# IB DP BIOLOGY

## Theme C · Interaction and Interdependence

## MARK SCHEME

C1 Respiration & Photosynthesis · C2 Cell Signalling
C3 Defence & Homeostasis · C4 Populations & Nutrient Cycles

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** — Aerobic respiration fully oxidizes glucose to carbon dioxide and water using oxygen, yielding far more ATP (approximately 30 ATP per glucose) than anaerobic respiration (approximately 2 ATP per glucose).

**2.** Answer: **B** — In alcoholic fermentation, carried out by yeast, glucose is converted into ethanol and carbon dioxide, regenerating $NAD^+$ so glycolysis can continue in the absence of oxygen.

**3.** Answer: **B** — The light-dependent reactions of photosynthesis take place in the thylakoid membranes of the chloroplast, where photosystems capture light energy to produce ATP and NADPH.

**4.** Answer: **B** — On a warm, sunny day, light intensity and temperature are unlikely to be limiting, so carbon dioxide concentration (normally low in the atmosphere, around 0.04%) commonly becomes the limiting factor.

**5.** Answer: **B** — Hormones are chemical messengers secreted directly into the bloodstream by endocrine glands, and are transported around the body to act on target cells that have the appropriate receptor.

**6.** Answer: **B** — Paracrine signalling involves the release of a signalling molecule that diffuses through the local environment to affect nearby target cells, rather than being transported through the blood.

**7.** Answer: **A** — A receptor is a protein (often membrane-bound) with a binding site complementary to a specific signalling molecule (ligand); binding of the ligand triggers a response within the target cell.

**8.** Answer: **B** — Once all available receptors are occupied (saturated), further increases in hormone concentration cannot increase the response further, so the response plateaus at a maximum value.

**9.** Answer: **B** — B lymphocytes that have been activated by a specific antigen differentiate into plasma cells, which secrete large quantities of antibodies specific to that antigen.

**10.** Answer: **C** — Memory B and T cells produced during the primary response allow a much faster ('anamnestic') and greater antibody response upon a second exposure to the same antigen.

**11.** Answer: **A** — Homeostasis is the maintenance of a relatively stable internal environment (e.g. body temperature, blood glucose, water balance) despite changes in the external environment, typically achieved via negative feedback.

**12.** Answer: **B** — Primary succession begins with hardy pioneer species, such as lichens and mosses, which can tolerate the harsh conditions of bare rock and begin to break it down, contributing to soil formation.

**13.** Answer: **B** — As succession proceeds, increasing habitat complexity and the accumulation of soil and nutrients create more available niches, so species richness generally increases before levelling off as the climax community is approached.

**14.** Answer: **B** — The climax community is the relatively stable, self-sustaining community of species that persists at the end of succession, so long as environmental conditions remain unchanged.

**15.** Answer: **C** — Nitrogen fixation is the process by which nitrogen-fixing bacteria (e.g. Rhizobium, free-living soil bacteria, or cyanobacteria) convert atmospheric nitrogen gas into ammonia/ammonium ions, which can then be used by plants.

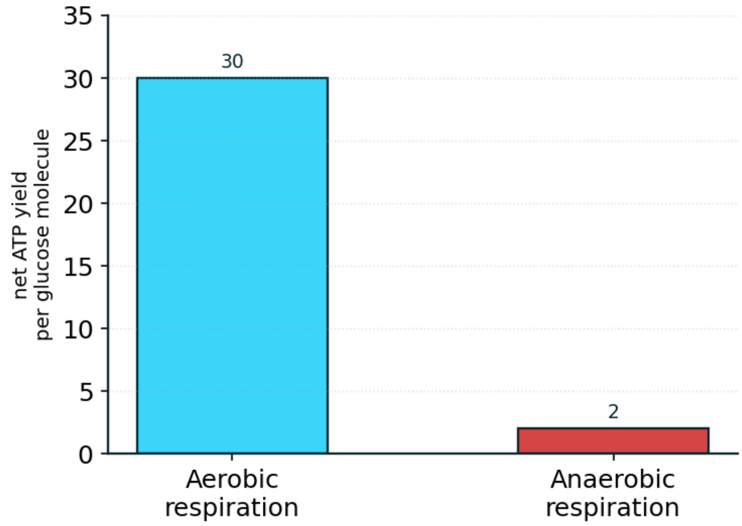
# Section B — Structured Questions: Worked Solutions (65 marks)

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

## C1 Respiration & Photosynthesis

**Question 1** [7 marks]

The bar chart shows the net ATP yield per molecule of glucose for aerobic and anaerobic respiration (given data).




*Net ATP yield per glucose molecule: aerobic vs anaerobic respiration (given data).*

**(a)** Using the graph, state which type of respiration produces more ATP per glucose molecule. **[2]**

**Aerobic respiration** produces far more ATP per glucose molecule (30 ATP), compared with only 2 ATP from anaerobic respiration. **A1 A1**

**(b)** Explain, in terms of oxygen availability, why anaerobic respiration produces far less ATP than aerobic respiration. **[2]**

Anaerobic respiration occurs in the **absence of oxygen**, so glucose is only **partially broken down** (e.g. to lactic acid, or ethanol and $CO_2$), via glycolysis alone. Aerobic respiration uses oxygen to **fully oxidize glucose** to $CO_2$ and water via the Krebs cycle and oxidative phosphorylation, releasing much more of the energy stored in glucose as ATP. **R1 R1**

**(c)** Calculate the ATP yield of anaerobic respiration as a percentage of the ATP yield of aerobic respiration. **[3]**

Percentage = (anaerobic ATP yield ÷ aerobic ATP yield) × 100% = (2 ÷ 30) × 100% = **6.7%**. **M1 M1 A1**

**Question 2** [6 marks]

Aerobic respiration takes place in stages within different parts of the cell.

**(a)** State the location in the cell where glycolysis occurs, and the location where the Krebs cycle and oxidative phosphorylation occur. **[2]**

**Glycolysis** occurs in the **cytoplasm (cytosol)**. The **Krebs cycle** occurs in the **mitochondrial matrix**, and **oxidative phosphorylation** occurs across the **inner mitochondrial membrane**. **A1 A1**

**(b)** State the overall word equation for aerobic respiration. **[2]**

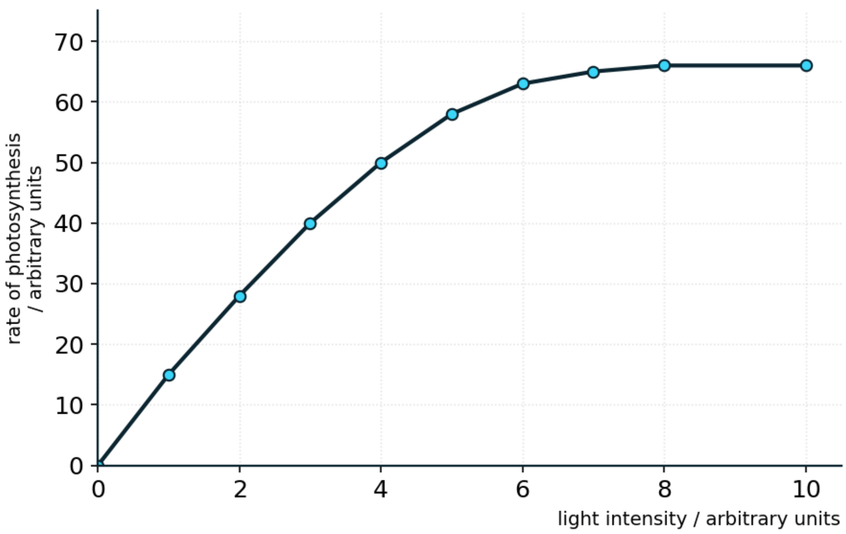
**Glucose + oxygen → carbon dioxide + water (+ energy/ATP)**. **A1 A1**

**(c)** Explain why muscle cells typically contain many mitochondria. **[2]**

Muscle cells require **large amounts of ATP** to power muscle contraction. Since mitochondria are the site of aerobic respiration (which produces far more ATP than anaerobic respiration), having **many mitochondria** allows muscle cells to generate ATP at a high enough rate to meet this energy demand. **R1 R1**

**Question 3** [7 marks]

The graph shows how the rate of photosynthesis in a plant changes with light intensity, at constant temperature and $CO_2$ concentration (given data).




*Rate of photosynthesis vs light intensity (given data).*

**(a)** Using the graph, describe the relationship between light intensity and rate of photosynthesis at low light intensities. **[2]**

At low light intensities, the rate of photosynthesis **increases roughly proportionally (linearly)** with light intensity, since light is the limiting factor on the rate of the light-dependent reactions. **A1 A1**

**(b)** Explain why the rate of photosynthesis plateaus at high light intensities. **[2]**

At high light intensities, light is **no longer the limiting factor**; instead, **some other factor** (such as $CO_2$ concentration or temperature) becomes limiting, and the rate of photosynthesis cannot increase further no matter how much the light intensity is increased. **R1 R1**

**(c)** Suggest, with a reason, what would happen to this graph if the $CO_2$ concentration were increased, with light intensity kept the same. **[3]**

If $CO_2$ was the limiting factor at high light intensity, **increasing $CO_2$ concentration** would allow the rate of photosynthesis to **rise to a new, higher plateau** (the initial low-light part of the curve would be largely unaffected, since light is limiting there, but the plateau at high light intensity would increase). **R1 R1 A1**

## C2 Cell Signalling

**Question 4** [6 marks]

Cells communicate with one another using a variety of signalling mechanisms.

**(a)** Distinguish between endocrine signalling and paracrine signalling. **[2]**

In **endocrine signalling**, a hormone is released into the blood by an endocrine gland and travels throughout the body to act on distant target cells. In **paracrine signalling**, a signalling molecule diffuses through the local extracellular fluid to act on nearby cells only. **A1 A1**

**(b)** Describe the general process of signal transduction. **[2]**

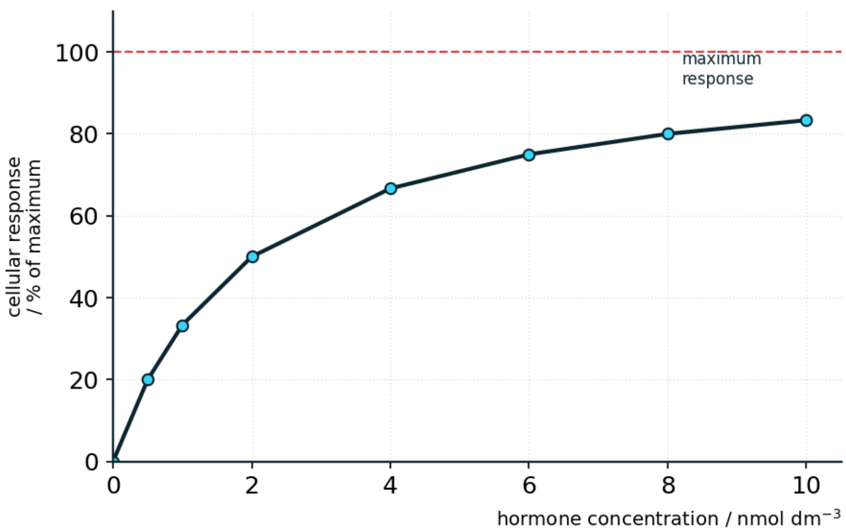
A **signalling molecule (ligand)** binds to a specific **receptor** on (or in) the target cell; this binding triggers a series of **intracellular changes** (a signalling pathway/cascade) that ultimately alters the activity of the target cell (e.g. switching on/off certain genes, or changing enzyme activity). **A1 A1**

**(c)** Explain why a hormone travelling in the blood affects only specific target cells, even though it reaches almost all cells in the body. **[2]**

Only cells with the **specific receptor** complementary to that hormone can respond to it; since receptors for a given hormone are only present on certain cell types (its **target cells**), other cells that lack the receptor are unaffected even though the hormone reaches them via the blood. **R1 A1**

**Question 5** [7 marks]

The graph shows how the response of a target cell changes with the concentration of a hormone, at a fixed number of receptors (computed).




*Cellular response vs hormone concentration (computed, saturating relationship).*

**(a)** Using the graph, describe the relationship between hormone concentration and cellular response at low hormone concentrations. **[2]**

At low hormone concentrations, the cellular response **increases steeply** as hormone concentration increases, since there is an excess of free (unoccupied) receptors available to bind the hormone. **A1 A1**

**(b)** Explain why the cellular response plateaus at high hormone concentrations. **[2]**

At high hormone concentrations, **all (or nearly all) of the available receptors are occupied** by hormone molecules at any given moment, so adding more hormone cannot increase the response any further – the response becomes limited by the number of receptors, not hormone concentration. **R1 R1**

**(c)** Suggest what would happen to this curve if the target cell responded to prolonged high hormone exposure by reducing its number of surface receptors (down-regulation). **[3]**

With **fewer receptors available**, the maximum possible response would be **lower** (the plateau of the curve would drop), and a **higher hormone concentration** would be needed to produce the same percentage response as before, since fewer binding sites are available at any given hormone concentration. **R1 R1 A1**

## C3 Defence & Homeostasis

**Question 6** [6 marks]

The immune system and homeostatic control mechanisms both rely on specific cells and feedback processes.

**(a)** Distinguish between the roles of B lymphocytes and T lymphocytes in immunity. **[2]**

**B lymphocytes** differentiate into plasma cells that **secrete antibodies** specific to a particular antigen (humoral immunity). **T lymphocytes** include helper T cells (which activate other immune cells) and cytotoxic T cells, which **directly destroy infected or abnormal cells** (cell-mediated immunity). **A1 A1**

**(b)** Define 'homeostasis', and give one example of a variable that is homeostatically controlled in the human body. **[2]**

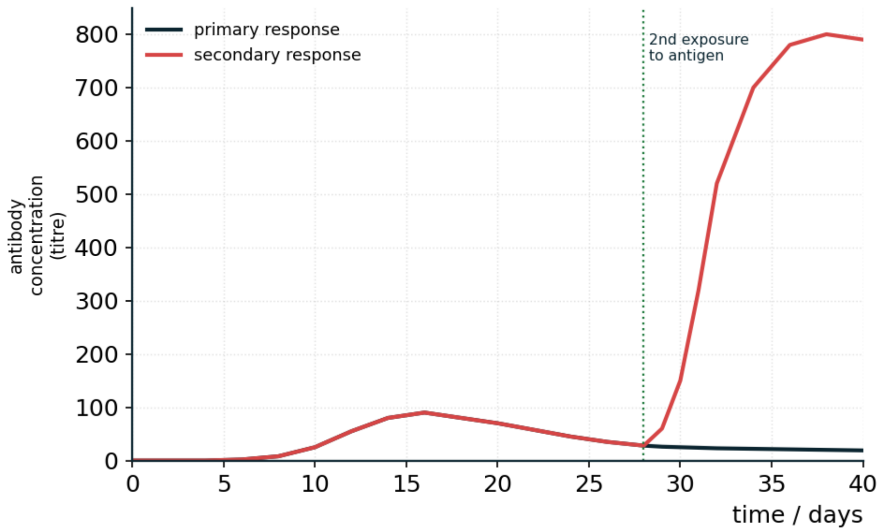
Homeostasis is the **maintenance of a stable internal environment** despite changes in external conditions. Example: **blood glucose concentration** (other valid examples: body temperature, blood pH, water balance). **A1 A1**

**(c)** Explain the general principle of negative feedback in homeostatic control. **[2]**

In negative feedback, a change in a variable **away from its set point (normal range) is detected** by receptors, triggering a response that **counteracts (reverses) the original change**, returning the variable back towards its set point/normal range. **R1 A1**

**Question 7** [7 marks]

The graph shows the concentration of antibodies in the blood (antibody titre) following a first exposure to an antigen, and following a second exposure to the same antigen on day 28 (given data).




*Primary and secondary antibody response to the same antigen (given data).*

**(a)** Using the graph, compare the lag time before antibody production begins to rise noticeably in the primary and secondary responses. **[2]**

In the **primary response**, there is a **longer lag phase** (several days) before antibody titre begins to rise noticeably. In the **secondary response** (after the second exposure at day 28), antibody titre begins to rise **much sooner**, with only a very short lag. **A1 A1**

**(b)** Using the graph, compare the peak antibody concentration reached in the primary and secondary responses. **[2]**

The peak antibody concentration in the **secondary response** (around 800 units) is **much greater** than the peak reached in the **primary response** (around 90 units). **A1 A1**

**(c)** Explain, in terms of memory cells, why the secondary response is faster and greater than the primary response. **[3]**

During the primary response, some activated B lymphocytes differentiate into long-lived **memory B cells** specific to that antigen, which persist in the body long after the infection has been cleared. On **second exposure to the same antigen**, these memory cells can **recognize the antigen and proliferate/differentiate into plasma cells much more rapidly** than in a first exposure (when the response begins from very few naive B cells), producing a faster, larger antibody response. **R1 R1 A1**

**Question 8** [6 marks]

Blood glucose concentration is controlled by hormones released from the pancreas.

**(a)** Describe how insulin helps to lower blood glucose concentration after a meal. **[2]**

A rise in blood glucose concentration stimulates the pancreas to release **insulin**, which causes body cells (e.g. muscle and liver cells) to **take up more glucose from the blood** and stimulates the liver to convert glucose into **glycogen** for storage, lowering blood glucose concentration. **A1 A1**

**(b)** Describe how glucagon helps to raise blood glucose concentration when it falls too low. **[2]**

A fall in blood glucose concentration stimulates the pancreas to release **glucagon**, which stimulates the liver to **break down glycogen into glucose** (glycogenolysis) and release it into the blood, raising blood glucose concentration. **A1 A1**

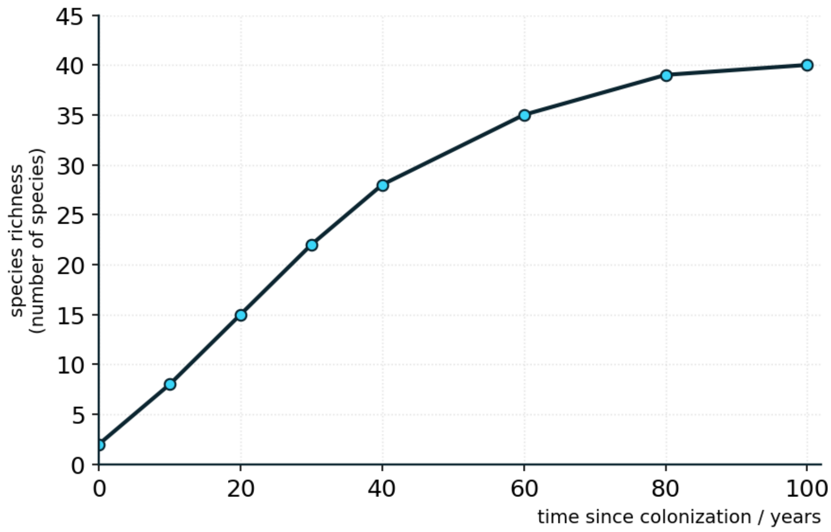
**(c)** Explain why blood glucose regulation is an example of negative feedback. **[2]**

A change in blood glucose concentration (too high or too low) is **detected** and triggers the release of a hormone (insulin or glucagon) that has an effect **opposite to the original change**, bringing blood glucose concentration **back towards its normal range** – this counteracting response is characteristic of negative feedback. **R1 A1**

## C4 Populations & Nutrient Cycles

**Question 9** [7 marks]

The graph shows how species richness changes over time as ecological succession proceeds on a newly exposed area of bare rock (given data).




*Species richness during ecological succession (given data).*

**(a)** Using the graph, describe how species richness changes over the course of succession. **[2]**

Species richness **increases steadily** from a very low value (2 species) at the start of succession, rising rapidly at first and then **levelling off** at around 40 species after about 80–100 years. **A1 A1**

**(b)** Explain why species richness tends to increase during the course of succession. **[2]**

As succession proceeds, earlier colonizing species (e.g. lichens, mosses) **modify the environment** (e.g. by contributing to soil formation and adding organic matter), creating **more habitats and niches** that become suitable for a wider range of species to colonize, increasing species richness. **R1 R1**

**(c)** Define 'climax community', and explain why the graph levels off at this stage. **[3]**

A climax community is the **relatively stable, self-sustaining community** of species that persists at the end of succession, so long as conditions remain unchanged. The graph levels off because the community has reached a **state of dynamic equilibrium**, where the habitat is now **saturated with the niches/species it can support**, and further significant increases in species richness are unlikely without a major disturbance or environmental change. **A1 R1 A1**

**Question 10** [6 marks]

Nitrogen is cycled between the atmosphere, soil, and living organisms via several microbial processes.

**(a)** Define 'nitrogen fixation', and name one type of organism capable of carrying it out. **[2]**

Nitrogen fixation is the conversion of **atmospheric nitrogen gas ($N_2$) into ammonia/ammonium ions**, a form that can be used by living organisms. Example organism: **nitrogen-fixing bacteria** (e.g. Rhizobium in root nodules, or free-living soil bacteria/cyanobacteria). **A1 A1**

**(b)** Describe the process of nitrification. **[2]**

Nitrification is carried out by **nitrifying bacteria** in the soil, which oxidize **ammonia/ammonium ions into nitrite ions, and then into nitrate ions** ($NH_3 \rightarrow NO_2^- \rightarrow NO_3^-$), a form of nitrogen that plants can readily absorb. **A1 A1**

**(c)** Describe the process of denitrification, and explain its effect on soil nitrate levels. **[2]**

Denitrification is carried out by **denitrifying bacteria** (mainly in waterlogged, low-oxygen soils), which convert **nitrate ions back into nitrogen gas**, releasing it into the atmosphere. This process **reduces (depletes) the concentration of nitrate available in the soil** for uptake by plants. **A1 R1**