

Supported Focus Companion

International Baccalaureate · IB Diploma · Biology · HL

Source-supported focus teaching; remaining qualification requirements are held

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Original teaching and practice · exercises.lol

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Water · supported focus

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

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Water: a molecular cause for a biological property

■ What would explain this observation?

- A water droplet holds together on a leaf. Its behaviour comes from interactions between molecules, not a skin made of solid water.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- 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.
- cohesion: Attraction between molecules of the same substance; adhesion: Attraction between different substances.



■ Choose evidence that can test it

- 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.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- 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.

Example:

Use $c = 4,180$ J/(kg K). Calculate Q for 0.200 kg water heated through 5.0 K. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- Hydrogen bonds between molecules differ from covalent bonds within a water molecule. Polarity alone does not make every substance dissolve well in water.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Boiling water normally breaks its O–H covalent bonds. This claim is false: Hydrogen bonds between molecules differ from covalent bonds within a water molecule. Polarity alone does not make every substance dissolve well in water.

Key:

Water: a molecular cause for a biological property: 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.

Nucleic acids · supported focus

International Baccalaureate · IB Diploma · Biology · HL

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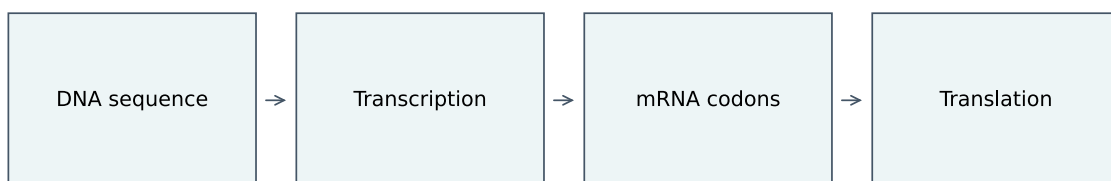
DNA, protein synthesis and evidence

■ What would explain this observation?

- 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.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- 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.
- transcription: Formation of RNA using a DNA template; translation: Formation of a polypeptide using an mRNA sequence.



■ Choose evidence that can test it

- 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 unexplained DNA triplet.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: an mRNA coding region contains 90 bases, including one stop codon. $\text{Codons} = \text{bases}/3 = 90/3 = 30$. A stop codon does not encode an amino acid, so the peptide contains 29 amino acids under this stated model.

Example:

A coding mRNA segment has 63 bases including a stop codon. Find peptide length. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- 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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Each DNA base encodes one complete amino acid. This claim is false: 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.

Key:

DNA, protein synthesis and evidence: 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.

Origins of cells · supported focus

International Baccalaureate · IB Diploma · Biology · HL

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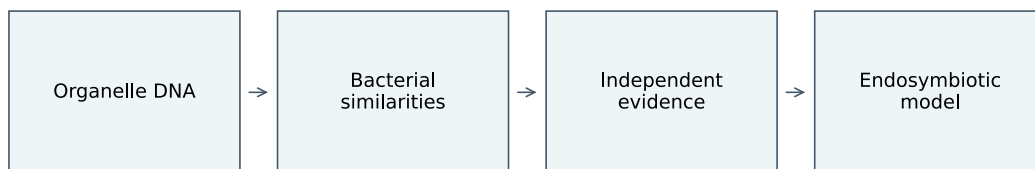
Origins of cells: evidence and limits

■ What would explain this observation?

- Mitochondria have their own DNA and divide within cells. These features invite an evolutionary explanation that can be tested against other evidence.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- 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.
- **endosymbiosis** : One organism living within another in an evolutionary association; **inference** : An explanation drawn from observations and reasoning.



■ Choose evidence that can test it

- 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.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: 18 of 24 compared sequence sites are identical. $\text{Identity} = 18/24 \times 100 = 75\%$. Identity across this short alignment cannot alone date an evolutionary split or establish that one organism is the direct ancestor of another.

Example:

21 of 28 compared sites match. Calculate percentage identity. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- 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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

One matching sequence proves the complete origin of life. This claim is false: 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.

Key:

Origins of cells: evidence and limits: 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.

Cell structure · supported focus

International Baccalaureate · IB Diploma · Biology · HL

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Cell measurements and scale

■ What would explain this observation?

- 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.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- 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.
- **magnification** : Image length divided by actual length; **resolution** : Ability to distinguish two close points.

Measured image length = 30 mm

Real cell length = 50 μm

—————
Scale must be stated

■ Choose evidence that can test it

- 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.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: a cell image is 30 mm long and represents a 50 micrometre cell. Use $\text{magnification} = \text{image size} / \text{actual size}$. Convert 30 mm to 30,000 micrometres. $\text{Magnification} = 30,000 / 50 = 600$. A 10 mm scale bar representing 20 micrometres gives the same ratio of 500 for every object in that image.

Example:

An image is 12 mm long; the cell is 40 micrometres long. Calculate magnification. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- A nucleus is not the only cell structure. Do not claim bacteria have no DNA, or that more magnification always means better resolution.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Every bacterial cell has a membrane-bound nucleus. This claim is false: A nucleus is not the only cell structure. Do not claim bacteria have no DNA, or that more magnification always means better resolution.

Key:

Cell measurements and scale: 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.

Viruses · supported focus

International Baccalaureate · IB Diploma · Biology · HL

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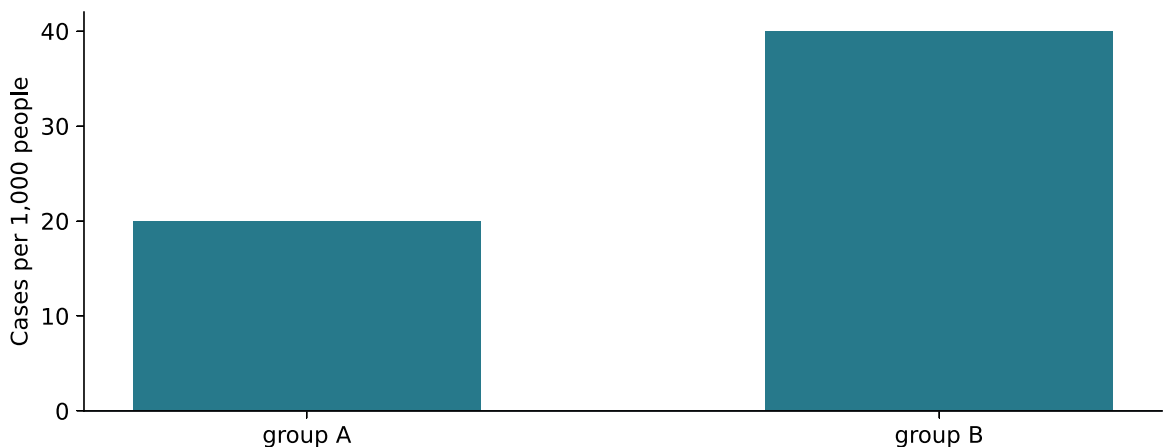
Disease transmission and immune response

■ What would explain this observation?

- 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.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- **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.
- pathogen : An agent that causes disease; antigen: A structure recognized by a specific immune response.



■ Choose evidence that can test it

- 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.

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: 18 cases occur in 900 people. Rate per 1,000 = cases / population $\times$ 1,000. Rate = $18/900 \times 1,000 = 20$ cases per 1,000. A second group with 10 cases in 250 people has 40 per 1,000, even though it has fewer cases.

Example:

12 cases occur among 600 people. Find cases per 1,000 people. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- 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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Every antibiotic is effective against every viral infection. This claim is false: 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.

Key:

Disease transmission and immune response: 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.

Diversity of organisms · supported focus

International Baccalaureate · IB Diploma · Biology · HL

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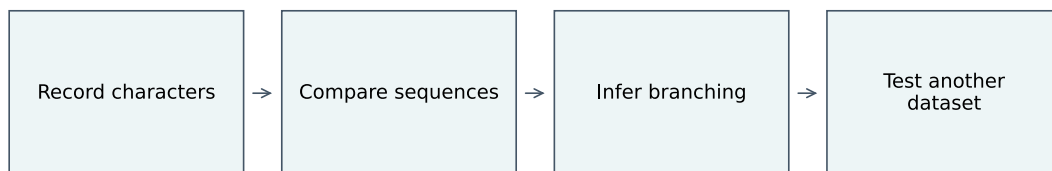
Diversity, classification and a branching model

■ What would explain this observation?

- Two species look similar but their DNA comparison places them in different branches. Classification uses several kinds of evidence rather than appearance alone.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- 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.
- taxon: A named group in a classification; **clade** : A common ancestor and all its descendants.



■ Choose evidence that can test it

- 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.

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- 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.

Example:

There are 8 differences in 50 aligned sites. Calculate percentage difference. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- 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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Every cladogram branch length is a measurement of elapsed time. This claim is false: 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.

Key:

Diversity, classification and a branching model: 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.

Evolution and speciation · supported focus

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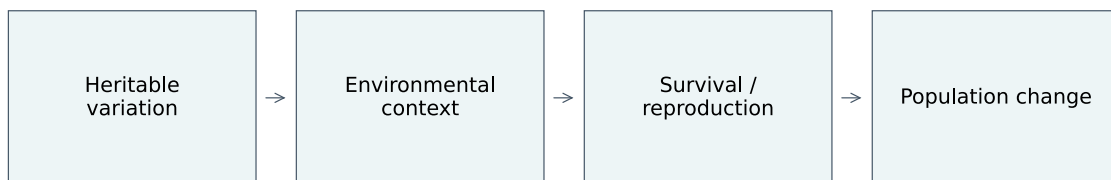
Adaptation : a function in an environment

■ What would explain this observation?

- Leaves in dry environments often have features that reduce water loss. The value of a feature depends on environmental conditions and trade-offs.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- 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.
- adaptation: A heritable feature benefiting survival or reproduction in a context; acclimatization: An individual adjustment to changed conditions during life.



■ Choose evidence that can test it

- 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.

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: water loss is 12 g from 0.20 square metres of leaf area over 2 h. Area-time-normalized rate = $12 / (0.20 \times 2) = 30 \text{ g}/(\text{m}^2 \text{ h})$. Comparisons require the same humidity and temperature.

Example:

Water loss is 8 g from 0.20 m² over 2 h. Calculate rate per area per hour. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- An individual organism does not evolve a new inherited trait because it needs it. A plausible story about function is a hypothesis requiring evidence.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Every useful individual response is evidence of a newly evolved inherited trait. This claim is false: An individual organism does not evolve a new inherited trait because it needs it. A plausible story about function is a hypothesis requiring evidence.

Key:

Adaptation: a function in an environment: 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.

Conservation of biodiversity · supported focus

International Baccalaureate · IB Diploma · Biology · HL

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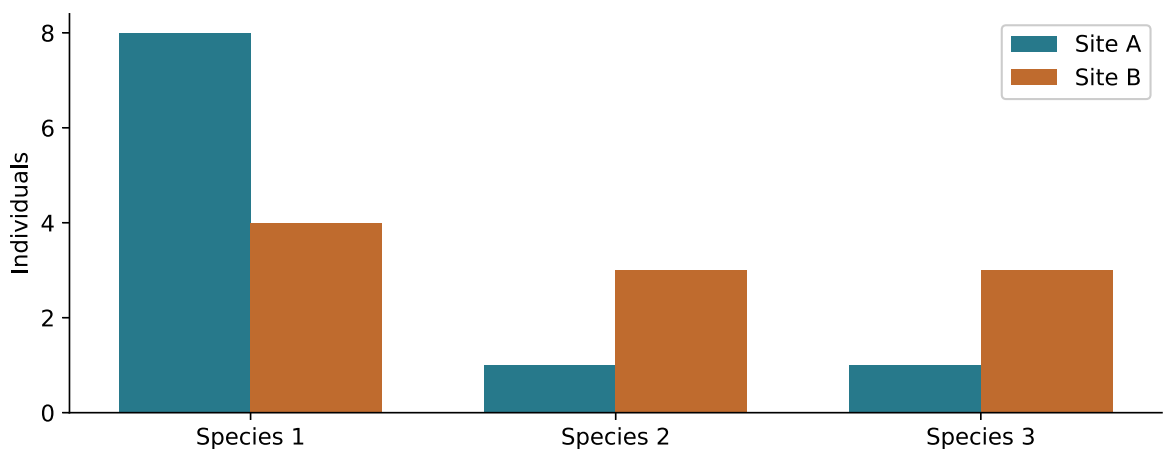
Biodiversity, conservation and sampling evidence

■ What would explain this observation?

- A site with many individuals can still be dominated by one species. Abundance, richness and **evenness** describe different features of biodiversity.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- **Species richness** counts species. Evenness concerns relative abundance. Conservation can protect habitats, populations or genetic diversity; a management judgement must state the conservation goal.
- species richness: The number of species recorded; evenness: How evenly individuals are distributed among species.



■ Choose evidence that can test it

- 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.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- 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.

Example:

A survey records 6, 5, 3 and 2 individuals in four species. Find species richness. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- 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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

A larger total number of individuals always means greater species richness. This claim is false: 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.

Key:

Biodiversity, conservation and sampling evidence: 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.

Carbohydrates and lipids · supported focus

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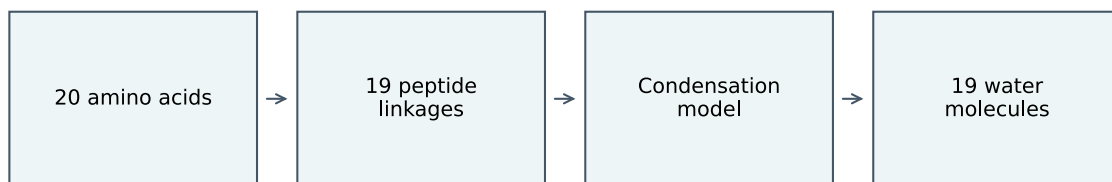
Biomolecule structure: bonds, polarity and function

■ What would explain this observation?

- 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.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- 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.
- peptide bond : A covalent linkage between amino-acid residues; **hydrolysis** : Breaking a linkage using water.



■ Choose evidence that can test it

- 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.

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- 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.

Example:

A single unbranched peptide contains 35 amino-acid residues. How many peptide bonds join them? Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- 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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Every protein is an enzyme and every lipid is a repeating-monomer polymer. This claim is false: 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.

Key:

Biomolecule structure: bonds, polarity and function: 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.

Membranes and membrane transport · supported focus

International Baccalaureate · IB Diploma · Biology · HL

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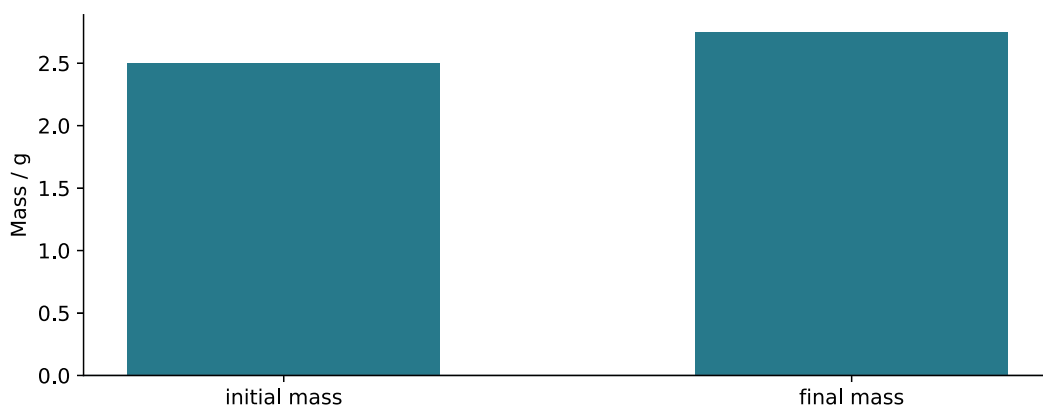
Osmosis and a fair potato experiment

■ What would explain this observation?

- 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.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- **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.
- osmosis: Net water movement through a partially permeable membrane; **control variable** : A factor kept constant for a fair comparison.



■ Choose evidence that can test it

- 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.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: initial mass 2.50 g; final mass 2.75 g. Use percentage change = $(\text{final} - \text{initial}) / \text{initial} \times 100$. Percentage change = $(2.75 - 2.50) / 2.50 \times 100 = +10\%$. A positive value means net water entry. Interpolate the concentration where the plotted trend crosses zero.

Example:

A 4.00 g cylinder ends at 3.60 g. Find percentage mass change. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- 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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

At zero net water movement no water molecules cross the membrane. This claim is false: 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.

Key:

Osmosis and a fair potato experiment: 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.

Cell specialization · supported focus

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

Supported HL focus. First assessment 2025; current subject brief acquired; full Biology guide not acquired. Remaining guide, assessment and practical requirements retain their recorded holds.

Prerequisites: read the stated quantities and units, use arithmetic and the model conditions below. Each lesson develops its own method before independent transfer.

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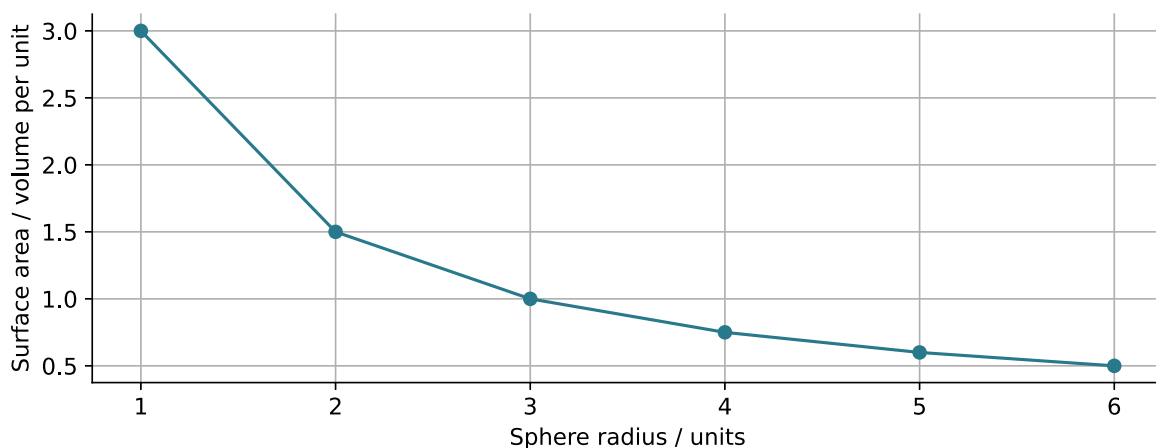
Specialized cells: structure linked to function

■ What would explain this observation?

- A root-hair cell and a red blood cell have different shapes because their functions impose different demands.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- **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.
- differentiation: Development of specialized cell structure and function; gene expression: Use of genetic information to produce a functional product.



■ Choose evidence that can test it

- 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.

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- 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.

Example:

For a sphere, surface area/volume = $3/r$. Find this ratio when $r = 6$ units. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- 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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

All mature animal cells lack a nucleus. This claim is false: 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.

Key:

Specialized cells: structure linked to function: 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.

Gas exchange · supported focus

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

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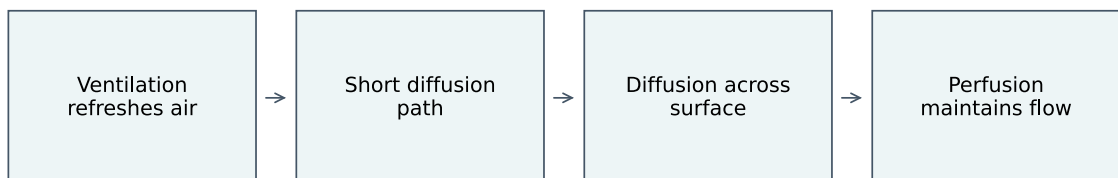
Gas exchange: maintaining diffusion gradients

■ What would explain this observation?

- An exchange surface can be very thin yet fail to deliver enough oxygen when **ventilation** or blood flow falls.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- 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.
- ventilation: Movement of air or water over an exchange surface; perfusion: Blood flow through tissue or an exchange surface.



■ Choose evidence that can test it

- 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.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- 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.

Example:

Tidal volume is 0.60 L and breathing rate is 10 breaths/min. Find minute ventilation. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- Air entering the lungs is not all exchanged with blood. Oxygen and carbon dioxide diffuse in opposite net directions because their own gradients differ.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Minute ventilation directly equals oxygen uptake. This claim is false: Air entering the lungs is not all exchanged with blood. Oxygen and carbon dioxide diffuse in opposite net directions because their own gradients differ.

Key:

Gas exchange: maintaining diffusion gradients: 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.

Transport · supported focus

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

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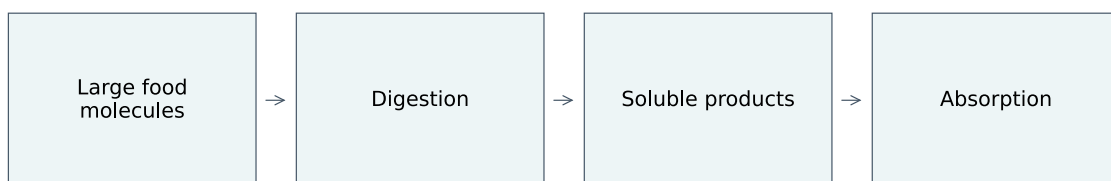
Digestion , transport and health evidence

■ What would explain this observation?

- Two foods can have the same mass but provide different nutrients. A health claim must distinguish the nutrient measured from the health outcome inferred.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- 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.
- **digestion**: Breakdown of large food molecules; **absorption** : Movement of soluble products into the body.



■ Choose evidence that can test it

- 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.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: 6 of 24 study participants report a condition. $\text{Proportion} = \text{cases} / \text{total}$. $\text{Percentage} = 6/24 \times 100 = 25\%$. The percentage describes this sample. It does not establish that one food caused the condition; confounders and how the sample was chosen matter.

Example:

9 of 36 participants report an outcome. Calculate the percentage. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- 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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

A correlation between diet and illness proves causation. This claim is false: 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.

Key:

Digestion, transport and health evidence: 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.

Muscle and motility · supported focus

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

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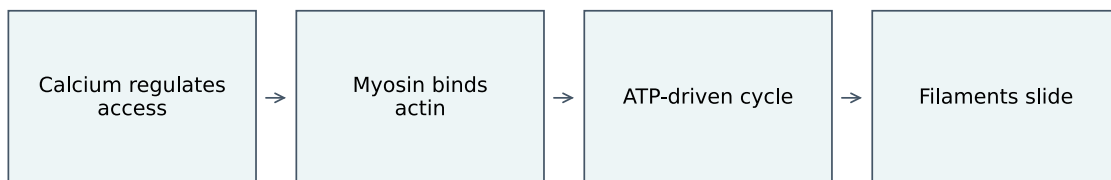
Muscle contraction: filaments slide

■ What would explain this observation?

- A **sarcomere** becomes shorter during contraction although its thick and thin filaments keep approximately the same length.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- 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 co-ordinated groups.
- sarcomere: The repeating contractile unit between two Z lines; cross-bridge: A myosin-actin interaction during the contraction cycle.



■ Choose evidence that can test it

- 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.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- 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%.

Example:

A sarcomere shortens from 3.0 to 2.4 micrometres. Calculate percentage shortening. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- 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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Contracting muscle shortens by shrinking every actin filament. This claim is false: 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.

Key:

Muscle contraction: filaments slide: 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.

Ecological niches · supported focus

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

Supported HL focus. First assessment 2025; current subject brief acquired; full Biology guide not acquired. Remaining guide, assessment and practical requirements retain their recorded holds.

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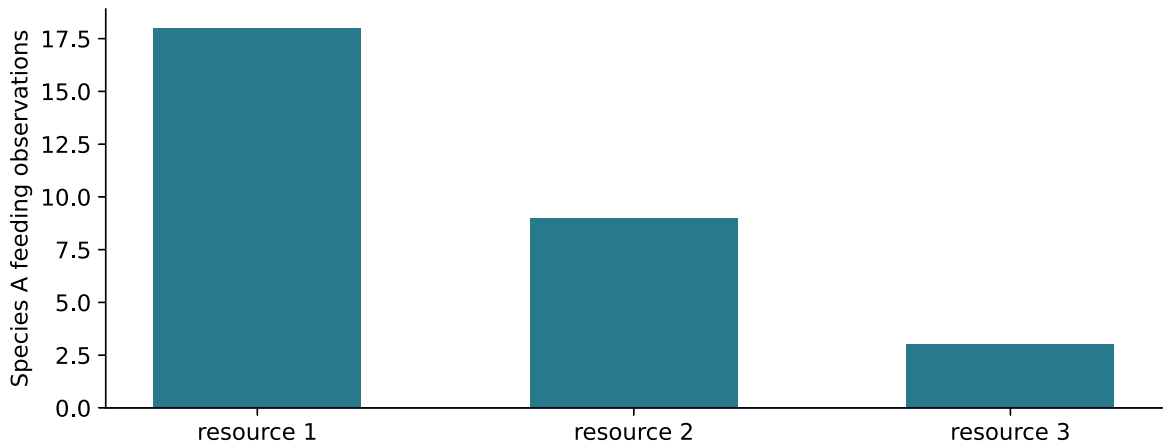
Ecological niches: resources, conditions and interactions

■ What would explain this observation?

- 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.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- An **ecological niche** includes how an organism uses resources, responds to conditions 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.
- ecological niche: The resource use, conditions and interactions associated with an organism's role; **resource partitioning** : Differences in resource use that can reduce overlap among organisms.



■ Choose evidence that can test it

- 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.

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- 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.

Example:

A species uses one resource in 12 of 40 feeding observations. Calculate the observed percentage. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- 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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Two species living in the same habitat necessarily have identical ecological niches. This claim is false: 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.

Key:

Ecological niches: resources, conditions and interactions: 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.

Enzymes and metabolism · supported focus

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

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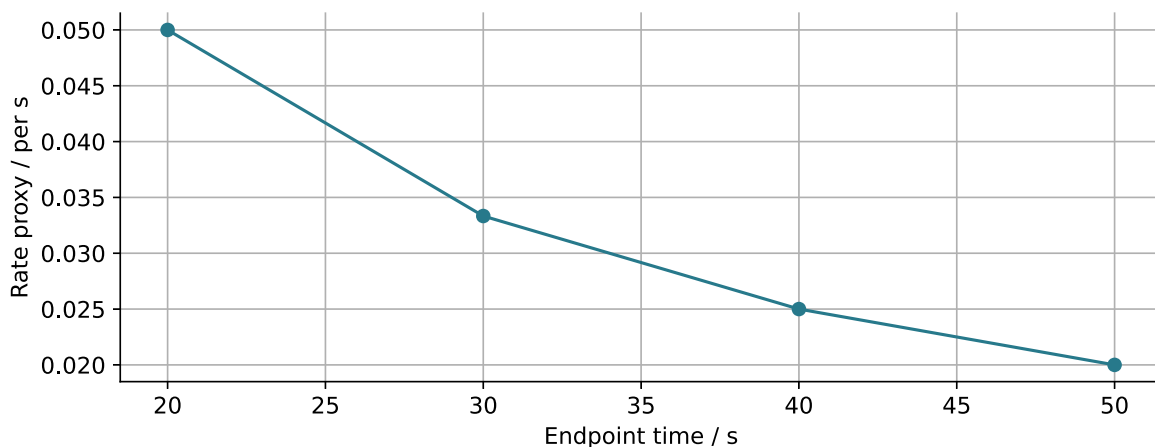
Enzyme rate and controlled measurements

■ What would explain this observation?

- An **enzyme** works quickly at one temperature and slowly at another. Heating can increase successful collisions, but excessive heat can change the active site.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- 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.
- enzyme: A biological catalyst; **denaturation** : A structural change that disrupts function.



■ Choose evidence that can test it

- Measure rate using product formed per unit time or a fixed endpoint. For an endpoint test, $1/\text{time}$ 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.

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: the endpoint is reached in 40 s. Use rate proxy = $1/\text{time}$. 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.

Example:

A fixed endpoint takes 50 s. Calculate the rate proxy $1/\text{time}$. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- 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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

A low temperature always permanently denatures an enzyme. This claim is false: 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.

Key:

Enzyme rate and controlled measurements: Measure rate using product formed per unit time or a fixed endpoint. For an endpoint test, $1/\text{time}$ is a rate proxy if the same amount of product or substrate change defines the endpoint each time.

Cell respiration · supported focus

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

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Respiration, ATP and energy transfers

■ What would explain this observation?

- A muscle can use oxygen while you exercise without producing a flame. **Respiration** transfers energy through a controlled series of reactions.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- 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.
- respiration: Cell reactions that transfer energy from substrates; ATP: A molecule that couples energy transfers in cells.



■ Choose evidence that can test it

- 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.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- 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 = $0.80 / (4.0 \times 2.0) = 0.10$ cubic centimetres per minute per gram. Normalizing allows a fairer comparison of samples of different mass.

Example:

0.60 cubic centimetres are used in 3.0 minutes by 2.0 g of tissue. Find the mass-specific rate. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- Breathing ventilates the lungs; respiration consists of chemical reactions in cells. A moving respirometer marker can also reflect temperature or pressure changes.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Breathing and cellular respiration are the same process. This claim is false: Breathing ventilates the lungs; respiration consists of chemical reactions in cells. A moving respirometer marker can also reflect temperature or pressure changes.

Key:

Respiration, ATP and energy transfers: 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.

Photosynthesis · supported focus

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

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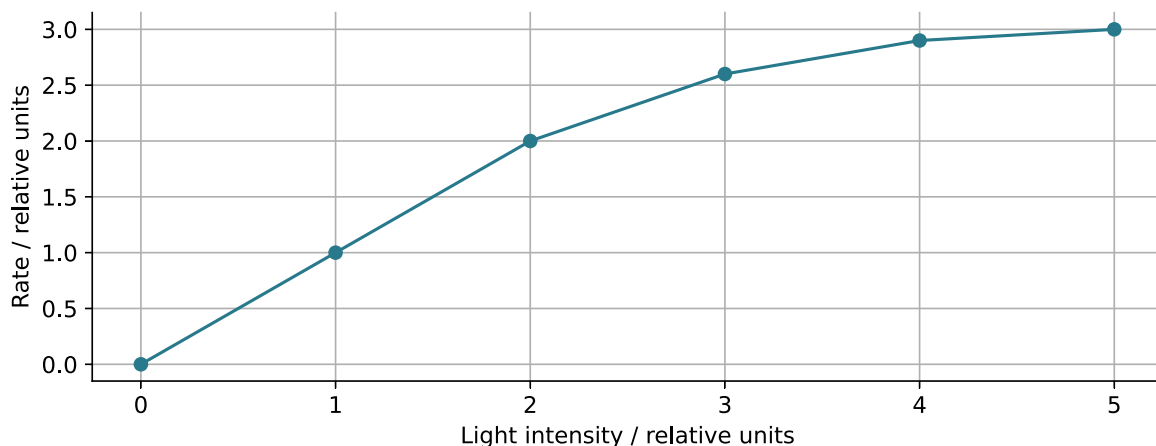
Photosynthesis and limiting factors

■ What would explain this observation?

- A brighter lamp does not always produce more oxygen from pondweed. Another factor may limit the process when light is already sufficient.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- **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.
- **limiting factor** : A factor whose shortage restricts rate; photosynthesis: Light-driven formation of carbohydrate.



■ Choose evidence that can test it

- 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.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: 6.0 cubic centimetres of gas are collected in 3.0 minutes. Use $\text{rate} = \text{volume}/\text{time}$. $\text{Rate} = 6.0/3.0 = 2.0$ cubic centimetres per minute. Bubble counts can be a rough proxy, but bubbles of different size make comparisons less reliable.

Example:

9.0 cubic centimetres of gas are collected in 3.0 minutes. Find the rate. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- Moving a lamp changes light and may also change temperature. A photosynthesis experiment needs control of heating, not just a ruler.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

All oxygen bubbles have exactly the same volume. This claim is false: Moving a lamp changes light and may also change temperature. A photosynthesis experiment needs control of heating, not just a ruler.

Key:

Photosynthesis and limiting factors: 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.

Chemical signalling · supported focus

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

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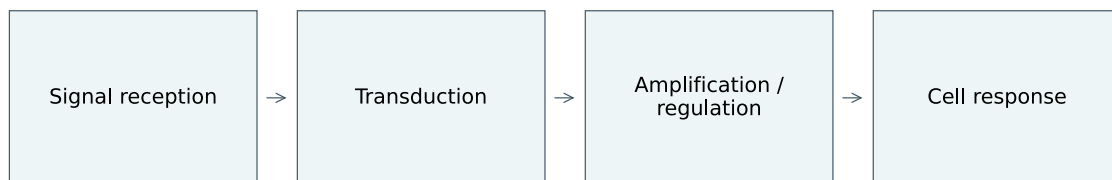
Cell signalling: a receptor selects the response

■ What would explain this observation?

- Two cell types encounter the same signal but respond differently. Their **receptors** and internal pathways determine what follows.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- A signalling molecule binds a compatible receptor. Receptor activation can initiate **signal 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.
- receptor: A molecule that binds a compatible signal; signal transduction: Conversion of signal reception into intracellular changes.



■ Choose evidence that can test it

- 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.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: response increases from 20 to 80 units. Fold change = $80/20 = 4$. Percentage increase = $(80-20)/20 \times 100 = 300\%$. A fourfold final value is not a 400% increase.

Example:

Response rises from 10 to 50 units. Calculate the fold change. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- A receptor is not interchangeable with every signalling molecule. Greater signal concentration does not imply unlimited response once the system saturates.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Fourfold final response means a 400% increase from baseline. This claim is false: A receptor is not interchangeable with every signalling molecule. Greater signal concentration does not imply unlimited response once the system saturates.

Key:

Cell signalling: a receptor selects the response: 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.

Neural signalling · supported focus

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

Supported HL focus. First assessment 2025; current subject brief acquired; full Biology guide not acquired. Remaining guide, assessment and practical requirements retain their recorded holds.

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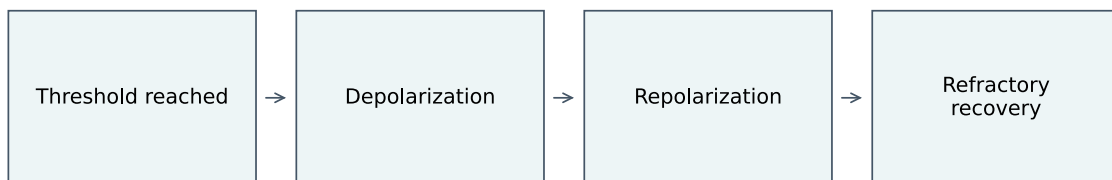
Neural signalling: impulses and synapses

■ What would explain this observation?

- A stronger stimulus can increase impulse frequency while each **action potential** remains a similar size.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- 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.
- action potential: A brief propagating change in membrane potential; synapse: A junction for communication between cells.



■ Choose evidence that can test it

- 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.

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- 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.

Example:

24 impulses occur in 0.40 s. Find impulse frequency. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- 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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

A stronger stimulus always makes each action potential larger. This claim is false: A neurotransmitter diffuses across the synaptic cleft; an action potential does not jump intact through the liquid gap. Excitatory input does not guarantee the postsynaptic cell reaches threshold.

Key:

Neural signalling: impulses and synapses: 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.

Integration of body systems · supported focus

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

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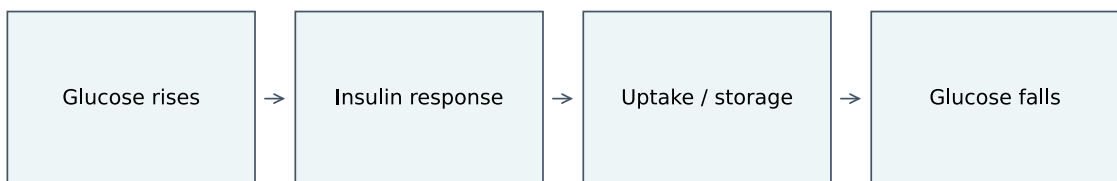
Feedback and internal conditions

■ What would explain this observation?

- Blood glucose rises after a meal, but usually does not keep rising indefinitely. A control system responds to the change in internal conditions.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- **Homeostasis** maintains internal conditions within suitable limits. Receptors detect changes, coordination centres process information, and effectors respond. **Negative feedback** opposes the original change.
- homeostasis: Maintenance of suitable internal conditions; negative feedback: A response opposing the original change.



■ Choose evidence that can test it

- 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.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- 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 = $2.0/5.0 \times 100 = 40\%$. The numerical change is evidence of a disturbance, not a diagnosis on its own.

Example:

A value rises from 4.0 to 5.0. Calculate the percentage increase. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- 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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Negative feedback always makes the measured value negative. This claim is false: 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.

Key:

Feedback and internal conditions: 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.

Populations and communities · supported focus

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

Supported HL focus. First assessment 2025; current subject brief acquired; full Biology guide not acquired. Remaining guide, assessment and practical requirements retain their recorded holds.

Prerequisites: read the stated quantities and units, use arithmetic and the model conditions below. Each lesson develops its own method before independent transfer.

These are original or explicitly fictional teaching examples, not actual measurements or completed assessed learner investigations.

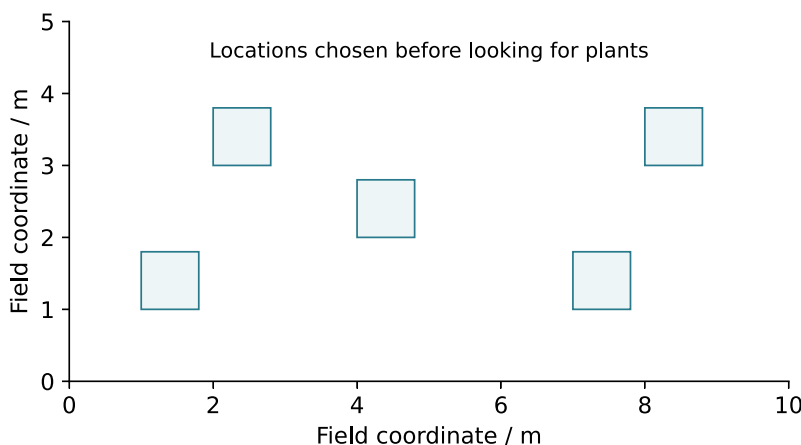
Sampling populations without choosing the answer

■ What would explain this observation?

- A field edge looks richer in plants than its centre. Choosing only the richest patches would build the desired result into the sampling method.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- 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.
- quadrat : A defined area used for sampling; population: Organisms of one species in a defined area.



■ Choose evidence that can test it

- 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.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- 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.

Example:

Mean count is 6 in a 0.5 square metre quadrat. Find density per square metre. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- Quadrats suit organisms that do not move quickly. A food chain arrow shows the direction of energy transfer, not the direction a predator travels.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Sampling only the most crowded patches gives an unbiased population estimate. This claim is false: Quadrats suit organisms that do not move quickly. A food chain arrow shows the direction of energy transfer, not the direction a predator travels.

Key:

Sampling populations without choosing the answer: 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.

Transfer of energy and matter · supported focus

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

Supported HL focus. First assessment 2025; current subject brief acquired; full Biology guide not acquired. Remaining guide, assessment and practical requirements retain their recorded holds.

Prerequisites: read the stated quantities and units, use arithmetic and the model conditions below. Each lesson develops its own method before independent transfer.

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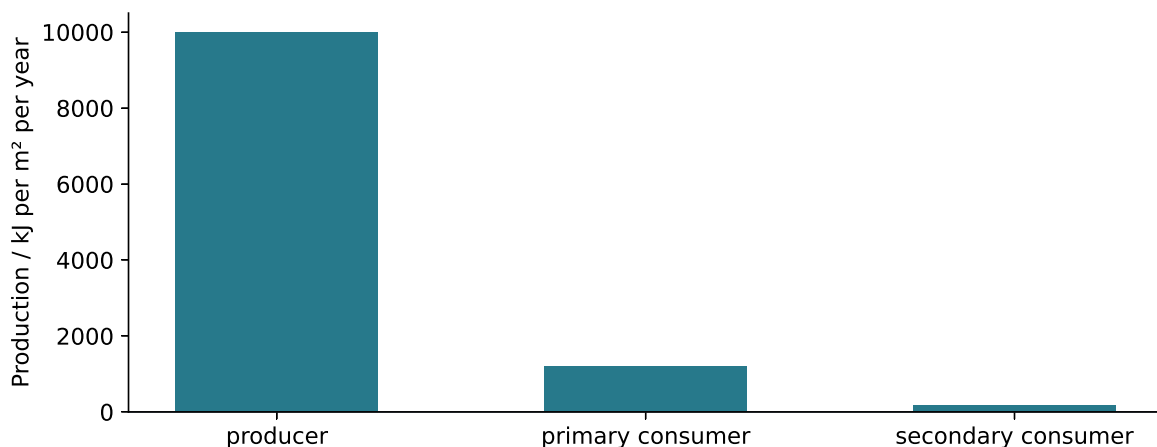
Energy transfer: use production and a stated boundary

■ What would explain this observation?

- 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.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- 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.
- trophic transfer efficiency: Production at one trophic level divided by production at the preceding level over a common interval; **assimilation** : Uptake of digested material into an organism's usable internal pool.



■ Choose evidence that can test it

- 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.

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: producer production is 10,000 kJ/m²/year and primary-consumer production is 1,200 kJ/m²/year. Transfer efficiency is $1,200/10,000 \times 100 = 12\%$. Secondary-consumer production of 180 kJ/m²/year gives $180/1,200 \times 100 = 15\%$ for that step. These different values show why a universal 10% assumption would misrepresent this dataset.

Example:

Producer production is 8,000 and primary-consumer production is 800 kJ/m²/year. Calculate transfer efficiency. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- 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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Respiration destroys energy instead of transferring it to other forms. This claim is false: 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.

Key:

Energy transfer: use production and a stated boundary: 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.

DNA replication · supported focus

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

Supported HL focus. First assessment 2025; current subject brief acquired; full Biology guide not acquired. Remaining guide, assessment and practical requirements retain their recorded holds.

Prerequisites: read the stated quantities and units, use arithmetic and the model conditions below. Each lesson develops its own method before independent transfer.

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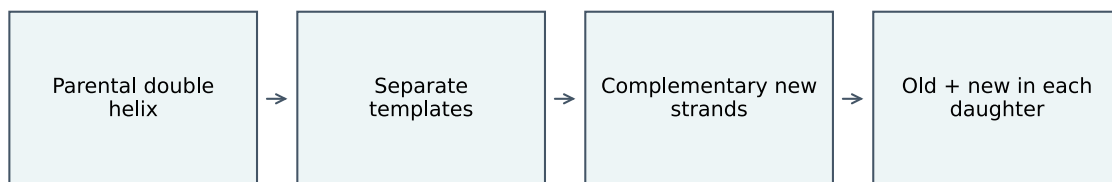
DNA replication: retain one strand in each daughter molecule

■ What would explain this observation?

- 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.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- DNA replication is semi-conservative. Complementary base pairing supports copying of the base sequence: adenine pairs with thymine and cytosine with guanine. The strands have opposite orientations. Helicase separates paired strands, while **DNA polymerase** DNA builds new DNA using a template and available nucleotides.
- **semi-conservative replication** : DNA copying in which each daughter double helix retains one parental strand; **DNA polymerase**: An enzyme that synthesizes DNA using a template.



■ Choose evidence that can test it

- 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.

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- 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 $2/4=50\%$.

Example:

One labelled double helix replicates for three complete rounds in unlabelled nucleotides. What percentage of the eight molecules contain an original strand? Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- 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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

DNA replication and transcription both produce the same type of nucleic-acid product. This claim is false: 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.

Key:

DNA replication: retain one strand in each daughter molecule: 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.

Cell and nuclear division · supported focus

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

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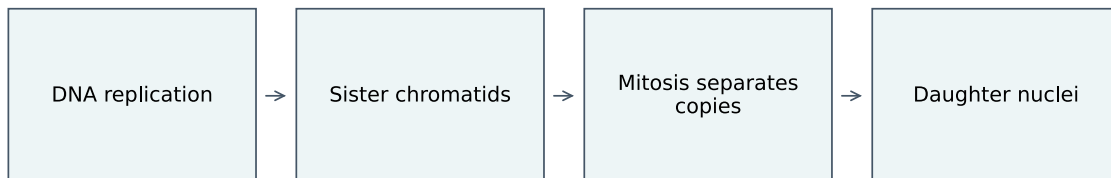
Cell division: count nuclei and chromosomes carefully

■ What would explain this observation?

- 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.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- 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.
- **mitotic index** : Fraction of scored cells undergoing mitosis; chromatid : One copy of a replicated chromosome before separation.



■ Choose evidence that can test it

- 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.

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- 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.

Example:

18 of 120 scored cells are dividing. Calculate mitotic index as a percentage. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- Replication doubles DNA amount without immediately doubling the chromosome count. Meiosis does not simply produce two identical diploid cells.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

DNA replication immediately doubles chromosome number under the centromere convention. This claim is false: Replication doubles DNA amount without immediately doubling the chromosome count. Meiosis does not simply produce two identical diploid cells.

Key:

Cell division: count nuclei and chromosomes carefully: 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.

Gene expression · supported focus

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

Supported HL focus. First assessment 2025; current subject brief acquired; full Biology guide not acquired. Remaining guide, assessment and practical requirements retain their recorded holds.

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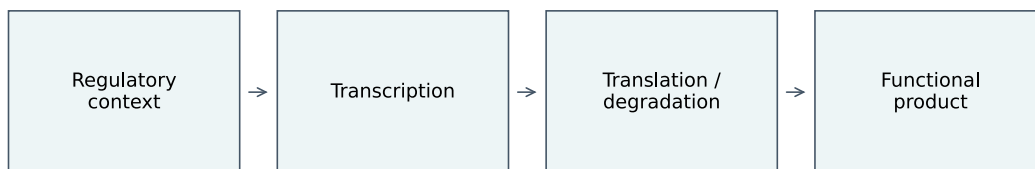
Gene expression: regulate products, not just genes

■ What would explain this observation?

- Two cells with the same genome make different proteins. Regulation changes which information is used and when.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- Gene expression can be regulated at transcription and later stages. A **transcription factor** can affect transcription through interactions with DNA and other proteins. **Epigenetic modifications** can influence expression without changing the underlying DNA sequence.
- transcription factor: A protein that influences transcription; epigenetic modification : A change affecting expression without changing the DNA sequence.



■ Choose evidence that can test it

- 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.

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- 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.

Example:

Transcript abundance is 15 in treatment and 5 in control. Find fold change. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- An epigenetic change is not automatically a DNA-sequence mutation. More mRNA does not guarantee proportionally more active protein.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Every change in gene expression is a mutation. This claim is false: An epigenetic change is not automatically a DNA-sequence mutation. More mRNA does not guarantee proportionally more active protein.

Key:

Gene expression: regulate products, not just genes: 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.

Water potential · supported focus

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

Supported HL focus. First assessment 2025; current subject brief acquired; full Biology guide not acquired. Remaining guide, assessment and practical requirements retain their recorded holds.

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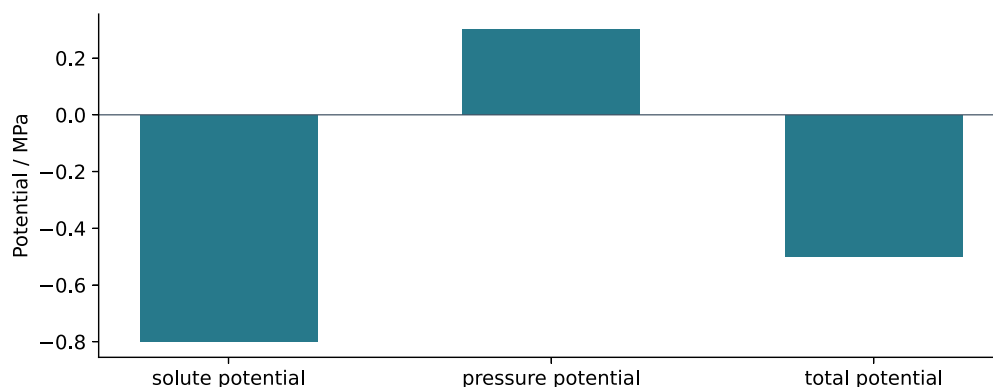
Water potential : include solute and pressure effects

■ What would explain this observation?

- 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.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- 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.
- water potential: A pressure-equivalent measure of the tendency of water to move relative to a reference; pressure potential: The pressure contribution to water potential in the stated model.



■ Choose evidence that can test it

- 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.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- 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.

Example:

Solute potential is -0.7 MPa and pressure potential is $+0.4$ MPa. Find total water potential. Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- 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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Solute concentration alone always determines water movement in a turgid plant cell. This claim is false: 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.

Key:

Water potential: include solute and pressure effects: 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.

Reproduction · supported focus

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

Supported HL focus. First assessment 2025; current subject brief acquired; full Biology guide not acquired. Remaining guide, assessment and practical requirements retain their recorded holds.

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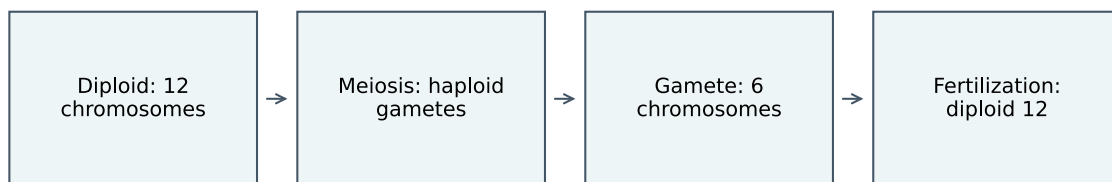
Sexual reproduction: meiosis and fertilization have different roles

■ What would explain this observation?

- Gametes normally contain one set of chromosomes, while **fertilization** joins two sets. Maintaining chromosome number across generations requires both processes.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- Meiosis reduces chromosome number when producing **haploid** cells from a diploid 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.
- haploid: Having one chromosome set in the stated life cycle; fertilization: Fusion of gamete nuclei to form a zygote.



■ Choose evidence that can test it

- 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.

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- 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.

Example:

A model organism has diploid chromosome number 20. How many chromosomes are normally in a gamete? Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- 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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

DNA replication alone changes a diploid cell into a tetraploid cell. This claim is false: 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.

Key:

Sexual reproduction: meiosis and fertilization have different roles: 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.

Inheritance · supported focus

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

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Inheritance, variation and probability

■ What would explain this observation?

- Two parents can carry a recessive **allele** without expressing the associated phenotype. Their children do not have to match the parents phenotypically.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- 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.
- allele: A variant of a gene; genotype: The alleles an organism carries.

Constructed Aa × aa cross

	A	a	
a	Aa	aa	One allele from each parent
a	Aa	aa	

Equal-probability model combinations

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

■ Choose evidence that can test it

- In a simple monohybrid cross $Aa \times Aa$, 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.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: $Aa \times Aa$ 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.

Example:

In $Aa \times aa$, what percentage of offspring are predicted to be aa? Use the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation.

■ Check the conclusion and its limits

- 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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

A dominant allele must be the most common allele in a population. This claim is false: 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.

Key:

Inheritance, variation and probability: In a simple monohybrid cross $Aa \times Aa$, 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.

Climate change · supported focus

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

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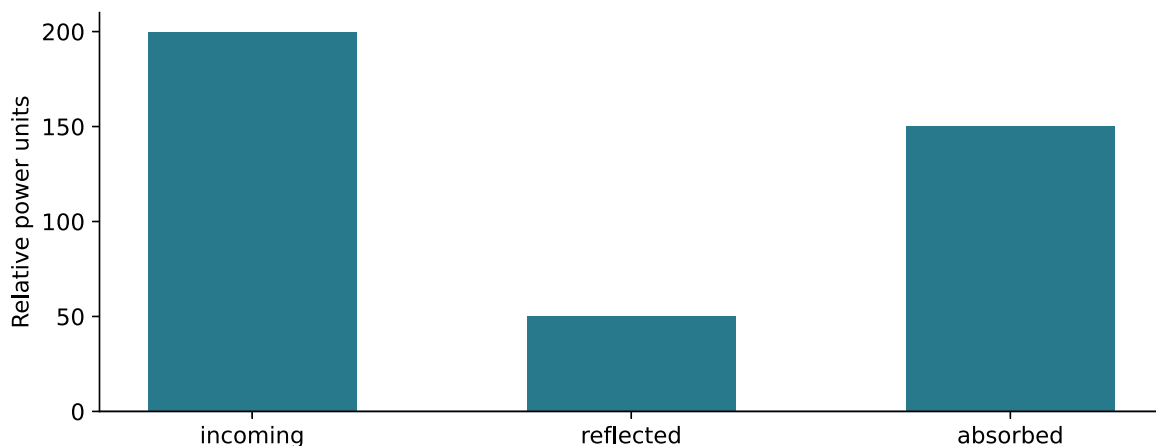
Climate evidence, energy budgets and policy

■ What would explain this observation?

- One cold day does not disprove a warming climate. Weather describes short-term conditions; climate describes distributions over longer times and regions.
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- 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.
- **mitigation** : Actions addressing causes of environmental change; **adaptation** : Actions reducing harm from environmental impacts.



■ Choose evidence that can test it

- 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.
-

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- 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.

Example:

Incoming energy is 240 units and reflected energy 72. Find reflected percentage. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- The greenhouse effect is not the same process as ozone depletion. A carbon footprint estimate depends on its system boundary.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

One local weather observation establishes a global climate trend. This claim is false: The greenhouse effect is not the same process as ozone depletion. A carbon footprint estimate depends on its system boundary.

Key:

Climate evidence, energy budgets and policy: 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.

Experimental programme · supported focus

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

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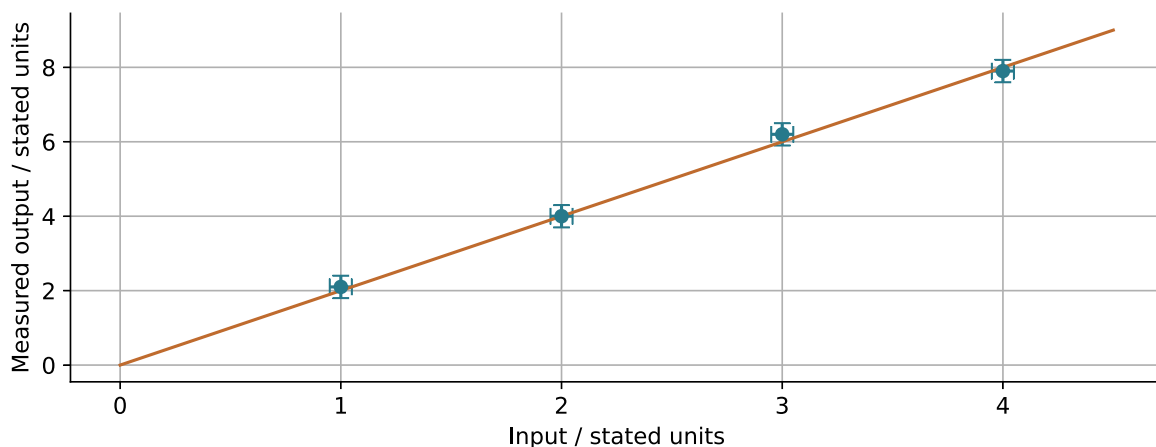
Uncertainty, gradients and model testing

■ What would explain this observation?

- 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.
 - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
-

■ Build the model

- Random variation makes repeated readings differ. **Systematic error** shifts results consistently. Absolute **uncertainty** has the measured unit; relative or percentage uncertainty compares uncertainty with the measured value.
- uncertainty: A quantified limitation on a measured result; systematic error: A consistent measurement bias.



■ Choose evidence that can test it

- 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.

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: length = 50.0 mm with uncertainty 1.0 mm. Percentage uncertainty = $\text{absolute uncertainty}/\text{value} \times 100 = 1.0/50.0 \times 100 = 2.0\%$. For a quotient of two independently measured quantities with maximum percentage uncertainties 2% and 3%, the summed maximum estimate is 5%.

Example:

A 40 cm reading has an absolute uncertainty of 1 cm. Find percentage uncertainty. Use the same sequence: known quantities → model → relation → substitution → unit and interpretation.

■ Check the conclusion and its limits

- 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.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

Repeating a measurement always removes a calibration offset. This claim is false: 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.

Key:

Uncertainty, gradients and model testing: 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.