For a full copy of the book, Call or inbox JBA JACOB on 0748656556

A'LEVEL CBC BIOLOGY ITEM BANK

WITH

MODEL RESPONSES

BY JBA JACOB

A Route To Excellence

THE COMPETENCY BASED CURRICULUM

FOREWORD

This A' Level CBC Biology Item Bank is designed to make advanced Biology both accessible and intellectually stimulating. Each task is carefully structured to align with competency-based assessment, promoting analytical reasoning, interpretation of data, and application of biological principles to real-world contexts. The progression of items guides learners from foundational understanding to higher-order thinking, ensuring coherent development of skills. The book consists of scenario-based items with responses, as well as self-test items, providing learners with opportunities to practice and reinforce their understanding independently.

The accompanying responses are precise and technically grounded, modeling the reasoning processes expected at advanced level. Beyond serving as an assessment tool, this item bank functions as a guide for structured inquiry, fostering problem-solving, critical analysis, and evidence-based thinking. It is crafted to make learning Biology not only rigorous and technically sound but also engaging, insightful, and deeply rewarding.

It is my hope that this item bank will inspire both learners and teachers to approach Biology with curiosity, confidence, and a sense of purpose. By engaging with these tasks, learners are encouraged to see beyond memorisation, to think critically, and to appreciate the elegance and relevance of Biology in everyday life. May this collection serve not only as a reference but as a companion in the journey toward scientific competence and lifelong intellectual growth.

SECTION ONE

(Items with responses)

The following compilation presents scenario-based items with detailed responses, demonstrating the reasoning and application of biological concepts expected at A' Level. Learners are encouraged to engage actively, analyse critically, and use the explanations to guide their own problem-solving.

1. In a Southeast Asian coastal village, illegal cyanide fishing is practiced; fishermen capture live fish for aquariums. This has led to a significant die-off of non-target coral reef species. A marine biologist, Dr.

Hakeem, collects tissue samples from affected damselfish. Cyanide is a potent inhibitor of cytochrome c oxidase.

Table: Metabolic Analysis of Damselfish Gill Tissue

Sample	**Cytochrome c oxidase activity** (% of normal)	**Gill cell membrane integrity** (% of cells damaged)	**Gill ATP concentration** (mM)	**Oxygen uptake rate** ($mgO_2/g/h$)
Unaffected fish	100	5	4.8	9.5
Cyanide exposed fish	3	60	0.8	1.2

Task:

(a) Explain, in simple steps, how cyanide inhibition of cytochrome c oxidase leads to the changes shown in the table above.

- ***Inhibition of cytochrome c oxidase: Cyanide binds to the iron-heme group of cytochrome c oxidase, the terminal enzyme of the mitochondrial electron transport chain, preventing electrons from being transferred to oxygen, the final electron acceptor. This causes a rapid decrease in cytochrome c oxidase activity from 100% in unaffected fish to 3% in cyanide-exposed fish, blocking the electron transport chain.***
- ***Disruption of oxidative phosphorylation: With the electron transport chain blocked, the proton gradient across the inner mitochondrial membrane cannot be maintained. This stops ATP production through oxidative phosphorylation, causing a rapid decrease in gill ATP concentration from 4.8 mM in normal fish to 0.8 mM in cyanide-exposed fish.***
- ***Reduced oxygen utilization: Since oxygen can no longer accept electrons at the end of the chain, mitochondria cannot use oxygen efficiently. This explains the decrease in oxygen uptake rate from 9.5 mg O_2/g/h in unaffected fish to 1.2 mg O_2/g/h in cyanide-exposed fish.***
- ***Loss of cell membrane integrity: ATP is required for active transport systems, such as sodium-potassium pumps, that maintain ion balance and cell membrane stability. Low ATP levels disrupt these systems, leading to swelling and damage of gill cells, increasing cell damage from 5% to 60%.***
- ***Overall metabolic collapse: The combination of blocked respiration, low ATP, and damaged membranes causes gill tissue to fail. This metabolic collapse reduces oxygen exchange and contributes to the death of non-target coral reef species in areas affected by cyanide fishing.***

(b) Using the information provided, propose strategies to solve the challenges.

- ***Enforcement and regulation: Increase coastal patrols and inspections, impose fines or penalties on cyanide fishers, and ensure laws banning cyanide fishing are actively applied.***
- ***Community awareness: Hold workshops and training for fishermen showing how cyanide fishing destroys reefs and reduces long-term fish catches, encouraging sustainable practices.***
- ***Alternative livelihoods: Provide resources and training for aquaculture, fish farming, or eco-friendly net fishing so fishermen can earn income without harming reefs.***
- ***Coral reef restoration: Establish coral nurseries, transplant resilient corals to damaged areas, and protect reef zones to help fish populations recover.***

- ***Research and monitoring: Regularly test water for cyanide, track fish health, and assess reef recovery to guide management decisions and prevent future damage.***

2. Mr. Owen, a biologist, observed several water-related phenomena. He noticed that small aquatic striders and fish milt can remain on the surface of water without sinking. He also observed that water moves steadily through narrow plant vessels from the roots to the leaves, and that during cold seasons, ice forms on the surface of water while aquatic organisms continue to survive below. Additionally, he noted that aquatic plants are able to grow successfully due to a certain property of water.

Task

(a) Which property of water enables insects and fish milt to remain on the water surface, and how does this benefit aquatic systems?

- ***The property is high surface tension of water, produced by strong cohesive hydrogen bonds between water molecules at the surface. This creates a resistant film that supports small organisms and materials. Ecologically, this allows surface-dwelling insects to forage and escape predators, and it keeps fish milt at the surface where fertilization can occur efficiently, supporting reproductive success in aquatic ecosystems.***

(b) Explain the property of water that allows it to rise through narrow plant vessels, and state its importance for plant survival.

- ***Cohesion-adhesion and capillary rise in vessels; Water moves through narrow plant vessels because of the combined effects of cohesion, which holds water molecules together, and adhesion, which enables them to adhere to the walls of xylem vessels. These forces generate capillary action, drawing water upward from roots to leaves. This movement is essential for plant survival because it supplies water for photosynthesis, maintains cell turgor, and supports transpirational cooling and mineral transport.***

(c) Which property of water explains the formation of ice on the surface of water, and why is this important for aquatic life?

- ***Density anomaly and freezing properties of water; The formation of ice on the surface of water is explained by water's density anomaly, where water expands and becomes less dense when it freezes due to the formation of a rigid hydrogen-bonded lattice. As a result, ice floats and forms an insulating layer at the surface. This insulation reduces heat loss from the underlying water, maintaining liquid conditions and stable temperatures that allow aquatic organisms to remain alive during cold seasons.***

(d) Explain how aquatic plants such as algae are able to make their own food, referring to the relevant property of water.

- ***Aquatic plants such as algae can manufacture their own food through photosynthesis, a process that relies on the high transparency of water, which allows solar radiation to penetrate water to photosynthetic tissues. This penetration of light enables chloroplasts within algal cells to absorb sufficient light energy for carbon fixation, ensuring continuous primary productivity in aquatic habitats.***

3. Early research on the structure of the cell membrane showed that lipid-soluble compounds passed rapidly into cells. The membrane was found to be selectively permeable to mineral ions, sugars and amino acids. Further work demonstrated that all membranes have the same basic structure but can differ greatly in the types of lipid and protein they contain. Many of the specialized proteins present provide a means of communication between cells and molecules in their environment.
(a) Apart from lipid solubility, suggest two factors which could affect the rate of penetration of a molecule through the membrane.

- ***Molecular size*: Smaller molecules diffuse more rapidly through the phospholipid bilayer than larger ones.**
- ***Electrical charge*: Uncharged molecules cross more easily than ions, which require specific transport proteins.**

(b) Describe how the structure of the cell membrane is related to

(i) its selective permeability

- ***Selective permeability is achieved through the organisation of the phospholipid bilayer and the specific membrane proteins embedded within it.***
- ***The phospholipid bilayer forms a hydrophobic core that allows only lipid-soluble molecules to diffuse through, while effectively excluding polar and charged substances. To manage the movement of these excluded molecules, the membrane incorporates specific transport proteins; such as channels, carriers, and pumps; that recognize and move only particular ions, sugars, or amino acids. Together, this enables the cell to regulate substance movement and maintain a stable internal environment.***

(ii) its communication with molecules in the cell's environment.

- ***Communication occurs through receptor proteins, glycoproteins, and glycolipids in the cell membrane. Receptor proteins bind specific extracellular signals, such as hormones or antigens, and initiate intracellular responses. The carbohydrate chains of glycoproteins and glycolipids allow cells to recognize, adhere to, and interact with other cells, enabling coordinated physiological activities.***

(c) Describe how prokaryotes and eukaryotes differ in terms of the membrane-bound structures they contain.

- ***Prokaryotes lack membrane-bound organelles, so processes such as respiration and photosynthesis occur on infoldings of the plasma membrane. Eukaryotes possess numerous membrane-bound structures, including the nucleus, endoplasmic reticulum, Golgi apparatus, mitochondria, lysosomes, and in plants, chloroplasts. These compartments allow specialization and efficient division of cellular functions.***

(d) If the membrane proteins present in the cell membrane were damaged, suggest what would happen to the cell membrane.

- ***Damaged carrier and channel proteins prevent ions and nutrients from moving in and out, disrupting essential cellular processes such as respiration and protein synthesis.***

- ***Receptor proteins that are damaged cannot detect extracellular signals, so the cell cannot respond to its environment.***
- ***Membrane-bound enzymes lose their activity if proteins are damaged, slowing vital biochemical reactions.***
- ***Damaged glycoproteins and glycolipids impair cell recognition and adhesion, preventing proper interactions with other cells.***

4. Farmers in Mbale (Mt. Elgon slopes) and Gulu (Northern Uganda) reported contrasting yields of beans and sorghum. Beans thrive in Mbale but fail in Gulu, while sorghum thrives in Gulu but shows yellowing and stunted growth in Mbale. A student investigation compared environmental factors, leaf anatomy, and photosynthetic activity of these crops in the two districts.

District	**Altitude (m)**	**Average temperature (°C)**	**Rainfall (mm/year)**	**Dominant vegetation**	**Type of leaf anatomy**	**Rate of CO_2 uptake ($\mu mol\ m^{-2}\ s^{-1}$)**	**Main excretory product**
Mbale	1600	20	1500	Bananas, Beans	No Kranz	18	Latex
Gulu	900	33	700	Acacia, Sorghum	Cranz present	32	Oils

Farmers from Gulu recently attempted growing beans using irrigation but yields remained low despite frequent watering.

Adapted: "Comparative analysis of C_3 and C_4 crop adaptations in East Africa". African plant science review 2022.

Tasks

(a) Assess why beans and Sorghum show contrasting performance in Mbale and Gulu.

- ***Beans are C3 plants with no Kranz anatomy, so RuBisCO can bind O_2 at high temperatures, causing photorespiration, which wastes RuBP and CO_2, reducing photosynthetic efficiency. Beans grow well in Mbale because the moderate temperature (20 °C) and high rainfall (1500 mm) favor CO_2 fixation, supporting good growth. In Gulu, high temperature (33 °C) and low rainfall (700 mm) increase photorespiration and limit CO_2 uptake, causing poor yields.***
- ***Sorghum is a C4 plant with Kranz anatomy. PEP carboxylase, which does not bind O_2, fixes CO_2 into oxaloacetate, converted to malate and shunted to bundle sheath cells, where CO_2 is released for the Calvin cycle. This concentrates CO_2 around RuBisCO, minimizing photorespiration and allowing efficient photosynthesis under high temperature, intense light, and low water. Sorghum thrives in Gulu, while cooler, wetter conditions in Mbale reduce its efficiency, explaining poor growth there.***

(b) Suggest the strategies that could help improve the yield of beans in Gulu based on the physiological and anatomical characteristics of the plants.

- ***Grow heat-tolerant C_3 bean varieties that maintain photosynthesis at high temperatures.***

- ***Use shading or agroforestry to reduce leaf temperature and light stress, lowering photorespiration.***
- ***Conserve soil moisture through mulching or drip irrigation to support stomatal opening and CO_2 uptake.***
- ***Ensure adequate soil fertility, especially nitrogen, to sustain photosynthesis.***
- ***Plant during cooler periods to reduce heat stress and improve growth.***