Student Book 2026

HKDSE Biology: Compulsory

Paper 1 · 2012–2025 · Sample and Practice Papers

Understand the ideas through examples, then apply them to complete examination questions.

Contents

[Reading guide] From understanding to independent answers 4
Guide Using the student and solutions books 4

[Part I] Graphs, calculations and scientific investigations 5
Inquiry From observations to evidence-based conclusions 5

[Part I · I] Cells and molecules 7
Concept I.a Molecules of life 7
Concept I.b Cell organisation and structure 8
Concept I.c Transport across membranes 10
Concept I.d The cell cycle and cell division 13
Concept I.e Enzymes, photosynthesis and respiration 15

[Part I · II] Genetics and evolution 20
Concept II.a Basic genetics 20
Concept II.b Molecular genetics 21
Concept II.c Biodiversity and evolution 24

[Part I · III] Life processes 26
Concept III.a Essential life processes in plants 26
Concept III.b Essential life processes in animals 27
Concept III.c Reproduction, growth and development 31
Concept III.d Coordination and response 33
Concept III.e Homeostasis 39
Concept III.f Ecosystems 40

[Part I · IV] Health and diseases 44
Concept IV.a Personal health 44
Concept IV.b Diseases and prevention 44
Concept IV.c Body defence mechanisms 45

[Part II · I] Cells and molecules: question types and practice 48
I.a Molecules of life 48
Type 1: Explain biological molecules through composition, structure and function (Degree of integration★★★☆☆) 48
I.b Cell organisation and structure 52
Type 1: Use microscopes and identify visible structures (Degree of integration★★☆☆☆) 52
Type 2: Calculate size from scale bars, fields of view and images (Degree of integration★★☆☆☆) 56
Type 3: Interpret membrane structure using evidence (Degree of integration★★★☆☆) 59
Type 4: Relate organelle structure to functions and cooperation (Degree of integration★★★☆☆) 63
I.c Transport across membranes 70
Type 1: Compare diffusion, carrier transport and energy requirements (Degree of integration★★★☆☆) 70
Type 2: Draw supported conclusions from permeability experiments (Degree of integration★★★☆☆) 75
Type 3: Predict cell, liquid-level and mass changes from water potential (Degree of integration★★★☆☆) 80
I.d The cell cycle and cell division 91
Type 1: Interpret the cell cycle, DNA amount and mitosis (Degree of integration★★★☆☆) 91
Type 2: Track chromosomes and variation through meiosis (Degree of integration★★★☆☆) 101
I.e Enzymes, photosynthesis and respiration 108
Type 1: Distinguish synthesis, breakdown and energy conversion (Degree of integration★★☆☆☆) 108
Type 2: Use enzyme models to explain specificity, reuse and inhibition (Degree of integration★★★☆☆) 109
Type 3: Design enzyme controls and interpret reaction curves (Degree of integration★★★☆☆) 115
Type 4: Track substances and energy in chloroplasts (Degree of integration★★★☆☆) 136
Type 5: Investigate photosynthesis using leaves, controls and gas exchange (Degree of integration★★★☆☆) 144
Type 6: Track respiratory pathways, ATP and electron carriers (Degree of integration★★★☆☆) 160
Type 7: Measure respiration with gas tests and respirometers (Degree of integration★★☆☆☆) 167

[Part II · II] Genetics and evolution: question types and practice 172
II.a Basic genetics 172
Type 1: Distinguish heredity and environment using twin and population data (Degree of integration★★★★☆) 172
Type 2: Infer genotypes from offspring ratios (Degree of integration★★★☆☆) 178
Type 3: Infer genetic risk from pedigrees and breeding data (Degree of integration★★★★☆) 188
Type 4: Interpret karyotypes and the scale of genetic changes (Degree of integration★★★☆☆) 198
II.b Molecular genetics 201
Type 1: Calculate base proportions using DNA structure and pairing (Degree of integration★★☆☆☆) 201
Type 2: Track protein synthesis through DNA, mRNA and tRNA (Degree of integration★★★☆☆) 204
Type 3: Connect DNA differences with proteins, traits and relationships (Degree of integration★★★☆☆) 211
II.c Biodiversity and evolution 219

Type 1: Classify organisms and use dichotomous keys (Degree of integration★★★☆☆) 219
Type 2: Infer relationships from molecules, fossils and branching points (Degree of integration★★★☆☆) 230
Type 3: Explain evolution through variation, reproduction and isolation (Degree of integration★★★☆☆) 239

[Part II · III] Life processes: question types and practice 250
III.a Essential life processes in plants 250
Type 1: Explain plant transport and support from root, stem and vascular structures (Degree of integration★★★☆☆) 250
Type 2: Investigate plant nutrition using cultures, tracers and growth data (Degree of integration★★★☆☆) 262
Type 3: Explain plant water loss using potometers and environmental data (Degree of integration★★★☆☆) 269
III.b Essential life processes in animals 284
Type 1: Calculate energy balance from nutrient composition (Degree of integration★★☆☆☆) 284
Type 2: Explain physical digestion using dentition and mouth structure (Degree of integration★★☆☆☆) 287
Type 3: Match digestive juices, organs and chemical digestion (Degree of integration★★★☆☆) 290
Type 4: Track nutrient absorption using adaptations of the small intestine (Degree of integration★★☆☆☆) 297
Type 5: Connect blood vessels, tissue fluid and lymph in exchange pathways (Degree of integration★★★★☆) 302
Type 6: Explain ventilation and gas exchange through pressure and surfaces (Degree of integration★★★★☆) 309
Type 7: Track blood, substances and pressure through circulation (Degree of integration★★★☆☆) 319
III.c Reproduction, growth and development 329
Type 1: Follow pollination and fertilisation from flower to fruit (Degree of integration★★☆☆☆) 329
Type 2: Compare genetic outcomes of sexual and vegetative reproduction (Degree of integration★★☆☆☆) 338
Type 3: Analyse growth, germination and flowering with measurements and experiments (Degree of integration★★★☆☆) 340
Type 4: Track gametes, fertilisation, embryos and maternal–fetal exchange (Degree of integration★★★☆☆) 347
III.d Coordination and response 358
Type 1: Trace hearing through vibrations and nerve impulses (Degree of integration★★☆☆☆) 359
Type 2: Explain vision through image formation, accommodation and the retina (Degree of integration★★☆☆☆) 362
Type 3: Relate joints, tendons and antagonistic muscles to movement (Degree of integration★★☆☆☆) 371
Type 4: Investigate auxin using barriers, controls and curves (Degree of integration★★★★☆) 378
Type 5: Track information through neurones, synapses and reflex arcs (Degree of integration★★☆☆☆) 391
III.e Homeostasis 403
Type 1: Explain negative feedback using blood-glucose and hormone data (Degree of integration★★★☆☆) 403
III.f Ecosystems 414
Type 1: Track carbon and nitrogen through cycle diagrams (Degree of integration★★★☆☆) 414
Type 2: Analyse energy transfer using food webs and pyramids (Degree of integration★★★☆☆) 428
Type 3: Explain species interactions through benefits, harm and niches (Degree of integration★★★☆☆) 437
Type 4: Study distribution using quadrats and transects (Degree of integration★★★☆☆) 450
Type 5: Explain succession using starting conditions, soil and community data (Degree of integration★★★☆☆) 457

[Part II · IV] Health and disease: question types and practice 466
IV.a Personal health 466
Type 1: Evaluate diet, exercise and health risks using data (Degree of integration★★★☆☆) 466
IV.b Diseases and prevention 472
Type 1: Choose prevention and control measures from transmission routes (Degree of integration★★☆☆☆) 472
Type 2: Connect organ damage, symptoms and disease data (Degree of integration★★★☆☆) 478
IV.c Body defence mechanisms 483
Type 1: Connect barriers, phagocytosis and inflammation in defence (Degree of integration★★★☆☆) 483
Type 2: Explain vaccination and immune memory using antibody curves (Degree of integration★★★☆☆) 489

[References and image credits] Sources of questions, marking references and images 504
Sources Curriculum and questions 504
Image credits Credits for knowledge diagrams and question figures 504

Chapter 1

From understanding to independent answers

Guide Using the student and solutions books

This book introduces ideas through concrete examples and diagrams, then develops recognisable question types through complete worked examples and focused practice. Read the relevant concept pages, follow the first step, reasoning and conclusion of each example, then attempt the practice independently. The student book contains all concepts and worked examples. The solutions book adds answers and explanations for every practice question in the same order.

The compulsory content covers cells and molecules, genetics and evolution, life processes, and health and diseases. The collection contains 753 complete Paper 1 questions from 2012-2025, the Sample Paper and the Practice Paper. Language versions, alternative scans and individual subparts are not counted as additional whole questions. Together, the compulsory and elective books contain 817 questions. Stars indicate the degree of integration of knowledge and reasoning in a whole question; they are not difficulty ratings or frequency statistics published by the HKEAA.

Paper 1A Question 9 in 2013 was excluded from marking in that examination. Its revised published version is retained here, with this distinction stated beside the question and in the explanation.

“Describe” requires the observed or measured change. “Explain” requires the mechanism. “According to the data” limits the conclusion to what the evidence supports. Each question is identified by year, paper and original question number. Marking references state the physical page number in the source document.

Source	Section A	Section B	Whole questions
2012	36	11	47
2013	36	10	46
2014	36	11	47
2015	36	11	47
2016	36	11	47
2017	36	11	47
2018	36	11	47
2019	36	11	47
2020	36	11	47
2021	36	11	47
2022	36	11	47
2023	36	11	47
2024	36	11	47
2025	36	11	47
Sample Paper	36	12	48
Practice Paper	36	12	48

This English edition uses the original English question papers for 2012–2024, the Sample Paper and the Practice Paper. The 2025 questions are English translations of the Chinese papers supplied with this collection; their diagrams, numerical data, subparts and mark allocations are retained.

Chapter 2

Graphs, calculations and scientific investigations

Inquiry From observations to evidence-based conclusions

Key ideas

① Bubbles appear when fresh liver is placed in hydrogen peroxide: this is an observation. A glowing splint relights in the gas: this is another observation. Concluding that the gas is oxygen connects the test result with the fact that oxygen supports combustion, so it is an inference.

② Descriptions and explanations answer different questions. A description states what was seen or measured; an explanation states why it happened. "The cell contents have pulled away from the cell wall" describes a visible change. "Water moved out of the cell down a water potential gradient" explains it. When asked to describe, giving only a cause does not answer the question.

③ The independent variable is the condition deliberately changed. The dependent variable is the measured result. Controlled variables are other conditions kept as similar as possible for a fair comparison. When comparing full-fat and semi-skimmed milk, milk type is the independent variable and indicator colour is the observed result. The milk volume, lipase volume and temperature should be the same in both tubes.

④ A control does not always mean "leave out the enzyme". The comparison must isolate the factor being tested. To test whether hydrogen peroxide is the substrate, compare fresh tissue in hydrogen peroxide with the same fresh tissue in water. To test the effect of heating the enzyme, compare fresh and boiled tissue in the same substrate solution.

⑤ Conclusions must stay within the evidence. Testing four tissues cannot establish the enzyme content of all animals and plants. Different final colours do not, on their own, reveal initial reaction rates. When judging statements about a graph, first identify what was actually measured.

A water absorbent above a leaf increases from 2.40 g to 2.49 g; one below increases from 2.43 g to 2.56 g. They absorb 0.09 g and 0.13 g respectively. Subtract each starting value before comparing changes. Subtracting only the final masses gives 0.07 g, which is not the difference in water loss from the two surfaces.

Check your understanding

1. Seeing a glowing splint relight is an _____ identifying the gas as oxygen is an _____.
2. In the comparison of two types of milk, the independent variable is _____, not the final colour.

Check answers:

1. Observation; inference. 2. Type of milk.

How to recognise the problem For "describe", "explain", "according to the graph", "independent variable" or "control", decide whether the answer requires an observation, mechanism, evidence or experimental design.

Key ideas

① Suppose aquatic plants under two colours of light produce oxygen volumes differing by only 0.01 mL, while the measuring instrument has an uncertainty of about 0.03 mL. The difference is smaller than the uncertainty in an individual measurement. Different numerical readings alone do not establish that light colour affected photosynthesis. Repeat the measurements, compare the spread of results and consider measurement precision.

② If another comparison gives a difference of 1 mL, the same 0.03 mL uncertainty is much smaller relative to that difference. This still does not constitute a formal statistical test. Repeat results, variation between samples and experimental design must also be considered.

③ Evaluate an error by asking whether it could affect this conclusion. When investigating water temperature and a fish's breathing frequency, warming may both increase metabolism and reduce dissolved oxygen. Measuring only temperature and breathing frequency leaves dissolved oxygen as an alternative explanation. Measure or control it to separate the two mechanisms.

④ A biotechnology investigation also begins with a question. For parentage testing with DNA fingerprints, establish which bands must have come from the parents, then explain how restriction digestion, electrophoresis and comparison produce interpretable evidence. PCR and electrophoresis are procedures used to obtain or analyse a sample, not themselves the dependent variable.

Check your understanding

1. Two groups differ by 0.01 mL and the instrument uncertainty is about 0.03 mL. Do the unequal numbers alone establish an effect?
2. A fish breathes faster after the water is warmed. Besides increased metabolism, what possible explanation should be checked?

Check answers:

1. No. The difference is smaller than the measurement uncertainty; consider repeats, variation and measurement error. 2. Dissolved oxygen may have decreased, stimulating faster breathing. Measure or control dissolved oxygen.

Cells and molecules

Chapter 3

Concept I.a Molecules of life

Key ideas

① Cut some bread, place cooking oil on paper and put egg white into hot water: these three foods behave differently. Starch in bread is a carbohydrate, cooking oil contains mainly lipids, and egg white contains mainly protein. Organisms use these substances to store energy, build structures and carry out reactions. To explain a molecule's role, connect its composition with what it does in a cell.

② Carbohydrates can be assembled from smaller sugar molecules. Cells use glucose in respiration. Plants join glucose units into starch for storage; animals mainly store carbohydrate as glycogen. Cellulose also contains glucose units, but their arrangement and linkage differ, making it suitable for plant cell walls. Humans lack enzymes that fully hydrolyse cellulose in the digestive tract. The same basic units can therefore produce different functions and digestibility.

③ Many common fats contain glycerol and fatty acids. They store substantial energy and can provide insulation and protection. Phospholipids have hydrophilic and hydrophobic regions and can form a bilayer in water, providing the structural basis of cell membranes. Energy supply is not the only function of lipids.

④ Proteins consist of amino acids joined in a particular sequence and folded into a particular shape. Amylase, antibodies and haemoglobin are proteins involved in catalysis, defence and oxygen transport respectively. Their amino acid sequences and folded structures are related to their functions. Proteins also form tissues such as muscle; the fact that some proteins are enzymes does not make all proteins enzymes.

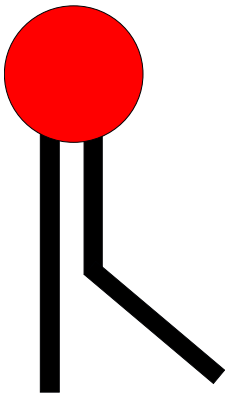
⑤ Nucleic acids include DNA and RNA. Their basic units are nucleotides, each containing a sugar, phosphate group and nitrogenous base. The base sequence stores or conveys genetic information. DNA and proteins are different classes of molecule: a gene can influence protein production without itself being a protein.

⑥ Water is a medium for many cellular reactions and is involved in transport and temperature regulation. Evaporating sweat absorbs heat from the skin. Inorganic ions may be needed in small amounts, but their functions cannot simply be replaced by other substances. Plants need nitrogen-containing ions to make amino acids, proteins, chlorophyll and other nitrogenous compounds; magnesium is also part of chlorophyll. Phosphorus forms part of the phosphate groups in phospholipids and nucleic acids. Nitrogen shortage can limit chlorophyll and membrane protein production; phosphorus shortage can limit membrane phospholipids and nucleic acids. Match each element to the relevant product: not every product contains both nitrogen and phosphorus. Calcium contributes to bones and teeth, while iron is a component of haemoglobin.

⑦ Food tests provide chemical evidence for particular classes of substance. Iodine solution turns blue-black with starch. Heating a sample with Benedict's solution in a hot water bath can give green, yellow, orange or brick-red colours or precipitates when reducing sugars are present. The biuret test gives purple with protein. Lipids can be identified by a persistent translucent grease spot. Know the reagent, required treatment and positive result before interpreting a test. Failure to turn blue-black does not mean that a sample contains no nutrients.

Food tests: check both the treatment and the positive evidence

Substance	Reagent or treatment	Positive result
Starch	Iodine solution	Blue-black
Reducing sugar	Benedict's solution; heat in a water bath	Green, yellow, orange or brick-red precipitate
Protein	Biuret reagent	Purple
Lipid	Place on paper; observe after water has dried	Persistent translucent grease spot



A phospholipid: the round head represents the hydrophilic region and the two tails the hydrophobic regions. This is a molecule, not a cell.

Check your understanding

1. The basic units of starch are _____ those of proteins are _____.
2. Iodine tests for _____ Benedict's solution with heating tests for _____.

Check answers:

1. Glucose; amino acids. 2. Starch; reducing sugars.

How to recognise the problem Compare basic units, structure and function. For food tests, connect the reagent and necessary treatment with the observed colour or precipitate.

Concept I.b Cell organisation and structure

Key ideas

① Onion scale epidermis has a layer of cells with relatively regular cell walls. Human cheek epithelial cells have less regular outlines and no cell walls. Both have a cell membrane, cytoplasm and nucleus. Onion scales grow underground, and their epidermal cells usually have no chloroplasts. "Plant cell" does not justify adding chloroplasts to every photograph.

② The cell membrane surrounds the cell contents and controls exchange with the surroundings. Proteins are distributed within a phospholipid bilayer and may transport substances, receive signals or perform other functions. The fluid mosaic model describes a mobile mixture of molecules, not a rigid solid sheet. Selective permeability means that substances differ in how readily they cross; it does not mean that all small molecules pass freely.

③ Chromosomes in the nucleus contain DNA involved in inheritance and the control of cell activities. Rough endoplasmic reticulum has attached ribosomes and is involved in protein production and processing. Ribosomes are sites of protein synthesis. Mitochondria carry out aerobic respiration and produce ATP, a molecule that transfers usable energy in cells. Chloroplasts carry out photosynthesis. The vacuole of a mature plant cell contains cell sap, and its water content affects turgor. The cell wall supports the cell and limits excessive expansion.

④ An antibody-secreting cell makes large amounts of protein, so it may have extensive rough endoplasmic reticulum and needs mitochondria to meet its energy demand. Connect "many antibodies" to protein synthesis and energy requirements, then explain the organelles. A list of organelle names alone does not establish a structure-function relationship.

⑤ Bacteria are prokaryotes. They lack a nucleus enclosed by a nuclear envelope and membrane-bound organelles such as mitochondria and chloroplasts. They still have a cell membrane, DNA and ribosomes and can carry out metabolism. Animal, plant, fungal and protist cells are eukaryotic. Lacking a nucleus does not mean lacking genetic material or being unable to respire.

⑥ Similar cells working together form a tissue. Different tissues cooperate in an organ, and organs form systems. Cardiac muscle, nervous tissue and connective tissue contribute to the heart, which belongs to the circulatory system. Before calculating actual size from a micrograph, express image size and actual size in the same units.

⑦ Magnification = image size ÷ actual size.

⑧ A cell measures 40 mm in a photograph and is actually 80 µm long. Convert the actual length first:

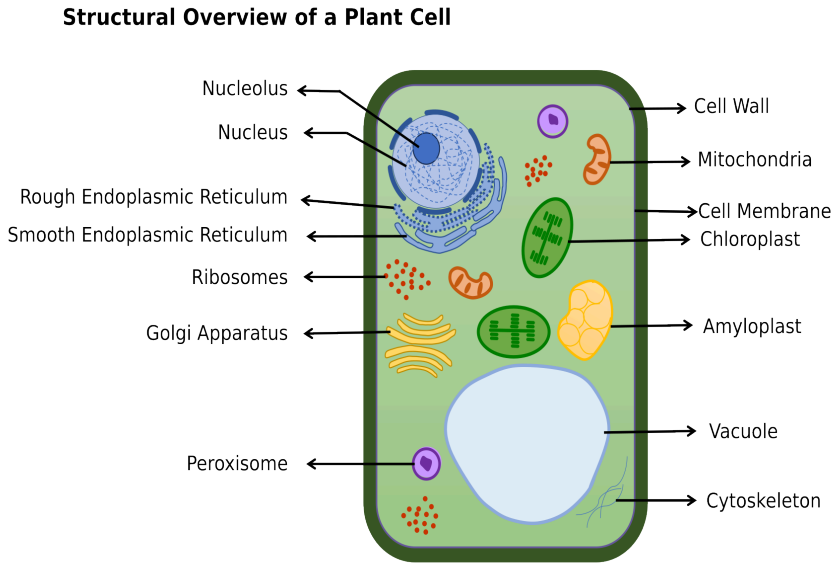
⑨ 80 µm = 80 ÷ 1000 mm = 0.08 mm.

⑩ Magnification = 40 mm ÷ 0.08 mm = 500 times.

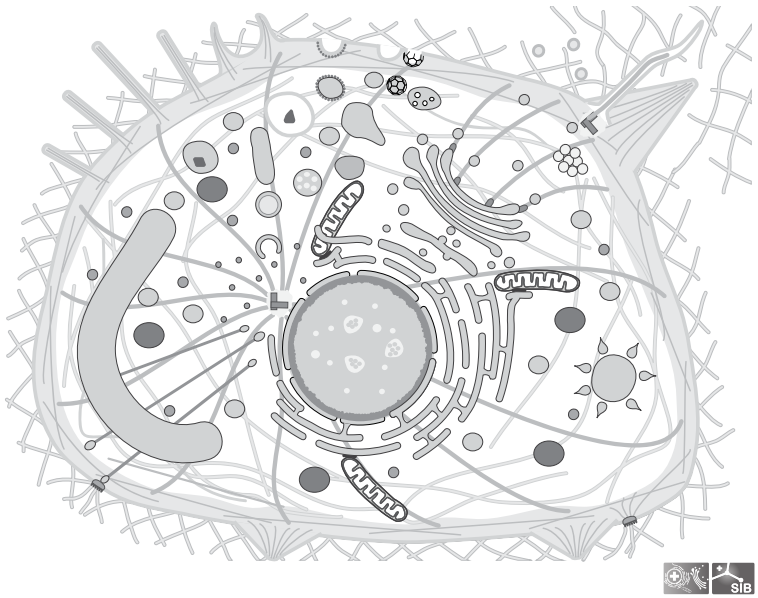
⑪ This ratio has no mm unit. Magnification is different from resolution: enlarging an image need not reveal additional distinguishable detail.

From cells to systems: the heart

Level	Example	Connection to the next level
Cell	Cardiac muscle cell	Many cells work together as muscle tissue
Tissue	Cardiac muscle, nervous and connective tissues	Different tissues together form the heart
Organ	Heart	Works with blood vessels in the circulatory system
System	Circulatory system	Transports blood and works with the respiratory and other systems



Overview of a plant cell. The diagram combines typical structures; not every plant cell contains all of them.



Overview of an animal cell: locate the nucleus, surrounding endoplasmic reticulum and mitochondria with folded inner membranes. Animal cells have no cell wall or chloroplasts.

Check your understanding

1. Bacteria have no membrane-enclosed _____, but still have DNA and _____.
2. A cell that is actually 0.10 mm long measures 30 mm in an image. Its magnification is _____.

Check answers:

1. Nucleus; ribosomes. 2. 300 times.

How to recognise the problem Identify visible structures, then connect them to the function asked about. Convert measurements to the same units before calculating.

Concept I.c Transport across membranes

Key ideas

① Place similar potato strips in water and concentrated sucrose solution. Their masses may change in opposite directions. Record each initial mass before calculating the change. A strip that was larger to begin with and remains heavier has not necessarily absorbed more water.

② Percentage change in mass = (final mass − initial mass) ÷ initial mass × 100%.

③ For a strip that increases from 2.00 g to 2.10 g:

④ Increase in mass = 2.10 − 2.00 = 0.10 g.

⑤ Percentage change = 0.10 ÷ 2.00 × 100% = 5%.

⑥ A positive value indicates net water uptake; a negative value indicates net water loss. Under these experimental conditions, a change close to zero can estimate the sucrose concentration at which internal and external water potentials are similar.

⑦ Water molecules move continuously. Across a selectively permeable membrane, water moves on balance from higher to lower water potential: this is osmosis. Molecules cross in both directions. “Net movement” is the difference between the two opposing movements, not the complete absence of movement in one direction.

⑧ In simple solutions without a pressure difference, adding sucrose lowers water potential. A sufficiently concentrated sucrose solution can therefore have a lower water potential than a plant cell’s contents, causing net movement of water out of the cell. State which two regions are being compared and which quantity is higher; “from high to low” alone is incomplete.

⑨ A plant cell has a cell wall, cell membrane and vacuole. Its relatively rigid wall does not shrink along with the softer contents when water is lost. As the vacuole loses water and the protoplast shrinks, the cell membrane may pull away from the wall: plasmolysis. Chloroplasts moving inwards with the cytoplasm may be visible in a micrograph.

⑩ Returning a plasmolysed cell to an appropriate environment of higher water potential can cause net water uptake and expansion of the contents. Severe damage may prevent complete recovery, so reversibility depends on the condition of the cell.

⑪ Distinguish diffusion, osmosis and mass flow. Water vapour leaving the stomata moves by gaseous diffusion. Water travelling through xylem vessels moves by mass flow. Net water movement across a cell membrane is analysed using water potential and selective permeability.

⑫ Diffusion results from continuous random particle movement and usually produces net movement from higher to lower concentration. Oxygen diffuses from alveoli into blood; its removal by red blood cells helps maintain the gradient. A larger exchange surface, shorter distance and steeper concentration gradient usually favour diffusion. At dynamic equilibrium, particles still move but the opposing rates are equal, so there is no net movement.

⑬ Oxygen can cross the phospholipid bilayer by simple diffusion. Glucose cannot readily cross the hydrophobic interior and may move down its concentration gradient through a specific transport protein: facilitated diffusion. This membrane-transport step does not require energy from cellular metabolism. A glucose carrier in a red blood cell membrane can move glucose on balance from higher to lower concentration. The presence of a carrier does not by itself indicate active transport. A limited number of carriers can also produce a plateau in transport rate; a plateau alone does not establish an ATP requirement.

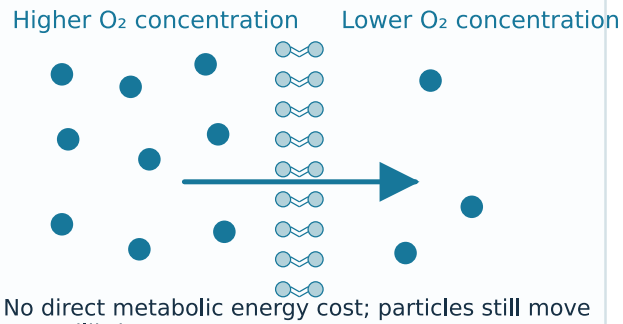
⑭ Active transport can move substances against a concentration gradient and requires transport proteins and metabolic energy. Root cells can take up mineral ions from a dilute external solution while maintaining a higher internal concentration. Oxygen shortage may restrict ATP supply and affect active transport. Do not apply this energy requirement to all diffusion or osmosis.

⑮ Red blood cells have no cell walls. In a sufficiently dilute solution, net water entry may cause them to burst: haemolysis. A plant cell wall resists expansion of the contents, allowing turgor pressure to develop. The presence or absence of a supporting cell wall explains the different responses.

In a waterweed leaf, the outer boundary may retain its polygonal shape while the green contents collect towards the centre. The combination of an unchanged wall and shrunken contents supports plasmolysis. “The cell becomes smaller” fails to distinguish the structures.

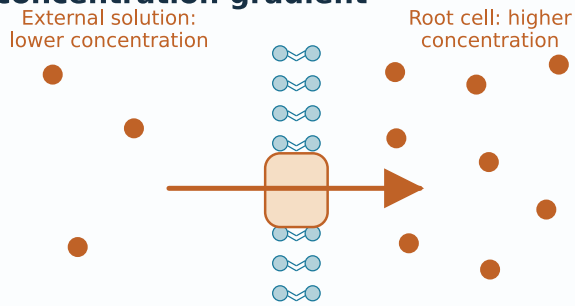
Membrane transport: identify the substance and compare both sides

Oxygen diffuses from higher to lower concentration



No direct metabolic energy cost; particles still move at equilibrium.

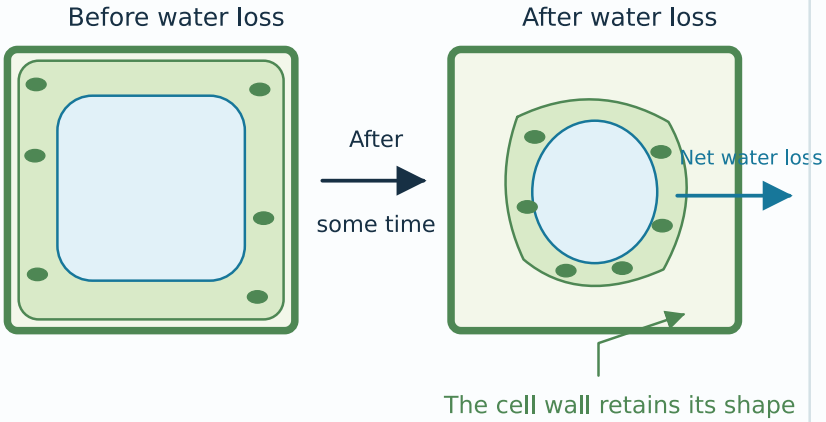
Root mineral uptake can oppose a concentration gradient



Transport proteins + metabolic energy (ATP)
Low oxygen can limit ATP supply and affect uptake.

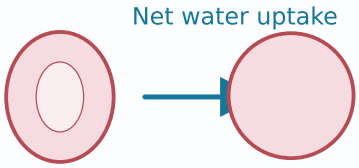
Osmosis: net water movement from higher to lower water potential

A plant cell in sufficiently concentrated sucrose solution



The vacuole and protoplast shrink; the cell membrane can pull away from the cell wall.

A red blood cell has no cell wall
In a sufficiently dilute solution

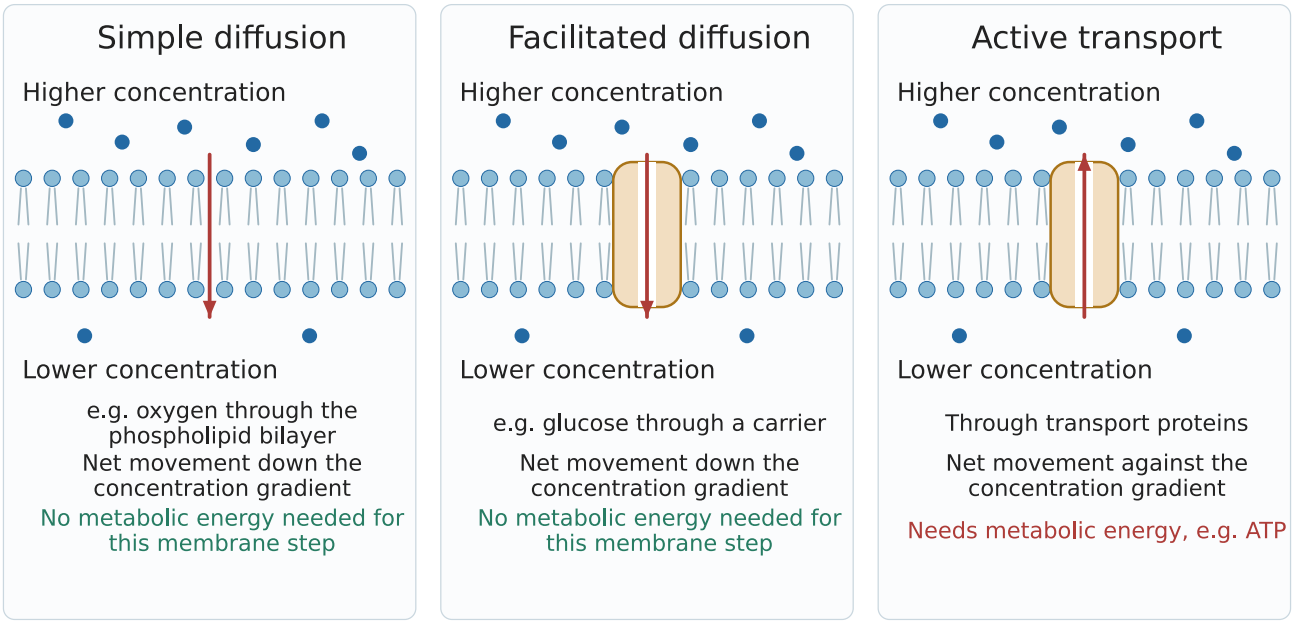


The cell swells
Too much water can cause haemolysis.

Arrows show net movement. Water molecules can cross both ways.

Compare water potential and solute distribution on the two sides, then follow the arrows showing net water movement.

Membrane transport: assess proteins, direction and energy supply separately



Arrows show net transport. A transport protein does not necessarily imply active transport. Facilitated diffusion can saturate because protein numbers are limited.

Compare the route through the membrane, the direction of net movement and the energy requirement of the transport step.

Check your understanding

1. In osmosis, water moves on balance from _____ to _____ water potential.
2. During plasmolysis, the structure that mainly shrinks inwards is the _____, not the entire cell wall.

Check answers:

1. Higher; lower. 2. Protoplast / contents enclosed by the cell membrane.

How to recognise the problem Identify whether water or solute is moving. Compare the relevant water potentials or concentrations, then check whether movement is against a gradient and requires metabolic energy.

Concept I.d The cell cycle and cell division

Key ideas

① After skin damage, neighbouring cells may divide to produce replacement cells. Each new cell normally needs a complete set of the original genetic information. DNA must therefore be copied before the copies are distributed in an orderly way. The cell cycle includes growth, DNA replication, nuclear division and cytokinesis; a cell is not physically splitting throughout the whole cycle.

② Consider a cell with only two homologous pairs: one long pair and one short pair. Each pair normally contains one chromosome from the father and one from the mother. Four chromosomes form two sets, written 2n = 4. Here n is the number in one set, so n = 2.

③ After DNA replication, a chromosome can consist of two sister chromatids joined at a centromere. DNA quantity has increased, but the chromosome number has not necessarily doubled. Count chromosomes using the centromeres or separation state specified in the question. Sister chromatids are copies of one chromosome; homologous chromosomes form a pair with corresponding gene loci, normally one paternal and one maternal.

④ During mitosis, chromosomes condense, align centrally and separate their sister chromatids towards opposite poles. Two nuclei form. With cytokinesis, this normally produces two daughter cells with the same chromosome number and similar genetic information. Mitosis supports growth, repair and some forms of asexual reproduction; mutations can still introduce differences.

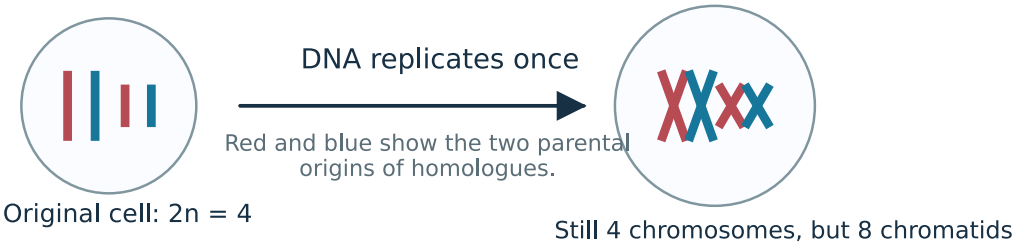
⑤ Meiosis has one round of DNA replication followed by two divisions. The first mainly separates homologous chromosomes; the second separates sister chromatids. It usually produces four haploid products. Human gametes have 23 chromosomes, and fertilisation restores 46 in the zygote. Halving followed by fusion prevents the chromosome number from doubling in every generation.

⑥ Meiosis also generates new genetic combinations through the arrangement and segregation of homologous pairs and through crossing over between paired homologues. Compare the number of divisions, the structures separated first, the number of products, their chromosome numbers and their genetic differences. “One gives identical cells and the other different cells” is not a sufficient comparison.

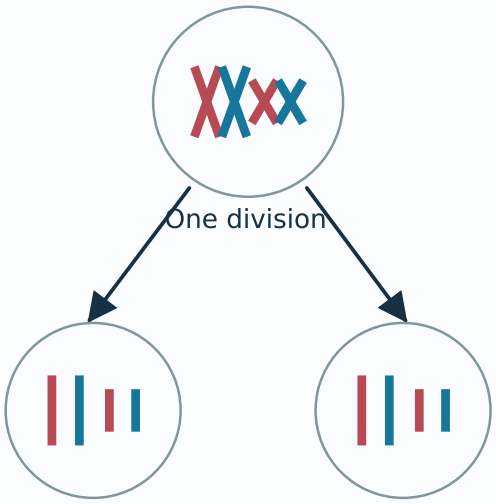
⑦ Return to the $2n = 4$ example. Before replication there are four chromosomes. After replication there are still four, each with two sister chromatids: eight chromatids in total. Mitosis separates the copies so that each daughter cell receives four chromosomes. After meiosis I, each cell has one chromosome from each pair: two replicated chromosomes. Meiosis II separates their sister chromatids, producing four products with two chromosomes each.

⑧ One X-shaped structure represents one replicated chromosome, not two chromosomes simply because it contains two visible strands. Check whether the question asks about one cell, one nucleus or the whole dividing cell. Without crossing over, two products of one meiosis can have the same combination. The fact that meiosis can increase variation does not mean that all four products must always be different.

After one DNA replication: what separates in mitosis and meiosis?



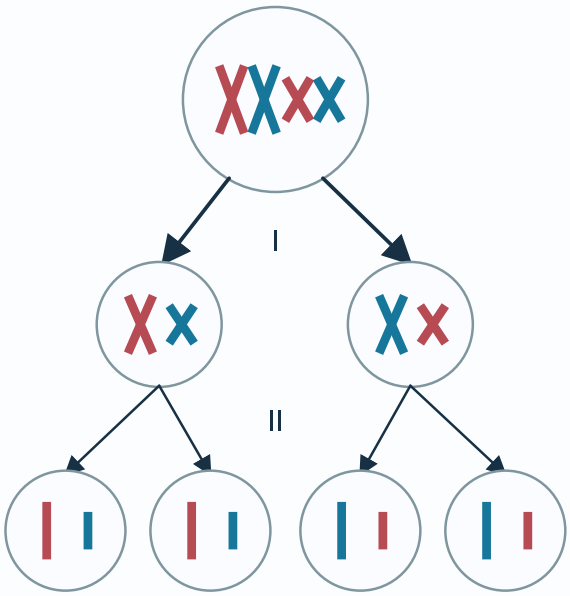
Mitosis: sister chromatids separate



Two daughter cells, each with 4 chromosomes.

Each daughter cell retains two homologous pairs. In this model without mutation, they are genetically identical.

Meiosis: homologues first, then sisters



Four products, each with 2 chromosomes (n = 2).

I separates homologues; II separates sister chromatids.

Crossing over is omitted; this distribution gives two combinations.

One X-shaped structure is one replicated chromosome. After its halves separate, each is counted as a chromosome.

Track chromosomes and DNA replication in a 2n = 4 cell. Count chromosomes separately from chromatids.

Check your understanding

1. Meiosis I mainly separates _____ meiosis II mainly separates _____.
2. A human sperm cell has 23 chromosomes. A normal zygote has _____.

Check answers:

1. Homologous chromosomes; sister chromatids. 2. 46.

How to recognise the problem Look for homologous pairing and identify which structures are separating before deciding the stage and products of division.

Concept I.e Enzymes, photosynthesis and respiration

Key ideas

① A germinating seed breaks down stored materials into smaller usable molecules and builds new cells from materials it absorbs or makes. Breaking down complex molecules is catabolism; making more complex molecules is anabolism. Together, these processes form metabolism. Different enzymes often catalyse successive steps in a metabolic pathway. Blocking one step may change the amounts of substances before and after it.

② Hydrogen peroxide can be decomposed. Catalase in liver makes this reaction occur faster. Hydrogen peroxide is the substrate: the substance on which the enzyme acts. Oxygen is one of the products. An enzyme is a biological catalyst, so it must not be shown as a product that appears only after the reaction.

③ To form water and oxygen, hydrogen peroxide must first overcome an energy barrier called the activation energy. Catalase provides a pathway with a lower activation energy. At the same temperature, more particles can therefore react successfully, and oxygen is produced faster. The enzyme does not supply extra energy or change the energy difference between the same starting substrates and final products. On energy diagrams, the two pathways should begin and end at the same levels, but the enzyme-catalysed pathway has a lower peak.

④ An enzyme has a specific three-dimensional structure. The region that binds the substrate and participates in catalysis is its active site. The lock-and-key model illustrates specificity through complementary shapes: not every substrate can bind suitably. A model highlights selected features. Its resemblance to a lock does not establish the enzyme's chemical composition or every detail of its reaction.

⑤ After catalysing a reaction, an enzyme can act on more substrate. A reaction may stop because substrate has run out, rather than because the enzyme has been used up. If bubbles reappear after more substrate is added, this supports the conclusion that the enzyme remains active and can be reused. If high temperature has altered the enzyme's structure, adding substrate may not restore its activity.

⑥ The location of an enzyme also matters. Digestive enzymes on the microvillus membrane of the small intestine are membrane-associated. Calvin-cycle enzymes in the chloroplast stroma are not membrane enzymes simply because the chloroplast itself has membranes.

⑦ Enzyme experiments often measure an effect of product formation instead of directly observing substrate disappearance. Bubbles indicate oxygen production in a catalase experiment. In a lipase experiment, fatty acids change the colour of a pH indicator. Connect the enzyme, substrate, product and measured observation explicitly.

⑧ Plants need carbon to make new organic matter. Carbon dioxide enters leaves from the air and is fixed into organic compounds by photosynthesis. These compounds can become storage materials or structures such as cell walls. Roots growing in soil do not mean that soil minerals account for most of the increase in plant biomass.

⑨ A leaf cross-section shows an organised arrangement of tissues. The epidermis surrounds the leaf, mesophyll carries out photosynthesis, and vascular bundles transport substances. Palisade cells are relatively elongated and closely packed. Spongy mesophyll has more conspicuous intercellular air spaces, which allow gases to move inside the leaf.

⑩ Relate tissue distribution to the light conditions of the leaf. The upper surface of a nearly horizontal leaf receives light more directly, so concentrating photosynthetic tissue near that surface helps capture incoming light. Both surfaces of a vertical leaf may receive light as the Sun's position changes; a more even distribution of photosynthetic tissue on both sides has a different functional significance.

⑪ When identifying an adaptation, first name the observed structure, then explain how it assists the function. Saying only 'more photosynthesis' gives no mechanism. The absence of a distinct palisade layer does not mean that a leaf cannot photosynthesise.

⑫ Carbon dioxide supplies carbon for new organic matter, but leaves also need water, light, suitable enzyme activity and mineral nutrition. Distinguish a short-term increase in fresh mass caused by water uptake from the actual formation of new organic material.

⑬ The lungs bring oxygen into the body, but the release of usable energy from nutrients takes place in cells. Cellular respiration is different from breathing in and out. The circulatory system connects gas exchange in the lungs with respiration in cells.

⑭ Aerobic respiration has several stages. Glycolysis occurs in the cytoplasm. Subsequent processing of pyruvate and the Krebs cycle occur mainly in the mitochondrial matrix. Electron transport and oxidative phosphorylation are associated

with the inner mitochondrial membrane. Distinguish an entire organelle from its matrix and membranes when stating a location.

⑮ NAD and FAD act as hydrogen/electron carriers. Their reduced forms donate electrons to the electron transport system and return to forms that can accept hydrogen/electrons again. This regeneration allows earlier reactions to continue. NAD participates in glycolysis, whereas FAD is not an essential carrier in glycolysis; their roles are not identical.

⑯ Electron transport is coupled to a proton gradient across the inner membrane. As protons flow back through ATP synthase, ATP is formed. ATP links energy supply to processes such as active transport, synthesis and muscle activity. It is a substance involved in energy transfer, not simply another name for 'energy'.

⑰ The simplified pathway producing lactate in muscle converts glucose into lactate without oxygen as a reactant. Its products differ from the ethanol and carbon dioxide produced by yeast. A rise in lactate during vigorous exercise does not mean that every cell in the body has stopped aerobic respiration.

⑱ Within a suitable range, increasing temperature increases particle movement and successful collisions, so enzyme-catalysed reactions can become faster. Excessive temperature can alter the enzyme's three-dimensional structure so that its active site no longer fits the substrate. pH can also affect the shape and charge of the active site. An inhibitor may compete for the active site or act elsewhere. Whether increasing substrate concentration reduces inhibition depends on the mechanism.

⑲ The photochemical reactions of photosynthesis occur on the thylakoid membranes of chloroplasts. Chlorophyll absorbs light energy; splitting water supplies electrons and releases oxygen. ATP and NADPH are formed. The Calvin cycle occurs in the stroma, fixes carbon dioxide into organic compounds, and uses ATP and NADPH to reduce three-carbon compounds. Some products contribute to sugar synthesis; others regenerate the carbon dioxide acceptor. Carbon fixation does not absorb light directly, but depends on products of the photochemical reactions. It is not a process that occurs only at night.

⑳ The overall relationship can be summarised as:

21. carbon dioxide + water → organic compounds + oxygen (requiring light energy and photosynthetic pigments).

22. If increasing light intensity at low light levels increases photosynthetic rate, light may be limiting. If more light has no effect after a plateau is reached, another condition may be limiting. A further treatment is needed to test carbon dioxide or another factor; the plateau alone does not identify a unique cause. Respiration consumes some photosynthetic products at the same time, so measured net gas exchange is not necessarily the gross photosynthetic rate.

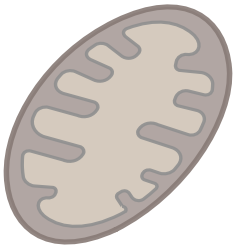
23. During glycolysis in the cytoplasm, glucose is converted through several steps into pyruvate, with a net production of ATP and NADH. Under aerobic conditions, pyruvate can form acetyl coenzyme A, which enters the Krebs cycle. Carbon is released progressively as carbon dioxide, and electron carriers accept high-energy electrons. During oxidative phosphorylation at the inner mitochondrial membrane, the carriers are reoxidised and energy supports the synthesis of a large amount of ATP. Oxygen is the final electron acceptor and water is formed.

24. When oxygen is insufficient, muscle cells can convert pyruvate into lactate; yeast can form ethanol and carbon dioxide. These conversions regenerate the carrier needed for glycolysis, allowing it to continue. They do not provide the full ATP yield of aerobic respiration. Compare pathways by location, oxygen requirement, products and energy supply.

Milk containing phenolphthalein and a suitable amount of alkali is pink. Lipase produces fatty acids, and the pink colour gradually disappears. The enzyme has not bleached the milk: the acid–base indicator responds to acid production.

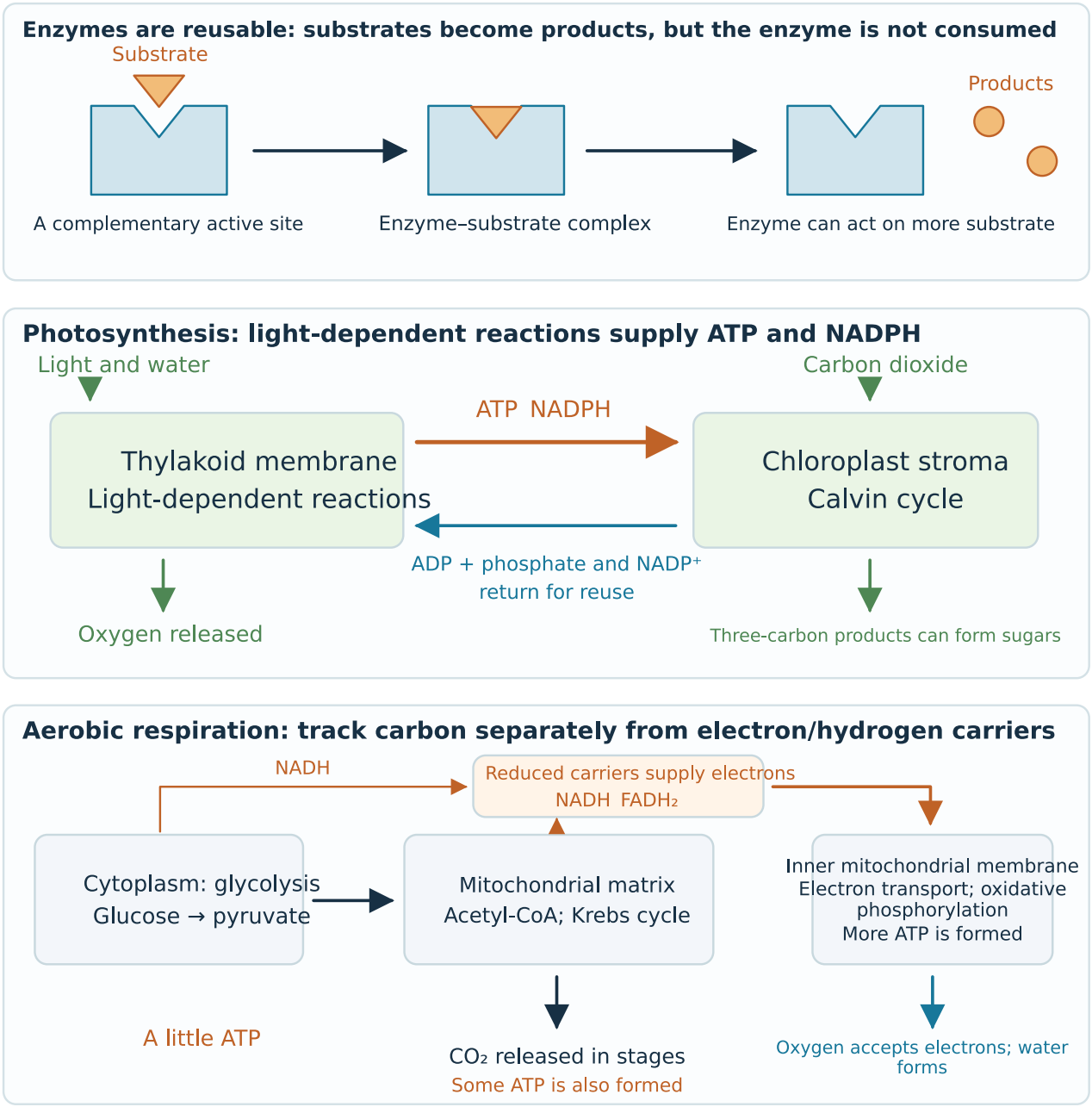
Of two leaf cross-sections, one may show a closely packed layer of elongated cells near the upper surface, while the other has more similar tissues on both sides. These are observations for comparing tissue distribution, not consecutive stages in the transformation of one leaf.

Covering the soil around roots with concrete can reduce oxygen supply. Root cells may then obtain less energy from respiration, impairing active mineral uptake. The covering does not directly block every xylem vessel inside the root.



Mitochondrion: the outer membrane encloses the organelle. Folds of the inner membrane form cristae and increase the membrane area available for associated reactions.

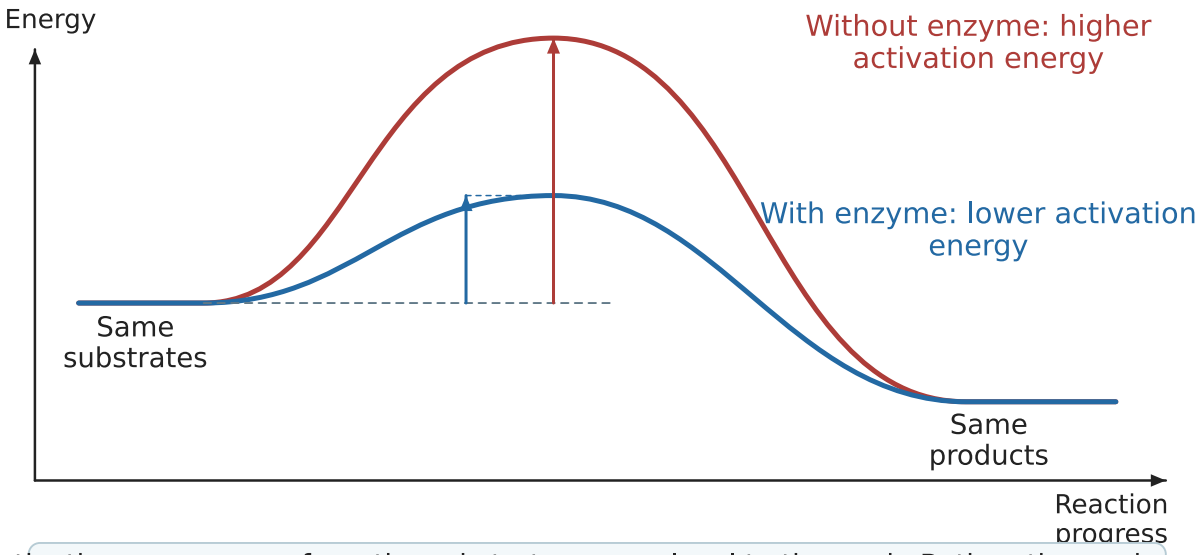
Metabolism: track substrates, reaction sites and energy transfer



Without oxygen, muscle pyruvate can form lactate; yeast can form ethanol and CO_2. Both regenerate NAD^+ needed for glycolysis.

Distinguish changes in substances from energy transfer. Enzymes catalyse reactions; they do not create the energy required.

Enzymes lower activation energy, without changing the reactants or products



Activation energy runs from the substrate energy level to the peak. Both pathways have the same overall energy change.

These curves show the energy barrier. Enzymes do not add energy to substrates and are not consumed in the reaction.

Both pathways use the same substrates and form the same products. The enzyme lowers the activation energy without changing the energy difference between substrates and products.

Check your understanding

1. The enzyme region that binds the substrate and participates in catalysis is its _____ the substance acted on is the _____.
2. Bubbles reappearing after more substrate is added support the conclusion that the enzyme can be _____.
3. The carbon in organic compounds formed by photosynthesis comes mainly from _____.
4. Explain a leaf adaptation by connecting an observed _____ with its _____.
5. Glycolysis occurs in the _____ oxidative phosphorylation is associated with the mitochondrial _____.
6. After donating electrons, an electron carrier is _____, allowing reuse.

Check answers:

1. Active site; substrate. 2. Reused. 3. Carbon dioxide. 4. Structure; function. 5. Cytoplasm; inner membrane. 6. Regenerated / returned to its oxidised form.

How to recognise the problem For enzyme questions, identify the substrate, products and measured variable. For metabolism, locate the process, then track carbon, electron carriers and ATP. Distinguish measured net change from the gross process when interpreting rate curves.

Genetics and evolution

Chapter 4

Concept II.a Basic genetics

Key ideas

① Some pea seeds are round and others are wrinkled. Round or wrinkled is an observable phenotype. The combination of alleles controlling the character is the genotype. Different versions of the same gene are called alleles. In a model where one pair of alleles controls seed shape, R represents the dominant allele for round seeds and r the recessive allele for wrinkled seeds. RR and Rr both produce round seeds, whereas rr produces wrinkled seeds. The round phenotype alone therefore cannot distinguish RR from Rr.

② The two alleles of an Rr plant separate during gamete formation. Each gamete receives one allele, either R or r. In this model, each type has a probability of one half. Dominance describes expression when both alleles are present; it does not mean that the dominant allele is necessarily more common, beneficial or powerful.

③ To cross two Rr plants, write R and r from one parent above a Punnett square and R and r from the other parent at its side. Each cell combines one allele from above with one from the side, giving RR, Rr, rR and rr. Rr and rR are the same genotype. The four cells therefore contain one RR, two Rr and one rr.

④ RR : Rr : rr = 1 : 2 : 1.

⑤ Round : wrinkled = 3 : 1 (under complete dominance).

⑥ These are theoretical probabilities for each fertilisation, not a fixed sequence of four offspring. A wrinkled offspring does not guarantee that the next three will be round. A small observed sample need not show exactly a 3 : 1 ratio.

⑦ To distinguish an RR round plant from an Rr round plant, cross it with rr. RR produces only R gametes, so all offspring with an rr parent are Rr. Rr produces R and r gametes, so rr offspring are possible. Even one wrinkled offspring rules out RR for the tested parent under this model. An entirely round finite sample supports RR but may not completely exclude Rr.

⑧ The law of segregation concerns the separation of the two alleles of one gene. Independent assortment concerns the relationship between different genes. Let L represent long fur, l short fur, B black fur and b white fur. A pure-breeding long-white parent LLbb produces only Lb gametes; a pure-breeding short-black parent llBB produces only lB gametes. All first-generation offspring are therefore LlBb. This conclusion does not require an assumption that the genes are unlinked. Uniform first-generation offspring do not by themselves demonstrate independent assortment.

⑨ Only when L/l and B/b are explicitly stated to assort independently can LlBb be treated as producing four equally likely gametes: LB, Lb, lB and lb. Probabilities for the two characters can be multiplied under that independence condition. New combinations of parental characters can result from meiotic reassortment and random fertilisation without a new mutation.

⑩ The ABO blood group system has three common alleles, I^A, I^B and i, but each person still carries only two copies. I^A and I^B are codominant; i is recessive to both. Group A may be I^AI^A or I^Ai, group B may be I^BI^B or I^Bi, group AB is I^AI^B and group O is ii. If a group A parent and a group B parent have a group O child, each parent must have supplied i. Under this model, their genotypes must therefore be I^Ai and I^Bi.

⑪ Combining their gametes gives I^AI^B, I^Ai, I^Bi and ii: AB, A, B and O each have probability one quarter. This ratio applies to these particular parental genotypes, not to every pairing of group A and group B parents.

⑫ A typical human body cell has 46 chromosomes, whereas a gamete has 23. A karyotype arranges chromosomes by features such as size and shape. X and Y differ in size and appearance. A standard karyotype can reveal changes in chromosome number or large structural changes, but cannot directly show a single-base substitution.

⑬ For X-linked inheritance, place the allele on its X chromosome. For a recessive character, let X^N carry the normal allele and X^n the recessive allele. A carrier mother X^NX^n produces X^N or X^n eggs; a normal father X^NY produces X^N or Y sperm. The four combinations are a normal non-carrier daughter, a carrier daughter, a normal son and a son expressing the character.

⑭ Without a condition specifying sex, one of the four combinations expresses the character:

⑮ probability of a child expressing the character = 1 ÷ 4 = 1/4.

⑯ If the child is known to be a boy, compare only the two possible sons:

⑰ probability that a boy expresses the character = 1 ÷ 2 = 1/2.

⑱ The denominator changes because sex is now a given condition. A father supplies Y to his son; the son's X comes from his mother. Do not draw the father's X passing directly to a son.

⑲ In a pedigree, first find parent–offspring combinations that can exclude an inheritance pattern. Two parents who do not express a recessive character may each carry its allele and have an affected child. The number of affected people alone does not establish dominance or recessiveness. An unaffected individual may be homozygous or a carrier; retain both possibilities until evidence excludes one.

⑳ Human height usually shows continuous variation and is influenced by several genes and environmental factors such as nutrition. ABO blood groups show discontinuous variation with distinct categories. Variation can arise from genetic recombination, mutation or environmental effects. Developing larger muscles through exercise does not mean that DNA in the person's gametes changes in the same way because it is needed. The next section follows the molecular steps needed to judge whether a gene mutation affects a protein and a character.

An X-bearing egg and an X-bearing sperm produce XX; an X-bearing egg and a Y-bearing sperm produce XY. In this simplified model, all eggs carry X and the difference comes from whether the fertilising sperm carries X or Y. Neither parent can consciously choose the combination.

Rr × Rr: each cell combines one allele from each parent

Gametes of one parent	R (1/2)	r (1/2)
R (1/2)	RR, round	Rr, round
r (1/2)	rR = Rr, round	rr, wrinkled

I^Ai × I^Bi: the same method for ABO blood groups

Gametes of one parent	I^B (1/2)	i (1/2)
I^A (1/2)	I^AI^B, group AB	I^Ai, group A
i (1/2)	I^Bi, group B	ii, group O

Carrier mother X^NX^n × normal father X^NY

Mother's gametes	Father: X^N (1/2)	Father: Y (1/2)
X^N (1/2)	X^NX^N: normal non-carrier daughter	X^NY: normal son
X^n (1/2)	X^NX^n: carrier daughter	X^nY: son expressing the character

Check your understanding

1. A normal human gamete contains _____ set of chromosomes; a typical body cell contains _____ sets.
2. The first-generation offspring of LLbb and llBB have genotype _____ at these two genes.
3. For the carrier-mother × normal-father cross above, the probability of an affected child without specifying sex is _____ if the child is known to be a boy, it is _____.

Check answers:

1. One; two. 2. LlBb. 3. 1/4; 1/2.

How to recognise the problem Define symbols clearly, write parental genotypes and possible gametes, then list their combinations. In pedigrees, first seek evidence that can exclude an inheritance pattern.

Concept II.b Molecular genetics

Key ideas

① Liver cells and pancreatic cells contain many of the same genes but do not make exactly the same proteins. The difference can arise from which genes are expressed, rather than from entirely different sets of DNA. A gene is a functional DNA sequence. A chromosome contains a long DNA molecule with associated proteins and can carry many genes.

② DNA usually forms a double helix of two complementary strands: A pairs with T and C with G. RNA generally uses U instead of T. The base sequence stores information, while linked sugars and phosphate groups form the backbone. Before deriving another sequence, establish whether the given strand is the DNA template strand, coding strand or mRNA.

③ Protein synthesis begins with transcription, which uses part of a DNA template to make RNA. In eukaryotic cells, this occurs mainly in the nucleus. The mRNA then reaches a ribosome. During translation, its information is read as three-base codons, tRNA brings the corresponding amino acids, and the amino acids are joined in sequence. Translation ends at a stop codon. A stop codon does not add another amino acid.

④ Read a short sequence from start to stop. The labels 5′ and 3′ indicate the ends and direction of a nucleic-acid strand. Complementary DNA strands run in opposite directions. Replacing bases without checking direction is insufficient.

⑤ DNA coding strand: 5′—ATG GCT TGA—3′.

⑥ DNA template strand: 3′—TAC CGA ACT—5′.

⑦ During transcription, complementary RNA is built from the template: A pairs with U, T with A, C with G and G with C. The resulting mRNA corresponds to the coding strand, with U in place of T:

⑧ mRNA: 5′—AUG GCU UGA—3′.

⑨ Reading in groups of three, AUG specifies methionine (Met), GCU specifies alanine (Ala), and UGA is a stop signal. tRNA brings the corresponding amino acids, which the ribosome joins by peptide bonds. The short chain formed is:

⑩ Met—Ala.

⑪ If coding-strand GCT changes to GTT, mRNA GCU changes to GUU, replacing Ala with Val at that position. If GCT changes to GCC, mRNA GCU becomes GCC, which still specifies Ala. Change the sequence first, then consult the genetic code to determine whether the substitution changes an amino acid.

⑫ DNA replication differs from transcription. The two original strands separate and each acts as a template for a new DNA strand, using A–T and C–G pairing. Each resulting double-stranded molecule contains one original strand and one new strand: this is semi-conservative replication. Replication allows genetic information to pass to daughter cells. Transcription produces RNA involved in gene expression; the products of both processes are not mRNA.

⑬ Gene mutations change DNA sequences, for example by base substitution, insertion or deletion. A change need not alter a protein: different codons may specify the same amino acid, or the change may occur in a non-coding region. A mutation that affects a protein's shape or amount can alter a character. Sickle-cell anaemia illustrates how a change in a haemoglobin gene can affect the protein and red blood cells.

⑭ Chromosome mutations affect chromosome number or the structure of larger segments. Down syndrome is commonly associated with an extra chromosome 21, a different scale of change from a single-base substitution. Mutations may arise spontaneously or be influenced by radiation or certain chemicals. The organism's needs do not determine which change occurs.

⑮ Recombinant DNA technology joins a selected DNA fragment to a vector. A suitable host may then make a desired substance, such as human insulin produced by genetically modified microorganisms. DNA fingerprinting compares variable regions between individuals and can support identification or parentage analysis. Conclusions must rely on corresponding bands or sequences, not merely on resemblance in appearance.

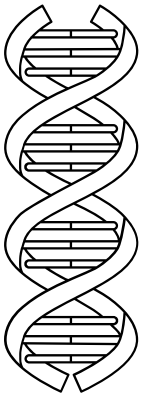
⑯ For parentage analysis, compare bands at the same positions. Suppose a father's two bands for an inherited DNA marker are at positions 1 and 3, and the mother's at positions 2 and 4. A child with bands at positions 1 and 4 could have received one from each parent. When several markers are examined, account for all relevant bands rather than

choosing one similar band. DNA fingerprinting compares patterns in selected variable regions; it does not read every base. Whole-genome sequencing and the reference sequence produced by the Human Genome Project address questions at a different scale.

⑰ The Human Genome Project supplied information including a reference human genome sequence and gene locations. This supports research into disease-associated variants and gene functions. It does not imply that everyone's sequence is identical or that sequence alone explains every disease and character. Gene expression, other genes and the environment may still affect the outcome.



A ribosome is shown as two subunits. It joins amino acids according to mRNA information; it is not the nucleus that stores the cell's genetic information.



DNA double helix: sugar–phosphate backbones run along the sides and complementary bases pair between them. The number of drawn rungs does not represent the actual length of a particular gene.

From a short DNA sequence to amino acids

Identify the strands: this example runs from a start codon to a stop codon

DNA coding strand 5′ — ATG GCT TGA — 3′

DNA template strand 3′ — TAC CGA ACT — 5′

Complementary pairs: A–T and C–G. The strands run in opposite directions.

Transcription: make RNA complementary to the template

mRNA 5′ — AUG GCU UGA — 3′

The mRNA sequence corresponds to the coding strand, with U in place of T.

Translation: a ribosome reads groups of three bases

AUG	GCU	UGA
Methionine (Met)	Alanine (Ala)	Stop signal

A stop signal is not an amino acid.

Short chain formed: Met — Ala

tRNA brings amino acids, which are joined by peptide bonds.

If coding-strand GCT becomes GTT, mRNA GCU becomes GUU: Ala is replaced by Val.
If GCT becomes GCC, both mRNA codons still specify Ala. A substitution need not change the amino acid.

Use the specified DNA strand and direction to derive mRNA, then read its bases in groups of three to identify the amino acids.

Check your understanding

1. In DNA, A usually pairs with _____ in RNA, _____ replaces T.
2. Making RNA from DNA information is _____ making a protein from mRNA information is _____.

Check answers:

1. T; U. 2. Transcription; translation.

How to recognise the problem Identify the molecule and stage first, then trace how the base sequence affects RNA, protein and the character. Sequence evidence supports only conclusions within its actual scope.

Concept II.c Biodiversity and evolution

Key ideas

① Yeast, bean seedlings and domestic dogs all have nuclei, but differ in how they obtain nutrients, their body structures and whether their cells have walls. Classification organises these comparable features and evolutionary relationships so that researchers can identify clearly which organisms they mean. Scientific names use binomial nomenclature: the first part is the genus name and the second the specific epithet. A species' scientific name allows clearer identification across languages than local common names.

② In the classification framework used in this course, the three domains are Bacteria, Archaea and Eukarya. The six kingdoms are Eubacteria, Archaebacteria, Protoctista, Fungi, Plantae and Animalia. Bacteria and archaea are both prokaryotic but belong to different domains. Modern classification also uses molecular evidence to infer relationships, so new evidence may change earlier groupings based only on appearance.

③ At each step, a dichotomous key provides two mutually exclusive features, such as "wings present" and "wings absent", and directs the user to another pair or a name. When identifying birds, check features such as beak shape and toe structure against the specimen or image. "They look similar" cannot replace following the decisions step by step, and a route cannot be invented from features that have not been observed.

④ A population may already contain inherited differences. Environmental conditions cause individuals to differ in their access to resources, survival and reproduction, allowing favourable traits to become more common among offspring. Over many generations, the proportions of traits in the population may change. This is the basic causal sequence of natural selection. An individual's need for a trait does not direct the production of the required mutation. The giraffe example must begin with inherited differences in neck length, then connect these to food height, competition, reproduction and inheritance. It cannot jump from "trying to stretch the neck" to longer-necked offspring. "Survival of the fittest" alone is incomplete. Without offspring or inherited differences, it does not explain why trait proportions change in the next generation. Evolution concerns populations across generations; one animal's growth during its lifetime is not evolution. Classification should reflect relatedness, and DNA sequences provide evidence for molecular comparison. Appearance, size and names can also offer clues, but the suggestion of "ancient" in the name archaebacteria is not evidence for how archaea should be separated from bacteria. Scientific ideas develop within a social and cultural setting, and their acceptance can be influenced by historical, religious and cultural factors. This is distinct from the evidence used to judge a theory's scientific validity. Whether the public likes an idea cannot directly establish whether it is scientifically true or false.

⑤ Speciation may involve a geographical barrier separating populations that previously exchanged genes. Genetic variation, different selection conditions and other evolutionary processes cause differences to accumulate over generations. If reproductive isolation eventually develops, the populations may become different species. A barrier does not instantly turn every individual into a new species on the day it appears.

⑥ Fossils preserve information about organisms from different periods and complement anatomical, embryological and DNA evidence. The fossil record is incomplete: the body parts that can be preserved, depositional conditions and locations where fossils are found are all subject to bias. Failure to find a particular intermediate form therefore does not prove that it never existed. In studying the origin of life, also distinguish scientific explanations that can be tested against evidence, the limitations of current evidence and claims of other kinds.

Where leaves remain high above the ground, longer-necked individuals obtain more food and have a greater chance of surviving and leaving offspring. The environment favours existing differences; high leaves do not instruct each giraffe to grow a long neck.

Check your understanding

1. Natural selection begins with existing _____ differences in a population.
2. For a favourable trait to become more common, differences in survival must be accompanied by _____ and _____.

Check answers:

1. Inherited. 2. Differences in reproduction; transmission of the trait to offspring.

How to recognise the problem Follow the mutually exclusive features step by step in identification questions. Begin evolution questions with inherited differences, then differences in survival and reproduction, before inferring population change over many generations.

Life processes

Chapter 5

Concept III.a Essential life processes in plants

Key ideas

① Place a leafy celery stalk in coloured water. The dye can move up the stalk and becomes especially visible at particular positions in a cut surface. These positions contain xylem, which carries water and dissolved minerals towards the leaves. The colour reveals the route of movement, but increasing colour intensity alone cannot tell us how much water is transported per minute.

② Plants can make organic substances from inorganic materials such as carbon dioxide and are autotrophs, but they still need water and minerals. Nitrogen deficiency may limit amino acid and protein synthesis; magnesium deficiency may affect chlorophyll formation. When comparing nutrient solutions, change only the mineral under investigation and keep other components, light and the plants' initial conditions as similar as possible.

③ Water uptake by roots, transport through the stem and loss from leaves form a connected pathway, but are different processes. Entry of water into living cells can involve osmosis. Long-distance movement through xylem is mass flow. After water evaporates inside the leaf, water vapour diffuses out through routes such as stomata; this loss forms part of transpiration. Root cells absorb mineral ions as well as water. Uptake against a concentration gradient requires active transport and energy. A shortage of oxygen around the roots affects aerobic respiration and hence energy-dependent uptake, giving soil aeration physiological importance. Stomata are pores regulated by guard cells. When other conditions are comparable, greater water loss from one leaf surface may be associated with more stomata or wider stomatal openings there. Choose the most appropriate conclusion supported by the experiment from the options given. One measurement of water loss is not a universal rule about stomatal distribution in all plants. An increase in the mass of an absorbent is the quantity recorded by the apparatus. Inferring water loss from a leaf surface depends on conditions such as a sealed apparatus and absorption of water vapour. It does not directly measure root water uptake, and certainly does not directly measure photosynthesis. When readings start at different values, compare their changes. If the upper apparatus gains 0.09 g and the lower gains 0.13 g over the same interval, the difference in water collected is:

④ Difference in mass increase = 0.13 − 0.09 = 0.04 g.

⑤ If the initial apparatus masses differ, simply subtracting the final values, 2.56 g − 2.49 g, includes the original apparatus mass difference and cannot represent the difference in water loss from the two leaf surfaces.

⑥ Xylem and phloem transport different materials. Xylem mainly carries water and minerals. Mature vessels are connected hollow structures, and their lignified walls also provide support. Phloem carries organic nutrients such as sucrose from a source to a site of use or storage; this is translocation. Mature leaves are often sources, while growing roots, young leaves and fruits may be sinks. Direction depends on the source and sink, so do not depict phloem transport as always downward.

⑦ Photosynthesis and respiration both occur in leaves. In dim light or darkness, respiration may cause net oxygen uptake and carbon dioxide release. In strong light, photosynthesis can exceed respiration and reverse the direction of net gas exchange. When the relevant photosynthetic and respiratory rates are equal, no net exchange may be detected externally, but neither process has necessarily stopped.

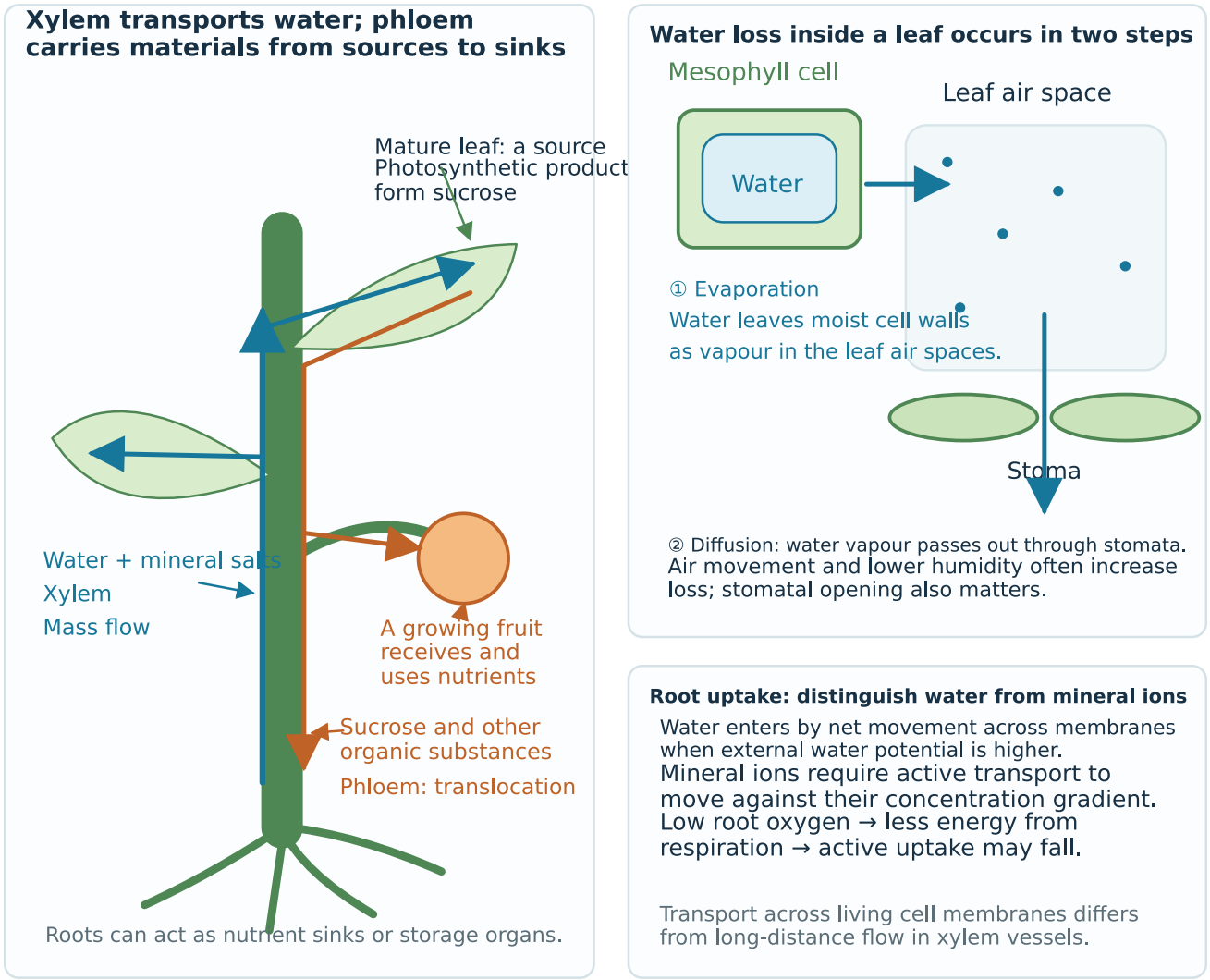
⑧ Stomatal opening and closure affect gas exchange and water loss. Lower humidity usually increases the difference in water vapour concentration between the leaf interior and outside air. Wind removes humid air near the leaf surface. Both therefore favour transpiration when stomatal and other conditions are comparable. A bubble potometer measures

water uptake rate. Some water is retained in tissues or used in other processes, so uptake estimates transpiration and cannot always be treated as exactly equal to it.

⑨ Support in herbaceous plants partly depends on turgid cells supporting one another. Water shortage reduces turgor pressure, so leaves and young stems may wilt. Woody plants contain more lignified tissue providing lasting support. In comparing them, explain the respective roles of cell water content and cell-wall material.

The absorbent apparatuses on the two leaf surfaces collect water vapour separately. Do not connect their results with an arrow suggesting that the upper surface "becomes" the lower one: they are parallel comparisons under shared conditions.

Water transport through a plant, and the separate pathway for sugars



Phloem transport runs from source to sink. Its direction can differ between regions; it is not always downwards.

Trace water and organic nutrients through roots, stems and leaves, distinguishing the materials and directions of xylem and phloem transport.

Check your understanding

1. Long-distance water transport in xylem mainly involves _____, while movement of water vapour out through stomata involves _____.
2. When comparing two absorbents, subtract each one's _____ from its final mass.

Check answers:

1. Mass flow; diffusion. 2. Initial mass.

How to recognise the problem In pathway questions, first distinguish water, minerals and organic nutrients. In rate questions, identify whether the apparatus actually measures water uptake or water loss. Include both photosynthesis and respiration when considering plant gas exchange.

Concept III.b Essential life processes in animals

Key ideas

① Eating rice, eggs and vegetables does not deliver whole pieces of food directly to muscles. The starch in rice and proteins in eggs must first be digested. Absorbable small molecules then pass through the intestinal wall into the body. Humans obtain organic substances made by other organisms and are heterotrophs. Ingestion, digestion, absorption, assimilation and egestion are distinct actions within the same overall pathway.

② A balanced diet supplies appropriate amounts of carbohydrates, lipids, proteins, vitamins, minerals, water and dietary fibre according to an individual's needs. A growing child needs materials for new tissues; increased activity usually raises energy requirements; pregnancy also changes some nutrient requirements. Human digestive enzymes do not fully break down fibre, but it helps faecal formation and intestinal function. A mismatch between intake and need can increase problems caused by deficiency or excess.

③ Teeth and chewing break food into smaller pieces, increasing the surface area available to enzymes: this is mechanical digestion. Enzymes hydrolyse large molecules into smaller ones: this is chemical digestion. The oesophagus mainly moves the food bolus by peristalsis. Churning and proteases contribute to digestion in the stomach. The small intestine receives pancreatic juice and bile and uses enzymes associated with its wall. Bile contains no digestive enzymes. Emulsification disperses large fat droplets into smaller droplets, making the fat more accessible to lipase.

④ The small intestine is long, and folds, villi and microvilli increase its absorptive surface area. Its thin epithelium shortens the distance materials cross. Dense blood vessels continually carry glucose and amino acids away, while lacteals participate in lipid transport. Absorption is movement across the intestinal wall into the internal environment. Assimilation is the use of absorbed materials by cells, such as assembling amino acids into their own proteins. The liver stores, converts and processes absorbed substances. Absorption and assimilation are not synonyms.

⑤ After food enters the mouth, teeth divide it into smaller pieces and saliva moistens it. Smaller pieces expose a greater total surface area for the same volume of food, allowing digestive enzymes easier access. This mechanical processing does not itself chemically break down large molecules. Digestion converts large molecules that cannot readily be absorbed directly into absorbable small molecules. Amylase breaks starch into smaller sugars; maltase must then break maltose down into glucose. Lipase breaks fats down into glycerol and fatty acids. Do not omit the different enzymes and products by reducing every process to "food becomes glucose". Absorption in the small intestine moves substances from the intestinal lumen across the epithelium into the body. To explain the rise in blood glucose after a meal, include both digestion and absorption: carbohydrates are first broken down to glucose, then glucose enters the blood from the small intestine. "Eating raises blood glucose" does not explain the connection. One important function of the large intestine is water absorption. Longer retention of undigested material usually allows more time for water absorption, making faeces drier and harder. If a graph measures only fibre intake and retention time, start with those two variables. Do not treat unmeasured volume or composition as a result already established by the graph. A dental formula records incisors, canines, premolars and molars, in order, on one side of the upper and lower jaws. When examining an X-ray, first establish whether one side or the whole row is being counted, then classify teeth by position and form. Do not substitute a memorised complete adult formula for the teeth actually shown.

⑥ The atria receive blood returning to the heart, while the ventricles pump blood out. The right atrium receives blood from the venae cavae, and the right ventricle pumps it into the pulmonary artery. The pulmonary veins return blood to the left atrium, and the left ventricle then pumps it into the aorta. Arteries and veins are distinguished by whether blood travels away from or towards the heart, not solely by oxygen content. The left ventricle supplies the systemic circulation at a higher pressure and has a thicker muscular wall. The right ventricle supplies the pulmonary circulation and has a thinner wall. In a dissection photograph, compare wall thickness first rather than guessing anatomical left and right from positions on the page. Ventricular contraction pumps blood into arteries, whose walls expand under pressure. Their subsequent elastic recoil helps maintain flow between heartbeats. Blood is not propelled along the arteries by

smooth-muscle peristalsis like food in the intestine. The coronary arteries supply the heart muscle itself. Plaques that narrow their lumen restrict the heart muscle's blood supply, reducing delivery of oxygen and respiratory substrates and potentially impairing its activity. Explain coronary heart disease by connecting the vessel change to heart-muscle supply, rather than stopping at "too much cholesterol". Gas exchange depends on a short diffusion distance and a maintained concentration difference. Thin alveolar walls lie close to capillaries, shortening the distance between alveolar gas and blood. Blood flow continually removes oxygen and brings carbon dioxide, helping maintain the differences needed for exchange. Only features visible in a photograph can be presented as direct evidence from that photograph. Tissue-fluid questions also require distinctions among pressure-driven fluid movement, osmosis and lymphatic drainage. Use the exchange model explicitly given in the question first. Do not extend a simplified textbook statement into a claim that all tissues have identical net return flow at all times.

⑦ During inhalation, the diaphragm contracts and flattens, while external intercostal muscles contract to raise the ribs. Thoracic volume increases, pressure inside the lungs falls below atmospheric pressure, and air enters down the pressure difference. During quiet exhalation, the relevant muscles relax and elastic recoil reduces volume. Pressure inside the lungs rises and air flows out. Air movement is ventilation; oxygen and carbon dioxide crossing the alveolar and capillary walls is gas exchange.

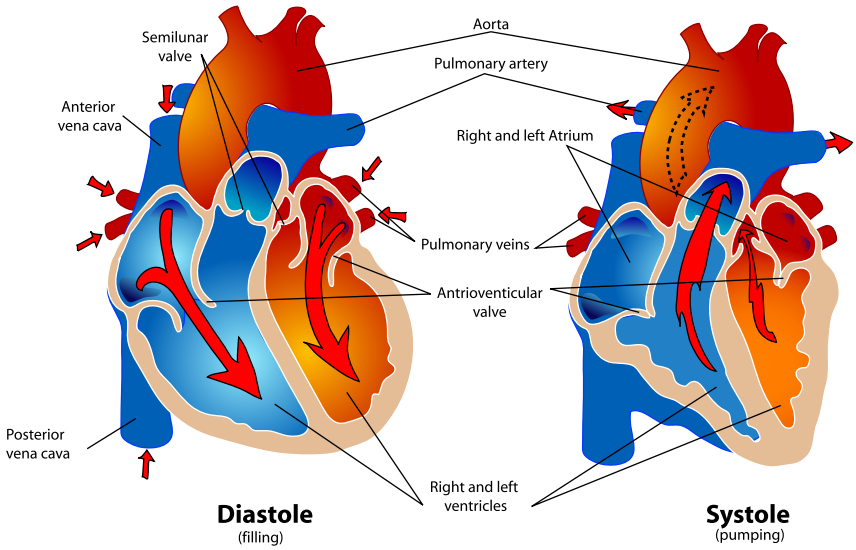
⑧ Numerous alveoli provide a large exchange surface. Thin walls shorten diffusion distance, a moist surface allows gases to dissolve first, and ventilation and blood flow maintain concentration differences. Oxygen is carried mainly by haemoglobin in red blood cells, whereas carbon dioxide is transported mainly as hydrogencarbonate. Carbon dioxide produced in tissues can travel in the blood to the lungs for removal; it is not produced only in the lungs.

⑨ Plasma transports dissolved substances, heat and blood cells. Red blood cells carry oxygen, white blood cells contribute to defence, and platelets contribute to clotting. Arteries have thick, elastic walls that withstand the higher pressure generated by the heart. Veins have lower pressure; some contain valves to prevent backflow, and skeletal-muscle contractions can assist return flow. Capillaries have thin walls that facilitate exchange with surrounding tissues.

⑩ Capillary pressure drives some plasma fluid out of the blood vessels to form tissue fluid, allowing exchange between blood and cells. Lymphatic vessels collect some of the tissue fluid that does not return directly to the blood. It becomes lymph and eventually returns to the venous circulation. Lymphatic circulation also contributes to lipid transport and immunity. Tissue fluid normally contains no red blood cells and fewer large plasma proteins; it is not identical to blood.

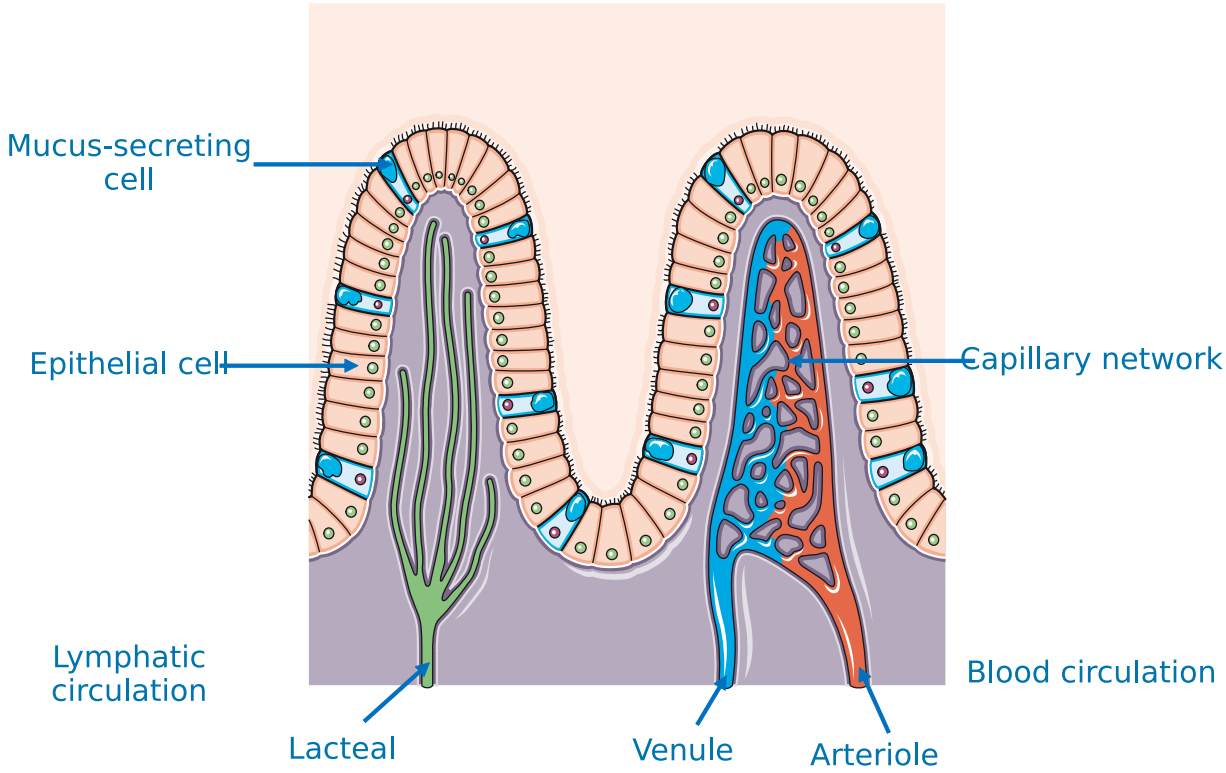
Add equal amounts of phenolphthalein indicator to two tubes of milk, then equal amounts of lipase and alkali. If one tube eventually loses its pink colour completely while the other remains pale pink, the immediate conclusion is that acidification differs. Without the time taken for the colour change, the amount of fat digested per minute still cannot be calculated.

A vessel carrying blood to the right atrium does not deliver it directly into the right ventricle. Blood still passes through the atrium and atrioventricular valve before entering the ventricle. Ignoring this sequence makes it easy to confuse the vena cava with the pulmonary artery.



Heart relaxation (left) and contraction (right). The aorta carries blood into the systemic circulation; the pulmonary artery carries blood towards the lungs, and the pulmonary veins return it. Follow the arrows to identify blood flow, then use pressure differences across valves to explain opening and closure. Red and blue schematically distinguish blood oxygen levels.

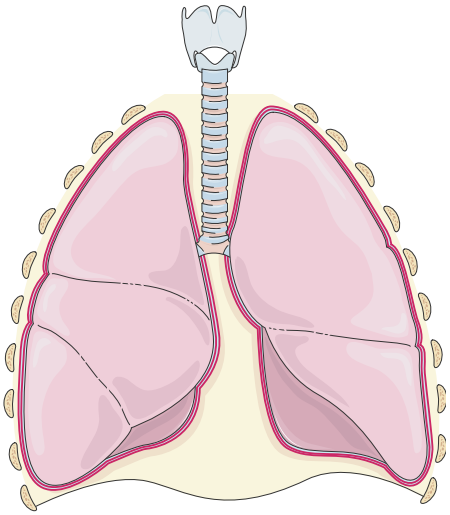
Intestinal villi: the surface epithelium and two transport routes after absorption



Every villus has a lacteal and a capillary network; they are shown separately here.

Glucose and amino acids mainly enter the blood; the main transport route for absorbed lipids involves the lacteals.

Each villus contains a lacteal and a capillary network, shown separately here. Glucose and amino acids mainly enter the blood, while the main route for lipid transport involves the lacteal.



Schematic positions of the lungs and airways. Air travels through the trachea, bronchi and smaller branches to the alveoli. The right and left lungs have different numbers of lobes; the outline shown is not an alveolus.

Check your understanding

1. Breaking large molecules down into absorbable small molecules is _____ moving the small molecules across the intestinal epithelium into the body is _____.
2. Lipase can break fats down into _____ and _____.
3. The right ventricle pumps blood into the _____ the left ventricle pumps it into the _____.
4. During ventricular relaxation, _____ of the vessel wall helps maintain blood flow in the aorta.

Check answers:

1. Digestion; absorption. 2. Glycerol; fatty acids. 3. Pulmonary artery; aorta. 4. Elastic recoil.

How to recognise the problem Arrange pathways using the actual starting and finishing points of food, oxygen or carbon dioxide. Link structures to area, distance, pressure or concentration differences. Treat ventilation and cellular respiration as separate processes.

Concept III.c Reproduction, growth and development

Key ideas

① Sexual reproduction involves fusion of gametes; asexual reproduction does not. Plants can reproduce in both ways. Potato flowers and seed-containing fruits are associated with sexual reproduction, while a tuber with buds can form new plants through vegetative propagation. A tuber contains stored materials and buds. Growing a new plant directly from it bypasses some steps in seed formation and establishment of a small seedling, shortening the time needed for propagation in cultivation. A tuber is neither a root nor a bulb: the name must match the actual structure. Although cells in a leaf and a tuber differ in function, their body cells usually have the same basic genetic composition. Reproductive cells in flowers and embryos formed by fertilisation inside fruits may have different chromosome-set numbers or genotypes. Functional differences caused by differentiation must not be confused with genetic differences caused by fertilisation or meiosis. Both nuclei and mitochondria can contain DNA, but their inherited sources differ. Nuclear DNA normally includes contributions from both parents, whereas human mitochondrial DNA is inherited mainly maternally. Sperm themselves contain mitochondria, so maternal inheritance cannot be explained by claiming that sperm have none. In a nuclear-transfer or mitochondrial-replacement procedure, trace separately whether a nucleus or mitochondria-containing cytoplasm is moved. A donor egg can retain mitochondria after its nucleus is removed. Adding another person's egg nucleus and the father's sperm therefore creates a situation in which nuclear DNA and mitochondrial DNA have different sources. Involvement of three people does not divide the DNA into three equal shares.

② During bacterial binary fission, genetic material is copied before the cell divides into two. Buds on a potato tuber can likewise form new plants. These asexual processes do not depend on gamete fusion and can usually increase numbers quickly while preserving favourable parental combinations. Sexual reproduction increases differences among offspring's

genetic combinations but requires gamete formation and fertilisation. Which method is more advantageous depends on environmental stability, dispersal needs and other conditions.

③ Anthers form pollen, stigmas receive it, and the style connects to the ovary containing ovules. Pollination transfers pollen from anther to stigma; fertilisation is fusion of a male gamete with an egg cell. A pollen grain germinates to form a pollen tube through which the male gamete reaches the ovule. After fertilisation, the zygote develops into an embryo, the ovule usually becomes a seed, and the ovary usually develops into a fruit. Pollination occurs first and does not guarantee successful fertilisation by every pollen grain.

④ Insect-pollinated flowers often use colour, scent or nectar to attract insects and have pollen that adheres readily. Wind-pollinated flowers often have exposed anthers, stigmas suited to trapping pollen, and large quantities of relatively light pollen. In comparisons, link features to how pollen leaves the anther, is transported and reaches the stigma. Seed or fruit dispersal helps offspring move away from the parent, reducing local competition and allowing them to reach other suitable sites.

⑤ In humans, testes produce sperm and ovaries produce eggs and secrete the relevant hormones. Sperm pass along the reproductive ducts to the urethra and leave the body. After ovulation, an egg enters the oviduct. A sperm's flagellum helps it swim, mitochondria in the middle piece provide energy, and the head contains genetic material. The larger egg supplies cytoplasm for early development. Fertilisation usually occurs in the oviduct; after early cell divisions, the embryo reaches the uterus and implants.

⑥ The placenta allows maternal and fetal blood to exchange oxygen, nutrients and metabolic wastes over a short distance, without substantial direct mixing of the blood under normal conditions. Maternal haemoglobin is not carried along the umbilical cord into the fetus. Oxygen first crosses the exchange barrier and is then transported by the fetal circulation. The placenta is also not a complete barrier to every drug and pathogen.

⑦ Identical twins arise when one zygote separates into two embryos; non-identical twins develop from two eggs fertilised separately. Birth involves processes including uterine contractions, cervical dilation and delivery of the baby. Parental care provides nutrition, protection and suitable developmental conditions. Breast milk supplies nutrients and some antibodies. This is receipt of ready-made antibodies; it does not mean that the infant has already formed its own memory cells against every infection.

⑧ Contraceptive methods act at different stages. Barrier methods prevent sperm entering or approaching the egg, hormonal methods can affect processes such as ovulation, and sterilisation blocks gamete-transport pathways. Explain which step a method prevents, rather than merely naming it. The full interaction of reproductive hormones is covered under hormonal control of the reproductive cycle.

⑨ Growth is an irreversible increase in body size or amount of material, while development includes changes in structure and function. After a seed absorbs water, enzyme activity resumes and stored materials are broken down to support respiration and growth. Dry mass may initially decrease before the young leaves photosynthesise sufficiently. An increase in fresh mass caused by water uptake therefore does not imply an equal gain in organic matter. Germination usually requires suitable water, oxygen and temperature; light requirements vary among species.

⑩ Height, leaf area, fresh mass and dry mass each capture some aspects of growth and miss others. Dry mass better reflects organic-matter accumulation but requires destructive measurement. Non-destructive measurements of height or area allow repeated comparisons of the same plant. The slope of a growth curve indicates the rate of increase in that quantity. A high point on the curve does not necessarily mark the time of fastest growth.

An enucleated donor egg receives the intended mother's egg nucleus and is then fertilised by her husband's sperm. Nuclear DNA comes from the woman and her husband; mitochondrial DNA comes mainly from the donor of the enucleated egg.

Check your understanding

1. A potato _____ bearing buds can reproduce by vegetative propagation.
2. Removing an egg's nucleus does not also remove the _____ in its cytoplasm.

Check answers:

1. Tuber. 2. Mitochondria.

How to recognise the problem First distinguish gamete formation, pollination, fertilisation, implantation and growth measurement. When linking structure to function, identify the step it helps. In graph questions, distinguish the value from its rate of increase.

Concept III.d Coordination and response

Key ideas

① When a hand touches a hot surface, skin receptors are stimulated, signals enter the nervous system, and muscles contract to withdraw the hand. This example identifies a stimulus, receptor, coordinating system, effector and response in sequence. The receptor detects a change, while the muscle carries out an action. Even if they lie close together, they have different roles.

② Receptors convert stimuli into nerve signals. Sensory neurones carry signals towards the central nervous system, while motor neurones carry signals from it to effectors. An effector may be a muscle or gland. Do not confuse a receptor with an effector simply because both occur in a limb. After a tap near the knee, the lower leg rapidly extends. The extensor muscle contracts and shortens, pulling on the bones to extend the joint. "Extensor" describes the joint movement the muscle causes; it does not mean that the muscle itself is passively lengthened. Spinal circuits can carry out reflexes rapidly without waiting for a conscious decision. Awareness of the tap or touch, however, requires the relevant signals to reach the cerebral cortex. The reflex and conscious awareness can therefore represent different levels of neural processing within the same event. In a neurone diagram, first use the direction of transmission to determine function, then support identification from the positions of the cell body, dendrites and axon. Do not rely solely on the orientation of a familiar textbook diagram, because the figure may be rotated or rearranged. Grey matter contains many neurone cell bodies, while white matter contains many myelinated nerve fibres. The cerebral cortex lies outside, with mainly white matter inside. In the spinal cord, the central H-shaped region is grey matter. The same tissue types need not have the same inner and outer arrangement in different organs.

③ The eye must focus light from an object on the retina. If the focus lies behind the retina, the rays have not converged sufficiently when they reach it; a convex lens can increase convergence. If the focus lies in front of the retina, convergence of incoming light must be reduced appropriately using a concave corrective lens. First trace where the rays actually meet, then choose the lens. Do not start by seeing "short sight" or "long sight" in an option and applying a memorised answer. The lens changes the light path; it does not move the retina to the focus. Sound passes through the eardrum and ossicles as mechanical vibrations to the inner ear. Movement of fluid in the cochlea stimulates sensory hair cells, which convert this stimulus into nerve signals carried to the brain by the auditory nerve. Damage to the eardrum or ossicles may impair sound transmission; damage to cochlear hair cells or the nerve-signal pathway is a different problem. Bone conduction through a metal rod, teeth and skull can bypass some outer- and middle-ear steps, but still requires inner-ear reception and nerve transmission. Each blank in a sequence must fit the physical or biological process before and after it. The first part involves vibrations and the later part nerve impulses. "Sound reaches the brain" cannot replace all the intervening steps.

④ The cerebrum is involved in conscious sensation, thinking and voluntary movement. The cerebellum coordinates movement and balance; the medulla oblongata contributes to automatic regulation of breathing and heart rate; and the spinal cord transmits signals and participates in reflexes. Sensory neurones carry signals towards the central nervous system, relay neurones connect pathways within it, and motor neurones carry signals to effectors.

⑤ When a nerve impulse reaches a presynaptic terminal, it can trigger neurotransmitter release. The transmitter diffuses across the synaptic cleft and binds to receptors on the postsynaptic membrane, producing a subsequent effect. The

distribution of release sites and receptors gives a typical chemical synapse a particular direction of transmission. Do not draw the synaptic cleft as an uninterrupted continuation of the axon.

⑥ For near vision, the ciliary muscle contracts, tension in the suspensory ligaments decreases, and the lens becomes thicker with greater refractive power. The changes are reversed for distant vision. This adjustment of lens shape is accommodation. The pupil reflex instead regulates the amount of light entering the eye: in bright light, circular muscles contract and constrict the pupil. These processes do not use the same muscles for the same purpose.

⑦ Rod cells are more sensitive in dim light. Cone cells help distinguish colours and fine detail, and colour blindness is associated with differences in the function of the relevant cones. The cochlea converts the mechanical vibrations of sound into nerve signals. Distinguish the ear's balance and hearing structures by their positions and functions.

⑧ The pinna collects sound waves, and the auditory canal carries them to the eardrum. Vibrations of the eardrum and ossicles pass into the inner ear, where cochlear sensory hair cells convert mechanical stimulation into nerve signals. The Eustachian tube connects the middle ear to the pharynx and helps equalise air pressure on the two sides of the eardrum. Semicircular canals mainly detect head rotation and contribute to balance; they are not hearing receptors. In the eye, the cornea and lens refract light together. The retina receives the image, and the optic nerve carries signals to the brain.

⑨ When a seedling receives light from one side, its shoot may gradually bend towards the light. Auxin distribution changes between the two sides. At suitable concentrations, cells on the side with more auxin elongate faster, producing curvature. Roots have a different sensitivity to auxin, and higher concentrations may inhibit root-cell elongation, so the shoot response cannot be applied unchanged to roots. Bending results from unequal growth on the two sides; the shoot tip does not walk towards light like an animal.

⑩ Endocrine glands secrete hormones into the blood, and corresponding effects occur only in cells with suitable receptors. Compared with nervous coordination, hormones usually travel in blood and may act more widely and for longer. Nervous signals usually follow specific pathways to particular sites. Speed and duration are general comparisons: they do not mean that every hormone is always slower than every nerve response by the same fixed factor.

⑪ The skeleton provides support and levers, while joints allow movement between bones. Tendons join muscles to bones; ligaments join bones to bones and stabilise joints. Hinge joints mainly allow flexion and extension in one plane, while ball-and-socket joints allow movement in more directions. During elbow flexion, the biceps contracts and the triceps is relatively relaxed; during extension, their roles reverse. Muscles pull by contracting and cannot actively push a bone back, so antagonistic pairs are needed. Neurotransmitter transmission at a neuromuscular junction can trigger a muscle response.

If a pathway runs from the spinal cord to a leg muscle, it is a motor pathway because of its direction of transmission, even if it is drawn at the top of the figure. Position on the page does not classify a neurone.

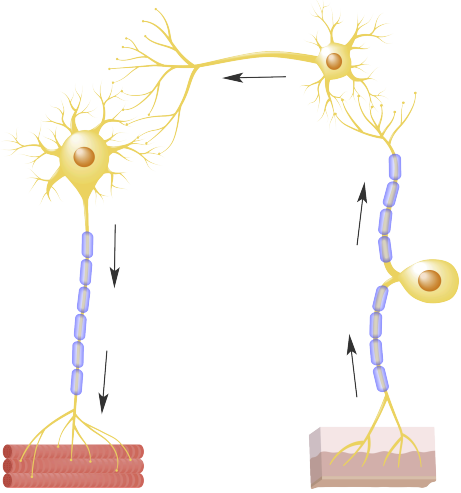
Biting a metal rod connected to a piano does not mean that sound waves travel directly along the metal into the brain. Conversion into sensory signals must still occur in the inner ear.

Near and distant vision: distinguish accommodation from the pupil reflex

Situation	Ciliary muscle	Suspensory-ligament tension	Lens and refractive power
Near vision	Contracts	Decreases	Thicker and more convex; refractive power increases
Distant vision	Relaxes	Increases	Thinner and flatter; refractive power decreases

Elbow flexion and extension: contracting muscles pull on bones

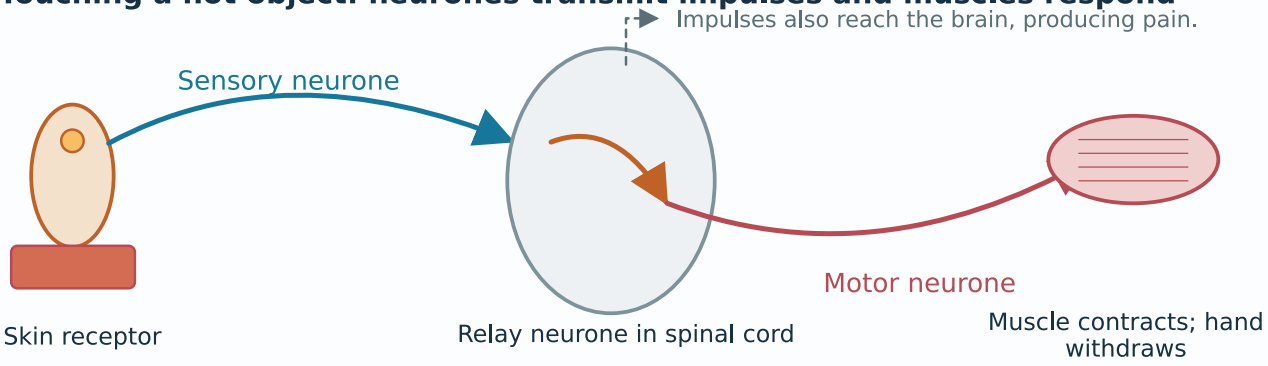
Movement	Biceps	Triceps
Elbow flexion	Contracts and shortens	Relatively relaxed
Elbow extension	Relatively relaxed	Contracts and shortens



Neurone form and transmission direction: the sensory neurone on the right receives information, which passes through the relay neurone above to the motor neurone on the left and then to the muscle below. Follow the arrows. A neurone is one cell; a nerve contains many nerve fibres and associated structures.

From stimulus to response: reflex arcs and negative feedback

Touching a hot object: neurones transmit impulses and muscles respond



After a meal: insulin restores blood glucose

Glucose is absorbed after a meal
Blood glucose rises

↓

Pancreatic β cells
secrete more insulin

↓

Muscles and other cells take up more glucose
More glycogen is made in liver and muscles

↓

Blood glucose falls towards the normal range
The stimulus for insulin secretion decreases

Negative feedback: responses counteract the initial deviation.

After water loss in sweat: ADH and the kidney

Water is lost in sweat
Blood plasma water potential falls

↓

The hypothalamus detects the change
The posterior pituitary releases more ADH

↓

Distal tubules / collecting ducts become more permeable to water
More water is reabsorbed into the blood

↓

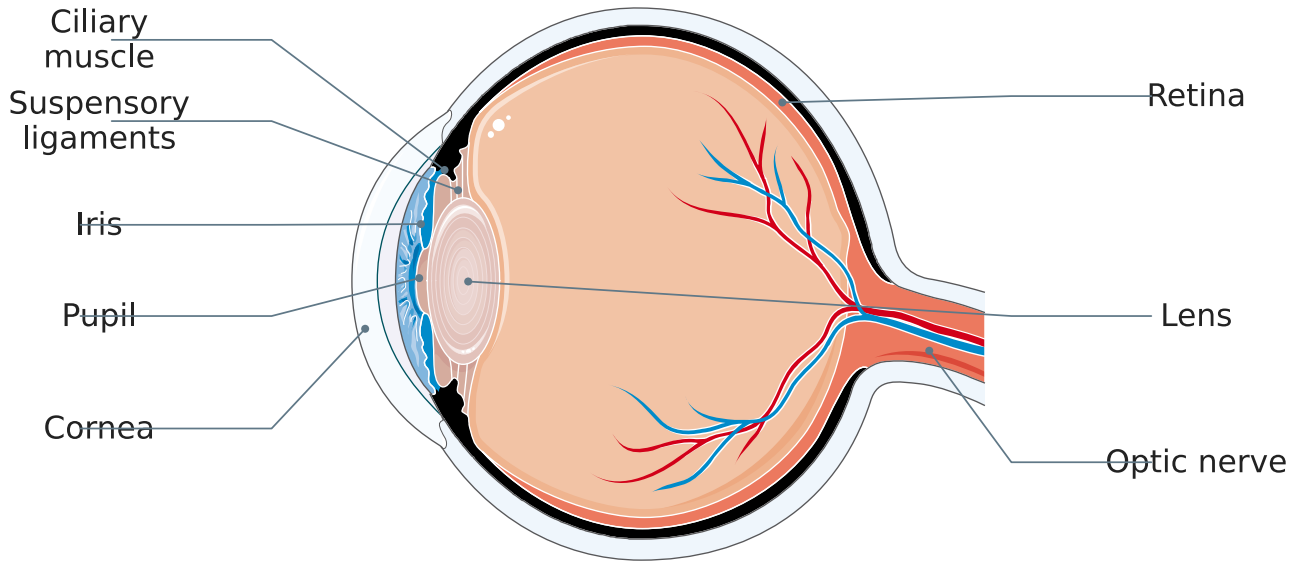
Plasma water potential rises; urine volume falls
Urine is more concentrated; the stimulus decreases

ADH is made in the hypothalamus and released by the posterior pituitary.

A reflex arc describes a neural pathway. Negative feedback describes how a response corrects a deviation.

Reflex arcs and negative feedback each have a defined signal pathway. Identify the stimulus and effector first.

Eye structure and accommodation: compare near and distant vision

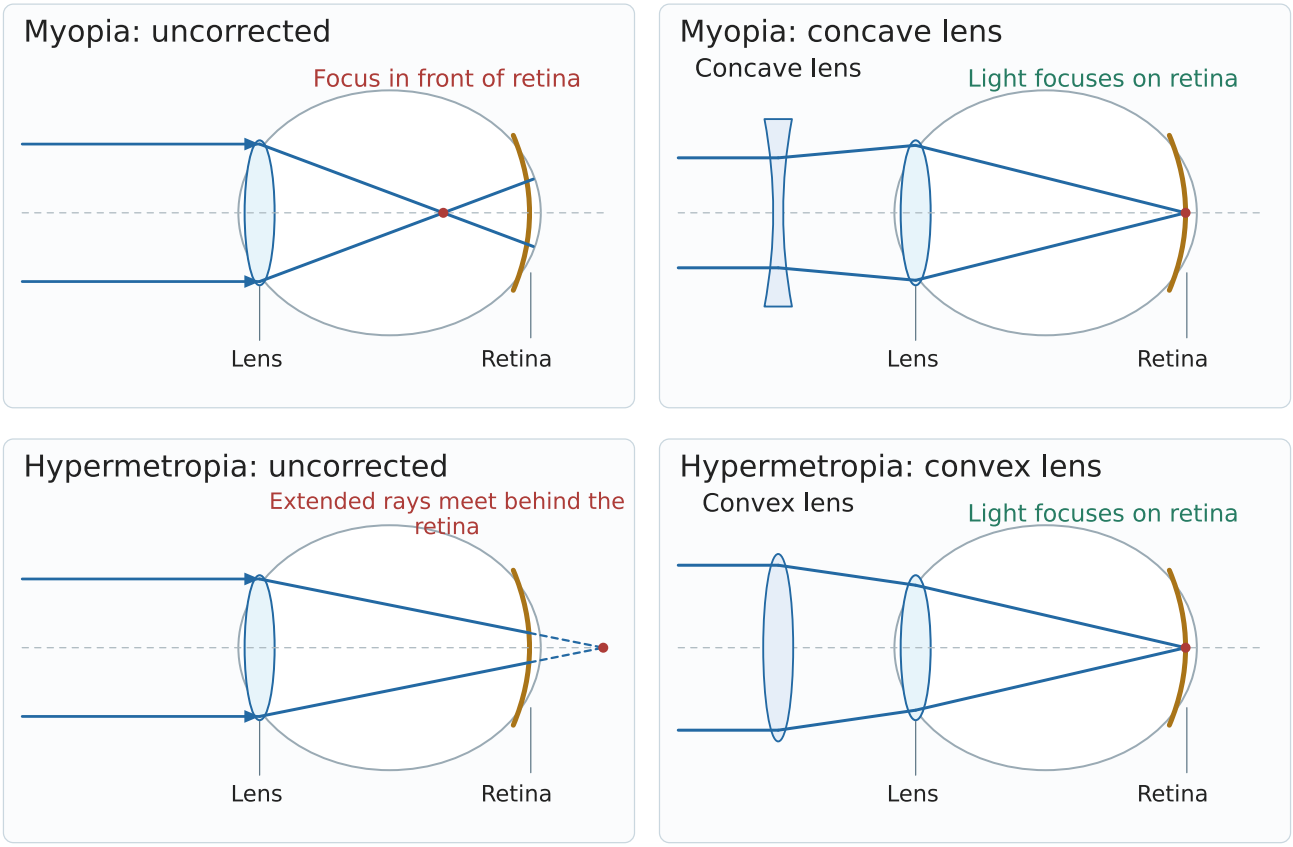


Structure / function	Near object	Distant object
Ciliary muscle	Contracts	Relaxes
Suspensory ligaments	Tension decreases	Tension increases
Lens	Thicker; more strongly curved	Thinner; less strongly curved
Converging power	Greater	Lower

The pupil is the opening in the iris. Accommodation changes lens curvature; the pupil reflex mainly controls how much light enters.

Follow the label lines to locate the cornea, iris, lens and retina. Suspensory ligaments attach to the lens, and the ciliary muscle alters their tension.

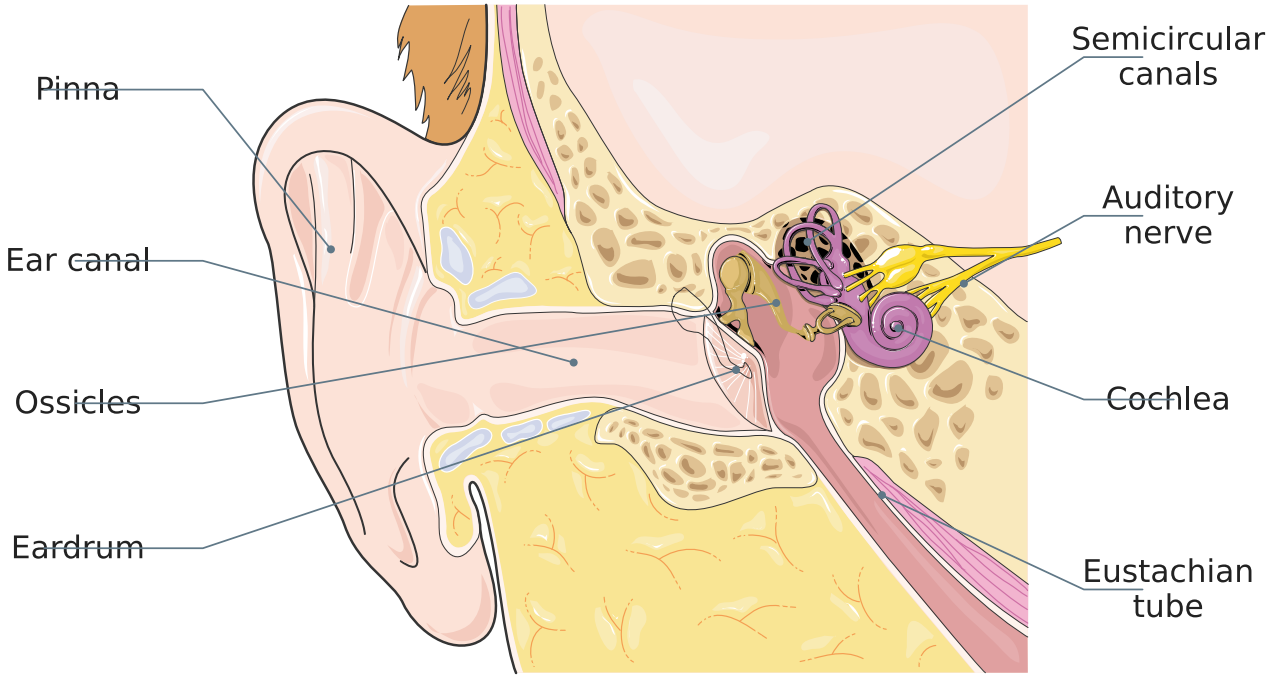
Myopia and hypermetropia: locate the focus, then choose the correcting lens



Parallel rays are shown without extra accommodation; only the main refraction is drawn. Blue dashes extend the ray paths, not an image through the eye wall.

Locate the point where the rays meet relative to the retina before selecting a corrective lens. Only the main light paths are shown, and distances are not to scale.

Ear structure: sound waves, mechanical vibrations and nerve impulses



Region	Main structures	Function
Outer ear	Pinna; ear canal	Collect and channel sound waves
Outer / middle ear boundary	Eardrum	Sound waves cause the eardrum to vibrate
Middle ear	Ossicles; Eustachian tube	Transmit vibrations; equalise pressure across the eardrum
Inner ear	Cochlea	Sensory hair cells convert stimuli into nerve impulses
Inner ear	Semicircular canals	Detect head rotation and help maintain balance

Auditory impulses travel to the brain. The Eustachian tube connects the middle ear to the pharynx, not to the ear canal.

Trace mechanical vibrations from the outer to the inner ear. The cochlea converts the stimulus into nerve signals. The Eustachian tube connects the middle ear and pharynx; semicircular canals contribute to balance.

Check your understanding

1. _____ neurones carry information towards the central nervous system; _____ neurones carry it from the central nervous system to muscles.
2. When the knee extends, the corresponding extensor muscle is _____, rather than lengthening itself.
3. If the focus lies behind the retina, a _____ lens can increase convergence.
4. Cochlear hair cells convert mechanical stimulation into _____, transmitted by the _____.

Check answers:

1. Sensory; motor. 2. Contracting / shortening. 3. Convex. 4. Nerve signals / nerve impulses; auditory nerve.

How to recognise the problem Identify the stimulus and effector before arranging the signal pathway. Explain accommodation, the pupil reflex, phototropism and antagonistic muscle action through the particular structures that change.

Concept III.e Homeostasis

Key ideas

① After a meal, carbohydrates are digested and absorbed, glucose enters the blood, and blood glucose rises. Under comparable conditions, different foods may produce different rates and magnitudes of increase. If a question compares

GI, first read the height and timing of the changes shown. A GI value does not represent every aspect of a food's nutritional value. Insulin is an important hormone that lowers blood glucose. It promotes glucose uptake and use by the relevant cells and conversion of glucose to glycogen for storage in cells such as liver and muscle cells. Increased use or storage lowers the glucose remaining in the blood. Negative feedback means that the system's response opposes the original deviation. A rise in blood glucose triggers responses that lower it. As glucose falls again, the original stimulus weakens, so the response should not continue increasing at the same strength. Regulation does not drive the variable ever lower without limit. A hormone curve is not the same as the curve for the regulated variable. Insulin responds to rising blood glucose, so its peak may occur later. If exact hormone concentrations are not given, draw only a justified relative pattern rather than inventing a concentration scale. When explaining a low-GI diet, connect a slower, smaller blood-glucose peak to a smaller regulatory demand. The shape of a curve alone cannot classify a food as absolutely safe or dangerous for every person.

② When blood glucose falls, the pancreas may increase glucagon secretion. Glucagon promotes glycogen breakdown and glucose release by the liver, raising blood glucose again. Insulin and glucagon act in opposite directions but together keep glucose within a suitable range. The pancreas secretes the hormones; the liver receives the signals and changes its metabolism. These roles cannot be exchanged.

③ Blood gases, water balance and body temperature are also important internal variables. A coordinating system detects a deviation and changes effector activity. If blood glucose is already high and a response makes it rise further, that response cannot be described as negative feedback opposing the deviation. Brief rises and falls can still occur during normal regulation. A curve that is not perfectly flat does not by itself indicate system failure.

A high-GI curve rising sharply and then falling does not require an insulin curve of exactly the same height at the same time. The two curves measure different substances and cannot share numerical values that have not been supplied.

Check your understanding

1. Insulin is a _____, not an enzyme that digests food.
2. Liver and muscle cells can convert glucose into _____ for storage.

Check answers:

1. Hormone. 2. Glycogen.

How to recognise the problem Separate the original deviation, sensing or control site, effector response and direction of recovery. A response must oppose the original deviation to qualify as negative feedback.

Concept III.f Ecosystems

Key ideas

① In a mangrove survey, all individuals of one fiddler-crab species within a particular area form a population. Populations of crabs, fish, plants and microorganisms living together form a community. That community, together with abiotic surroundings such as water, soil, light and salinity, forms an ecosystem. A biome describes broadly similar ecological types over a larger geographical scale, while the biosphere includes the regions of Earth in which life occurs.

② Streams, rocky shores, mangroves, grasslands and woodlands have different abiotic conditions. Rocky-shore organisms may face drying caused by tides and the force of waves; mangrove plants face salinity and oxygen-poor mud. When explaining an adaptation, identify the constraint first, then explain how a structure or behaviour reduces its effect.

③ A habitat is where an organism lives. Its ecological niche includes how it uses resources and interacts with other organisms. Two species living in the same place need not eat the same food, be active at the same time or have identical roles, so both may maintain populations there. Predator, parasite and consumer describe different aspects of an organism's role. A fungus obtaining resources from a living host while harming it is most specifically described as parasitic. A top predator may regulate other consumers through predation. Saying only that these organisms "maintain ecological balance" does not explain how they act. A pyramid of numbers compares individual counts; a pyramid of biomass compares the organic matter present at a particular time. Many tiny phytoplankton can reproduce rapidly and

be eaten rapidly, so a large number of individuals can coexist with a small standing biomass. This does not mean energy increases up the food chain. Primary and secondary succession begin under different conditions. Primary succession can start on bare sites without existing soil; secondary succession usually begins with soil or remnants of a previous community. They are not fixed first and second stages that every site must undergo in sequence, and further disturbance can alter the direction of succession. The carbon cycle follows carbon atoms, not a molecule that stays unchanged forever. Carbon from carbon dioxide enters organic substances through photosynthesis, moves along food chains by feeding, and may return to carbon dioxide through respiration and decomposition. Over long periods, the same atom may enter different substances and carbon stores many times. Tracing a carbon atom from food to exhaled air still requires digestion, absorption, transport in the circulation, cellular respiration and gas exchange in the lungs. A human body is not merely a mouth and lungs. Omitting intermediate transport fails to explain how the material actually reaches the next stage.

④ Relationship questions require the effects on both participants. A predator gains food and the prey is eaten. Competitors both experience adverse effects from competing for limited resources. Both participants benefit in mutualism. In commensalism, one benefits while the other shows no clear effect. A parasite obtains resources from and harms its host. Two birds living in the same tree cannot be assigned one of these relationships from location alone.

⑤ A food-chain arrow points from the organism eaten to its consumer, showing transfer of matter and energy. In grass → grasshopper → frog, grass is the producer, while grasshoppers and frogs are consumers at different trophic levels. Decomposers act on remains and wastes from several trophic levels. Respiration transfers energy as heat at each level, and some food is not eaten or assimilated, leaving less energy for transfer to the next level.

⑥ When comparing net production at two trophic levels, energy transfer efficiency = energy in new biomass at the next trophic level ÷ energy in new biomass at the original trophic level × 100%. Both quantities must refer to the same area and time interval.

⑦ If, in the same grassland over the same interval, plant net production contains 10000 kJ and herbivore net production contains 1200 kJ, then:

⑧ Energy transfer efficiency = 1200 ÷ 10000 × 100% = 12%.

⑨ Check exactly which energy quantity is the denominator. Do not mix incident solar energy, ingested energy and biomass energy in the same ratio.

⑩ The nitrogen cycle connects nitrogen-containing organic substances with different inorganic nitrogen forms. Decomposition of remains and wastes can produce ammonium. Under aerobic conditions, nitrifying bacteria convert ammonium first to nitrite and then to nitrate. Plants absorb inorganic nitrogen and assimilate it into substances such as amino acids, which animals obtain by feeding. Nitrogen fixation converts atmospheric nitrogen into usable nitrogen compounds; denitrification can convert nitrate to nitrogen gas. The names may sound similar, but the directions and conditions differ.

⑪ Compare plants → humans with plants → livestock → humans. The latter contains an extra trophic level. Livestock respiration and decomposition of wastes return some organic carbon to carbon dioxide and reduce the energy available to humans. Microorganisms in the digestive systems of ruminants such as cattle can also produce methane. A carbon footprint is the direct and indirect greenhouse-gas emissions associated with an activity, usually expressed as carbon dioxide equivalents. Both carbon dioxide and methane absorb some infrared radiation emitted by Earth. Reducing the relevant demand for livestock can lower some emissions, but plants also respire, and cultivation, processing and transport must still be included in the comparison.

⑫ Quadrats can estimate the density and distribution of plants or less mobile organisms. To infer conditions across a grassland, choose positions using an appropriate random method and take enough replicates. Do not place quadrats only where organisms appear most abundant. Line or belt transects can investigate change along an environmental gradient, such as distribution from the shore inland. Measurements of light, temperature, pH, humidity, oxygen and

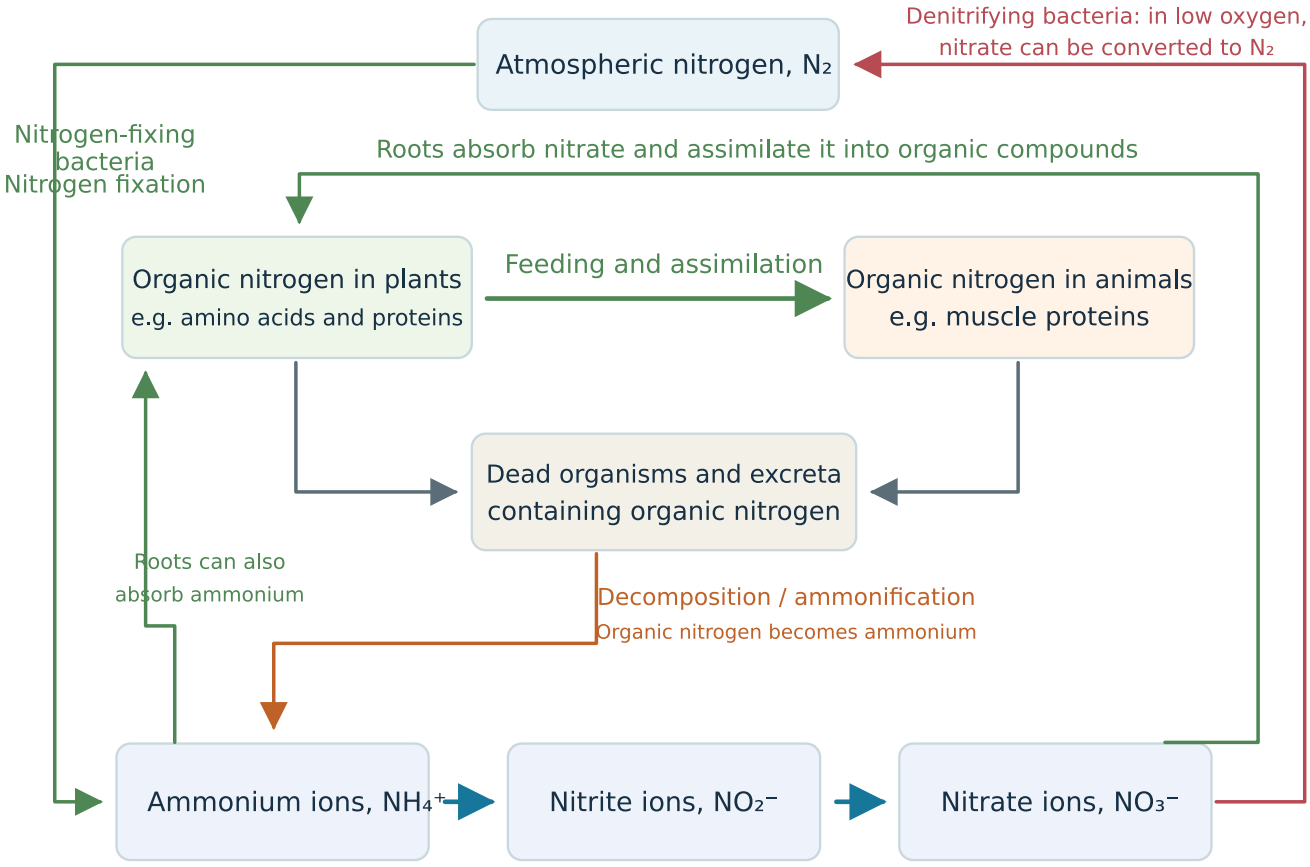
salinity should correspond to the same places and times. Correlation does not mean that all other causal explanations have been excluded.

⑬ For example, survey plantain plants with square quadrats of side length 0.50 m. Each quadrat has an area of 0.50 × 0.50 = 0.25 m². Establish coordinates across the grassland, select positions using random numbers, and count using the same boundary rule. Suppose five quadrats contain 2, 4, 3, 1 and 5 plants: 15 plants in a total sampled area of 5 × 0.25 = 1.25 m². Estimated density is therefore 15 ÷ 1.25 = 12 plants m^{-2}. If the quadrats represent the entire 200 m² grassland, the estimated population is 12 × 200 = 2400 plants. This is an estimate subject to sampling error, not a count of every individual.

⑭ If the grassland has clearly different microhabitats, obtain appropriate samples from each and account for their areas. Results from one corner cannot simply be applied to the whole site. To compare shore-to-inland changes, place quadrats at fixed distances along a transect and record organisms and environmental conditions at the same positions. Consecutive quadrats along one line cannot be described as a random sample of the entire habitat.

A carbon atom once present in a dinosaur's organic matter may return to carbon dioxide through decomposition and then cycle repeatedly through plant fixation and respiration. If it eventually enters a nutrient eaten by a person, carbon dioxide produced in cellular respiration may carry that atom out in the person's breath.

The nitrogen cycle: identify the form of nitrogen and the organisms' roles



Nitrification: nitrogen is oxidised in two steps by appropriate microorganisms. These steps generally require oxygen. Decomposers are not all nitrifying bacteria.

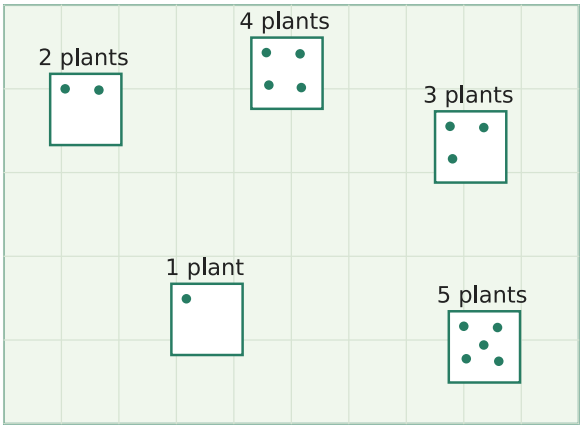
Plants generally cannot use atmospheric nitrogen directly to make proteins.

Animals obtain organic nitrogen mainly from food. Decomposition, nitrification, fixation and denitrification are distinct processes.

For every arrow, identify the starting and finishing nitrogen-containing substances and the process involved.

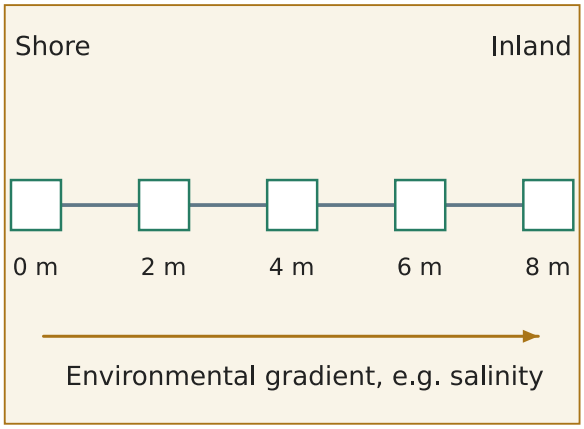
Quadrats and transects: estimate a mean or investigate an environmental gradient

Random quadrats: select positions using random coordinates



Quadrats are enlarged for clarity; positions are selected using random numbers.

Transect: sample at intervals along the environmental gradient



Start with the observations	Calculation and explanation
Area of each quadrat	0.50 × 0.50 = 0.25 m²
Five quadrats: 2, 4, 3, 1, 5 plants	15 plants in a total sampled area of 1.25 m²
Estimated density	15 ÷ 1.25 = 12 plants m⁻²

For a 200 m² site, the estimate is 2400 plants, provided the sample represents the whole site. Sampling error remains.

Random quadrats estimate average conditions across an area. Sampling by distance along a transect investigates an environmental gradient. The two methods choose positions for different purposes.

Check your understanding

1. A pyramid of biomass compares the _____ at a particular time, not the rate of production over an interval.
2. A carbon _____ can repeatedly move through the carbon cycle while retaining its identity; the same carbon dioxide _____ does not remain unchanged forever.

Check answers:

1. Standing biomass. 2. Atom; molecule.

How to recognise the problem Establish whether the subject is an individual, population or community. Identify the direction of matter and energy transfer for each arrow. Match a survey's sampling method to the distribution or abundance question being investigated.

Health and diseases

Chapter 6

Concept IV.a Personal health

Key ideas

① A person without a fever may still be chronically sleep-deprived, unable to function normally because of stress, or lacking supportive relationships. Health involves physical, mental and social well-being, rather than simply checking for a named disease.

② When assessing a lifestyle, connect each behaviour to how it affects health. An appropriate diet supplies materials for activity and repair, regular activity supports cardiovascular, respiratory and metabolic function, sleep and rest support recovery, and good hygiene reduces some infection risks. These factors often interact. One food or one exercise session cannot establish a person's overall health.

③ Public-health data can compare illness and deaths between groups, but population size and age structure must be considered. Ten cases among 100 people and twenty cases among 1000 people give different comparisons when expressed as case counts or proportions. Before interpreting health data, establish whether the quantity is a count, proportion, incidence rate or mortality rate.

One person may experience problems in different dimensions of health

Life situation	Main dimension	Effect that can be explained
Chronic lack of sleep	Physical and mental	Insufficient recovery; concentration and mood may also be affected
Persistent stress disrupts normal life	Mental	Absence of fever does not establish good overall health
Lack of relationships offering help and support	Social	Support may be harder to obtain when difficulties arise

Check your understanding

1. Alongside physical well-being, health includes _____ and _____ well-being.

Check answers:

1. Mental; social.

How to recognise the problem Identify the dimension of health first, then connect living conditions to specific biological or social effects. Check denominators before comparing data.

Concept IV.b Diseases and prevention

Key ideas

① Cholera pathogens can enter the digestive tract in contaminated food or water, whereas dengue viruses are transmitted by infected mosquitoes. Both are infectious diseases, but their transmission routes require different preventive measures. "Stay healthy" does not identify the route to interrupt. Influenza can spread through the respiratory route, hepatitis B through blood and certain body fluids, and tuberculosis through inhalation of particles carrying the bacterium. Organise explanations around the pathogen, its exit from one host and entry into another.

② Antibiotics can act on particular bacterial structures or processes, for example by interfering with cell-wall formation. Viruses lack the same cellular structures and independent metabolism, so an antibiotic cannot be assumed effective merely because both are pathogens. Different antimicrobial agents also have different ranges of action; judge them using the evidence given.

③ Resistance may arise from existing inherited differences or new mutations. When an antibiotic kills more susceptible bacteria, resistant bacteria are more likely to survive and reproduce, increasing the proportion resistant. Selection changes population composition; every bacterium does not actively redesign itself to acquire the same gene for survival. Resistance genes can also spread between bacteria. Antibiotic misuse may increase selection pressure and affect existing microbial communities.

④ Non-infectious diseases do not share a pathogen-transmission route of this kind. Cancer involves failure of normal cell-proliferation control, which may form tumours and, in some cases, invade other tissues. Coronary heart disease may restrict blood supply to heart muscle because coronary arteries narrow or become blocked. Smoking, diet, inheritance and other exposures can affect particular risks, but an association does not mean that everyone with a risk factor will develop the disease.

⑤ Diabetes involves abnormal blood-glucose regulation. Type 1 commonly involves destruction of insulin-producing cells and insufficient insulin. Type 2 commonly involves reduced cellular responsiveness to insulin, sometimes accompanied by inadequate secretion. Insulin treatment can help some patients lower blood glucose by changing cellular glucose use and storage. It does not chemically destroy all the sugar in the blood directly.

⑥ Disease prevention can act at several levels. Safe water supplies and sewage treatment reduce exposure to pathogens; vector control reduces transmission of particular diseases; and vaccination establishes targeted immune responses and memory in advance. Vaccination programmes can also reduce opportunities for pathogen transmission in a community. Their effects still depend on the pathogen, vaccine and population. No vaccine should be described as permanently effective against every infection.

Check your understanding

1. A rise in the proportion of resistant bacteria after antibiotic use can be explained by _____.
2. The immediate transport problem in coronary heart disease is restricted blood supply to the _____.

Check answers:

1. Natural selection. 2. Heart muscle / myocardium.

How to recognise the problem For infectious diseases, trace the transmission route first. For non-infectious diseases, identify the affected cells, organs or regulatory mechanism. Explain which step each preventive measure interrupts.

Concept IV.c Body defence mechanisms

Key ideas

① When a small splinter punctures a finger, it breaks the previously intact skin barrier. Blood clotting helps seal the wound. The area may become red, swollen, warm and painful, while white blood cells arrive and remove invading material. These responses do not wait for recognition of one particular strain and are part of non-specific defence.

② Intact skin provides a physical barrier. Mucus traps particles and microorganisms, and respiratory cilia move it towards a site from which it can be removed. Phagocytes surround and ingest pathogens, then break them down by intracellular digestion. Inflammation can increase local blood flow and vessel permeability, helping defensive components reach the affected area. Redness and swelling result from these changes and are not, by themselves, proof that defence has failed.

③ Specific immunity targets particular antigens. Appropriate B lymphocytes can be activated to proliferate and differentiate into antibody-secreting cells. Antibodies bind corresponding antigens, blocking their effects or assisting other defensive processes. T lymphocytes include types involved in coordination and elimination of infected cells; not all T cells secrete antibodies.

④ A response takes time to develop on first exposure to an antigen. Memory cells formed during it can produce a faster, stronger response on re-exposure to the same antigen. When comparing primary and secondary response curves, examine the initial delay, rate of rise, peak and duration together.

⑤ Active immunity develops through the person's own immune response to an antigen, such as after infection or vaccination. Passive immunity involves receiving ready-made antibodies, including certain antibodies transferred from mother

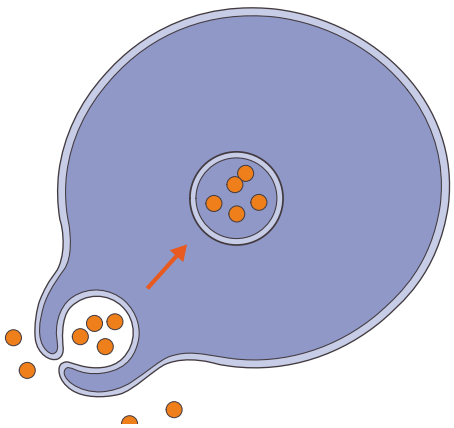
to fetus. Passive immunity can provide protection rapidly, but the antibodies gradually degrade. The transfer itself does not normally establish corresponding memory cells in the recipient.

⑥ Infectious diseases involve pathogens that can pass between people or through vectors. Non-infectious diseases such as coronary heart disease cannot be explained by the same transmission routes. For a causes-of-death chart, first classify the listed diseases, then compare them. Listing only the top five does not mean that other diseases do not exist. Sanitation and healthcare access affect disease outcomes at different stages. Water supply and sewage treatment influence pathogen exposure. Inadequate healthcare or unaffordable costs may hinder timely diagnosis and treatment. Each explanation needs its own mechanism, rather than repeating low income twice. Immune recognition is specific. If antigen structure changes, existing antibodies may no longer bind as effectively. Viral variation therefore affects the match between immune protection and the pathogen. Do not assign everyone's antibodies an exact one-year lifespan. ABO blood groups depend on A and B antigens on red blood cells. Group O red cells lack these two antigens and thus have broader compatibility in a model considering only ABO red-cell compatibility. This does not mean that group O whole blood or plasma can be given unconditionally to everyone. Blood has different components. Red cells carry antigens, while plasma can carry antibodies, so compatibility rules for one component cannot simply be copied to the other. Actual transfusions also involve antigens such as Rh and compatibility testing. Preserve the model's limits when reading past questions, and do not use historical donation intervals as current personal advice.

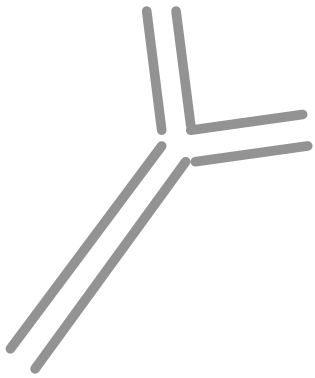
Even within group O, red cells and plasma contain different substances. Absence of A and B antigens on red cells does not imply absence of antibodies recognising A and B in the plasma.

Re-exposure to the same antigen: compare response times first

Feature	First exposure	Re-exposure to the same antigen
Onset	Usually a longer delay	Memory cells allow a faster response
Rise in corresponding antibodies	Slower	Usually faster and greater
Reason	The primary specific response must develop	Corresponding memory cells already exist
Scope	Specific to that antigen	Does not imply an equally rapid response to all other antigens



Phagocytosis: the cell membrane surrounds a foreign particle to form a vesicle, followed by intracellular processing. The arrow shows engulfment of the particle; it does not depict an antibody actively ingesting a pathogen.



A Y-shaped antibody. The tips of its two arms bind corresponding antigens. An antibody is a protein, not a white blood cell or phagocyte.

Check your understanding

1. Group O red blood cells lack ____ and ____ antigens on their surfaces.
2. 'Compatible red blood cells' does not automatically mean 'compatible ____'.

Check answers:

1. A; B. 2. Plasma / whole blood.

How to recognise the problem First locate the defence at the entry barrier, phagocytosis or a specific response. Then distinguish producing one's own antibodies from receiving ready-made antibodies. Compare response timing and strength for the same antigen.

Chapter 7

Cells and molecules: question types and practice

I.a Molecules of life

First read the explanations and diagrams in Concept I.a, then work through the question types in this section. Each worked example retains the complete original question and explanation. The subsequent exercises require progressively more integration of information, based on the demands of the whole question.

Type 1 Explain biological molecules through composition, structure and function

Degree of integration ★★★☆☆

Key ideas

① Break a DNA nucleotide into sugar, phosphate and a base, and a protein into amino acids, to avoid treating a gene as a protein. Starch, glycogen and cellulose all relate to glucose, but their linkages and functions differ.

② Identify substances in food tests through the reagent, treatment and positive result: iodine solution tests for starch; Benedict's solution with heating tests for reducing sugars. If the reaction mixture contains an enzyme, a protein test may also be positive.

③ When explaining protein function, connect its specific conformation to its binding target or role. Every example in an essay must complete this causal link.

How to recognise the problem For composition, identify the basic units. For function, identify a specific cellular activity. For test results, list all substances already present when the test begins.

Example 1 [HKDSE Biology 2016 Paper 1A Q4]

Which of the following parts of the nucleotide make up the backbone of a polynucleotide strand?

A. sugar and base
B. sugar and phosphate
C. base and phosphate
D. base, sugar and phosphate

Solution Answer: B

Following the outside of a polynucleotide chain, you encounter alternating pentose sugars and phosphate groups. The bases project inwards from the sugars and take part in complementary base pairing. The backbone therefore consists of sugar and phosphate, so choose B. Distinguish the three components of a nucleotide from the two components forming the backbone of the chain.

Method: Distinguish the constituent units first, then connect structure with use.

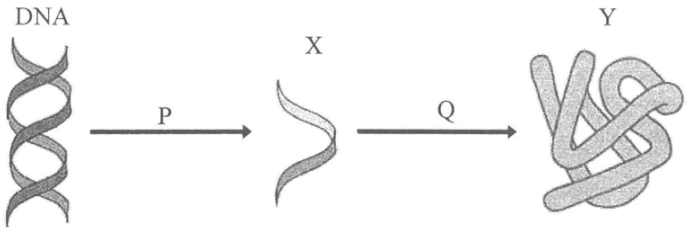
Examiner's comment (source page(s) 1)

Sugar and phosphate alternate along the DNA backbone; a nucleotide also contains a nitrogenous base. First distinguish a particular part of the structure from the complete repeating unit.

Marking reference: HKDSE Biology 2016 Paper 1A Q4, official marking scheme, source page(s) 1.

Example 2 [HKDSE Biology 2021 Paper 1A Q2]

Directions: Questions 1 to 3 refer to the diagram below, which shows the flow of gene expression within a cell:



Y could be

(1) an enzyme.
(2) a hormone.
(3) an antibody.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

Solution Answer: D

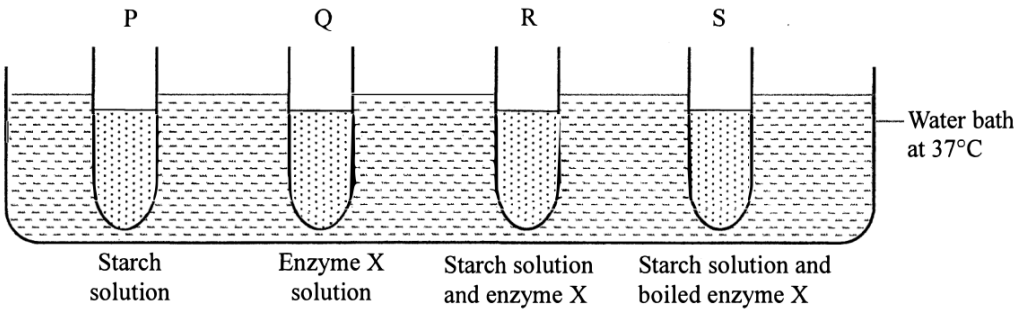
Y is a protein formed when the polypeptide produced by translation folds. Enzymes can be proteins, hormones such as insulin are proteins, and antibodies are also proteins. All three could therefore be Y. The question says "could be"; this does not mean that all hormones are proteins, since steroid hormones are a different class of substances. Choose D.

Method: Distinguish the constituent units first, then connect structure with use.

Marking reference: HKDSE Biology 2021 Paper 1A Q2, official marking scheme, source page(s) 1.

Example 3 [HKDSE Biology 2017 Paper 1A Q3]

Directions: Questions 2 to 4 refer to the diagram below, which shows four test tubes prepared by a student to investigate the action of a starch-digesting enzyme X:



The student conducted some tests on the content of each test tube at the beginning and after 30 minutes. Which of the following correctly shows the results of the tests for tube R at the beginning?

	Benedict's test	***Iodine test***	***Test for proteins***
A.	negative	positive	positive
B.	negative	positive	negative
C.	positive	negative	negative
D.	positive	negative	positive

Solution Answer: A

Initially, R contains starch and enzyme X, with no detectable starch digestion products yet. Starch gives a positive iodine test. The enzyme is a protein, so the protein test is positive. Under the conditions of this experiment, Benedict's test is negative. The results are therefore negative, positive and positive, respectively: choose A. Do not confuse "an enzyme is not a food" with "an enzyme is not a protein".

Method: Distinguish the constituent units first, then connect structure with use.

Examiner's comment (source page(s) 2)

At the start, little starch has been digested, so the iodine test is still positive whereas the reducing-sugar test need not be positive. Enzymes are proteins, so the protein test must also be considered.

Marking reference: HKDSE Biology 2017 Paper 1A Q3, official marking scheme, source page(s) 1.

Example 4 [HKDSE Biology 2013 Paper 1B Q10]

For the following question, candidates are required to present their answer in essay form. Criteria for marking will include relevant content, logical presentation and clarity of expression.

1. Proteins serve different functions in our body and their functional role is closely related to their conformation (shape). Describe how protein molecules can have different conformations and explain how the different conformations enable them to carry out different functions. (11 marks)

Solution Essay; original allocation: 11 mark(s)

Method: Distinguish the constituent units first, then connect structure with use.

Proteins consist of amino acids joined by peptide bonds into polypeptide chains. Different proteins have different types, numbers and sequences of amino acids. These sequences are encoded by the base sequences of the corresponding genes. Interactions between amino acids cause a polypeptide chain to fold into a particular three-dimensional conformation. Some proteins also contain several associated polypeptide chains, allowing a variety of shapes and binding sites to form. These shapes are suited to particular functions. For example, an enzyme's active site is complementary to a particular substrate, allowing the enzyme to bind it and catalyse a specific metabolic reaction. A neurotransmitter receptor has an appropriate binding site; binding of the neurotransmitter can trigger a response in the postsynaptic cell. Antibody binding sites recognise specific antigens and help the body defend itself against pathogens. Haemoglobin has sites that bind oxygen, enabling oxygen transport. Thus, a protein's sequence determines its folding and binding properties, and different binding properties suit proteins to catalysis, signalling, defence and transport.

The official scheme allows up to 3 marks for how conformation arises, up to 5 marks for how conformation enables function, and up to 3 marks for organisation and expression. The essay must link binding sites in the examples to their specific functions; simply listing protein names is insufficient. Do not claim that all proteins have the active sites characteristic of enzymes.

Examiner's comment (source page(s) 3)

The essay must link amino acid sequence, protein conformation and function. Describing translation alone or merely listing functions is insufficient.

Marking reference: HKDSE Biology 2013 Paper 1B Q10, official marking scheme, source page(s) 6.

Practice

1. [HKDSE Biology 2013 Paper 1A Q3]

⟵ *Hint: Distinguish the constituent units first, then connect structure with use.*

Directions: Questions 1 to 3 refer to the table below, which shows the relative amounts of mitochondria, chloroplasts and endoplasmic reticulum in four cell types P, Q, R and S:

Cell type	*Relative amount of the sub-cellular structure*		
	Mitochondrion	*Chloroplast*	*Endoplasmic reticulum*
P	+	++	+
Q	+++	-	+
R	+++	-	+++
S	+	-	+

Key: number of '+' indicates the relative amount of the sub-cellular structure
'-' indicates the absence of the sub-cellular structure

Which of the following carbohydrate(s) is/are likely to be found in cell type P?

(1) starch
(2) glucose
(3) glycogen

A. (1) only
B. (2) only
C. (1) and (2) only
D. (2) and (3) only

2. [HKDSE Biology 2016 Paper 1A Q3]

⟵ *Hint: Distinguish the constituent units first, then connect structure with use.*

In which of the following pairs of carbohydrates can Benedict's test be used to distinguish the two carbohydrates from one another?

(1) sucrose and starch
(2) sucrose and maltose
(3) glucose and maltose
(4) glucose and starch

A. (1) and (3) only
B. (1) and (4) only
C. (2) and (3) only
D. (2) and (4) only

3. [HKDSE Biology 2024 Paper 1A Q1]

⟵ *Hint: Distinguish the constituent units first, then connect structure with use.*

Fertilisers usually contain nitrogen and phosphorous compounds. They can be used by plants for the synthesis of

(1) cell walls.
(2) chlorophyll.
(3) cell membranes.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

4. [HKDSE Biology 2025 Paper 1A Q3 (English translation)]

⟵ *Hint: Distinguish the constituent units first, then connect structure with use.*

Plants can use nitrates to synthesise components of _____.

(1) chromosomes
(2) endoplasmic reticulum
(3) thylakoid membranes

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

5. [HKDSE Biology Sample Paper Paper 1A Q5]
Hint: Distinguish the constituent units first, then connect structure with use.

Which of the following are made up of proteins?

(1) finger nails
(2) chromosomes
(3) amylase

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

6. [HKDSE Biology 2012 Paper 1A Q2]
Hint: Distinguish the constituent units first, then connect structure with use.

Plants carry out photosynthesis to produce glucose which is required for the formation of

(1) cellulose.
(2) protein.
(3) starch.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

I.b Cell organisation and structure

First read the explanations and diagrams in Concept I.b, then work through the question types in this section. Each worked example retains the complete original question and explanation. The subsequent exercises require progressively more integration of information, based on the demands of the whole question.

Type 1 Use microscopes and identify visible structures

Degree of integration ★★☆☆☆

Key ideas

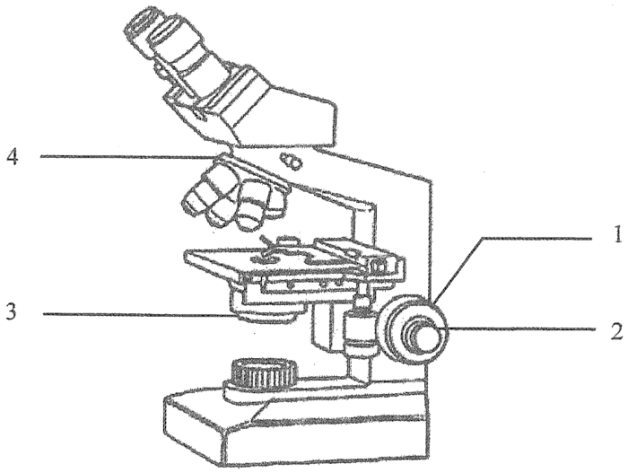
① Locate the target under low power and move it to the centre of the field before switching to high power. Usually use fine adjustment to sharpen the image. The field of view becomes smaller at higher magnification; the original cell has not grown.

② Details not visible in a photograph are not direct evidence. For example, seeing a nucleus under a light microscope does not mean that the DNA double helix can be resolved.

How to recognise the problem First identify whether the question concerns operating sequence, image orientation or recognisable structures; each uses different evidence.

Example 1 [HKDSE Biology 2015 Paper 1A Q1]

Which of the following parts of the microscope should be adjusted to obtain a clear and sharp image when you switch from low-magnification to high-magnification observation?



A. 1 and 4 only
B. 2 and 3 only
C. 1, 3 and 4 only
D. 2, 3 and 4 only

Solution Answer: D

Structure 4 is the objective lens; a high-power objective is needed to switch to high-power viewing. Structure 2 is the fine-adjustment knob, which makes small focusing adjustments to sharpen the image. Structure 3 is the diaphragm, which adjusts the amount of light entering and makes the darker high-power field clear and bright. These adjustments address magnification, focus and brightness, respectively, so the required structures are 2, 3 and 4. Choose D.

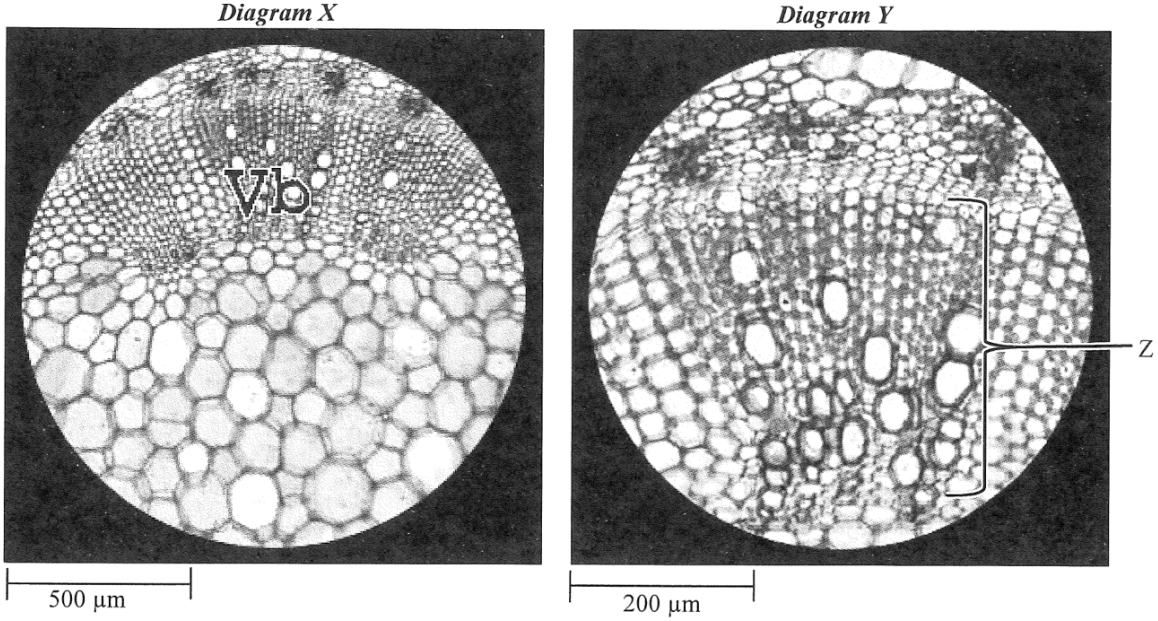
Method: First distinguish operation, image orientation and visible structures.

Marking reference: HKDSE Biology 2015 Paper 1A Q1, official marking scheme, source page(s) 1.

Example 2 [HKDSE Biology 2020 Paper 1A Q22]

Directions: Questions 22 to 24 refer to the photomicrographs below, which show the stem section of a plant observed under a microscope. Diagram Y shows a higher magnification of the vascular bundle (Vb) in Diagram X:

Diagram X ***Diagram Y***



Key: Vb = vascular bundle

Which of the following combinations shows the correct steps for using the microscope in order to obtain the image in Diagram Y from that of Diagram X?

	Step 1	*Step 2*
A.	Move the slide towards the observer so that Vb is in the centre of the field of view.	Change the objective from 4X to 10X and adjust the focus.
B.	Change the objective from 10X to 40X and adjust the focus.	Move the slide towards the observer so that Vb is in the centre of the field of view.
C.	Move the slide away from the observer so that Vb is in the centre of the field of view.	Change the objective from 4X to 10X and adjust the focus.
D.	Change the objective from 10X to 40X and adjust the focus.	Move the slide away from the observer so that Vb is in the centre of the field of view.

Solution **Answer: C**

Method: First distinguish operation, image orientation and visible structures.

First move vascular bundle Vb to the centre of the field of view, then switch to high power. Switching first reduces the field of view, so a target away from the centre may disappear. In image X, Vb lies towards the top. To move the image downwards, move the slide in the opposite direction, away from the observer.

The scale bars have similar lengths in the two images but represent 500 µm and 200 µm, respectively. Magnification has therefore increased by about 500÷200 = 2.5 times, corresponding to a change of objective from 4× to 10×. C matches the movement direction, sequence of operations and magnification change.

Marking reference: HKDSE Biology 2020 Paper 1A Q22, official marking scheme, source page(s) 1.

Practice

1. [HKDSE Biology 2014 Paper 1A Q5]

⟵ *Hint: First distinguish operation, image orientation and visible structures.*

Directions: Questions 3 to 5 refer to the following study:
A student wants to use an ordinary light microscope to observe the binary fission of a photosynthesizing protist under high magnification. A temporary mount of the protist is placed on the stage of the microscope.

Which of the following structures would be observable in the above study?

A. Ribosome
B. Chloroplast
C. Mitochondrion
D. Endoplasmic reticulum

2. [HKDSE Biology 2014 Paper 1A Q3]

⟵ *Hint: First distinguish operation, image orientation and visible structures.*

Directions: Questions 3 to 5 refer to the following study:
A student wants to use an ordinary light microscope to observe the binary fission of a photosynthesizing protist under high magnification. A temporary mount of the protist is placed on the stage of the microscope.

Below are some steps in using a light microscope:

(1) Focus with 10X objective
(2) Focus with 40X objective
(3) Search the field with 10X objective
(4) Search the field with 40X objective
(5) Move the slide until the protist is located in the centre of the field
(6) Adjust light intensity if necessary

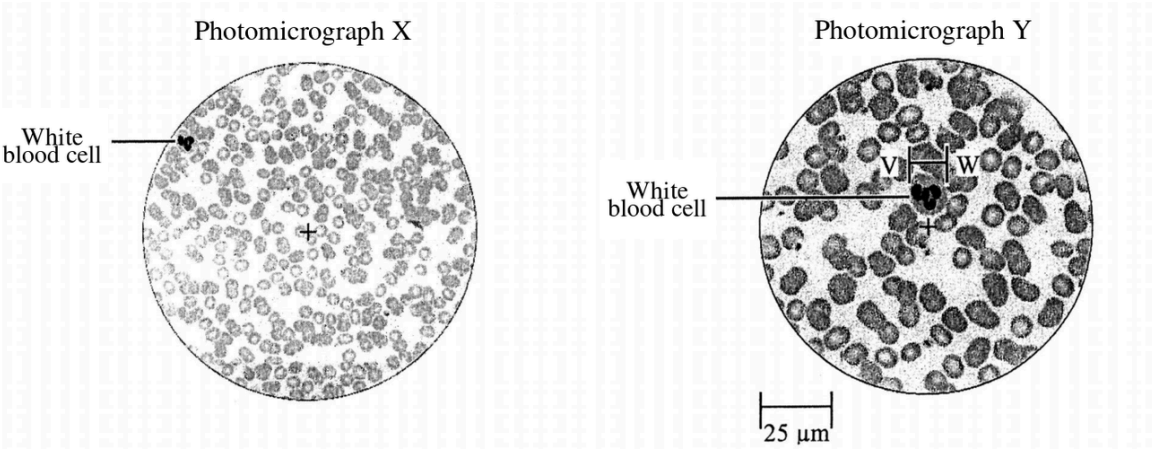
Which of the following is the most reasonable sequence of steps for the above study?

A. (1), (3), (5), (6)
B. (2), (6), (4), (5)
C. (1), (2), (4), (5), (6)
D. (1), (3), (5), (2), (6)

3. [HKDSE Biology 2025 Paper 1A Q1 (English translation)]

⟵ *Hint: First distinguish operation, image orientation and visible structures.*

Directions: Refer to photomicrographs X and Y below to answer Questions 1 and 2. They show a human blood smear viewed under a light microscope. Photomicrograph Y shows the white blood cell in photomicrograph X at a higher magnification.



Which combination below describes the correct steps for operating the microscope to obtain the image shown in photomicrograph Y from that shown in photomicrograph X?

	Step 1	Step 2
A.	Switch to an objective lens with a higher magnification and adjust the focus.	Move the slide away from the observer, then to the left, to place the white blood cell at the centre of the field of view.
B.	Switch to an objective lens with a higher magnification and adjust the focus.	Move the slide towards the observer, then to the right, to place the white blood cell at the centre of the field of view.
C.	Move the slide away from the observer, then to the left, to place the white blood cell at the centre of the field of view.	Switch to an objective lens with a higher magnification and adjust the focus.
D.	Move the slide towards the observer, then to the right, to place the white blood cell at the centre of the field of view.	Switch to an objective lens with a higher magnification and adjust the focus.

Type 2 Calculate size from scale bars, fields of view and images

Degree of integration ★★☆☆☆

Key ideas

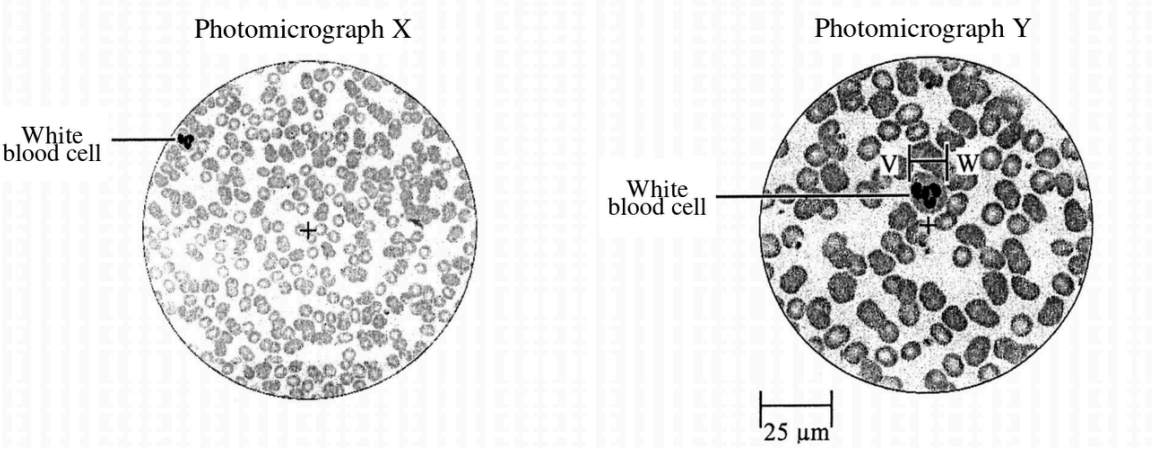
① If a 10 μm scale bar measures 20 mm in a photograph and the cell measures 60 mm, the actual cell length is 60 ÷ 20 × 10 = 30 μm. Both measurements must be taken from the same photograph.

② To estimate density, first calculate the field-of-view area, then divide the number of individuals by that area. Doubling the radius quadruples the area; do not merely double the count.

How to recognise the problem First write actual length = image length ÷ image scale-bar length × scale-bar value, then make the mm and μm units consistent.

Example 1 [HKDSE Biology 2025 Paper 1A Q2 (English translation)]

Directions: Refer to photomicrographs X and Y below to answer Questions 1 and 2. They show a human blood smear viewed under a light microscope. Photomicrograph Y shows the white blood cell in photomicrograph X at a higher magnification.



What is the actual diameter of the white blood cell in photomicrograph Y (i.e. VW)?

A. 12.5 μm
B. 20.0 μm
C. 50.0 μm
D. 0.5 cm

Solution **Answer: A**

The image length of WX is about half the length of the 25 µm scale bar. The cell diameter is approximately 0.5×25 = 12.5 µm: choose A. Neither 20.0 µm nor 50.0 µm matches the length ratio in the photograph. The value 0.5 cm confuses a measurement on the image with the cell's actual size.

Method: Use the scale bar to calculate actual length, then make the length units consistent.

Key knowledge

Actual length = target length in the photograph ÷ scale-bar length in the photograph × actual length represented by the scale bar.

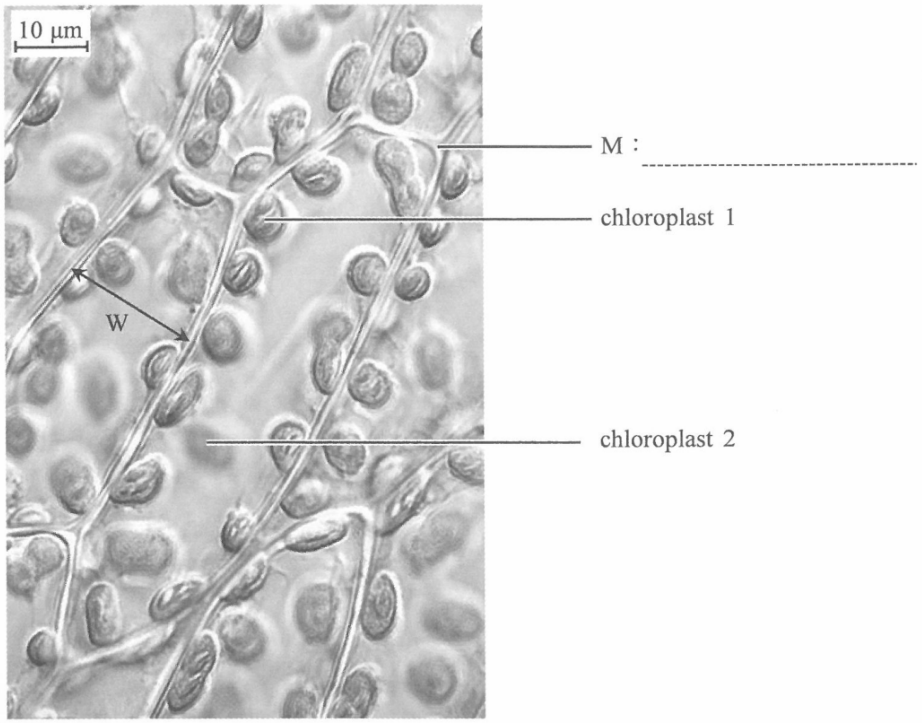
Common error

When the photograph is enlarged on a screen or paper, both the target and scale bar enlarge together, so their length ratio remains usable.

Marking reference: HKDSE Biology 2025 Paper 1A Q2, official marking scheme, source page(s) 51.

Example 2 [HKDSE Biology 2022 Paper 1B Q3]

The photomicrograph below shows some unstained plant cells:



(a) Label structure M. (1 mark)

(b) What is the actual length of W shown in the photomicrograph? (1 mark)

(c) Chloroplast 1 appears sharp in this photomicrograph while chloroplast 2 appears blurred. To obtain a sharper image of chloroplast 2, how should you operate the microscope? (1 mark)

(d) Some structures of chloroplast cannot be distinguished in this photomicrograph. State ***one*** of these structures. (1 mark)

(e) Give ***one*** equipment that can be used to observe the structure stated in (d). (1 mark)

Solution **a; original allocation: 1 mark(s)**

M: cell wall.

M points to the clearly visible outer boundary between adjacent plant cells. A plant cell wall is relatively thick and has a fixed shape, so it can be identified in this light micrograph.

Method: Use the scale bar to calculate actual length, then make the length units consistent.

b; original allocation: 1 mark(s)

Approximately 19 µm (18–20 µm is acceptable).

Use the same ruler to measure W and the 10 µm scale bar on the image: actual W = (image length of W ÷ image length of scale bar) × 10 µm. W is about 1.9 times the scale-bar length, giving approximately 19 µm. Include the micrometre unit.

c; original allocation: 1 mark(s)

Turn the fine-adjustment knob to focus the image of chloroplast 2.

The two chloroplasts lie at different depths. A slight change in the distance between the objective and specimen brings the plane containing chloroplast 2 into focus. There is no need to switch to a higher-power objective first.

d; original allocation: 1 mark(s)

Thylakoid membranes (grana or the chloroplast's inner and outer membranes are also acceptable).

Seeing the whole chloroplast does not mean that all its fine internal membrane structures can be resolved. Thylakoid membranes are below the effective resolving limit of this light micrograph.

e; original allocation: 1 mark(s)

Electron microscope.

An electron microscope has higher resolving power and can resolve ultrastructures such as membranes and grana inside chloroplasts. Merely magnifying a light-microscope image cannot recover detail that was not originally resolved.

Examiner's comment (source page(s) 4)

Calculate W using the scale bar and include a unit. Focus a blurred image first: increased magnification cannot replace focusing. When asked for structures inside chloroplasts, do not answer mitochondria or endoplasmic reticulum.

Marking reference: HKDSE Biology 2022 Paper 1B Q3, official marking scheme, source page(s) 3.

Practice

1. [HKDSE Biology 2016 Paper 1A Q12]

Hint: Use the scale bar to calculate actual length, then make the length units consistent.

A student wants to estimate the stomatal density of the upper and lower epidermis of a leaf using a microscope. Which of the following combinations correctly shows the magnification that should be used and the reason?

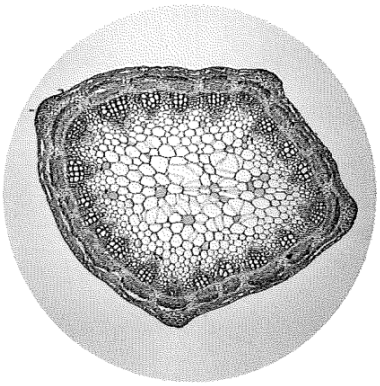
	Magnification	***Reason***
A.	low magnification	show a larger field of view
B.	low magnification	give a brighter image
C.	high magnification	show more cellular details
D.	high magnification	give a clearer image

2. [HKDSE Biology 2023 Paper 1A Q13]

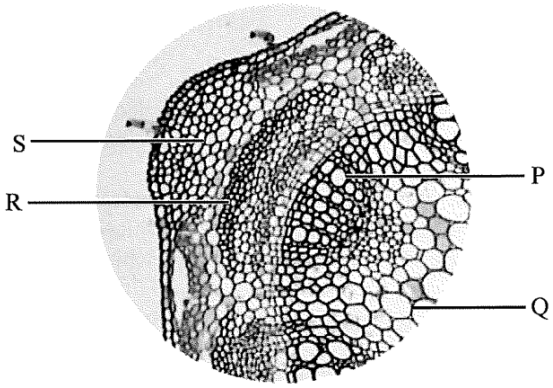
Hint: Use the scale bar to calculate actual length, then make the length units consistent.

Directions: Questions 12 to 14 refer to the photomicrographs below, which show the images of the cross section of a certain part of plant viewed under different magnifications:

Low magnification



High magnification



The images above are shown to scale. Which of the following combinations correctly matches the eyepiece and objective used for the two magnifications (i.e. eyepiece x objective)?

	Low magnification	*High magnification*
A.	10X x 4X	10X x 10X
B.	10X x 4X	10X x 25X
C.	10X x 4X	10X x 40X
D.	10X x 10X	10X x 40X

Type 3 Interpret membrane structure using evidence

Degree of integration ★★★☆☆

Key ideas

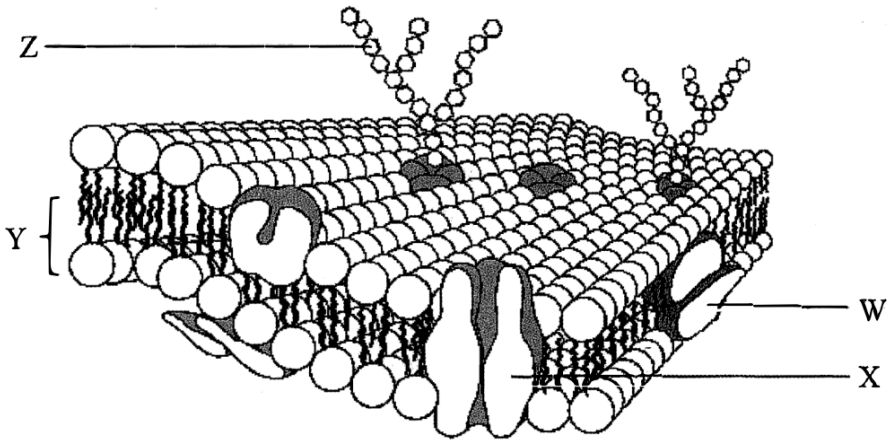
① A phospholipid has a hydrophilic head and hydrophobic tails. Water occurs on both sides of the membrane, so both layers' heads face water and the tails face the membrane interior. Proteins embedded in the bilayer can participate in transport, signalling or catalysis.

② Gradual mixing of labelled proteins after cell fusion supports lateral movement of proteins. It does not directly show that all membrane proteins have the same function.

How to recognise the problem Identify the feature actually shown by the diagram or experiment, then connect that evidence to a specific position or activity in the model.

Example 1 [HKDSE Biology 2016 Paper 1A Q1]

Directions: Questions 1 and 2 refer to the schematic diagram below, which shows the structure of a cell membrane:



Which of the following molecules contributes to the fluidity of the cell membrane?

A. W
B. X
C. Y
D. Z

Solution Answer: C

First identify the bracket labelled Y: it marks the bilayer of phospholipid molecules. Phospholipids are not rigidly fixed in position; they can move laterally within the membrane, giving it fluidity. Therefore choose Y (C). X is a transmembrane protein and Z is an external carbohydrate chain. The fact that proteins can also move must not lead you to misidentify the main bilayer component labelled in the diagram.

Method: Connect experimental evidence to a specific feature of the membrane model.

Marking reference: HKDSE Biology 2016 Paper 1A Q1, official marking scheme, source page(s) 1.

Example 2 [HKDSE Biology 2015 Paper 1B Q6]

The table below lists some historical developments about the discovery of the structure of cell membrane:

Year	*Scientists*	*Historical events*
1895	Overton	Discovered that lipid-soluble substances could penetrate cells easily
1917	Langmuir	Discovered that the major component of cell membrane exhibited both water-loving and water-hating properties
1925	Gorter & Grendal	Extracted lipids from the cell membrane of red blood cells and spread the lipids in a single layer on a water surface; found that the area of the layer was double the surface area of the cell membrane
1972	Singer & Nicolson	Proposed the Fluid Mosaic Model to explain the structure of cell membranes

(a) What is the major component noted by Overton and Langmuir? (1 mark)

(b) Gorter and Grendal proposed that the major component identified in (a) existed as a bilayer (Bilayer Model). With reference to the observation of Langmuir, suggest how this major component is oriented and arranged in the cell membrane. Explain your answer. (3 marks)

(c) (i) The Bilayer Model proposed by Gorter and Grendal did not mention another major component of the cell membrane. What is this component? (1 mark)

(ii) With reference to the Fluid Mosaic Model, briefly describe the orientation of this component in the cell membrane. (2 marks)

(d) Models are often used by scientists to explain their findings. Complete the following table to elaborate on the aspects of the nature of science involved in the use of scientific models. (2 marks)

Nature of science	*Elaboration*
Science is evidence based	
	Models are used to simulate an invisible structure or illustrate a theory.

Solution (a); original allocation: 1 mark(s)

Phospholipids.

The table describes a component with both hydrophilic and hydrophobic properties, matching the hydrophilic heads and hydrophobic tails of phospholipids.

Method: Connect experimental evidence to a specific feature of the membrane model.

(b); original allocation: 3 mark(s)

Phospholipids form a bilayer with their hydrophilic heads facing the aqueous solutions inside and outside the cell, and their hydrophobic tails facing each other towards the bilayer's interior.

Water is the main solvent in both intracellular and extracellular fluids. The hydrophilic heads can therefore contact water on either side, while the hydrophobic tails avoid water and gather in the membrane's centre. Link orientation to the environments on both sides, rather than merely repeating the word "bilayer".

(c)(i); original allocation: 1 mark(s)

Proteins.

The phospholipid bilayer alone does not fully describe cell-membrane structure. The membrane also contains proteins involved in transport, reception of signals and other functions.

(c)(ii); original allocation: 2 mark(s)

Proteins are scattered within or on the surface of the phospholipid bilayer in an asymmetric mosaic arrangement.

"Mosaic" in the fluid mosaic model means that proteins are dispersed in a lipid background: some span the membrane and others lie on one side. It does not mean a continuous, orderly protein layer covering each face of the membrane.

(d); original allocation: 2 mark(s)

Evidence-based reasoning: scientific models are built from observations and experimental data and may be revised in the light of new evidence. Using models to represent structures that cannot be seen directly also illustrates the role of imagination and creativity in science. Experiments on lipid properties and surface area in the table supported the bilayer idea, while later evidence led to new models. Models are constrained by evidence but also use reasonable imaginative representations of structures that cannot be directly observed. These two features are compatible.

Examiner's comment (source page(s) 3)

Phospholipid hydrophilic heads face the aqueous solutions on both sides; hydrophobic tails face the membrane's interior. In explaining the development of models, state clearly how new evidence changed the description of protein positions and fluidity.

Marking reference: HKDSE Biology 2015 Paper 1B Q6, official marking scheme, source page(s) 3.

Practice

1. [HKDSE Biology 2013 Paper 1A Q1]

Hint: Connect experimental evidence to a specific feature of the membrane model.

Directions: Questions 1 to 3 refer to the table below, which shows the relative amounts of mitochondria, chloroplasts and endoplasmic reticulum in four cell types P, Q, R and S:

Cell type	*Relative amount of the sub-cellular structure*		
	Mitochondrion	*Chloroplast*	*Endoplasmic reticulum*
P	+	++	+
Q	+++	-	+
R	+++	-	+++
S	+	-	+

Key: number of '+' indicates the relative amount of the sub-cellular structure
'-' indicates the absence of the sub-cellular structure

Which cell type is found in the lining of the air sacs in the lungs?

A. P
B. Q
C. R
D. S

2. [HKDSE Biology 2020 Paper 1A Q1]

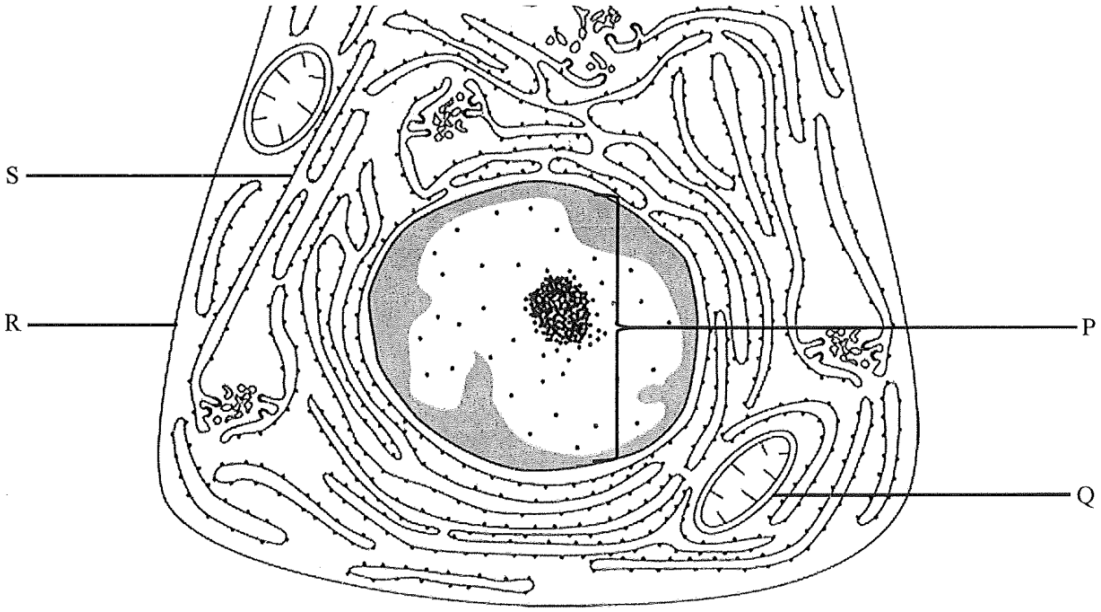
Hint: Connect experimental evidence to a specific feature of the membrane model.

Which of the following sub-cellular structures can be found in a prokaryotic cell?

A. cell wall, ribosome, cell membrane
B. ribosome, cell membrane, chloroplast
C. cell wall, cell membrane, mitochondria
D. cell membrane, chloroplast, mitochondria

3. [HKDSE Biology 2023 Paper 1A Q1]
← Hint: Connect experimental evidence to a specific feature of the membrane model.

Directions: Questions 1 to 3 refer to the schematic diagram below, which shows part of a pancreas cell:



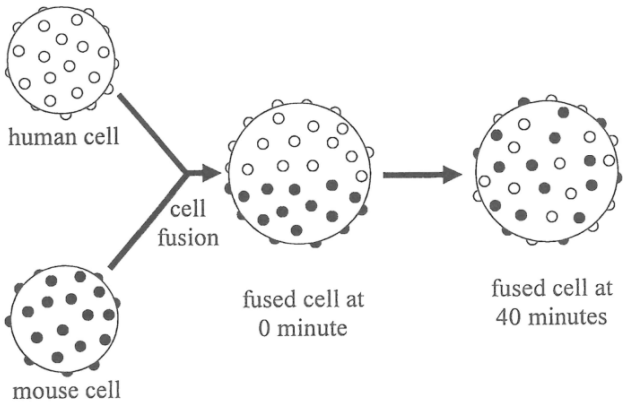
Which of the following cellular components can also be found in a prokaryotic cell?

A. P
B. Q
C. R
D. S

4. [HKDSE Biology 2024 Paper 1A Q3]
← Hint: Connect experimental evidence to a specific feature of the membrane model.

The schematic diagram below shows an investigation into cell membranes. The cell surface proteins of a human cell were labelled with a red dye while those of a mouse cell were labelled with a green dye. The two cells were then fused. The distribution of the cell surface proteins at 0 minute and 40 minutes are shown below:

Key:
○ surface protein stained red
● surface protein stained green



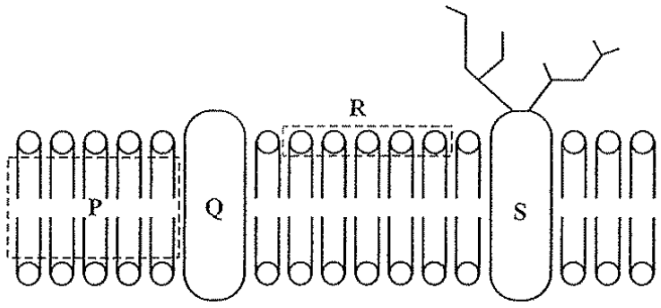
Which of the following properties of the cell membrane can be used to explain the change in the distribution of the surface proteins of the fused cell shown in this investigation?

(1) A cell membrane is fluid in nature.
(2) A cell membrane is differentially permeable.
(3) A cell membrane is an asymmetric structure.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

5. [HKDSE Biology Sample Paper Paper 1A Q3]
Hint: Connect experimental evidence to a specific feature of the membrane model.

The diagram below shows the fluid mosaic model of the cell membrane:



Which labelled part would restrict the movement of ions across the membrane?

A. P
B. Q
C. R
D. S

6. [HKDSE Biology 2023 Paper 1A Q4]
Hint: Connect experimental evidence to a specific feature of the membrane model.

Which of the following processes ***does not*** involve membrane proteins?

A. transcription of DNA to form mRNA
B. absorption of minerals by root hair cells
C. digestion of carbohydrates in the small intestine
D. transmission of nerve impulse between two neurones

Type 4 Relate organelle structure to functions and cooperation

Degree of integration ★★★☆☆

Key ideas

① A protein-secreting cell first expresses the gene, then synthesises the polypeptide on ribosomes. The endoplasmic reticulum and Golgi apparatus process and transport it before vesicles release it. This is a material pathway, so separate statements that the nucleus controls activity and the endoplasmic reticulum makes protein are insufficient.

② Other questions ask whether a cell can perform an activity after losing a structure. Infer the limitation from the missing step.

How to recognise the problem For cooperation, coordinated functions or loss of a structure, connect the product of one step to the next rather than merely recalling organelle names.

Example 1 [HKDSE Biology 2013 Paper 1A Q2]

Directions: Questions 1 to 3 refer to the table below, which shows the relative amounts of mitochondria, chloroplasts and endoplasmic reticulum in four cell types P, Q, R and S:

Cell type	*Relative amount of the sub-cellular structure*		
	Mitochondrion	*Chloroplast*	*Endoplasmic reticulum*
P	+	++	+
Q	+++	-	+
R	+++	-	+++
S	+	-	+

Key: number of '+' indicates the relative amount of the sub-cellular structure
'-' indicates the absence of the sub-cellular structure

Which cell type would you expect to be insulin-producing cells in the pancreas?

A. P
B. Q
C. R
D. S

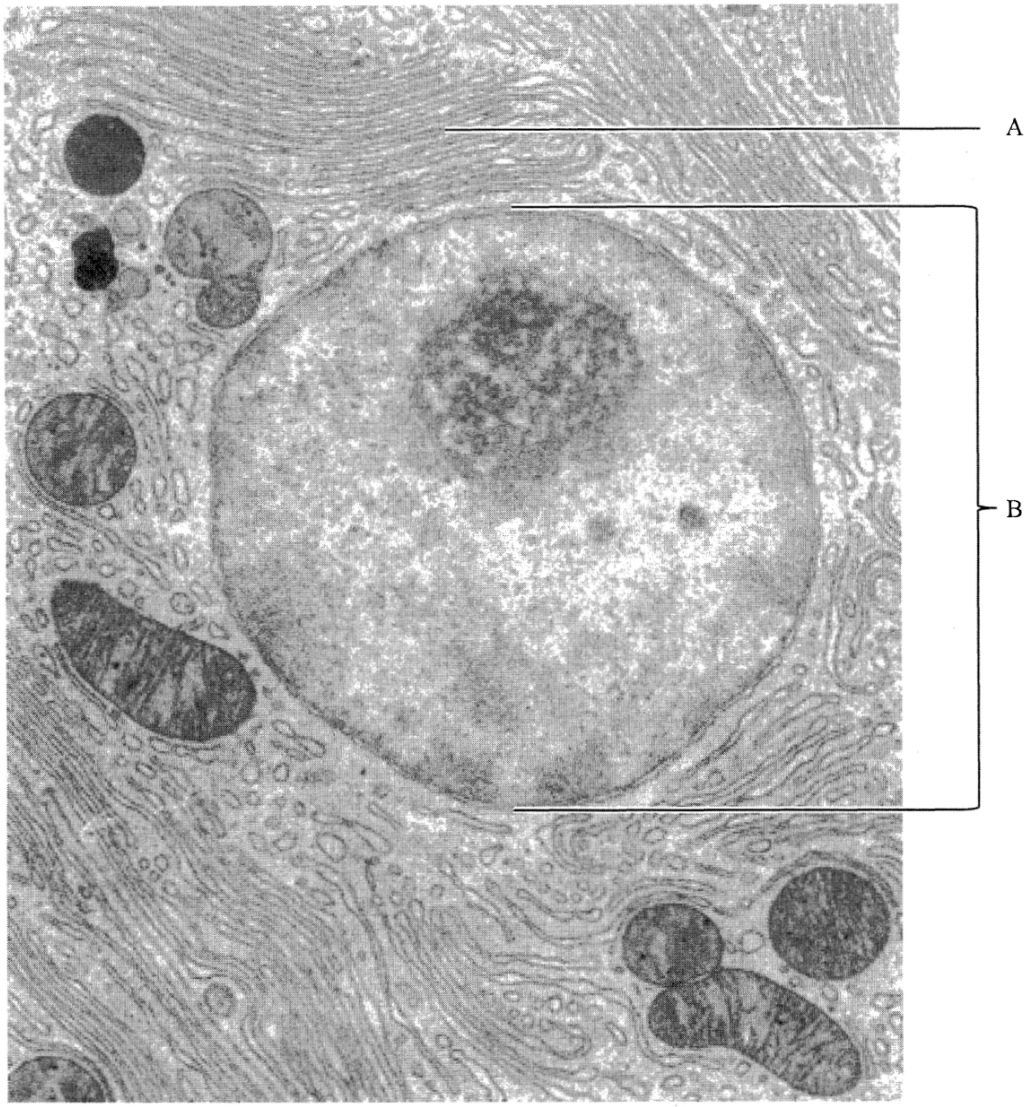
Solution **Answer: C**

Insulin is a secreted protein. Cells producing it need abundant rough endoplasmic reticulum for ribosome-associated protein synthesis and processing, as well as mitochondria to supply energy. R in the table has both abundant endoplasmic reticulum and many mitochondria, so choose C.

Method: Trace the product's destination, then connect the organelles' roles.

Marking reference: HKDSE Biology 2013 Paper 1A Q2, official marking scheme, source page(s) 1.

Example 2 [HKDSE Biology 2017 Paper 1B Q4]



The electron micrograph on the opposite page shows some structures of a human cell.

(a) Label A and B. (2 marks)

A: _____ B: _____

(b) Which stage of the cell cycle is shown in this photomicrograph? Give a reason to support your answer. (2 marks)

(c) The cell was obtained from the pancreas. How do A and B work together such that this cell can perform its function? (4 marks)

Solution (a); original allocation: 2 mark(s)

A: endoplasmic reticulum; B: nucleus.

A is the membranous network around the nucleus, showing features of rough endoplasmic reticulum in this image. B is enclosed by a nuclear membrane and contains genetic material. Follow the endpoints of the label lines; do not confuse these structures with mitochondria simply because mitochondria also have folded membranes.

(b); original allocation: 2 mark(s)

Interphase; DNA is in the form of loosely arranged chromatin, rather than condensed into clearly visible chromosomes.

Active metabolism, gene expression and growth continue during interphase. The intact organisation of the nucleus and absence of separating chromosomes support this identification. "Chromosomes are not visible" does not mean that the cell has no DNA.

(c); original allocation: 4 mark(s)

Genes in the nucleus are first transcribed into mRNA. After leaving the nucleus, mRNA is translated by ribosomes attached to the rough endoplasmic reticulum, producing protein hormones or digestive enzymes for secretion.

This cooperation links information to function: B stores the relevant genes → transcription produces mRNA → mRNA enters the cytoplasm → ribosomes on A synthesise proteins. Proteins are then processed and transported through the membrane system. Insulin and many digestive enzymes secreted by the pancreas are proteins, but do not claim that all hormones are proteins.

Method: Trace the product's destination, then connect the organelles' roles.

Examiner's comment (source page(s) 3)

Identify the cell-cycle stage using evidence visible in the photograph. Explain cooperation between pancreatic-cell structures by linking gene transcription, RNA movement to the cytoplasm, protein synthesis and secretion in the correct sequence.

Marking reference: HKDSE Biology 2017 Paper 1B Q4, official marking scheme, source page(s) 3.

Practice

1. [HKDSE Biology 2012 Paper 1A Q1]

Hint: Trace the product's destination, then connect the organelles' roles.

Which of the following tissue types has the greatest number of mitochondria?

A. the wall of an air sac
B. the wall of a capillary
C. the inner wall of a lymph vessel
D. the inner wall of the small intestine

2. [HKDSE Biology 2014 Paper 1A Q23]

Hint: Trace the product's destination, then connect the organelles' roles.

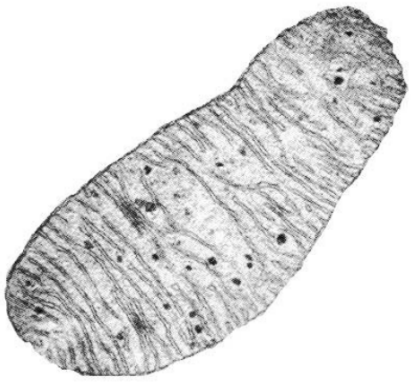
Which of the following cell types has the highest density of mitochondria?

A. Root hair cells
B. Leaf epidermal cells
C. Spongy mesophyll cells
D. Palisade mesophyll cells

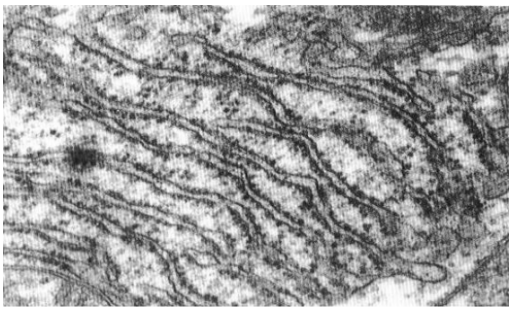
3. [HKDSE Biology Sample Paper Paper 1A Q2]

Hint: Trace the product's destination, then connect the organelles' roles.

Directions: Questions 1 and 2 refer to the electron micrographs and the table below. The electron micrographs show two sub-cellular structures, P and Q, of a eukaryotic cell, while the table shows the relative abundance of these two structures in four cell types in the human body:



P



Q

Cell type	Structure P	Structure Q
1	++++	+++
2	++++	+
3	+	+
4	–	–

Key: number of '+' represents the relative abundance of the structure
'–' represents absence of the structure

Which of the following can be found in structure P?

(1) ATP
(2) enzymes
(3) glycogen

A. (1) only
B. (1) and (2) only
C. (2) and (3) only
D. (1), (2) and (3)

4. [HKDSE Biology 2019 Paper 1A Q15]
Hint: Trace the product's destination, then connect the organelles' roles.

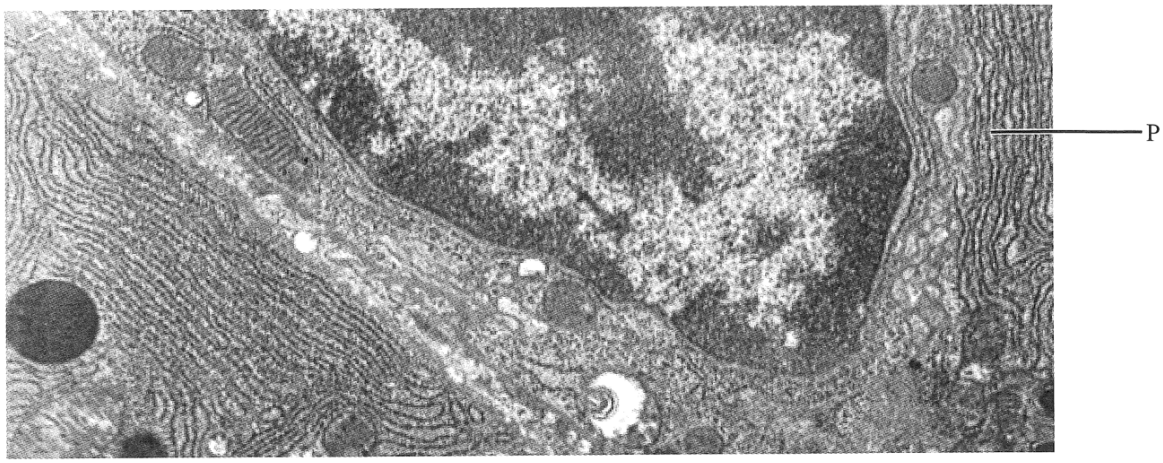
Which of the following description(s) of human red blood cells is/are correct?

(1) They cannot synthesise enzymes or proteins for repair because of the absence of the nucleus.
(2) They will stop functioning one day because haemoglobin will be used up.
(3) They do not have an energy supply because of the absence of mitochondria.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

5. [HKDSE Biology 2020 Paper 1A Q9]
Hint: Trace the product's destination, then connect the organelles' roles.

The electron micrograph below shows an organelle P:



Which of the following are possibly produced by organelle P in the cells of the pancreas?

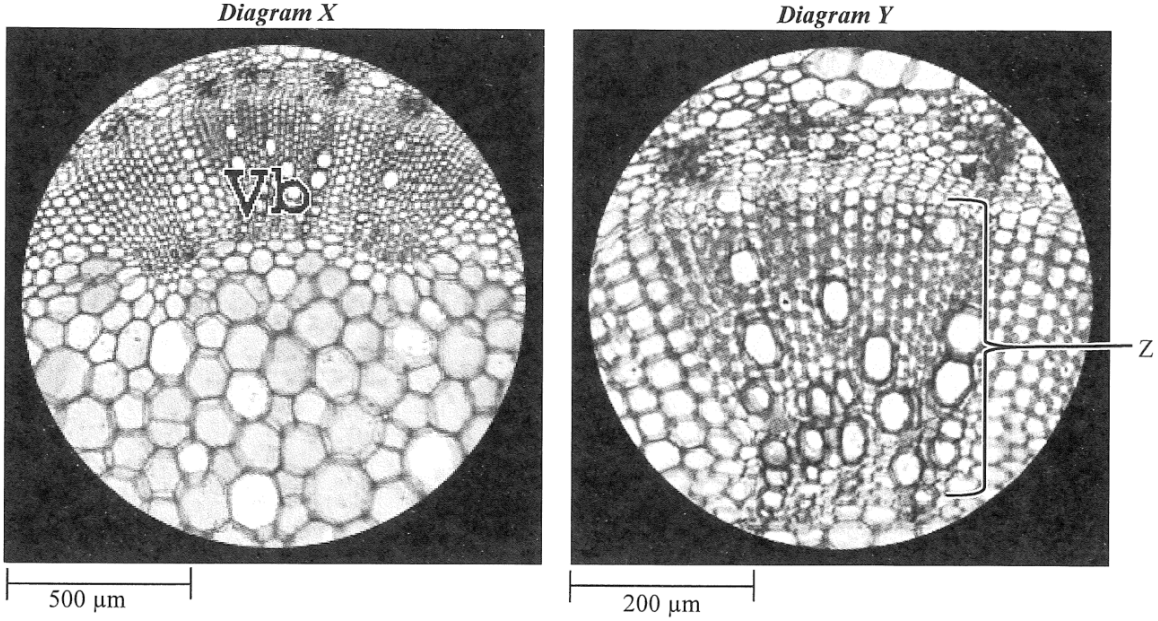
(1) amylase
(2) insulin
(3) lipase

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

6. [HKDSE Biology 2020 Paper 1A Q24]
← Hint: Trace the product's destination, then connect the organelles' roles.

Directions: Questions 22 to 24 refer to the photomicrographs below, which show the stem section of a plant observed under a microscope. Diagram Y shows a higher magnification of the vascular bundle (Vb) in Diagram X:

Diagram X ***Diagram Y***



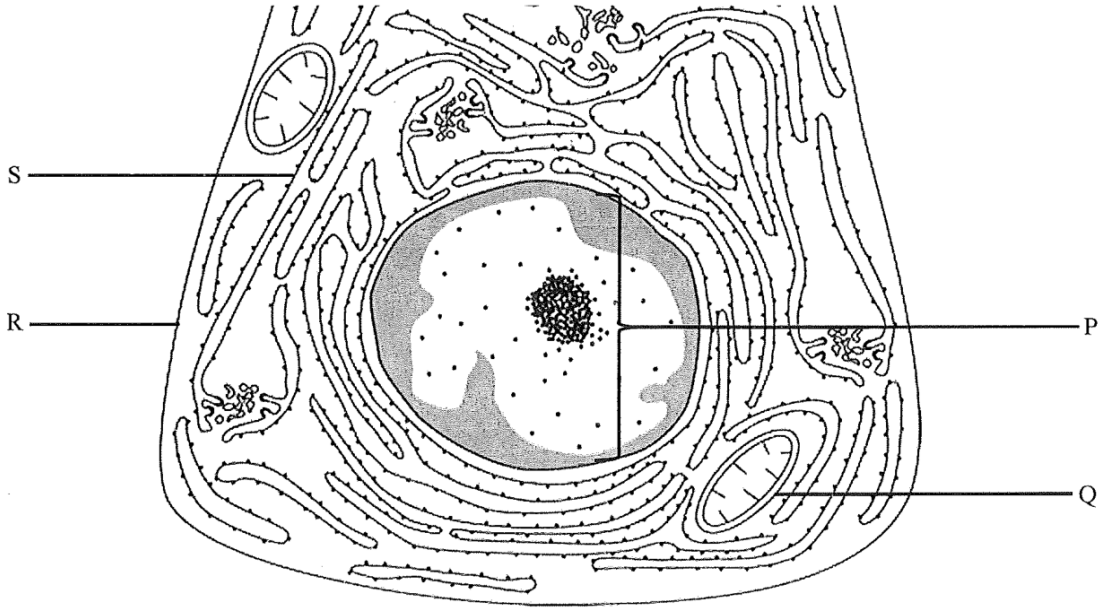
Key: Vb = vascular bundle

Which of the following structures is commonly found in all the cells shown in Diagram Y?

A. vacuole
B. cell wall
C. cytoplasm
D. cell membrane

7. [HKDSE Biology 2023 Paper 1A Q2]
← Hint: Trace the product's destination, then connect the organelles' roles.

Directions: Questions 1 to 3 refer to the schematic diagram below, which shows part of a pancreas cell:

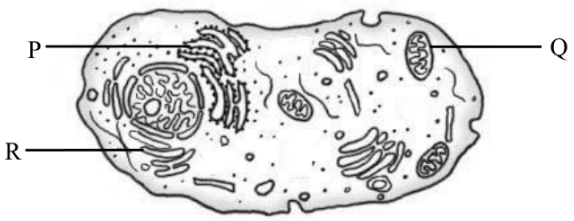


If the pancreas cell is supplied with radioactively labelled amino acids, which of the following cellular components is likely to have an increase in radioactivity first?

A. P
B. Q
C. R
D. S

8. [HKDSE Biology Practice Paper Paper 1A Q3]
Hint: Trace the product's destination, then connect the organelles' roles.

The following diagram shows an animal cell with some of its organelles:

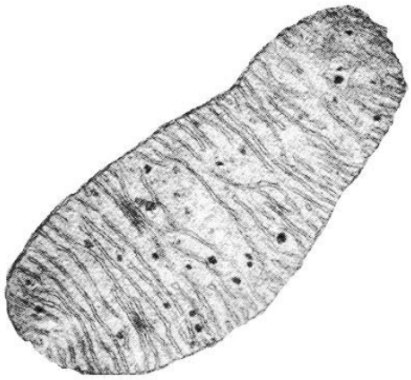


Which of the labelled structures are particularly abundant in an enzyme-secreting cell?

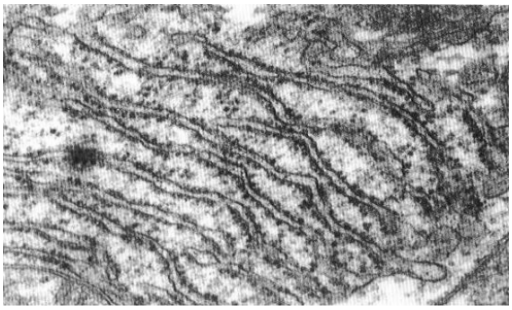
A. P and Q only
B. P and R only
C. Q and R only
D. P, Q and R

9. [HKDSE Biology Sample Paper Paper 1A Q1]
Hint: Trace the product's destination, then connect the organelles' roles.

Directions: Questions 1 and 2 refer to the electron micrographs and the table below. The electron micrographs show two sub-cellular structures, P and Q, of a eukaryotic cell, while the table shows the relative abundance of these two structures in four cell types in the human body:



P



Q

Cell type	Structure P	Structure Q
1	++++	+++
2	++++	+
3	+	+
4	–	–

Key: number of '+' represents the relative abundance of the structure
'–' represents absence of the structure

The relative abundance of structures P and Q in the epithelial cells of the air sacs of the lungs is most likely to be similar to that of

A. cell type 1.
B. cell type 2.
C. cell type 3.
D. cell type 4.

10. [HKDSE Biology 2023 Paper 1B Q2]
Hint: Trace the product's destination, then connect the organelles' roles.

All cells are derived from stem cells. They undergo differentiation in which the cells change in form and shape which enable them to perform specialised functions.

(a) It is found that the lens of the eye is composed of cells without organelles. If the organelles of these cells had not been degraded during differentiation, describe how the functioning of the lens would have been affected. (2 marks)

(b) Suggest a type of plant cell which also experiences degradation of cellular components during differentiation. Explain the significance of the degradation to the function of the cell type. (2 marks)

I.c Transport across membranes

First read the explanations and diagrams in Concept I.c, then work through the question types in this section. Each worked example retains the complete original question and explanation. The subsequent exercises require progressively more integration of information, based on the demands of the whole question.

Type 1 Compare diffusion, carrier transport and energy requirements

Degree of integration ★★★☆☆

Key ideas

① Oxygen diffuses net from higher to lower concentration; some molecules require membrane proteins to cross. If an ion is already more concentrated inside a cell but continues to be taken up from outside, movement against its concentration gradient requires an energy supply.

② Osmosis across a membrane differs from bulk liquid flow in xylem. Consider direction, membrane proteins and energy together; protein involvement alone is insufficient.

How to recognise the problem Draw the inside and outside of the cell and their concentrations, compare the net movement direction, then check the evidence for carriers and metabolic energy.

Example 1 [HKDSE Biology 2015 Paper 1A Q2]

Which of the following processes requires metabolic energy?

A. glucose moves across the epithelium of the ileum
B. carbon dioxide moves across the wall of air sacs
C. oxygen moves into mesophyll cells
D. water moves along the xylem

Solution Answer: A

Glucose can enter epithelial cells from the ileum lumen by active transport supported by energy, which meets the question's requirement. Net movement of gases across thin walls can occur by diffusion, while water flow along xylem is driven mainly by transpiration pull. Consider the substance, the structure it passes through and the transport mechanism together. Choose A.

Method: Compare internal and external concentrations before identifying movement and energy requirements.

Marking reference: HKDSE Biology 2015 Paper 1A Q2, official marking scheme, source page(s) 1.

Example 2 [HKDSE Biology 2019 Paper 1A Q8]

According to the requirements of various methods of transport across the cell membrane, which of the following combinations is correct?

	Requirements		
	Energy input	***Membrane protein***	***Concentration gradient***
A.	phagocytosis	active transport	osmosis
B.	diffusion	osmosis	active transport
C.	active transport	phagocytosis	phagocytosis
D.	osmosis	diffusion	diffusion

Solution Answer: A

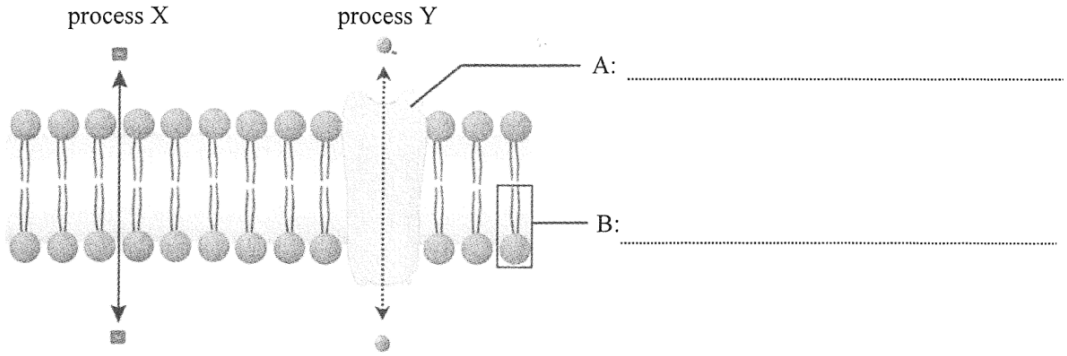
Phagocytosis requires energy; active transport requires membrane transport proteins; and osmosis involves net water movement caused by differences in conditions on the two sides. The entire row in A is correct. Simple diffusion itself does not require energy supplied by cellular metabolism, and active transport does not require movement down a concentration gradient.

Method: Compare internal and external concentrations before identifying movement and energy requirements.

Marking reference: HKDSE Biology 2019 Paper 1A Q8, official marking scheme, source page(s) 1.

Example 3 [HKDSE Biology 2020 Paper 1B Q4]

The following diagram shows a cell membrane and the movement of some substances across it:



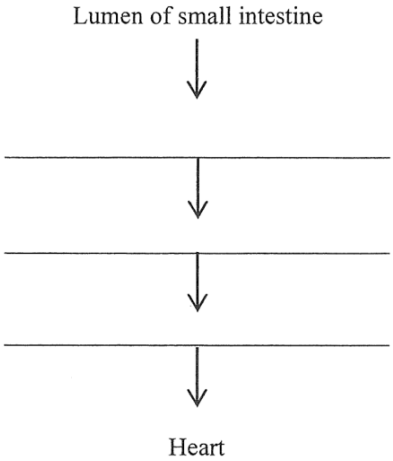
(a) Label structures A and B. (2 marks)

(b) X and Y represent two different processes by which substances pass through the cell membrane.

(i) Give ***one*** digested product which is absorbed through process X in the human body. (1 mark)

(ii) Give ***one*** digested product which is absorbed through process Y in the human body. (1 mark)

(iii) The digested products absorbed through process X are transported from the small intestine to the heart. Complete the following flowchart to show the vessels involved in the transport. (3 marks)



Solution a; original allocation: 2 mark(s)

A: protein; B: phospholipid.

B encloses one membrane molecule with a hydrophilic head and hydrophobic tails. Write "phospholipid", rather than treating B as the whole bilayer. A is the membrane protein associated with the other transport pathway.

Method: Compare internal and external concentrations before identifying movement and energy requirements.

b(i); original allocation: 1 mark(s)

Fatty acid.

The arrow for X passes through the phospholipid region. The question uses the school-level model in which products of fat digestion can cross the lipid region. Fatty acid is an appropriate answer; the marking scheme also accepts glycerol. Give a small molecule formed after digestion, rather than undigested fat, lipids or oil droplets.

b(ii); original allocation: 1 mark(s)

Glucose.

Glucose is a monosaccharide produced by digestion of carbohydrates such as starch. It requires suitable membrane proteins to help it cross the membrane, matching Y. Amino acids are also acceptable. The two-way arrow alone does not establish that Y must be active transport; this subpart asks for a digestion product absorbed by the pathway.

b(iii); original allocation: 3 mark(s)

Small-intestine lumen → lacteal → lymphatic vessel → subclavian vein → heart.

This subpart continues the fat-absorption pathway X. Material first enters a lacteal in a villus, travels through lymphatic vessels, and finally joins venous blood returning to the heart. The three spaces for vessels should be filled with lacteal, lymphatic vessel and subclavian vein, in that order. Do not substitute the capillary–hepatic portal vein route mainly used by glucose and amino acids. In reality, fats may be reassembled and packaged inside epithelial cells; this flow sequence focuses on long-distance transport after absorption.

Marking reference: HKDSE Biology 2020 Paper 1B Q4, official marking scheme, source page(s) 3, 4.

Practice

1. [HKDSE Biology 2013 Paper 1A Q5]

Hint: Compare internal and external concentrations before identifying movement and energy requirements.

Which of the following descriptions of the function of membrane proteins is ***incorrect***?

A. Some membrane proteins serve as antigens for cell recognition.
B. Some membrane proteins serve as enzymes for cellular metabolism.
C. Some membrane proteins act as barriers which prevent the entry of some substances.
D. Some membrane proteins act as carriers which transport some substances across the membrane.

2. [HKDSE Biology 2014 Paper 1A Q2]

Hint: Compare internal and external concentrations before identifying movement and energy requirements.

Which of the following events ***does not*** involve the functioning of membrane proteins?

A. Transmission of nerve impulses across a synapse
B. Absorption of glucose in the small intestine
C. Transport of oxygen by haemoglobin
D. Recognition of pathogens

3. [HKDSE Biology 2021 Paper 1A Q8]

Hint: Compare internal and external concentrations before identifying movement and energy requirements.

Which of the following combinations correctly lists the requirements of both osmosis and diffusion?

	Concentration gradient	*Energy supply*	*Selectively permeable membrane*
A.	Yes	No	Yes
B.	Yes	No	No
C.	No	Yes	Yes
D.	No	Yes	No

4. [HKDSE Biology Sample Paper Paper 1B Q1]

Hint: Compare internal and external concentrations before identifying movement and energy requirements.

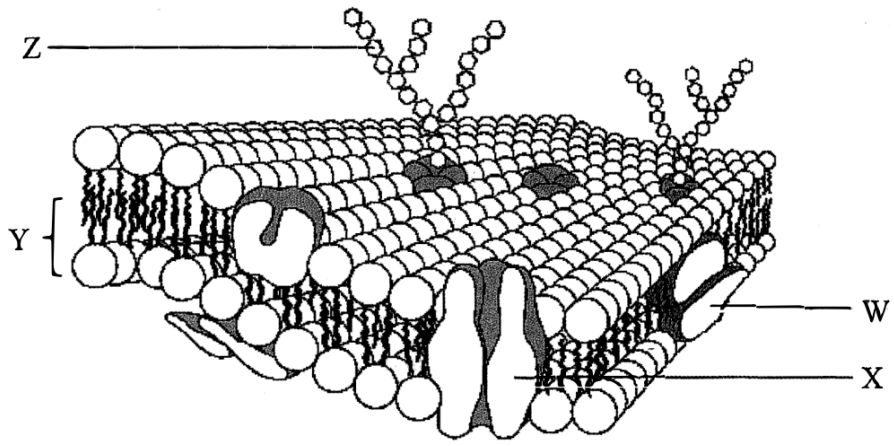
For each of the biological processes listed in column 1, select ***one*** type of membrane transport mechanisms listed in column 2 that accounts for the process. Put the appropriate letter in the space provided. (2 marks)

Column 1		***Column 2***
Haemolysis of red blood cells when placed in 0.1% sodium chloride solution	.....	A. active transport B. diffusion C. osmosis D. phagocytosis
Uptake of oxygen into red blood cells	.....	

5. [HKDSE Biology 2016 Paper 1A Q2]

Hint: Compare internal and external concentrations before identifying movement and energy requirements.

Directions: **Questions 1 and 2 refer to the schematic diagram below, which shows the structure of a cell membrane:**



If the membrane is located at the inner surface of the small intestine, the absorption of amino acids is likely to be achieved via

A. W.
B. X.
C. Y.
D. Z.

6. [HKDSE Biology 2018 Paper 1A Q36]

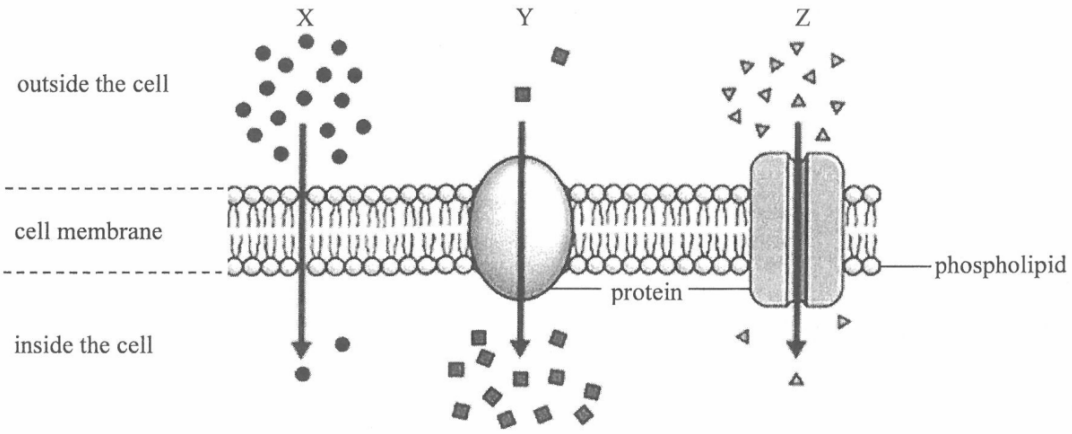
Hint: Compare internal and external concentrations before identifying movement and energy requirements.

Which of the following processes mainly involves osmosis?

A. movement of water along the xylem in plants
B. movement of water vapour out of stomata in plants
C. movement of water from tissue fluid to capillaries in humans
D. movement of water from tissue fluid to lymph capillaries in humans

7. [HKDSE Biology 2022 Paper 1A Q1]
Hint: Compare internal and external concentrations before identifying movement and energy requirements.

The diagram below shows three different ways by which substances pass through a cell membrane:

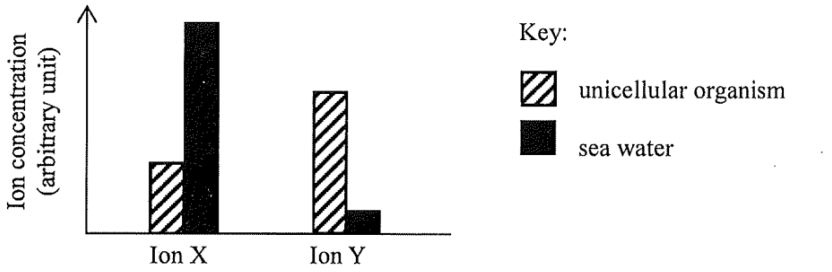


Which of the following combinations correctly matches the substances with their corresponding ways of passing through the cell membrane?

	X	*Y*	*Z*
A.	oxygen	glucose	water
B.	glucose	water	oxygen
C.	water	oxygen	glucose
D.	water	glucose	oxygen

8. [HKDSE Biology 2023 Paper 1A Q31]
Hint: Compare internal and external concentrations before identifying movement and energy requirements.

The graph below shows the concentration of ions in a unicellular organism and the sea water surrounding it:

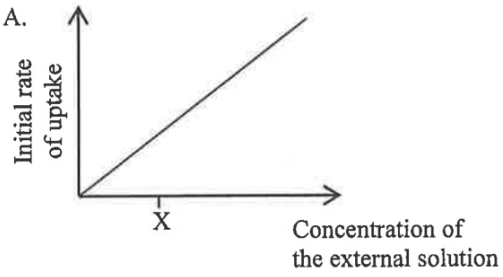


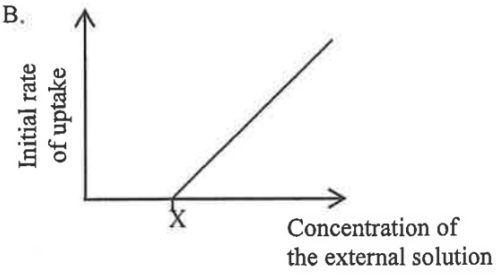
Which of the following is most likely to occur in order to maintain the conditions shown in the above graph?

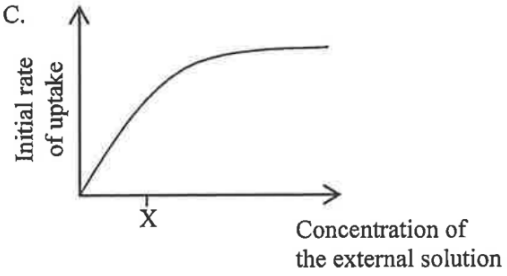
A. Ion X moves out of the organism by diffusion.
B. Ion X moves into the organism by active transport.
C. Ion Y moves into the organism by active transport.
D. Ion Y moves out of the organism by active transport.

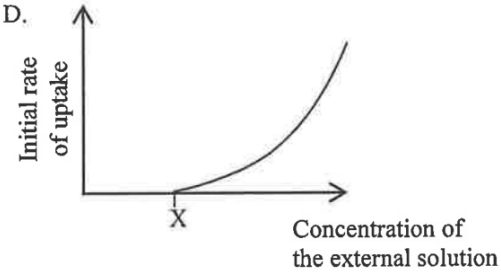
9. [HKDSE Biology 2019 Paper 1A Q11]
Hint: Compare internal and external concentrations before identifying movement and energy requirements.

Solutions of different concentrations of a solute with a small molecular size were prepared and some plant cells were immersed in each of the solutions. Which of the following graphs shows the initial rate of uptake of the solute by means of diffusion?
(Note: X is the concentration of the solute inside the plant cells)

A.


B.


C.


D.


10. [HKDSE Biology Practice Paper Paper 1B Q11]
Hint: Compare internal and external concentrations before identifying movement and energy requirements.

Digested food is absorbed into the epithelial cells of the villi.

(a) With reference to the structure of the cell membrane as illustrated by the fluid mosaic model of cell membrane, explain the following:

(i) Fatty acids (non-polar molecules) can diffuse across the cell membrane into the epithelial cell. (2 marks)

(ii) Amino acids (polar molecules) can be taken up from the intestinal lumen into the epithelial cell but cannot diffuse across the epithelial cell membrane back to the lumen. (3 marks)

(b) Name a mechanism for transporting glucose across the cell membrane. State a difference between this mechanism and diffusion. (2 marks)

Type 2 Draw supported conclusions from permeability experiments

Degree of integration ★★★☆☆

Key ideas

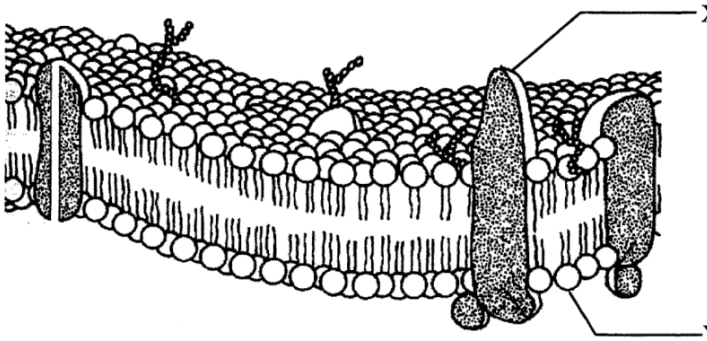
① If beetroot pigment leaks from cells into the external solution, its colour can indirectly indicate membrane damage. Control tissue size, washing and treatment duration. In contrast, droplet displacement caused by a group of cells measures only the net result. Zero displacement does not show that every cell exchanges no water.

② Distinguish individual-cell activity from the group's average result.

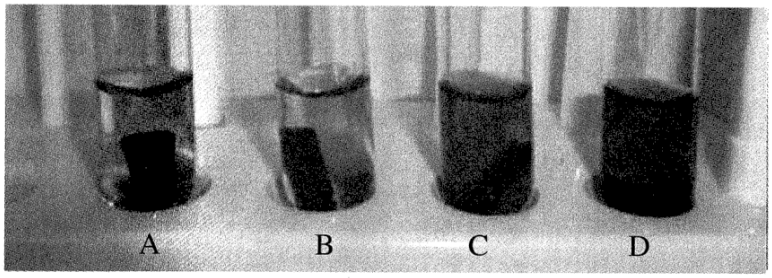
How to recognise the problem State what the apparatus measures, then identify the assumptions needed to infer membrane properties. Additional photographs can test those assumptions.

Example 1 [HKDSE Biology 2014 Paper 1B Q7]

(a) The following is a schematic diagram of a cell membrane. In the spaces provided, label membrane components X and Y. (2 marks)



(b) The vacuoles of beetroot cells contain a red pigment which will be released from the cells if the cell membrane and vacuole membrane are damaged. In an investigation, Gary placed identical cylinders of beetroot tissues into four test tubes. Each tube contained the same volume of alcohol at different concentrations. The following photograph shows the appearance of the solutions bathing the beetroot cylinders after 30 minutes:



(i) From the result of the above investigation, deduce which test tube contained the highest concentration of the alcohol. (4 marks)

(ii) After three hours, Gary found that the colour intensity of the solutions of all the test tubes became the same. Suggest an explanation for this. (2 marks)

Solution a; original allocation: 2 mark(s)

X: protein; Y: phospholipid.

X is embedded in the membrane; Y forms its main bilayer framework. Each earns 1 mark.

b(i); original allocation: 4 mark(s)

D, because it has the highest alcohol concentration. Alcohol disrupts the phospholipid structure of membranes, increasing the permeability of both the cell membrane and tonoplast. More red pigment escapes from the vacuole, so the solution becomes darkest.

The red pigment is stored mainly in the vacuole and must cross both the tonoplast and cell membrane to leave the cell. A darker colour does not mean that alcohol causes the cells to make more pigment.

b(ii); original allocation: 2 mark(s)

If pigment has diffused sufficiently in all groups after 3 hours, the final colour will be the same in every tube. Each group began with the same amount of beetroot and the same solution volume, so the total amount of releasable pigment is equal. Alcohol mainly changes the rate of pigment leakage.

Method: Identify the directly measured quantity before deciding what can be inferred.

Distinguish "which is darker at a particular time" from "the final amount after sufficient diffusion". Reaching the same endpoint does not mean that initial membrane permeability was identical.

Examiner's comment (source page(s) 3)

Pigment escapes by diffusion, not osmosis. Alcohol disrupts phospholipids and changes the rate at which equilibrium is reached, rather than the final total pigment available from equal amounts of material.

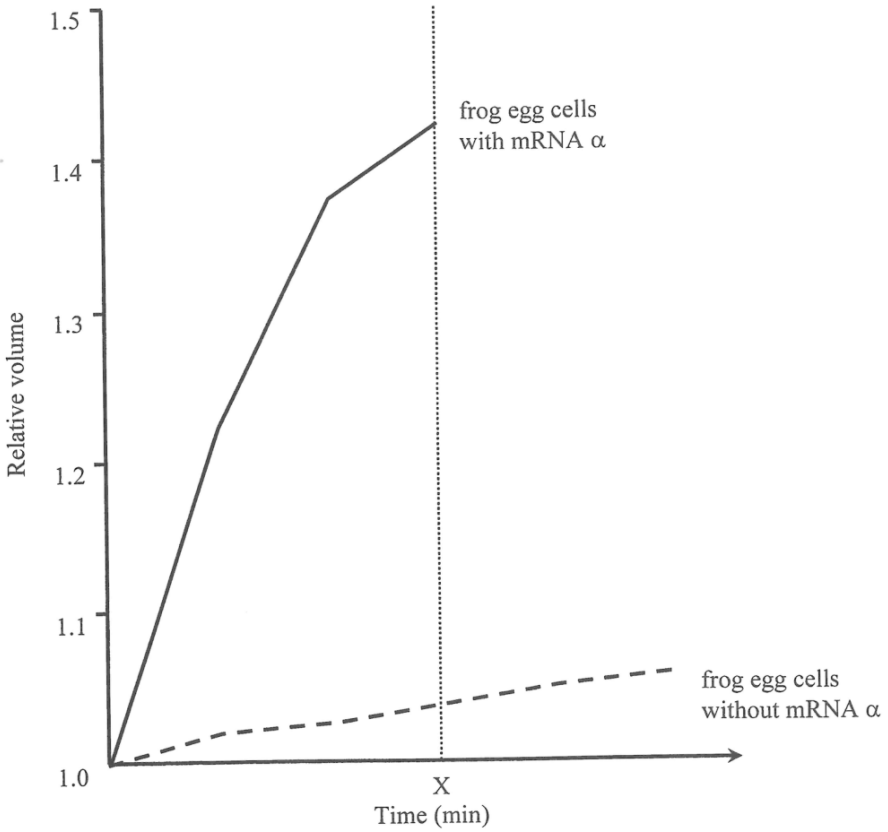
Marking reference: HKDSE Biology 2014 Paper 1B Q7, official marking scheme, source page(s) 4.

Example 2 [HKDSE Biology 2024 Paper 1B Q5]

In an experiment, mRNA α was isolated from a mammalian cell and then injected into a frog egg cell. The expression of mRNA α eventually led to the presence of protein α on the cell membrane of the frog egg.

(a) Describe how the injected mRNA α led to the presence of protein α on the cell membrane of the frog egg. (3 marks)

(b) In another experiment, frog egg cells received an injection of a fixed amount of water with or without mRNA α. After that, these two types of frog egg cells were transferred to pure water. The changes in the relative volumes ($\frac{\text{new volume}}{\text{original volume}}$) of these two types of frog egg cells are shown in the graph below:



(i) Explain why there was an increase in the relative volume of the frog egg cells without mRNA α after they were transferred to pure water. (2 marks)

(ii) Based on the difference shown in the results of the two types of frog egg cells, deduce the function of protein α on the cell membrane. (3 marks)

(iii) Suggest why no data were obtained from frog egg cells with mRNA α after X minutes. (1 mark)

Solution a; original allocation: 3 mark(s)

mRNA α is translated at ribosomes on the rough endoplasmic reticulum into a polypeptide. The polypeptide folds into protein α, which is then transported to and inserted into the cell membrane.

Method: Identify the directly measured quantity before deciding what can be inferred.

The injected material is already mRNA, so no further transcription is needed first. Ribosomes join amino acids in the order specified by the codons. The protein folds into its particular shape and is transported through the intracellular membrane system to become a membrane protein.

b(i); original allocation: 2 mark(s)

Pure water has a higher water potential than the inside of the egg cell. Water enters through the cell membrane by osmosis, increasing the cell's volume.

Solutes inside the cell lower its water potential. Since the membrane allows water through, net water entry from the higher external water potential occurs even without injection of mRNA α.

b(ii); original allocation: 3 mark(s)

Protein α is probably a water-channel protein that increases membrane permeability to water.

The volume of eggs injected with mRNA α rises faster. At time X, their relative volume is about 1.42, compared with about 1.04 in the control. External water potential is the same, and the difference is the newly expressed protein α. Faster water uptake supports the idea that α provides channels for water passage. Movement is down a water-potential gradient and need not be interpreted as active transport.

b(iii); original allocation: 1 mark(s)

The egg cell bursts after taking in too much water.

A frog egg has no cell wall to resist swelling. Rapid entry of a large amount of water ruptures its membrane, so the original intact cell's volume can no longer be measured.

Examiner's comment (source page(s) 70)

After mRNA injection, translation, folding and transport of protein to the membrane occur; do not describe the process as transcription again. Rapid volume increase is osmotic water uptake, not cell division. Compare the rates of volume increase before inferring increased membrane permeability to water.

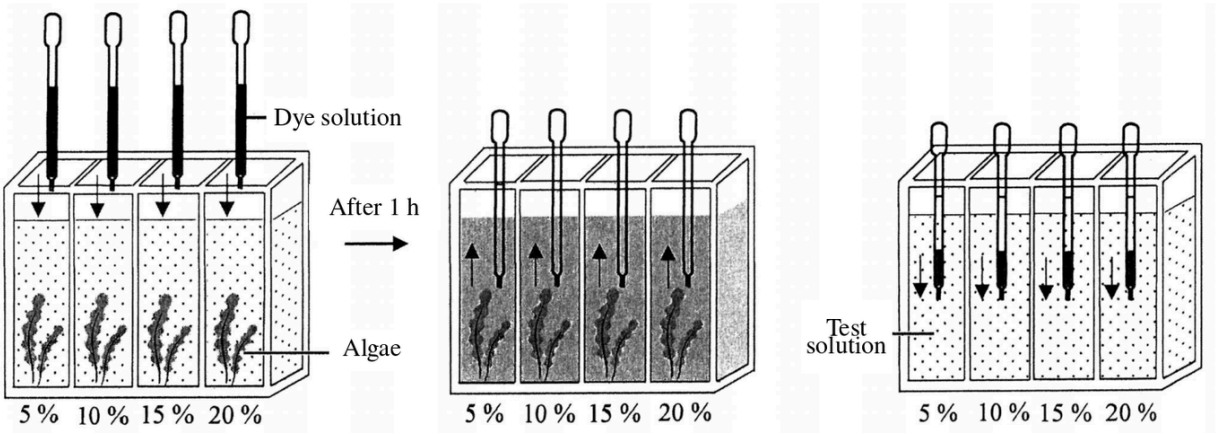
Marking reference: HKDSE Biology 2024 Paper 1B Q5, official marking scheme, source page(s) 52, 53.

Practice

1. [HKDSE Biology 2025 Paper 1A Q13 (English translation)]

Hint: Identify the directly measured quantity before deciding what can be inferred.

Directions: Refer to the following investigation of the water potential of a species of alga to answer Questions 12 to 14. The procedure is shown below:

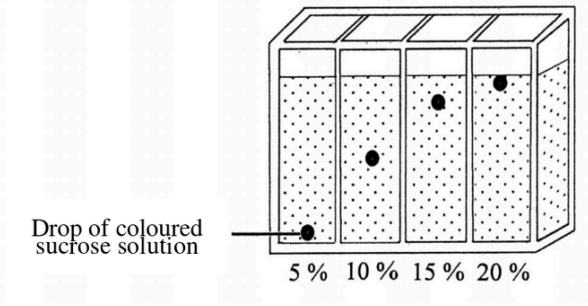


Step 1: Add the alga and a few drops of dye solution to sucrose solutions of different concentrations.

Step 2: After one hour, use a dropper to take up a drop of the coloured sucrose solution.

Step 3: Prepare the same set-up as in step 1, but without adding the alga. Transfer a drop of the coloured sucrose solution to the centre of the corresponding test solution.

The diagram below shows the positions of the coloured sucrose drops immediately after they move in the test solutions:

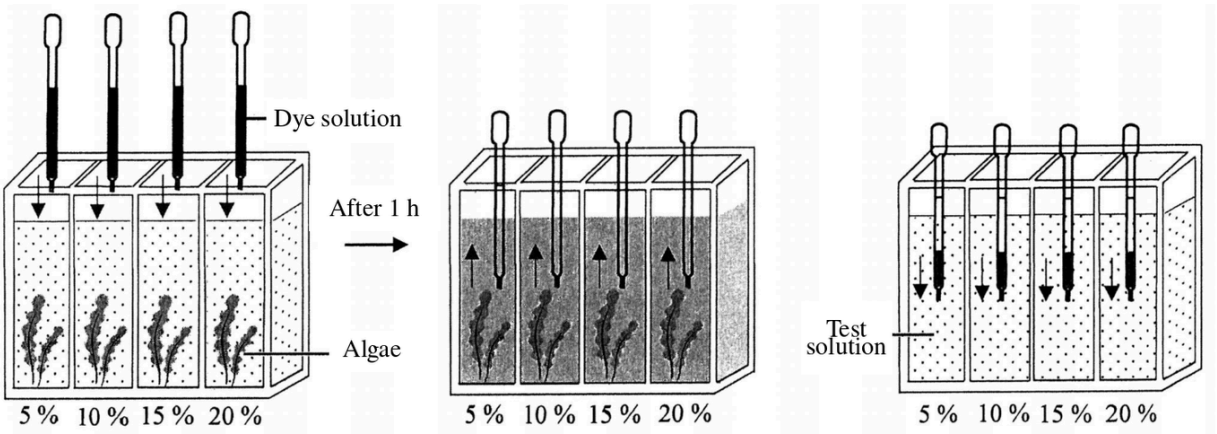


Which of the following should be done to confirm the experimental results?

A. Calculate the percentage change in the surface area of this alga.
B. Measure the change in the dry mass of this alga.
C. Measure the change in the liquid level of the sucrose solution.
D. Observe the appearance of the cells of this alga under a light microscope.

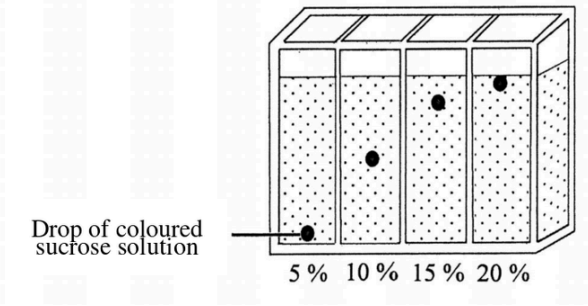
2. [HKDSE Biology 2025 Paper 1A Q12 (English translation)]
← *Hint: Identify the directly measured quantity before deciding what can be inferred.*

Directions: Refer to the following investigation of the water potential of a species of alga to answer Questions 12 to 14. The procedure is shown below:



Step 1: Add the alga and a few drops of dye solution to sucrose solutions of different concentrations.
Step 2: After one hour, use a dropper to take up a drop of the coloured sucrose solution.
Step 3: Prepare the same set-up as in step 1, but without adding the alga. Transfer a drop of the coloured sucrose solution to the centre of the corresponding test solution.

The diagram below shows the positions of the coloured sucrose drops immediately after they move in the test solutions:



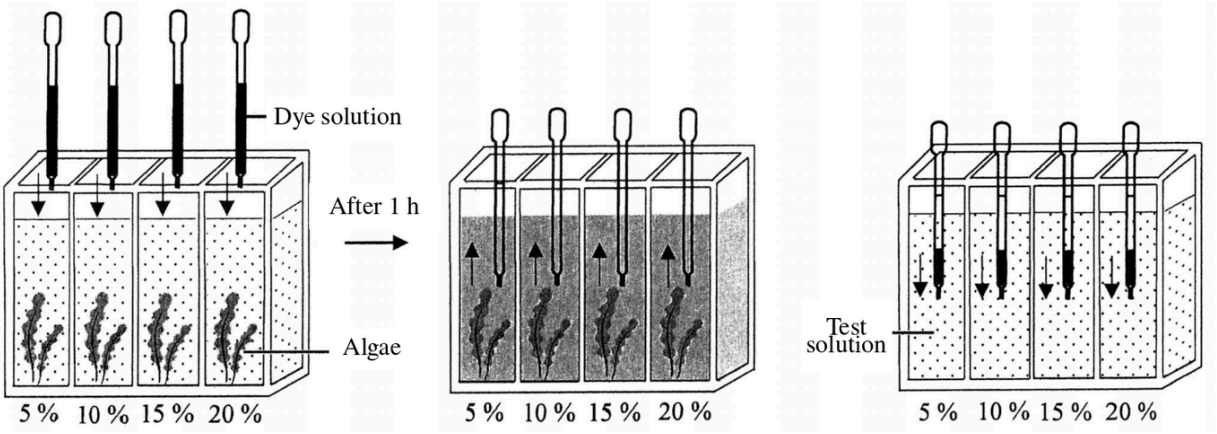
Based on the position of the coloured sucrose drop immediately after it moves in the 10% test solution, which of the following statement(s) is/are correct?

(1) The density of the coloured sucrose solution is closest to that of 10% sucrose solution.
(2) The water potential of all cells of this alga is equal to that of 10% sucrose solution.
(3) There is no net movement of water between 10% sucrose solution and the cells of this alga.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

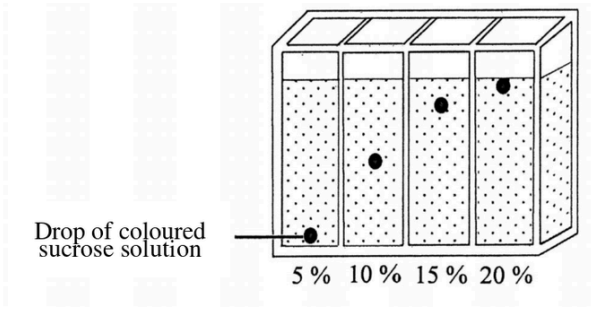
3. [HKDSE Biology 2025 Paper 1A Q14 (English translation)]
Hint: Identify the directly measured quantity before deciding what can be inferred.

Directions: Refer to the following investigation of the water potential of a species of alga to answer Questions 12 to 14. The procedure is shown below:



Step 1: Add the alga and a few drops of dye solution to sucrose solutions of different concentrations.
Step 2: After one hour, use a dropper to take up a drop of the coloured sucrose solution.
Step 3: Prepare the same set-up as in step 1, but without adding the alga. Transfer a drop of the coloured sucrose solution to the centre of the corresponding test solution.

The diagram below shows the positions of the coloured sucrose drops immediately after they move in the test solutions:



Which of the following statements is a valid assumption for this experiment?

A. The cell membranes of all cells of this alga are differentially permeable.
B. Solutes do not move between the cells of this alga and the sucrose solution.
C. No subjective human error occurs when observing the movement of the coloured sucrose solution.
D. The water potentials of the cells of this alga and the sucrose solution become equal after the cells have been immersed for one hour.

Type 3 Predict cell, liquid-level and mass changes from water potential

Degree of integration ★★★☆☆

Key ideas

① In a sucrose solution with lower water potential, a plant cell loses water net and its vacuole shrinks. The relatively rigid cell wall can remain in place while the protoplast separates from it. For dialysis tubing, first determine whether water and each solute can cross the membrane.

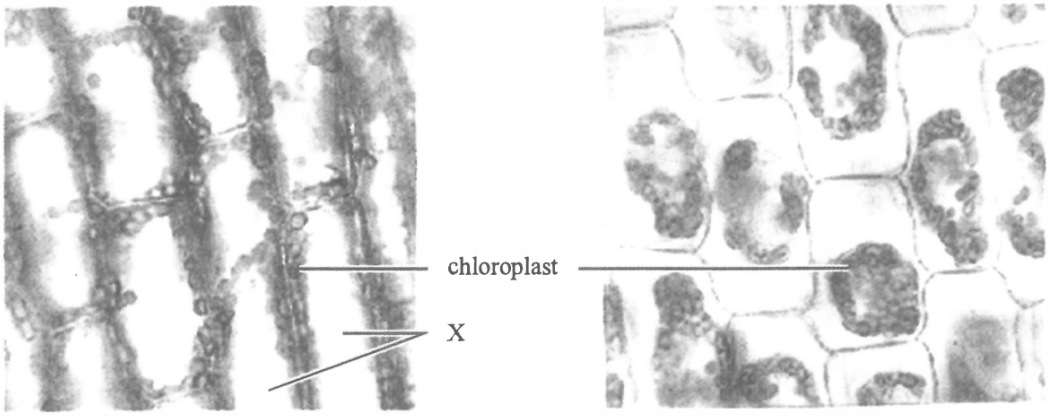
② If 2.00 g of tissue becomes 2.20 g, percentage mass change is (2.20 − 2.00) ÷ 2.00 × 100% = 10%. The denominator must be the original mass.

How to recognise the problem State membrane selective permeability, relative water potentials, net water movement and the observable result in order. No net change does not mean that water molecules stop moving.

Example 1 [HKDSE Biology 2018 Paper 1B Q2]

The leaf of an aquatic plant was placed in a concentrated sucrose solution and observed under a light microscope. Photomicrographs A and B show the appearance of the cells at the beginning of the experiment and after five minutes respectively:

Photomicrograph A – at the beginning ***Photomicrograph B – after five minutes***



(a) X is an organelle which is invisible without staining. Name this organelle. (1 mark)

(b) Comparing the two photomicrographs, state ***two*** observable changes in the appearance of the cells after five minutes. (2 marks)

(c) Explain how the observable changes stated in (b) are brought about. (2 marks)

Solution Reading the question and choosing a method

Method: Compare water potential, permeability and net water movement in sequence.

The question asks first for visible changes and then for their causes. Describe the images before discussing water potential and the direction of net movement.

a; original allocation: 1 mark(s)

Vacuole.

X points to the large clear region inside the cell. The large plant-cell vacuole contains cell sap, and its outline may be indistinct without staining. Do not call it an intercellular space merely because it looks empty.

b; original allocation: 2 mark(s)

The cell membrane and cytoplasm shrink away from the cell wall. The chloroplasts move with the cell contents and become concentrated nearer the centre.

Comparing the photographs, the rigid cell wall retains approximately the same outer outline while the chloroplast-containing material shrinks inwards. Describe separation of the

membrane/cytoplasm from the wall and concentration of chloroplasts towards the centre. A smaller vacuole is also an acceptable change. This subpart asks only for two visible changes. "Water moves out" cannot replace a description of appearance, because molecular water movement is not a structural change directly shown in the photograph.

c; original allocation: 2 mark(s)

The concentrated external sucrose solution has a lower water potential than the cell contents. Water moves out of the cells by osmosis, causing the vacuole and cell contents to shrink.

Begin by comparing water potentials inside and outside the cell. Do not merely say "the outside concentration is high" without identifying the substance. Sucrose lowers external water potential. Across the selectively permeable cell membrane, water moves on balance from the higher water potential inside to the lower water potential outside. Water loss reduces the volumes of the vacuole and protoplast, while the wall does not shrink correspondingly, producing plasmolysis.

Examiner's comment (source page(s) 3)

Describe visible changes in the photographs before explaining osmosis. Hypertonic and hypotonic are relative to another solution. Here the external sucrose solution has a lower water potential than the cell contents.

Marking reference: HKDSE Biology 2018 Paper 1B Q2, official marking scheme, source page(s) 2.

Example 2 [HKDSE Biology Practice Paper Paper 1A Q5]

The table below shows the ratios of initial mass to final mass of three fresh potato cylinders which have been immersed in sucrose solutions of three different concentrations for 30 minutes:

	Solution P	Solution Q	Solution R
Ratio of initial mass to final mass	0.9	1.4	1.2

Which of the following can be deduced from the results?

(1) The water potential of the potato cylinders is higher than that of solution P.
(2) There is a net movement of water from the potato cylinders to solution Q.
(3) Solution Q has a higher sucrose concentration than solution R.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

Solution Answer: D

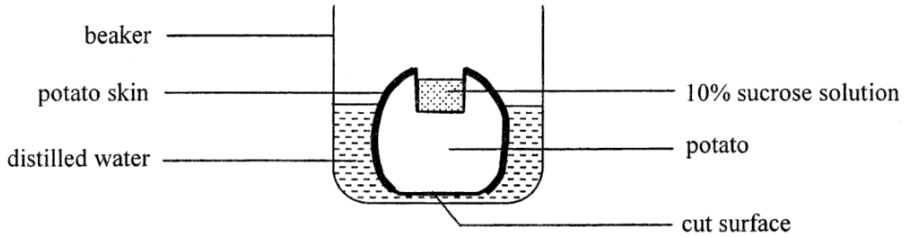
Method: Compare water potential, permeability and net water movement in sequence.

For P, initial mass/final mass = 0.9, so final mass is greater and the potato gained water. Solution P therefore has a higher water potential than the potato strip, making (1) false. Q's ratio of 1.4 indicates water loss, so (2) is true. Compared with R's ratio of 1.2, Q caused greater water loss, supporting a higher concentration and lower water potential in Q; (3) is true. Choose D. Interpret the numerator and denominator first: 0.9 does not mean a 10% mass loss.

Marking reference: HKDSE Biology Practice Paper Paper 1A Q5, official marking scheme, source page(s) 2.

Example 3 [HKDSE Biology 2013 Paper 1A Q25]

Directions: Questions 23 to 25 refer to the diagram below, which shows an experiment on osmosis using a potato tuber. A washed potato was cut to form a base. After that, a cavity was made and a 10% sucrose solution was added into the cavity. The whole potato was then placed into a beaker containing some distilled water. After 1 day, the level of sucrose solution rose.



Which of the following treatments will lead to a higher final level of the sucrose solution after 1 day?

(1) using 5% sucrose solution instead of 10% sucrose solution
(2) using 20% sucrose solution instead of 10% sucrose solution
(3) peeling off all the potato skin instead of just cutting the bottom of the potato

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

Solution Answer: B

A 20% sucrose solution has a lower water potential than a 10% solution, allowing more water to enter and a higher final liquid level to be reached. Statement (2) is correct. A 5% solution produces a smaller water-potential difference. Removing more epidermis mainly increases the rate of water entry, without changing the final level determined by water-potential equilibrium, so do not include (3).

Method: Compare water potential, permeability and net water movement in sequence.

Examiner's comment (source page(s) 2)

Increasing the area available for water entry changes the rate, not the final level determined by water-potential equilibrium.

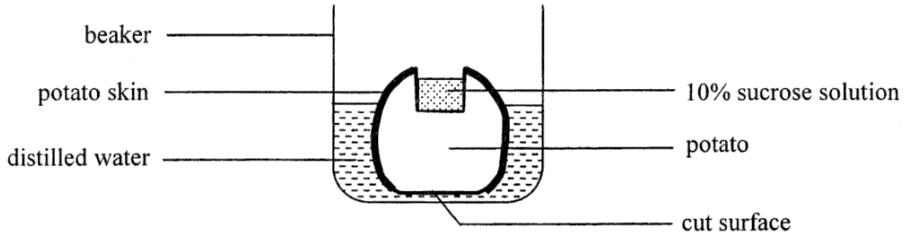
Marking reference: HKDSE Biology 2013 Paper 1A Q25, official marking scheme, source page(s) 1.

Practice

1. [HKDSE Biology 2013 Paper 1A Q24]

Hint: Compare water potential, permeability and net water movement in sequence.

Directions: Questions 23 to 25 refer to the diagram below, which shows an experiment on osmosis using a potato tuber. A washed potato was cut to form a base. After that, a cavity was made and a 10% sucrose solution was added into the cavity. The whole potato was then placed into a beaker containing some distilled water. After 1 day, the level of sucrose solution rose.



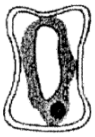
The diagram below shows the appearance of a cell in contact with distilled water in the beaker at the beginning of the experiment:

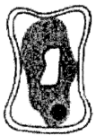


Which of the following diagrams correctly shows the appearance of the same cell at the end of the experiment?

A. 

B. 

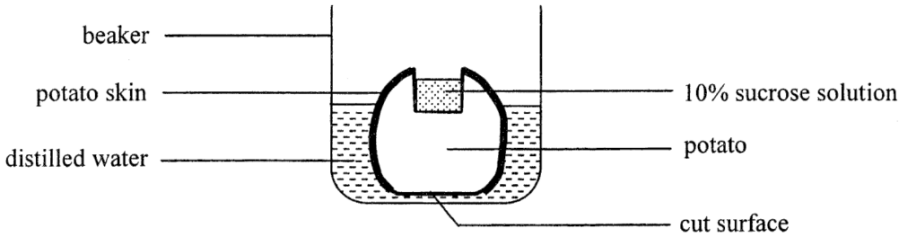
C. 

D. 

2. [HKDSE Biology 2013 Paper 1A Q23]

Hint: Compare water potential, permeability and net water movement in sequence.

Directions: Questions 23 to 25 refer to the diagram below, which shows an experiment on osmosis using a potato tuber. A washed potato was cut to form a base. After that, a cavity was made and a 10% sucrose solution was added into the cavity. The whole potato was then placed into a beaker containing some distilled water. After 1 day, the level of sucrose solution rose.

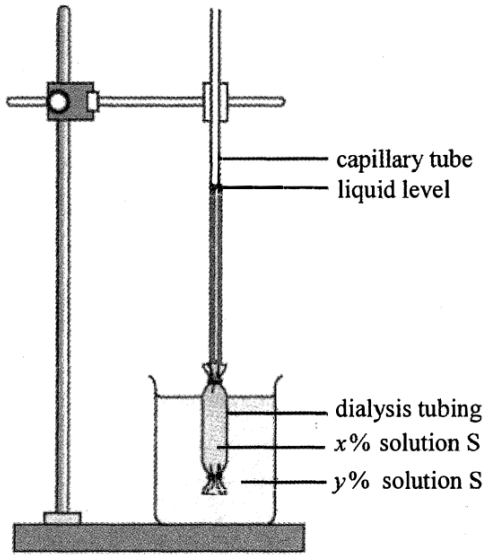


The level of sucrose solution inside the cavity rose because osmosis has taken place, which means that

A. water was drawn mainly from the cells in contact with the sucrose solution.
B. water was initially drawn from the cells in contact with the distilled water.
C. water moved from the distilled water along the cell wall of the potato cells to the cavity.
D. water moved from the distilled water through the cell membrane of the potato cells to the cavity.

3. [HKDSE Biology 2016 Paper 1A Q25]
Hint: Compare water potential, permeability and net water movement in sequence.

Directions: Questions 24 and 25 refer to the diagram below, which shows an experimental set-up for studying osmosis:

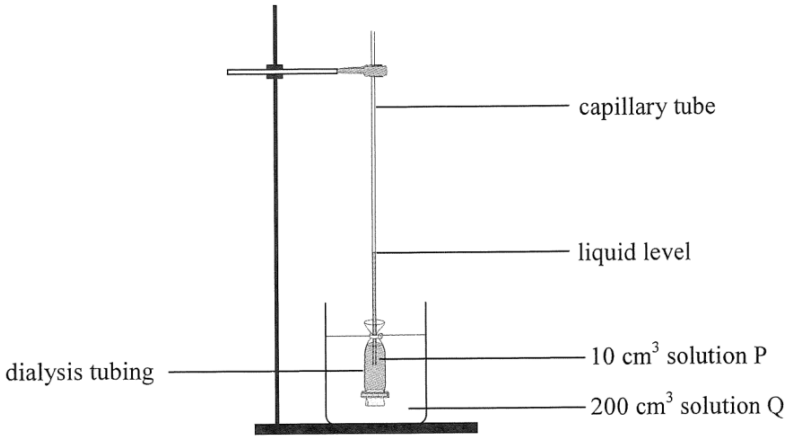


Which of the following modifications will result in a faster rise in the liquid level?

A. use a smaller volume of x% solution S
B. use a larger volume of y% solution S
C. use a shorter capillary tube
D. use a longer piece of dialysis tubing

4. [HKDSE Biology 2020 Paper 1A Q2]
Hint: Compare water potential, permeability and net water movement in sequence.

Directions: Questions 2 and 3 refer to the diagram below, which shows a set-up for investigating the permeability of dialysis tubing. 10 cm^3 of solution P was added to the dialysis tubing, with one end tied and the other end connected to a capillary tube. The dialysis tubing was then placed in a beaker with 200 cm^3 of solution Q. When solutions P and Q are mixed, a blue colour will be observed.



At the end of the investigation, the liquid level inside the capillary tube had risen and only the solution inside the dialysis tubing became blue. Which of the following conclusions can be drawn from the results?

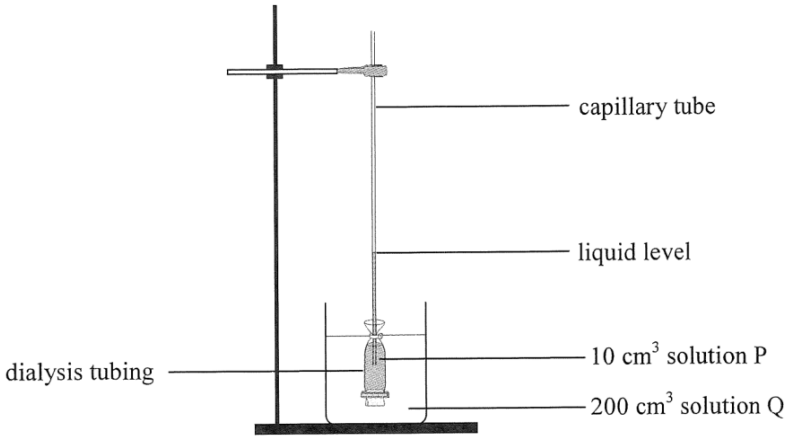
(1) Solute of solution P can pass through the dialysis tubing.
(2) Solute of solution Q can pass through the dialysis tubing.
(3) There is a net movement of water into the dialysis tubing.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

5. [HKDSE Biology 2020 Paper 1A Q3]

Hint: Compare water potential, permeability and net water movement in sequence.

Directions: Questions 2 and 3 refer to the diagram below, which shows a set-up for investigating the permeability of dialysis tubing. 10 cm^3 of solution P was added to the dialysis tubing, with one end tied and the other end connected to a capillary tube. The dialysis tubing was then placed in a beaker with 200 cm^3 of solution Q. When solutions P and Q are mixed, a blue colour will be observed.



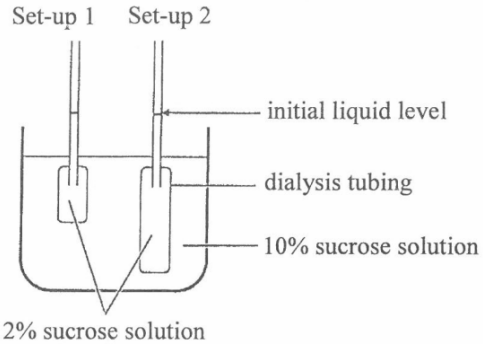
If the investigation is repeated with water instead of solution Q, which of the following results will be obtained?

A. The liquid level in the capillary tube will not rise at all.
B. The liquid level in the capillary tube will rise to a lower level.
C. The liquid level in the capillary tube will rise to a higher level.
D. The liquid level in the capillary tube will rise to the same level.

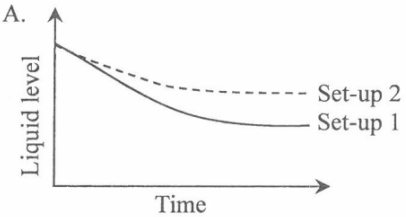
6. [HKDSE Biology 2022 Paper 1A Q35]

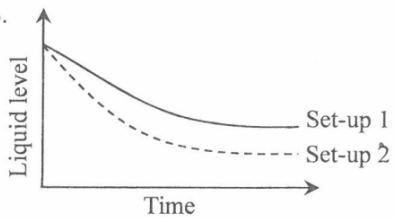
Hint: Compare water potential, permeability and net water movement in sequence.

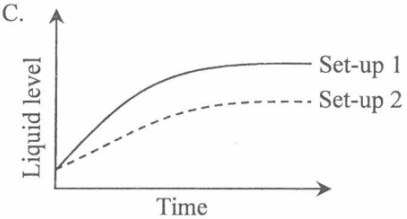
Directions: Questions 35 and 36 refer to the diagram below, which shows two set-ups used for investigating osmosis. Two dialysis tubings of different lengths were filled with 2% sucrose solution and then submerged in 10% sucrose solution. All solutions were kept at 25°C.

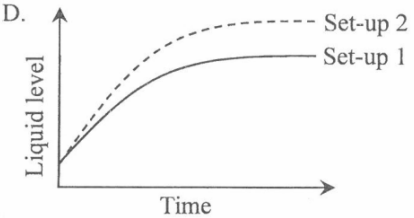


Which of the following graphs correctly shows the change in the liquid levels of set-ups 1 and 2?

A.


B.


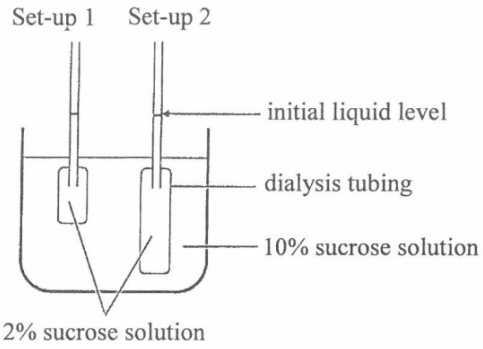
C.


D.


7. [HKDSE Biology 2022 Paper 1A Q36]

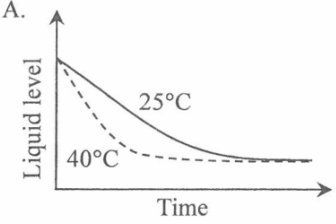
Hint: Compare water potential, permeability and net water movement in sequence.

Directions: Questions 35 and 36 refer to the diagram below, which shows two set-ups used for investigating osmosis. Two dialysis tubings of different lengths were filled with 2% sucrose solution and then submerged in 10% sucrose solution. All solutions were kept at 25°C.

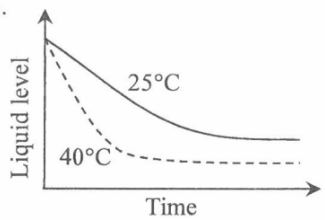


If the experiment was repeated with the same setting except that the solutions were kept at 40°C, which of the following graphs correctly shows the change in the liquid levels of set-up 1 at different temperatures?

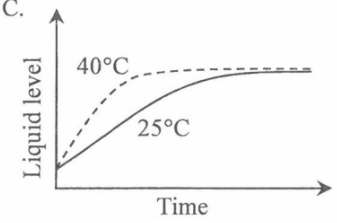
A.



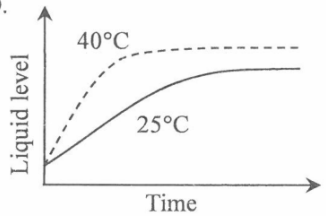
B.



C.



D.



8. [HKDSE Biology Sample Paper Paper 1A Q4]

Hint: Compare water potential, permeability and net water movement in sequence.

The diagram below shows the lengths of three fresh potato cylinders before and after they were immersed in three sucrose solutions of different concentrations for one hour:

	Solution X	Solution Y	Solution Z
Before immersion			
After immersion			

When arranged from the lowest to the highest water potential, the sequence of the three solutions would be

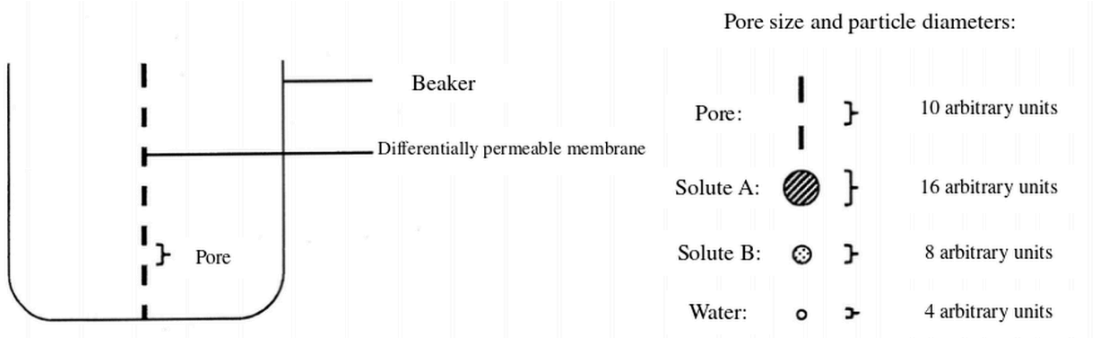
A. X, Z, Y.
B. Y, X, Z.
C. Y, Z, X.
D. Z, Y, X.

9. [HKDSE Biology 2017 Paper 1B Q2]
Hint: Compare water potential, permeability and net water movement in sequence.

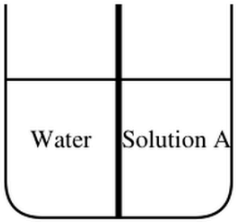
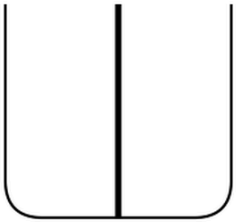
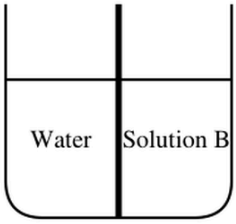
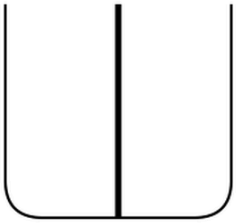
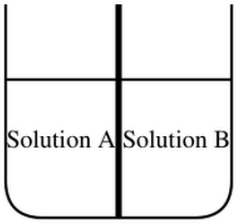
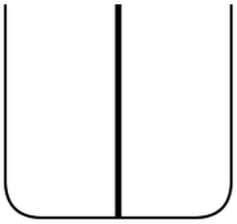
Denise ate a piece of pineapple preserved in a sugar solution and noticed that it was softer than fresh pineapple. Explain this phenomenon. (3 marks)

10. [HKDSE Biology 2025 Paper 1B Q2 (English translation)]
Hint: Compare water potential, permeability and net water movement in sequence.

The diagram below shows a set-up for investigating diffusion and osmosis. A differentially permeable membrane divides a beaker into two equal compartments. The pore size of the membrane and the diameters of the particles involved in this investigation are shown below in arbitrary units:



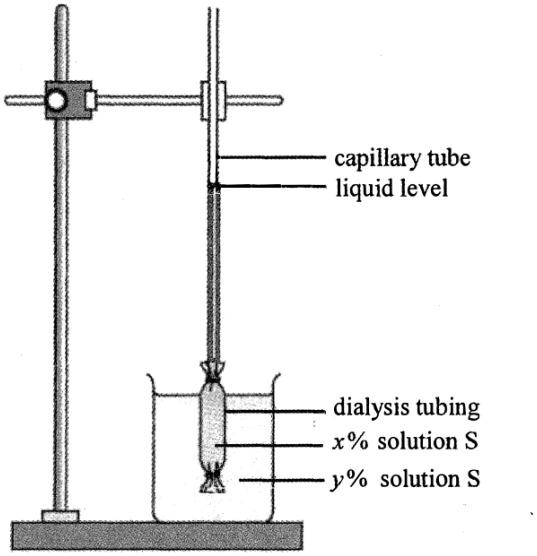
In this investigation, liquids are poured into the two compartments and left for 5 hours. The diagrams below show the initial liquid levels at the start of the investigation. Draw the final liquid levels for each set-up. (3 marks)

Initial liquid levels	Final liquid levels
(a) 	
(b) 	
(c) 	

11. [HKDSE Biology 2016 Paper 1A Q24]

Hint: Compare water potential, permeability and net water movement in sequence.

Directions: Questions 24 and 25 refer to the diagram below, which shows an experimental set-up for studying osmosis:



After three hours, the liquid level has risen. What can be deduced from this result?

(1) Solution S diffuses into the dialysis tubing.
(2) Value of x is larger than that of y.
(3) Solute of solution S cannot pass through the dialysis tubing.

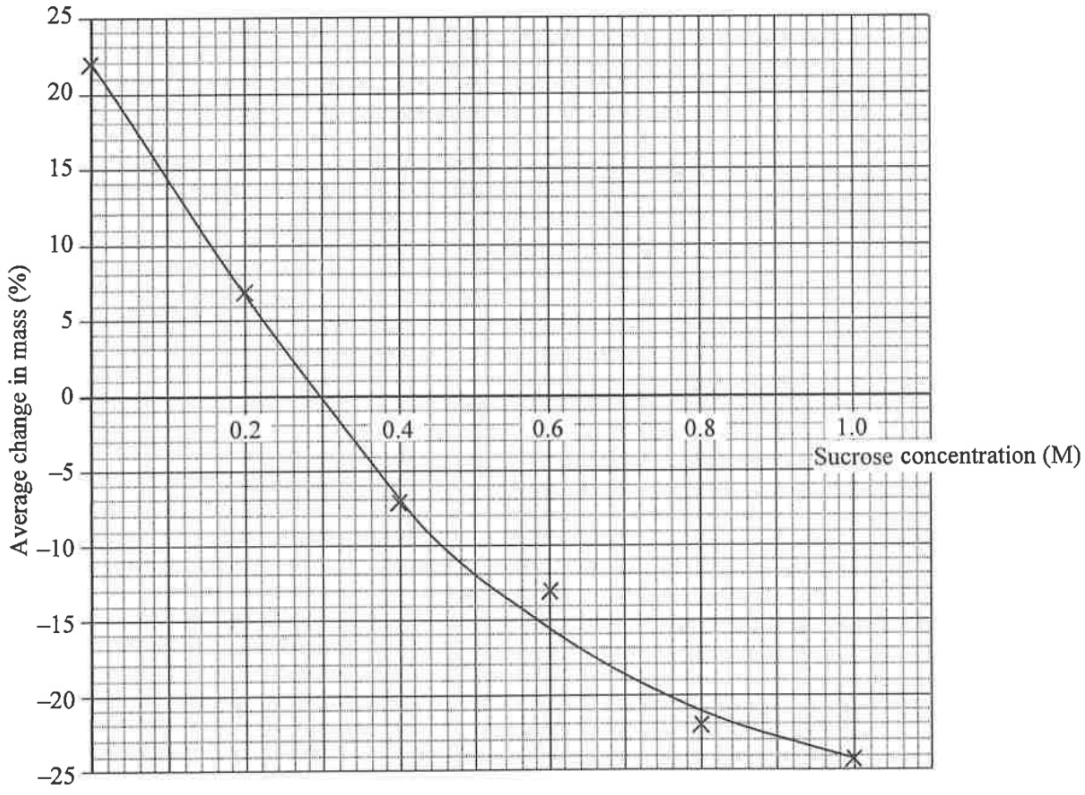
A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

12. [HKDSE Biology 2019 Paper 1B Q6]
Hint: Compare water potential, permeability and net water movement in sequence.

Johnny conducted an experiment to determine the water potential of potato tuber cells. He measured the masses of fresh potato cylinders before and after immersing them in sucrose solutions at different concentrations (0M, 0.2M, 0.4M, 0.6M, 0.8M, and 1.0M). Below shows the major steps in the experiment:

Step 1: Cut potato tubers into cylinders
Step 2: Blot dry the surface of the potato cylinders
Step 3: Weigh the potato cylinders (initial mass)
Step 4: Immerse three potato cylinders in each concentration of sucrose solution for two hours
Step 5: Remove and blot dry the surface of the potato cylinders
Step 6: Reweigh the potato cylinders (final mass)
Step 7: Calculate the average percentage change in mass of the potato cylinders in each solution

The results are shown in the graph below:

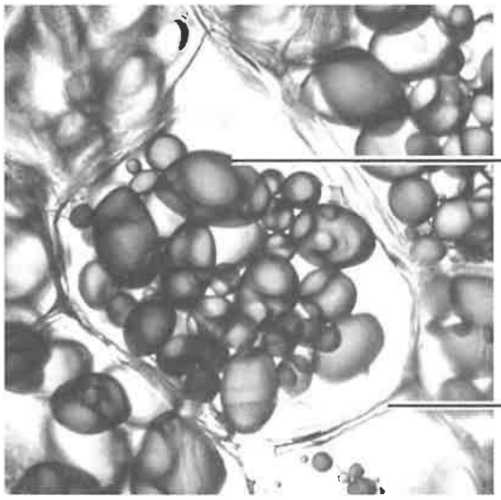


(a) With reference to the graph, which sucrose solution concentration has the same water potential as the potato cells? Explain your answer. (3 marks)

(b) If Johnny skipped step 2 by mistake for all samples, how would this affect the curve and the deduced value of the concentration of the sucrose solution in (a)? Sketch a curve on the graph on the facing page to show the effect. (1 mark)

(c) In terms of experimental design, what is the importance of putting three potato cylinders in each concentration of sucrose solution? (1 mark)

(d) Johnny prepared a slide of freshly sectioned potato cylinder and stained it with iodine solution. The photomicrograph below shows the section. Label structures X and Y. (2 marks)



(e) In the middle of the 19th century, there was a severe attack on potato crops by a plant pathogen in Ireland. As the potato was the major staple food at that time, many Irish people died of starvation. Vegetative propagation of potatoes was blamed for the high vulnerability of the potato crops. Explain the rationale for this claim. (2 marks)

I.d The cell cycle and cell division

First read the explanations and diagrams in Concept I.d, then work through the question types in this section. Each worked example retains the complete original question and explanation. The subsequent exercises require progressively more integration of information, based on the demands of the whole question.

Type 1 Interpret the cell cycle, DNA amount and mitosis

Degree of integration ★★★☆☆

Key ideas

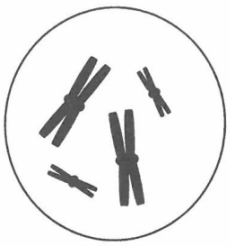
① Count chromosomes by centromere units. After DNA replication, one chromosome can contain two sister chromatids. Increased DNA content does not mean more chromosome sets. Reassess the counting unit when sister chromatids separate.

② A graph showing values per cell may differ from one showing values per nucleus. If every cell divides once per round, producing eight cells from one requires $2^3 = 8$, or three rounds.

How to recognise the problem Identify the vertical-axis counting unit, then place DNA replication, chromatid separation and cytokinesis in sequence on the timeline.

Example 1 [HKDSE Biology 2022 Paper 1A Q4]

Directions: Questions 4 and 5 refer to the diagram below, which shows the appearance of chromosomes in a cell at the early stage of meiotic cell division.



What is the chromosome number in the somatic cells of this organism?

A. 2
B. 4
C. 8
D. 16

Solution **Answer: B**

The diagram contains four replicated chromosomes. Although each has two sister chromatids, each is counted as one chromosome by its single centromere. The chromosome number of this organism's somatic cells is therefore 4, not 8.

Method: Check the vertical-axis unit, then locate replication and division stages.

Marking reference: HKDSE Biology 2022 Paper 1A Q4, official marking scheme, source page(s) 1.

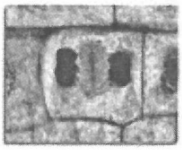
Example 2 [HKDSE Biology 2021 Paper 1B Q5]

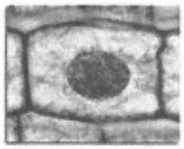
A student prepared cells of an onion root tip for observing cell division under a light microscope.

(a) What type of cell division is likely to take place in the root tip of an onion? Explain your answer. (2 marks)

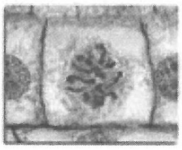
(b) Suggest ***one*** necessary step to make the chromosomes observable under a light microscope. (1 mark)

(c) Some events of the cell division are randomly shown in the following photomicrographs:


V


W


X


Y


Z

(i) Starting with photomicrograph W, arrange the photomicrographs in the correct order to show the sequence of events in cell division. (1 mark)

W → → → →

(ii) A normal onion root cell has 16 chromosomes. Complete the following table to show the number of chromosomes and chromatids in photomicrographs Y and Z. (2 marks)

Photomicrograph	Number of chromosomes	Number of chromatids
Y		
Z		

Solution a; original allocation: 2 mark(s)

Mitosis. The root tip is a vegetative part of the plant undergoing growth.

Increasing the number of somatic cells at the root tip allows the root to grow, and daughter cells normally retain the original chromosome number. Meiosis associated with gamete formation does not apply to this root-tip growth context.

b; original allocation: 1 mark(s)

Stain the chromosomes with a suitable dye.

Staining increases the contrast between chromosomes and other cell components, making otherwise translucent material easier to identify under a light microscope.

c(i); original allocation: 1 mark(s)

W→Y→X→Z→V.

W has an intact nucleus. In Y, condensed chromosomes are visible. In X, chromosomes lie at the centre. In Z, sister chromatids separate and move towards opposite poles. V has

Method: Check the vertical-axis unit, then locate replication and division stages.

two daughter nuclei. Ordering these structural changes is more reliable than memorising the image letters.

c(ii); original allocation: 2 mark(s)

Y: 16 chromosomes, 32 chromatids; Z: 32 chromosomes, 0 chromatids.

In Y, DNA has replicated and each chromosome has two sister chromatids. The centromeres have not separated, so there are still 16 chromosomes. In Z, sister chromatids separate and each becomes an independent chromosome, giving 32 in the whole cell before it divides. This paper's marking scheme calls the separated structures chromosomes, so the chromatid entry is 0. Do not use the number of replicated DNA molecules as the chromosome count at every stage.

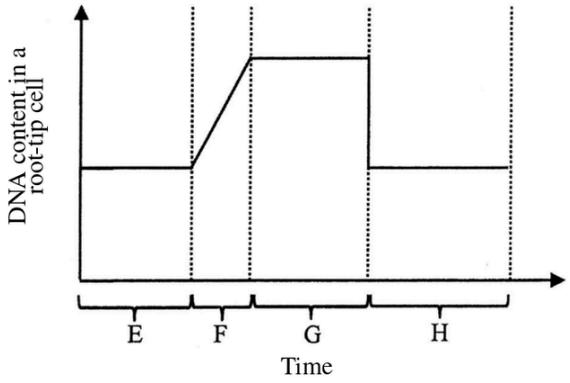
Examiner's comment (source page(s) 4)

DNA replication occurred before division. Once sister chromatids separate, each is called a chromosome. Chromosome number may therefore increase during anaphase, but the same structures must not simultaneously be counted again as chromatids.

Marking reference: HKDSE Biology 2021 Paper 1B Q5, official marking scheme, source page(s) 3.

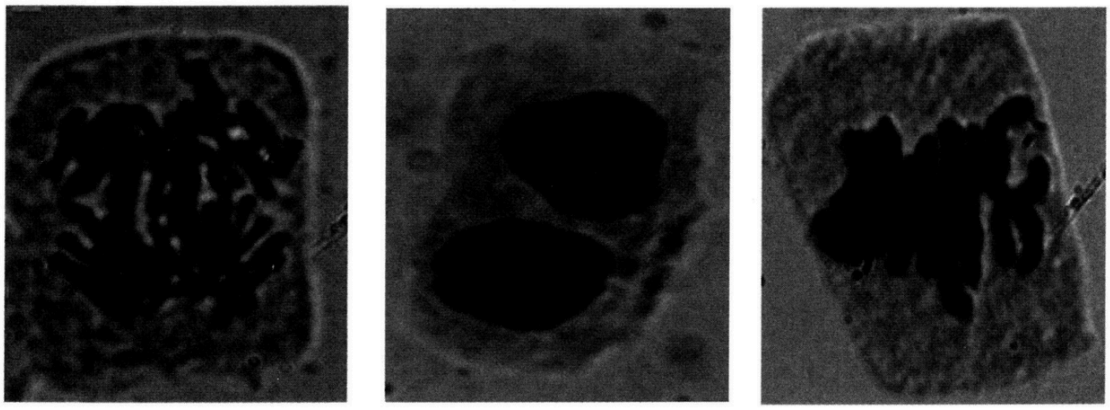
Example 3 [HKDSE Biology 2025 Paper 1A Q25 (English translation)]

Directions: Refer to the graph below to answer Questions 25 and 26. It shows changes in the amount of DNA in a root-tip cell during cell division:



The photomicrographs below show three different stages (X, Y and Z) of cell division:

Stage X Stage Y Stage Z



Which of the following correctly matches the stages of cell division to the time intervals in the graph?

	Stage X	Stage Y	Stage Z
A.	E	H	F
B.	F	G	G
C.	G	G	G
D.	G	H	G

Solution **Answer: C**

X and Z show chromosome arrangements during mitosis, both in stage G after DNA replication is complete. Although Y shows two daughter nuclei, both are still inside one cell. The graph measures DNA per cell, so Y is also in G. All three are G: choose C. A and B place mitotic images in the DNA-replication stage F. D mistakes the appearance of two nuclei for completion of division into two cells and incorrectly selects H.

Method: Check the vertical-axis unit, then locate replication and division stages.

Key knowledge

DNA replicates before division. Separation of chromosomes during mitosis does not immediately halve DNA in the whole cell if the cytoplasm has not yet divided.

Common error

First check whether the vertical axis measures "per cell" or "per nucleus".

Examiner's comment (source page(s) 70)

DNA is measured per whole cell. When two daughter nuclei have formed but cytokinesis is incomplete, total DNA per cell has not yet halved. Distinguish nuclear division from cytoplasmic division.

Marking reference: HKDSE Biology 2025 Paper 1A Q25, official marking scheme, source page(s) 51.

Practice

1. [HKDSE Biology 2014 Paper 1A Q4]

Hint: Check the vertical-axis unit, then locate replication and division stages.

Directions: Questions 3 to 5 refer to the following study:
A student wants to use an ordinary light microscope to observe the binary fission of a photosynthesizing protist under high magnification. A temporary mount of the protist is placed on the stage of the microscope.

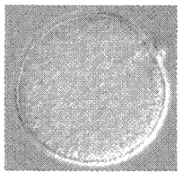
Which of the following correctly describes binary fission of the protist?

A. The amount of organelles in the daughter cell is the same as that in the mother cell.
B. The number of chromosomes in the daughter cell is half of that in the mother cell.
C. The alleles found in the daughter cells are different from each other.
D. The sizes of the daughter cells are similar to each other.

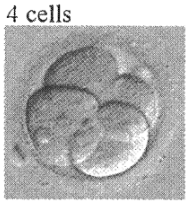
2. [HKDSE Biology 2017 Paper 1A Q22]
Hint: Check the vertical-axis unit, then locate replication and division stages.

Directions: Questions 21 to 23 refer to the following photomicrographs of the same magnification. The photomicrographs show some early stages of embryo development:

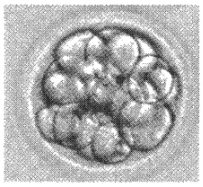
I. 1 cell



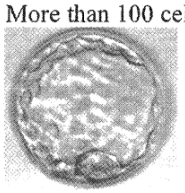
II. 4 cells



III. 16 cells



IV. More than 100 cells

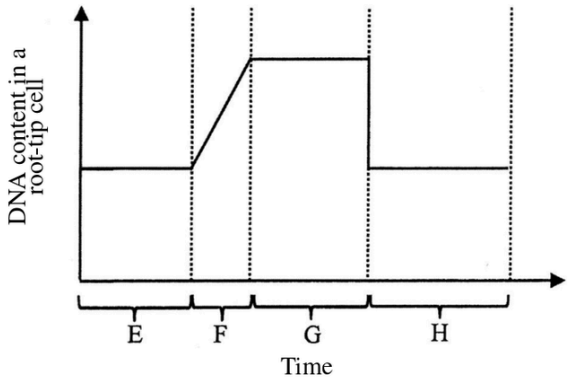


How many cell cycles has the cell in stage I gone through to reach stage III?

A. 2 cycles
B. 3 cycles
C. 4 cycles
D. 5 cycles

3. [HKDSE Biology 2025 Paper 1A Q26 (English translation)]
Hint: Check the vertical-axis unit, then locate replication and division stages.

Directions: Refer to the graph below to answer Questions 25 and 26. It shows changes in the amount of DNA in a root-tip cell during cell division:



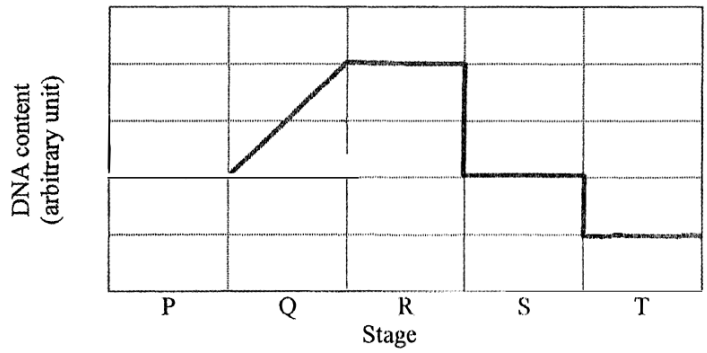
Which of the following are functions of this type of cell division in plants?

(1) Formation of an embryo from a zygote
(2) Proliferation of parenchyma cells
(3) Replacement of root-cap cells

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

4. [HKDSE Biology 2016 Paper 1A Q20]
← Hint: Check the vertical-axis unit, then locate replication and division stages.

Directions: Questions 18 to 20 refer to the graph below, which shows the change in the DNA content of a cell undergoing a certain division:



Sister chromatids separate from one another during the transition from

A. P to Q.
B. Q to R.
C. R to S.
D. S to T.

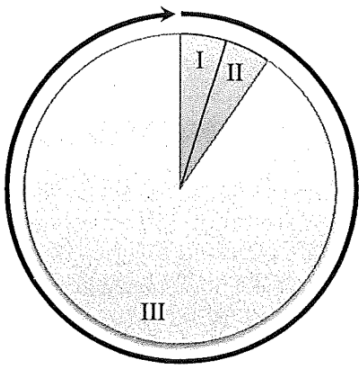
5. [HKDSE Biology 2020 Paper 1A Q20]
← Hint: Check the vertical-axis unit, then locate replication and division stages.

The amount of DNA in cell P immediately before mitosis is x. After division, there are 4 chromosomes in each daughter cell. Which of the following descriptions is correct?

A. The amount of DNA in the daughter cell is 0.5 x.
B. The amount of DNA in each chromosome is 0.25 x.
C. There are 8 chromosomes in the diploid state of cell P.
D. There are 8 chromosomes in cell P immediately before division.

6. [HKDSE Biology 2023 Paper 1A Q5]
← Hint: Check the vertical-axis unit, then locate replication and division stages.

Directions: Questions 5 and 6 refer to the diagram below, which shows three stages of a cell cycle:

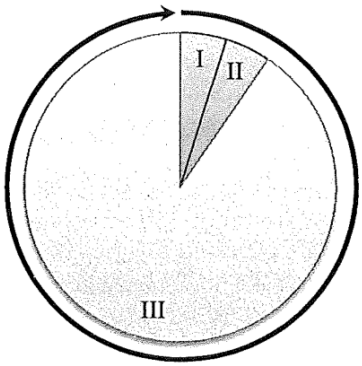


Which of the following correctly describes the events in the cell cycle?

A. The cytoplasm is halved in stage I.
B. Sister chromatids separate in stage II.
C. The cell synthesises more organelles in stage III.
D. Chromatin condenses to form chromosomes in stage III.

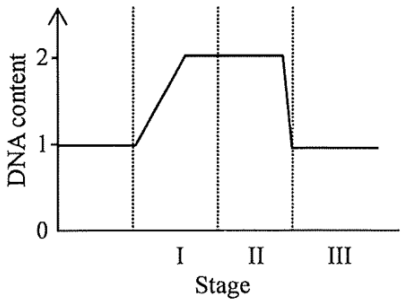
7. [HKDSE Biology 2023 Paper 1A Q6]
Hint: Check the vertical-axis unit, then locate replication and division stages.

Directions: Questions 5 and 6 refer to the diagram below, which shows three stages of a cell cycle:

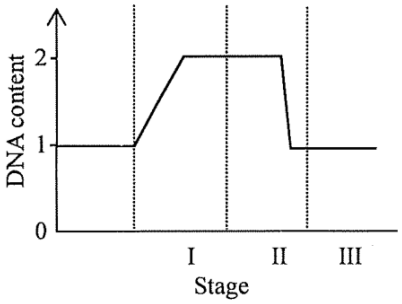


Which of the following graphs correctly matches the changes in the DNA content in the cell with the three stages of the cell cycle?

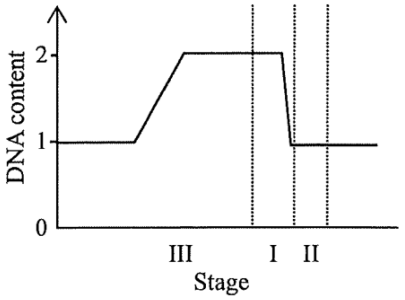
A.



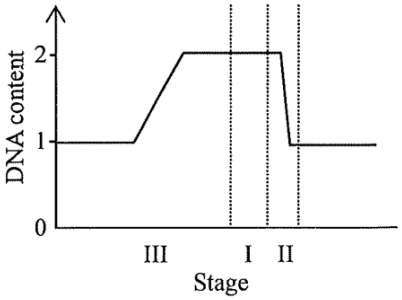
B.



C.

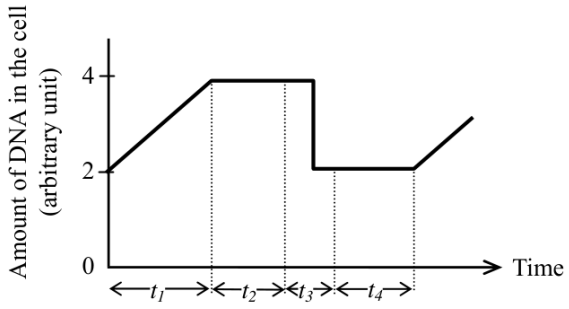


D.



8. [HKDSE Biology Practice Paper Paper 1A Q2]
Hint: Check the vertical-axis unit, then locate replication and division stages.

The graph below shows the change in the amount of DNA in a cell which is undergoing cell division:



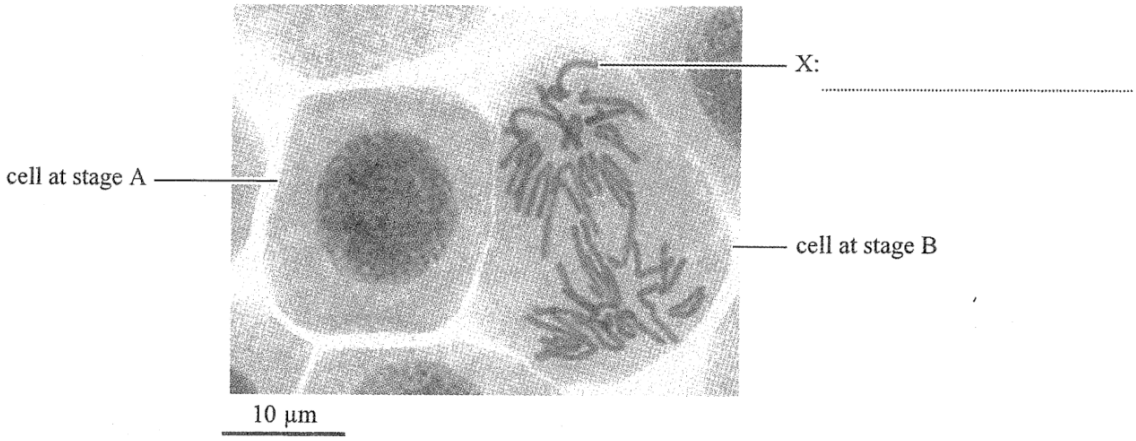
Which of the following statements correctly describes the event that is taking place in the respective time period?

A. During t_1, the nuclear membrane disappears.
B. During t_2, the homologous chromosomes pair up.
C. During t_3, the homologous chromosomes separate.
D. During t_4, the synthesis of cell organelles takes place.

9. [HKDSE Biology 2015 Paper 1B Q2]

Hint: Check the vertical-axis unit, then locate replication and division stages.

The photomicrograph below shows the appearance of genetic materials at two different stages of the cell cycle:



(a) Label structure X shown in the photomicrograph. (1 mark)

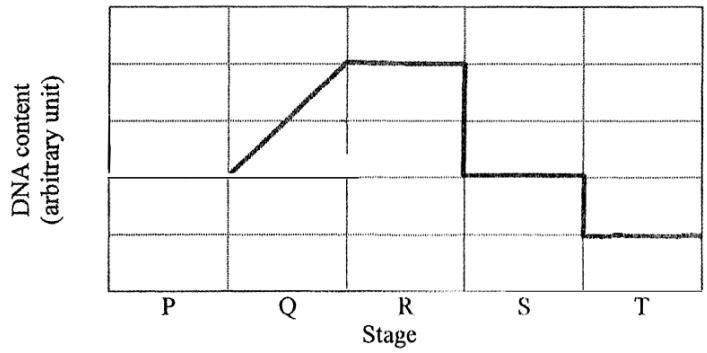
(b) With reference to the appearance of the genetic materials shown in the photomicrograph, at which stage, A or B, is transcription more likely to take place? Explain your answer. (2 marks)

(c) In the space provided below, state the cause for the different outcomes of mitosis and meiosis. (2 marks)

	Outcome		*Cause*
	Mitosis	*Meiosis*	
Number of daughter cells	2	4	
DNA content in daughter cells	2N	1N	

10. [HKDSE Biology 2016 Paper 1A Q19]
Hint: Check the vertical-axis unit, then locate replication and division stages.

Directions: Questions 18 to 20 refer to the graph below, which shows the change in the DNA content of a cell undergoing a certain division:



Which of the following stages best represent(s) interphase?

A. P only
B. Q only
C. P and Q only
D. P, Q and R only

11. [HKDSE Biology 2014 Paper 1B Q3]
Hint: Check the vertical-axis unit, then locate replication and division stages.

Before the early 20th century, scientists generally held the belief:

"Cell division resulted in the loss of genetic material so that each cell in a multicellular organism would contain only the genetic material specific to its particular cell type."

In 1902, Hans Spemann performed one of the earliest experiments on animal cloning. He used a fine hair to separate the cells of a two-celled amphibian embryo, and found that each cell was able to develop into a complete organism.

(a) Why did Spemann's experiment disprove the early belief about cell division? (1 mark)

(b) Elaborate on how the above example can be used to demonstrate the two aspects of the nature of science listed in the table below. (2 marks)

Nature of Science	***Elaboration***
Scientific knowledge is tentative and subject to change.	
Interpretation of observations is guided by our prior understanding of other theories and concepts.	

(c) Using the current understanding about cell division, explain how genetic material is preserved in mitosis. (3 marks)

Type 2 Track chromosomes and variation through meiosis

Degree of integration ★★★☆☆

Key ideas

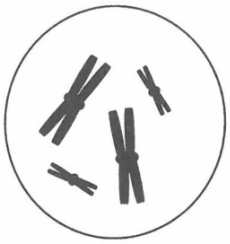
① Start with one homologous pair. The first meiotic division separates the homologous chromosomes of maternal and paternal origin; the second separates sister chromatids. Each gamete ultimately receives one chromosome from each pair, allowing fertilisation to restore pairs.

② Independent assortment of different homologous pairs and crossing over between homologous chromosomes rearrange alleles; they do not create new alleles from nothing.

How to recognise the problem Distinguish homologous chromosomes from sister chromatids before identifying the division. When discussing variation, distinguish new alleles from new combinations.

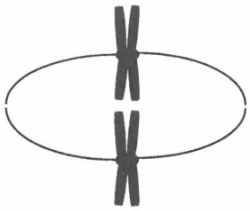
Example 1 [HKDSE Biology 2022 Paper 1A Q5]

Directions: Questions 4 and 5 refer to the diagram below, which shows the appearance of chromosomes in a cell at the early stage of meiotic cell division.

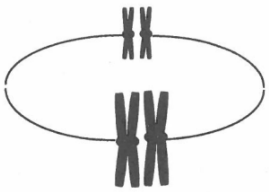


Which of the following diagrams correctly shows the arrangement of chromosomes found at a later stage of the cell division?

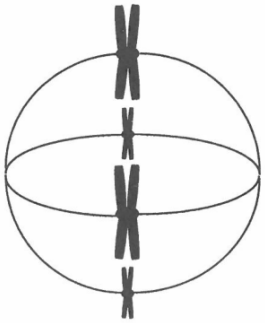
A.



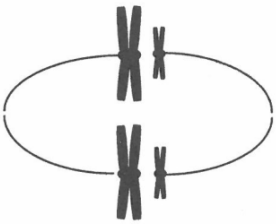
B.



C.



D.



Solution **Answer: B**

The two long chromosomes form one homologous pair, and the two short ones form another. At metaphase I, homologous chromosomes align in pairs at the equator while the sister chromatids of each chromosome remain attached. B shows this paired arrangement. Do not arrange all chromosomes as unpaired individual units in one row.

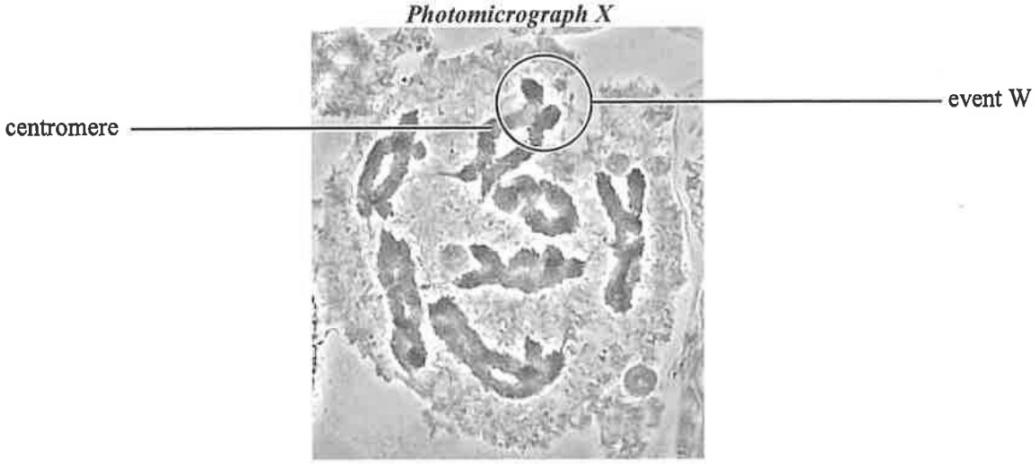
Method: First distinguish homologous chromosomes from sister chromatids.

Marking reference: HKDSE Biology 2022 Paper 1A Q5, official marking scheme, source page(s) 1.

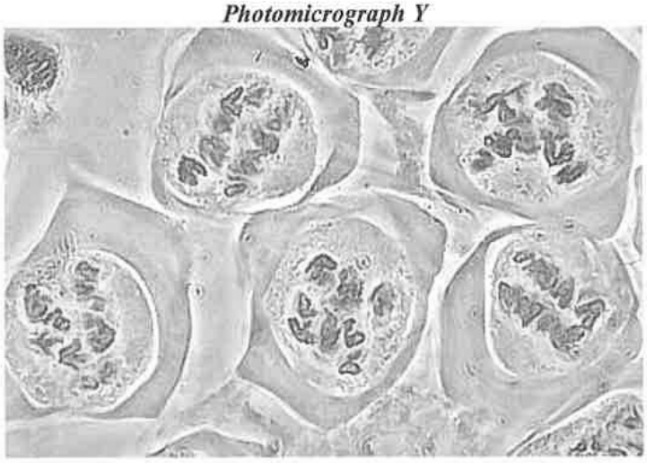
Example 2 [HKDSE Biology 2019 Paper 1B Q3]

The photomicrographs below show some stages of meiosis taking place in a flower:

Photomicrograph X



Photomicrograph Y



Photomicrograph Z



(a) State ***one*** floral structure in which this type of division takes place. (1 mark)

(b) (i) Name event W shown in Photomicrograph X. (1 mark)

(ii) Briefly describe what happens in event W. What is the importance of event W? (2 marks)

(c) (i) Which photomicrograph, Y or Z, shows the first meiotic division? Give a piece of evidence to support your answer. (2 marks)

(ii) What is the purpose of the first and second meiotic divisions respectively? (2 marks)

Solution a; original allocation: 1 mark(s)

Anther; an ovule inside the ovary is also acceptable.

Relevant mother cells undergo meiosis before pollen and embryo sacs form. The question asks for one floral structure: specify the anther or the location of the ovule, rather than the whole flower.

Method: First distinguish homologous chromosomes from sister chromatids.

b(i); original allocation: 1 mark(s)

Crossing over.

W in micrograph X shows a cross-shaped connection between homologous chromosomes, corresponding to crossing over during meiotic prophase.

b(ii); original allocation: 2 mark(s)

Non-sister chromatids of homologous chromosomes exchange corresponding DNA segments, producing new combinations of alleles and increasing genetic variation.

One homologue is paternal and the other maternal. Exchanging segments at corresponding positions recombines existing alleles. Crossing over is not an exchange of positions of whole chromosomes and does not necessarily create new alleles.

c(i); original allocation: 2 mark(s)

Y; paired/separating homologous chromosomes are visible, a feature of meiosis I.

Judge chromosome behaviour. Paired homologous structures can still be recognised in Y, placing it in the first division. In Z, the two groups have entered a further division. Image darkness is not the criterion.

c(ii); original allocation: 2 mark(s)

The first division separates homologous chromosomes; the second separates sister chromatids.

The first distributes the members of each homologous pair to different cells, halving the number of sets. The second distributes the two sister chromatids of each chromosome to different daughter cells. The structures separated in the two divisions are different.

Examiner's comment (source page(s) 4)

Eggs and pollen grains are products associated with meiosis, not the locations within a flower requested here. Crossing over occurs between non-sister chromatids of homologous chromosomes. The first division separates homologues and the second separates sister chromatids; do not say that both divisions halve chromosome number.

Marking reference: HKDSE Biology 2019 Paper 1B Q3, official marking scheme, source page(s) 2.

Example 3 [HKDSE Biology 2012 Paper 1B Q11]

For the following question, candidates are required to present their answer in essay form. Criteria for marking will include relevant content, logical presentation and clarity of expression.

Mitosis and meiosis are important processes that ensure the continuity of life. Contrast the two processes and state the significance of their differences. (11 marks)

Solution **Essay; original allocation: 11 mark(s)**

Method: First distinguish homologous chromosomes from sister chromatids.

Mitosis involves one nuclear division. Homologous chromosomes do not pair, and replicated sister chromatids separate. It normally produces two daughter cells with the same chromosome number and genetic composition as the parent. It therefore increases the number of somatic cells with the same functions for growth and tissue repair, while also maintaining inherited characteristics in asexually produced offspring. Meiosis consists of two consecutive nuclear divisions after one DNA replication. In the first division, homologous chromosomes pair, crossing over may occur, and homologues subsequently separate. The second division separates sister chromatids. Resulting gametes contain only one chromosome from each homologous pair, halving chromosome number. Fusion of two gametes at fertilisation restores the normal number, preventing repeated doubling across generations. Random distribution of different homologous chromosomes and crossing over also create new allele combinations, increasing genetic variation among sexually produced offspring.

Link each difference in division to its biological significance, rather than writing two disconnected lists of terms. The official content allocation is up to 8 marks, covering pairing/separation and the number of divisions, together with implications for maintaining chromosome number, genetic stability and variation. Up to 3 further marks are for expression and organisation. Do not claim that mitosis involves no chromosome separation or that DNA replicates twice in meiosis.

Examiner's comment (source page(s) 2)

The essay must compare the two divisions and link differences to their significance. Describing the processes separately from memory does not by itself constitute a comparison.

Marking reference: HKDSE Biology 2012 Paper 1B Q11, official marking scheme, source page(s) 5.

Practice

1. [HKDSE Biology 2019 Paper 1A Q12]

Hint: First distinguish homologous chromosomes from sister chromatids.

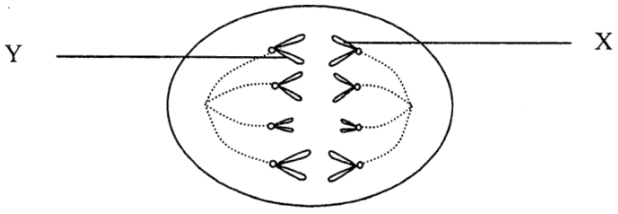
Which of the following statements about the human egg and sperm is correct?

A. Both have the same number of genes.
B. Both have the same amount of cytoplasm.
C. Both have the same amount of food reserve.
D. Both have the same number of chromosomes.

2. [HKDSE Biology 2013 Paper 1A Q18]

Hint: First distinguish homologous chromosomes from sister chromatids.

The diagram below shows a dividing cell which is forming an animal's egg cell:

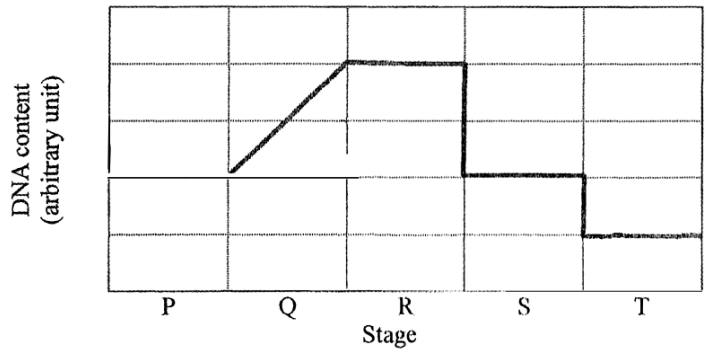


What conclusion about the cell division can be drawn from the diagram?

A. The diagram shows a mitotic cell division.
B. The diagram shows the first meiotic cell division.
C. X and Y are homologous chromosomes.
D. Each daughter cell will have four chromosomes.

3. [HKDSE Biology 2016 Paper 1A Q18]
Hint: First distinguish homologous chromosomes from sister chromatids.

Directions: Questions 18 to 20 refer to the graph below, which shows the change in the DNA content of a cell undergoing a certain division:



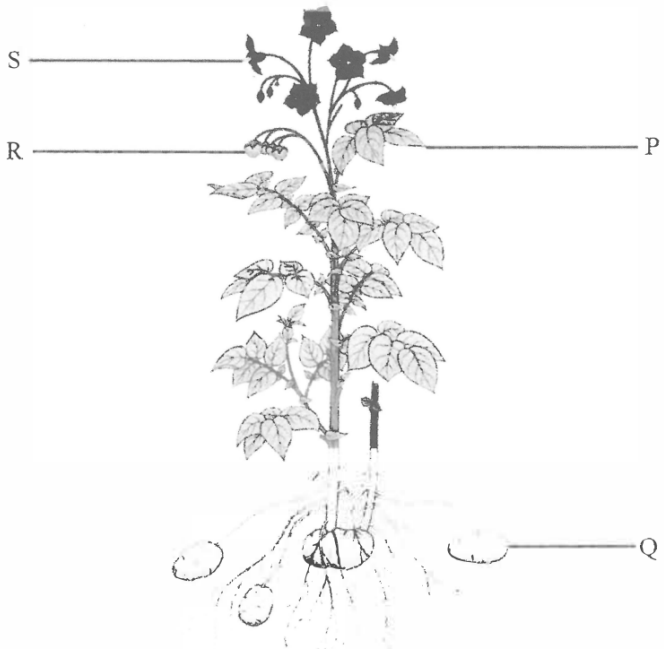
Which of the following can be deduced from the graph?

(1) There are two divisions.
(2) There is one DNA duplication.
(3) DNA content is halved at the end of the whole process.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

4. [HKDSE Biology 2018 Paper 1A Q16]
Hint: First distinguish homologous chromosomes from sister chromatids.

Directions: Questions 15 to 17 refer to the following diagram, which shows the structures of a potato plant:



Which of the following labelled structures contain cells with different genotypes?

A. P and Q
B. P and S
C. Q and R
D. R and S

5. [HKDSE Biology 2024 Paper 1A Q4]
← Hint: First distinguish homologous chromosomes from sister chromatids.

Directions: Questions 4 to 6 refer to the diagram below, which shows the appearance of chromosomes in a cell at the early stage of meiotic cell division:

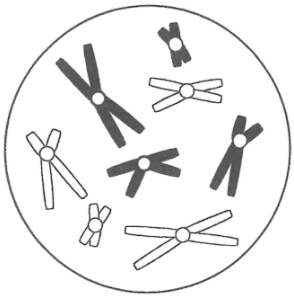


If the amount of DNA in this cell is β, what is the amount of DNA in a non-dividing somatic cell of this organism?

A. ¼ β
B. ½ β
C. β
D. 2 β

6. [HKDSE Biology 2024 Paper 1A Q5]
← Hint: First distinguish homologous chromosomes from sister chromatids.

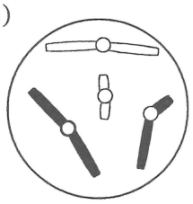
Directions: Questions 4 to 6 refer to the diagram below, which shows the appearance of chromosomes in a cell at the early stage of meiotic cell division:



Which of the following diagrams show the possible combinations of the chromosomes in the daughter cells?

(1)

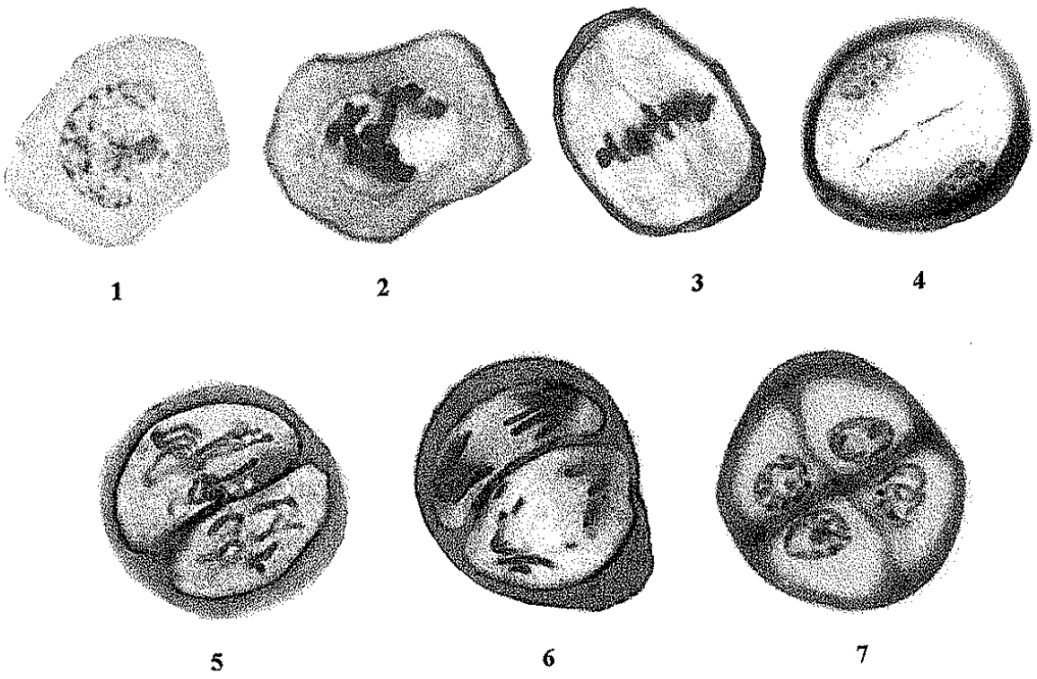

(2)


(3)


A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

7. [HKDSE Biology Sample Paper Paper 1B Q4]
Hint: First distinguish homologous chromosomes from sister chromatids.

The photomicrographs below show changes in a cell when it undergoes a certain type of cell division:



(a) State ***two*** processes occurring in stage 1 which prepare the cell for this type of cell division. (2 marks)

(b) Explain the significance of the behaviour of chromosomes in stage 3 to the outcomes of this type of cell division. (4 marks)

I.e Enzymes, photosynthesis and respiration

First read the explanations and diagrams in Concept I.e, then work through the question types in this section. Each worked example retains the complete original question and explanation. The subsequent exercises require progressively more integration of information, based on the demands of the whole question.

Type 1 Distinguish synthesis, breakdown and energy conversion

Degree of integration ★★☆☆☆

Key ideas

① Linking many glucose molecules into glycogen requires chemical-bond formation and energy input, so it is anabolic. Breaking large organic molecules into smaller ones is catabolic. Chewing fragments food without changing molecular structure and is physical processing.

② Cells transfer some released energy into ATP, which then supports energy-requiring activities. Do not say that matter itself disappears by becoming energy.

How to recognise the problem Examine molecular size and chemical change, not only visible fragmentation. Then ask whether energy is stored, transferred or released.

Example 1 [HKDSE Biology 2017 Paper 1A Q1]

Which of the following combinations correctly matches the process with the type of metabolism involved?

	Process	*Type of metabolism*
A.	digestion of lipids in the small intestine	anabolism
B.	storage of excess energy in the form of glycogen	catabolism
C.	assimilation of amino acids to form muscle fibres	anabolism
D.	absorption of digested food in the small intestine	catabolism

Solution Answer: C

Assembly of amino acids into muscle proteins is anabolism, or anabolic metabolism, so choose C. Digestion of fats in the small intestine is breakdown; formation of glycogen from glucose is synthesis; absorption of digestion products across membranes is transport, not the same as catabolism.

Method: Examine chemical changes in molecules before identifying energy transformations.

Marking reference: HKDSE Biology 2017 Paper 1A Q1, official marking scheme, source page(s) 1.

Practice

1. [HKDSE Biology 2014 Paper 1A Q1]

Hint: Examine chemical changes in molecules before identifying energy transformations.

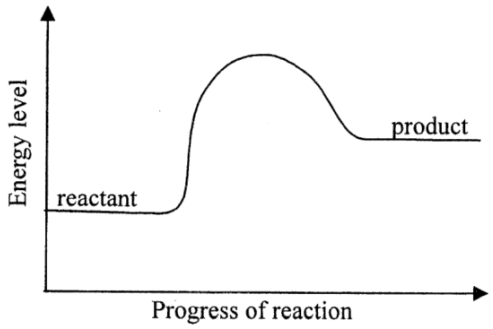
Which of the following is a catabolic process?

A. Conversion of glucose to glycogen
B. Absorption of glucose
C. Emulsification of fat
D. Digestion of starch

2. [HKDSE Biology 2013 Paper 1A Q6]

Hint: Examine chemical changes in molecules before identifying energy transformations.

Directions: Questions 6 and 7 refer to the graph below, which shows the energy levels of the reactant and product of a biochemical reaction in the presence of its enzyme:



The reaction shown in the graph is

A. an anabolic process because energy is absorbed.
B. an anabolic process because energy is released.
C. a catabolic process because energy is absorbed.
D. a catabolic process because energy is released.

3. [HKDSE Biology 2016 Paper 1A Q8]

Hint: Examine chemical changes in molecules before identifying energy transformations.

Which of the following combinations correctly matches the biochemical reaction with the type of metabolism involved?

	Biochemical reaction	*Type of metabolism*
A.	conversion of glucose to pyruvate	anabolism
B.	conversion of protein to amino acids	anabolism
C.	conversion of amino acids to urea	catabolism
D.	conversion of glucose to glycogen	catabolism

Type 2 Use enzyme models to explain specificity, reuse and inhibition

Degree of integration ★★★☆☆

Key ideas

① An enzyme's active site fits its substrate. The enzyme can catalyse another reaction after one is complete, so renewed bubbling after fresh substrate is added supports its continued activity.

② Another molecule occupying the substrate's binding site may inhibit the reaction. Testing whether higher substrate concentration reduces inhibition can assess a competitive model. A model has limited scope: a lock-and-key diagram cannot establish every enzyme's composition and optimum conditions.

How to recognise the problem Add substrate to test reuse; change substrate to test specificity. For inhibition, connect molecular shape, binding location and experimental results.

Example 1 [HKDSE Biology 2018 Paper 1A Q3]

Directions: Questions 2 to 4 refer to an experiment on the enzyme catalase, which speeds up the breakdown of hydrogen peroxide to release oxygen. John added a 1 cm^3 cube of pig liver to a boiling tube containing 5 mL hydrogen peroxide solution. Gas bubbles were released and he used a glowing splint to test the gas. He repeated the experiment with beef, potato and apple. The results are shown below:

Tissue	*Rate of bubbles released*	*Glowing splint re-lit*
Pig liver	Moderate	Yes
Beef	Moderate	Yes
Potato	Slow	Yes
Apple	Slow	Yes

When the release of gas bubbles had stopped, John added more hydrogen peroxide solution to the boiling tubes. Which of the following combinations correctly shows the expected result and the explanation of this additional experiment?

	Expected result	*Explanation*
A.	Gas bubbles released	Catalase is specific in its action.
B.	Gas bubbles released	Catalase is reusable.
C.	No gas bubbles	Catalase has been used up.
D.	No gas bubbles	Catalase is denatured.

Solution Reading the question and choosing a method

Method: Connect binding location, molecular shape and reaction outcome.

After the reaction stops, substrate is added; no additional enzyme is supplied.

Answer: B

Distinguish the roles: hydrogen peroxide is the substrate being broken down, and catalase is the catalyst. Substrate is gradually consumed, while an enzyme can catalyse another reaction after completing one catalytic cycle. When hydrogen peroxide is added after bubbling stops, the existing enzyme can break down the newly supplied substrate, releasing oxygen and producing bubbles again. This supports enzyme reusability and matches both the result and explanation in B. Specificity explains which substrate an enzyme acts on; it is not the direct reason bubbling restarts after substrate addition. Choose B.

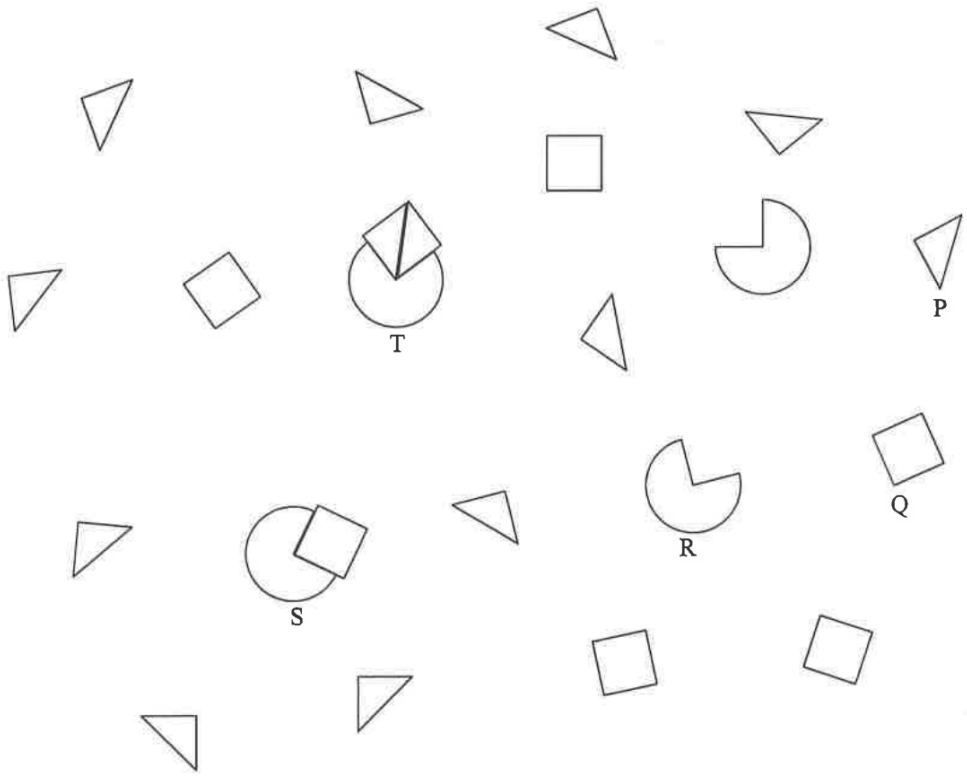
Common error

No bubbles do not necessarily mean that the enzyme has been used up. Consider whether substrate has become insufficient.

Marking reference: HKDSE Biology 2018 Paper 1A Q3, official marking scheme, source page(s) 1.

Example 2 [HKDSE Biology 2019 Paper 1B Q2]

The schematic diagram below shows a reaction mixture of an anabolic reaction catalysed by an enzyme. Drawings P, Q, R, S, and T represent different components of the mixture:



(a) Which drawing represents the substrate in this anabolic reaction? Explain your answer. (2 marks)

(b) Which drawing represents the enzyme? Explain your answer. (2 marks)

Solution a; original allocation: 2 mark(s)

P.

P is the smaller triangular molecule. Two P molecules can join to form the larger Q, matching the anabolic assembly of smaller molecules into a larger one. T shows two P molecules coming together and joining; S shows the larger product temporarily attached to the enzyme.

b; original allocation: 2 mark(s)

R.

R is the enzyme with a specifically shaped depression, its active site, which accommodates substrate P or the resulting Q. T and S are states of the same enzyme bound to substrates/ products, not two additional enzymes. After the product leaves, the enzyme can participate again.

Examiner's comment (source page(s) 3, 4)

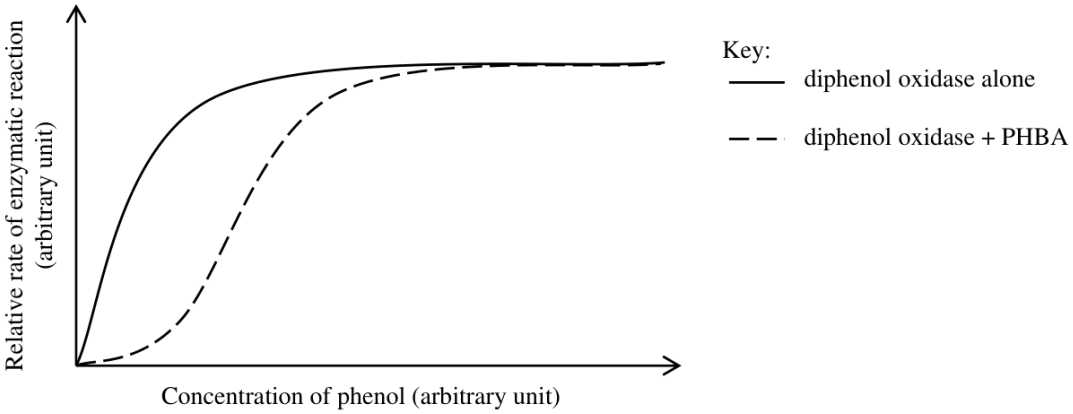
Some candidates reproduced definitions of synthesis or breakdown without identifying substrate P and enzyme R from the diagrams. Explain R using the visible evidence that it remains after the reaction and can be reused. Do not rely solely on general properties, such as heat resistance or specificity, that cannot be observed in the figure.

Marking reference: HKDSE Biology 2019 Paper 1B Q2, official marking scheme, source page(s) 2.

Method: Connect binding location, molecular shape and reaction outcome.

Example 3 [HKDSE Biology Practice Paper Paper 1B Q4]

When a slice of apple is exposed to air, it quickly turns brown. This is because the enzyme diphenol oxidase catalyzes the oxidation of phenols in the apple to dark-coloured products. In an experiment, the effect of a chemical, PHBA, on the rate of this enzymatic reaction was investigated. The experiment was carried out at the same temperature and the same concentration of diphenol oxidase was used. The results are shown in the graph below:



(a) Deduce the relationship between PHBA and diphenol oxidase. (3 marks)

(b) Draw a curve in the above graph to show the effect of PHBA on the rate of enzymatic reaction if a higher concentration of PHBA had been used. (1 mark)

(c) Suggest one other factor that should be kept constant in this experiment. Explain how this factor may affect the activity of the enzyme. (3 marks)

Solution a; original allocation: 3 mark(s)

PHBA is a competitive inhibitor. At the same relatively low phenol concentration, the reaction is slower with PHBA. However, increasing the concentration of phenol substrate allows the same maximum rate as without PHBA to be reached.

The unchanged maximum rate is key evidence. More substrate can compete for enzyme active sites, reducing the inhibitor's relative effect. Naming competitive inhibition without citing the graph does not complete the inference.

b; original allocation: 1 mark(s)

Draw a curve further to the right of the original dashed PHBA curve: lower rates at the same relatively low phenol concentrations, but the same plateau at high concentration.

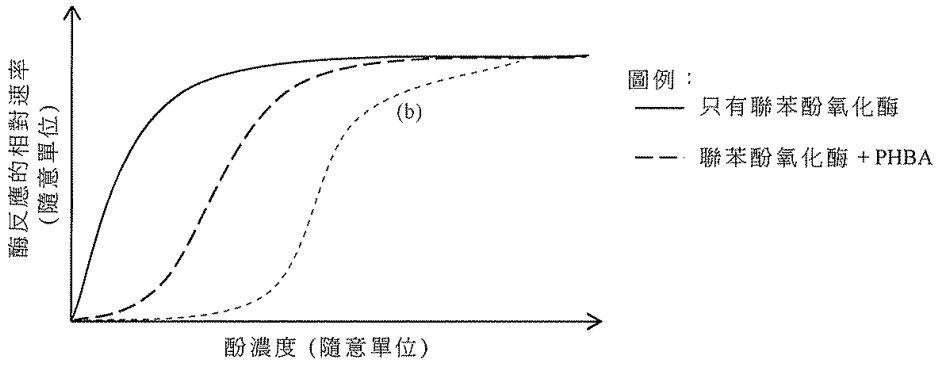
The completed official sketch is shown below. More competitive inhibitor changes the substrate concentration needed to reach high rates; do not lower the maximum plateau.

c; original allocation: 3 mark(s)

Keep pH the same. Changes in pH can alter charges or conformation at the active site, making substrate binding and enzyme–substrate complex formation more difficult and changing reaction rate.

Temperature and enzyme concentration are already controlled in the question, so neither answers "another" factor. Nor should substrate concentration, deliberately varied on the horizontal axis, be described as constant.

Method: Connect binding location, molecular shape and reaction outcome.



Higher PHBA concentration shifts the curve rightwards without changing the maximum rate.

Examiner's comment (source page(s) 1, 5, 9)

The high-, medium- and lower-performing examples all show the need to support competitive inhibition using the shared plateau at high substrate concentration. Naming it alone is insufficient. The lower-performing example repeated temperature, which was already controlled, so it could not earn the mark for another control factor in (c).

Marking reference: HKDSE Biology Practice Paper Paper 1B Q4, official marking scheme, source page(s) 4.

Practice

1. [HKDSE Biology 2018 Paper 1A Q1]
← *Hint: Connect binding location, molecular shape and reaction outcome.*

Which of the following processes involves enzymes on cell membranes?

A. excretion of carbon dioxide by the lungs
B. transport of water along the xylem vessel
C. Calvin cycle in the chloroplasts of plant cells
D. digestion of carbohydrates in the small intestine

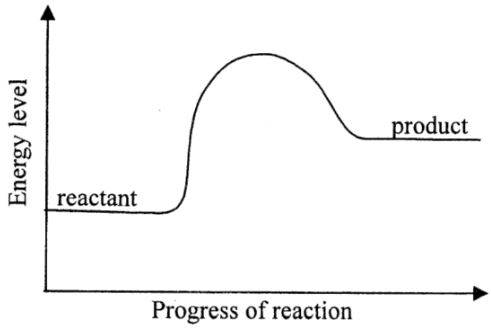
2. [HKDSE Biology 2018 Paper 1A Q27]
← *Hint: Connect binding location, molecular shape and reaction outcome.*

'Lock and Key' is a scientific model which is a selective representation used to explain that enzymes

A. are biological catalysts.
B. are specific in action.
C. are protein in nature.
D. are required in small amounts.

3. [HKDSE Biology 2013 Paper 1A Q7]
← Hint: Connect binding location, molecular shape and reaction outcome.

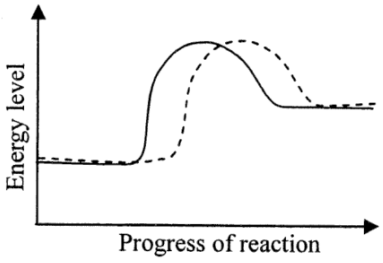
Directions: Questions 6 and 7 refer to the graph below, which shows the energy levels of the reactant and product of a biochemical reaction in the presence of its enzyme:



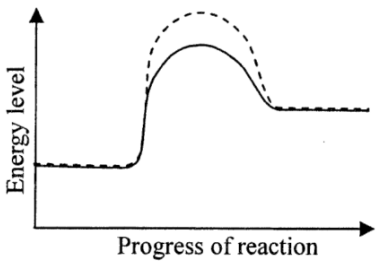
Which of the following graphs correctly shows the change in the energy level of the reaction if the enzyme involved is absent?

Key: ———— with the enzyme
-------- without the enzyme

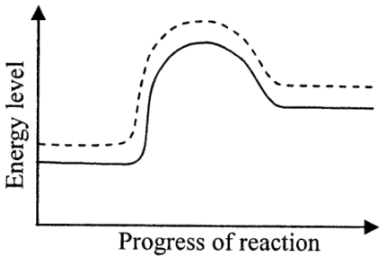
A.



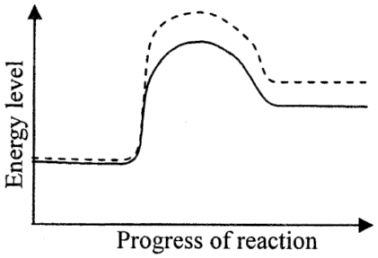
B.



C.



D.



4. [HKDSE Biology 2017 Paper 1A Q5]
← Hint: Connect binding location, molecular shape and reaction outcome.

Different animals produce different maltases to digest maltose. The maltases produced have different molecular sizes. Which of the following descriptions of these maltases is correct?

A. Their active sites have similar shape.
B. Their amino acid sequences are the same.
C. They have the same optimum temperature.
D. They have the same three-dimensional structure.

5. [HKDSE Biology 2020 Paper 1A Q8]
← Hint: Connect binding location, molecular shape and reaction outcome.

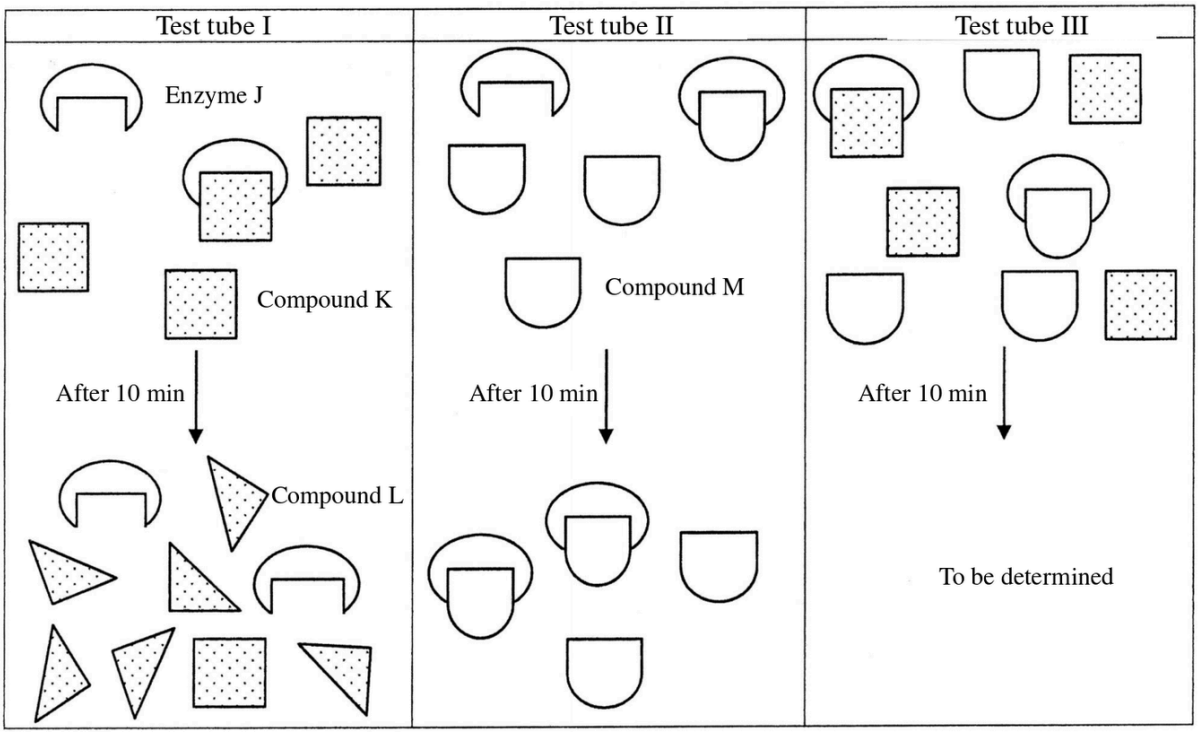
Which of the following descriptions of the active site of an enzyme is correct?

(1) It can be used again.
(2) It is the part of the enzyme on which its substrate can fit.
(3) Its shape is determined by the amino acid sequence of the enzyme.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

6. [HKDSE Biology 2025 Paper 1A Q9 (English translation)]
Hint: Connect binding location, molecular shape and reaction outcome.

The diagrams below show the contents of three test tubes at the beginning and end of enzyme reactions:



Which combination below is correct regarding the expected result in test tube III?

	Concentration of compound L in test tube III compared with test tube I	Reason
A.	Lower	Compound M occupies the active site of enzyme J.
B.	Lower	Compound M destroys the active site of enzyme J.
C.	The same	Enzyme J cannot react with compound M to form products.
D.	Higher	Test tube III contains both compounds K and M.

Type 3 Design enzyme controls and interpret reaction curves

Degree of integration ★★★☆☆

Key ideas

① A catalase reaction can be measured by oxygen production per minute. In a lipase reaction, fatty-acid production can be indicated by a colour change. For temperature comparisons, equilibrate both enzyme and substrate at the chosen temperature before mixing and starting timing.

② The slope of a cumulative-product curve represents rate. Its final plateau mainly indicates the total product that can form. Reciprocal reaction time can compare rates only with the same endpoint; different endpoints cannot be compared directly.

How to recognise the problem Distinguish the independent variable, directly measured quantity and inferred rate. Each control should address a specific alternative explanation.

Example 1 [HKDSE Biology 2018 Paper 1A Q2]

Directions: Questions 2 to 4 refer to an experiment on the enzyme catalase, which speeds up the breakdown of hydrogen peroxide to release oxygen. John added a 1 cm^3 cube of pig liver to a boiling tube containing 5 mL hydrogen peroxide solution. Gas bubbles were released and he used a glowing splint to test the gas. He repeated the experiment with beef, potato and apple. The results are shown below:

Tissue	*Rate of bubbles released*	*Glowing splint re-lit*
Pig liver	Moderate	Yes
Beef	Moderate	Yes
Potato	Slow	Yes
Apple	Slow	Yes

Which of the following statements is an observation of the experiment?

A. These tissues contained catalase.
B. Oxygen gas was released in the reaction.
C. The gas released re-lit the glowing splint.
D. Animal tissues had more catalase than plant tissues.

Solution Reading the question and choosing a method

Method: Identify variables, measurements and controls, then read the curve's slope.

Separate directly visible events from explanations inferred from them.

Answer: C

Bubbles form and the gas relights a glowing splint. These are directly observed, so C is an observation. Identifying the gas as oxygen uses prior knowledge that oxygen supports combustion and is an inference. Concluding that the tissue contains catalase also infers the presence of a substance from a reaction. Generalising from the bubbling rates of four tissues to enzyme content in all plants and animals is even further removed from direct observation. Choose C.

Common error

"The gas is oxygen" may be reasonable, but it remains an interpretation of the test result rather than the observed event itself.

Examiner's comment (source page(s) 1)

Relighting of a glowing splint is directly observed; identifying the collected gas as oxygen is an inference using existing knowledge.

Marking reference: HKDSE Biology 2018 Paper 1A Q2, official marking scheme, source page(s) 1.

Example 2 [HKDSE Biology 2015 Paper 1B Q7]

Hydrogen peroxide is a by-product of some metabolic reactions inside our body. If it were allowed to accumulate, it would kill our cells. Fortunately, we have an enzyme called catalase which speeds up the breakdown of hydrogen peroxide into water and oxygen. A student planned to investigate the effect of temperature on the activity of catalase. Below are the steps the student has drafted for his investigation:

(1) Extract catalase from an animal organ.
(2) Mix 5 mL 0.1% hydrogen peroxide solution with 1 mL catalase extract.
(3) Place the mixture in a water bath set at 0°C.
(4) Measure and record the volume of oxygen gas released in the first 5 minutes.
(5) Repeat steps (2) to (4) with the water bath set at 20°C, 40°C and 60°C.

(a) Suggest an animal organ in which catalase is present in great abundance and from which the enzyme can be obtained. Explain why this organ has so much catalase. (2 marks)

(b) The student has missed out an important step in his drafted procedure. What is it? Explain the importance of this step. (2 marks)

(c) You are provided with the following apparatus and materials:

measuring cylinder, boiling tube, one-hole stopper, glass tubing, rubber tubing, pipette, ink, water trough, clip

Choose the appropriate apparatus and materials to assemble a set-up for measuring the rate of oxygen production. Draw the set-up in the space below. (3 marks)

Set-up for measuring the rate of oxygen production

Solution (a); original allocation: 2 mark(s)

Liver; its extensive metabolic and detoxification reactions require breakdown of the hydrogen peroxide they produce.

Name the organ, then link its metabolic activity to hydrogen peroxide as a by-product. Catalase breaks hydrogen peroxide down into water and oxygen, reducing cellular damage from its accumulation.

(b); original allocation: 2 mark(s)

Before mixing, place hydrogen peroxide and enzyme extract separately in a water bath at the specified temperature for about 10 minutes. Then mix them to start the reaction.

If they are mixed before entering the bath, reaction begins before the set temperature is reached. Oxygen collected during the first five minutes would not all have been produced at that temperature. Prior equilibration ensures that reaction temperature meets the comparison requirements when timing begins.

(c); original allocation: 3 mark(s)

Seal the large test tube containing the reaction mixture with a one-hole stopper. Connect a delivery tube to an inverted, water-filled measuring cylinder in a water trough. Collect oxygen by water displacement and read the gas volume produced in a specified time.

The diagram must show gas-tight connections, a graduated vessel for measuring gas volume, and labels for the reaction mixture and gas-flow direction. Dividing the volume collected in the first 5 minutes by 5 minutes gives an average oxygen-production rate for comparison. Keep enzyme quantity, substrate quantity and concentration, and other relevant factors constant.

Method: Identify variables, measurements and controls, then read the curve's slope.

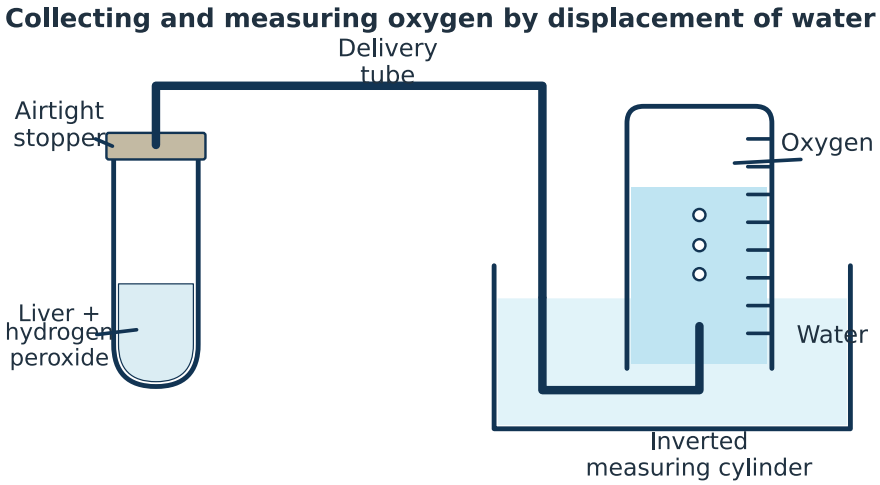


Diagram answering the original question.

Examiner's comment (source page(s) 3)

Both enzyme and substrate should equilibrate at the specified temperature before mixing and timing. Use the apparatus supplied in the question to measure oxygen. The diagram must show airtight connections and the gas-collection method.

Marking reference: HKDSE Biology 2015 Paper 1B Q7, official marking scheme, source page(s) 3, 4.

Example 3 [HKDSE Biology 2024 Paper 1B Q6]

Shirley came across an article about some beans containing an amylase inhibitor as a defence against insects. She wondered if the amylase inhibitor would also work in the human body and if it did, whether it could be used as a food supplement for weight management. She discussed the idea with her classmate Johnson. They had different ideas:

Shirley: I think we should test if the bean extract can inhibit pancreatic amylase.

Johnson: Perhaps we can use salivary amylase instead of pancreatic amylase.

(a) With reference to the process of digestion, which amylase would produce more valid results for developing a food supplement that targets weight management? Explain your answer. (3 marks)

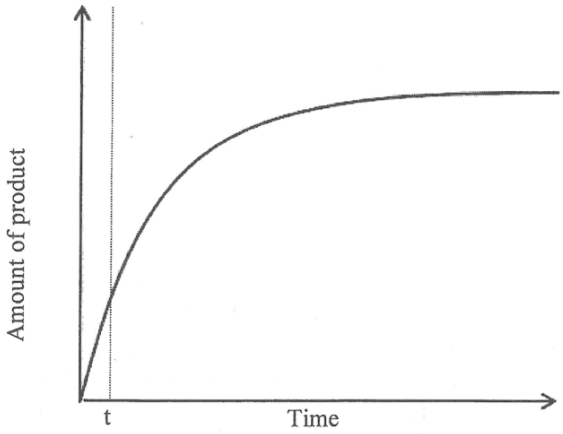
(b) The table below shows the reaction mixtures prepared for the investigation:

Solution	*Volume of solution used in each set-up (mL)*	
	Set-up I	*Set-up II*
1% starch solution	15	15
Amylase solution	5	5
Bean extract	0	5
Buffer solution (to maintain the pH)	5	5
Water	5	0

(i) Explain the purpose of adding water to set-up I. (2 marks)

(ii) Suggest ***one*** method to determine the rate of starch digestion and state clearly the measurement taken to show the rate of starch digestion. (2 marks)

(c) The graph below shows the amount of product formed over time when amylase is working normally:



The experiment was repeated with the addition of bean extract at time t. If the bean extract can inhibit the amylase being studied, what will be the change in the amount of product formed? On the above graph, sketch a line to show the results. (1 mark)

(d) Shirley and Johnson shared their ideas with their professor. Their professor suggested that they should conduct an *in vivo* experiment using mice with the control group fed with starchy food and the experimental group fed with a mixture of starchy food and bean extract.

(i) Explain why the result of an *in vivo* experiment is more valid than that of *in vitro* experiment in this case. (1 mark)

(ii) Apart from monitoring the change in body weight of the mice, their professor suggested that they should take blood samples from the mice after the meals for analysis. Which component of the blood should they monitor? What would be the expected results of the control group and the experimental group if their ideas actually worked? (2 marks)

(e) Suggest how the amylase inhibitor helps the bean defend against insects. (1 mark)

Solution a; original allocation: 3 mark(s)

Method: Identify variables, measurements and controls, then read the curve's slope.

Pancreatic amylase is more suitable.

Most starch digestion occurs in the small intestine, which is long and retains food for a relatively long time. Pancreatic amylase is a principal enzyme breaking down starch there. To investigate reducing energy obtained from starch, inhibiting this stage is more relevant than testing only salivary amylase, which acts briefly in the mouth.

b(i); original allocation: 2 mark(s)

Make the total volume 30 mL in both apparatuses and maintain equal starch and enzyme concentrations.

Apparatus II receives 5 mL of extract, so apparatus I receives the same volume of water. Otherwise, unequal dilution would alter substrate and enzyme concentrations, and any rate difference could not be attributed solely to the inhibitor.

b(ii); original allocation: 2 mark(s)

Take a drop of reaction mixture at regular intervals for the iodine test and record the time until no blue-black colour appears.

Iodine detects remaining starch. Since starting starch quantities are equal, a shorter time for its complete disappearance indicates a higher average digestion rate. The reciprocal of the time can be used for comparison. A single colour test without timing is insufficient because rate describes change with time.

c; original allocation: 1 mark(s)

Before t, the curve overlaps the original. After t, it rises more slowly and lies below the original.

Adding inhibitor does not remove product already formed, so the curve must remain continuous at t, without a sudden drop. Enzyme inhibition reduces product formation per unit

time, giving a smaller gradient. The diagram shows one suitable curve. Because inhibition strength and reversibility are unspecified, the final plateau cannot be uniquely determined.

d(i); original allocation: 1 mark(s)

An in vivo experiment includes multiple factors in the digestive tract and better represents the extract's effect in a real body.

A test tube examines only a specified mixture and does not reproduce all effects of varying pH, other enzymes, absorption and metabolism. An extract that inhibits in vitro might be broken down in vivo or fail to reach its target. Verification in an animal therefore addresses the original question more closely.

d(ii); original allocation: 2 mark(s)

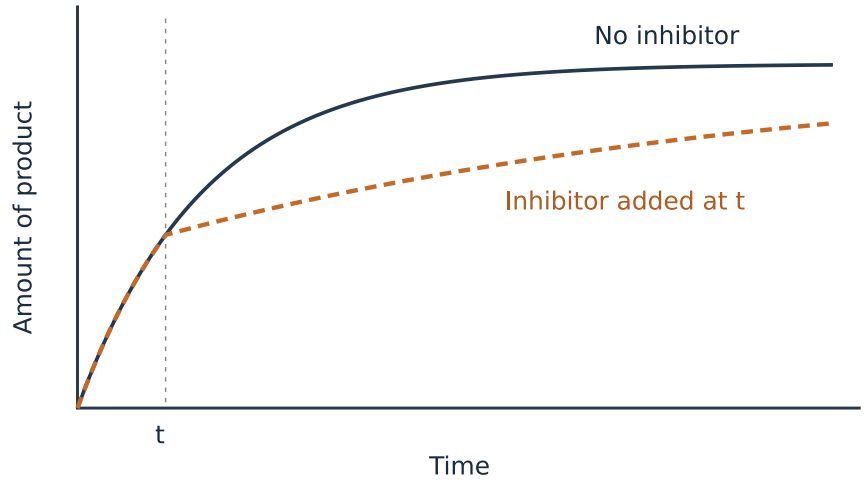
Measure blood glucose. If effective, the experimental group's blood glucose rises more slowly after a meal or remains lower than the control's.

Sugars from starch digestion are ultimately absorbed into the blood as glucose. If amylase inhibition reduces or delays glucose supply, blood glucose should be lower at the same post-meal time or rise more slowly. This connects enzyme inhibition to an actual consequence for absorption.

e; original allocation: 1 mark(s)

It makes starch in the beans harder for insects to digest, reducing their energy gain and discouraging feeding or causing them to feed on other plants.

This chemical defence acts on digestive enzymes. There is no need to assume that it directly kills insects: reduced nutrient utilisation can already make the beans less likely to be eaten.



Product quantity before and after inhibitor addition; the orange curve overlaps the control before t.

Examiner's comment (source page(s) 70, 71)

Equal water volumes maintain total volume and enzyme/substrate concentrations. Measuring digestion rate requires timed sampling or the time to completion. Since inhibitor is added only at t, the curves must overlap before t, and existing product cannot suddenly disappear. Impaired digestion can explain the beans' defence against insects without assuming direct killing.

Marking reference: HKDSE Biology 2024 Paper 1B Q6, official marking scheme, source page(s) 53, 54.

Practice

1. [HKDSE Biology 2023 Paper 1A Q15]

⟵ *Hint: Identify variables, measurements and controls, then read the curve's slope.*

Directions: Questions 15 to 17 refer to an investigation about enzymes in fruits. Amy learned that some fruits contained proteases which can be used as meat tenderisers. She wanted to find a suitable fruit juice for the slow cooking of steak, i.e. mixing the steak with fruit juice in a sealed bag and then cooking it in a water bath set at around 50°C to 70°C for 1 hour. The procedure of her investigation is shown below:

1. Extract fruit juice from pineapple.
2. Add 15 mL of pineapple juice in 3 boiling tubes respectively with labels 50°C, 60°C and 70°C.
3. Put the tubes into water baths set at respective temperatures for 1 hour.
4. Let the tubes cool down to room temperature.
5. Add 3 egg white cubes of size 1 cm^3 into each tube.
6. (Step for the measurement of the dependent variable)
7. Repeat the above steps with papaya, kiwi and lemon instead of pineapple.

Based on the procedure given, how many independent variable(s) is / are being studied?

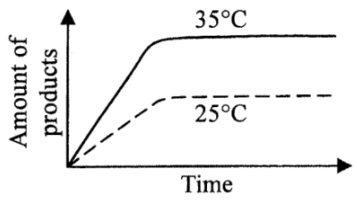
A. 1
B. 2
C. 3
D. 4

2. [HKDSE Biology 2014 Paper 1A Q9]

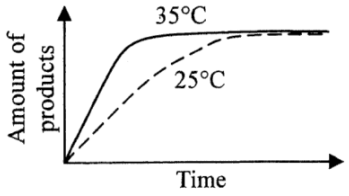
⟵ *Hint: Identify variables, measurements and controls, then read the curve's slope.*

Which of the following graphs correctly shows the changes in the amount of products in a reaction catalyzed by a human enzyme at different temperatures?

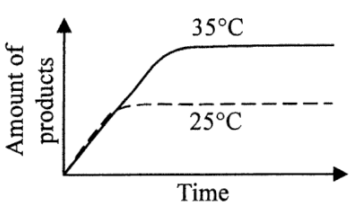
A.



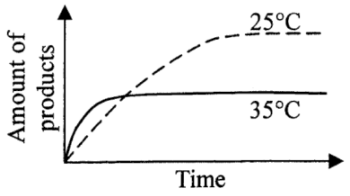
B.



C.



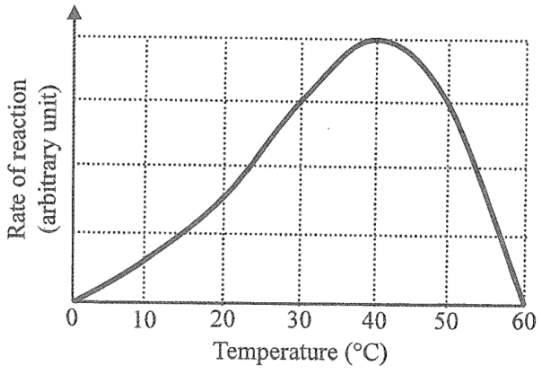
D.



3. [HKDSE Biology 2015 Paper 1A Q3]

⟵ *Hint: Identify variables, measurements and controls, then read the curve's slope.*

The graph below shows the effect of temperature on enzyme activity:



Which of the following statements correctly describes the enzyme reaction?

A. The enzyme is denatured at 0°C and 60°C.
B. The reaction taking place at 50°C is faster than that at 20°C.
C. There are more collisions between substrate and enzyme molecules at 40°C than 60°C.
D. The amount of product collected at the end of the reaction is greatest if the reaction takes place at 40°C.

4. [HKDSE Biology 2016 Paper 1A Q27]
Hint: Identify variables, measurements and controls, then read the curve's slope.

Which of the following statements about enzymes is ***incorrect***?

A. Enzymes are produced by cells.
B. Enzymes are denatured at extreme temperatures.
C. There could be more than one specific enzyme to catalyse the same reaction.
D. When an enzyme encounters the same substrates, it always produces the same products.

5. [HKDSE Biology 2018 Paper 1A Q4]
Hint: Identify variables, measurements and controls, then read the curve's slope.

Directions: Questions 2 to 4 refer to an experiment on the enzyme catalase, which speeds up the breakdown of hydrogen peroxide to release oxygen. John added a 1 cm^3 cube of pig liver to a boiling tube containing 5 mL hydrogen peroxide solution. Gas bubbles were released and he used a glowing splint to test the gas. He repeated the experiment with beef, potato and apple. The results are shown below:

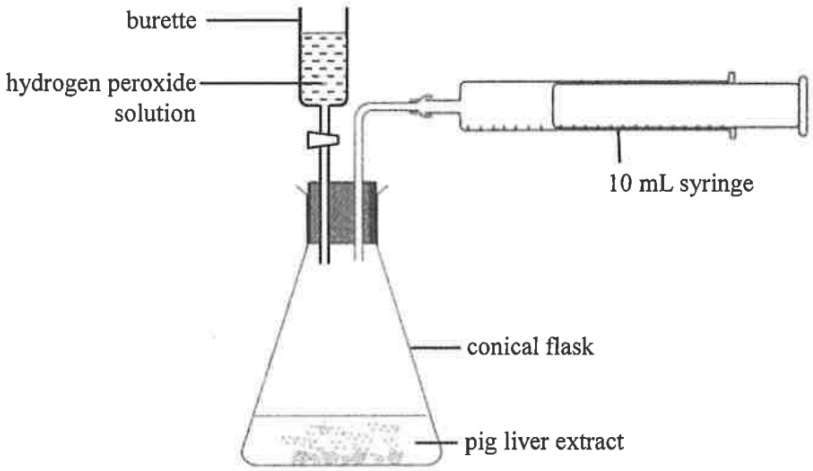
Tissue	*Rate of bubbles released*	*Glowing splint re-lit*
Pig liver	Moderate	Yes
Beef	Moderate	Yes
Potato	Slow	Yes
Apple	Slow	Yes

In order to prove that hydrogen peroxide is the substrate of this enzymatic reaction, which of the following steps should be used as a control?

A. Repeat the experiment using water and the tissues.
B. Repeat the experiment using water and boiled tissues.
C. Repeat the experiment using hydrogen peroxide but no tissues.
D. Repeat the experiment using hydrogen peroxide and boiled tissues.

6. [HKDSE Biology 2019 Paper 1A Q9]
Hint: Identify variables, measurements and controls, then read the curve's slope.

Directions: Questions 9 and 10 refer to the diagram below, which shows an experimental set-up prepared by a student to investigate the effect of temperature on catalase activity. Pig liver extract contains catalase which speeds up the breakdown of hydrogen peroxide into oxygen and water. A fixed volume of hydrogen peroxide solution was added to the liver extract and a 10 mL syringe was used to collect the oxygen gas released from the reaction mixture.



In the trial run conducted at room temperature, the student found that the volume of oxygen released was greater than the maximum collection volume of the syringe. How should he modify the set-up in order to collect valid data when repeating the experiment at different temperatures?

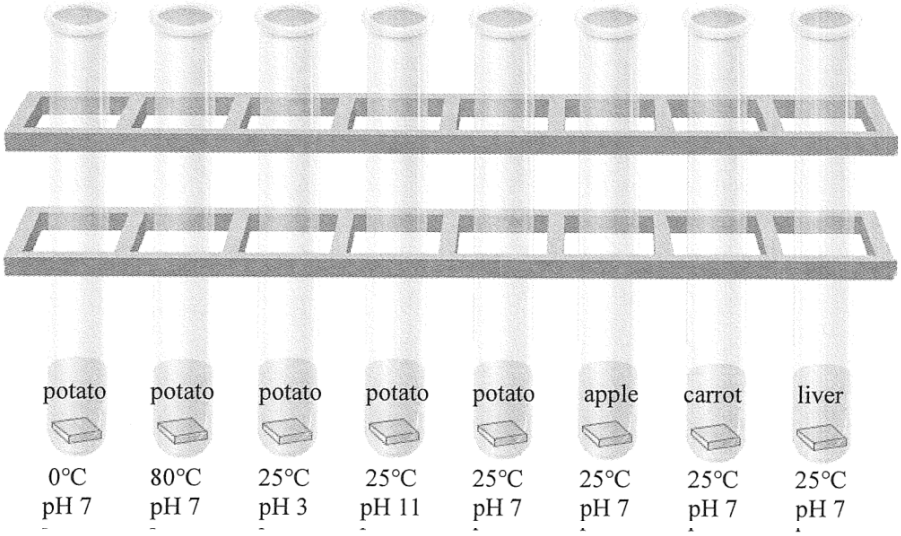
(1) use a larger syringe
(2) use a larger conical flask
(3) reduce the volume of the hydrogen peroxide solution added

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

7. [HKDSE Biology 2020 Paper 1A Q6]

Hint: Identify variables, measurements and controls, then read the curve's slope.

Directions: Questions 6 and 7 refer to the diagram below, which shows a set-up for investigating the activity of catalase in living tissues. Catalase is an enzyme which can break down hydrogen peroxide. Each test tube contains the same amount of hydrogen peroxide solution at the same concentration. A piece of living tissue is added into each tube as indicated below:



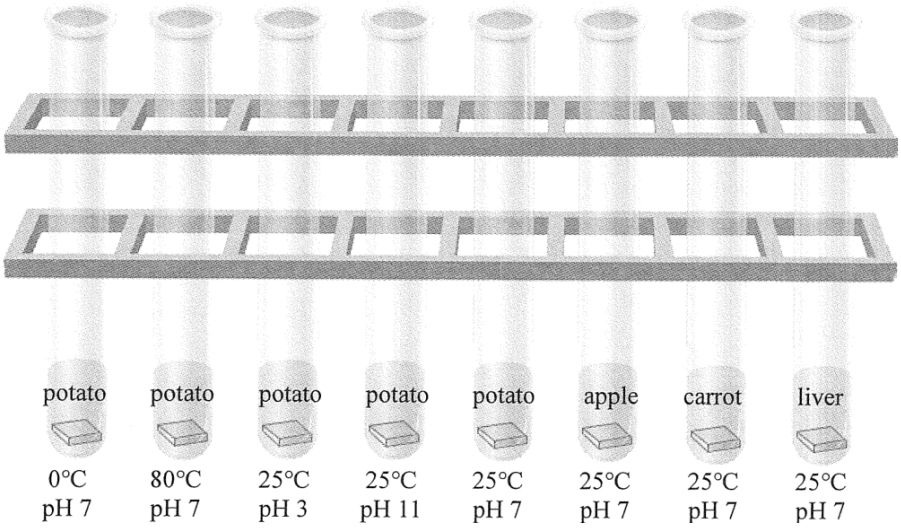
How many independent variables are being studied in this investigation?

A. 2
B. 3
C. 4
D. 8

8. [HKDSE Biology 2020 Paper 1A Q7]

Hint: Identify variables, measurements and controls, then read the curve's slope.

Directions: Questions 6 and 7 refer to the diagram below, which shows a set-up for investigating the activity of catalase in living tissues. Catalase is an enzyme which can break down hydrogen peroxide. Each test tube contains the same amount of hydrogen peroxide solution at the same concentration. A piece of living tissue is added into each tube as indicated below:



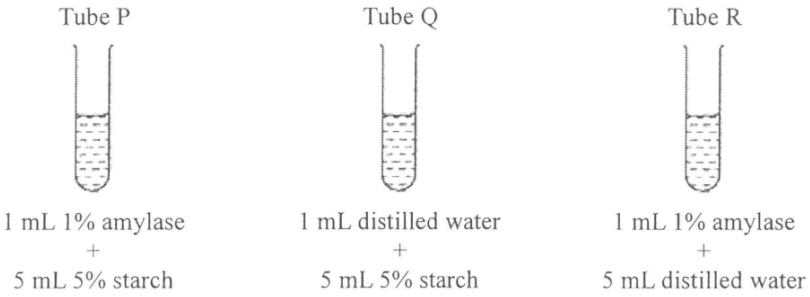
Which of the following control variables is most important for a fair comparison in the above investigation?

A. mass of living tissues
B. shape of living tissues
C. volume of living tissues
D. surface area of living tissues

9. [HKDSE Biology 2021 Paper 1A Q9]

Hint: Identify variables, measurements and controls, then read the curve's slope.

Directions: Questions 9 and 10 refer to the diagram below, which shows three set-ups used in the study of the activity of amylase:



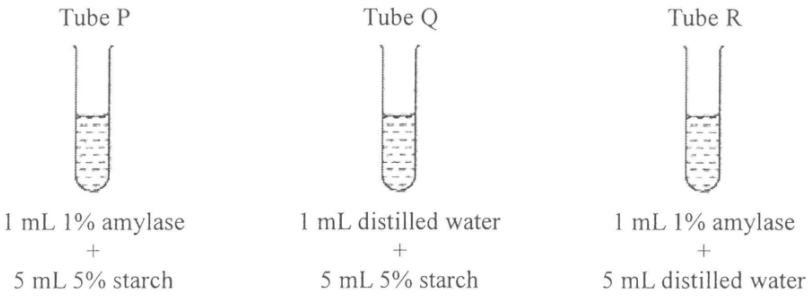
We can conclude the action of amylase on starch by comparing the results of tubes

A. P and Q only.
B. P and R only.
C. Q and R only.
D. P, Q and R.

10. [HKDSE Biology 2021 Paper 1A Q10]

Hint: Identify variables, measurements and controls, then read the curve's slope.

Directions: Questions 9 and 10 refer to the diagram below, which shows three set-ups used in the study of the activity of amylase:



If the following tests are conducted on the reaction mixture of tube P, which test(s) will give the same result at the beginning of the experiment and after 10 minutes?

(1) iodine test
(2) albustix paper
(3) Benedict's test

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

11. [HKDSE Biology 2023 Paper 1A Q16]
⟵ Hint: Identify variables, measurements and controls, then read the curve's slope.

Directions: Questions 15 to 17 refer to an investigation about enzymes in fruits. Amy learned that some fruits contained proteases which can be used as meat tenderisers. She wanted to find a suitable fruit juice for the slow cooking of steak, i.e. mixing the steak with fruit juice in a sealed bag and then cooking it in a water bath set at around 50°C to 70°C for 1 hour. The procedure of her investigation is shown below:

1. Extract fruit juice from pineapple.
2. Add 15 mL of pineapple juice in 3 boiling tubes respectively with labels 50°C, 60°C and 70°C.
3. Put the tubes into water baths set at respective temperatures for 1 hour.
4. Let the tubes cool down to room temperature.
5. Add 3 egg white cubes of size 1 cm^3 into each tube.
6. (Step for the measurement of the dependent variable)
7. Repeat the above steps with papaya, kiwi and lemon instead of pineapple.

Step 6 is about the measurement of the dependent variable. Which of the following can be used for measuring the dependent variable for this investigation?

(1) the time taken for the disappearance of the egg white cubes
(2) the change in shape of the egg white cubes after a fixed time
(3) the change in weight of the egg white cubes after a fixed time

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

12. [HKDSE Biology 2023 Paper 1A Q17]
⟵ Hint: Identify variables, measurements and controls, then read the curve's slope.

Directions: Questions 15 to 17 refer to an investigation about enzymes in fruits. Amy learned that some fruits contained proteases which can be used as meat tenderisers. She wanted to find a suitable fruit juice for the slow cooking of steak, i.e. mixing the steak with fruit juice in a sealed bag and then cooking it in a water bath set at around 50°C to 70°C for 1 hour. The procedure of her investigation is shown below:

1. Extract fruit juice from pineapple.
2. Add 15 mL of pineapple juice in 3 boiling tubes respectively with labels 50°C, 60°C and 70°C.
3. Put the tubes into water baths set at respective temperatures for 1 hour.
4. Let the tubes cool down to room temperature.
5. Add 3 egg white cubes of size 1 cm^3 into each tube.
6. (Step for the measurement of the dependent variable)
7. Repeat the above steps with papaya, kiwi and lemon instead of pineapple.

Which of the following is the assumption for this investigation?

A. The proteases are present in the fruits tested.
B. The proteases remain active at high temperatures.
C. The proteases are still functioning after extraction.
D. The actions of the proteases on egg white cubes and steaks are similar.

13. [HKDSE Biology 2025 Paper 1A Q4 (English translation)]
⟵ Hint: Identify variables, measurements and controls, then read the curve's slope.

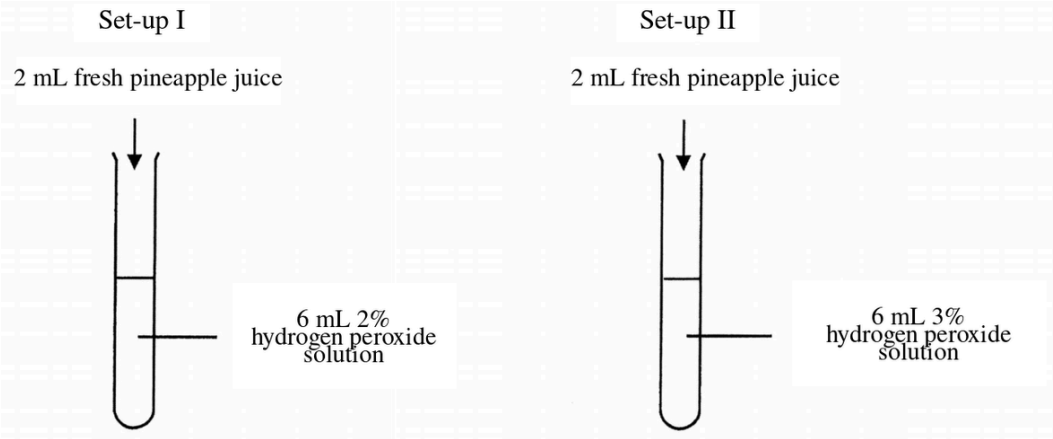
Which of the following method(s) can distinguish a sample of human gastric-juice extract from a sample of pancreatic-juice extract?

(1) Mix each sample with egg-white solution and carry out a protein test after one hour.
(2) Mix each sample with starch solution and carry out an iodine test after one hour.
(3) Mix each sample with sucrose solution and carry out Benedict's test after one hour.

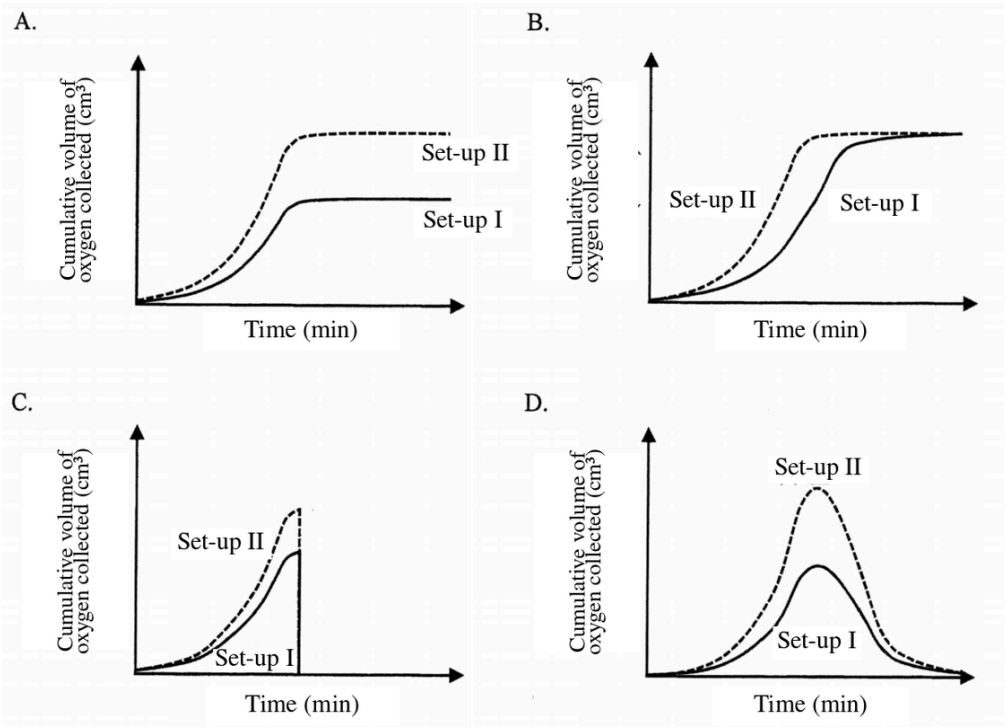
A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

14. [HKDSE Biology 2025 Paper 1A Q10 (English translation)]
⟵ Hint: Identify variables, measurements and controls, then read the curve's slope.

Directions: Refer to the diagrams below to answer Questions 10 and 11. They show two set-ups used to demonstrate the reaction between catalase in fresh pineapple and hydrogen peroxide at 20 °C.

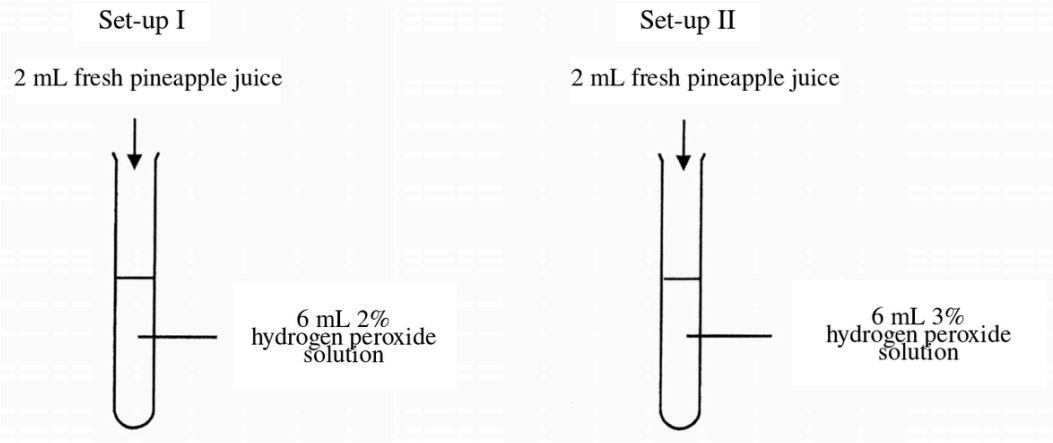


Which graph correctly shows the results of set-ups I and II?



15. [HKDSE Biology 2025 Paper 1A Q11 (English translation)]
⟵ Hint: Identify variables, measurements and controls, then read the curve's slope.

Directions: Refer to the diagrams below to answer Questions 10 and 11. They show two set-ups used to demonstrate the reaction between catalase in fresh pineapple and hydrogen peroxide at 20 °C.



To prepare fresh juice for this experiment, fresh fruit pieces are ground with distilled water and filtered through filter paper. To compare the catalase concentrations in two different fruits, which variable does NOT need to be kept the same when extracting the two juices separately?

A. Temperature during extraction
B. Total cut-surface area of the fruit pieces
C. Total mass of the fruit pieces
D. Volume of distilled water

16. [HKDSE Biology 2025 Paper 1A Q35 (English translation)]
Hint: Identify variables, measurements and controls, then read the curve's slope.

Directions: Refer to the table below to answer Questions 35 and 36. It shows the growth of bacterium X, which can infect human wounds, in three different media:

Medium	Time required for the number of bacteria X to double (min)	Percentage change in the amount of protein P used for respiration in bacteria X (%)	Percentage change in the amount of protein Q used for translation in bacteria X (%)
Culture medium + tea tree oil M	80	−20	−20
Culture medium + tea tree oil N	30	−5	0
Culture medium	30	0	0

Which of the following deductions about tea tree oil M can be made from the table?

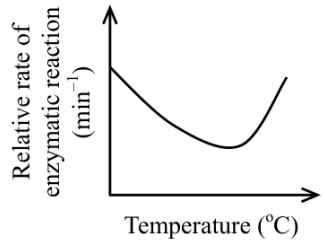
A. Tea tree oil M inhibits the growth of bacteria X more effectively than tea tree oil N.
B. Tea tree oil M promotes healing of human wounds more effectively than tea tree oil N.
C. Tea tree oil M reduces the respiratory rate of bacteria X by 20%.
D. Tea tree oil M reduces translation in bacteria X, thereby lowering their respiratory rate.

17. [HKDSE Biology Practice Paper Paper 1A Q4]

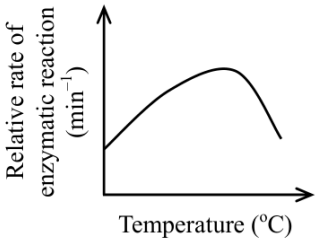
Hint: Identify variables, measurements and controls, then read the curve's slope.

In an experiment to investigate the effect of temperature on the activity of a digestive enzyme X, the time taken for the digestion of a fixed amount of substrate by this enzyme was recorded. Which of the following graphs shows the most likely results of the experiment?

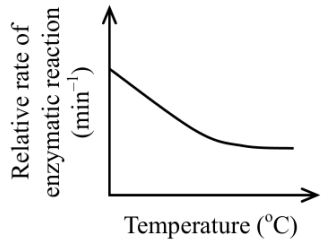
A.



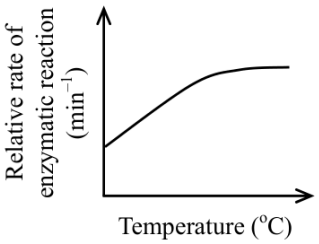
B.



C.



D.



18. [HKDSE Biology 2021 Paper 1B Q4]

Hint: Identify variables, measurements and controls, then read the curve's slope.

Glycogen and a disaccharide named trehalose are two common types of energy reserve found in insect species A. An experiment was conducted to study the energy reserve used for flying in this insect species. Three groups of insect species A were respectively injected with equal volumes of physiological saline, an inhibitor of trehalose-digesting enzyme and an inhibitor of glycogen-digesting enzyme. The insects were then stimulated to fly until they were exhausted. The flight time of each individual was recorded in the following table:

Solution injected	Samples of insect species A	Flight time (s)	Mean flight time (s)
physiological saline	1	150	165.6
	2	138	
	3	168	
	4	210	
	5	162	
inhibitor of trehalose-digesting enzyme	6	42	
	7	78	
	8	114	
	9	90	
	10	102	
inhibitor of glycogen-digesting enzyme	11	132	
	12	192	
	13	174	
	14	162	
	15	156	

(a) Complete the above table by calculating the mean flight time (to the nearest 1 decimal place) for the groups injected with the respective inhibitors. (1 mark)

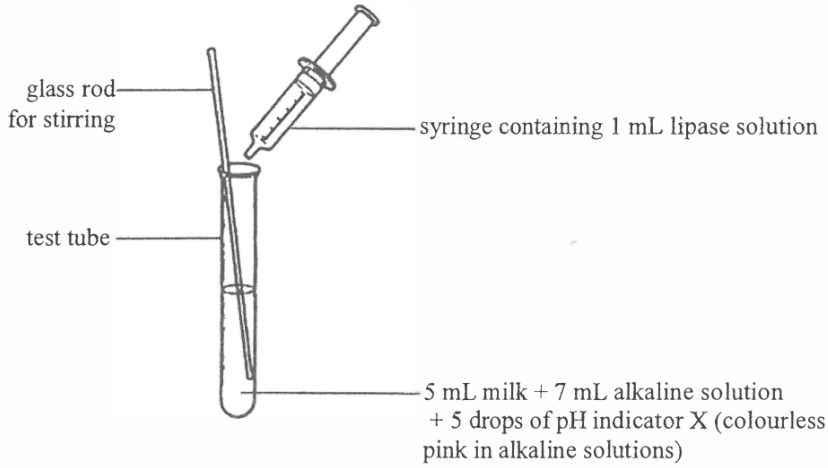
(b) With reference to the aim of the experiment, what conclusions can you draw from the data? Explain your answer. (4 marks)

(c) Among individual insects, suggest ***one*** difference which led to different flight times within each group. (1 mark)

19. [HKDSE Biology 2018 Paper 1B Q8]

Hint: Identify variables, measurements and controls, then read the curve's slope.

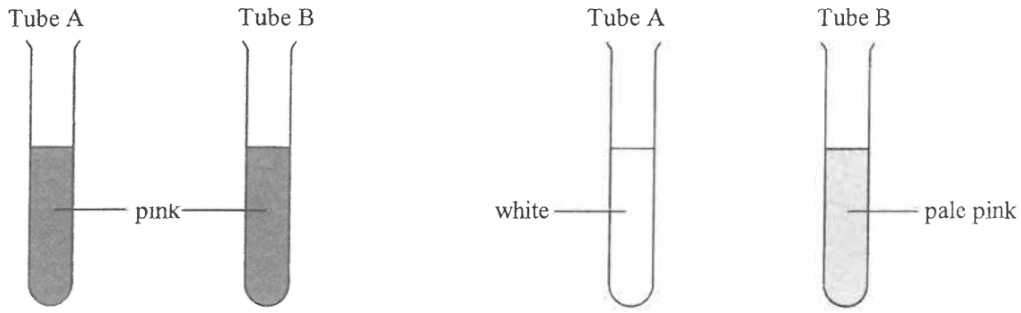
A student used the following set-up to compare the fat digestion of full fat fresh milk and half fat fresh milk:



(a) Write a simple word equation of fat digestion. (2 marks)

(b) Two test tubes, each with a different type of milk, were prepared. The colour of each mixture was recorded immediately after the addition of lipase solution, and then monitored until there was no more change in colour. The colours of the mixtures at the beginning and the end are shown in Diagram I and Diagram II respectively:

Diagram I (at the beginning) ***Diagram II (at the end)***



(i) What is the independent variable in this investigation? (1 mark)

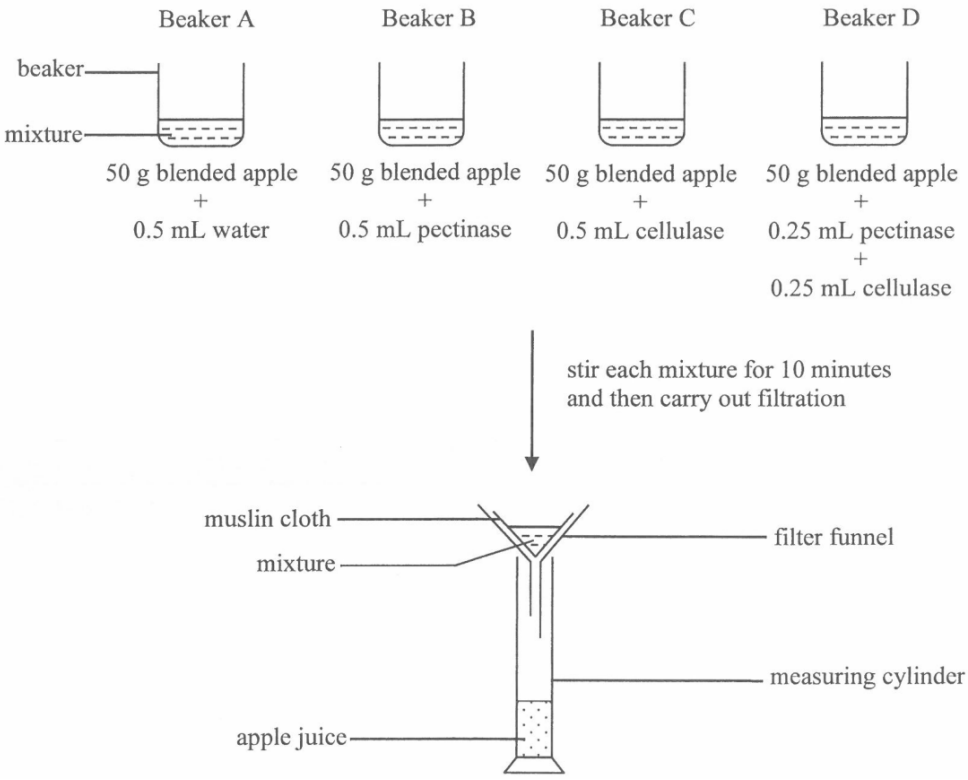
(ii) Describe the results of this investigation. (2 marks)

(iii) Which test tube (A or B) was the one with full fat fresh milk? Explain your answer. (4 marks)

20. [HKDSE Biology 2022 Paper 1B Q5]

Hint: Identify variables, measurements and controls, then read the curve's slope.

Pectinase and cellulase are enzymes that break down the chemical components of plant cell walls. The following experiment investigates the effects of these two enzymes on the production of apple juice:



Beaker	Mixture	Volume of apple juice produced (mL)				Cost of enzyme(s) for producing 1 mL apple juice
		Trial 1	Trial 2	Trial 3	Average	
A	0.5 mL water + 50 g blended apple	2.0	1.0	3.0	2.0	---
B	0.5 mL pectinase + 50 g blended apple	33.5	31.0	28.5	31.0	
C	0.5 mL cellulase + 50 g blended apple	4.5	4.0	3.5	4.0	
D	0.25 mL pectinase + 0.25 mL cellulase + 50 g blended apple	34.0	32.0	36.0	34.0	

(a) State the independent variable and dependent variable of this experiment. (2 marks)

(b) Why are three trials better than one trial? (1 mark)

(c) The enzyme solutions used in the experiment were at the same concentration. The prices of 0.5 mL pectinase and 0.5 mL cellulase were $13 and $7 respectively. Complete the above table to show the cost of enzyme(s) for producing 1 mL of apple juice. (2 marks)

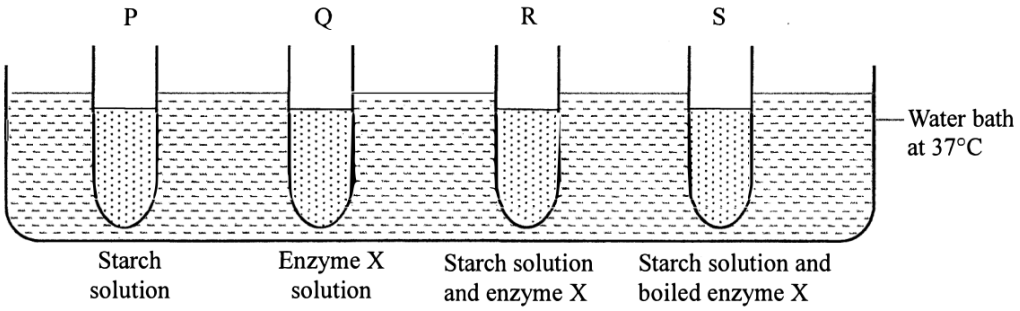
(d) Based on the answer in (c), which is the most cost-effective means for producing apple juice? (1 mark)

(e) Explain why the apple juice collected from Beaker D is clearer than that from Beaker A. (1 mark)

21. [HKDSE Biology 2017 Paper 1A Q4]

Hint: Identify variables, measurements and controls, then read the curve's slope.

Directions: Questions 2 to 4 refer to the diagram below, which shows four test tubes prepared by a student to investigate the action of a starch-digesting enzyme X:



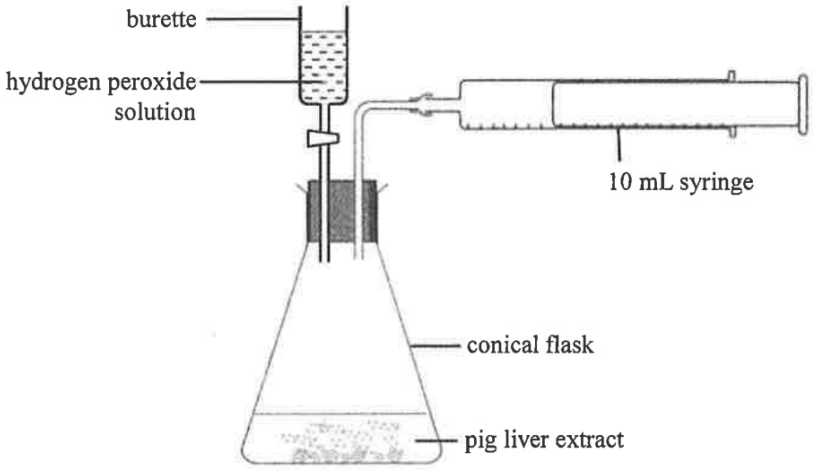
Which of the following is ***not*** the purpose of the experimental design?

	Design	***Purpose***
A.	setting up tube P	to show the result of iodine test if starch is present
B.	setting up tube Q	to show that enzyme X alone cannot give positive result in Benedict's test
C.	setting up tube S	to show that enzyme X is denatured after boiling
D.	setting up water bath	to simulate the temperature of the human body

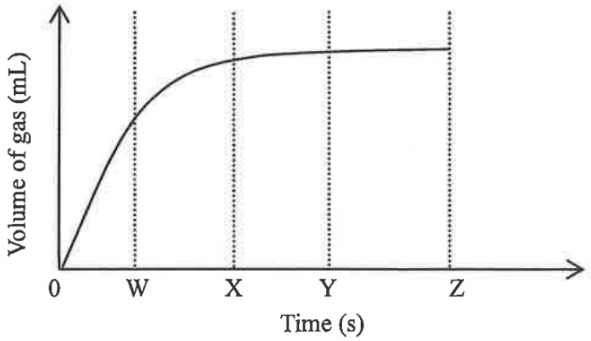
22. [HKDSE Biology 2019 Paper 1A Q10]

Hint: Identify variables, measurements and controls, then read the curve's slope.

Directions: Questions 9 and 10 refer to the diagram below, which shows an experimental set-up prepared by a student to investigate the effect of temperature on catalase activity. Pig liver extract contains catalase which speeds up the breakdown of hydrogen peroxide into oxygen and water. A fixed volume of hydrogen peroxide solution was added to the liver extract and a 10 mL syringe was used to collect the oxygen gas released from the reaction mixture.



After modifying the set-up, the following graph was obtained which shows the volume of gas collected over time at room temperature:

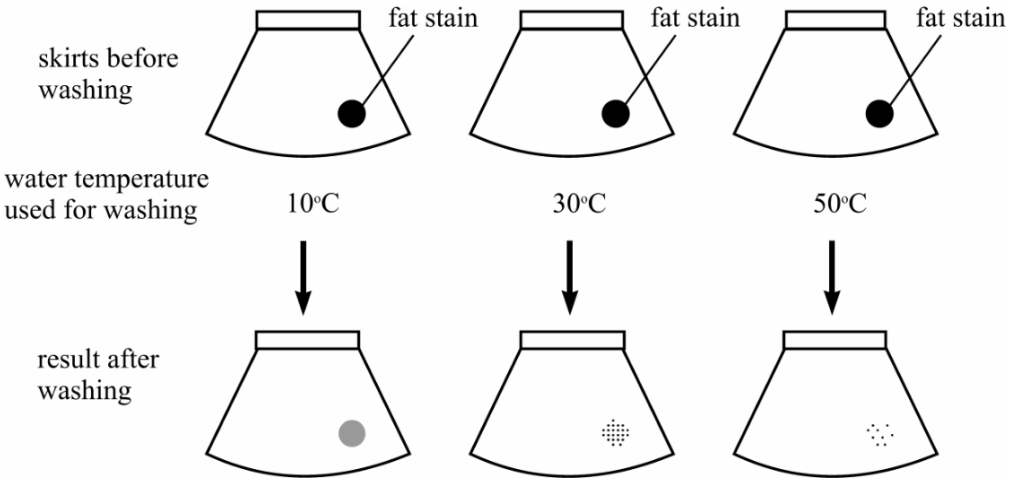


The student planned to use the volume of gas collected over a fixed period of time as the dependent variable to study the effect of different temperatures on catalase activity. Which of the following is the most suitable time period for the measurement?

A. 0 – W
B. 0 – X
C. 0 – Y
D. 0 – Z

23. [HKDSE Biology Sample Paper Paper 1B Q9]
Hint: Identify variables, measurements and controls, then read the curve's slope.

One of the applications of enzymes in everyday life is found in biological washing powders. To study the effectiveness of a biological washing powder, three identical skirts with identical fat stains were washed with the washing powder solutions of the same concentration but at different water temperatures. The investigation and its results are outlined below:



(N.B. The investigation was repeated at the three temperatures, but no washing powder was used. The fat stains on all three skirts remained unchanged.)

(a) Suggest an explanation why the fat stain can be removed by using the biological washing powder. (3 marks)

(b) What conclusion can be drawn from the results of this investigation? (1 mark)

(c) A student queried whether or not biological washing powder is more effective than ordinary (non-biological) washing powder in removing fat stains. If you were the student, describe how you would carry out an investigation to find out which washing powder is more effective.
(5 marks)

.....

.....

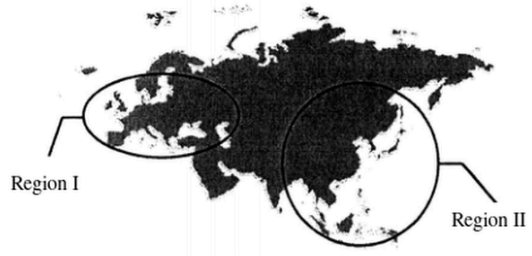
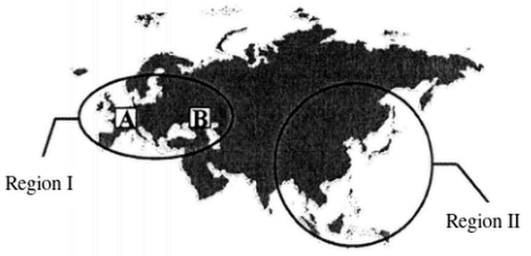
.....

.....

24. [HKDSE Biology 2025 Paper 1B Q5 (English translation)]
Hint: Identify variables, measurements and controls, then read the curve's slope.

Lactase digests the lactose in milk. Children produce less lactase after they stop being breastfed. People who lose the ability to produce lactase become lactose intolerant and develop associated symptoms, such as intestinal gas and diarrhoea, after drinking milk. Some people continue to produce lactase throughout adulthood, exhibiting the lactose-tolerance trait.

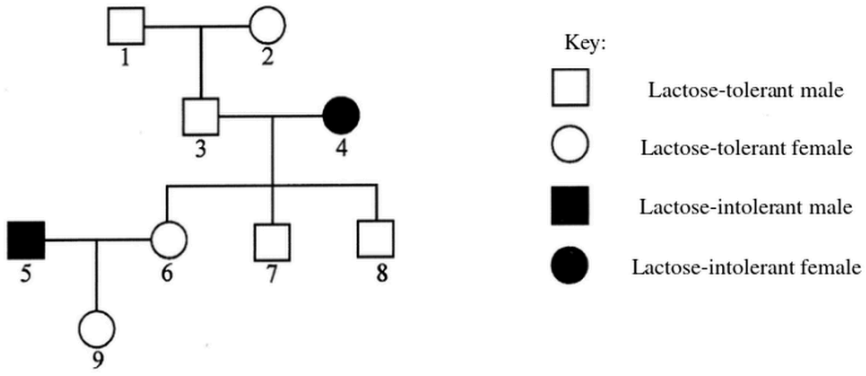
(a) It has been hypothesised that lactose tolerance resulted from natural selection under different agricultural practices in the past. The diagrams below show two regions with different past agricultural practices and their present-day population distributions of lactose tolerance.

Past agricultural practices	Present-day population distribution of lactose tolerance
	
Region I: mainly livestock rearing for milk and meat Region II: mainly crop cultivation	Region I: 80–100% of the population lactose tolerant Region II: 0–20% of the population lactose tolerant

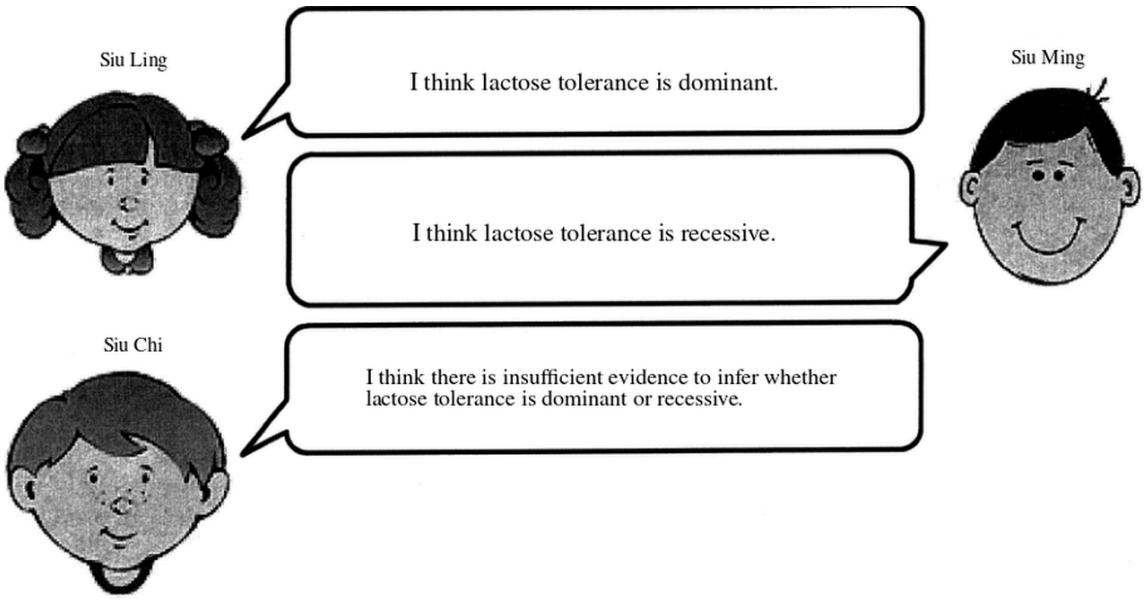
(i) The lactose-tolerance trait is known to result from a mutation. With reference to the diagrams above, propose an explanation for the population distributions of lactose tolerance in regions I and II. (4 marks)

(ii) In location A, the sequence of an allele conferring lactose tolerance has been identified in an individual. An individual in location B is lactose tolerant but does not have this allele. Suggest a possible reason for this observation. (1 mark)

(b) The following pedigree shows the inheritance of lactose tolerance and lactose intolerance:



In this family, inheritance of lactose tolerance and lactose intolerance is known to be controlled by a single gene. After studying the pedigree above, Siu Ling, Siu Ming and Siu Chi express the following views about inheritance of lactose tolerance:



Whose view about the inheritance of lactose tolerance is correct? Explain your answer. (2 marks)

(c) Lactase can be used to produce lactose-free milk for people with lactose intolerance. Alginate beads containing lactase (Figure I) are placed in a column (Figure II), and the following steps are carried out:

1. Pour milk into the column until it just covers the alginate beads.
2. Wait for two minutes.
3. Open the tap and allow all the milk to drain into a beaker.
4. Repeat steps 1–3 using the collected milk to produce the next milk sample, until the sixth milk sample has been collected.

Figure I

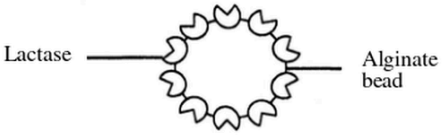
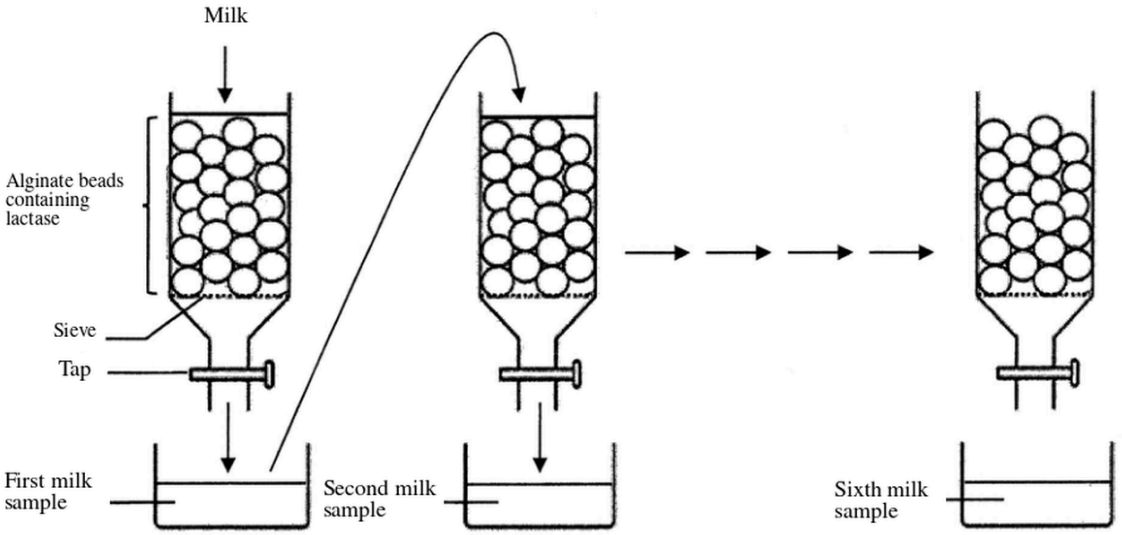


Figure II



Notes:
1. The same column and its alginate beads are used throughout the procedure.
2. All collected milk samples are tested with glucose test strips.

Figure III

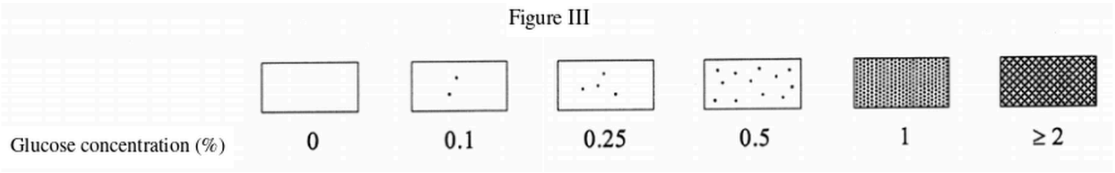


Figure III above shows the reference chart for glucose test strips. The table below shows the test results:

Sample	Cumulative time (minutes)	Glucose test-strip result
First milk sample	2	
Second milk sample	4	
Third milk sample	6	
Fourth milk sample	8	
Fifth milk sample	10	
Sixth milk sample	12	

(i) Write the word equation for the digestion of lactose by lactase. (1 mark)

(ii) Based on the results above, a student concludes that the glucose concentration in the third milk sample collected is three times that in the first milk sample collected. Do you agree with this conclusion? Briefly explain. (2 marks)

(iii) Suggest how the reliability of these experimental results can be confirmed. (2 marks)

(iv) Suppose the procedure is changed so that milk is poured into the column four times and remains in it for three minutes each time. Predict the final glucose concentration after 12 minutes. (1 mark)

(v) Siu Fa tastes the lactose-free milk produced and finds it sweeter than fresh milk. She is concerned that drinking lactose-free milk will give her more energy than drinking fresh milk. Do you think her concern is justified? Explain your answer. (2 marks)

Type 4 Track substances and energy in chloroplasts

Degree of integration ★★★☆☆

Key ideas

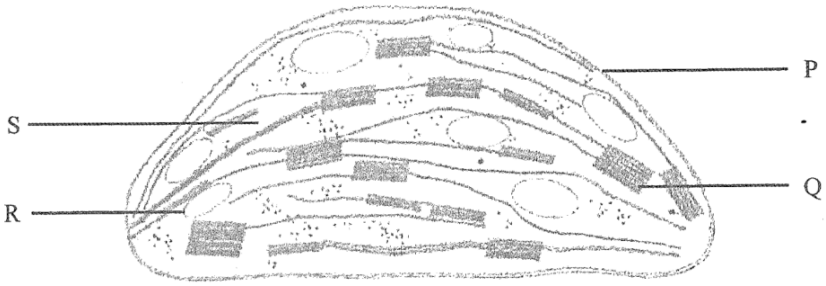
① Photochemical reactions occur on thylakoid membranes, producing ATP and reducing power. The Calvin cycle in the stroma uses these to incorporate carbon from carbon dioxide into organic substances. On a light-to-dark transition, supply from the photochemical reactions changes first, followed by effects on dependent steps.

② For an intermediate's concentration, compare both production and consumption. Reduced production does not mean that its concentration must rise.

How to recognise the problem Label the locations, then trace ATP, reducing power and carbon-containing substances. If conditions change suddenly, compare each intermediate's input and output.

Example 1 [HKDSE Biology 2015 Paper 1A Q4]

Directions: Questions 4 and 5 refer to the schematic diagram below, which shows the structures of a chloroplast:



Regeneration of the carbon dioxide acceptor takes place at

A. P.
B. Q.
C. R.
D. S.

Solution Answer: D

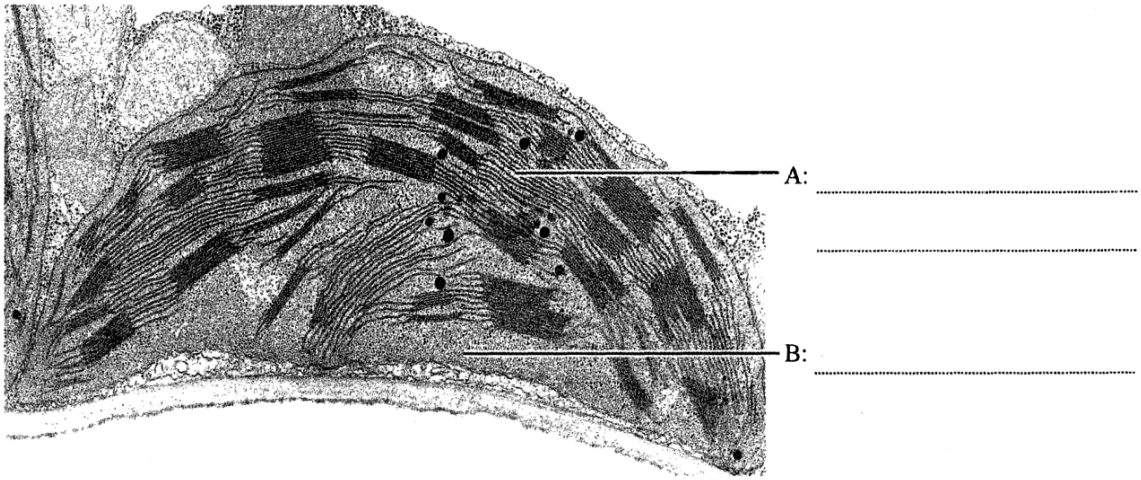
The carbon dioxide acceptor RuBP is regenerated during the Calvin cycle. These enzyme-controlled reactions occur in the chloroplast stroma. S points to the stroma outside the thylakoids, so choose S. Identify the reaction compartment before matching it to the letter. Choose D.

Method: Locate the reactions, then trace matter and energy.

Marking reference: HKDSE Biology 2015 Paper 1A Q4, official marking scheme, source page(s) 1.

Example 2 [HKDSE Biology 2016 Paper 1B Q3]

The diagram below shows the electron micrograph of an organelle:



(a) Label A and B. (2 marks)

(b) State a type of plant cell that contains this organelle. (1 mark)

(c) What is the functional relationship between A and B? (3 marks)

Solution (a); original allocation: 2 mark(s)

A: thylakoid membrane; B: stroma.

Method: Locate the reactions, then trace matter and energy.

The stacked dark membrane sheets inside the chloroplast are thylakoids; the surrounding fluid is the stroma. A points specifically to a membrane, so name the thylakoid membrane. B points to the surrounding chloroplast stroma.

(b); original allocation: 1 mark(s)

Palisade mesophyll cell.

These cells contain many chloroplasts and carry out photosynthesis. Spongy mesophyll cells or guard cells are also acceptable specific examples. Do not broadly claim that every plant cell has chloroplasts.

(c); original allocation: 3 mark(s)

A carries out photochemical reactions, producing ATP and NADPH for carbon fixation in B.

Connect the reactions by following substances. Thylakoid membranes absorb light energy, temporarily storing energy and reducing power in ATP and NADPH, respectively. Carbon-fixation reactions in the stroma use both to convert carbon dioxide into organic substances. Conversely, stromal reactions regenerate $NADP^+$, allowing it to accept electrons again in the light-dependent reactions. Listing two reaction names alone does not explain how they cooperate.

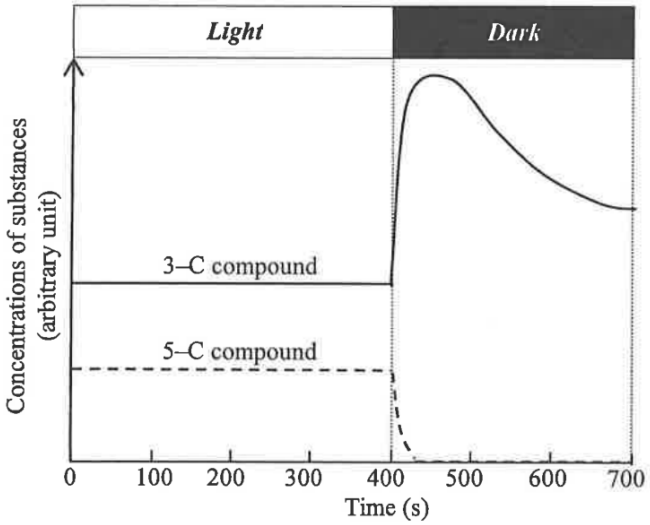
Examiner's comment (source page(s) 3)

When asked how structures cooperate, describe a continuous transfer of substances or information from one to the other. Listing their functions separately does not answer the relationship.

Marking reference: HKDSE Biology 2016 Paper 1B Q3, official marking scheme, source page(s) 2.

Example 3 [HKDSE Biology 2019 Paper 1A Q4]

The graph below shows the changes in the relative concentrations of a 3–C compound and a 5–C compound (carbon dioxide acceptor) in the Calvin cycle in green plant cells which have been kept in bright light and then in darkness.



Which of the following is ***not*** a reason why the concentration of the 5–C compound decreased in the dark?

A. The 5–C compound was converted to the 3–C compound.
B. The 5–C compound combined with carbon dioxide to form glucose directly.
C. Regeneration of 5–C compound stopped because there was no ATP from photochemical reactions.
D. Regeneration of 5–C compound stopped because there was no NADPH from photochemical reactions.

Solution Answer: B

In darkness, light-dependent reactions no longer continuously supply ATP and NADPH, affecting regeneration of the 5-C carbon dioxide acceptor. Existing acceptor can still be consumed by carbon fixation. Combination of the 5-C acceptor with carbon dioxide first forms a 3-C product, not glucose directly, so B is not a correct explanation.

Method: Locate the reactions, then trace matter and energy.

Marking reference: HKDSE Biology 2019 Paper 1A Q4, official marking scheme, source page(s) 1.

Practice

1. [HKDSE Biology 2013 Paper 1A Q9]

Hint: Locate the reactions, then trace matter and energy.

). Which of the following substances are produced in photochemical reactions of photosynthesis?

(1) ATP
(2) oxygen
(3) NADPH

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

2. [HKDSE Biology 2017 Paper 1A Q6]

Hint: Locate the reactions, then trace matter and energy.

Which of the following reactions in photosynthesis takes place on the thylakoid membrane?

A. regeneration of carbon dioxide acceptor
B. reduction of 3-C compound
C. photolysis of water
D. carbon dioxide fixation

3. [HKDSE Biology 2018 Paper 1A Q29]

Hint: Locate the reactions, then trace matter and energy.

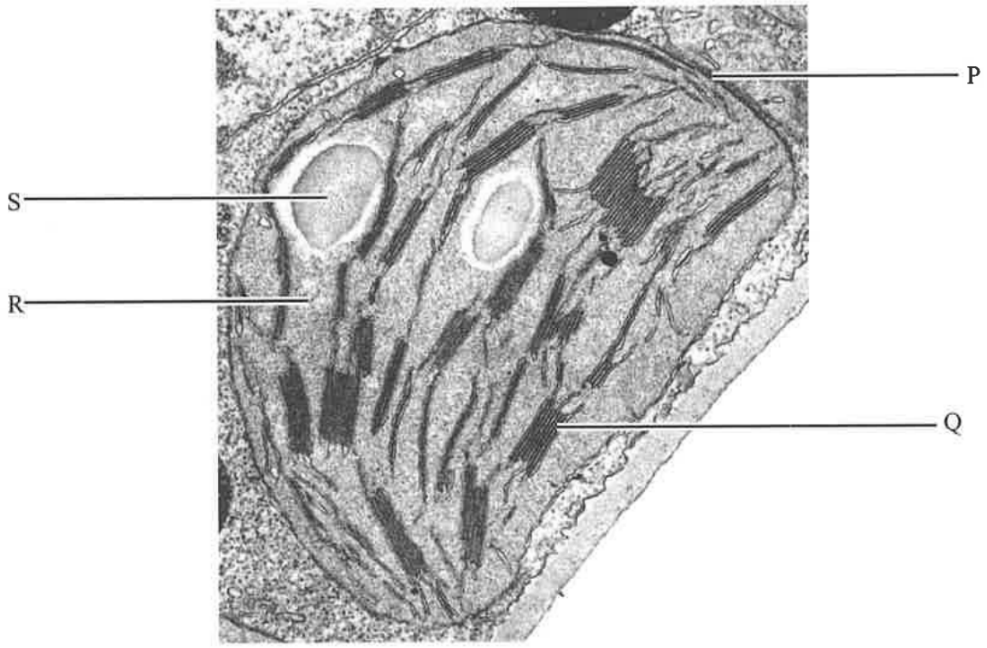
Which of the following substances contribute(s) most to the increase in biomass of a plant?

A. water
B. oxygen
C. minerals
D. carbon dioxide

4. [HKDSE Biology 2019 Paper 1A Q1]

Hint: Locate the reactions, then trace matter and energy.

Directions: Questions 1 and 2 refer to the electron micrograph below, which shows a chloroplast of a plant cell:



During photosynthesis, light is captured at

A. P.
B. Q.
C. R.
D. S.

5. [HKDSE Biology 2024 Paper 1A Q7]
Hint: Locate the reactions, then trace matter and energy.

Which of the following combinations about the stages of photosynthesis is correct?

	Photochemical reactions	*Calvin cycle*
A.	produces oxygen	produces water
B.	requires carbon dioxide	requires NADPH
C.	occurs in stroma	occurs in grana
D.	light is the energy source	ATP is the energy source

6. [HKDSE Biology 2025 Paper 1A Q20 (English translation)]
Hint: Locate the reactions, then trace matter and energy.

Which combination below is correct regarding the stages of photosynthesis?

	Photochemical reactions	Carbon fixation
A.	Occur in the thylakoid membrane	Occurs in the stroma
B.	Produce glucose	Produces oxygen
C.	Require ATP	Requires ADP
D.	Require NAD	Requires NADH

7. [HKDSE Biology Practice Paper Paper 1A Q6]
Hint: Locate the reactions, then trace matter and energy.

In photosynthesis, photochemical reactions are essential for the carbon fixation that follows. This is because in photochemical reactions,

(1) oxygen is liberated.
(2) NADPH is generated.
(3) the carbon dioxide acceptor is regenerated.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

8. [HKDSE Biology 2012 Paper 1A Q23]
Hint: Locate the reactions, then trace matter and energy.

Which of the following descriptions about the role of light in photosynthesis are correct?

(1) Activation of chlorophyll provides high energy electrons.
(2) Photolysis of water releases oxygen for use in carbon fixation.
(3) Photolysis of water releases hydrogen for the formation of NADPH.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

9. [HKDSE Biology 2013 Paper 1A Q8]
Hint: Locate the reactions, then trace matter and energy.

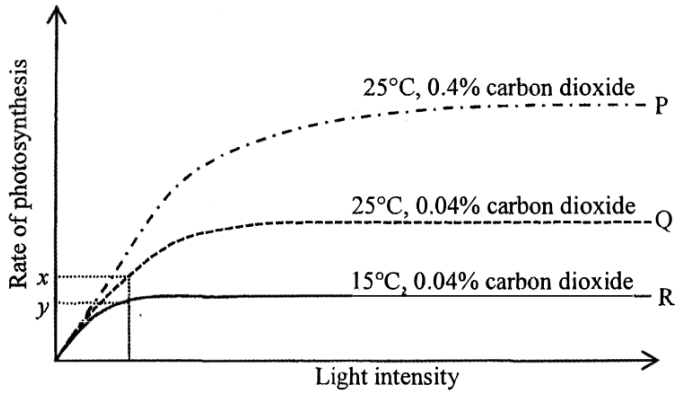
Which of the following processes in photosynthesis require energy input from ATP?

(1) fixation of carbon dioxide and the formation of 3-C compound
(2) reduction of 3-C compound leading to the formation of glucose
(3) regeneration of carbon dioxide acceptor

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

10. [HKDSE Biology 2016 Paper 1A Q10]
Hint: Locate the reactions, then trace matter and energy.

Directions: Questions 9 and 10 refer to the diagram below, which shows the rate of photosynthesis of a plant under different conditions:

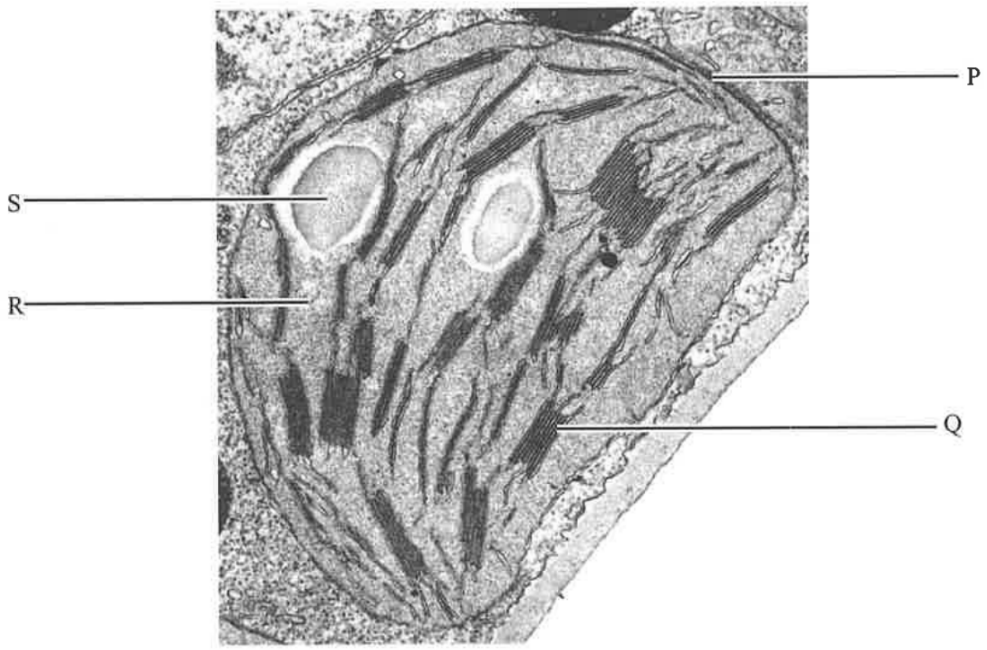


Which of the following descriptions best accounts for the higher rate of photosynthesis of P as compared to Q?

A. All conditions are optimum in P.
B. There is a faster diffusion of carbon dioxide into the leaves.
C. More carbon dioxide can be used as raw material for photosynthesis.
D. Carbon dioxide concentration in P is much higher than that in the atmosphere.

11. [HKDSE Biology 2019 Paper 1A Q2]
Hint: Locate the reactions, then trace matter and energy.

Directions: Questions 1 and 2 refer to the electron micrograph below, which shows a chloroplast of a plant cell:



Carbon dioxide with radioactively labelled oxygen was provided to the plant cell for photosynthesis. Radioactivity can be detected in

A. oxygen produced at Q.
B. oxygen produced at R.
C. glucose produced at Q.
D. glucose produced at R.

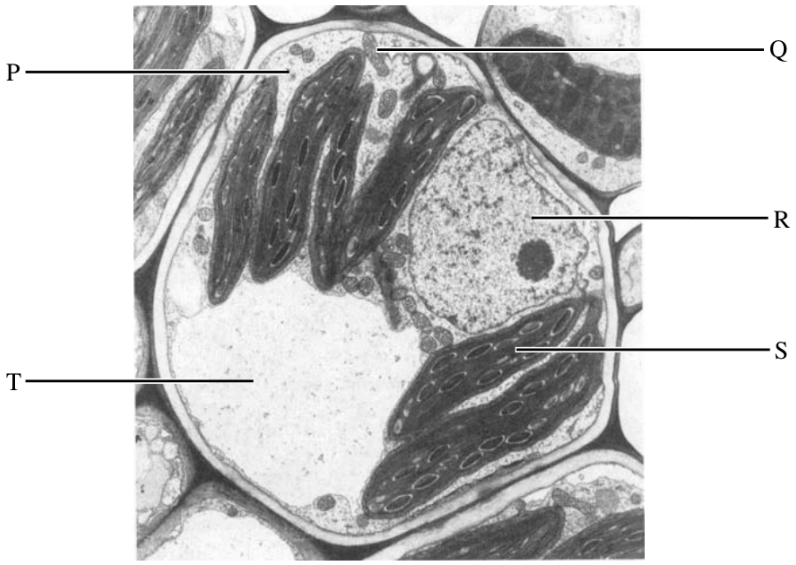
12. [HKDSE Biology Sample Paper Paper 1A Q6]
Hint: Locate the reactions, then trace matter and energy.

A certain weed-killer acts by blocking the flow of electrons along the electron transport chains in photophosphorylation. Which of the following processes would still occur in the plant sprayed with the weed-killer?

A. formation of ATP
B. photolysis of water
C. formation of NADPH
D. photoactivation of chlorophyll

13. [HKDSE Biology Practice Paper Paper 1B Q2]
Hint: Locate the reactions, then trace matter and energy.

The following shows an electronmicrograph of a cell taken from a leaf:



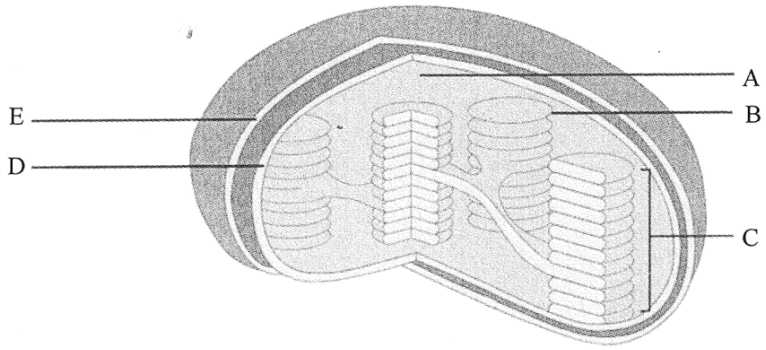
(a) Name the type of cell shown in the electronmicrograph. (1 mark)

(b) Using the letters in the electronmicrograph, fill in the table below to show the structures in which ATP is synthesised. State the process by which ATP is synthesised in each structure. (4 marks)

Structure	Process of ATP synthesis

14. [HKDSE Biology 2020 Paper 1B Q1]
Hint: Locate the reactions, then trace matter and energy.

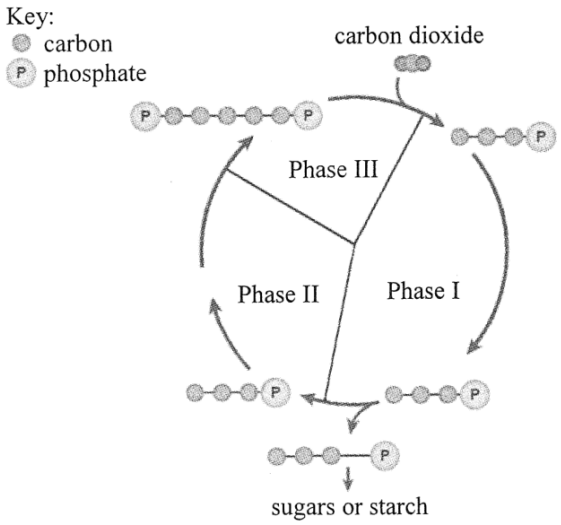
The diagram below shows the structures in a chloroplast:



(a) Using the letters from the diagram, list ***all*** of the structures that contain photosynthetic pigments. (1 mark)

(b) Structure C produces intermediates that are used in the Calvin Cycle. State the intermediates. (1 mark)

(c) The diagram below shows a simplified Calvin Cycle:



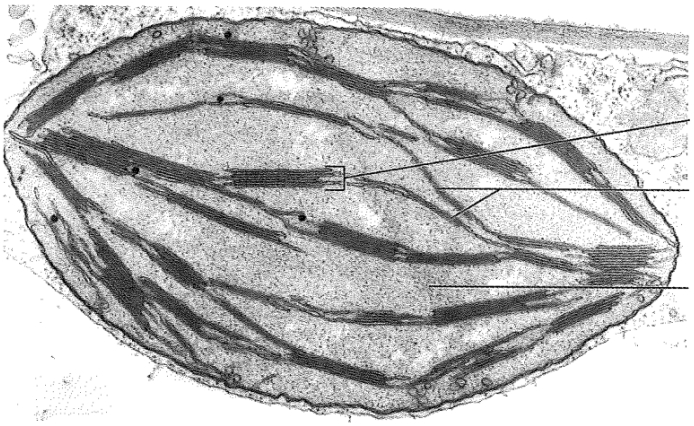
Match the three phases with the following reactions: (2 marks)

Reactions	***Phase***
Regeneration of carbon dioxide acceptor	.....
Reduction of 3C compound	.....
Carbon dioxide fixation	.....

15. [HKDSE Biology 2023 Paper 1B Q5]

Hint: Locate the reactions, then trace matter and energy.

An electron micrograph of a chloroplast is shown below:



(a) Label structure Y. (1 mark)

(b) State the energy conversion which takes place at X and its importance in photosynthesis. (2 marks)

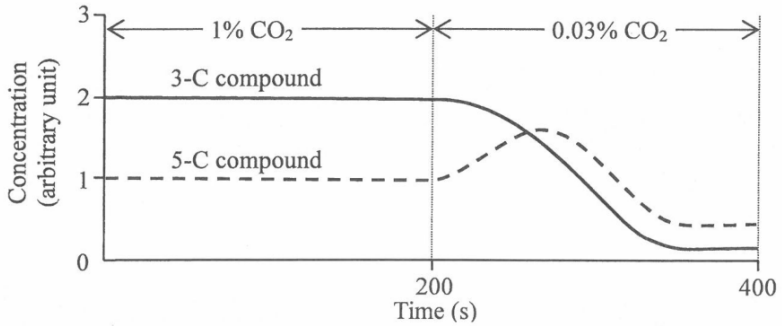
(c) To which type of metabolism does the overall reaction at Z belong? Explain your answer. (2 marks)

(d) Describe how the photosynthetic products of the leaves are stored in the underground tubers of a potato plant. (3 marks)

16. [HKDSE Biology 2022 Paper 1A Q26]

Hint: Locate the reactions, then trace matter and energy.

Directions: Questions 26 and 27 refer to an experiment in which a green algal culture was supplied with 1% carbon dioxide for 200 s and then followed by 0.03% carbon dioxide for another 200 s. The changes in the relative concentrations of a 3-C compound and a 5-C compound in the Calvin cycle of the green algae are shown below:



When the carbon dioxide concentration switched from 1% to 0.03%, which of the following combinations correctly shows the initial change of the concentration of the compound and its explanation?

	Initial change in concentration	*Explanation*
A.	3-C compound decreases	reduction of 3-C compound has increased
B.	3-C compound decreases	ATP from photochemical reactions has decreased
C.	5-C compound increases	carbon fixation has decreased
D.	5-C compound increases	regeneration of carbon dioxide acceptor has increased

Type 5 Investigate photosynthesis using leaves, controls and gas exchange

Degree of integration ★★★☆☆

Key ideas

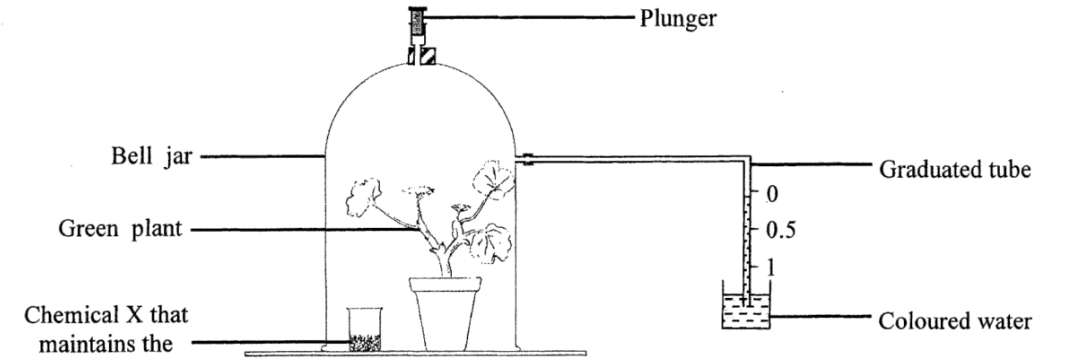
① Plants photosynthesise and respire simultaneously in light. If photosynthesis produces 8 units of oxygen per minute and respiration uses 3 units, the apparatus measures only 5 units of net oxygen release.

② Oxygen uptake in darkness can estimate respiration, provided respiratory rates are comparable. Leaf illumination also depends on orientation, shading and tissue distribution. Equal total area does not guarantee equal illumination of every part.

How to recognise the problem For oxygen, carbon dioxide or mass curves, first distinguish gross from net quantities, then explain using controls and limiting factors.

Example 1 [HKDSE Biology 2014 Paper 1A Q7]

Directions: Questions 6 to 8 refer to the diagram below, which shows a set-up used to determine the rate of photosynthesis of a green plant. During the study, the position of the plunger remained unchanged.



The rate obtained was lower than the actual rate of photosynthesis of the plant. Which of the following is the most probable reason for this?

A. The plant also carried out respiration during the study.
B. The plant also carried out transpiration during the study.
C. The air temperature might have increased during the study.
D. The atmospheric pressure might have decreased during the study.

Solution Answer: A

Method: Distinguish gross from net quantities before identifying limiting factors.

The plant also respires, consuming some oxygen produced by photosynthesis. The apparatus therefore measures net oxygen production, which is lower than gross photosynthetic oxygen production. Transpiration does not directly consume photosynthetically produced oxygen, and changes in temperature or atmospheric pressure are not the most direct biological explanation here.

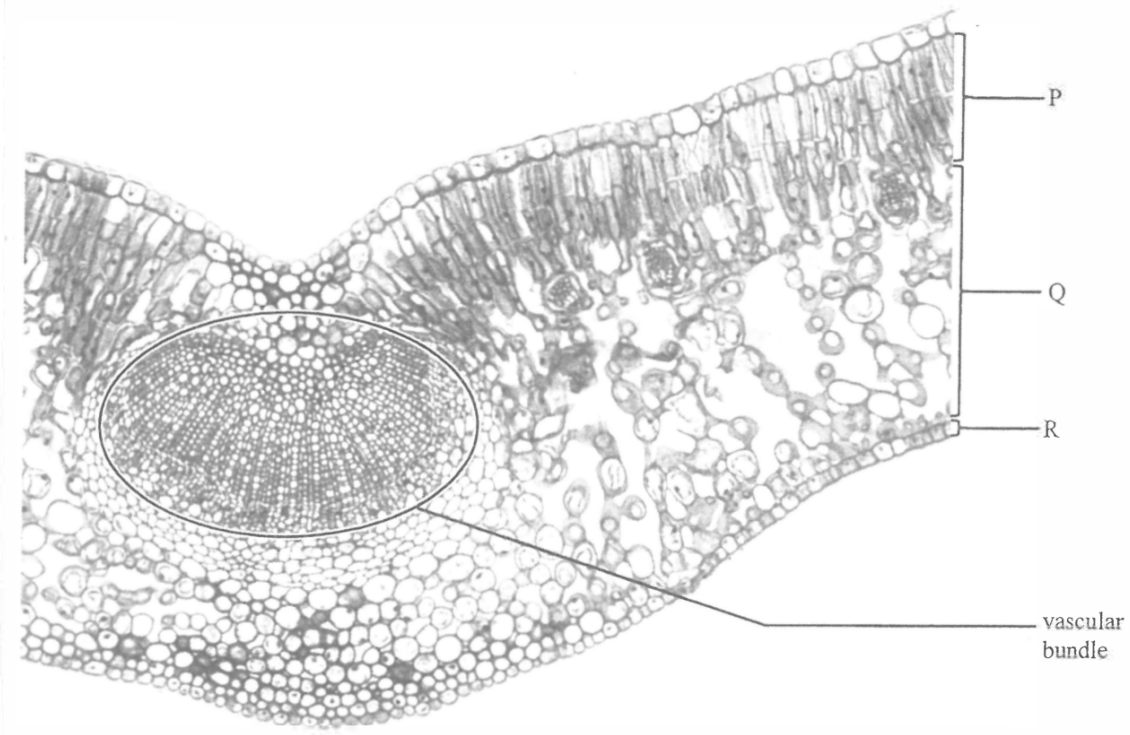
Examiner's comment (source page(s) 2)

Respiration consumes oxygen while photosynthesis occurs, so net oxygen production is lower than gross production.

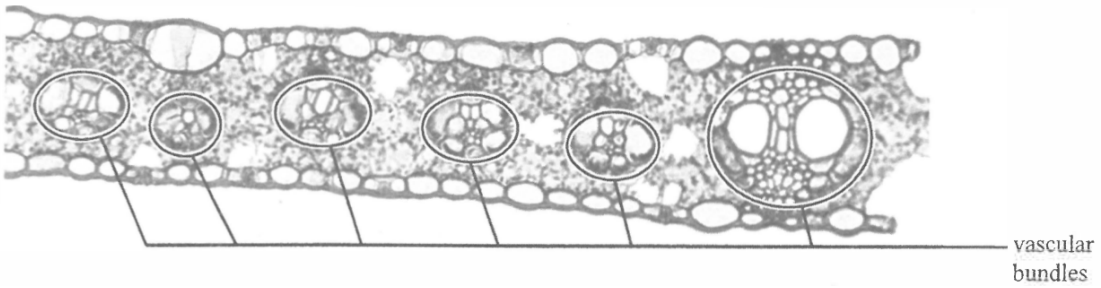
Marking reference: HKDSE Biology 2014 Paper 1A Q7, official marking scheme, source page(s) 1.

Example 2 [HKDSE Biology 2018 Paper 1B Q3]

Photomicrograph X



Photomicrograph Y



Photomicrographs X and Y on the opposite page (page 4) show the cross sections of two leaves taken from different plant species.

(a) (i) Comparing the cell shapes of both leaves, which labelled tissue (P, Q or R) in Photomicrograph X is absent from Photomicrograph Y? (1 mark)

(ii) With reference to Photomicrograph X, what is the observable adaptive feature of the tissue identified in (i)? What is the significance of this adaptive feature? (2 marks)

(b) The leaf in Photomicrograph Y was taken from a plant species with leaves oriented vertically, as shown in the following photograph:



Explain how the distribution of the photosynthetic tissue in these leaves is related to the vertical orientation of the leaves. (3 marks)

Solution **Reading the question and choosing a method**

Method: Distinguish gross from net quantities before identifying limiting factors.

Identify the actual difference in cellular arrangement between the transverse sections, then include leaf orientation in the explanation.

a(i); original allocation: 1 mark(s)

P.

P in X is palisade tissue consisting of closely packed, elongated cells. Y has no equivalent distinct palisade layer. The presence of mesophyll cells in both images does not mean that all tissues are identical.

a(ii); original allocation: 2 mark(s)

P's cells are closely packed near the upper epidermis, where they readily receive light falling on the upper leaf surface, favouring light absorption for photosynthesis.

State an arrangement or position visible in the photograph, then explain its significance. The upper side of a horizontal leaf receives light more directly. Closely packed photosynthetic tissue near that surface can use incident light effectively. The question specifies observable adaptations. Do not merely recite "many chloroplasts" without checking that the photograph shows them.

b; original allocation: 3 mark(s)

When the leaf grows vertically, both surfaces may receive light, and photosynthetic tissue is distributed more evenly near both sides. The leaf can therefore photosynthesise effectively as the sun's position or light direction changes.

A horizontal leaf often has a more consistent illuminated surface. In vertical leaf Y, light can arrive from different sides as its direction changes. It would therefore be inappropriate to concentrate the main photosynthetic tissue at one fixed "upper" side. Link lighting conditions to the cross-section: both sides receive light, so photosynthetic cells are more evenly distributed. As illumination changes through the day, tissue near the lit surface can continue to use the light.

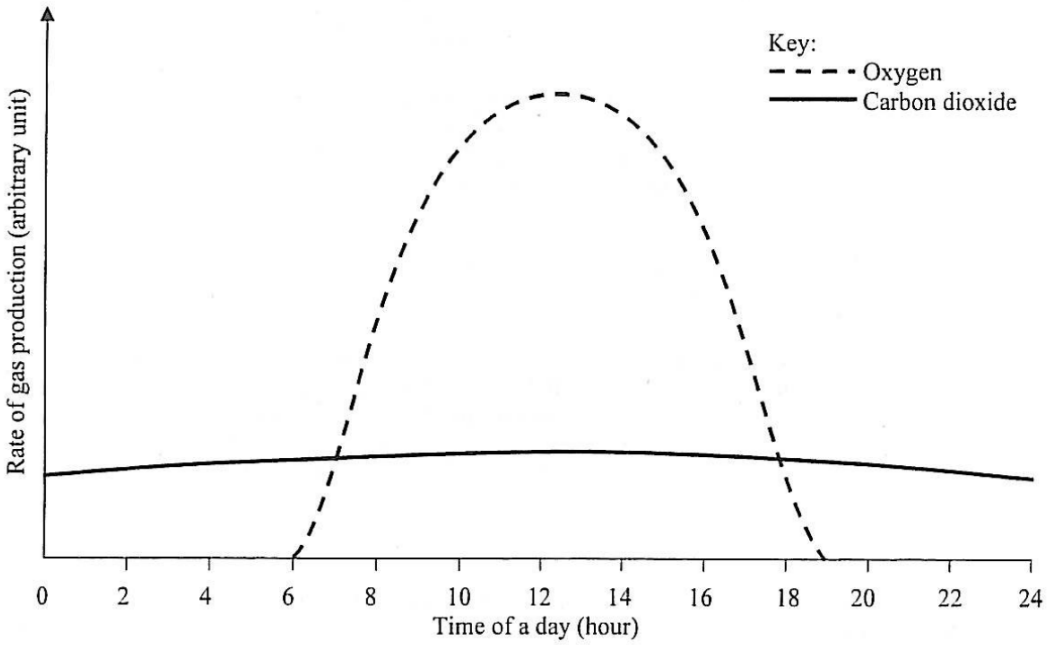
Examiner's comment (source page(s) 3, 4)

Observable features must come from the photograph; chloroplast abundance not shown cannot be claimed as an observation. The link between vertical leaves and illumination of both sides connects sunlight direction to photosynthetic-tissue distribution.

Marking reference: HKDSE Biology 2018 Paper 1B Q3, official marking scheme, source page(s) 2.

Example 3 [HKDSE Biology 2012 Paper 1B Q5]

The graph below shows the oxygen production rate and carbon dioxide production rate of a local plant on a summer day:



(a) State the times at which there is no net exchange of gases into or out of the leaves. (1 mark)

(b) Sketch a line on the above graph to show the oxygen production rate of the plant on a winter day. (2 marks)

(c) The area below the line showing the oxygen production rate is usually greater than the area below the line showing the carbon dioxide production rate. Explain the importance of this observation. (4 marks)

Solution a; original allocation: 1 mark(s)

Approximately 7:00 and 18:00.

The intersections indicate equal rates of photosynthetic oxygen production and respiratory carbon dioxide production. Their gas effects cancel, giving no net gas exchange.

Method: Distinguish gross from net quantities before identifying limiting factors.

b; original allocation: 2 mark(s)

The winter oxygen-production curve should be lower and remain above zero for a shorter daylight interval.

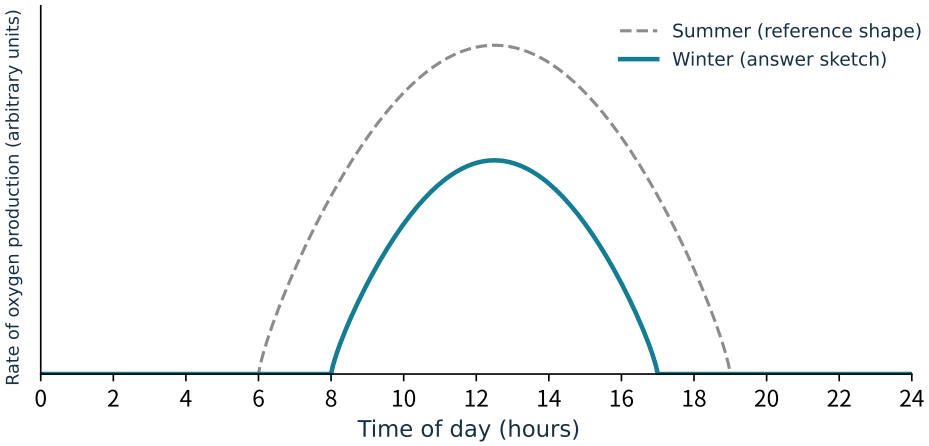
Draw a daytime hump below the summer curve. It leaves zero later and returns earlier, representing shorter daylight, and has a lower peak, representing slower photosynthesis. Each feature earns 1 mark. Do not draw a negative curve throughout the day.

c; original allocation: 4 mark(s)

The area under the oxygen-production curve represents food made by photosynthesis during the day; the area under the carbon-dioxide-production curve represents food consumed in respiration. Only when the first area is larger does the plant have a net food/energy surplus for growth and reproduction.

An instantaneous rate does not represent a whole-day total, so compare areas under rate–time curves. Food made during faster daytime photosynthesis must also supply respiration

continuing at night. If total daily production only balances total consumption, insufficient net material remains to build new tissue.



Winter sketch: a lower curve over a shorter daylight interval. No numerical winter data were supplied.

Examiner's comment (source page(s) 1)

The winter curve must show both shorter daylight and a lower rate. Comparing areas concerns plant food production and consumption, not atmospheric gas balance.

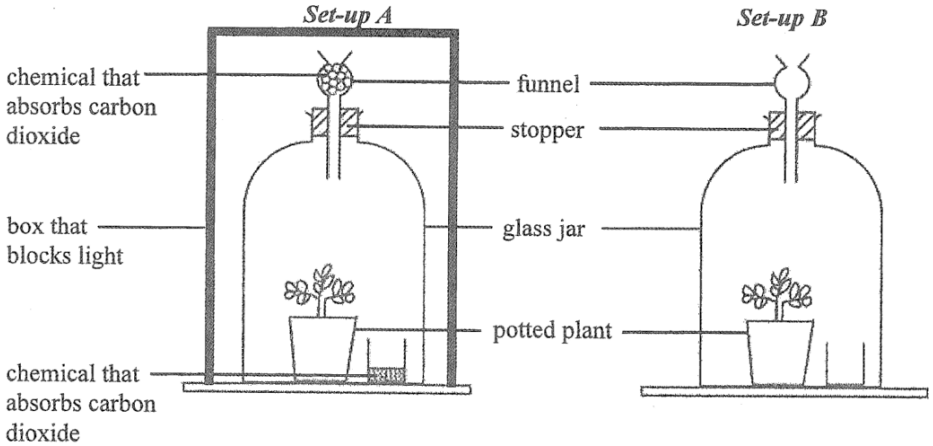
Marking reference: HKDSE Biology 2012 Paper 1B Q5, official marking scheme, source page(s) 2, 3.

Practice

1. [HKDSE Biology 2015 Paper 1A Q11]

Hint: Distinguish gross from net quantities before identifying limiting factors.

Directions: Questions 11 and 12 refer to the following experiment. A student put two similar plants in darkness for 24 hours and then placed them in the following set-ups to conduct an investigation on photosynthesis:



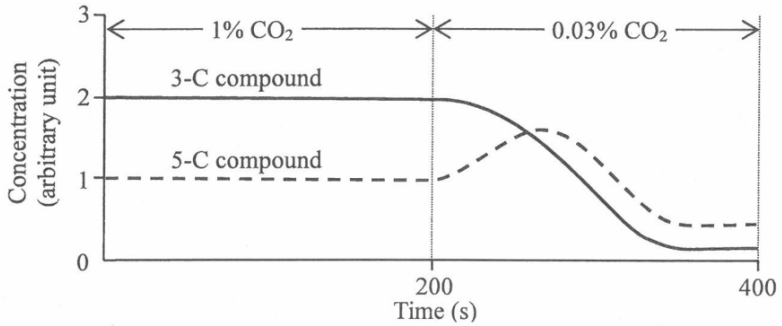
At the end of the experiment, leaves were taken from the plants in set-ups A and B for the iodine test. Arrange the following steps in the correct order:

(1) Put the leaf in boiling water for 5 minutes.
(2) Add iodine solution to the leaf.
(3) Put the leaf in hot alcohol solution for 5 minutes.
(4) Put the leaf in water at room temperature for a few seconds.

A. (1), (2), (3), (4)
B. (1), (3), (4), (2)
C. (2), (3), (4), (1)
D. (4), (3), (2), (1)

2. [HKDSE Biology 2022 Paper 1A Q27]
Hint: Distinguish gross from net quantities before identifying limiting factors.

Directions: Questions 26 and 27 refer to an experiment in which a green algal culture was supplied with 1% carbon dioxide for 200 s and then followed by 0.03% carbon dioxide for another 200 s. The changes in the relative concentrations of a 3-C compound and a 5-C compound in the Calvin cycle of the green algae are shown below:



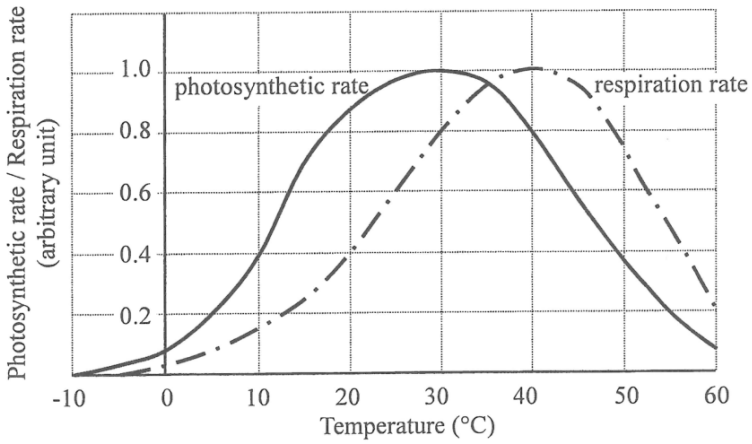
Which of the following factors should be kept constant throughout the experiment?

(1) pH
(2) temperature
(3) light intensity

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

3. [HKDSE Biology 2024 Paper 1A Q9]
Hint: Distinguish gross from net quantities before identifying limiting factors.

Directions: Questions 8 and 9 refer to the graph below, which shows the changes in the photosynthetic rate and respiration rate of a rice crop at different temperatures while the light intensity and concentration of carbon dioxide were kept constant:



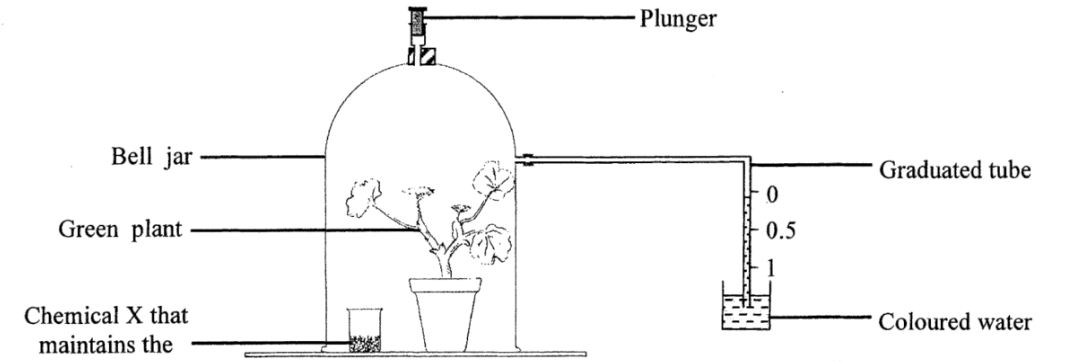
Based on the data shown in the graph, which of the following is / are possible explanation(s) of the drop in the two rates?

(1) Transpiration rate increases at higher temperatures.
(2) The enzymes involved denature at higher temperatures.
(3) The two processes take place at different organelles of the cell.

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

4. [HKDSE Biology 2014 Paper 1A Q6]
← *Hint: Distinguish gross from net quantities before identifying limiting factors.*

Directions: Questions 6 to 8 refer to the diagram below, which shows a set-up used to determine the rate of photosynthesis of a green plant. During the study, the position of the plunger remained unchanged.

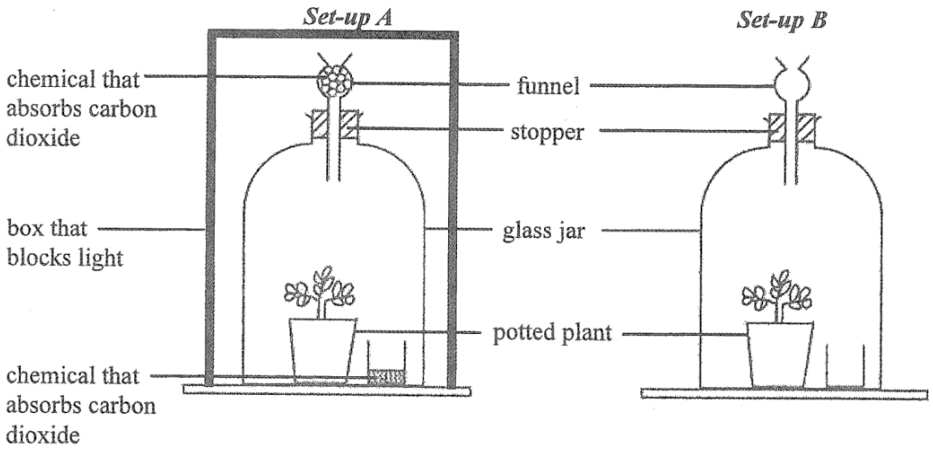


Based on the results, what was the rate of photosynthesis of this plant?

A. 0.6 mL oxygen released per hour
B. 0.3 mL oxygen released per hour
C. 0.6 mL carbon dioxide absorbed per hour
D. 0.3 mL carbon dioxide absorbed per hour

5. [HKDSE Biology 2015 Paper 1A Q12]
← *Hint: Distinguish gross from net quantities before identifying limiting factors.*

Directions: Questions 11 and 12 refer to the following experiment. A student put two similar plants in darkness for 24 hours and then placed them in the following set-ups to conduct an investigation on photosynthesis:

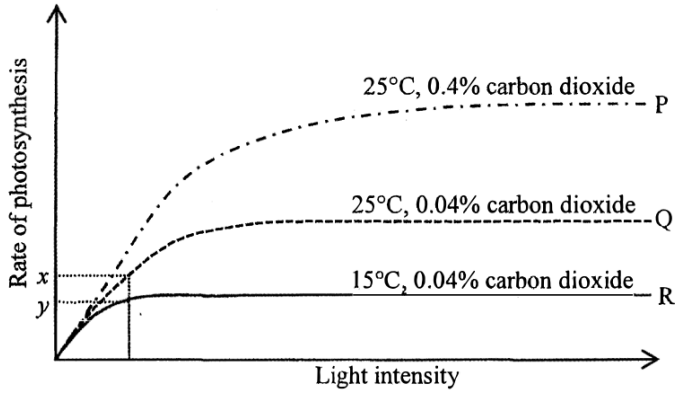


12. After the iodine test, the leaf taken from set-up A was brown while the leaf taken from set-up B was blue-black. Which of the following conclusions can be drawn from the results?

A. Light is necessary for photosynthesis.
B. Carbon dioxide is necessary for photosynthesis.
C. Both light and carbon dioxide are necessary for photosynthesis.
D. Photosynthesis occurs in the plant in set-up B but not in set-up A.

6. [HKDSE Biology 2016 Paper 1A Q9]
Hint: Distinguish gross from net quantities before identifying limiting factors.

Directions: Questions 9 and 10 refer to the diagram below, which shows the rate of photosynthesis of a plant under different conditions:

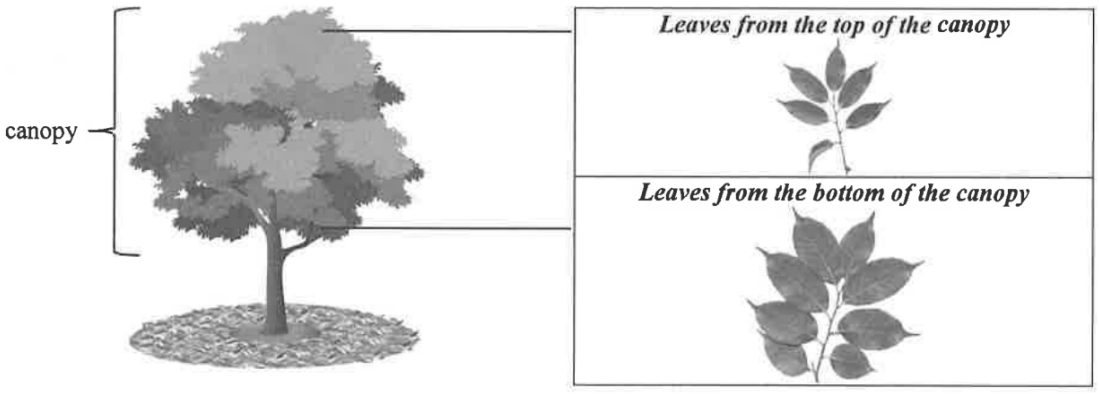


The factor(s) that determine(s) the difference in the values of x and y in the diagram is / are

A. temperature.
B. light intensity.
C. carbon dioxide concentration.
D. light intensity and temperature.

7. [HKDSE Biology 2019 Paper 1A Q5]
Hint: Distinguish gross from net quantities before identifying limiting factors.

The photographs on the right below show leaves taken from different parts of the canopy of the same tree. (Note: The photographs are of the same magnification.)



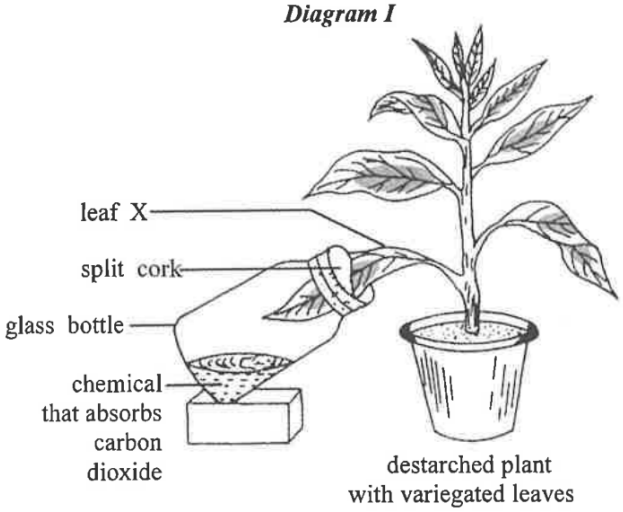
Which of the following is the most likely explanation for the differences between the leaves taken from the two parts of the canopy?

A. The leaves from the top of the canopy are smaller because they do not receive sufficient water for growth.
B. The leaves from the top of the canopy are smaller because they can reduce water loss due to transpiration.
C. The leaves from the bottom of the canopy are larger because they can store more food from photosynthesis.
D. The leaves from the bottom of the canopy are larger because they can collect light escaped through the top of the canopy.

8. [HKDSE Biology 2019 Paper 1A Q7]
Hint: Distinguish gross from net quantities before identifying limiting factors.

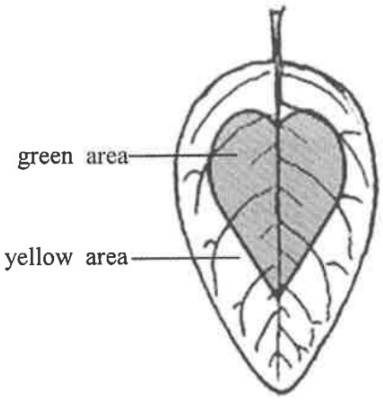
Directions: Questions 6 and 7 refer to Diagram I and Diagram II below. Diagram I shows a set-up prepared by a student to study the conditions for photosynthesis. Diagram II shows the leaf surface of a variegated leaf X before the experiment.

Diagram I



destarched plant with variegated leaves

Diagram II

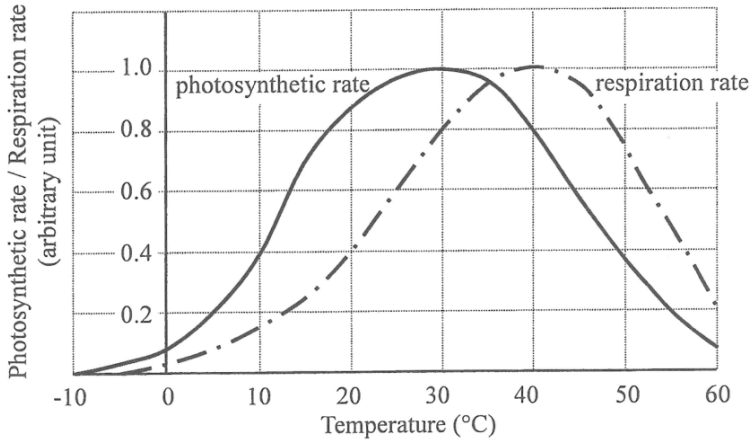


How many independent variables were being studied in the experiment?

A. 1
B. 2
C. 3
D. 4

9. [HKDSE Biology 2024 Paper 1A Q8]
Hint: Distinguish gross from net quantities before identifying limiting factors.

Directions: Questions 8 and 9 refer to the graph below, which shows the changes in the photosynthetic rate and respiration rate of a rice crop at different temperatures while the light intensity and concentration of carbon dioxide were kept constant:



Which of the following interpretations about the graph is correct?

A. The crop has maximum growth at 30°C.
B. The crop does not absorb water at 40°C.
C. The crop reaches compensation point at 35°C.
D. The crop has greatest net production of food at 20°C.

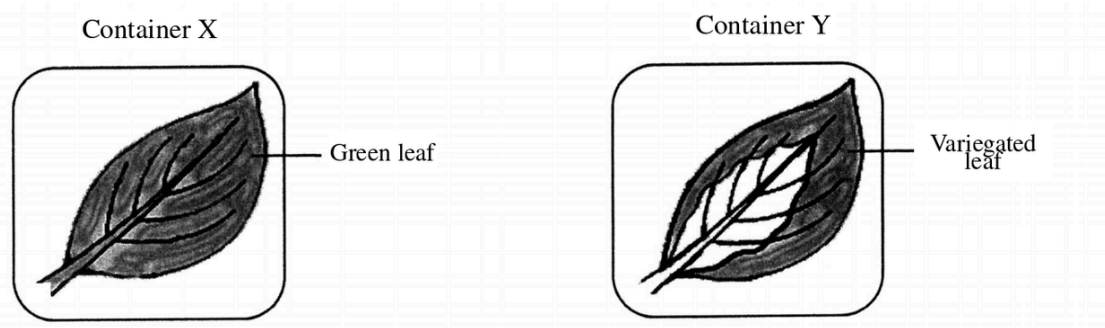
10. [HKDSE Biology 2025 Paper 1A Q23 (English translation)]
⟵ Hint: Distinguish gross from net quantities before identifying limiting factors.

Compound M can block the normal functioning of the electron transport chain in mitochondria. If farmland is contaminated with compound M, what effects may this have on plants growing there?

	Rate of mineral uptake	Rate of water uptake
A.	Decreases	Decreases
B.	Remains unchanged	Decreases
C.	Decreases	Remains unchanged
D.	Remains unchanged	Remains unchanged

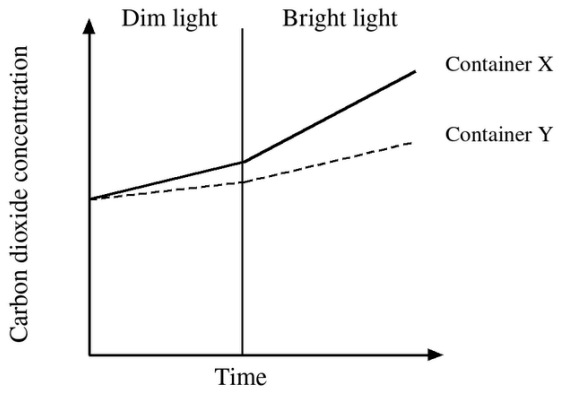
11. [HKDSE Biology 2025 Paper 1A Q24 (English translation)]
⟵ Hint: Distinguish gross from net quantities before identifying limiting factors.

A green leaf and a variegated leaf from the same plant are equal in size. They are placed in containers X and Y respectively, as shown below:

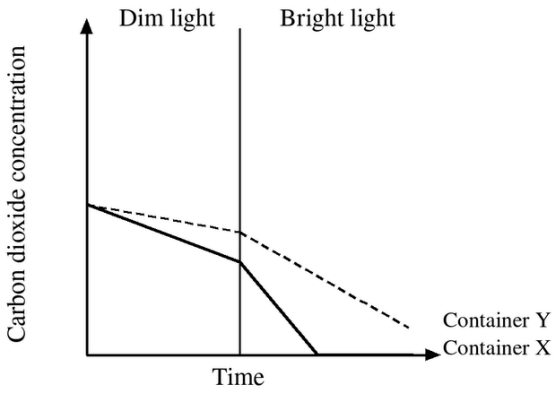


The variegated leaf reaches its compensation point in dim light. Which graph shows the changes in carbon dioxide concentration in containers X and Y when the light changes from dim to bright?

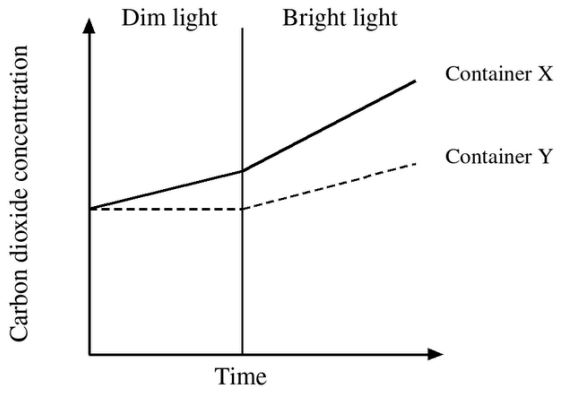
A.



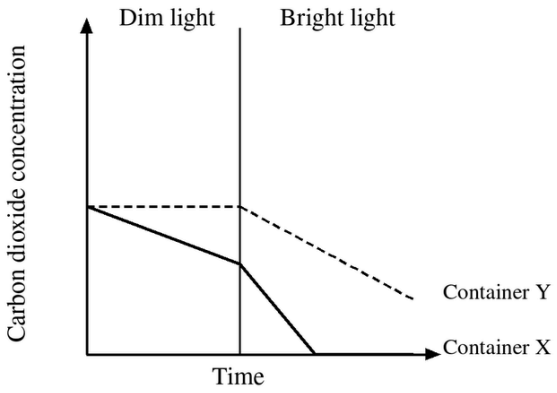
B.



C.



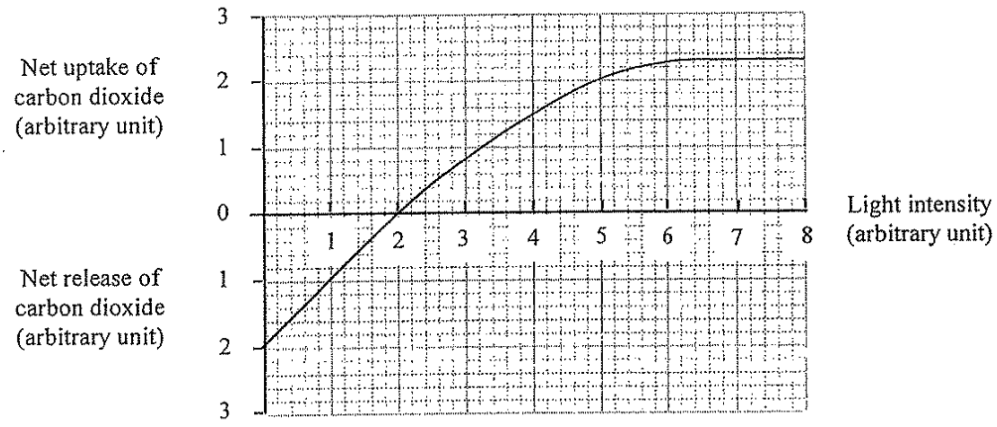
D.



12. [HKDSE Biology Sample Paper Paper 1A Q8]

Hint: Distinguish gross from net quantities before identifying limiting factors.

The graph below shows the exchange of carbon dioxide between a green plant and the atmosphere under different light intensities:



Which of the following can be deduced from the graph?

(1) At 1 unit of light intensity, only respiration occurs.
(2) At 2 units of light intensity, no net photosynthesis occurs.
(3) At 7 units of light intensity, the rate of photosynthesis is higher than the rate of respiration.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

13. [HKDSE Biology Sample Paper Paper 1A Q9]

Hint: Distinguish gross from net quantities before identifying limiting factors.

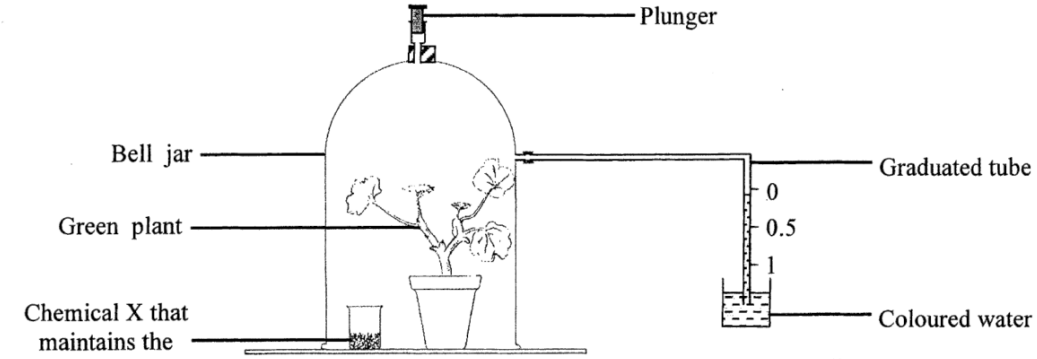
For a plant exposed to adequate light, under which of the following conditions would carbon dioxide concentration most likely be the limiting factor on its rate of photosynthesis?

	Temperature (°C)	*Carbon dioxide concentration (%)*
A.	5	0.01
B.	5	0.04
C.	25	0.01
D.	25	0.04

14. [HKDSE Biology 2014 Paper 1A Q8]

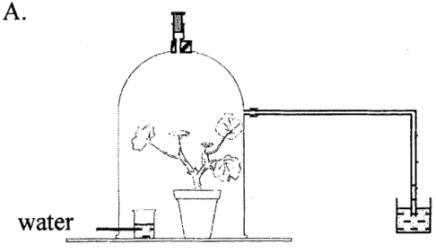
Hint: Distinguish gross from net quantities before identifying limiting factors.

Directions: Questions 6 to 8 refer to the diagram below, which shows a set-up used to determine the rate of photosynthesis of a green plant. During the study, the position of the plunger remained unchanged.

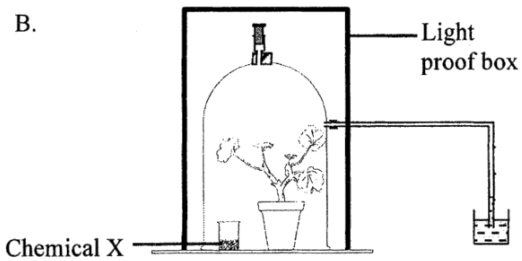


Which of the following set-ups can be used as a control for the above study to find out the actual rate of photosynthesis?

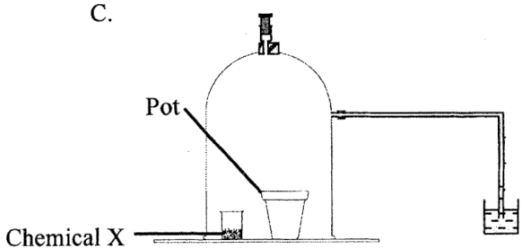
A.



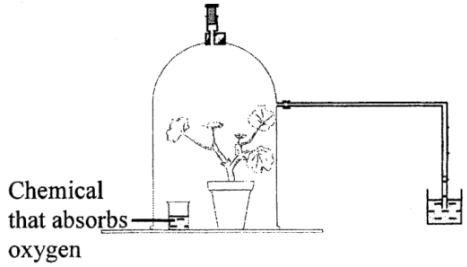
B.



C.



D.

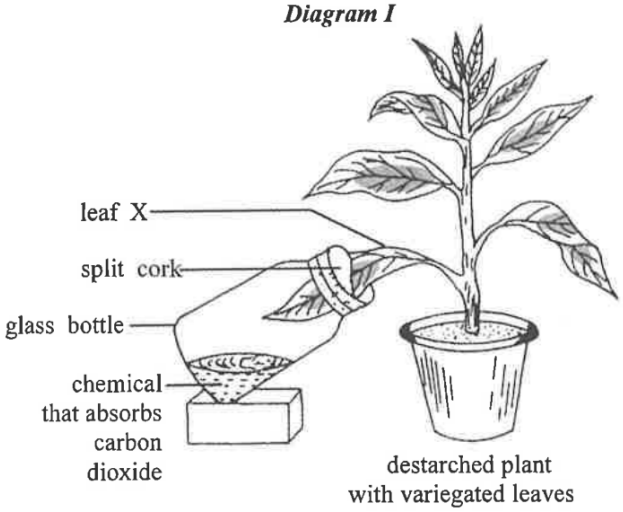


15. [HKDSE Biology 2019 Paper 1A Q6]

Hint: Distinguish gross from net quantities before identifying limiting factors.

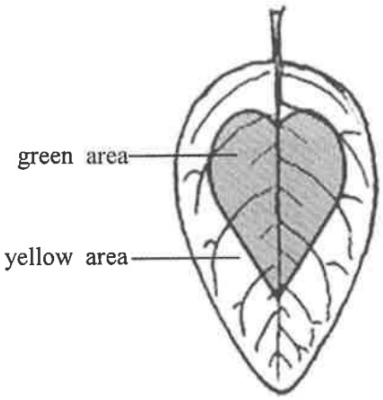
Directions: Questions 6 and 7 refer to Diagram I and Diagram II below. Diagram I shows a set-up prepared by a student to study the conditions for photosynthesis. Diagram II shows the leaf surface of a variegated leaf X before the experiment.

Diagram I



destarched plant with variegated leaves

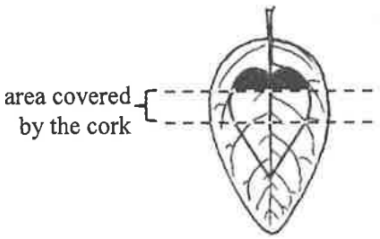
Diagram II



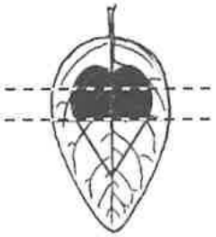
After leaving the set-up under sunlight for several hours, iodine test was carried out on leaf X. Which of the following diagrams correctly shows the results?

Key: ☐ brown
■ blue black

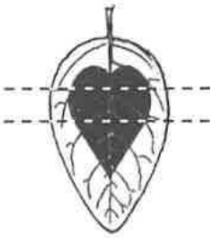
A.



B.



C.

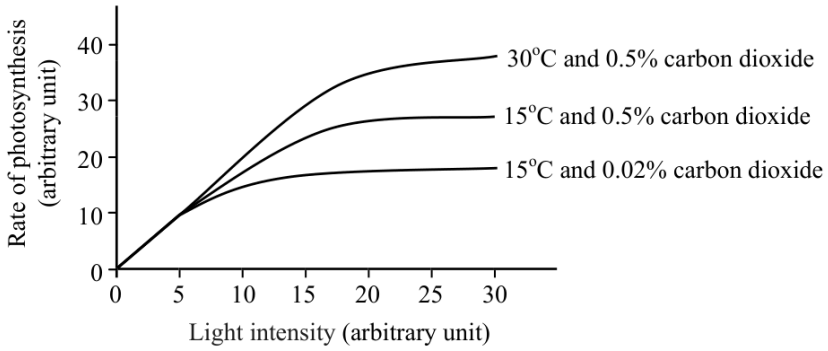


D.



16. [HKDSE Biology Practice Paper Paper 1A Q8]
Hint: Distinguish gross from net quantities before identifying limiting factors.

The graph below shows the rate of photosynthesis of a plant at different temperatures and carbon dioxide concentrations when light intensity increases:

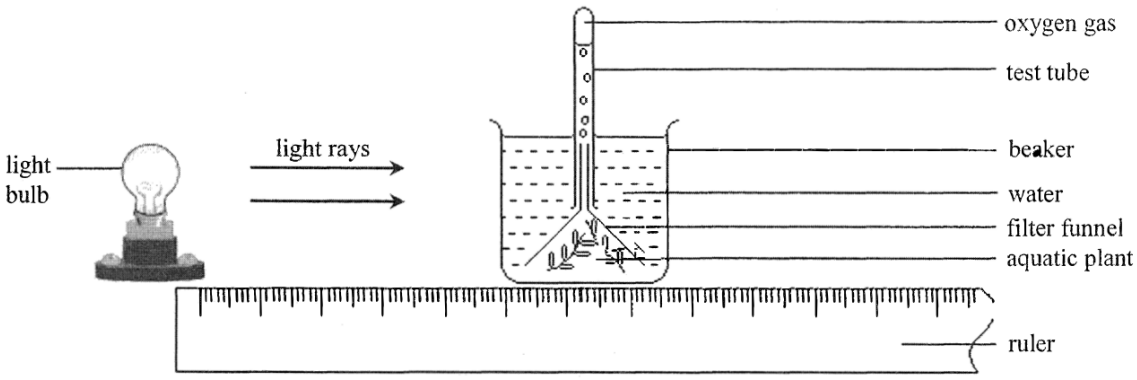


Which of the following descriptions about the rate of photosynthesis of this plant can be deduced from the graph?

A. Below 3 units of light intensity, light intensity is the factor limiting this plant's photosynthetic rate.
B. At 25 units of light intensity and 0.02% carbon dioxide, temperature is the factor limiting this plant's photosynthetic rate.
C. At 25 units of light intensity, 15°C and 0.5% carbon dioxide, carbon dioxide concentration is the factor limiting this plant's photosynthetic rate.
D. At 25 units of light intensity, 15°C and 0.5% carbon dioxide, this plant's photosynthetic rate doubles when the temperature is doubled.

17. [HKDSE Biology 2017 Paper 1B Q7]
Hint: Distinguish gross from net quantities before identifying limiting factors.

The diagram below shows an experimental set-up for investigating the effect of light intensity on the rate of photosynthesis:



(a) What is the assumption behind using the volume of oxygen released per unit time to indicate the photosynthetic rate? Explain your answer. (2 marks)

(b) Suggest ***one*** modification to this experimental set-up to make sure that the result is due to the independent variable only. Explain your answer. (3 marks)

(c) What is the significance of the *two* products of the photochemical reactions to the whole photosynthetic process? (4 marks)

18. [HKDSE Biology 2021 Paper 1B Q8]

Hint: Distinguish gross from net quantities before identifying limiting factors.

The table below shows the average blade area, blade thickness and thickness of the palisade mesophyll of leaves collected from the upper and lower regions of a tree species:

Location of leaves	Average blade area (cm^2)	Average blade thickness (μm)	Average thickness of palisade mesophyll (μm)
Upper region	62	177	45
Lower region	72	152	33

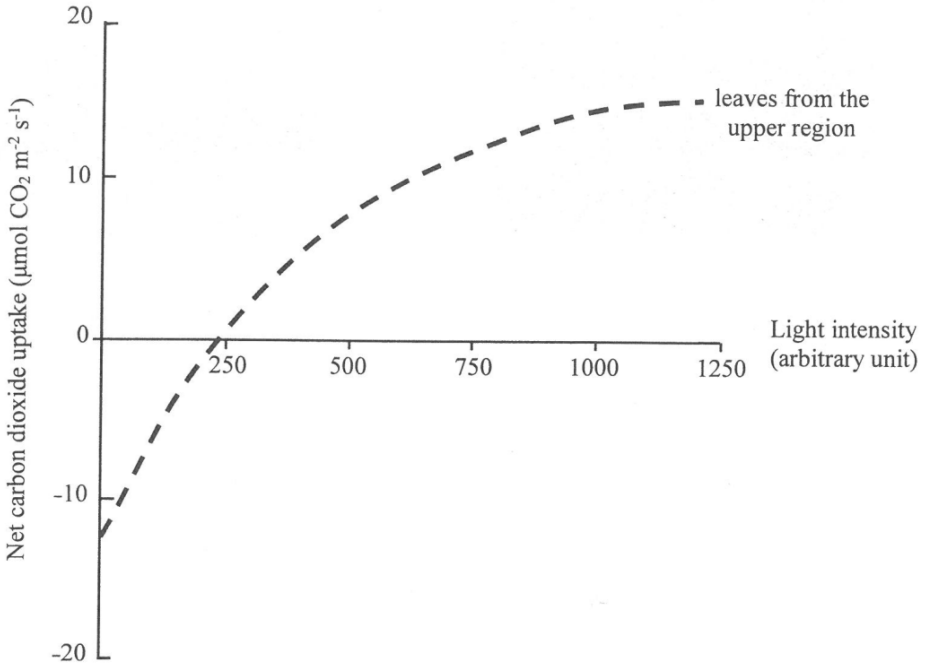
(a) Compare the average blade area of leaves from the upper region and that from the lower region. With respect to the difference in surface area, suggest ***one*** adaptive advantage of the leaves from the lower region. (2 marks)

(b) (i) Compare the average thickness of the palisade mesophyll of leaves from the upper region and that from the lower region. (1 mark)

(ii) Between the two types of leaves, suggest ***one*** possible structural difference which would lead to the difference stated in (b)(i). (1 mark)

(iii) How would you confirm your answer in (b)(ii)? (2 marks)

(c) Leaves at different regions of a tree are adapted to different light intensities. The graph below shows the change in the net carbon dioxide uptake by leaves from the upper region of a tree at different light intensities:



(i) Why are there negative values for net carbon dioxide uptake? (1 mark)

(ii) On the above graph, sketch a line to show the change in net carbon dioxide uptake by leaves from the lower region of a tree at different light intensities. (2 marks)
(Note: Neglect the difference in the average blade area between the two types of leaves when you sketch the line.)

Type 6 Track respiratory pathways, ATP and electron carriers

Degree of integration ★★★☆☆

Key ideas

① Glucose first undergoes glycolysis in the cytoplasm to form pyruvate. The relevant later reactions occur in mitochondria in eukaryotic cells. Oxidative phosphorylation uses the proton gradient established by electron transport to form ATP and enables reuse of the relevant carriers.

② Isolated mitochondria may not use glucose directly because the earlier cytoplasmic reactions are absent. Under anaerobic conditions, fermentation regenerates NAD^+ so that glycolysis can continue.

How to recognise the problem Locate reactions in the cytoplasm, mitochondrial matrix and inner membrane. If a step is inhibited, identify the material or electron pathway interrupted.

Example 1 [HKDSE Biology 2023 Paper 1A Q11]

Which of the following processes produce ATP?

(1) glycolysis
(2) Calvin cycle
(3) photochemical reactions

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

Solution Answer: B

Method: Trace matter, electrons and ATP by reaction location.

Glycolysis produces ATP by substrate-level phosphorylation, and photochemical reactions also form ATP. The Calvin cycle uses ATP for reduction and regeneration of intermediates rather than producing ATP overall. Only (1) and (3) are correct.

Marking reference: HKDSE Biology 2023 Paper 1A Q11, official marking scheme, source page(s) 1.

Example 2 [HKDSE Biology 2015 Paper 1A Q6]

Which of the following combinations correctly compares the aerobic respiration and anaerobic respiration of muscle cells?

	Aerobic respiration	*Anaerobic respiration*
A.	occurs only when oxygen is present	occurs only when oxygen is absent
B.	produces more NADH	produces less NADH
C.	glycolysis takes place	no glycolysis
D.	takes place only inside the mitochondria	takes place only in the cytoplasm

Solution Answer: B

Method: Trace matter, electrons and ATP by reaction location.

Both pathways begin with glycolysis. Aerobic respiration then includes pyruvate oxidation and the Krebs cycle, forming more reduced coenzyme NADH. In the anaerobic muscle pathway, pyruvate is reduced to lactate to regenerate NAD^+ without these later oxidative steps. The table's comparison of NADH production is therefore correct. Choose B.

Marking reference: HKDSE Biology 2015 Paper 1A Q6, official marking scheme, source page(s) 1.

Example 3 [HKDSE Biology 2012 Paper 1B Q9]

Control (without treatment)	100%	100%	100%
Drug X	2%	3%	5%
Drug Y	20%	15%	150%

The data for the control are set as 100% for comparative purpose.

(a) Suggest the key process that is inhibited by drug X. Explain your answer. (3 marks)

(b) Suggest the key process that is inhibited by drug Y. Explain why there is an accumulation of pyruvate in the muscle cells after treatment with drug Y. (3 marks)

(c) Instead of incubating in the presence of oxygen, the untreated muscle cells were incubated under anaerobic conditions. Predict the change in the cellular ATP, NADH and lactate levels. (3 marks)

(d) A student would like to study the enzymes involved in glycolysis, the Krebs cycle and oxidative phosphorylation separately. Suggest which cellular components he needs to isolate for the investigation. (3 marks)

Method: Trace matter, electrons and ATP by reaction location.

Solution a; original allocation: 3 mark(s)

X inhibits glycolysis. Pyruvate falls to 5% of the control, indicating inhibition of the step producing it. Since glycolysis lies upstream, its inhibition also deprives the Krebs cycle and oxidative phosphorylation of substrates, greatly reducing ATP and reduced NAD.

Identify the diagnostic product first: pyruvate is produced by glycolysis. "ATP is low, so some respiratory stage is inhibited" does not distinguish among the three candidates.

b; original allocation: 3 mark(s)

Y inhibits the Krebs cycle. Glycolysis continues to produce pyruvate, but subsequent utilisation is impaired, causing accumulation to 150% of the control. Downstream supplies of reduced NAD and ATP consequently decrease.

The crucial clue is increased pyruvate, not a decrease in every quantity. Continued upstream supply combined with reduced downstream consumption causes an intermediate to accumulate.

c; original allocation: 3 mark(s)

ATP decreases; reduced NAD decreases; lactate increases.

Oxygen shortage limits oxidative phosphorylation, lowering total ATP production. Muscle cells increase lactate fermentation, reducing pyruvate to lactate while oxidising reduced NAD. This regenerates NAD so glycolysis can continue. These answers follow the whole-cell measurements specified in this paper.

d; original allocation: 3 mark(s)

Glycolysis: cytosol. Krebs cycle: mitochondrial matrix. Oxidative phosphorylation: inner mitochondrial membrane.

The locations follow the pathway's sequence. The electron-transport system and ATP synthase on the inner membrane participate together in oxidative phosphorylation. Do not place it on the outer membrane.

Examiner's comment (source page(s) 2)

Use the major respiratory stages and products to infer the blockage; every intermediate reaction need not be memorised. Pyruvate accumulation indicates continued upstream supply with impaired downstream utilisation.

Marking reference: HKDSE Biology 2012 Paper 1B Q9, official marking scheme, source page(s) 4.

Practice

1. [HKDSE Biology 2018 Paper 1A Q11]

Hint: Trace matter, electrons and ATP by reaction location.

Which of the following processes takes place at the inner membrane of mitochondria?

A. glycolysis
B. conversion of pyruvate to acetyl CoA
C. Krebs cycle
D. oxidative phosphorylation

2018-DSE-BIO 1A-4 7

2. [HKDSE Biology 2018 Paper 1A Q26]

Hint: Trace matter, electrons and ATP by reaction location.

After vigorous exercise, the blood lactic acid concentration of an athlete increases. Which of the following word equations correctly shows the process that leads to the formation of lactic acid?

A. glucose → lactic acid
B. glucose → lactic acid + water
C. glucose → lactic acid + carbon dioxide
D. glucose + oxygen → lactic acid + carbon dioxide

3. [HKDSE Biology 2019 Paper 1A Q3]
← Hint: Trace matter, electrons and ATP by reaction location.

Which of the following process(es) in the respiratory pathways release(s) carbon dioxide?

(1) Oxidative phosphorylation
(2) Reactions in the Krebs cycle
(3) Conversion of glucose to pyruvate

A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

4. [HKDSE Biology 2020 Paper 1A Q4]
← Hint: Trace matter, electrons and ATP by reaction location.

Which of the following descriptions of anaerobic respiration in muscles is correct?

A. It involves glycolysis.
B. It produces lactic acid and carbon dioxide.
C. It takes place in the matrix of mitochondria.
D. It takes place on the inner membrane of mitochondria.

5. [HKDSE Biology 2020 Paper 1A Q5]
← Hint: Trace matter, electrons and ATP by reaction location.

Which of the following combinations correctly matches the stages of cellular respiration and the metabolites produced?

	Stage	*Metabolite produced*
A.	Glycolysis	acetyl-CoA
B.	Glycolysis	ATP
C.	Krebs Cycle	NAD
D.	Krebs Cycle	pyruvate

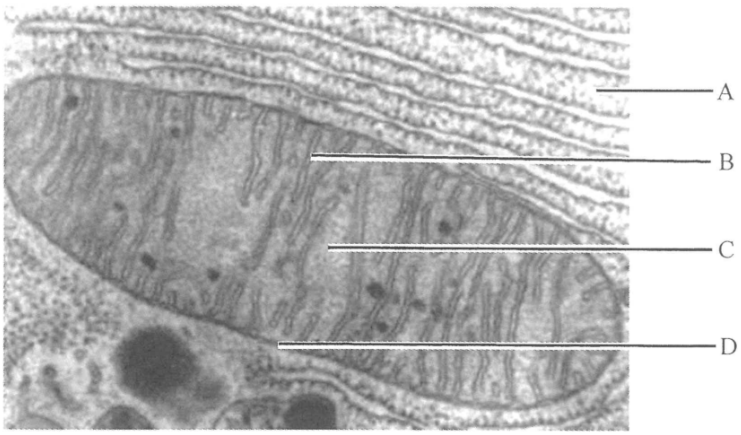
6. [HKDSE Biology 2021 Paper 1A Q4]
← Hint: Trace matter, electrons and ATP by reaction location.

Which of the following pairs of molecules contains the greatest amount of stored energy?

A. ADP and NAD
B. ADP and NADH
C. ATP and NAD
D. ATP and NADH

7. [HKDSE Biology 2021 Paper 1A Q6]
Hint: Trace matter, electrons and ATP by reaction location.

Directions: Questions 5 and 6 refer to the electron micrograph below, which shows a mitochondrion in an animal cell:



Anaerobic respiration takes place at

A. A.
B. B.
C. C.
D. D.

8. [HKDSE Biology 2022 Paper 1A Q14]
Hint: Trace matter, electrons and ATP by reaction location.

Directions: Questions 13 and 14 refer to the table below, which shows the effect of different substrates on the rate of anaerobic respiration of yeast:

Substrate	Average amount of carbon dioxide produced after 10 min (ppm)
Glucose	395.2
Maltose	345.8
Sucrose	222.2
Fructose	198.2

In this investigation, which part of the yeast cell produces carbon dioxide?

A. cytoplasm
B. cell membrane
C. matrix of mitochondria
D. inner membrane of mitochondria

9. [HKDSE Biology Practice Paper Paper 1A Q7]
Hint: Trace matter, electrons and ATP by reaction location.

Which of the following correctly lists the substances formed in the Krebs cycle?

A. water and NADH
B. water and carbon dioxide
C. carbon dioxide and NADH
D. water, carbon dioxide and NADH

10. [HKDSE Biology 2014 Paper 1B Q1]
⟵ Hint: Trace matter, electrons and ATP by reaction location.

For each of the biomolecules listed in Column 1, select from Column 2 one phrase that matches it. Put the appropriate letter in the space provided. (3 marks)

Column 1		Column 2
NADPH	.....	A. a product of oxidative phosphorylation
pyruvate	.....	B. a product of photochemical reactions
NAD	.....	C. a product of carbon fixation
		D. a product of glycolysis

11. [HKDSE Biology 2013 Paper 1A Q10]
⟵ Hint: Trace matter, electrons and ATP by reaction location.

Which of the following combinations best describes the processes involved in respiration?

	Oxygen is required	***Carbon dioxide is released***
A.	Conversion of pyruvate to acetyl CoA	Glycolysis
B.	Conversion of pyruvate to acetyl CoA	Krebs Cycle
C.	Oxidative phosphorylation	Glycolysis
D.	Oxidative phosphorylation	Krebs Cycle

12. [HKDSE Biology 2014 Paper 1A Q14]
⟵ Hint: Trace matter, electrons and ATP by reaction location.

Which of the following processes produce ATP?

(1) Glycolysis
(2) Krebs cycle
(3) Conversion of pyruvate to lactic acid

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

13. [HKDSE Biology 2016 Paper 1A Q26]
⟵ Hint: Trace matter, electrons and ATP by reaction location.

Which of the following processes in aerobic respiration release NADH?

(1) glycolysis
(2) Krebs cycle
(3) oxidative phosphorylation

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

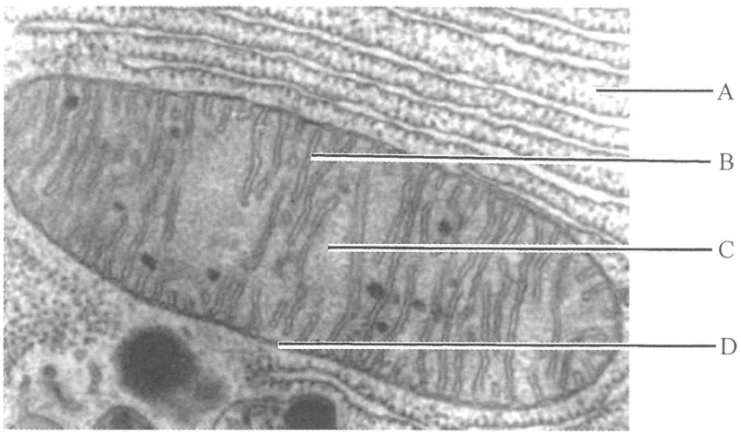
14. [HKDSE Biology 2017 Paper 1A Q7]
⟵ Hint: Trace matter, electrons and ATP by reaction location.

Which of the following combinations correctly matches the reaction in aerobic respiration with the location where it takes place?

	Reaction in aerobic respiration	***Location***
A.	regeneration of NAD	cytoplasm
B.	production of carbon dioxide	cytoplasm
C.	conversion of pyruvate to acetyl-CoA	mitochondrion
D.	conversion of triose phosphate to pyruvate	mitochondrion

15. [HKDSE Biology 2021 Paper 1A Q5]
⟵ Hint: Trace matter, electrons and ATP by reaction location.

Directions: Questions 5 and 6 refer to the electron micrograph below, which shows a mitochondrion in an animal cell:

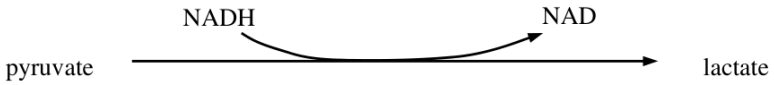


Which of the following substances passes through D into the mitochondrion during aerobic respiration?

A. glucose
B. pyruvate
C. acetyl-CoA
D. triose phosphate

16. [HKDSE Biology Sample Paper Paper 1A Q7]
⟵ Hint: Trace matter, electrons and ATP by reaction location.

The word equation below shows the conversion of pyruvate to lactate by the enzyme lactate dehydrogenase:

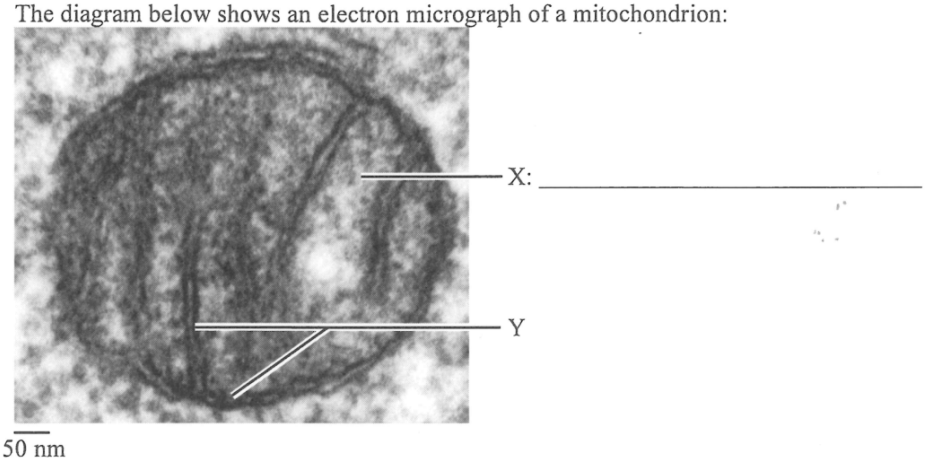


Under anaerobic conditions, if lactate dehydrogenase in a mammalian cell is inhibited, which of the following would occur?

A. The cell pH would decrease.
B. Glycolysis would become slower.
C. ATP production would increase.
D. The rate of reactions in the Krebs cycle would become higher.

17. [HKDSE Biology 2024 Paper 1B Q3]
← Hint: Trace matter, electrons and ATP by reaction location.

The diagram below shows an electron micrograph of a mitochondrion:



(a) Label X in the above diagram. (1 mark)

(b) Describe ***one*** observable feature of Y and explain how this feature is related to the functioning of mitochondria. (2 marks)

(c) Chemical Z can inhibit an enzyme found in X.

(i) Which key process of respiration would be inhibited? (1 mark)

(ii) If chemical Z is added to a plant cell culture, how would this affect the respiratory pathway? (3 marks)

18. [HKDSE Biology 2025 Paper 1A Q19 (English translation)]
← Hint: Trace matter, electrons and ATP by reaction location.

The following steps are carried out to investigate aerobic respiration:

1. Add a mitochondrial suspension to a test tube.
2. Add glucose solution to the test tube and mix it thoroughly with the mitochondrial suspension.
3. Measure the oxygen concentration of the mixture in the test tube for 5 minutes.
4. Add pyruvate solution to the test tube and mix it thoroughly with the existing mixture.
5. Measure the oxygen concentration of the mixture in the test tube for another 5 minutes.

Which combination below correctly describes the changes in oxygen concentration in the test tube?

	After adding glucose solution	After adding pyruvate solution
A.	Decreases	Decreases
B.	Decreases	Remains unchanged
C.	Remains unchanged	Decreases
D.	Remains unchanged	Remains unchanged

Type 7 Measure respiration with gas tests and respirometers

Degree of integration ★★☆☆☆

Key ideas

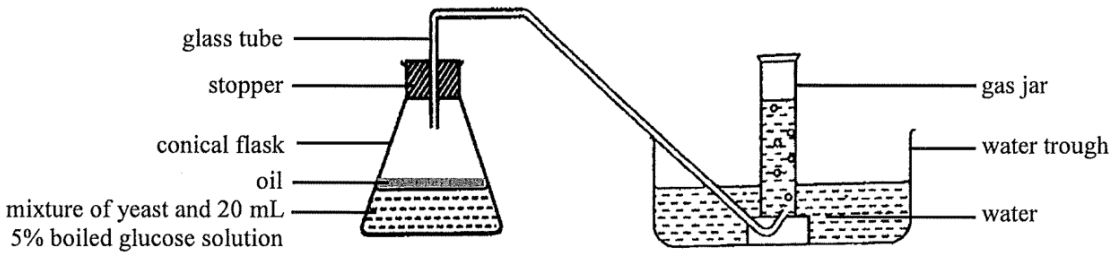
① With a carbon dioxide absorbent in a respirometer, consumed oxygen is not replaced by carbon dioxide, so gas volume falls and the droplet moves towards the lower-pressure side. Without an absorbent, gas change also depends on carbon dioxide production.

② Clear limewater becoming cloudy supports the presence of carbon dioxide. Cloudiness alone cannot precisely quantify an uncalibrated respiratory rate.

How to recognise the problem List gases consumed, produced and absorbed before determining volume or pressure changes.

Example 1 [HKDSE Biology 2023 Paper 1A Q7]

Directions: Questions 7 and 8 refer to the diagram below, which shows a set-up used to investigate the rate of respiration in yeast:



Which of the following word equations correctly shows the reaction being investigated?

A. glucose → carbon dioxide + water
B. glucose → carbon dioxide + ethanol
C. glucose + oxygen → carbon dioxide + water
D. glucose + oxygen → carbon dioxide + ethanol

Solution Answer: B

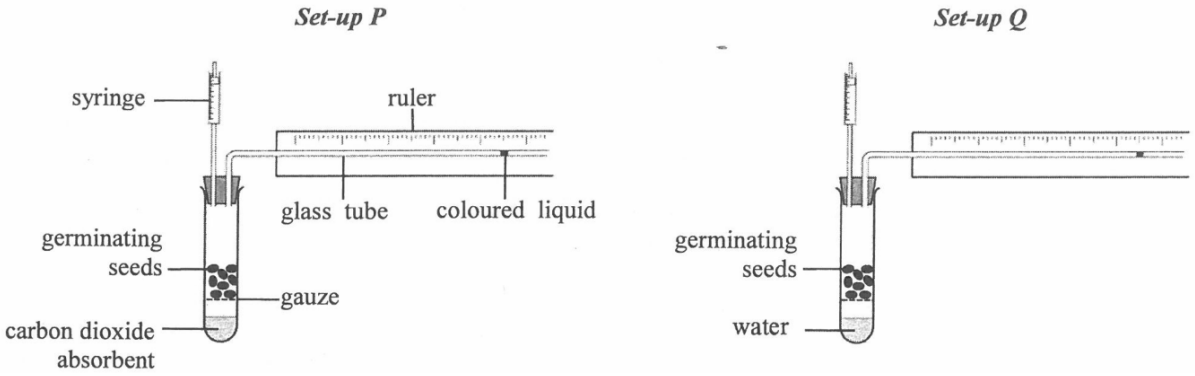
Boiling the glucose solution first removes dissolved oxygen, while the oil layer prevents air from entering again. The investigation therefore concerns anaerobic respiration. Yeast breaks down glucose into ethanol and carbon dioxide without requiring oxygen as a reactant.

Method: List gas consumption, production and absorption separately.

Marking reference: HKDSE Biology 2023 Paper 1A Q7, official marking scheme, source page(s) 1.

Example 2 [HKDSE Biology 2022 Paper 1A Q11]

Directions: Questions 11 and 12 refer to the diagram below, which shows two set-ups used for the investigation of the gas exchange in germinating seeds:



Assuming that the environmental conditions are the same, what will happen to the coloured liquid in each set-up?

	Set-up P	*Set-up Q*
A.	moves to the right	moves to the left
B.	moves to the left	stays still
C.	stays still	moves to the left
D.	stays still	moves to the right

Solution **Answer: B**

In P, the seeds consume oxygen during respiration, and the carbon dioxide produced is removed by the absorbent. The total amount of gas and the pressure in the sealed vessel decrease, so the droplet moves towards the vessel, to the left. In Q, carbon dioxide is not absorbed. The oxygen consumed is approximately replaced by the carbon dioxide produced, so the droplet remains in roughly the same position.

Method: List gas consumption, production and absorption separately.

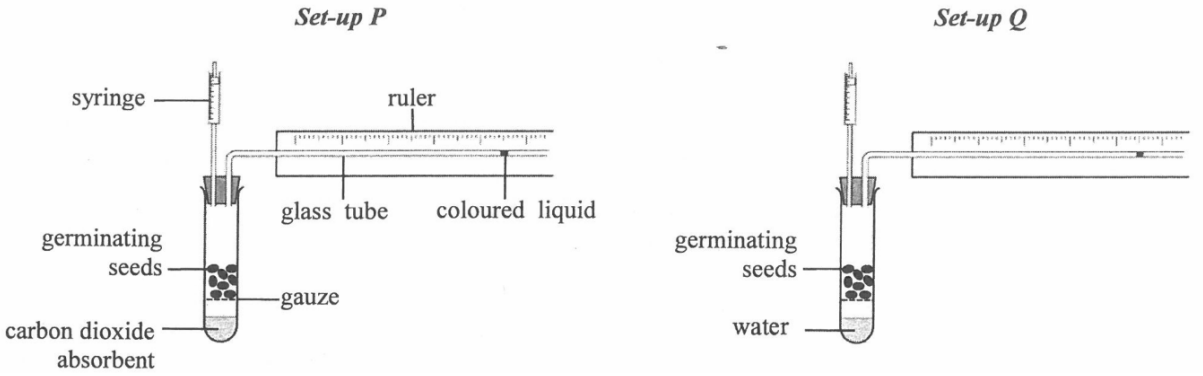
Marking reference: HKDSE Biology 2022 Paper 1A Q11, official marking scheme, source page(s) 1.

Practice

1. [HKDSE Biology 2022 Paper 1A Q12]

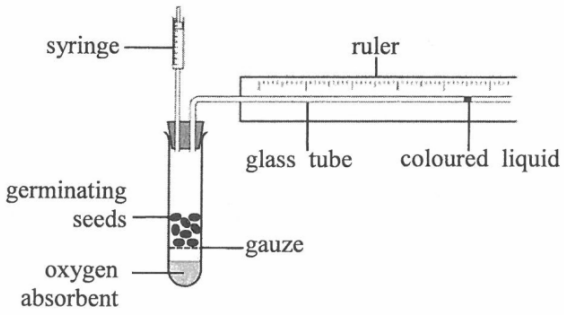
Hint: List gas consumption, production and absorption separately.

Directions: Questions 11 and 12 refer to the diagram below, which shows two set-ups used for the investigation of the gas exchange in germinating seeds:

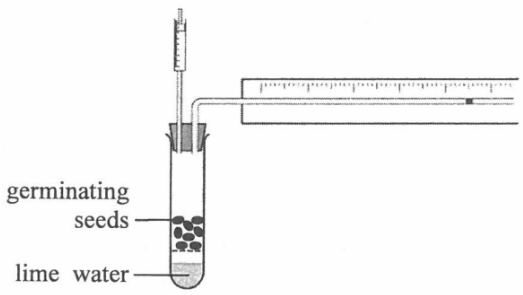


Which of the following modified set-ups can be used to show the identity of the gas produced in the investigation?

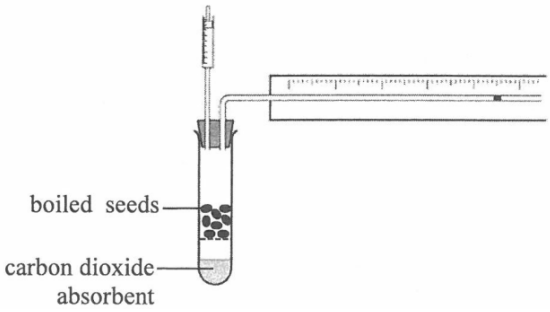
A.



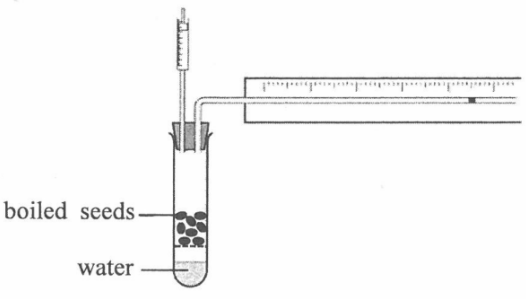
B.



C.



D.



2. [HKDSE Biology 2022 Paper 1A Q13]

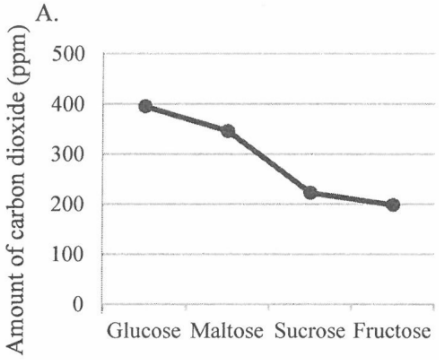
Hint: List gas consumption, production and absorption separately.

Directions: Questions 13 and 14 refer to the table below, which shows the effect of different substrates on the rate of anaerobic respiration of yeast:

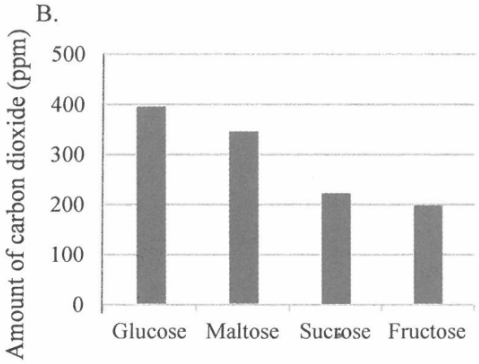
Substrate	Average amount of carbon dioxide produced after 10 min (ppm)
Glucose	395.2
Maltose	345.8
Sucrose	222.2
Fructose	198.2

Which of the following graphs is most suitable for presenting the data in the table?

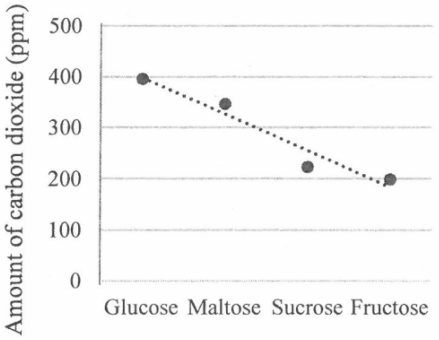
A.



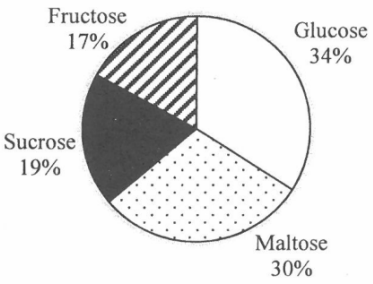
B.



C.



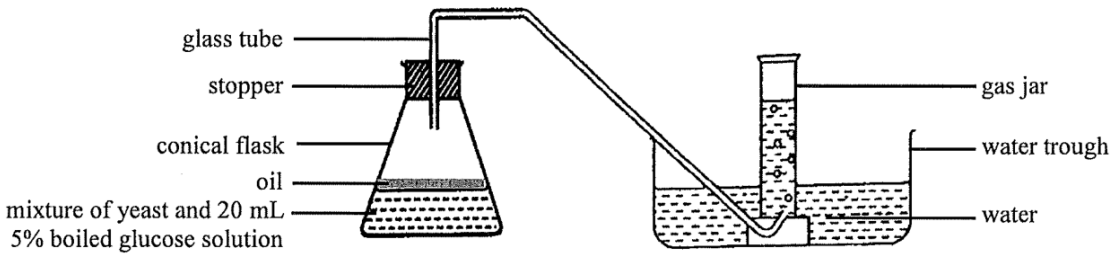
D.



3. [HKDSE Biology 2023 Paper 1A Q8]

Hint: List gas consumption, production and absorption separately.

Directions: Questions 7 and 8 refer to the diagram below, which shows a set-up used to investigate the rate of respiration in yeast:

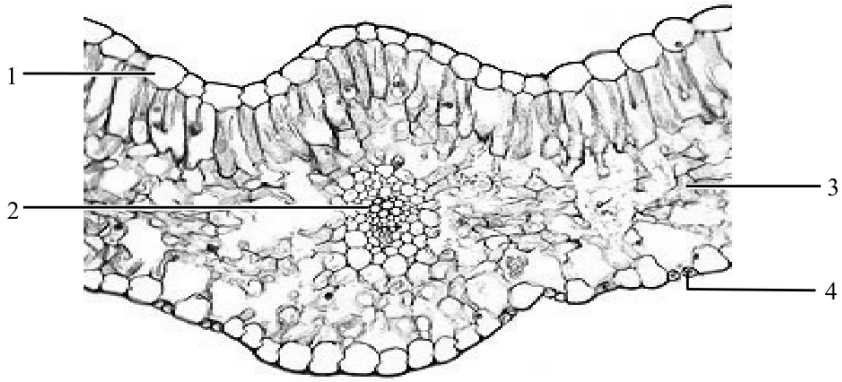


Which of the following modifications about the set-up can improve the accuracy of the experiment?

A. use a measuring cylinder instead of a gas jar
B. use a larger conical flask to contain the mixture
C. use a glass tube with a smaller internal diameter
D. use 30 mL instead of 20 mL of 5% boiled glucose solution

4. [HKDSE Biology Practice Paper Paper 1A Q33]
← Hint: List gas consumption, production and absorption separately.

The photograph below shows the cross section of a leaf:



There is a gas released by the leaf when it is placed in darkness. From which of the labelled cells is this gas released?

A. 1 and 2 only
B. 1 and 4 only
C. 2 and 3 only
D. 1, 3 and 4 only

Chapter 8

Genetics and evolution: question types and practice

II.a Basic genetics

First read the explanations and diagrams in Concept II.a, then work through the question types in this section. Each worked example retains the complete original question and explanation. The subsequent exercises require progressively more integration of information, based on the demands of the whole question.

Type 1 Distinguish heredity and environment using twin and population data

Degree of integration ★★★★☆

Key ideas

① Identical twins normally share the same genetic constitution and can be used to investigate environmental effects and gene expression. If a trait is not always identical in identical twins, this does not support the strong claim that one gene completely determines its expression.

② Continuous variation often involves multiple genes and environmental effects. A discontinuous visible classification does not automatically prove single-gene control.

How to recognise the problem Identify conditions shared by the comparison groups, then use inconsistent observations to limit the conclusion. Do not treat an association as the sole cause.

Example 1 [HKDSE Biology 2015 Paper 1A Q16]

Variation in skin colour exists among different human races. Which of the following factors plays the major role in determining this variation?

A. exercise
B. nutrition
C. inheritance
D. exposure to sunlight

Solution **Answer: C**

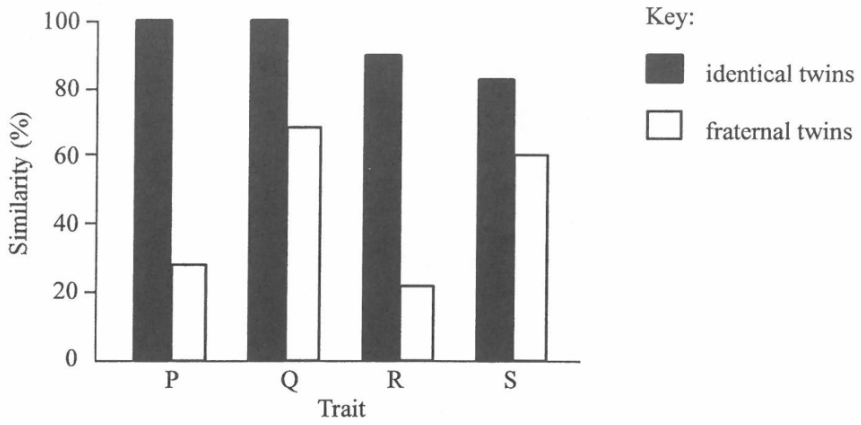
The question compares skin colour among different human populations. The main determining factor is inherited differences affecting pigment formation. Sunlight exposure can change an individual's skin colour, but this environmental effect does not replace the main inherited factor underlying the differences between populations asked about here. Choose C.

Marking reference: HKDSE Biology 2015 Paper 1A Q16, official marking scheme, source page(s) 1.

Method: Compare shared conditions, then use differences to limit the conclusion.

Example 2 [HKDSE Biology 2022 Paper 1A Q6]

A large survey about the inheritance of four traits in identical twins and fraternal twins has been conducted. The similarity of these four traits among the individuals in each type of twins are shown in the graph below:



Which trait is most affected by environmental factors?

A. P
B. Q
C. R
D. S

Solution Answer: D

Identical twins have the same genetic composition. If a trait is not completely concordant between them, this suggests an environmental influence. Of the four traits, S has the lowest concordance among identical twins and the smallest difference in concordance between identical and non-identical twins. This indicates a relatively smaller contribution of shared genes to similarity and a relatively greater environmental contribution.

Method: Compare shared conditions, then use differences to limit the conclusion.

Marking reference: HKDSE Biology 2022 Paper 1A Q6, official marking scheme, source page(s) 1.

Example 3 [HKDSE Biology 2017 Paper 1B Q10]

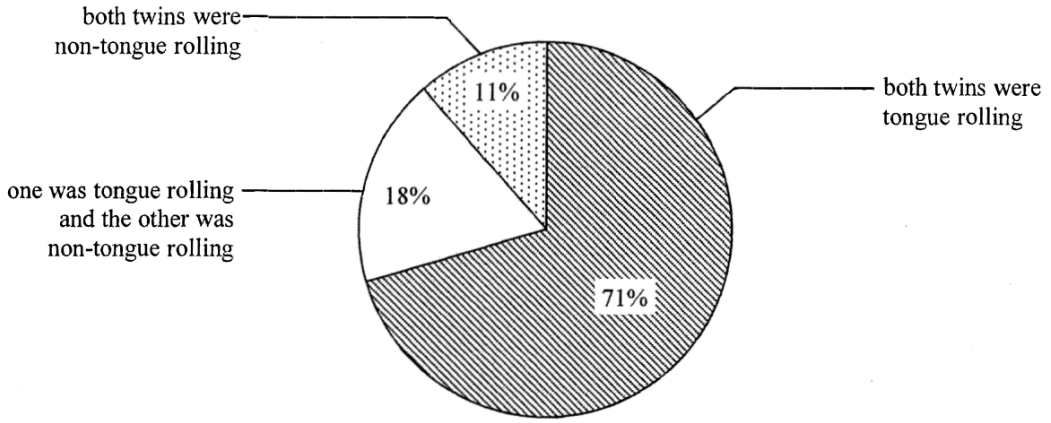
Case	Characters of parents	Tongue rolling offspring	Non-tongue rolling offspring
I	tongue rolling x tongue rolling	28	5
II	tongue rolling x non-tongue rolling	33	22

(i) Does the trait of tongue rolling ability show continuous or discontinuous variation? Explain your answer. (2 marks)

(ii) Sturtevant concluded that tongue rolling is the dominant phenotype while non-tongue rolling is the recessive phenotype. With reference to the above table, explain how he arrived at this conclusion. (2 marks)

(b) In 1965, the offspring of a group of non-tongue rolling parents were studied. It was found that more than 30% of the offspring were tongue rollers. Does this finding support Sturtevant's conclusion in (a)(ii)? Explain your answer. (2 marks)

(c) In 1971, another study on identical twins was carried out to further explore the factors influencing the tongue rolling trait. The results are summarised in the chart below:



(i) What is the advantage of using identical twins as the subjects for the study? (2 marks)

(ii) With reference to the above chart, complete the following table with data that support the conclusions. (2 marks)

Conclusion	Evidence
Genetic factors play a significant role in the determination of the tongue rolling trait.	
There are other factors influencing the tongue rolling trait.	

Ideas about science	Put a '✓' in the appropriate spaces below
Science is a process of ongoing inquiries.	
Science is affected by social and cultural factors.	
Scientists may not arrive at the same conclusions about the same set of data.	
Scientific investigations may not require doing experiments in laboratories.	

(ii) Elaborate on how the development of knowledge about the inheritance of the tongue rolling trait can be used to demonstrate that scientists have to be open-minded. (1 mark)

Solution (a)(i); original allocation: 2 mark(s)

Method: Compare shared conditions, then use differences to limit the conclusion.

Discontinuous variation. The question divides people into two categories, able and unable to roll their tongues, with no intermediate category.

Classify the variation by how the trait is recorded. Here, there are distinct categories, rather than a numerical measurement that varies continuously from low to high. This classification alone does not establish that a single gene controls the trait.

(a)(ii); original allocation: 2 mark(s)

In case I, two parents who can roll their tongues have children who cannot. Under a single-gene model, this suggests that the allele for inability to roll the tongue is masked in the parents.

Let R represent the allele for tongue rolling and r the allele for inability to roll the tongue. Rr × Rr can produce rr offspring, explaining the observation of 28 children who can roll their tongues and 5 who cannot. The key is that two parents with the same phenotype produce offspring with another phenotype, showing that the parents can carry an allele that is not expressed. A finite sample need not give an exact 3:1 ratio.

(b); original allocation: 2 mark(s)

The findings do not support the hypothesis. If inability to roll the tongue were a single-gene recessive trait, rr, then rr × rr should produce only rr offspring. However, over 30% of the children in the study could roll their tongues.

Compare the prediction derived from the hypothesis with the new data. The new results do not fit the prediction that two non-rollers must produce only non-rollers, so the original explanation based on single-gene dominance and recessiveness is insufficient. Do not simply declare the new data incorrect in order to retain the earlier conclusion.

(c)(i); original allocation: 2 mark(s)

Identical twins have almost the same genetic composition. If a trait were determined entirely by inheritance, their phenotypes should agree.

If phenotypic differences remain when genetic background is controlled, other influences are suggested. Using twins does not automatically eliminate all environmental differences; such differences can instead help test an exclusively genetic explanation.

(c)(ii); original allocation: 2 mark(s)

Genetic factors are important: 71% + 11% = 82% of the twin pairs have the same phenotype.

Other factors also contribute: 18% of the twin pairs have different phenotypes.

Concordant phenotypes include both "both can roll" and "neither can roll", so the two percentages must be added rather than simply quoting 71%. The 18% discordance despite shared genetic composition shows that a simple single-gene model cannot fully explain tongue rolling. The figure of 82% is not a direct estimate of heritability either.

(d)(i); original allocation: 2 mark(s)

Tick "Science is a continuous process of inquiry" and "Scientific research does not necessarily require experiments in a laboratory".

The studies in 1940, 1965 and 1971 continually tested earlier hypotheses using new observations. Family and twin surveys need not involve experimental procedures in a laboratory. The question presents new data obtained in different studies, not different conclusions drawn from the same data. It also provides no evidence about social or cultural factors.

(d)(ii); original allocation: 1 mark(s)

Scientists are willing to question and reassess established conclusions, seeking evidence from different families and twin studies.

An open mind does not mean accepting every claim unconditionally. It means being willing to revise an explanation when new evidence becomes available. Explain directly how the later studies challenged the original single-gene hypothesis to connect the answer to this context.

Examiner's comment (source page(s) 4)

Identical twins have the same genetic composition. If genes alone determine a trait, their phenotypes are expected to agree. Support counterexamples with actual data, and recognise the need to revise the original single-gene model.

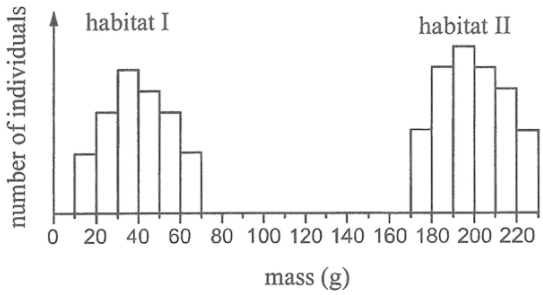
Marking reference: HKDSE Biology 2017 Paper 1B Q10, official marking scheme, source page(s) 5, 6.

Practice

1. [HKDSE Biology 2024 Paper 1A Q15]

Hint: Compare shared conditions, then use differences to limit the conclusion.

The graph below shows the masses of the same plant species grown in two different habitats:



Which of the following can be deduced from the graph?

A. The mass of the species is affected by two genes.
B. The mass of the species is affected by environment.
C. Discontinuous variation is shown in the mass of the species.
D. The mass of the species in habitat II is more affected by environment than that in habitat I.

2. [HKDSE Biology 2012 Paper 1A Q15]

Hint: Compare shared conditions, then use differences to limit the conclusion.

Identical twins have the same

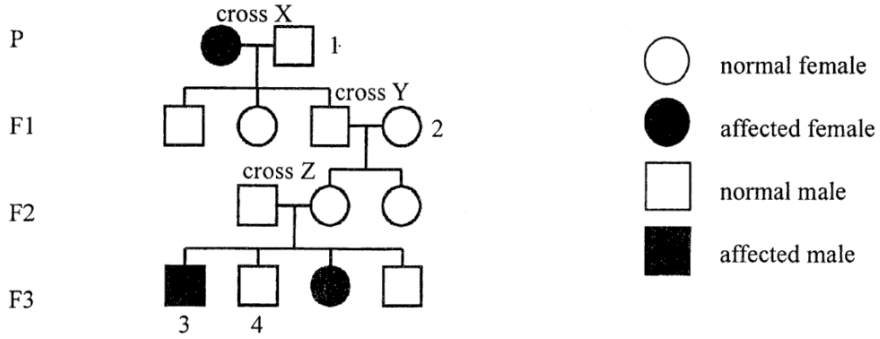
(1) genotype.
(2) traits involving continuous variations.
(3) traits involving discontinuous variations.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

3. [HKDSE Biology 2013 Paper 1A Q17]

Hint: Compare shared conditions, then use differences to limit the conclusion.

Directions: Questions 15 to 17 refer to the pedigree below, which shows the inheritance of a certain trait controlled by a pair of alleles located on an autosome (i.e. non-sex chromosome):

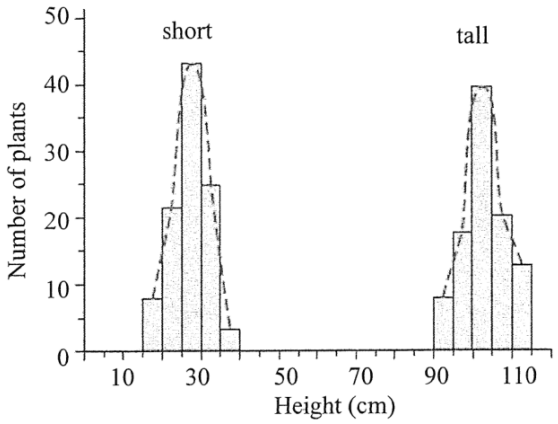


If individuals 3 and 4 are twins, which of the following conclusions can be drawn?

A. They are developed from the same fertilised egg.
B. They are developed from different fertilised eggs.
C. They are genetically different for characters displaying continuous variation.
D. They are genetically different for characters displaying discontinuous variation.

4. [HKDSE Biology 2020 Paper 1A Q33]
Hint: Compare shared conditions, then use differences to limit the conclusion.

Directions: Questions 33 and 34 refer to the following graph, which shows the variations in the height of a certain type of plant:

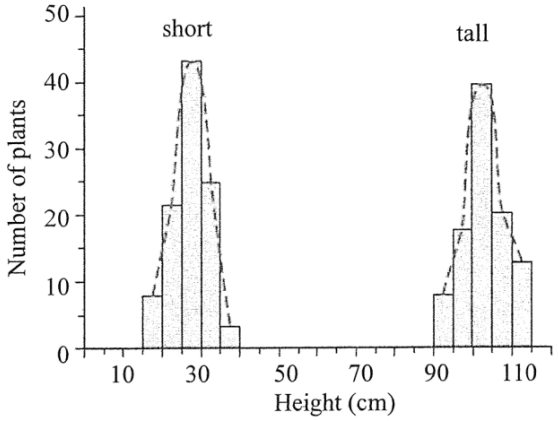


Which of the following conclusions can be drawn from the above graph?

A. The short and tall plants are of two different species.
B. The two traits, short and tall, are controlled by a pair of alleles.
C. More samples should be taken to cover the full range of heights.
D. The height of the plants displays the properties of continuous and discontinuous variations.

5. [HKDSE Biology 2020 Paper 1A Q34]
Hint: Compare shared conditions, then use differences to limit the conclusion.

Directions: Questions 33 and 34 refer to the following graph, which shows the variations in the height of a certain type of plant:



Which of the following factors contributes ***least*** to the variations shown?

A. the height of the parental plants
B. the light intensity in the environment
C. the independent assortment of chromosomes
D. the oxygen concentration in the environment

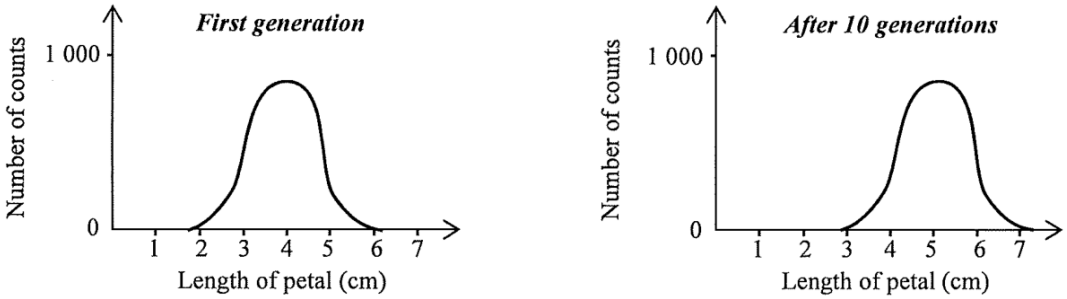
6. [HKDSE Biology 2021 Paper 1A Q12]
Hint: Compare shared conditions, then use differences to limit the conclusion.

A pair of identical twins were adopted by two different families. After the twins grow up, which of the following descriptions about them will most likely apply?

A. They have different shapes of earlobe.
B. They have the same pattern of fingerprint.
C. They have different degrees of short sightedness.
D. They have the same number of freckles on their faces.

7. [HKDSE Biology 2023 Paper 1A Q24]
Hint: Compare shared conditions, then use differences to limit the conclusion.

Directions: Questions 24 and 25 refer to the information about the introduction of a foreign plant species to a local botanic garden. Over the years, the gardener noted that there was a change in the size of its flowers. The graphs below show the variations of the petal length of this plant species in the first generation and after 10 generations:



Which of the following correctly describe the inheritance of the petal length in this plant species?

(1) The petal length is affected by environmental factors.
(2) The inheritance of the petal length is controlled by a number of genes.
(3) The variation in the petal length is a result of independent assortment.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

Type 2 Infer genotypes from offspring ratios

Degree of integration ★★★☆☆

Key ideas

① In Aa × aa, the parents form A and a gametes, and a gametes, respectively. Half the offspring are expected to be Aa and half aa. When working backwards, identify recessive offspring first: each must receive a recessive allele from both parents.

② The ABO A and B alleles can be codominant. In a joint analysis of two traits, probabilities can be multiplied only under appropriate independence conditions. If observed ratios differ from expectations, consider conditions such as survival, fertilisation and gamete selection.

How to recognise the problem Start with the offspring phenotype that most constrains the parents. Write the parents, gametes and offspring rather than guessing a ratio.

Example 1 [HKDSE Biology 2024 Paper 1A Q17]

Directions: Questions 16 to 18 refer to the table below, which shows the results of some crosses in one type of plants. This type of plant produces individuals either bearing male flowers with stamens only or female flowers with carpels only. The colour of the flower is controlled by a single gene.

Cross	*Male parent*	*Female parent*	*Offspring*
1	white flowers	white flowers	all white flowers
2	red flowers	white flowers	all red flowers
3	white flowers	red flowers	all red flowers
4	red flowers	white flowers	some red flowers, some white flowers
5	?	red flowers	some red flowers, some white flowers

Which of the following combinations is most likely the result from Cross 4?

	No. of individuals with red flowers	*No. of individuals with white flowers*
A.	26	73
B.	48	46
C.	69	37
D.	71	25

Solution **Answer: B**

Let R represent red and r represent white. In cross 4, the white-flowered female parent must be rr. Since white-flowered offspring are produced, the red-flowered male parent must be Rr. Rr × rr gives approximately equal numbers of Rr and rr offspring, so 48 red and 46 white best fit a 1:1 ratio. The observed numbers need not be exactly equal.

Method: Use offspring phenotypes to constrain parental genotypes first.

Marking reference: HKDSE Biology 2024 Paper 1A Q17, official marking scheme, source page(s) 49.

Example 2 [HKDSE Biology 2015 Paper 1B Q4]

Roger is found to be suitable for donating blood to recipients with blood types different from his own. However, he cannot receive a blood transfusion from his parents. The blood types of his father and mother are A and B respectively.

(a) What is Roger's blood type? (1 mark)

(b) Given that:

I^A represents the allele for producing antigen A on the surface of red blood cells
I^B represents the allele for producing antigen B on the surface of red blood cells
i represents the allele that does not lead to the production of any antigens on the surface of red blood cells

(i) Using the above symbols, state Roger's genotype. (1 mark)

(ii) Using the above symbols, state the genotypes of his parents. (2 marks)

Father: _____ Mother: _____

(c) Explain why Roger cannot receive blood transfusions from his parents. (3 marks)

Solution **(a); original allocation: 1 mark(s)**

Blood group O.

The boy's blood can be donated to people of other blood groups, but he cannot receive blood from his group A father or group B mother. In the model used in this question, which considers only ABO antigens, group O red blood cells carry neither A nor B antigens and fit these conditions.

Method: Use offspring phenotypes to constrain parental genotypes first.

(b)(i); original allocation: 1 mark(s)

ii.

The question defines i as the allele that does not produce A or B antigens. A person with blood group O must inherit one i allele from each parent, giving genotype ii.

(b)(ii); original allocation: 2 mark(s)

Father: I^Ai; mother: I^Bi.

The father has blood group A but must provide an i allele to produce an ii child, so his other allele is I^A. Similarly, the mother must carry both I^B and i. The parents cannot have the corresponding homozygous dominant genotypes, as they would then be unable to pass i to their child.

(c); original allocation: 3 mark(s)

The boy's plasma contains anti-A and anti-B antibodies. These react with A or B antigens on his parents' red blood cells, causing agglutination and possibly haemolysis.

Match the recipient's antibodies with the antigens on the donor's red blood cells to explain the incompatibility. This is the ABO teaching model used in the original question; actual blood transfusion also requires consideration of other blood-group antigens and compatibility testing.

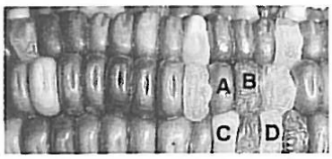
Examiner's comment (source page(s) 3)

Use the ABO allele symbols given in the question. In particular, do not replace lower-case i with capital I. Explain that the recipient's antibodies bind to antigens on the transfused red blood cells, causing agglutination.

Marking reference: HKDSE Biology 2015 Paper 1B Q4, official marking scheme, source page(s) 3.

Example 3 [HKDSE Biology 2012 Paper 1B Q8]

The photograph below shows the appearances of some kernels of a corn:

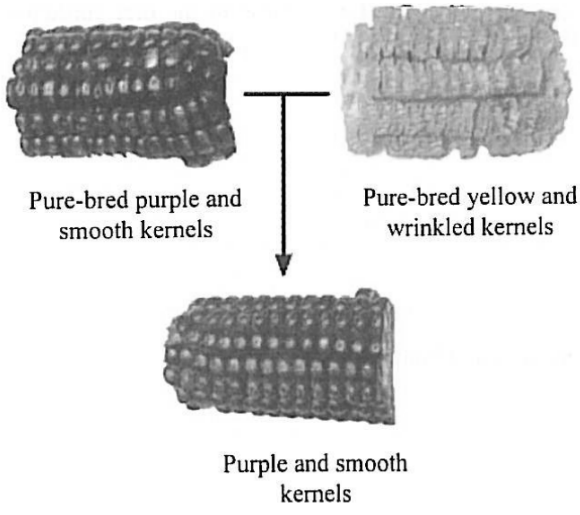


Kernel	Appearance
A	Purple and smooth
B	Purple and wrinkled
C	Yellow and smooth
D	Yellow and wrinkled

The purple colour is produced by a pigmented layer within the kernels. If the layer is not pigmented, the yellow colour of the inner tissue becomes visible. Whether the kernel is smooth or wrinkled is due to the type of food stored inside it. Smooth kernels (starchy corn) store starch while wrinkled kernels (sweet corn) store soluble sugars. The surface of the sweet corns becomes wrinkled when the corn dries up.

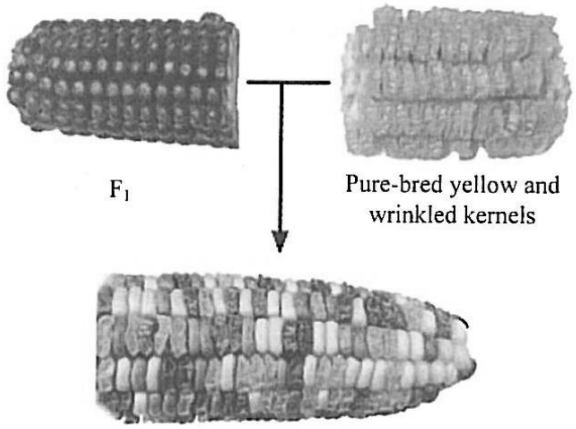
(a) With reference to osmosis, explain why the kernels of sweet corn become wrinkled when they dry up but the kernels of starchy corn remain smooth. (4 marks)

(b) The two traits of the kernels are controlled by genes located on different homologous chromosomes. The following diagram shows the result of a cross between two pure-bred corn plants, one with purple and smooth kernels and the other with yellow and wrinkled kernels:



(i) Based on the results of the cross, deduce which phenotypes are dominant. (3 marks)

(ii) The F_1 generation produced was crossed with pure-bred corn plants with yellow and wrinkled kernels, as shown below:



Explain the results of the cross using Mendel's law of inheritance. (4 marks)
(Marks will not be awarded for genetic diagrams.)

(c) When Mendel proposed how traits are inherited, chromsomes had not yet been discovered. In your opinion, how did Mendel come up with his hypothesis? (3 marks)

Solution a; original allocation: 4 mark(s)

Method: Use offspring phenotypes to constrain parental genotypes first.

Sweet corn contains more soluble sugars, so its cells have a lower water potential and absorb more water by osmosis during development. Starch is insoluble in water and has a smaller effect on water potential. On drying, sweet corn loses more water and its internal volume decreases. The seed coat cannot contract correspondingly, so wrinkles form. Starchy corn loses less water and shrinks less, leaving a smoother surface.

First relate "sugar or starch" to the number of dissolved particles, then to water potential and water movement. Sugar does not itself pull the seed coat into wrinkles: the wrinkles result from changes in water content and volume during drying. The official scheme lists several connected points, with a maximum of 4 marks for this part.

b(i); original allocation: 3 mark(s)

Purple colour and a smooth surface are dominant traits. The pure-breeding parents carry only the alleles for purple / smooth or yellow / wrinkled, respectively. The F1 offspring receive one allele of each pair from each parent and are all heterozygous, yet all are purple and smooth. These are therefore the traits expressed in the heterozygotes.

Using P and p for colour and S and s for shape, the parents are PPSS and ppss, and the F1 offspring are PpSs. Determine dominance from the phenotype of the heterozygote, not from which trait is more common in nature.

b(ii); original allocation: 4 mark(s)

The pure-breeding yellow, wrinkled parent produces only one type of gamete. The F1 has two pairs of different alleles, with the two genes on different chromosomes. Independent assortment during meiosis produces four types of gamete. Fertilisation between each of these four types and the gametes from the yellow, wrinkled parent produces four genotypes, giving four phenotypes: purple smooth, purple wrinkled, yellow smooth and yellow wrinkled.

Specifically, PS, Ps, pS and ps combine with ps to give PpSs, Ppss, ppSs and ppss, respectively. The original question requires an explanation in words. A genetic diagram alone is insufficient if it omits independent assortment and the origins of the gametes.

c; original allocation: 3 mark(s)

Mendel conducted many controlled crosses, recorded and counted offspring with different phenotypes, and used the regular numerical ratios to make logical inferences and propose hypotheses such as the segregation of hereditary factors.

The fact that he had not observed chromosomes did not prevent him from developing a model from observable offspring traits. The key points are extensive experiments, quantitative results and inference from those results, rather than a claim that he directly observed genes segregating.

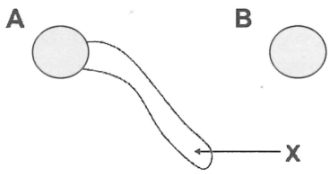
Examiner's comment (source page(s) 2)

During development, sweet corn first absorbs more water because of its lower water potential; it later loses water and becomes wrinkled as it dries. Water enters the air by evaporation, not by osmosis. To explain the four types of offspring, describe how the F1 produces four types of gamete.

Marking reference: HKDSE Biology 2012 Paper 1B Q8, official marking scheme, source page(s) 3, 4.

Example 4 [HKDSE Biology 2024 Paper 1B Q10]

In an investigation, pollen grains collected from a single flower were cultured in an artificial medium. After 48 hours incubation, they were observed under a light microscope. Two types of pollen grains with different appearances were observed, as shown in the diagram below:



(a) The number of each type of pollen grains is approximately the same. It is known that the formation of structure X is controlled by a single gene. Deduce the genotype of the parent plant producing these two types of pollen grains. (4 marks)

(b) If these two types of pollen grains land on a stigma of the flower of the same species, which type of pollen grains will lead to formation of seed? Explain your answer. (3 marks)

(c) 100 seeds were collected from the parent plant in (a) after self-pollination. According to your answer in (b), complete the following table to show the proportion of genotypes in these seeds. (1 mark)

Solution a; original allocation: 4 mark(s)

Method: Use offspring phenotypes to constrain parental genotypes first.

The parent plant is heterozygous for the gene controlling pollen-tube formation.

Pollen is formed following meiosis and is haploid, with only one allele at this locus in each grain. Pollen A can form pollen tube X and carries the functional allele; pollen B cannot form a tube and carries the other allele. Both pollen types are produced by the same plant in approximately equal numbers. This shows that the parent carries both alleles, with approximately half of the meiotic products receiving each.

b; original allocation: 3 mark(s)

Only type A pollen can lead to seed formation.

The pollen tube grows towards the ovule and delivers the male gamete to the egg cell in the embryo sac, allowing them to fuse in fertilisation. The ovule can then develop into a seed. Type B forms no pollen tube, so its male gamete cannot reach the egg cell. Even if it lands on the stigma, this step cannot proceed normally.

c; original allocation: 1 mark(s)

If the allele allowing pollen-tube formation is dominant, the percentages are: homozygous dominant 50%, heterozygous 50%, and homozygous recessive 0%. If it is recessive, the corresponding percentages are 0%, 50% and 50%.

Do not simply apply the 1:2:1 ratio for selfing a heterozygote, because only one type of male gamete can achieve fertilisation here. Let F represent the functional allele and f the

other allele. All successful male gametes carry F, while the eggs still carry F or f in equal proportions. The seeds are therefore half FF and half Ff. Expression in haploid pollen does not by itself establish whether F is dominant or recessive in the diploid plant. Either ordering of the percentages must be consistent with the chosen definition of dominance.

Examiner's comment (source page(s) 73)

Pollen is haploid: do not treat each grain as carrying two alleles. Only male gametes associated with pollen that can form a tube can reach the egg cell in the embryo sac, so the effective male gametes have already been selected. Even self-pollination therefore no longer gives the usual 1:2:1 ratio.

Marking reference: HKDSE Biology 2024 Paper 1B Q10, official marking scheme, source page(s) 57.

Practice

1. [HKDSE Biology 2014 Paper 1A Q12]

Hint: Use offspring phenotypes to constrain parental genotypes first.

Which of the following combinations of blood groups of parents may produce offspring with blood group AB?

(1) A x B
(2) AB x O
(3) AB x AB

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

2. [HKDSE Biology 2021 Paper 1A Q11]

Hint: Use offspring phenotypes to constrain parental genotypes first.

The human ABO blood group system is controlled by multiple alleles. Alleles I^A and I^B lead to the presence of antigens A and B on the surface of red blood cells respectively. Allele i leads to the absence of antigens A and B on the surface of red blood cells. How many genotypes are involved in the ABO blood group system?

A. 3
B. 4
C. 6
D. 8

3. [HKDSE Biology 2021 Paper 1A Q17]

Hint: Use offspring phenotypes to constrain parental genotypes first.

Although Mendel proposed that the characteristics of the pea plants were controlled by a pair of 'heredity factors', it was not recognised during his lifetime. His idea was later accepted in the early 20th century because it was supported by

A. the theory of natural selection.
B. the same patterns of inheritance in fruit flies.
C. the behaviours of chromosomes in cell division.
D. the discovery of the double helix structure of DNA.

4. [HKDSE Biology 2013 Paper 1A Q13]

Hint: Use offspring phenotypes to constrain parental genotypes first.

A man and his wife are heterozygous for blood type A and B respectively. What is the probability of their son having blood type AB?

A. 0
B. 1/4
C. 1/2
D. 3/4

5. [HKDSE Biology 2014 Paper 1A Q10]
← Hint: Use offspring phenotypes to constrain parental genotypes first.

Directions: Questions 10 and 11 refer to the following two crosses of fruit flies. In fruit flies, males are the heterogametic sex (XY) and the wing shape (normal wing or cut wing) is controlled by a single gene.

	Cross I	***Cross II***
Parents	Normal wing female x Cut wing male	Cut wing female x Normal wing male
F_1	12 normal wing females 11 normal wing males	11 normal wing females 11 cut wing males
F_2	71 normal wing females 34 normal wing males 35 cut wing males	32 normal wing females 33 cut wing females 36 normal wing males 38 cut wing males

Which of the following observations from Cross I best supports the conclusion that normal wing is the dominant phenotype?

A. All the F_1 individuals are normal wing.
B. The ratio of normal wing individuals to cut wing individuals in F_2 is 3:1.
C. There are more normal wing individuals than cut wing individuals in the F_2.
D. Normal wing males are more or less the same in number as cut wing males in the F_2.

6. [HKDSE Biology 2018 Paper 1A Q12]
← Hint: Use offspring phenotypes to constrain parental genotypes first.

Directions: Questions 12 and 13 refer to the information below. Kathy had two pure-bred cats, one had long white fur while the other had short black fur. It is known that fur length and fur colour are controlled by two different genes respectively. The two cats gave birth to four kittens which had long black fur.

Which of the following conclusions can be drawn based on the above case?

(1) Long fur is dominant over short fur.
(2) The four kittens have the same genotype for fur length and fur colour.
(3) The genes controlling fur length and fur colour are located on different chromosomes.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

7. [HKDSE Biology 2018 Paper 1A Q13]
← Hint: Use offspring phenotypes to constrain parental genotypes first.

Directions: Questions 12 and 13 refer to the information below. Kathy had two pure-bred cats, one had long white fur while the other had short black fur. It is known that fur length and fur colour are controlled by two different genes respectively. The two cats gave birth to four kittens which had long black fur.

After the kittens had grown up, they interbred and gave birth to the second filial generation (F_2). Among the F_2 kittens, there was one with short white fur. Which of the following processes mostly likely contributed to the occurrence of this new phenotype?

(1) Mutation
(2) Random fertilisation of gametes
(3) Independent assortment of chromosomes

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

8. [HKDSE Biology 2021 Paper 1A Q16]
Hint: Use offspring phenotypes to constrain parental genotypes first.

In the crossing of a red-flowered plant with a white-flowered plant, half of the F1 offspring were red-flowered and the other half were white-flowered. When the F1 white-flowered plants were self-crossed, all the F2 offspring were white-flowered. What can be concluded?

A. The red-flowered parental plant was homozygous.
B. The white-flowered parental plant was heterozygous.
C. White flower is the dominant character in this species of plant.
D. Red flower is the dominant character in this species of plant.

9. [HKDSE Biology 2022 Paper 1A Q3]
Hint: Use offspring phenotypes to constrain parental genotypes first.

In Mendel's experiment, he proposed that a characteristic of the pea plants was controlled by a pair of 'heredity factors'. These factors can be separated in a 'process' before passing to the offspring. According to the current understanding of genetics, what do the 'heredity factors' and the 'process' represent respectively?

	Heredity factors	***Process***
A.	alleles	first meiotic cell division
B.	alleles	second meiotic cell division
C.	chromosomes	first meiotic cell division
D.	chromosomes	second meiotic cell division

10. [HKDSE Biology 2024 Paper 1A Q6]
Hint: Use offspring phenotypes to constrain parental genotypes first.

Directions: Questions 4 to 6 refer to the diagram below, which shows the appearance of chromosomes in a cell at the early stage of meiotic cell division:



Mendel's law can be used to explain the combinations of chromosomes in the daughter cells in Question 5. Which of the following correctly shows the corresponding Mendel's law and the stage of meiotic cell division as described by the law?

	Mendel's law	***Stage***
A.	Law of segregation	first meiotic cell division
B.	Law of segregation	second meiotic cell division
C.	Law of independent assortment	first meiotic cell division
D.	Law of independent assortment	second meiotic cell division

11. [HKDSE Biology 2024 Paper 1A Q16]
Hint: Use offspring phenotypes to constrain parental genotypes first.

Directions: Questions 16 to 18 refer to the table below, which shows the results of some crosses in one type of plants. This type of plant produces individuals either bearing male flowers with stamens only or female flowers with carpels only. The colour of the flower is controlled by a single gene.

Cross	*Male parent*	*Female parent*	*Offspring*
1	white flowers	white flowers	all white flowers
2	red flowers	white flowers	all red flowers
3	white flowers	red flowers	all red flowers
4	red flowers	white flowers	some red flowers, some white flowers
5	?	red flowers	some red flowers, some white flowers

It is known that the sex determination of this plant is similar to that of humans. Which of the following combinations correctly describes the allele for white flower in this plant?

	Dominant or recessive	*Location of the allele*
A.	dominant	autosome
B.	dominant	sex chromosome
C.	recessive	autosome
D.	recessive	sex chromosome

12. [HKDSE Biology 2024 Paper 1A Q18]
Hint: Use offspring phenotypes to constrain parental genotypes first.

Directions: Questions 16 to 18 refer to the table below, which shows the results of some crosses in one type of plants. This type of plant produces individuals either bearing male flowers with stamens only or female flowers with carpels only. The colour of the flower is controlled by a single gene.

Cross	*Male parent*	*Female parent*	*Offspring*
1	white flowers	white flowers	all white flowers
2	red flowers	white flowers	all red flowers
3	white flowers	red flowers	all red flowers
4	red flowers	white flowers	some red flowers, some white flowers
5	?	red flowers	some red flowers, some white flowers

Which of the following statements about Cross 5 is correct?

A. The female parent could be a homozygote.
B. The male parent could be a homozygote with red flowers.
C. The male parent could be a homozygote with white flowers.
D. The male parent could be a heterozygote with white flowers.

13. [HKDSE Biology Practice Paper Paper 1A Q11]
Hint: Use offspring phenotypes to constrain parental genotypes first.

A couple has two children. The son is of blood group B and the daughter is of blood group A. Which of the following is **not** a possible combination of genotypes of this couple?

(Note: The alleles responsible for the production of antigen A, antigen B and not producing antigen A or B are represented by I^A, I^B and i respectively.)

A. I^Ai and I^Bi
B. I^AI^A and I^Bi
C. I^AI^B and I^AI^B
D. I^AI^B and I^Bi

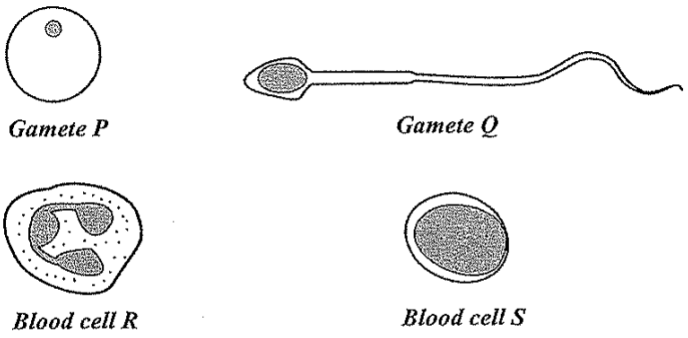
14. [HKDSE Biology Practice Paper Paper 1A Q13]
Hint: Use offspring phenotypes to constrain parental genotypes first.

In guinea pigs, the genes for fur colour and hair length are located on different chromosomes. The alleles for black fur and long hair are recessive to the alleles for brown fur and short hair respectively. Guinea pigs which are heterozygous for both fur colour and hair length are allowed to breed. Of the 112 offspring produced, how many are expected to have black fur and short hair?

A. 21
B. 28
C. 56
D. 63

15. [HKDSE Biology Sample Paper Paper 1A Q19]
⟵ Hint: Use offspring phenotypes to constrain parental genotypes first.

Directions: Questions 19 and 20 refer to the diagrams below, which show four different types of cells found in humans:



Which of the following statements about the chromosome content of the cells is / are correct?

(1) P and Q contain the same number of chromosomes.
(2) P and R must contain an X chromosome.
(3) Q and S must contain a Y chromosome.

A. (1) only
B. (3) only
C. (1) and (2) only
D. (2) and (3) only

16. [HKDSE Biology Sample Paper Paper 1A Q30]
⟵ Hint: Use offspring phenotypes to constrain parental genotypes first.

The chance of giving birth to a boy to that of a girl is 1:1. This is because

(1) each egg is fertilized by one sperm only.
(2) the fertilization of eggs and sperms is random.
(3) sperms carrying different sex chromosomes are produced in equal proportions.

A. (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

17. [HKDSE Biology 2017 Paper 1A Q8]
⟵ Hint: Use offspring phenotypes to constrain parental genotypes first.

In humans, blood group B is dominant to blood group O. In a family, the father and mother are of blood groups O and B respectively. They have two children who are of blood group B. The father concludes that his wife must be homozygous for blood group B. Is this conclusion correct?

A. No, because there are other blood groups besides blood groups B and O.
B. No, because even if the mother is heterozygous, each child has a 50% chance to be of blood group B.
C. Yes, because the father has no allele for blood group B, all alleles for blood group B must have come from the mother.
D. Yes, because if the mother is heterozygous, one child should be of blood group B and the other should be of blood group O.

18. [HKDSE Biology Sample Paper Paper 1B Q7]
Hint: Use offspring phenotypes to constrain parental genotypes first.

Mr and Mrs Chan gave birth to a pair of twins, Anne and Jane. The table below lists some characters shown by the twins:

Character	Anne	Jane
Body mass (at the age of 6)	20 kg	21 kg
Colour vision	normal	normal
Blood group	O	AB
IQ	110	105

(a) State the type of twins they belong to. Explain how you arrive at your answer. (3 marks)

(b) Given that the alleles for the antigens that determine blood groups are I^A, I^B and i, state the genotypes of Mr and Mrs Chan. (2 marks)

(c) Allele I^A codes for an enzyme responsible for forming antigen A on the surface of red blood cells. Outline the processes in which allele I^A is expressed to form this enzyme. (6 marks)

Type 3 Infer genetic risk from pedigrees and breeding data

Degree of integration ★★★★☆

Key ideas

① Unaffected parents producing an affected child can support recessive inheritance under a simplified single-gene model, but conditions such as sex must still be checked. In X-linked questions, write the allele on the X chromosome: sons receive their X from their mother; daughters receive one X from each parent.

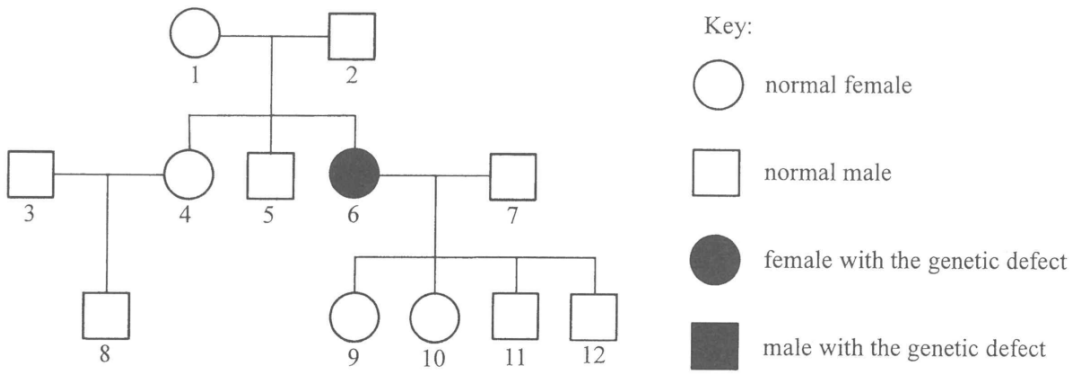
② An unaffected individual of unknown genotype may be homozygous or a carrier. Do not automatically make every unaffected person homozygous. In probability questions, distinguish a child known to be male from one whose sex is unspecified.

③ Relatives are more likely to carry the same harmful recessive allele inherited from a common ancestor. Mating may increase the chance of homozygosity for that allele. The risk concerns allele combinations, not a claim that every purebred individual is diseased.

How to recognise the problem Use the most informative parent–offspring relationship to exclude models, list possible genotypes for each unknown individual, then calculate the conditional probability.

Example 1 [HKDSE Biology 2021 Paper 1A Q13]

Directions: Questions 13 to 15 refer to the pedigree below, which shows the inheritance of a certain genetic defect controlled by a pair of alleles.



The phenotype of individual 6 can be explained by the fact that this individual received a defective allele on

A. an autosome from each parent.
B. the Y chromosome from the father.
C. an X chromosome from the mother.
D. an X chromosome from each parent.

Solution Answer: A

Individuals 1 and 2 are phenotypically unaffected but have an affected daughter, 6, supporting a recessive disease allele. If the condition were X-linked recessive, an affected daughter's father would also carry and express the allele, contradicting the unaffected father shown. Individual 6 therefore inherited one recessive allele on an autosome from each parent. Choose A.

Method: Exclude inheritance models first, then list possible genotypes.

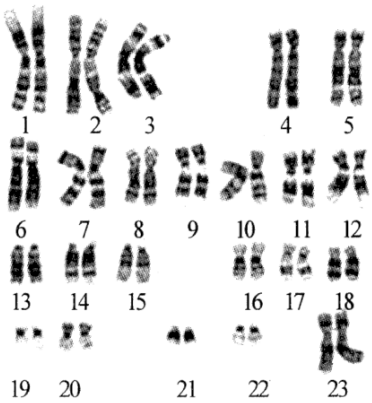
Marking reference: HKDSE Biology 2021 Paper 1A Q13, official marking scheme, source page(s) 1.

Example 2 [HKDSE Biology 2013 Paper 1B Q4]

Red-green colour blindness is an X-linked recessive trait in humans. Peter is red-green colour blind while his daughter, Mary, is normal.

(a) Deduce Mary's genotype without using a genetic diagram. (4 marks)

(b) Mary is an expectant mother. The photomicrograph below shows the karyotype of her foetus:



(i) From the photomicrograph, can we deduce whether this foetus will be red-green colour blind or not? Explain your answer. (2 marks)

(ii) Is the foetus a boy or a girl? Explain your answer with reference to the photomicrograph. (3 marks)

Solution a; original allocation: 4 mark(s)

Method: Exclude inheritance models first, then list possible genotypes.

The woman is a heterozygous carrier. Her father is colour-blind, so his only X chromosome carries the recessive colour-blindness allele. A daughter must inherit this X chromosome from her father. Since she has normal colour vision, the other X chromosome, inherited from her mother, must carry the dominant allele for normal colour vision. Her genotype is therefore X^NX^n.

The original question requires an explanation without a genetic diagram. State the father's allele, transmission of the X chromosome from father to daughter, the requirement for her normal phenotype and the conclusion that she is heterozygous. A genotype symbol alone is insufficient.

b(i); original allocation: 2 mark(s)

No. A karyotype shows only chromosome number and appearance, not the specific alleles controlling red-green colour vision.

Colour blindness is usually not an abnormality in the size or number of a whole chromosome. Even a very clear photograph cannot reveal whether either X chromosome carries the colour-blindness allele from its appearance.

b(ii); original allocation: 3 mark(s)

The fetus is female. The two chromosomes in pair 23 have similar sizes and lengths and are both X chromosomes, giving XX.

Connect the visible features of chromosome pair 23 to XX. Do not conclude that the fetus is female merely because no Y is labelled in the photograph.

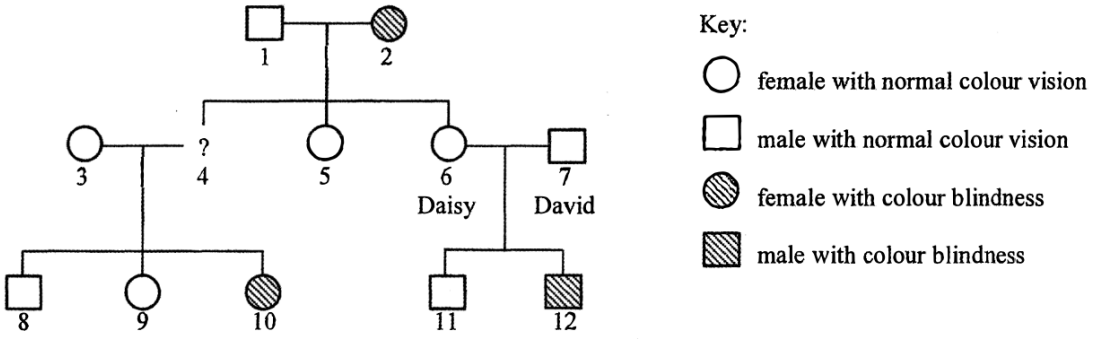
Examiner's comment (source page(s) 2)

The daughter inherits the X chromosome carrying the recessive allele from her colour-blind father. A chromosome photograph shows number and appearance, not specific alleles.

Marking reference: HKDSE Biology 2013 Paper 1B Q4, official marking scheme, source page(s) 3.

Example 3 [HKDSE Biology 2016 Paper 1B Q10]

Colour blindness is an X-linked recessive genetic disorder. The pedigree below shows the inheritance of colour blindness in a family:



(a) **Colour blindness is due to the abnormal development of photoreceptors. State the relevant type of photoreceptors and the location inside the eyeball where these photoreceptors are most abundant.** **(2 marks)**

(b) **Given that the dominant allele of colour vision is represented by R while the recessive allele is represented by r, determine all the possible genotypes and phenotypes of the offspring of individuals 1 and 2 using a genetic diagram.** **(5 marks)**
(Note: Punnett square is not accepted)

(c) Draw all possible representation(s) for individual 4 with reference to the key of the pedigree. (1 mark)

(d) Daisy (individual 6) has recently given birth to a baby girl. Since one of her sons suffered from colour blindness (individual 12), Daisy worried that their daughter would have colour blindness too. David (individual 7) reassured her by saying that:

Don't worry. Our daughter will be fine because I have normal colour vision!

Justify David's claim. (5 marks)
(Note: Marks will not be awarded for genetic diagrams.)

Solution (a); original allocation: 2 mark(s)

Method: Exclude inheritance models first, then list possible genotypes.

Cone cells; the yellow spot of the retina.

Cone cells are responsible for colour vision. The yellow spot contains a high density of cone cells and provides the greatest visual acuity. Rod cells mainly support vision in dim light and cannot explain the colour-vision defect in this question.

(b); original allocation: 5 mark(s)

Parents: individual 1 is X^RY and individual 2 is X^rX^r. The father's gametes carry X^R or Y, while all the mother's gametes carry X^r. All daughters are X^RX^r, with normal colour vision but carrying the allele; all sons are X^rY and colour-blind.

First establish X^RY for the unaffected male and X^rX^r for the colour-blind female. Then show the gametes formed by meiosis and use arrows to connect the possible fertilisation combinations. The diagram below follows the sequence parents–gametes–offspring and meets the requirement that a Punnett square is not accepted. Write R and r on X; do not arbitrarily put the same alleles on Y.

(c); original allocation: 1 mark(s)

The symbol must be a filled square, representing a colour-blind male.

Individual 4 is a son of individuals 1 and 2. His mother supplies only X^r, and a son receives Y from his father, so he must be X^rY. The same conclusion follows from individual 4 having a colour-blind daughter, 10, with an unaffected female: that daughter must receive X^r from her father. Both lines of reasoning lead to a filled square.

(d); original allocation: 5 mark(s)

The man has normal colour vision, so his only X chromosome must carry X^R. All his daughters inherit this X^R from him. Even if a daughter inherits X^r from her mother, X^R masks the recessive X^r, so she still has normal colour vision.

Explain five connected points in words: a male has only one X chromosome; his normal phenotype establishes that it carries R; a daughter must inherit her father's X; R is dominant over r; therefore, whether the mother supplies R or r, no daughter will be colour-blind because of the recessive allele in this pedigree. The question explicitly awards no marks for a genetic diagram, so provide a complete written explanation for this part.

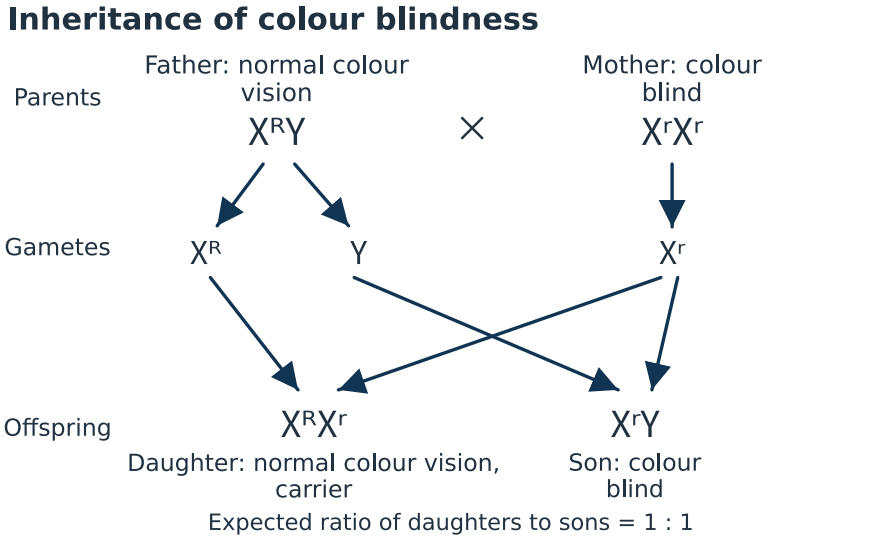


Diagram answer for the original question

Examiner's comment (source page(s) 3)

The genetic diagram must show parents, gametes and offspring, using the symbols specified in the question. An affected male in a pedigree must be drawn as a filled square; writing a description beside it is insufficient.

Marking reference: HKDSE Biology 2016 Paper 1B Q10, official marking scheme, source page(s) 5.

Example 4 [HKDSE Biology 2019 Paper 1B Q11]

You are required to present your answer in essay form to the following question. Criteria for marking will include relevant content, logical presentation and clarity of expression.

Nowadays, keeping pets (such as dogs and cats) is becoming popular in Hong Kong. Some people prefer pure-bred pets to hybrid pets. However, pure-bred pets usually have higher risks of suffering from genetic diseases than hybrid pets because of the ways they are bred. Pure-bred pets are produced by crossing close relatives to keep a pure bloodline. Explain why genetic diseases are often carried by recessive alleles. By comparing the effects of the two breeding processes on the genetic composition of the offspring, discuss why pure-bred pets are at a higher risk of suffering from genetic diseases than hybrid pets. (11 marks)

Solution Extended response; original allocation: 11 mark(s)

Method: Exclude inheritance models first, then list possible genotypes.

Alleles associated with inherited diseases can arise by mutation. Whether a harmful allele readily persists in a population depends on whether it is expressed in individuals and how it affects reproduction. In the simplified model used in the question, a dominant harmful allele causes disease even in a heterozygote. It is more readily exposed to natural selection, which may reduce survival or reproduction and hence the chance of transmission to the next generation. If the allele is recessive, a normal dominant allele can mask its effects in healthy heterozygous carriers. They can still reproduce and pass on the recessive allele, allowing such harmful alleles to persist more readily.

Pure-bred pets are repeatedly inbred to maintain particular characteristics. Relatives share ancestors and are more likely to have inherited the same alleles. Their offspring are therefore more likely to receive the same allele from both parents, increasing homozygosity at many loci over successive generations. If both parents carry the same recessive disease allele, their offspring are more likely to be homozygous recessive and affected. For example, two unaffected Aa carriers can produce an affected aa offspring, showing that a healthy

appearance does not exclude a genetic risk. This example does not imply that every mating between relatives carries the same fixed risk.

The parents of cross-bred pets come from different lineages and tend to have more different allele combinations, making their offspring more likely to remain heterozygous at the relevant loci. A harmful recessive allele from one parent may be masked by a normal dominant allele from the other, so recessive inherited diseases are expressed less often. The central comparison is how breeding methods change allele combinations and the probability of homozygosity. Inbreeding does not necessarily generate more mutations; nor are all pure-bred animals necessarily affected or all cross-bred animals entirely free of inherited disease. First compare the opportunities for natural selection to act on dominant and recessive harmful alleles. Then compare how mating between relatives and mating between different lineages affect homozygosity, and finally link this to expression of inherited disease. This answers both why recessive diseases are common and why pure-bred animals face a higher risk. Clear organisation and terminology also matter for marking. A list such as "similar genes, inbreeding, more disease" without causal connections is insufficient.

Examiner's comment (source page(s) 7)

The report notes that many responses used genetic terminology without explaining how recessive disease alleles can remain masked in heterozygotes and be passed on. Inbreeding increases the chance that the same harmful recessive allele from both parents comes together in a homozygote. Pure-bred does not mean homozygous at every gene, and cross-bred does not mean heterozygous at every gene.

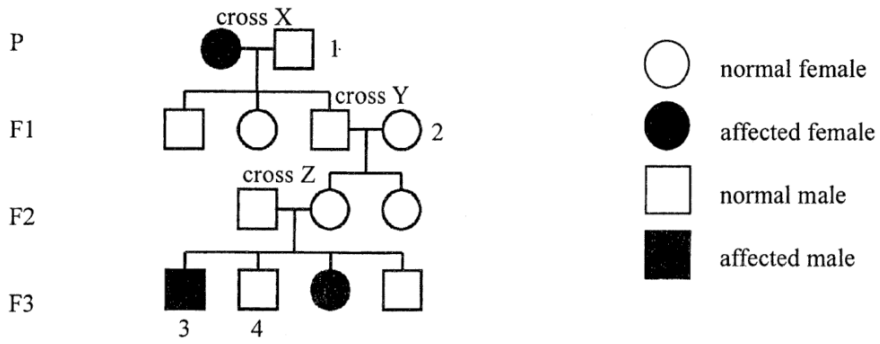
Marking reference: HKDSE Biology 2019 Paper 1B Q11, official marking scheme, source page(s) 6.

Practice

1. [HKDSE Biology 2013 Paper 1A Q15]

Hint: Exclude inheritance models first, then list possible genotypes.

Directions: Questions 15 to 17 refer to the pedigree below, which shows the inheritance of a certain trait controlled by a pair of alleles located on an autosome (i.e. non-sex chromosome):

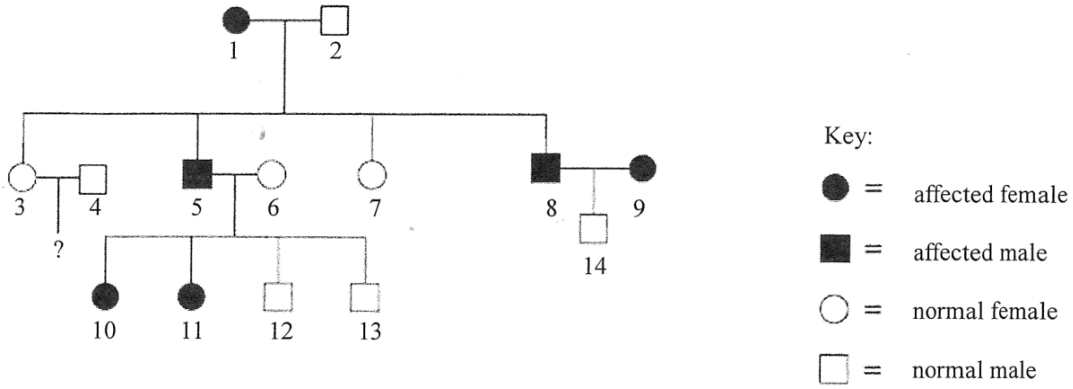


Which cross(es) can be used to deduce which phenotype is dominant?

A. cross Y only
B. cross Z only
C. crosses X and Y only
D. crosses X and Z only

2. [HKDSE Biology 2020 Paper 1A Q36]
← Hint: Exclude inheritance models first, then list possible genotypes.

Directions: Questions 35 and 36 refer to the pedigree below, which shows the inheritance of a genetic disorder.

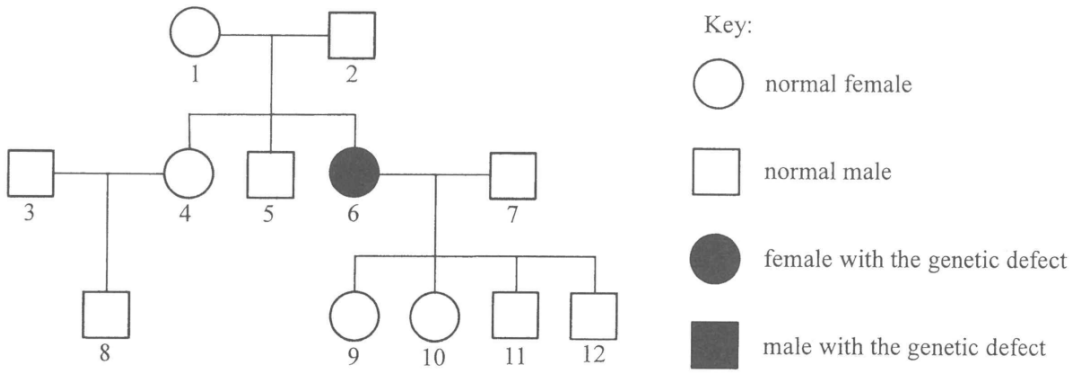


What is the probability of individual 3 and individual 4 giving birth to a normal male?

A. 0
B. 0.25
C. 0.5
D. 1

3. [HKDSE Biology 2021 Paper 1A Q14]
← Hint: Exclude inheritance models first, then list possible genotypes.

Directions: Questions 13 to 15 refer to the pedigree below, which shows the inheritance of a certain genetic defect controlled by a pair of alleles.

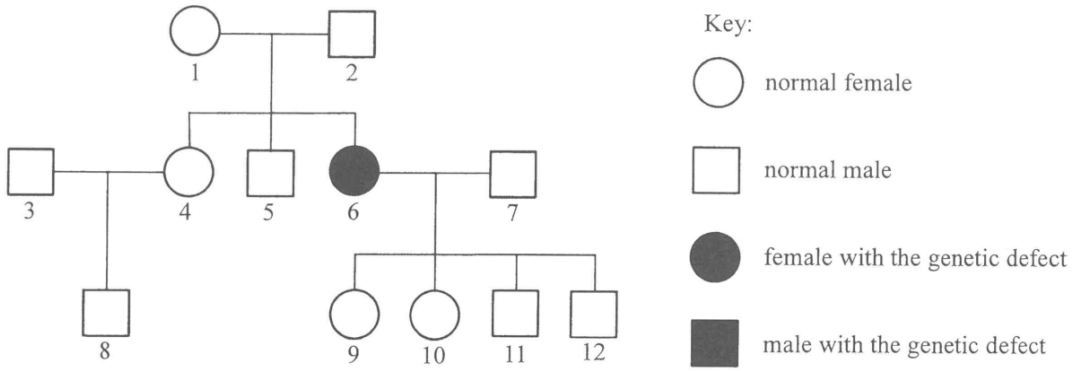


The offspring of individuals 6 and 7 are normal because each receives a

A. normal allele from the father.
B. normal allele from each parent.
C. defective allele from the father.
D. defective allele from the mother.

4. [HKDSE Biology 2021 Paper 1A Q15]
⟵ *Hint: Exclude inheritance models first, then list possible genotypes.*

Directions: Questions 13 to 15 refer to the pedigree below, which shows the inheritance of a certain genetic defect controlled by a pair of alleles.

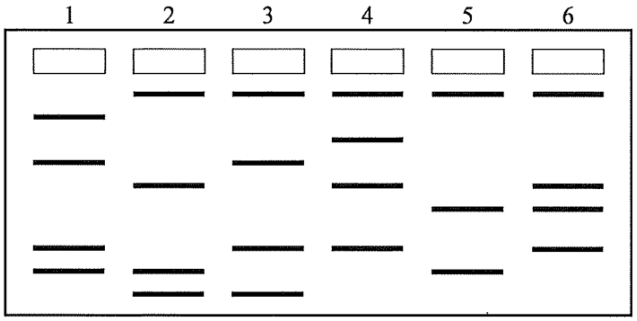


Which of the following correctly shows the possible genotype(s) of individual 8?

A. heterozygous only
B. homozygous dominant only
C. homozygous recessive only
D. homozygous dominant and heterozygous

5. [HKDSE Biology 2023 Paper 1A Q26]
⟵ *Hint: Exclude inheritance models first, then list possible genotypes.*

The DNA fingerprints below show the screening of a rare genetic disease in a family of six members:



The onset of the disease occurs in adulthood. Members 2 and 6 have already shown the symptoms of the disease. Which member is likely to have inherited this disease too?

A. 1
B. 3
C. 4
D. 5

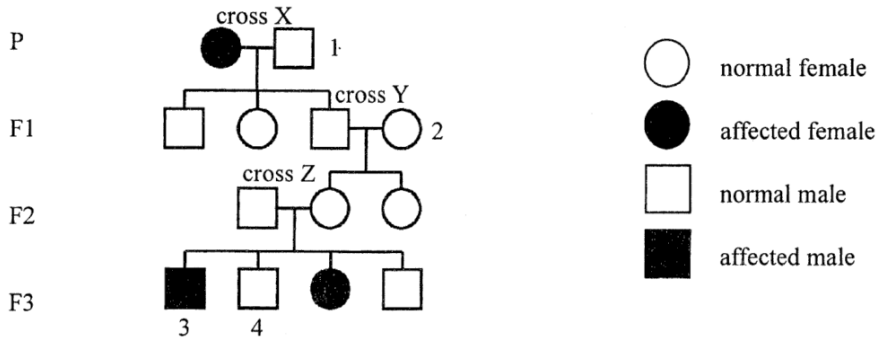
6. [HKDSE Biology 2025 Paper 1A Q27 (English translation)]
⟵ *Hint: Exclude inheritance models first, then list possible genotypes.*

Inherited disease Z in fruit flies is controlled by a pair of alleles. A male fruit fly with disease Z is crossed with an unaffected female. Their offspring consist of 120 unaffected males and 116 affected females. Which combination below is correct regarding the allele for disease Z?

	Dominant or recessive	Location of the allele causing disease Z
A.	Dominant	On an autosome
B.	Dominant	On a sex chromosome
C.	Recessive	On an autosome
D.	Recessive	On a sex chromosome

7. [HKDSE Biology 2013 Paper 1A Q16]
Hint: Exclude inheritance models first, then list possible genotypes.

Directions: Questions 15 to 17 refer to the pedigree below, which shows the inheritance of a certain trait controlled by a pair of alleles located on an autosome (i.e. non-sex chromosome):



What are the probable genotypes of individuals 1 and 2?

	Individual 1	***Individual 2***
A.	homozygous	homozygous
B.	homozygous	homozygous or heterozygous
C.	homozygous or heterozygous	homozygous
D.	homozygous or heterozygous	homozygous or heterozygous

8. [HKDSE Biology 2014 Paper 1A Q11]
Hint: Exclude inheritance models first, then list possible genotypes.

Directions: Questions 10 and 11 refer to the following two crosses of fruit flies. In fruit flies, males are the heterogametic sex (XY) and the wing shape (normal wing or cut wing) is controlled by a single gene.

	Cross I	***Cross II***
Parents	Normal wing female x Cut wing male	Cut wing female x Normal wing male
F_1	12 normal wing females 11 normal wing males	11 normal wing females 11 cut wing males
F_2	71 normal wing females 34 normal wing males 35 cut wing males	32 normal wing females 33 cut wing females 36 normal wing males 38 cut wing males

From Cross II, we can conclude that

✓A. the gene for the wing shape is located on the X-chromosome because the cut wing phenotype was passed from the female parent to the F_1 males.

B. the law of independent assortment was demonstrated because new phenotypes, including normal wing females and cut wing males, were found in F_2.

C. the normal wing male parent is heterozygous because four combinations of phenotypes were observed in F_2.

D. the gene for the wing shape is located on an autosome because a ratio of 1:1:1:1 was shown in F_2.

9. [HKDSE Biology 2019 Paper 1A Q14]
Hint: Exclude inheritance models first, then list possible genotypes.

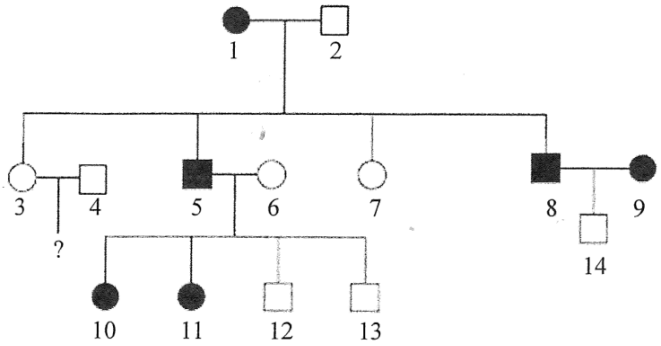
In a family, the father is red-green colour blind (a recessive X–linked trait) and is of blood group A, while the mother has normal vision and is of blood group B. Which of the following could be the phenotypes of their biological child?

(1) a normal-vision girl with blood group O
(2) a red-green colour blind girl with blood group O
(3) a red-green colour blind boy with blood group AB

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

10. [HKDSE Biology 2020 Paper 1A Q35]
Hint: Exclude inheritance models first, then list possible genotypes.

Directions: Questions 35 and 36 refer to the pedigree below, which shows the inheritance of a genetic disorder.



Key:
- ● = affected female
- ■ = affected male
- ○ = normal female
- □ = normal male

35. Which of the following combinations correctly shows the possible types of inheritance of this disorder?

	Autosomal dominant	*Autosomal recessive*	*X-linked dominant*	*X-linked recessive*
A.	✓		✓	
B.	✓			✓
C.		✓	✓	
D.		✓		✓

11. [HKDSE Biology 2023 Paper 1B Q6]
Hint: Exclude inheritance models first, then list possible genotypes.

Colour blindness is an inherited disorder due to defective functioning of the cone cells in the retina. There are many types of colour blindness. For example, people with red-green colour blindness fail to distinguish between red and green colours while those with total colour blindness experience total loss of colour vision.

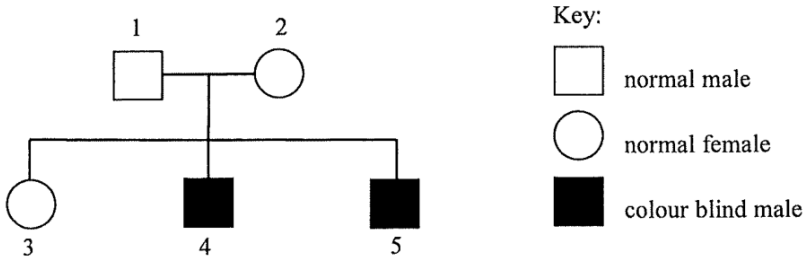
(a) Based on the functioning of cone cells, suggest why the condition of red-green colour blindness is different from that of total colour blindness. (1 mark)

(b) Red-green colour blindness is caused by a recessive allele on the X-chromosome while total colour blindness is caused by a recessive allele which is located on an autosome. The table below shows the percentage occurrence of red-green colour blindness and total colour blindness in men and women:

	Men	Women
Red-green colour blindness	8%	0.5%
Total colour blindness	0.00001%	0.00001%

With reference to the inheritance of the two types of colour blindness, suggest why the occurrence of red-green colour blindness in men as compared to women differs from that of total colour blindness. (4 marks)

(c) The pedigree below shows the inheritance of red-green colour blindness in a family:



(i) The couple is expecting another child. Using 'B' to represent the allele for normal vision and 'b' to represent the allele for red-green colour blindness, construct a genetic diagram to find out the probability of this newborn being a girl with red-green colour blindness. (4 marks)
(Note: Punnett square is not accepted.)

(ii) Individuals 4 and 5 are twins. Can you determine whether they are identical twins or fraternal twins? Explain your answer. (2 marks)

Type 4 Interpret karyotypes and the scale of genetic changes

Degree of integration ★★★☆☆

Key ideas

① A karyotype shows chromosome number and large structural differences, such as an extra chromosome. It generally cannot directly reveal a single-base substitution. X and Y differ in size and form, while autosomes can be matched into similar homologous pairs.

② Separate chromosome-level evidence before discussing gene-level traits.

How to recognise the problem For detection by karyotyping, first ask whether the change is large enough to be recognised in a chromosome image.

Example 1 [HKDSE Biology 2018 Paper 1B Q5]

The photomicrograph below shows the paired homologous chromosomes of a normal boy for karyotyping:



(a) Circle the sex chromosomes on the above photomicrograph. (1 mark)

(b) State the type of cells, somatic cells or gametes, from which the karyotype was obtained. Explain your answer. (2 marks)

(c) It is commonly thought that the sex of offspring is mainly determined by the mother. Explain why this is *not* true. (3 marks)

Solution Reading the question and choosing a method

Method: Check whether the scale of change is visible in a karyotype.

A normal male's sex chromosomes are a larger X and a smaller Y, not an identical-looking pair of autosomes.

a; original allocation: 1 mark(s)

Circle the X and Y sex chromosomes, the pair with different lengths, in the diagram.

Most autosomes have been arranged into pairs of similar size and shape. The sex-chromosome pair contains a larger X and a smaller Y. Circle both chromosomes in this pair, not just the shortest chromosome.

b; original allocation: 2 mark(s)

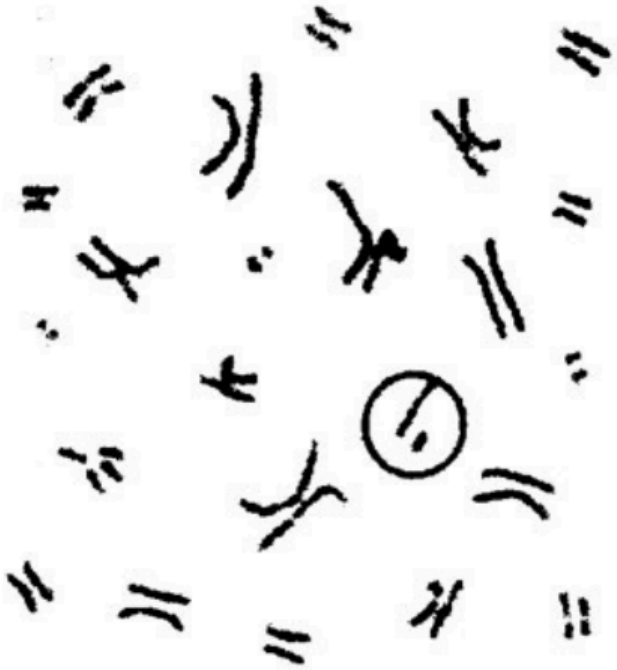
The chromosomes come from a body cell, because there are two sets: 46 chromosomes in total, arranged in 23 pairs.

Use the number of sets and the total number of chromosomes as evidence. A normal gamete contains only one set of 23 chromosomes, not the two sets shown. State "body cell" first, then support it with "46 chromosomes / two sets". Do not simply say "it is a body cell because it has X and Y". The key is the complete chromosome complement, rather than considering only one chromosome.

c; original allocation: 3 mark(s)

The mother's eggs normally carry only an X chromosome, while the father's sperm can carry X or Y. Which sperm type fertilises an egg is random. Under the XX / XY model in this question, the offspring's chromosomal sex therefore depends on the sperm involved in fertilisation, rather than being determined by the mother alone.

The two actual combinations make this clear: an X-bearing egg and an X-bearing sperm form XX; an X-bearing egg and a Y-bearing sperm form XY. The egg supplies X in both cases. The difference is whether the sperm supplies X or Y. Saying that the sperm type determines the combination does not mean that the father consciously chooses a sperm, nor does it assign responsibility to either parent. The fertilisation combination arises randomly.



The circled position in the official marking reference contains the X and Y chromosomes, which differ in length.

Examiner's comment (source page(s) 4)

Arranging chromosomes in pairs makes them easier to inspect; it does not mean the photograph comes from a gamete undergoing meiosis. Identify a body cell from its 46 chromosomes / two chromosome sets, not from the way the chromosomes are displayed in pairs.

Marking reference: HKDSE Biology 2018 Paper 1B Q5, official marking scheme, source page(s) 3.

Practice

1. [HKDSE Biology 2015 Paper 1A Q26]

← *Hint: Check whether the scale of change is visible in a karyotype.*

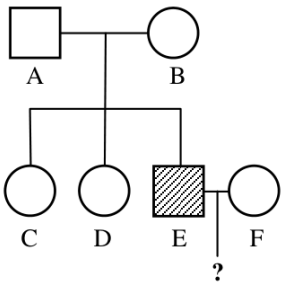
During pregnancy, amniotic fluid containing foetal cells can be obtained for karyotyping. This helps to determine whether the foetus

(1) is male or female.
(2) has Down syndrome or not.
(3) is a carrier of Sickle-cell anaemia.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

2. [HKDSE Biology Practice Paper Paper 1B Q9]
Hint: Check whether the scale of change is visible in a karyotype.

A couple (A and B) does not have any family history of Down syndrome, but the female (B) has a family history of colour blindness. The two daughters of this couple do not have colour blindness, but one of them (C) has Down syndrome. The son (E) has colour blindness. The pedigree of this family is shown in the following diagram:



Key:
- Male with normal colour vision
- Colour-blind male
- Female with normal colour vision

(a) Normal people have 23 pairs of chromosomes in the cell nucleus, but people with Down syndrome have an extra chromosome in the 21st pair of chromosomes. Explain how this couple could give birth to a Down syndrome child (C). (2 marks)

(b) (i) In humans, colour blindness is a sex-linked trait. Based on the above pedigree, deduce the genotype of the mother (B) with respect to colour vision.
(Marks will **not** be awarded for genetic diagrams.) (5 marks)

(ii) F is a carrier of the colour blindness allele. With the aid of a genetic diagram, find the probability of E and F giving birth to a colour-blind daughter. (5 marks)

Genetic diagram:

Probability of E and F giving birth to a colour-blind daughter: _____

II.b Molecular genetics

First read the explanations and diagrams in Concept II.b, then work through the question types in this section. Each worked example retains the complete original question and explanation. The subsequent exercises require progressively more integration of information, based on the demands of the whole question.

Type 1 Calculate base proportions using DNA structure and pairing

Degree of integration ★★☆☆☆

Key ideas

① In double-stranded DNA, A pairs with T and G with C. If A makes up 20% of the entire double-stranded molecule, T also makes up 20%, leaving 30% each for G and C. These equalities need not hold within an individual strand.

② Sugar and phosphate form the outer backbone; differences in base sequence provide the main coding differences.

How to recognise the problem Identify whether the question counts a single strand, double-stranded DNA or RNA before using pairing ratios. For model research, distinguish observed evidence from the proposed structure.

Example 1 [HKDSE Biology 2022 Paper 1A Q2]

Adenine (A) and cytosine (C) together make up 50% of the total amount of nitrogenous bases in DNA molecules. Which of the following features of DNA provide the basis to explain this phenomenon?

(1) DNA has a helical structure.
(2) DNA is a double-stranded molecule.
(3) The nitrogenous bases are paired complementarily.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

Solution **Answer: C**

In double-stranded DNA, A pairs with T and C pairs with G, so A = T and C = G. Writing the total number of bases as A + T + C + G = 2(A + C) shows that A + C accounts for half of the total. Both double-stranded structure and complementary base pairing are required. Whether DNA is coiled into a helix does not determine this proportion.

Method: Identify single-stranded DNA, double-stranded DNA or RNA before using base pairing.

Marking reference: HKDSE Biology 2022 Paper 1A Q2, official marking scheme, source page(s) 1.

Example 2 [HKDSE Biology 2020 Paper 1A Q18]

Directions: Questions 18 and 19 refer to the following passage about the discovery of DNA structure:

> Many scientists tried to uncover the structure of DNA. In 1952, Franklin took the first X-ray photograph of DNA, which revealed its helical shape. Her colleague, Wilkins, showed some of Franklin's unpublished findings to Watson without her knowledge. Shortly after, Watson and Crick made a crucial advance when they proposed that the DNA molecule was made up of two chains of nucleotides paired to form a double helix. In 1962, Watson, Crick and Wilkins were awarded the Nobel Prize.

Which of the following aspects of the Nature of Science can be exemplified in the above story?

(1) A good scientific experiment must include carefully designed controls.
(2) Scientists are both collaborative and competitive by nature.
(3) Doing science requires imagination and creativity.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

Solution **Answer: C**

This account of scientific history describes how scientists obtained, exchanged and used evidence about DNA structure. Different researchers both competed and used information supplied by one another, corresponding to (2). Proposing a double-helix model from evidence such as X-ray photographs required organising a structure that had not been seen directly into a testable model, corresponding to (3). Choose C.

Statement (1) concerns experimental control groups, but the passage does not describe an experiment comparing treatments with a control group. A general experimental principle cannot be treated as something demonstrated by this passage. Base the answer on the text, rather than selecting every statement about science that sounds correct.

Method: Identify single-stranded DNA, double-stranded DNA or RNA before using base pairing.

Marking reference: HKDSE Biology 2020 Paper 1A Q18, official marking scheme, source page(s) 1.

Practice

1. [HKDSE Biology 2013 Paper 1A Q4]

Hint: Identify single-stranded DNA, double-stranded DNA or RNA before using base pairing.

For different DNA nucleotides, the part that varies from one to another is the

A. base.
B. ribose.
C. deoxyribose.
D. phosphate group.

2. [HKDSE Biology 2013 Paper 1A Q12]

Hint: Identify single-stranded DNA, double-stranded DNA or RNA before using base pairing.

The DNA of a eukaryotic cell contains 20% adenine (A) bases. What is the percentage of cytosine (C) bases in this DNA?

A. 60%
B. 40%
C. 30%
D. 20%

3. [HKDSE Biology 2020 Paper 1A Q19]
Hint: Identify single-stranded DNA, double-stranded DNA or RNA before using base pairing.

Directions: Questions 18 and 19 refer to the following passage about the discovery of DNA structure:

> Many scientists tried to uncover the structure of DNA. In 1952, Franklin took the first X-ray photograph of DNA, which revealed its helical shape. Her colleague, Wilkins, showed some of Franklin's unpublished findings to Watson without her knowledge. Shortly after, Watson and Crick made a crucial advance when they proposed that the DNA molecule was made up of two chains of nucleotides paired to form a double helix. In 1962, Watson, Crick and Wilkins were awarded the Nobel Prize.

Which of the following descriptions of the molecular structure of DNA proposed by Watson and Crick is correct?

A. The two chains run in opposite directions.
B. The bases link up the nucleotides to form a chain.
C. The sugar that makes up nucleotides has two types.
D. The phosphate that makes up nucleotides has at least four types.

4. [HKDSE Biology Practice Paper Paper 1A Q1]
Hint: Identify single-stranded DNA, double-stranded DNA or RNA before using base pairing.

In a DNA molecule of yeast, 30% of the nitrogenous bases are guanine (G). What is the ratio of cytosine (C) to thymine (T) in this DNA molecule?

A. 1:1
B. 2:1
C. 3:2
D. 3:7

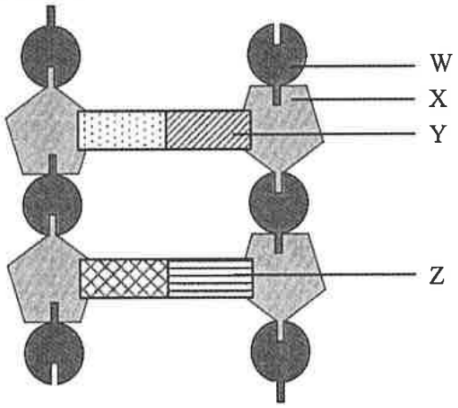
5. [HKDSE Biology 2018 Paper 1A Q28]
Hint: Identify single-stranded DNA, double-stranded DNA or RNA before using base pairing.

The DNA model proposed by Watson and Crick leads to the understanding of how

A. organisms store genetic codes.
B. organisms share a common ancestor.
C. cells produce instructions for protein synthesis.
D. cells can pass genetic information to the next generation.

6. [HKDSE Biology 2019 Paper 1A Q13]
Hint: Identify single-stranded DNA, double-stranded DNA or RNA before using base pairing.

The diagram below shows a DNA model:



Which of the following combinations shows the most probable identities of molecules W, X, Y, and Z?

	W	*X*	*Y*	*Z*
A.	sugar	phosphate	cytosine	thymine
B.	sugar	phosphate	cytosine	guanine
C.	phosphate	sugar	adenine	thymine
D.	phosphate	sugar	adenine	guanine

7. [HKDSE Biology 2024 Paper 1A Q2]
Hint: Identify single-stranded DNA, double-stranded DNA or RNA before using base pairing.

The genetic material of a virus contains 1966 adenine (A), 2343 guanine (G), 1749 thymine (T) and 2368 cytosine (C). Based on this information, which of the following combinations of the genetic material for this virus is correct?

	Nucleic acid	*Pentose*
A.	single-stranded	deoxyribose
B.	single-stranded	ribose
C.	double-stranded	deoxyribose
D.	double-stranded	ribose

Type 2 Track protein synthesis through DNA, mRNA and tRNA

Degree of integration ★★★☆☆

Key ideas

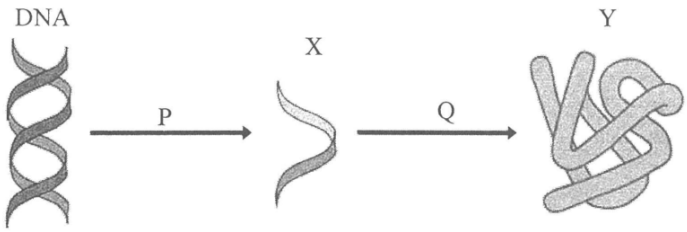
① If the DNA coding-strand sequence in the specified direction is ATG, the corresponding mRNA sequence is AUG. The template strand is complementary to mRNA. Codons are on mRNA and are read in groups of three bases; tRNA anticodons pair with them.

② Moving the starting point by one base may change every subsequent group. Identify direction, strand and reading frame before consulting the table. A nucleic-acid sequence binding complementarily to a particular mRNA may obstruct translation. Such restriction of gene expression does not mean that DNA has mutated.

How to recognise the problem Label the template, product and 5′ and 3′ directions first. Triplets in different locations with different roles should not be given interchangeable names.

Example 1 [HKDSE Biology 2021 Paper 1A Q3]

Directions: Questions 1 to 3 refer to the diagram below, which shows the flow of gene expression within a cell:



Which of the following combinations correctly states what process P is and where process Q takes place?

	What process P is	*Where process Q takes place*
A.	translation	cytoplasm
B.	translation	nucleus
C.	transcription	cytoplasm
D.	transcription	nucleus

Solution Answer: C

P produces messenger RNA from DNA and is called transcription. Q arranges amino acids according to the messenger RNA code and is called translation. Translation occurs at ribosomes in the cytoplasm; do not assign Q the nuclear location of transcription. Select "P is transcription; Q occurs in the cytoplasm". Choose C.

Method: Label template, product and direction before pairing bases.

Marking reference: HKDSE Biology 2021 Paper 1A Q3, official marking scheme, source page(s) 1.

Example 2 [HKDSE Biology 2017 Paper 1A Q9]

If the base sequence on the coding strand of the DNA is AAC, which of the following combinations correctly shows the mRNA codon and the tRNA anticodon?

	mRNA codon	*tRNA anticodon*
A.	AAC	UUG
B.	AAC	TTG
C.	UUG	AAC
D.	TTG	AAC

Solution Answer: A

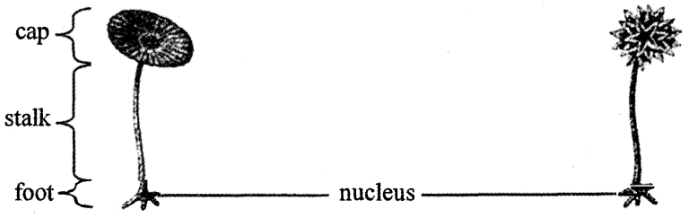
The question gives the coding strand. The mRNA sequence matches it, with T replaced by U. AAC contains no T, so the mRNA sequence remains AAC. The complementary tRNA anticodon is UUG. Choose A. Only when the template strand is given should the complementary sequence be taken first; do not automatically complement any sequence simply because it is DNA.

✓ Method: Label template, product and direction before pairing bases.

Marking reference: HKDSE Biology 2017 Paper 1A Q9, official marking scheme, source page(s) 1.

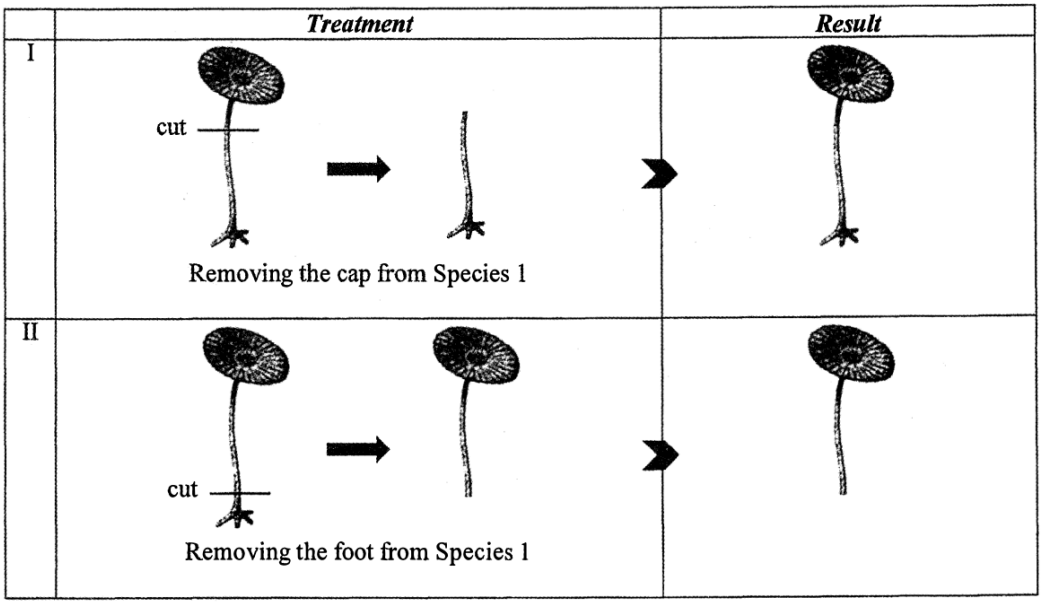
Example 3 [HKDSE Biology 2016 Paper 1B Q8]

8. In 1930s, a Danish biologist J. Hämmerling tried to find out where the genetic information was stored inside the eukaryotic cell. He used some unicellular algae called *Acetabularia* to carry out a series of experiments. The diagram below shows the morphology of two species of algae used in his study:



Species 1 with round-shaped cap — Species 2 with flower-shaped cap

He divided Species 1 into two groups, removing the cap from one group (I) and the foot from another group (II). He then observed if any regeneration occurred in the remaining parts. The diagram below shows the treatments and the results:

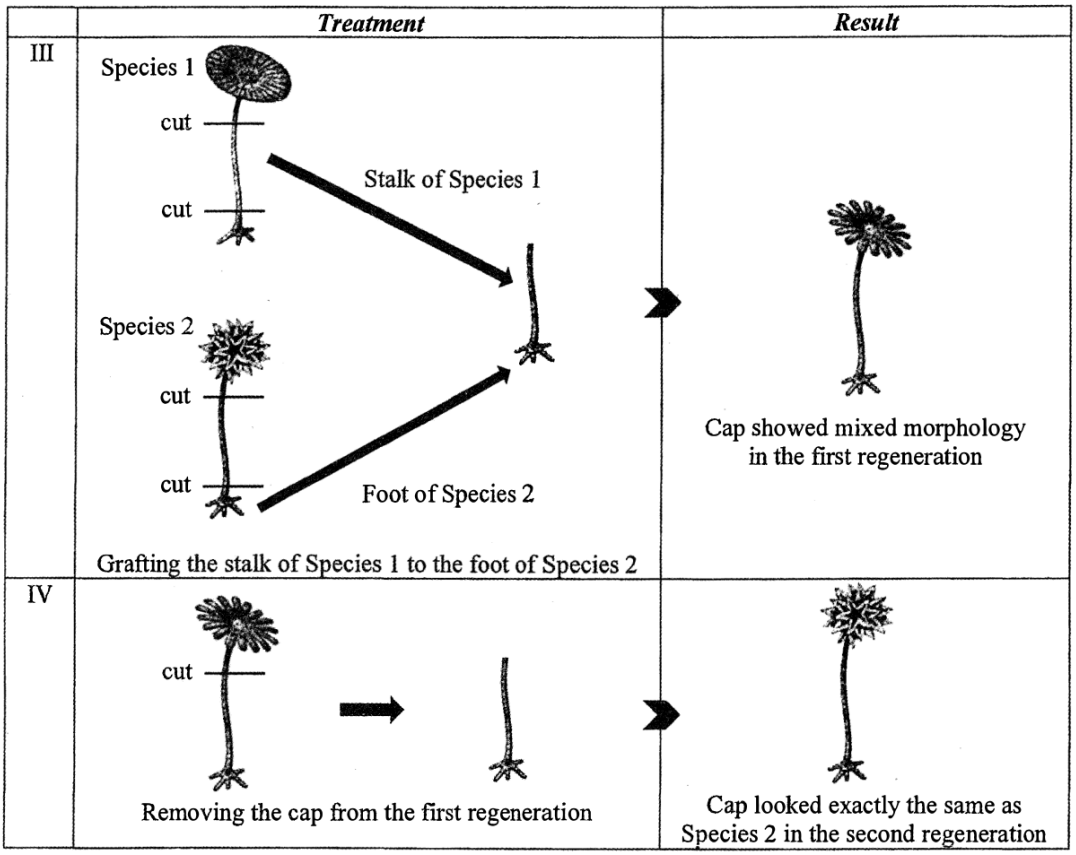


(a) Describe the results of the above experiment. (2 marks)

(b) Based on the results, Hämmerling hypothesized that:

The hereditary information is stored in the foot of the algal cell.

Hämmerling further studied the expression of hereditary information by grafting the stalk of Species 1 to the foot of Species 2. After grafting, the cap formed from the first regeneration showed a mixed morphology (III). He then removed the regenerated cap. The cap formed from the second regeneration looked exactly the same as Species 2 (IV). The diagram below shows the treatments and the results:



(i) Hämmerling concluded that when the cut stalk was transplanted, it contained some short-lived instruction derived from the foot of Species 1, resulting in a mixed morphology of the cap in the first regeneration.

(1) Suggest the type of biomolecule that carried the short-lived instruction. (1 mark)

(2) How could the biomolecule suggested in (1) affect the morphology of the cap? (2 marks)

(ii) How do the results from this experiment support Hämmerling's hypothesis? (2 marks)

(c) Give ***one*** aspect about the nature of science that can be demonstrated in the above discovery and give a reason to support your answer. (2 marks)

Solution (a); original allocation: 2 mark(s)

The stalk and base remaining after removal of the cap regenerate a cap. The cap and stalk remaining after removal of the base do not regenerate a base.

Describe the visible results for each group before introducing an explanation involving the nucleus into a description-only question. In I, the removed cap regenerates; in II, the base does not grow back. Both results are needed for the comparison.

✓ Method: Label template, product and direction before pairing bases.

(b)(i)(1); original allocation: 1 mark(s)

RNA, more specifically messenger RNA, mRNA.

The temporary instructions can move from the base containing the nucleus into the stalk and persist for a time after the original base is removed. This fits degradable RNA, rather than the complete set of stably stored DNA.

(b)(i)(2); original allocation: 2 mark(s)

mRNA acts as a template for translation and directs protein production. These structural proteins or enzymes affect cap formation and shape.

Connect the information to substances that can influence form. The mRNA base sequence determines the amino acid sequence of a protein. Proteins contribute to cell structures or control metabolism, thereby affecting the shape of the regenerating cap.

(b)(ii); original allocation: 2 mark(s)

The second regenerated cap completely resembles species 2 rather than species 1, which supplied the stalk. This supports the presence of the lasting genetic information in the base from species 2.

The initially mixed shape can be explained by temporary instructions from species 1 remaining in the stalk. After the cap is removed and regeneration is allowed again, these temporary instructions decline, and continuing instructions from the species 2 base determine the final form. The second regeneration result is therefore necessary to identify the long-term source of information.

(c); original allocation: 2 mark(s)

Scientific knowledge is based on experimental evidence. Hämmerling inferred the location of genetic information by comparing the results of different removals, grafts and regeneration.

First name an aspect of the nature of science, then link it to a specific action or result in this investigation. Creativity and imagination are also acceptable, supported by the design of grafts between different species to distinguish the effects of the stalk and base. Merely writing “science is creative” does not complete the justification.

Examiner’s comment (source page(s) 3)

The second regeneration tests whether the first result was caused only by temporary substances already present. Connect RNA lifespan, protein synthesis and the shape of the regenerated structure to infer the role of the nucleus from the experiment.

Marking reference: HKDSE Biology 2016 Paper 1B Q8, official marking scheme, source page(s) 4.

Example 4 [HKDSE Biology 2022 Paper 1B Q9]

Antibiotics have been widely used to treat bacterial infections. They work by killing bacteria or inhibiting their growth. However, some strains of bacteria have developed resistance to antibiotics.

(a) How can antibiotics kill bacteria or inhibit their growth? State ***three*** possible ways. (3 marks)

(b) Bacterium R is a pathogenic bacterium which possesses an antibiotic resistance gene. Its gene product can break down antibiotic X. Scientists have suggested a new approach to fight against bacterium R. This new approach involves the use of a synthetic polynucleotide which binds to the mRNA transcribed from the antibiotic resistance gene. The expression of the gene is then inhibited. By administering this synthetic polynucleotide together with antibiotic X, bacterium R can be killed.

The base sequences of the synthetic polynucleotide and part of the mRNA are shown below:

synthetic polynucleotide: AGT GAC TCG GTC AGC

mRNA: ... AUG UCU GUU CCA UCA UCA CUG AGC CAG UCG GCC AUU AAU GCC AAC UAG ...

(i) On the mRNA, underline the base sequence to which the synthetic polynucleotide will bind. (1 mark)

(ii) Explain how the synthetic polynucleotide can inhibit the expression of the antibiotic resistance gene. (3 marks)

(iii) Suggest ***one*** advantage of using synthetic polynucleotides to fight against antibiotic resistant bacteria. (1 mark)

Solution a; original allocation: 3 mark(s)

Method: Label template, product and direction before pairing bases.

Inhibit cell-wall synthesis; damage the cell membrane; interfere with protein synthesis.

Inhibiting cell-wall synthesis makes it difficult for bacteria to maintain their shape and resist osmotic pressure. Damaging the cell membrane causes cell contents to leak out. Preventing ribosomes from synthesising proteins stops essential enzymes and structural proteins from being made. Interference with DNA replication is another acceptable mechanism.

b(i); original allocation: 1 mark(s)

Underline UCA CUG AGC CAG UCG on the mRNA.

In the synthetic sequence AGT GAC TCG GTC AGC, A pairs with U in RNA, T with A, G with C, and C with G. Matching the bases one by one gives UCA CUG AGC CAG UCG, which occurs as a continuous segment in the mRNA shown.

b(ii); original allocation: 3 mark(s)

The complementary nucleic acid binds to the mRNA, making that segment double-stranded. This prevents normal binding of the ribosome or tRNA to the mRNA and stops translation.

The ribosome must be able to read the mRNA codons, and tRNAs must be able to pair with them. After pairing with the synthetic nucleic acid, the segment is no longer available as a normal readable single strand. tRNAs cannot deliver the corresponding amino acids according to the codons, so the resistance protein cannot be synthesised. The bacterium can therefore no longer break down antibiotic X. This method prevents gene expression; it does not necessarily delete the resistance gene from the bacterium.

b(iii); original allocation: 1 mark(s)

A specific complementary nucleic acid can be designed to target the sequence of a known resistance gene.

Once the relevant mRNA sequence is known, a new targeting sequence can be designed through complementary base pairing to inhibit synthesis of that resistance protein specifically. The specificity comes from matching base sequences.

Examiner's comment (source page(s) 6)

A complementary nucleic acid inhibits translation; this does not mean that the mRNA sequence is rewritten, and the question need not be treated as a codon-mutation problem. Antibiotics and antibodies are different. Explain how nucleic-acid pairing interferes with the action of the ribosome or tRNA.

Marking reference: HKDSE Biology 2022 Paper 1B Q9, official marking scheme, source page(s) 6.

Practice

1. [HKDSE Biology 2012 Paper 1A Q18]

Hint: Label template, product and direction before pairing bases.

Which of the following descriptions about transcription is correct?

A. tRNA pairs with ribosome to produce amino acids.
B. mRNA pairs with ribosome to produce proteins.
C. Free DNA nucleotides pair with DNA template strand to produce DNA.
D. Free RNA nucleotides pair with DNA template strand to produce mRNA.

2. [HKDSE Biology 2013 Paper 1A Q11]

Hint: Label template, product and direction before pairing bases.

Which of the following statements about codons is correct?

A. A codon may consist of bases A, C, G or T.
B. A codon is a triplet of bases on transfer RNA.
C. Most amino acids are coded by more than one codon.
D. All codons code for amino acids.

3. [HKDSE Biology 2014 Paper 1A Q16]

Hint: Label template, product and direction before pairing bases.

Which of the following biomolecules are associated with transcription?

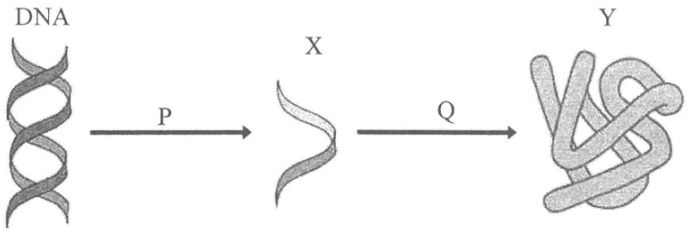
(1) DNA
(2) mRNA
(3) amino acid

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

4. [HKDSE Biology 2021 Paper 1A Q1]

Hint: Label template, product and direction before pairing bases.

Directions: Questions 1 to 3 refer to the diagram below, which shows the flow of gene expression within a cell:



X represents

A. a transfer RNA.
B. a DNA template.
C. a ribosomal RNA.
D. a messenger RNA.

5. [HKDSE Biology Sample Paper Paper 1A Q28]
← Hint: Label template, product and direction before pairing bases.

The gene for colour vision is sex-linked. It can be found in

(1) cone cells.
(2) egg cells.
(3) liver cells.

A. (1) only
B. (1) and (2) only
C. (2) and (3) only
D. (1), (2) and (3)

6. [HKDSE Biology 2012 Paper 1A Q19]
← Hint: Label template, product and direction before pairing bases.

The tRNA anticodon for the sequence AGT on the coding strand of DNA is

A. UCA.
B. AGU.
C. TCA.
D. AGT.

7. [HKDSE Biology 2023 Paper 1A Q27]
← Hint: Label template, product and direction before pairing bases.

Directions: Questions 27 and 28 refer to the following nucleotide sequence found on a mRNA molecule:

AUGGCUAACUAUAACGCU
↑
translation starts

How many different codons are found on this nucleotide sequence?

A. 3
B. 4
C. 5
D. 6

8. [HKDSE Biology 2023 Paper 1A Q28]
← Hint: Label template, product and direction before pairing bases.

Directions: Questions 27 and 28 refer to the following nucleotide sequence found on a mRNA molecule:

AUGGCUAACUAUAACGCU
↑
translation starts

Which of the following statements about the mRNA molecule are correct?

(1) It can be found in the nucleus.
(2) It can be found in the cytoplasm.
(3) Its corresponding sequence on the DNA coding strand is TACCGATTGATATTGCGA.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

9. [HKDSE Biology Practice Paper Paper 1A Q9]
Hint: Label template, product and direction before pairing bases.

Directions: Questions 9 and 10 refer to the following table, which shows six codons and the corresponding amino acids translated from these codons:

mRNA codon	AAG	CUA	CCU	GUA	GAU	CAU
amino acid	lysine	leucine	proline	valine	aspartic acid	histidine

The sequence of amino acids in a certain part of a polypeptide is shown below:

—lysine—proline—histidine—aspartic acid—

Which of the following is the correct sequence of the nucleotides on the non-template DNA (coding DNA) for this part of the polypeptide?

A. AAGCCTCATGAT
B. TTCGGAGTACTA
C. AAGCCUCAUGAU
D. UUCGGAGUACUA

10. [HKDSE Biology Sample Paper Paper 1A Q29]
Hint: Label template, product and direction before pairing bases.

One of the mRNA codons for the amino acid proline is CCG. How many proline molecules are present in a short peptide which consists of five amino acids and is synthesized from the following DNA template?

CCGGGCGCAGGCACG

→

direction of transcribing the DNA template

A. 0
B. 1
C. 2
D. 3

Type 3 Connect DNA differences with proteins, traits and relationships

Degree of integration ★★★☆☆

Key ideas

① A changed base may leave a codon specifying the same amino acid, change it to another amino acid or create a stop signal. Even an amino-acid change has a functional effect that depends on its position and folding.

② A complete explanation of disease connects DNA, protein structure, cellular function and phenotype.

③ DNA-profile questions use a different type of evidence: compare bands at corresponding positions and trace offspring bands to the two parents under the inheritance model.

④ Mark bands that the known father can supply first. The remaining relevant bands must be explained by a candidate mother. Finally, check every offspring and every band. A profile does not directly read every base, and a few matching bands do not establish identical whole genomes.

⑤ Pedigrees track traits and inheritance relationships among family members. DNA fingerprints compare particular variable regions. The Human Genome Project provides information such as reference sequences. These methods complement one another, but a question answerable by one method cannot automatically be answered by another.

How to recognise the problem Identify whether the evidence is a base sequence, DNA bands or family traits. For sequences, work through codons to proteins; for bands, check sources and corresponding positions. Do not treat a profile as whole-genome sequencing.

Example 1 [HKDSE Biology 2013 Paper 1A Q19]

Directions: Questions 19 and 20 refer to the nucleotide sequence of a certain functional gene segment found in four different species of organisms P, Q, R and S:

AACGTCGAAA	(organism P)
AACCTCGAAA	(organism Q)
AGGCTAGAAA	(organism R)
AGGCTAGTAA	(organism S)

The differences in the sequences shown above are most probably caused by

A. crossing over.
B. gene mutation.
C. random fertilisation.
D. chromosomal mutation.

Solution Answer: B

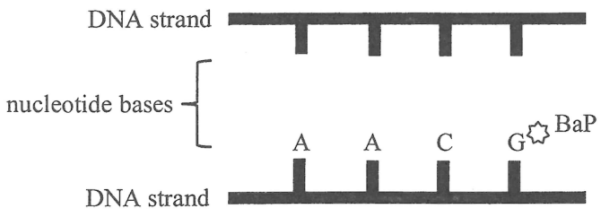
Method: Distinguish sequence evidence from profile evidence, then infer step by step.

The fragments have the same length but different bases at corresponding positions. The most direct explanation is base substitution caused by gene mutation. Crossing over and random fertilisation mainly recombine existing genetic material and do not directly explain these changes at corresponding base positions. The figure also provides no evidence of a change in whole-chromosome number or large-scale chromosome structure.

Marking reference: HKDSE Biology 2013 Paper 1A Q19, official marking scheme, source page(s) 1.

Example 2 [HKDSE Biology 2024 Paper 1B Q2]

BaP is a carcinogenic chemical which is commonly found in grilled meats. It can attach randomly to the nucleotides of DNA molecules. When it is attached to guanine (G), this G will be misread as thymine (T). The diagram below shows part of nucleotide sequence of one strand of a DNA molecule with BaP attached to a G:



(a) On the above diagram, write down the nucleotide sequence found in the opposite strand of the DNA when misreading happens. (1 mark)

(b) Suggest ***one*** reason why this type of mutation may ***not*** affect the functioning of the protein formed. (1 mark)

(c) If this type of mutation accumulates over time in the DNA molecules, there is a chance that it will affect the functioning of the protein formed and subsequently lead to tumour formation. Suggest which cellular process this protein controls. (1 mark)

Solution a; original allocation: 1 mark(s)

Method: Distinguish sequence evidence from profile evidence, then infer step by step.

From left to right: T T G A.

Normal pairing is A–T and C–G. The final base was G, but attachment of BaP causes it to be misread as T. The newly paired base is therefore A, rather than the C that would normally pair with G. The four positions are TTGA in order.

b; original allocation: 1 mark(s)

The new codon may still specify the original amino acid.

Because the genetic code is degenerate, some base substitutions leave the amino acid sequence unchanged, allowing the protein to retain its function. Another valid explanation is that an amino acid changes without affecting the active site or an essential part of the structure. One complete reason is sufficient.

c; original allocation: 1 mark(s)

For example, control of cell division / the cell cycle.

If a protein regulating the cell cycle malfunctions, a cell may continue dividing when it should not, allowing cells to accumulate into a tumour. Control of cell death, differentiation or DNA repair is also acceptable, but identify a specific cellular process.

Examiner's comment (source page(s) 69)

Once the final G is misread as T, it should pair with A; do not continue to apply normal G–C pairing. DNA does not use U either. Degeneracy means that different codons can specify the same amino acid, not that they directly specify the same protein.

Marking reference: HKDSE Biology 2024 Paper 1B Q2, official marking scheme, source page(s) 51.

Example 3 [HKDSE Biology 2020 Paper 1B Q9]

The following DNA sequence shows the coding strand of part of a gene found in insect species A:

… ATG GTC GTA TAC GCT ACC CTG TCG ATG CTA GCT AGC …

(a) Which of the following correctly shows the sequence of the mRNA corresponding to the underlined sequence of this coding strand? Put a '✓' in the appropriate box to indicate your choice. (1 mark)

☐ AUG GUC GUA UAC GCU ACC

☐ UAC CAG CAU AUG CGA UGG

(b) Using the following codon table, write the amino acid sequence of the protein translated from the mRNA in (a). (2 marks)

First base of the codon	Second base of the codon: U	C	A	G	Third base of the codon
U	Phe	Ser	Tyr	Cys	U
					C
	Leu		STOP	STOP	A
				Trp	G
C	Leu	Pro	His	Arg	U
					C
			Gln		A
					G
A	Ile	Thr	Asn	Ser	U
					C
	Met		Lys	Arg	A
					G
G	Val	Ala	Asp	Gly	U
					C
			Glu		A
					G

(c) It was found that the gene has two alleles. The difference between the two alleles in the underlined sequence is highlighted below:

allele1: … ATG GTC GTA TA**C** GCT ACC …

allele 2: … ATG GTC GTA TA**G** GCT ACC … (mutated)

(i) What kind of mutation is this? (1 mark)

(ii) With reference to the codon table, describe how this mutation affects the protein translated from this gene. (3 marks)

(iii) Individuals from insect species A exist in two forms, green bodied and brown bodied. Individuals with a green body have only allele 1. Some of those with a brown body have both allele 1 and allele 2 while others have only allele 2.

If the body colour of insect species A was only caused by the mutation of this gene, which allele (1 or 2) would be recessive? Explain your answer. (3 marks)
(Note: Marks will not be awarded for genetic diagrams.)

Method: Distinguish sequence evidence from profile evidence, then infer step by step.

Solution a; original allocation: 1 mark(s)
AUG GUC GUA UAC GCU ACC.
The question explicitly identifies the given DNA strand as the coding strand. The mRNA sequence matches it in the same direction, with T replaced by U. The other, template strand is complementary to mRNA. Tick the first sequence; do not complement the coding strand again.
b; original allocation: 2 mark(s)
Met–Val–Val–Tyr–Ala–Thr.
Each group of three bases forms a codon. Read the chosen mRNA in order using the table: AUG gives Met, GUC gives Val, GUA also gives Val, UAC gives Tyr, GCU gives Ala, and ACC gives Thr. Locate each entry using its first, second and third bases; do not look up DNA T directly in an mRNA codon table. Although GUC and GUA differ, they can code for the same amino acid.
c(i); original allocation: 1 mark(s)
Gene mutation, specifically a base substitution.
C is replaced by G at the corresponding position in the two alleles, without increasing or decreasing the sequence length. This is a change in the base sequence within one gene, not a mutation in chromosome number.
c(ii); original allocation: 3 mark(s)
TAC on the coding strand changes to TAG, so UAC in the mRNA becomes the stop codon UAG. Translation ends prematurely, producing a shorter polypeptide and a final protein with a different shape.
The original fourth codon, UAC, adds Tyr. After substitution, UAG is a STOP signal: translation terminates here; no amino acid called "STOP" is added. The original amino acid at this position and those after it are no longer joined to the chain. Its length and sequence therefore change, and its folded shape may change as well. Do not merely write "the mutation makes the protein different"; connect the codon change, termination of translation and protein structure.
c(iii); original allocation: 3 mark(s)
Allele 1 is recessive.
Green individuals have only allele 1. Some brown individuals have only allele 2, while others have both 1 and 2. The decisive observation is that heterozygotes with both alleles are brown, showing that expression of 2 masks 1. The green phenotype associated with 1 appears only in the absence of 2, so 1 is recessive. The question states that no marks are awarded for genetic diagrams. Explain the genotype–phenotype comparisons in words. Do not assume that allele 1 is dominant merely because it is the unmutated form.
Marking reference: HKDSE Biology 2020 Paper 1B Q9, official marking scheme, source page(s) 6, 7.

Example 4 [HKDSE Biology 2025 Paper 1B Q11 (English translation)]

Answer the following question in essay form. Assessment will take into account the relevance of the content, logical organisation and clarity of expression.

Pedigree analysis and the Human Genome Project both provide genetic information for screening for genetic diseases. Compare the biological principles involved in these two approaches. Suggest two applications of genetic information in the diagnosis and monitoring of genetic diseases. (11 marks)

Solution **Complete extended-response example; original allocation: 11 mark(s)**

Method: Distinguish sequence evidence from profile evidence, then infer step by step.

Both pedigree analysis and sequence data established through the Human Genome Project can assist screening for inherited diseases, but they obtain information in different ways. Pedigree analysis first collects information across several generations about family members' traits, affected status, sex and parent–child relationships, and presents it in a pedigree. Patterns of transmission between parents and children are then used to infer whether a disease is dominant or recessive and whether autosomal or sex-linked inheritance fits better. This infers the mode of inheritance from family phenotypes; it does not directly read the DNA base sequence.

Once an appropriate inheritance model is established, the phenotypes of parents and offspring can be used to infer possible genotypes and estimate the probability of passing the disease to the next generation. For example, in a condition established as autosomal recessive, if both parents are Aa, then Aa × Aa can produce AA, Aa, Aa and aa. Each pregnancy has a one-in-four probability of producing an aa child. If the pedigree lacks sufficient evidence to exclude alternatives, several possibilities must be retained. Dominance or recessiveness cannot be determined simply by counting affected people.

The Human Genome Project collected cell samples, extracted DNA and determined base sequences to establish a human genome reference sequence that researchers could share. To apply these data in screening an individual, a separate cell sample can be taken from that person and the relevant DNA sequence read. Comparing it with the reference sequence and information on known disease-causing variants can identify the alleles or variants present. The inheritance pattern can then be used to infer the risk of developing or transmitting disease. The reference sequence works together with subsequent research on variation: not every base that differs from the reference causes disease, and the genome project itself did not directly diagnose everyone's diseases.

This information has two specific applications. First, combined with family history and clinical information, it can help identify people carrying a particular disease-causing variant early and support faster, more accurate diagnosis of the corresponding inherited disease. Second, people confirmed to be at increased risk or already affected can receive regular monitoring targeted at the relevant disease, allowing disease progression to be detected early and care or treatment to be adjusted. The first application improves diagnosis and the second improves ongoing monitoring; both use the genetic information obtained.

The official content-mark limits are 6 marks for comparing the biological principles and 2 marks for two applications, with a further 3 marks for communication. Organise the response as "how data are obtained → how genetic information is inferred → two applications in diagnosis and monitoring". Contrast family phenotypes with DNA sequences, without misrepresenting pedigree analysis as sequencing an individual's genes.

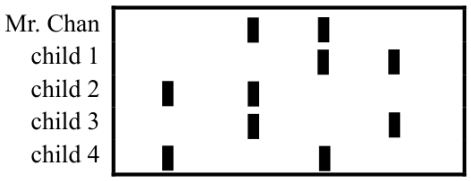
Examiner's comment (source page(s) 75)

The comparison is between pedigree analysis and the Human Genome Project. The latter studies DNA base sequences, not protein amino acid sequences. Applications must relate to diagnosis or prediction of inherited disease. Continuously checking whether an adult's DNA subsequently mutates does not address the inherited risk intended by the question.

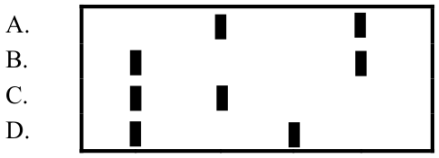
Marking reference: HKDSE Biology 2025 Paper 1B Q11, official marking scheme, source page(s) 59, 60.

Example 5 [HKDSE Biology Practice Paper Paper 1A Q14]

Mr. Chan and Mrs. Chan are the biological parents of four children. The DNA profiles of Mr. Chan and the four children are shown below:



Which of the following is likely to be the DNA profile of Mrs. Chan?



Solution Answer: B

Every child's bands must be traceable to the parents. First cross out the two positions that the father can supply. The remaining left-hand band and far-right band in the children must both come from the mother. Only B has both positions. Do not simply choose the pattern that looks most similar to one child.

Method: Distinguish sequence evidence from profile evidence, then infer step by step.

Marking reference: HKDSE Biology Practice Paper Paper 1A Q14, official marking scheme, source page(s) 2.

Practice

1. [HKDSE Biology 2025 Paper 1A Q29 (English translation)]

Hint: Distinguish sequence evidence from profile evidence, then infer step by step.

The photomicrographs below show two types of human cell:



Which of the following correctly explains the different appearances of the two cell types?

A. They have different gene copies.
B. They have different gene expression.
C. They have different genomes.
D. They have different numbers of chromosomes.

2. [HKDSE Biology 2014 Paper 1A Q19]

Hint: Distinguish sequence evidence from profile evidence, then infer step by step.

Which of the following is ***not*** an application of DNA fingerprinting?

A. Forensic science
B. Screening for genetic diseases
C. Sequencing of the human genome
D. Identification of Chinese medicines

3. [HKDSE Biology 2020 Paper 1A Q17]
Hint: Distinguish sequence evidence from profile evidence, then infer step by step.

'Transgenic organisms produced by recombinant DNA technology have more potential in terms of evolution than those produced by traditional breeding.'

Which of the following is the best reason for this?

A. Recombinant DNA technology creates new species.
B. Recombinant DNA technology produces new phenotypes.
C. Recombinant DNA technology transfers genes within a species.
D. Recombinant DNA technology transfers genes between different species.

4. [HKDSE Biology 2023 Paper 1A Q30]
Hint: Distinguish sequence evidence from profile evidence, then infer step by step.

Directions: Questions 29 and 30 refer to the phylogenetic relationship of five bacterial species. Enzyme X is found in most bacteria. The table below shows the number of nucleotide differences in the genes encoding enzyme X of five bacterial species (J, K, L, M and N):

	J	K	L	M	N
J	0	61	32	112	89
K	-	0	50	119	94
L	-	-	0	119	77
M	-	-	-	0	124
N	-	-	-	-	0

The nucleotide sequence of the genes encoding enzyme X have some differences among the five species. Yet, the enzyme X in these five species still serve the same function. Which of the following are possible explanations for this phenomenon?

(1) The polypeptides formed have the same length.
(2) There are more than one genetic code for the same amino acid.
(3) The differences do not affect the shape of the active site of enzyme X.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

5. [HKDSE Biology Practice Paper Paper 1A Q10]
Hint: Distinguish sequence evidence from profile evidence, then infer step by step.

Directions: Questions 9 and 10 refer to the following table, which shows six codons and the corresponding amino acids translated from these codons:

mRNA codon	AAG	CUA	CCU	GUA	GAU	CAU
amino acid	lysine	leucine	proline	valine	aspartic acid	histidine

The following shows the nucleotide sequences of two mRNA molecules, the first one being transcribed from a normal allele and the second one from the mutated allele:

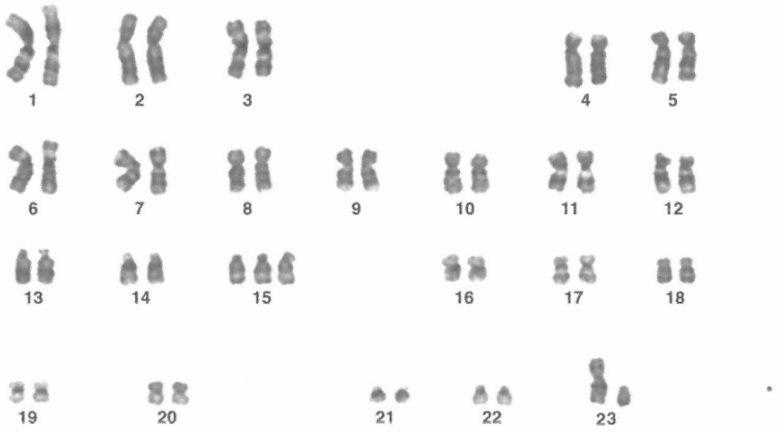
mRNA transcribed from the normal allele: CCUGAUCCUCUACCUCAU
mRNA transcribed from the mutated allele: CCUGAUCCUGUACCUCAU

Which of the following amino acids is absent in the polypeptide translated from the mutated allele?

A. histidine
B. aspartic acid
C. valine
D. leucine

6. [HKDSE Biology 2022 Paper 1B Q4]
Hint: Distinguish sequence evidence from profile evidence, then infer step by step.

The photomicrograph below shows the karyotype of a patient who is suffering from a certain brain disease:



(a) What is the gender of this patient? Describe ***one*** observable feature from the karyotype to support your answer. (2 marks)

(b) (i) Describe the abnormality shown in the karyotype. (1 mark)

(ii) State the type of mutation involved in this abnormality. (1 mark)

(iii) How would this abnormality affect the mRNA level in the brain cells of this patient? (1 mark)

(c) The cerebellum is one of the regions affected by this disease. In relation to the function of the cerebellum, suggest ***one*** difficulty that would be experienced by this patient. (1 mark)

7. [HKDSE Biology 2018 Paper 1B Q9]
Hint: Distinguish sequence evidence from profile evidence, then infer step by step.

Although most DNA is stored in the nucleus, mitochondria also have a small amount of their own DNA. The mitochondrial DNA contains some genes coding for enzymes which are essential for oxidative phosphorylation. Mutations of these mitochondrial genes cause Leigh syndrome, which is a rare and fatal metabolic disease.

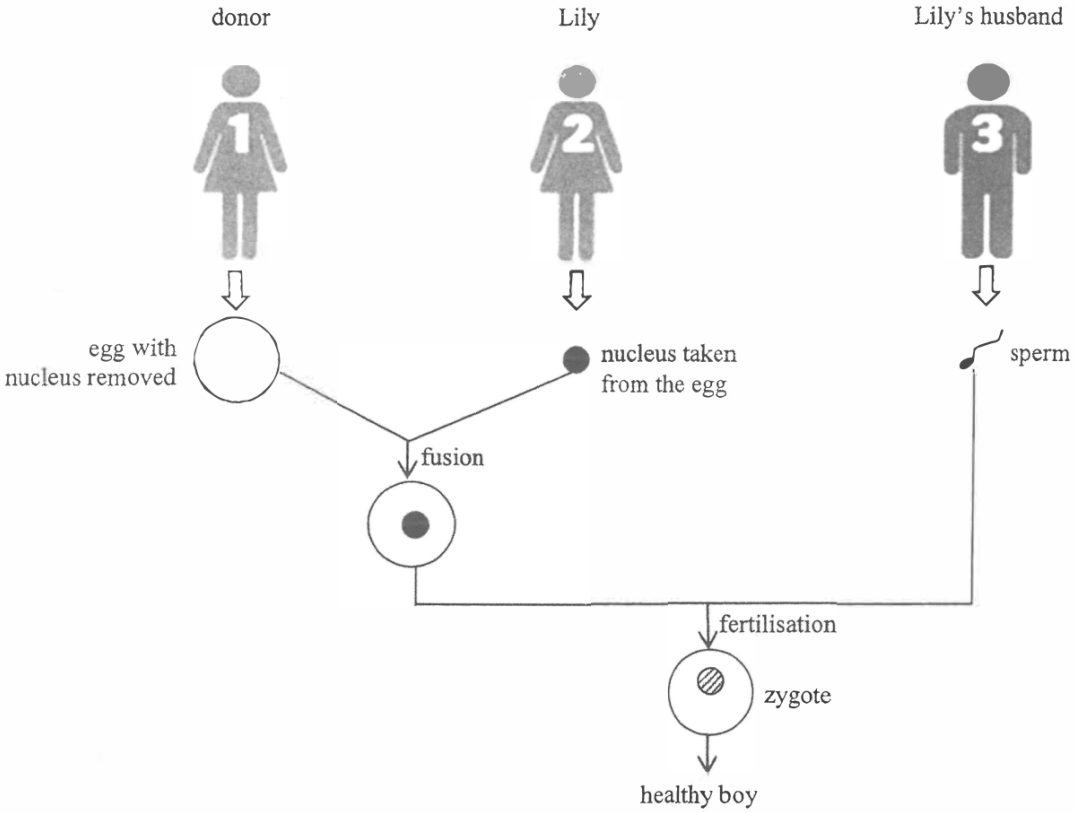
(a) Explain why gene mutations in the mitochondrial DNA can affect oxidative phosphorylation. (4 marks)

(b) What are the major products of oxidative phosphorylation? State their significance. (4 marks)

(c) Lily had two children who died from Leigh syndrome. It was found that her eggs contained mutated mitochondrial genes. Her children suffered from the disease because normally mitochondria in zygotes come from the eggs while sperms do not contribute any.

(i) With regard to the fertilisation process and the structure of sperms, suggest why sperms do not contribute any mitochondria to zygotes. (1 mark)

(ii) By using a new method called the 'three-parent baby' technique, Lily gave birth to a healthy boy in 2016. Below are the main steps in the technique:



Identify the source(s) of DNA of the nucleus and mitochondria in the boy's cells. (2 marks)

Nucleus:

Mitochondria:

II.c Biodiversity and evolution

First read the explanations and diagrams in Concept II.c, then work through the question types in this section. Each worked example retains the complete original question and explanation. The subsequent exercises require progressively more integration of information, based on the demands of the whole question.

Type 1 Classify organisms and use dichotomous keys

Degree of integration ★★★☆☆

Key ideas

① Each step in a dichotomous key gives mutually exclusive features, such as feathers present versus absent, leading along the appropriate path to an identification. It is an identification tool, not automatically a phylogenetic tree.

② Prokaryotes and eukaryotes are distinguished by cellular features such as a membrane-bound nucleus, not body size or chlorophyll alone.

How to recognise the problem Determine whether the task asks for identification, construction of a key or explanation of classification. Use features actually visible in the diagram at each step.

Example 1 [HKDSE Biology Practice Paper Paper 1A Q17]

The following dichotomous key can be used to identify five species of amphibian:

1 (a)	the skin is rough	2
1 (b)	the skin is smooth	3
2 (a)	the dorsal side has coloured stripes	Species P
2 (b)	the dorsal side does not have coloured stripes	Species Q
3 (a)	the toes have sticky pads	4
3 (b)	the toes do not have sticky pads	Species R
4 (a)	the limbs are spotted	Species S
4 (b)	the limbs are not spotted	Species T

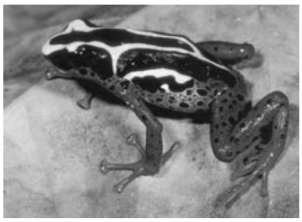
Use the above key to identify the three amphibians in the following photographs.



Amphibian (1)



Amphibian (2)



Amphibian (3)

	Amphibian (1)	*Amphibian (2)*	*Amphibian (3)*
A.	species R	species Q	species S
B.	species Q	species S	species R
C.	species T	species R	species P
D.	species T	species Q	species S

Solution **Answer: D**

(1) has smooth skin, suckers on its toes and no spots on its limbs. Following 1b → 3a → 4b gives T. (2) has rough skin and no coloured stripe on its back. Following 1a → 2b gives Q. (3) has smooth skin, suckers and spotted limbs. Following 1b → 3a → 4a gives S. Choose D.

Method: Classify at each step using features recognisable in the diagram.

Marking reference: HKDSE Biology Practice Paper Paper 1A Q17, official marking scheme, source page(s) 2.

Example 2 [HKDSE Biology 2016 Paper 1B Q4]

The following diagrams show the appearance of five flowering plants:



lesser celandine



hyacinth



wild daffodil



primrose



dead nettle

(a) In the following table, put a '✓' in the appropriate boxes to show the features of each flowering plant. (2 marks)

	Leaves with parallel veins	Leaves with network veins	Single flower	Cluster of flowers	Other features
lesser celandine					heart-shaped leaves
hyacinth					funnel-like flowers
wild daffodil					trumpet-like flowers
primrose					club-shaped leaves
dead nettle					two-lipped flowers

(b) Using the information from the table in (a), complete the following dichotomous key: (3 marks)

1a	The plant has leaves with parallel veins	.....	2
1b	The plant has leaves with network veins	.....	3
2a		.....	hyacinth
2b		.....	wild daffodil
3a	The plant has two-lipped flowers	.....	
3b	The plant does not have two-lipped flowers	.....	
4a		.....	lesser celandine
4b		.....	primrose

(c) Study the following statement:

The dichotomous key shows that the lesser celandine and primrose have a closer evolutionary relationship.

Do you agree? Explain your answer. (2 marks)

Solution (a); original allocation: 2 mark(s)

Lesser celandine: net-like veins, solitary flowers. Hyacinth: parallel veins, flowers in clusters. Wild daffodil: parallel veins, solitary flowers. Primrose: net-like veins, solitary flowers. Dead nettle: net-like veins, flowers in clusters.

Inspect the leaf veins first, then the flower arrangement, for each plant. Several flowers on one plant do not necessarily mean that each stalk bears an inflorescence: in the original primrose illustration, each flower stalk bears one flower. The official scheme awards marks separately for the leaf-vein and flower-arrangement columns, so check both sets of features.

(b); original allocation: 3 mark(s)

2a: flowers in clusters / funnel-shaped flowers. 2b: solitary flowers / trumpet-shaped flowers. 3a: dead nettle. 3b: 4. 4a: heart-shaped leaves. 4b: club-shaped leaves.

Step 1 has already placed the parallel-veined hyacinth and daffodil together at step 2, so 2a and 2b must distinguish their different flower features. Within the net-veined group, first identify dead nettle by its two-lipped flowers. The two remaining plants then proceed to step 4, where leaf shape distinguishes lesser celandine from primrose. Each pair of branches should be mutually exclusive and account for all the remaining organisms.

(c); original allocation: 2 mark(s)

Disagree. Adjacent branches in an identification key do not necessarily indicate close evolutionary relationships.

This key successively eliminates plants using convenient visible features. It does not compare common ancestry, homologous features or DNA sequences. Similar appearance can also result from adaptation to similar environments. Two plants cannot therefore be identified as the closest relatives simply because the key separates them only at the final step.

Examiner's comment (source page(s) 3)

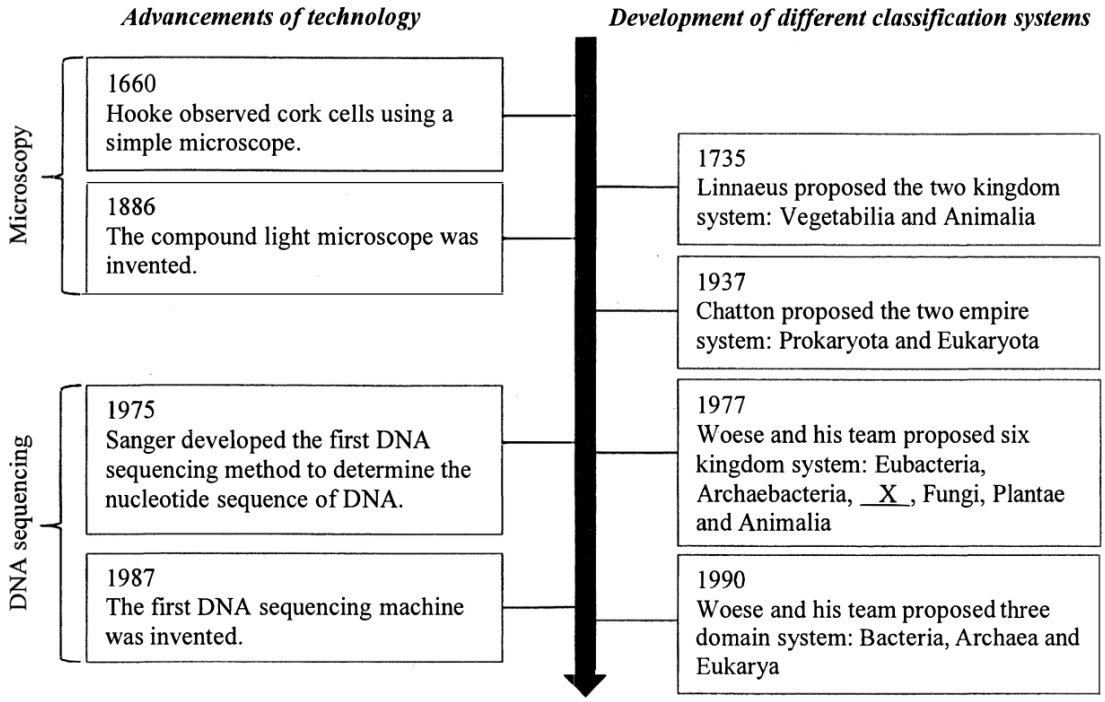
A dichotomous key must use observable, mutually exclusive features from the illustrations. It is used for identification and is not equivalent to a tree describing evolutionary relationships.

Marking reference: HKDSE Biology 2016 Paper 1B Q4, official marking scheme, source page(s) 2, 3.

Method: Classify at each step using features recognisable in the diagram.

Example 3 [HKDSE Biology 2017 Paper 1B Q6]

The chart below shows the timeline of some major advancements of technology and the development of different classification systems:



(a) Name kingdom X in the six kingdom system proposed by Woese and his team in 1977. (1 mark)

(b) How did the following technological advancements contribute to the development of different classification systems? (4 marks)

Microscopy:

DNA sequencing:

Solution (a); original allocation: 1 mark(s)

Kingdom Protoctista.

The six kingdoms listed already include Eubacteria, Archaebacteria, Fungi, Plantae and Animalia. The missing kingdom is Protoctista. Eliminate the names already present one by one; do not fill a "kingdom" blank with a name from the later three-domain system.

(b); original allocation: 4 mark(s)

Microscopy reveals internal cell structures and allows prokaryotes to be distinguished from eukaryotes. DNA sequencing provides nucleotide differences that can be used to infer relatedness, helping classification reflect evolutionary relationships more accurately.

For each technology, explain both the evidence obtained and how that evidence affects classification. Microscopy does more than magnify an organism: it reveals differences in organisation, such as whether a nucleus is present. Sequencing does more than show that DNA exists: it allows researchers to compare corresponding molecular regions and distinguish groups that are difficult to separate by appearance.

Examiner's comment (source page(s) 3)

"Technology has advanced" alone does not explain a change in classification. Identify the new features revealed by microscopy or molecular methods and explain how they distinguish organisms previously grouped together.

Marking reference: HKDSE Biology 2017 Paper 1B Q6, official marking scheme, source page(s) 4.

Method: Classify at each step using features recognisable in the diagram.

Practice

1. [HKDSE Biology 2013 Paper 1A Q21]

⟵ *Hint: Classify at each step using features recognisable in the diagram.*

Which of the following combinations shows the correct information about Eubacteria and Protista?

	Eubacteria	***Protista***
A.	bigger in size	smaller in size
B.	absence of cell wall	presence of cell wall
C.	presence of true nucleus	absence of true nucleus
D.	absence of mitochondria	presence of mitochondria

2. [HKDSE Biology 2014 Paper 1A Q15]

⟵ *Hint: Classify at each step using features recognisable in the diagram.*

Which of the organisms below belong to the domain Eukarya?

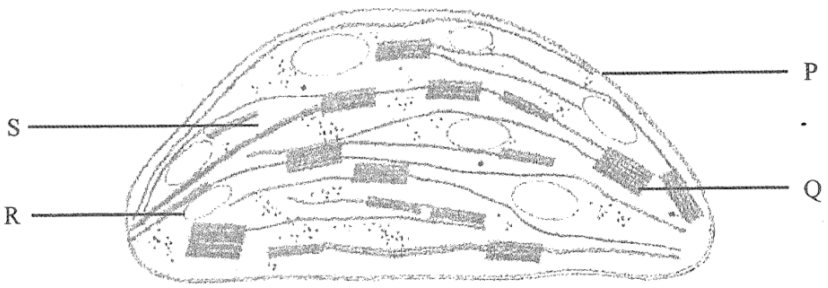
(1) Yeast
(2) Amoeba
(3) Mouse

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

3. [HKDSE Biology 2015 Paper 1A Q5]

⟵ *Hint: Classify at each step using features recognisable in the diagram.*

Directions: Questions 4 and 5 refer to the schematic diagram below, which shows the structures of a chloroplast:



Which of the following kingdoms contain organisms that possess the above organelle?

(1) Eubacteria
(2) Protista
(3) Plantae

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

4. [HKDSE Biology 2016 Paper 1A Q15]
Hint: Classify at each step using features recognisable in the diagram.

Directions: Questions 14 and 15 refer to the information below. Five new species of eubacteria were discovered in Antarctic ice core samples. The nucleotide sequences of the gene that codes for an essential protein of these new species were compared. The table below shows the number of nucleotide differences between the species:

	Number of nucleotide differences				
Species	P	Q	R	S	T
P	-	4	12	11	22
Q		-	12	11	19
R			-	4	22
S				-	22
T					-

Which of the following cell components can be found in these species?

A. nucleus
B. cell wall
C. chloroplast
D. mitochondrion

5. [HKDSE Biology Practice Paper Paper 1A Q15]
Hint: Classify at each step using features recognisable in the diagram.

Which of the following combinations shows the correct classification of the organism according to the Three Domain System?

	Organism	***Kingdom***	***Domain***
A.	nitrifying bacteria	Archaebacteria	Bacteria
B.	amoeba	Animalia	Eukarya
C.	yeast	Fungi	Archaea
D.	algae	Protista	Eukarya

6. [HKDSE Biology Practice Paper Paper 1A Q16]
Hint: Classify at each step using features recognisable in the diagram.

Below are the scientific names of four species of shrimps:

(1) *Leptochela japonicus*
(2) *Metapenaeus japonicus*
(3) *Metapenaeus joyneri*
(4) *Metapenaeopsis dura*

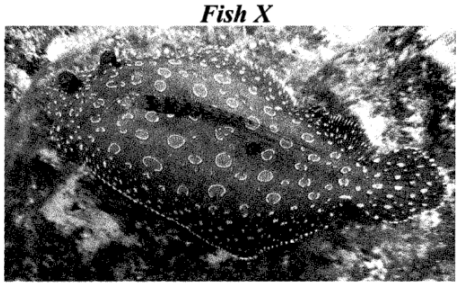
Which two of the above species should have the closest phylogenetic relationship?

A. (1) and (2)
B. (1) and (4)
C. (2) and (3)
D. (3) and (4)

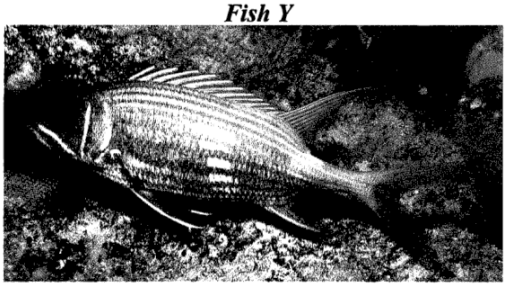
7. [HKDSE Biology 2014 Paper 1A Q17]
Hint: Classify at each step using features recognisable in the diagram.

Directions: Questions 17 and 18 refer to the following photographs of two different fish:

Fish X



Fish Y



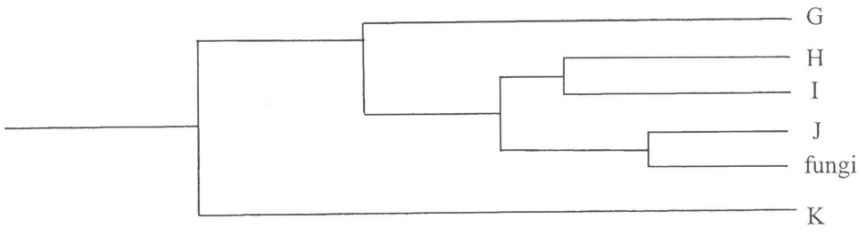
Using the dichotomous key below to identify the fish:

1a	Both eyes on the top of the head	2
1b	One eye on each side of the head	3
2a	Has long whip-like tail	*Aetobatus narinari*
2b	Has short, blunt tail	*Bothus mancus*
3a	Has spots on its body surface	4
3b	Does not have spots on its body surface.....	5
4a	Has chin whiskers	*Pseudupeneus maculatus*
4b	Does not have chin whiskers	*Sphoeroides spengleri*
5a	Has stripes on its body surface	*Holocentrus rufus*
5b	Does not have stripes on its body surface	*Parapriacanthus guentheri*

	Fish X	***Fish Y***
A.	*Bothus mancus*	*Pseudupeneus maculatus*
B.	*Bothus mancus*	*Holocentrus rufus*
C.	*Aetobatus narinari*	*Parapriacanthus guentheri*
D.	*Aetobatus narinari*	*Sphoeroides spengleri*

8. [HKDSE Biology 2021 Paper 1A Q28]
Hint: Classify at each step using features recognisable in the diagram.

Directions: Questions 28 and 29 refer to the diagram below, which shows an evolutionary tree demonstrating the phylogenetic relationship of the six kingdoms:

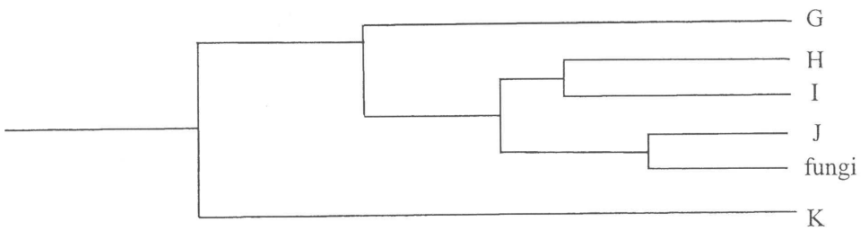


Which of the following combinations correctly shows the kingdoms represented by G, J and K in the evolutionary tree?

	G	***J***	***K***
A.	Archaebacteria	Animalia	Eubacteria
B.	Archaebacteria	Plantae	Eubacteria
C.	Eubacteria	Plantae	Protista
D.	Eubacteria	Animalia	Protista

9. [HKDSE Biology 2021 Paper 1A Q29]
Hint: Classify at each step using features recognisable in the diagram.

Directions: Questions 28 and 29 refer to the diagram below, which shows an evolutionary tree demonstrating the phylogenetic relationship of the six kingdoms:



Which of the following pairs of organisms belongs to the same domain?

A. G and K
B. G and H
C. H and J
D. J and K

10. [HKDSE Biology 2025 Paper 1B Q3 (English translation)]
Hint: Classify at each step using features recognisable in the diagram.

An environmental impact assessment for the proposed San Tin Technopole development found four species of waterbird feeding in and around fishponds. Their photographs are shown below:

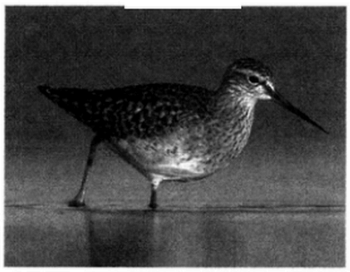
Waterbird A



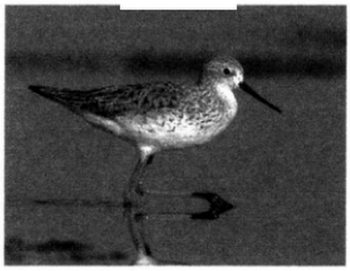
Waterbird B



Waterbird C



Waterbird D



(a) Use the key below to identify waterbirds A and C. Write the scientific name of each waterbird and the sequence of choices used in the key to identify it. (2 marks)

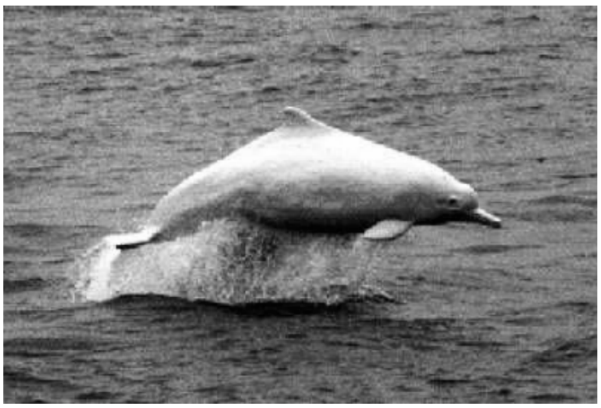
Key choice	Characteristic	Proceed to / identification
1a	Bill shorter than the head	Greater sand plover (*Charadrius leschenaultii*)
1b	Bill not shorter than the head	2
2a	Bill curved	Eurasian curlew (*Numenius arquata*)
2b	Bill straight	3
3a	No black stripe between the eye and bill	Marsh sandpiper (*Tringa stagnatilis*)
3b	Black stripe between the eye and bill	Wood sandpiper (*Tringa glareola*)

Waterbird	Sequence of choices used for identification	Scientific name
A		
C		

(b) Which two waterbirds have the greatest difference in ecological niches? Explain your answer using evidence from the photographs. (3 marks)

11. [HKDSE Biology Sample Paper Paper 1B Q3]
Hint: Classify at each step using features recognisable in the diagram.

The photograph below shows a kind of dolphin that can be found in the coastal areas of Hong Kong:



(a) Based on ***two*** features of the dolphin observed in the photograph, state how each feature enables it to adapt to this habitat. (2 marks)

(b) This dolphin is a protected species in Hong Kong. State how ***two*** human activities might pose threats to its survival in Hong Kong waters. (2 marks)

(c) According to the modern classification systems, dolphin and goldfish belong to the same group but different sub-groups. State ***two*** structural differences between these two animals that form the basis for classifying them into different sub-groups. (2 marks)

12. [HKDSE Biology Sample Paper Paper 1B Q5]

Hint: Classify at each step using features recognisable in the diagram.

During the course of history, scientists have developed different systems for classifying the diverse range of living organisms based on different criteria. The table below lists some of the different classification systems developed in the past centuries:

<table>
<tr><td>Scientist</td><td>Linnaeus</td><td>Chatton</td><td>Copeland</td><td>Whittaker</td><td>Woese et al.</td><td>Woese et al.</td></tr>
<tr><td>Year of proposal</td><td>1735</td><td>1937</td><td>1956</td><td>1969</td><td>1977</td><td>1990</td></tr>
<tr><td>System</td><td>2 kingdoms</td><td>2 empires</td><td>4 kingdoms</td><td>5 kingdoms</td><td>6 kingdoms</td><td>3 domains</td></tr>
<tr><td rowspan="6">Group</td><td rowspan="2">(not treated)</td><td rowspan="2">Prokaryota</td><td rowspan="2">Prokaryota</td><td rowspan="2">Prokaryota</td><td>Eubacteria</td><td>Bacteria</td></tr>
<tr><td>Archaebacteria</td><td>Archaea</td></tr>
<tr><td rowspan="4">Eukaryota</td><td>Protoctista</td><td>Protista</td><td>Protista</td><td rowspan="4">Eukarya</td></tr>
<tr><td rowspan="2">Vegetabilia</td><td rowspan="2">Plantae</td><td>Fungi</td><td>Fungi</td></tr>
<tr><td>Plantae</td><td>Plantae</td></tr>
<tr><td>Animalia</td><td>Animalia</td><td>Animalia</td><td>Animalia</td></tr>
</table>

(a) In 1937, Chatton classified all living organisms into two empires. List ***two*** major differences between these two empires. (2 marks)

.....

.....

.....

(b) Complete the key below, which serves to classify eukaryotic organisms into four kingdoms as proposed by Whittaker: (3 marks)

1a Predominantly unicellular……..……....…..…....Protista
1b Multicellular……...……..…2

2a [ ] …… [ ]

2b [ ] …… [ ]

3a [ ] …… [ ]

3b [ ] …… [ ]

(c) Suggest ***two*** reasons why the classification system of organisms keeps changing over time. (2 marks)

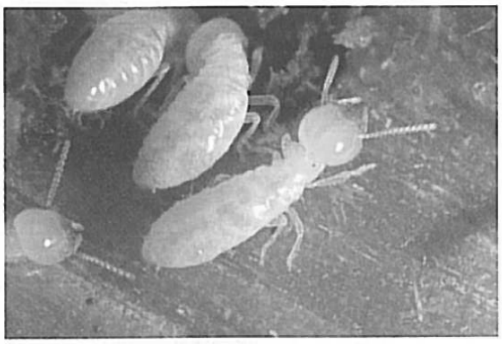
13. [HKDSE Biology 2012 Paper 1B Q4]

Hint: Classify at each step using features recognisable in the diagram.

The following key can be used for identifying organisms under the same phylum:

1a	Absence of eyes	----------	2
1b	A pair of eyes	----------	3
2a	Six legs	----------	Class A
2b	More than six legs	----------	Class B
3a	Six legs	----------	Class C
3b	More than six legs	----------	Class D

(a) Using the above key, identify which class organism X shown in the photograph below belongs to. (1 mark)



(b) Suggest a characteristic of the habitat of organism X. Explain your answer. (2 marks)

(c) A newly found organism Y has a pair of eyes and fewer than six legs. Although it is believed that this organism belongs to this phylum, it cannot be identified by using the above key. Explain why this problem occurs. (1 mark)

(d) Suggest ***one*** way to collect more information which can be used for deciding whether organism Y belongs to this phylum. (2 marks)

Type 2 Infer relationships from molecules, fossils and branching points

Degree of integration ★★★☆☆

Key ideas

① Fewer differences between corresponding sequences in two species can support a more recent common ancestor. Compare equivalent genes or proteins. Relatedness on a tree depends on shared branch points, not how close the printed names are.

② Fossils provide evidence of past forms and ages, but preservation is uneven. Absence of fossils does not prove that an organism never existed.

How to recognise the problem Find the most recent shared branch point, then check whether sequence, fossil or geographical evidence supports that relationship.

Example 1 [HKDSE Biology 2018 Paper 1A Q9]

Which of the following statements provides the best reason for classifying unicellular organisms into domain Bacteria and Archaea?

A. Archaea are more ancient than bacteria.
B. Archaea are smaller than bacteria.
C. The DNA sequences of archaea are distinct from those of bacteria.
D. The compositions of the cell wall and cell membrane of archaea are different from those of bacteria.

Solution **Reading the question and choosing a method**

To make classification reflect evolutionary relationships, look for evidence that allows genetic differences to be compared.

Method: Find the shared branch point, then check the supporting evidence.

Answer: C

DNA sequences allow genetic similarities and differences between organisms to be compared. Molecular differences between bacteria and archaea provide important evidence for separating them, so C best answers the question. Body size alone, or a claim that one group is "older", cannot establish a reliable classification of relationships. Cell-wall and cell-membrane composition also have taxonomic value, but the molecular genetic evidence selected here relates more directly to relatedness. Choose C.

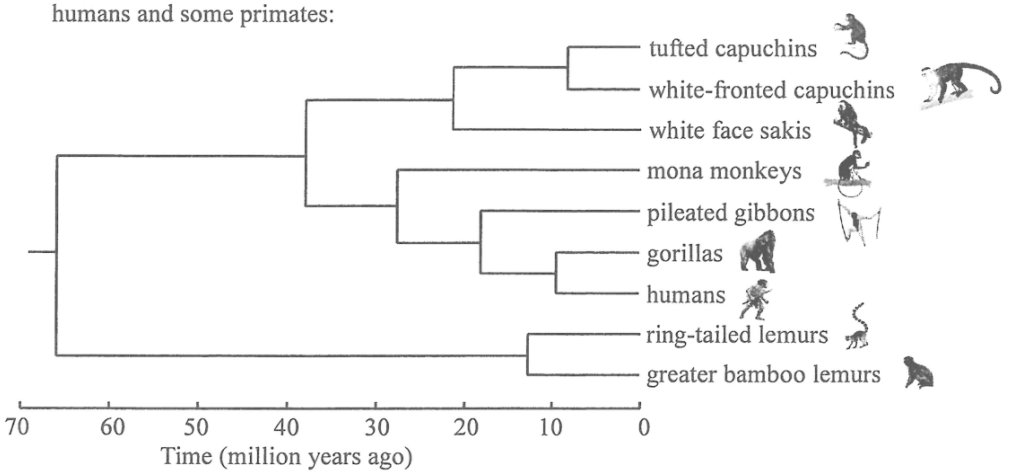
Common error

Treating the suggestion of "ancient" in the name archaebacteria as evidence for classification.

Marking reference: HKDSE Biology 2018 Paper 1A Q9, official marking scheme, source page(s) 1.

Example 2 [HKDSE Biology 2024 Paper 1A Q12]

Directions: Questions 12 and 13 refer to the diagram below, which shows the phylogenetic relationships between humans and some primates:



Which of the following statements about these primates is correct?

A. Pileated gibbons share a common ancestor with gorillas and humans.
B. Gorillas have a closer relationship with ring tailed lemurs than white face sakis.
C. White face sakis are the common ancestor of tufted capuchins and white-fronted capuchins.
D. The difference between gorillas and humans is the same as that of ring-tailed lemurs and greater bamboo lemurs.

Solution **Answer: A**

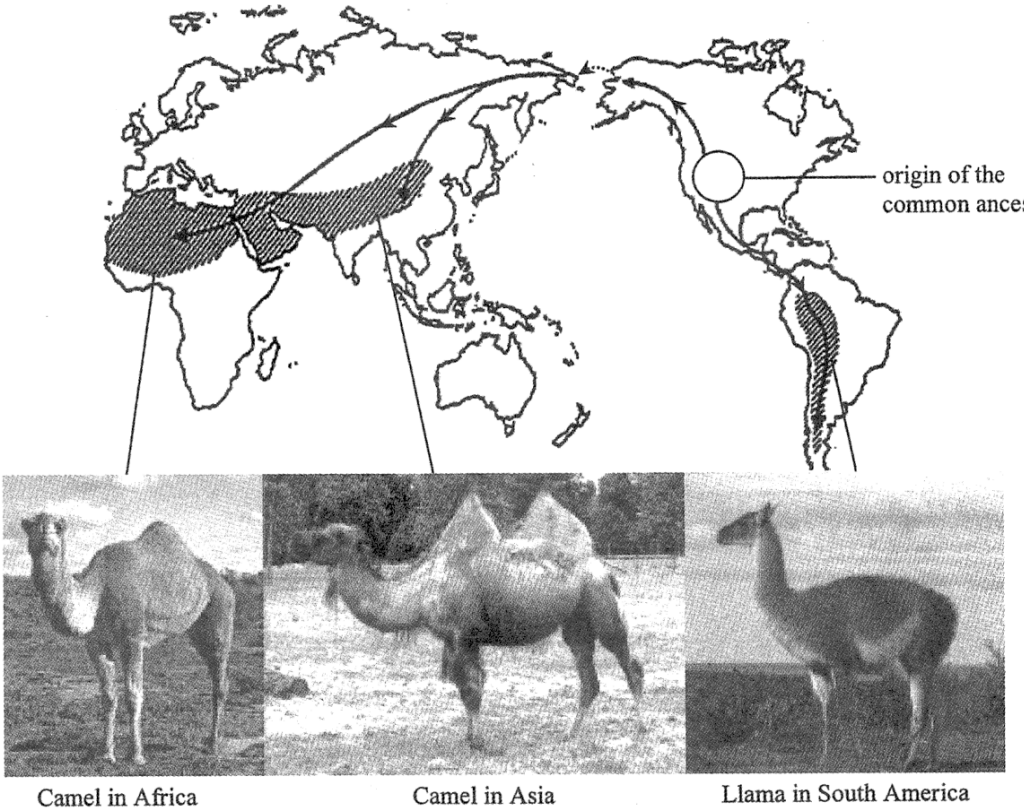
Tracing the branches of the capped gibbon, gorilla and human to the left brings them together, showing that the three share a common ancestor. The living white-faced saki is not the ancestor of another living monkey species. Nor can two pairs of branches be assumed to differ equally merely because both are drawn next to one another. Use divergence times and the information actually provided in the diagram.

Method: Find the shared branch point, then check the supporting evidence.

Marking reference: HKDSE Biology 2024 Paper 1A Q12, official marking scheme, source page(s) 49.

Example 3 [HKDSE Biology 2015 Paper 1B Q10]

Fossil records suggest that camels in Africa and Asia and llamas in South America evolved from a common ancestor 6 million years ago. The diagram below shows the possible migration routes of the common ancestor at the time before the continents were separated and the locations (shaded areas) where the camels and llamas are found at present:



Camel in Africa | Camel in Asia | Llama in South America

(a) Based on the information given, draw a diagram to show the evolutionary tree of the three animals. (2 marks)

Evolutionary tree of camels in Africa and Asia and llamas in South America

(b) Explain how the common ancestor might have given rise to the two different animal species (camels and llamas) in the above case. (4 marks)

(c) Suggest another way to establish the evolutionary relationship among the above animals. (1 mark)

(d) Give *two* limitations of fossil records as evidence for evolution. (2 marks)

Solution (a); original allocation: 2 mark(s)

All three branch from a common ancestor. African and Asian camels join in the more closely related branch, while South American llamas diverge from that lineage earlier.

The migration routes support one camel lineage entering Eurasia and Africa and another entering South America. Use branching points to show common ancestry and relative relatedness. Left and right positions may be exchanged, but the branching relationships cannot be changed arbitrarily.

(b); original allocation: 4 mark(s)

Continental separation geographically isolated the ancestral populations. Different environments in the different regions favoured different advantageous inherited variations through natural selection. Differences accumulated over generations until reproductive isolation developed: the populations could no longer interbreed effectively and had become different species.

Method: Find the shared branch point, then check the supporting evidence.

A complete explanation links isolation, different selection pressures, accumulation of genetic differences and reproductive isolation in that order. The environment does not purposefully create particular mutations to meet an organism's needs. Selection acts on inherited differences that already exist or arise subsequently.

(c); original allocation: 1 mark(s)

Compare DNA sequences or amino acid sequences of important proteins.

Molecular sequences provide measurable genetic similarities that can be considered alongside structural and geographical evidence to infer relatedness.

(d); original allocation: 2 mark(s)

Not all organisms have the opportunity to become fossils. Fossils that do form may later be destroyed or be incomplete.

Fossilisation requires suitable preservation conditions, and fossils remain subject to geological processes afterwards. The fossil record is therefore not a complete, continuous list of ancestors. These two limitations concern formation and subsequent preservation, respectively.

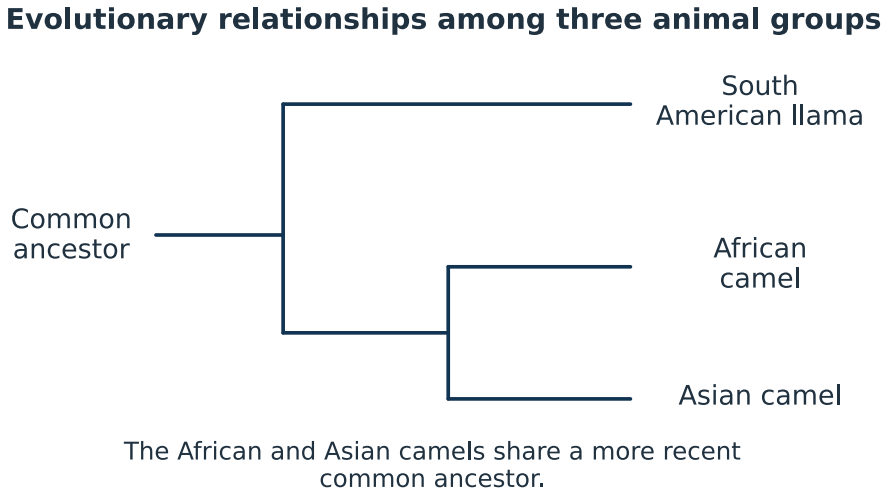


Diagram answer for the original question

Examiner's comment (source page(s) 3)

Connect geographical isolation to restricted gene flow, accumulation of inherited differences and reproductive isolation. Molecular comparisons should specify corresponding DNA sequences or amino acid sequences of the same protein.

Marking reference: HKDSE Biology 2015 Paper 1B Q10, official marking scheme, source page(s) 5.

Practice

1. [HKDSE Biology 2023 Paper 1A Q29]

Hint: Find the shared branch point, then check the supporting evidence.

Directions: Questions 29 and 30 refer to the phylogenetic relationship of five bacterial species. Enzyme X is found in most bacteria. The table below shows the number of nucleotide differences in the genes encoding enzyme X of five bacterial species (J, K, L, M and N):

	J	K	L	M	N
J	0	61	32	112	89
K	-	0	50	119	94
L	-	-	0	119	77
M	-	-	-	0	124
N	-	-	-	-	0

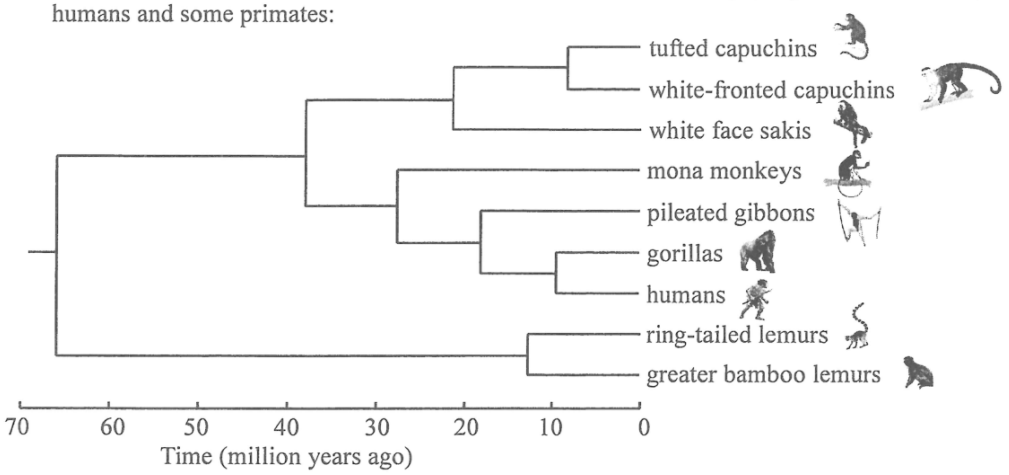
With regard to the phylogenetic relationship to L, arrange the species in the correct order from closely related to distantly related.

A. L, J, K, N, M
B. L, J, M, N, K
C. L, M, N, K, J
D. L, N, M, K, J

2. [HKDSE Biology 2024 Paper 1A Q13]

Hint: Find the shared branch point, then check the supporting evidence.

Directions: Questions 12 and 13 refer to the diagram below, which shows the phylogenetic relationships between humans and some primates:



Which of the following methods can be used to construct the above phylogenetic relationships of the primates?

(1) comparing the fossil records of different primates
(2) comparing the DNA samples from different primates
(3) comparing the key protein samples from different primates

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

3. [HKDSE Biology Practice Paper Paper 1A Q21]

Hint: Find the shared branch point, then check the supporting evidence.

Which of the following is **not** a limitation of the use of fossil records as evidence for evolution?

A. Fossils are damaged and incomplete.
B. Some organisms may not form fossils.
C. Fossils are found in different sedimentary rock layers.
D. Fossils present in inaccessible areas are not available to us for study.

4. [HKDSE Biology 2013 Paper 1A Q20]

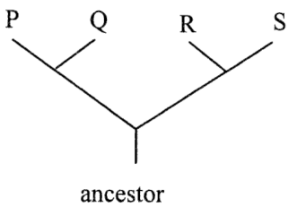
Hint: Find the shared branch point, then check the supporting evidence.

Directions: Questions 19 and 20 refer to the nucleotide sequence of a certain functional gene segment found in four different species of organisms P, Q, R and S:

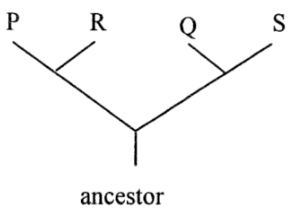
AACGTCGAAA	(organism P)
AACCTCGAAA	(organism Q)
AGGCTAGAAA	(organism R)
AGGCTAGTAA	(organism S)

Based on the above information, which of the following diagrams best represents the evolutionary tree of organisms P, Q, R and S?

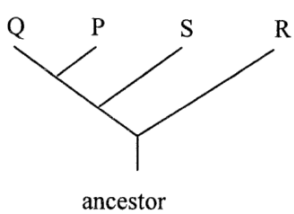
A.



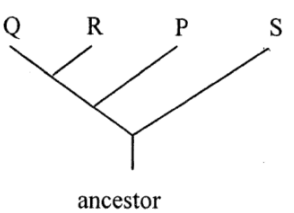
B.



C.



D.

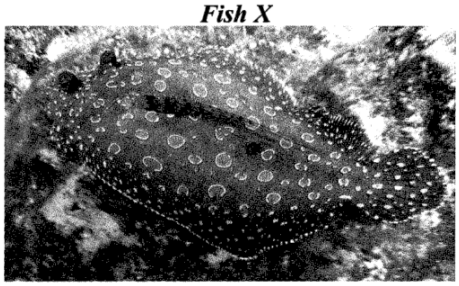


5. [HKDSE Biology 2014 Paper 1A Q18]

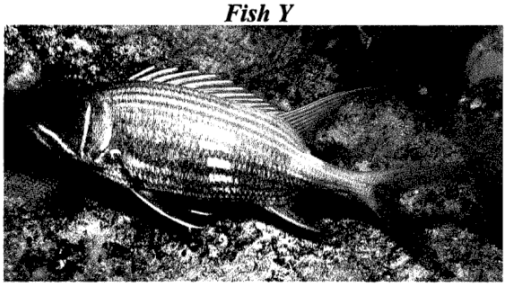
Hint: Find the shared branch point, then check the supporting evidence.

Directions: Questions 17 and 18 refer to the following photographs of two different fish:

Fish X



Fish Y



Which of the following allow further study of the phylogenetic relationship between the two fish?

(1) Compare the amino acid sequences of their functional proteins
(2) Compare their internal body structure
(3) Compare their living habitats and behaviours

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

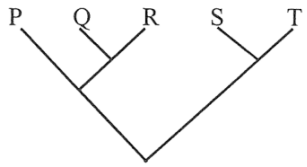
6. [HKDSE Biology 2020 Paper 1A Q15]
Hint: Find the shared branch point, then check the supporting evidence.

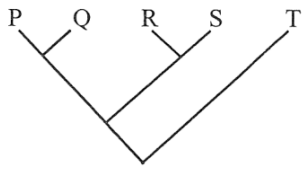
The table below shows the presence or absence of some traits in five species:

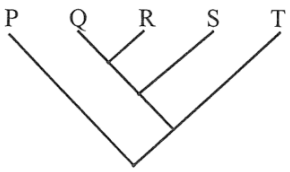
	Trait				
Species	1	2	3	4	5
P	+	+	−	+	−
Q	+	+	−	−	−
R	+	−	−	−	+
S	+	−	+	−	+
T	−	−	−	−	−

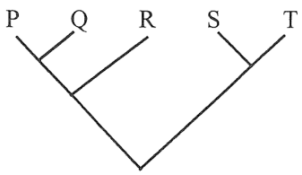
Key:
+ presence of trait
− absence of trait

Which of the following evolutionary trees best illustrates the phylogenetic relationship of the five species?

A.


B.


C.


D.


7. [HKDSE Biology 2022 Paper 1A Q7]
Hint: Find the shared branch point, then check the supporting evidence.

The table below shows the comparison among three groups of organisms X, Y and Z:

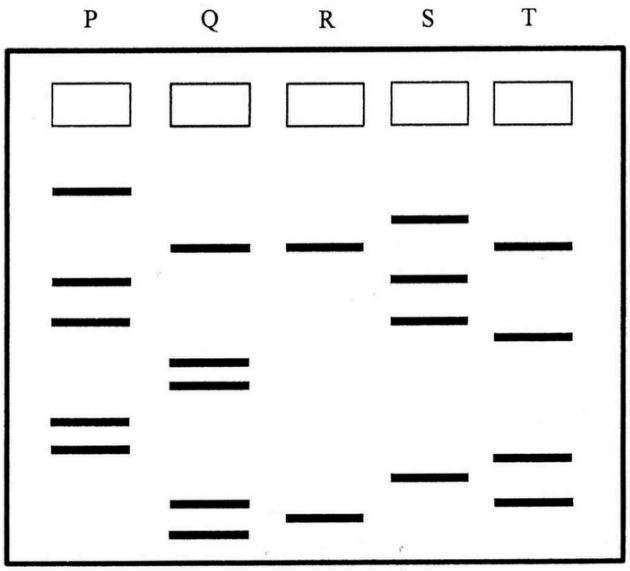
	X	Y	Z
Cell wall	Present	Present	Absent
Similarity of the amino acid sequence of a protein found in all three organisms (X as a reference)	100%	45%	55%

With reference to the information above, which of the following can be deduced?

A. Both X and Y are prokaryotes.
B. Y is least advanced among the three.
C. X has a closer phylogenetic relationship with Z than Y.
D. Y has a closer phylogenetic relationship with Z than X.

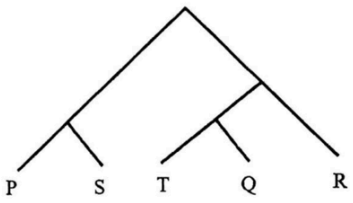
8. [HKDSE Biology 2025 Paper 1A Q28 (English translation)]
Hint: Find the shared branch point, then check the supporting evidence.

Species P, Q, R, S and T all evolved from the same ancestor. Their DNA fingerprints are shown below:

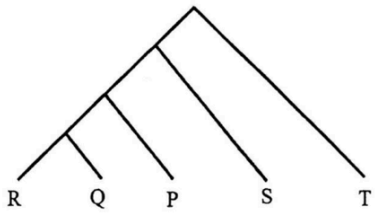


Which evolutionary tree best represents the phylogenetic relationships among these five species?

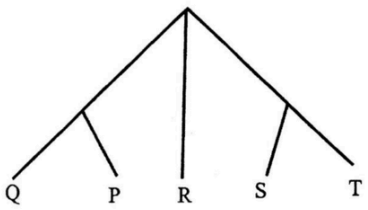
A.



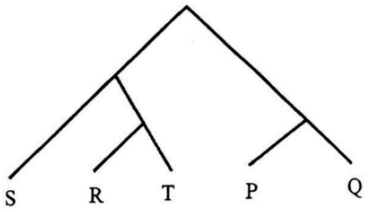
B.



C.



D.



9. [HKDSE Biology 2016 Paper 1A Q14]

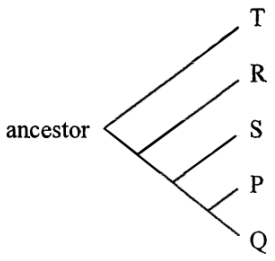
Hint: Find the shared branch point, then check the supporting evidence.

Directions: Questions 14 and 15 refer to the information below. Five new species of eubacteria were discovered in Antarctic ice core samples. The nucleotide sequences of the gene that codes for an essential protein of these new species were compared. The table below shows the number of nucleotide differences between the species:

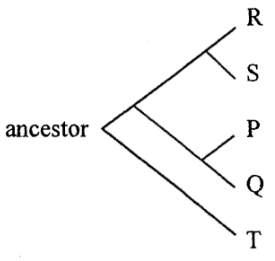
	Number of nucleotide differences				
Species	P	Q	R	S	T
P	-	4	12	11	22
Q		-	12	11	19
R			-	4	22
S				-	22
T					-

Which of the following evolutionary trees best illustrates the phylogenetic relationship of the five species?

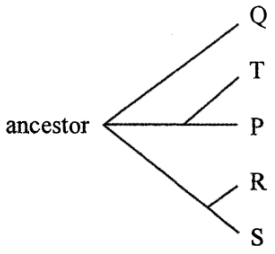
A.



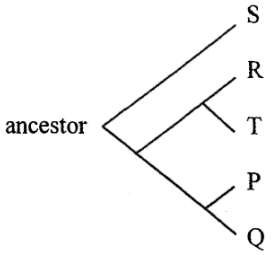
B.



C.



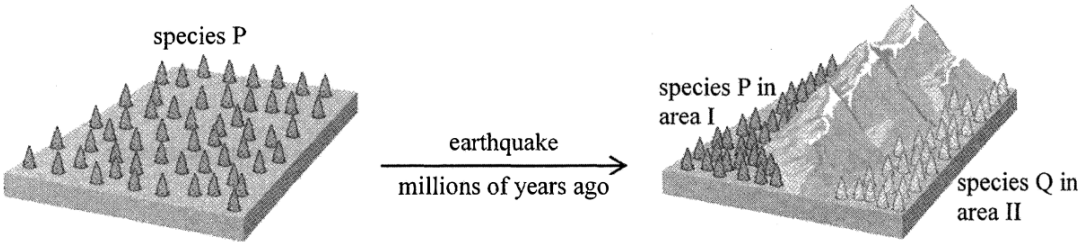
D.



10. [HKDSE Biology 2017 Paper 1A Q11]

Hint: Find the shared branch point, then check the supporting evidence.

Directions: Questions 10 and 11 refer to the diagram below. A high mountain resulting from an earthquake millions of years ago has led to the separation of areas I and II. A new tree species Q is found in area II:



Which of the following descriptions of the above incident is most likely to be correct?

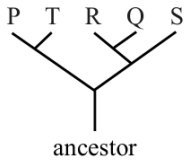
A. Q is more adaptive than P.
B. P grows equally well in areas I and II.
C. Areas I and II have similar environmental conditions.
D. P and Q belong to the same Family in the classification system.

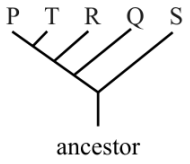
11. [HKDSE Biology Practice Paper Paper 1A Q23]
Hint: Find the shared branch point, then check the supporting evidence.

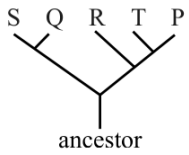
In constructing an evolutionary tree, it is assumed that the more similarities shared between two species, the closer is their phylogenetic relationship. The amino acid sequences of a certain protein in five species of organisms were analysed and compared. The following table shows the number of amino acid differences between the amino acid sequence of species P and that of each of the other four species:

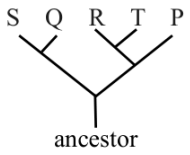
Species	Q	R	S	T
The number of amino acid differences between the amino acid sequence of species P and that of the other species	31	16	36	1

Assuming that these five species of organisms arose from the same ancestral stock, which of the following diagrams best represents the evolutionary tree constructed using the above information?

A. 

B. 

C. 

D. 

Type 3 Explain evolution through variation, reproduction and isolation

Degree of integration ★★★☆☆

Key ideas

① Heritable differences already exist within a population. Environmental conditions give some individuals a better chance of surviving and reproducing, allowing the relevant alleles to increase in later generations. Organisms do not purposefully mutate because they need a trait.

② Prolonged isolation reduces gene flow, and accumulated differences may lead to reproductive isolation. Geographical separation alone does not guarantee different species.

How to recognise the problem Write pre-existing variation → environmental differences → survival and reproduction → inheritance → changing proportions across generations. For new species, add gene flow and reproductive isolation.

Example 1 [HKDSE Biology 2013 Paper 1A Q22]

Which of the following observations is ***not*** related to the process of evolution?

A. Some variations are not inheritable.
B. Organisms compete for resources to survive.
C. Environmental changes give stress to organisms.
D. Variations exist among different individuals of the same species.

Solution **Answer: A**

Natural selection changes the proportions of inherited variations over generations. Variation caused solely by the environment and not passed to offspring cannot accumulate through this mechanism to produce genetic evolution. Competition for resources, environmental pressures and variation among members of the same species are all relevant conditions for natural selection.

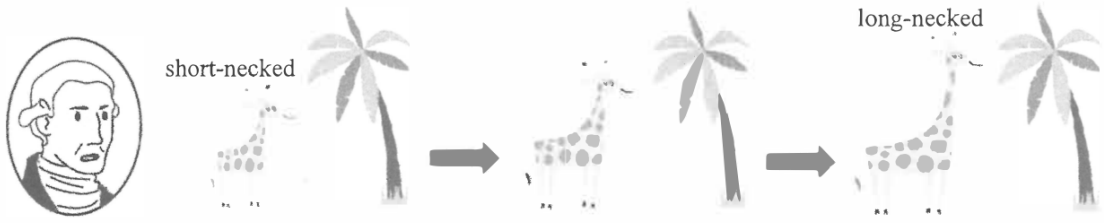
Method: Trace pre-existing variation through reproduction to changing proportions across generations.

Marking reference: HKDSE Biology 2013 Paper 1A Q22, official marking scheme, source page(s) 1.

Example 2 [HKDSE Biology 2018 Paper 1B Q10]

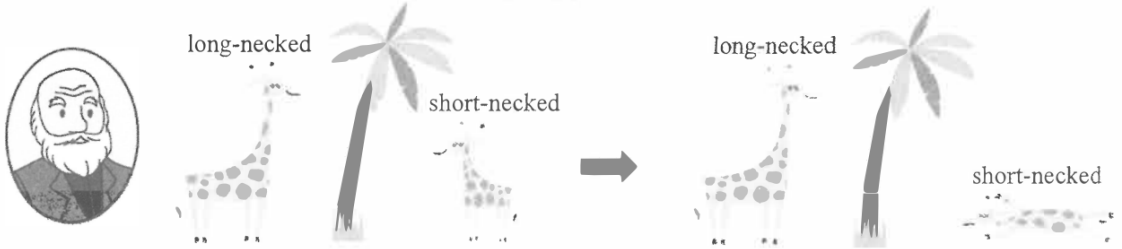
Both Lamarck and Darwin contributed greatly to the understanding of evolution. They proposed different explanations for the evolution of long necks in giraffes, as shown below:

Lamarck's idea about evolution



Long necks evolved as generations of giraffes stretched their necks to feed on leaves at high level above the ground

Darwin's idea about evolution



Giraffes with long necks were born by chance and had more offspring due to their competitive advantage over those with short necks

(a) Put a '✓' in the appropriate box to indicate whether the ideas listed were proposed by the scientists. You may put more than one '✓' for each idea. (2 marks)

	Lamarck	Darwin
Characters acquired during life time can be passed on to the next generation		
Organisms become more adaptive to the environment over the generations		

(b) Based on the current understanding of evolution, elaborate on the view of Darwin on the evolution of the giraffe's long neck. (4 marks)

(c) In Darwin's era, his idea caused intense debates. The concept of humans evolving from common ancestors along with other species was unacceptable to many people due to their religious belief. What does this tell us about the nature of science? (1 mark)

Solution Reading the question and choosing a method

Natural selection changes the proportion of inherited traits in a population. It does not cause individuals to produce a particular variation deliberately because they need it.

✓ *Method: Trace pre-existing variation through reproduction to changing proportions across generations.*

a; original allocation: 2 mark(s)

Acquired characteristics can be inherited: tick Lamarck only. Better adaptation to the environment after several generations: tick both Lamarck and Darwin.

The first row compares the mechanisms proposed by the two explanations. Lamarck's illustration shows changes acquired by an individual through use being passed to offspring; Darwin's illustration does not. The second row describes an outcome that both historical explanations attempted to explain, so both columns apply. Knowing that a theory has problems does not mean every statement in its column should be left unticked.

b; original allocation: 4 mark(s)

The original giraffe population already contained inherited differences in neck length. In the environment shown, with food high above the ground, longer-necked individuals could obtain food more easily and therefore had a greater chance of surviving and producing offspring. Their offspring could inherit the advantageous neck-length trait. Over many generations, the proportion of longer-necked individuals in the population gradually increased. Begin with existing variation, not a desire to eat leaves high up. Next, connect the environmental conditions to differences in access to resources. Then include reproduction and inheritance: surviving longer alone does not explain why the trait becomes more common among offspring. The final change concerns proportions in the population across generations. One giraffe stretching its neck during its lifetime does not constitute this evolutionary process.

c; original allocation: 1 mark(s)

Science is related to its social and cultural context, and acceptance of scientific ideas can be influenced by social and cultural factors.

The question specifically mentions religious beliefs influencing public acceptance of evolution. Identify the development of science within a social and cultural setting. Do not replace this with a claim that an unpopular theory must be scientifically wrong.

Examiner's comment (source page(s) 6)

Natural selection changes the proportion of inherited traits in a population. Merely saying that the number of longer-necked individuals increases does not fully explain the change relative to shorter-necked individuals.

Marking reference: HKDSE Biology 2018 Paper 1B Q10, official marking scheme, source page(s) 4, 5.

Example 3 [HKDSE Biology 2025 Paper 1B Q4 (English translation)]

In 1859, Alfred Russel Wallace proposed Wallace's line, an imaginary boundary separating the biogeographical regions of Southeast Asia and Australia. He noticed marked differences in some terrestrial animal species on the two sides of this imaginary line, as shown below:



(a) Mammals originating in Asia are mainly placental mammals (e.g. tigers and elephants), whereas those originating in Australia are mainly marsupials with pouches (e.g. koalas and kangaroos). Using your knowledge of evolution, explain this difference in mammalian distribution between the two regions. (3 marks)

(b) Suggest a class of vertebrates occurring on both sides of Wallace's line that does not show marked differences. Explain your answer. (2 marks)

Solution (a); original allocation: 3 mark(s)

Method: Trace pre-existing variation through reproduction to changing proportions across generations.

The distant ancestors of the mammals on the two sides became geographically isolated. Abiotic and / or biotic conditions in Australia were more favourable to the survival of marsupials. The populations on the two sides evolved independently over a long period, producing different species or structures.

The three marking points are isolation, differences in environmental selection and evolutionary divergence accumulated over generations. Do not merely repeat which side of the map contains kangaroos, or treat Wallace's line as a direct cause of mutation.

(b); original allocation: 2 mark(s)

For example, birds can fly across geographical barriers such as sea channels and disperse to both sides, so this boundary is unlikely to isolate them completely.

The question specifies vertebrates, not only mammals. Bats, suitable fish or marine mammals are also acceptable if their ability to fly or swim is explicitly linked to overcoming isolation. One mark is awarded for an appropriate animal group and one for explaining its ability.

Examiner's comment (source page(s) 72)

Evolutionary differences can accumulate after geographical isolation. Do not describe adaptation as an individual instantly remodelling its body because it needs to. Vertebrates may cross barriers by flying or swimming; insects are not vertebrates.

Marking reference: HKDSE Biology 2025 Paper 1B Q4, official marking scheme, source page(s) 54.

Example 4 [HKDSE Biology 2021 Paper 1B Q11]

You are required to present your answer to the following question in essay form. Criteria for marking will include relevant content, logical presentation and clarity of expression.

Variations are important to the continuity of a population. Discuss how these variations are brought about within a population and how variations can enable the population to cope with the diverse environmental conditions and environmental changes over time. (11 marks)

Solution Essay; original allocation: 11 mark(s)

Method: Trace pre-existing variation through reproduction to changing proportions across generations.

Variation arises from genetic recombination, mutation and environmental effects. It allows a population to use different resources and respond to environments that change over time. Individuals in the same population are not identical in all their traits. In sexual reproduction, gametes are produced by meiosis. Independent assortment of homologous chromosomes produces gametes with different chromosome combinations, while crossing over between homologous chromosomes recombines alleles. Random fusion of different eggs and sperm further produces zygotes with different combinations of parental genetic material. Offspring of the same species can therefore show many genetic differences.

Mutation can produce new alleles and is a source of new genetic variation. The environment also affects traits: for example, plants of the same variety may grow to different sizes under different light or nutrient conditions. Such environmentally caused phenotypic differences are not necessarily inherited and must not be confused with new alleles.

At a given time, differences among individuals may make them better at using different resources or occupying slightly different ecological niches, reducing competition. For example, individuals with different feeding structures or preferences may use foods of different sizes or types.

When the environment changes over time, existing inherited variation supplies the material for natural selection. Individuals with traits better suited to the new conditions are more likely to survive and reproduce, passing favourable alleles to their offspring. Less well-suited individuals leave fewer offspring. Over many generations, the proportion of favourable traits may rise, increasing the population's chance of persistence. The environment does not

direct the creation of new traits according to an individual's needs; it causes differences in reproductive success among existing variants.

The marking reference limits content marks to 5 for sources of variation and 3 for its importance, with a further 0–3 marks for communication and organisation. A complete essay should therefore connect sources of variation, resource use under different conditions and selection under changing conditions into a causal account, rather than merely listing terms.

Examiner's comment (source page(s) 7)

Crossing over occurs between non-sister chromatids of homologous chromosomes. Sister chromatids initially are identical copies produced by DNA replication. Variation exists first, and the environment then favours better-suited individuals. Do not claim that a particular variation appears only when the environment requires it.

Marking reference: HKDSE Biology 2021 Paper 1B Q11, official marking scheme, source page(s) 6.

Practice

1. [HKDSE Biology 2014 Paper 1A Q13]

Hint: Trace pre-existing variation through reproduction to changing proportions across generations.

The average height of men in a developed country rose by 10 cm between 1890 and 1980. Which of the following is the most probable reason for this observation?

A. Chemical pollution induced mutations leading to the increase in height.
B. Spontaneous mutation resulted in a shift to taller height.
C. The better nutrition supply promoted growth.
D. A taller height had a better chance of survival.

2. [HKDSE Biology 2020 Paper 1A Q16]

Hint: Trace pre-existing variation through reproduction to changing proportions across generations.

Australia has some plant and animal species which cannot be found elsewhere in the world. Which of the following is likely to be the key factor that led to the occurrence of these unique plant and animal species in Australia?

A. isolation
B. mutation
C. competition
D. environmental stress

3. [HKDSE Biology 2024 Paper 1A Q11]

Hint: Trace pre-existing variation through reproduction to changing proportions across generations.

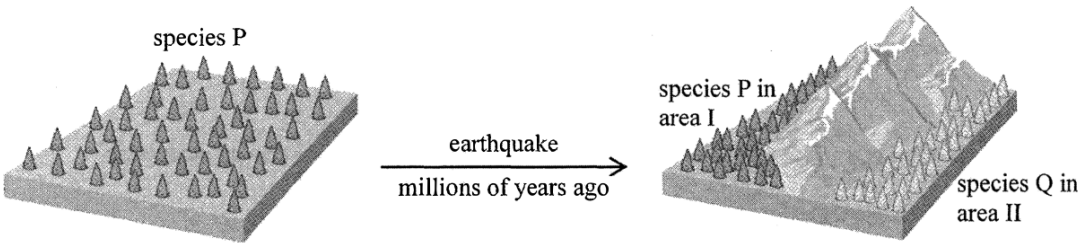
Sharks are considered 'living fossils' because their appearance closely resembles shark fossils from millions of years ago. Which of the following is the most likely reason for the close resemblance?

A. Sharks have few predators.
B. Sharks have a wide range of prey.
C. A shark's body is well-adapted to the ocean environment.
D. A shark's body is most advanced as compared to other species in oceans.

4. [HKDSE Biology 2017 Paper 1A Q10]

Hint: Trace pre-existing variation through reproduction to changing proportions across generations.

Directions: Questions 10 and 11 refer to the diagram below. A high mountain resulting from an earthquake millions of years ago has led to the separation of areas I and II. A new tree species Q is found in area II:



Which of the following processes were likely to have been involved in the formation of new species Q?

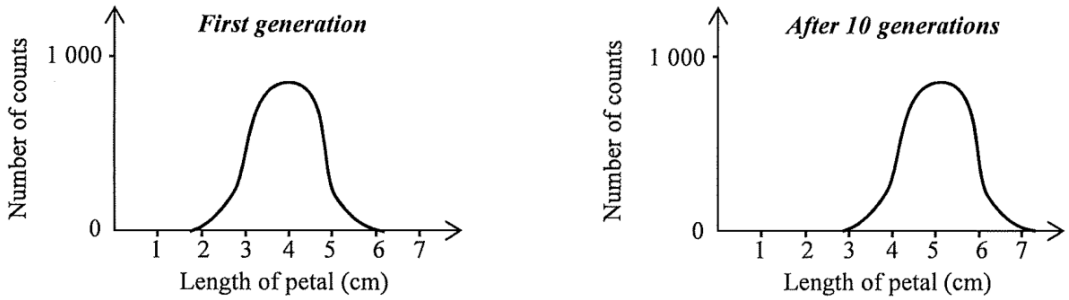
(1) mutation
(2) isolation
(3) natural selection

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

5. [HKDSE Biology 2023 Paper 1A Q25]

Hint: Trace pre-existing variation through reproduction to changing proportions across generations.

Directions: Questions 24 and 25 refer to the information about the introduction of a foreign plant species to a local botanic garden. Over the years, the gardener noted that there was a change in the size of its flowers. The graphs below show the variations of the petal length of this plant species in the first generation and after 10 generations:

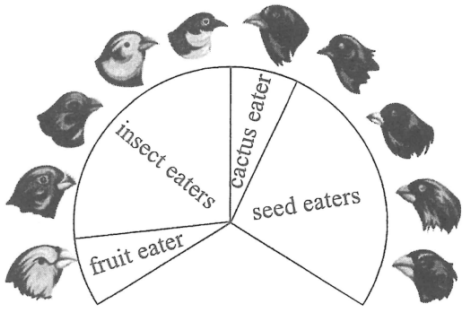


Which of the following is the most probable explanation for the change in the petal length of this plant species?

A. Larger flowers produce more nectar.
B. Local climate favours the growth of this plant species.
C. Local insects are attracted by flowers with longer petals.
D. Mutations occur and accumulate throughout the 10 generations.

6. [HKDSE Biology 2024 Paper 1A Q14]
⟵ *Hint: Trace pre-existing variation through reproduction to changing proportions across generations.*

Darwin's finches are a group of small birds isolated on the Galapagos Islands. These birds show variations in forms and function of their beak as shown in the diagram below:

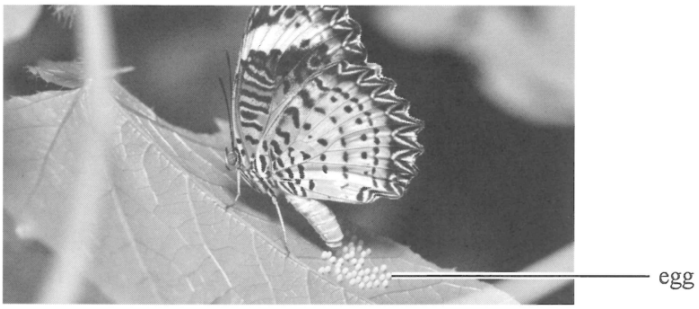


What is the significance of these variations to the survival of Darwin's finches on the Galapagos Islands?

A. The variations promote natural selection.
B. They can distinguish each other by their beaks.
C. They interbreed to produce offspring with more variations.
D. They have different ecological niches to reduce competition.

7. [HKDSE Biology 2024 Paper 1A Q35]
⟵ *Hint: Trace pre-existing variation through reproduction to changing proportions across generations.*

Directions: Questions 34 and 35 refer to some information about the interaction among three organisms: butterflies, plant species X and ants. Butterflies lay eggs on the leaf surfaces of plant species X. When caterpillars hatch from the eggs, they feed on the leaves. Plant species X secretes a sugary solution on their leaves. Ants are attracted to feed on the sugary solution and the eggs.



It is believed that the ancestors of plant species X did not possess the structure to secrete a sugary solution on their leaves. Which of the following are the possible reasons that could have led to the emergence of this structure in plant species X?

(1) Spontaneous mutations of leaf cells of the ancestors.
(2) Gene mutation during meiotic cell division of the ancestors.
(3) Individuals with this structure survived better than those without this structure.

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

8. [HKDSE Biology Practice Paper Paper 1A Q12]
⟵ *Hint: Trace pre-existing variation through reproduction to changing proportions across generations.*

Which of the following processes may increase the variation of a particular character within a population?

A. the mutation of genes
B. the separation of homologous chromosomes during meiosis
C. the independent assortment of homologous chromosomes during meiosis
D. the random fertilisation of gametes

9. [HKDSE Biology Practice Paper Paper 1A Q22]
Hint: Trace pre-existing variation through reproduction to changing proportions across generations.

Which of the following are necessary for speciation?

(1) the competition within a species
(2) the existence of variation within a species
(3) different populations of a species being isolated for a long time

A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

10. [HKDSE Biology 2023 Paper 1B Q11]
Hint: Trace pre-existing variation through reproduction to changing proportions across generations.

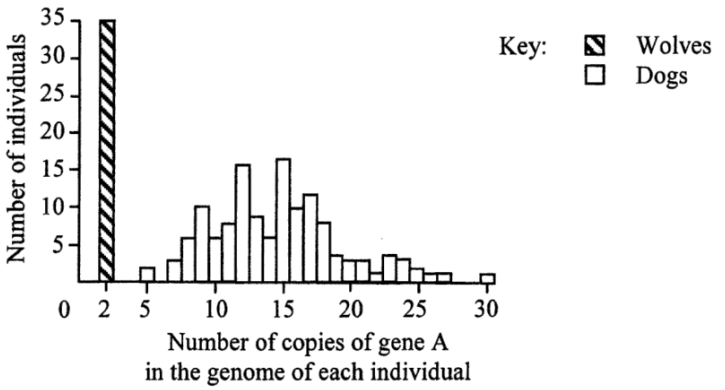
You are required to present your answer to the following question in essay form. Criteria for marking will include relevant content, logical presentation and clarity of expression.

In agricultural practice, some crops are reproduced asexually to improve production efficiency. An increase in yield of these crops is observed in recent years due to a steady increase in the average global temperature. Meanwhile, some scientists worry that crops reproduced asexually are at high risk of extinction due to environmental changes and diseases if global warming persists.

Explain the increased yield of these crops due to global warming and the rationale behind the concern of the scientists. (11 marks)

11. [HKDSE Biology 2014 Paper 1B Q6]
Hint: Trace pre-existing variation through reproduction to changing proportions across generations.

It is generally believed that domestic dogs evolved from ancient wolves. A recent study comparing the genomes of wolves and dogs suggests that genes with key roles in starch digestion were selected during the domestication of wolves into dogs. One of these genes was gene A, which codes for amylase. This gene may exist in many copies in a genome. The following graph shows the number of individuals having different numbers of copies of gene A in 35 wolves and 136 dogs:



(a) Based on the data above and the gene expression processes, explain why the amylase activity in dogs is generally higher than that in wolves. (3 marks)

(b) It is hypothesized that in ancient times, wolves might have been attracted to waste dumps near early human settlements and consumed human food waste. Suggest how the domestication of wolves would have led to the selection of multiple copies of gene A. (5 marks)

(c) Describe an experiment which can compare the different amylase activities of wolves and dogs. (4 marks)

12. [HKDSE Biology 2022 Paper 1B Q10]

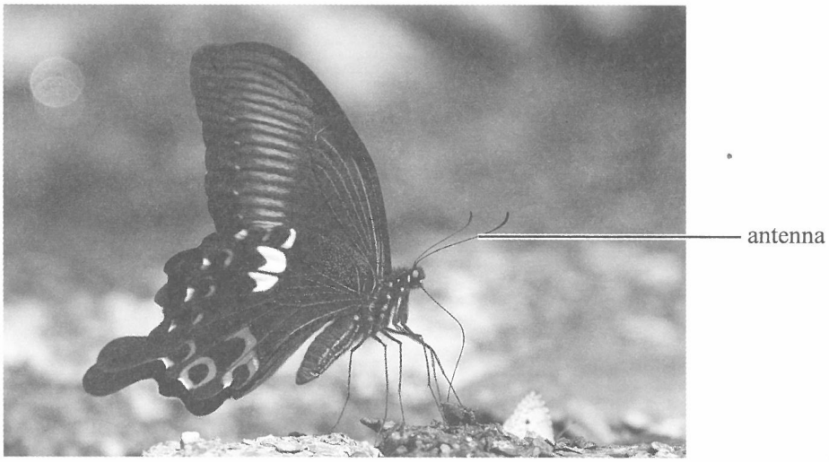
Hint: Trace pre-existing variation through reproduction to changing proportions across generations.

Habenaria is a genus of orchids with dull-coloured and scented flowers, which attract moths for pollination at night. In the group, *H. rhodocheila* is an exceptional species with reddish flowers which lack a detectable scent. It was found that no insects visited the flowers of *H. rhodocheila* at night for pollination while insect species A consumed nectar from the flowers in the daytime.

(a) The following dichotomous key can be used to identify the group to which insect species A belongs:

1a	with wings	.....	2
1b	without wings	.....	Group P
2a	antennae longer than head	.....	3
2b	antennae shorter than head	.....	Group Q
3a	wings rest at their sides	.....	Group R
3b	wings rest together upright	.....	Group S

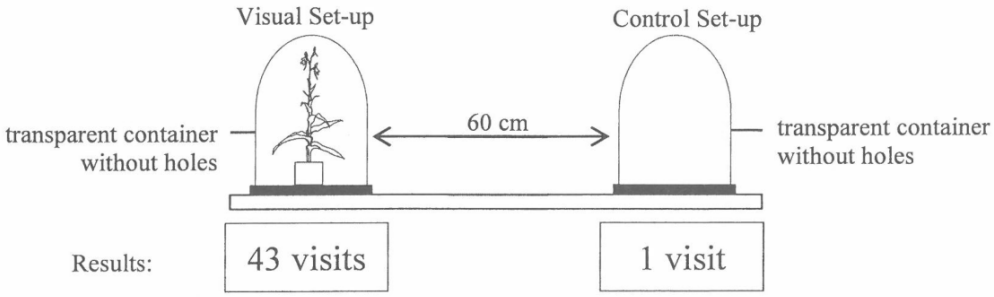
The photograph below shows the appearance of species A at rest. Using the above key, write down the sequence which leads to the identification. (1 mark)



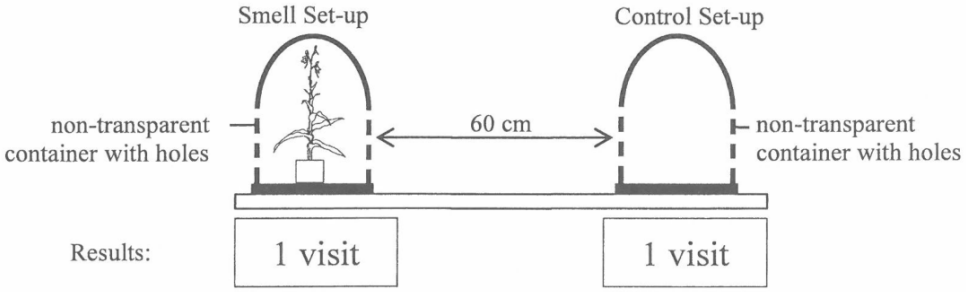
(b) In this case, *H. rhodocheila* was evolved from other *Habenaria* species. Suggest how the speciation of *H. rhodocheila* could be facilitated by different insect pollinators. (3 marks)

(c) To determine if insect species A is attracted to the flowers of *H. rhodocheila* by its appearance or its smell (if any), researchers designed an investigation as shown in the diagrams below:

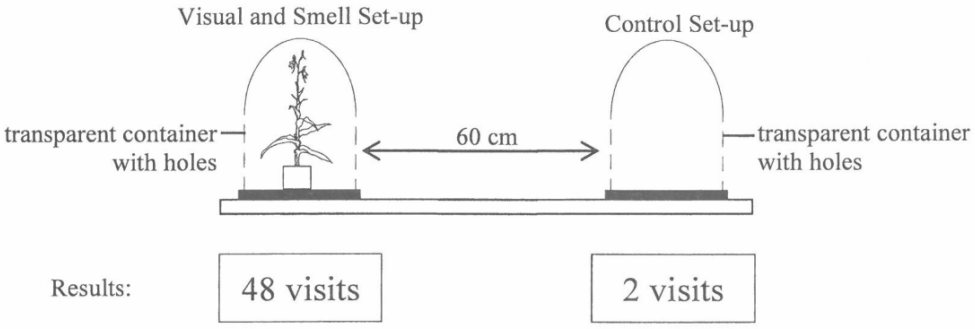
Treatment 1:



Treatment 2:



Treatment 3:



In each treatment, two set-ups were placed in an open area at a distance of 60 cm from each other for one hour. After that, the position of the two set-ups was exchanged for another hour. During the two-hour period, if an individual of species A approached any set-up to a distance of less than 10 cm, it was counted as one visit. The number of visits to each set-up is shown in the boxes in the above diagrams.

(i) To ensure that the investigation was a fair test, exchanging the positions of the two set-ups was a necessary step. Explain why. (1 mark)

(ii) With reference to the aim of the investigation, what conclusions can you draw from the results of Treatment 1 and Treatment 2 respectively? (4 marks)

.....

.....

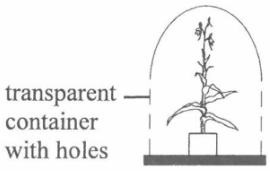
.....

(iii) When Ann and Ken compared the results of the three treatments, they had different interpretations. Ann thought that the larger number of visits in Treatment 3 might reflect a synergistic effect of visual and smell attractions while Ken thought that it might be simply due to random variations. To verify Ann's idea, they decided to conduct a further investigation with two more treatments for comparison.

The diagrams below show the Visual and Smell Set-up. In each treatment, complete the corresponding Control Set-up by putting a '✓' in the appropriate boxes to show the conditions that should be adopted. (2 marks)

Treatment 4:

Visual and Smell Set-up



Conditions for the corresponding Control Set-up:

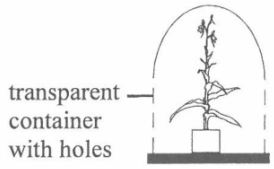
☐ with plant ☐ without plant

☐ transparent container ☐ non-transparent container

☐ container with holes ☐ container without holes

Treatment 5:

Visual and Smell Set-up



Conditions for the corresponding Control Set-up:

☐ with plant ☐ without plant

☐ transparent container ☐ non-transparent container

☐ container with holes ☐ container without holes

Chapter 9

Life processes: question types and practice

III.a Essential life processes in plants

First read the explanations and diagrams in Concept III.a, then work through the question types in this section. Each worked example retains the complete original question and explanation. The subsequent exercises require progressively more integration of information, based on the demands of the whole question.

Type 1 Explain plant transport and support from root, stem and vascular structures

Degree of integration ★★★☆☆

Key ideas

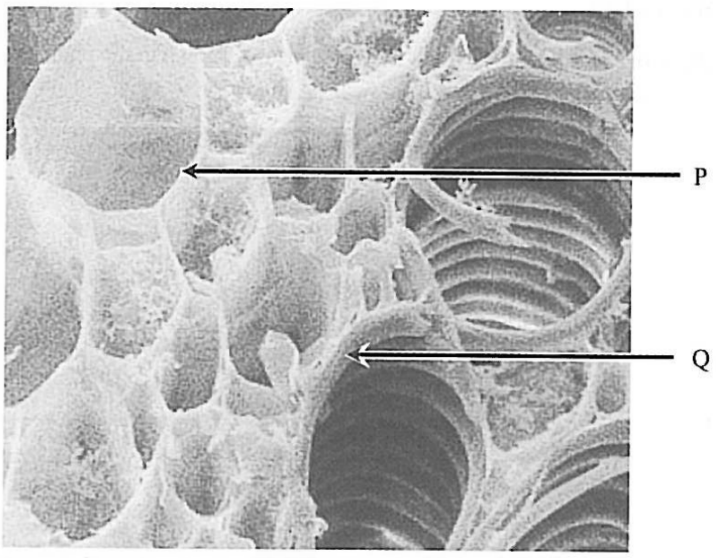
① Root hairs increase contact area with the soil. Mineral-ion uptake may require metabolic energy, while water enters down a water-potential gradient. Continuous hollow xylem vessels allow water flow. Their lignified walls support the plant and prevent collapse under tension.

② Phloem transports organic nutrients, so removing it differs from cutting xylem. A low-power plan shows tissue distribution rather than individual cells.

How to recognise the problem Identify tissues from position and structure, then trace the transported substances. For support, distinguish turgor pressure from lignified walls.

Example 1 [HKDSE Biology 2012 Paper 1B Q3]

The electron micrograph below shows part of the stem of a plant containing two cell types, P and Q:



(a) Based on the photograph shown, state the difference between cell types P and Q in the structure indicated by the arrow heads. (1 mark)

(b) Describe how these cells contribute to the support of the plant. (4 marks)

Solution a; original allocation: 1 mark(s)

Cell Q has a thicker cell wall than cell P.

Compare the cell walls in the photograph directly. Do not mistake the cavity in the centre of a cell for the thickness of its wall.

b; original allocation: 4 mark(s)

When water is available, P absorbs water and becomes turgid, providing support through turgor pressure. Q has a thick, rigid cell wall that provides mechanical support.

P is a living cell with a relatively thin wall. As water enters its vacuole by osmosis, the cell contents press outwards against the wall. The opposing force from the wall establishes turgor, keeping the tissue firm. Q has a thick, strong cell wall that can resist compression even when its central cavity contains no living cell contents. One mark each is allocated to P becoming turgid, support through turgor, Q having a thick wall, and support from the rigidity of that wall.

Examiner's comment (source page(s) 1)

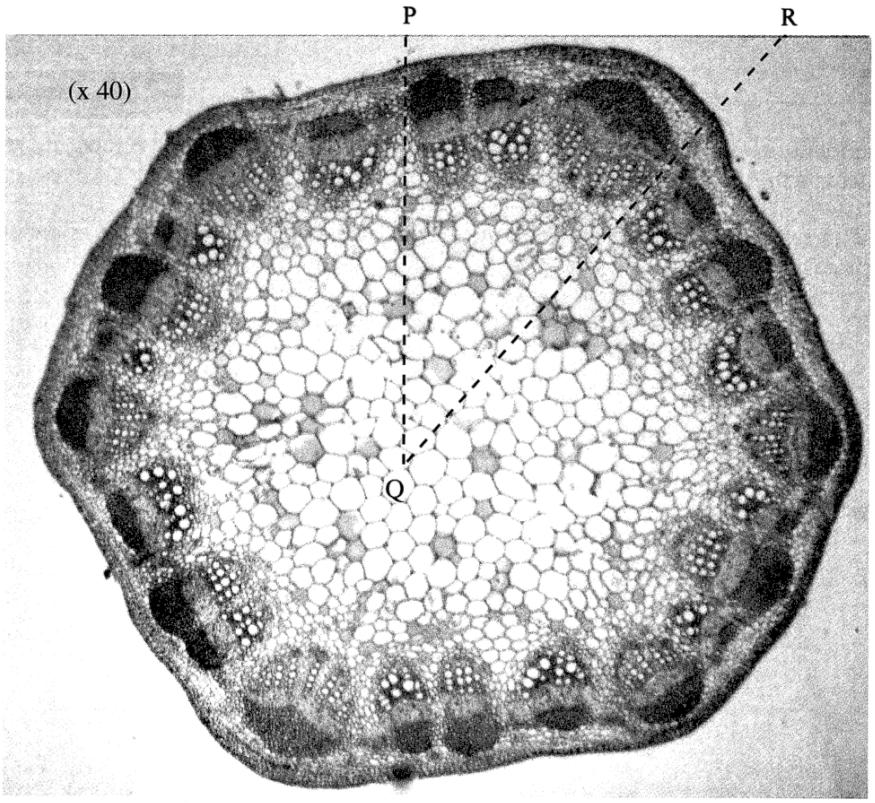
A comparison of the photograph must explicitly refer to cell-wall thickness. The question asks about support, so an answer about transport in phloem or xylem does not address it.

Marking reference: HKDSE Biology 2012 Paper 1B Q3, official marking scheme, source page(s) 2.

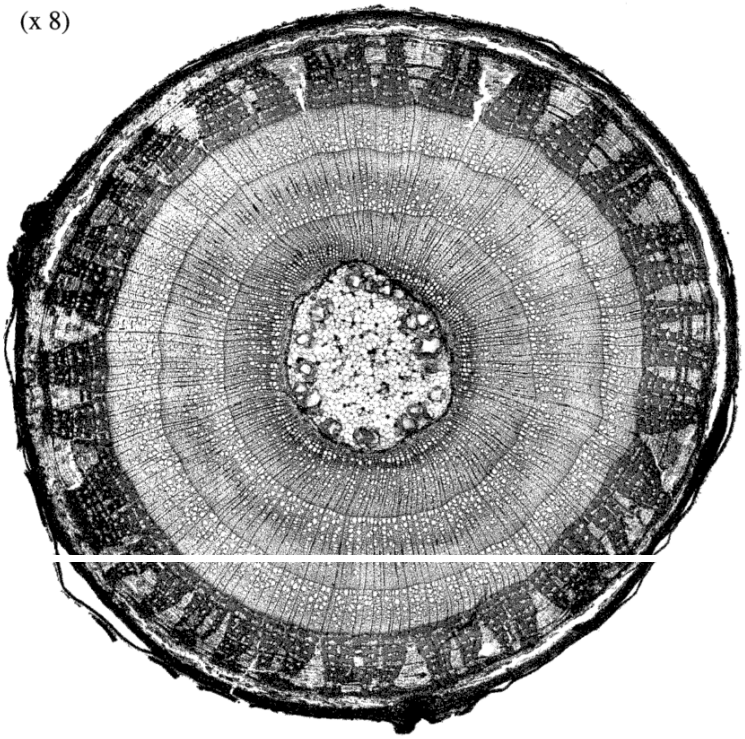
Method: Identify tissue position, then trace transport or support.

Example 2 [HKDSE Biology 2014 Paper 1B Q4]

Photomicrograph A – Stem of plant A



Photomicrograph B – Stem of plant B



4. Cross sections of the stems from two different dicotyledonous plants, A and B, are shown in Photomicrograph A and Photomicrograph B on the opposite page.

(a) With reference to Photomicrograph A, draw a labelled low-power diagram of sector PQR in the space below. (5 marks)

(b) With reference to the photomicrographs, deduce the major means of support in plants A and B. (4 marks)

Solution a; original allocation: 5 mark(s)

Draw the overall tissue outlines within sector PQR, with the title 'Low-power plan of a transverse section of the stem of plant A'. From the outside inwards, label the epidermis, cortex, sclerenchyma in the vascular bundles, phloem, xylem and central pith, identifying at least three accurately.

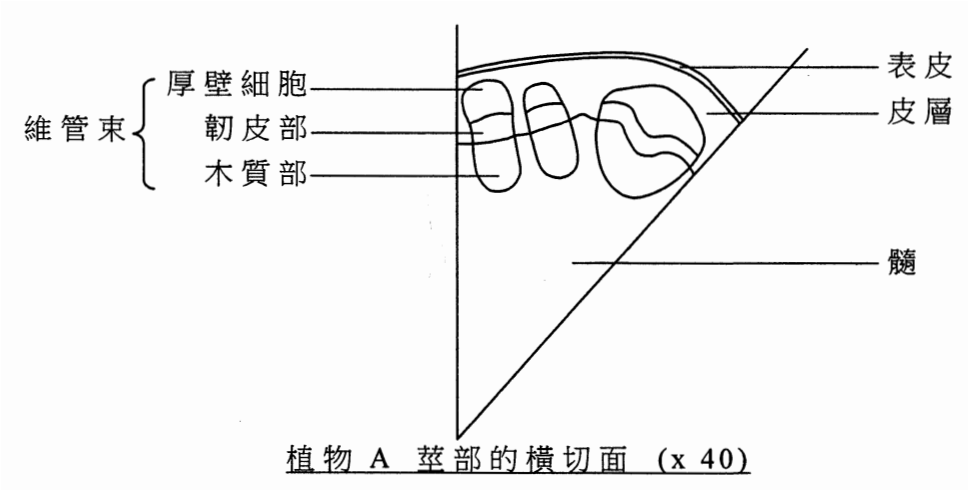
A low-power plan shows the relative positions and proportions of tissue regions, without drawing individual cells. The curved outer boundary, positions of the vascular bundles and central pith must match the photograph. The title earns 1 mark, resemblance to the specimen 1 mark, and three appropriate labels 1 mark each. The official answer diagram below allows direct comparison of the outlines and label lines.

Method: Identify tissue position, then trace transport or support.

b; original allocation: 4 mark(s)

Plant A contains more parenchyma cells. Water uptake makes these cells turgid, keeping the tissue firm and providing support. Plant B contains a large amount of xylem and thick-walled, lignified tissue; its rigid cell walls provide mechanical support.

The explanation is not simply that both plants have cell walls and therefore have the same support mechanism. A depends more on the water content and turgor of living cells. In B, the walls of abundant lignified tissue continue to provide support even after the cells die at maturity. For each plant, 1 mark is allocated to the structure and 1 to the mechanism.



Official example of a low-power plan: draw tissue outlines only and place labels according to the proportions and positions in the original photograph.