Course notes

International Baccalaureate · IB Diploma · Biology · HL

IB IB Diploma · Biology · HL: teaching notes

Version: First assessment 2025

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

Assessment and course boundaries

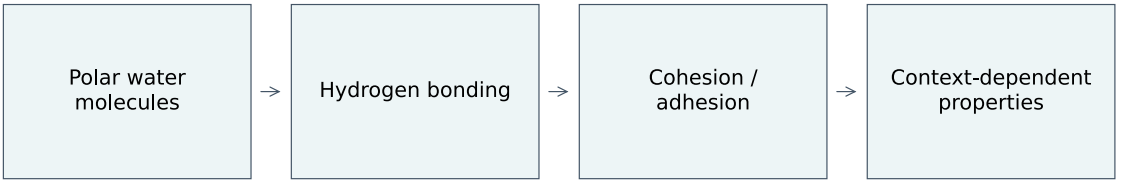
- Unity/diversity, form/function, interaction/interdependence and continuity/change organize the course; there are no old option topics.
- SL excludes origins of cells, viruses, classification/cladistics, muscle/motility, chemical signalling and gene expression as HL-only topics; mixed topics also have AHL details needing the guide.
- Paper 1: 1A MCQ and 1B data; Paper 2: short/extended responses. SL durations 1.5/1.5 h; HL 2/2.5 h; weights 36%/44%. Scientific investigation 20%, maximum 3,000 words.
- Practical work 40 h, collaborative sciences project 10 h and individual scientific investigation 10 h.

Water: a molecular cause for a biological property

Official-unit focus: A.1.1 Water

A water droplet holds together on a leaf. Its behaviour comes from interactions between molecules, not a skin made of solid water.

Water molecules are polar. Attraction between the partially positive hydrogen of one molecule and a partially negative oxygen of another gives hydrogen bonding. Cohesion is attraction between water molecules; adhesion is attraction to another surface.



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The same intermolecular interactions help explain surface tension and the energy needed to change temperature. Heating changes molecular motion and interactions; it does not normally break the covalent O–H bonds.

Compare equal drops on clean surfaces under fixed temperature. Measure contact angle or spreading consistently. A detergent changes the system, so record concentration rather than treating all liquids as equivalent.

■ Checked worked case

Known: 0.100 kg of water warms by 5.0 K; specific heat capacity is 4,180 J/(kg K). $Q = mc\Delta T = 0.100 \times 4{,}180 \times 5.0 = 2{,}090$ J. This calculation excludes energy absorbed by the container and lost to the surroundings.

■ Common error

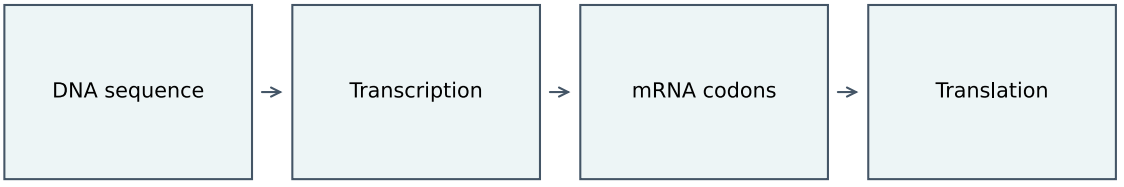
Hydrogen bonds between molecules differ from covalent bonds within a water molecule. Polarity alone does not make every substance dissolve well in water.

DNA, protein synthesis and evidence

Official-unit focus: A.1.2 Nucleic acids; D.1.2 Protein synthesis; D.1.3 Mutations and gene editing

A change in DNA can affect a protein, but not every DNA change changes the amino-acid sequence. The effect depends on the sequence and how it is used.

DNA stores information in a base sequence. Complementary base pairing supports copying. During gene expression, transcription makes RNA and translation uses codons to assemble an amino-acid sequence.



A codon comprises three bases. The genetic code is degenerate: more than one codon can specify the same amino acid. A substitution can therefore be silent, while insertions or deletions can shift the reading frame.

Keep DNA template, coding DNA and mRNA distinct. State the strand used and write sequences in the required direction. Use a codon table for mRNA, not an unex-

plained DNA triplet.

■ Checked worked case

Known: an mRNA coding region contains 90 bases, including one stop codon. Codons = bases/3 = 90/3 = 30. A stop codon does not encode an amino acid, so the peptide contains 29 amino acids under this stated model.

■ Common error

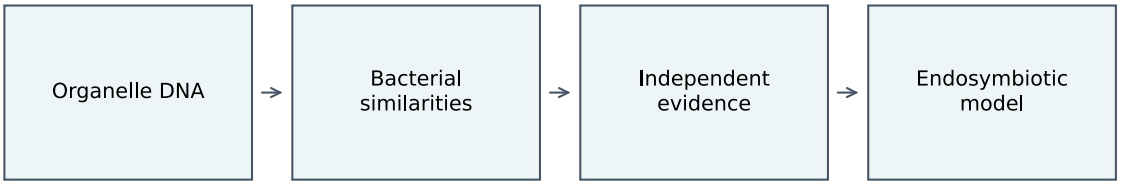
The number of bases is not automatically the number of amino acids. Real genes include regulatory regions and, in eukaryotes, often introns; a whole gene length is not a peptide-length calculation.

Origins of cells: evidence and limits

Official-unit focus: A.2.1 Origins of cells

Mitochondria have their own DNA and divide within cells. These features invite an evolutionary explanation that can be tested against other evidence.

The endosymbiotic model explains mitochondria and chloroplasts as descendants of bacteria living within another cell lineage. Double membranes, ribosomes, DNA and division provide several lines of evidence. This model is distinct from a complete explanation for the origin of the first life.



Independent observations strengthen a model when they make a consistent prediction. Similarity is evidence to evaluate alongside ancestry, sequence comparisons and alternative explanations, rather than proof from one feature.

Use attributed micrographs and sequence data. Separate observations from inferences in a table. Check whether each comparison concerns a mitochondrion, chloroplast, bacterial cell or eukaryotic nucleus.

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■ Checked worked case

Known: 18 of 24 compared sequence sites are identical. Identity = 18/24 × 100 = 75%. Identity across this short alignment cannot alone date an evolutionary split or establish that one organism is the direct ancestor of another.

■ Common error

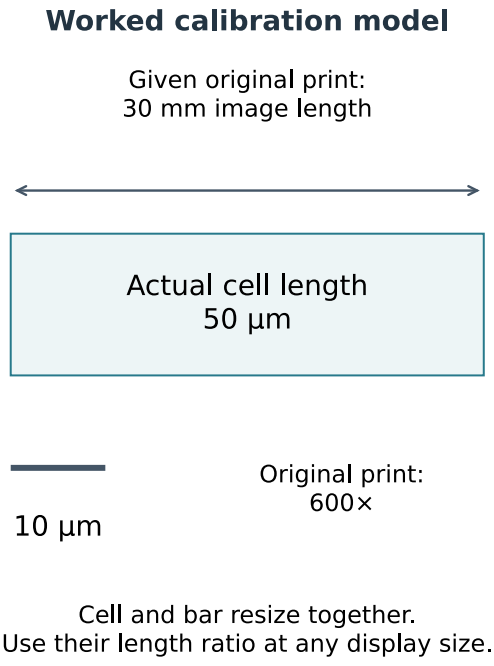
The endosymbiotic model does not say that every organelle arose from an engulfed bacterium. A laboratory model of early chemistry is not a recreation of the whole historical event.

Cell measurements and scale

Official-unit focus: A.2.2 Cell structure; B.2.2 Organelles and compartmentalization

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.



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

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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

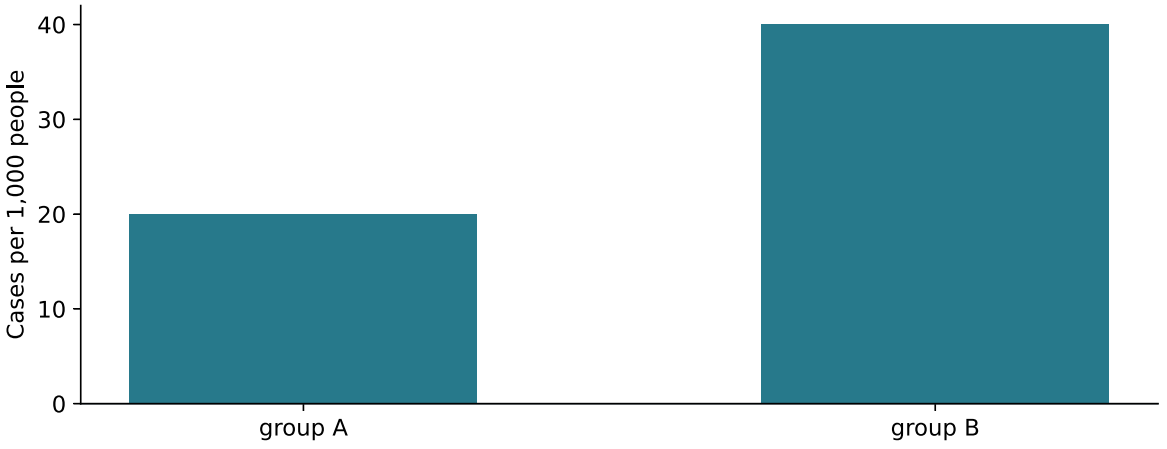
A nucleus is not the only cell structure. Do not claim bacteria have no DNA, or that more magnification always means better resolution.

Disease transmission and immune response

Official-unit focus: A.2.3 Viruses; C.3.2 Defence against disease

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

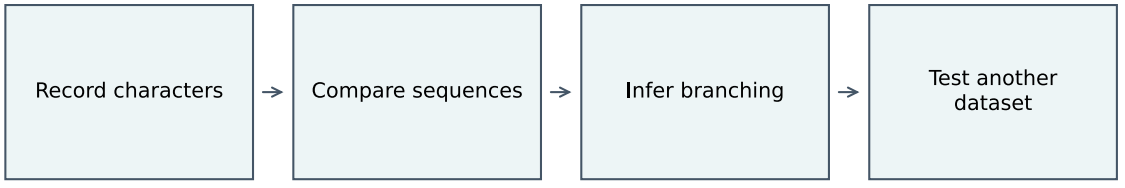
Antibiotics do not act on viruses in the same way they act on bacteria. A vaccine is not an immediate cure for an established infection.

Diversity, classification and a branching model

Official-unit focus: A.3.1 Diversity of organisms; A.3.2 Classification and cladistics

Two species look similar but their DNA comparison places them in different branches. Classification uses several kinds of evidence rather than appearance alone.

A species is a biological grouping; a taxon is a named classification group. A cladogram represents a hypothesis of relationships based on shared derived characteristics or molecular evidence. A branch point represents a common ancestor, not an individual alive today.



Read relationships from the branching order. Rotating branches at a node does not change ancestry. A branch length represents time or change only when the diagram gives a scale.

Record character states in a matrix before drawing a tree. Define which state is ancestral using an appropriate comparison. Test whether a new molecular dataset supports the same grouping.

■ Checked worked case

Known: an alignment contains 40 sites, with 6 differences. Difference proportion = 6/40 = 0.15, or 15%. This is an observed comparison, not a calibrated molecular clock unless rate assumptions and corrections are supplied.

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■ Common error

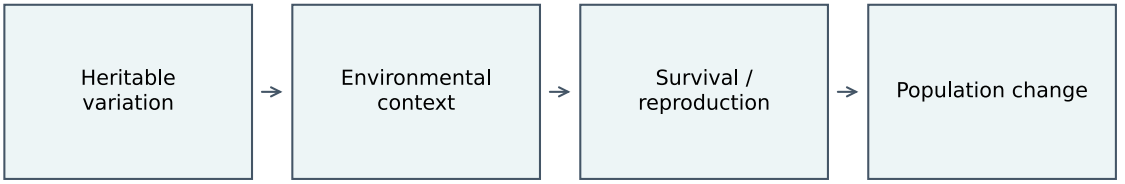
A modern species is not automatically the ancestor of another modern species. Similarity caused by convergent evolution can mislead a classification based on one trait.

Adaptation: a function in an environment

Official-unit focus: A.4.1 Evolution and speciation; B.4.1 Adaptation to environment; D.4.1 Natural selection

Leaves in dry environments often have features that reduce water loss. The value of a feature depends on environmental conditions and trade-offs.

An adaptation is a heritable feature associated with improved survival or reproduction in particular conditions. A thick cuticle can reduce evaporation; stomatal control affects gas exchange and water loss. Acclimatization is an individual response during life and is different from evolutionary adaptation.



Explain both a benefit and a cost. Reducing stomatal opening conserves water but can limit carbon dioxide entry. A feature cannot be judged as universally best without its ecological context.

Compare replicated observations across a measured environmental gradient. Account for relatedness, leaf area and age. Use local permitted plant observations rather than removing protected species.

■ Checked worked case

Known: water loss is 12 g from 0.20 square metres of leaf area over 2 h. Area-time-normalized rate = $12/(0.20 \times 2) = 30$ g/(m^2 h). Comparisons require the same humidity and temperature.

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■ Common error

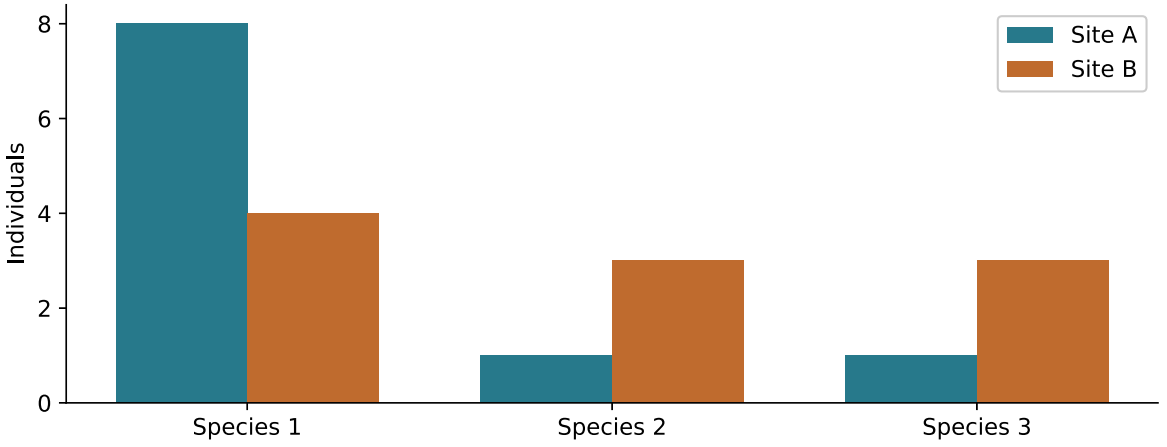
An individual organism does not evolve a new inherited trait because it needs it. A plausible story about function is a hypothesis requiring evidence.

Biodiversity, conservation and sampling evidence

Official-unit focus: A.4.2 Conservation of biodiversity

A site with many individuals can still be dominated by one species. Abundance, richness and evenness describe different features of biodiversity.

Species richness counts species. Evenness concerns relative abundance. Conservation can protect habitats, populations or genetic diversity; a management judgement must state the conservation goal.



Compare surveys with similar area, effort, season and identification rules. A diversity index is meaningful only with its formula and conventions specified. Habitat fragmentation can affect movement and gene flow even when total area changes little.

Use non-destructive field sampling approved by the school. Identify organisms with a suitable key and record uncertain identifications rather than inventing species. Combine ecological evidence with stakeholder perspectives on land use.

■ Checked worked case

Known: site A has counts 8, 1 and 1; site B has 4, 3 and 3. Both have richness 3 and total abundance 10. The most abundant species occupies 80% in A and 40% in B. B is more even under these counts.

■ Common error

An index cannot by itself explain the cause of a difference. A newly recorded species may reflect improved observation rather than a recent ecological arrival.

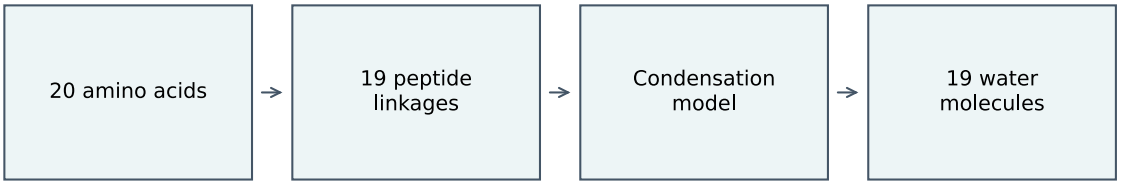
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Biomolecule structure: bonds, polarity and function

Official-unit focus: B.1.1 Carbohydrates and lipids; B.1.2 Proteins

Starch, a triglyceride and a protein can all contain carbon, hydrogen and oxygen, yet their structures and functions differ. An element list alone does not identify a biomolecule.

Carbohydrates include monosaccharides and polymers joined by glycosidic bonds. A triglyceride has glycerol joined to three fatty acids by ester bonds. Proteins contain amino-acid residues joined by peptide bonds; side chains and folding contribute to their properties. These structures support storage, membrane or functional roles depending on the molecule.



Condensation forms a linkage with a small molecule such as water released in the simplified model; hydrolysis uses water to break such a linkage. Polymer sequence, branching, polarity and three-dimensional shape matter. Saturated fatty acids have no carbon-carbon double bond, while unsaturated fatty acids have at least one; this difference can influence packing under stated conditions.

Use labelled molecular models and identify the actual linkage rather than memorizing shapes alone. Compare an attributed structure with the proposed function, mark polar and non-polar regions where justified, and distinguish a monomer from a residue within a polymer. Food tests provide evidence of chemical groups under specific conditions, not complete molecular structures.

■ Checked worked case

Known: a single unbranched peptide formed from 20 amino acids contains 19 peptide linkages. In a simplified condensation accounting model, forming these links releases 19 water molecules. A triglyceride formed from one glycerol and three fatty acids has three ester linkages and releases three waters in the corresponding model. These are linkage counts, not complete pathways in living cells.

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■ Common error

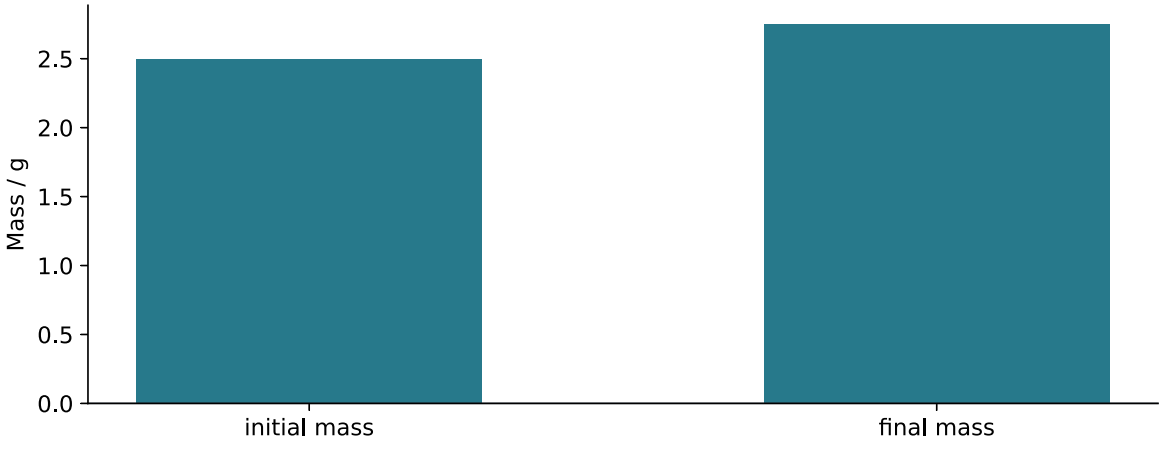
Not every protein is an enzyme, and not every catalyst is a protein. Lipids are not all polymers of repeating monomers. A protein can lose function when its folding changes without every peptide bond being broken.

Osmosis and a fair potato experiment

Official-unit focus: B.2.1 Membranes and membrane transport

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.

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.

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■ Common error

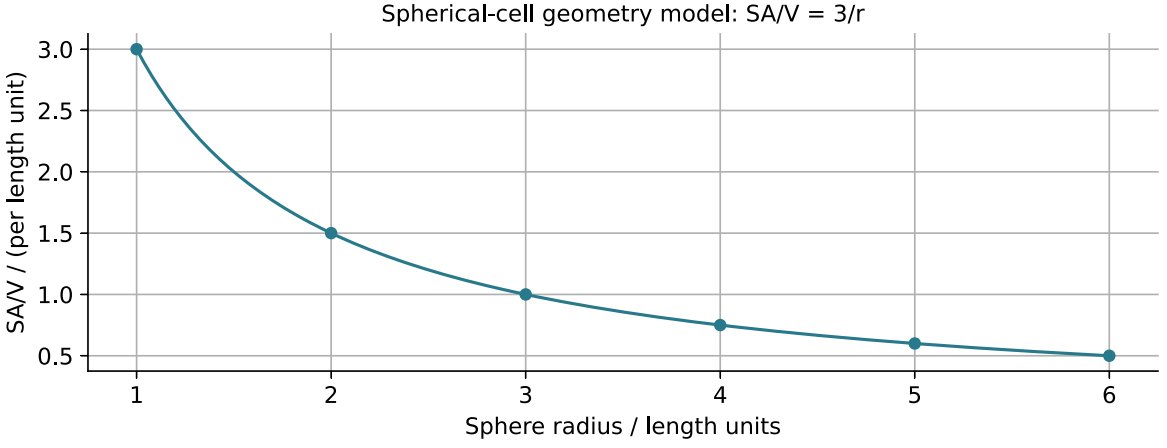
Blotting removes surface solution. Weighing a wet cylinder without blotting adds liquid that did not enter the cells. Repeats reduce random variation but do not correct a miscalibrated balance.

Specialized cells: structure linked to function

Official-unit focus: B.2.3 Cell specialization

A root-hair cell and a red blood cell have different shapes because their functions impose different demands.

Differentiation produces specialized cells through different patterns of gene expression. A root-hair extension increases exchange area. A mammalian red blood cell lacks a nucleus at maturity and contains haemoglobin; this is a specific adaptation, not a rule for all animal cells.



Link a named feature to a mechanism and then to the function. Increased area can support exchange, but membrane proteins, gradients and metabolic demand also matter. Stem cells retain different degrees of developmental potential.

Compare scaled drawings of named cells. Label the structure, state the function and explain the causal link. Use tissue-specific examples rather than saying every specialized cell has every adaptation.

■ Checked worked case

Known: a spherical model cell has radius 2 units. Surface area/volume = 3/r = 1.5 per unit. A radius of 4 gives 0.75 per unit. Doubling radius halves this ratio, even though total area increases.

■ Common error

Specialization does not usually require a cell to lose most of its genes. The spherical calculation models geometry; it does not describe every actual cell shape.

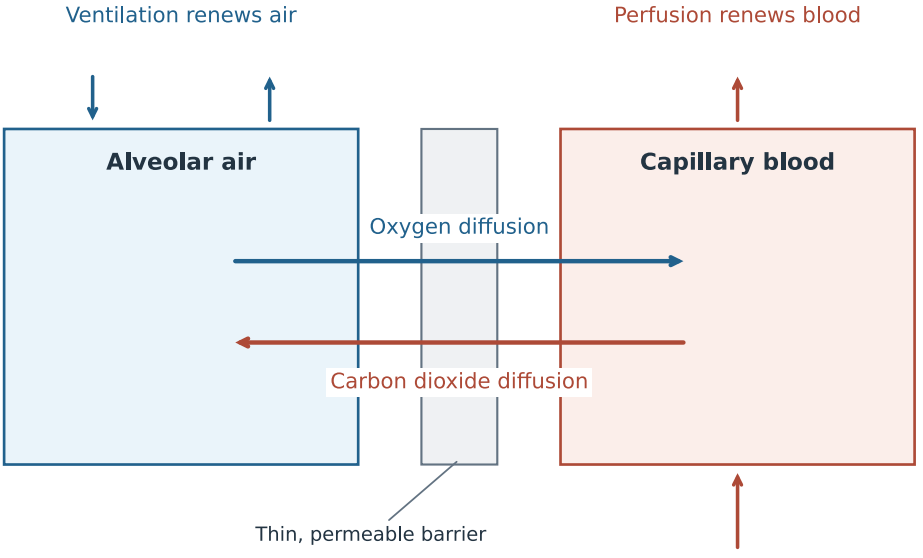
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Gas exchange: maintaining diffusion gradients

Official-unit focus: B.3.1 Gas exchange

An exchange surface can be very thin yet fail to deliver enough oxygen when ventilation or blood flow falls.

Gas exchange occurs by diffusion across a surface. Large area, short diffusion distance and maintained concentration gradients support transfer. Ventilation refreshes the external medium; perfusion carries gases to and from the exchange surface.



Bulk flow renews each side; gases cross by diffusion.
Directions shown for a ventilated mammalian lung with incoming blood.

Distinguish movement of the whole medium from diffusion across the membrane. Ventilation and perfusion work together, while haemoglobin helps transport oxygen in blood. A change in breathing rate alone does not measure oxygen uptake.

Use an approved model or published respiratory data. Compare exchange surface area, diffusion path and flow. For human demonstrations use voluntary resting measurements; do not induce breathlessness or hyperventilation.

■ Checked worked case

Known: tidal volume is 0.50 L and breathing rate is 12 breaths/min. Minute ventilation = $0.50 \times 12 = 6.0$ L/min. This includes dead-space ventilation and is not identical to alveolar ventilation.

■ Common error

Air entering the lungs is not all exchanged with blood. Oxygen and carbon dioxide diffuse in opposite net directions because their own gradients differ.

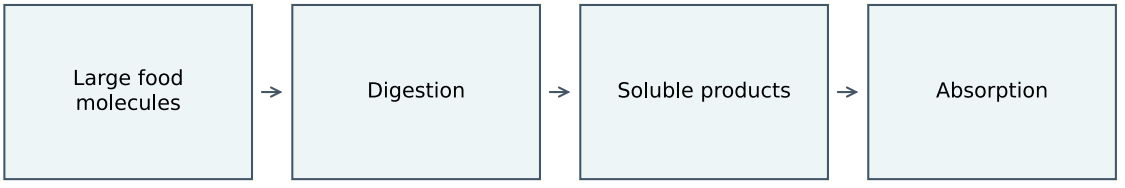
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Digestion, transport and health evidence

Official-unit focus: B.3.2 Transport

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 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.

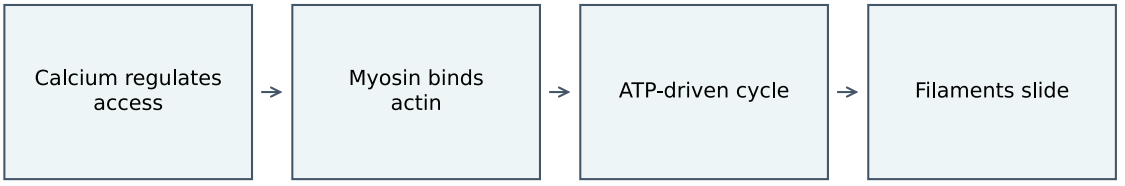
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Muscle contraction: filaments slide

Official-unit focus: B.3.3 Muscle and motility

A sarcomere becomes shorter during contraction although its thick and thin filaments keep approximately the same length.

Actin and myosin interact in a sliding-filament mechanism. Calcium permits the interaction through regulatory proteins; ATP binding and hydrolysis support the cross-bridge cycle. Skeletal muscles pull through tendons and work in coordinated groups.



During shortening, overlap increases. The A-band length stays approximately constant while I bands and the H zone become smaller. Movement at a joint also depends on tendon insertion, lever geometry and opposing muscle activity.

Annotate two sarcomere diagrams at different lengths using the same scale. Track band widths separately from filament length. Use prepared models or existing images, not painful or maximal-exertion tasks.

■ Checked worked case

Known: sarcomere length changes from 2.5 to 2.0 micrometres. Percentage shortening = $(2.5 - 2.0)/2.5 \times 100 = 20\%$. This does not mean either filament shortened by 20%.

■ Common error

ATP is required for myosin detachment as well as the continuing cycle. A muscle pulling harder does not mean all its fibres become shorter under every load.

Ecological niches: resources, conditions and interactions

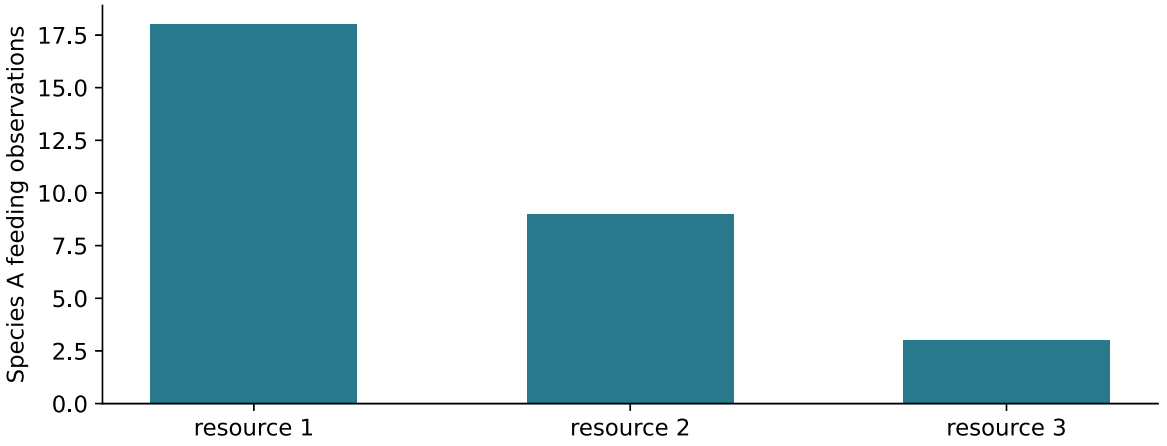
Official-unit focus: B.4.2 Ecological niches

Two species can share a habitat while using different resources or using the same resource at different times. A niche describes more than a location.

An ecological niche includes how an organism uses resources, responds to conditions

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and interacts with other organisms. A fundamental niche describes potential conditions without restrictive biotic interactions in the model; a realized niche describes the conditions occupied when those interactions operate. Competition can restrict resource use or distribution.



Separate a habitat observation from a causal claim about a niche boundary. Absence from a site can reflect dispersal, detection, abiotic conditions or interactions. Resource partitioning can reduce overlap, but an observational difference alone does not prove that competition caused it. Compare alternative explanations and the timescale of evidence.

Use permitted field observations or an attributed dataset. Record species identification confidence, resource category, time, abiotic conditions and sampling effort. Repeat observations at several locations rather than choosing only patches that fit the hypothesis. Non-destructive comparisons or approved models should be used instead of removing native species or introducing competitors.

■ Checked worked case

Known: fictional birds A use resource categories in counts 18, 9 and 3 out of 30 observations; birds B use 3, 9 and 18. Their shared middle category is 30% for each, but the preferred categories differ. This is evidence of different observed resource use. It does not alone establish their full niches or demonstrate the cause of the difference.

■ Common error

A niche is not identical to a trophic level or a habitat. A realized niche is a context-dependent model, and an incomplete survey cannot establish every tolerance limit or competitive interaction.

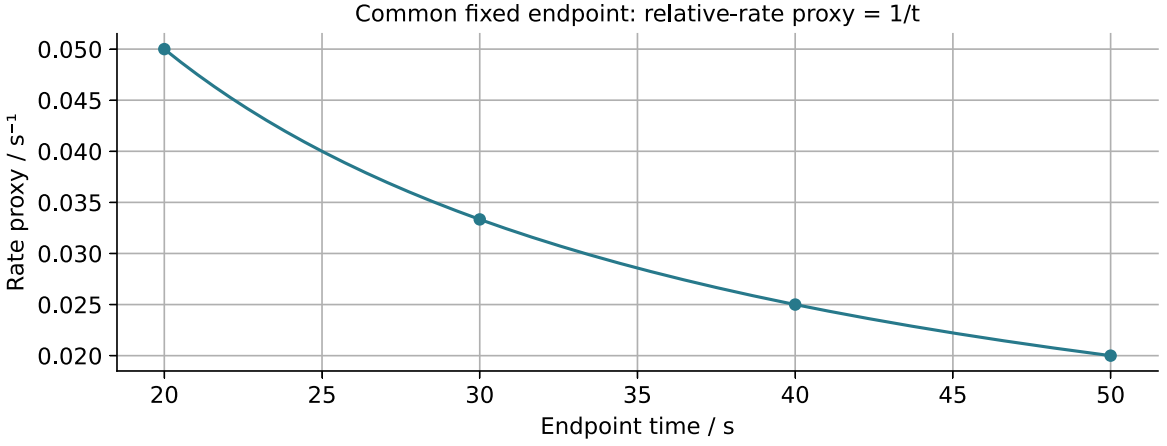
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Enzyme rate and controlled measurements

Official-unit focus: C.1.1 Enzymes and metabolism

An enzyme works quickly at one temperature and slowly at another. Heating can increase successful collisions, but excessive heat can change the active site.

An enzyme is a biological catalyst. The substrate binds at an active site whose shape and chemical properties support the reaction. A catalyst increases rate without being used up overall.



Measure rate using product formed per unit time or a fixed endpoint. For an endpoint test, 1/time is a rate proxy if the same amount of product or substrate change defines the endpoint each time.

For starch digestion, equilibrate enzyme and starch in a water bath, control pH with buffer, mix measured volumes, and test samples with iodine at fixed intervals. Use a clean spot for each test. Do not put iodine into the reaction mixture.

■ Checked worked case

Known: the endpoint is reached in 40 s. Use rate proxy = 1/time. Rate proxy = $1/40 = 0.025$ per second. At 20 s the proxy is 0.050 per second, twice as large. This comparison is valid only if the same endpoint and starting concentrations are used.

■ Common error

An optimum is specific to the enzyme and conditions. Low temperature usually slows the reaction; it does not necessarily denature the enzyme. Endpoint intervals limit precision.

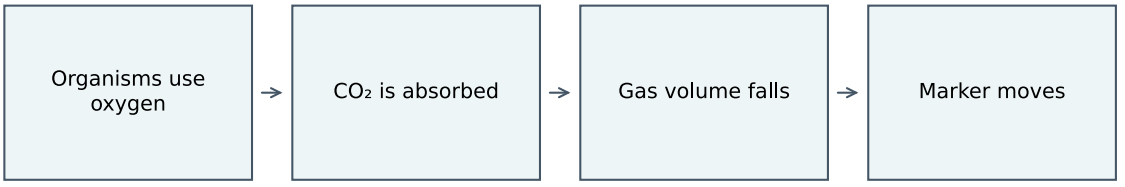
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Respiration, ATP and energy transfers

Official-unit focus: C.1.2 Cell respiration

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

Aerobic respiration uses oxygen and releases carbon dioxide and water from organic substrates. Energy released can support ATP formation. ATP hydrolysis can be coupled to processes such as active transport and muscle contraction.



Anaerobic processes allow ATP production when oxygen supply cannot support the required aerobic rate, but give less ATP per glucose. In humans lactate can accumulate; yeast can produce ethanol and carbon dioxide.

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.

■ Common error

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

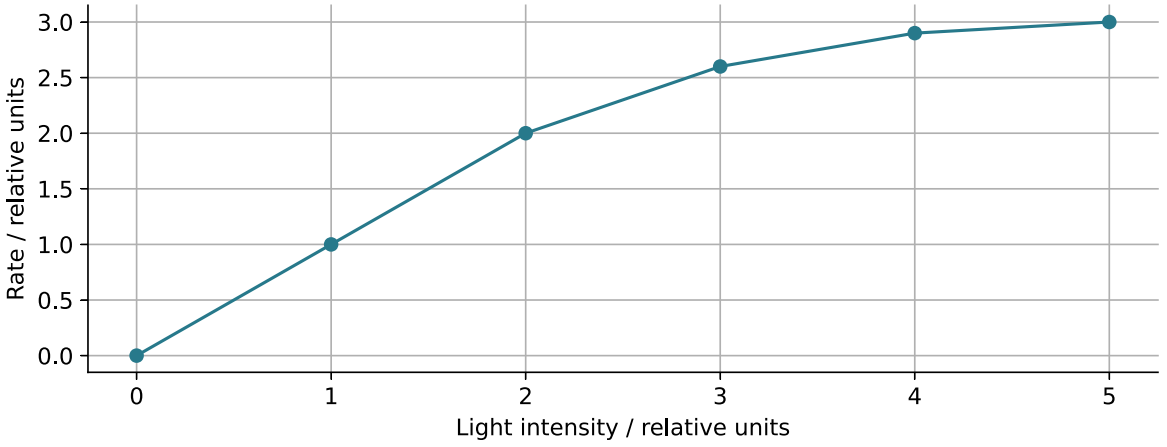
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Photosynthesis and limiting factors

Official-unit focus: C.1.3 Photosynthesis

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.

■ 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.

Cell signalling: a receptor selects the response

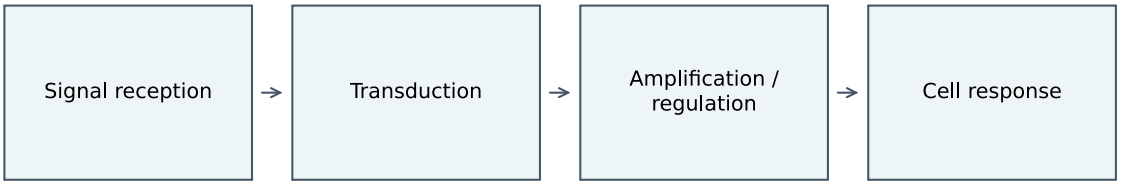
Official-unit focus: C.2.1 Chemical signalling

Two cell types encounter the same signal but respond differently. Their receptors and internal pathways determine what follows.

A signalling molecule binds a compatible receptor. Receptor activation can initiate sig-

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nal transduction through intracellular molecules. The resulting response may change enzyme activity, transport or gene expression. A signal need not enter the cell to cause an effect.



Distinguish signal reception, transduction and response. Amplification can allow a small extracellular change to produce a larger intracellular effect. Different receptors or pathways can give different responses to one signal.

Use an attributed dataset comparing signal concentration and response. Include an untreated control and, where supplied, receptor-blocking evidence. Do not infer the whole pathway from a concentration-response graph alone.

■ Checked worked case

Known: response increases from 20 to 80 units. Fold change = 80/20 = 4. Percentage increase = (80−20)/20 × 100 = 300%. A fourfold final value is not a 400% increase.

■ Common error

A receptor is not interchangeable with every signalling molecule. Greater signal concentration does not imply unlimited response once the system saturates.

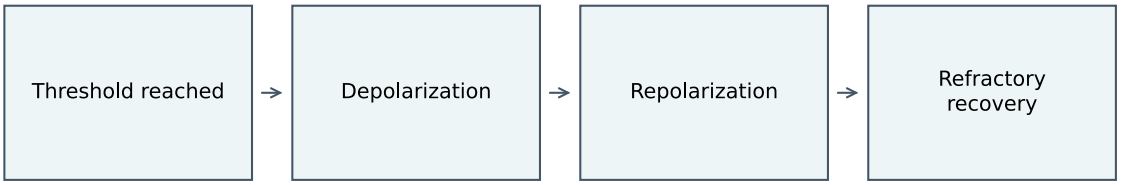
Neural signalling: impulses and synapses

Official-unit focus: C.2.2 Neural signalling

A stronger stimulus can increase impulse frequency while each action potential remains a similar size.

An action potential is a brief change in membrane potential involving voltage-gated ion channels. Depolarization followed by repolarization propagates along a neuron. At a chemical synapse, transmitter release can alter the next cell membrane potential.

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The all-or-none principle applies to an individual action potential. Stimulus information can be encoded by frequency and recruitment. Myelination permits saltatory conduction between nodes rather than making ions move freely through myelin.

Interpret supplied voltage-time traces and compare time intervals. Identify threshold, rising phase and recovery before explaining ions. Use classroom models rather than electrical stimulation of people.

■ Checked worked case

Known: 30 impulses occur in 0.50 s. Frequency = count/time = 30/0.50 = 60 Hz. This is impulse frequency, not an estimate of propagation speed.

■ Common error

A neurotransmitter diffuses across the synaptic cleft; an action potential does not jump intact through the liquid gap. Excitatory input does not guarantee the post-synaptic cell reaches threshold.

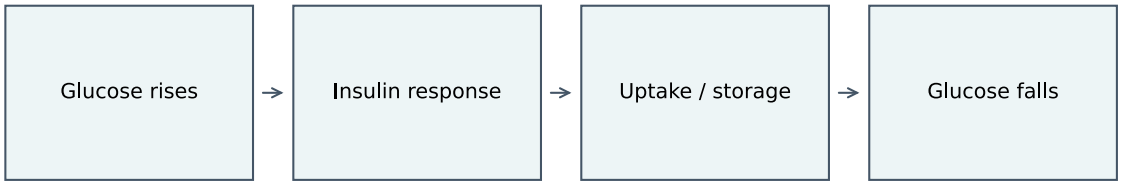
Feedback and internal conditions

Official-unit focus: C.3.1 Integration of body systems; D.3.3 Homeostasis

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.

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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.

■ 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.

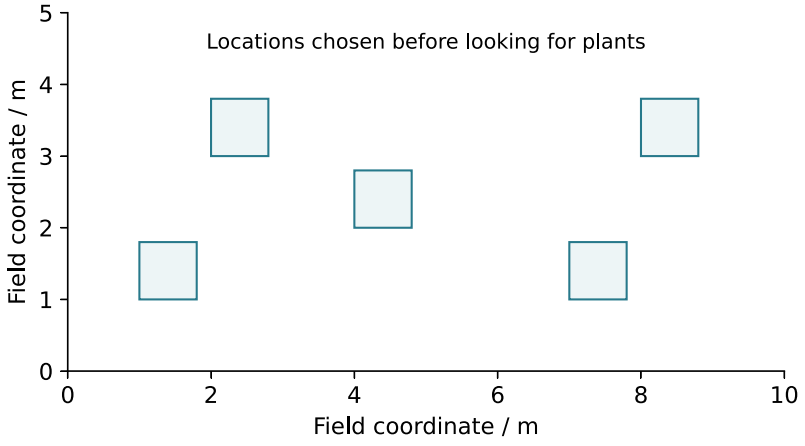
Sampling populations without choosing the answer

Official-unit focus: C.4.1 Populations and communities; D.4.2 Sustainability and change

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.

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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.

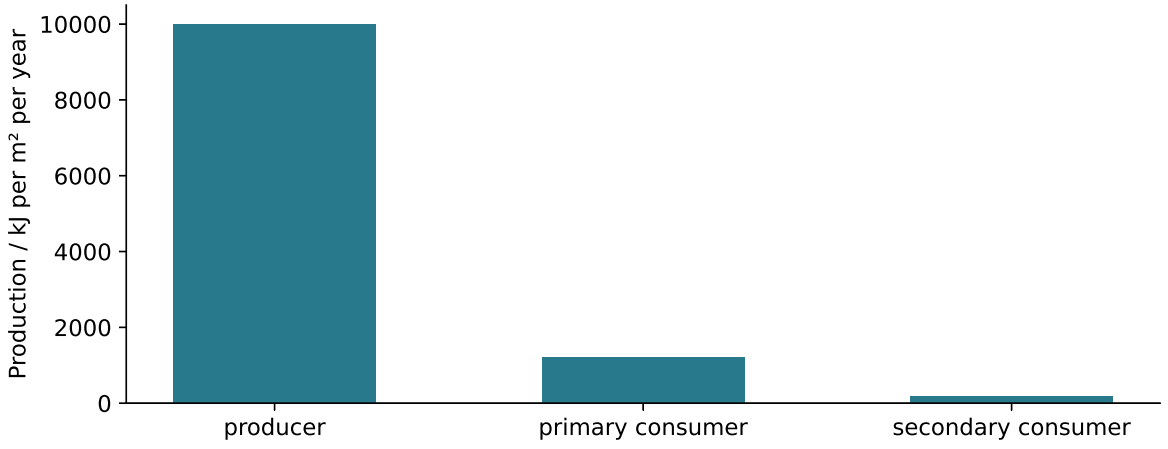
Energy transfer: use production and a stated boundary

Official-unit focus: C.4.2 Transfer of energy and matter

Energy available as new biomass usually decreases along a food chain. Energy is conserved overall, but some transferred energy leaves the next-level production pathway.

Producers convert an energy input into chemical energy in organic material. Consumers obtain material by feeding. Trophic transfer efficiency compares production available at one level with production at the preceding level over a common area and time. Energy can enter detrital pathways, remain in uneaten material, leave in egested waste or be transferred as heat through respiration.

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Use the same energy units and period in numerator and denominator. Distinguish ingestion, assimilation and production: consumed energy is not all assimilated, and assimilated energy is not all stored as new biomass. An energy pyramid records a flow per area per time; a standing biomass snapshot is a different quantity.

Analyse attributed or fictional ecosystem budget data. Draw a boundary and arrows for feeding, detritus and heat transfer. Identify which values are measured and which inferred, and check whether the budget includes decomposers. Avoid treating a fixed 10% rule as a universal measurement for every ecosystem.

■ Checked worked case

Known: producer production is 10,000 kJ/m^2/year and primary-consumer production is 1,200 kJ/m^2/year. Transfer efficiency is 1,200/10,000×100=12%. Secondary-consumer production of 180 kJ/m^2/year gives 180/1,200×100=15% for that step. These different values show why a universal 10% assumption would misrepresent this dataset.

■ Common error

Energy is not destroyed when respiration transfers it as heat. Material can cycle through an ecosystem, while usable energy flow depends on continuing input. A count pyramid or biomass snapshot cannot automatically be substituted into an energy-efficiency calculation.

DNA replication: retain one strand in each daughter molecule

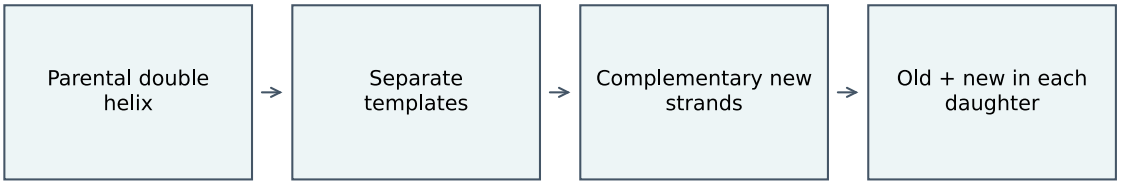
Official-unit focus: D.1.1 DNA replication

After DNA replication, each daughter double helix contains one pre-existing strand and one newly synthesized strand. Copying a molecule is different from expressing its information.

DNA replication is semi-conservative. Complementary base pairing supports copying of the base sequence: adenine pairs with thymine and cytosine with guanine. The

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strands have opposite orientations. Helicase separates paired strands, while DNA polymerase builds new DNA using a template and available nucleotides.



New DNA is synthesized in the 5′ to 3′ direction. In a simplified fork model, one new strand can be synthesized continuously while the other is produced in fragments that are joined. Distinguish these molecular mechanisms from the later separation of chromosomes during cell division. Copying errors can occur despite proofreading and repair.

Use labelled strand models or an attributed experimental diagram. Mark old and new material with both labels and colours so the meaning survives monochrome viewing. Track successive rounds using a stated starting population and assumptions. A classroom model illustrates predictions; it is not direct evidence about enzyme activity or a substitute for experimental results.

■ Checked worked case

Known: one double-stranded molecule contains two labelled original strands. After one complete round in unlabelled nucleotides, two molecules each contain one labelled strand. After two rounds, four molecules exist: two retain one labelled original strand and two contain only unlabelled strands. The fraction containing an original strand is 2/4=50%.

■ Common error

Replication uses DNA as a template to make DNA; transcription uses a DNA template to make RNA. A predicted label distribution assumes complete rounds and no degradation or exchange of the labelled material.

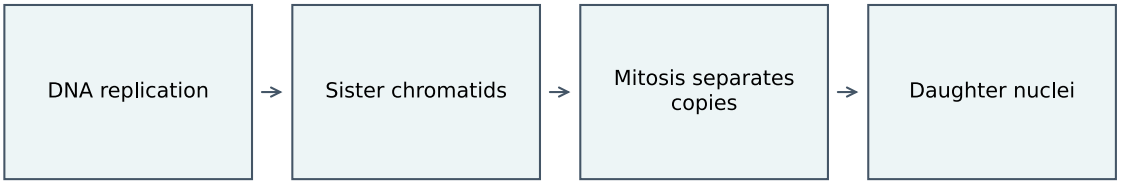
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Cell division: count nuclei and chromosomes carefully

Official-unit focus: D.2.1 Cell and nuclear division

A root-tip image contains cells at different stages of mitosis. A snapshot can estimate the fraction of cells dividing, but it does not time one observed cell directly.

DNA replication occurs before mitosis. Mitosis separates sister chromatids, preserving chromosome number in daughter nuclei. Meiosis includes homologous chromosome separation and normally halves the chromosome number while generating variation.



Count chromosomes by centromeres under the stated convention. DNA amount and chromosome number are different quantities. Crossing over and independent assortment contribute to meiotic variation.

Use a prepared root-tip slide or a labelled image. Define a counting rule and field selection before counting. Distinguish dividing cells from damaged or ambiguous cells and report exclusions.

■ Checked worked case

Known: 25 dividing cells among 200 scored cells. Mitotic index = 25/200 = 0.125, or 12.5%. Estimating phase duration from this proportion requires assumptions about a steady, representative cell population.

■ Common error

Replication doubles DNA amount without immediately doubling the chromosome count. Meiosis does not simply produce two identical diploid cells.

Gene expression: regulate products, not just genes

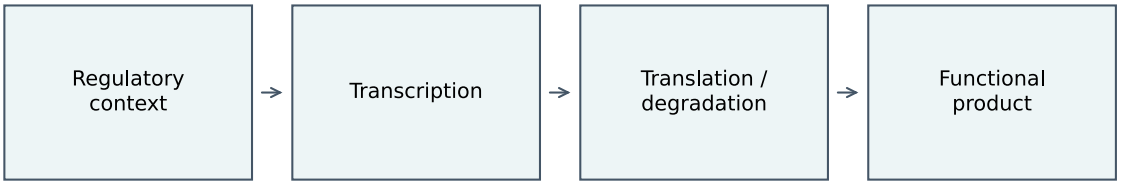
Official-unit focus: D.2.2 Gene expression

Two cells with the same genome make different proteins. Regulation changes which information is used and when.

Gene expression can be regulated at transcription and later stages. A transcription

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factor can affect transcription through interactions with DNA and other proteins. Epigenetic modifications can influence expression without changing the underlying DNA sequence.



Distinguish a measured mRNA change from a protein or functional change. Translation, degradation and protein modification can all intervene. Regulation is specific to a cell context and environmental conditions.

Compare treated and control expression data after checking normalization and replicates. Use evidence from a supplied perturbation to discuss causal models, rather than equating every association with a direct mechanism.

Checked worked case

Known: normalized transcript abundance is 12 in treatment and 3 in control. Fold change = 12/3 = 4. Equal normalized abundance does not require equal absolute cell counts in the two raw samples.

Common error

An epigenetic change is not automatically a DNA-sequence mutation. More mRNA does not guarantee proportionally more active protein.

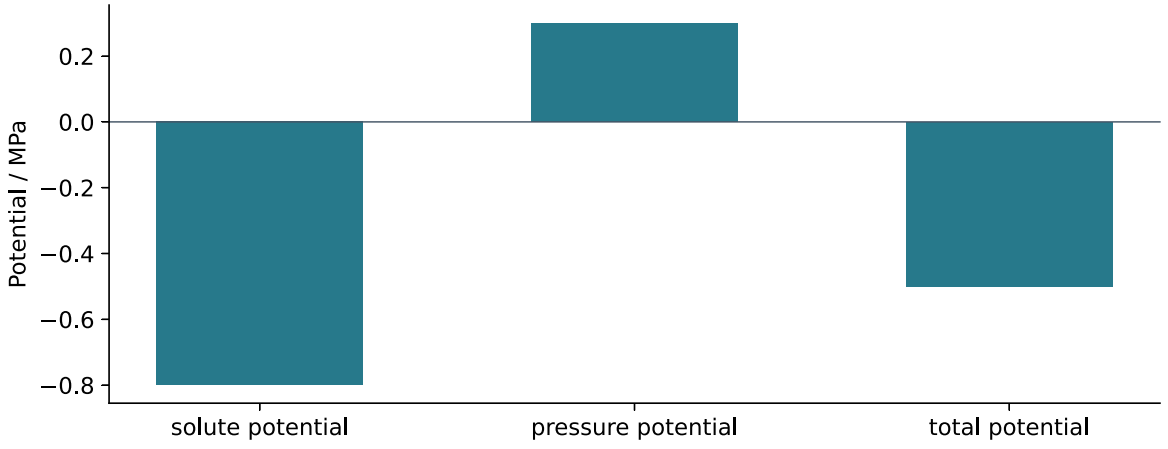
Water potential: include solute and pressure effects

Official-unit focus: D.2.3 Water potential

A plant cell can stop gaining net water even while its contents contain solute. The cell wall permits pressure to build, altering the water-potential balance.

Water potential describes the tendency of water to move relative to a chosen reference, with pressure units. In the simplified cell model, water potential equals solute potential plus pressure potential. Dissolved solute lowers solute potential; positive pressure can raise water potential. Net water movement through a water-permeable membrane is from higher to lower water potential.

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Compare the complete water potentials of the two sides rather than solute concentrations alone. A turgid cell can have the same total water potential as its surroundings despite unequal solute potential. At equilibrium there is no net transfer, but water molecules can continue moving in both directions.

Use provided potential values and labelled plant-cell models. State the reference and units before adding components. For school tissue investigations, control temperature, tissue dimensions, time and blotting, and estimate a zero-change point from repeated measurements. Do not claim the mass method separately measures cell pressure without further evidence.

■ Checked worked case

Known: a cell has solute potential −0.8 MPa and pressure potential +0.3 MPa, so total potential is −0.5 MPa. Surrounding solution is −0.2 MPa. Water tends to enter the cell because −0.2 is higher than −0.5. If the cell components change to −0.8 and +0.6 MPa, its total is −0.2 MPa, matching the surroundings in this simplified model.

■ Common error

More negative is lower, not higher. The additive cell model has stated boundaries and does not require pretending that every real tissue has one uniform value. Loss of turgor and cell-wall support differ from a rigid wall directly controlling solute concentration.

Sexual reproduction: meiosis and fertilization have different roles

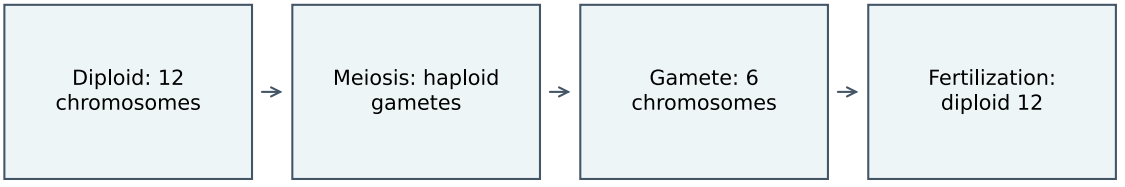
Official-unit focus: D.3.1 Reproduction

Gametes normally contain one set of chromosomes, while fertilization joins two sets. Maintaining chromosome number across generations requires both processes.

Meiosis reduces chromosome number when producing haploid cells from a diploid

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starting cell. Homologous chromosomes separate in meiosis I, while sister chromatids separate in meiosis II. Fertilization combines haploid gamete nuclei to form a diploid zygote. Sexual reproduction can create new combinations of existing alleles.



Distinguish homologous chromosomes from sister chromatids, and chromosome number from DNA quantity. Replication before meiosis copies DNA without doubling the number of chromosome sets. Crossing over and independent assortment contribute to genetic variation, while random fertilization further changes combinations. These processes do not make every offspring genetically distinct under every conceivable condition.

Use a labelled model organism with a stated chromosome number. Track chromosome sets through replication, meiosis I, meiosis II and fertilization. Use anonymous model data rather than personal family or reproductive-health information. Compare organism life cycles carefully; flowering-plant and animal reproductive structures require their own additional teaching.

■ Checked worked case

Known: a model organism has diploid chromosome number 2n=12. A gamete has n=6. After fertilization, the zygote has 12 chromosomes. With six independently assorting chromosome pairs and ignoring crossing over, there are 2^6=64 possible maternal/paternal chromosome combinations in a gamete. This is a model count, not a probability of an individual phenotype.

■ Common error

A gamete is not made by halving the size of an ordinary cell. Independent assortment counts assume distinct homologous alternatives and do not include crossing-over outcomes. Human and plant reproduction cannot be fully replaced by a monohybrid Punnett grid.

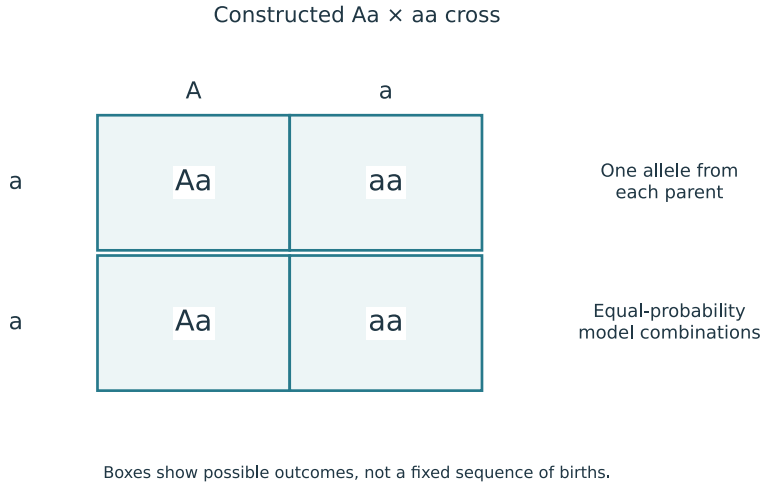
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Inheritance, variation and probability

Official-unit focus: D.3.2 Inheritance

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.



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.

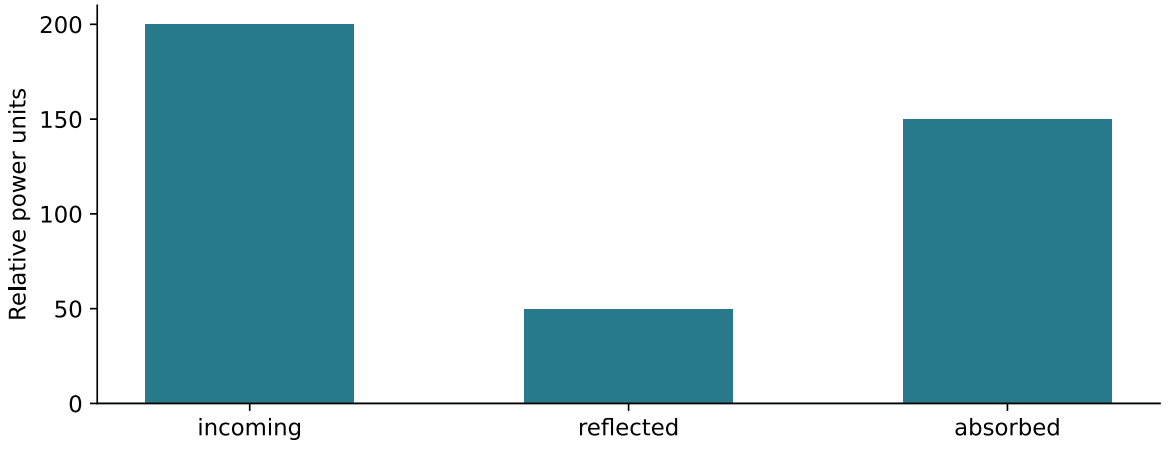
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Climate evidence, energy budgets and policy

Official-unit focus: D.4.3 Climate change

One cold day does not disprove a warming climate. Weather describes short-term conditions; climate describes distributions over longer times and regions.

The Earth energy balance includes incoming solar radiation, reflection, absorption and outgoing infrared radiation. Greenhouse gases absorb and emit infrared radiation. Feedback can alter the response to an initial forcing.



Distinguish mitigation, which addresses drivers, from adaptation, which reduces harm from impacts. A policy assessment needs evidence about effectiveness, cost, equity and uncertainty; one criterion is not the entire decision.

Compare multi-year data using consistent baselines. State the region, timescale and uncertainty. At HL, connect a management decision to law, economics and ethics rather than treating these lenses as extra definitions only.

■ Checked worked case

Known: a surface receives 200 power units and reflects 50. Absorbed input = incoming-reflected = 200-50 = 150. Reflected fraction = 50/200 = 0.25 = 25%. A change in reflectivity alters the absorbed budget under this model.

■ Common error

The greenhouse effect is not the same process as ozone depletion. A carbon footprint estimate depends on its system boundary.

Uncertainty, gradients and model testing

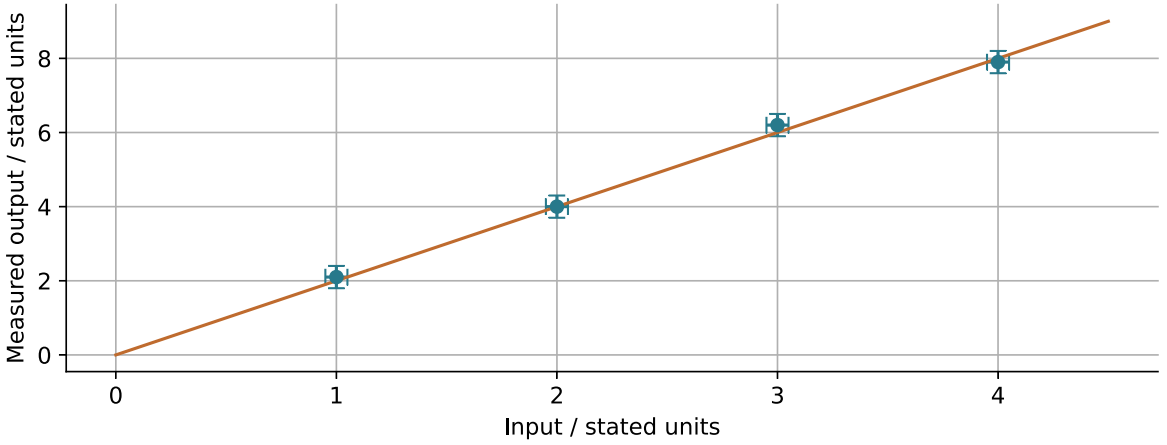
Official-unit focus: Practical Experimental programme

A line passing near every data point is useful, but its gradient can still be uncertain. A graph is evidence for a model within the measurement range.

Random variation makes repeated readings differ. Systematic error shifts results con-

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sistently. Absolute uncertainty has the measured unit; relative or percentage uncertainty compares uncertainty with the measured value.



For a product or quotient, adding fractional uncertainties is a common maximum-uncertainty approximation. For a difference, add absolute uncertainties. A nonzero intercept can reveal an offset or an incomplete model.

Show units on axes and choose a sensible scale. Plot uncertainty bars where justified, draw a best-fit line rather than joining every point, and estimate steepest and shallowest plausible gradients when the course method calls for them.

■ Checked worked case

Known: length = 50.0 mm with uncertainty 1.0 mm. Percentage uncertainty = absolute uncertainty/value $\times 100 = 1.0/50.0 \times 100 = 2.0\%$. For a quotient of two independently measured quantities with maximum percentage uncertainties 2% and 3%, the summed maximum estimate is 5%.

■ Common error

Repeating readings reduces random uncertainty in a mean but does not automatically remove a zero error. Do not quote more decimal places than your measurement can support.

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