IB DP BIOLOGY

Theme B · Form and Function

MARK SCHEME

B1 Molecules & Metabolism · B2 Cell Structure
B3 Gas Exchange & Transport · B4 Ecology

Standard and Higher Level · Syllabus 2025

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Original exam-style questions written for the IB Diploma Programme Biology course (first assessment 2025)

Section A — Multiple Choice: Answer Key (15 marks)

1. Answer: **B** — Starch (a polysaccharide made of Δ-glucose) is the main long-term energy storage molecule in plants; glycogen is the equivalent storage molecule in animals, and cellulose is a structural (not storage) polysaccharide.

2. Answer: **B** — Enzymes are biological catalysts: they lower the activation energy of a reaction by providing an alternative reaction pathway, and are not consumed or permanently changed in the process.

3. Answer: **B** — Beyond the optimum temperature, the enzyme becomes denatured: the bonds maintaining its tertiary structure break, changing the shape of the active site so the substrate can no longer bind effectively, sharply decreasing the rate.

4. Answer: **B** — The active site is the specific region of an enzyme, with a shape complementary to its substrate, where the substrate binds and the reaction is catalysed.

5. Answer: **A** — Magnification = image size ÷ actual size; it describes how much larger an image appears compared with the real object.

6. Answer: **B** — Resolution is the ability to distinguish between two separate points that are close together; a microscope with higher resolution can reveal finer detail.

7. Answer: **C** — Ribosomes (free in the cytoplasm or bound to the rough endoplasmic reticulum) are the sites of protein synthesis (translation).

8. Answer: **B** — Cells specialized for absorption typically have many microvilli projecting from their surface, which greatly increases the surface area available for the absorption of nutrients.

9. Answer: **B** — Alveoli provide an efficient gas exchange surface due to their large total surface area, extremely thin (one cell thick) walls that minimize diffusion distance, and a dense capillary network maintaining a steep diffusion gradient.

10. Answer: **A** — On the steep, middle portion of the sigmoid curve, a small change in the partial pressure of oxygen produces a large change in haemoglobin saturation, allowing efficient oxygen unloading in respiring tissues.

11. Answer: **B** — Deoxygenated blood from the body returns via the vena cava into the right atrium, before passing to the right ventricle and being pumped to the lungs.

12. Answer: **B** — The carrying capacity, K, is the maximum population size of a species that a given environment can sustain indefinitely, limited by available resources.

13. Answer: **A** — In the exponential growth phase, resources are still abundant (not yet limiting), so population growth rate depends mainly on the intrinsic reproductive rate of the organisms.

14. Answer: **C** — Density-dependent factors (such as food/resource availability, predation, and disease) have an effect that increases in intensity as population density increases, unlike density-independent factors (e.g. natural disasters, extreme weather).

15. Answer: **B** — Cellular respiration, carried out by all living organisms, releases carbon dioxide as a waste product back into the atmosphere.

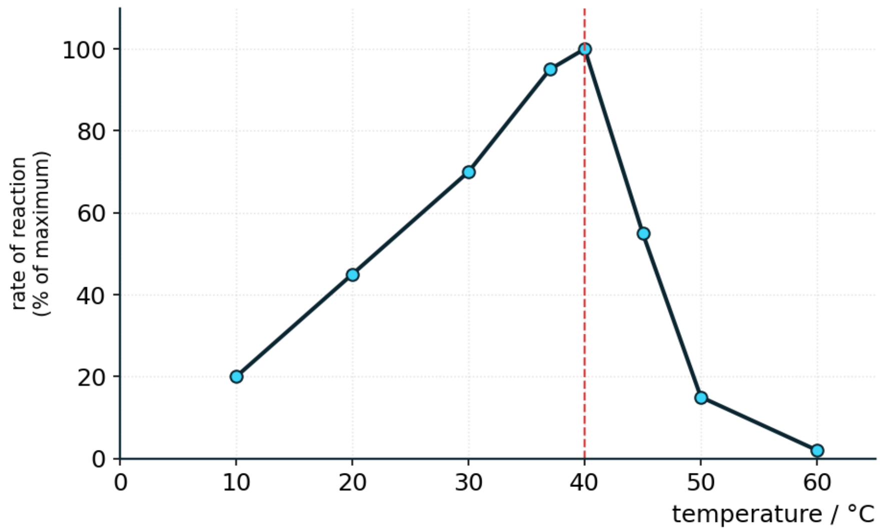
Section B — Structured Questions: Worked Solutions (65 marks)

Mark-scheme notation: M = method mark, A = accuracy mark (dependent on the preceding M mark), R = reasoning mark.

B1 Molecules & Metabolism

Question 1 [7 marks]

The graph shows how the rate of an enzyme-catalysed reaction changes with temperature (given data).



Rate of an enzyme-catalysed reaction vs temperature (given data).

(a) Using the graph, identify the optimum temperature for this enzyme. **[2]**

The optimum temperature is approximately **40°C**, where the rate of reaction is at its maximum (100%). **A1 A1**

(b) Describe and explain the shape of the curve between 10°C and the optimum temperature. **[2]**

The rate of reaction **increases** as temperature rises towards the optimum. This is because increasing temperature increases the **kinetic energy** of both enzyme and substrate molecules, increasing the frequency of successful collisions between the enzyme's active site and the substrate. **A1 R1**

(c) Explain, in terms of protein structure, why the rate of reaction drops sharply above the optimum temperature. **[3]**

Above the optimum temperature, the enzyme begins to **denature**: the excess kinetic energy breaks the hydrogen bonds and other interactions that maintain the enzyme's precise **tertiary structure**. This changes the shape of the **active site**, so it is no longer complementary to the substrate, and the substrate can no longer bind effectively – causing the sharp drop in rate. **R1 R1 A1**

Question 2 [6 marks]

Enzymes are highly specific biological catalysts.

(a) Describe how enzymes increase the rate of a reaction. **[2]**

Enzymes **lower the activation energy** required for a reaction to occur, by providing an alternative reaction pathway (via formation of an enzyme-substrate complex), without themselves being used up in the reaction. **A1 A1**

(b) Explain why enzymes are described as specific, in terms of the shape of their active site. **[2]**

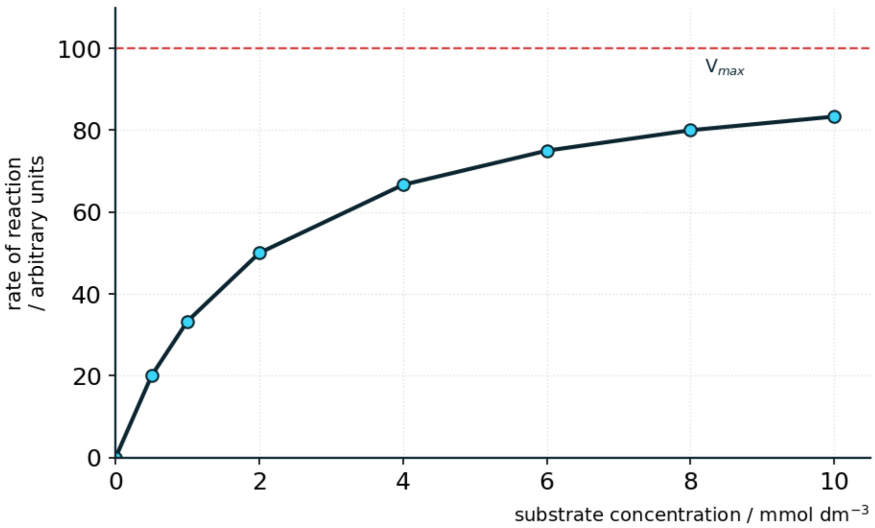
Each enzyme has an **active site with a specific three-dimensional shape** that is complementary to only one particular substrate (or a small group of very similar substrates), so an enzyme will generally only catalyse one specific reaction. **R1 A1**

(c) Distinguish between the lock-and-key model and the induced-fit model of enzyme action. **[2]**

In the **lock-and-key model**, the active site is assumed to have a fixed shape that is already perfectly complementary to the substrate. In the **induced-fit model**, the active site is flexible and **changes shape slightly as the substrate binds**, moulding around it to form a closer fit. **A1 A1**

Question 3 [7 marks]

The graph shows how the rate of an enzyme-catalysed reaction changes with substrate concentration, at a fixed enzyme concentration (computed).



Rate of reaction vs substrate concentration (computed).

(a) Using the graph, describe the relationship between substrate concentration and rate of reaction at low substrate concentrations. **[2]**

At low substrate concentrations, the rate of reaction **increases steeply and roughly proportionally** with substrate concentration, because there is an excess of free enzyme active sites available. **A1 A1**

(b) Explain why the rate of reaction plateaus (reaches a maximum, V_{max}) at high substrate concentrations. **[2]**

At high substrate concentrations, **all (or almost all) of the available active sites are occupied** by substrate at any given moment (the enzyme is 'saturated'), so adding more substrate cannot further increase the rate – the rate becomes limited by the amount of enzyme present, not substrate. **R1 R1**

(c) Suggest what would happen to this graph if more enzyme were added, with substrate remaining in excess. **[3]**

Adding more enzyme would **increase the number of available active sites**, allowing more enzyme-substrate complexes to form per unit time. The graph would show the **same general shape**, but V_{max} would be **higher** (the curve would plateau at a greater rate), since substrate is no longer the limiting factor at the same concentrations as before. **R1 R1 A1**

B2 Cell Structure

Question 4 [6 marks]

Eukaryotic cells contain many different membrane-bound organelles, each with specific functions.

(a) State the function of the mitochondrion and the function of a ribosome. **[2]**

The **mitochondrion** is the site of aerobic respiration, producing ATP. A **ribosome** is the site of protein synthesis (translation of mRNA into a polypeptide). **A1 A1**

(b) Describe the role of the rough endoplasmic reticulum and the Golgi apparatus in processing a protein destined for secretion. **[2]**

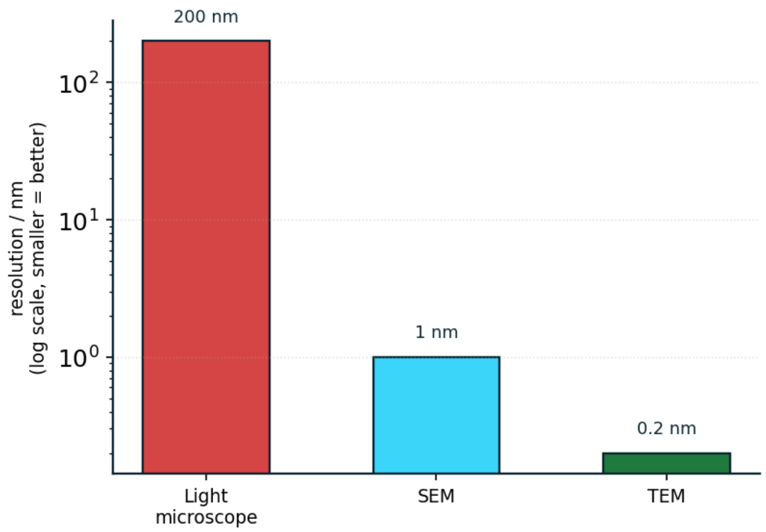
Proteins are synthesized by ribosomes on the **rough endoplasmic reticulum**, which folds and processes them; they are then transported (in vesicles) to the **Golgi apparatus**, which further modifies, sorts, and packages the protein into vesicles for secretion from the cell. **A1 A1**

(c) Explain why cells that secrete large amounts of protein (e.g. pancreatic cells) contain many mitochondria and an extensive rough endoplasmic reticulum. **[2]**

Protein synthesis and secretion are **energy-demanding processes** (requiring ATP for translation and vesicle transport), so many mitochondria are needed to supply sufficient ATP. An **extensive rough ER** provides a large surface area of ribosomes, allowing a high rate of protein synthesis to meet the cell's secretory demands. **R1 R1**

Question 5 [7 marks]

The graph (on a logarithmic scale) compares the resolution achievable with a light microscope, a scanning electron microscope (SEM), and a transmission electron microscope (TEM) (given data).



Resolution of different types of microscope (given data, log scale; smaller value = better resolution).

(a) Using the graph, identify which type of microscope has the best (smallest) resolution. **[2]**

The **TEM (transmission electron microscope)** has the best resolution, with a value of only 0.2 nm, compared with 1 nm for the SEM and 200 nm for the light microscope. **A1 A1**

(b) Define resolution, and explain why electron microscopes can reveal more detail than light microscopes. **[2]**

Resolution is the **minimum distance between two points** at which they can still be distinguished as separate. Electron microscopes use **beams of electrons**, which have a much shorter wavelength than visible light; since resolution improves as wavelength decreases, electron microscopes can distinguish much finer detail than light microscopes. **A1 R1**

(c) An image of a cell organelle taken with an electron microscope has a width of 40 mm on the printed page, at a magnification of ×20,000. Calculate the actual width of the organelle, in micrometres (µm). **[3]**

Actual size = image size ÷ magnification = 40 mm ÷ 20,000 = 0.0020 mm. Converting to µm (1 mm = 1000 µm): actual size = 0.0020×1000 = **2.0 µm**. **M1 M1 A1**

Question 6 [6 marks]

Multicellular organisms contain many types of specialized (differentiated) cells.

(a) Define 'cell differentiation'. **[2]**

Cell differentiation is the process by which **unspecialized (stem) cells develop specific structures and functions**, becoming distinct types of specialized cell, through the selective expression of particular genes. **A1 A1**

(b) Describe two structural adaptations of a named specialized cell, related to its function. **[2]**

Example: a **sperm cell** has a **flagellum (tail)** for swimming towards the egg, and many **mitochondria** (packed around the flagellum base) to provide ATP for movement. (Any other valid specialized cell and matching adaptations is acceptable.) **A1 A1**

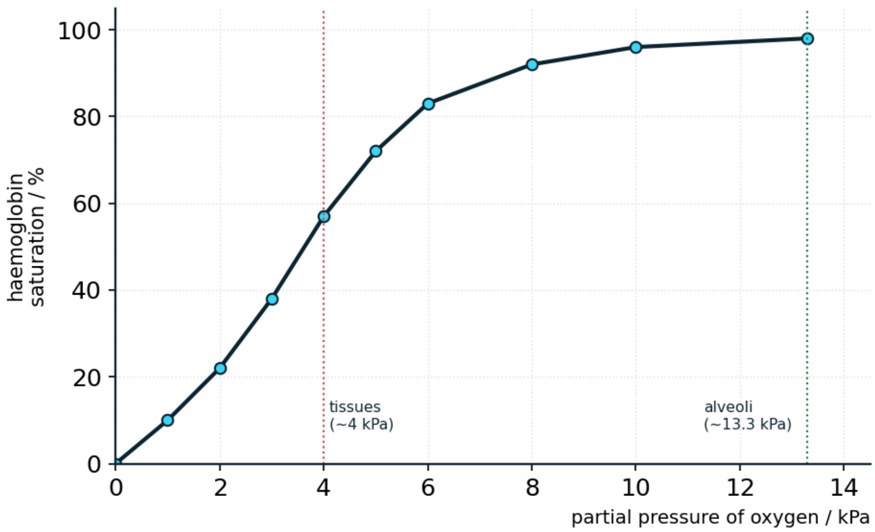
(c) Explain, in terms of gene expression, why differentiated cells generally cannot change into a different cell type. **[2]**

Although differentiated cells generally retain the **full set of genes** present in the original zygote, only a **specific subset of genes is expressed** (switched on) in each cell type, while others are permanently switched off; this fixed pattern of gene expression maintains the cell's specialized structure and function. **R1 R1**

B3 Gas Exchange & Transport

Question 7 [7 marks]

The graph shows the oxyhaemoglobin dissociation curve: the percentage saturation of haemoglobin with oxygen at different partial pressures of oxygen (given data).



Oxyhaemoglobin dissociation curve (given data).

(a) Using the graph, state the percentage saturation of haemoglobin at the partial pressure of oxygen found in respiring tissue (~4 kPa) and in the alveoli (~13.3 kPa). **[2]**

At respiring tissue (pO_2 ≈ 4 kPa), haemoglobin saturation is approximately **57%**. At the alveoli (pO_2 ≈ 13.3 kPa), haemoglobin saturation is approximately **98%.** **A1 A1**

(b) Using the graph, explain why haemoglobin readily loads oxygen in the lungs and readily unloads it in respiring tissues. **[2]**

In the **lungs (alveoli)**, the high pO_2 (~13.3 kPa) means haemoglobin becomes almost fully saturated, so it **loads (binds) oxygen readily**. In **respiring tissues**, the lower pO_2 (~4 kPa, since oxygen is being used in respiration) corresponds to a much lower saturation, so haemoglobin **releases (unloads) a large proportion of its oxygen** to supply the tissue. **R1 R1**

(c) Explain the physiological significance of the steep, S-shaped (sigmoid) middle portion of the curve. **[3]**

The steep middle portion means that over the **range of pO_2 found between the lungs and respiring tissues**, a relatively small drop in pO_2 causes a **large decrease in haemoglobin saturation**. This allows haemoglobin to **unload a large amount of oxygen** to tissues over a physiologically realistic range of oxygen partial pressures, making oxygen delivery highly efficient, especially to actively respiring tissues where pO_2 is lowest. **R1 R1 A1**

Question 8 [6 marks]

Efficient gas exchange depends on the structure of the gas exchange surface and the mechanics of ventilation.

(a) State three general features of an efficient gas exchange surface. **[2]**

Any three of: a **large surface area** (relative to the volume of the organism); **thin walls** (short diffusion distance); a **good blood supply** (to maintain a diffusion gradient); being kept **moist** (for gases to dissolve); good **ventilation** (to maintain a diffusion gradient). **A1 A1**

(b) Describe how the alveoli of the lungs are specifically adapted for efficient gas exchange. **[2]**

The lungs contain **millions of alveoli**, giving a very large total surface area; each alveolus has walls only **one cell thick**, minimizing diffusion distance; and each alveolus is surrounded by a dense network of **capillaries**, maintaining steep concentration gradients for oxygen and carbon dioxide. **A1 A1**

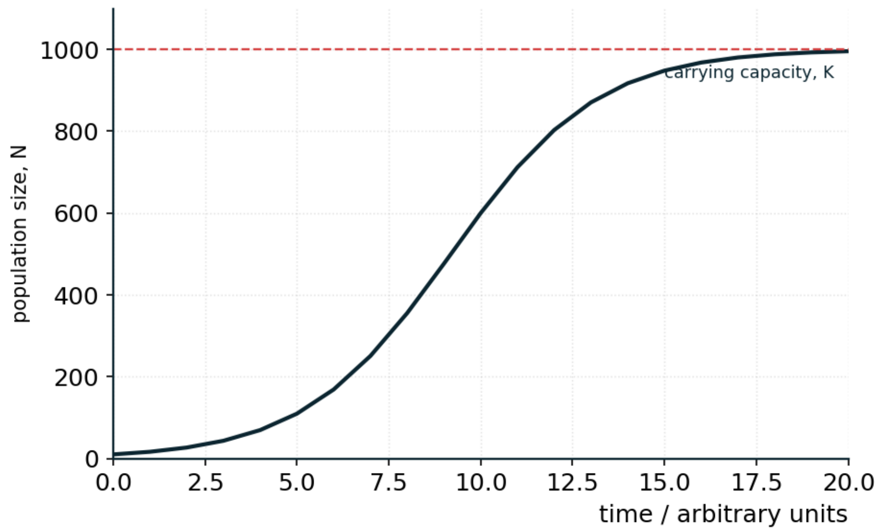
(c) Describe the role of the diaphragm and the intercostal muscles during inspiration (breathing in). **[2]**

During inspiration, the **diaphragm contracts and flattens**, and the external **intercostal muscles contract**, raising the rib cage upward and outward. Together these increase the volume of the thoracic cavity, decreasing the pressure inside the lungs below atmospheric pressure, so air flows in. **A1 A1**

B4 Ecology

Question 9 [7 marks]

The graph shows the logistic growth of a population introduced into a new habitat over time (computed model).



Logistic population growth curve (computed model).

(a) Using the graph, identify the carrying capacity, K, of this population, and describe how the population growth rate changes over time. **[2]**

The carrying capacity is approximately **K = 1000**. Growth rate is initially slow, then **increases rapidly (exponential-like phase)**, before **slowing down and levelling off** as the population size approaches K. **A1 A1**

(b) Explain why population growth slows as the population size approaches the carrying capacity. **[2]**

As population size increases, resources such as **food, space, and water become increasingly limited** relative to the number of individuals, and **competition (intraspecific)** for these resources increases; this reduces the birth rate and/or increases the death rate, slowing net population growth. **R1 R1**

(c) Suggest two density-dependent factors that could limit further population growth as the population nears K. **[3]**

Any two of: increased **intraspecific competition for food/resources**; increased spread of **disease** (which spreads more readily at high population density); increased **predation** (predators attracted to a dense prey population); build-up of **toxic waste products** at high density. **A1 A1 A1**

Question 10 [6 marks]

Carbon is cycled between the atmosphere, living organisms, and the physical environment.

(a) Describe two processes that remove carbon dioxide from the atmosphere. **[2]**

Any two of: **photosynthesis** by plants, algae, and photosynthetic bacteria (converting CO_2 into organic carbon compounds); **dissolving** of CO_2 into ocean water; formation of **carbonate sediments/fossil fuels** over geological time. **A1 A1**

(b) Describe two processes that release carbon dioxide into the atmosphere. **[2]**

Any two of: **(cellular) respiration** by living organisms; **combustion** of fossil fuels or biomass; **decomposition** of dead organic matter by decomposers; **volcanic activity**. **A1 A1**

(c) Explain how the combustion of fossil fuels has disrupted the natural balance of the carbon cycle. **[2]**

Fossil fuels store carbon that was **removed from the atmosphere over millions of years**; burning them releases this carbon as CO_2 **much faster than natural processes can remove it** (e.g. by photosynthesis or ocean absorption), causing atmospheric CO_2 concentration to rise steadily, enhancing the greenhouse effect. **R1 R1**