control lens shape. Correct diagram labels must distinguish a boundary, an opening, a transparent structure and a nerve.

Use a teacher-provided eye cross-section and safe ordinary-light observations or photographs. Locate each structure and write its function. Do not shine intense lights or lasers into an eye, touch eye structures or apply medicines. Compare pupil-size diagrams at the same scale rather than mistaking an enlarged image for an actual physiological change.

■ Checked worked case

Known: a supplied circular-pupil model changes diameter from 2 mm to 4 mm. Radius doubles, so opening area increases by a factor of $2^2 = 4$. This geometrical model concerns the opening; it does not imply that a person perceives exactly four times the brightness or that the retina has enlarged.

■ Common error

The iris controls pupil size; the pupil does not itself contract as a muscle. The optic nerve carries information and does not refract light. Bright/dim adaptation and near/far focusing require different explanations. All eye objectives in this AQA section are both-tier Biology content.

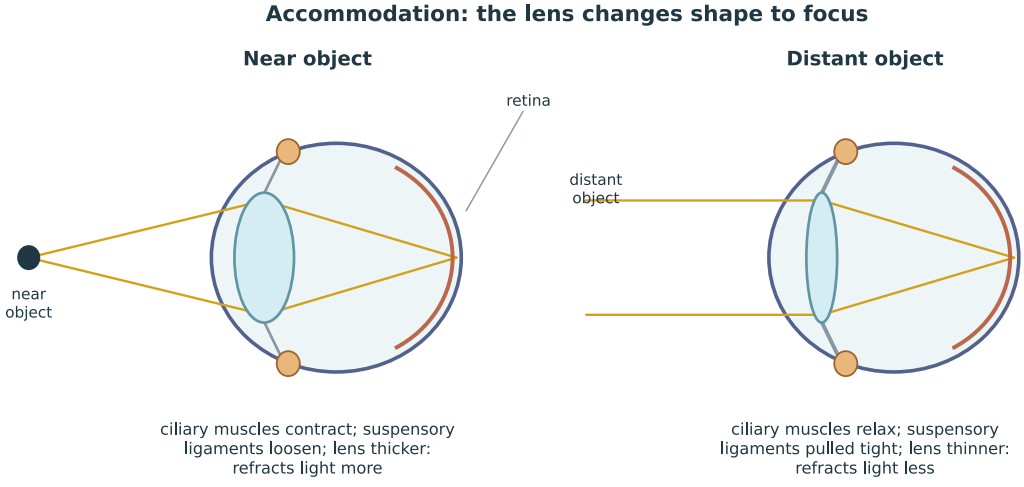
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Accommodation: near and distant objects

Official-unit focus: 4.5 Homeostasis and response

A close object and a distant object need different lens shapes to form a focused image on the same retina. Trace muscle, ligament and lens changes in order.

Accommodation is changing the lens shape to focus on objects at different distances. For a near object, ciliary muscles contract, suspensory ligaments loosen and the lens becomes thicker, refracting light more strongly. For a distant object, ciliary muscles relax, the ligaments are pulled tight and the lens is pulled thin, refracting light less strongly.



The lens does not actively pull itself into shape like a muscle. Explain the mechanical connection: ciliary-muscle action changes tension in the suspensory ligaments, allowing or pulling the elastic lens into the appropriate shape. A change in pupil size alone does not supply the required accommodation explanation.

Use a labelled paper or elastic-lens model under teacher supervision. Compare near and far configurations and annotate the three linked changes. Interpret ray diagrams by checking that rays focus on the retina. A diagram should clearly distinguish focusing from the separate bright/dim pupil response; do not apply pressure or chemicals to a real eye.

■ Checked worked case

Known: a supplied drawing magnifies a model lens dimension tenfold. A 25 mm drawn thickness represents 2.5 mm in the stated model; a 15 mm drawing represents 1.5 mm. The geometrical comparison shows which model is thicker but does not give a real person's lens dimensions or calculate focusing power.

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■ Common error

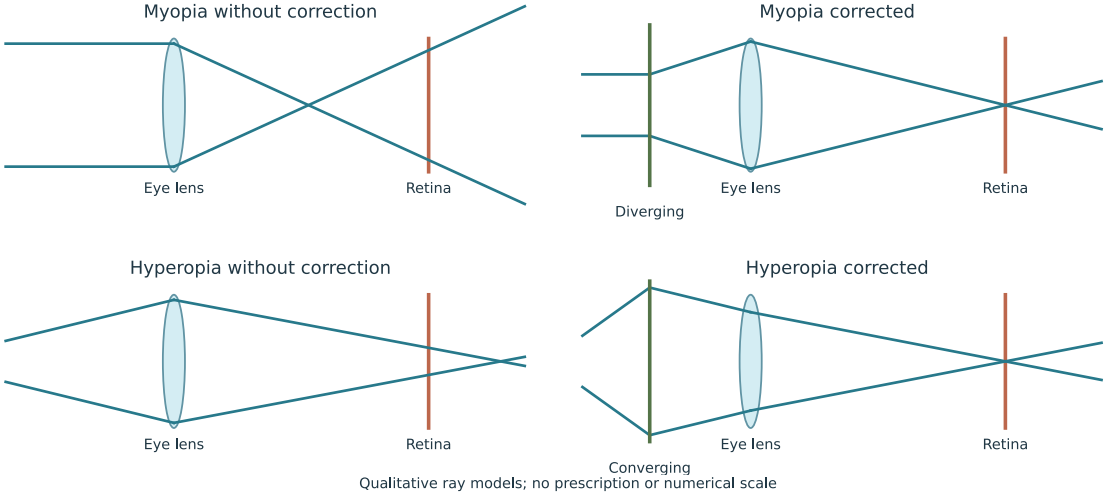
Near focusing uses contracted ciliary muscles and loose ligaments, not the reverse. For distance, tightening the ligaments pulls the lens thin. Drawing thickness and actual thickness need a stated scale. This section does not require a clinical eye test or a spectacle prescription.

Eye defects: restore focus to the retina

Official-unit focus: 4.5 Homeostasis and response

A blurry image can arise because rays focus before or beyond the retina. A corrective lens changes their direction before they reach the eye's own focusing structures.

In myopia, or short sightedness, rays from a distant object focus in front of the retina. A diverging spectacle lens changes the incoming rays so that the eye focuses them on the retina. In hyperopia, or long sightedness, rays from a near object would focus behind the retina. A converging spectacle lens helps bring the focus forwards onto it.



Qualitative ray models; no prescription or numerical scale

Interpret the ray diagram using the position of the retina and focus, then the effect of the external lens. The specification also identifies hard and soft contact lenses, laser surgery changing corneal shape and a replacement lens in the eye. These are correction technologies; choosing between them needs individual professional assessment rather than a classroom rule.

Trace supplied rays with a ruler and label before-retina, on-retina or behind-retina focus. Compare diagrams with the same orientation. Use safe model lenses and a screen if teacher-approved, never a laser directed at an eye. Explain how refraction corrects the indicated defect without prescribing a lens strength.

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■ Checked worked case

Known: a supplied diagram is drawn at five times the model scale. A drawn 10 mm distance between a focus and retina represents 2 mm in that model. This converts drawing size only. It does not reveal a spectacle power, an eye diagnosis or a real distance inside someone's eye.

■ Common error

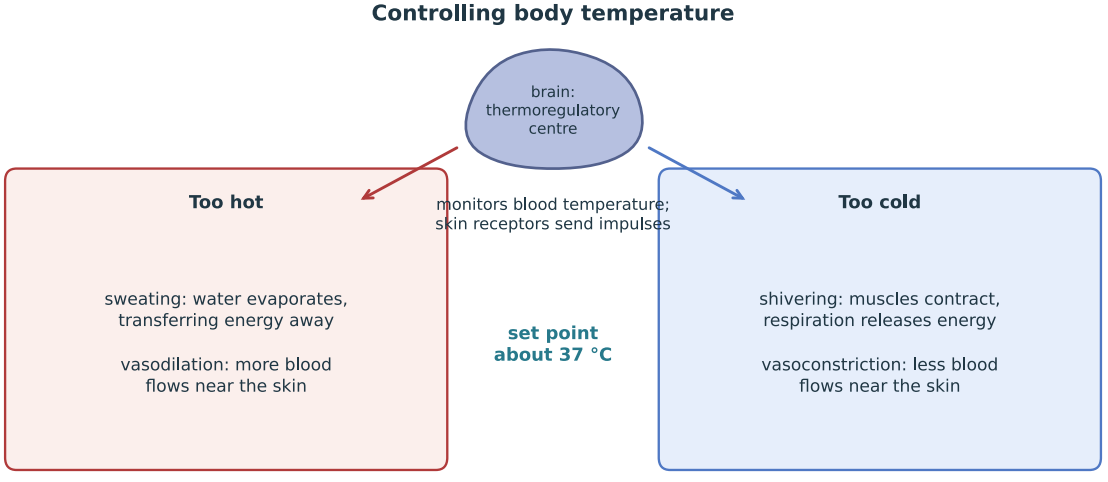
Myopia is corrected with a diverging lens, while the supplied hyperopia model uses a converging lens. A retina drawn on the wrong side can reverse an interpretation. Accommodation is the eye changing its own lens shape; a spectacle lens is an external correction.

Temperature control: detect hot and cold

Official-unit focus: 4.5 Homeostasis and response

The skin can detect a change outside while the brain also monitors blood temperature. These signals help coordinate responses to keep internal conditions suitable.

The thermoregulatory centre in the brain monitors and controls body temperature. It contains receptors sensitive to the blood temperature. Temperature receptors in the skin send nervous impulses to this centre. When temperature is too high, blood vessels supplying the skin dilate, called vasodilation, and sweat glands produce sweat.



When temperature is too low, those blood vessels constrict, called vasoconstriction, sweating stops and skeletal muscles contract repeatedly in shivering. These are co-ordinated responses rather than conscious choices alone. The specification connects hot-condition responses with transfer of energy from skin to the environment; the separate Higher lesson explains each mechanism in a stated context.

Arrange detection, coordination and response cards for hot and cold scenarios. Identify

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the receptors separately from sweat glands and muscles as effectors. Use supplied fictional temperature records; do not expose participants to extreme heat or cold, restrict fluids or provoke shivering experimentally. A safe model comparison can use ordinary containers rather than people.

■ Checked worked case

Known: a fictional record has temperatures 37.1, 37.3, 37.0 and 37.2 °C. Mean = 148.6/4 = 37.15 °C and range = 0.3 °C. These values illustrate summarizing controlled-condition data, not a diagnostic boundary. A mean alone can hide the sequence and speed of a response.

■ Common error

The thermoregulatory centre is in the brain, not the skin. Skin receptors detect change while sweat glands produce a response. Vasodilation and vasoconstriction have opposite effects on blood delivery near the surface; avoid swapping their names.

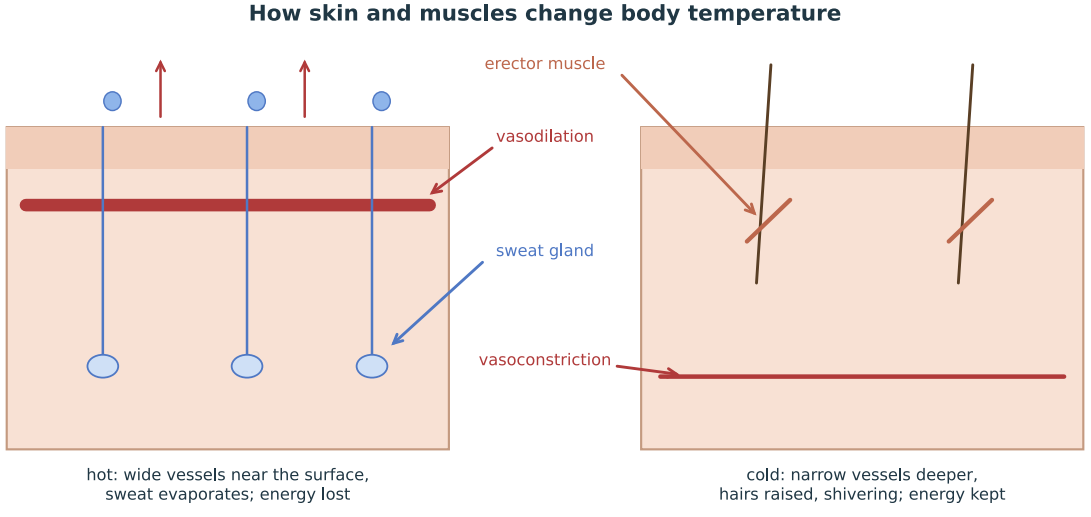
Higher Tier: explain heating and cooling mechanisms

Higher Tier focus; see section scope notes.

Official-unit focus: 4.5 Homeostasis and response

Sweat left on the skin does not give the same cooling as sweat that evaporates. Explain the energy transfer, not simply the presence of liquid.

Vasodilation increases blood flow through vessels near the skin surface, increasing the transfer of energy from the blood through the skin to the environment under suitable conditions. Evaporation of sweat requires energy, which is transferred from the skin and helps cool the body. Higher humidity can reduce evaporation, limiting this cooling mechanism.



Vasoconstriction reduces blood flow near the skin surface and therefore reduces energy

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loss there. Stopping sweating avoids further evaporative cooling. Shivering is repeated skeletal-muscle contraction; increased muscle activity and respiration transfer more energy, helping warm the body. Blood is diverted from surface vessels rather than all circulation stopping.

Interpret fictional hot/cold scenarios with stated air temperature, airflow or humidity. Predict which transfer changes and justify the mechanism. A teacher-approved wet/dry cloth model can illustrate evaporation at ordinary temperatures, but its heat transfer is not identical to a human body. Do not test dehydration, extreme environments or forced exercise in participants.

■ Checked worked case

Known: a safe fictional cloth model loses 3.6 g water by evaporation in 12 min, a mean of 0.30 g per minute. A matched humid-air model loses 1.8 g, or 0.15 g per minute. The lower mass-loss rate supports reduced evaporation under those model conditions; it does not calculate body temperature without additional energy data.

■ Common error

Shivering does not warm the body mainly by bones rubbing together. Evaporation transfers energy even though the remaining sweat may feel cool. A cloth mass-loss result measures water loss rather than automatically measuring heat energy or a person's core temperature.

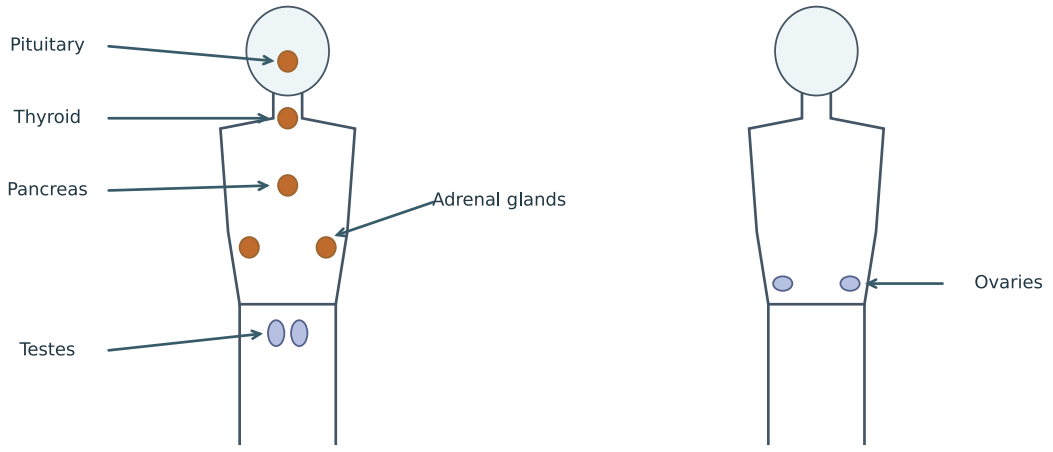
Endocrine coordination: blood carries the message

Official-unit focus: 4.5 Homeostasis and response

A hormone travels in blood, yet only suitable targets respond. Transport through the circulation is different from an electrical impulse along a neurone.

The endocrine system consists of glands secreting chemical hormones directly into the bloodstream. Blood carries a hormone to a target organ, where it produces an effect. Compared with nervous responses, hormonal effects are generally slower and last longer. The pituitary in the brain releases several hormones in response to body conditions; some stimulate other glands to release hormones.

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Schematic gland positions; reproductive organs on separate outlines

Locate the pituitary below the brain, thyroid in the neck, adrenal glands above the kidneys and pancreas in the abdomen. Ovaries lie in the pelvis and testes in the scrotum. These positions help identify glands on a body diagram; a gland's position is not the location of every target it affects. The term master gland describes the pituitary's coordinating role, not production of every hormone.

Label a teacher-provided body outline, then trace gland → blood → target → effect for a supplied hormone. Contrast that route with receptor → nerve pathway → effector. Use model data only; classroom investigations must not involve administering hormones or collecting sensitive personal medical information.

■ Checked worked case

Known: in a fictional transport model, a stated messenger travels a 30 cm route in 6 seconds. Model mean transport speed = distance/time = 5 cm per second. This arithmetic concerns the supplied model, not a universal hormone response time. Transport, target detection and the resulting cellular response are separate stages.

■ Common error

The pancreas is a gland, while insulin is a hormone it produces. Blood distribution does not mean all cells respond identically. A hormonal response cannot be assigned a fixed universal speed from one fictional transport calculation.

Insulin and two different diabetes models

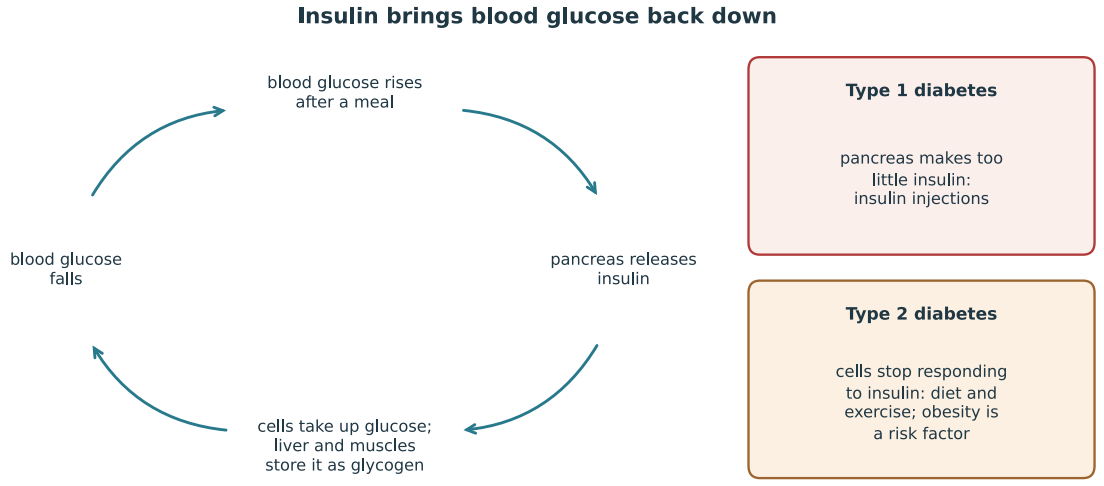
Official-unit focus: 4.5 Homeostasis and response

Two people can have raised blood glucose for different reasons. Distinguish the amount of insulin produced from the response of target cells.

The pancreas monitors and controls blood glucose concentration. If glucose is too high it releases insulin. Insulin promotes movement of glucose from blood into cells, and

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excess glucose in liver and muscle cells is converted to glycogen for storage. These responses lower the blood glucose concentration towards a suitable level.



In the specified Type 1 diabetes model, the pancreas produces insufficient insulin and insulin injections replace the missing hormone. In Type 2, cells no longer respond adequately to insulin; the specification describes carbohydrate-controlled diet and exercise as management principles and obesity as a risk factor. These are course comparisons, not individualized treatment plans or a claim that every person has the same management needs.

Compare fictional glucose curves with the same units and time origin. Identify the peak, subsequent trend and response to a stated intervention. Keep glucose concentration separate from total glucose mass and glycogen storage. Use supplied data only; do not take blood samples, alter meals, administer insulin or collect students' diagnoses.

■ Checked worked case

Known: a fictional concentration changes from 8.0 to 6.4 arbitrary units after the stated response. Decrease = 1.6 units and percentage decrease = $1.6/8.0 \times 100 = 20\%$. This describes that curve, not a diagnostic cutoff or a dose calculation. The mechanism requires uptake and storage, not the pancreas filtering blood.

■ Common error

Insulin and glycogen are different substances. Type 2 does not mean the pancreas necessarily produces no insulin. Obesity is a risk factor rather than proof of an individual diagnosis. Higher-only glucagon/negative-feedback interaction is taught separately.

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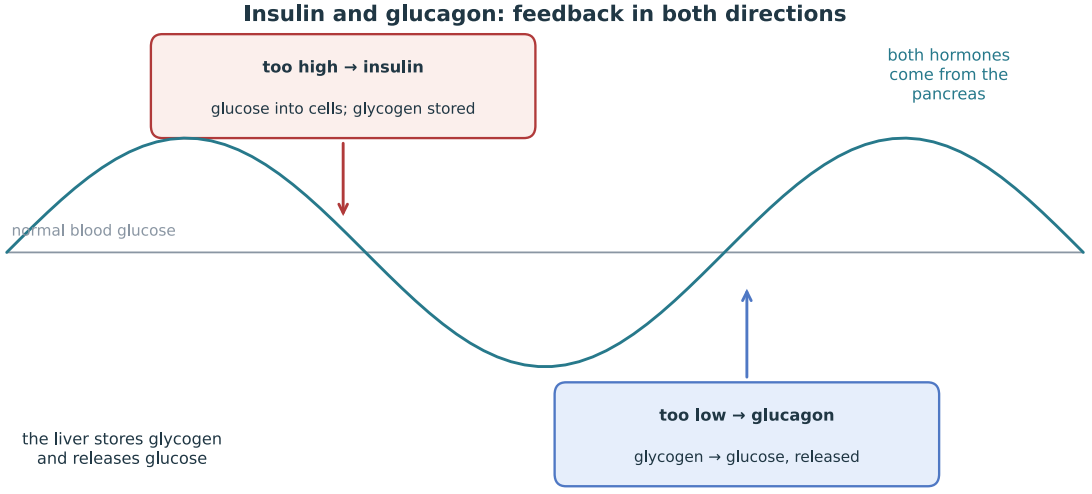
Higher Tier: opposing responses stabilize glucose

Higher Tier focus; see section scope notes.

Official-unit focus: 4.5 Homeostasis and response

A system needs a response to low glucose as well as high glucose. The two hormones act in opposite directions but support the same regulated condition.

When blood glucose is too low, the pancreas releases glucagon. This causes glycogen to be converted into glucose, which is released into the blood. When glucose is too high, insulin promotes uptake and storage. Negative feedback means a response opposes the original change and reduces the stimulus for continuing that response.



Trace two separate pathways: high glucose → insulin → lower glucose, and low glucose → glucagon → higher glucose. Both respond to the regulated variable. Do not say that glucagon and insulin simply cancel each other at all times, or that the system always holds one perfectly unchanging number.

Interpret supplied feedback diagrams and fictional glucose curves. For each arrow, state whether glucose rises or falls and why. Compare an initial disturbance with the later corrective trend. This is a model-analysis task; no fasting experiment, medication adjustment or blood sampling belongs in classroom practice.

■ Checked worked case

Known: a fictional low-glucose record rises from 3.0 to 4.2 arbitrary units after the stated glucagon response. Increase = 1.2 units, or 40% relative to the starting value. The percentage summarizes the data; it does not establish a clinical target or prove that glycogen stores are unlimited.

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■ Common error

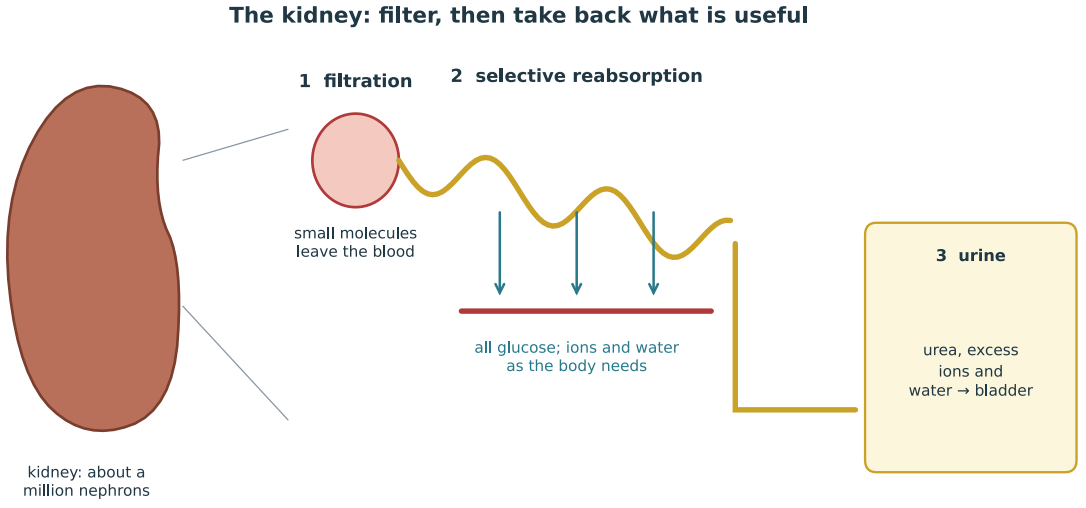
Glucagon is a hormone, glycogen is a stored carbohydrate and glucose is a sugar. Their similar names do not mean they perform the same role. Negative feedback opposes a change; positive feedback would amplify it. The exact response depends on available stores and the stated model.

Kidneys: filtration and selective reabsorption

Official-unit focus: 4.5 Homeostasis and response

Useful glucose can enter filtered fluid without being lost in the final urine. Filtration is followed by selective return of needed substances to the blood.

Water leaves the body during exhalation. Sweat carries water, ions and urea, while kidneys remove excess water, ions and urea in urine. The specification distinguishes these losses from selective control by the kidneys. If cells gain or lose too much water by osmosis, they do not function efficiently. More concentrated fluid outside causes net water loss through the partially permeable cell membrane and shrinking; more dilute fluid causes net entry and swelling.



Kidneys produce urine by filtering blood and selectively reabsorbing useful substances, including glucose, some ions and water. A substance in the initial filtrate is not automatically a waste product. The final composition depends on what is reabsorbed. Detailed nephron structure and other urinary-system anatomy are not required by this GCSE section.

Use supplied tables of amounts before filtration, in filtrate and after reabsorption. Keep amount and concentration distinct: removing water can change concentration even when the amount of a substance does not rise. Trace material across a paper filtration model; do not collect urine or medical information from students.

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■ Checked worked case

Known: a fictional filtered sample contains 8 units of glucose and all 8 are reabsorbed. The stated final sample contains zero glucose units. If 20 water units are filtered and 16 reabsorbed, 4 remain in the model urine. These are simple amount balances, not real kidney volumes or diagnostic measurements.

■ Common error

Reabsorption moves useful material back into blood; it is not the same as producing it. Urine and initial filtrate are different. The kidneys do not make urea in this model; Higher Tier liver processing and ADH permeability control are taught separately.

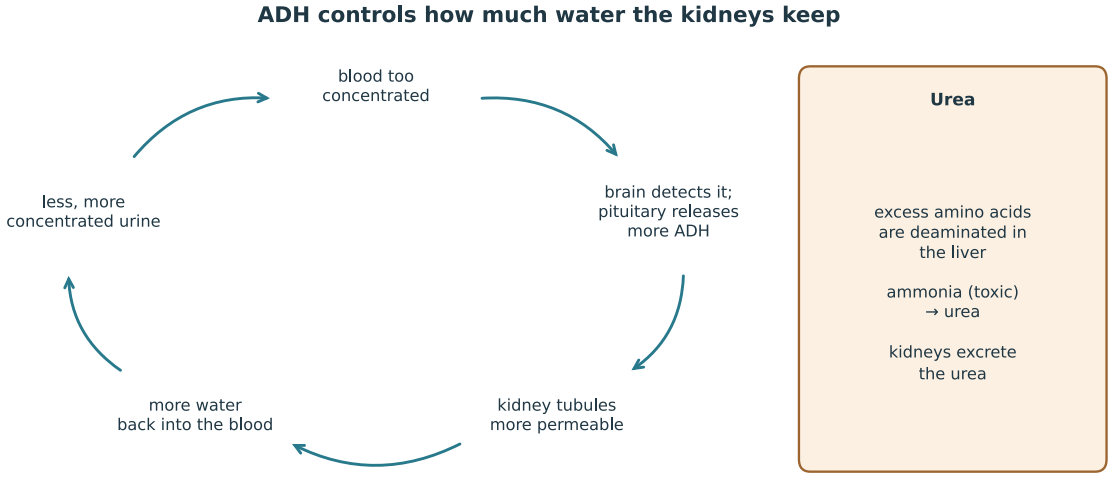
Higher Tier: ADH and nitrogen waste

Higher Tier focus; see section scope notes.

Official-unit focus: 4.5 Homeostasis and response

The liver processes excess amino acids, while the kidneys remove the resulting waste. Water balance additionally needs a hormone-controlled adjustment of reabsorption.

Digestion produces amino acids. Excess amino acids are deaminated in the liver, forming ammonia; because ammonia is toxic it is immediately converted to urea for safe excretion. The kidneys remove urea in urine. This separates waste formation in the liver from removal by the kidneys.



When blood is too concentrated, the pituitary releases more ADH. ADH increases the permeability of kidney tubules to water, so more water is reabsorbed into blood. Less water remains in urine. As blood returns towards suitable concentration, the stimulus for ADH release decreases: negative feedback opposes the original disturbance.

Trace two labelled models: amino acids → liver processing → urea → kidney excretion,

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and concentrated blood → ADH → permeability → water return. Interpret supplied amounts without confusing hormone concentration with urine volume. Use model evidence only; never investigate dehydration or hormone dosing in participants.

■ Checked worked case

Known: a fictional filtration model has 100 water units. Reabsorption changes from 90 to 96 units under a stated ADH response. Water remaining falls from 10 to 4 units, a 60% decrease. The calculation applies to this fixed filtered amount; it does not give an ADH dose or a universal human urine volume.

■ Common error

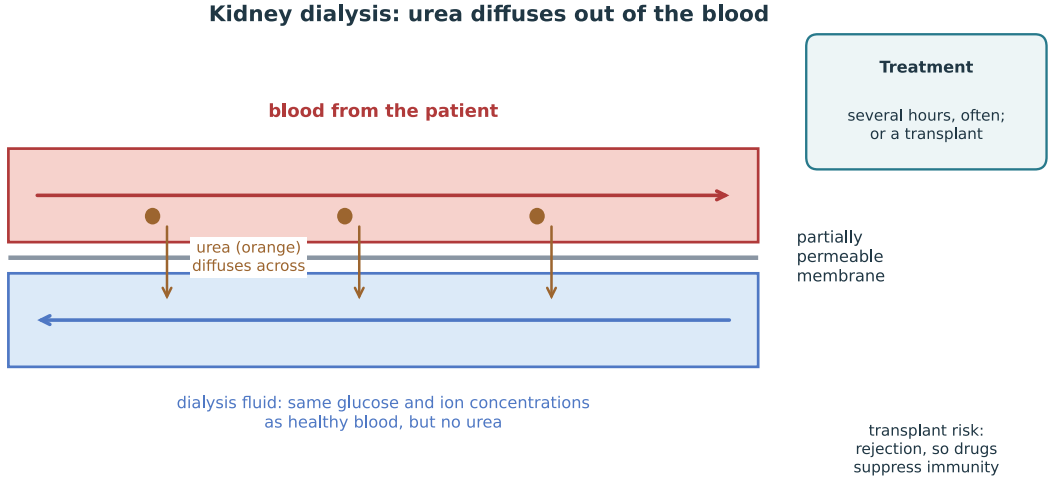
ADH changes permeability rather than directly turning water into glucose. More water reabsorption generally means a smaller water volume in urine in the stated model. Ammonia and urea are different, and the liver–not the kidney–is the specified site of deamination and urea formation.

Dialysis and transplant: compare evidence and burdens

Official-unit focus: 4.5 Homeostasis and response

A failed kidney cannot simply be replaced by a filter that removes every dissolved substance. A dialysis system must remove wastes while avoiding loss of needed materials.

In dialysis, blood and dialysis fluid are separated by a partially permeable membrane. Small dissolved substances can diffuse across; cells and large proteins remain in blood. Dialysis fluid is prepared with suitable glucose and ion concentrations so that needed amounts are not unnecessarily lost, while urea diffuses from its higher concentration in blood into the fluid.



Dialysis needs repeated treatment and imposes time and practical burdens. A successful kidney transplant can restore continuing kidney function, but needs a suitable

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donor, surgery and management of rejection. Compare risks, availability, lifestyle effects and evidence of benefit. Neither route should be presented as suitable for every individual or as a guaranteed cure.

Analyse fictional treatment summaries and membrane models with stated particle sizes and concentrations. Draw the expected net diffusion directions for urea and a named useful solute. This school task does not involve blood handling, human dialysis equipment or personal treatment recommendations.

■ Checked worked case

Known: a fictional model has 24 waste units before dialysis and 9 after the stated interval. Removed amount = 15 units; proportion removed = $15/24 \times 100 = 62.5\%$. This is an amount comparison. It does not establish a real treatment schedule, and fluid volumes would be needed to compare concentrations correctly.

■ Common error

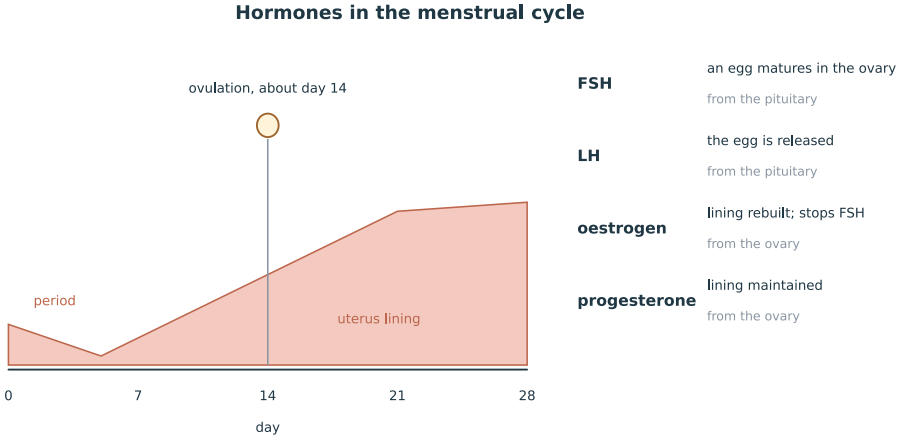
Dialysis is not selective because it recognizes the name of a waste; membrane permeability and concentration differences matter. Cells and large proteins should not cross the stated membrane. A transplant decision includes ethical and practical considerations beyond a single removal percentage.

Reproductive hormones: named roles before interactions

Official-unit focus: 4.5 Homeostasis and response

Maturing an egg, releasing it and maintaining a uterus lining are different events. Match each hormone with its stated role before interpreting a whole cycle.

At puberty reproductive hormones cause secondary sex characteristics to develop. Oestrogen is the main female reproductive hormone produced by ovaries; testosterone is the main male hormone from testes and stimulates sperm production. Ovulation is release of an egg from an ovary. The specification's approximately 28-day model is a simplified cycle, not a rule that every person has the same timing.



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FSH causes an egg to mature in an ovary. LH stimulates its release. Oestrogen and progesterone are involved in maintaining the uterus lining. An egg matures before it is released; ovulation is not fertilization or menstruation. Both-tier teaching requires these roles; the hormone interactions and graph analysis are separately Higher Tier.

Use anonymized model-cycle cards, locating ovary and uterus and placing maturation, ovulation and lining changes in order. Compare a simplified diagram with its stated assumptions. Do not collect classmates' menstrual histories, predict individual fertility from a model or conduct a hormone experiment.

■ Checked worked case

Known: a supplied model uses a 28-day cycle and marks an event 14 days after its stated start. This is half of that model interval. If a different diagram has a different length, read its labels rather than forcing the event to day 14. A classroom time fraction does not establish a contraceptive or pregnancy prediction.

■ Common error

FSH and LH have different roles. Testosterone is not produced by the ovary in this course model. Variation in real cycle timing means the simplified 28-day representation is used for biological explanation rather than personal forecasting.

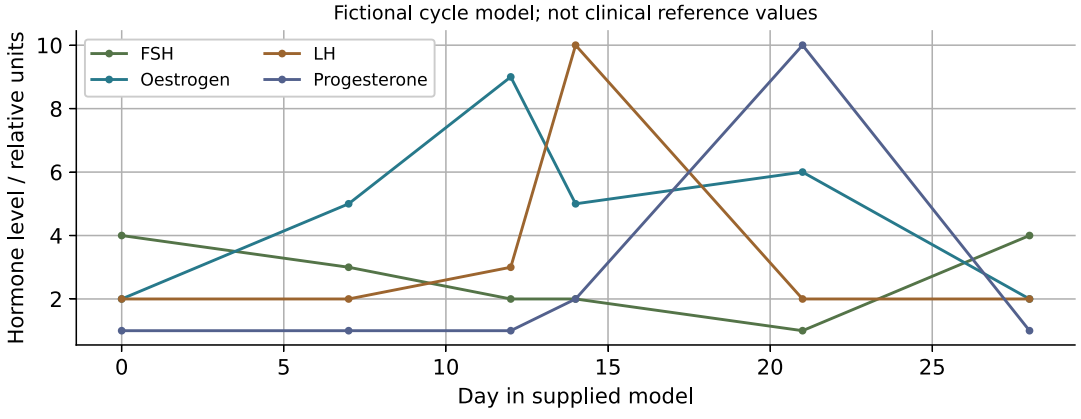
Higher Tier: hormones interact across the cycle

Higher Tier focus; see section scope notes.

Official-unit focus: 4.5 Homeostasis and response

A peak on a hormone graph is useful when connected to its effect and to other hormones. A cycle cannot be explained as four unrelated definitions.

FSH from the pituitary stimulates egg maturation and ovarian oestrogen production. Oestrogen supports rebuilding the uterus lining, inhibits FSH and, at the appropriate stage, stimulates LH release. The LH surge triggers ovulation. Progesterone maintains the lining and inhibits FSH and LH; falling progesterone allows lining loss and the start of another cycle.



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Read the supplied curves for the same time interval. Identify a hormone peak, connect it with the specified effect and explain an inhibition or stimulation arrow. Do not describe every increase as negative feedback: stimulation of the LH surge differs from inhibition of FSH. The simplified cycle model does not determine an individual's cycle dates.

Use fictional hormone graphs labelled with units or relative levels. Distinguish reading a value, describing a trend and explaining a mechanism. Relate a stated LH peak to the model ovulation event and a progesterone decline to lining loss. These are graph-analysis tasks, not instructions for personal fertility prediction or medication use.

■ Checked worked case

Known: a fictional LH curve rises from 2 to 10 relative units between two labelled days. Increase = 8 units and fold increase = $10/2 = 5$. The peak timing must be read separately from its height. A fivefold change does not mean five eggs are necessarily released.

■ Common error

Hormone concentration and egg number are different quantities. Inhibiting FSH reduces further maturation in the stated model rather than removing every hormone instantly. Menstruation is linked to falling support for the lining, not to the egg being physically washed out of the ovary.

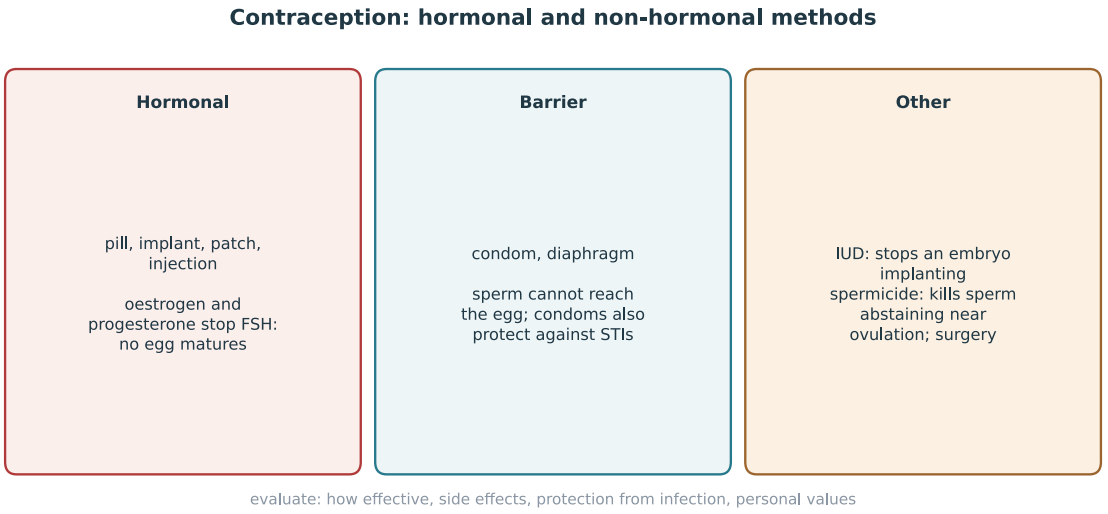
Contraception: mechanisms and evidence

Official-unit focus: 4.5 Homeostasis and response

Two methods can reduce pregnancy risk at different points in reproduction. Compare their mechanisms and evidence rather than assume one method answers every person's needs.

The specification describes oral hormones inhibiting FSH so eggs do not mature, and slow-release progesterone injections, implants or patches inhibiting maturation/release. Condoms and diaphragms form barriers to sperm reaching an egg; spermicides kill or disable sperm. Timed abstinence avoids intercourse when an egg may be in the oviduct; sterilisation interrupts gamete transport.

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Intrauterine methods include hormone-releasing devices and non-hormonal copper devices. The specification mentions prevention of implantation; the NHS reference explains copper's main effect on sperm survival and fertilisation, with a possible additional implantation effect. Distinguish pregnancy prevention from protection against sexually transmitted infections. Evaluate use requirements, reversibility, evidence and values without inventing universal success rates.

Use supplied fictional method comparisons with stated denominators and observation periods. Separate biological mechanism from practical use and ethical judgement. No classroom task should involve medical procedures, personal sexual histories or selecting a method for a student. Clinical clarification: Oxford University Hospitals, Copper IUD leaflet, page 5.

■ Checked worked case

Known: a fictional one-year comparison records 6 pregnancies among 300 users under stated use conditions. The observed proportion is 2%, not 6%. It describes those data, not a real method's published effectiveness. Different observation periods or typical/perfect use prevent a simple direct comparison.

■ Common error

A hormonal method does not necessarily protect against infection. A simplified calendar model cannot establish an individual safe interval. Scientific evidence informs effectiveness and risks, but choices also involve values, access and preferences.

Higher Tier: fertility hormones and IVF

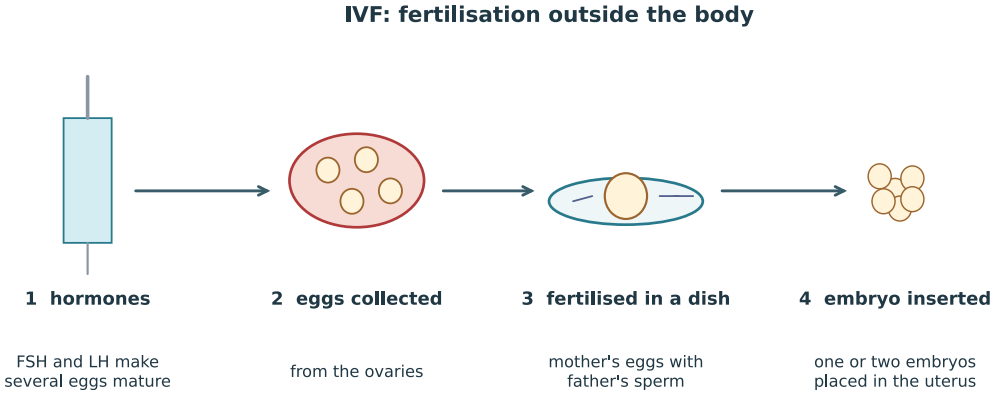
Higher Tier focus; see section scope notes.

Official-unit focus: 4.5 Homeostasis and response

Fertilisation in a laboratory is only one stage of IVF. The sequence also requires

maturing eggs, developing embryos and transfer to the uterus.

FSH and LH can be used as fertility drugs to stimulate egg maturation and release, after which pregnancy may occur through the usual route. In IVF these hormones stimulate maturation of several eggs. Eggs are collected and fertilised with sperm in a laboratory; fertilised eggs develop into embryos before transfer to the uterus.



evaluate: emotionally and physically stressful; low success rates; multiple births are risky

The specification describes transfer of one or two tiny embryos. This is its teaching sequence, not a current clinical recommendation about embryo number. Treatment can be physically and emotionally stressful, success is uncertain and multiple births can carry risks to mother and babies. Evaluate benefits and risks using the stated evidence and perspectives rather than promise a guaranteed baby.

Arrange an anonymized model IVF sequence and analyse fictional success data with a clearly defined outcome. Distinguish fertilisation, embryo transfer, pregnancy and live birth; rates for these outcomes are not interchangeable. Actual treatment is professionally supervised and does not become a school performance task or experiment on participants.

■ Checked worked case

Known: a fictional dataset records 18 stated successful outcomes among 60 treatment cycles. Observed rate = $18/60 \times 100 = 30\%$. This is a per-cycle rate for that definition, not a cumulative chance for a person after several cycles. Independence cannot be assumed without supporting information.

■ Common error

IVF does not place an unfertilised egg directly into the uterus as its final defining step. Fertilisation and implantation are different events. The course model must not be used to prescribe hormone doses or embryo numbers.

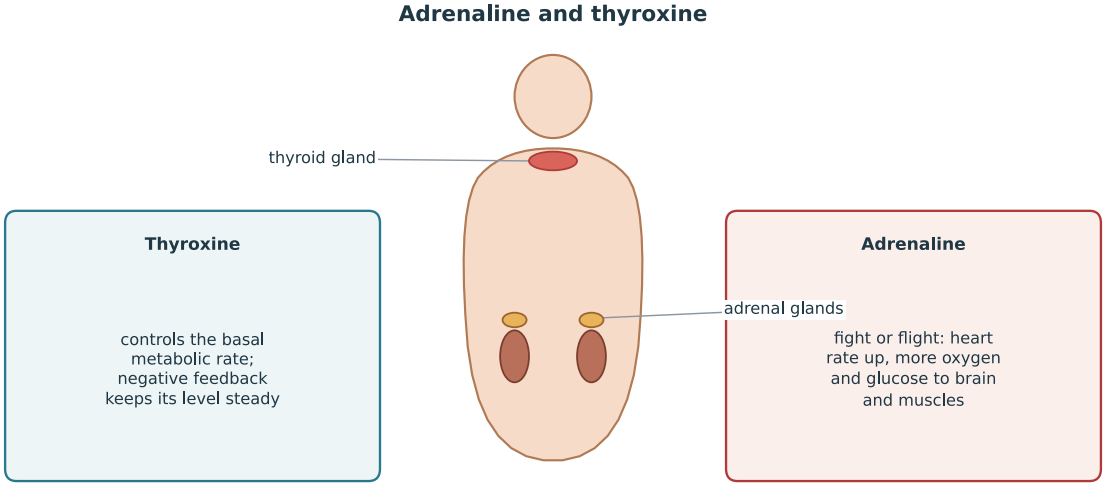
Higher Tier: thyroxine feedback and adrenaline response

Higher Tier focus; see section scope notes.

Official-unit focus: 4.5 Homeostasis and response

A rapid stress response and continuing metabolic regulation have different purposes. Identify the gland, hormone and effect before drawing a feedback loop.

Adrenaline is released by adrenal glands in fear or stress. It increases heart rate and boosts oxygen and glucose delivery to brain and muscles, preparing for fight-or-flight. Thyroxine is released by the thyroid and stimulates basal metabolic rate, supporting growth and development. Thyroxine levels are controlled by negative feedback.



A supplied thyroxine control diagram may show low thyroxine stimulating pituitary signalling to the thyroid, followed by thyroxine release. Raised thyroxine then reduces the stimulating signal. Explain how that opposes the initial fall. Do not assign the same negative-feedback sequence to every adrenaline event merely because both substances are hormones.

Compare fictional gland–hormone–effect diagrams and labelled time records. State which change is the stimulus and how the response changes the regulated variable. School tasks must not provoke fear, distress or dangerous exertion, administer hormones or interpret classmates' health. Use supplied data to analyse mechanisms and model boundaries.

■ Checked worked case

Known: a fictional resting energy-use model rises from 80 to 92 relative units. Increase = 12 units, or 15% of the starting value. This illustrates interpreting a stated metabolic response, not measuring a hormone level or diagnosing a thyroid condition. Hormone concentration requires its own units and evidence.

■ Common error

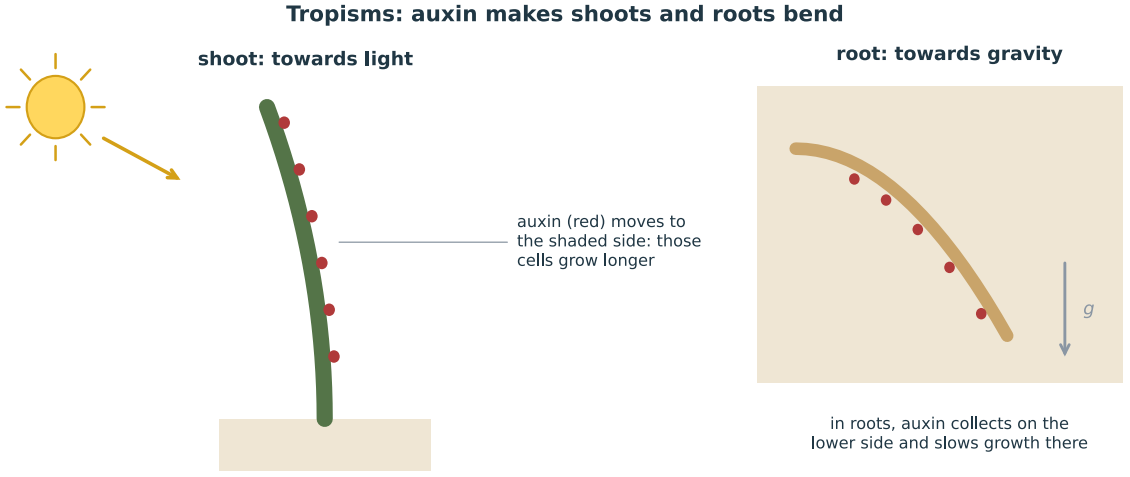
Adrenal glands and thyroid are different glands. Basal metabolic rate concerns resting metabolic activity rather than only visible movement. Negative feedback reduces a disturbance; an arrow labelled inhibition needs an explanation of what is inhibited and why.

Seedling responses: unequal growth makes a bend

Official-unit focus: 4.5 Homeostasis and response

A seedling bending towards light has not simply moved its whole stem sideways. Different growth on its two sides changes its direction.

Plants produce hormones coordinating growth and responses to light and gravity. Phototropism is a growth response to light; gravitropism is a growth response to gravity. Unequal auxin distribution causes unequal growth in roots and shoots. In the usual shoot model, more auxin on the shaded side increases elongation there, bending the shoot towards light.



Roots and shoots respond differently. In a horizontal root, more auxin on the lower side inhibits elongation relative to the upper side, so the root bends downwards. In a shoot, greater lower-side elongation bends it upwards. Explain the growth difference rather than claim that gravity pulls all the cells into a new shape.

For RP8 use teacher-approved newly germinated seedlings. Compare a planned light direction or orientation with a suitable control, keeping species, initial age, water, temperature and observation time comparable. Record lengths and careful labelled drawings showing direction. Do not test hormone effects on people; avoid touching growing tips or changing light and gravity conditions simultaneously.

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■ Checked worked case

Known: a fictional shoot model grows 6 mm on its shaded side and 4 mm on the illuminated side during one interval. Growth difference = 2 mm. The longer side helps explain bending towards light, but this difference alone does not calculate the bend angle without geometry and tissue information.

■ Common error

A tropism is growth in relation to a directional stimulus, not every plant movement. Auxin does not have the same elongation effect in every root and shoot situation. Gibberellin and ethene roles are Higher Tier and are taught separately.

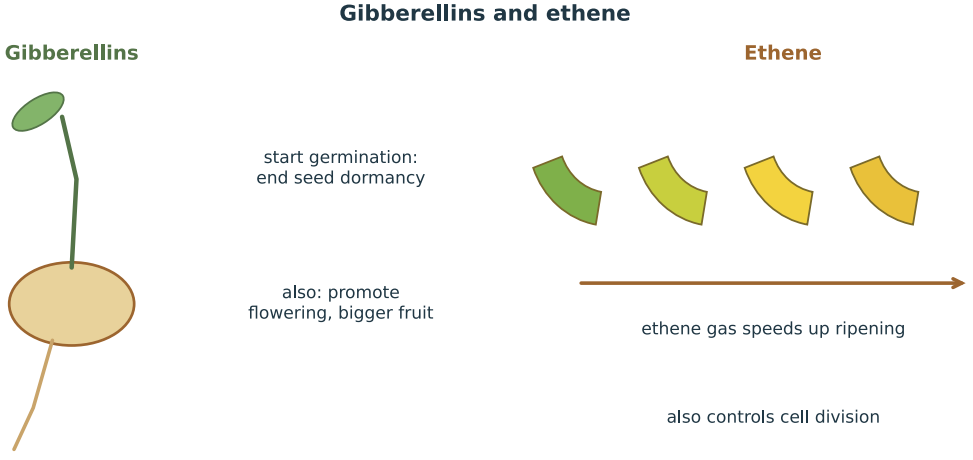
Higher Tier: germination and fruit ripening signals

Higher Tier focus; see section scope notes.

Official-unit focus: 4.5 Homeostasis and response

A seed beginning growth and a fruit ripening involve different hormone roles. Correctly naming the signal matters before considering a commercial use.

Gibberellins are plant hormones important in initiating seed germination. Ethene controls cell division and fruit ripening. These roles are required at Higher Tier, but the mechanisms by which the hormones act are not required. Hormones coordinate responses; they are not the stored food supplying all growth material.



Distinguish a hormone effect from the conditions needed for the response. A viable seed still needs suitable environmental conditions. A fruit-ripening comparison needs a matched variety, maturity and observation period. A greater observed response in one treatment does not prove that every species or developmental stage behaves identically.

Interpret teacher-provided germination and ripening records with controls. Count ger-

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minated seeds using a stated criterion and compare proportions rather than raw counts from unequal groups. School work uses only approved materials; do not release ethene gas or handle concentrated hormone products unsupervised. The task is role/evidence analysis, not molecular-pathway memorization.

Checked worked case

Known: a fictional germination trial has 24 germinated seeds among 40 in one stated condition and 15 among 30 in another. Proportions are 60% and 50%, a difference of 10 percentage points. A control and matched conditions are needed before attributing the difference to a hormone.

Common error

Ethene and ethanol are different substances. Gibberellins are not auxins and need not have the same growth effects. The specification excludes detailed molecular mechanisms here, so a correct GCSE explanation names the role and interprets the supplied evidence.

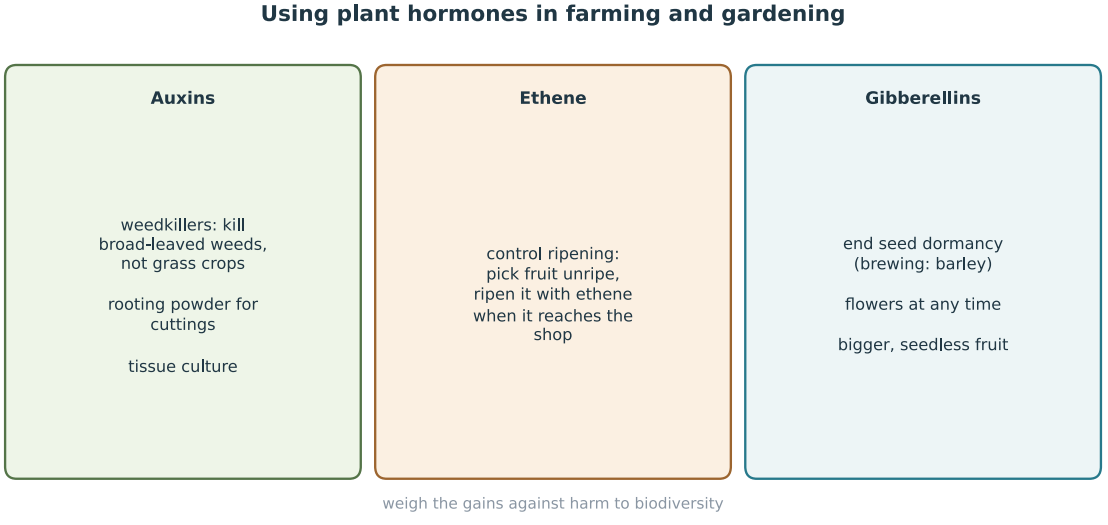
Higher Tier: controlling plant growth commercially

Higher Tier focus; see section scope notes.

Official-unit focus: 4.5 Homeostasis and response

A grower may want roots on a cutting, controlled fruit ripening or germination at the right time. The useful hormone depends on the intended result.

Auxins are used as weed killers, rooting powders and to promote growth in tissue culture. Ethene is used in the food industry to control fruit ripening during storage and transport. Gibberellins can end seed dormancy, promote flowering and increase fruit size. Match the use to a specific effect rather than calling every product a general fertilizer.



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A weed-killer application can change plant diversity and affect organisms depending on those plants. Evaluate intended crop benefits alongside non-target effects, biodiversity and the stated treatment conditions. A rooting comparison measures root formation, while a fruit-size comparison needs dimensions or mass; neither is automatically evidence for the other hormone uses.

Use fictional horticultural trials or teacher-supervised approved propagation. Keep plant variety, cutting size, growth conditions and observation time comparable. Follow school product handling instructions; do not apply weed killers to a habitat or release ripening gases as an independent school task. Tissue culture requires approved aseptic methods rather than unknown cultures.

■ Checked worked case

Known: a fictional rooting trial has 18 rooted cuttings among 24 with a stated treatment and 12 among 24 in a control. Proportions are 75% and 50%; difference = 25 percentage points. This supports the stated rooting comparison, not an unlimited dose response or a recommendation for every plant.

■ Common error

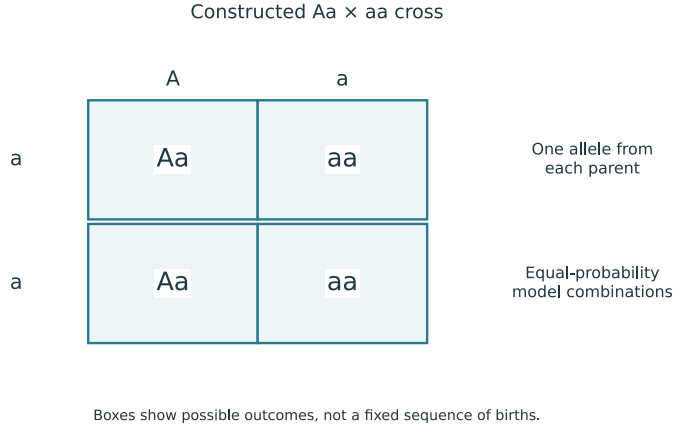
Hormones coordinate growth; mineral fertilizers provide nutrients and are a different intervention. A result for cuttings does not prove a fruit-ripening effect. Commercial benefits do not remove the need to evaluate non-target and biodiversity effects.

Inheritance, variation and probability

Official-unit focus: 4.6 Inheritance, variation and evolution

Two parents can carry a recessive allele without expressing the associated phenotype. Their children do not have to match the parents phenotypically.

An allele is a variant of a gene. A genotype lists alleles; a phenotype is the expressed characteristic, influenced by genotype and sometimes environment. Dominant and recessive describe the relationship between alleles, not how common they are.



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In a simple monohybrid cross Aa × Aa, gametes carry A or a. Combining independent gametes gives AA, Aa, Aa and aa. The predicted probabilities describe many possible fertilizations, not a fixed order of children.

Write parental genotypes and gametes before making the grid. State the inheritance model and phenotype key. Use a pedigree to check consistency with a model; do not infer certainty from a small family alone.

■ Checked worked case

Known: Aa × Aa with complete dominance. Probability of aa = 1/4 = 25%. Probability of the dominant phenotype = 3/4 = 75%. If four children are born, there is no guarantee that exactly one has the recessive phenotype.

■ Common error

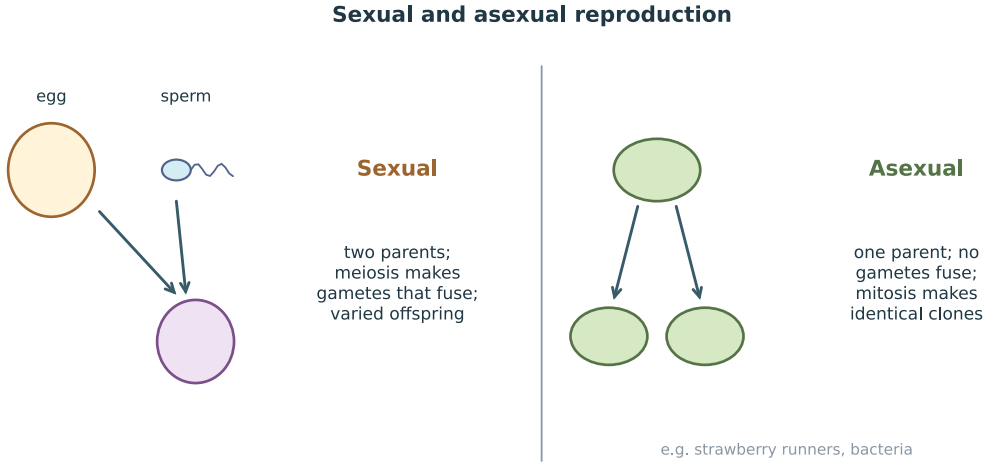
A dominant allele can be rare. Mutation is a source of new variation; selection changes the relative success of existing variants rather than directing mutations toward a goal.

Sexual and asexual reproduction: what joins?

Official-unit focus: 4.6 Inheritance, variation and evolution

A strawberry plant can form a runner or produce seeds. Counting visible plants is not enough to decide which reproductive process happened.

Sexual reproduction involves fusion of male and female gametes. In animals these are sperm and egg cells. In flowering plants pollen carries male gametes and the egg is the female gamete. Genetic information from two gametes mixes, producing variation in offspring. Meiosis forms the gametes; fertilisation joins them.



Asexual reproduction uses one parent without fusion of gametes. There is no mixing of information from two parents; mitosis produces genetically identical offspring called

clones in the school model. A clone can still grow differently in a different environment. Genetic identity is not a promise of identical height, health or every visible feature.

Sort supplied life-cycle descriptions by evidence: identify gamete fusion, number of parents and whether genetic information mixes. Draw two separate routes, rather than placing meiosis and mitosis as alternative names for the same division. Use prepared plant examples without treating human family characteristics as class investigation data.

■ Checked worked case

Known: a parent produces 12 runner-derived plants and 8 seed-derived plants. Asexual proportion = 12/(12+8) = 0.60, or 60%. This counts reproduction routes, not the proportion of DNA inherited from each parent. Seed-derived plants are not classified as clones simply because their flowers look similar.

■ Common error

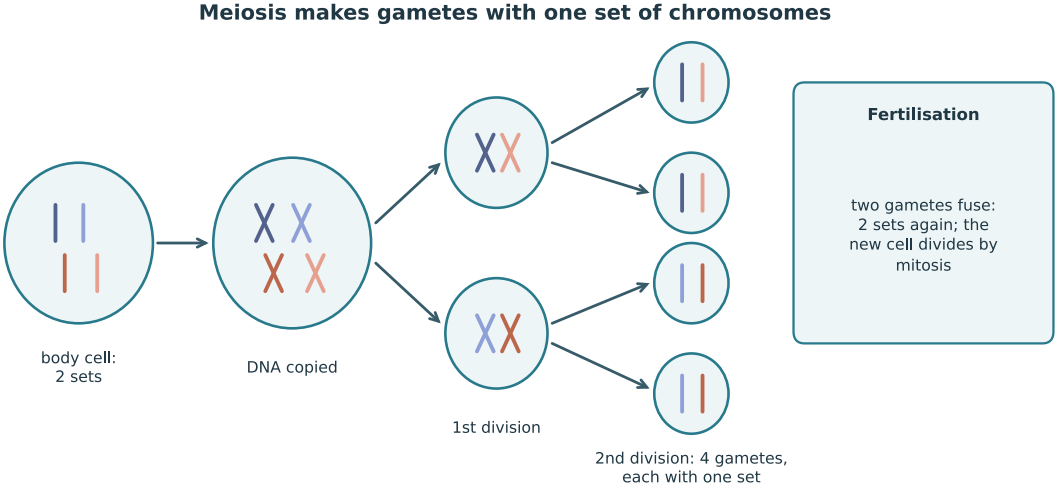
Pollen is not an egg cell. Mitosis also supports growth after sexual reproduction, so finding mitosis alone does not show how an organism originally formed. The key difference between reproductive routes is gamete fusion and genetic mixing.

Meiosis halves; fertilisation restores

Official-unit focus: 4.6 Inheritance, variation and evolution

If gametes kept the ordinary body-cell chromosome number, fusion would double it each generation. Meiosis solves that problem before fertilisation.

Cells in reproductive organs divide by meiosis to form gametes. Genetic information is copied and the cell divides twice, forming four gametes. Each has one set of chromosomes and the gametes are genetically different. GCSE Biology requires this overall account, not recall of named meiotic stages or detailed chromosome-exchange mechanisms.



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Fusion of two gametes restores the normal number of chromosomes in the new cell. The new cell divides by mitosis, increasing the number of cells. As the embryo develops, cells differentiate and become specialised. Copying DNA before division does not mean the final gametes keep two chromosome sets.

Use coloured chromosome cards to represent sets, label a body cell and gamete clearly, and trace two gametes into one fertilised cell. Keep chromosome number separate from the number of cells. State that a simple card model demonstrates number conservation rather than all mechanisms producing variation.

■ Checked worked case

Known: in a fictional species, an ordinary cell has 18 chromosomes. Each gamete has 9. Fertilisation combines 9+9 to restore 18; later mitosis maintains 18 in each ordinary daughter cell. Four gametes each having 9 means 36 chromosomes across four separate cells, not 36 within each gamete.

■ Common error

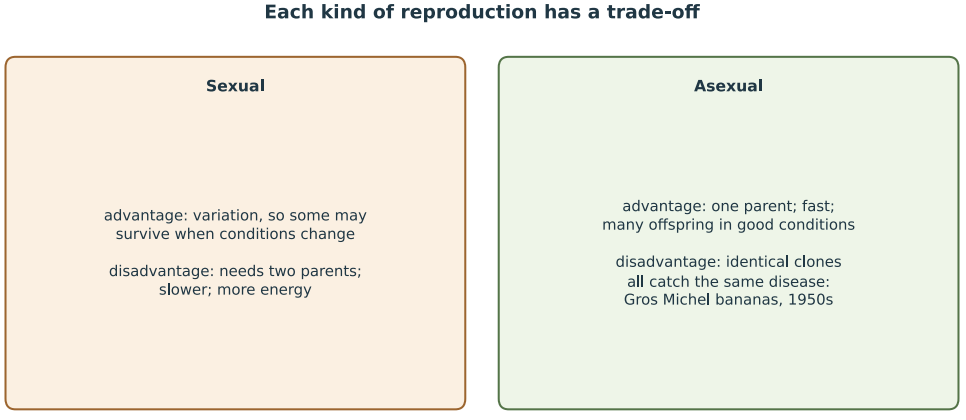
Meiosis does not make four identical ordinary body cells. Fertilisation is fusion rather than a division. The four-cell outcome is the specification's overall model; detailed gamete development and stage names are outside this objective.

Reproductive advantages depend on conditions

Official-unit focus: 4.6 Inheritance, variation and evolution

A nursery wants many plants with one successful characteristic, while a changing habitat rewards variation. The useful reproductive route depends on the question being asked.

Sexual reproduction produces variation. If the environment changes, some offspring may have inherited characteristics giving a survival advantage through natural selection. Humans can select parents and offspring with useful characteristics over generations. Finding mates and forming gametes can cost time and energy.



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Asexual reproduction needs only one parent, avoids finding a mate and can produce many identical offspring quickly when conditions are favourable. Shared inherited susceptibility can become a disadvantage if conditions change. Malaria parasites reproduce asexually in the human host and sexually in the mosquito. Many fungi use asexual spores but also sexual reproduction. Strawberries can form runners and seeds; daffodils can divide bulbs as well as form seeds.

Compare supplied life-cycle and environmental evidence using benefit → condition → limitation. For an unfamiliar organism, use the described reproduction rather than guessing its biology. School observations of runners or bulb division can illustrate asexual routes; do not culture pathogens or use infected material.

■ Checked worked case

Known: a supplied model starts with 5 clones and each produces 3 surviving new plants during one interval. New plants = 15; with the original 5 retained, total = 20. This differs from replacing each parent with three offspring. State which count the question requests before calculating a growth advantage.

■ Common error

Asexual reproduction is not always superior and sexual variation does not guarantee survival. A fungus producing spores is not necessarily using only one reproductive route. Natural selection acts on existing variation rather than organisms choosing a useful change.

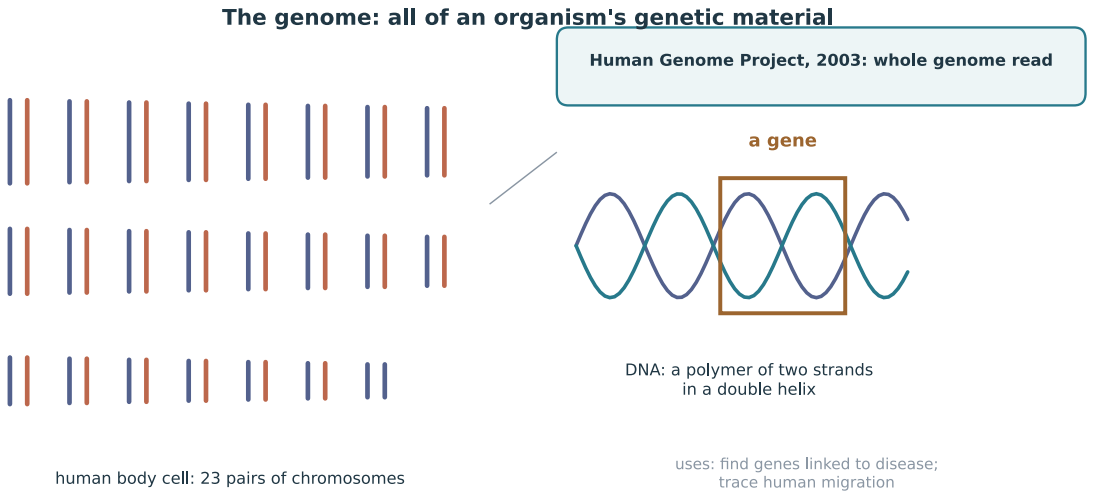
DNA, genes and the whole genome

Official-unit focus: 4.6 Inheritance, variation and evolution

A gene is a section, a chromosome is an organised structure and a genome is the whole genetic collection. These words describe different scales.

DNA is the genetic material found in chromosomes in the nucleus in the ordinary animal-cell model. It is a polymer with two strands forming a double helix. A gene is a small section of DNA on a chromosome. It codes for a particular sequence of amino acids that forms a specific protein. The genome is the entire genetic material of an organism.

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Studying the human genome helps researchers search for genes linked to disease, understand inherited disorders and investigate treatments. Comparing inherited DNA patterns also helps trace human migration in the past. A statistical link is not proof that a gene alone determines a person's future health; many characteristics involve several genes and environmental influences.

Use a paper scale model showing chromosome → DNA section → gene, then explain why the genome includes more than one selected gene. Evaluate a fictional genome-study claim by identifying what was measured, whether the evidence supports association or cause, and what additional environmental information is missing.

■ Checked worked case

Known: a model DNA strand contains 1,200 bases and a marked gene occupies 180. Marked fraction = 180/1,200 = 15%. This is a supplied model, not a claim about typical human gene length or the percentage of the human genome that codes for proteins. A marked gene is only one part of the whole collection.

■ Common error

A genome is not one chromosome or all the proteins in a cell. DNA is not made of amino acids; proteins are. Genome information can inform research without justifying deterministic predictions or disclosure of personal genetic information.

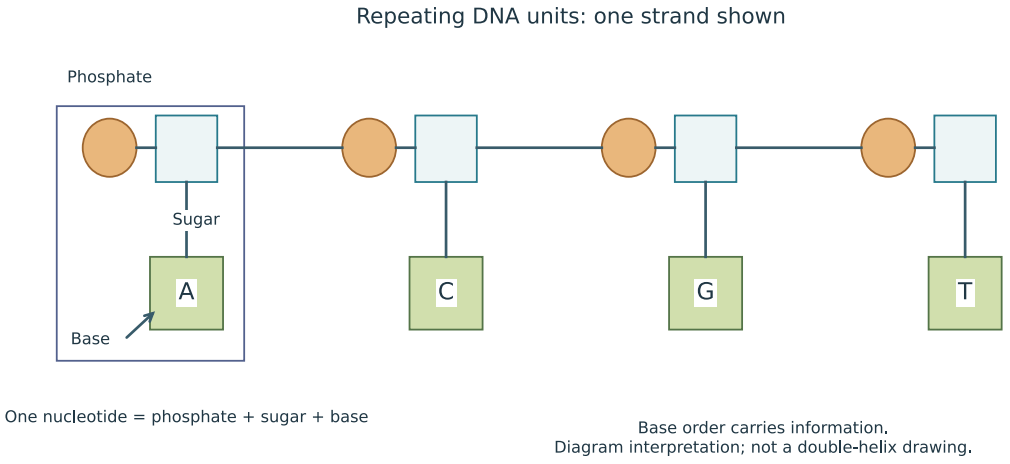
DNA nucleotides and the order of information

Official-unit focus: 4.6 Inheritance, variation and evolution

Four kinds of base can encode many different sequences. The information is in their order, not simply how many different base letters exist.

DNA is a polymer made of repeating nucleotide units. Each nucleotide contains a sugar, a phosphate group and one of four bases: A, C, G or T. The long strands

contain alternating sugar and phosphate sections, with a base attached to each sugar. The molecule has two strands arranged as a double helix.



In the specified simple model, a sequence of three bases codes for a particular amino acid. The order of bases controls the order in which amino acids are assembled into a protein. Moving the same letters into a different order can change the information. Complementary pairing and the simple synthesis mechanism belong to the Higher lesson, so do not demand those details in a common-tier task.

Identify sugar, phosphate and base in a supplied nucleotide diagram and trace repeating units along a strand. Interpret a diagram rather than memorising an elaborate drawing: reproducing the DNA structure diagram is not required. Use a teacher-supplied triplet-to-amino-acid key when decoding a fictional sequence; no memorised genetic-code table is needed.

■ Checked worked case

Known: a fictional coding sequence has 27 bases arranged into complete three-base groups. It contains $27/3 = 9$ groups in this simplified exercise. The prompt excludes start and stop details. Real interpretation requires information about which region is coding; dividing every base in a whole chromosome by three is not a valid protein-length calculation.

■ Common error

A nucleotide is not just its base. Sugar and phosphate form the strand framework, while base order carries the sequence information. Three-base grouping here is an explicit classroom model, not a promise that all genomic DNA becomes protein.

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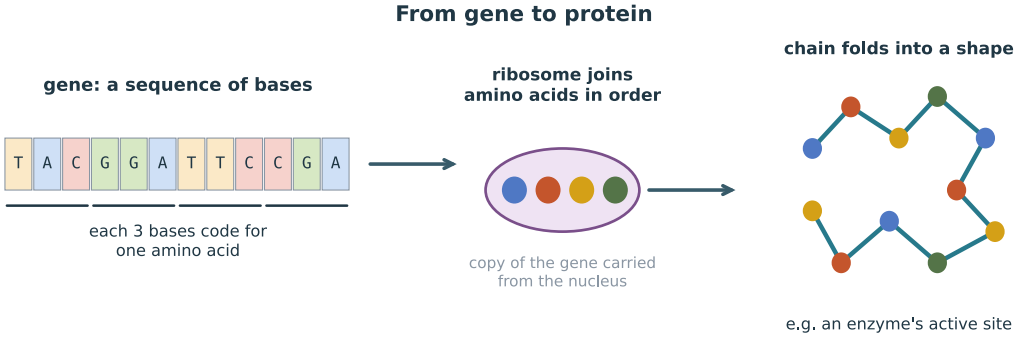
Higher Tier: sequence, protein shape and gene expression

Higher Tier focus; see section scope notes.

Official-unit focus: 4.6 Inheritance, variation and evolution

A DNA change can alter a protein's shape, leave its function unchanged, or change how much protein is made. These are different causal routes.

Complementary DNA strands pair A with T and C with G. Proteins are synthesised on ribosomes according to a template. Carrier molecules bring specific amino acids, which join in the correct order. The completed chain folds into a unique shape suited to its function, such as an enzyme, a hormone or a structural protein including collagen.



a mutation changes the bases: the protein may work the same, worse, or not at all; test it

A change in coding DNA can change the amino-acid sequence and therefore folding. An enzyme's active site may no longer fit its substrate, or a structural protein may lose strength. Most mutations do not change the protein, or change it too little to alter its appearance or function. Non-coding DNA can control whether genes are switched on or off; variants there may affect expression without changing the coded amino-acid sequence.

Use supplied short sequences and an explicit classroom code key. First distinguish a coding-region change from an expression-control change, then trace only the consequence supported by the prompt. Detailed structures of mRNA, tRNA, amino acids and proteins are not required. Model substitutions or insertions with cards rather than treating all mutations as harmful.

■ Checked worked case

Known: a supplied strand is A C G T. Its complementary sequence is T G C A in the paired display. In a separate fictional sample, 4 of 80 observed variants alter the measured phenotype: $4/80 \times 100 = 5\%$. These supplied frequencies do not establish a universal mutation rate or prove the remaining variants have no effect in every environment.

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■ Common error

DNA does not assemble the protein directly inside the nucleus in this account: synthesis takes place on ribosomes. A changed sequence does not automatically create a useful or harmful phenotype. Non-coding means not coding a protein, not having no function.

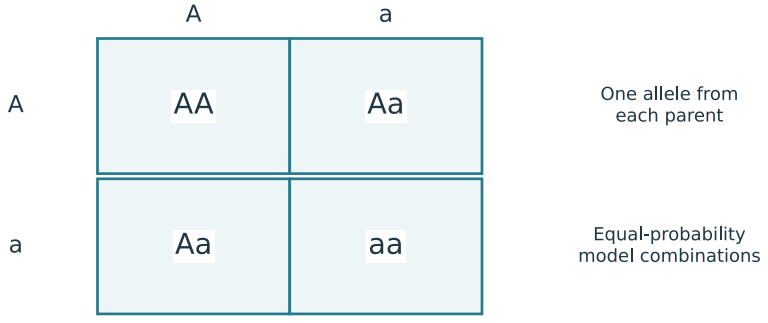
Alleles, genotype and phenotype: read a cross

Official-unit focus: 4.6 Inheritance, variation and evolution

A dominant allele can be uncommon in a population. Dominance describes expression in a genotype, not how frequent or desirable the characteristic is.

An allele is a version of a gene. The genotype is the alleles present; phenotype is the expressed characteristic. In the simple single-gene model, a dominant allele is expressed when one copy is present. A recessive allele is expressed when two recessive copies are present and the dominant allele is absent. AA and aa are homozygous; Aa is heterozygous.

Provided Aa × Aa grid: read the outcomes



Boxes show possible outcomes, not a fixed sequence of births.

A gamete carries one allele from the pair. A supplied Punnett square combines one allele from each parent. Its four boxes show equally likely combinations when the prompt gives equally likely gametes, not four children who must be born in that exact pattern. The specification names mouse fur colour and human red–green colour blindness as examples of genetic control; use a supplied inheritance key and do not assume both follow an identical autosomal cross. Most phenotype features involve multiple genes, often interacting with the environment, so the simple model has a defined scope.

Complete a provided grid using its labelled gametes and allele key. Count genotypes separately from phenotypes, reduce ratios and express probabilities as fractions or percentages. For a family tree, use symbols and relationships supplied in the legend;

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do not infer private family genetics from appearance. Constructing a whole Punnett cross from a verbal scenario is a separately marked Higher objective.

■ Checked worked case

Known: a provided Aa×Aa grid contains AA, Aa, Aa and aa. Genotype ratio is 1:2:1. With complete dominance, phenotype ratio is 3:1; recessive probability is $1/4 = 25\%$. In a large supplied model of 200 independent offspring the expected recessive number is 50, but observed counts can differ.

■ Common error

Dominant does not mean stronger, healthier or more common. Heterozygous does not mean two different genes: it means different alleles at the model gene. Probability for one offspring is not changed by the outcome of an earlier independent birth.

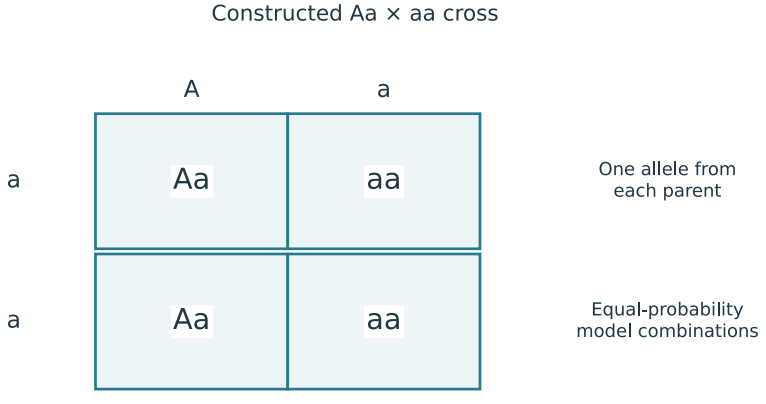
Higher Tier: construct a genetic cross from evidence

Higher Tier focus; see section scope notes.

Official-unit focus: 4.6 Inheritance, variation and evolution

Two dominant-looking parents have a recessive offspring in a stated simple model. Their appearance alone was not enough to identify their genotypes.

Start with the allele key. In a completely dominant single-gene model, a recessive offspring has genotype aa and must receive an a allele from each parent. If both parents show the dominant phenotype, each also has A, so both are Aa. List each parent's possible gametes, A and a, before filling the cross.



Each box combines one allele from each parent: AA, Aa, Aa and aa. State genotype and phenotype probabilities separately. The inference depends on the stated model: one gene, complete dominance and no new mutation. Do not apply it unchanged to

characteristics controlled by many genes or to a scenario with incomplete dominance.

Write the key, infer parental genotypes using the evidence, label gametes along the grid edges and combine them. Show each step so a mistaken parental assumption is visible. Compare the predicted distribution with supplied observed counts; small samples often deviate from expected proportions without disproving the model.

■ Checked worked case

Known: an Aa parent crossed with aa produces Aa, aa, Aa, aa. Recessive probability is 1/2. In 60 independent model offspring the expected count is 30. For two independent offspring, probability both are recessive is $1/2 \times 1/2 = 1/4$. Multiplication applies because the prompt states independent outcomes.

■ Common error

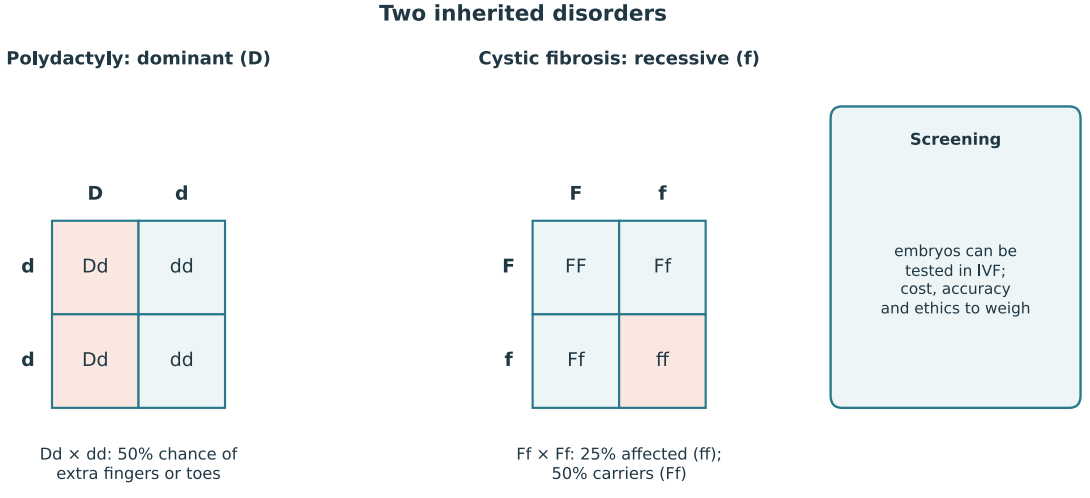
Writing only a 3:1 ratio earns no explanation of where it came from. Aa×aa does not give 3:1. A recessive outcome is possible again even when the previous offspring was recessive; the model has no memory of earlier births.

Inherited disorders and screening judgements

Official-unit focus: 4.6 Inheritance, variation and evolution

A person can carry a recessive allele without expressing the disorder in a simple model. Screening results and ethical decisions answer different questions.

The specification uses polydactyly, extra fingers or toes, as an example of a dominant inherited allele. It uses cystic fibrosis, a disorder of cell membranes, as a recessive example. In a supplied simple model with F as the non-disorder allele and f as recessive, FF and Ff do not express the disorder while ff does. Ff is a carrier.



For a supplied Ff×Ff grid, the expected outcomes are FF, Ff, Ff and ff. Each offspring has a 1/4 chance of ff, a 1/2 chance of being a carrier and a 3/4 chance of not expressing

the disorder in this model. Not expressing the disorder is not the same as not carrying its allele. Use the prompt's explicit allele key; letter choice alone does not define dominance.

Interpret provided grids and family trees, then consider embryo screening using the evidence supplied. Discuss possible reduction of suffering, cost, access, embryo selection and differing ethical views. Separate what screening can detect from the decision people make with that information. No student should be asked to disclose genetic diagnoses or make personal treatment decisions in class.

■ Checked worked case

Known: the given model predicts 1/4 affected offspring. Among 160 independent model offspring, expected number = $160 \times 1/4 = 40$. Carrier expectation is $160 \times 1/2 = 80$. These are expectations, not a forecast for one family or a measure of screening accuracy.

■ Common error

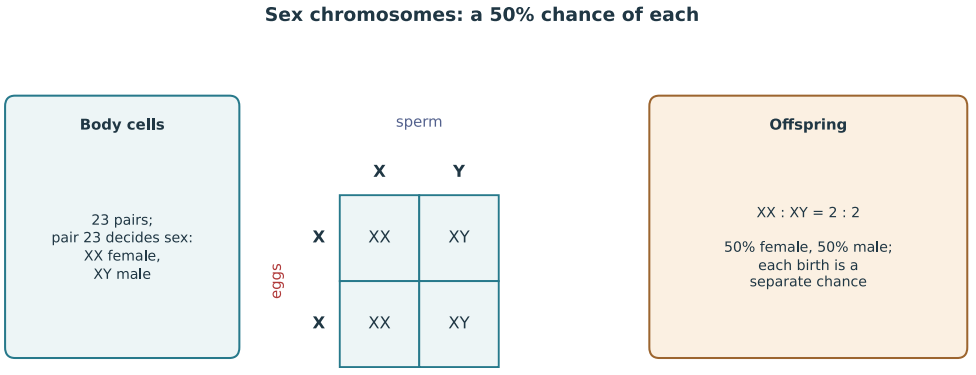
Dominant inheritance does not mean every child of an affected parent must be affected. A heterozygous dominant parent and a homozygous recessive parent can produce both phenotypes. Real clinical interpretation may be more complex; classroom conclusions are restricted to the supplied model.

Chromosome inheritance in the XX/XY model

Official-unit focus: 4.6 Inheritance, variation and evolution

The specified XX/XY cross predicts equal chances at each fertilisation. It does not require every family to have equal numbers of the two outcomes.

Ordinary human body cells contain 23 pairs of chromosomes. The specification's basic model uses 22 other pairs and one sex-chromosome pair. It represents female cells as XX and male cells as XY. An egg carries X; sperm carry X or Y. The model assumes equal probabilities for the two sperm types.



Combining X with X gives XX; combining X with Y gives XY. A cross with egg labels X and X and sperm labels X and Y has two XX and two XY boxes. Expected ratio is 1:1 and probability is 1/2 for each outcome. This is the GCSE chromosome-inheritance model, not a complete account of human sex development or gender.

Draw the labelled cross, distinguish ordinary cells from gametes and show where each chromosome comes from. Use fictional families or large model data, without asking students about their own chromosomes or identities. Explain why a previous outcome does not change the next independent probability.

■ Checked worked case

Known: a supplied model has 80 independent fertilisations with equal XX/XY probability. Expected XX count is $80 \times 1/2 = 40$ and expected XY count is 40. An observed 43:37 split is possible; expectations are not guarantees. A body cell has 46 chromosomes, whereas a gamete has 23, including one sex chromosome.

■ Common error

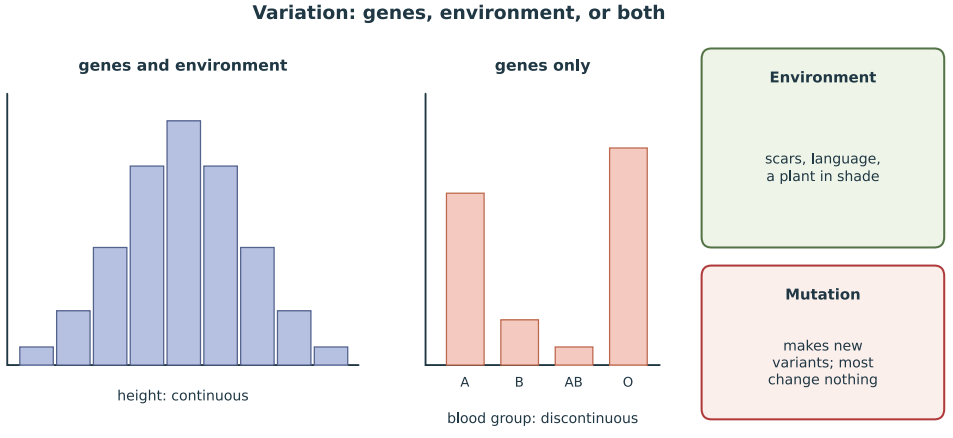
An egg in the specified model does not contain both X and Y. The sex-chromosome pair is included in the 23 pairs, not added as a twenty-fourth pair. Equal probability does not alternate outcomes or require the next child to balance previous outcomes.

Variation: inherited information and environment

Official-unit focus: 4.6 Inheritance, variation and evolution

Genetically identical plants can grow to different heights in different light. Different heights alone do not establish that the plants have different alleles.

Variation means differences in characteristics among individuals in a population. Some differences result from inherited genes, some from conditions during development and many from an interaction between genes and environment. There is usually extensive genetic variation within a population of a species. Sexual reproduction reshuffles inherited information; new genetic variants originate through mutation.



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Mutations occur continuously. Most do not affect the phenotype, some influence it and very few determine a new phenotype in the specification's account. A variant that gives an advantage after an environmental change can become more common through selection. The environment does not intentionally produce exactly the mutation an organism needs.

Compare supplied plant records with genotype and growing conditions stated. Hold one factor constant when testing another. For height data, calculate a mean and range, label units and inspect the distribution. Use fictional or plant measurements instead of sensitive personal characteristics; a visible association needs further evidence before attributing cause.

■ Checked worked case

Known: four cloned plants in one condition have heights 12, 14, 15 and 15 cm. Mean = 56/4 = 14 cm; range = 15−12 = 3 cm. A different mean in another condition is compatible with an environmental effect, but conclusions require matched age, soil, water and measurement methods.

■ Common error

Variation is not limited to genetic differences. The same genotype can produce different phenotypes in different environments. A mutation can have no measured effect under one set of conditions, so a phenotype observation does not reveal every DNA difference.

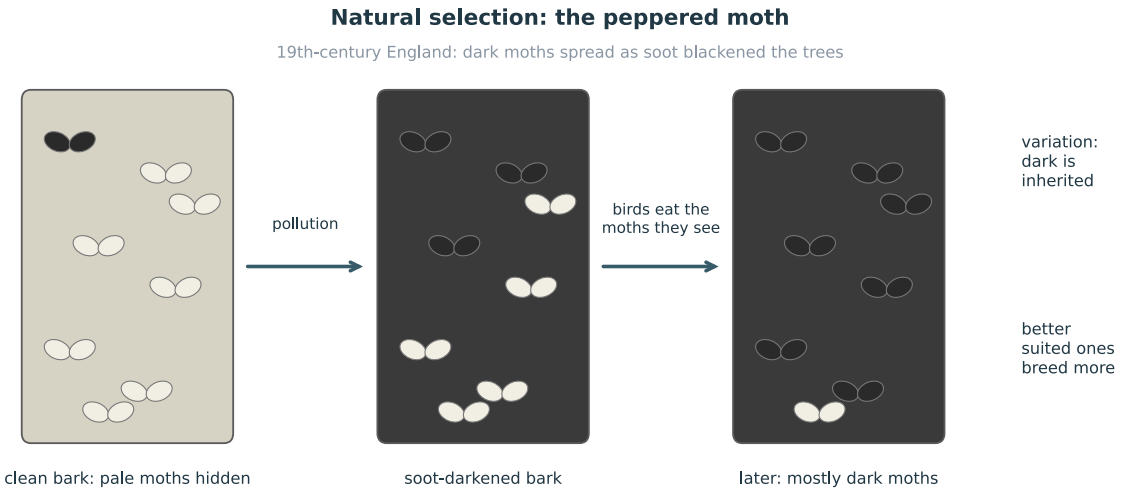
Natural selection changes a population over generations

Official-unit focus: 4.6 Inheritance, variation and evolution

A dark beetle does not become light because a habitat becomes pale. Selection changes which inherited variants leave more offspring.

Evolution is a change in inherited characteristics of a population over time. In natural selection, individuals vary and some phenotypes are better suited to their environment. Those individuals are more likely to survive and reproduce successfully. They pass the associated inherited characteristics to offspring, so the relevant variants become more common over generations.

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The theory explains living species evolving from simple early life forms over more than three billion years. Selection acts on an existing population with variation; it does not mean every individual changes during its lifetime. If two populations become sufficiently different that they cannot interbreed to produce fertile offspring, they form separate species in the specified model.

Use a paper population with stated inherited colours and a changing background. Count each variant before and after a simulated selection event, then represent reproduction by survivors. Explain the model's limitations: real survival has many causes, and changing frequency in one round is evidence of selection rather than proof of a new species.

■ Checked worked case

Known: a population begins with 20 dark and 80 pale model beetles. After selection, 10 dark and 70 pale remain. Pale survivor fraction = $70/80 = 87.5\%$, compared with $10/20 = 50\%$ for dark beetles. Pale frequency among survivors is $70/80 = 87.5\%$; the same number here arises from different denominators, which must be identified.

■ Common error

Fitness means reproductive success in the environment, not physical strength alone. Individuals do not choose beneficial inherited changes. A new species requires evidence about interbreeding and fertile offspring, not only a difference in appearance.

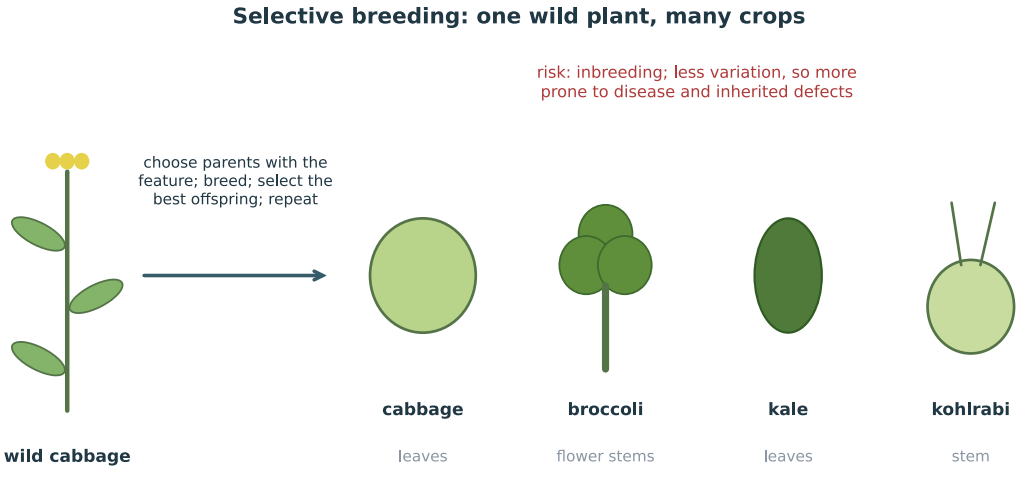
Selective breeding: repeat selection, retain the risks

Official-unit focus: 4.6 Inheritance, variation and evolution

Choosing a high-yielding parent is only the first step. Selective breeding needs offspring selection across generations and attention to unintended effects.

Selective breeding, or artificial selection, means humans breeding plants and animals

for chosen inherited characteristics. Select parents with the desired feature from a mixed population, breed them, select offspring showing the feature and breed those. Repeat over many generations. Examples include disease resistance in food crops, greater meat or milk production, a gentle nature in dogs and large or unusual flowers.



Useful and attractive characteristics are not necessarily the same. Repeatedly breeding closely related individuals can cause inbreeding, making some breeds more prone to disease or inherited defects. A narrow breeding population may reduce variation. Evaluate production benefits alongside health, welfare and resilience rather than treating one selected measurement as the whole organism's value.

Analyse supplied breeding records with yield, disease and parentage stated. Identify the chosen criterion, describe the repeated selection sequence and compare any health costs. A classroom task can use fictional pedigrees and plant data; animal breeding or welfare interventions are not student experiments.

■ Checked worked case

Known: a fictional crop's mean yield rises from 2.4 to 3.0 kg per plant after the stated selection programme. Increase = 0.6 kg; percentage increase = $0.6/2.4 \times 100 = 25\%$. Without matched conditions or a comparison line, this observation alone cannot attribute all the increase to inherited selection.

■ Common error

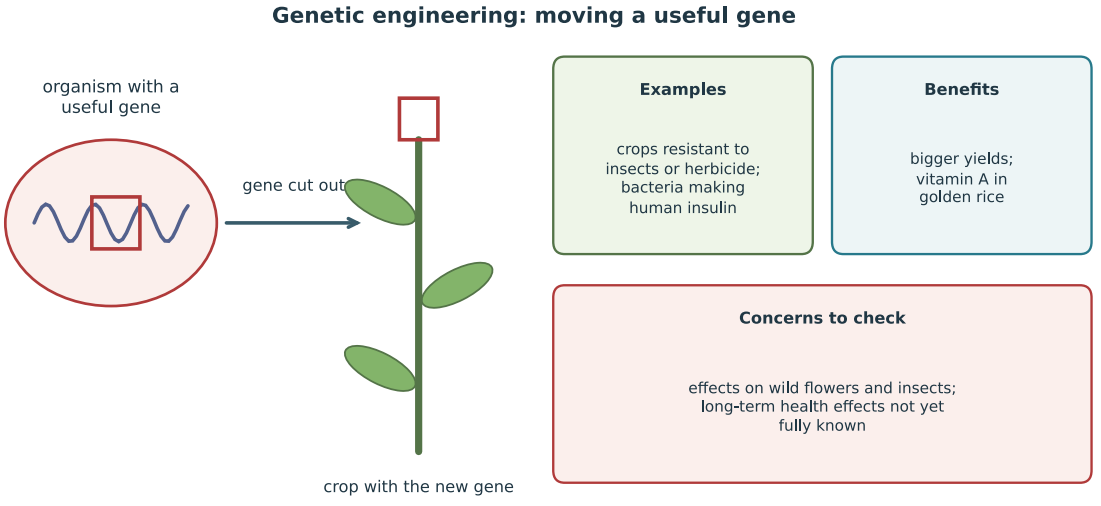
Selective breeding does not insert a chosen gene directly into a cell. It uses reproduction and selection over generations. Choosing every parent from one family can intensify inherited risks; a greater average yield is not proof that all other traits improved.

Genetic engineering: trait, evidence and trade-offs

Official-unit focus: 4.6 Inheritance, variation and evolution

A bacterium can be engineered to make a human protein. Transferring a gene is different from repeatedly breeding whole organisms.

Genetic engineering modifies an organism's genome by introducing a gene from another organism to give a desired characteristic. Examples include crop disease resistance or improved fruit production, insect-resistant and herbicide-resistant crops, and bacteria producing human insulin. Introducing the gene allows the recipient cells to make the useful protein in the stated model.



Potential agricultural benefits include improved yield or reduced crop damage. Evaluation also considers effects on wild flowers, insects, gene movement and farming practices. Medical benefits include production of useful substances and research on inherited disorders. The specification records objections and questions about long-term effects; these are issues to evaluate with evidence, not proof that every engineered product has the same risks.

Compare supplied trials with treated and comparison crops, matched conditions, yield and non-target species counts. Distinguish the engineered trait from any additional pesticide treatment. State a conclusion supported by the particular data and identify further evidence needed. This classroom work uses supplied evidence; actual organism engineering is not required.

■ Checked worked case

Known: a supplied crop trial has mean yields of 8.0 and 9.6 tonnes per hectare. Difference = 1.6; percentage increase relative to the comparison = $1.6/8.0 \times 100 = 20\%$. The denominator is the comparison yield. This does not by itself establish environmental safety or show that all GM crops increase yield by 20%.

■ Common error

Genetic engineering does not necessarily make an organism larger or immune to every disease. Herbicide resistance in a crop is different from insect resistance. Detailed enzymes and vectors are separately Higher-only; common-tier evaluation uses the stated gene transfer and evidence.

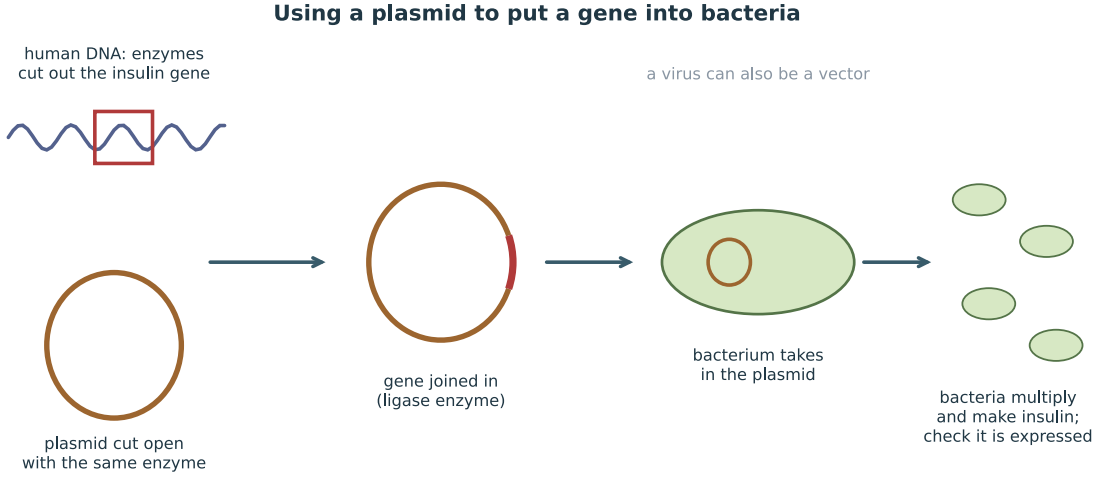
Higher Tier: isolate, insert and transfer a gene

Higher Tier focus; see section scope notes.

Official-unit focus: 4.6 Inheritance, variation and evolution

The useful gene, the carrier and the protein it helps produce are three different things. Keep their roles separate in a transfer diagram.

Enzymes isolate the required gene from donor genetic material. The gene is inserted into a vector, usually a bacterial plasmid or a virus. The vector introduces the gene into the required cells. Transfer into animal, plant or microorganism cells at an early developmental stage allows them to develop with the desired characteristic in the specification's model.



A plasmid is a small DNA ring, not the human protein product. A vector carries the chosen gene; recipient cells use genetic information to make a product. A virus vector is not a requirement that all engineered organisms become diseased. The general stages are required at Higher Tier, without needing an advanced laboratory protocol or every enzyme name.

Order labelled paper stages: donor gene isolation → vector insertion → recipient-cell transfer → desired characteristic. Explain what each stage achieves. Use diagrams and supplied success data; school students should not attempt genetic engineering or culture unknown microorganisms for this lesson.

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■ Checked worked case

Known: a fictional transfer study starts with 250 recipient cells and 40 contain the target gene after the stated procedure. Transfer proportion = $40/250 \times 100 = 16\%$. Presence of the gene alone does not prove every cell produces the intended amount of functional protein; a product measurement would add different evidence.

■ Common error

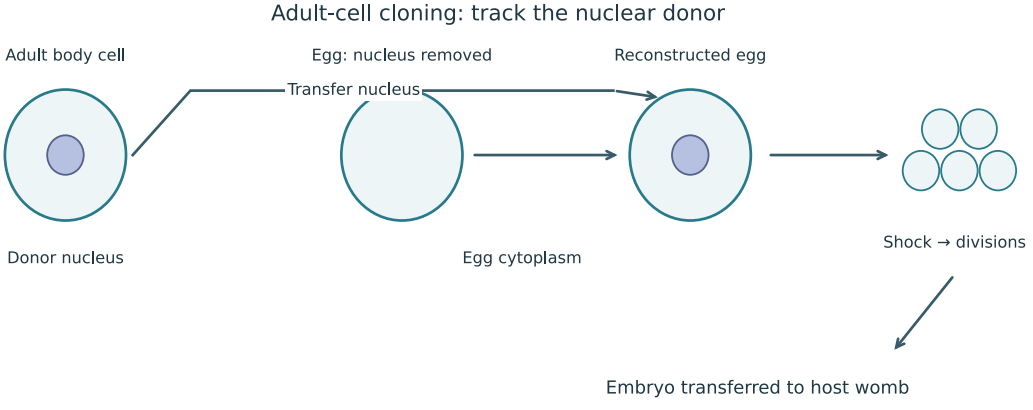
The vector is not another word for the gene. Isolating a gene alone does not show transfer succeeded. Distinguish introducing information from measuring expression, and do not claim every cell or every later offspring necessarily has the trait without supplied evidence.

Cloning routes: identify the genetic source

Official-unit focus: 4.6 Inheritance, variation and evolution

An animal clone can develop in a host that did not provide its body-cell nucleus. Identify which role supplies the specified genetic information.

Plant tissue culture uses small groups of plant cells to grow identical new plants, useful in nurseries and preserving rare species. Cuttings are an older, simpler way to produce new plants from a parent. Embryo transplant cloning splits cells from an early animal embryo before specialisation, then transfers the resulting identical embryos into host mothers.



Body-cell donor supplies nuclear genetic information; host supplies developmental environment.

In adult-cell cloning, remove the nucleus from an unfertilised egg and insert a nucleus from an adult body cell such as skin. An electric shock stimulates division into an embryo. When it forms a ball of cells, transfer it into a female's womb. The specified embryo genetic-information comparison concerns the adult nuclear donor; the host supplies the developmental environment. Detailed mitochondrial inheritance is outside

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this GCSE account.

Draw separate diagrams for plant cloning, embryo splitting and adult nuclear transfer. A teacher-supervised plant cutting can be observed over time with matched care; animal procedures remain diagram/evidence study. Compare useful genetic uniformity with vulnerability to shared disease, costs, animal welfare and ethical objections. Cloning a rare plant is not a substitute for protecting its habitat.

■ Checked worked case

Known: a nursery roots 36 of 48 cuttings. Success = $36/48 \times 100 = 75\%$. This measures establishment in that trial, not proof that every genetic characteristic or adult size is identical. Conditions during growth can affect phenotype even when plants are genetic clones in the stated model.

■ Common error

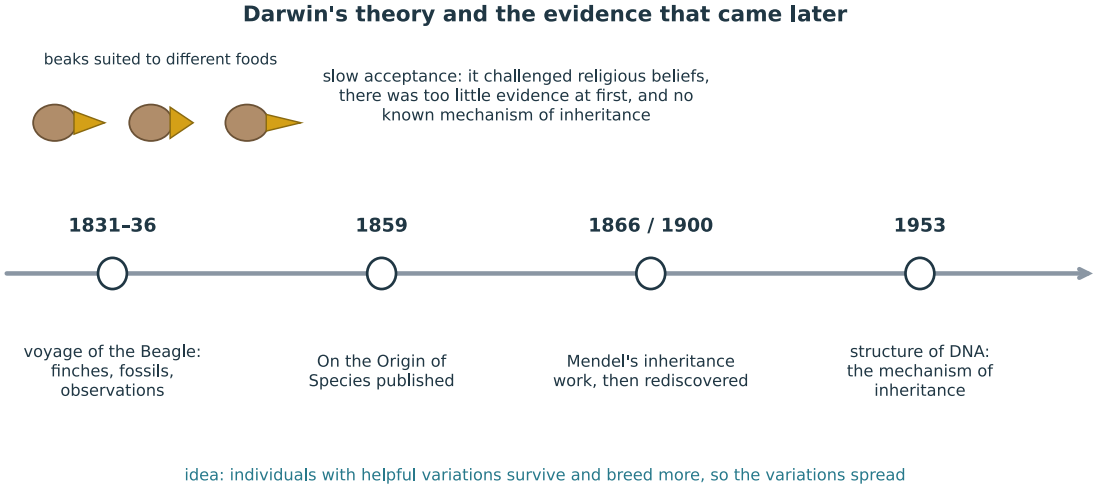
Adult-cell cloning does not fertilise an egg with the donor skin cell. Embryo splitting and adult nuclear transfer start from different material. A genetically identical group does not provide the variation benefits of sexual reproduction.

Darwin's explanation and why acceptance took time

Official-unit focus: 4.6 Inheritance, variation and evolution

A theory can unite observations before every underlying mechanism is known. Darwin's account of selection developed from years of evidence and discussion.

Darwin drew on observations during a round-the-world voyage, later experiments, discussions and developing knowledge of geology and fossils. His account linked variation within a species to better survival and breeding by individuals suited to their environment. Their inherited characteristics could become more common in later generations. He published On the Origin of Species in 1859.



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Acceptance was gradual. The ideas challenged widespread beliefs about separate creation, available evidence was initially insufficient to convince many scientists, and the inheritance mechanism was not yet understood. Lamarck's explanation relied mainly on changes acquired during an organism's lifetime being inherited; this is not how inheritance operates in the vast majority of the specified examples. A study of creationism is not required.

Compare two fictional explanations of a population changing: one says individuals developed a feature by use and passed it on; the other says inherited variants differed in reproductive success. Identify the mechanism rather than choosing by the scientist's name alone. Place publication and later inheritance evidence on a timeline.

■ Checked worked case

Known: a classroom timeline marks 1859 publication and a supplied later evidence date of 1909. Interval = 1909−1859 = 50 years. The arithmetic illustrates the stated interval; it does not claim that one discovery on one day resolved every inheritance question.

■ Common error

Darwin did not know the modern molecular DNA mechanism. Missing that mechanism at publication does not erase later supporting evidence. Do not describe natural selection as organisms deliberately improving themselves or treat a historical controversy as current scientific uncertainty about every aspect of evolution.

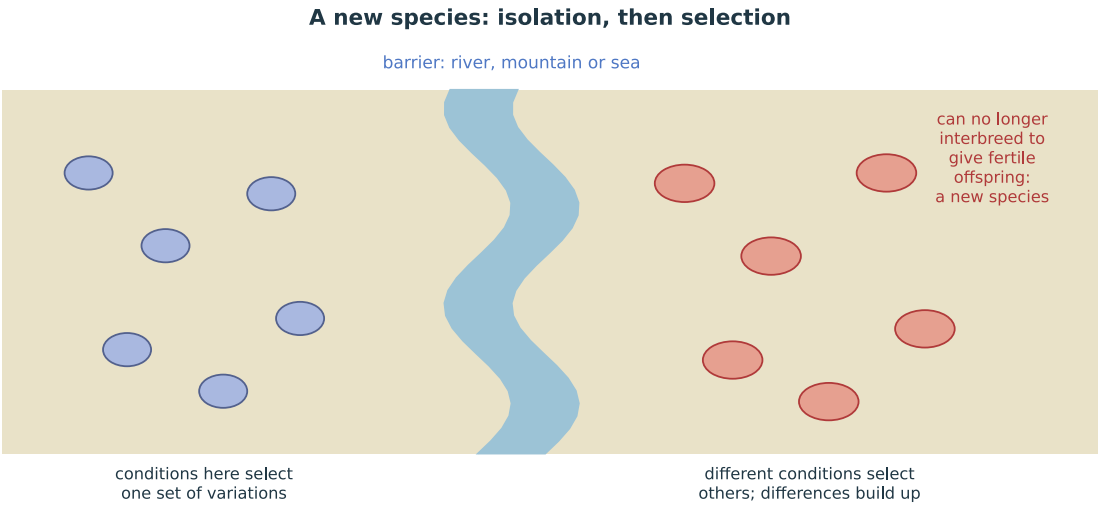
Wallace and the separation of populations

Official-unit focus: 4.6 Inheritance, variation and evolution

A barrier can separate one population into two, but a barrier alone does not instantly create two species. The later inherited differences matter.

Alfred Russel Wallace independently proposed natural selection. Joint writings with Darwin in 1858 helped prompt Darwin's book the next year. Wallace gathered evidence worldwide, studied warning colouration and made pioneering contributions to speciation. Later evidence developed the current understanding; it was not the work of one scientist alone.

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A population may become geographically separated. The groups experience different conditions and selection pressures, with inherited variation in each. Different variants leave more offspring, and differences accumulate over generations. If the groups can no longer interbreed to produce fertile offspring, they are separate species under the specified definition.

Use a fictional island model with a new barrier and different food sources. Explain each causal link rather than writing only isolation → new species. Identify what evidence would test reproductive isolation. Warning colouration can affect predator behaviour, but do not infer speciation merely from a different colour.

■ Checked worked case

Known: in a supplied island model, an advantageous variant rises from 10% to 35% in one population. Increase = 25 percentage points, not 25%. Relative percentage increase = $(35-10)/10\times100 = 250\%$. Neither statistic alone shows that fertile interbreeding has stopped.

■ Common error

Geographical isolation is not proof of a new species. Different appearance alone is insufficient. The key final criterion is failure to produce fertile offspring by interbreeding, and the explanation must connect inherited variation with reproductive success over generations.

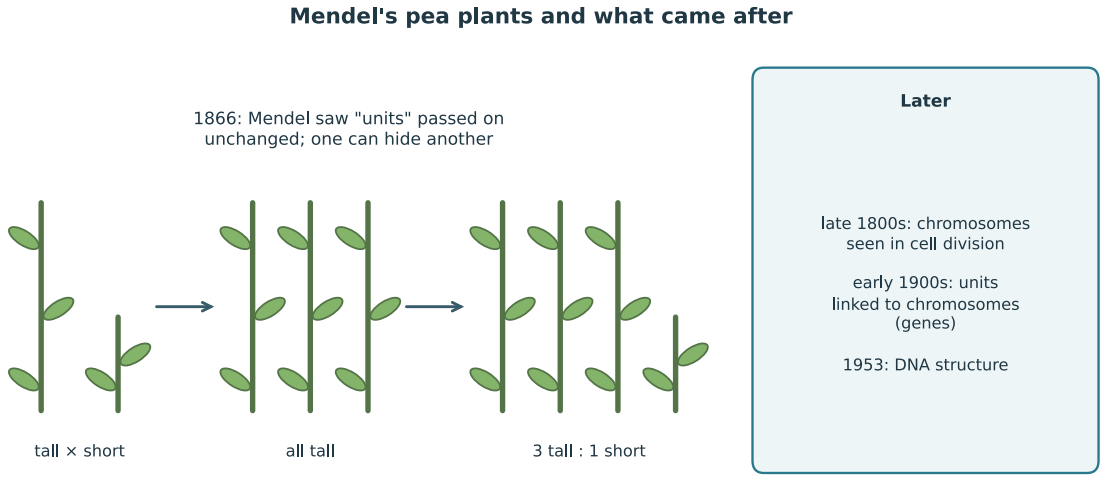
Mendel's units and later chromosome evidence

Official-unit focus: 4.6 Inheritance, variation and evolution

Mendel could infer inherited units from breeding results without seeing a DNA molecule. Later observations connected his model with cell structures.

In the mid-nineteenth century Mendel bred plants and recorded inherited character-

istics. He proposed units passed unchanged from parents to descendants. A feature could disappear in one generation and reappear in another, consistent with inherited units persisting rather than permanently blending. His work was not widely recognised during his lifetime.



Scientists did not yet understand chromosomes and the molecular basis of inheritance, making the importance of his results difficult to recognise. In the late nineteenth century, chromosome behaviour during division was observed. Early in the twentieth century, similarities with Mendel's units supported locating genes on chromosomes. Mid-twentieth-century work established DNA structure and how genes function. Many scientists contributed.

Read a supplied plant-breeding record with generations and counts. Distinguish the observed pattern from the inferred explanation, and identify later evidence that could connect units to chromosomes. Do not claim Mendel used a DNA sequencing machine or observed the molecular gene directly.

■ Checked worked case

Known: a fictional second generation contains 150 dominant and 50 recessive phenotypes. Ratio = 150:50 = 3:1; recessive fraction = 50/200 = 25%. These counts illustrate a model prediction, not a transcription of one specific historical experiment. A close ratio supports the model but does not reveal the DNA sequence.

■ Common error

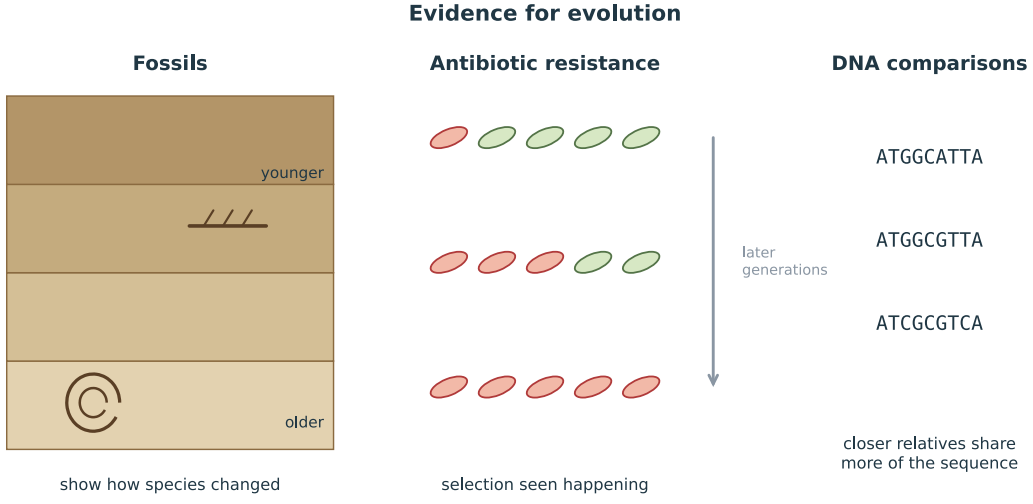
Delayed recognition is not evidence that Mendel had no results. His units are now related to genes; calling them genes retrospectively must not suggest he knew their molecular structure. Inheritance theory developed as independent lines of evidence became connected.

Evolutionary evidence: independent lines support an explanation

Official-unit focus: 4.6 Inheritance, variation and evolution

A fossil series and a changing bacterial population provide different kinds of evidence. Their value is stronger when they support the same causal account.

Evolution by natural selection is widely accepted because evidence has accumulated. Genetics shows inherited characteristics can pass to offspring through genes. Fossils show organisms and patterns of change through time. Bacterial populations demonstrate that resistant inherited variants can survive selection and become more common as susceptible bacteria are removed.



Each line answers a different question. A fossil gives evidence of past organisms but usually cannot show their complete DNA. A resistance dataset can show population change over generations but is not a complete history of all life. Agreement between inheritance mechanisms, historical records and observed selection strengthens the explanation.

For each supplied dataset, write observation → supported inference → limitation. Compare relative ages of fossils with a labelled evolutionary tree and inspect bacterial counts before and after a stated treatment. Use prepared records only; evolving antibiotic resistance by culturing organisms is not a classroom activity.

■ Checked worked case

Known: a fictional bacterial sample contains 5 resistant cells out of 100 before selection and 20 out of 40 afterwards. Frequencies are 5% and 50%, an increase of 45 percentage points. Absolute numbers and frequencies both change here; a different dataset could show frequency rising while total resistant count stays unchanged.

■ Common error

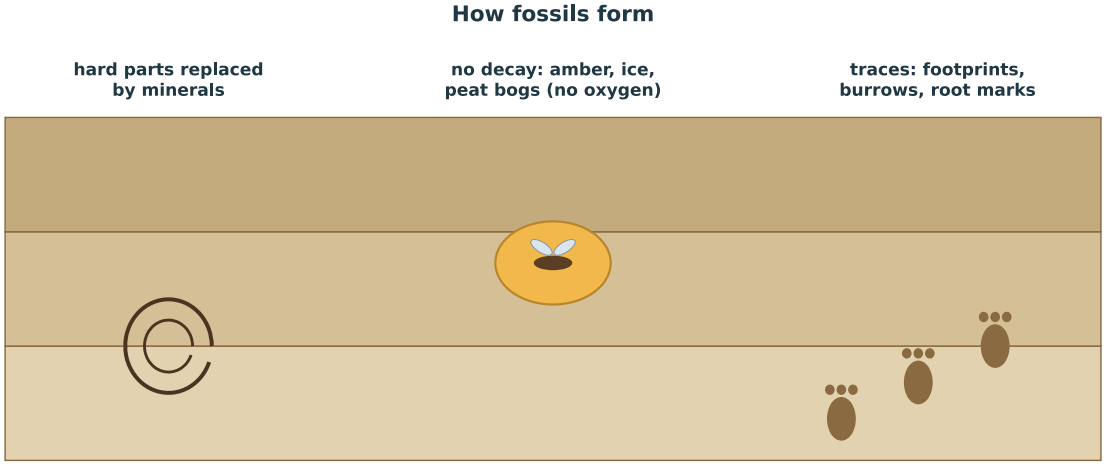
An incomplete fossil record is not the same as no evidence. A resistant individual surviving does not mean antibiotics gave it an intentional adaptation. Selection and inheritance explain the population change without a goal-directed mechanism.

Fossils, preservation and an incomplete record

Official-unit focus: 4.6 Inheritance, variation and evolution

A footprint can be a fossil even when no body remains. Fossil evidence includes traces as well as preserved parts.

Fossils are preserved remains or traces of organisms from the past, found in rocks. Parts may persist when conditions needed for decay are absent. Minerals can replace parts as they decay. Footprints, burrows and rootlet traces can also be preserved. Each route preserves different information about the organism.



gaps: soft bodies rarely fossilise; many fossils are destroyed by geological activity

Many early organisms were soft-bodied and left few traces. Geological processes have destroyed much of the evidence. The record is therefore incomplete, limiting certainty about exactly how life began. Fossils nevertheless reveal how much or little organisms have changed and support reconstructions of evolutionary relationships.

Interpret supplied fossil charts using their age axis and legend. Distinguish millions of years before present from a forward calendar timeline. In a tree, use branch points to identify shared ancestry; the left-to-right order of tips does not make one living species the ancestor of another.

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■ Checked worked case

Known: fossil A is dated to 120 million years before present and fossil B to 85 million years before present. A is older by 35 million years. A missing fossil in one layer does not prove the species never existed then: preservation, exposure and sampling can differ.

■ Common error

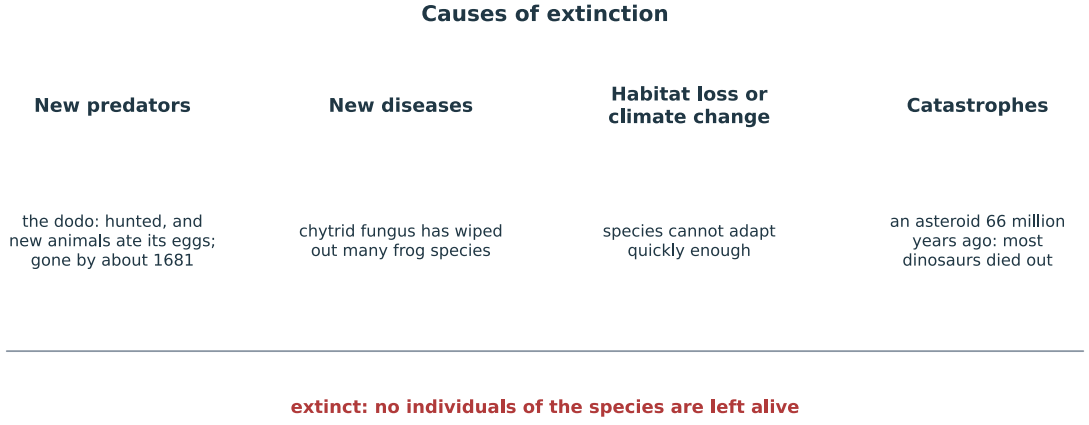
A fossil does not need to contain living tissue or a complete skeleton. Older dates before present have larger numerical values. An evolutionary tree is a model of relationships based on evidence, not a ladder ranking organisms as better or worse.

Extinction: no surviving individuals

Official-unit focus: 4.6 Inheritance, variation and evolution

A species missing from one pond may still survive elsewhere. Extinction refers to the whole species, not just one sampling location.

Extinction occurs when no individuals of a species remain alive. Environmental changes can make resources or conditions unsuitable. New predators, diseases or competitors can reduce survival and reproduction. Catastrophic events can remove populations rapidly. Several pressures may interact, so an explanation should use the evidence in the particular scenario.



A small, fragmented population may be vulnerable to loss even when some individuals survive a disturbance. If mortality exceeds successful reproduction for long enough, the number can reach zero. A local disappearance is not global extinction unless the evidence shows no surviving population elsewhere. An unsuccessful survey alone does not establish that conclusion.

Read supplied population records with births, deaths and migration stated. Identify

mechanisms, calculate net change and separate observations from proposed causes. Consider detection limits and unsurveyed habitats. Conservation discussion should examine feasible actions and uncertainty rather than asserting that every decline has one cause.

■ Checked worked case

Known: a closed fictional population starts with 30 individuals, has 8 surviving births and 14 deaths during one interval. Final count = 30+8−14 = 24. The decline is $6/30 \times 100 = 20\%$. A decline does not yet equal extinction, and repeating this arithmetic assumes unchanged rates that the evidence may not support.

■ Common error

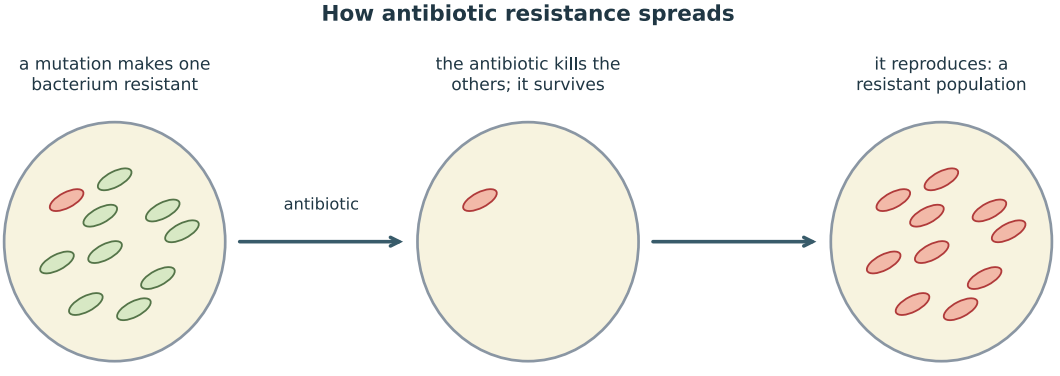
Extinction is not one individual dying or a species moving away from one site. A low population count is a warning, not a claim of zero. Evolutionary adaptation cannot be assumed to rescue every population quickly enough.

Antibiotic resistance: selection acts on bacteria

Official-unit focus: 4.6 Inheritance, variation and evolution

It is the bacteria that become resistant to a drug, rather than the patient becoming resistant. Antibiotic exposure changes which bacterial variants survive.

Mutations produce bacterial variants, some resistant to a particular antibiotic. Susceptible bacteria are killed or inhibited while resistant ones survive and reproduce. Fast reproduction can rapidly increase the resistant strain's population, and it can spread between hosts. MRSA is the specification's example of antibiotic resistance; resistance to one antibiotic does not automatically mean resistance to every possible treatment.



e.g. MRSA. Slow it down: only prescribe antibiotics when needed; finish the course

The specification calls for avoiding inappropriate antibiotic prescribing, including use

against viral infections, restricting agricultural antibiotic use and completing prescribed treatment. Current NHS information likewise says to follow the healthcare professional's directions. New antibiotic development is slow and expensive. The selection explanation must not say bacteria mutate deliberately because treatment was stopped or that every resistant infection has no treatment.

Analyse supplied before/after counts and distinguish resistant frequency from total bacterial number. Use paper models or prepared data, never culture resistant pathogens. This teaching task does not set treatment length or advise medication changes; the NHS stewardship reference provides the clinical wording alongside the exam specification.

■ Checked worked case

Known: a model has 10 resistant and 90 susceptible bacteria before exposure. Afterwards, 10 resistant and 10 susceptible remain. Resistant number stays 10, but frequency rises from 10% to 50%. This selection event alone changes frequency without requiring a new mutation during exposure. Later reproduction can increase absolute numbers.

■ Common error

Antibiotics do not treat viral infection. Finishing a prescribed course does not guarantee that every bacterium in every real infection is killed. Mutation supplies variants and selection changes their representation; these processes must not be confused. NHS stewardship reference.

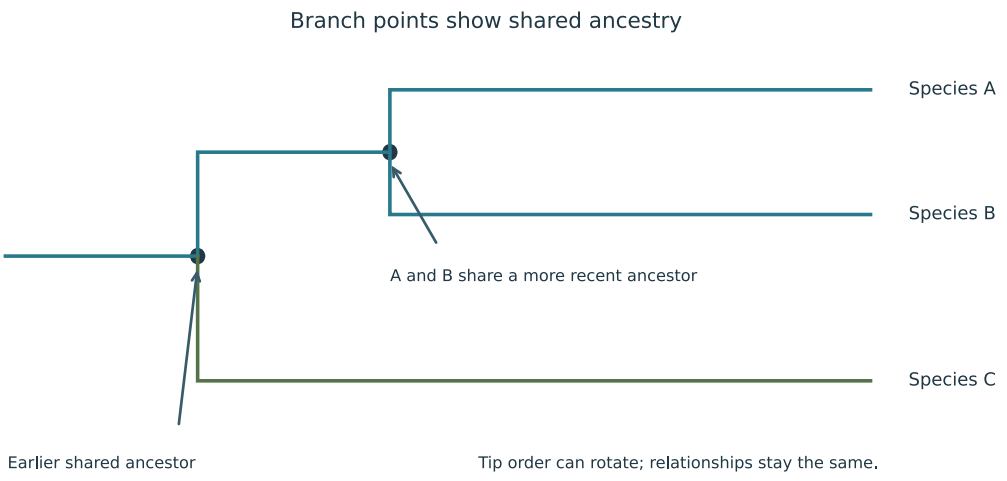
Classification, domains and evolutionary trees

Official-unit focus: 4.6 Inheritance, variation and evolution

Two organisms can look similar without being the closest relatives. New evidence from cells and chemistry can revise their classification.

Linnaeus classified organisms using structure and characteristics. The traditional hierarchy is kingdom, phylum, class, order, family, genus and species. Binomial names use genus and species: for example, Homo sapiens. The genus begins with a capital and the species name with lower case; the complete scientific name is normally italicised.

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Improved microscopy revealed internal structures and biochemical analysis provided further relationship evidence. Woese's three-domain system separates archaea, bacteria and eukaryota; eukaryota includes protists, fungi, plants and animals. The specification describes archaea using older primitive-bacteria wording and extreme habitats; treat archaea as a separate domain rather than all bacteria or a claim that every archaeon lives in an extreme habitat.

Use a supplied classification table to identify the most specific shared group. On an evolutionary tree, find the most recent shared branch point to compare relationships. Living-organism classification data and fossil evidence inform these trees. Rotating branches around a node does not change the relationships, and tip order alone is not an evolutionary sequence.

■ Checked worked case

Known: a supplied group contains 12 plants, 8 fungi and 10 animals, all assigned to eukaryota. Total = 30; fungi comprise $8/30 \times 100 = 26.7\%$ to one decimal place. This sample percentage does not measure the global proportions of domains or kingdoms.

■ Common error

A binomial name has two parts, not all seven hierarchy ranks. Archaea and bacteria are separate domains in this system. An evolutionary tree does not say that a living species at one tip must be the direct ancestor of a living species at another tip.

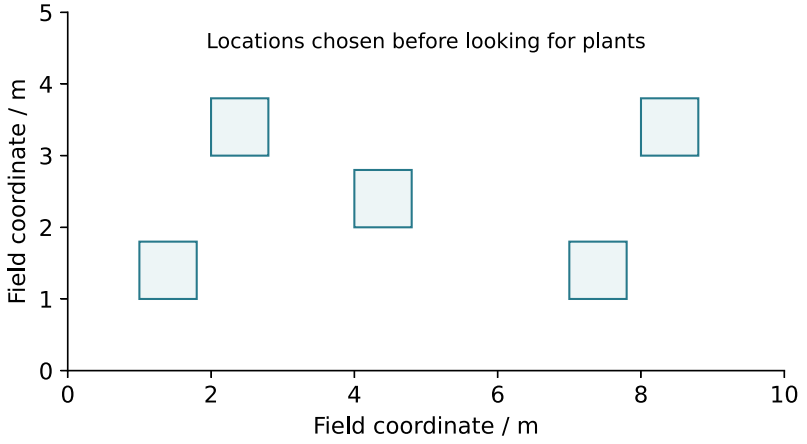
Sampling populations without choosing the answer

Official-unit focus: 4.7 Ecology

A field edge looks richer in plants than its centre. Choosing only the richest patches would build the desired result into the sampling method.

A population consists of organisms of one species in a defined area. Random quadrats

estimate density without deliberately selecting patches. A transect investigates change along an environmental gradient.



Estimate total abundance by multiplying mean density by area, with consistent units. This assumes sampled areas represent the habitat. Patchiness and too few samples widen uncertainty.

Choose coordinates with random numbers before visiting the patches. Record quadrat area and counting rules. For a transect, use fixed distances and measure a relevant abiotic variable. Do not damage habitats or sample unsafe locations.

■ Checked worked case

Known: five 0.25 square metre quadrats contain 3, 4, 6, 5 and 2 plants. Mean count $= 20/5 = 4$. Density $= 4/0.25 = 16$ plants per square metre. Estimated abundance in 100 square metres $= 16 \times 100 = 1{,}600$ plants.

■ Common error

Quadrats suit organisms that do not move quickly. A food chain arrow shows the direction of energy transfer, not the direction a predator travels.

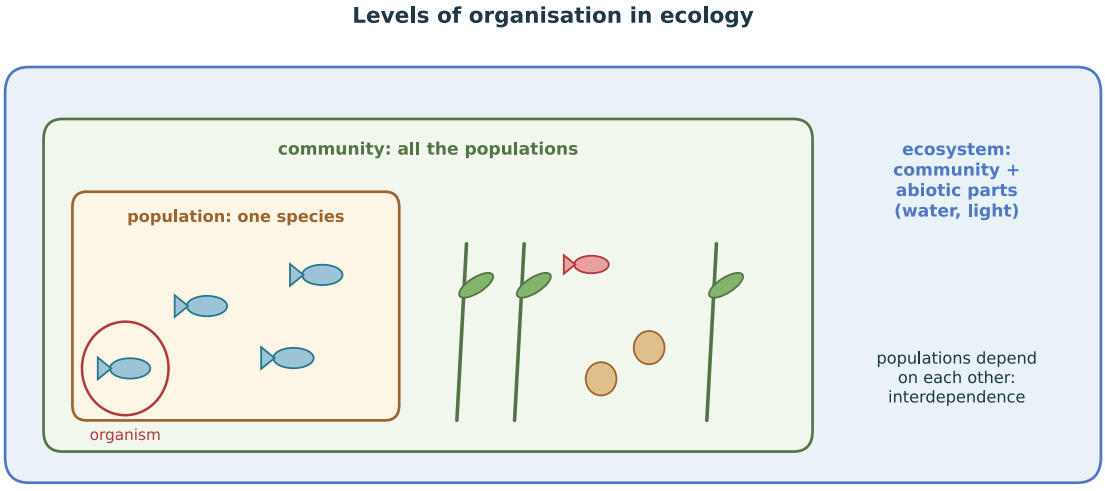
Communities: competition and interdependence

Official-unit focus: 4.7 Ecology

Removing a pollinator can affect plants and the animals that depend on them. A community is a network of relationships, not just a species list.

An organism is one individual. A population comprises organisms of one species in a place; a community includes the populations of different species. An ecosystem includes that community interacting with non-living conditions. Plants compete for light, space, water and mineral ions. Animals often compete for food, mates and territory.

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Interdependence means species rely on others for resources or services, including food, shelter, pollination and seed dispersal. Removing one species can affect many others. In a stable community, species and environmental factors are in balance and population sizes remain fairly constant, although short-term fluctuations can occur.

Record school-approved field observations without disturbing nests or protected habitats. In supplied tables, identify which count refers to one population and which measure describes the community. Explain a removal scenario with a stated link, then consider indirect effects and alternative explanations.

■ Checked worked case

Known: a fictional community contains 25 rabbits, 5 foxes and 70 plants of one counted species. Rabbit population is 25; the three counted groups total 100 individuals. This total is not biodiversity and is not a complete ecosystem measurement, because other species and non-living factors were not counted.

■ Common error

Competition occurs both within and between species. A larger total number of organisms does not necessarily mean more species. Stability does not require every population count to remain exactly unchanged every day.

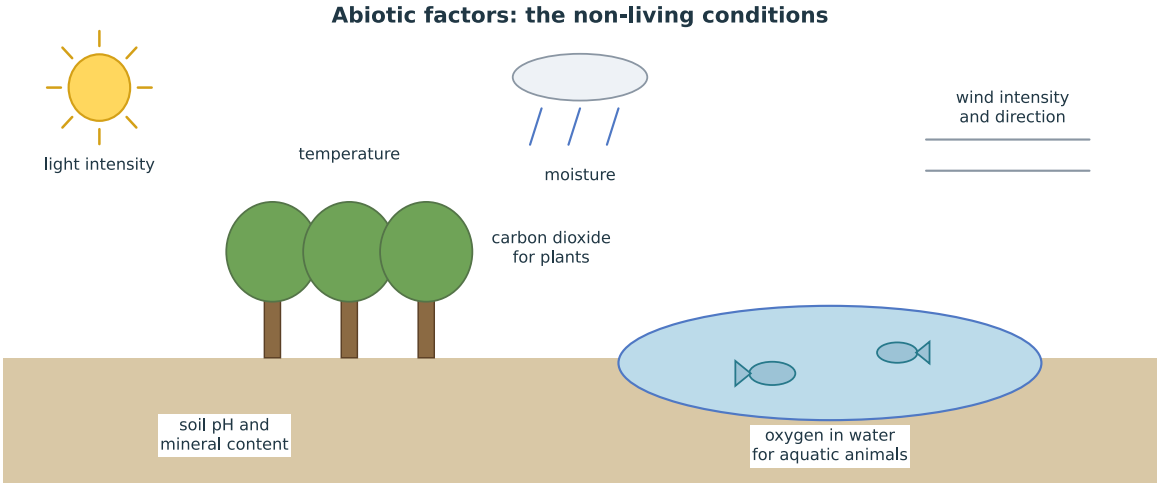
Abiotic factors: use the context to explain change

Official-unit focus: 4.7 Ecology

Two ponds can have different animal populations because dissolved oxygen differs. The relevant non-living factor depends on the organisms and habitat.

Abiotic factors are non-living environmental conditions. Light and carbon dioxide influence photosynthesis. Temperature affects biological reactions and survival. Moisture, soil pH and mineral content affect plants; wind changes conditions including

water loss and dispersal. Oxygen availability affects aquatic animals that respire aerobically.



A change can favour one species while disadvantaging another. More of a factor is not always better: organisms have suitable ranges, and a limiting factor can change. A relationship between population count and temperature is an association unless other changes are considered or controlled.

Measure a school-approved factor at matched locations and times, or use supplied records. Label graph axes with the measured variable and units, choose an appropriate scale and distinguish individual observations from a fitted trend. Keep sampling effort comparable and identify correlated factors.

■ Checked worked case

Known: supplied plant counts at light readings of 100, 200 and 300 arbitrary units are 4, 9 and 9. The increase from 100 to 200 is five plants, but the last interval shows no additional increase. This pattern does not support an unlimited straight-line response or establish light as the only cause.

■ Common error

Oxygen in water is different from carbon dioxide used by plants. Abiotic means non-living, not unimportant. A measured association should be explained cautiously, especially where temperature, moisture and light change together.

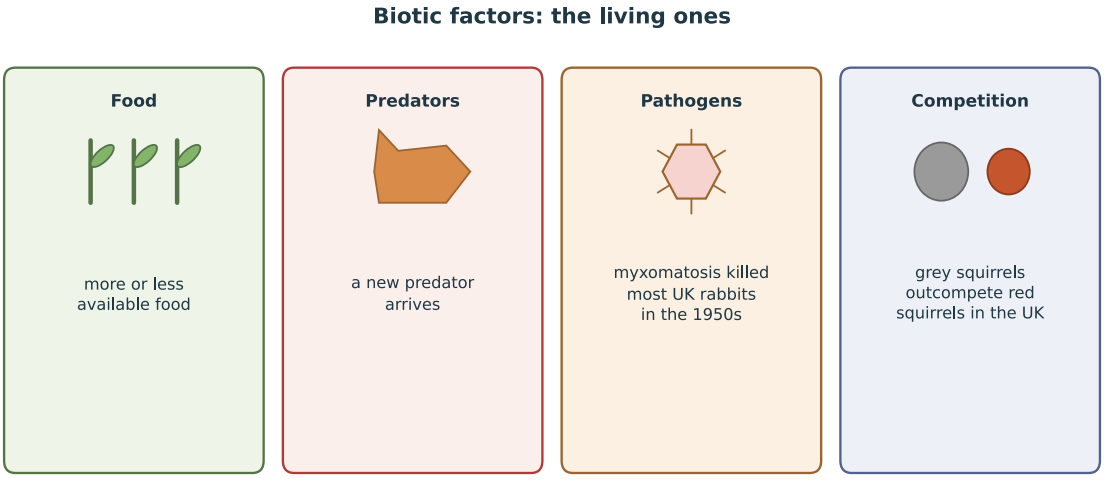
Biotic factors: changing living relationships

Official-unit focus: 4.7 Ecology

A plant's decline after a competing species arrives could reflect competition, but matching dates alone do not rule out drought or disease.

Biotic factors arise from living organisms and their interactions. Food availability

affects survival and breeding. New predators may reduce prey, pathogens can cause disease, and competitors can reduce access to resources. If a population becomes too small or dispersed, individuals may have difficulty finding mates and successful breeding can fall.



The effect can spread through interdependent populations. Fewer prey may later reduce predator numbers; less pollination can reduce seed production. Explain the immediate link before proposing indirect changes. Not every new species outcompetes all existing species, and the effect depends on resources and local conditions.

Use supplied before/after data with sampling effort and abiotic conditions stated. Identify alternative explanations and suggest useful comparison locations or repeated observations. Do not introduce organisms or pathogens into habitats to test an explanation; classroom work uses existing safe observations and prepared evidence.

■ Checked worked case

Known: a fictional prey count changes from 80 to 60 after a new predator arrives. Decrease = $20/80 \times 100 = 25\%$. This describes the change, not proof that predation caused every loss. Births, migration, sampling and other pressures may also contribute.

■ Common error

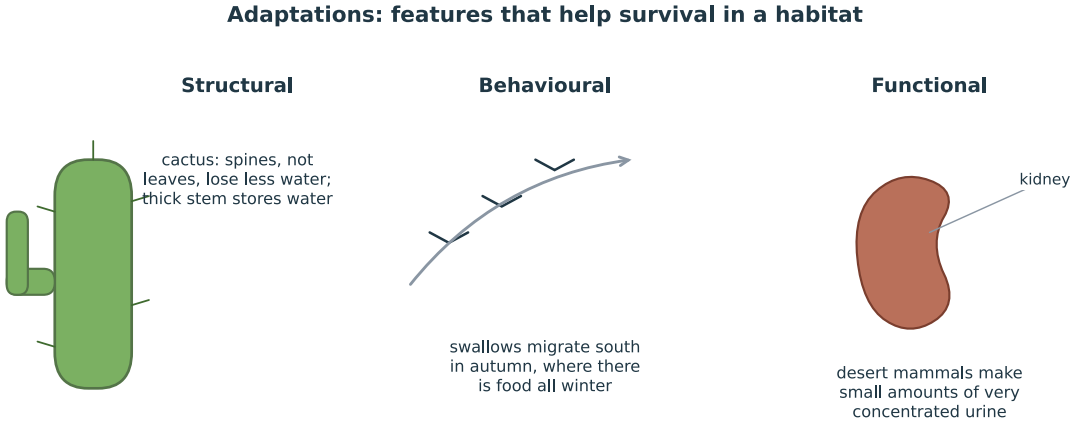
A pathogen is biotic; temperature is abiotic. Food availability is a living-resource relationship even when a record measures its amount numerically. A fall in a population does not necessarily mean that the species became globally extinct.

Adaptations: feature, effect and environmental advantage

Official-unit focus: 4.7 Ecology

A thick fur coat has a different value in a cold habitat and a hot one. An adaptation explanation needs the environmental condition as well as the feature.

Adaptations are features that help organisms survive in conditions where they normally live. Structural adaptations concern body features, behavioural adaptations concern actions and functional adaptations concern biological processes. A supplied desert-plant example might have a reduced leaf surface limiting water loss; the explanation must connect that feature to scarce water.



extremophiles live in extreme conditions: bacteria in hot vents, high salt or pressure

Some organisms live in extreme temperature, pressure or salt concentrations and are called extremophiles. The specification includes bacteria living near deep-sea vents. Extreme is relative to the usual conditions for many organisms, not a statement that no life can function there. Adaptations do not guarantee survival under every change.

For an unfamiliar organism, read the supplied feature and habitat and write feature → effect → advantage. Classify the adaptation using the evidence, allowing that one description can include more than one kind. Use pictures or prepared material; do not expose animals or people to stressful environments.

■ Checked worked case

Known: two fictional leaf models lose 12 and 8 water units over the same interval. Reduction in the second model is $(12-8)/12\times100 = 33.3\%$ to one decimal place. A controlled model helps test an effect, but a real plant also depends on roots, stomata and environmental conditions.

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■ Common error

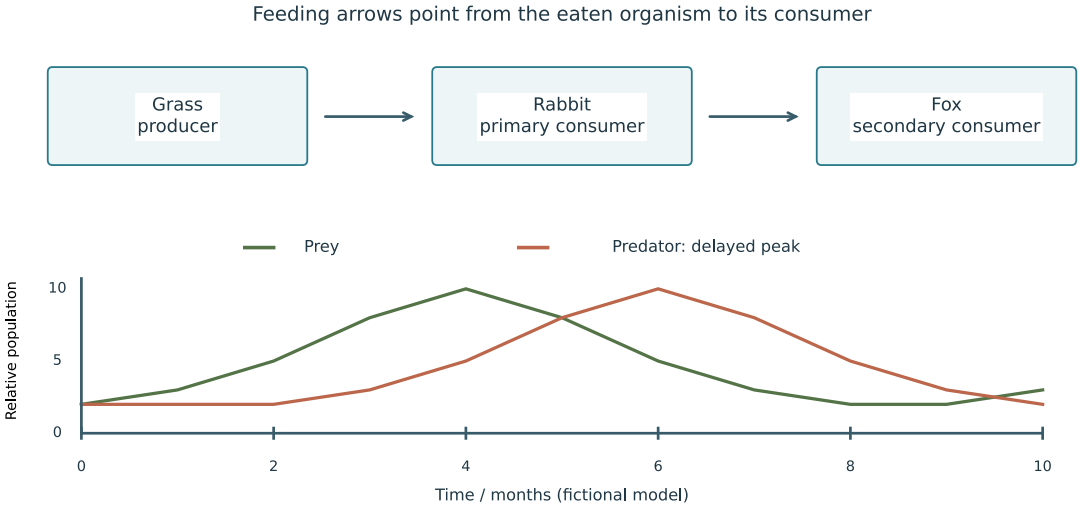
Saying an organism is adapted because it lives there repeats the observation without explaining it. Functional means a biological process, not simply that a shape is useful. An extremophile is not necessarily an organism from every extreme environment.

Food chains and predator–prey cycles

Official-unit focus: 4.7 Ecology

A food-chain arrow points from the organism eaten towards the eater. Reversing it changes the feeding relationship being shown.

Photosynthetic plants and algae are producers: they make glucose and other molecules that form biomass. Producers begin the specified food chains. Primary consumers eat producers, secondary consumers eat primary consumers and tertiary consumers eat secondary consumers. Predators kill and eat prey; the same organism can be a consumer in more than one feeding route.



In a stable community, prey and predator numbers can rise and fall in cycles. More prey can support more predators after a delay; greater predation can reduce prey, followed by fewer predators when food is scarce. The pattern is a model affected by other food, disease, migration and environmental factors.

Read the arrow key, identify each feeding step and interpret population graphs by axes and peaks. Compare the timing of prey and predator peaks instead of assuming simultaneous changes. Use supplied data; observations should not involve harming organisms to demonstrate feeding.

■ Checked worked case

Known: a fictional prey peak occurs at month 4 and a predator peak at month 6. Lag = 2 months. This does not mean the predator count must equal the prey count or that every ecosystem has a two-month cycle. Read each curve's units and scale before comparing magnitudes.

■ Common error

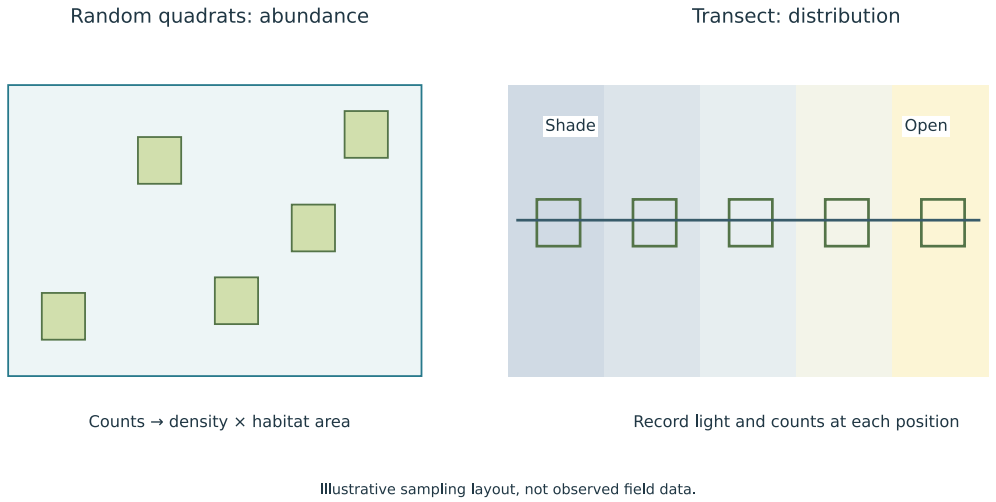
Plants also respire, but photosynthesis makes them producers in this model. A predator may have predators of its own. Population cycles do not imply that every prey death is due to the named predator or that extinction must follow a trough.

Required practical 9: abundance and distribution

Official-unit focus: 4.7 Ecology

Placing every quadrat beside the easiest path can bias a population estimate. A sampling method must match the question and represent the habitat.

A quadrat samples a known area. For a population estimate, generate random coordinates across the defined accessible study area, count the target species using a consistent boundary rule and repeat. Mean count per quadrat divided by quadrat area estimates density; multiply by habitat area for estimated abundance. A transect with systematic sampling helps examine distribution along an environmental gradient.



Illustrative sampling layout, not observed field data.

Required practical 9 measures a common species and investigates a factor affecting its distribution. Measure the factor, such as light intensity, at comparable sampling locations. Random sampling estimates the wider population; a single gradient transect is not automatically representative of the whole habitat. Mean, median and mode describe different properties of the recorded counts.

Complete actual school-supervised fieldwork with teacher-approved access, sensible

weather precautions and minimal disturbance. Record coordinates, quadrat area, counts and factor measurements. Repeat sufficient samples, keep effort and species identification consistent, plot labelled axes and explain uncertainty from patchiness and restricted access.

■ Checked worked case

Known: five 0.25 m^2 quadrats contain 2, 4, 4, 5 and 5 plants. Mean = 20/5 = 4; density = 4/0.25 = 16 plants/m^2. A 30 m^2 habitat estimate is 480 plants. Median is 4; the data are bimodal at 4 and 5. This is an estimate conditional on representative sampling.

■ Common error

Do not multiply a quadrat count directly by habitat area without accounting for quadrat area. A transect measures a pattern along a route, not proof of causation. Destroying plants to count them is unnecessary. A written worksheet supports but does not replace field experience.

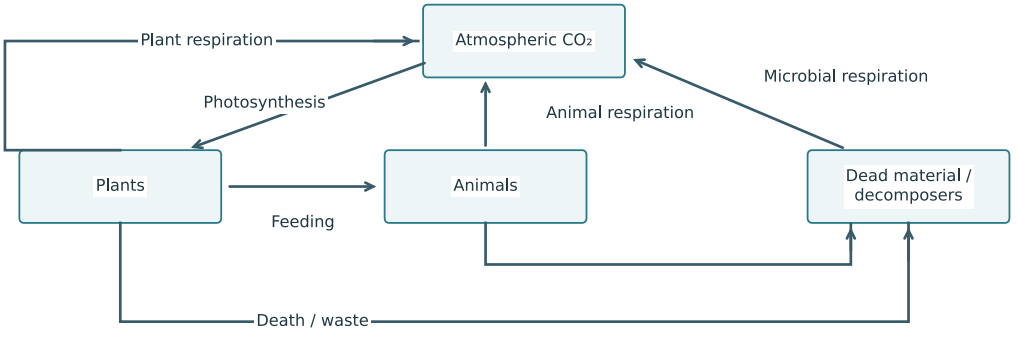
Carbon cycles through living and non-living stores

Official-unit focus: 4.7 Ecology

Carbon in a leaf can enter an animal, a decomposer or the air. A cycle traces atoms through several routes rather than one compulsory sequence.

Photosynthesis takes carbon dioxide from the atmosphere into organic molecules in producers. Feeding transfers carbon-containing molecules to consumers. Plants, animals and microorganisms respire, releasing carbon dioxide. Decomposers break down dead material and waste; their respiration returns carbon dioxide and mineral ions return to the soil through decomposition.

Carbon transfers: several routes return to the atmosphere



Stored fuels → combustion → atmospheric CO_2

Materials cycle; energy does not follow the same recycling account.

Carbon can remain in organic stores, including fuels formed over long periods. Com-

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bustion releases carbon dioxide from carbon-containing fuels or biomass. Materials cycle between biotic and abiotic components and provide building blocks for later organisms. Energy transfers through the system rather than being recycled in the same way.

Interpret a cycle diagram by naming the process at each arrow. Identify alternative routes out of a living organism: feeding, respiration or death and decomposition. Use stated stores and transfers in a mass balance; do not confuse a carbon amount with a carbon-dioxide volume unless a conversion is given.

■ Checked worked case

Known: in a closed fictional carbon account, plants gain 50 carbon units by photosynthesis, transfer 18 by feeding and release 12 by respiration during one interval. Net plant-store increase = 50−18−12 = 20 units, with all other transfers explicitly excluded. This is a store balance, not an energy-efficiency calculation.

■ Common error

Plants both photosynthesise and respire. Decomposition does not make carbon disappear. Not every arrow goes from one organism to the next trophic level, and the nitrogen cycle is not required by this specification section.

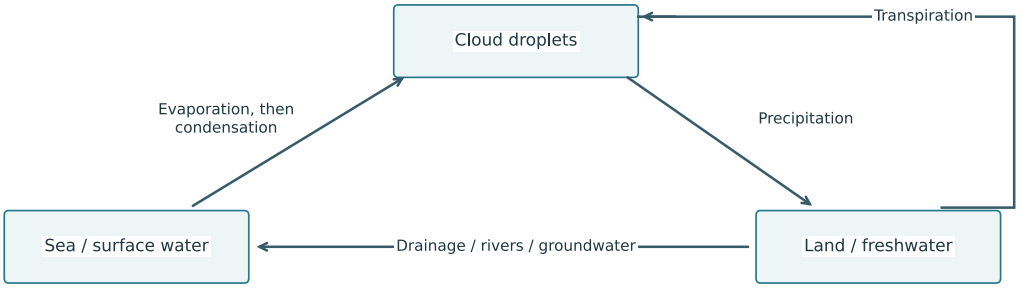
Water cycle: evaporation is not disappearance

Official-unit focus: 4.7 Ecology

Water evaporating from a pond has changed state and location. The molecules can later return as precipitation rather than being used up.

Water evaporates from seas, lakes and other wet surfaces; plants also release water vapour through transpiration. Vapour condenses into droplets as it cools, forming clouds. Precipitation returns water to land and sea. Water on land can drain through rivers or move into soil and groundwater before returning to the sea.

Water cycle: change of state and movement between stores



Organisms take up and return water; local availability can change.

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Freshwater supply supports plants and animals on land. Organisms take up water and later return it through processes including excretion, respiration and transpiration. The water cycle includes both abiotic stores and biological transfers. A diagram can simplify the system, but not all rainwater immediately travels through the same route.

Trace processes on a supplied diagram and distinguish changes of state from movement between places. In a school model, observe teacher-approved evaporation or condensation without assuming it reproduces the scale of global circulation. For balances, define the store, time interval and any inflow or outflow omitted.

■ Checked worked case

Known: a fictional pond begins with 200 water units, gains 40 in rain and loses 25 by evaporation and 15 by drainage. Final store = 200+40−25−15 = 200 units. An unchanged store can still involve large transfers; it does not mean the cycle stopped.

■ Common error

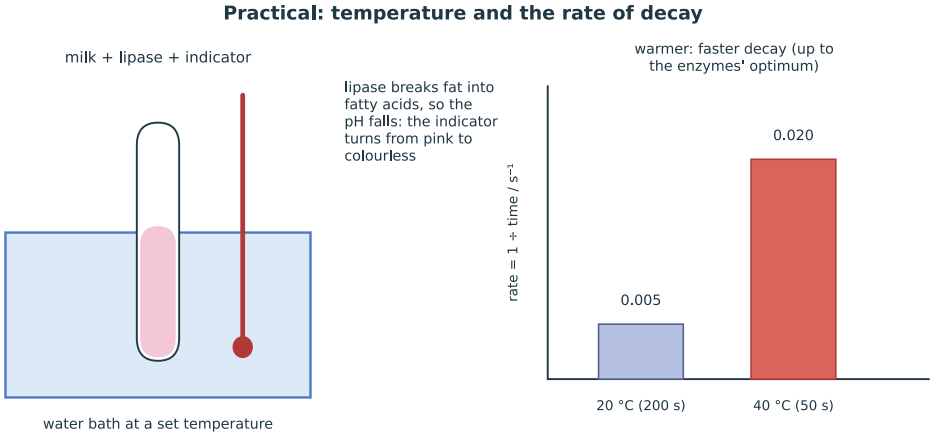
Evaporation is liquid changing to vapour; condensation is the reverse. Precipitation is not the same as transpiration. Water can be recycled while its availability at a particular habitat changes, so global cycling does not guarantee local water supply.

Required practical 10: conditions and decay rate

Official-unit focus: 4.7 Ecology

A faster pH change in milk can indicate faster decay under a defined method. Compare rates over the same stated endpoint rather than only final colour.

Microorganisms decompose biological material. Suitable temperature and water support their reactions, while oxygen supports aerobic respiration; excessive temperature can inhibit or kill organisms rather than continually increasing rate. Composting aims to provide conditions for rapid decomposition and produces material used as a natural fertiliser. Anaerobic decay can produce methane, which biogas generators collect as fuel.



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Required practical 10 investigates the effect of temperature on fresh-milk decay rate by measuring pH change. Use teacher-approved fresh milk, reagents, controlled water baths and a consistent endpoint. The AQA handbook models faster decay with lipase acting on fresh milk or cream made alkaline using sodium carbonate, with Cresol red changing from purple to yellow. Lipase produces fatty acids; natural microbial decay instead lowers pH through processes including lactic-acid production. These are different mechanisms.

In the handbook model, equilibrate separate milk and lipase tubes in each water bath, add a fixed lipase amount to the milk mixture, start timing immediately and stir until the same yellow endpoint. Keep milk volume, starting pH and reagent concentrations comparable; repeat at several measured temperatures. Record temperature and time or a pH-time series, then use the defined rate measure. Do not taste material, culture unknown spoilage organisms or heat sealed gas-producing containers. Complete actual supervised laboratory work rather than replacing it with an invented written practical.

■ Checked worked case

Known: a supplied pH record falls from 8.0 to 7.0 in 5 min. Mean magnitude of pH change = $1.0/5 = 0.20$ pH units/min. pH is a logarithmic measure, so this is a method-defined comparison, not a direct mass production rate. If using time to a fixed endpoint, compare 1/time instead.

■ Common error

A lower endpoint pH without timing is not a rate. Oxygen is not required for every kind of decomposition; distinguish aerobic compost processes from anaerobic biogas production. A temperature optimum should be inferred from supplied data rather than assumed universal.

Higher Tier: environmental change shifts distributions

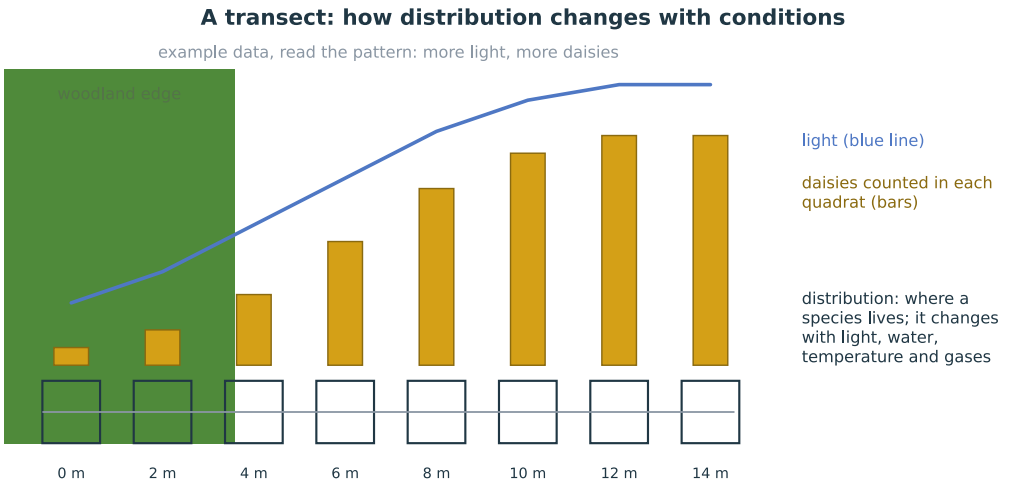
Higher Tier focus; see section scope notes.

Official-unit focus: 4.7 Ecology

A species recorded farther north after warming provides a distribution pattern, but surveying more northern sites could also change the record.

Environmental changes affect where species can survive and reproduce. Temperature, available water and atmospheric gas composition may change seasonally, across geographic locations or through human activity. A factor can move conditions outside a species' suitable range, while making a different location more suitable.

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Distribution is where organisms occur; abundance is how many occur. A geographic shift need not mean total population size increased. Evaluate whether records cover comparable seasons, sampling methods and areas. Competing species, dispersal barriers and habitat availability can alter the expected response to an abiotic change.

Map supplied presence records with coordinates or distances and compare like-for-like surveys. Explain a plausible mechanism using the stated species requirements, then identify alternative factors. Include uncertainty from detection, short records and incomplete coverage. Do not turn an association into a universal migration prediction.

■ Checked worked case

Known: a fictional northern range boundary changes from 200 to 245 km from a reference point over 15 years. Shift = 45 km; mean boundary-shift rate = 3 km/year. This is a mapped range statistic, not the travelling speed of an individual animal or proof that every year changed equally.

■ Common error

The same environmental change does not benefit every species. A distribution boundary is not an individual's movement path. A seasonal record and a long-term geographic trend are different comparisons and should not be mixed without explanation.

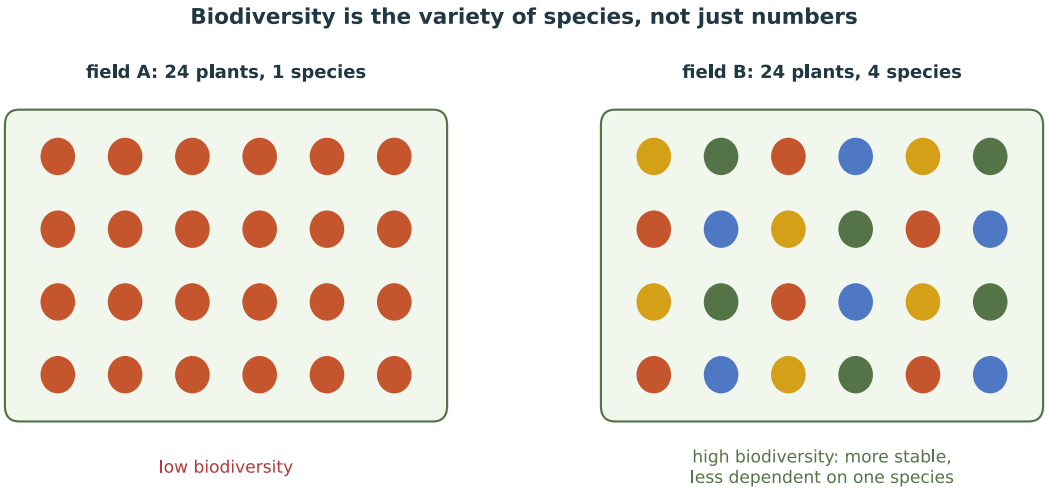
Biodiversity: count species, explain resilience

Official-unit focus: 4.7 Ecology

A field with thousands of one crop can have fewer species than a small mixed meadow. Abundance and biodiversity measure different things.

Biodiversity is the variety of different species within an ecosystem or across Earth. A community with more alternative feeding and shelter relationships may depend less

on any single species, supporting stability when one population changes. Human life relies on functioning ecosystems and their resources; many human activities reduce species variety.



A species count is one useful measure, but an incomplete survey misses organisms and does not describe every aspect of diversity. The specification's stability account is a mechanism to explain rather than a guarantee that every diverse ecosystem resists every disturbance. Habitat condition, population sizes and interactions also matter.

Compare supplied species lists using equal area and effort. Separate number of species from total individuals, then explain how loss of one species might affect a stated network. Evaluate conservation proposals using habitat needs and monitoring evidence, without claiming that a short species list measures all global biodiversity.

■ Checked worked case

Known: site A has 80 individuals across 4 recorded species; site B has 60 individuals across 7 recorded species. B has greater recorded species variety despite fewer individuals. Difference in recorded richness $= 7-4 = 3$ species. This comparison is conditional on equally effective sampling.

■ Common error

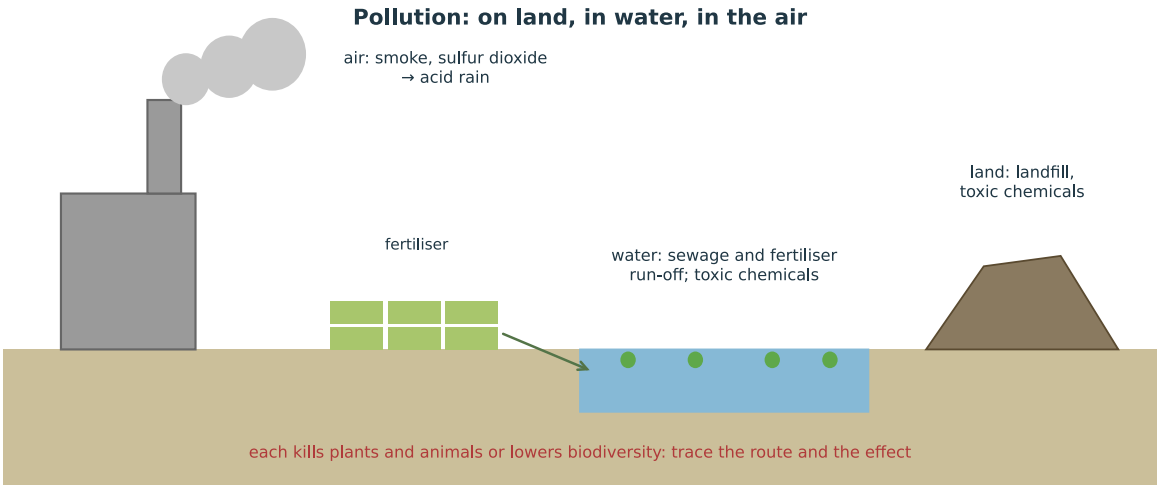
A larger population of one species does not necessarily increase biodiversity. A missing species after one survey may reflect detection limits. Stability is supported by several interacting processes, so a species count alone cannot prove the cause of resilience.

Waste and pollution: trace the exposure route

Official-unit focus: 4.7 Ecology

Waste placed on land can later enter water. Classify the source and trace how organisms encounter it rather than assuming pollution stays where it begins.

More people and greater resource consumption can produce more waste. If waste and chemicals are not managed appropriately, pollution affects water, air and land. Water can receive sewage, fertilisers and toxic chemicals. Air pollution includes smoke and acidic gases. Land pollution includes landfill and toxic substances.



Pollutants can kill plants and animals or change the conditions needed for survival, reducing biodiversity. Fertiliser runoff can stimulate excessive algal growth; subsequent microbial decomposition can reduce dissolved oxygen and affect aquatic animals. This mechanism differs from a toxic substance directly poisoning an organism.

Analyse a supplied source → movement → exposure → effect chain. Compare upstream/downstream records or matched sites, identifying other possible causes. Classroom investigations use prepared water-quality records or safe approved sampling, not sewage handling, toxic chemicals or deliberate pollution.

■ Checked worked case

Known: a fictional waste account contains 120 kg generated and 45 kg recovered for reuse or recycling. Unrecovered amount = 75 kg; recovery percentage = 45/120×100 = 37.5%. Unrecovered is not automatically all released as pollution: controlled treatment and disposal must also be considered.

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■ Common error

Pollution categories describe routes, not a rule that one substance affects only one medium. More recycling does not remove every production impact. An oxygen decline in water needs a supported mechanism; it is not proof that all pollution acts identically.

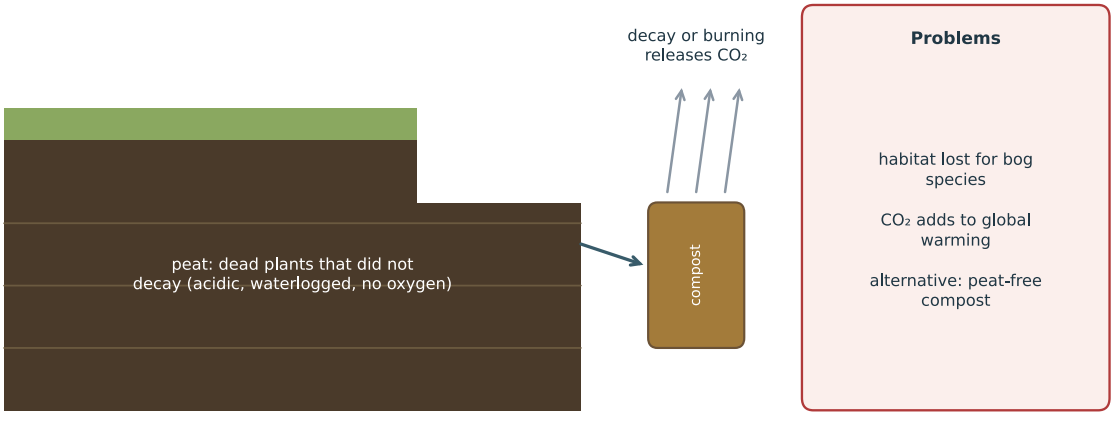
Land use and peat: habitat and carbon consequences

Official-unit focus: 4.7 Ecology

Peat can be sold as compost while its removal destroys a habitat and exposes stored carbon. An evaluation needs both production and environmental consequences.

Building, quarrying, farming and dumping waste reduce land available for other organisms. Habitat removal affects plants, animals and microorganisms, and fragmentation can separate surviving populations. Peat bogs support particular communities; extracting peat for garden compost reduces this habitat and its biodiversity.

Peat bogs: a carbon store that is being dug up



Peat contains accumulated organic material. Decay or burning releases carbon dioxide into the atmosphere. Keeping peat intact helps retain that carbon store. The specification asks students to weigh cheap available compost and food-production needs against habitat conservation and reduced emissions. Alternative materials also require evidence about cost, performance and environmental impacts.

Use supplied land-area and carbon-account records to compare proposals. Distinguish the area directly removed from surrounding habitat affected by drainage or fragmentation. State the stakeholder benefit and the ecological cost, then identify practical alternatives and what monitoring could test their effects.

■ Checked worked case

Known: a fictional peat habitat falls from 80 to 60 hectares after the stated land-use change. Area loss = 20 hectares, or 25% of the starting area. This does not imply a 25% loss of every species: species distribution and habitat quality are also needed.

■ Common error

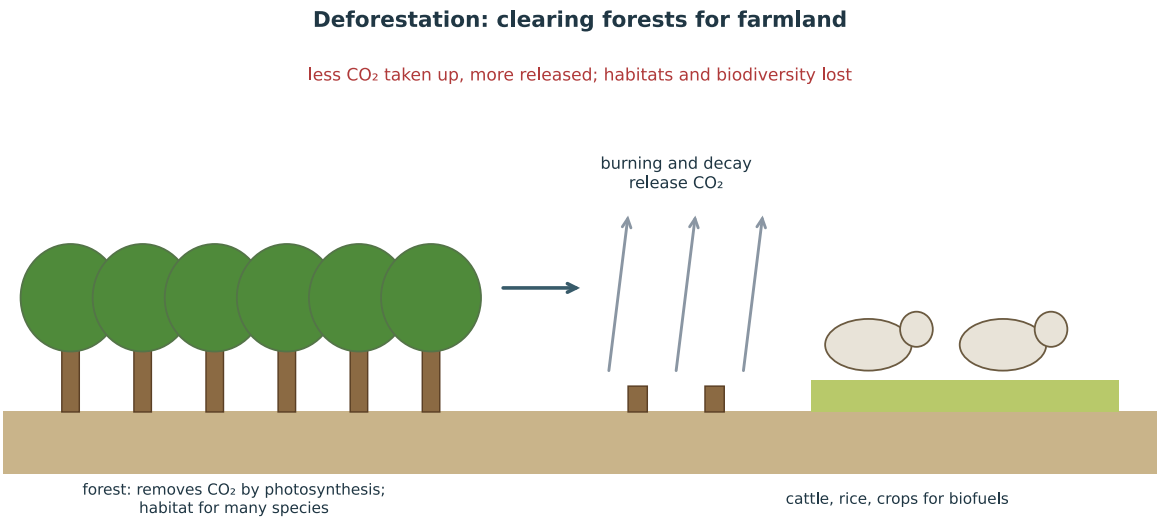
Peat is not simply an inexhaustible mineral fertiliser. Habitat loss and carbon release are separate consequences. A percentage area change cannot be converted directly into carbon emissions without a supplied carbon-density and release model.

Deforestation: land demand and ecological effects

Official-unit focus: 4.7 Ecology

Replacing a forest with a crop can increase one useful product while removing many habitats. Food or fuel output is only one part of the decision.

The specification identifies tropical forest clearance for cattle, rice cultivation and biofuel crops. Forest removal destroys habitat and can reduce biodiversity. Burning cleared material releases carbon dioxide; later decay can also release carbon. Fewer trees can reduce photosynthetic uptake compared with the original forest, although replacement plants also photosynthesise.



The result depends on the replacement system, what happens to the wood and the time interval. A claim that every biofuel has no emissions ignores land-use change and production. Evaluate food, income and energy benefits alongside habitat, carbon and other environmental consequences using the supplied evidence.

Compare a fictional land-use proposal with retained-forest and alternative-site options. Use area, production and stated carbon-transfer records separately, avoiding double counting carbon released from the same material. Explain the biological mechanism

rather than writing only deforestation is bad.

■ Checked worked case

Known: a supplied 150-hectare region retains 105 hectares of forest after clearance. Cleared area = 45 hectares, or 30%. This describes that region; it is not a current global deforestation statistic. A biodiversity conclusion also needs information about which habitats and species were affected.

■ Common error

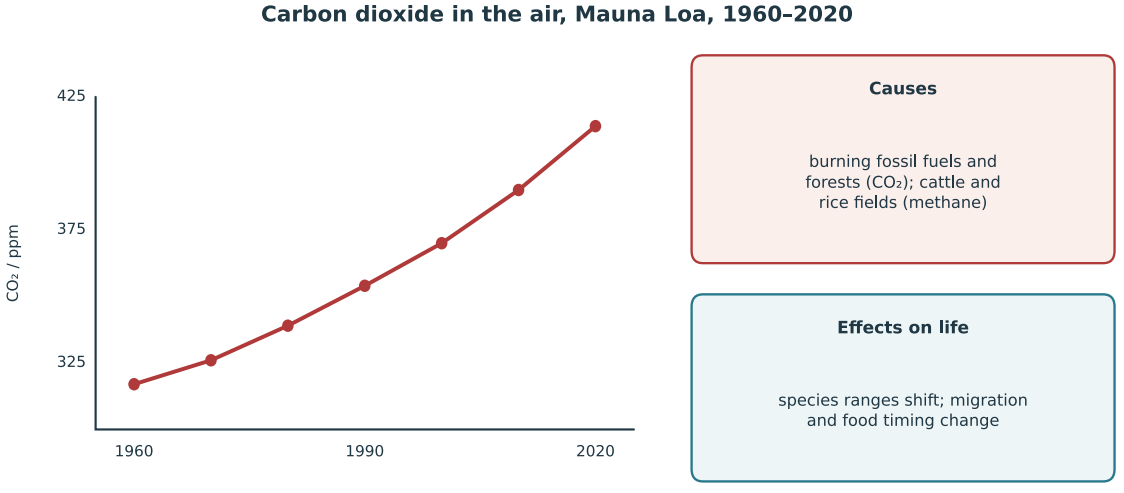
Trees do not store carbon only while alive: dead wood and soil can also be stores. Carbon dioxide release and reduced future uptake are different terms. A new crop's photosynthesis does not automatically replace all original habitat or carbon storage.

Global warming: biological effects and evidence

Official-unit focus: 4.7 Ecology

A warmer average climate does not mean every habitat changes identically or every species benefits. Biological effects depend on conditions and interactions.

Carbon dioxide and methane are greenhouse gases. Increasing their atmospheric concentrations contributes to global warming. Changing temperature and rainfall can alter suitable habitats, species distributions, food availability and breeding timings. Some organisms gain suitable conditions while others lose them, and interactions may become mismatched.



Scientific consensus on climate change draws on systematic reviews of many peer-reviewed publications, not one weather observation. Complex local outcomes can be uncertain or incomplete because interacting factors, future emissions and biological responses vary. Uncertainty about a particular population's future does not erase the wider evidence for warming.

Interpret supplied long-term temperature and biological records, distinguishing climate trends from short-term weather. Identify timescales, comparison methods and other possible causes of a local population change. Explain an impact through changed abiotic conditions or interdependence, with a limitation supported by the data.

■ Checked worked case

Known: a fictional mean-temperature series rises from 12.0 to 13.2 °C over 30 years. Change = 1.2 °C; model average change = 0.04 °C/year. This arithmetic describes the supplied series, not a current global estimate or a claim that each year warmed uniformly. Percentage change in Celsius is not an appropriate substitute.

■ Common error

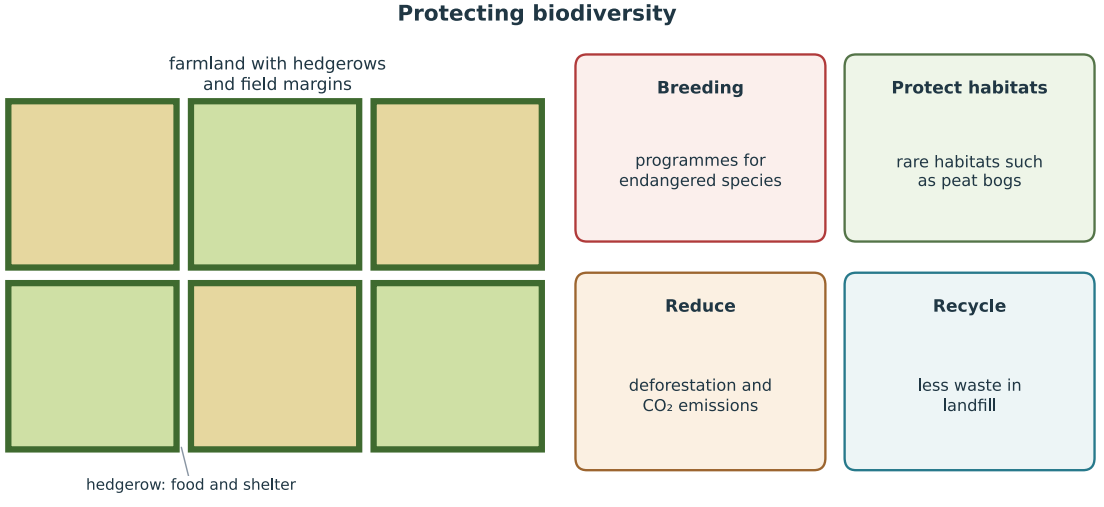
One cold day does not disprove a long-term trend. A shift in a species range is not automatically an increase in biodiversity. A local correlation requires careful attribution, and a fictional classroom graph must not be presented as observed global climate data.

Maintaining biodiversity: evaluate a programme

Official-unit focus: 4.7 Ecology

Breeding endangered animals without protecting suitable habitat may leave nowhere for them to survive. Conservation measures need to work together.

Conservation programmes can breed endangered species and protect or regenerate rare habitats. Field margins and hedgerows restore shelter and resources around single-crop fields. Reducing deforestation and carbon-dioxide emissions can limit wider pressures. Recycling resources reduces demand for some new materials and landfill disposal.



Each measure has benefits and limitations. Breeding needs genetic diversity and suitable release conditions; habitat restoration takes time; land set aside for biodiversity

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may compete with production. Human interactions can be positive or negative depending on the action and its context. A justified evaluation weighs evidence and conflicting pressures rather than listing only advantages.

Compare supplied proposals with costs, species records and local needs. State which mechanism each action targets and propose matched monitoring before and after implementation. Use equal survey effort and suitable comparison areas where possible. Do not release captive organisms or introduce species as a classroom experiment.

■ Checked worked case

Known: equal-effort surveys record 8 species before a fictional habitat programme and 12 afterwards. Increase = 4 species, or 50% of the initial recorded richness. A comparison site and repeated seasons would help determine whether the programme contributed to the change.

■ Common error

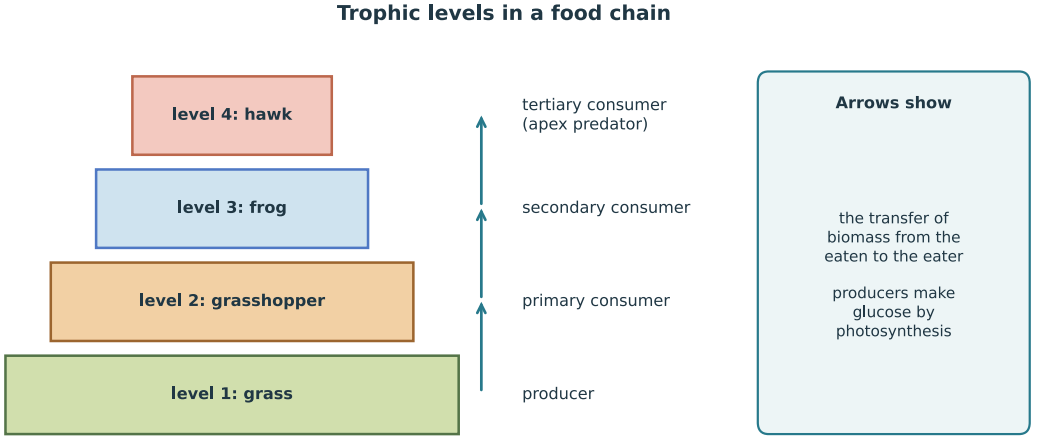
A larger release count alone does not show successful conservation. A field margin supports more than decorative plants: it can provide food, shelter and connectivity. Recycling cannot repair every habitat already lost, so different measures address different pressures.

Trophic levels and extracellular decomposition

Official-unit focus: 4.7 Ecology

A decomposer acts on dead material from several trophic levels. It is not simply the next predator above an apex consumer.

Trophic level 1 contains producers such as plants and algae. Primary consumers at level 2 eat producers; secondary consumers at level 3 eat primary consumers; tertiary consumers at level 4 eat secondary consumers. An apex predator has no predators in the stated ecosystem. Level refers to a feeding position rather than size or intelligence.



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Decomposers break down dead plants, animals and waste. They secrete enzymes into their surroundings; enzymes digest large molecules into small soluble products that diffuse into the microorganism. This extracellular digestion lets material from several levels return to the system through microbial activity and material cycling.

Label a supplied food chain and use the arrow legend to identify feeding positions. In a food web an organism may occupy different positions along different routes. Trace dead material separately to decomposers. Use prepared diagrams rather than feeding experiments or unknown microbial cultures.

■ Checked worked case

Known: a model chain contains grass → insect → bird → hawk. Grass is level 1, insect level 2, bird level 3 and hawk level 4. There are three feeding transfers from grass to hawk. The number of transfers is one less than the number of levels in this linear chain.

■ Common error

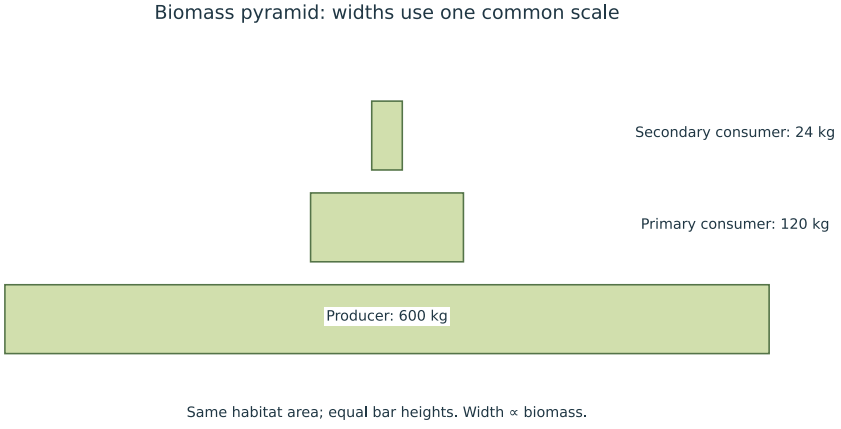
Carnivore does not always mean level 3: a carnivore eating another carnivore can be level 4. Enzymes act outside a decomposer before soluble products enter it. The apex label depends on the supplied ecosystem, not a universal claim about the species.

Draw a biomass pyramid to a stated scale

Official-unit focus: 4.7 Ecology

Many tiny plants can have more total biomass than a few large animals. A biomass pyramid represents mass at each level rather than organism count.

A pyramid of biomass represents relative biomass at successive trophic levels. Producers, trophic level 1, form the bottom bar. Use the supplied biomass measure, commonly dry mass per unit area, consistently. Bars at higher levels are centred above the lower bars, and their widths are proportional to the stated biomass.



The pyramid is a diagram of a defined sample or estimate, not the physical shape of an ecosystem. Equal bar heights allow width to represent relative amount. Biomass and energy are related but are not the same quantity; do not label a kilogram dataset in joules. Organism numbers also require different data.

Convert all masses into one unit, choose a scale fitting the page and calculate each width. Centre bars, label organisms, trophic levels and units and keep producer placement clear. If one bar is too small to draw accurately, state a scale limitation rather than silently giving it a false width.

■ Checked worked case

Known: supplied biomasses are 600, 120 and 24 kg over the same area. At 100 kg per centimetre, widths are 6.0, 1.2 and 0.24 cm. Keep a common scale; drawing each bar to a separate convenient scale destroys the quantitative comparison.

■ Common error

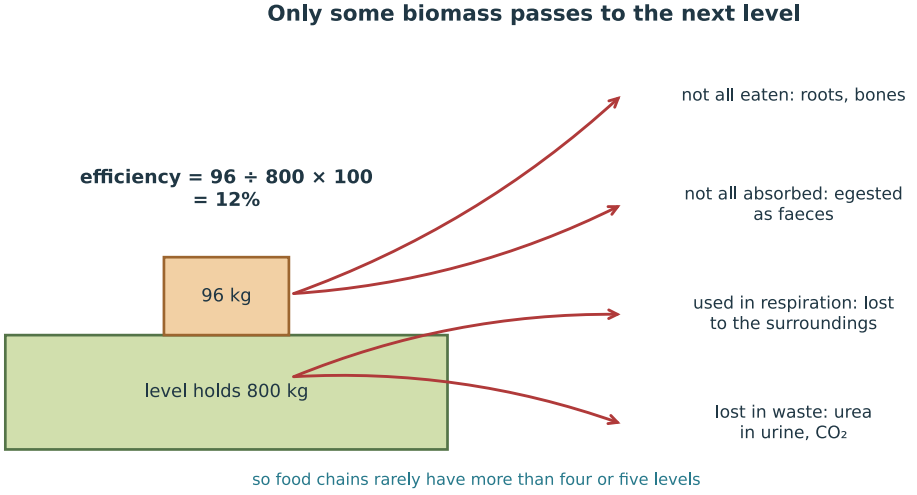
Pyramid width does not represent the height of an organism. More individuals does not always mean greater biomass. Masses from different habitat areas need comparable per-area units before being placed in one pyramid.

Biomass transfer: account for losses

Official-unit focus: 4.7 Ecology

Eating 100 kg of material does not add 100 kg to an animal's body. Some is not absorbed and some supports respiration and other processes.

Producers transfer only about 1% of incident light energy through photosynthesis in the specification's approximate account. Only about 10% of biomass transfers from one trophic level to the next. Actual efficiencies depend on the supplied data, so these figures are guides rather than universal exact constants.



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Not all ingested material is absorbed; some is egested as faeces. Absorbed material can be lost as respiration products, including carbon dioxide and water, or in excretion such as water and urea. Much glucose is used in respiration rather than retained as growth. Biomass available to higher consumers consequently decreases, helping explain smaller supported populations in a stated chain.

Calculate transfer efficiency as biomass at the next level divided by biomass at the previous level, multiplied by 100. Use comparable mass units and sampling areas. Distinguish egestion of unabsorbed food from excretion of metabolic waste. A biomass ratio alone does not predict exact organism numbers without their individual masses.

■ Checked worked case

Known: supplied producer biomass is 800 kg and primary-consumer biomass 96 kg. Transfer efficiency = $96/800 \times 100 = 12\%$. Use 12%, not force the answer to 10%. The remaining amount has several possible routes and cannot all be assigned to one named loss without more data.

■ Common error

Respiration transfers energy and releases material; do not call energy a lost kilogram of biomass. Ingested and absorbed are different amounts. A second transfer compounds the reduction rather than adding the percentages from two levels.

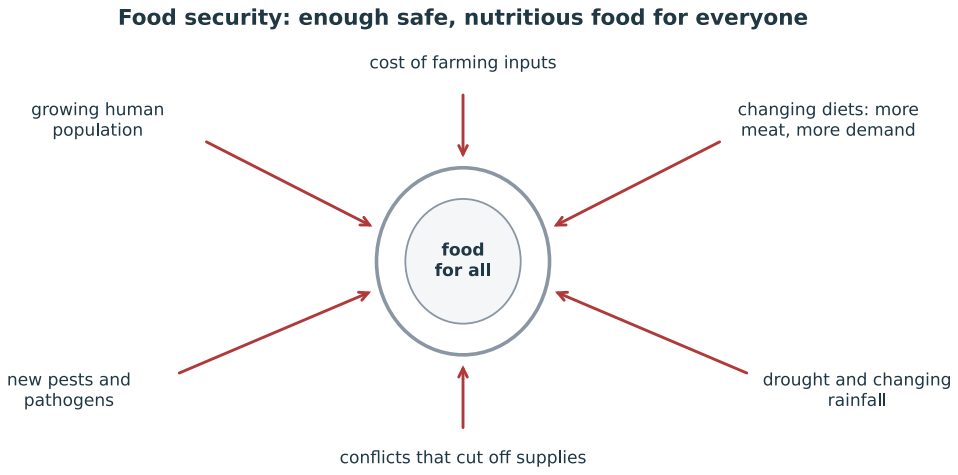
Food security: production, access and pressures

Official-unit focus: 4.7 Ecology

A region can produce food yet fail to provide enough for all its people. Production, transport, affordability and distribution all affect the outcome.

Food security means having enough food to feed a population. The specification identifies population increase, changing diets and international transport of scarce resources, new crop pests and pathogens, environmental changes such as failed rains, agricultural-input costs and conflict affecting water or food. These pressures can interact rather than act independently.

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Sustainable responses need to maintain production without exhausting the conditions that support it. Greater output can help, but inaccessible or unaffordable food does not solve every shortage. A shift towards resource-demanding foods changes how land and feed are used. Use the supplied context instead of assuming one response fits every country.

Compare fictional production and population records using consistent time and food units. Calculate production per person, then identify losses, transport or access information missing from the simple ratio. Evaluate a response with a biological mechanism and a limitation, distinguishing short-term relief from longer-term sustainability.

■ Checked worked case

Known: a model region produces 12,000 food units for 3,000 people. Mean available production = 4 units/person before losses or distribution. If population rises to 4,000 with output unchanged, the ratio falls to 3. This is an accounting model, not a nutritional requirement or evidence that everyone receives the mean amount.

■ Common error

A higher total output does not guarantee higher output per person. Conflict and cost can restrict access without reducing biological yield directly. Avoid using fictional classroom values as real population or famine statistics.

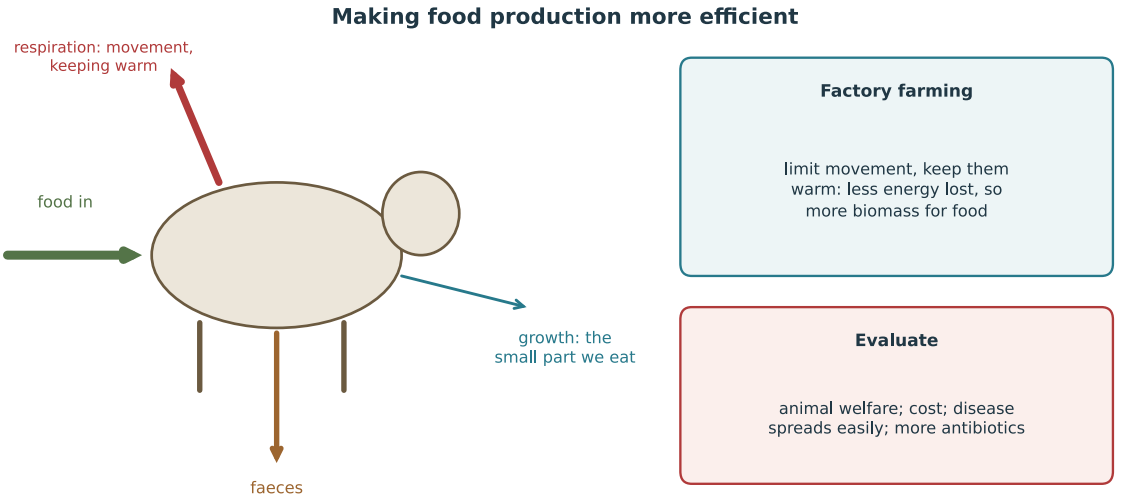
Intensive farming: efficiency and welfare

Official-unit focus: 4.7 Ecology

Keeping animals warm and limiting movement may leave more resources for growth. Whether that method is acceptable requires more than a growth calculation.

Food-production efficiency can increase when less of the energy from food is used for movement or maintaining body temperature. Some intensive systems restrict move-

ment and control environmental temperature. High-protein foods can supply amino acids for growth. These methods do not remove the need for respiration, suitable nutrition or healthy conditions.



Higher growth or feed efficiency can support production, but limiting movement can raise animal-welfare concerns. Heating and maintaining facilities have costs and environmental impacts. Disease risk and health depend on management. Evaluate benefits, burdens and ethical objections with supplied evidence rather than presenting confinement as automatically desirable.

Use fictional feeding and growth records with matched age, breed, feed and measurement interval. Calculate an explicitly defined efficiency and identify what it omits. This is a data-evaluation task; students must not restrict animal movement or alter animal temperature to conduct an efficiency experiment.

■ Checked worked case

Known: a model animal gains 4 kg from 20 kg of feed. Defined mass-conversion efficiency $= 4/20 \times 100 = 20\%$. The ratio is not an energy efficiency unless energy contents are supplied, and it does not itself measure welfare, health or the cost of heating.

■ Common error

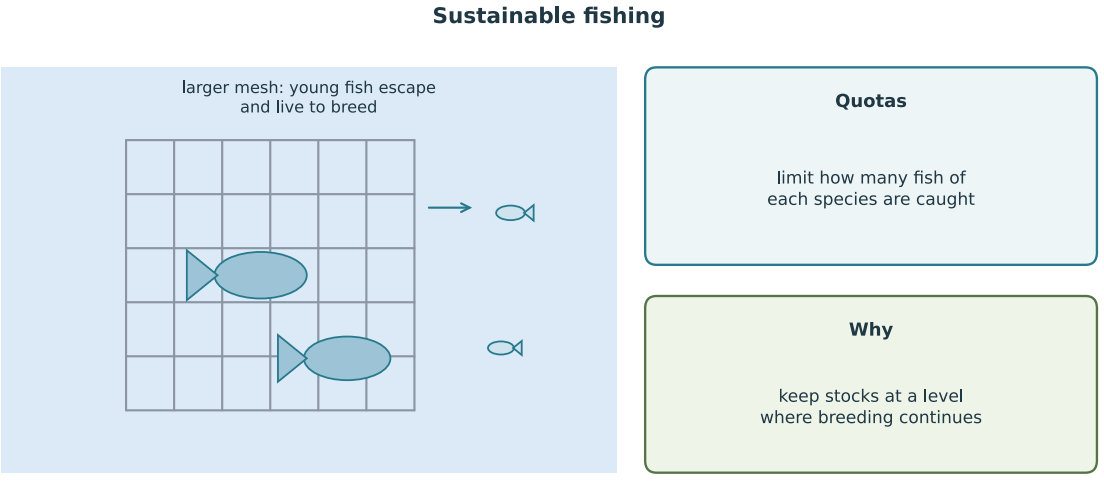
Food mass, biomass gain and energy are different measures. Protein is not a substitute for every other nutrient. A numerically efficient system can still have disadvantages, which a reasoned evaluation should address directly.

Sustainable fisheries: allow breeding to continue

Official-unit focus: 4.7 Ecology

A catch limit can reduce removals, while mesh size changes which fish are caught. These measures address different parts of stock conservation.

Fish stocks must remain large enough for successful breeding if populations are to persist. Catching too many individuals can reduce later recruitment. Quotas limit the permitted catch. Suitable net mesh sizes allow smaller, often younger fish to escape and have an opportunity to breed before capture. The effect depends on species and gear.



Conservation needs evidence about population trends, recruitment and actual removals. A quota alone does not guarantee sustainability if it is too high, ignored or combined with other pressures. Bigger mesh is not a universal solution for every species; bycatch and habitat effects also matter when information is supplied.

Compare fictional stock records, catch limits and size distributions. Explain how the proposed measure changes breeding opportunity or removals, then evaluate monitoring and enforcement. No current numerical fishing regulation is inferred from a classroom example; use the prompt's stated model values.

■ Checked worked case

Known: a closed model stock begins at 1,000 fish, gains 300 surviving recruits, loses 150 to other deaths and 200 to catch. Final stock = 950. A catch of 200 therefore does not maintain the starting stock under these particular assumptions. Changing recruitment changes the sustainable removal estimate.

■ Common error

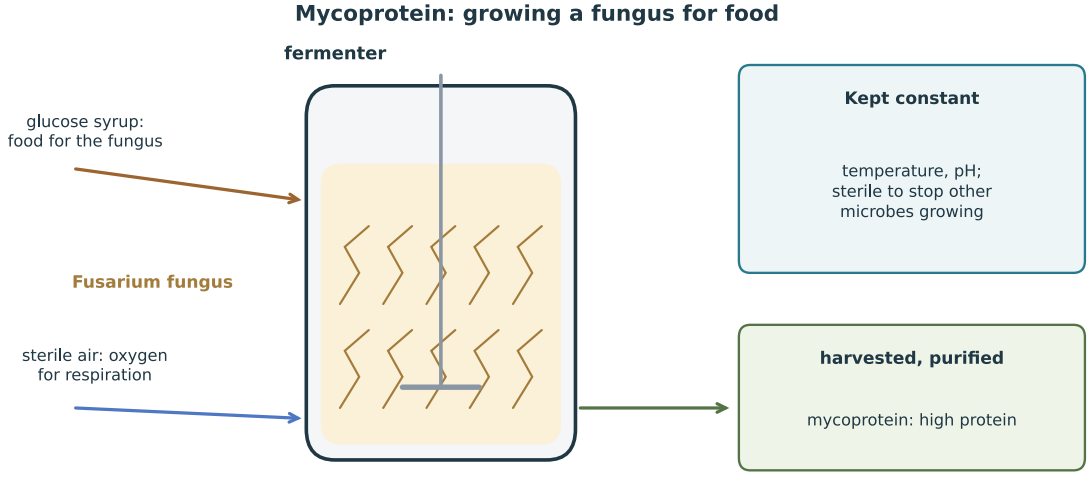
A quota is a limit, not the number automatically caught. A fish escaping capture does not guarantee it survives to breed. Local disappearance and global extinction are different outcomes, and long-term recovery needs repeated evidence.

Biotechnology: controlled culture and useful products

Official-unit focus: 4.7 Ecology

The culture organism and the purified product are different. A fermenter needs conditions for growth, while harvesting makes the intended material available.

Modern biotechnology grows microorganisms in large quantities for useful products. Fusarium is a fungus cultured on glucose syrup under aerobic conditions to produce protein-rich mycoprotein suitable for vegetarians. Biomass is harvested and purified. Oxygen, nutrients and suitable conditions support the culture; it is not simply left to grow without control.



Genetically modified bacteria can produce human insulin, which is harvested and purified for medical use. GM crops can increase useful output or nutritional value; golden rice is the specified nutritional example. These approaches connect genetic information with practical production but still need evidence about yield, quality, cost and environmental effects.

Read a supplied production flow and distinguish organism growth, product formation, harvesting and purification. Explain why an aerobic culture needs oxygen and why contamination or unsuitable temperature changes output. Use prepared data or school-approved models; no insulin production or unknown fungal culture is a classroom requirement.

■ Checked worked case

Known: a fictional process starts with 50 kg harvested biomass and retains 40 kg after the stated purification. Recovery = $40/50 \times 100 = 80\%$. This is product recovery, not protein percentage or genetic-transfer success. Those measures need different denominators and data.

■ Common error

Fusarium is a fungus, not a bacterium or a green plant. Mycoprotein production is aerobic in this specification, so do not replace it with an anaerobic brewing account. Golden rice illustrates nutritional modification, not a claim that every GM crop solves all food-security problems.

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