DSE Biology Compulsory Part

Frequently Asked 2-4 Marks Long Questions by Topic
With Model Answers

Compiled from DSE (2012-2025), HKCEE (1984-2011), and HKAL (1984-2013) Past Papers

Part I: Cells and Molecules of Life

1.1 Molecules of Life

Food Tests (Benedict's Test / Iodine Test / Biuret Test)

Frequency: Very High - DSE 2012, 2014, 2015, 2016, 2022, 2023; HKCEE 1990, 1993, 2000, 2003, 2007; HKAL multiple years

Q1. Describe the procedures and expected results of the Benedict's test for reducing sugars. **(3 marks)**

Source: DSE 2016 MC3; HKCEE multiple years

Model Answer:

- Add Benedict's solution to the food sample in a test tube. (1)

- Heat the mixture in a water bath at about 80°C for a few minutes. (1)

- If reducing sugars are present, the colour changes from blue to green/yellow/orange/brick-red precipitate. (1)

Q2. A student performed the iodine test on a food sample. Describe the expected colour change and explain what this indicates. **(2 marks)**

Source: DSE 2015 MC11-12; HKCEE 2003

Model Answer:

- Add iodine solution to the food sample; if starch is present, the colour changes from brown/yellow to blue-black. (1)

- This indicates the food sample contains starch. (1)

Q3. Design an experiment using food tests to identify the nutrients present in an unknown food sample. State the reagent, procedure, and expected results. **(4 marks)**

Source: DSE 2014 B6c; HKCEE 1990, 2000

Model Answer:

- For reducing sugars: add Benedict's solution and heat in water bath; positive result = brick-red precipitate. (1)

- For starch: add iodine solution; positive result = blue-black colour. (1)

- For protein: add Biuret reagent (NaOH then CuSO4); positive result = purple/violet colour. (1)

- For lipids: rub sample on filter paper; positive result = translucent/greasy spot that does not disappear. (1)

Q4. Explain why Benedict's test gives a negative result with sucrose but a positive result after the sucrose has been treated with acid. **(3 marks)**

Source: HKCEE 1998; HKAL 2000

Model Answer:

- Sucrose is a non-reducing sugar, so it cannot reduce Benedict's solution directly. (1)

- Acid treatment hydrolyses sucrose into glucose and fructose (by breaking the glycosidic bond). (1)

- Glucose and fructose are reducing sugars, which can reduce Benedict's solution to give a brick-red precipitate. (1)

Structure and Properties of Biomolecules

Frequency: High - DSE 2013, 2016, 2019, 2021, 2024; HKAL 1995, 1999, 2003, 2007

Q1. Describe two structural differences between starch and cellulose. Explain how these differences relate to their functions. **(4 marks)**

Source: DSE 2013 B10; HKAL 1999

Model Answer:

- Starch has a coiled/branched structure (amylose/amylopectin), making it compact for energy storage. (2)

- Cellulose has straight, unbranched chains with hydrogen bonds between adjacent chains, forming microfibrils. (1)

- This gives cellulose high tensile strength, making it suitable as a structural component of plant cell walls. (1)

Q2. Explain how the structure of a protein molecule is related to its function, using one named example. **(3 marks)**

Source: DSE 2013 B10; HKAL 1995, 2003

Model Answer:

- Proteins have a specific 3D conformation (shape) determined by the sequence of amino acids and folding pattern. (1)

- E.g. Haemoglobin: has a quaternary structure with four polypeptide subunits, each containing a haem group with iron. (1)

- The specific shape of haemoglobin allows it to bind reversibly with oxygen, enabling efficient oxygen transport. (1)

Q3. State two functions of lipids in the human body and explain how the properties of lipids enable them to perform these functions. **(4 marks)**

Source: DSE 2016 B9; HKAL 2007

Model Answer:

- Energy storage: lipids store more energy per unit mass than carbohydrates because they have a higher proportion of C-H bonds. (1+1)

- Thermal insulation: subcutaneous fat layer under the skin is a poor conductor of heat, helping to conserve body heat / maintain body temperature. (1+1)

Q4. Explain why water is important for living organisms. Give two properties of water and relate each to a biological function. **(4 marks)**

Source: HKAL 1995, 2005; DSE Essay topic

Model Answer:

- Water is a good solvent (due to its polarity) — it dissolves ions and polar molecules, serving as a transport medium (e.g. blood plasma transports nutrients and wastes). (1+1)

- Water has a high specific heat capacity — it absorbs a lot of heat with only a small rise in temperature, helping to maintain a stable body/environmental temperature. (1+1)

Diet and Nutrition

Frequency: Medium - DSE 2016, 2018, 2021; HKCEE 1994, 1999, 2005

Q1. A person's diet consists mainly of rice and vegetables. Explain why this diet may lead to nutritional deficiency. Suggest how the diet could be improved. **(3 marks)**

Source: DSE 2016 M5-6; HKCEE 1999

Model Answer:

- This diet lacks sufficient protein / essential amino acids, as rice and vegetables contain mainly carbohydrates and dietary fibre. (1)

- Protein deficiency may lead to poor growth and repair of body tissues / weakened immune system. (1)

- The person should include meat, fish, eggs, milk or legumes in the diet to provide adequate protein / essential amino acids. (1)

Q2. State the roles of two different inorganic ions in the human body. **(2 marks)**

Source: DSE 2016 B9; HKCEE 2005

Model Answer:

- Calcium ions: component of bones and teeth / required for blood clotting / muscle contraction. (1)

- Iron ions: component of haemoglobin in red blood cells for oxygen transport. (1)

1.2 Cellular Organization

Organelle Identification and Function

Frequency: Very High - DSE 2012-2025; HKAL 1992-2007

Q1. The diagram shows an electron micrograph of a cell. Identify organelle X and state its function. **(2 marks)**

Source: DSE 2012 MC1, 2014 MC23; HKAL 1997, 2000, 2005

Model Answer:

- Name of organelle X (e.g. mitochondrion / rough endoplasmic reticulum / Golgi apparatus — depending on the micrograph). (1)

- Function: e.g. Mitochondrion — site of aerobic respiration to produce ATP / energy for cellular activities. (1)

Q2. Name two organelles that are bounded by a double membrane. For each organelle, state its function. **(4 marks)**

Source: HKAL 1993, 1999; DSE 2017

Model Answer:

- Nucleus: contains DNA / chromosomes; controls cellular activities / stores genetic information. (1+1)

- Mitochondrion: site of aerobic respiration; produces ATP / releases energy from organic molecules. (1+1)

Q3. Describe the sequence of organelles involved in the synthesis and secretion of a protein from a cell. **(3 marks)**

Source: HKAL 2003; DSE 2013, 2021

Model Answer:

- Nucleus (DNA transcribed to mRNA) → Ribosome on rough endoplasmic reticulum (mRNA translated into polypeptide). (1)

- Rough ER → Golgi apparatus (protein is modified, processed and packaged into vesicles). (1)

- Vesicles move to and fuse with the cell membrane, releasing the protein outside the cell by exocytosis. (1)

Q4. Explain how the structure of the mitochondrion is related to its function in cellular respiration. **(3 marks)**

Source: DSE 2012 MC1; HKAL 1993, 1999

Model Answer:

- The inner membrane is highly folded into cristae, providing a large surface area for oxidative phosphorylation / attachment of electron transport chain enzymes. (1)

- The matrix contains enzymes for the Krebs cycle. (1)

- The double membrane creates separate compartments, allowing the establishment of a proton gradient for ATP synthesis. (1)

Q5. Name two organelles that are found abundantly in mammalian liver cells. Relate their abundance to the functions of the liver cells. **(4 marks)**

Source: HKAL 2000

Model Answer:

- Mitochondria — liver cells carry out many metabolic reactions (e.g. deamination of amino acids, detoxification) that require large amounts of energy / ATP. (1+1)

- Smooth endoplasmic reticulum — liver cells are involved in detoxification of drugs/alcohol and synthesis of lipids/cholesterol, which take place on the smooth ER. (1+1)

Microscopy and Cell Size Calculation

Frequency: High - DSE 2014, 2015, 2022; HKAL 1997, 2007; HKCEE 2008

Q1. The magnification of the micrograph is x10,000. The length of the organelle in the micrograph is 5 cm. Calculate the actual size of the organelle. Show your working. **(2 marks)**

Source: DSE 2014 MC3, MC5, 2015 MC1; HKAL 1997

Model Answer:

- Actual size = Image size / Magnification = 5 cm / 10,000 = 0.0005 cm = 5 µm. (1)

- Correct working and unit conversion shown. (1)

Q2. State two cellular structures present in all living cells. **(2 marks)**

Source: HKCEE 2008; DSE 2022

Model Answer:

- Cell membrane (controls entry and exit of substances). (1)

- Cytoplasm (site of metabolic reactions) / DNA / genetic material / ribosomes. (1)

Q3. Tabulate two major differences in cellular organization between prokaryotic and eukaryotic organisms. **(4 marks)**

Source: HKAL 1995; DSE 2019

Model Answer:

- Prokaryotes have no true nucleus (DNA in nucleoid region, not bounded by nuclear membrane); eukaryotes have a true nucleus with a nuclear membrane. (1+1)

- Prokaryotes lack membrane-bound organelles (e.g. no mitochondria, no ER); eukaryotes have membrane-bound organelles (e.g. mitochondria, ER, Golgi apparatus). (1+1)

1.3 Movement of Substances across Cell Membrane

Osmosis Experiments

Frequency: Very High - DSE 2012-2024; HKCEE 1990-2007; HKAL 1998-2010

Q1. A potato strip was placed in a concentrated sugar solution. Describe and explain the changes in the potato strip after 30 minutes. **(3 marks)**

Source: DSE 2012 B8a, 2016 M24-25; HKCEE 1994, 1996

Model Answer:

- The potato strip becomes shorter / softer / flaccid. (1)

- The sugar solution has a lower water potential than the potato cells. (1)

- Water moves out of the potato cells by osmosis (from higher to lower water potential), causing the cells to become plasmolysed / lose turgor. (1)

Q2. Explain why red blood cells burst when placed in distilled water, but plant cells do not. **(3 marks)**

Source: DSE 2013 MC23-25; HKCEE 1990, 1991; HKAL 2008, 2010

Model Answer:

- Distilled water has a higher water potential than the cytoplasm of both types of cells, so there is a net movement of water from distilled water to both cells by osmosis. (1)

- Red blood cells have no cell wall; as water enters, the cell swells and eventually bursts (lysis). (1)

- Plant cells have a rigid cellulose cell wall which resists further expansion; the cell becomes turgid but does not burst because the cell wall provides support against the inward pressure. (1)

Q3. Describe the changes in a plant cell when placed in a hypertonic solution. Use a labelled diagram to illustrate plasmolysis. **(4 marks)**

Source: DSE 2016 M24-25; HKCEE 1991, 1996; HKAL 2007

Model Answer:

- The hypertonic solution has a lower water potential than the cell sap; water moves out of the vacuole by osmosis. (1)

- The vacuole shrinks and the cytoplasm contracts. (1)

- The cell membrane pulls away from the cell wall (plasmolysis). The cell wall remains intact as it is fully permeable. (1)

- Diagram: labelled cell wall, cell membrane detached from cell wall, shrunken vacuole, gap between cell wall and cell membrane filled with external solution. (1)

Q4. In an osmosis experiment, the solution level in the capillary tube rose initially and then remained unchanged. Explain these observations. **(3 marks)**

Source: HKCEE 1998; HKAL 2008

Model Answer:

- Initially, the solution inside the dialysis tubing has a lower water potential than the surrounding water. (1)

- Water enters the tubing by osmosis, causing the solution level in the capillary tube to rise. (1)

- Eventually, the hydrostatic pressure of the raised solution column counterbalances the osmotic pressure; equilibrium is reached and the level stops rising. (1)

Fluid Mosaic Model and Membrane Transport

Frequency: High - DSE 2013-2023; HKAL 2001-2010

Q1. With reference to the fluid mosaic model, describe two features of the cell membrane and explain how each is related to the function of the membrane. **(4 marks)**

Source: DSE 2015 B6; HKAL 2001, 2003, 2006, 2010

Model Answer:

- "Fluid" — phospholipid molecules can move laterally within the bilayer; this allows the membrane to be flexible and enables cell movement / fusion of vesicles. (1+1)

- "Mosaic" — proteins are scattered throughout the phospholipid bilayer; channel proteins allow specific water-soluble substances to pass through / carrier proteins facilitate active transport. (1+1)

Q2. Compare and contrast diffusion and active transport across the cell membrane. **(4 marks)**

Source: HKAL 1993; DSE 2014 B7

Model Answer:

- Similarity: both move substances across the cell membrane. (1)

- Diffusion moves substances from high to low concentration (down the concentration gradient); active transport moves substances from low to high concentration (against the gradient). (1)

- Diffusion does not require energy (ATP); active transport requires energy (ATP). (1)

- Diffusion does not require carrier proteins (for simple diffusion); active transport requires specific carrier/transport proteins. (1)

Q3. Explain how the nature and arrangement of phospholipid molecules in the cell membrane affect its permeability to different substances. **(4 marks)**

Source: HKAL 2003; DSE 2019

Model Answer:

- Phospholipid molecules have hydrophilic (polar) heads facing outwards and hydrophobic (non-polar) fatty acid tails facing inwards, forming a bilayer. (1)

- The hydrophobic interior of the bilayer is impermeable to water-soluble / charged / polar molecules (e.g. ions, glucose). (1)

- Small non-polar molecules (e.g. O2, CO2) and fat-soluble substances can pass through the lipid bilayer by simple diffusion. (1)

- Water-soluble substances require channel proteins or carrier proteins to cross the membrane. (1)

Q4. State one example of active transport in the human body and explain its functional significance. **(3 marks)**

Source: HKAL 1993; DSE 2023

Model Answer:

- Example: Absorption of glucose / amino acids in the small intestine (from the lumen into the epithelial cells of villi). (1)

- Active transport allows nutrients to be absorbed against the concentration gradient, even when their concentration in the blood is already higher than in the gut lumen. (1)

- This ensures maximum / efficient absorption of nutrients from digested food. (1)

1.4 Enzymes and Metabolism

Enzyme Properties and Specificity

Frequency: Very High - DSE 2014-2024; HKCEE 1990-2002; HKAL 1995-2003

Q1. Using the lock-and-key model, explain why enzymes are specific to their substrates. **(3 marks)**

Source: DSE 2014 MC9, 2015 MC3; HKAL 1996, 2002

Model Answer:

- Each enzyme has a specific 3D shape at its active site. (1)

- Only substrates with a complementary shape can fit into the active site (like a key fitting into a lock). (1)

- Other substrates with different shapes cannot bind to the active site, so the enzyme only catalyses one specific reaction. (1)

Q2. Explain the effect of temperature on enzyme activity. Describe what happens to the enzyme at temperatures above the optimum. **(4 marks)**

Source: DSE 2015 B7; HKCEE 1990, 1995; HKAL 1995

Model Answer:

- As temperature increases from low, enzyme activity increases because molecules have more kinetic energy, so enzyme-substrate collisions are more frequent. (1)

- At the optimum temperature, the rate of reaction is at its maximum. (1)

- Above the optimum temperature, the enzyme is denatured — the heat breaks hydrogen bonds / disrupts the 3D shape of the enzyme. (1)

- The active site changes shape and can no longer bind with the substrate; this is irreversible. (1)

Q3. Describe an experiment to investigate the effect of pH on the activity of catalase. State the dependent, independent, and one controlled variable. **(4 marks)**

Source: DSE 2014 B6c; HKCEE 2003; HKAL 2000

Model Answer:

- Independent variable: pH of the solution (use buffer solutions at different pH values, e.g. pH 3, 5, 7, 9, 11). (1)

- Dependent variable: rate of oxygen gas production (measure volume of gas collected per unit time). (1)

- Controlled variable: temperature / concentration of hydrogen peroxide / amount of catalase extract. (1)

- Procedure: Add the same amount of catalase to hydrogen peroxide at each pH; collect oxygen gas using a gas syringe or by water displacement; record gas volume at regular intervals. (1)

Q4. Compare and contrast the effects of a competitive inhibitor and a non-competitive inhibitor on enzyme activity. **(4 marks)**

Source: HKAL 1995, 1997; DSE 2016 M27

Model Answer:

- Competitive inhibitor has a similar shape to the substrate and competes for the active site; non-competitive inhibitor binds to a site other than the active site (allosteric site). (1)

- Competitive inhibition can be overcome by increasing substrate concentration (substrate outcompetes the inhibitor); non-competitive inhibition cannot be overcome by increasing substrate concentration. (1)

- Both types of inhibitors reduce the rate of the enzymatic reaction. (1)

- Competitive inhibitor does not change the shape of the active site; non-competitive inhibitor changes the shape of the active site (so substrate can no longer bind). (1)

Q5. The graph shows the effect of substrate concentration on enzyme activity. The curve levels off at point X. Explain why. **(2 marks)**

Source: DSE 2018; HKAL 1999; HKCEE 2002

Model Answer:

- At point X, all enzyme active sites are occupied by substrate molecules (enzyme is saturated). (1)

- Further increase in substrate concentration cannot increase the reaction rate because there are no more free active sites available; the enzyme concentration becomes the limiting factor. (1)

Enzyme Experiments (Amylase, Catalase, Protease)

Frequency: High - DSE 2014, 2015, 2022; HKCEE 1993-2008

Q1. A student performed an experiment using catalase from potato. Explain why the rate of gas production decreases over time. **(3 marks)**

Source: HKCEE 1993, 2003; DSE 2015 B7

Model Answer:

- As the reaction proceeds, the substrate (hydrogen peroxide) is gradually used up / its concentration decreases. (1)

- Fewer substrate molecules are available to collide with enzyme active sites. (1)

- Therefore the frequency of enzyme-substrate complex formation decreases, and the rate of reaction slows down. (1)

Q2. Fresh ginger juice can coagulate milk protein but boiled ginger juice cannot. Explain this observation. **(2 marks)**

Source: HKCEE 2002, 2008; DSE 2022

Model Answer:

- Fresh ginger juice contains a protease enzyme which acts on the soluble milk protein (casein), converting it into an insoluble form, causing coagulation. (1)

- Boiling denatures the protease enzyme in the ginger juice (destroys its 3D structure / active site shape), so it can no longer catalyse the coagulation reaction. (1)

Q3. Suggest how you would modify an experiment to show that substance X is a competitive inhibitor of amylase. **(2 marks)**

Source: HKAL 2002; DSE 2021

Model Answer:

- Repeat the experiment with increasing concentrations of substrate (starch) while keeping the concentration of substance X constant. (1)

- If the inhibition can be reversed / the reaction rate increases with increasing substrate concentration, then X is a competitive inhibitor (as substrate outcompetes X for the active site). (1)

Q4. A biological washing powder contains protease. Explain why it should not be used with water above 60°C and should not be used with silk or wool. **(2 marks)**

Source: HKCEE 1995

Model Answer:

- Water above 60°C would denature the protease enzyme, destroying its active site shape, so it cannot digest the protein stains. (1)

- Silk and wool are made of protein (keratin/fibroin); the protease in the washing powder would digest/damage the protein fibres of these fabrics. (1)

1.5 Cell Cycle and Division

Mitosis and Meiosis

Frequency: Very High - DSE 2012-2025; HKAL 1999-2011

Q1. Compare mitosis and meiosis in terms of: (i) number of cell divisions, (ii) number of daughter cells produced, (iii) chromosome number of daughter cells. **(3 marks)**

Source: DSE 2012 B11, 2015 B2, 2016 M18-20; HKAL 1999

Model Answer:

- (i) Mitosis involves one cell division; meiosis involves two successive cell divisions. (1)

- (ii) Mitosis produces 2 daughter cells; meiosis produces 4 daughter cells. (1)

- (iii) Mitosis produces diploid (2n) daughter cells (same as parent); meiosis produces haploid (n) daughter cells (half of parent). (1)

Q2. State the biological significance of meiosis in sexual reproduction. **(2 marks)**

Source: DSE 2015 B2, 2019; HKAL 2003

Model Answer:

- Meiosis halves the chromosome number in gametes, so that when two gametes fuse during fertilization, the diploid chromosome number is restored in the offspring. (1)

- Meiosis produces genetically different gametes (through crossing over and independent assortment), contributing to genetic variation in the offspring. (1)

Q3. The diagram shows cells at different stages of cell division. Identify the stage shown and explain your reasoning. **(3 marks)**

Source: DSE 2016 M18-20; HKAL 2007

Model Answer:

- Identify the stage based on chromosome arrangement (e.g. metaphase I: homologous pairs line up at the equator in bivalents). (1)

- Key features to identify: whether chromosomes are in pairs (meiosis I) or single (meiosis II/mitosis); whether they are at the equator or being pulled apart. (1)

- Reasoning: e.g. "Homologous chromosomes are lined up in pairs at the cell equator, indicating metaphase I of meiosis." (1)

Q4. Explain why daughter cells produced by meiosis are genetically different from each other. State two processes that contribute to genetic variation. **(4 marks)**

Source: DSE 2021, 2023; HKAL 2003, 2011

Model Answer:

- Independent assortment: during metaphase I, homologous chromosome pairs line up randomly at the equator; the orientation of each pair is random, producing different combinations of maternal and paternal chromosomes in the daughter cells. (1+1)

- Crossing over: during prophase I, homologous chromosomes form bivalents and exchange segments of chromatids at chiasmata; this creates new combinations of alleles on the same chromosome. (1+1)

Q5. A cell has 2n = 6 chromosomes. Draw the arrangement of chromosomes at metaphase I and metaphase II of meiosis. **(2 marks)**

Source: DSE 2014 B3c; HKAL 2007

Model Answer:

- Metaphase I: 3 bivalents (pairs of homologous chromosomes) lined up at the cell equator; each bivalent consists of 4 chromatids. (1)

- Metaphase II: 3 individual chromosomes (each consisting of 2 sister chromatids joined at the centromere) lined up at the equator. (1)

1.6 Cellular Energetics (Photosynthesis and Respiration)

Photosynthesis

Frequency: Very High - Tested in EVERY DSE year 2012-2025; HKAL every year

Q1. The graph shows the rate of CO_2 uptake by a plant at different light intensities. Explain why the rate of CO_2 uptake levels off at high light intensity. **(3 marks)**

Source: DSE 2012 B5, 2014 MC6-8, 2016 B3; HKAL multiple years

Model Answer:

- At low light intensities, light is the limiting factor; increasing light intensity increases the rate of photosynthesis. (1)

- At high light intensities, the rate levels off because another factor becomes limiting (e.g. CO_2 concentration or temperature). (1)

- All the available CO_2 is being fixed / all chlorophyll molecules are already saturated with light, so increasing light intensity further has no additional effect. (1)

Q2. Define the compensation point of a plant. Explain what happens to the rate of photosynthesis and respiration at the compensation point. **(3 marks)**

Source: DSE 2014 B1, 2016 M9-10; HKAL 1999, 2003

Model Answer:

- The compensation point is the light intensity at which the rate of photosynthesis equals the rate of respiration. (1)

- At the compensation point, the amount of CO_2 produced by respiration equals the amount of CO_2 used in photosynthesis. (1)

- There is no net gas exchange with the environment (no net uptake or release of CO_2 / O_2). (1)

Q3. Describe how you would design an experiment to investigate the effect of light intensity on the rate of photosynthesis using aquatic plants. **(4 marks)**

Source: DSE 2015 MC4; HKCEE multiple years; HKAL 2005

Model Answer:

- Place an aquatic plant (e.g. Elodea/Hydrilla) in a beaker of water with a light source at a measured distance. (1)

- Count the number of oxygen bubbles released per minute (or collect gas in an inverted test tube) as a measure of photosynthetic rate. (1)

- Change the distance of the light source from the plant (to vary light intensity); repeat at several distances. (1)

- Control variables: temperature (use a heat shield/water screen), CO_2 concentration (add $NaHCO_3$), same plant specimen, same time interval. (1)

Q4. Compare the light-dependent reactions and the light-independent reactions of photosynthesis in terms of: (i) site, (ii) raw materials, (iii) products. **(3 marks)**

Source: DSE 2016 B3; HKAL 1995, 2001, 2007

Model Answer:

- (i) Site: Light-dependent reactions occur on the thylakoid membranes (grana); light-independent reactions (Calvin cycle) occur in the stroma. (1)

- (ii) Raw materials: Light-dependent reactions use water and light energy; light-independent reactions use CO_2, ATP and NADPH. (1)

- (iii) Products: Light-dependent reactions produce ATP, NADPH and O_2 (from photolysis of water); light-independent reactions produce triose phosphate / G3P / glucose. (1)

Q5. Explain why plants release CO_2 at night but absorb CO_2 during the day. **(3 marks)**

Source: DSE 2012 B5; HKAL 2003; HKCEE 2005

Model Answer:

- At night, there is no light so photosynthesis cannot occur; only respiration takes place, releasing CO_2. (1)

- During the day, both photosynthesis and respiration occur; the rate of photosynthesis exceeds the rate of respiration. (1)

- The net effect is that more CO_2 is absorbed for photosynthesis than is released by respiration, so the plant shows a net uptake of CO_2. (1)

Respiration

Frequency: Very High - DSE 2012-2024; HKAL every year

Q1. Compare aerobic respiration and anaerobic respiration in terms of: (i) oxygen requirement, (ii) end products, (iii) amount of energy released. **(3 marks)**

Source: DSE 2012 B9, 2015 MC6; HKAL 1995, 2001

Model Answer:

- (i) Aerobic respiration requires oxygen; anaerobic respiration does not require oxygen. (1)

- (ii) Aerobic: end products are CO_2 and water; Anaerobic: end products are ethanol + CO_2 (in yeast) or lactic acid (in muscle cells). (1)

- (iii) Aerobic respiration releases much more energy / produces more ATP (about 38 ATP per glucose); anaerobic respiration releases much less energy (2 ATP per glucose) because glucose is only partially broken down. (1)

Q2. Explain why yeast can produce CO_2 and ethanol during fermentation. State one commercial application. **(3 marks)**

Source: DSE 2019; HKCEE 2000, 2007; HKAL 2003

Model Answer:

- Yeast carries out anaerobic respiration (alcoholic fermentation) in the absence of oxygen. (1)

- Glucose is broken down to pyruvate by glycolysis; pyruvate is then converted to ethanol and CO_2 by fermentation enzymes. (1)

- Commercial application: bread making (CO_2 makes dough rise) / wine/beer making (ethanol is the alcohol produced). (1)

Q3. A student investigated the rate of respiration of germinating seeds using a respirometer. Explain why potassium hydroxide (KOH) is placed inside the apparatus. **(2 marks)**

Source: DSE 2014 MC14; HKCEE 2001; HKAL 2005

Model Answer:

- KOH absorbs the CO_2 produced by the germinating seeds during respiration. (1)

- This ensures that any decrease in gas volume in the apparatus is due solely to oxygen consumption, allowing the rate of oxygen uptake to be measured accurately. (1)

Q4. Describe the role of ATP in living organisms. Explain why ATP is described as the "energy currency" of cells. **(3 marks)**

Source: DSE 2021; HKAL 1999, 2003, 2007

Model Answer:

- ATP (adenosine triphosphate) is the immediate energy source for cellular activities. (1)

- When ATP is hydrolysed to ADP and inorganic phosphate, energy is released for processes such as muscle contraction, active transport, and biosynthesis. (1)

- ATP is called the "energy currency" because it is continuously produced (by respiration) and consumed (by energy-requiring reactions), acting as a common intermediate that transfers energy between energy-releasing and energy-requiring reactions. (1)

Part II: Genetics and Evolution

2.1 Basic Genetics

Monohybrid Cross and Genetic Diagrams

Frequency: Very High - DSE 2012-2025; HKAL every year; HKCEE every year

Q1. Using a genetic diagram, show the expected phenotypic ratio of offspring from a cross between two heterozygous parents (Aa x Aa). **(3 marks)**

Source: DSE 2012, 2015, 2017; HKAL multiple years

Model Answer:

- Parents: Aa x Aa; Gametes: A, a from each parent. (1)

- Punnett square: AA, Aa, Aa, aa → Phenotypic ratio = 3 dominant : 1 recessive. (1)

- Genotypic ratio: 1 AA : 2 Aa : 1 aa. (1)

Q2. In a cross between a tall plant (Tt) and a short plant (tt), predict the ratio of tall to short plants in the offspring. Draw a genetic diagram. **(4 marks)**

Source: DSE 2013, 2019; HKCEE 1993, 1998

Model Answer:

- Parents: Tt (tall) x tt (short). (1)

- Gametes: T and t from Tt parent; t from tt parent. (1)

- Punnett square: Tt, Tt, tt, tt → 2 Tt (tall) : 2 tt (short). (1)

- Expected phenotypic ratio = 1 tall : 1 short (i.e. 50% tall, 50% short). (1)

Q3. A couple are both carriers for a recessive genetic disease. Using a genetic diagram, calculate the probability that their child will be affected. **(3 marks)**

Source: DSE 2015, 2021, 2023; HKCEE 2001, 2005

Model Answer:

- Both parents are carriers: Aa x Aa (where a = allele for the disease). (1)

- Punnett square: AA, Aa, Aa, aa. (1)

- Probability of an affected child (aa) = 1/4 = 25%. (1)

Q4. Explain the difference between genotype and phenotype, using a named example. **(2 marks)**

Source: DSE 2017; HKCEE 1996

Model Answer:

- Genotype is the genetic makeup / combination of alleles of an organism (e.g. Tt); phenotype is the observable characteristic / physical appearance (e.g. tall). (1)

- Example: A person with genotype Ii for blood group has phenotype blood group A (where I^A is dominant over i). (1)

Sex-linked Inheritance

Frequency: High - DSE 2014-2024; HKAL 1997-2007

Q1. Colour blindness is a sex-linked recessive condition. A carrier woman marries a normal man. Show the expected genotypes and phenotypes of their children. **(4 marks)**

Source: DSE 2014, 2019; HKAL 2003

Model Answer:

- Mother (carrier): X^B X^b; Father (normal): X^B Y. (1)

- Gametes: Mother: X^B, X^b; Father: X^B, Y. (1)

- Offspring: X^B X^B (normal girl), X^B X^b (carrier girl), X^B Y (normal boy), X^b Y (colour-blind boy). (1)

- Probability of a colour-blind child = 1/4 (25%); only sons can be affected (50% of sons). (1)

Q2. Explain why sex-linked recessive conditions (e.g. haemophilia) are more common in males than in females. **(3 marks)**

Source: DSE 2016, 2022; HKAL 1997

Model Answer:

- The gene for haemophilia is located on the X chromosome; there is no corresponding allele on the Y chromosome. (1)

- Males have only one X chromosome (XY), so if they inherit one copy of the recessive allele, they will express the condition (X^h Y). (1)

- Females have two X chromosomes (XX); they would need two copies of the recessive allele (X^h X^h) to express the condition, which is much rarer. A female with one copy (X^H X^h) is a carrier but unaffected. (1)

Q3. A family pedigree shows the inheritance of a genetic disorder. Determine whether the disorder is autosomal or sex-linked, dominant or recessive. Explain. **(4 marks)**

Source: DSE 2019, 2024; HKAL 2007

Model Answer:

- If two unaffected parents produce an affected child, the disorder is recessive (both parents must be carriers). (1)

- If the disorder appears only in males (or predominantly in males) and is transmitted through carrier mothers, it is likely X-linked recessive. (1)

- If both males and females are equally affected, it is more likely autosomal. (1)

- Key evidence: track the allele through generations; use genetic diagrams to confirm consistency with the proposed mode of inheritance. (1)

Variation

Frequency: High - DSE 2015-2023; HKAL 1999, 2005

Q1. Distinguish between continuous variation and discontinuous variation. Give one example of each in humans. **(4 marks)**

Source: DSE 2015, 2018; HKAL 1999

Model Answer:

- Continuous variation: characteristics show a range of intermediate phenotypes with no distinct categories (a bell-shaped / normal distribution). (1)

- Example: height, body mass, skin colour. Controlled by many genes (polygenic inheritance) and influenced by the environment. (1)

- Discontinuous variation: characteristics show distinct, separate categories with no intermediate forms. (1)

- Example: ABO blood group, tongue rolling ability. Usually controlled by one or a few genes, not significantly influenced by the environment. (1)

Q2. Explain why identical twins raised in different environments may show different phenotypes for certain characteristics. **(3 marks)**

Source: DSE 2020, 2023; HKAL 2005

Model Answer:

- Identical twins have the same genotype (same DNA / same set of alleles) because they develop from the same fertilized egg. (1)

- However, some characteristics (especially those showing continuous variation) are influenced by environmental factors such as diet, exercise, climate, etc. (1)

- Different environments can cause different gene expression / different phenotypes; e.g. one twin raised with better nutrition may be taller than the other. (1)

Q3. State two sources of genetic variation in sexually reproducing organisms. **(2 marks)**

Source: DSE 2018; HKAL 2003

Model Answer:

- Independent assortment of homologous chromosomes during meiosis (produces different combinations of chromosomes in gametes). (1)

- Crossing over between homologous chromosomes during prophase I of meiosis / random fusion of gametes during fertilization / mutation. (1)

2.2 Molecular Genetics

DNA Structure and Replication

Frequency: High - DSE 2013-2024; HKAL 1999-2009

Q1. Describe the structure of a DNA molecule, including the arrangement of nucleotides and the nature of the bonds between the two strands. **(4 marks)**

Source: DSE 2013, 2016; HKAL 1999, 2003

Model Answer:

- DNA is a double-stranded molecule arranged in a double helix. (1)

- Each strand is a polynucleotide chain; each nucleotide consists of a deoxyribose sugar, a phosphate group, and a nitrogenous base (A, T, C, or G). (1)

- The two strands are held together by hydrogen bonds between complementary base pairs: adenine pairs with thymine (A-T, 2 hydrogen bonds); cytosine pairs with guanine (C-G, 3 hydrogen bonds). (1)

- The two strands run antiparallel to each other; the sugar-phosphate backbone forms the outside of the helix. (1)

Q2. Explain the significance of complementary base pairing in DNA replication. **(3 marks)**

Source: DSE 2018, 2022; HKAL 2005

Model Answer:

- Complementary base pairing ensures that each new strand is an exact copy of the original: A always pairs with T, and C always pairs with G. (1)

- Each original strand serves as a template; free nucleotides align by complementary base pairing and are joined by DNA polymerase. (1)

- This ensures accurate / faithful copying of genetic information from parent cell to daughter cells. (1)

Q3. Describe the process of semi-conservative DNA replication. State the evidence that supports this model. **(4 marks)**

Source: DSE 2020; HKAL 2009

Model Answer:

- The double helix unwinds and the two strands separate (hydrogen bonds between base pairs are broken). (1)

- Each original strand acts as a template; free DNA nucleotides pair with exposed bases by complementary base pairing (A-T, C-G). (1)

- DNA polymerase joins the nucleotides together to form new strands; each new DNA molecule consists of one original strand and one new strand (semi-conservative). (1)

- Evidence: Meselson and Stahl's experiment using heavy nitrogen (15N) and light nitrogen (14N) showed that after one round of replication, all DNA molecules had intermediate density (one heavy and one light strand). (1)

Protein Synthesis (Transcription and Translation)

Frequency: High - DSE 2013-2025; HKAL 1999-2007

Q1. Describe the process of transcription. State where it occurs and name the product formed. **(3 marks)**

Source: DSE 2013, 2017; HKAL 1999

Model Answer:

- Transcription occurs in the nucleus. (1)

- The DNA double helix unwinds and one strand (template strand) is used as a template; RNA polymerase reads the template strand and assembles a complementary mRNA molecule (using free RNA nucleotides by complementary base pairing: A-U, T-A, C-G, G-C). (1)

- The product is messenger RNA (mRNA), which then leaves the nucleus through nuclear pores and moves to the ribosome in the cytoplasm. (1)

Q2. Using the given mRNA sequence, determine the amino acid sequence. The codon table is provided. **(2 marks)**

Source: DSE 2019, 2022; HKAL 2003

Model Answer:

- Read the mRNA sequence in groups of three bases (codons), from the start codon (AUG). (1)

- Use the codon table to identify the corresponding amino acid for each codon; write out the amino acid sequence in order. (1)

Q3. Explain how a point mutation in DNA may or may not affect the protein produced. **(3 marks)**

Source: DSE 2021, 2025; HKAL 2007

Model Answer:

- A point mutation involves a change in one base pair in the DNA sequence, which changes the corresponding codon in mRNA. (1)

- It may affect the protein: the changed codon may code for a different amino acid, altering the primary structure and potentially the 3D shape/function of the protein (e.g. sickle-cell anaemia). (1)

- It may NOT affect the protein: the genetic code is degenerate (multiple codons code for the same amino acid), so the changed codon may still code for the same amino acid (silent mutation). (1)

Genetic Engineering and DNA Technology

Frequency: High - DSE 2014-2025; HKAL 2003-2011

Q1. Describe the steps involved in producing a genetically modified (GM) organism using recombinant DNA technology. **(4 marks)**

Source: DSE 2017, 2021; HKAL 2003, 2007

Model Answer:

- Identify and isolate the desired gene from the donor organism (using restriction enzymes to cut the DNA at specific recognition sites). (1)

- Cut a plasmid (vector) with the same restriction enzyme; insert the gene into the plasmid using DNA ligase to form recombinant DNA. (1)

- Introduce the recombinant plasmid into the host organism (e.g. bacterium) by transformation. (1)

- Select and culture the successfully transformed organisms; the host organism expresses the desired gene / produces the desired protein. (1)

Q2. Explain the principle of gel electrophoresis and state one application. **(3 marks)**

Source: DSE 2019, 2023; HKAL 2007

Model Answer:

- DNA fragments (cut by restriction enzymes) are placed in wells on an agarose gel and an electric current is applied. (1)

- DNA is negatively charged, so fragments move towards the positive electrode; smaller fragments move faster/further through the gel, separating fragments by size. (1)

- Application: DNA profiling / paternity testing / forensic identification / comparing DNA samples. (1)

Q3. Describe how PCR can be used to amplify a specific DNA fragment. State one application of PCR. **(4 marks)**

Source: DSE 2014, 2025; HKAL 2011

Model Answer:

- Denaturation: heat the DNA sample to ~95°C to separate the two strands (break hydrogen bonds). (1)

- Annealing: cool to ~55°C to allow short DNA primers to bind to complementary sequences flanking the target region. (1)

- Extension: heat to ~72°C; heat-stable DNA polymerase (Taq polymerase) extends the primers by adding free nucleotides, synthesising new complementary strands. (1)

- Repeat the cycle many times (20-30 cycles) to produce millions of copies. Application: forensic analysis / diagnosis of genetic diseases / amplifying DNA from small samples. (1)

Q4. State one benefit and one ethical concern of genetic engineering. **(2 marks)**

Source: DSE 2017, 2023; HKAL 2007

Model Answer:

- Benefit: production of useful substances (e.g. human insulin by GM bacteria) / development of disease-resistant crops / gene therapy for genetic diseases. (1)

- Ethical concern: potential risks of releasing GM organisms into the environment / unknown long-term effects on health / issues of "playing God" / unequal access to the technology. (1)

2.3 Biodiversity and Evolution

Classification and the Six Kingdoms

Frequency: High - DSE 2012-2022; HKAL 1999, 2003

Q1. State three features used to classify organisms into the six kingdoms. **(3 marks)**

Source: DSE 2016, 2022; HKAL 1999

Model Answer:

- Cell type: prokaryotic vs. eukaryotic. (1)

- Cell structure: presence/absence of cell wall; type of cell wall material (e.g. peptidoglycan in bacteria, cellulose in plants, chitin in fungi). (1)

- Mode of nutrition: autotrophic (photosynthesis) vs. heterotrophic (ingestion / absorption / saprophytic). (1)

Q2. Compare and contrast the features of prokaryotes and eukaryotes. **(4 marks)**

Source: DSE 2012; HKAL 1995, 2003

Model Answer:

- Prokaryotes have no true nucleus (DNA in nucleoid, not bounded by membrane); eukaryotes have a true nucleus bounded by a double nuclear membrane. (1)

- Prokaryotes lack membrane-bound organelles; eukaryotes have membrane-bound organelles (e.g. mitochondria, ER, Golgi apparatus). (1)

- Prokaryotes have smaller ribosomes (70S); eukaryotes have larger ribosomes (80S). (1)

- Both have DNA as genetic material, cell membrane, cytoplasm and ribosomes. (1)

Q3. Explain what is meant by a binomial naming system. Give one advantage. **(2 marks)**

Source: DSE 2018; HKAL 2003

Model Answer:

- The binomial naming system gives each species a two-part scientific name: the first part is the genus name and the second part is the species name (e.g. Homo sapiens). (1)

- Advantage: it provides a universal / internationally standardised naming system that avoids confusion caused by different common names in different languages. (1)

Evolution and Natural Selection

Frequency: Very High - DSE 2014-2025; HKAL multiple years

Q1. Using the theory of natural selection, explain how antibiotic-resistant bacteria develop in a population. **(4 marks)**

Source: DSE 2015, 2018, 2021; HKAL 2003, 2007

Model Answer:

- Within a bacterial population, there is genetic variation; some bacteria may carry a mutation that confers resistance to an antibiotic. (1)

- When the antibiotic is applied, most non-resistant bacteria are killed; the resistant bacteria survive (survival of the fittest / selective advantage). (1)

- The resistant bacteria reproduce and pass on the resistance allele to their offspring. (1)

- Over generations, the proportion of resistant bacteria in the population increases; eventually the population becomes largely antibiotic-resistant. (1)

Q2. State two pieces of evidence that support the theory of evolution. **(2 marks)**

Source: DSE 2014, 2017; HKAL 1999

Model Answer:

- Fossil records: fossils show gradual changes in organisms over time; older/simpler fossils are found in deeper rock layers, and more complex/recent fossils are found in upper layers. (1)

- Comparative anatomy: homologous structures (e.g. pentadactyl limb in different vertebrates) suggest common ancestry / DNA/protein sequence comparison shows similarities between related species. (1)

Q3. Describe the process of speciation. Explain how geographical isolation can lead to the formation of new species. **(4 marks)**

Source: DSE 2016, 2019, 2022; HKAL 2005, 2011

Model Answer:

- A population is separated into two groups by a geographical barrier (e.g. mountain range, river, ocean). (1)

- The two groups are exposed to different environmental conditions / selection pressures. (1)

- Different mutations arise and different alleles are selected for in each group (natural selection acts differently on each population). (1)

- Over many generations, the two groups become so genetically different that they can no longer interbreed to produce fertile offspring; they become separate species (reproductive isolation). (1)

Q4. Explain the difference between homologous and analogous structures. How do homologous structures provide evidence for evolution? **(4 marks)**

Source: DSE 2017, 2023; HKAL 2003

Model Answer:

- Homologous structures have the same basic structural plan / embryonic origin but may have different functions (e.g. human arm, whale flipper, bat wing — all have the pentadactyl limb pattern). (1)

- Analogous structures have similar functions but different structural plans / embryonic origins (e.g. wings of insects and wings of birds). (1)

- Homologous structures suggest that organisms sharing them evolved from a common ancestor (divergent evolution). (1)

- The modifications of homologous structures reflect adaptation to different environments / ways of life, supporting the theory of natural selection. (1)

Part III: Organisms and Environment

3.1 Essential Life Processes in Plants

Transpiration and Water Transport

Frequency: High - DSE 2013-2024; HKAL every year

Q1. Describe how water is transported from the roots to the leaves of a plant. Name the tissue involved. **(3 marks)**

Source: DSE 2016, 2020; HKAL 1997, 2005

Model Answer:

- Water is absorbed by root hair cells from the soil by osmosis (the cell sap has a lower water potential than the soil solution). (1)

- Water moves across the root cortex (from cell to cell by osmosis) and enters the xylem vessels. (1)

- Water is transported upwards through xylem vessels by the transpiration pull (a continuous column of water is pulled up due to evaporation of water from the leaves / cohesion-tension mechanism). (1)

Q2. Explain how transpiration helps in the transport of water in plants. State two environmental factors that affect the rate of transpiration. **(4 marks)**

Source: DSE 2013, 2018; HKAL 1999, 2003

Model Answer:

- Transpiration is the loss of water vapour from the leaves through stomata. (1)

- As water evaporates from the mesophyll cells, it lowers the water potential in the leaf; this creates a transpiration pull that draws water up through the xylem (cohesion-tension). (1)

- Factor 1: Temperature — higher temperature increases the kinetic energy of water molecules, increasing the rate of evaporation and transpiration. (1)

- Factor 2: Wind / humidity — wind blows away water vapour from the leaf surface, maintaining a steep diffusion gradient; low humidity also increases transpiration. (1)

Q3. Describe how you would use a potometer to investigate the effect of wind on the rate of transpiration. **(4 marks)**

Source: DSE 2022; HKAL 2001; HKCEE 2003

Model Answer:

- Set up a potometer with a leafy shoot sealed airtight; note the position of the air bubble in the capillary tube. (1)

- Place the set-up in still air; measure the distance the air bubble moves in a fixed time period (e.g. 10 minutes) — this indicates the rate of water uptake. (1)

- Repeat with a fan blowing on the shoot (windy condition); compare the rate of bubble movement. (1)

- The bubble should move faster with wind, indicating a higher rate of transpiration. Keep other variables constant (temperature, light, same shoot). (1)

Q4. Compare the structure of xylem vessels and phloem sieve tubes. Relate their structures to their functions. **(4 marks)**

Source: DSE 2024; HKAL 1997, 2005

Model Answer:

- Xylem: dead cells with no cytoplasm / end walls broken down to form continuous hollow tubes; walls thickened with lignin for support; transports water and mineral ions upwards. (1+1)

- Phloem sieve tubes: living cells with thin cellulose walls; end walls have sieve plates with pores; cytoplasm but no nucleus; companion cells provide metabolic support; transports organic solutes (sucrose/amino acids) both upwards and downwards. (1+1)

Nutrition in Flowering Plants

Frequency: Medium - DSE 2015-2021; HKAL 1997-2005

Q1. State three mineral ions essential for plant growth. For each, state its role in the plant. **(3 marks)**

Source: DSE 2019; HKAL 2001

Model Answer:

- Nitrate ions (NO_3^-): needed for synthesis of amino acids and proteins, which are essential for growth. (1)

- Magnesium ions (Mg^{2+}): component of chlorophyll molecules; needed for photosynthesis. (1)

- Phosphate ions (PO_4^{3-}): component of ATP and nucleic acids (DNA/RNA); needed for energy transfer and growth. (1)

Q2. Describe how nitrate ions are absorbed by root hair cells from the soil. Explain why this process requires energy. **(3 marks)**

Source: DSE 2015, 2021; HKAL 1997, 2005

Model Answer:

- Nitrate ions are absorbed by root hair cells by active transport. (1)

- The concentration of nitrate ions inside the root hair cell is higher than in the soil solution; therefore ions must be moved against the concentration gradient. (1)

- Active transport requires ATP (produced by respiration in mitochondria) to power carrier proteins in the cell membrane to transport the ions into the cell. (1)

3.2 Essential Life Processes in Animals

Human Digestive System

Frequency: High - DSE 2013-2023; HKCEE every year; HKAL multiple years

Q1. Describe the digestion of starch in the human alimentary canal, from the mouth to absorption in the small intestine. **(4 marks)**

Source: DSE 2013, 2017; HKCEE 1995, 2000; HKAL 2005

Model Answer:

- In the mouth, salivary amylase hydrolyses starch into maltose (in slightly alkaline conditions). (1)

- In the duodenum, pancreatic amylase continues to hydrolyse remaining starch into maltose. (1)

- Maltase (on the brush border of small intestine epithelial cells) hydrolyses maltose into glucose. (1)

- Glucose is absorbed into the blood capillaries of the villi by active transport / facilitated diffusion. (1)

Q2. Explain the role of bile in the digestion of fats. State where bile is produced and where it acts. **(3 marks)**

Source: DSE 2015, 2021; HKCEE 2002; HKAL 2006

Model Answer:

- Bile is produced by the liver and stored in the gall bladder; it is released into the duodenum (small intestine). (1)

- Bile salts emulsify large fat globules into smaller fat droplets (emulsification). (1)

- This increases the total surface area of fats for lipase to act on, speeding up the rate of fat digestion. (Bile itself does not contain digestive enzymes.) (1)

Q3. Describe two structural adaptations of the small intestine that increase the efficiency of nutrient absorption. **(4 marks)**

Source: DSE 2019, 2023; HKCEE 1997; HKAL 1999

Model Answer:

- Villi: finger-like projections on the inner wall that greatly increase the surface area for absorption. (1)

- Each villus has a dense network of blood capillaries (for absorbing glucose and amino acids) and a lacteal (for absorbing fatty acids and glycerol). (1)

- Microvilli on the epithelial cells of the villi further increase the surface area. (1)

- The epithelium is only one cell thick, providing a short diffusion distance for nutrients to enter the blood. (1)

Q4. Some digestive enzymes are secreted as inactive forms (proenzymes/zymogens). Explain the significance of this. **(2 marks)**

Source: HKAL 2006; DSE 2021

Model Answer:

- Proenzymes (e.g. pepsinogen) are inactive and do not digest the cells that produce and store them; this protects the glandular cells from self-digestion. (1)

- They are activated only when released into the appropriate part of the alimentary canal (e.g. pepsinogen is activated to pepsin by HCl in the stomach). (1)

Gas Exchange in Humans

Frequency: High - DSE 2014-2022; HKAL 1991-2002; HKCEE multiple years

Q1. Describe two structural features of the alveoli that make them efficient for gas exchange. **(2 marks)**

Source: DSE 2014, 2018; HKCEE 1997; HKAL 1995

Model Answer:

- Alveoli have very thin walls (one cell thick), providing a short diffusion distance for gases. (1)

- Alveoli are numerous and have a very large total surface area; they are also surrounded by a dense network of blood capillaries, maintaining a steep concentration gradient for efficient gas exchange. (1)

Q2. Explain the mechanism of inhalation in humans, including the roles of the diaphragm and intercostal muscles. **(4 marks)**

Source: DSE 2016, 2022; HKCEE 2000; HKAL 2002

Model Answer:

- The external intercostal muscles contract, pulling the rib cage upwards and outwards. (1)

- The diaphragm muscles contract, causing the diaphragm to flatten / move downwards. (1)

- These actions increase the volume of the thoracic cavity. (1)

- The air pressure inside the lungs decreases (becomes lower than atmospheric pressure), so air is drawn into the lungs. (1)

Q3. Compare the composition of inhaled air and exhaled air. Explain the differences. **(3 marks)**

Source: DSE 2020; HKCEE 1994, 2005; HKAL 1995

Model Answer:

- Exhaled air has less oxygen (~16%) than inhaled air (~21%), because oxygen is absorbed into the blood at the alveoli for aerobic respiration. (1)

- Exhaled air has more CO_2 (~4%) than inhaled air (~0.04%), because CO_2 is a waste product of respiration released from blood into the alveoli. (1)

- Exhaled air has more water vapour, because water evaporates from the moist respiratory surfaces in the lungs. (1)

Transport in Humans (Circulatory System)

Frequency: Very High - DSE 2012-2024; HKAL every year

Q1. Compare the structure of arteries, veins, and capillaries. Relate each structure to its function. **(4 marks)**

Source: DSE 2014, 2020; HKAL 1997, 2005

Model Answer:

- Arteries: thick, muscular, elastic walls to withstand high blood pressure from the heart; narrow lumen maintains high pressure; carry blood away from the heart. (1)

- Veins: thinner walls with less muscle; wider lumen to reduce resistance; have valves to prevent backflow; carry blood towards the heart at low pressure. (1)

- Capillaries: walls are only one cell thick to allow exchange of substances between blood and tissues; very narrow lumen forces red blood cells to pass in single file, maximising exchange. (1)

- Capillaries form extensive networks to provide a large surface area for exchange. (1)

Q2. Explain the advantage of a double circulatory system in mammals. **(3 marks)**

Source: DSE 2016, 2023; HKAL 1999, 2003

Model Answer:

- In a double circulatory system, blood passes through the heart twice in one complete circuit: once through the pulmonary circulation (heart → lungs → heart) and once through the systemic circulation (heart → body → heart). (1)

- Blood pressure drops as blood passes through the capillaries in the lungs; the second pass through the heart restores high blood pressure for the systemic circulation. (1)

- This ensures that oxygenated blood is delivered to the body tissues at high pressure, allowing efficient / rapid delivery of oxygen and nutrients. (1)

Q3. Describe how the cardiac cycle maintains the flow of blood through the heart. Include the roles of valves. **(4 marks)**

Source: DSE 2018, 2024; HKAL 2001

Model Answer:

- Atrial systole: both atria contract, pushing blood through the open atrioventricular (AV) valves into the ventricles. (1)

- Ventricular systole: both ventricles contract, blood pressure rises; AV valves close (preventing backflow to atria, producing the first heart sound); blood is pushed through the semilunar valves into the aorta and pulmonary arteries. (1)

- Diastole: heart muscles relax; semilunar valves close (preventing backflow from arteries); blood flows from the veins into the atria. (1)

- Valves ensure one-way flow of blood through the heart, preventing backflow. (1)

Q4. Explain how oxygen is transported from the lungs to the body tissues. Include the role of haemoglobin. **(3 marks)**

Source: DSE 2012, 2021; HKAL 1993, 2004

Model Answer:

- In the lungs, oxygen diffuses from the alveoli into the red blood cells (due to the higher concentration of O2 in the alveoli). (1)

- Oxygen binds reversibly with haemoglobin to form oxyhaemoglobin (Hb + 4O2 → HbO8). (1)

- In the body tissues, where the oxygen concentration is low, oxyhaemoglobin dissociates / releases oxygen, which diffuses into the tissue cells for respiration. (1)

3.3 Reproduction, Growth and Development

Human Reproductive System

Frequency: High - DSE 2013-2024; HKAL 1999-2007

Q1. Describe the roles of oestrogen and progesterone in the menstrual cycle. **(4 marks)**

Source: DSE 2013, 2019; HKAL 2003, 2007

Model Answer:

- Oestrogen is secreted by the developing follicle in the ovary; it stimulates the repair and thickening of the uterine lining (endometrium) after menstruation. (1)

- A surge in oestrogen level triggers ovulation (release of the ovum from the follicle). (1)

- Progesterone is secreted by the corpus luteum (yellow body) after ovulation; it further thickens and maintains the uterine lining, preparing it for possible implantation of an embryo. (1)

- If fertilisation does not occur, the corpus luteum degenerates, progesterone level drops, and the uterine lining breaks down (menstruation). (1)

Q2. Explain how the oral contraceptive pill prevents pregnancy. **(3 marks)**

Source: DSE 2015, 2022; HKAL 1999

Model Answer:

- The pill contains synthetic oestrogen and/or progesterone. (1)

- These hormones inhibit the secretion of FSH from the pituitary gland (negative feedback), preventing the development and maturation of follicles in the ovary. (1)

- Without a mature follicle, ovulation does not occur, so fertilisation cannot take place. (1)

Q3. Describe the process of fertilization in humans, from ovulation to implantation. **(4 marks)**

Source: DSE 2020, 2024; HKAL 2003

Model Answer:

- Ovulation: a mature ovum is released from the follicle in the ovary and enters the oviduct (Fallopian tube). (1)

- Fertilisation: a sperm penetrates the jelly coat of the ovum (using enzymes from the acrosome); the nuclei of the sperm and ovum fuse to form a diploid zygote. (1)

- The zygote divides repeatedly by mitosis as it moves along the oviduct towards the uterus, forming a ball of cells (embryo). (1)

- Implantation: the embryo embeds itself into the thickened uterine lining (endometrium), where it will develop further. (1)

Q4. Compare sexual reproduction and asexual reproduction in terms of genetic variation in the offspring. **(3 marks)**

Source: DSE 2013, 2022; HKAL 1999

Model Answer:

- Sexual reproduction involves the fusion of two gametes (from two parents); offspring are genetically different from each other and from the parents. (1)

- Genetic variation arises from meiosis (crossing over, independent assortment) and random fertilisation. (1)

- Asexual reproduction involves only one parent and mitosis; offspring are genetically identical to the parent (clones) — no genetic variation. (1)

3.4 Coordination and Response

Nervous System and Reflex Arc

Frequency: Very High - DSE 2013-2025; HKAL every year

Q1. Draw and label a reflex arc. Describe the pathway of a nerve impulse in a withdrawal reflex. **(4 marks)**

Source: DSE 2013, 2018; HKAL 1999, 2005

Model Answer:

- Receptor (pain receptor in skin) detects the stimulus (e.g. touching a hot object). (1)

- Sensory neurone transmits the nerve impulse from the receptor to the spinal cord (CNS). (1)

- Relay neurone (interneurone) in the spinal cord transmits the impulse to the motor neurone. (1)

- Motor neurone transmits the impulse to the effector (muscle), which contracts to pull the hand away. (1)

Q2. Compare and contrast nervous coordination and hormonal coordination in humans. **(4 marks)**

Source: DSE 2015, 2021; HKAL 2003, 2007

Model Answer:

- Nervous: signal transmitted as electrical nerve impulses along neurones; hormonal: signal transmitted as chemical hormones through the blood. (1)

- Nervous: fast transmission / rapid response; hormonal: slower transmission / slower response. (1)

- Nervous: short-lived / precise / localised effect; hormonal: longer-lasting / widespread effect on target organs. (1)

- Both serve to coordinate body functions and maintain homeostasis. (1)

Q3. Describe the structure of a synapse and explain how a nerve impulse is transmitted across it. **(4 marks)**

Source: DSE 2016, 2023; HKAL 2001

Model Answer:

- A synapse is the junction between two neurones, with a synaptic gap between them. (1)

- When a nerve impulse arrives at the presynaptic membrane, synaptic vesicles fuse with the membrane and release neurotransmitter (e.g. acetylcholine) into the synaptic gap by exocytosis. (1)

- The neurotransmitter diffuses across the gap and binds to specific receptors on the postsynaptic membrane. (1)

- This triggers a new nerve impulse in the postsynaptic neurone. The neurotransmitter is then broken down by enzymes (to prevent continuous stimulation). (1)

Q4. Explain how the eye adjusts to focus on a near object (accommodation). Include the roles of the ciliary muscle and suspensory ligaments. **(3 marks)**

Source: DSE 2019, 2025; HKAL 2003

Model Answer:

- The ciliary muscles contract, causing the ring of ciliary body to become smaller in diameter. (1)

- This reduces the tension on the suspensory ligaments (they become slack). (1)

- The elastic lens becomes thicker / more convex (due to its own elasticity), increasing its refractive power so that the image of the near object is focused on the retina. (1)

Tropism in Plants

Frequency: Medium - DSE 2014-2023; HKAL 1999-2009

Q1. Describe an experiment to demonstrate phototropism in a plant shoot. Explain the role of auxin in this response. **(4 marks)**

Source: DSE 2014, 2021; HKAL 1999, 2005

Model Answer:

- Place a young seedling (e.g. coleoptile) near a unilateral light source. After a few days, the shoot bends towards the light (positive phototropism). (1)

- Auxin is produced at the shoot tip and migrates to the shaded side of the shoot. (1)

- Higher auxin concentration on the shaded side promotes cell elongation on that side, causing the shaded side to grow faster. (1)

- The unequal growth causes the shoot to bend towards the light source. (1)

Q2. Explain the biological significance of positive gravitropism in roots and negative gravitropism in stems. **(3 marks)**

Source: DSE 2017, 2023; HKAL 2009

Model Answer:

- Positive gravitropism in roots: roots grow downwards into the soil, anchoring the plant firmly and reaching water and mineral ions for absorption. (1)

- Negative gravitropism in stems: stems grow upwards away from the ground, exposing the leaves to maximum sunlight for photosynthesis. (1)

- These responses ensure the survival of the plant by optimising its access to essential resources (water, minerals, light). (1)

3.5 Homeostasis

Blood Glucose Regulation

Frequency: Very High - DSE 2012-2024; HKAL 1998-2010

Q1. Describe how blood glucose level is regulated when it rises above normal after a meal. Include the roles of the pancreas and liver. **(4 marks)**

Source: DSE 2012, 2018; HKAL 1998, 2005

Model Answer:

- After a meal, blood glucose level rises above normal. (1)

- The beta cells of the islets of Langerhans in the pancreas detect the rise and secrete more insulin into the blood. (1)

- Insulin stimulates liver cells to convert excess glucose into glycogen (glycogenesis) for storage. (1)

- Insulin also stimulates body cells to increase uptake and oxidation of glucose for energy; blood glucose level returns to normal. (1)

Q2. Explain the difference between Type I and Type II diabetes mellitus in terms of their causes. **(4 marks)**

Source: DSE 2015, 2022; HKAL 2010

Model Answer:

- Type I diabetes: the beta cells of the pancreas are destroyed (by autoimmune attack), so little or no insulin is produced. (1)

- Blood glucose level remains high because cells cannot take up glucose without insulin; treated by insulin injections. (1)

- Type II diabetes: body cells become resistant to insulin / do not respond properly to insulin (insulin resistance), even though insulin may be produced in normal or even higher amounts. (1)

- Often associated with obesity / lack of exercise / genetic factors; treated by dietary control, exercise, and sometimes medication. (1)

Q3. Explain the concept of negative feedback, using the regulation of blood glucose level as an example. **(3 marks)**

Source: DSE 2020, 2024; HKAL 2003

Model Answer:

- Negative feedback is a mechanism in which a change in a physiological parameter triggers a response that reverses the change, restoring the parameter to its normal / set level. (1)

- When blood glucose rises above normal: insulin is secreted → glucose converted to glycogen → blood glucose drops back to normal. (1)

- When blood glucose falls below normal: glucagon is secreted → glycogen converted to glucose → blood glucose rises back to normal. The response always opposes the original change. (1)

Q4. A person was given a glucose tolerance test. The graph shows changes in blood glucose level over time. Describe and explain the changes. **(4 marks)**

Source: DSE 2015, 2022; HKAL 2005

Model Answer:

- After drinking the glucose solution, blood glucose level rises sharply as glucose is absorbed from the small intestine into the blood. (1)

- The pancreas detects the rise and secretes insulin; insulin stimulates cells to take up glucose and the liver to convert glucose to glycogen. (1)

- Blood glucose level gradually decreases and returns to the fasting level (normal range) within about 2 hours in a healthy person. (1)

- In a diabetic person, blood glucose rises higher and takes much longer to return to normal (or may not return), due to insufficient insulin production or insulin resistance. (1)

Osmoregulation

Frequency: High - DSE 2012-2022; HKAL 1999-2005

Q1. Describe the role of the kidneys in osmoregulation. Include the roles of ADH and the collecting duct. **(4 marks)**

Source: DSE 2014, 2018; HKAL 1999, 2005

Model Answer:

- When blood water potential is low (dehydrated): the pituitary gland secretes more ADH (antidiuretic hormone) into the blood. (1)

- ADH makes the walls of the collecting ducts more permeable to water, so more water is reabsorbed from the collecting ducts back into the blood. (1)

- A small volume of concentrated urine is produced. (1)

- When blood water potential is high (overhydrated): less ADH is released, collecting ducts become less permeable to water, less water is reabsorbed, and a large volume of dilute urine is produced. (1)

Q2. Explain what happens to the volume and concentration of urine produced when a person drinks a large amount of water. **(3 marks)**

Source: DSE 2016, 2022; HKAL 2003

Model Answer:

- Drinking a large amount of water increases the water potential of the blood / dilutes the blood. (1)

- Less ADH is secreted by the pituitary gland in response. (1)

- The collecting ducts become less permeable to water, so less water is reabsorbed; a large volume of dilute urine is produced to remove the excess water. (1)

Q3. Explain how the loop of Henle helps to concentrate the urine. **(3 marks)**

Source: DSE 2012, 2020; HKAL 1999

Model Answer:

- The descending limb of the loop of Henle is permeable to water; water moves out by osmosis into the surrounding hypertonic medulla. (1)

- The ascending limb actively pumps out sodium and chloride ions into the medulla, making the medulla progressively more concentrated (creating a high solute concentration in the medulla). (1)

- This high solute concentration in the medulla draws water out of the collecting duct (in the presence of ADH), concentrating the urine. (1)

Temperature Regulation

Frequency: High - DSE 2015-2023; HKAL 1995-2005

Q1. Describe the physiological responses of the human body when the environmental temperature drops below normal body temperature. **(4 marks)**

Source: DSE 2015, 2021; HKAL 1995, 2001

Model Answer:

- Vasoconstriction: arterioles in the skin constrict, reducing blood flow to the skin surface, thereby reducing heat loss by radiation. (1)

- Shivering: skeletal muscles contract and relax rapidly and involuntarily, generating heat from increased respiration. (1)

- Erector muscles contract, causing body hairs to stand upright, trapping a layer of insulating air near the skin surface. (1)

- Increased metabolic rate: the body increases the rate of respiration (e.g. by secreting more thyroxine), generating more heat. (1)

Q2. Explain why there is an increase in blood flow to the skin during exercise, and how this helps in temperature regulation. **(4 marks)**

Source: DSE 2015, 2018; HKAL 2005

Model Answer:

- During exercise, the rate of respiration in muscles increases greatly, producing more heat as a by-product; body temperature rises. (1)

- The hypothalamus detects the rise and triggers vasodilation: arterioles in the skin dilate, increasing blood flow to the skin surface. (1)

- More blood flows near the skin surface, so more heat is lost to the environment by radiation / convection / conduction. (1)

- Increased sweating also occurs; as sweat evaporates from the skin surface, it absorbs latent heat of vaporisation, cooling the body. (1)

Q3. Explain why sweating helps to cool the body. State the role of the hypothalamus in temperature regulation. **(3 marks)**

Source: DSE 2017, 2023; HKAL 2001

Model Answer:

- Sweat is produced by sweat glands in the skin and secreted onto the skin surface. (1)

- As the sweat evaporates, it absorbs latent heat of vaporisation from the body, thereby cooling the body down. (1)

- The hypothalamus acts as the thermoregulatory centre: it detects changes in blood temperature and sends nerve impulses to effectors (sweat glands, blood vessels, muscles) to trigger appropriate responses to restore normal body temperature. (1)

3.6 Ecosystems

Food Chains, Food Webs and Energy Flow

Frequency: High - DSE 2013-2023; HKAL every year

Q1. Using the food web provided, identify a food chain with four trophic levels. Explain why energy decreases at each successive trophic level. **(4 marks)**

Source: DSE 2013, 2019; HKAL 1999, 2003

Model Answer:

- Identify a valid food chain, e.g. grass → grasshopper → frog → snake (four trophic levels). (1)

- At each trophic level, organisms use energy from food for life processes (respiration), releasing energy as heat, which is lost to the environment. (1)

- Not all parts of organisms are eaten or digested; some energy is lost in faeces and urine. (1)

- Therefore, only about 10% of energy is transferred to the next trophic level; energy decreases at each successive level. (1)

Q2. Explain why the number of trophic levels in a food chain is usually limited to four or five. **(2 marks)**

Source: DSE 2017, 2023; HKAL 2001

Model Answer:

- Energy is lost at each trophic level (as heat from respiration, in faeces, urine, and dead matter). (1)

- By the 4th or 5th trophic level, there is insufficient energy remaining to support another level of consumers. (1)

Q3. Describe the roles of decomposers in an ecosystem. **(2 marks)**

Source: DSE 2015, 2021; HKAL 2003

Model Answer:

- Decomposers (e.g. bacteria, fungi) break down dead organisms and organic waste by secreting enzymes extracellularly (saprophytic nutrition). (1)

- They release inorganic nutrients (e.g. nitrates, phosphates) back into the soil, making them available for uptake by plants; this is essential for nutrient recycling. (1)

Nutrient Cycles and Pollution

Frequency: High - DSE 2014-2024; HKAL 1997-2005

Q1. Describe the role of nitrogen-fixing bacteria and nitrifying bacteria in the nitrogen cycle. **(4 marks)**

Source: DSE 2014, 2020; HKAL 1997, 2005

Model Answer:

- Nitrogen-fixing bacteria (e.g. Rhizobium in root nodules of leguminous plants) convert atmospheric nitrogen gas (N2) into ammonium compounds (NH4+) that plants can use. (1)

- This is the main way nitrogen from the atmosphere enters the living system. (1)

- Nitrifying bacteria (e.g. Nitrosomonas, Nitrobacter) in the soil convert ammonium compounds (NH4+) first to nitrites (NO2-) and then to nitrates (NO3-). (1)

- Nitrates are the main form of nitrogen absorbed by plant roots for synthesising amino acids and proteins. (1)

Q2. Explain how the burning of fossil fuels contributes to the enhanced greenhouse effect. Describe one possible consequence. **(3 marks)**

Source: DSE 2016, 2022; HKAL 2001

Model Answer:

- Burning fossil fuels releases large amounts of CO2 into the atmosphere. (1)

- CO2 is a greenhouse gas; it traps infrared radiation (heat) that would otherwise escape from the Earth, causing the atmosphere to warm up (enhanced greenhouse effect / global warming). (1)

- Consequence: melting of polar ice caps → rise in sea level → flooding of coastal areas / changes in climate patterns / disruption of ecosystems / more extreme weather events. (1)

Q3. Explain what is meant by eutrophication. Describe the sequence of events that leads to the death of aquatic organisms. **(4 marks)**

Source: DSE 2018, 2024; HKAL 1997, 2001

Model Answer:

- Eutrophication is the enrichment of water bodies with excess nutrients (nitrates and phosphates), often from fertiliser runoff or sewage discharge. (1)

- The excess nutrients stimulate rapid growth of algae (algal bloom) on the water surface. (1)

- The dense algal layer blocks sunlight from reaching submerged aquatic plants, which die due to lack of photosynthesis. (1)

- Decomposers (bacteria) break down the dead algae and plants, using up dissolved oxygen in the water (increased BOD); aquatic organisms (fish) suffocate and die due to lack of oxygen. (1)

Q4. State two ways in which CO_2 is released into the atmosphere and two ways in which it is removed. **(2 marks)**

Source: DSE 2014, 2020; HKAL 2003

Model Answer:

- Released: (i) respiration by living organisms; (ii) combustion of fossil fuels / burning of organic matter / decomposition. (1)

- Removed: (i) photosynthesis by plants / algae (CO_2 fixed into organic compounds); (ii) dissolving in oceans / formation of carbonate rocks (e.g. limestone). (1)

Part IV: Health and Diseases

4.1 Personal Health

Balanced Diet and Lifestyle

Frequency: Medium - DSE 2014-2021; HKCEE 1994-2005

Q1. Explain why a person's diet should include both proteins and carbohydrates. State the main function of each. **(3 marks)**

Source: DSE 2016, 2021; HKCEE 1994, 1999

Model Answer:

- Carbohydrates are the main source of energy for the body; they are broken down during respiration to release ATP for cellular activities. (1)

- Proteins are needed for growth and repair of body tissues; they are broken down into amino acids which are used to build new proteins (e.g. enzymes, structural proteins, antibodies). (1)

- A balanced diet requires both: carbohydrates provide energy, while proteins provide building materials that carbohydrates cannot supply. (1)

Q2. State two health problems associated with a diet high in saturated fats. Explain why. **(3 marks)**

Source: DSE 2014, 2018; HKCEE 2005

Model Answer:

- Obesity: excess fat intake leads to excess energy, which is stored as body fat, increasing body weight. (1)

- Coronary heart disease / atherosclerosis: high intake of saturated fats raises blood cholesterol levels; cholesterol deposits on the inner walls of arteries forming plaques, narrowing the lumen and reducing blood flow to the heart. (1)

- This can lead to blood clots (thrombosis) that block coronary arteries, causing heart attack. (1)

Q3. Describe two harmful effects of smoking on the respiratory system. **(2 marks)**

Source: DSE 2018; HKCEE 2001

Model Answer:

- Tar in cigarette smoke is a carcinogen that can cause mutations in lung cells, leading to uncontrolled cell division and lung cancer. (1)

- Smoke irritates the bronchial lining, causing excess mucus production and damage to cilia; mucus accumulates, leading to chronic bronchitis / smoker's cough; it can also destroy alveolar walls, reducing surface area for gas exchange (emphysema). (1)

4.2 Diseases

Infectious Diseases

Frequency: Very High - DSE 2013-2025; HKAL 2003, 2007

Q1. State three methods of transmission of infectious diseases. For each, give one example. **(3 marks)**

Source: DSE 2013, 2019; HKAL 2003

Model Answer:

- Airborne / droplet transmission: e.g. influenza / tuberculosis (pathogens spread through coughing or sneezing). (1)

- Through contaminated food/water: e.g. cholera / hepatitis A (pathogens ingested with food or water). (1)

- Through body fluids / sexual contact: e.g. AIDS / hepatitis B (pathogens spread through blood, semen, etc.) / through vectors: e.g. malaria (transmitted by mosquito bites). (1)

Q2. Explain how antibiotics work to kill bacteria. State why antibiotics are not effective against viral infections. **(3 marks)**

Source: DSE 2015, 2021; HKAL 2007

Model Answer:

- Antibiotics interfere with bacterial metabolic processes, e.g. inhibiting cell wall synthesis (causing the bacterium to burst), or inhibiting protein synthesis / DNA replication. (1)

- These targets (e.g. peptidoglycan cell wall, 70S ribosomes) are specific to bacteria and not found in human cells, so antibiotics selectively kill bacteria. (1)

- Viruses do not have their own metabolic machinery (no cell wall, no ribosomes); they use the host cell's machinery to replicate, so antibiotics have no target to act on in viruses. (1)

Q3. Using the theory of natural selection, explain how antibiotic-resistant strains of bacteria can develop. **(4 marks)**

Source: DSE 2017, 2022; HKAL 2007

Model Answer:

- Within a bacterial population, random mutations may produce individuals with genes conferring resistance to an antibiotic. (1)

- When the antibiotic is used, most non-resistant bacteria are killed, but resistant bacteria survive (selective advantage). (1)

- The resistant bacteria reproduce rapidly (short generation time), passing the resistance gene to offspring. (1)

- Over time, the proportion of resistant bacteria increases; eventually the antibiotic becomes ineffective against the population. Overuse/misuse of antibiotics accelerates this process. (1)

Q4. Suggest two measures to reduce the development of antibiotic resistance. **(2 marks)**

Source: DSE 2020, 2023; HKAL 2007

Model Answer:

- Complete the full course of prescribed antibiotics (to ensure all bacteria, including partially resistant ones, are killed). (1)

- Do not use antibiotics unnecessarily (e.g. for viral infections) / avoid self-medication / doctors should prescribe antibiotics only when necessary / use narrow-spectrum antibiotics when possible. (1)

Q5. Compare the structural differences between bacteria and viruses. **(3 marks)**

Source: DSE 2025; HKAL 2003, 2007

Model Answer:

- Bacteria are cellular organisms with a cell membrane, cytoplasm, ribosomes (70S), and DNA (circular, in nucleoid); viruses are non-cellular / acellular, consisting of only a protein coat (capsid) surrounding nucleic acid (DNA or RNA). (1)

- Bacteria have their own metabolic machinery and can reproduce independently by binary fission; viruses cannot carry out metabolic activities on their own and must infect a host cell to replicate. (1)

- Bacteria are typically larger (1-10 μm); viruses are much smaller (20-300 nm) and can only be seen with an electron microscope. (1)

Non-infectious Diseases (Cancer, Cardiovascular Diseases)

Frequency: High - DSE 2014-2024; HKAL 2005

Q1. Explain what is meant by a tumour. Distinguish between a benign tumour and a malignant tumour. **(3 marks)**

Source: DSE 2014, 2020; HKAL 2005

Model Answer:

- A tumour is a mass of cells formed by uncontrolled cell division (due to mutations in genes controlling the cell cycle). (1)

- A benign tumour grows slowly, is enclosed in a capsule, does not invade surrounding tissues, and does not spread to other parts of the body. (1)

- A malignant tumour (cancer) grows rapidly, invades surrounding tissues, and can spread to other parts of the body through the blood or lymph (metastasis). (1)

Q2. Describe two risk factors for cardiovascular diseases. For each, explain how it increases the risk. **(4 marks)**

Source: DSE 2016, 2022; HKCEE 2005

Model Answer:

- High-fat diet: excess saturated fat increases blood cholesterol level → cholesterol deposited on artery walls → atherosclerosis → narrowed lumen → reduced blood flow to the heart → increased risk of heart attack. (1+1)

- Smoking: nicotine increases heart rate and blood pressure; carbon monoxide reduces the oxygen-carrying capacity of blood; chemicals damage artery walls, promoting plaque formation → increased risk of coronary heart disease. (1+1)

Q3. Explain how smoking increases the risk of lung cancer and coronary heart disease. **(4 marks)**

Source: DSE 2018, 2024; HKCEE 2001

Model Answer:

- Lung cancer: tar in cigarette smoke contains carcinogens that cause mutations in the DNA of lung cells, leading to uncontrolled cell division and tumour formation. (1)

- Chronic exposure damages the respiratory epithelium, increasing the likelihood of cancerous changes. (1)

- Coronary heart disease: chemicals in smoke damage the lining of arterial walls, promoting deposition of cholesterol/plaque (atherosclerosis). (1)

- Nicotine causes vasoconstriction and raises blood pressure; carbon monoxide reduces oxygen-carrying capacity of blood, putting more strain on the heart. (1)

4.3 Body Defence Mechanisms

Non-specific and Specific Immune Responses

Frequency: Very High - DSE 2013-2025; HKAL every year

Q1. Describe two non-specific defence mechanisms of the human body against pathogens. **(2 marks)**

Source: DSE 2013, 2019; HKAL 1999, 2003

Model Answer:

- Skin: acts as a physical barrier; the outer layer of dead keratinised cells prevents pathogen entry; sebum has antimicrobial properties. (1)

- Mucous membranes / HCl in stomach: mucus in the respiratory tract traps pathogens and is moved by cilia to the pharynx; HCl in gastric juice kills most ingested pathogens. (1)

Q2. Explain the difference between the primary immune response and the secondary immune response. Use a graph to illustrate. **(4 marks)**

Source: DSE 2015, 2021; HKAL 2003, 2007

Model Answer:

- Primary response: on first exposure to a pathogen, the immune system takes a longer time (days to weeks) to produce antibodies, as B lymphocytes must be activated and differentiate into plasma cells. The antibody level rises slowly and reaches a relatively low peak. (1)

- Memory cells are produced and remain in the body after the primary response. (1)

- Secondary response: on subsequent exposure to the same pathogen, memory cells are rapidly activated; they divide and differentiate into plasma cells much faster, producing a larger amount of antibodies in a shorter time. (1)

- Graph: should show a slow, low peak for the first exposure, and a rapid, high peak for the second exposure, with a shorter lag time. (1)

Q3. Describe the roles of B lymphocytes and T lymphocytes in the specific immune response. **(4 marks)**

Source: DSE 2017, 2023; HKAL 2001, 2007

Model Answer:

- B lymphocytes: when activated by an antigen, they divide and differentiate into plasma cells, which produce and secrete specific antibodies (humoral immune response). (1)

- Some B lymphocytes become memory cells that provide long-term immunity (faster response on re-exposure). (1)

- T lymphocytes (killer T cells / cytotoxic T cells): recognise and destroy body cells that are infected by viruses / cancerous cells / transplanted foreign cells (cell-mediated immune response). (1)

- Helper T cells assist in activating B lymphocytes and other immune cells by releasing chemical signals (cytokines). (1)

Q4. Distinguish between active immunity and passive immunity. Give one example of each. **(4 marks)**

Source: DSE 2019, 2025; HKAL 2003, 2005

Model Answer:

- Active immunity: the body produces its own antibodies and memory cells in response to an antigen; long-lasting because memory cells remain. (1)

- Example: natural active immunity — after recovering from an infection; artificial active immunity — vaccination. (1)

- Passive immunity: ready-made antibodies are received from an external source; short-lasting because no memory cells are produced. (1)

- Example: natural passive immunity — antibodies transferred from mother to baby via placenta or breast milk; artificial passive immunity — injection of antiserum/antibodies. (1)

Vaccination and Antibodies

Frequency: Very High - DSE 2013-2025; HKAL 2003-2011

Q1. Explain the principle behind vaccination. Why is a vaccinated person protected when they encounter the real pathogen? **(4 marks)**

Source: DSE 2013, 2021; HKAL 2003, 2007

Model Answer:

- A vaccine contains weakened / killed pathogens or their antigens, which cannot cause the disease. (1)

- When injected, the antigens stimulate the immune system to mount a primary immune response: B lymphocytes produce antibodies and memory cells are formed. (1)

- If the vaccinated person is later exposed to the actual pathogen, the memory cells recognise the antigen and rapidly initiate a secondary immune response. (1)

- Large quantities of specific antibodies are produced quickly, destroying the pathogen before it can cause disease (the person is immune). (1)

Q2. Explain why a person needs to be vaccinated against influenza every year. **(2 marks)**

Source: DSE 2017, 2023; HKAL 2007

Model Answer:

- The influenza virus has a high mutation rate; its surface antigens change frequently (antigenic variation / antigenic drift). (1)

- The memory cells and antibodies from a previous vaccination may not recognise the new strain, so a new vaccine matching the current strain is needed each year. (1)

Q3. Describe how antibodies help to defend the body against pathogens. State two ways in which antibodies can neutralize pathogens. **(3 marks)**

Source: DSE 2019, 2025; HKAL 2003

Model Answer:

- Antibodies are specific proteins produced by plasma cells that bind to specific antigens on pathogens. (1)

- Agglutination: antibodies cause pathogens to clump together, preventing them from entering cells and making them easier to be engulfed by phagocytes. (1)

- Neutralisation: antibodies bind to toxins produced by pathogens, neutralising them / antibodies coat the surface of pathogens (opsonisation), marking them for destruction by phagocytes. (1)

Q4. Explain the biological basis of allergy. Describe the sequence of events during an allergic response. **(4 marks)**

Source: DSE 2020, 2024; HKAL 2011

Model Answer:

- An allergen (e.g. pollen, dust mite, certain food) is a normally harmless substance that triggers an inappropriate immune response in sensitive individuals. (1)

- On first exposure, the immune system produces antibodies (IgE) specific to the allergen; these IgE antibodies attach to the surface of mast cells. (1)

- On subsequent exposure, the allergen binds to the IgE antibodies on the mast cells, triggering the mast cells to release histamine and other chemicals. (1)

- Histamine causes vasodilation (redness), increased capillary permeability (swelling / oedema), mucus secretion (runny nose), and contraction of smooth muscle in airways (difficulty breathing); these produce the symptoms of allergy. (1)