SAMPLE ASSESSMENT ITEMS

CELL BIOLOGY

A rural community using a shallow well has reported a spike in severe gastrointestinal illness. A public health officer suspects microbial contamination and sends water samples to a lab. The lab identifies a high concentration of *Vibrio cholerae* bacteria. The officer also tests a patient's intestinal tissue biopsy and finds damage to the epithelial lining. Data on the bacteria's structure and its effect on intestinal cells is compiled.

Data:

Parameter	Lab Finding	Normal Condition
Bacterial Cell: Presence of Nuclear Envelope	Absent	Absent (Prokaryote)
Bacterial Cell: Presence of Peptidoglycan in cell wall	Present	Present (Eubacteria)
Intestinal Epithelial Cells: Junction Integrity	Disrupted, pores formed	Tight junctions intact
Intestinal Lumen: Chloride Ion Concentration	High	Low
Patient's Blood: Water Content	Low (Dehydrated)	Normal

Task:

(a) Analyse the ultrastructural features that classify *Vibrio cholerae* as a prokaryotic eubacterium and explain how it disrupts the function of the intestinal epithelial tissue, leading to dehydration.

(b) Propose community health strategy to treat the current crisis and prevent future contamination, justifying each step based on the cellular and physiological processes involved.

A local dairy cooperative in Sembabule has reported that their packaged milk is spoiling unusually quickly, developing a sour taste and thick texture. The problem started after they switched to a new plastic bottle that lets in more light. A food scientist tests the milk and identifies a surge in the population of *Lactobacillus* bacteria. She investigates the effect of light on the activity of lactase enzyme, which is naturally present in milk, and on bacterial growth.

Data:

Milk Storage Condition	Lactase Enzyme Activity (%)	*Lactobacillus* Count (CFU/dm^3)	pH of Milk
Stored in Dark (Control)	100%	1.0×10^3	6.7
Stored in Light (New Bottle)	45%	1.0×10^8	4.5

Task:

(a) Explain how the change in storage condition affects the lactase enzyme and how this, in turn, creates a favourable environment for the bacterial proliferation that spoils the milk.

(b) Propose a scientifically sound solution for the dairy cooperative to prevent this spoilage, justifying your proposal by linking the properties of enzymes and the requirements for bacterial growth.

A fisherman on Lake Albert has been hospitalized with jaundice and fatigue. He has been exposed to industrial solvents known to be lipid soluble. A doctor orders a liver biopsy. A comparison of a micrograph of the patient's liver tissue with a healthy sample is conducted, focusing on the organelles.

Data:

Cellular Component	Observation in Patient's Liver Tissue	Function in Healthy Liver Cell
Rough Endoplasmic Reticulum	Fragmented and reduced	Protein synthesis (e.g., albumin)
Smooth Endoplasmic Reticulum	Highly proliferated	Detoxification and lipid metabolism
Mitochondria	Swollen, cristae damaged	ATP production
Plasma Membrane	Increased fluidity	Selective barrier

Task:

(a) Analyse the changes in the ultrastructure of the liver cells and relate these changes to the patient's symptoms and the lipid-soluble nature of the toxin.

(b) Based on the cellular analysis, propose management plan for the patient to support liver recovery and prevent further damage.

A horticulturist is growing tomato seedlings in a greenhouse for transplanting. Despite regular watering, the seedlings are wilting. An agronomist notes that a concentrated fertilizer was applied directly to the seedlings' roots a day before the wilting started. She analyses root cells from a healthy seedling and a wilted one.

Data:

Parameter	Healthy Root Cell	Wilted Root Cell
Turgor Pressure	High	Low
Central Vacuole Size	Large	Small and shrunken
Solute Concentration in Cytoplasm	0.9%	2.5%
Condition of Plasma Membrane	Pulled away from cell wall (Plasmolysed)	Intact and attached to cell wall

Task:

(a) Explain the role of water and the properties of the plasma membrane in maintaining turgor pressure. Analyse how the fertilizer application led to wilting (plasmolysis) at the

cellular level.
(b) Propose a rescue protocol for the wilted seedlings and a revised fertilization strategy to prevent a recurrence, justifying your answer based on the principles of water movement in plant cells.

NUTRITION

Farmers in the Nakasongola district, known for its hot and dry conditions, have been struggling with low yields from their traditional maize (a C3 plant) crops. A local agricultural officer has introduced a trial plot of sorghum (a C4 plant) alongside the maize. Over the growing season, she collected data on plant performance during the peak dry month.
Data Table: Plant Physiological Data during Peak Dry Month

Parameter	Maize (C3)	Sorghum (C4)
Stomatal Density (stomata/mm²)	250	150
CO_2 Compensation Point (ppm)	50	5
Rate of Photosynthesis at 40°C (µmol/m²/s)	15	32
Water Use Efficiency (g biomass/kg H_2O)	3.5	7.8
Mid-day Stomatal Aperture (µm)	2	5
Visible Leaf Wilting	Severe	Minimal

The officer needs to explain these results to the farmers to encourage a shift in farming practices.
Task:
(a) Analyse how the differences in photosynthetic pathways between C3 and C4 plants account for the observed data in stomatal density, CO_2 compensation point, and water use efficiency.
(b) Propose a detailed plan for the farmers to transition to more C4 crops, justifying how this plan addresses the specific environmental challenges of the Nakasongola district.

A research student at a botanical garden is studying the effect of light intensity on two plant species: Rice (a C3 plant) and Sugarcane (a C4 plant). She placed them in growth chambers with different light conditions and measured the rate of oxygen production. However, a malfunction in one chamber caused a sudden, sustained increase in oxygen concentration around the rice plants. She recorded the following data.
Data Table: Photosynthetic Response to Varying Conditions

Plant Type	Light Condition	O_2 Production Rate (mL/h)	Photorespiration Rate (µmol/m²/s)	Final Biomass (g)
Rice (C3)	Intermittent Light	12	8	45
Rice (C3)	Continuous High Light + High O_2	8	22	32
Sugarcane (C4)	Intermittent Light	18	2	68

Sugarcane (C4)	Continuous High Light + High O_2	25	1	85

The student is confused by the drastic reduction in rice biomass under high O_2 conditions.
TASK:
(a) Explain the biochemical basis for the observed differences in photorespiration and oxygen production between the two plant species under the different light and oxygen conditions.
(b) Based on the data, suggest strategies a farmer could use to minimise yield losses in C3 crops due to photorespiration. Justify each suggestion.

In a bid to improve urban food security, Kampala City Council is promoting vertical farming in stackable units indoors. A community group is growing Nakati (Solanum aethiopicum) and Amaranthus (Amaranthus dubius) in these units. They notice that the Nakati plants are not thriving as well as the Amaranthus under the artificial LED lights. They measure the light saturation point and find that Nakati saturates at lower light intensities than Amaranthus.
Data Table: Plant Performance in Controlled Indoor Environment

Parameter	Nakati (C3)	Amaranthus (C4)
Light Saturation Point (µmol photons/m²/s)	500	1500+
Optimal Temperature for Growth (°C)	20-25	30-40
Leaf Chlorophyll Content (mg/g)	1.8	2.5
Biomass produced per unit light (g/mol photons)	0.5	1.1
Observed Leaf Yellowing	Yes	No

The group needs to adjust their farming protocol to ensure both crops grow successfully.
TASK:
(a) Relate the concepts of light-dependent and light-independent reactions to the differences in the light saturation point and biomass production per unit light between the two types of plants.
(b) Propose a modified plan for the vertical farm, including specific adjustments to the physical setup and lighting regime, to optimise the growth of both C3 and C4 crops simultaneously.

TRANSPORT

In Kampala city, a group of boda-boda riders often park at busy junctions, exposing themselves to heavy traffic fumes. Over time, some riders developed symptoms of headaches, dizziness, and difficulty concentrating. A health survey tested blood samples from three groups: rural farmers (control), boda-boda riders, and traffic police officers.
Table: Average Blood Gas Levels and Heart Rates

Group	Carboxyhaemoglobin (%)	Oxygen Saturation (%)	Average Heart Rate (beats/min)	Breathlessness Complaints (%)
Rural farmers	0.5	98	72	2
Boda-boda riders	8.0	89	95	40
Traffic police officers	12.5	83	110	70

Task:

(a) Explain how the changes in blood gas levels affect oxygen transport and energy supply in boda-boda riders and traffic officers.

(b) Using the data, analyse why traffic officers are more affected than boda-boda riders.

(c) Propose public health and personal strategies to reduce health risks from carbon monoxide in such environments.

In Mukono, a family keeps guinea pigs as pets. Their 14-year-old daughter, Jane, develops sneezing, watery eyes, and skin rashes whenever she plays with them. Interestingly, her twin brother, John, has never shown such symptoms despite playing with the pets daily.

Doctors carried out the following tests:

Table: Blood Test Results

Parameter	Jane	John	Reference (Normal)
IgE antibody levels (IU/ml)	340	60	<100
Histamine release after allergen exposure	High	Normal	Normal
White blood cell count	Normal	Normal	Normal

Task:

(a) Explain why Jane shows allergic reactions but John does not, even though they are twins.

(b) Analyse how histamine contributes to Jane's symptoms.

(c) Propose medical and lifestyle strategies that can help Jane manage her condition.

During a football tournament in Gulu, three players, Peter, Musa, and Akena, collapsed after a 90-minute match. Their medical records were compared.

Table: Player Health Data

Player	Resting Pulse (bpm)	Pulse after Match (bpm)	Oxygen Saturation (%)	Recovery Time to Normal Pulse (min)	Medical History
Peter	65	120	96	4	Regular runner
Musa	72	160	82	15	Smoker
Akena	70	140	90	10	Mild anaemia

Task:

(a) Explain the differences in recovery time among the three players.

(b) Analyse how smoking and anaemia affect oxygen delivery and athletic performance.

(c) Propose training and lifestyle strategies to improve Musa's and Akena's performance and health.

In Lira, an outbreak of measles affected children in a village. Health workers vaccinated all children, but a few still developed mild symptoms. Laboratory tests compared antibody levels in three groups:

Table: Average Antibody Levels after Vaccination

Group	Antibody Levels (arbitrary units)	Severity of Symptoms
Fully vaccinated, healthy children	High	None
Vaccinated but mildly symptomatic	Moderate	Mild
Unvaccinated children	Low	Severe

Task:

(a) Explain why some vaccinated children still developed mild symptoms.

(b) Analyse how antibodies protect the body from measles infection.

(c) Propose strategies to improve the effectiveness of vaccination campaigns in rural communities.

RESPIRATION

A miner was rescued after being trapped in a section of a gold mine where a fire had used up the oxygen. He was unconscious and had a faint smell of bitter almonds on his breath. At the hospital, his blood oxygen levels were normal after being given pure oxygen, but he remained in a coma. Doctors suspected cyanide poisoning from the smoke, which binds to cytochrome c oxidase in the electron transport chain. Tests were conducted on his muscle cells.

Data:

Parameter	Patient's Muscle Cells	Healthy Muscle Cells
Mitochondrial Membrane Potential	Low	High
NADH / NAD+ Ratio	High (High NADH)	Low (Low NADH)
Intracellular ATP Concentration	Very Low	Normal / High
Blood Lactate Level	Very High	Normal
Oxygen Saturation in Venous Blood	High	Low

Task:

(a) Analyse how cyanide poisoning disrupts the specific stages of cellular respiration in the mitochondrion, leading to the observed cellular and systemic conditions.

(b) Propose a two-stage emergency treatment protocol for the patient, justifying each stage based on the biochemical disruption caused by cyanide.

A marathon runner, Jane, “hit the wall” at the 32-kilometer mark, experiencing extreme fatigue, muscle cramps, and disorientation. Her coach noted that she had primarily trained with short, high-intensity runs and had a low-carbohydrate diet in the days leading up to the race. A blood test was taken immediately after she dropped out.

Data:

Metabolic Parameter	Jane's Post-Race Level	Normal Resting Level
Blood Glucose Level	2.1 mmol/L	4.0 - 5.5 mmol/L
Muscle Glycogen Stores	Depleted	Full
Blood Ketone Bodies	High	Low
Respiratory Quotient (RQ)	0.7	0.85 (Mixed diet)

Task:
(a) Explain the role of acetyl-CoA as a key metabolite. Analyse how Jane's diet and training led to the depletion of specific respiratory substrates, forcing her body to switch to alternative fuels and causing her to “hit the wall.”
(b) Propose a revised training and nutritional plan for Jane to prevent this in future marathons, justifying your plan based on the biochemistry of cellular respiration for sustained energy production.

A climber attempting to summit Mount Everest is struggling with severe fatigue and shortness of breath at the base camp. A doctor measures his physiological parameters and compares them to his sea-level baseline. The climber had not undergone proper acclimatization. The doctor explains that low oxygen (hypoxia) affects the final stage of cellular respiration.

Data:

Parameter	At Sea Level	At Base Camp
Arterial Oxygen Saturation	98%	75%
Resting Heart Rate	60 bpm	95 bpm
Mitochondrial Density in Muscle Cells	Normal	Increased (after weeks)
ATP Production Rate	Normal	Decreased
Blood 2,3-DPG (Bisphosphoglycerate) Level	Normal	Increased

Blood 2,3-DPG (2,3-BPG) is a small organic molecule found in red blood cells (RBCs) that plays a crucial role in regulating how tightly hemoglobin binds to oxygen.

Task:
(a) Explain the role of oxygen in the electron transport chain and analyse the body's short-term (heart rate, 2,3-DPG) and potential long-term (mitochondrial density) responses to maintain ATP production in a low-oxygen environment.
(b) Justify a scientific acclimatization protocol for future climbers to safely enhance their cellular respiration efficiency at high altitude.

HOMEOSTASIS

During a marathon in a hot, humid climate, a runner, Sarah, collapsed. She was disoriented, had a rapid, weak pulse, and her skin was hot and dry. Bystanders reported she had been drinking large amounts of pure water throughout the race but had not consumed any electrolytes. Medical tests at the event revealed the following data.

Data:

Parameter	Sarah's Reading	Normal Range
Core Body Temperature	40.1 °C	36.5 - 37.5 °C
Blood Sodium Concentration	125 mmol/L	135 - 145 mmol/L
Plasma ADH (Vasopressin) Level	Low	High (in dehydration)
Skin Moisture	Dry	Moist (from sweating)

Task:

(a) Analyse Sarah's homeostatic imbalance. Explain the failure of the negative feedback mechanisms for temperature regulation and water balance, linking her symptoms to the data provided.

(b) Propose a revised hydration strategy for marathon runners to prevent this condition, justifying it based on the principles of osmoregulation and thermoregulation.

A farmer in a semi-arid region planted maize (a mesophyte) and a local, hardy millet variety on the same plot. After a heatwave, the maize is severely wilted, while the millet remains healthy. The farmer had used a new, broad-leaf herbicide that can affect stomatal function. An agronomist analyses leaf samples from both plants.

Data:

Plant	Stomatal Density (per mm^2)	Cuticle Thickness (µm)	Observation during Heatwave
Maize (Mesophyte)	250	5	Stomata closed, leaves wilted
Hardy Millet (Xerophyte)	50	15	Stomata partially open, leaves turgid

Task:

(a) Compare and contrast the osmoregulatory adaptations of the maize and millet, explaining how these differences account for their response to the heatwave.

(b) Advise the farmer on two sustainable water management strategies to protect his maize crop in future dry spells, justifying your advice with the physiological data.

The kangaroo rat is a desert rodent that survives without drinking water. It produces extremely concentrated urine and has highly efficient nasal passages that reduce water loss during breathing. Researchers are studying its kidney function and comparing it to a common rat (a mesic-adapted rodent).

Data:

Parameter	Kangaroo Rat	Common Rat
Max Urine Concentration (mOsm/L)	5000	1400
Loop of Henle Length (relative to kidney size)	Very Long	Short
Metabolic Water Production from seeds	High	Low
Water Loss through Respiration	Very Low	High

Task:
(a) Analyse the role of the kidney structure (Loop of Henle) and other adaptations in the kangaroo rat's homeostatic system for maintaining water balance.
(b) Using the principle of negative feedback, describe how the kangaroo rat's body would respond to the ingestion of a small amount of salty food.

A patient received general anesthesia for a major surgery. After the operation, nurses are monitoring his recovery. They note his blood pressure is unstable, he feels nauseous, and his body temperature is dropping. The patient had been given intravenous fluids and his room was kept cool.

Data:

Parameter	Patient's Status (4 hours post-op)	Normal Homeostatic Set Point
Core Body Temperature	35.2 °C	37.0 °C
Blood Pressure	Fluctuating between high and low	Stable
Blood Glucose Level	5.0 mmol/L	4.0 - 5.5 mmol/L
Shivering Response	Absent	Present (if cold)

Task:
(a) Analyse how the general anesthesia and cool room temperature have disrupted the patient's homeostatic control systems for temperature and blood pressure, with reference to negative feedback loops.
(b) Propose two nursing interventions to help the patient regain homeostatic stability, explaining the physiological rationale for each.

Mangrove trees thrive in salty coastal waters, a environment that would dehydrate and kill most plants. They have special roots (pneumatophores) that grow upwards for oxygen and mechanisms to exclude or excrete salt. A researcher compares a mangrove (a halophyte) to a bean plant (a glycophyte) grown in saline conditions.

Data:

Plant Type	Salt Concentration in Sap (mM)	Structure for Salt Excretion	Survival in Seawater
Mangrove (Halophyte)	100	Salt glands on leaves	Thrives
Bean Plant (Glycophyte)	500	None	Wilted and dies

Task:

(a) Explain the osmoregulatory adaptations that allow the mangrove to maintain a stable internal water potential despite being surrounded by seawater.

(b) Mangroves are vital for coastal protection. Propose a strategy for the conservation of mangroves in an area threatened by logging and rising sea levels, justifying it based on their unique homeostatic adaptations.

COORDINATION

Farmers on the steep slopes of Kigezi highlands have reported that their bean seedlings are growing at a pronounced angle instead of upright, leading to poor light capture and reduced yields. An agricultural officer, Mr. Tugume, observes that the fields are on a consistent slope and that farmers have recently switched to a new, cheaper auxin-based herbicide to control weeds. He suspects the plant's growth responses are being disrupted. He measures the hormone levels and growth patterns in seedlings from a flat control field and the sloping field.

Data:

Parameter	Seedlings on Flat Field	Seedlings on Sloping Field
Auxin Concentration on lower side of stem (ng/g)	15	45
Gibberellin Concentration (ng/g)	25	10
Stem Angle from Vertical (degrees)	5	35
Root Growth on lower side (cm/week)	2.0	3.5
Time to Flowering (days)	60	75

Task:

(a) Analyse the role of plant hormones in causing the observed growth patterns (angle, delayed flowering) in the beans on the sloping field.

(b) Propose and justify a plan for the farmers to correct the growth pattern and improve yields, ensuring sustainable agricultural practice.

A renowned keyboardist, Maria, has been struggling with slower finger movements and delayed response during her live performances, especially in cold, air-conditioned studios. Her doctor rules out muscle issues and suspects a problem with neural transmission. Maria mentions she follows a very low-fat diet and had a minor cut on her finger treated with a topical anaesthetic cream before her last performance. Tests were conducted on her motor neurones at normal (37°C) and cool (20°C) temperatures.

Data:

Parameter	At 37°C	At 20°C
Speed of Impulse Transmission (m/s)	120	65
Rate of Neurotransmitter Release at synapse	High	Low
Rate of Na+/K+ pump activity	High	Low
Myelin Sheath Integrity (%)-	100	100

Task:

(a) Explain how the factors of temperature and the local anaesthetic are affecting impulse transmission and synaptic function, leading to Maria's slower finger movements.

(b) Propose a scientifically sound management plan for Maria to prevent these issues during future performances and support her neural health.

A scuba diving instructor, Ben, experienced severe vertigo and nausea after a deep dive where he rapidly ascended to the surface to assist a student. Since then, he has had trouble maintaining balance, especially in the dark. An ENT specialist finds no physical damage but conducts tests on Ben's vestibular system compared to a healthy individual. The dive occurred in murky water with poor light penetration.

Data:

Test	Ben's Results	Normal Results
Response of semicircular canals to rapid head turn	Normal	Normal
Response of otolith organs to linear movement/gravity	Slowed and exaggerated	Normal
Ability to balance on one foot with eyes open	30 seconds	60 seconds
Ability to balance on one foot with eyes closed	5 seconds	45 seconds

Task:

(a) Analyse which part of Ben's balance system was affected by the rapid pressure change and explain the physiological reason for his symptoms, linking them to the test results.

(b) Propose a rehabilitation strategy for Ben to regain his balance and suggest a safety protocol for future dives to prevent a recurrence.

A seed company in Jinja is struggling with the poor and uneven germination of a new hybrid squash variety. The seeds are high quality but remain dormant. Researchers suspect an issue with the hormonal balance controlling dormancy and germination. They treat a batch of seeds with different growth regulators and observe the germination rate and early growth.

Data:

Seed Treatment	% Germination after 7 days	Average Stem Length (cm)	Observation
No treatment (Control)	10%	2.0	Hard seed coat
Gibberellic Acid	95%	8.5	Vigorous growth
Abscisic Acid (ABA)	0%	0.0	No growth
Cytokinin	40%	4.0	Slow, bushy growth

Task:

(a) Explain the role of Gibberellic Acid, Abscisic Acid, and Cytokinin in breaking seed dormancy and promoting the germination and early growth observed in the data.

(b) Propose a practical and commercial method for the seed company to treat their seeds to ensure uniform germination for farmers, justifying your choice based on the hormonal actions.

In a savanna ecosystem, researchers are studying the elaborate courtship display of the male Long-tailed Widowbird. The male performs a slow, fluttering flight over its territory to show off its extremely long tail to females. Researchers experimentally manipulated tail length and observed the effects on mating success and predator avoidance.

Data:

Bird Group	Average Tail Length	Number of Nests in Territory	% Attacked by Predators
Normal Males	50 cm (normal)	4	15%
Males with shortened tails	20 cm	1	10%
Males with elongated tails	80 cm	6	35%

Task:

(a) Analyse the adaptive significance of the long tail courtship behaviour in terms of reproductive success and survival, using the data to explain the trade-off involved.

(b) Based on the principles of natural and sexual selection, predict how the tail length in the population might change over time if a new, faster predator is introduced, and justify your prediction.

INHERITANCE AND EVOLUTION

In Kampala's industrial zone, several factories have been operating for more than 15 years, releasing untreated smoke and wastewater into the surrounding community. Residents often complain of constant coughs, eye irritation, and unusual skin growths. The local health centre reports that many factory workers have been diagnosed with lung cancer or other abnormal cell growths. Doctors suspect that exposure to carcinogenic chemicals is damaging the workers' DNA.

A molecular biology lab analysed blood samples from factory workers and a nearby village with no factories.

Table: Genetic and Cellular Data

Group	Mutation frequency in cell cycle control genes (%)	DNA repair enzyme activity (% of normal)	Rate of abnormal cell division (%)	Average life expectancy (yrs)
Control	1	95	2	70
Exposed	20	40	25	55

Task:

(a) (i)Analyse how increased mutations and reduced DNA repair activity can lead to abnormal cell division and cancer.

(ii)Explain the relationship between environmental exposure and reduced life expectancy.

(b) Propose sustainable strategies to reduce cancer risk in such communities.

In response to prolonged droughts in eastern Uganda, a local biotechnology startup partnered with Makerere University to develop drought-resistant maize using recombinant DNA technology. Farmers who tested the new variety reported higher yields even with less rainfall. However, environmental activists and some community members raised concerns about the impact of the maize on human health, pollinators, and biodiversity. Some families reported mild allergic reactions after eating the new maize flour.

Data from experimental farms

Trait	Traditional maize	GM drought-resistant maize
Average yield (tons/ha)	2.5	4.2
Water requirement (litres/plant)	18	10
Pollinator visits (per flower/day)	20	12
Reports of allergic reactions in consumers (%)	0	3

Task:

(a)(i) Assess how recombinant DNA technology contributed to the traits of the new maize.

(ii)Explain the ethical, social, and environmental implications of adopting this GM maize.

(b) Propose strategies to balance high yields with environmental sustainability and public health.

A farmer in Kamuli District runs a rabbit project to increase family income. He began with two white rabbits that he assumed would only produce white offspring. However, when the rabbits reproduced, some of the young turned out black. Thinking that food or environmental conditions had caused the change, he adjusted the rabbits' diet and shelter. Despite these changes, the colour differences persisted in future generations. The farmer grew puzzled when the following results were recorded:

Offspring counts over generations

Cross	White kits	Black kits	Total kits
1st generation	22	18	40
2nd generation	60	20	80

The farmer's neighbour suggested he consult an agricultural extension worker, who hinted that coat colour was genetically controlled rather than caused by feeding or the environment.

Task:

(a) (i)Use Mendelian principles to explain how white parents can produce black offspring.

(ii) Analyse the ratios to determine the likely genotypes of the parents.
(b) Suggest strategies to help the farmer understand and apply genetics correctly for better breeding.

Queen Elizabeth National Park is home to two antelope species that occupy different habitats. Species A lives in open savannahs with tall grass, where predators such as lions chase prey at high speeds. Species B lives in swampy lowlands with dense vegetation, where movement is restricted, but food is plentiful. Park rangers noticed that the two species show striking differences in body structure and physiology, influencing their survival rates against predators.
Research Data

Trait	Species A	Species B
Leg length (cm)	95	70
Lung surface area (cm^2)	420	310
Heart rate at rest (beats/min)	60	75
Predation escape success (%)	90	65

Task:
(a) Explain how the traits of each species are evolutionary adaptations to their specific habitats.
(b) Analyse how these differences improve chances of survival and reproduction.
(c) Suggest conservation strategies to protect these antelope species under increasing human encroachment.

In Arua District, cassava is the main food and income source for many households. Farmers relied on pesticides to control a pest outbreak that began 8 years ago. Initially, the pesticides worked, but now the pests have become harder to kill. Farmers complain of falling cassava yields and rising production costs. Bird and lizard populations, which previously preyed on the pests, have declined due to habitat destruction and hunting.
Field Data Collected

Year	Resistant pest frequency (%)	Cassava yield loss (%)	Pesticide cost (UGX millions)
1	5	2	1
4	25	12	5
8	70	40	12

Task:
(a) Explain how natural selection led to pesticide resistance in the pest population.
(b) Analyse how reduced predator populations affect resistance spread.
(c) Suggest integrated pest management strategies.

In a Ugandan game reserve, a study of the African buffalo population over 30 years shows a dramatic decline in average horn size. Rangers note that poachers have consistently targeted the largest, biggest-horned bulls. Genetic analysis reveals that the allele for large horns (L) is incompletely dominant over the allele for small horns (S), with heterozygotes (LS) having medium-sized horns. A recent population survey was conducted.

Data:

Genotype	Phenotype	% of Population 30 years ago	% of Population now
LL	Large Horns	36%	9%
LS	Medium Horns	48%	42%
SS	Small Horns	16%	49%

Task:

(a) Analyse how poaching has acted as a selective pressure, using the data to explain the change in genotype frequencies over time. Predict the likely long-term evolutionary trajectory of horn size in this population.

(b) Propose a conservation management plan for the reserve that balances the need to deter poaching with the goal of maintaining the genetic diversity of the buffalo population.

A agricultural research station is developing a new drought-resistant rice strain. However, a puzzling observation is made: a cross between a true-breeding drought-resistant plant and a true-breeding drought-sensitive plant produces offspring (F1 generation) that are all drought-resistant but fail to flower and thus produce no seeds. Further investigation reveals that the gene for drought resistance is located on the same chromosome as a gene essential for flowering, and the two genes are very closely linked.

Data:

Parental Generation	F1 Generation Phenotype	F2 Generation (from F1 self-cross)
Drought-Resistant Flowering x Drought-Sensitive Flowering	100% Drought-Resistant, Non-Flowering	Not obtained (F1 is sterile)

Task:

(a) Explain the genetic phenomenon of autosomal linkage that is causing the non-flowering trait to be inherited along with drought resistance in the F1 generation, and why this prevents the production of an F2 generation.

(b) Propose a modern gene technology technique that could be used to separate the two linked genes and create a drought-resistant, flowering rice plant. Justify your choice.

A hospital is battling an outbreak of *Staphylococcus aureus* bacteria that is resistant to the antibiotic methicillin (MRSA). The gene for methicillin resistance (mecA) is located on a mobile genetic element. The hospital's records show a correlation between increased use of methicillin and the rise in MRSA infections from 5% to 60% over five years. Data on the bacterial population before and after a major methicillin treatment program is analyzed.

Data:

Time Period	% of S. aureus population with mecA gene	Average Patient Recovery Time (days)
Before intensive methicillin use	5%	4
After 5 years of intensive use	60%	12

Task:

(a) Apply the concept of natural selection to explain the rapid increase in the frequency of the methicillin-resistant bacteria in the hospital population.

(b) Propose an integrated hospital policy to manage the MRSA outbreak and prevent the further evolution and spread of antibiotic resistance.

A population of finches colonized two isolated volcanic islands. On Island A, the main food source is large, hard seeds. On Island B, the main food source is small, soft insects. After 10,000 years of separation, scientists find that finches from the two islands have different beak shapes and can no longer interbreed. Genetic analysis shows a difference in alleles related to beak development.

Data:

Population	Primary Food Source	Predominant Beak Shape	Genetic Compatibility with Original Population
Original Mainland	Mixed	Generalised	N/A
Island A	Large, hard seeds	Large, crushing beaks	Cannot interbreed
Island B	Small, soft insects	Thin, probing beaks	Cannot interbreed

Task:

(a) Analyse the evolutionary mechanisms (including the type of speciation and the isolating mechanisms involved) that led to the formation of two new finch species from the original mainland population.

(b) Predict what might happen to the genetic diversity of the Island B finches if a disease wiped out the insect population and justify your prediction.

A couple, both of whom have Sickle Cell Trait (heterozygous for the sickle cell allele, HbA/HbS), are seeking genetic counselling. They are concerned about the probability of their children having Sickle Cell Anaemia. The counsellor explains that the HbS allele is codominant with the normal HbA allele. The couple also lives in a region with a high prevalence of malaria.

Data:

Genotype	Phenotype	Phenotype Description
HbA HbA	Normal	No sickle cell, susceptible to malaria
HbA HbS	Sickle Cell Trait	Mild or no symptoms; resistant to malaria
HbS HbS	Sickle Cell Anaemia	Severe sickle cell disease

Task:

(a) Using a genetic cross, calculate the probability that this couple will have a child with Sickle Cell Anaemia. Then, analyse the evolutionary advantage that maintains the HbS allele in the population despite its harmful effects in the homozygous state.

(b) Advise the couple on the health implications for each possible genotype their child could

have, and discuss one modern biotechnological application that could be relevant to their situation.

A smallholder farmer in Mbale observed unusual seed variations in his hybrid bean plants (Phaseolus vulgaris). He initially crossed pure yellow–round seeds (YYRR) with pure green–wrinkled seeds (yyrr). In the F_2 generation, the farmer noted unexpected ratios that deviated slightly from the classical 9:3:3:1.
To understand the inheritance pattern, a biology class replicated his experiment and obtained the following F_2 results from 160 seeds:

Phenotype	Number of Seeds
Yellow-round	88
Yellow-wrinkled	32
Green-round	30
Green-wrinkled	10

Task:
(a) Analyse the results and determine whether the genes for seed colour and shape are linked. Calculate the recombination frequency.
(b) Explain the significance of crossing over in producing the observed phenotypes.
(c) Propose sustainable strategies the farmer could apply to improve seed genetic diversity and maintain desirable traits.

Students in a genetics club at a local school conducted a cross between *Drosophila melanogaster* with red eyes and normal wings (RRNN) and white eyes with vestigial wings (rrnn).
In the F_2 generation, they obtained:

Phenotype	Observed Number
Red eyes, normal wings	410
Red eyes, vestigial wings	90
White eyes, normal wings	100
White eyes, vestigial wings	400

Tasks:
(a) Determine whether the genes are linked or independently assorted and calculate the crossing-over value.
(b) Explain how chromosome behaviour during meiosis accounts for the results obtained.
(c) Suggest practical applications of understanding genetic linkage in animal breeding or disease control.

In a maize research station in Lira, scientists are studying linkage between kernel colour and sugar content.

A dihybrid cross between plants heterozygous for both traits (CcSs) produced the following offspring:

Phenotype	Observed (%)
Coloured-sweet	42
Coloured-starchy	8
Colourless-sweet	10
Colourless-starchy	40

Tasks

(a) Calculate the recombination frequency and determine the linkage distance between the two genes.

(b) Explain how environmental factors could influence phenotypic ratios in such crosses.

(c) Based on the information provided in the context, propose strategies maize breeders can use to enhance desired kernel quality and maintain yield.

GROWTH AND DEVELOPMENT

Farmers in the Mubende district have reported a 50% failure in the germination of their mango seeds over the last two planting seasons. The seeds that do germinate produce stunted seedlings with weak stems. A local agricultural officer, Mr. Ssemakula, notes that farmers have been storing their seeds in a communal, damp warehouse and planting them directly into fields with compacted soil that was recently cleared of a eucalyptus forest. He suspects that the pre- and post-germination conditions are to blame. Laboratory tests on the seeds and soil reveal the following:

Data:

Parameter	Farmer's Seeds	Ideal Condition for Mango Seeds
Seed Moisture Content	18%	10-12%
Soil Compaction (psi)	350	< 200
Soil pH	4.5	6.0 - 7.5
Presence of Abscisic Acid (ABA) in seed	High	Low (dormant seeds)
Secondary Growth onset in seedlings	Delayed (8 weeks)	Normal (4 weeks)

Task:

(a) Analyse how the pre-germination storage conditions and post-germination soil properties are affecting the growth and development of the mango plants, with reference to primary and secondary growth.

(b) Propose and justify a sustainable plan for the farmers to improve seed viability and seedling establishment, ensuring future orchard productivity.

A Kampala urban farming initiative promotes using household food waste to create compost. However, residents complain that the compost decomposes very slowly and is often full of large, white larvae. The initiative's coordinator discovers that the compost piles are kept in sealed, dark plastic bins with little moisture. An entomologist identifies the larvae as the grubs of the African Black Soldier Fly, which are typically efficient decomposers. Data from an experiment comparing different compost conditions is below:

Data:

Compost Condition	Decomposition Time (weeks)	Larval Mass (g)	Adult Fly Emergence	Final Compost Quality
Sealed, Dry Bin	12	5	Low	Poor, lumpy
Aerated, Moist Pile	4	25	High	Excellent, crumbly
Aerated, Dry Pile	8	12	Medium	Fair, coarse

Task:

(a) Analyse the role of the insect growth stages in this ecosystem and explain how the compost conditions are affecting their contribution to waste management.

(b) Propose and justify a modified compost management plan that enhances decomposition, manages the insect population beneficially, and improves the initiative's sustainability.

A community near Lake Mburo relies on a papyrus wetland to filter water and provide habitat for insects that pollinate their crops. Recently, crop yields have dropped, and a biodiversity survey shows a decline in aquatic insect populations. A researcher, Dr. Nalwanga, investigates and finds that a nearby flower farm is using a new systemic pesticide. She samples water and insect larvae from three sites.

Data:

Site	Pesticide Concentration (ppb)	% Gill Deformity in Mayfly Larvae	Chironomid (Bloodworm) Larvae Count	Adult Dragonfly Count
Upstream (Control)	0	2%	150	25
Near Flower Farm Outflow	50	65%	400	5
Downstream (Community Wetland)	10	25%	300	12

Note: Chironomid larvae are pollution-tolerant, while mayfly and dragonfly larvae are pollution-sensitive.

Task:

(a) Analyse the data to explain how the pesticide pollution is disrupting the insect life cycles and their role in this ecosystem, including water quality assessment and pollination.

(b) Using the concept of insect growth stages as bio-indicators, propose a sustainable conservation plan to restore the wetland's health and secure community food production.

A research station in Fort Portal is experimenting with growing tomatoes in a high-tech greenhouse to ensure year-round production. However, the plants grow tall and spindly with few flowers and fruits, despite adequate water and nutrients. The technicians note that the greenhouse glass filters out specific light wavelengths and that the plants are grown at a very high density. Measurements of plant growth and hormone levels are taken.

Data:

Parameter	Greenhouse Tomatoes	Healthy Field Tomatoes
Internode Length	Long	Short
Stem Diameter (Secondary Growth)	Low	High
Auxin Concentration	High	Moderate

Light Quality: Greenhouse glass filters out Far-Red light, altering the Red: Far-Red ratio.

Seed Dormancy: Seeds used had a 95% germination rate, showing no dormancy issues.

Task:

(a) Analyse the factors of light quality and planting density that are affecting the primary and secondary growth of the tomatoes and explain how this impacts their development and fruit production.

(b) Propose and justify changes to the greenhouse management strategy to promote optimal plant growth structure and improve agricultural productivity.

A beekeeper in Bushenyi is concerned about his honeybee colonies. He observes that his hives are not producing enough honey, and the bees seem disoriented. He also notices a strange lack of wax moths and small hive beetles in his infested hives, which would normally be controlled by healthy bees. An agroecologist suggests the problem might be linked to the nearby maize fields, where farmers have recently switched to a new neonicotinoid-coated seed. Samples of pollen, bees, and hive pests are collected.

Data:

Sample	Neonicotinoid Residue	Bee Larval Survival Rate	Hive Pest (Wax Moth) Count	Honey Production (kg/hive)
Hive near old orchard (Control)	Negligible	90%	10	25
Hive near new maize fields	High	45%	45	8
Collected Pollen (from maize fields)	High	N/A	N/A	N/A

Task:

(a) Analyse how the pesticide is affecting the growth, development, and behaviour of the honeybees and explain the subsequent impact on the hive ecosystem and pest population.

(b) Propose an integrated sustainable plan for the beekeeper and the farmers to ensure pollinator health, effective waste management in the hive (pest control), and long-term food security (honey production and crop pollination).

ECOLOGY

A cooperative of smallholder farmers on the slopes of Mount Elgon has reported a 50% failure rate in their new coffee seedlings. The seedlings wilt and die within weeks of transplanting, despite adequate rainfall. A soil analysis ruled out common nutrient deficiencies. An agronomist from the National Agricultural Research Organisation (NARO) suspects the problem is linked to root development and water transport. She investigates a healthy seedling from a nursery and a wilting seedling from the field.

Table: Comparative Analysis of Coffee Seedling Tissues

Parameter	Healthy Seedling	Wilting Seedling
Root Hair Density (hairs/mm)	45	12
Lignin Deposition in Xylem Vessels (Relative %)	100%	40%
Stomatal Density (pores/mm²)	250	310
Abscisic Acid (ABA) concentration (ng/g)	5	25
Rate of Water Uptake (ml/hr)	10	3

Task:
(a) Analyse the data to explain how the structural and hormonal differences between the healthy and wilting seedlings lead to the failure in water transport and subsequent wilting.
(b) Using the principles of plant growth and osmoregulation, propose a three-stage plan for the farmers to improve seedling survival rates before and after transplanting.

A community project in Nakasongola District aimed at achieving food security through tomato farming is failing. The tomato plants grow tall and leafy but produce very few flowers and almost no fruit. The farmers have been using a fertilizer rich in nitrogen and phosphorus. A field visit also revealed an absence of bees and other pollinators. A biology student suggests the issue might be related to plant coordination and nutrient allocation.

Table: Hormonal and Resource Allocation in Tomato Plants

Tissue Sample	Auxin Level (relative)	Gibberellin Level (relative)	Cytokinin Level (relative)	Sugar Concentration in Fruits (mg/g)
Vegetative Shoot Tip	90	85	40	N/A
Floral Bud	10	15	60	N/A
Developing Fruit	25	30	75	50 (in the few fruits that formed)

Task:
(a) Explain how the observed hormonal imbalance (high auxin/gibberellin in shoots, low in

flowers) leads to excessive vegetative growth at the expense of flower and fruit development (a phenomenon known as apical dominance).
(b) Propose biological strategies to promote flowering and fruiting, and one ecological strategy to address the pollination issue, ensuring a sustainable tomato yield for the community.

In a village outside Jinja, people and cattle share a pond for water. Recently, several children developed severe neurological symptoms, and some cattle died. The symptoms include uncontrolled muscle spasms and impaired neural function. Investigators found a nearby small-scale gold mining operation that uses mercury. Mercury is known to bind to sulphydryl groups in proteins, inhibiting their function.

Table: Physiological Data from Affected Individuals

Sample	Synaptic Vesicle Count (vesicles/end-plate)	Acetylcholine Release per Stimulus (molecules)	Muscle ATP Level (% of normal)	Blood Mercury Level (ppb)
Healthy Child	$2.0x10^7$	$1.0x10^8$	100%	<5
Symptomatic Child	$2.1x10^7$	$2.0x10^6$	45%	55

Task:
(a) Analyse how mercury contamination affects impulse transmission at the synapse and disrupts cellular energy production, leading to the observed neurological symptoms and muscle failure.
(b) Propose strategies to prevent further contamination and provide clean water, ensuring the community's health and food security (from livestock).

The home range of a famous mountain gorilla family in Bwindi Impenetrable National Park has shrunk by 30% over the past decade due to agricultural encroachment. Park rangers have recorded concerning data on the group's health and behaviour. The gorillas are now more frequently in contact with another group, leading to conflicts. They also travel longer distances for less food.

Table: Gorilla Population and Health Metrics

Metric	10 Years Ago	Present Day
Group Size	15	18
Average Body Mass Index (BMI) of Adults	28	24
Frequency of Inter-group Conflicts (per year)	2	10
Number of Plant Species in Diet	65	48
Observed Genetic Diversity Index (from fecal samples)	0.81	0.73

Task:

(a) Analyse how the reduction in habitat size and food availability is influencing the gorillas' population dynamics, social behaviour, and long-term genetic health.

(b) Propose a sustainable conservation plan with key strategies that address the ecological and genetic challenges faced by this gorilla family, while also considering the needs of the local human population.

A new community farm was established on the slopes of Mount Rwenzori (3000m above sea level) to grow potatoes. However, the yield is very low, and the tubers are small. The plants appear stunted. A researcher suspects that the low atmospheric pressure and temperature at high altitude are affecting the plants' internal physiology. She compares the Rwenzori potatoes with the same variety grown at a lower altitude (1200m).

Table: Physiological Comparison of Potato Plants

Parameter	Low-Altitude Plant	High-Altitude (Rwenzori) Plant
Chlorophyll Concentration (mg/g)	2.5	3.1
Stomatal Conductance (mmol/m²/s)	250	180
Mitochondrial Density in Root Cells (per cell)	150	220
Sucrose concentration in Phloem (mg/ml)	25	15
Average Tuber Mass (g)	120	60

Task:

(a) Explain how high-altitude conditions could lead to the observed physiological changes and ultimately result in reduced tuber growth.

(b) The community cannot relocate the farm. Propose practical strategies, involving agricultural practice and involving a technological solution, to mitigate the effects of high altitude and improve tuber yield.

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