UGANDA ADVANCED CERTIFICATE OF EDUCATION

S.5

BIOLOGY Paper 1 (Theory)

SECTION A(Compulsory)

Item 1

Cystic Fibrosis is a genetic disease caused by a faulty ion channel protein, leading to thick mucus that blocks ducts and tubes lined with epithelium. In the pancreas, this blocks the release of digestive enzymes. A researcher is studying how the resulting nutrient malabsorption affects cellular respiration in intestinal epithelial cells. **Table: Analysis of Intestinal Epithelial Cells in a CF Model**

Cell Parameter	Cystic Fibrosis Model	Healthy Model
Thickness of mucus layer	150 μm	50 μm
Glucose absorption efficiency	30%	95%
Pyruvate Dehydrogenase Activity	Low	Normal
Mitochondrial ATP Output	Low	Normal

Task:

a. Analyse the sequence of events, from the faulty protein to the thick mucus, and finally to the reduced ATP output in the intestinal epithelial cells, explaining the role of glucose and pyruvate dehydrogenase.

____

____

____

____

____

____

____

____

____

____

____

____

____

b. Justify a nutritional supplement strategy that could bypass the blocked digestive enzymes and provide substrates to support the aerobic respiration of the gut epithelium.

____

____

____

____

____

____

____

____

____

Item 2

In **Karamoja**, farmers are testing **sorghum** and **amaranthus** for drought resistance. During prolonged dry spells, sorghum stays green and continues growing, while amaranthus wilts rapidly and shows reduced leaf area. Scientists recorded data on **leaf anatomy, chloroplast density, stomatal behaviour, and water content** of both plants under the same conditions. **Data**

Plant	**Leaf Type**	**Average Leaf Water Content (%)**	**Chloroplasts per Mesophyll Cell**	**Average Stomatal Opening (µm)**	**Photosynthetic Pathway**
Sorghum	Narrow with thick cuticle	80	60	2.0	C_4
Amaranthus	Broad with thin cuticle	55	38	4.5	C_3

Reference:*"Drought Adaptations and Photosynthetic Pathway Efficiency in Tropical Crops, Journal of Plant Ecology (2022)."*

Task:

Using the information provided,

a. Explain the physiological reasons why sorghum survives better than Amaranthus under drought.

b. Propose strategies to enhance drought resistance of Amaranthus in Karamoja.

SECTION B

PART I

Item 3

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 Oxygyen. (mg/L)	Phytoplankton density (cells/mLx10^3)	Fish Density (fish/m^2)	Predator Abundance (per $100m^2$)	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.

Item 4

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	Grass and Lichens	10	1.8	5	30
3	Shrubs	25	2.9	14	55
6	Young trees and shrubs	42	3.6	22	75
10	Mature forest	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.

SECTION B

PART II

Item 5

A couple, both of whom have Sickle Cell Trait (heterozygous for the sickle cell allele, $Hb^A Hb^S$), 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
$Hb^A Hb^A$	Normal	No sickle cell, susceptible to malaria
$Hb^A Hb^S$	Sickle Cell Trait	Mild or no symptoms; resistant to malaria
$Hb^S Hb^S$	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.

b. Analyse the evolutionary advantage that maintains the HbS allele in the population despite its harmful effects in the homozygous state.

c. 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.

Item 6

At Mbarara Regional Hospital, a 25 year old Rhesus Negative woman presented with Jaundice and fatigue. She received no Rh prophylaxis after her first delivery. Ultra sound 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	High	Detected	Negative
Bilirubin.	1.5	18.0	<1.2/<10
Reticulocyte	3	15`	0.5-2.0/3-7

Reference. Journal of Reproductive Immunology (2022). Maternal Antibodies and fetal Oxygen Transport In Rhesus Diseases.

Task.

a. Analyse how the immune response from the first pregnancy led to anti D antibodies formation and how this now interferes with foetal oxygen transport.

b. Suggest integrated strategies to prevent Rh related immune attacks including screening, immunoglobulin therapy, education and record keeping.

END