P530/1
BIOLOGY
Paper 1
July – August 2026
3 hours

KAMSSA JOINT MOCK EXAMINATIONS

Uganda Advanced Certificate of Education

BIOLOGY

Paper 1
(Theory)
3 hours

Instructions to candidates

- 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.

SECTION A

ITEM 1

A 52-year-old woman named **Mary** had experienced continuous tiredness, unexplained weight loss, reduced appetite, and a painless lump in her left breast for approximately four months. As her condition progressed, she developed persistent chest pain together with shortness of breath. She was referred to the Uganda Cancer Institute for specialized medical examination. Based on her clinical presentation, doctors suspected breast cancer resulting from a mutation in a gene responsible for regulating cell division.

Under normal conditions, body cells possess the **TP53 gene**, which directs the synthesis of the p53 protein. This protein detects DNA damage, repairs damaged cells where possible, or initiates programmed cell death (apoptosis) in cells that cannot be repaired. These functions prevent uncontrolled cell division and tumour development. However, mutation of the TP53 gene may alter the structure of the p53 protein, reducing its ability to regulate the cell cycle. Consequently, damaged cells continue dividing rapidly, leading to tumour formation that requires large amounts of glucose and energy for continuous growth.

To investigate the suspected mutation, the doctor requested analysis of the TP53 gene together with tests on cellular respiration and tumour development. The laboratory findings are presented in **Table 1**.

Table 1: Mary's laboratory report

Parameter	Mary's results	Normal range
Sequence of TP53 gene	ATG, GCT, TTT, GAC, ACA	ATG, GCT, CTT, GAC, ACA
Function of p53 protein	Reduced activity	High activity
Average number of functional mitochondria per cell	28	12–18
ATP produced per glucose molecule	36–38	30–38
Cell division rate	Very high	Controlled
Tumour size	Large	No tumour

After examining the report, one oncologist recommended **gene therapy** to restore the normal TP53 gene so that functional p53 protein could once again be produced.

Another oncologist proposed **chemotherapy combined with drugs that reduce glucose uptake by tumour cells**, arguing that limiting the energy available to tumour cells would reduce their rate of division.

Your classmates have studied Mary's laboratory report together with the doctors' recommendations and would like to understand how the findings explain her condition and how they can be applied to improve human health.

Task

(a) Analyse the laboratory report in relation to Mary's signs and symptoms by explaining how mutation of the **TP53 gene** affected the parameters shown above.

(b) Assess the effectiveness of the two treatment recommendations.

Using evidence from **Table 1** together with your knowledge of genetics, protein synthesis and cellular respiration, recommend the better strategy for improving Mary's health and justify your answer using biological principles.

RESPONSE

(a) Analysis

*The **TP53 gene sequence** changed from **ATG, GCT, CTT, GAC, ACA** to **ATG, GCT, TTT, GAC, ACA**, indicating a mutation in the TP53 gene. The mutation altered the genetic information used during protein synthesis, producing a **p53 protein with reduced activity**. Consequently, damaged DNA was not effectively repaired and abnormal cells were not eliminated by apoptosis. These damaged cells continued dividing uncontrollably, leading to tumour formation.*

*The **activity of the p53 protein** decreased from **high** to **reduced**. Since p53 regulates the cell cycle, repairs damaged DNA and initiates apoptosis in irreparably damaged cells, its reduced activity allowed genetically abnormal cells to continue undergoing mitosis. This caused the **very high cell division rate**, resulting in enlargement of the tumour and progression of breast cancer.*

*The **average number of functional mitochondria** increased from the normal **12–18** to **28** per cell. Rapidly dividing tumour cells required large amounts of ATP for DNA replication, protein synthesis and continuous mitosis. The increased number of mitochondria enhanced aerobic respiration, supplying sufficient ATP to sustain rapid tumour growth. Consequently, the tumour consumed large quantities of glucose and body reserves, contributing to Mary's **weight loss, reduced appetite and persistent fatigue**.*

*The **ATP produced per glucose molecule** remained **36–38**, which is within the normal range. This indicates that individual mitochondria were functioning efficiently despite the mutation. However, because tumour cells divided rapidly, the total demand for ATP increased markedly. The excessive energy requirement depleted nutrients and body energy stores, causing **general body weakness and loss of body mass**.*

*The **cell division rate** increased from **controlled** to **very high** because reduced p53 activity failed to arrest the cell cycle. Continuous mitosis produced excessive numbers of abnormal cells, leading to progressive tumour enlargement and invasion of surrounding tissues.*

*The **tumour size** increased from **absent** to **large**. The enlarging tumour invaded nearby tissues and compressed surrounding structures, producing the **painless breast lump**, persistent **chest pain**, and **shortness of breath** as oxygen supply to normal tissues became compromised.*

Therefore, the TP53 gene mutation reduced p53 activity, resulting in uncontrolled cell division, increased mitochondrial activity, sustained ATP production and rapid tumour growth, which collectively caused Mary's breast cancer and associated clinical symptoms.

(b) Evaluation

Gene therapy

*Gene therapy restores the normal **TP53 gene**, enabling synthesis of functional p53 protein. Functional p53 repairs damaged DNA, arrests the cell cycle and induces apoptosis of abnormal cells, thereby controlling tumour growth at its genetic origin.*

However, gene therapy is expensive, technically demanding and may not successfully reach every cancer cell. It may also trigger immune reactions or unintended genetic changes, while large established tumours may still require additional treatment.

***Judgement:** It offers the most effective long-term treatment because it corrects the underlying genetic defect responsible for uncontrolled cell division.*

Chemotherapy combined with drugs that reduce glucose uptake

Chemotherapy destroys rapidly dividing cancer cells, while glucose uptake inhibitors reduce glucose entry into tumour cells, limiting ATP production required for continuous cell division. This slows tumour growth and may reduce tumour size.
However, chemotherapy also destroys rapidly dividing healthy cells, causing side effects such as hair loss, bone marrow suppression and reduced immunity. Glucose restriction does not correct the TP53 mutation, allowing surviving tumour cells to continue proliferating.
Judgement: *It is effective in reducing tumour burden but mainly controls disease progression rather than eliminating its underlying cause.*
Overall recommendation
Mary should receive ***gene therapy*** *as the primary treatment because it restores normal TP53 function and directly addresses the genetic cause of the disease. Chemotherapy combined with glucose uptake inhibitors should be used as supportive treatment to reduce tumour size and improve treatment outcomes.*

ITEM 2
Farmers in **Kitgum District** in Northern Uganda experience difficult crop-growing conditions characterized by high temperatures, limited rainfall, intense sunlight and infertile soils.
To improve agricultural productivity, the Ministry of Agriculture introduced two crop varieties, **Variety X** and **Variety Y**. After two planting seasons, Variety X consistently produced high yields, whereas Variety Y produced poor yields and frequently wilted during drought periods.
To investigate these differences, researchers collected the following information.
Table: Characteristics of Variety X and Variety Y

Feature	Variety X	Variety Y
Proportion of leaf collenchyma tissue	High	Low
Development of bundle sheath cells	Well developed	Poorly developed
Light saturation point	High	Low
Reaction to abscisic acid in leaves	Rapid	Slow

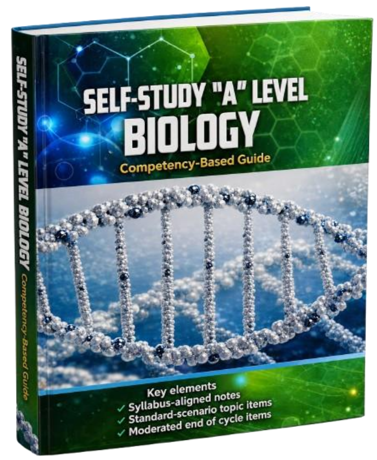
To improve food security in Kitgum, agricultural advisers proposed two possible approaches:
1. Apply **synthetic abscisic acid** to Variety Y during dry periods to promote stomatal closure, and apply **nitrogenous fertilizers** to increase leaf area.
2. Discontinue cultivation of Variety Y and encourage farmers to grow only **Variety X**, together with **mulching** to conserve soil moisture.

Task
(a) Using the information provided in the table, analyse and explain the differences in yield and drought tolerance observed between **Variety X** and **Variety Y**.
(b) Critically assess the two strategies proposed by the agricultural advisers and recommend the most appropriate approach for improving food production and food security in Kitgum District.

RESPONSE

(a) Analysis

*The **proportion of leaf collenchyma tissue** was **high in Variety X** but **low in Variety Y**. Collenchyma provides flexible mechanical support to leaves, allowing them to remain upright under high temperatures and intense sunlight. This maintains a large exposed surface area for photosynthesis. In Variety Y, reduced collenchyma caused leaves to wilt more readily during drought, reducing light interception and lowering crop yield.*



*The **bundle sheath cells** were **well developed in Variety X** but **poorly developed in Variety Y**. Well-developed bundle sheath cells concentrate carbon dioxide around Rubisco, minimizing photorespiration under high temperatures and increasing photosynthetic efficiency. Poorly developed bundle sheath cells in Variety Y increased photorespiration, reducing carbohydrate production and crop productivity.*

*The **light saturation point** was **high in Variety X** but **low in Variety Y**. Variety X continued increasing its photosynthetic rate under intense sunlight before reaching maximum capacity, producing more glucose for growth and yield. Variety Y reached light saturation earlier, limiting photosynthesis and reducing food production.*

*The **response to abscisic acid** was **rapid in Variety X** but **slow in Variety Y**. Rapid stomatal closure reduced water loss through transpiration during drought, maintaining cell turgidity and physiological activity. Slow stomatal closure in Variety Y resulted in excessive water loss, wilting and reduced drought tolerance.*

***Therefore,** Variety X possessed superior structural and physiological adaptations for efficient photosynthesis and water conservation, enabling higher yields and greater drought tolerance than Variety Y under Kitgum's environmental conditions.*

(b) Evaluation

Application of synthetic abscisic acid and nitrogen fertilizer

Synthetic abscisic acid promotes stomatal closure during water stress, reducing transpiration and conserving water. Nitrogen fertilizer increases chlorophyll formation and leaf growth, improving photosynthetic capacity and crop growth.

However, repeated application increases production costs and depends on continued farmer inputs. These treatments do not improve the genetically poor bundle sheath development or low light saturation point of Variety Y, so drought tolerance remains limited.

***Judgement:** It provides temporary improvement but does not overcome the inherent genetic weaknesses of Variety Y.*

Growing Variety X together with mulching

Variety X possesses natural adaptations for drought tolerance, including well-developed bundle sheath cells, rapid ABA response and high light saturation. Mulching conserves soil moisture, lowers soil temperature, suppresses weeds and improves water availability, further enhancing crop growth and yield.

However, dependence on a single variety may reduce genetic diversity and increase vulnerability if new pests or diseases emerge.

***Judgement:** It provides the most sustainable and reliable long-term strategy for improving crop production under Kitgum's climatic conditions.*

recommendation

*The most appropriate strategy is to cultivate **Variety X together with mulching** because it combines naturally drought-tolerant plant characteristics with improved soil moisture conservation, resulting in consistently higher yields and improved food security.*

ITEM 3

Daniel, a 19-year-old male, was diagnosed with **Type 1 Diabetes Mellitus** two years ago. He attends a health centre every month for routine blood glucose monitoring and general medical assessment. During a recent community outreach programme, Daniel received a **tetanus booster vaccination**. A follow-up blood test conducted three weeks later showed that his antibody concentration had increased markedly from **40 IU/L** to **280 IU/L**.

Because individuals with Type 1 Diabetes often experience complications related to metabolism and resistance to infection, the attending clinician investigated how Daniel's **core body temperature** influences the ability of haemoglobin to deliver oxygen and the rate at which immune cells produce antibodies.

The results are presented in **Table 4**.

Table 4: Relationship between core body temperature, oxygen delivery and immune response

Core Body Temperature (°C)	Oxygen Released by Haemoglobin (ml O_2/100 ml blood)	Antibody Production Rate
40.0	0.34	Extremely High
37.5	0.39	High
35.5	0.47	Poor

To improve management of his condition, the clinician suggested the following five treatment options:

i. Avoid all sources of carbohydrates in order to prevent blood sugar spikes.

ii. Administer prescribed insulin immediately before meals containing carbohydrates.

iii. Switch to a high-protein, low-carbohydrate diet with healthy fats.

iv. Maintain a stable body temperature around **37°C** by avoiding overheating, dehydration and prolonged exposure to cold.

v. Engage in moderate physical exercise daily to improve insulin sensitivity and blood circulation.

Daniel is unsure which of these recommendations would provide the greatest benefit and seeks professional guidance.

Task

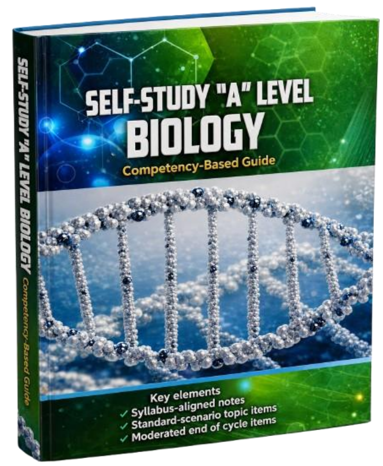
(a) Analyse and explain how changes in body temperature and immunization influenced Daniel's body functions.

(b) Critically evaluate each of the five treatment options proposed by the clinician and recommend the best combination of strategies for Daniel, giving reasons for your choice.

RESPONSE

(a) Analysis

*Daniel's **antibody concentration** increased from **40 IU/L** before immunization to **280 IU/L** after receiving the tetanus booster vaccine. The vaccine stimulated memory B-lymphocytes to proliferate rapidly and differentiate into plasma cells, producing large quantities of specific antibodies against tetanus toxins. Consequently, Daniel developed stronger acquired immunity, reducing the likelihood of tetanus infection.*



*The **oxygen released by haemoglobin** decreased from **0.47 ml O_2/100 ml blood at 35.5°C** to **0.39 ml at 37.5°C** and **0.34 ml at 40.0°C**. At higher body temperatures, haemoglobin has a lower affinity for oxygen and releases oxygen more readily to actively respiring tissues. This supplies sufficient oxygen for aerobic respiration and ATP production during increased metabolic activity.*

*The **antibody production rate** was **poor at 35.5°C**, **high at 37.5°C** and **extremely high at 40.0°C**. Moderate increases in body temperature stimulate enzyme activity and increase the metabolic rate of immune cells, accelerating antibody synthesis. However, excessive body temperature maintained for long periods may denature enzymes and damage body tissues despite the increased immune response.*

*Daniel suffers from **Type 1 Diabetes Mellitus**, where pancreatic β-cells fail to produce sufficient insulin. Without adequate insulin, glucose uptake by body cells is reduced, limiting substrate availability for respiration. Consequently, despite adequate oxygen delivery, ATP production declines, resulting in fatigue and poor metabolic control if insulin is not administered.*

Therefore, immunization increased Daniel's antibody concentration, while changes in body temperature influenced oxygen delivery and immune activity. Appropriate insulin therapy remains essential for normal glucose utilization and energy production.

(b) Evaluation

Avoid all carbohydrates

Avoiding carbohydrates reduces the rise in blood glucose after meals and may reduce the amount of insulin required.

However, carbohydrates are the body's principal respiratory substrate. Complete avoidance may result in hypoglycaemia, ketosis, reduced ATP production and poor physical performance.

Judgement: *It is inappropriate because carbohydrates are essential; intake should be controlled rather than completely eliminated.*

Administer insulin before carbohydrate-containing meals

Insulin promotes glucose uptake by body cells, stimulates glycogen synthesis and lowers blood glucose concentration. This enables glucose to be used efficiently during aerobic respiration to produce ATP.

However, incorrect insulin dosage or administration without adequate food intake may cause severe hypoglycaemia.

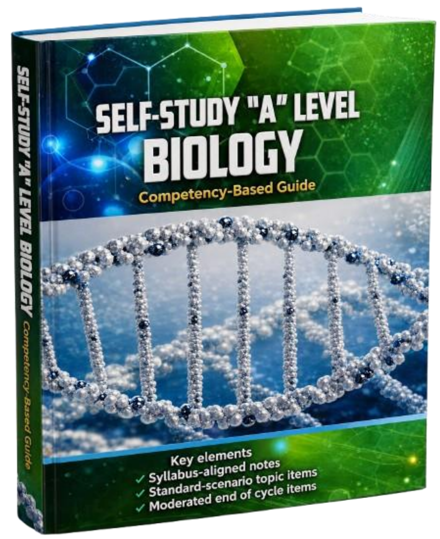
Judgement: *It is one of the most effective treatments because it directly replaces the missing hormone.*

High-protein, low-carbohydrate diet with healthy fats

Protein supports tissue repair, while healthy fats provide an alternative energy source and reduce rapid increases in blood glucose.
However, excessive restriction of carbohydrates may reduce energy availability and increase fat metabolism, predisposing Daniel to ketosis if insulin is inadequate.
Judgement: *It is beneficial only when combined with carefully controlled carbohydrate intake.*

Maintain body temperature around 37°C
Maintaining normal body temperature allows enzymes involved in respiration and immune responses to function efficiently. It also prevents excessive dehydration or enzyme denaturation associated with extreme temperatures.
However, body temperature alone cannot regulate blood glucose or replace insulin deficiency.
Judgement: *It is useful as supportive management but cannot control diabetes independently.*

Moderate daily exercise
Moderate exercise increases insulin sensitivity, improves blood circulation and promotes glucose uptake by skeletal muscles, helping regulate blood glucose concentration.
However, prolonged or vigorous exercise without adequate insulin or carbohydrate intake may cause hypoglycaemia.
Judgement: *It is highly beneficial when appropriately supervised and combined with insulin therapy.*



Recommendation
Daniel should primarily ***administer insulin before carbohydrate-containing meals****, maintain a* ***balanced diet with controlled carbohydrate intake****, engage in* ***moderate daily exercise****, and maintain a* ***normal body temperature****. Complete avoidance of carbohydrates is not recommended because glucose remains the principal substrate for cellular respiration.*

ITEM 4
A national sports science institute is preparing a new programme entitled **"Human Performance Under Extremes"** to train two groups of elite athletes. One group consists of **winter endurance athletes** who compete in Arctic environments with temperatures ranging from **−40°C to −20°C**. The second group consists of **desert endurance athletes** who compete in desert conditions where temperatures range from **40°C to 50°C**.
The institute intends to determine whether both groups can train within the same environmental chamber or whether each group requires a specialized training environment. To guide this decision, sports physiologists measured several physiological characteristics associated with oxygen transport, thermoregulation, kidney function, circulation and neuromuscular coordination.
The findings are summarized in **Table 3**.
Table 3: Physiological data for winter athletes and desert endurance athletes

Feature	Winter Endurance Athletes	Desert Endurance Athletes

Position of oxygen dissociation curve	Slight right shift	Slight left shift
Blood flow to extremities during exercise	Low	High
Lower critical temperature for performance (°C)	−30	+28
Glomerular filtration rate (mL per minute)	120	20

The institute later received a report that a group of desert athletes had been relocated for training to a high-altitude mountainous region where the average temperature was **20°C**, oxygen availability was lower than at sea level, and water was abundant. The athletes successfully adapted to the new conditions and demonstrated improved performance over several seasons.

Task

(a) Analyse the differences in the physiological characteristics of the two athlete groups and explain how these differences contribute to their performance and survival in their respective environments.

(b) Using additional physiological parameters that should be measured before the final decision is made, assess whether both groups should train in the same environmental chamber under similar environmental conditions. Justify your choice.

RESPONSE

a) Analysis

*The **oxygen dissociation curve** showed a **slight right shift in winter endurance athletes** but a **slight left shift in desert endurance athletes**. A right shift reduces the affinity of haemoglobin for oxygen, allowing more oxygen to be released to active tissues for aerobic respiration in cold environments. A left shift increases haemoglobin affinity for oxygen, improving oxygen loading in the lungs where dehydration and heat stress may reduce oxygen availability.*

***Blood flow to the extremities** was **low in winter athletes** but **high in desert athletes**. Reduced peripheral blood flow conserves body heat by minimizing heat loss from the skin in cold environments. Increased peripheral blood flow in desert athletes enhances heat loss through radiation and evaporation, preventing overheating during exercise.*

*The **lower critical temperature** was **−30°C in winter athletes** but **+28°C in desert athletes**. Winter athletes can maintain normal metabolic activity at much lower environmental temperatures due to physiological adaptation to cold. Desert athletes begin experiencing cold stress at relatively higher temperatures because they are adapted to hot climates.*

*The **glomerular filtration rate** was **120 mL/min in winter athletes** but only **20 mL/min in desert athletes**. Higher filtration rates allow efficient removal of metabolic wastes when water is readily available. Reduced filtration in desert athletes conserves water by reducing urine formation, an important adaptation for survival in hot, dry environments.*

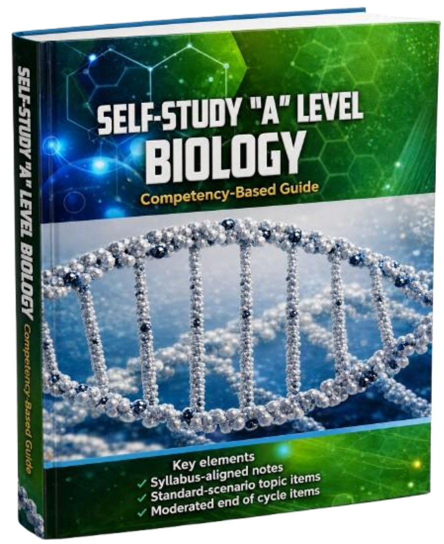
*Following relocation to a **high-altitude environment**, desert athletes adapted by increasing physiological efficiency under reduced oxygen availability. Long-term acclimatization improved oxygen transport and utilization, contributing to enhanced athletic performance despite lower atmospheric oxygen concentration.*

***Therefore**, both athlete groups possess distinct circulatory, respiratory, thermoregulatory and renal adaptations that maximize survival and performance in their respective environments.*

(b) Evaluation

Training both groups in the same environmental chamber
A common training chamber would simplify programme management and reduce operational costs. General fitness, muscular strength and cardiovascular endurance could be improved simultaneously.
However, winter athletes require cold conditions to maintain cold adaptations, whereas desert athletes require hot conditions to preserve heat adaptations. Exposure to unsuitable temperatures may reduce physiological efficiency and compromise performance.
Judgement: *A single environmental chamber cannot adequately maintain the specialized adaptations required by both groups.*

Separate specialized environmental chambers
Separate chambers allow each group to train under environmental conditions that closely resemble their competitive habitats. This maintains adaptations involving oxygen transport, thermoregulation, kidney function and circulation, maximizing athletic performance.
However, specialized facilities are more expensive to construct, operate and maintain.
Judgement: *Despite the higher cost, specialized training environments provide the most effective preparation for elite performance.*



Recommendation
The institute should ***train each group in separate specialized environmental chambers*** *because the athletes possess different physiological adaptations to temperature, oxygen availability, circulation and water conservation. Additional parameters such as* ***haemoglobin concentration, red blood cell count, ventilation rate, sweat rate, core body temperature, plasma osmolarity and heart rate*** *should also be monitored before finalizing training programmes.*

ITEM 5
Fruit farms provide favourable habitats for the fruit fly, *Drosophila melanogaster*, whose larvae develop inside light-coloured ripe fruits. Scientists have recently observed that these fruit flies are becoming less common, and the surviving individuals are increasingly found in darker fruits. At the same time, insectivorous predator birds appear to consume fewer flies, making the remaining population less visible.
To investigate the possible evolutionary changes, researchers studied two inherited characteristics in the fruit fly population:

- **Body colour**, controlled by two alleles where the dominant allele produces **light body colour** and the recessive allele produces **black body colour**.
- **Wing type**, controlled by two alleles where the dominant allele produces **normal wings** and the recessive allele produces **vestigial (short) wings**.

Scientists crossed a **test fly** with **black body and vestigial wings** with a **heterozygous light-bodied, normal-winged fly**. The offspring obtained are shown below.
Table 1: Results from the test cross

Phenotype of offspring	Number of individuals
Light coloured body, normal wings	123
Light coloured body, vestigial wings	07
Black body, normal wings	06
Black body, vestigial wings	132

Researchers also compared fruit fly populations before and after the dry season.

Table 2: Population changes before and after the dry season

Phenotype of offspring	Before dry season	After dry season
Light body, normal wing	25670	26403
Black body, vestigial wing	12300	9000

Task

(a) Explain the differences observed in:

(i) the results of the test cross.

(ii) the fruit fly populations before and after the dry season.

(b) Using evidence from the table and biological principles, evaluate the challenges that scientists have identified as possible causes of the declining fruit fly population in Luweero.

RESPONSE

(a) Analysis

*The **test cross** produced **123 light-bodied normal-winged** and **132 black-bodied vestigial-winged** offspring, compared with only 7 **light-bodied vestigial-winged** and **6 black-bodied normal-winged** offspring. The high numbers of parental phenotypes indicate that the genes controlling body colour and wing type are **linked** on the same chromosome and are usually inherited together. The few recombinant offspring resulted from **crossing over** during prophase I of meiosis, where exchange of chromosomal segments produced new allele combinations.*

*The **light-bodied normal-winged population** increased from **25,670** before the dry season to **26,403** after the dry season. This indicates that individuals possessing these characteristics had a selective advantage, enabling greater survival and reproductive success under the prevailing environmental conditions. Consequently, favourable alleles became more common in the population.*

*The **black-bodied vestigial-winged population** decreased from **12,300** to **9,000** after the dry season. Individuals with vestigial wings were less efficient at escaping predators and dispersing to suitable habitats, reducing their survival. The decline also suggests that environmental selection acted against this phenotype, decreasing its frequency within the population.*

*The observation that surviving fruit flies were increasingly found in **darker fruits** indicates that changes in habitat influenced natural selection. Darker fruits provided better camouflage against predators, increasing survival of flies occupying these fruits and altering the distribution of the population.*

***Therefore,** linkage produced predominantly parental phenotypes, while crossing over generated few recombinants. Environmental selection during the dry season favoured better-adapted flies, altering phenotype frequencies through natural selection.*

(b) Evaluation

Predation by insectivorous birds

Predatory birds remove large numbers of fruit flies from the population, reducing breeding individuals and lowering population size. Predation also acts as a selective force by eliminating more conspicuous individuals.
However, predation mainly removes weaker or poorly adapted individuals and therefore contributes to natural selection that maintains healthier populations.
Judgement: *Predation contributes to population decline but is also an important natural evolutionary force.*

Habitat shift to darker fruits
Occupation of darker fruits provides camouflage, reducing visibility to predators and increasing survival of some individuals. It also allows better-adapted flies to reproduce successfully.
However, reliance on fewer suitable fruits may increase competition for food and breeding sites, limiting further population growth.
Judgement: *Habitat shift improves survival of adapted individuals but cannot completely prevent overall population decline if suitable habitats remain limited.*

Reduced genetic variation due to selection
Natural selection increases the frequency of favourable phenotypes while reducing less adapted ones, improving adaptation to changing environmental conditions.
However, prolonged selection may reduce genetic diversity, limiting the population's ability to adapt to future environmental changes or disease outbreaks.
Judgement: *Selection improves short-term adaptation but excessive reduction in genetic diversity may threaten long-term survival.*

Recommendation
Conservation efforts should maintain ***diverse fruit habitats****, reduce unnecessary destruction of breeding sites and preserve* ***genetic diversity*** *within the fruit fly population. This supports continued adaptation while maintaining stable population sizes.*

ITEM 6
For the past **25 years**, an environmental agency has monitored a **riverine wetland ecosystem** that has undergone rapid environmental degradation due to increasing human activities. The scientists measured changes in **water temperature, turbidity, dissolved oxygen, plant community diversity**, and **fish population health**.
Researchers also monitored changes in the gene pool of a native **tilapia** species known to differ in heat tolerance. Two alleles were identified:

- **H-allele:** Associated with high-temperature tolerance.
- **h-allele:** Associated with low-temperature tolerance.

The environmental and biological changes recorded in the wetland are shown below.
Table: Changes recorded in the wetland ecosystem

Year	Mean Water Temperature (°C)	Water Turbidity (NTU)	Dissolved Oxygen (mg/L)	Frequency of H-allele (%)	Aquatic Macrophyte Richness	Mean Fish Biomass (g/m³)
2000	22.0	15	8.0	22	9	48.0
2005	23.9	22	7.1	30	8	43.5
2010	24.8	38	6.2	46	7	36.0
2015	25.7	52	5.0	61	6	27.0
2020	27.6	75	4.1	75	5	18.5
2025	29.5	94	3.4	86	4	10.2

Wetland managers proposed the following restoration strategies:

Strategy 1: Breed and release tilapia possessing a high proportion of the **H-allele** into the wetland. Predators would be excluded for **three years** to allow the heat-tolerant fish population to become established and increase fish biomass.

Strategy 2: Restore the catchment by planting indigenous riparian vegetation, restrict farming along wetland edges, and construct siltation ponds upstream to trap sediments and cool surface runoff.

Task

(a) Analyse and explain the trends observed in **dissolved oxygen**, **aquatic macrophyte richness**, **frequency of the H-allele**, and **mean fish biomass** over the **25-year** period.

(b) Critically evaluate **Strategy 1** and **Strategy 2** as long-term solutions for restoring the wetland to its condition in the year **2000**. Conclude by recommending the most appropriate restoration strategy.

RESPONSE

(a) Analysis

*The **dissolved oxygen concentration** decreased steadily from **8.0 mg/L in 2000** to **3.4 mg/L in 2025**. Increasing water temperature reduced the solubility of oxygen, while higher turbidity limited photosynthesis by aquatic plants. Reduced oxygen availability lowered aerobic respiration in aquatic organisms, contributing to declining fish survival and biomass.*

*The **aquatic macrophyte richness** declined from **9 species** to **4 species** over the 25-year period. Increased turbidity reduced light penetration, lowering photosynthesis and plant growth. Loss of aquatic vegetation reduced habitat availability, oxygen production and food resources for aquatic organisms, further destabilizing the wetland ecosystem.*

*The **frequency of the H-allele** increased from **22%** to **86%**. Rising water temperatures favoured fish carrying the heat-tolerant allele, allowing these individuals to survive and reproduce more successfully than heat-sensitive fish. Consequently, natural selection increased the frequency of the H-allele within the population.*

*The **mean fish biomass** decreased from **48.0 g/m³** to **10.2 g/m³**. Reduced dissolved oxygen, declining aquatic vegetation, increasing turbidity and environmental degradation lowered fish survival, growth and reproduction, causing a progressive decline in the fish population despite the increase in heat-tolerant individuals.*

Therefore, *environmental degradation reduced dissolved oxygen and aquatic vegetation while increasing selection for heat tolerance. However, the improved frequency of the H-allele could not compensate for deteriorating habitat conditions, leading to a major decline in fish biomass.*

(b) Evaluation

Strategy 1: Release heat-tolerant tilapia and exclude predators

Introducing fish carrying a high frequency of the ***H-allele*** *increases the proportion of individuals capable of surviving elevated water temperatures. Temporary predator exclusion also allows the population to increase rapidly during establishment.*

However, this strategy does not reduce water temperature, improve dissolved oxygen, decrease turbidity or restore aquatic vegetation. Once predators return, fish remain exposed to poor environmental conditions that continue limiting survival.

Judgement: *It provides only a temporary increase in fish numbers because it addresses the fish rather than the degraded ecosystem.*

Strategy 2: Restore riparian vegetation, restrict farming and construct siltation ponds

Riparian vegetation cools surface runoff, stabilizes riverbanks and reduces erosion. Restricting farming decreases nutrient and sediment input, while siltation ponds reduce turbidity before water enters the wetland. These measures improve light penetration, increase photosynthesis, raise dissolved oxygen and restore aquatic habitats, allowing recovery of fish populations and biodiversity.

However, ecosystem restoration requires considerable financial investment and several years before full ecological recovery is achieved.

Judgement: *It provides the most sustainable long-term restoration because it addresses the underlying environmental causes of ecosystem degradation.*

Overall recommendation

Strategy 2 *is the most appropriate restoration approach because it restores the physical and ecological conditions of the wetland, improving dissolved oxygen, aquatic vegetation and fish habitats.*

Strategy 1 *may be used only as a supplementary measure after habitat restoration has begun to accelerate recovery of the heat-tolerant fish population.*