MEGA LECTURE

IB DP BIOLOGY

Theme A · Unity and Diversity

MARK SCHEME

A1 Water & Nucleic Acids · A2 Cells

A3 Classification & Diversity · A4 Interaction & Ecosystems

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** — Hydrogen bonds between water molecules must absorb a large amount of energy to break as temperature rises, giving water an unusually high specific heat capacity, which helps buffer temperature changes in living organisms.

2. Answer: **C** — Adenine pairs with thymine via two hydrogen bonds (A–T), while guanine pairs with cytosine via three hydrogen bonds (G–C); this is complementary base pairing.

3. Answer: **C** — Proteins are polymers made of amino acid monomers, linked together by peptide bonds.

4. Answer: **B** — A peptide bond forms between the carboxyl group of one amino acid and the amino group of another, in a condensation reaction that releases one molecule of water.

5. Answer: **A** — Cell theory states that all living organisms are composed of cells, cells are the smallest unit of life, and all cells arise from pre-existing cells by cell division.

6. Answer: **B** — Prokaryotic cells have a single circular DNA molecule (and sometimes plasmids) lying free in the cytoplasm, not enclosed within a nuclear envelope, unlike eukaryotic cells.

7. Answer: **B** — Surface area increases with the square of radius while volume increases with the cube of radius, so the surface area to volume ratio decreases as a cell gets larger.

8. Answer: **B** — The fluid mosaic model describes the membrane as a phospholipid bilayer in which proteins are embedded, and both phospholipids and proteins can move laterally within the layer (giving it a fluid, mosaic-like structure).

9. Answer: **B** — A binomial name consists of the genus name (capitalized) followed by the species epithet (lower case), both conventionally written in italics, e.g. Homo sapiens.

10. Answer: **D** — Kingdom is the broadest (highest) of the ranks listed; each kingdom contains many phyla, each phylum contains many genera, and each genus contains one or more species.

11. Answer: **C** — The biological species concept defines a species as a group of organisms that can interbreed with one another to produce fertile offspring.

12. Answer: **B** — Primary consumers (herbivores) feed directly on producers (autotrophs, usually plants or algae), occupying the second trophic level.

13. Answer: **B** — On average, only about 10% of the energy available at one trophic level is incorporated into the biomass of the next trophic level; the rest is lost as heat (respiration), in faeces/waste, or is not consumed.

14. Answer: **C** — Mutualism is a type of interspecific interaction in which both species benefit, such as the relationship between flowering plants and their pollinators.

15. Answer: **B** — More prey provides more food for predators, so the predator population increases, but only after a time lag (needed for increased survival/reproduction of predators); the predator population then reduces the prey population, and the cycle repeats.

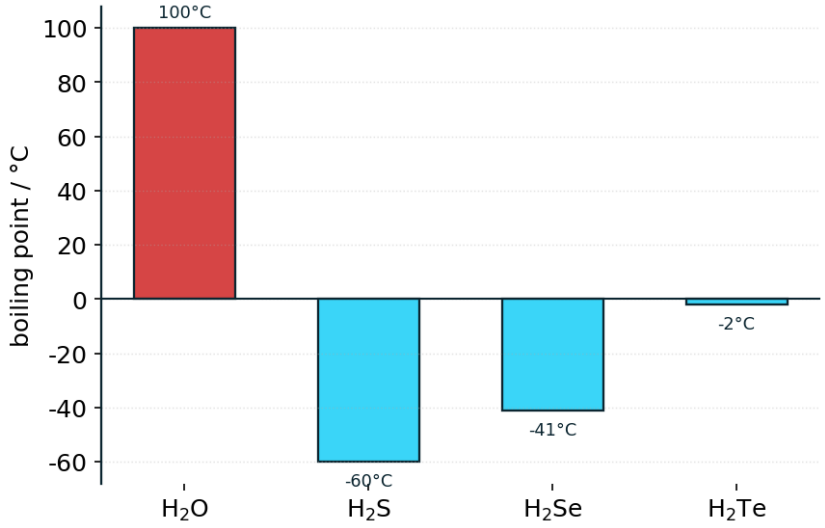
Section B — Structured Questions: Worked Solutions (65 marks)

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

A1 Water & Nucleic Acids

Question 1 [7 marks]

The bar chart shows the boiling points of the Group 16 hydrides of oxygen, sulfur, selenium, and tellurium (given data).



Boiling points of the Group 16 hydrides (given data).

(a) Using the graph, identify which hydride does not fit the general trend shown by the other three, and state its identity. **[2]**

H_2O (water) does not fit the trend: unlike the other three hydrides, its boiling point (100°C) is far higher than expected for its molecular size. **A1 A1**

(b) Explain, in terms of intermolecular forces, why water has an unexpectedly high boiling point compared to the general trend of the other Group 16 hydrides. **[2]**

Water molecules are held together by **hydrogen bonds**, which form between the δ^+ hydrogen atom of one water molecule and a lone pair on the $\delta-$ oxygen atom of another. Hydrogen bonds are much **stronger than the van der Waals' forces** that hold together H_2S, H_2Se, and H_2Te (which lack O−H, N−H, or F−H bonds), so more energy is needed to separate water molecules, raising its boiling point. **R1 R1**

(c) The boiling points of H_2S, H_2Se, and H_2Te increase roughly linearly with molar mass (due to increasing van der Waals' forces). Using this trend, estimate the boiling point water would be expected to have if it followed the same trend, and hence calculate the size of the anomaly (the difference between this predicted value and the actual boiling point of water). **[3]**

Extrapolating the linear trend of H_2S, H_2Se and H_2Te to the molar mass of H_2O (18.02 g mol^{-1}) predicts an expected boiling point of approximately **−73°C**. The actual boiling point of water is 100°C, so the anomaly (difference) is approximately 100 − (−73) ≈ **173°C**. **M1 M1 A1**

Question 2 [6 marks]

Water has several properties that make it essential to living organisms.

(a) Define 'cohesion' and 'adhesion' as properties of water, and give one biological example of each. **[2]**

Cohesion is the attraction between water molecules themselves (due to hydrogen bonding), e.g. it allows a continuous column of water to be pulled up the xylem of a plant. **Adhesion** is the attraction between water molecules and other polar surfaces, e.g. water molecules adhering to the walls of xylem vessels. **A1 A1**

(b) Explain why water's high specific heat capacity is biologically important. **[2]**

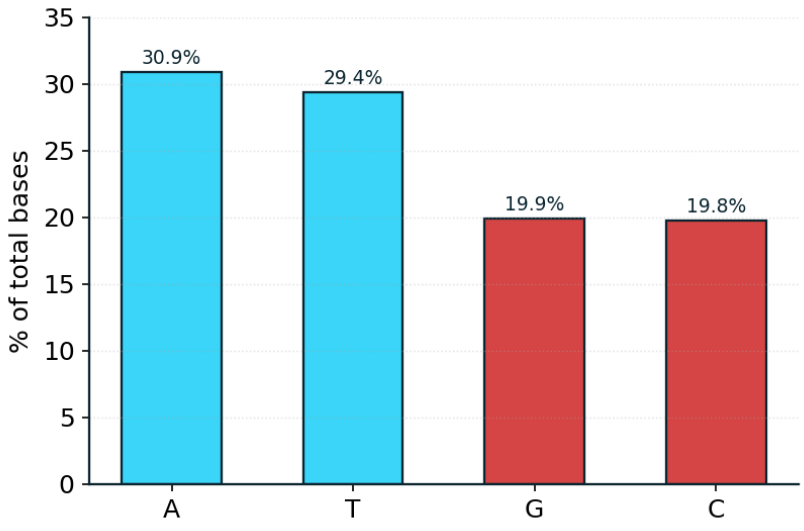
A high specific heat capacity means water can **absorb or release a large amount of heat energy with only a small change in temperature**. This helps organisms (and aquatic habitats) maintain a relatively **stable internal/external temperature**, buffering them against rapid temperature fluctuations. **R1 A1**

(c) Explain why water is described as a good solvent for polar and ionic substances. **[2]**

Water is a **polar molecule** (with a δ^+ end at the hydrogen atoms and a $\delta-$ end at the oxygen atom). This allows water molecules to surround and separate ions or other polar molecules, forming hydrogen bonds/electrostatic attractions with them, which keeps the solute particles dissolved (in solution). **R1 A1**

Question 3 [7 marks]

The bar chart shows the percentage of each of the four nitrogenous bases in a sample of human DNA (given data).



Base composition of human DNA (given data).

(a) Using the graph, state the relationship (Chargaff's rule) illustrated by this data. **[2]**

The data illustrates **Chargaff's rule**: the percentage of adenine is approximately equal to the percentage of thymine (30.9% ≈ 29.4%), and the percentage of guanine is approximately equal to the percentage of cytosine (19.9% ≈ 19.8%). **A1 A1**

(b) Explain, in terms of base pairing, why %A ≈ %T and %G ≈ %C. **[2]**

In double-stranded DNA, adenine on one strand always **pairs specifically with thymine** on the complementary strand, and guanine always **pairs specifically with cytosine**. Since every A on one strand corresponds to exactly one T on the other (and every G to one C), the total amounts of A and T (and of G and C) in the whole DNA molecule must be equal. **R1 R1**

(c) This DNA sample contains a total of 3.0×10^{9} base pairs. Calculate the number of guanine bases present in the sample. **[3]**

Total number of bases (both strands) = $2 \times 3.0\times10^{9} = 6.0\times10^{9}$. Number of guanine bases = 19.9% $\times\ 6.0\times10^{9}$ = $\mathbf{1.19\times10^{9}}$. **M1 M1 A1**

A2 Cells

Question 4 [6 marks]

Cell theory is a foundational idea in biology, though some exceptions and unusual cases exist.

(a) State two components of the (modern) cell theory. **[2]**

Any two of: **all living organisms are composed of one or more cells**; the **cell is the smallest unit of life** (the basic functional unit of living organisms); **all cells arise from pre-existing cells** by cell division. **A1 A1**

(b) Identify two structural features that distinguish prokaryotic cells from eukaryotic cells. **[2]**

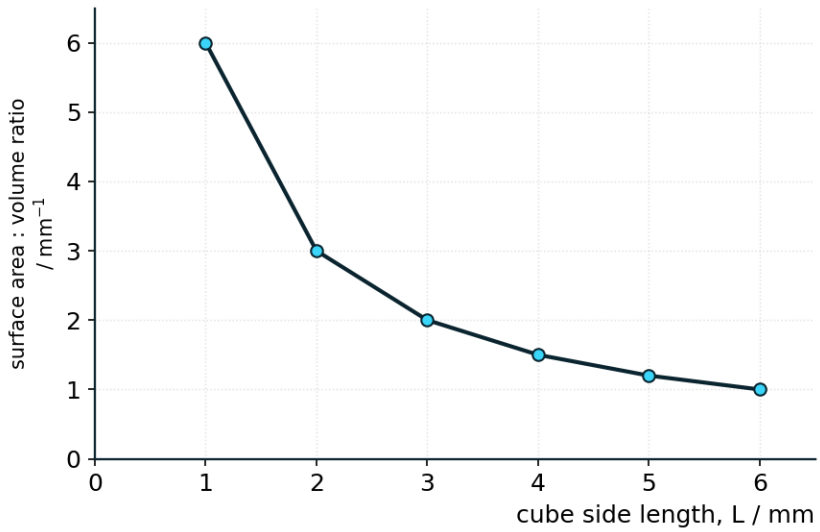
Any two valid contrasts, e.g. prokaryotic cells have **no membrane-bound nucleus** (DNA is free in the cytoplasm) whereas eukaryotic cells have a **nucleus enclosed by a nuclear envelope**; prokaryotic cells have **no membrane-bound organelles** (e.g. no mitochondria), whereas eukaryotic cells do; prokaryotic cells are generally **much smaller** than eukaryotic cells. **A1 A1**

(c) Suggest why viruses are generally not considered to satisfy the cell theory. **[2]**

Viruses are **not made of cells** (they lack a cell-surface membrane, cytoplasm, and ribosomes of their own) and **cannot reproduce independently** – they can only replicate by hijacking the metabolic machinery of a living host cell, so they do not meet the criteria of the cell theory. **R1 R1**

Question 5 [7 marks]

The graph shows how the surface area to volume (SA:V) ratio of a cube-shaped cell changes with the length of its side, L (computed for cubes from L = 1 mm to L = 6 mm).



Surface area : volume ratio vs cube side length (computed: SA:V = 6÷L).

(a) Using the graph, describe the relationship between cube side length and surface area to volume ratio. **[2]**

As the side length, L, **increases, the surface area to volume ratio decreases**; the relationship is a curve that falls steeply at first and then levels off (an inverse relationship, SA:V ∝ 1÷L). **A1 A1**

(b) Calculate the surface area to volume ratio for a cube-shaped cell of side length 4 mm, showing your working. **[2]**

Surface area = $6L^2 = 6\times4^2 = 96$ mm^2. Volume = $L^3 = 4^3 = 64$ mm^3. SA:V ratio = 96÷64 = **1.50 mm^{-1}**. **M1 A1**

(c) Explain why a large surface area to volume ratio is advantageous for a cell, and why this places an upper limit on cell size. **[3]**

A cell exchanges materials (e.g. oxygen, glucose, waste products) with its environment **across its surface (membrane)**, while these materials are used/produced throughout its **volume**. A large SA:V ratio means there is **more membrane area available per unit volume** to supply the cell's needs, allowing efficient diffusion. As a cell grows larger, its SA:V ratio **decreases**, so beyond a certain size diffusion becomes too slow to supply/remove materials fast enough, limiting how large a single cell can become. **R1 R1 R1**

Question 6 [6 marks]

The fluid mosaic model describes the structure of the cell-surface membrane.

(a) Describe the basic structure of the cell-surface membrane according to the fluid mosaic model. **[2]**

The membrane consists of a **phospholipid bilayer** (two layers of phospholipid molecules, with hydrophilic heads facing outward and hydrophobic tails facing inward), with **protein molecules embedded** within or spanning the bilayer. **A1 A1**

(b) Explain the meaning of the term 'fluid' in the fluid mosaic model. **[2]**

'Fluid' refers to the fact that phospholipid molecules (and many proteins) are **not fixed in position** but can **move laterally** within their layer of the membrane, giving the membrane a flexible, dynamic structure rather than a rigid one. **R1 A1**

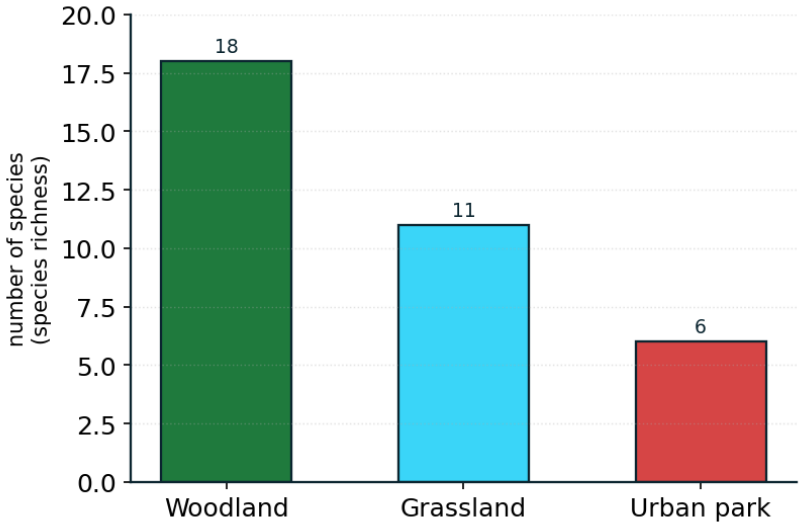
(c) State two functions carried out by proteins embedded in the cell-surface membrane. **[2]**

Any two of: acting as **channels or carriers** for the transport of specific substances across the membrane; acting as **receptors** for hormones or other signalling molecules; acting as **enzymes** that catalyse reactions at the membrane surface; acting as **cell-recognition markers** (e.g. glycoproteins). **A1 A1**

A3 Classification & Diversity

Question 7 [7 marks]

The bar chart shows the number of different species recorded using quadrat sampling in three different habitats (given data).



Species richness recorded in three habitats (given data).

(a) Using the graph, identify the habitat with the greatest species richness. **[2]**

Woodland has the greatest species richness, with 18 species recorded, compared with 11 in grassland and 6 in the urban park. **A1 A1**

(b) Define the term 'species richness', and explain how it differs from 'species diversity'. **[2]**

Species richness is simply the **number of different species** present in a given area/community. **Species diversity** is a broader measure that takes into account **both the number of species and the relative abundance (evenness)** of individuals of each species, not just a simple count. **A1 R1**

(c) Suggest two reasons why the urban park habitat might have lower species richness than the woodland. **[3]**

Any two valid reasons, e.g. the urban park has **less varied habitat structure/fewer niches** (e.g. fewer plant layers, less leaf litter) than a woodland; it may experience **more human disturbance** (trampling, mowing, pollution, noise); it may have been **more recently created/less time to be colonized** by species; it may have **lower structural/vegetation diversity** (e.g. mown grass and few tree species) providing fewer resources and habitats. **R1 R1 R1**

Question 8 [6 marks]

Classification systems organize the diversity of living organisms.

(a) State the two parts of a binomial name, and describe the convention used when writing one. **[2]**

A binomial name consists of the **genus name** (written with a capital first letter) followed by the **species epithet** (written in lower case); the whole name is conventionally written in **italics** (or underlined if handwritten), e.g. Panthera leo. **A1 A1**

(b) List the following taxonomic ranks in order from broadest to narrowest: species, phylum, kingdom, genus. **[2]**

From broadest to narrowest: **Kingdom → Phylum → Genus → Species**. **A1 A1**

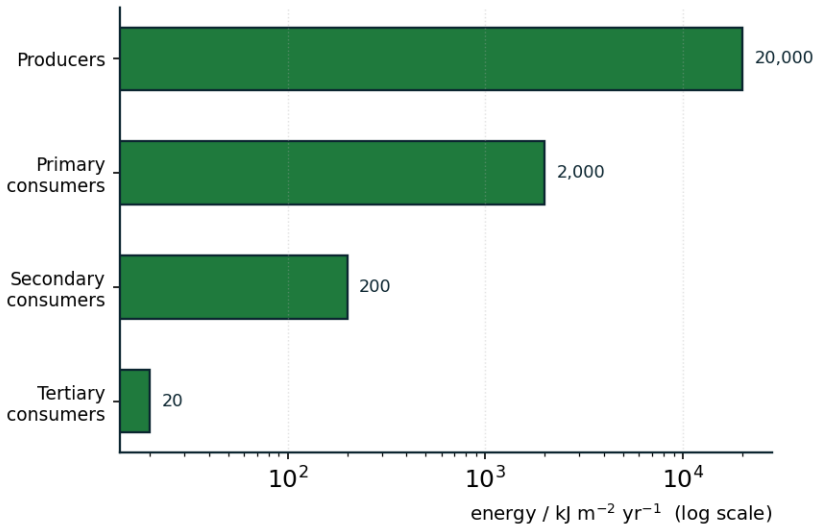
(c) Define the biological species concept. **[2]**

The biological species concept defines a species as a group of organisms that **can interbreed (under natural conditions) to produce fertile offspring**, and that are reproductively isolated from other such groups. **A1 A1**

A4 Interaction & Ecosystems

Question 9 [7 marks]

The bar chart (on a logarithmic scale) shows the energy available at each trophic level of a food chain over one year (given data).



Energy available at successive trophic levels (given data, log scale).

(a) Using the graph, calculate the percentage of energy transferred from producers to primary consumers. **[2]**

Percentage transferred = (energy in primary consumers ÷ energy in producers) × 100% = (2000 ÷ 20000) × 100% = **10%**. **M1 A1**

(b) Explain why energy transfer between trophic levels is never 100% efficient. **[2]**

Energy is lost at each trophic level because: not all of the organisms/biomass at one level is **eaten** by the next; some ingested material is **not digested** and is lost in faeces/waste; and much of the absorbed energy is used in **respiration** and ultimately lost as **heat** to the environment (especially in maintaining body temperature/movement), rather than being converted into new biomass. **R1 R1**

(c) Explain why food chains rarely have more than four or five trophic levels. **[3]**

Because only about **10% of energy is transferred** from one trophic level to the next, the total amount of energy available **decreases rapidly** at each successive level. After four or five transfers, so little energy remains that there is **not enough to support a viable population** of organisms at a further trophic level, so food chains are limited in length. **R1 R1 A1**

Question 10 [6 marks]

Organisms within an ecosystem interact with one another in various ways.

(a) Define 'interspecific competition', and give an example. **[2]**

Interspecific competition is competition **between individuals of different species** for the same limited resource (e.g. food, light, space, water). Example: red squirrels and grey squirrels competing for the same food and habitat resources in a woodland. **A1 A1**

(b) Define 'mutualism', giving an example. **[2]**

Mutualism is an interaction between two different species in which **both species benefit**. Example: flowering plants and their insect pollinators – the plant gains pollination while the insect gains a food source (nectar/pollen). **A1 A1**

(c) Using the terms 'predator' and 'prey', explain why predator population cycles typically lag behind prey population cycles. **[2]**

When the **prey** population increases, there is more food available, so the **predator** population also begins to increase, but only after a **time lag** (time needed for increased survival and reproduction). As predators increase, they consume more prey, causing the prey population to fall; the predator population then also falls (again after a lag), due to reduced food supply, and the cycle repeats. **R1 R1**