BIOLOGY ITEM BANK

ITEM 1

A commercial famer in Wakiso district has been experiencing massive fish kills in his Nile Perch ponds. He recently started using a new chemical algaecide to clear green pond scum. A NEMA aquatic biologist collected tissue samples from the dead fish and compared them to healthy fish from untreated pond. The laboratory analysis focused on mitochondrial function, membrane structure and cellular respiration outputs. The results are shown in the table below.

Parameter	Healthy fish(untreated pond)	Dying fish(treated pond)
Inner mitochondrial membrane fluidity	Normal	Highly rigid and impermeable.
NADH concentration in the matrix (mol/g tissue)	4.5	18.2
Lactic acid concentration in blood (mg/L)	1.2	9.8
ATP synthase activity(%)	100	12
Rate of mitosis in the gill epithelial cells	High	Extremely low

TASK

Analyse how the chemical algaecide alters the bio-molecular structure and cellular respiration processes in the fish, leading to the observed physiological changes and death. Propose biological strategies to restore the health of the remaining fish and the pond ecosystem.

ITEM 2

Victoria Nile is a source of food and income for the communities living along it. However, the community near a textile factory have reported to the district authorities that the fish catches have significantly reduced over the past few months. The authorities requested Dr. Achen, a fisheries biologist from National Environmental Management Authority (NEMA) to carry out an investigation. She suspected that the cause was pollution from the factory that releases wastes containing heavy metals and cyanide into the lake.

She caged fish at two different sites; a clean control site (no pollution) and a site near the factory outflow. She investigated the effects of the heavy metals on the gill and mitochondrial structures and ATP synthesis. The data she collected is provided in table 1.

FISH GROUP	**Control(no pollution)**	**Polluted site- factory out flow.**
ATP concentration($\mu mol/g$)	9.5	2.2
Number of ribosomes per mitochondria($\times 10^6$)	9.8	1.3
Concentration of oxidised NAD ($\mu mol/gtissue$)	7.2	1.3
Space between cells of the gill epithelium	0.5	6.0
Amount of cynanide in river water (mg/L)	0.01	1.00
Amount of lead (Pb) in river water.	1.00	1.00
Thickness of the gill squamous.	Thin	Thick

You are tasked with analysing her findings and proposing a course of action.

Task

Analyse how cellular and tissue changes in the fish from the polluted site affect respiration and result in reduced fish catches to propose and justify a sustainable management plan to ensure health of organisms in the river.

ITEM 3

In some fishing communities in **Kalangala District (Lake Victoria)**, illegal use of cyanide has been reported as a method of capturing live fish for sale to aquarium traders. Although the method allows easy capture of target fish, it has been associated with the death of non-target species and declining fish populations.

A marine biologist conducted a study comparing fish from **cyanide-exposed zones** and **non-exposed zones**. Tissue samples were analyzed, and the following results were obtained:

Sample	**Cytochrome oxidase activity(%ge of the normal)**	**Gill membrane integrity(%ge of cells damaged)**	**Gill ATP concentration**	**Oxygen uptake**
Unaffected fish	**100**	**5**	**4.8**	**9.5**
Cyanide exposed fish.	**3**	**60**	**0.8**	**1.2**

TASK:

Explain how the cyanide chemical leads to the observed changes in the table and propose strategies to restore the health of the remaining fish.

ITEM 4

In some areas of **Kampala**, medications such as paracetamol and certain antibiotics are stored in conditions of high temperature and direct sunlight due to limited storage facilities. Health workers have reported that patients using these drugs show **reduced recovery rates**, increased fatigue, and, in some cases, symptoms of cellular damage.A laboratory investigation was conducted using liver cells exposed to:**Properly stored drugs** and **Heat-degraded drugs**

The following data were obtained:

Parameter	Cells exposed to degraded drugs	Cells exposed to properly stored drugs.
Functional enzyme activity(%)	**35**	**88**
ATP concentration	**2.4**	**7.1**
Mitochondrial membrane integrity(%)	**58**	**95**
Cell membrane permeability(%)	**70**	**28**
Rate of oxygen consumption(mg/O_2 /g/hr)	**2.9**	**8.5**
Level of denatured Proteins	**45**	**10**

Using the data provided, analyse how exposure to degraded drugs alters and propose strategies that can be used to improve health outcomes in Kampala.

ITEM 5

Napak district is one of the agricultural areas in Uganda. It is a lowland area with high temperature, shallow soils that have limited organic matter and very low moisture. Farmers grow both native and non-native crops, however, they often get low yields from the non-native crops unlike from the native crops.

The farmers invited agricultural extension workers to study the situation and propose strategies to improve the yields. They conducted a study in the district and the data collected on native and non-native crops grown is shown in table 2.

Table 2

Condition	Native plants	Non-native crops grown
The type of leaf anatomy	Kranz anatomy present	Kranz anatomy absent
Distribution of stomata	Many stomata on lower leaf epidermis	Many stomata on upper leaf epidermis
Size of leaf cuticle	Thick	Thin
Number of hairs on the leaf	Numerous	Very few

You are part of the team invited by the agricultural extension officer to analyse the data and propose strategies to the farmers on how to improve their crop yields.

Task:

(a) Account for the difference in the yields between native and non-native crops grown in the district, and propose strategies to enhance productivity and resilience.

ITEM 6

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	**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.

ITEM 7

"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.

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
Chrysanthmum	9	Cytokinin spray	Multiple flower buds, bushier growth	Some buds are too small for the market
Tomato	12	Ethylene spray	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.

(b) (ii) Explain the opposing effects of auxin and cytokinins on plant growth, as demonstrated in the data.

(c) (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.

ITEM 8

Nabuin zonal agricultural research and development institute (Nabuin ZAKDI) in Karamoja, is evaluating the resilience of Rice (C3) and Maize (C4) to simulate the changing climates of tropical regions like Karamoja. Two separate trials were conducted.

In trial 1, the plants were grown in well-watered gardens, but one set grown in an open field and another set grown under shades of tall trees where they could periodically receive sunflecks (short flashes of light) when wind shakes the branches of the tall trees.

In trial 2, rice and maize were grown in another field, but were subjected to drougnt period for two weeks, which severely lowered the soil moisture to induce water stress. In all cases the productivity of the two crops was determined. The following data was obtained.

Plant	**Conditions of the garden**	**Net photosynthesis rate**	**Photorespiration rate.**	**Total biomass**

Rice(C3)	Well-watered open	11.2	18	72
	Well watered, shade with sunflecks	24.5	12	185
	Dry(water stress)	9.4	45	62
Maize(C4)	Well-watered open	38.6	1	320
	Well watered, shade with sunflecks	14.8	1	105
	Dry(water stress)	29.2	2	215

TASK;

(a) Basing on the data in the table above, explain the differences in productivity of the two crops when grown in well-watered open and shady gardens with sunflecks and under conditions of water stress.

(b) Basing on the results from the study above, suggest and explain the practical agriculture strategies farmers in such changing climate of the tropics can apply to maximize productivity of both C3 and C4 plants.

ITEM 9

During the District Multi-Sport Championship in Soroti district (Altitude 1130m above sea level and temperature 30°C),Alex and Chris, were among the participants in 400m race

Athlete profiles and pre-competition factors:

- **Alex (400m Sprint):** Trained at the Teryet National grounds in Kapchorwa, a high-altitude facility (2,200 m above sea level and temperature 21°C).
- **Chris (400m Sprint)**: Trained at Namboole National Stadium in Wakiso, a low-altitude facility (1,128 m above sea level).

Immediately after the events,Chris showed signs of extreme fatigue, collapsed and injured his lower leg.

Chris' coach wondered why Alex did not show signs of extreme fatigue and asked the first aider to investigate since he was suspecting Alex of sports doping. The first-aid team recorded the following measurements in table 3 immediately after each event.

Table 3

Parameter	**Alex**	**Chris**
Pulse rate after race (beats/min)	115	155
Blood oxygen saturation (%)	93	85
Breathing rate (breaths/min)	18	28
Stroke volume (ml/beat)	120	100

The first aider has presented to Chris's coach and he is seeking a scientific explanation for the differences between the participants and expert advice on post-race management of Chris.

Task

Explain how the athletes' performance and observed conditions after the race were influenced by differences in training environments; explain the thermoregulatory adjustment in Alex's body on reaching Soroti and propose strategies for safe management of Chris's condition after the race.

ITEM 10

Brian a re-known fastest sprinter in the region has recently lost many races. This has caused him to lose self-confidence, become depressed and he also says that he feels unsteady whenever he turns his head quickly. However, he is seen to perform impressive warm-up routines during training whenever his girlfriend is around, an act his coach jokingly calls his "courtship display."

His coach noticed that Brian's reaction time to the start signal is slower than that of his peers and he sometimes staggers and leans forward when walking and running. Worried that he might be having a medical condition affecting his performance, Brian's coach referred him to a medical doctor who conducted tests and compared his results with reference values typical of healthy sprinters. Brian's laboratory and clinical results are shown in table 4.

Table 4

Parameter	Brian's Result	Normal Reference (trained athletes)
Total synaptic vesicles at the motor end-plate (vesicles per end-plate)	8.0×10^{5}	2.0×10^{6}
Acetylcholine per synaptic vesicle (molecules·vesicle^{-1})	5.0×10^{3}	1.0×10^{4}
Arteriole wall smooth muscle (media thickness)in μm	12	22
Core temperature at the onset of sweating (°C)	39.0	37.2
Whole-body sweat rate at 36 °C ambient	0.2	1.0 L·h^{-1}
Endolymph volume in vestibular apparatus μL (normal range per ear)	60	70–170
Structure of otolith organs	Increased mechanical stiffness	Normal elasticity

On receiving the test results from Brian, the coach could not understand them. You have been tasked with interpreting the results for the coach.

Task:

Account for the physiological mechanisms underlying Brian's observed symptoms and behaviours, explain their survival value, and propose strategies to improve his performance.

ITEM 11

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(cell/μL)	6800	4500
Respiration rate(breaths/min)	16	24

CO concentration(ppm)	0	120

Reference: En2vironmental 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.

ITEM 12

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.

Item 13

Farmers in Kayunga District use a pesticide to control beetles that destroy the flowers of coffee plants. However, over the past five years, the pesticide has become less effective, as the beetle population has continued to increase.

Findings from an investigation conducted by the district research team show that 20% of the beetles possess a recessive pesticide-resistance allele leading to a decline in coffee yields and pollinator population , while bird populations feeding in the fields increased.

You have been tasked to analyse these findings and help the district officials on how to manage pests.

Tasks

(a) Analyse the increase in pesticide-resistant beetles and predict the population of those with pesticide resistant allele, evaluate the effects of changing pollinator and bird populations on coffee yields, and propose a biologically justified, integrated pest management strategy for the district

Item 14

In western Uganda, communities around Budongo Forest Reserve report increasing native rodent species invasions into crop gardens. The National Forestry Authority(NFA) directed an investigation into the complaints of communities. The investigation showed that the population of native rodent species in the forest declined, while that of non-native rodent species increased.The non-native rodents have stronger limbs, larger incisors, and a higher reproductive rate. The native species therefore, are outcompeted by the non-native species and end up in crop gardens.

The investigation further showed that deforestation and farming have degraded and fragmented the forest into three isolated patches, each with distinct conditions. Unlike before the formation of the patches, the native rodent species are unable to move throughout the forest restricting interbreeding within patches only. The breeding experiments between native rodent species from the different patches A, B and C showed that those from:

- A can not mate with those from B at all
- B can mate with C, but their offspring are infertile
- C and A can mate but a zygote never forms

Tasks

Analyse the ecological and evolutionary interactions in the forest to propose a management plan for Budongo Forest that restores the forest, controls the invasive rodents, and conserves native biodiversity while supporting local livelihoods.