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ITEM 1

A community in Lira shares a pond for fishing, livestock watering, and bathing. Recently, fish and livestock have died, and people report skin rashes. A rusty pipeline from an abandoned mine was found leaking into the pond. Water analysis showed high levels of lead (Pb). Samples from pond algae, fish gills, and goat liver were studied.

Data:

Sample	Control (Clean Source)	Contaminated Pond
Algae: Chlorophyll content	High	Very Low
Algae: Cell wall integrity	Intact	Compromised
Fish Gills: Ciliated cell activity	Active	Paralyzed
Fish Gills: Mucus thickness	Normal	Very Thick
Goat Liver: Catalase enzyme activity (%)	100	25
Goat Liver: Number of intact mitochondria	Numerous	Few, swollen

Task:

(a) Explain how the contaminants could affect organisms at different biological levels, from the cellular organelles of algae to the tissue systems of fish and mammals.

(b) Propose a multi-step community action plan to tackle this environmental health crisis.

ITEM 2

A pharmaceutical company in Fort Portal is cultivating *Cinchona* trees for quinine, an anti-malarial drug. The trees are grown on slopes with good drainage. The company notices that trees receiving morning shade but afternoon sun produce bark with higher quinine concentration. They measure photosynthetic activity and guard cell behaviour.

Tree Group	Light Exposure	Avg. Stomatal Aperture (Afternoon)	Net Photosynthesis Rate	Quinine Yield
A	Full Sun All Day	Small	Moderate	Low
B	Morning Shade, Afternoon Sun	Large	High	High
C	Mostly Shaded	Medium	Low	Moderate

Task:

(a) Link the behaviour of the guard cells (stomatal aperture) in Group B to the processes of the light-dependent reactions and the subsequent high quinine yield.

(b) Recommend a practical lighting strategy for the plantation and justify it using the concepts of photosynthesis and carbon fixation for secondary product synthesis.

ITEM 3

Near the Rwenzori mountains, a community grows Arabica coffee at high altitude. They find that beans from plants exposed to occasional mild cold stress have a richer aroma. Researchers suspect this stress alters the plant's metabolism. They study chloroplast activity and energy pathways under different temperature regimes.

Condition	Temperature Range	Ratio of Cyclic : Non-Cyclic Photophosphorylation	Observation on Bean Development

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Standard	Consistently Cool (15-18°C)	Low : High	Good yield, standard aroma
Experimental	Cool with Brief Chills (10°C)	High : Low	Slightly lower yield, enhanced aroma oils

Task:

(a) Explain the role of cyclic photophosphorylation in helping the plant cope with the brief cold stress, and how this might redirect photosynthetic intermediates.

(b) Propose a sustainable farming practice that could mimic this beneficial stress to improve bean quality without severely compromising yield.

Item 4

In a swampy area of the Nile delta, farmers are attempting to grow cotton (a mesophyte). The plants grow tall but produce very little cotton boll fibre. The fibres are primarily cellulose. Soil analysis shows low nitrate availability. Experts compare the growth to native mesophytes and nearby xerophytes.

Plant / Condition	Soil Water	Nitrate Level	Primary Carbon Allocation Observed	Growth Outcome
Cotton (Swamp Field)	Very High	Low	To new shoots and leaves	Lush vegetation, weak fibres
Native Reed (Swamp)	Very High	Low	To structural rhizomes	Strong perennial growth
Desert Acacia (Nearby)	Very Low	Moderate	To protective resins & oils	Slow, sturdy growth

Task:

(a) Analyse how the environmental conditions likely disrupt the normal balance between carbon and nitrogen metabolism in cotton, leading to poor fibre production.

(b) Suggest one soil management strategy and one plant selection/breeding strategy to improve fibre yield in this region.

ITEM 5

Students at Gulu University collected water hyacinth (*Eichhornia crassipes*) leaves from two sites on the Nile: a clean upstream site and a downstream site near a mining outflow. They prepared wet mounts and used a light microscope to study leaf epidermal cells, calculating cell sizes and observing structural changes.

Parameter	Clean Site	Polluted Site
Average cell length (µm)	80	120
Chloroplast count per cell	15	5
Cell wall thickness (µm)	1.2	2.5
Vacuole size relative to cell (%)	70	40
Visible cytoplasmic streaming	Yes	No
Presence of plasmolysed cells (%)	0	60

Tasks:

(a) Analyse how pollution affects the ultrastructure and function of plant cells.

(b) Suggest how water hyacinths could be managed to reduce pollution impact, and propose a school-based monitoring project.

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ITEM 6

A poultry farm in Wakiso experienced sudden deaths in chickens. The birds had been fed maize stored in a poorly ventilated silo. A veterinarian suspected cyanide poisoning from fungal contamination (producing cyanogenic compounds). Tissue samples from the heart and liver of dead and healthy birds were compared.

Parameter	Healthy Chicken	Affected Chicken
Mitochondrial density in heart cells (per μm^2)	0.8	0.3
Cytochrome c oxidase activity (% of normal)	100	15
Blood oxygen saturation (%)	98	75
Lactic acid in muscle (mmol/L)	2	12
ATP level in liver cells (µmol/g)	5.5	1.2
Cell death markers in brain tissue (relative units)	10	85

Task:

(a) Explain how cyanide acts as a respiratory poison, disrupting specific stages of cellular respiration and leading to tissue damage, especially in high-energy organs.

(b) Outline a farm management plan to prevent such poisoning.

ITEM 7

A clinic in Kampala reports that a common antibiotic is becoming less effective. Researchers suspect that some bacterial strains have altered their plasma membrane composition, reducing drug uptake. They compared membrane properties of antibiotic-sensitive and resistant *E. coli* strains.

Table 4: Bacterial Plasma Membrane Analysis

Parameter	Sensitive Strain	Resistant Strain
Membrane fluidity index	0.6	0.3
Phospholipid saturation (%)	40	75
Cholesterol-like molecule content (%)	5	20
Porin protein channel density (per μm^2)	500	200
Antibiotic influx rate (ng/min)	100	20
ATP-dependent efflux pump activity (%)	10	90

Tasks:

(a) Analyse how changes in membrane fluidity, composition, and protein channels affect the permeability and transport of antibiotics into bacterial cells.

(b) Propose two strategies to enhance antibiotic effectiveness against resistant strains, based on membrane biology and inhibition principles.

ITEM 8

Farmers in Apac District report that stored cassava roots quickly develop soft rot. A study compared the parenchyma tissue structure of freshly harvested and rotten cassava roots, focusing on cell wall integrity and enzyme activity.

Table 5: Cassava Parenchyma Tissue Analysis

Parameter	Fresh Cassava	Rotten Cassava
Cell wall thickness (µm)	3.0	1.2
Pectinase enzyme activity (units/g)	10	120
Starch grain integrity (scale 1-10)	9	2

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Intercellular air spaces (% of tissue)	5	25
Microbial (fungal) hyphae presence (per mm^2)	0	200
Water potential of tissue (kPa)	-500	-100

Task:

(a) Explain how enzymatic degradation of cell wall components and changes in tissue organization lead to soft rot and nutrient loss in cassava.

(b) Suggest storage methods farmers could adopt to slow down tissue degradation, based on controlling enzyme activity and microbial growth.

ITEM 9

Bean farmers in Masaka have reported poor yields and stunted plants. A new pesticide was introduced that contains a compound similar in structure to phosphoenolpyruvate (PEP), a substrate in glycolysis. Farmers using this pesticide also report fatigue and dizziness. Scientists compared root cells from healthy beans grown without pesticide with affected beans. They used light microscopy to measure root hair length and examined mitochondrial structure in both plant cells and soil bacteria.

Parameter	Healthy Beans (No Pesticide)	Affected Beans (With Pesticide)
Pyruvate kinase activity (% of normal)	100	35
PEP substrate concentration (mM)	5.0	1.2
Mitochondrial cristae density in root cells	High	Low
Root hair length (µm) - microscopy	800	300
Soil bacterial count (prokaryotic cells/g)	10^8	10^5
Fluidity of root cell plasma membrane	Normal	Reduced
ATP production in root cells (µmol/g/h)	45	12
Xylem vessel diameter (µm)	30	18

Task:

(a) Explain how the pesticide compound interferes with glycolysis through enzyme inhibition, and how this affects mitochondrial function, plant tissue structure, and soil microorganism populations.

(b) Design an integrated farming approach that protects crop health while maintaining soil biodiversity.

ITEM 10

Lake Bunyonyi has developed thick green algal mats that block sunlight and reduce oxygen. The algae produce a toxin that irreversibly binds to cytochrome c oxidase in the electron transport chain. Fish and aquatic plants are dying. Scientists compared water samples from clear areas with those from algal bloom areas, examining algal cells (eukaryotic) and aquatic bacteria (prokaryotic) under electron microscopy.

Parameter	Clear Water Area	Algal Bloom Area
Cytochrome c oxidase activity (% of normal)	100	5
Algal cell count (eukaryotic cells/mL)	10^3	10^7
Bacterial diversity (prokaryotic species count)	25	5
Mitochondrial damage in fish gill cells (%)	0	75
ATP production in aquatic plants (µmol/g/h)	30	8

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Phloem transport rate in plants (relative)	100	40
Plasma membrane integrity in fish cells (%)	95	50
Algal cell diameter (µm) - microscopy	10	15

Task:
(a) Analyse how the algal toxin affects cellular respiration in different organisms, and how changes in microbial populations and cellular structures disrupt the lake ecosystem.
(b) Propose a biologically sound management strategy to control the algal bloom and restore lake health.

ITEM 11
A Kampala meat processing plant finds that meat from stressed cattle is tough and takes longer to tenderize with proteolytic enzymes. The stress hormone cortisol increases in these animals, affecting enzyme function. Scientists compared muscle tissue from relaxed and stressed cattle, examining enzyme activity, mitochondrial structure, and connective tissue organization.

Parameter	Relaxed Cattle Meat	Stressed Cattle Meat
Protease enzyme concentration (units/g)	100	45
Collagen substrate availability (mg/g)	50	30
Mitochondrial number per muscle cell	200	90
Connective tissue (collagen) thickness (µm)	15	25
ATP concentration in muscle (mmol/kg)	28	14
Fluidity of muscle cell membranes	Normal	Reduced
Bacterial contamination (prokaryotic cells/g)	10^2	10^4
Sarcomere length (µm) - microscopy	2.5	1.8

Task:
(a) Explain how cortisol might affect protease enzyme concentration and substrate availability, and how changes in mitochondrial function and tissue structure lead to tougher meat.
(b) Suggest handling and processing modifications to improve meat quality and safety.

ITEM 12
Dairy cows in Mbarara fed on grass treated with a herbicide show reduced milk production. The herbicide contains a compound that resembles acetyl-CoA and competitively inhibits citrate synthase in the Krebs cycle. Veterinarians compared liver cells from affected cows with those from healthy cows grazing on untreated pasture.

Parameter	Healthy Cows (Untreated Pasture)	Affected Cows (Treated Pasture)
Citrate synthase activity (% of normal)	100	35
Acetyl-CoA substrate concentration (mM)	2.0	0.8
Mitochondrial cristae surface area (relative)	100	45
Milk fat (lipid) content (%)	4.0	2.5
Rumen bacterial diversity (prokaryotic species)	30	12
Hepatocyte (liver cell) membrane integrity (%)	95	60
ATP production in mammary gland cells	High	Low
Blood ketone concentration (mM)	0.5	2.8

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Task:
(a) Analyse how the herbicide affects the Krebs cycle through competitive inhibition, and how this disrupts mitochondrial function, lipid production, and microbial populations in the rumen.
(b) Develop a pasture management and dietary plan to restore cow health and milk production.

ITEM 13
A textile factory in Jinja discharges wastewater containing a dye that inhibits ATP synthase by binding irreversibly to its active site. Downstream vegetable farmers using this water report wilting plants. Scientists compared root cells from vegetables irrigated with clean water versus contaminated water, examining enzyme activity, mitochondrial structure, and membrane properties.

Parameter	Clean Water Irrigation	Contaminated Water Irrigation
ATP synthase activity (% of normal)	100	15
ADP substrate concentration (mM)	1.5	3.8
Mitochondrial inner membrane integrity	Intact	Damaged
Root hair density (per mm) - microscopy	150	40
Xylem vessel clogging (%)	0	65
Plasma membrane lipid composition	Normal	Altered (more saturated)
Soil protozoan count (eukaryotic cells/g)	10^5	10^3
Cellulose deposition in cell walls (relative)	100	60

Task:
(a) Explain how the dye acts as an irreversible enzyme inhibitor, and how this affects oxidative phosphorylation, plant tissue structure, and soil organism populations.
(b) Propose treatment methods for the wastewater and agricultural strategies to rehabilitate affected farms.

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