

EXCEL IN BIOLOGY



For
Advanced secondary
IN JUST A DAY

SEMINAR GUIDE 2026

Chapter 1: STRUCTURE OF THE EXAMINATION PAPERS

There will be **two** examination papers for Biology at the Advanced Secondary level.

1. P530/1 BIOLOGY PAPER 1 (THEORY)

Duration: 3 hours

Instructions:

- This examination paper consists of **two** sections; **A** and **B**. It has **six** items.
- Section **A** has **two** compulsory items.
- Section **B** has two parts: **I** and **II**. Respond to one item from each part.
- Respond to **four** items in all.
- All responses must be written in answer booklet(s) provided.
- Any additional item(s) responded to will not be scored.

Guidance on the expectations of the tasks in Biology P530/1

FOR ANALYSIS; part (a) Candidates are required to;

- Make meaning of the data i.e. Interpret data (Identify patterns, trends, changes, implications, conclusions etc.)
- Explain the meaning of the data by linking biological mechanisms/ processes to the observations in the scenario.

FOR EVALUATION; part (b) Candidates are required to;

- Make an opinion on a strategy/or mention an appropriate strategy or intervention to solve a challenge
- Explain the effectiveness of the strategy in solving the challenge (how it solves the challenges & its shortcomings/side effects/negatives etc.)
- Base on the extent of the effectiveness to make a decision on the strategy (e.g. use only once, combine this strategy with others etc.)

What is assessed/examined in P530/1 Biology paper 1 (Theory)

Section A		
Item	Assessment objective	Topics/sub-topics
Item 1: Cellular Organization, Respiration, and Molecular Analysis	Evaluate the significance of the interactions that sustain life and energy production by analyzing the structure of cells, tissues and levels of organization, the roles of biomolecules (water, lipids, proteins, and nucleic acids), and the processes of ATP production, cell division, and protein synthesis, in order to apply these biological principles to challenges in genetic technologies and health improvement.	• Cell Biology • Respiration • Inheritance and Evolution: ✓ Nucleic acids: structure and function ✓ Gene technology
Item 2: Plant physiology and adaptation	Evaluate plant structure and physiology by analyzing structural adaptations and photosynthetic pathways in C ₃ and C ₄ , environmental influences on photosynthesis, plant adaptations (to water availability), growth, photoperiodism, and the hormonal control of growth, to promote sustainable agricultural practices that improve crop yield and food security.	• Nutrition in plants • Co-ordination: ✓ Plants hormones and response • Growth in Plants

Section B		
Part I: Item 3 and Item 4: Analysis of animal systems and behaviours in adapting to environmental changes for health, survival, and welfare	Evaluate the structure and physiology of animal sensory organs and systems (circulatory, nervous, immune, and homeostatic) by analyzing blood circulation, gas transport, immunity (vaccination and allergies), neural transmission, sensory perception, homeostatic control, and the role of adaptive behaviours in survival, to make informed health decisions and promote animal welfare	• Transport in Humans • Homeostasis • Coordination: ✓ Impulse transmission ✓ Sensory receptors ✓ Behaviour
Part II: Item 5 and Item 6: Genetic, evolutionary, and ecological dynamics	Evaluate the principles of genetics, evolutionary mechanisms, and ecological interactions by analyzing Mendelian and non-Mendelian genetics, species evolution, speciation, resistance, extinction, population dynamics, ecosystem balance, and carbon emissions, to create sustainable strategies for managing invasive species, enhancing food security, and mitigating climate change.	• Inheritance and Evolution: ✓ Mendelian and non-Mendelian inheritance ✓ Evolutionary advancements in life process in Animals ✓ Speciation and extinction • Growth in Plants and Development in Insects • Ecology

2. P530/2 BIOLOGY PAPER 2 (PRACTICAL)

- This examination paper consists of **two** items. Respond to **both** items.
- Write all responses in the spaces provided.
- Use sharp pencils for drawings. Coloured pencils should not be used.
- Show all your working for any calculation.
- No extra paper is allowed. Any work written on additional sheets will not be scored.

What is assessed in P530/2 Biology paper 2 (Practical)

Item	Assessment Criteria (what scorers will look for in your responses)	Practical areas
Item 1: Comparative Observational Investigations This item requires relating structural and behavioural mechanisms to the survival advantage of the organism.	A candidate is expected to: a) Dissection: • Produce a clear, logical procedure for dissection. • Orient the specimen correctly. • Open the body cavity systematically to expose internal structures. • Displace internal organs carefully to display the required structures. • Make systematic observations with accurate measurements of external and internal structures. • Produce a neat, well-labeled drawing of the observed structures.	• Dissection of a mammal, preferably a rat. • Comparative study of structures with a dissected toad/frog or cockroach.

	b) Microscopy: • Set up and focus the microscope correctly to observe cells or tissues and identify their visible structures. • Produce neat, well-labeled drawings that show the essential details observed. c) Analysis of the findings: • Candidates should compare the features observed in the dissected specimen with those of the related structures shown in pictures. • They should link each structural feature directly to its adaptive significance for survival in the given habitat and to the organism's mode of life.	
Item 2: Scientific investigations	• This item assesses candidates' ability to plan, conduct, and interpret an investigation, and then use the results to make justified recommendations. • A candidate's findings must be presented in a scientific report that includes: 1. Aim – state what to do and why? 2. Hypothesis – give a prediction linked to the scenario in comparative form, with a correct explanation. 3. Variables: – identify independent, dependent, and controlled variables. 4. Risks and Mitigations – outline possible risks and how they are managed. 5. Procedure – write a clear, relevant procedure in correct sequence, showing materials used and how controlled variables were managed. 6. Results – present data systematically, preferably in a table. 7. Data analysis – provide explanations, draw a conclusion, and make recommendations.	• Food tests • Enzyme activity • Osmosis • Diffusion

Chapter 2: RESPONSES TO SEMINAR ITEMS

P530/1 BIOLOGY PAPER 1 (THEORY)

SECTION A

1. Cellular Organization, Respiration, and Molecular Analysis

Item 1.1:

(a) Relationship between the data and farmers' complaints

Increased water temperature and reduced pH of the swamp water beyond the normal range caused reduced microbial decomposition activity, resulting in accumulation of undecomposed organic wastes and foul smell.

The untreated hot effluent released from the soap and textile factory increased the swamp water temperature from the normal range and lowered the pH from the normal range, creating unfavourable conditions for decomposer microorganisms. The high temperature increased the kinetic energy of microbial enzyme molecules, causing excessive vibrations that broke weak hydrogen and hydrophobic bonds maintaining the enzyme's tertiary structure. This distorted the three-dimensional shape of the enzyme's active site, preventing specific substrates involved in decomposition from fitting properly, thereby reducing enzyme-substrate complex formation and slowing microbial decomposition. In addition, the acidic pH increased hydrogen ion concentration, and these hydrogen ions interacted with ionic bonds between amino acid side chains in microbial enzymes, disrupting the bonds that maintain the enzyme's three-dimensional structure. The altered active site could no longer bind effectively with its substrates, reducing enzyme activity and limiting the breakdown of organic wastes. Consequently, undecomposed organic matter accumulated in the swamp and underwent anaerobic decomposition, releasing foul-smelling gases such as hydrogen sulphide and methane, which caused the reported bad smell.

Reduced root cell ATP production also reduced root cell mitotic activity below normal levels caused stunted growth and poor root development of crops.

The contaminated swamp water reduced root cell ATP production from below the reference because it contained inhibitors of cytochrome oxidase, an enzyme involved in the electron transport chain during aerobic respiration. Inhibition of cytochrome oxidase prevented the transfer of electrons to oxygen, reducing proton pumping across the inner mitochondrial membrane and decreasing the proton gradient required for ATP synthesis by ATP synthase during oxidative phosphorylation. The resulting shortage of ATP reduced energy availability for active transport of mineral ions into root cells, synthesis of growth-related molecules and other metabolic activities required for normal root functioning, leading to stunted crop growth and poor root development.

The contaminated irrigation water also reduced root cell mitotic activity far below the reference because it contained colchicine, a chemical that prevents spindle fibre formation during cell division. Without spindle fibres, chromosomes could not attach and separate correctly during metaphase and anaphase, disrupting chromosome movement and preventing successful completion of mitosis. Since the root apical meristem depends on continuous mitotic division to produce new cells for root elongation and branching, the reduced mitotic activity limited root cell production, resulting in poorly developed roots and reduced crop growth.

(b) Evaluation of the recommendations

Use of organic manure by farmers

Using organic manure is effective because it contains activators that bind on the allosteric sites of enzyme cytochrome oxidase increasing the rate at which it catalyzes combination of electrons, hydrogen ions and oxygen producing more ATP. However, the activators maybe released slowly and the quantity to be applied may not be easy to determine. Organic manure alone may not also solve the problem because it does not remove toxic contaminants such as colchicine and cytochrome oxidase inhibitors already present in the irrigation water. Therefore, I recommend the use of organic manure as a supplementary measure to improve soil fertility, but it should be combined with stopping the use of contaminated irrigation water and controlling the source of factory effluents to restore normal crop growth.

Treatment and cooling of factory wastewater

Treating and cooling factory wastewater would be effective because wastewater treatment processes can remove toxic chemicals, organic pollutants and suspended materials before discharge into the swamp. Cooling the wastewater would reduce thermal pollution, allowing decomposer microorganisms to function within their optimum temperature range and restoring normal enzyme activity involved in decomposition. Neutralising the acidic effluent would also restore the pH closer to the optimum range required for microbial enzymes and plant root function. However, wastewater treatment systems require proper maintenance, and monitoring, and incomplete treatment may allow harmful chemicals such as colchicine and enzyme inhibitors to remain in the discharged water. Therefore, I strongly recommend treatment and cooling of factory wastewater because it directly addresses the source of contamination and prevents continued ecological damage to decomposers, crops and the surrounding community.

Item 1.2:

(a) Relationship between the data and farmers' complaints

Reduced root cell ATP production below the reference caused reduced root cell mitotic activity below the normal level leading to stunted growth and poor fruit production of tomato plants.

Mining contaminants in the soil contained lead and mercury compounds which inhibited mitochondrial enzymes involved in aerobic respiration in root cells. These heavy metals interfered with electron transport chain enzymes, reducing electron transfer and proton pumping across the inner mitochondrial membrane, thereby reducing the proton gradient required for ATP synthesis by ATP synthase during oxidative phosphorylation. The resulting ATP shortage reduced energy supply for root cell mitosis to form longer more branched roots which increase the surface area for uptake of nutrients but the reduced ATP also reduced energy for active uptake of essential mineral ions like nitrates, phosphates, potassium and magnesium, required for synthesis of proteins and other metabolic activities required for growth and reproduction. Consequently, tomato plants had limited resources for vegetative development and fruit formation, leading to stunted growth and poor fruit production. The contaminated soil also reduced root cell mitotic activity because heavy metal toxicity interfered with processes involved in successful cell division. Lead and mercury ions disrupted the formation and functioning of spindle fibres by binding to proteins involved in the mitotic apparatus, preventing accurate chromosome movement during metaphase and anaphase. This reduced the production of new root cells required for root elongation and branching, limiting water and mineral uptake and contributing to poor plant growth and reduced fruit development.

Reduced soil pH below the normal range caused reduced chloroplast number per leaf cell resulting in yellowing of leaves, stunted growth and poor fruit development.

The acidic soil conditions increased hydrogen ion concentration, and these hydrogen ions interacted with ionic bonds between amino acid side chains of plant enzymes, disrupting the bonds that maintain the enzymes' tertiary structures. This altered the three-dimensional shape of enzyme active sites, preventing substrates from fitting correctly and reducing enzyme-substrate complex formation. Consequently, metabolic reactions involved in nutrient uptake, assimilation, synthesis of growth regulators and formation of essential plant compounds became less efficient, contributing to reduced growth and poor fruit development. The acidic soil also increased heavy metals' solubility and uptake which reduced chloroplast formation and survival in leaf cells, lowering the photosynthetic capacity of tomato plants. The reduced number of chloroplasts caused yellowing of leaves and decreased the amount of chlorophyll containing structures available to absorb light energy, reducing light dependent reactions such as photolysis of water, ATP production and reduction of NADP to NADPH. The reduced production of ATP and NADPH limited the Calvin cycle reactions involved in carbon dioxide fixation and carbohydrate synthesis, resulting in decreased glucose production required for respiration, growth and fruit formation hence poor fruit development.

(b) Effectiveness of the proposed recommendations

Application of agricultural lime to neutralize soil acidity

Agricultural lime would be effective because it reduces excessive hydrogen ion concentration in acidic soils, restoring soil pH closer to the optimum range required for plant enzyme activity. By reducing hydrogen ion interference with ionic bonds in enzyme proteins, lime helps maintain the correct three-dimensional structure of enzyme active sites, allowing substrates to bind effectively and restoring metabolic processes necessary for plant growth. However, lime does not directly remove lead and mercury compounds from the soil, meaning heavy metal inhibition of mitochondrial enzymes and other cellular processes may continue. Therefore, I recommend applying agricultural lime as a supportive measure to restore suitable soil conditions,

but it should be combined with measures that remove heavy metal contamination for complete recovery of crop productivity.

Introduction of phytoremediation plants to remove heavy metals

Phytoremediation would be effective because certain plants can absorb heavy metals such as lead and mercury through their root systems and accumulate or immobilize them in plant tissues. This reduces the concentration of toxic metals in the soil, decreasing their inhibition of mitochondrial enzymes and other cellular proteins, thereby allowing normal respiration, ATP production and growth processes to resume. However, phytoremediation plants may require time to remove sufficient amounts of heavy metals, and contamination may persist if the plants do not have a high capacity for metal uptake. Therefore, I recommend phytoremediation as an effective biological approach for gradually reducing heavy metal toxicity and restoring soil quality.

Relocating food crop production away from contaminated sites

Relocating food crop production would be effective because it prevents tomato plants from absorbing lead and mercury compounds through their roots. This avoids heavy metal interference with mitochondrial enzymes, chloroplast development and other cellular processes, allowing plants grown in uncontaminated soils to maintain normal ATP production, photosynthesis and cell division required for healthy growth and fruit production. However, relocation does not correct the existing contamination of the abandoned mining site or restore the ecological function of the affected land. I recommend relocation as an immediate measure to protect crop productivity and food safety while long-term soil restoration measures are implemented.

Item 1.3:

(a) Relationship between the data and Amina's health problems

Reduced water efflux from epithelial cells caused increased thickness of the mucus layer, resulting in recurrent respiratory infections.

The deletion mutation in the CFTR gene altered the structure and function of chloride ion transport proteins located on epithelial cell membranes, reducing movement of chloride ions out of epithelial cells. A deletion of the three-base triplet in the CFTR gene removes the amino acid phenylalanine at position 508 of the CFTR protein, causing abnormal folding and failure of the chloride transport protein. Since water movement across epithelial surfaces occurs by osmosis following ion concentration gradients, reduced chloride secretion decreased the movement of water into the airway surface fluid, resulting in reduced hydration of mucus and increased mucus thickness. The thick and sticky mucus became difficult for cilia lining the respiratory tract to move, reducing mucociliary clearance and preventing efficient removal of trapped dust particles and microorganisms. Consequently, bacteria and other pathogens remained in the airways for longer periods, allowing increased microbial multiplication and triggering repeated immune responses, which caused frequent respiratory infections.

Reduced mitochondrial activity caused reduced energy availability, resulting in fatigue and poor growth.

Reduced mitochondrial activity decreased the efficiency of aerobic respiration because impaired mitochondrial function reduced electron transport chain activity and oxidative phosphorylation. This reduced the formation of the proton gradient across the inner mitochondrial membrane required for ATP synthesis by ATP synthase, resulting in reduced ATP production. The shortage of ATP limited energy supply for active transport processes, protein synthesis, tissue repair, cell division and other anabolic activities required for normal growth and development. In addition, reduced ATP availability in muscle cells decreased the energy required for repeated muscle contraction and maintenance of normal physiological activities, causing fatigue. The reduced energy supply therefore contributed to poor growth and reduced physical endurance in Amina.

(b) Critique of the recommendations

Initiating gene therapy trials

Gene therapy would be effective because it aims to introduce a functional copy of the CFTR gene into affected epithelial cells. The restored gene would enable production of normal CFTR membrane proteins, improving chloride ion transport across epithelial membranes. This would increase water movement into airway secretions, reduce mucus viscosity, restore mucociliary clearance and decrease accumulation of pathogens in the respiratory tract. However, gene therapy trials may not immediately correct all affected cells, and immune responses against introduced genetic material or delivery vectors may reduce effectiveness. Therefore, I recommend gene therapy as a potential long-term treatment because it targets the underlying genetic cause of the disorder rather than only managing the symptoms.

Providing regular chest physiotherapy

Chest physiotherapy would be effective because physical techniques such as controlled coughing and airway clearance exercises help loosen and remove thick mucus from the respiratory tract. Removing accumulated mucus improves movement of cilia, enhances clearance of trapped microorganisms and reduces the likelihood of bacterial colonisation, thereby lowering respiratory infections. However, chest physiotherapy does not correct the defective CFTR protein or prevent the continuous production of abnormal thick mucus. Therefore, I recommend regular chest physiotherapy as an important supportive treatment to reduce complications while other treatments address the underlying defect.

Administering medicines to clear the airways

Airway-clearing medicines would be effective because they reduce mucus viscosity by breaking down mucus components or increasing airway hydration, making secretions easier to remove. This improves airflow, enhances mucociliary clearance and reduces accumulation of pathogens, helping to decrease respiratory infections and improve breathing.

However, these medicines only manage the effects of the CFTR mutation and do not restore chloride transport across epithelial membranes, meaning abnormal mucus production may continue. Therefore, I recommend airway-clearing medicines as part of symptom management while combining them with treatments such as gene therapy that target the root genetic cause.

Item 1.4:

(a) Relationship between the data and athletes' complaints

Increased ATP concentration caused reduced pyruvate concentration, resulting in increased lactic acid accumulation and severe muscle fatigue.

The Mega-Boost supplement directly supplied ATP and NADH into mitochondria, causing an abnormal increase in ATP concentration within muscle cells. The high ATP levels created negative feedback inhibition on glycolysis, reducing the activity of key glycolytic enzymes such as phosphofructokinase and slowing the conversion of glucose to pyruvate in the cytoplasm. The reduced pyruvate availability limited entry of carbon intermediates into the Krebs cycle, reducing normal aerobic respiration and causing greater dependence on anaerobic glycolysis during prolonged exercise. Consequently, pyruvate was converted into lactic acid by lactate dehydrogenase to regenerate NAD^+ required for glycolysis, causing excessive lactic acid accumulation, reduced muscle pH, inhibition of enzyme activity involved in contraction and impaired actin-myosin interaction, leading to severe muscle fatigue and collapse.

Increased rate of lipid breakdown caused mitochondrial cristae damage, resulting in impaired aerobic energy production and muscle fatigue.

The Mega-Boost supplement stimulated excessive lipid breakdown as alternative to inhibited glucose breakdown, increasing fatty acid oxidation inside mitochondria. The high metabolic demand generated excessive reducing equivalents and electron flow through the electron transport chain, increasing production of reactive oxygen species. These free radicals damaged mitochondrial membranes and caused swelling of mitochondrial cristae, reducing the surface area available for electron transport chain complexes and ATP synthase activity. Consequently, oxidative phosphorylation became less efficient, reducing sustainable ATP production during long-distance exercise and contributing to muscle fatigue and collapse.

(b) Evaluation of medical interventions

Administering 100% oxygen gas during recovery

Administration of oxygen would be effective because oxygen acts as the final electron acceptor in the electron transport chain, allowing continued aerobic respiration and regeneration of water at cytochrome oxidase. Increased oxygen availability would support oxidative phosphorylation, improve ATP production and enhance conversion of lactic acid back into pyruvate for removal through aerobic metabolism.

However, oxygen alone cannot reverse mitochondrial cristae damage or prevent excessive ATP-induced inhibition of glycolysis caused by Mega-Boost and pure oxygen inhibits the carotid and aortic bodies which regulate breathing so is also fatal.

Therefore, I recommend oxygen therapy but not using pure oxygen as a supportive emergency treatment during recovery not as a complete solution to the supplement-induced metabolic disturbance.

Feeding high-glucose syrup after collapse

High-glucose syrup would be effective because glucose provides substrate for glycolysis, producing pyruvate that can enter mitochondria for aerobic respiration and generate ATP through the Krebs cycle and oxidative phosphorylation. However, the athletes already had excessive ATP levels and damaged mitochondria, meaning additional glucose may cause hyperglycemia, increase glycolytic activity and potentially worsen

lactic acid accumulation if aerobic respiration remains impaired. Therefore, I do not recommend glucose administration as the primary intervention because the main problem is mitochondrial dysfunction rather than lack of glucose supply.

Administering a drug that competitively inhibits fatty acid oxidation before the race

The drug would be effective because it reduces excessive fatty acid breakdown, decreasing the supply of fatty acids entering mitochondria for β -oxidation. This reduces excessive electron flow, reactive oxygen species formation and mitochondrial membrane damage, allowing mitochondria to maintain efficient oxidative phosphorylation during prolonged exercise. However, excessive inhibition of lipid oxidation may reduce an athlete's ability to use fats as a long-term energy source during endurance exercise. Therefore, I recommend controlled inhibition of excessive lipid oxidation because it directly prevents the metabolic imbalance responsible for mitochondrial damage and fatigue.

Item 1.5:

(a) Relationship between the data and patients' symptoms

Reduced DNA polymerase activity caused increased cells stalled in S-phase, resulting in blistering and reduced wound healing.

The organic skin-lightening serum reduced DNA polymerase activity, an enzyme required for DNA replication during the S-phase of the cell cycle. Reduced DNA polymerase activity prevented efficient addition of nucleotides to newly forming DNA strands, causing incomplete DNA replication and accumulation of cells arrested in S-phase. Since epidermal renewal depends on continuous division of basal cells to replace damaged surface cells, reduced cell proliferation decreased production of new keratinocytes required for repairing damaged tissue. Consequently, the epidermis became thin, fragile and unable to heal minor injuries effectively, leading to blistering and delayed wound healing.

Reduced cellular cholesterol-to-phospholipid ratio caused reduced intracellular water volume, resulting in translucent and fragile skin.

The reduced cholesterol-to-phospholipid ratio weakened the structural stability and selective permeability of epidermal cell membranes. Cholesterol normally regulates membrane fluidity by filling spaces between phospholipids and reducing excessive movement of phospholipid molecules. Reduced cholesterol made membranes more permeable, allowing excessive leakage of water and ions from cells, resulting in decreased intracellular water volume. The loss of cellular hydration reduced epidermal thickness and transparency increased, making underlying blood vessels more visible and causing the skin to appear translucent.

(b) Evaluation of proposed interventions

Applying topical barrier ointment containing synthetic cholesterol

The cholesterol-rich ointment would be effective because cholesterol molecules can integrate into phospholipid bilayers of epidermal cell membranes, restoring membrane stability and reducing excessive permeability. This would improve water retention within skin cells, restore barrier function and reduce skin fragility. However, the ointment would not correct reduced DNA polymerase activity or restore normal basal cell division required for replacing damaged epidermal cells. Therefore, I recommend it as supportive treatment for restoring the skin barrier but not as the main treatment for impaired skin regeneration.

Mechanical dermabrasion to remove blistered epidermal layers

Dermabrasion would remove damaged superficial epidermal cells, allowing healthier underlying tissue to form a new surface layer. It may hence temporarily improve appearance by removing abnormal skin layers. However, because DNA replication and basal cell proliferation are impaired, the remaining cells may not divide effectively to regenerate new epidermis, increasing the risk of delayed healing and further tissue damage. Therefore, I do not recommend dermabrasion because it may worsen the inability of the skin to repair itself.

Synthetic growth factor drug to stimulate basal cell growth

A growth factor drug would be effective because it stimulates signaling pathways that activate basal cell division and differentiation, increasing production of new keratinocytes needed for epidermal repair. This would help replace damaged cells and improve wound healing. However, increased cell division cannot be fully effective if DNA polymerase activity remains severely reduced because cells cannot complete DNA replication required before mitosis. Therefore, I recommend growth factor treatment only after correcting the cellular damage caused by the serum to allow normal DNA replication.

Item 1.6:**(a) Relationship between the data and students' complaints****Reduced cytochrome c oxidase activity caused reduced ATP production in muscle cells, resulting in persistent fatigue during sports activities.**

Carbon monoxide from faulty heating equipment reduced cytochrome c oxidase activity by binding strongly to the enzyme's haem group in mitochondria, preventing oxygen from acting as the final electron acceptor in the electron transport chain. This interrupted electron transfer and reduced proton pumping across the inner mitochondrial membrane, decreasing the proton gradient required for ATP synthesis by ATP synthase. The resulting reduction in ATP production limited energy supply for muscle contraction, active transport and other cellular activities during exercise, causing persistent fatigue and poor physical performance.

Reduced mitochondrial density in muscle cells also, caused reduced ATP production and increased fatigue during exercise.

The reduced number of mitochondria in skeletal muscle cells decreased the total capacity for aerobic respiration. Fewer mitochondria contained fewer electron transport chains and ATP synthase enzymes, reducing oxidative phosphorylation and limiting ATP generation during prolonged exercise. Consequently, muscle cells relied more on anaerobic respiration, causing faster accumulation of lactic acid and reduced muscle efficiency, contributing to fatigue.

Reduced cytochrome activity also reduced mitotic skin epithelial activity below reference in students exposed to CO causing reduced slow recovery from minor skin injuries:

Carbon monoxide binds to and inhibits cytochrome oxidase enzyme in the mitochondrial electron transport chain, reducing the transfer of electrons to oxygen as the final electron acceptor. This disrupts oxidative phosphorylation, decreases proton gradient formation and ATP synthesis, thereby limiting the energy available for DNA replication and mitotic division of skin epithelial cells.

Reduced ATP supply slows proliferation of basal epidermal cells responsible for replacing damaged cells, decreasing epidermal regeneration and tissue repair, which results in delayed recovery from minor skin injuries.

(b) Evaluation of recommendations**Improving dormitory ventilation**

Improved ventilation would be effective because it increases exchange of indoor air with fresh air, reducing carbon monoxide concentration and increasing oxygen availability. This prevents carbon monoxide binding to cytochrome c oxidase, allowing normal electron transport chain activity, oxidative phosphorylation and ATP production. However, ventilation alone may not prevent continued carbon monoxide release if faulty heating systems remain in use. Therefore, I recommend improved ventilation as an immediate protective measure but it should be combined with removal of the pollution source.

Replacing faulty heating systems

Replacing faulty heating systems would be effective because it removes the source of carbon monoxide production, preventing further inhibition of cytochrome c oxidase in mitochondria. Restored oxygen utilization would improve aerobic respiration, ATP production and normal cellular function. However, replacement alone may not detect future air quality problems unless environmental conditions are regularly monitored. Therefore, I strongly recommend replacing faulty systems because it directly eliminates the cause of carbon monoxide exposure.

Conducting regular indoor air quality monitoring

Regular monitoring would be effective because it allows early detection of harmful gases such as carbon monoxide before concentrations reach levels that interfere with mitochondrial respiration. Early detection enables corrective action, preventing prolonged inhibition of cytochrome c oxidase and cellular energy failure. However, monitoring only identifies the problem and does not itself remove carbon monoxide or restore damaged mitochondrial function. Therefore, I recommend regular monitoring as a preventive measure alongside proper ventilation and safe heating systems.

2. Plant Physiology and Adaptation

Item 2.1:

(a) Relationship between the data and farmers' complaints

High temperature and reduced water availability caused increased ABA levels and stomatal closure, resulting in reduced photosynthesis and low crop yields.

The high temperature and limited water availability in open fields caused water stress in tomato plants, stimulating increased synthesis of abscisic acid (ABA) in roots and leaves. ABA was transported to guard cells where it triggered ion efflux, particularly loss of potassium ions, causing water to leave guard cells by osmosis and reducing guard cell turgidity. The reduced turgidity caused stomata to close, decreasing gaseous exchange between the leaf and atmosphere. Consequently, less carbon dioxide entered the leaf mesophyll cells, limiting carbon dioxide fixation by RuBisCO during the Calvin cycle and reducing carbohydrate production from phosphoglycerate required for growth and fruit development.

The reduced photosynthesis in open-field tomato plants limited the production of glucose and other assimilates required for respiration, synthesis of structural materials and formation of fruits. Since tomato plants are C₃ plants, reduced carbon dioxide availability increased photorespiration because RuBisCO increasingly acted as an oxygen-fixing enzyme, reducing the efficiency of carbon fixation. Consequently, fewer organic products were available for biomass accumulation, resulting in smaller fruits and lower crop yields.

Reduced stomatal opening caused reduced transpiration and limited water and mineral uptake, resulting in smaller leaves and fruits.

The mostly closed stomata of open-field tomato plants reduced transpiration from leaves, decreasing the transpiration pull responsible for upward movement of water and dissolved mineral ions through the xylem. Reduced mineral supply limited availability of essential nutrients required for chlorophyll synthesis, enzyme production and formation of new plant tissues. Reduced water uptake decreased the availability of water molecules for photolysis in the light-dependent stage of photosynthesis, resulting in fewer hydrogen ions (H⁺) for the reduction of NADP⁺ to NADPH and reduced replacement of electrons lost from Photosystem II. Consequently, less NADPH and ATP were produced, limiting the light-independent stage of the Calvin cycle where CO₂ is fixed into carbohydrates and other organic food substances. Consequently, leaf expansion and fruit development were reduced, producing smaller hairy leaves and smaller fruits compared with greenhouse-grown plants.

(b) Evaluation of greenhouse use and survival strategies

Use of greenhouse structures

Greenhouse cultivation would be effective because it creates a controlled environment with suitable temperature and adequate water availability, reducing water stress and ABA production. Lower ABA levels maintain stomatal opening, allowing greater carbon dioxide uptake and increasing photosynthesis, carbohydrate production and fruit development. However, greenhouse conditions alone do not guarantee maximum yield if other factors such as mineral nutrition, pests and diseases are not properly managed. Therefore, I recommend greenhouse cultivation because it directly modifies the environmental conditions causing stomatal closure and reduced photosynthesis in open fields.

Smaller hairy leaves as a survival strategy

Smaller hairy leaves would be effective because reduced leaf surface area decreases water loss through transpiration, while leaf hairs trap a layer of still air around the leaf surface, reducing the water vapour gradient between the leaf and atmosphere. This helps maintain water balance during drought conditions. However, smaller hairy leaves reduce the total surface area available for light absorption and carbon dioxide uptake, limiting photosynthesis and reducing crop productivity. Therefore, I consider smaller hairy leaves an effective survival adaptation under drought stress but undesirable for maximizing commercial tomato yield.

Smaller fruits as a survival strategy

Smaller fruits would be effective because they reduce the amount of water and assimilates required for fruit development, allowing the plant to survive periods of limited water availability. However, smaller fruits reduce economic yield because less edible biomass is produced for the market. Therefore, smaller fruits are beneficial for plant survival but disadvantageous for commercial tomato production.

Item 2.2:**(a) Relationship between the data and farmers' complaints**

Reduced soil moisture caused reduced guard cell turgidity and reduced stomatal aperture, resulting in reduced photosynthesis and low grain yield.

Drought conditions reduced water availability in the soil, limiting water absorption by maize roots and reducing water movement to leaves. Reduced water supply decreased guard cell turgidity because guard cells lost water, causing potassium ions and other solutes to move out due to ABA release, and reducing osmotic water uptake. The loss of turgidity caused stomatal closure, reducing carbon dioxide entry into leaf mesophyll cells. Consequently, carbon dioxide fixation during the Calvin cycle decreased, reducing glucose and carbohydrate production required for respiration, vegetative growth and grain filling, resulting in low grain yield.

Reduced stomatal aperture caused reduced photosynthetic activity leading to premature leaf wilting due to reduced water regulation.

The reduced stomatal aperture due to water stress decreased transpiration, which initially conserved water but also reduced the cooling effect of evaporation from leaves. Under prolonged high temperatures, leaf tissues accumulated heat, causing cellular stress and reduced enzyme efficiency. In addition, reduced carbon dioxide uptake lowered photosynthesis and carbohydrate production needed to maintain cellular activities including formation of sugar in guard cells which increase osmotic pressure and water uptake. Continued water deficit reduced cell turgidity throughout leaf tissues, causing loss of rigidity and premature wilting of maize leaves.

Reduced photosynthetic rate caused reduced seed development, resulting in poor germination of harvested grain.

Drought stress reduced photosynthetic rate, limiting production of carbohydrates required for formation and filling of maize grains. Reduced assimilate supply limited accumulation of starch, proteins and stored nutrients within seeds, producing poorly developed embryos and reduced food reserves. The much ABA released also moved to the seeds and it's a germination inhibitor. During germination, these seeds lacked sufficient stored nutrients to support respiration, enzyme activation and early seedling growth, and had a lot of abscisic acid resulting in poor germination percentage.

(b) Evaluation of recommendations**Irrigation scheduling**

Irrigation scheduling would be effective because it supplies water during critical growth stages when maize requires adequate hydration for maintaining guard cell turgidity, stomatal opening and photosynthesis. Adequate water availability restores carbon dioxide uptake, carbohydrate production and grain filling, improving yield. However, irrigation does not alter the plant's genetic ability to tolerate prolonged drought conditions. Therefore, I recommend irrigation scheduling as an effective method for maintaining productivity during periods of predictable water shortage.

Planting drought-tolerant varieties

Drought-tolerant varieties would be effective because they possess adaptations such as efficient root systems, improved water-use efficiency and better stomatal regulation, allowing them to maintain photosynthesis under limited water availability. These characteristics enable continued carbohydrate production and grain development during drought conditions. However, drought tolerance does not completely eliminate the need for adequate soil moisture, especially during severe prolonged drought. Therefore, I recommend planting drought-tolerant varieties as a long-term strategy for maintaining maize productivity under changing climatic conditions.

Applying mulches to conserve soil moisture

Mulching would be effective because it reduces evaporation from the soil surface, maintaining higher soil moisture levels available for root absorption. Adequate soil moisture helps maintain root water uptake, guard cell turgidity and stomatal opening, allowing continued carbon dioxide uptake and photosynthesis. However, mulch alone cannot supply water once soil moisture becomes severely depleted during prolonged drought. Therefore, I recommend mulching as a complementary strategy alongside appropriate irrigation and drought-resistant varieties to conserve available soil moisture.

Item 2.3:**(a) Relationship between the data and farmers' complaints**

Reduced stomatal aperture caused reduced photosynthetic rate, reducing mature bean weight, resulting in poor bean development and low yield.

Continuous exposure of coffee plants to intense sunlight increased leaf temperature and evaporative water loss through transpiration, causing water deficit and reduced water availability in leaf tissues. The reduced water supply decreased guard cell turgidity, resulting in partial stomatal closure, which limited transpiration-driven movement of water and mineral ions through the xylem and reduced diffusion of carbon dioxide into the leaf mesophyll cells. In addition, reduced water availability decreased the supply of water molecules for photolysis during the light-dependent stage of photosynthesis, resulting in fewer hydrogen ions (H^+) for the reduction of $NADP^+$ to NADPH and reduced replacement of electrons lost from Photosystem II. Consequently, reduced production of NADPH and ATP limited the light-independent stage of the Calvin cycle, decreasing CO_2 fixation by RuBisCO and reducing formation of phosphoglyceraldehyde (PGAL), which is used to synthesize glucose and other carbohydrates. The decline in carbohydrate production reduced the supply of assimilates required for respiration, vegetative growth and bean filling, while limited water and mineral availability further restricted metabolic processes involved in bean expansion and maturation. Consequently, coffee beans developed poorly, attained lower mature weight and resulted in reduced overall yield.

Reduced photosynthetic rate caused reduced aroma oil concentration, resulting in poor aroma quality of coffee beans.

The reduced photosynthetic activity in fully exposed coffee plants which are in water stress lowered production of carbohydrates and metabolic intermediates required for synthesis of secondary metabolites such as aromatic oils. Reduced glucose availability limited formation of carbon skeletons used in biochemical pathways responsible for producing volatile aromatic compounds in coffee beans. Consequently, fewer aroma oils accumulated during bean maturation, reducing the characteristic aroma quality of harvested coffee.

(b) Effectiveness of recommendations**Maintaining shade trees**

Maintaining shade trees would be effective because they reduce excessive solar radiation reaching coffee leaves, lowering leaf temperature and reducing excessive transpiration. Reduced water loss maintains guard cell turgidity, allowing stomata to remain sufficiently open for carbon dioxide uptake and continued photosynthesis. This improves carbohydrate production, bean filling and synthesis of aroma compounds. However, excessive shading may reduce light availability below the optimum level, limiting photosynthesis. Therefore, I recommend maintaining properly managed shade trees because they provide a balanced microclimate that supports coffee productivity.

Conserving soil moisture through mulching

Mulching would be effective because it reduces evaporation from the soil surface, maintaining water availability for root absorption. Adequate water supply maintains cell turgidity, supports stomatal opening and enhances carbon dioxide uptake required for photosynthesis and bean development. However, mulching alone cannot prevent excessive heat stress if coffee plants remain continuously exposed to intense sunlight. Therefore, I recommend mulching as a complementary practice alongside shade management.

Selecting varieties adapted to local climatic conditions

Selecting locally adapted varieties would be effective because such plants possess physiological traits suited to the prevailing environment, such as efficient water use, appropriate stomatal regulation and tolerance to high temperatures. These adaptations allow maintenance of photosynthesis and bean development under local climatic conditions. However, adapted varieties may still experience reduced productivity under extreme environmental changes beyond their tolerance range.

Therefore, I recommend selecting climate-adapted varieties as a long-term strategy for maintaining coffee productivity.

Item 2.4:**(a) Relationship between the data and crop performance**

Increased ABA concentration caused complete stomatal closure, resulting in severe wilting and reduced yield in Crop P.

The high ABA concentration in Crop P indicated severe water stress caused by drought and heat conditions. ABA produced in stressed roots and leaves was transported to guard cells where it stimulated potassium ion efflux and reduced water uptake by guard cells through osmosis. The loss of guard cell turgidity caused

stomatal closure, reducing gas exchange and limiting carbon dioxide entry into leaf tissues. Although stomatal closure reduced further water loss, it also reduced photosynthesis, limiting glucose production required for respiration, growth and crop yield. Continued water stress caused loss of cell turgor throughout leaf tissues, resulting in severe wilting and reduced productivity.

High enzyme affinity for oxygen caused increased photorespiration, resulting in reduced photosynthesis and yield of Crop P.

Crop P had enzymes with high affinity for oxygen, indicating that RuBisCO was more likely to bind oxygen instead of carbon dioxide under drought and high-temperature conditions. Oxygen fixation by RuBisCO initiated photorespiration, a process that consumes energy, uses RUBP, consumes NADPH and releases previously fixed carbon without producing glucose. This reduced the efficiency of carbon fixation and decreased carbohydrate availability for growth and yield formation. Consequently, Crop P experienced reduced productivity during prolonged heat and drought conditions.

Low ABA concentration and partially open stomata caused maintained photosynthesis, resulting in high yield of Crop Q.

Crop Q maintained lower ABA levels, allowing guard cells to retain water and remain partially turgid, keeping stomata partially open. The partially open stomata permitted continuous carbon dioxide entry into leaves, maintaining Calvin cycle activity and glucose production. In addition, Crop Q had zero enzyme affinity for oxygen, meaning Rubisco fixed carbon dioxide efficiently without diverting reactions into photorespiration. Consequently, more carbohydrates were available for respiration, growth and crop yield formation.

(b) Evaluation of proposed implementations

Installing high-pressure irrigation arrays to continuously spray the canopy of Crop P

Continuous canopy irrigation would be effective because it increases leaf water availability and reduces leaf temperature through evaporative cooling. Increased hydration would maintain guard cell turgidity, reduce ABA-induced stomatal closure and improve carbon dioxide uptake for photosynthesis.

However, continuous irrigation does not correct Crop P's high oxygen affinity of Rubisco, meaning photorespiration would continue reducing photosynthetic efficiency under heat stress. Therefore, I do not recommend continuous canopy irrigation as the main solution because it only addresses water stress and not the underlying physiological limitation.

Spraying Crop Q with a synthetic anti-transpirant to force complete stomatal closure

The anti-transpirant would reduce water loss by causing stomatal closure, helping conserve water during drought conditions. However, complete stomatal closure would prevent carbon dioxide entry into leaves, reducing photosynthesis and carbohydrate production. Since Crop Q already has efficient drought adaptation and maintains productivity through partially open stomata, forcing closure would reduce its yield advantage. Therefore, I do not recommend this treatment because it disrupts the natural adaptation that allows Crop Q to maintain high productivity.

Constructing plastic greenhouse tunnels and pumping artificial high-purity carbon dioxide

Greenhouse tunnels with increased carbon dioxide would be effective because elevated carbon dioxide concentration increases carbon fixation by Rubisco, reducing competition between carbon dioxide and oxygen and decreasing photorespiration in Crop P. This would improve glucose production and support growth and yield. However, greenhouse conditions may not eliminate water stress responses if temperature and humidity are not properly controlled, and excessive heat may continue affecting enzyme activity and plant physiology. Therefore, I recommend greenhouse modification with controlled environmental conditions because it directly improves carbon fixation while reducing heat-related limitations.

Item 2.5:

(a) Relationship between the data and maize complaints

Reduced root ethylene concentration caused reduced root aerenchyma formation, resulting in root rot and severe stunting of maize.

The prolonged waterlogging reduced oxygen availability around maize roots, creating hypoxic conditions that stimulated only limited production of ethylene because maize roots had a poor ability to sense and respond to oxygen deficiency. In waterlogged plants, ethylene normally accumulates because its diffusion from submerged tissues is restricted, and this hormone activates programmed cell death in specific root cortical cells, creating interconnected air spaces known as aerenchyma. However, the low ethylene concentration in maize reduced stimulation of cortical cell breakdown and formation of aerenchyma, leaving most root tissues dense and poorly ventilated.

The poorly developed aerenchyma restricted internal movement of oxygen from aerial parts of the plant to submerged roots, causing severe oxygen deficiency in root cells. Low oxygen reduced aerobic respiration because oxygen could not act efficiently as the final electron acceptor in the mitochondrial electron transport chain. Consequently, oxidative phosphorylation declined, reducing ATP production required for active transport of mineral ions, root growth and maintenance of living root tissues. Energy shortage weakened root cells, reduced their ability to exclude toxic compounds and made them susceptible to anaerobic microbial attack, resulting in root decay and poor water and mineral uptake. The reduced root function limited overall plant growth, causing severe stunting.

Reduced root aerenchyma volume and reduced bundle sheath PEP carboxylase activity caused reduced photosynthesis, resulting in yellowing leaves and poor maize growth.

The low aerenchyma volume in maize reduced oxygen diffusion to roots under waterlogged conditions, impairing root respiration and reducing active uptake of essential minerals such as nitrogen and magnesium. Nitrogen deficiency reduced amino acid and protein synthesis, including production of enzymes required for chlorophyll formation, while magnesium deficiency affected chlorophyll molecule formation because magnesium is the central ion in chlorophyll structure. Consequently, chlorophyll concentration in leaves decreased, reducing light absorption and causing yellowing of maize leaves.

In addition, maize showed reduced bundle sheath PEP carboxylase activity, indicating impaired carbon fixation in its C₄ photosynthetic pathway. Normally, mesophyll cell PEP carboxylase fixes atmospheric carbon dioxide into four-carbon compounds that are transported to bundle sheath cells where carbon dioxide is released for Rubisco activity. Reduced PEP carboxylase activity decreased initial carbon dioxide fixation, limiting carbon supply for the Calvin cycle. This reduced glucose production required for respiration, growth and biomass accumulation, further contributing to stunted growth and reduced productivity.

Reduced root aerenchyma formation and reduced oxygen availability caused reduced nitrogen uptake, resulting in yellowing leaves and reduced growth of maize.

Waterlogged soil conditions reduced oxygen availability around maize roots, limiting aerobic respiration in root cells. The resulting ATP shortage reduced activity of ATP-dependent transport proteins involved in active uptake of nitrate ions and other mineral nutrients from the soil. Reduced nitrogen uptake limited synthesis of amino acids, enzymes and chlorophyll molecules required for normal leaf function.

As chlorophyll formation declined, leaves became yellow due to reduced light absorption capacity, lowering photosynthetic efficiency. The combined effects of reduced nutrient uptake and reduced carbohydrate production limited cell division, protein synthesis and tissue expansion, resulting in poor growth of maize compared with lowland rice.

(b) Evaluation of proposed interventions

Digging shallow drainage channels in the maize field

Digging shallow drainage channels would be effective because it removes excess water from the maize field, increasing oxygen diffusion through soil pores and improving oxygen availability around roots. Increased oxygen supply restores aerobic respiration in root cells, improving ATP production required for active mineral uptake, root growth and maintenance of healthy tissues. Improved soil aeration would reduce root decay and enhance nutrient uptake, allowing better plant growth.

However, excessive drainage may reduce water availability during dry periods because maize requires adequate soil moisture for continuous growth.

Therefore, I recommend shallow drainage channels because they directly correct the main problem of oxygen deficiency caused by prolonged waterlogging.

Timed planting during non-rainy seasons

Timed planting would be effective because it reduces the likelihood of maize experiencing prolonged waterlogging during early growth stages when root development and establishment are critical. Avoiding periods of excessive rainfall allows roots to develop under well-aerated soil conditions, promoting normal respiration, nutrient uptake and photosynthesis. However, seasonal rainfall patterns can be unpredictable, meaning maize may still experience unexpected flooding after planting. Therefore, I recommend timed planting as a preventive strategy but it should be combined with improved drainage systems.

Applying moderate artificial nitrogen fertilizers

Applying moderate nitrogen fertilizers would be effective because nitrogen is required for synthesis of amino acids, proteins, enzymes and chlorophyll molecules needed for photosynthesis and plant growth. Increasing nitrogen availability can improve chlorophyll formation, restore green leaf colour and enhance photosynthetic capacity. However, nitrogen fertilizer cannot correct the oxygen deficiency caused by waterlogged soils or restore damaged roots because root respiration and nutrient uptake remain impaired under anaerobic

conditions. Therefore, I recommend moderate nitrogen application only as a supplementary measure after improving soil aeration through drainage.

SECTION B

Part I: Analysis of animal systems and behaviours in adapting to environmental changes for health, survival, and welfare

Item 3.1:

(a) Relationship between the data and Tere's symptoms

Increased body temperature caused increased sympathetic nerve impulse firing, resulting in increased sweating, increased heart rate and skin blood vessel dilation.

The high body temperature detected in Tere stimulated thermoreceptors in the hypothalamus, which detected the increase above the normal set point and activated the thermoregulatory centre. The hypothalamus increased sympathetic nervous system activity, causing a rise in sympathetic nerve impulse firing. These impulses stimulated sweat glands through cholinergic sympathetic fibres, increasing sweat secretion. Evaporation of sweat from the skin surface removed latent heat of vaporization from the body, helping lower body temperature.

The increased sympathetic activity also stimulated the sinoatrial node of the heart, increasing the rate of electrical impulse generation and causing faster heart contractions. This increased cardiac output improved blood flow to the skin where heat could be lost to the environment. Sympathetic stimulation also caused relaxation of smooth muscles in skin arterioles through thermoregulatory pathways, producing vasodilation and increasing blood flow near the skin surface, making blood vessels more visible.

Increased memory B-lymphocyte cells caused an enhanced immune response, resulting in elevated body temperature and headache.

The high percentage of memory B-lymphocytes indicated previous exposure to malaria antigen through vaccination, resulting in immune memory formation. When malaria-related antigens entered the body, memory B cells rapidly differentiated into plasma cells that produced large amounts of specific antibodies. The antigen-antibody response activated immune cells and stimulated release of pyrogenic cytokines which stimulated the hypothalamus to increase the thermoregulatory set point, stimulating physical, metabolic and behavioral responses which increase body temperature, producing fever as part of the immune response. The elevated temperature increased metabolic activity and stimulated inflammatory responses, which contributed to production of pain mediators and dilation of intracranial blood vessels, causing a mild headache.

(b) Evaluation of doctor's advice

Taking a cold shower

A cold shower would be effective because cold water increases heat transfer from the body surface to the environment, reducing skin temperature and lowering body temperature through conduction. Cooling also reduces stimulation of thermoreceptors responsible for activating heat-loss responses. However, excessive cooling may trigger vasoconstriction and reduce heat loss if the body responds by conserving heat. Therefore, I recommend a moderately cold shower as a temporary method for reducing discomfort but not as a treatment for the underlying cause of fever.

Exercising

Exercise would not be effective because muscle contraction increases metabolic activity and respiration, producing more heat through ATP breakdown. This would further increase body temperature and worsen sweating, increased heart rate and dehydration.

Therefore, I do not recommend exercise during fever because the body is already under thermal stress.

Recovery without malaria treatment

Natural recovery may occur because memory B cells can produce antibodies that rapidly neutralize malaria antigens. However, relying only on immunity may be risky because malaria parasites can multiply inside red blood cells, causing haemolysis and complications since the immune response often insufficient. Therefore, I do not recommend avoiding treatment unless malaria infection has been medically ruled out.

Item 3.2:

(a) Relationship between the data and students' symptoms

Reduced pH of contaminated water caused increased histamine concentration, resulting in allergic skin reactions.

The acidic contaminated water damaged the protective barrier of the skin by disrupting epidermal proteins and lipids. The increased hydrogen ion concentration interfered with ionic bonds between amino acid side chains of structural proteins, altering their three-dimensional structure and weakening the epidermal barrier. This increased penetration of chemical irritants and allergens into deeper skin layers.

The invading substances were taken up by antigen-presenting cells, triggering activation of lymphocytes and production of IgE antibodies. IgE antibodies bound to receptors on mast cells, causing mast cell degranulation and release of histamine. Histamine bound to receptors on dermal blood vessels and sensory nerve endings, causing vasodilation, increased capillary permeability, redness, swelling and itching, producing allergic skin reactions.

Reduced oxygen dissociation efficiency caused reduced synaptic transmission speed, resulting in dizziness and irregular heartbeat during activity.

Lead contamination from the battery recycling plant interfered with oxygen transport by reducing effective oxyhemoglobin concentration in the blood. Reduced oxygen delivery limited aerobic respiration in neurones, decreasing oxidative phosphorylation and ATP production in mitochondria. The shortage of ATP reduced the ability to synthesize the neural transmitter substance for effective synaptic transmission and the activity of the sodium-potassium pumps that maintain resting membrane potential and restore ion gradients after action potentials.

Consequently, neuronal depolarization, impulse propagation and neurotransmitter release became less efficient, reducing coordination between nervous system centers responsible for balance and cardiovascular control. This impaired neural regulation produced dizziness and abnormal heart rhythm during physical activity.

(b) Evaluation of recommendations**Neutralization of waste**

Neutralization would be effective because it restores wastewater pH closer to the range suitable for biological systems. Reduced acidity prevents damage to skin proteins and maintains normal enzyme and cellular function. However, neutralization alone does not remove heavy metals such as lead that interfere with oxygen transport and nervous system function. Therefore, I recommend neutralization as part of treatment but not as the only solution.

Medical antihistamine treatment

Antihistamines would be effective because they competitively bind to histamine receptors on blood vessels and sensory nerve endings, preventing histamine from causing vasodilation, increased permeability, swelling and itching. However, antihistamines only relieve symptoms and do not eliminate exposure to contaminated water. Therefore, I recommend their use as temporary symptom control while removing the source of contamination.

Installation of wastewater treatment systems

Wastewater treatment would be effective because it removes acidic pollutants and toxic heavy metals before discharge into the swamp, preventing damage to human physiological systems and aquatic organisms. However, treatment systems require proper operation and monitoring to maintain effectiveness. Therefore, I strongly recommend wastewater treatment because it addresses the root cause of contamination.

Item 3.3:

(a) Relationship between the data and reported effects

The increase in river water temperature above the normal range caused reduced oxygen dissociation efficiency, resulting in reduced oxygen availability for the fish and heat stress to the livestock that consumed the hot water, leading to rapid breathing and increased heart rate.

The heated wastewater released from the sugar factory increased the temperature of River Nabajuzi, reducing the ability of water to retain dissolved oxygen and lowering oxygen availability for fish respiration. In fish, the reduced oxygen concentration limited oxygen diffusion across the gill surfaces and reduced the amount of oxygen transported to tissues, causing cellular hypoxia. To compensate, fish increased ventilation movements of the gills and accelerated heart rate to maintain oxygen delivery to body tissues, but prolonged oxygen deficiency reduced aerobic respiration in mitochondria, lowering ATP production required for muscle

contraction, ion regulation and vital metabolic processes, eventually causing exhaustion and death. Drinking heated water increased the animals' internal body temperature, stimulating thermoreceptors that activated the hypothalamus and sympathetic nervous system to initiate thermoregulatory responses. As a result, heart rate increased to raise cardiac output and transport more warm blood to peripheral tissues for heat dissipation, while respiratory rate increased to enhance evaporative heat loss from the respiratory tract. Prolonged heat stress also increased metabolic rate, oxygen demand and water loss through panting, causing dehydration and electrolyte imbalance, which further stimulated the cardiovascular and respiratory systems to maintain tissue oxygenation, body temperature and homeostasis, thereby manifesting as persistent rapid breathing and increased heart rate.

Increased ADH secretion and slowed neural impulse transmission, lead to rapid breathing and increased heart rate in livestock.

Drinking heated water increased body temperature, activating hypothalamic thermoreceptors that stimulated panting as the major mechanism of evaporative heat loss in livestock. Prolonged panting caused excessive loss of water, increasing plasma osmolarity and reducing blood volume, which stimulated hypothalamic osmoreceptors and cardiovascular baroreceptors to trigger increased secretion of antidiuretic hormone (ADH) from the posterior pituitary gland. ADH increased the permeability of the distal convoluted tubules and collecting ducts to water, thereby increasing water reabsorption into the bloodstream and conserving body fluids during dehydration. However, continued dehydration disturbed electrolyte balance, particularly sodium and potassium ion concentrations required for maintaining neuronal resting membrane potentials. These ionic disturbances reduced the efficiency of depolarisation, action potential propagation and synaptic transmission, slowing neural impulse conduction and impairing coordination of physiological responses during severe heat stress.

(b) Evaluate the effectiveness of the recommendations

Cooling of industrial effluent before discharge

Cooling the industrial effluent before discharge would be effective because it would restore river temperatures closer to the normal physiological range, preventing thermal pollution and reducing heat stress in livestock while improving conditions for aquatic organisms. Cooler water retains higher concentrations of dissolved oxygen, improving oxygen diffusion across fish gills and supporting efficient aerobic respiration, ATP production, growth and survival. Lower water temperatures would also reduce excessive activation of thermoregulatory mechanisms in livestock, thereby decreasing panting, dehydration, ADH secretion and electrolyte disturbances. However, cooling the wastewater alone may not remove dissolved sugars, organic matter or other industrial contaminants that could still degrade water quality and harm aquatic life. Therefore, I recommend cooling of effluent together with complete treatment of industrial wastewater before discharge.

Construction of buffer reservoirs

Construction of buffer reservoirs would be effective because the reservoirs allow heated wastewater to cool naturally before entering the river while reducing sudden thermal shock to aquatic organisms. Buffer reservoirs also increase the residence time of wastewater, allowing suspended solids to settle and reducing the immediate impact of pollutants on the river ecosystem. This helps maintain more stable water temperatures, improves dissolved oxygen availability and reduces physiological stress on both aquatic organisms and livestock using the water downstream. However, buffer reservoirs may become ineffective if wastewater volumes exceed their capacity or if accumulated pollutants are not periodically removed. Therefore, I recommend buffer reservoirs as an additional protective measure but only alongside proper wastewater treatment and regular maintenance.

Strict regulation of industrial discharge

Strict regulation of industrial discharge would be effective because it ensures industries comply with environmental standards governing wastewater temperature and quality before discharge into natural water bodies. Effective regulation prevents recurrent thermal pollution, maintains favourable conditions for fish respiration, nervous system function and reproduction, while protecting livestock and communities that depend on the river. It also encourages industries to install wastewater treatment systems and adopt cleaner production technologies, promoting long-term conservation of aquatic ecosystems. However, regulations are only effective when supported by continuous environmental monitoring, strict enforcement and appropriate penalties for non-compliance. Therefore, I strongly recommend strict regulation because preventing pollution at its source provides the most sustainable solution for protecting River Nabajuzi and the organisms that depend on it.

Item 3.4:**(a) Relationship between David's parameters and his symptoms**

Reduced ADH concentration caused increased water loss, resulting in profound dehydration and contributing to disorientation.

Alcohol consumption inhibited secretion of antidiuretic hormone (ADH) from the posterior pituitary gland, causing the reduced ADH concentration observed in David. Normally, ADH binds to receptors on kidney collecting duct cells, stimulating insertion of aquaporin water channels into cell membranes and increasing water reabsorption into the blood. Reduced ADH levels decreased aquaporin insertion, making collecting ducts less permeable to water and causing more water to remain in urine.

Consequently, excessive water was lost through frequent urination, reducing blood volume and increasing blood osmolarity. Dehydration reduced efficient circulation and oxygen delivery to brain cells, affecting neuronal metabolism and neurotransmission. The resulting disturbance in brain function contributed to severe disorientation, poor coordination and impaired judgement.

Altered endolymph fluid dynamics, damaged sensory hair cell integrity, caused impaired vestibular signalling, resulting in inability to walk straight and severe disorientation.

The loud music exposure and alcohol consumption disrupted normal functioning of the vestibular system located in the semicircular canals. Altered viscosity and turbulent movement of endolymph changed the stimulation of sensory hair cells located within the semicircular canals. Normally, movement of endolymph bends stereocilia on hair cells, generating receptor potentials that are converted into nerve impulses informing the brain about head movement and balance.

The abnormal fluid movement produced inaccurate signals from vestibular receptors to the cerebellum and brainstem. The brain therefore received conflicting information about body position and movement, reducing coordination between visual, vestibular and proprioceptive systems. This impaired balance control, causing disorientation and inability to walk in a straight line.

Increased cochlear sensory hair cell damage caused increased sensory nerve stimulation, resulting in persistent ringing in the ears.

The prolonged exposure to extreme noise levels damaged sensory hair cells in the cochlea responsible for converting sound vibrations into electrical nerve impulses. Excessive sound intensity caused over-bending of stereocilia, calcium ion overload and production of reactive oxygen species, leading to cellular damage and abnormal spontaneous activity of auditory neurones.

The damaged hair cells sent inappropriate electrical signals through the auditory nerve even in the absence of external sound. The brain interpreted these abnormal signals as sound, producing the sensation of continuous ringing or tinnitus.

Increased heart rate resulted from alcohol-induced physiological stress and contributed to dehydration-related symptoms.

Alcohol consumption and dehydration activated the sympathetic nervous system, increasing sympathetic stimulation of the sinoatrial node of the heart. This increased the rate of cardiac depolarisation and accelerated heart contractions, raising heart rate. The increased heart activity attempted to maintain blood circulation despite reduced blood volume caused by dehydration, contributing to cardiovascular strain and worsening dizziness.

(b) Evaluation of medical team proposals**Giving plain distilled water**

Providing water would be effective because it restores fluid balance, increases blood volume and reduces dehydration caused by reduced ADH activity and excessive water loss. Restored hydration improves circulation and oxygen delivery to brain cells, helping recovery from dizziness and confusion.

However, plain distilled water lacks electrolytes such as sodium and potassium, which are important for maintaining osmotic balance and normal nerve and muscle function. Therefore, I recommend controlled rehydration with fluids containing appropriate electrolytes rather than distilled water alone.

Quiet rehabilitation environment

A quiet environment would be effective because it reduces further stimulation of damaged cochlear hair cells, allowing recovery of auditory pathways and reducing worsening of tinnitus. Reduced sensory stimulation also allows the nervous system to recover from alcohol-induced impairment.

However, a quiet environment does not repair permanently damaged cochlear hair cells. Therefore, I recommend a quiet environment as supportive therapy for recovery.

3. Quitting alcohol

Stopping alcohol consumption would be effective because it prevents repeated inhibition of ADH secretion and reduces alcohol-induced damage to nervous tissue. Maintaining normal ADH function supports water balance, while avoiding alcohol protects vestibular coordination and auditory function.

Therefore, I strongly recommend cessation of alcohol use to prevent long-term complications though he may miss the social benefits associated with drinking.

Item 3.5:

(a) Physiological mechanisms causing Chevonne's symptoms

Reduced red blood cell count caused reduced oxygen saturation leading to dizziness and muscle cramps

Chevonne had a lower red blood cell count than the reference student, which reduced the oxygen-carrying capacity of her blood because fewer haemoglobin molecules were available to bind and transport oxygen. At the high altitude of the Rwenzori Mountains, where oxygen availability is already reduced, this resulted in lower blood oxygen saturation, causing insufficient oxygen delivery to body tissues. Reduced oxygen supply to the brain decreased aerobic respiration and ATP production in neurons, resulting in severe dizziness, while reduced oxygen supply to skeletal muscles caused increased dependence on anaerobic respiration, leading to lactic acid accumulation, muscle fatigue and cramps during physical activity.

Reduced ADH concentration caused excessive urination and dehydration, worsening muscle cramps

Chevonne had a lower ADH concentration than the reference student, reducing the ability of her kidneys to conserve water. Reduced ADH action decreased the permeability of the distal convoluted tubules and collecting ducts to water by limiting insertion of aquaporin-2 channels, causing reduced water reabsorption and increased urine formation. Excessive water loss caused dehydration and disturbed electrolyte balance, particularly sodium and potassium ion concentrations required for normal nerve transmission and muscle contraction, thereby contributing to muscle cramps and reduced physical performance. Normal core temperature maintained thermal homeostasis despite altitude stress. Chevonne's core body temperature remained similar to the reference value, indicating that thermoregulation was maintained despite exposure to the cold mountain environment. Normal body temperature allowed enzymes involved in respiration, nerve transmission and muscle contraction to function effectively; however, it did not compensate for the reduced oxygen availability and dehydration caused by high altitude exposure, which remained the main causes of her dizziness, excessive urination and muscle cramps.

(b) Evaluation of suggestions

Highly concentrated glucose solution

Glucose would provide substrate for glycolysis and ATP production, supplying energy to cells. However, glucose cannot solve the main problem of inadequate oxygen delivery caused by altitude-induced hypoxia. Therefore, I do not recommend glucose as the primary treatment.

100% oxygen therapy

Oxygen therapy would be effective because increasing oxygen concentration improves diffusion into blood, increasing oxygen saturation and restoring aerobic respiration. This increases ATP production and improves brain and muscle function.

However, oxygen therapy does not immediately increase red blood cell numbers.

Therefore, I recommend oxygen therapy as an immediate treatment.

Resting before continuing

Rest would be effective because it reduces oxygen demand by decreasing muscle activity, allowing available oxygen to meet cellular requirements while acclimatization occurs. Therefore, I recommend rest as it allows gradual physiological adaptation.

Item 3.6:

(a) Effects of bee stings on Leah and Daniel

Increased histamine concentration caused swelling, increased pain receptor activity and sympathetic responses leading to severe symptoms

Bee venom introduced foreign antigens into Leah's and Daniel's bodies, triggering an immune response that stimulated mast cells and basophils to release histamine. The elevated blood histamine concentration above the healthy baseline increased capillary permeability, allowing more plasma fluid to escape into surrounding

tissues, causing swelling around the sting sites. Leah experienced a much greater histamine increase, causing widespread fluid accumulation in facial tissues and resulting in severe facial swelling, while Daniel's lower histamine response caused mainly localized swelling around the sting areas.

The increased histamine concentration also sensitised sensory pain receptors, causing the action potential frequency in sensory pain receptors to increase above the healthy baseline. Histamine and venom chemicals lowered the threshold for stimulation of nociceptors, causing more frequent nerve impulses to travel to the brain and produce the sensation of extreme pain. Leah's greater histamine response caused a higher frequency of pain impulses than Daniel, explaining why her pain was more severe despite both receiving bee stings.

Increased pain signalling caused sympathetic activation leading to increased heart rate, sweating and dizziness

The intense pain and stronger inflammatory response activated Leah's sympathetic nervous system, causing her heart rate and sweating rate to rise above the healthy baseline. The increased heart rate enhanced cardiac output to maintain blood supply during the stress response, while increased sweating represented an autonomic response to the physical stress caused by venom exposure. However, excessive sweating increased fluid loss, while histamine-induced vasodilation increased movement of fluid into tissues, reducing effective circulating blood volume. This contributed to reduced blood flow to the brain, causing dizziness in Leah. Daniel showed smaller increases in heart rate and sweating because his immune response remained localized and produced less systemic stress. (b) Evaluation of treatments

Ice-cold compress for Daniel

The cold compress reduced swelling by causing vasoconstriction, decreasing blood flow and limiting movement of fluid into tissues. Cooling also reduced sensory nerve activity, lowering pain transmission. However, it does not prevent histamine release or remove venom effects. Therefore, it is effective for local symptom relief:

Adrenaline injection for Leah

Adrenaline was effective because it stimulated alpha receptors causing vasoconstriction and beta receptors improving airway and cardiovascular function during severe allergic reactions. It reduces life-threatening effects of anaphylaxis.

However, adrenaline does not directly remove histamine from tissues. Therefore, it was appropriate for Leah's severe systemic reaction.

Antihistamine drugs

Antihistamines would be effective because they competitively bind histamine receptors, preventing histamine from causing vasodilation, increased permeability, swelling and pain stimulation. However, they do not immediately reverse severe airway obstruction caused by anaphylaxis. Therefore, antihistamines are recommended as additional treatment after emergency adrenaline where necessary.

Item 3.7:

(a) Effect of pheromones on male twig borer responses

Increased pheromone concentration caused increased antennal receptor stimulation and increased sensory neurone firing, resulting in disrupted mating behaviour.

Synthetic female pheromones were detected by chemoreceptors on male antennae, causing changes in receptor membrane potential. Increased pheromone concentration caused stronger receptor depolarisation, increasing sensory neurone action potential frequency. These impulses travelled through sensory pathways to the insect nervous system, activating behavioural responses associated with locating females.

At moderate concentrations, males showed directed flight because pheromone signals provided accurate orientation information. However, excessive pheromone stimulation produced sensory overload, causing excessive neuronal firing and inability to process directional information correctly. This resulted in frantic circling and failure to locate the female source.

2. Excessive pheromone concentration caused sensory disruption, resulting in cessation of flight.

At very high pheromone concentration, continuous stimulation caused extreme receptor activation and possible sensory adaptation or neural fatigue. The nervous system became unable to accurately interpret pheromone gradients required for navigation. As a result, males lost coordinated flight behaviour and dropped, preventing successful mating.

(b) Evaluation of pheromone disruption strategy

Pheromone disruption would be effective because it interferes with male ability to locate females, reducing mating success and lowering pest population growth without directly harming non-target organisms. However, it may be less effective if pest populations are very high or if pheromone coverage is incomplete. Therefore, I recommend it as part of integrated pest management.

Other strategies

Biological control

Introducing natural predators or pathogens would reduce twig borer populations naturally. However, introduced organisms must be carefully selected to avoid ecological imbalance.

Cultural control

Removing infested coffee twigs and maintaining plantation hygiene reduces breeding sites and pest survival. Therefore, I recommend combining cultural practices with pheromone disruption for sustainable pest control.

Resistant coffee varieties

Planting resistant varieties would reduce pest damage because plants possess defensive traits limiting insect establishment. Therefore, resistant varieties provide long-term protection and should be combined with other control methods.

Part II: Inheritance, Evolutionary trends and ecological dynamics

Item 4.1:

a) Let the allele for drought resistance be **D**, Let the allele for drought susceptible be **d**, Let the allele for pest resistance be **R**, and Let the allele for pest susceptible be **r**

Crossing pure breeds of the two grass varieties

Parental phenotypes: Drought resistant but pest susceptible X Drought susceptible but pest resistant

Parental genotypes:

DDrr

X

ddRR

Meiosis:

Gametes:

Dr

dR

Random fertilization:

Offspring genotype:

DdRr

Offspring genotype:

Drought and pest resistant

The hybrid grass variety is resistant to both drought and pests, enabling it to survive and grow successfully under harsh environmental conditions where water shortage and pest attacks would normally reduce productivity.

People who consumed meat from cattle fed on sprayed plants experienced food poisoning due to bioaccumulation and biomagnification of pesticide chemicals along the food chain. The pesticide applied to plants was absorbed and stored in plant tissues; when cattle fed on these contaminated plants, the pesticide accumulated in their body tissues. Humans who consumed the contaminated meat received higher concentrations of the pesticide, leading to toxic effects and symptoms of chemical food poisoning.

b) Evaluation of methods used to improve grass production and control pests

Controlled breeding is effective because it allows selection and crossing of grass varieties with desirable characteristics, such as drought resistance, pest resistance and high nutritional value. Crossing pure breeding lines increases the likelihood of producing hybrids that combine beneficial traits, enabling them to survive harsh conditions and provide more reliable animal feed. However, continuous selection for only preferred traits may reduce genetic diversity, making the grass population more vulnerable to future environmental changes or emerging pests.

Irrigation during drought conditions is effective because it supplies water required for photosynthesis, maintains cell turgidity and enables transport of mineral nutrients through the plant vascular system.

Adequate water availability promotes growth and increases grass yield. However, excessive irrigation may cause waterlogging, reduce soil aeration and promote leaching of essential mineral nutrients into deeper soil layers, reducing soil fertility.

Biological pest control is effective because natural predators or parasites reduce pest populations without introducing harmful chemicals that accumulate in food chains or pollute the environment. It provides an environmentally sustainable method of pest management. However, biological control acts slowly, and introduced predators may fail to control the target pest if they have alternative food sources or do not adapt well to the environment. Therefore, suitable biological control agents should be carefully selected, or biodegradable pesticides should be used as safer alternatives where necessary.

Item 4.2:

(a)

Reduced soil moisture content increased the frequency of the dwarf allele (d) in maize in the deforested area, resulting in the emergence of dwarf maize plants and poor crop performance.

Deforestation exposed agricultural land to increased evaporation and reduced water retention, creating drought stress conditions that acted as a selective pressure on maize populations. The higher frequency of the dwarf allele indicates that plants carrying this allele survived and reproduced more successfully under the altered environment, increasing its representation in the population through natural selection. Reduced soil moisture limited water uptake by maize roots, causing stomatal closure, reduced carbon dioxide entry into leaves and decreased photosynthetic activity, lowering carbohydrate production needed for cell division and elongation, which resulted in reduced plant height and dwarf characteristics.

The decrease in insect metamorphosis success caused a reduction in species richness in the deforested area resulting in a decline in insect populations available as a protein source and reduced ecosystem stability.

Deforestation destroyed insect breeding habitats and altered microclimatic conditions such as humidity and temperature, making conditions unsuitable for successful egg development, larval growth and transformation into adult stages. The reduced metamorphosis success lowered recruitment of new adult insects, while loss of habitat reduced the number of insect species capable of surviving in the ecosystem. Consequently, reduced insect diversity weakened ecological interactions such as pollination, decomposition and food-web relationships, reducing ecosystem resilience and decreasing availability of edible insects for the community.

(b) **Evaluation of recommended interventions in restoring ecological balance and genetic stability**

Reforestation of buffer zones

Reforestation would be effective because restoring forest vegetation increases canopy cover, reduces soil moisture loss through evaporation and improves water retention, creating favourable conditions for maize growth and insect survival. The recovered vegetation also restores habitats required for insect breeding, increasing insect diversity and improving ecosystem interactions such as pollination and decomposition. However, reforestation is a slow process and may not immediately reduce the already increased frequency of the dwarf allele in maize populations. Therefore, I recommend reforestation because it addresses the environmental conditions driving ecological instability and provides a foundation for long-term ecosystem recovery.

Conservation of insect breeding habitats

Conservation of insect breeding habitats would be effective because protecting forest patches and natural vegetation preserves breeding sites, food sources and suitable microhabitats required for insect reproduction and metamorphosis. This would increase insect population sizes, restore species richness and improve availability of edible insects as a protein resource. However, habitat protection alone may not overcome other pressures such as climate variability, excessive harvesting or continued habitat disturbance. Therefore, I recommend conservation of breeding habitats alongside sustainable harvesting practices because maintaining insect diversity is essential for ecosystem stability and community food security.

Controlled selective breeding of crops

Controlled selective breeding would be effective because farmers can select maize varieties with desirable alleles for drought tolerance, improved growth and high yield, preventing excessive dominance of undesirable dwarf traits. Maintaining genetic diversity through planned breeding increases the ability of maize populations to adapt to future environmental changes. However, improved genetic traits cannot fully overcome severe environmental stress caused by degraded soils and reduced water availability. Therefore, I recommend

controlled selective breeding as a complementary strategy alongside habitat restoration and improved farming practices rather than as a standalone solution.

Item 4.3:

(a)

The increase in resistant allele frequency among pests in areas with intensive pesticide use resulted in reduced effectiveness of pesticides and contributed to reduced crop yield.

Frequent pesticide application acted as a strong directional selection pressure by eliminating susceptible pests while allowing resistant individuals to survive and reproduce. These resistant pests inherited and passed resistance alleles to subsequent generations, causing the resistance allele frequency to increase within the population. As resistant pests became dominant, pesticides became less effective, allowing pest populations to increase and cause greater feeding damage to crops, reducing photosynthetic capacity, plant growth and final agricultural productivity.

The reduction in edible insect population density and decline in soil nitrogen content under high pesticide use caused loss of biodiversity, reduced soil fertility and decreased ecosystem productivity.

Broad-spectrum pesticides affected non-target insects such as grasshoppers and termites, reducing their populations and disrupting ecological roles such as decomposition, nutrient cycling and energy transfer within food webs. At the same time, pesticide contamination reduced populations and activity of beneficial soil microorganisms responsible for nitrogen fixation and decomposition of organic matter. Reduced nitrogen availability limited synthesis of chlorophyll, proteins and enzymes in crops, reducing photosynthesis, plant growth and crop productivity while weakening overall ecosystem functioning.

(b) Evaluation of proposed interventions in restoring genetic diversity, ecological stability and agricultural productivity

Integrated pest management (IPM)

Integrated pest management would be effective because it combines biological control, crop rotation, resistant crop varieties and selective pesticide application, reducing excessive chemical pressure on pest populations. Lower selection pressure slows the spread of resistance alleles and maintains greater genetic variation among pests while conserving beneficial insects. However, IPM requires continuous monitoring, farmer training and timely decision-making, which may limit adoption by some farmers. Therefore, I recommend IPM because it provides sustainable pest regulation while reducing evolutionary resistance and maintaining ecosystem stability.

Reduction of chemical pesticide use

Reducing chemical pesticide use would be effective because it decreases selection pressure favouring resistant pests and reduces toxicity towards non-target insects such as edible insects and beneficial organisms. Reduced chemical contamination also allows recovery of soil microorganisms involved in nitrogen cycling, improving soil fertility and crop productivity. However, excessive reduction without alternative pest control measures may result in increased pest damage and lower yields. Therefore, I recommend reducing pesticide dependence while replacing it with biological and cultural pest management methods.

Promotion of ecological farming practices

Ecological farming practices would be effective because methods such as crop rotation, organic manure use, intercropping and habitat conservation increase soil microbial diversity, restore nutrient cycling and support natural pest regulation. Improved microbial activity enhances nitrogen availability, while diversified habitats promote beneficial insects that maintain ecological balance. However, ecological farming may require more labour, technical knowledge and time before improvements in productivity are achieved. Therefore, I recommend ecological farming because it restores natural biological processes and provides a sustainable approach to maintaining agricultural productivity and biodiversity.

Item 4.4:

(a) **The decrease in oxygen concentration caused a reduction in fish genetic diversity in the irrigated lake and contributed to reduced fish survival, declining fish catches and loss of an important protein source for the community.**

Water diversion for irrigation reduced the volume, circulation and mixing of lake water, limiting oxygen replenishment from the atmosphere and lowering dissolved oxygen concentration required for efficient

aerobic respiration in fish. The reduced oxygen availability caused hypoxic stress, forcing fish to increase energy expenditure on maintaining homeostasis rather than growth and reproduction. Low oxygen conditions reduced mitochondrial oxidative phosphorylation, decreasing ATP production needed for active swimming, feeding, osmoregulation, immune responses and gamete formation, resulting in reduced reproductive success and increased mortality. Furthermore, prolonged environmental stress reduced the size and genetic diversity of surviving fish populations because sensitive genotypes were selectively eliminated, leaving fewer individuals and fewer alleles within the population. The reduced genetic diversity lowered the evolutionary potential of fish because limited genetic variation reduced the probability of possessing adaptive traits needed to survive future environmental changes, diseases and fluctuations in water quality, accelerating population decline.

The increase in algal biomass in the irrigated lake and reduction in crop yield index were associated with nutrient enrichment, deterioration of irrigation water quality and poor crop performance in farming communities.

Large-scale irrigation farming increased the movement of agricultural fertilizers containing nitrates and phosphates into the lake through surface runoff, causing nutrient enrichment that stimulated rapid algal reproduction and excessive algal blooms. The dense algal growth reduced light penetration into deeper water layers, limiting photosynthesis of submerged aquatic plants and altering aquatic productivity. When algae died, decomposer microorganisms increased their activity, consuming large amounts of dissolved oxygen during aerobic respiration and creating oxygen-deficient conditions harmful to fish and aquatic insect larvae. The decomposition process also released additional nutrients, maintaining a cycle of eutrophication and further deterioration of water quality. The poor-quality irrigation water affected crops because elevated salt concentrations reduced the water potential of the soil solution, making water absorption by root cells more difficult through osmosis. Salinity stress also caused ionic toxicity, disrupted enzyme activity, reduced stomatal opening and lowered photosynthetic efficiency, resulting in reduced carbohydrate production, impaired growth and decreased crop yield.

(b) Evaluation of recommendations in addressing ecological degradation and genetic loss

Controlled water abstraction

Controlled water abstraction would be effective because regulating the amount of water removed from the lake maintains natural water levels, water circulation and oxygen exchange, creating favourable conditions for fish survival and reproduction. Maintaining adequate water volume reduces stagnation and improves dissolved oxygen availability, allowing fish to maintain aerobic respiration, growth, reproduction and normal physiological functioning. Stable lake conditions also reduce environmental stress that contributes to loss of sensitive fish genotypes, allowing genetically diverse individuals to survive and reproduce. However, controlling abstraction alone may not completely restore the ecosystem if nutrient pollution from farming activities continues to stimulate algal blooms and oxygen depletion. Therefore, I recommend controlled water abstraction because restoring natural hydrological conditions is essential, but it should be combined with pollution control measures for complete ecosystem recovery.

Reduction of fertilizer runoff

Reducing fertilizer runoff would be effective because it decreases the excessive entry of nitrates and phosphates into the lake, preventing eutrophication and reducing harmful algal blooms. Lower nutrient loading limits excessive algal growth, maintains clearer water, improves oxygen availability and restores conditions suitable for fish, aquatic insects and other organisms. Reduced fertilizer pollution also protects irrigation water quality by preventing accumulation of dissolved substances that interfere with plant water uptake and crop physiological processes. However, reducing fertilizer application without alternative soil fertility methods may reduce nutrient availability for crops and negatively affect agricultural production. Therefore, I recommend reduction of fertilizer runoff alongside practices such as organic manure application and precision fertilizer use because it balances ecosystem conservation with sustainable crop production.

Conservation of breeding fish populations

Conservation of breeding fish populations would be effective because protecting mature reproductive fish ensures continued reproduction and maintains the transfer of diverse alleles to future generations. A larger breeding population reduces genetic drift and inbreeding, preserving genetic variation required for adaptation to environmental stress, diseases and changing lake conditions. Conservation areas such as protected breeding grounds would also allow juvenile fish to develop safely, increasing recruitment and improving fish population recovery. However, protecting breeding populations alone cannot overcome continued problems such as low oxygen levels, pollution or habitat degradation that threaten fish survival. Therefore, I

recommend conservation of breeding populations together with restoration of water quality because genetic diversity can only be maintained when environmental conditions support survival and reproduction.

Item 4.5:

(a) The increase in wetland water temperature caused a reduction in rice root mitotic index resulting in impaired root development, reduced plant growth and declining rice yields among farmers.

Discharge of warm industrial effluent increased wetland temperature beyond the optimum range required for normal cellular processes in rice plants. Elevated temperatures caused heat stress by altering protein structure, reducing enzyme efficiency and disturbing membrane stability, which affected essential processes involved in DNA replication and cell cycle progression. The reduced mitotic index indicates that fewer root meristem cells were undergoing division, limiting the production of new cells required for root elongation and development. Poor root growth reduced the surface area available for absorption of water and mineral ions such as nitrates, phosphates and potassium needed for enzyme activation, chlorophyll formation and protein synthesis. Reduced nutrient and water uptake caused stomatal closure, decreased carbon dioxide absorption and lowered photosynthetic activity, resulting in reduced carbohydrate production, poor biomass accumulation and decreased grain formation, ultimately reducing rice productivity.

The increase in mosquito larval survival and reduction in dragonfly population density in the polluted wetland caused increased mosquito populations, reduced biological control and disruption of wetland ecological balance.

Industrial pollutants altered wetland environmental conditions and negatively affected sensitive predatory insects such as dragonflies, reducing their survival, reproduction and population density. Dragonflies naturally regulate mosquito populations by feeding on mosquito larvae and adults, so their decline reduced predator pressure and allowed more mosquito larvae to survive and complete development into adults. Increased mosquito survival changed the structure of the wetland food web by disrupting predator-prey relationships and reducing biodiversity. The larger mosquito population increased the probability of malaria transmission because more mosquito vectors were available to acquire and transmit malaria parasites between humans. The imbalance also indicated reduced ecosystem resilience because the loss of predator species weakened the wetland's natural ability to regulate organism populations.

(b) Evaluation of proposed solutions in restoring ecosystem stability and agricultural productivity

Installation of effluent cooling systems

Effluent cooling systems would be effective because they reduce the temperature of industrial discharge before it enters the wetland, preventing thermal pollution and restoring suitable environmental conditions for plants and aquatic organisms. Lower temperatures would improve enzyme functioning, maintain membrane stability and allow normal DNA replication and mitotic activity in rice root meristem cells, promoting stronger root development and improved crop productivity. Cooler water would also reduce physiological stress on aquatic organisms, supporting recovery of sensitive species and restoring ecological interactions. However, cooling systems only address temperature pollution and may not remove toxic chemicals present in untreated effluent that could continue harming organisms. Therefore, I recommend installation of cooling systems together with complete effluent treatment because controlling both heat and chemical pollution is necessary for sustainable ecosystem recovery.

Biological mosquito control using predators

Biological mosquito control would be effective because conserving or increasing populations of natural predators such as dragonflies restores predator-prey relationships and naturally reduces mosquito numbers. Predators consume mosquito larvae and adults, decreasing mosquito survival and reproduction while avoiding the ecological damage caused by chemical insecticides. Restoration of predator populations improves biodiversity and strengthens ecological regulation within the wetland ecosystem. However, biological control may not succeed if pollution continues destroying predator habitats and reducing their survival. Therefore, I recommend biological mosquito control alongside pollution reduction and habitat restoration because predators require a healthy ecosystem to maintain long-term mosquito regulation.

Restoration of wetland vegetation

Restoration of wetland vegetation would be effective because plants provide habitats, breeding areas and food resources required by diverse organisms, helping rebuild disrupted ecological relationships. Vegetation improves wetland functioning by trapping pollutants, absorbing excess nutrients, stabilizing soil and improving water quality, thereby creating better conditions for rice growth and aquatic biodiversity. Re-

established plant communities also support insects such as dragonflies by providing shelter and suitable reproductive environments, helping restore natural pest regulation. However, vegetation restoration is a gradual process and cannot immediately eliminate existing toxic pollution or reverse all ecological damage. Therefore, I recommend wetland vegetation restoration because it provides a long-term foundation for ecosystem recovery when combined with effective pollution control measures.

Item 4.6:

(a) Apply the Hardy-Weinberg principle to determine the change in frequency of the resistance allele (r) from 2022 to 2025. Evaluate how the resulting genetic and population changes affect ecosystem balance in Lake Victoria.

Change in resistant allele frequency and reduced effectiveness of biological control of water hyacinth

The decline in surviving susceptible weevils from 2022 to 2025 increased the frequency of the recessive resistance allele (r) in the weevil population, but the overall reduction in weevil numbers weakened biological control, allowing rapid increase of water hyacinth biomass and disruption of Lake Victoria's ecosystem.

Using the Hardy-Weinberg principle:

$$p^2 + 2pq + q^2 = 1$$

where:

- **p = frequency of susceptible allele (R)**
- **q = frequency of resistant allele (r)**

Since resistant individuals have genotype rr, the frequency of resistant individuals represents q^2 .

2022

Total weevils sampled = 10,000

Surviving susceptible weevils = 6,400

Susceptible proportion:

$$6400/10000 = 0.64$$

Therefore resistant individuals:

$$1 - 0.64 = 0.36$$

$$q^2 = 0.36$$

$$q = \sqrt{0.36} = 0.60$$

Therefore, frequency of resistant allele **r = 0.60**

2025

Total weevils sampled = 5,500

Surviving susceptible weevils = 1,045

Susceptible proportion:

$$1045/5500 = 0.19$$

Resistant individuals:

$$1 - 0.19 = 0.81$$

$$q^2 = 0.81$$

$$q = \sqrt{0.81} = 0.90$$

Therefore, frequency of resistant allele **r = 0.90**

The frequency of the resistant allele therefore increased from approximately **0.60 to 0.90**, showing strong natural selection caused by the fungal pathogen. The fungus acted as an environmental selective pressure by killing susceptible weevils carrying the dominant susceptible allele (R), while resistant individuals with genotype rr survived and reproduced more successfully. Over generations, resistant individuals contributed a larger proportion of genes to the next generation, causing an increase in the resistance allele frequency. However, despite increased genetic resistance, the total weevil population declined greatly, reducing grazing pressure on water hyacinth and allowing the weed to expand.

Increase in water hyacinth biomass and ecological imbalance affecting fisheries

The increase in water hyacinth biomass from 15.2 tons/ha to 55.3 tons/ha caused blockage of fishing routes, oxygen depletion and reduced productivity of Lake Victoria's aquatic ecosystem.

The decline in weevil population reduced consumption of water hyacinth because fewer larvae and adults were available to feed on the weed. Water hyacinth reproduced rapidly through vegetative propagation, allowing extensive mats to cover the lake surface. These dense mats reduced light penetration into water, limiting photosynthesis of submerged aquatic plants and reducing primary productivity. When large amounts

of weed material died and decomposed, aerobic microorganisms increased oxygen consumption, lowering dissolved oxygen concentration. Reduced oxygen availability impaired fish respiration, growth, reproduction and survival, contributing to declining fish catches and threatening the fishing economy.

(b) Evaluate the course of action being planned by the fisheries department and recommend accordingly.

Spraying the entire lake surface with strong chemical fungicide

Spraying fungicide would be effective because eliminating the fungal pathogen would reduce mortality among susceptible weevils, allowing the remaining population to recover and continue controlling water hyacinth. This could restore biological control and reduce dependence on physical weed removal.

However, applying strong fungicides across the entire lake could kill non-target microorganisms, aquatic insects and other organisms, disrupting food chains and contaminating fish consumed by humans. It may also create further ecological problems by disturbing natural microbial communities.

Therefore, I do not recommend whole-lake fungicide spraying; instead, I recommend targeted fungal control and conservation of resistant weevils because it maintains biological balance while allowing natural selection to restore effective control.

Manual harvesting of water hyacinth by local youth

Manual harvesting would be effective because physically removing water hyacinth immediately opens fishing routes, improves water circulation and reduces weed biomass. It also provides employment opportunities for local communities.

However, water hyacinth reproduces rapidly through fragments and underground structures, meaning incomplete removal may allow rapid regrowth. Large-scale harvesting also requires continuous labour and financial resources.

Therefore, I recommend manual harvesting as a short-term emergency measure but combine it with restoration of resistant weevil populations for sustainable long-term control.

Encouraging fish farming and reducing dependence on lake fishing

Fish farming would be effective because it provides an alternative source of fish protein and income while allowing Lake Victoria's ecosystem time to recover. Controlled aquaculture reduces pressure on declining wild fish populations.

However, fish farming does not address the main ecological problem of water hyacinth invasion and may introduce challenges such as disease transmission, high production costs and genetic contamination if farmed fish escape.

Therefore, I recommend fish farming only as a supplementary strategy while restoring the natural lake ecosystem through biological weed control and habitat management.

Item 4.7:

(a) Analyse the data provided and describe the inheritance pattern that led to the observed offspring and explain the pattern of energy flow and pesticide distribution across the organisms.

Inheritance pattern showing linkage between growth rate and EUS resistance

The excess production of fast-growing resistant offspring (415) and slow-growing susceptible offspring (405), compared with the fewer recombinant offspring, indicates that the growth gene (G/g) and resistance gene (E/e) are linked on the same chromosome.

The parental combinations were:

- Fast-growing resistant (GE) = 415
- Slow-growing susceptible (ge) = 405

The recombinant combinations were:

- Fast-growing susceptible (Ge) = 90
- Slow-growing resistant (gE) = 93

The high frequency of parental combinations shows that the two genes are inherited together more often than expected under independent assortment. The lower number of recombinant offspring resulted from crossing over during meiosis, where homologous chromosomes exchanged segments. The recombination frequency is:

$$\frac{(90+93)}{(998)} \approx 18\%$$

This indicates that the genes are linked but sufficiently separated to allow some crossing over. This inheritance pattern is useful in selective breeding because breeders can maintain the desirable combination of rapid growth and disease resistance, producing tilapia populations with improved productivity and survival.

Energy flow and pesticide biomagnification through the wetland food chain

The decrease in net energy assimilation from phytoplankton and rice algae to mature Nile tilapia, together with increasing organochlorine pesticide concentration at higher trophic levels, shows inefficient energy transfer and biomagnification of toxic chemicals.

Energy decreased progressively because organisms use most absorbed energy for respiration, movement, reproduction and maintaining body functions, with only a small fraction transferred to the next trophic level. Therefore, large predators such as mature tilapia receive much less available energy compared with primary producers.

In contrast, pesticide residues increased from 0.05 mg/kg in producers to 38.50 mg/kg in mature tilapia because persistent organochlorine compounds are not easily broken down or eliminated. Small organisms accumulate pesticides, and predators consume many contaminated prey, causing biomagnification. High pesticide concentration damages fish tissues, weakens immunity and increases susceptibility to diseases such as EUS, contributing to fish deaths and reduced food security.

(b) Propose and evaluate sustainable intervention policies for the Doho community that addresses both genetic stock enhancement and wetland ecological stability.

Selective breeding of EUS-resistant fast-growing tilapia

Selective breeding would be effective because farmers can increase the frequency of E and G alleles, producing fish populations with improved growth performance and disease resistance. This reduces losses from EUS and improves aquaculture productivity.

However, excessive selection for only desirable traits may reduce genetic diversity, making populations vulnerable to future diseases or environmental changes.

Therefore, I recommend selective breeding while maintaining genetic variation through controlled breeding programmes because both productivity and adaptability are important.

Reduction of persistent organochlorine pesticide use

Reducing persistent pesticide use would be effective because it decreases toxic residues entering water systems and reduces biomagnification through aquatic food chains. Lower contamination allows recovery of plankton, fish and other aquatic organisms.

However, farmers may experience increased pest damage if pesticides are withdrawn without alternatives.

Therefore, I recommend replacing persistent pesticides with integrated pest management involving biological control and safer pesticides.

Promotion of ecological rice-fish farming

Ecological rice-fish farming would be effective because fish can control some rice pests naturally while nutrient cycling between rice and fish improves productivity. Reduced chemical use protects biodiversity and maintains wetland stability.

However, successful implementation requires farmer training, proper stocking and monitoring to prevent disease spread.

Therefore, I recommend ecological rice-fish farming because it supports both food production and conservation of wetland ecosystems.

Item 4.8:

(a) Analyse the provided information to explain the impact of the processing plant on the water ecosystem and how this led to observed evolutionary changes.

Increase in pollution-tolerant chironomid larvae and decline of sensitive mayfly larvae due to industrial selection pressure

The dominance of chironomid larvae near the factory outlet and disappearance of mayfly larvae indicate that untreated tea processing effluent created environmental conditions that favoured pollution-tolerant organisms while eliminating sensitive species.

Industrial effluent introduced organic pollutants and toxic substances into River Mpanga, reducing water quality and oxygen availability. Mayfly larvae require clean, oxygen-rich water and therefore declined rapidly near the pollution source. Chironomid larvae possess adaptations such as haemoglobin pigments that allow survival in low oxygen and polluted conditions. The pollution acted as a selective pressure, causing individuals with tolerance traits to survive and reproduce while susceptible organisms declined. Over time, this changed the genetic composition and community structure of aquatic organisms, resulting in dominance of tolerant chironomid populations.

Increase in algal biomass and decline in fish biomass causing reduced fisheries productivity

The increase in algal biomass near the outflow and decline in fish biomass caused deterioration of water quality and reduced fish catches reported by fishermen.

Nutrients and organic matter in untreated effluent stimulated excessive algal growth, producing algal blooms. Dense algae reduced light penetration and disrupted aquatic plant photosynthesis. When algae decomposed, microorganisms consumed dissolved oxygen, creating hypoxic conditions. Low oxygen reduced fish aerobic respiration, ATP production, growth and reproduction, causing fish populations to decline near the pollution source. Further downstream, dilution reduced pollution intensity, allowing partial recovery of aquatic organisms and increased fish biomass.

(b) Evaluate the water restoration strategies being proposed by the district environmental officers.

Installation of an effluent treatment plant

An effluent treatment plant would be effective because it removes toxic substances, organic waste and excess nutrients before wastewater enters the river. This improves oxygen levels, reduces pollution pressure and allows sensitive organisms such as mayflies and fish to recover.

However, treatment plants require high investment, regular maintenance and effective management.

Therefore, I recommend installation of an effluent treatment plant because preventing pollution at the source provides the most sustainable solution.

Restoration of riverbank vegetation

Restoring riverbank vegetation would be effective because plants trap pollutants, reduce soil erosion, absorb nutrients and provide habitats for aquatic organisms. Vegetation also stabilizes water temperature and improves ecosystem resilience.

However, vegetation restoration alone cannot remove pollutants already released into the river.

Therefore, I recommend riverbank restoration together with pollution prevention because healthy habitats are necessary for ecosystem recovery.

Controlled restocking of native fish species

Controlled restocking would be effective because it increases fish populations after improving water quality and restores ecological roles within the aquatic food web. Using native species maintains local adaptations. However, restocking polluted waters would result in continued mortality and wasted resources.

Therefore, I recommend restocking only after effective pollution control because successful recovery requires both healthy habitats and viable fish populations.

P530/2 BIOLOGY PAPER 2 (PRACTICAL)

1. Comparative Observational Investigation: Biological structures and Microscopy

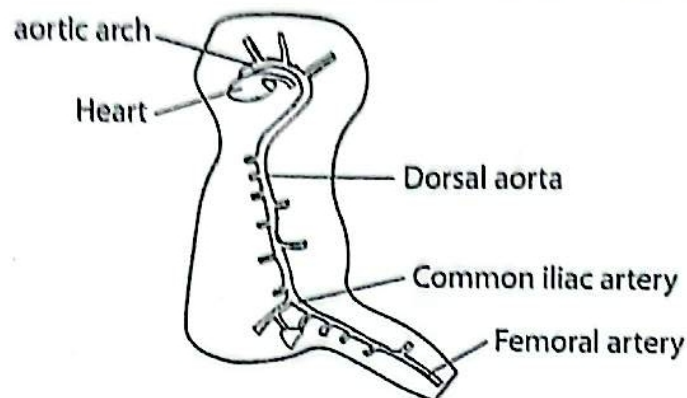
Item 1.2.1

Procedure for dissection.

- Specimen E was placed ventral side uppermost on the dissecting board and it's pinned through the feet.
- The skin was lifted at the mid-ventral line and an incision was made along that line, extending from the lower jaw to the genitals.
- The skin was made loose from the body wall and pinned back on both sides of the specimen.
- A mid-line incision was made along the abdomen, cutting from the diaphragm to the pelvic girdle.
- The separated body wall was pinned back to expose the abdominal viscera clearly.
- The liver lobes were displaced anteriorly to reveal the stomach and esophagus.
- The hepatic portal vein is traced from the liver and is ligatured, and cut at the distal end of the ligature.
- The stomach and ileum were gently displaced to the right, to ligature the coeliac and anterior mesenteric arteries and are cut at the distal end of the ligature.
- The oesophagus and the rectum were cut gently to extract out the gut in the abdominal region, but not to destroy the posterior mesenteric artery

- The muscles of the pelvic girdle were cut to reveal the pubic symphysis without damaging the arteries or vein of the hind limbs and widened the legs again, and re-pinned them again.
- The xiphoid cartilage was gripped using forceps and raised. The falciform ligament was cut using a pair of scissors so that the liver can fall further away from the diaphragm. the diaphragm was cut away to expose the path of the dorsal aorta.
- The xiphoid cartilage was firmly held up and cut using a pair of scissors through the chest cavity to the posterior end up to the clavicle bones.
- Part of the rib cage was cut away on both sides to expose the arches, blood vessels, heart, and also the connective tissue, the thymus gland and fat tissue were removed from the heart.
- The blood vessels supplying nutrients to the limbs were traced.

Drawing showing blood vessel supplying nutrients to the left/right hind limb of a rat.



A table showing the relative length and thickness of limbs of a rat.

Limb Type	Relative Length (cm)	Relative Thickness (mm)
Fore limb	5.6	40
Hind limb	8.0	65
Tail.	13.4	12

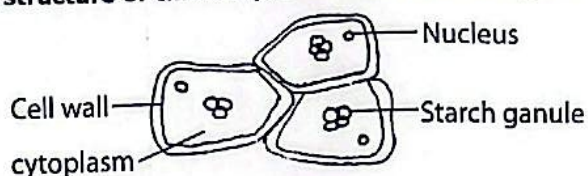
In comparison, the rat is a more adapted terrestrial organism than the cockroach because:

- The hind limbs of the rat are four times longer than those of the cockroach for faster locomotion.
- The hind limbs are 25 times thicker and muscular than those of a cockroach to provide a stronger propulsion force during locomotion.
- possession of a long tail (which is almost equal length to the rest of the body) to provide balance of the body during fast locomotion.
- Possession of an efficient circulatory system for fast transportation of nutrients (respiratory gases) to limbs which leads to a high metabolic output because a lot of energy is generated.
- Possession of an endoskeleton with joints for stronger attachment of thick muscles and support of body weight during locomotion.

Procedure for microscopy:

- Using a sharp blade, a thin tissue is cut and placed onto the glass slide.
- 3 drops of iodine solution are put onto the tissue and is stained for 5 minutes.
- Using a filter paper, excess iodine solution is removed and the tissue is covered using a cover slip.
- The slide is mount onto the stage of the microscope and observed under low/medium power of the microscope.

A drawing showing the structure of three representative cells of specimen Y under low/medium power of a microscope.



(ii) the tissues possess;

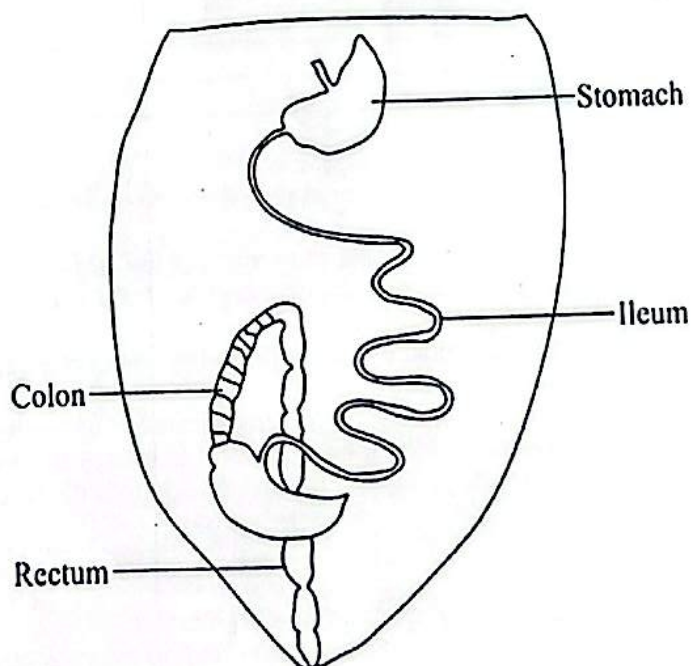
- Numerous parenchyma tissues to increase surface area for storage of starch granules.
- Closely packed starch granules for increased storage of food into the cells.

Item 1.2.2

Procedure of dissection

- Place specimen E ventral side uppermost on the dissecting board and pin it through the feet.
- Lift the skin at the mid-ventral line and make an incision along this line, extending from the lower jaw to the genitals.
- Loosen the skin from the body wall and pin it back on both sides of the specimen.
- Make a mid-line incision along the abdomen, cutting from the diaphragm to the pelvic girdle.
- Pin back the separated body wall to expose the abdominal viscera clearly.
- Displace the liver lobes anteriorly to reveal the stomach.
- Displace the bulk of the ileum to the left, and the caecum & colon to the lower right, to expose all relevant structures.

A drawing of specimen E showing relevant structures of the gut



Measurements

Structure	Toad(mm)	Rat (mm)
Stomach	48	80
Ileum	150	840
Hindgut	58	175

b) Microscopic evidence of the nutritional advantage the rats

*A drawing of one cell of specimen C stained with iodine as observed under medium power.
(The diagram shows a plant cell with starch filled structures)*

(c) Analysis of the findings to justify the differences in the survival abilities of the common toad and the rat.

Rats are better adapted to terrestrial habitats than toads because:

- The much longer ileum in rats provides a large surface area for absorbing digested nutrients increasing energy gain
- The longer hindgut allows more time to complete digestion and absorption of nutrients, hence ensuring food availability to the rat.
- The combination of a starch-rich diet enables rats to accumulate larger energy stores allowing them to withstand periods of food shortage better than toads

2. Scientific investigations

Item 2.2.1

Aspect	Response.
Aim.	An experiment to determine the change in length of the Irish potato cylinders and change in volume of water to find out which water sample is appropriate and hence suitable for planting the water lily in the lake.
Hypothesis.	Water sample D (or any other) caused a largest increase in length of Irish potato cylinder and decrease in volume of water hence suitable for planting the water lily in the lake.
Variables.	Independent: ▪ Concentration of water samples. Dependent: ▪ Change in length of Irish potato cylinder. ▪ Change in volume of water sample. Control: ▪ Size of cork borer. ▪ Initial length of Irish potato.
Risks and mitigation.	Risk: ▪ Cuts from sharp knives when peeling the Irish potato tuber. Mitigation: ▪ Handle cutting knives with care.
Errors.	▪ Accurately determining the final volume of water sample due to some water remaining on the surface of the tissue when removed from the test tubes.
Procedure.	▪ Using a cork borer, six Irish potato cylinders were obtained from specimen Y, each having initial length 5cm. ▪ Six test tubes were labelled A, B, C, D, E, and F, and in each 10cm³ of the water samples A, B, C, D, E, and F were poured. ▪ One cylinder of specimen Y was obtained and placed into each of the test tubes ensuring that it is immersed into the solution and are left to stand for 40 minutes. ▪ After 40 minutes, the cylinders were removed from solutions, one at a time using a long dissecting pin (forceps) and placed on a filter paper. ▪ The final length of the cylinders and volume of water sample were the determined.

Results:	Test tube	Final volume of water sample(cm ³)	Change in volume of water sample(cm ³) (FV-IV).	Final Length of Irish potato cylinder(cm)	Change in length of Irish potato cylinder(cm) (FL-IL).
	A	9.00	-1.00	5.2	0.2
	B	9.30	-0.70	5.1	0.1
	C	10.00	0.00	5.0	0.0
	D	10.30	0.30	4.9	-0.1
	E	10.60	0.60	4.7	-0.3
	F	10.70	0.7	4.5	-0.5
Analysis.	Either: Plot a graph of change in volume of water sample against water sample. Or: Plot a graph of change in length of Irish potato cylinder against water sample. Explanation: A: There was highest decrease in volume and highest increase in length of the cylinder because water sample A was highly hypotonic/highest solute potential/very low osmotic pressure than the Irish potato tissues cells hence there was a very high net gain of water by osmosis. B: There was high decrease in volume and high increase in length of the cylinder because water sample B was slightly hypotonic/high solute potential/ low osmotic pressure than the Irish potato tissues cells hence there was high net gain of water by osmosis. C: There was no increase/ decrease in volume or decrease/ increase in length of the cylinder because water sample C was isotonic/equal osmotic pressure to that the Irish potato tissues cells hence there was no net gain or net loss of water by osmosis. D: There was a slight increase in volume and slight decrease in length of the cylinder because water sample D was slightly hypertonic/slightly low solute potential/slightly high osmotic pressure than the Irish potato tissues cells hence there was a slightly low net loss of water by osmosis. E: There was a high increase in volume and a high decrease in length of the cylinder because water sample E was more hypertonic/low solute potential/high osmotic pressure than the Irish potato tissues cells hence there was a low net loss of water by osmosis. F: There was highest increase in volume and highest decrease in length of the cylinder because water sample F was most hypertonic/very low solute potential/very high osmotic pressure than the Irish potato tissues cells hence there was highest net loss of water by osmosis.				
Conclusion and recommendation.	Water sample A showed the highest increase in length and decrease in volume of water because a lot of water was absorbed by the Irish potato tissues by osmosis, hence, it shows a significant response to growth than either water sample B or C. Therefore, its more suitable and appropriate for planting the water Lilly.				

END

We extend our heartfelt wishes to all learners for great success in the forthcoming UNEB examinations. May your dedication and hard work open doors to rewarding futures in Medicine, Surgery, Nursing, Dentistry, and other Biology-related fields. Continue to pursue excellence with confidence, and may your aspirations be fulfilled – Biology Department, Buddo Secondary School.