P530/1
BIOLOGY
Paper 1
2026
3 hours

UGANDA NATIONAL EXAMINATIONS BOARD

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

Respond to **both** *items in this section.*

Item 1

John was persistently wheezing and feeling fatigue. He was then taken to a specialized hospital for medical care. Basing on his signs and symptoms, the doctor suspected a condition affecting the epithelial tissue lining John's respiratory system.

Normally, the cell membrane of the epithelial cells of the tissue contains a protein that regulates water movement in and out of the epithelial cell. The synthesis of the protein is controlled by a gene called cystic fibrosis transmembrane conductance regulator (CFTR) gene.

A defect in the CFTR gene can affect the protein function. Since the doctor suspected a defect in the protein, the he requested for a CFTR gene test and other parameters.

The Laboratory report from the doctor's request is shown in **Table 1**.

Table 1: Showing John's laboratory report

Parameter	**John's results**	**Normal range**
Sequence of CFTR gene	ATG, GCT, TTT, GAC, ACA	ATG, GCT, CTT, GAC, ACA
Rate of water movement out of epithelial cells	Low	High
Mitochondrial activity	Low	High
Thickness of mucus on epithelial cells	Very thick	Thin
Status of airways	Blocked	Open

The doctor recommended that John takes a supplement of a coenzyme for fatigue, then either gene therapy or dilators for persistent wheezing (*dilators act on the muscle cells of the bronchioles making them relax and widen for some time*).

Your classmates saw John's laboratory report and the doctor's recommendations and would wish to understand what they mean in relation to human health.

Task:

a) Analyse the laboratory report in relation to John's signs and symptoms.
b) Assess the effectiveness of the doctor's recommendation.

Item 2

Due to frequent changes in climatic conditions that lead to poor crop yields, farmers have been advised to start using greenhouses for tomato growing. A greenhouse is a house-like structure covered with a transparent/translucent roof and walls that create a controlled environment for growing crops.

To determine the suitable conditions to be used in the greenhouses, the farmers hired an agricultural officer who carried out trial tomato-growing using four greenhouses. Each greenhouse had different conditions and the results of the trial are as shown in **table 2**.

Table 2: Showing tomato growing under different greenhouse conditions

Growth and physiological traits	**Greenhouse and its conditions**			
	Greenhouse 1 (32°C + auxins)	**Greenhouse 2** (32°C + gibberellins)	**Greenhouse 3** (25°C + auxins)	**Greenhouse 4** (25°C + gibberellins)
Germination rate (%)	Moderate	Moderate	Moderate	High
Photosynthetic rate (μ mol $CO_2/m^2/s$)	High	High	Low	Low
Number of branches	Few	Very many	Few	many

For good yields, the agricultural officer recommended that the conditions of the greenhouse should **not** be kept constant all through. The farmers need to know how to implement the recommendation.

Task:

a) Analyse the relationship between the conditions of the greenhouse and the growth and physiological traits of tomatoes.
b) Justify the recommendation of the agricultural officer and advise the farmers.

SECTION B

Part I

Respond to **one** *item from* **this** *part.*

Item 3

Aisha, a young adult managing Type-one Diabetes mellitus, attends regular medical check-ups including getting vaccinations at a local health centre.

Following a recent vaccination for hepatitis **B** that she recieved, her blood showed a successful immune response: her antibody concentration rose from 50 units per 100 ml to 275 units per 100 ml of blood.

Since Type-one Diabetes management involves dealing with metabolic and immune challenges, her doctor also reviewed the impact of her body temperature on oxygen-carrying capacity and antibody production.

Table 3: Showing the effects of body temperature on oxygen carrying capacity and antibody production

Body Temperature *(°C)*	Oxygen carrying capacity of Blood *(ml of O_2/100ml of blood)*	Antibody Production
38	0.38	High
37	0.40	Moderate
35	0.46	Low

The medical doctor is suggesting any one of the following interventions to address Aisha's health condition;

i. Aisha eliminates carbohydrate from her diet
ii. Takes insulin injections 30 minutes after every carbohydrate meal
iii. Takes a lipid rich diet.

Aisha needs to understand the effectiveness of each intervention before making a choice.

Task:

a) Analyse how vaccination and changes in body temperature affected the functioning of Aisha's body.

b) Evaluate the effectiveness of each intervention by the doctor in management of Aisha's condition.

Item 4

A study was conducted to determine the effects of high altitude on the physiological functioning of an athlete. An athlete was chosen to participate in the study. Study team recorded the resting heart rate of the athlete at low altitude. He was then moved to high altitude.

Upon arrival at high altitude site, the medical team noted that the athlete's resting heart rate had increased to 80 beats per minute from his normal low altitude value of 60 beats per minute. Two days later, as required by the study, the athlete underwent a rigorous running session to evaluate his physiological response to the new altitude during running.

During the running session, the athlete's heart rate increased further, the blood pH lowered below 7.5 and his performance during that training was poor. The physiological state of the athlete was recorded two hours before the running session, 30 minutes into the run and two hours after the running session. After running, the pH normalized. The data was then recoded in Table 4.

Table 4: The Athlete's physiological changes while in high-altitude site.

Parameter	before and after the running session	During the running session
Blood to skeletal muscle ($cm^3/minute$)	500	1000
Blood to intestines and liver ($cm^3/minute$)	400	200
Heart rate (*beats per minute*)	80	90
Temperature ($°C$)	37	37.8

It was concluded that high altitude did not help the athlete perform well in the running session. The study team need ways of using altitude to improve performance of athletes in running activities.

Task:

a) Analyse the physiological changes in the athlete's body in the study

b) Propose measures the study can use to ensure altitude benefits Athletes.

Part II

Respond to **one** *item from this part.*

Item 5

A conservation body introduced **two** pure breeding breeds of birds **A** and **B** belonging to the same bird species into a woodland ecosystem. The breeds had pure contrasting characteristics and also interbred freely. The woodland contained abundant hard seeds, insect larvae in hardwood tree logs, flying insects and all these served as food to the birds. For two years, the bird characteristics remained the same.

Table ***5*** *Shows the bird populations and their characteristics.*

Bird breed	*No. of birds introduced*	*No. of birds after 2 years*	*Characteristics*
A	58	187	Hard beaks, long wings
B	62	46	Soft beaks, short wings

Two years after introduction of the birds, leaf-eating caterpillars invaded the woodland. To control the invasion, the conservation body sprayed the area with an insecticide. The birds fed on the dead caterpillars and later traces of the insecticide were detected in the birds' bodies.

Ten years after spraying, a new bird offspring with a new combination of characteristics emerged from **A** and **B.** The conservation body labeled the new offspring *breed C* and it had characteristics; hard beaks and short wings.

The population of insect larvae in the woodland decreased greatly **two** years after spraying, but became more abundant 10 years after spraying.

Table 6 showing changes in bird populations and bird characteristics over time

Bird breed	*No. of birds 2 years after spraying*	*No. of birds 10 years after spraying*	*Bird Characteristics*
A	23	16	Hard beaks, long wings
B	46	12	Soft beaks, short wings
C	87	269	Hard beaks, short wings

Based on the changes in the woodland, the conservation body **recommends** that for any future caterpillar invasion; other methods should be used instead of insecticides. There is need to evaluate the effectiveness of the methods before use so that the woodland ecosystem can be conserved.

Task:

a) Analyse the inheritance patterns and population changes of organisms in the woodland.

b) Evaluate the effectiveness of the recommendation of the conservation body in relation to ecosystem stability.

Item 6

A mountain ecosystem with a climax community was destroyed by a severe landslide after heavy floods. Bare rocky grounds remained and the natural recovery process took **20 years**.

Table **7** shows a record of various organisms and other components of the ecosystem up to **20 years** after the heavy floods.

Table 7 *Showing the variation*

Years after the heavy floods	*Dominant vegetation type*	*Soil nitrates(ppm)*	*Amount of energy/Biomass (units)*	*No. of rabbits & climbing squirrels*	*No. of wolves*
3	Mosses	2.1	0.5	0	0
7	Grasses	5.5	20.6	10	06
13	Shrubs	9.2	86.7	64	18
20	Forest	16.8	186.7	72	09

The climbing squirrels feed on tree fruits and spend most of the time in trees, while rabbits feed on vegetation.

The ecosystem is often disturbed by rampant soil erosion and animal grazing.

Scientists also studied the changes in the two varieties of mosses in the ecosystem for a number years and the findings are shown in **table 8**.

Table 8: *Population of varieties of mosses over time*

Years after the flood	*Population of Mosses*	
	with thin walled cells	*with thick walled cells*
3	110	962
7	246	426
13	864	124
20	1180	96

There is a need to improve the productivity of the ecosystem.

Task:

a) Analyse the changes in the population of different organisms and also the change in dominant vegetation in the ecosystem over the **20-year** period.

b) Devise justified ways to improve biomass of the mountain ecosystem.

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P530/1 BIOLOGY

SCORING GUIDE

FOR THE SAMPLE PAPER

Turn Over

P530/1 BIOLOGY

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.)

ITEM 1

Part (a):

- John's CFTR gene contains a base substitution (CTT to TTT) a mutation, which alters the amino acid sequence and tertiary structure of the CFTR protein, producing a non-functional protein that affects chloride ion movement.
- The wrong CFTR gene transcribes a wrong mRNA because of the substituted (wrong) base TTT. This mRNA moves out of the nucleus to the rough endoplasmic reticulum. The mRNA attaches to the ribosomes then tRNA transfer amino acids to the mRNA. The faulty base code then attaches to a corresponding tRNA carrying a different amino acid from the normal one. The ribosome in translation produced a protein with a different sequence of amino acids. Once translated, the formed protein chain enters the endoplasmic reticulum to be folded into its complex shape. Because of the wrong sequence of amino acids, the protein folds incorrectly. The wrong protein is destroyed hence no chloride channels for the cell.
- Chloride ions cannot move out of the airway epithelial cells, so no osmotic gradient forms and less water enters the mucus, producing thick, dehydrated mucus that accumulates in the airways.
- Mucus in the narrowed airways causes turbulent airflow, producing wheezing, while the accumulated mucus stimulates the cough reflex, causing a persistent cough.
- Blocked airways reduce oxygen uptake, leaving less oxygen available for aerobic respiration and lowering ATP production (as indicated by low mitochondrial activity). Less ATP is produced than the metabolic needs of John's body hence feeling fatigue

Part (b):

- The coenzyme supplement supports aerobic respiration and ATP production, which may improve energy availability and partially reduce fatigue; however, it does not; correct the CFTR mutation, restore chloride transport, or prevent thick mucus forming, so it is useful only as supportive treatment and not a long-term solution.
- Gene therapy introduces a functional CFTR gene so functional proteins are produced. This restores chloride transport, allowing water into the mucus thinning it, this addresses the root cause; although it risks an immune response as the immune system may attack the viral vector delivering the gene/may not reach all cells/treatment may need repeating; it is the most effective long-term option.
- Bronchodilators relax bronchiole smooth muscle to widen the airways, giving rapid relief of wheezing, but they do not remove mucus or correct the defect and hence their effect is temporary, so they provide only short-term symptomatic relief.

  Gene therapy should therefore be the preferred long-term treatment, with bronchodilators for immediate relief and coenzyme supplements to manage fatigue; a combination of all three, with gene therapy as the foundation, is likely to give the greatest benefit.

ITEM 2

Part (a):

- Germination is highest in Greenhouse 4 (25°C with gibberellins) because germination enzymes work close to their optimum at 25°C, whereas at 32°C enzyme activity is reduced by partial denaturation.

  This is because in greenhouse 4, gibberellins stimulate amylase, which hydrolyses stored starch into sugars for respiration and embryo growth, so the combination of optimum temperature and gibberellins gives the highest germination rate as in Greenhouse 4.
- Photosynthetic rate is high at 32°C and low at 25°C regardless of hormone type, because enzymes such as RuBisCO are more active at 32°C, increasing carbon fixation and glucose production; temperature is therefore the determining factor, while the growth regulators have little influence on photosynthesis.
- Gibberellin-treated plants produce the most branches (highest in Greenhouse 2 with gibberellins+ 32°C) because gibberellins promote lateral bud growth while auxins maintain apical dominance, and higher temperature increases the rate of these enzyme-controlled growth processes.

Part (b):

- No single greenhouse condition is best for all three parameters(germination rate, photosynthetic rate, number of branches), so different conditions suit different growth stages.
- Greenhouse 4 (25°C with gibberellins) gives the highest germination rate hence most seedlings from seeds, but because photosynthetic rate is low at 25°C it is unsuitable for later growth and fruiting, making it best for the germination stage only.
- Greenhouse 2 (32°C with gibberellins) gives the highest photosynthetic rate and most branches, providing more fruiting sites, but its lower germination rate makes it best used only after seedlings are established.

  Therefore, the farmers should use conditions of Greenhouse 4 during germination then switch to conditions of Greenhouse 2 for growth and branching; maintaining gibberellins throughout and avoiding auxins as the main treatment since auxins suppress branching and do not aid germination.

SECTION B

PART I

ITEM 3

Part (a):

- Antibody concentration rose from 50 to 275 units per 100 ml because vaccine antigens activated specific B lymphocytes, which underwent clonal expansion into plasma cells producing antibodies while some became memory cells; the rise shows a successful immune response.
- Oxygen-carrying capacity fell as temperature rose because haemoglobin's affinity for oxygen decreases at higher temperatures as its structure may be altered, so during fever, less oxygen is delivered to respiring cells.
- Antibody production increased with temperature, being highest at 38°C, because antibody synthesis is enzyme-controlled and higher temperatures raise reaction rates, so a mild fever enhances the immune response.

  However, the same high temperature reduces oxygen delivery to tissues, creating a trade-off, and very high temperatures may eventually denature enzymes, impairing antibody synthesis and other cellular processes.

Part (b):

- Aisha has type 1 diabetes and cannot produce insulin, so effective treatment must restore the ability to regulate blood glucose.
- Eliminating carbohydrates in her diet reduces glucose absorbed after meals, but it does not replace insulin and forces reliance on fat metabolism, increasing the risk of making the blood very acidic from fat metabolism, being difficult to sustain, it is not an effective treatment.
- Insulin injections replace the missing hormone, promoting glucose uptake and glycogen synthesis thereby lowering blood glucose and directly address the cause; although injecting 30 minutes after meals may allow prolonged hyperglycaemia and incorrect doses risk hypoglycaemia, with injection before meals it is the most effective intervention.
- A lipid-rich diet reduces glucose intake but does not replace insulin, raises the risk of making the blood very acidic from lipid metabolism, and may increase cardiovascular risk, so it is ineffective as a primary treatment.
- Aisha should have insulin therapy with a balanced diet, matching carbohydrate intake to insulin dosage to minimise both hyperglycaemia and hypoglycaemia.

ITEM 4

Part (a):

- Resting heart rate rose from 60 to 80 bpm at high altitude because the lower partial pressure of oxygen in air leads to a drop in oxygen saturation in blood; chemoreceptors in blood vessels detect this drop and send signals to the cardiovascular centre in the brain which then stimulates the sympathetic nervous system, causing the heart to beat faster and harder to deliver more blood carrying oxygen per unit time to counter the oxygen deficit.
- During running session, blood flow to muscles doubled from 500 to 1000 cm^3 per minute while flow to the gut and liver fell from 400 to 200, as blood vessels inside active skeletal muscles vasodilated (widened) and digestive arterioles vasoconstricted. The active skeletal muscles need more oxygen and glucose for respiration and also require blood to remove metabolic wastes like carbon dioxide and lactic acid.
- Blood pH fell below 7.5 during the running session because the skeletal muscles respired anaerobically producing lactic acid with hydrogen ions that lowered the pH. This change was detected by the chemoreceptors in the carotid bodies, these sent signals to medulla oblongata (brain) which then signaled the respiratory muscles to contract harder and faster, this resulted into heavy panting removing excess carbon dioxide, reducing acidity hence raising pH.

  (*similar negative mechanism restores* **temperature**, **heart rate** after running)

  After the running session, pH, blood flow and body temperature returned to normal as demand for energy fell. The brain activated the parasympathetic nervous system which made the body to conserve energy. This is negative feedback, it restored conditions, but heart rate stayed at 80 bpm rather than 60 because the athlete remained at high altitude.

Part (b):

- Poor performance came from reduced oxygen availability and lactic acid build-up, so preparation should improve oxygen delivery and delay anaerobic metabolism.
- Altitude acclimatisation over several weeks stimulates kidneys to release a hormone erythropoietin, this moves to the bone marrow to increase production of more red blood cells, haemoglobin concentration and oxygen-carrying capacity, directly addressing the main cause; although it takes weeks to develop, it is the most effective preparation.
- Good carbohydrate and adequate hydration in the diet; carbohydrate loading and hydration increase glycogen stores and maintain plasma volume to fuel respiration and support cardiac output, but cannot overcome reduced oxygen at altitude, so the best preparation combines all approaches with acclimatisation as the priority.

PART II

ITEM 5

Part (a):

- The genes controlling the characteristics of the bird varieties are linked since the characteristics persisted without intermediates for 2 years. These varieties are pure-breeding, a base substitution mutation in the wing-length gene could have occurred, changed long wings to short wings while retaining the hard-beak allele. This mutation could have happened due to accumulation of the insecticide in the bird breed **A** which had hard beaks allele. With such mutation, when mating occurs between the bird with mutation and breed B, the offspring carries the combination of hard beaks, short wings alleles from breed **A** (mutated) and soft beaks, short wings alleles from breed **B**. This offspring has characteristics of breed **C**
- Before spraying, breed **A** increased from 58 to 187 while breed **B** fell from 62 to 46, because of hard beaks and long wings, breed A exploit more food sources, improving survival and reproduction, so natural selection favoured breed **A**.
- After spraying, breed **A** fell to 23 and breed **B** to 12 while breed **C** rose to 269, as the insecticide cut food resources and toxins biomagnified in birds eating contaminated insects; breed **C** was better suited to the altered environment, so the new selection pressures favoured bird breed **C**.

Part (b):

- Spraying controlled caterpillars but disrupted the ecosystem, so effective management should control pests while maintaining biodiversity and food-web stability.
- Insecticide spraying rapidly reduces leaf-eating caterpillars numbers and prevents vegetation damage, but it kills non-target organisms, toxins biomagnify through food chains into predatory birds, and bird diversity falls, so it is effective short-term but harmful to long-term stability.
- Biological control using native predators suppresses leaf-eating caterpillars without chemical pollution, preserving food webs and biodiversity and giving long-term control, but predators may establish slowly and non-native predator species could create new problems like feeding on other non-target organisms, so biological control is more responsible than spraying provided native predators are used.
- Integrated Pest Management combines biological, cultural, mechanical and limited chemical methods, reducing pesticide dependence and biomagnification hence maintaining biodiversity, but it is more complex, costly and needs monitoring; it is the most appropriate long-term strategy, with long-term monitoring to detect changes early.

ITEM 6

Part (a):

- Vegetation changed from bare rock through mosses, grasses and shrubs to forest, showing primary succession; mosses are pioneer species that weather rock and add organic matter, forming soil and raising nitrate concentration, allowing grasses then shrubs to establish until soil nitrate reached 16.8 ppm by year 20, supporting a stable forest climax community.
- Biomass rose from 0.5 to 186.7 units because larger, more complex vegetation has greater leaf area for photosynthesis, fixing more carbon, while rising nitrates support protein synthesis and growth, increasing primary productivity.
- Rabbits and squirrels were absent at year 3 as mosses gave little food or habitat; rabbits and squirrels appeared with grasses and increased with shrubs, and by year 20 forest provided seeds, fruits and shelter for tree-dwelling squirrels, so herbivores increased with the increase in producer biomass.
- Wolves were absent at year 3, rose from 6 to 18 as rabbits increased, then fell to 9 by year 20 because more prey were squirrels, which live up in trees and are less accessible to ground-hunting wolves, reducing effective prey availability.
- Thick-walled mosses dominated initially (962 vs 110) because dry, exposed conditions favoured reduced water loss, but as soil moisture rose thin-walled mosses grew faster as less material was needed for forming walls, rising to 1180 by year 20 — an example of natural selection.

Part (b):

- Biomass increased as soil nitrate concentration rose, so improving nutrient availability and reducing soil or vegetation loss should increase biomass.
- Soil enrichment with compost or fertiliser raises nitrate availability for amino acid and protein synthesis in plants, promoting growth, but excess fertiliser may cause runoff, eutrophication and soil acidification, so it must be managed carefully, with organic compost being more sustainable.
- Carry out reforestation with native trees to accelerate progression to the highest-biomass forest stage, as trees increase photosynthesis, add nutrients through leaf litter and stabilise soil, but young trees may fail in poor soil, so it works best combined with prior soil improvement.
- Ensure soil erosion control to conserve nutrient-rich topsoil and nitrates and support other measures, but can be costly and some ground cover may compete with seedlings; it is essential, as nutrients cannot accumulate if erosion continues.

  Therefore, the most effective strategy combines all measures in sequence — erosion control first, then soil enrichment, then reforestation — giving the greatest long-term increase in biomass while maintaining ecosystem stability.