CELL BIOLOGY

1. Researchers in Mbale District compared lung tissue samples from long-term smokers and non-smokers to understand why smokers often experience shortness of breath, fatigue, and persistent coughing. Some samples were obtained from individuals who had been working in poorly ventilated areas and had diets low in antioxidants.

Observation	Non-smoker	Smoker
Elastic fiber content (%)	95	40
Collagenase enzyme activity (%)	100	180
Alveolar wall thickness (µm)	2	5
Number of alveoli per mm²	120	70
Vital capacity (L)	4.8	2.9

Reference: *Respiratory Tissue Research Journal, 2023 "Connective Tissue Remodeling in Chronic Smokers"*

Task:

(a) Explain how enzyme activity and connective tissue changes contribute to reduced lung efficiency.

(b) Suggest physiologically supported strategies to prevent or reverse such damage.

2. Medical students at Mulago Hospital examined epithelial samples from residents living near Kampala's Northern Bypass, where traffic pollution is heavy. Residents reported frequent coughing and throat irritation. The polluted zone had visibly darker dust deposits and frequent temperature inversions at night, reducing air movement.

Parameter	Control (Suburban Area)	Polluted Zone
Ciliated epithelial cell density (cells/mm²)	320	110
Mucus viscosity (Pa·s)	0.8	2.3
Lysozyme enzyme activity (%)	100	40
Alveolar macrophage count	1200	600
Bacterial colonies per sample	5	25

Reference: *Urban Health and Air Quality Studies (2024) "Cilia Damage and Lysozyme Inhibition by Pollutants"*

Task:

(a) Explain how structural and enzymatic changes in the respiratory epithelium impair its function.

(b) Propose and justify community and biological strategies to reduce damage and restore respiratory health.

3. Two muscle samples were examined following exercise-related injuries. One belonged to a patient consuming high protein and vitamin-rich meals, while the other came from a patient with low dietary protein intake and chronic inflammation.

Sample	Myofibril alignment	Nuclei/fiber	Collagen deposition	CK Enzyme Activity (U/L)
Normal	Regular	5	Low	120
Injured	Disorganized	10	High	400

Reference: *Human Physiology Review (2022), "Regenerative Mechanisms in Skeletal Muscle Injury"*

Task:

(a) Analyse how these changes show structure function relationships and muscle repair mechanisms.

(b) Suggest strategies to promote healthy muscle regeneration and prevent fibrosis using the clues provided.

4. A clinic investigated how smoking and chemical exposure affect respiratory health. Samples from a smoker and a healthy non-smoker were analysed. The smoker also reported frequent dehydration and poor dietary habits.

Tissue Type	Cilia Density (per mm²)	Goblet Cells (per mm²)	Mucus Thickness (µm)	Oxygen Uptake Rate (mL/min)
Healthy	280	80	5	200
Smoker	100	200	15	90

Reference: *African Journal of Pulmonary Research (2023), "Histological Impacts of Smoking on Lung Tissues"*

Task:

(a) Explain how structural changes in epithelial tissue impair its function.

(b) Suggest five public-health or lifestyle strategies to reduce tissue damage and promote recovery.

5. A medical investigation explored why diabetic patients experience delayed wound healing after skin burns. Samples were collected from two patients one with controlled glucose levels and another with poorly managed diabetes. The diabetic patient also had reduced physical activity and poor hydration habits.

Observation	Normal Skin	Diabetic Burn Skin
Epidermal cell division rate (cells/day)	240	80
Collagenase activity (%)	100	40
Fibroblast density (per mm²)	1200	700
Capillary density	Normal	Sparse
Blood glucose (mmol/L)	4.8	10.5

Reference: *Medical Biochemistry Today (2024) "Enzyme Dysfunction and Delayed Healing in Diabetes"*

Task:

(a) Analyse how enzyme activity and tissue organisation influence wound repair.

(b) Suggest measures to improve recovery in diabetic patients.

6. A team of students at Gulu University investigated why some individuals experience bloating and fatigue after heavy meals. They compared intestinal enzyme activity and tissue features in two groups: one consuming a balanced diet rich in fruits and fiber, and another eating mostly fatty, processed foods.

Parameter	Balanced Diet Group	High-Fat Diet Group
Lipase activity (%)	100	50
Villi height (µm)	500	250
Goblet cell count (per mm²)	60	120
Absorption rate (mg/min)	150	70
Intestinal mucus thickness (µm)	5	15

Reference: *Nutrition and Cell Function Research (2023), "Dietary Fat and Enzyme Activity in Human Intestines"*

Task:

(a) Explain how differences in enzyme activity and tissue structure affect digestion and absorption.

(b) Suggest dietary and physiological strategies to maintain healthy intestinal function.

7. In a rural health study, medical interns investigated why some farmers exposed to pesticide residues developed fatigue and yellowish eyes. Liver tissue samples were analysed for enzyme activity and structure. Many farmers lacked protective gear and drank untreated water from nearby irrigation canals.

Parameter	Control (Unexposed)	Exposed Farmers
Catalase activity (%)	100	45
ALT enzyme level (U/L)	30	95
Liver cell density (cells/mm²)	500	280
Mitochondrial density	Normal	Reduced
Blood bilirubin (mg/dL)	0.8	2.5

Reference: *Environmental Health and Biochemistry Journal (2024) "Pesticide-Induced Enzyme Inhibition in Human Liver Tissues"*

Task:

(a) Explain how pesticide exposure affects enzyme function and tissue structure in the liver.

(b) Propose biologically sound strategies to prevent or reverse such damage in farming communities.

TRANSPORT

8. Three Ugandan athletes trained under different environmental conditions and participated in a national cross-country competition. Doctors assessed their blood and immune indicators before and after the race. One athlete trained at high altitude, another at sea level, and a third in a humid, polluted city.

Parameter	High Altitude (Kapchorwa, 2200 m)	Sea Level (Entebbe, 1135 m)	Polluted Lowland (Jinja)
Haemoglobin (g/dL)	17.8	15.0	14.2
Blood oxygen saturation (%)	93	98	90
White blood cell count (cells/µL)	7,000	6,200	5,000
Pulse rate after race (beats/min)	120	145	160
Recovery time (min)	3	7	10

Reference: *African Journal of Exercise Immunology (2024). "Altitude Adaptations and Immune Resilience in Athletes."*

Task:

(a) Explain how differences in oxygen transport and immune cell activity influence performance and recovery.

(b) Suggest physiological and immunological strategies to strengthen endurance, immunity, and recovery in different training environments.

9. Residents living near charcoal-burning sites in Fort Portal often complain of fatigue and recurrent chest infections. Health workers investigated possible links between carbon monoxide (CO) exposure, blood oxygen transport, and immune performance.

Parameter	Control Group	Exposed Residents
Oxyhaemoglobin (%)	96	78
Carboxyhaemoglobin (%)	0.5	15
White blood cell count (cells/µL)	6,800	4,500
Respiration rate (breaths/min)	16	24
CO concentration (ppm)	0	120

Reference: *Environmental and Human Health Research (2023). "Carbon Monoxide Interference in Oxygen Transport and Immune Suppression."*

Task:

(a) Analyse how carbon monoxide affects oxygen transport and weakens immune protection.

(b) Suggest biological and public-health strategies to prevent and manage such exposure while maintaining respiratory and immune health.

10. At Mbarara Regional Hospital, a 25-year-old Rhesus-negative woman (Gravida 2) presented with jaundice and fatigue. She received no Rh prophylaxis after her first delivery. Ultrasound shows her baby has liver enlargement and anaemia.

Parameter	Mother (Rh–)	Baby (Rh+)	Normal Range
Haemoglobin (g/dL)	8.5	10.0	12–16 / 14–24
Anti-D antibody titre	High (1:128)	Detected	Negative
Bilirubin (mg/dL)	1.5	18.0	<1.2 / <10
Reticulocyte count (%)	3	15	0.5–2.0 / 3–7

Reference: *Journal of Reproductive Immunology (2022). "Maternal Antibodies and Fetal Oxygen Transport in Rhesus Disease."*
Task:
(a) Explain how the immune response from the first pregnancy led to anti-D antibody formation and how this now interferes with fetal oxygen transport.
(b) Suggest integrated strategies to prevent Rh-related immune attacks, including screening, immunoglobulin therapy, education, and record-keeping.

11. During a biology field trip to UWEC, a student with a known peanut allergy developed an anaphylactic reaction after sharing snacks. Her breathing became laboured and her blood pressure dropped.

Parameter	Joy (During Reaction)	Normal Value
Blood histamine (ng/mL)	80	< 25
Heart rate (beats/min)	110	60–100
Breathing rate (breaths/min)	30	12–20
Blood pressure (mmHg)	85/50	110/70
Plasma antibody (IgE IU/mL)	220	< 100

Reference: *Clinical Immunology and School Health Journal (2023). "Circulatory and Immune Reactions in Anaphylaxis."*
Task:
(a) Analyse how the interaction of IgE, histamine, and circulatory changes results in Joy's symptoms.
(b) Propose coordinated immunological and circulatory strategies for school-based allergy management.

12. Following a measles outbreak in Lira District, health teams compared blood samples of vaccinated and unvaccinated children. Some unvaccinated children were treated with herbal "immune boosters."

Parameter	Vaccinated	Unvaccinated
Measles IgG antibody (IU/mL)	180	10
Lymphocyte count (cells/µL)	5000	3400
Haemoglobin (g/dL)	13.8	12.5
Infection rate (%)	2	45
Vaccination coverage (%)	85	50

Reference: *World Health Organization (2023). "Vaccination, Herd Immunity, and Blood Health."*

Task:

(a) Explain how vaccination strengthens both immunity and the overall health of the circulatory system.

(b) Propose strategies to enhance effective vaccination, reduce infection rates, and sustain immune protection in the community.

13. Medical students investigated the cardiovascular and immune responses of three subjects during treadmill exercise.

Parameter	Athlete	Sedentary Adult	Anaemic Individual
Resting heart rate (beats/min)	58	75	88
Stroke volume (mL)	120	70	60
Haemoglobin (g/dL)	17	15	10
White blood cell count (cells/µL)	7,000	5,000	4,200
Recovery time (min)	2	8	12

Reference: *Journal of Sports Medicine and Immunology (2024). "Exercise-Induced Changes in Blood and Immune Function."*

Task:

(a) Describe how circulation and immune response interact during and after exercise.

(b) Suggest strategies to improve cardiovascular performance and strengthen immune recovery.

14. At Kawempe Hospital, patients with dust allergies were treated using antihistamines and immunotherapy. Doctors monitored changes in immune markers and blood flow parameters.

Parameter	Before Treatment	After Antihistamine	After Immunotherapy
Serum IgE (IU/mL)	320	280	120
Eosinophil count (cells/µL)	600	550	250
Capillary dilation (relative)	High	Moderate	Normal
Sneezing episodes/day	18	10	2

Reference: *Immunopathology and Human Physiology Reports (2023). "Circulatory–Immune Interactions in Respiratory Allergies."*

Task:

(a) Explain how changes in blood vessel dilation and antibody activity relate to the symptoms of allergic rhinitis.

(b) Propose comprehensive strategies combining circulatory, immune, and environmental management to reduce allergic reactions.

NUTRITION

15. The "Kampala City Greens" initiative installed vertical hydroponic farms in several urban schools to improve student nutrition. Students in a biology club decided to investigate the effect of enriching the air with carbon dioxide on their lettuce crop. They set up four growth chambers with different Carbon dioxide levels. After 4 weeks, they harvested the lettuce and measured key components. The club president noted that while yields increased initially, the growth seemed to "level off" at the highest CO_2 level, even though the plants looked healthy and the lights were left on for 12 hours each day. The school's physics teacher also mentioned that the fans used for air circulation in the 1000 ppm chamber were not very powerful.

Table: The Effect of CO_2 Enrichment on Lettuce in a Hydroponic System

CO_2 Concentration (ppm)	Biomass Yield (g/plant)	Glucose Content (mg/g)	Stomatal Density (stomata/mm²)	Observation Notes
400 (Ambient)	28	32	220	Normal, leafy appearance
600	37	39	200	Lush, dark green leaves
800	42	41	185	Very robust growth
1000	41	39	180	Large leaves, but slight yellowing at tips

Task:

(a) Analyse the data to explain the trend in biomass and glucose content. Using the concept of limiting factors, explain why increasing carbon dioxide beyond 800 ppm did not lead to a further increase in yield.

(b) The initiative wants to scale up this project efficiently. Propose four scientifically-sound strategies to maintain an optimal growth environment and prevent the yield plateau, using clues from the scenario and data.

16. A women's cooperative in Mbarara received funding to build greenhouses for year-round crop production. They constructed two different types: a high-tech Greenhouse A with transparent, sealed polycarbonate panels, and a low-tech Greenhouse B with a semi-shaded, breathable mesh roof. They planted maize (a C4 plant) in both, and beans (a C3 plant) in both. After two months, they noticed distinct differences in plant health and water usage. The cooperative also found their water bills for Greenhouse A were significantly higher, as they had to run a misting system frequently to cool the plants.

Table: Growth Parameters in Two Different Greenhouse Types

Parameter	Greenhouse A (Transparent, Sealed)	Greenhouse B (Semi-Shaded, Ventilated)
Average Noon Temperature (°C)	38	29
Peak Light Intensity (lux)	110,000	50,000
Photosynthetic Rate - Maize (μmol CO_2/m²/s)	48	35
Photosynthetic Rate - Beans (μmol CO_2/m²/s)	22	30
Leaf Chlorophyll Concentration - Beans (mg/g)	3.5	5.8
Water Used per Week (Litres/m²)	85	45

Task:

(a) i. Explain why maize showed a higher photosynthetic rate in the hotter, brighter Greenhouse A, while beans performed better in the cooler, shadier Greenhouse B. Link your answer to the photorespiratory adaptations of C3 and C4 plants.

ii. Explain the inverse relationship between light intensity and chlorophyll concentration observed in the bean plants.

(b) The cooperative wants to design a new, improved greenhouse that maximizes yield for both crop types while conserving resources. Propose management strategies, justifying each with evidence from the data and biological principles.

17. In the Nakasongola district, known for its frequent dry spells, a community-based organization is teaching farmers about crop water management. They set up a demonstration plot comparing maize (a C4 plant) and common beans (a C3 plant). During a particularly dry week, they observed that the bean plants wilted severely by midday, their leaves curling and turning a pale green, while the maize plants remained relatively upright and green. To demonstrate what was happening at the cellular level, they used a microscope to show how plant cells lose water under osmotic stress.

Table: Plant Response to Simulated Drought Conditions (One Week Without Irrigation)

Parameter	Maize (C4 Plant)	Beans (C3 Plant)
Stomatal Conductance (mmol $H_2O/m^2/s$)	125	45
Leaf Relative Water Content (%)	78%	52%
Midday Leaf Wilting Score (1=No wilt, 5=Severe wilt)	2	4
Photosynthetic Rate (µmol $CO_2/m^2/s$)	28	11
Observation Notes	Leaves slightly curled, colour dark green	Leaves severely curled, pale green/yellowing

Reference: Chaves, M. M., et al. (2016). *Understanding plant responses to drought from genes to the whole plant*. Functional Plant Biology, 30(3), 239-264.

Task:

(a) i. Explain the relationship between stomatal conductance, leaf water content, and photosynthetic rate as seen in the data.

ii. Using the concept of osmotic potential, explain why the bean plants lost turgor pressure (wilted) more dramatically than the maize plants.

(b) The farmers need strategies to protect their crops, especially beans, during the dry season. Propose practical, water-efficient strategies they could adopt, justifying each strategy with evidence from the data and the underlying plant biology.

18. In an agricultural biotechnology project, students tested how temperature affects enzyme activity in the photosynthetic process. They compared PEP carboxylase (C4 enzyme) and Rubisco (C3 enzyme) at different temperatures.

Temperature (°C)	PEP Carboxylase activity (relative units)	Rubisco activity (relative units)
20	75	85
25	90	100
30	98	90
35	100	60
40	90	30

At 35°C, maize plants maintained high photosynthetic rates, while wheat plants showed reduced growth and curled leaves.

Task:

(a) Analyse the data to explain why C4 plants outperform C3 plants at high temperatures.

(b) Using the clues, propose strategies farmers could apply to sustain food security amid rising global temperatures.

19. 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.

RESPIRATION

20. In Kiruhura District, Friesian cows are producing 30% less milk during the dry season. The animals graze in open fields with no shade and limited water access. Farmers report fast shallow breathing, dry tongues, and frequent lying down during midday. Blood tests show reduced hemoglobin and mitochondrial enzyme activity. In contrast, cows grazing near a shaded valley with water troughs maintain normal productivity.

Parameter	Affected Herd (Open Field)	Healthy Herd (Shaded Valley)
Body temperature (°C)	40.2	38.3
Breathing rate (breaths/min)	90	50
Blood hemoglobin (g/dL)	7.8	11.5
ATP synthase activity (% of normal)	60	100
Milk yield (L/day)	9	15

Task

(a) Analyse how the data show effects of heat on oxygen uptake, mitochondrial activity, and milk production.

(b) Propose strategies to restore herd productivity.

21. In Mukono, a farmer fed cassava leaves that had wilted for several hours to his rabbits. Within minutes, several rabbits collapsed. The veterinarian recorded bright red venous blood and no visible lung obstruction. Laboratory tests indicated NADH accumulation and decreased ATP production. Brain and heart tissues were most damaged, while rabbits given water mixed with sodium thiosulfate survived.

Observation	Control Rabbits	Poisoned Rabbits
Breathing rate (breaths/min)	45	110
Venous blood colour	Dark red	Bright red
Mitochondrial ATP (µmol/mg protein)	5.5	0.2
NADH concentration (µmol/g tissue)	0.3	2.1
Tissue damage severity	None	High in brain and heart
Survival rate (%)	100	40

Task

(a) Explain how cyanide interferes with respiration and why heart and brain tissues show severe damage.

(b) Propose prevention strategies to solve the challenges.

22. At a national competition, three horses trained in different environments Thunder (lake region), Dust (polluted highway), and Flame (indoor stable). During a 1000 m sprint under 30 °C, they showed distinct performance outcomes.

Horse	Training Site	Resting Pulse (beats/min)	Pulse After Race	Blood O_2 (%)	Muscle ATP (% normal)	Recovery Time (min)
Thunder	Lakeside (fresh air)	38	110	96	100	3
Dust	Highway (polluted air)	42	160	82	60	11
Flame	Indoor stable	40	130	89	78	6

Task

(a) Analyse the data to explain how oxygen uptake and ATP production affect recovery time in the horses.

(b) Suggest strategies to improve Dust's respiratory efficiency and performance.

23. Three students Amos (footballer), Joan (inactive), and Peter (swimmer), performed a 10-minute cycling test. Joan was seen breathing mainly through her mouth, ate sugary snacks before the test, and drank little water.

Student	Activity Level	Resting Heart Rate (beats/min)	Pulse After Test	Blood O_2 (%)	Recovery Time (min)
Amos	Regular football	68	120	96	2
Joan	Rarely exercises	75	160	83	9
Peter	Swimmer	65	125	94	3

Task

(a) Explain how the physiological differences influenced oxygen use and energy output.

(b) Propose lifestyle strategies to improve Joan's respiratory efficiency and recovery.

24. A Senior Five interschool marathon was held on a hot afternoon. Three students, Aisha, Paul, and Ivan, were tested before and after the race.

Parameter	Aisha (trained)	Paul (untrained)	Ivan (anaemic)
Resting pulse (bpm)	60	72	85
ATP level in muscle (µmol/g) after race	4.5	2.2	1.5
Lactic acid (mmol/L)	2.0	6.3	5.5
Recovery time (min)	2	10	12

Task:

(a) Analyse how differences in oxygen supply, training, and haemoglobin content affected ATP production and recovery in the three athletes.

(b) Suggest strategies for improving endurance and recovery among students, using evidence from the data.

HOMEOSTASIS

25. A student participating in a long-distance race on a hot, humid day suddenly collapses. She is disoriented, her skin is hot and dry, and her body temperature is measured at 41°C. Her teammate, who finished the race, is also hot but is profusely sweating and has a body temperature of 38.5°C. The collapsed student had been taking an over-the-counter antihistamine for allergies in the days leading up to the race. A first-aid responder notes that her water bottle is still full; she had avoided drinking to prevent getting a "stitch."

Physiological Data at Time of Collapse:

Parameter	Collapsed Student	Sweating Student
Core Temperature (°C)	41.0	38.5
Skin Condition	Hot, Dry	Cool, Clammy
Heart Rate (bpm)	130	105
State of Consciousness	Disoriented	Alert

Task:

(a) (i) Explain the homeostatic mechanisms the body uses to regulate temperature during exercise and why the collapsed student's system failed.

(ii) Analyse the role of the hypothalamus, skin, and behavioural responses in this scenario.

(b) Propose a set of safety guidelines for athletes training in hot conditions to prevent such incidents, justifying each guideline based on the principles of thermoregulation.

26. During a geography field trip in Karamoja, students camped in semi-desert grasslands. Temperatures reached 39°C at noon and dropped to 15°C at night. One group forgot their shade tent and drinking water. By the second day, two students showed:

- Increased breathing and dry lips
- Dizziness and low urine output
- Hot skin but reduced sweating

Another student, who had been taking energy drinks with caffeine, remained alert but later developed muscle cramps.

The school nurse measured the following:

Student	Body Temp (°C)	Urine Volume (mL/hr)	Pulse (beats/min)	Plasma ADH Level (pg/mL)
A (no shade, no water)	39.8	8	120	20
B (same as A)	39.2	10	118	22
C (with caffeine)	37.5	40	85	6
D (in shade, hydrated)	36.8	60	75	5

Task:

(a) Analyse how the physiological responses observed in the students demonstrate temperature regulation and water balance mechanisms in humans.

(b) Suggest scientifically sound strategies to prevent dehydration and overheating during future field trips, using evidence from the scenario.

27. 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.

28. A research team studied the behavioural and physiological adaptations of the Camel (a desert endotherm) to maintain thermal and water balance (homeostasis) in an arid environment with ambient temperatures reaching 45◦C. The camel can tolerate a core body temperature fluctuation of up to 6◦C to conserve water. During the day, the camel *relies on preferential heat* loss from its ears and seeking shade under acacias to maintain a stable internal temperature. When water is scarce, the camel produces highly concentrated urine and reduces its sweating rate. The animal's ability to allow its body temperature to rise during the hottest part of the day acts as a physiological adaptation.

Table: Physiological Responses of a Camel over a 24-Hour Cycle

Time of Day	Core Body Temperature (◦C)	Sweat Rate (mL/m2/hr)	Urine Concentration (Osmolality, mOsm/kg)
06:00 (Coolest)	36.0	5	1500
15:00 (Hottest)	41.5	12	1500
20:00 (Cooling)	38.0	8	1500

Task:

(a) Explain how the camel's ability to tolerate a rising core body temperature during the day acts as an adaptive mechanism for maintaining water balance in the desert.

(b)Analyse the scenario and data to suggest strategies that collectively enable the camel to survive in its extreme environment, integrating both its physiological and behavioural adaptations.

29. The Water Lily (*Nymphaea alba*) is an obligate hydrophyte (aquatic plant). It has adapted to its water-logged environment where the roots are often in an anoxic (oxygen-depleted) substrate. A student studied the stem and root cross-sections of the water lily, comparing them to a typical mesophyte (bean plant). The main challenge for the water lily is not water stress, but rather oxygen deficiency in the roots and the need to transport oxygen to its submerged parts. The water lily has *a large proportion of a specialized tissue called aerenchyma* in its petioles and roots, forming continuous air channels. The student also noted that the *stomata are only present on the upper surface* of the floating leaves. The *leaf cuticle is thin*, and the *root is poorly developed* compared to the mesophyte.

Table: Structural Characteristics of Water Lily (Hydrophyte) and Bean Plant (Mesophyte)

Structural Characteristic	Water Lily (Hydrophyte)	Bean Plant (Mesophyte)
Percentage of Aerenchyma in Root/Petiole	60%	<5%
Stomata Location	Upper Leaf Surface Only	Both Surfaces
Root Mass (% of Total Biomass)	10%	35%
Cuticle Thickness	Thin	Thick

Task:

(a) Analyse the structural data and scenario to explain how the presence of aerenchyma and the stomata location are key osmoregulatory and structural adaptations that facilitate the survival of the hydrophyte in its habitat.

(b) The bean plant (mesophyte) would die in the water-logged environment. Using the data and your knowledge of plant physiology, propose strategies used by the water lily to manage its internal environment in the face of anoxic conditions.

COORDINATION

30. The Ugandan Ministry of Health is launching a public awareness campaign on substance abuse. To demonstrate the effects on the nervous system, a physiology lab used a frog nerve-muscle preparation to simulate synaptic transmission. They tested substances commonly misused in local communities. During the demonstration, they noted that the effect of the anaesthetic was reversible after washing the preparation with a saline solution, but the alcohol's effect persisted longer. They also observed that the caffeine-treated muscle twitched spontaneously even without stimulation after a while.

Table: Effects of Different Substances on Synaptic Transmission in a Frog Nerve-Muscle Preparation

Treatment	Neurotransmitter Released (%)	Postsynaptic Potential Amplitude (mV)	Muscle Contraction Strength
Control (Normal saline)	100	50	Strong and coordinated
Local Anaesthetic (Lidocaine)	25	12	Very weak, delayed
Caffeine	130	65	Strong, but with subsequent spasms
Alcohol (Ethanol)	45	20	Weak and uncoordinated

Reference: Kandel, E. R., Schwartz, J. H., & Jessell, T. M. (2021). *Principles of Neural Science* (6th ed.). McGraw-Hill Education.

Task:

(a) i. Explain how the local anaesthetic and alcohol disrupt the process of impulse transmission at the synapse.

ii. Explain how caffeine enhances synaptic transmission and why it led to muscle spasms.
(b) The awareness campaign needs practical strategies. Propose targeted public health strategies to mitigate the negative effects of such substances on human nervous coordination and behaviour. Justify each strategy using the biological evidence from the data and scenario.

31. "Bloom Uganda," a horticultural company in Mukono, specializes in growing roses (a long-day plant), chrysanthemums (a short-day plant), and tomatoes (day-neutral but sensitive to ethylene) for export. The new farm manager is reviewing data from last season. She notes that while auxin application promoted stem elongation in roses, it also inhibited lateral bud growth, increasing the need for pruning. The use of ethylene gas in the tomato greenhouse successfully ripened fruits uniformly for a large order, but it also caused premature yellowing and abscission of older leaves. Workers have suggested installing energy-efficient LED lights that can be programmed to emit specific red and far-red wavelengths.

Table 2: Growth Parameters and Hormonal Application in Controlled Environments

Crop	Photoperiod (Hours Light)	Hormone Application	Resulting Effect	Commercial Issue
Rose	14	Auxin Spray	Taller stems, delayed lateral flowering	High pruning costs, uneven flower batches
Chrysanthemum	9	Cytokinin Spray	Multiple flower buds, bushier growth	Some buds too small for market
Tomato	12	Ethylene Gas	Uniform fruit ripening	Leaf yellowing and drop

Reference: Taiz, L., Zeiger, E., Møller, I.M., & Murphy, A. (2018). *Plant Physiology and Development* (6th ed.). Sinauer Associates.

Task:
(a) i. Analyse the role of photoperiodism in triggering flowering in the rose and chrysanthemum.
ii. Explain the opposing effects of auxin and cytokinins on plant growth, as demonstrated in the data.
iii. Explain the dual role of ethylene in the tomato greenhouse as both a ripening hormone and a stress hormone.
(b) To improve profitability and sustainability, propose integrated strategies for the farm manager. Your strategies should optimize the use of light and hormones to improve yield quality, reduce negative side-effects, and lower energy costs. Justify each proposal using the data.

32. During the inter-house athletics championship at St. Mary's College in Soroti, the sports medicine team investigated factors affecting athletes' reaction times. They tested the runners' reaction times to a starter's pistol sound under different conditions. They found that athletes who performed a proper warm-up had faster reactions. One sprinter, David, had a minor injury and applied a topical local anaesthetic cream to his thigh; his reaction time was significantly slower in his race. Another athlete, who had been resting on a cold bench before her event, also showed a delayed start.

Table: Athlete Reaction Time Under Different Pre-Race Conditions

Condition	Average Reaction Time (milliseconds)	Core Body Temperature (°C)	Athlete Feedback
Resting at 25°C	320	36.5	Normal
After Warm-up	280	37.8	Alert and ready
After Cold Pack Application	400	35.0	Felt "sluggish"
With Local Anaesthetic Cream	450	36.5	Numbness at application site

Reference: Purves, D., Augustine, G.J., & Fitzpatrick, D. (2018). *Neuroscience* (6th ed.). Sinauer Associates.

Task:

(a) i. Explain the effect of increased body temperature (from warm-up) on the speed of nerve impulse transmission.

ii. Explain how the local anaesthetic cream works at the molecular level to slow down David's reaction time.

(b) The games department wants to create a safety guideline. Propose evidence-based recommendations for athletes to optimize their nervous system function and prevent injuries related to slow reaction times. Justify each recommendation using the principles of neural transmission.

33. A student biology club at Makerere University is studying vision adaptation. They recruited volunteers, including Sarah, who struggles to see clearly in dim light (nyctalopia), and John, who finds bright light painful and often wears sunglasses (photophobia). Using an ophthalmoscope, they observed that Sarah's retina appeared normal, but John's had fewer pigmented cells in the macula lutea. They tested visual acuity and light adaptation times under different lighting conditions.

Table: Visual Function Tests Under Different Light Intensities

Light Condition	Pupil Diameter (mm)	Time to Read Chart (s) - Rod Vision	Time to Read Chart (s) - Cone Vision	Colour Perception Accuracy (%)
Dim Light (10 lux)	7.5	4.5 (Sarah: 12.0)	N/A	N/A
Normal Room (500 lux)	4.0	2.0	1.8	98
Bright Light (2000 lux)	2.5	N/A	1.5 (John: 3.5)	99

Task:

(a) i. Explain the roles of rods and cones in the retina, linking their function to the data in the table.

ii. Using the data, analyse the likely causes of Sarah's nyctalopia and John's photophobia.

iii. Describe the reflex arc involved in pupil constriction under bright light and its protective function.

(b) Propose practical strategies that the students can recommend to improve visual comfort and safety for people with similar conditions to Sarah and John, or for the general public in different light environments. Justify each strategy based on the physiology of the eye.

34. Rangers in Bwindi Impenetrable National Park are monitoring chimpanzee populations. They have observed distinct behavioural patterns in two neighbouring troops, the “Mubwindi” and “Rushaga” groups, in response to seasonal fruit scarcity and the presence of tourists. The Mubwindi group, which is habituated to tourists, has started using sticks to extract honey from hives, a behaviour not seen before. The Rushaga group, deeper in the forest, remains wary of humans but is more efficient at cracking hard nuts using stones. Rangers note that the Mubwindi group's new tool-use behaviour is being copied by younger chimps.

Table: Observed Chimpanzee Behaviours and Context

Troop	Dominant Behaviour	Stimulus/Context	Observed Outcome	Type of Behaviour (Innate/Learned)
Mubwindi	Stick tool use	Tourist presence, honey availability	New food source accessed, learned by juveniles	Learned
Rushaga	Stone tool use	Natural nut abundance, no human contact	Consistent, efficient feeding	Innate (Instinct)
Both	Loud alarm calls	Sight of a leopard	Group flees to trees	Innate (Fixed Action Pattern)
Both	Grooming	After feeding, during rest	Strengthened social bonds	Learned (Habituation?)

Reference: Goodall, J. (2020). *60 Years at Gombe: A Tribute to Chimpanzee Behaviour and Conservation*. The Jane Goodall Institute.

Task:

(a) i. Distinguish between innate and learned behaviour, giving one example of each from the data.

ii. Explain the adaptive significance of the loud alarm calls for the chimpanzees' survival.

iii. Analyse how the “stick tool use” behaviour in the Mubwindi troop demonstrates social learning and its potential advantage.

(b) Propose management strategies for the park that consider the impact of tourism, protect natural habitats, and ensure the transmission of these adaptive behaviours to future generations.

INHERITANCE AND EVOLUTION

35. 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.

36. 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.

37. 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.

38. 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.

39. 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.

40. 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.

41. 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.

42. 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.

43. 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.

44. 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 modern biotechnological application that could be relevant to their situation.

45. 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.

46. 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.

47. 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

Task

(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

48. Researchers in Arua District studied how storage and environmental factors affect the germination of groundnut seeds in different storage conditions. Some seeds had been treated with traditional ash-based pesticides, while others were stored in sealed tins or ventilated sacks.

Condition	Storage Duration (months)	Moisture Content (%)	Temperature (°C)	Germination Rate (%)	Root Length (cm)
A	0	10	25	95	12.8
B	3 (sealed tins)	8	30	60	7.2
C	3 (ventilated sacks)	6	27	80	11.4
D	6 (treated with ash)	7	25	75	9.8

Reference: *East African Agricultural Science Review (2024). "Seed Storage and Germination Efficiency in Tropical Crops."*
Task:
(a) Analyse the data to explain how environmental and storage factors influence pre- and post-germination processes.
(b) Suggest sustainable agricultural strategies to improve seed germination, reduce dormancy, and maintain seed quality.

49. Students at Iganga Senior Secondary School investigated how different nutrient sources influence the growth and long-term health of bean plants. Some plots received compost, others chemical fertilizer, while a third group combined both.

Treatment	Average Height (cm) after 6 weeks	Leaf Count	Stem Diameter (mm)	Soil pH	Number of Pods per Plant
Compost	45	20	6	6.8	18
NPK Fertilizer	52	17	5	5.4	22
Compost + NPK	55	22	7	6.5	25

Reference: *Uganda Journal of Sustainable Agriculture (2023). "Nutrient Management and Growth Trends in Leguminous Crops."*
Task:
(a) Explain how nutrient source influences growth rate, sustainability, and soil health.
(b) Propose integrated farming strategies to improve yields while maintaining long-term soil fertility.

50. A community near River Katonga reported poor maize yields. Samples of irrigation water and soil were collected from three farms one near the upstream forest, another near a sugar factory, and a third in a lowland wetland.

Site	Water Source	Dissolved Oxygen (mg/L)	Heavy Metal Content (ppm)	Germination Rate (%)	Mean Shoot Height (cm)
A	Forest stream	8.5	0.2	92	15.5
B	Factory outlet	3.2	4.5	48	7.2
C	Wetland outlet	5.1	2.1	70	11.3

Reference: *Environmental and Crop Science Journal (2022). "Industrial Pollution and Crop Germination Rates in Tropical Soils."*

Task:

(a) Analyse how water quality parameters affect germination, energy production, and seedling growth.

(b) Suggest community-based strategies to ensure clean irrigation water and improve seed germination.

51. A horticultural project in Mbarara tested how different plant growth regulators affect young tomato seedlings. Farmers wanted to improve growth consistency and early flowering.

Treatment	Hormone Type	Concentration (ppm)	Average Height (cm)	Leaf Count	Flowering Time (days)
A	None (control)	0	15	8	60
B	Auxin	20	25	11	55
C	Gibberellin	15	30	13	45
D	Ethylene	10	18	9	70

Reference: *Plant Growth Regulation Studies (2023). "Hormonal Control of Early Tomato Development."*

Task:

(a) Explain how the data demonstrate the roles of different growth hormones in plant development.

(b) Propose safe, cost-effective, and sustainable strategies to regulate plant growth and enhance crop yields.

52. An urban waste recycling group in Kampala used black soldier fly larvae to process organic market waste. The group noticed that waste type and moisture content affected larval survival and compost yield.

Waste Type	Moisture (%)	Larval Survival (%)	Compost Yield (kg)	Processing Time (days)
Vegetable	15	95	6.2	7
Fruit	12	90	5.8	8
Meat	9	70	3.0	10
Mixed	11	85	4.5	9

Reference: *Journal of Applied Entomology (2024). "Insect Bioconversion of Organic Waste for Sustainable Agriculture."*

Task:

(a) Analyse the data to explain how waste characteristics influence insect growth and decomposition efficiency.

(b) Propose environmentally friendly strategies to optimize insect farming and waste recycling in urban areas.

53. A rural school agricultural club in Tororo reared crickets to explore their potential as a source of food and feed. They monitored growth, nutrient composition, and reproduction at different stages.

Development Stage	Duration (days)	Survival Rate (%)	Protein Content (%)	Feed Intake (g/day)
Egg	6	100	—	—
Nymph	25	85	55	0.2
Adult	45	80	65	0.4

Reference: *Food and Agricultural Insects Research Journal (2023). "Cricket Farming and Food Security in East Africa."*

Task:

(a) Analyse the relationship between the insect's growth stages and its contribution to food security.

(b) Propose realistic strategies to improve insect farming for nutrition and sustainability.

54. Scientists in Kabale District assessed water quality in streams draining farmland by studying aquatic insect diversity.

Site	Insect Species Diversity (Shannon Index)	Pollution Tolerance Index	Nitrate Level (mg/L)	Water Clarity (NTU)
A	2.8	Low	1.5	5
B	1.2	High	6.8	25
C	1.9	Moderate	3.4	12

Reference: *Environmental Monitoring Review (2024). "Aquatic Insects as Indicators of Water Quality in Agricultural Ecosystems."*

Task:

(a) Use the data to explain how aquatic insect diversity indicates water quality.

(b) Suggest strategies to maintain clean water and biodiversity in agricultural regions.

ECOLOGY

55. In 2025, heavy floods from the Rwenzori slopes destroyed farmlands and swept away vegetation along River Nyamwamba. A restoration team conducted a 6-year study to understand how the ecosystem recovered naturally and how this affected local agriculture and carbon storage.

Year After Flood	Dominant Vegetation	Soil Carbon (g/kg)	Crop Yield (tons/ha)	Bird Species Count	Average Flood Intensity Index
1	Bare soil, algae	2.1	0.5	8	9.0
3	Grasses and shrubs	5.5	1.8	18	6.4
5	Young trees and crops	8.2	2.6	27	4.2
6	Mature forest and agroforestry	10.4	3.4	35	3.5

Reference: *East African Environmental Restoration Review (2024). "Post-Flood Succession and Carbon Sequestration in Mountain Ecosystems."*

Task:

(a) Analyse how ecological succession, population recovery, and carbon storage contributed to ecosystem stability and food production.

(b) Propose sustainable strategies to enhance ecosystem restoration, flood resilience, and food security in flood-prone regions.

56. Mabira Forest Reserve, once a rich biodiversity hotspot, has experienced deforestation due to agriculture, charcoal burning, and settlement expansion. Scientists recently discovered a rapid spread of an invasive vine species (*Mikania micrantha*) in cleared areas, altering microclimates and reducing regeneration.

Site	Tree Canopy Cover (%)	Soil Moisture (%)	Invasive Vine Cover (%)	CO_2 Concentration (ppm)	Native Tree Seedlings (per m^2)
A (intact forest)	90	35	0	390	25
B (partially cleared)	50	22	30	430	12
C (deforested edge)	20	10	65	470	3

Reference: *Uganda Forestry and Climate Adaptation Report (2023). "Deforestation, Invasive Plants, and Carbon Balance in Mabira Forest."*

Task:

(a) Explain how deforestation, carbon imbalance, and invasive species interactions affect biodiversity, microclimate, and energy flow.

(b) Suggest integrated management strategies to restore forest stability and mitigate the combined effects of deforestation, invasive species, and climate change.

57. A regional ecological team studied changes in Lake Victoria's fish community over a decade. They found that nutrient pollution, increased fishing pressure, and introduction of non-native fish had disrupted trophic interactions and reduced overall ecosystem productivity.

Parameter	2015	2020	2025
Phytoplankton Biomass (mg/L)	4.2	6.8	8.5
Dissolved Oxygen (mg/L)	8.1	6.2	4.8
Native Fish Diversity	26	18	12
Introduced Species Proportion (%)	5	25	40
Annual Catch Yield (tons)	25000	19000	14000
Average Household Fish Consumption (kg/person/year)	19	15	10

Reference: *African Inland Waters Research (2024). "Nutrient Pollution and Energy Disruption in Lake Victoria Fisheries."*

Task:

(a) Analyse how changes in nutrient input, population dynamics, and energy flow have altered food availability and ecosystem stability.

(b) Propose integrated strategies to restore ecological balance, ensure sustainable fisheries, and promote food security.

58. Rapid urbanization around Wakiso has converted wetlands and forests into residential areas. This has increased carbon emissions, reduced biodiversity, and altered local microclimates. Environmental researchers assessed changes in ecosystem parameters between 2010 and 2025.

Year	Urban Land Area (km^2)	Average Surface Temperature (°C)	Vegetation Cover (%)	Carbon Emissions (tons CO_2/year)	Bird Species Count	Flood Incidence (events/year)
2010	120	28.0	65	150,000	68	2
2015	160	29.5	50	190,000	55	4
2020	210	31.0	38	230,000	42	7
2025	250	33.2	25	300,000	35	10

Reference: *Urban Sustainability and Ecology Journal (2024). "Carbon Dynamics and Biodiversity Loss in Expanding African Cities."*

Task:

(a) Analyse how urban expansion simultaneously affects population dynamics, carbon balance, and energy flow in the ecosystem.

(b) Propose urban ecology strategies to restore biodiversity, reduce carbon footprint, and enhance resilience in growing cities.

59. Communities around Lake Albert depend heavily on fishing for income and food. Over the past decade, local fisheries officers observed that fish catch per unit effort has declined despite increasing fishing intensity. Environmental scientists conducted a study to determine changes in fish population density in different fishing zones with varying resource conditions.

Zone	Dissolved Oxygen (mg/L)	Phytoplankton Density (cells/mL ×10^3)	Fish Density (fish/m^2)	Predator Abundance (per 100 m^2)	Fishing Intensity (boats/km^2)
A (protected bay)	8.0	180	32	3	2
B (moderate activity)	6.2	150	18	5	5
C (heavily fished)	4.5	110	7	2	9

Reference: *East African Aquatic Ecology Journal (2024). "Population Regulation and Resource Depletion in Tropical Lakes."*

Task:

(a) Analyse how differences in resource availability, oxygen levels, and human activity affect fish population density and community interactions.

(b) Propose evidence-based strategies to restore sustainable fishing and biodiversity around Lake Albert.

60. After a wildfire in Mt. Elgon National Park, ecologists studied vegetation regrowth and soil changes over 10 years. Data were collected from plots representing different years of recovery.

Year Since Fire	Dominant Vegetation	Soil Nitrogen (mg/kg)	Organic Matter (%)	Species Richness	Ground Cover (%)
1	Grasses, lichens	10	1.8	5	30
3	Shrubs	25	2.9	14	55
6	Young trees, shrubs	42	3.6	22	75
10	Mature forest species	60	4.2	30	90

Reference: *Uganda Forestry Research Institute (2023). "Post-Fire Succession and Soil Nutrient Dynamics in Mt. Elgon."*

Task:

(a) Explain how the data illustrate ecological succession and the recovery of ecosystem structure and function.

(b) Design sustainable ecological restoration strategies that ensure biodiversity and soil recovery.