



# BUDDO SECONDARY SCHOOL

## Advanced Secondary BIOLOGY SEMINAR 2026

### P530/1 BIOLOGY PAPER 1 (THEORY) – SAMPLE ITEMS

#### SECTION A

#### 1. Cellular Organization, Respiration, and Molecular Analysis

##### Item 1.1

In Masindi District, a vegetable farming community uses a nearby swamp for dumping organic domestic wastes and some farmers use its water for irrigating their nearby gardens. Recently, a soap and textile factory was constructed upstream and began releasing untreated hot waste water into the stream flowing through the swamp. After a few months, the community started complaining about accumulation of undecomposed wastes producing a foul smell and also farmers that use the swamp water for crop irrigation complained about stunted growth and poor root development of the crops. Environmental officers from NEMA carried out investigations and made the following reports; presented in the **Table 1.1**.

**Table 1.1:** Effects of contaminated irrigation water on crop roots and microbial activity

| Parameter                                                           | Normal water | Affected swamp water |
|---------------------------------------------------------------------|--------------|----------------------|
| Water temperature (°C)                                              | 20–29        | 45                   |
| pH                                                                  | 6–8          | 4                    |
| Root cell ATP (%) in plants irrigated with swamp water              | 99           | 10                   |
| Root cell mitotic activity (%) in plants irrigated with swamp water | 100          | 18                   |

The officers further noted that the water contained colchicine, a chemical that prevents spindle fiber formation in root cells and also contained inhibitors of enzyme cytochrome oxidase. They recommended the farmers to use organic manure because it contains enzyme activators and the factory to treat and cool its waste water.

##### Task:

- Explain how the data obtained by the NEMA officers from the gardens is related to the farmer's complaints.
- Evaluate the effectiveness of the officers' recommendations to the farmers and the factory.

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##### Item 1.2

In Kasese District, farmers growing tomatoes near an abandoned mining site noticed unusual crop problems. They complained of stunted growth, yellowing leaves, and poor fruit production despite adequate rainfall and fertilizer application. Agricultural scientists from the National Agricultural Research Organization (NARO) and Makerere University School of Agricultural Sciences carried out field and physiological assessments and produced the data shown in **Table 1.2**.

**Table 1.2:** Effects of mining contamination on plant cell function

| Parameter                        | Uncontaminated Soil | Contaminated Soil |
|----------------------------------|---------------------|-------------------|
| Root cell ATP production (%)     | 100                 | 22                |
| Root cell mitotic activity (%)   | 100                 | 28                |
| Chloroplast number per leaf cell | 20                  | 6                 |
| Soil pH                          | 6.8                 | 3.9               |

Laboratory analysis showed the presence of lead and mercury compounds capable of inhibiting mitochondrial enzymes and recommended applying agricultural lime to neutralize soil acidity, introducing phytoremediation plants to remove heavy metals, and relocating food crop production away from contaminated sites.

**Task:**

- Explain how the data obtained from the gardens is related to the farmers' complaints.
- Assess the effectiveness of the proposed recommendations for improving crop productivity.

**KISUBI MAPEERA S.S****Item 1.3**

In Luwero District, a young child named Amina was repeatedly admitted to hospital with recurrent respiratory infections, poor growth, and fatigue. Clinical pathologists and medical geneticists from the referral hospital carried out genetic analysis and epithelial tissue studies and established the results shown in Table 1.3.

**Table 1.3:** Effects of CFTR gene defect on epithelial tissue function

| Parameter                                    | Healthy child | Amina |
|----------------------------------------------|---------------|-------|
| Mitochondrial activity (%)                   | 100           | 15    |
| Water efflux                                 | 100           | 10    |
| Thickness of mucus layer (relative units)    | 1.0           | 5.5   |
| Frequency of respiratory infections per year | 1             | 8     |

Medical specialists concluded that a mutation in the CFTR gene had altered membrane transport proteins reducing movement of chloride ions out of epithelial cells. The specialists recommended initiating gene therapy trials, providing regular chest physiotherapy, and administering medicines to clear the air ways.

**Task**

- Account for how the data obtained from Amina is related to her health problems.
- Critique the effectiveness of the recommendations proposed by the medical specialists.

**MUNYONYO HIGH SCHOOL****Item 1.4**

During a national marathon training camp in Kapchorwa, athletes were introduced to a new energy supplement called "Mega-Boost", which was marketed as being able to increase cellular energy production instantly. However, several athletes who consumed the supplement developed severe muscle fatigue and collapsed during long-distance races, despite maintaining normal blood glucose levels. These unexpected health problems raised concern among the camp organizers and medical staff.

To investigate further, sports physiologists examined the effect of the supplement on aerobic respiration in muscle cells. Laboratory analysis revealed that the supplement directly stimulated the production of ATP and NADH inside the mitochondria. Electron microscopy also showed that prolonged use of the supplement caused swelling of mitochondrial cristae in muscle fibres. The results of these investigations were summarized in Table 1.4.

**Table 1.4:** Effect of 'mega-boost' supplement on muscle cell respiration in athletes

| Parameter                                                          | Normal athlete | Athlete using "Mega-Boost" |
|--------------------------------------------------------------------|----------------|----------------------------|
| ATP concentration in muscle cells ( $\text{mmol kg}^{-1}$ muscle)  | 5.2            | 18.6                       |
| Pyruvate concentration in cytoplasm ( $\text{mmol L}^{-1}$ )       | 3.3            | 1.2                        |
| Lactic acid concentration in muscle cells ( $\text{mmol L}^{-1}$ ) | 1.5            | 14.2                       |
| Rate of lipid breakdown                                            | Moderate       | Very High                  |

Following the collapses, the medical team attempted the following interventions:

- Administering 100% oxygen gas to the collapsed athletes during recovery.
- Feeding the athletes a high-glucose syrup immediately after they collapsed.
- Administering a drug that competitively inhibits fatty acid oxidation (lipid breakdown) before the race.

**Task:**

- Analyze the findings to explain how the Mega Boost supplement led to the severe muscle fatigue and collapse during long-distance races.
- Evaluate the effectiveness of the interventions made by the medical team.

**MADONNA HIGH SCHOOL MUKONO**

**Item 1.5**

A booming cosmetic clinic in Kampala introduced a fast-acting "organic" skin-lightening serum. After two months of use, patients rushed back to the clinic complaining that their skin had become fragile and translucent (superficial blood vessels became more visible), dehydrated, severely blistered, and incapable of healing from minor scratches/wounds.

A dermatologist teamed up with a molecular biologist to investigate the serum's effect on the skin epidermal tissue. The results of the investigations done were then summarized in **Table 1.5**.

To manage the severe side effects in the affected patients and keep the drug on market, the consulting doctors intend to prescribe a topical barrier ointment highly concentrated with synthetic cholesterol to be applied twice daily or perform a mechanical dermabrasion (exfoliation) procedure to scrub away the blistered epidermal layers. The dermatologist however suggested that a synthetic growth factor drug would rather be more helpful as it would strongly stimulate growth of skin basal cells.

**Table 1.5:** Effects of skin-lightening serum on epidermal tissue parameters

| Parameter                                                | Healthy Skin (Pre-treatment) | Affected Skin (Post-treatment) |
|----------------------------------------------------------|------------------------------|--------------------------------|
| DNA Polymerase enzyme activity (units)                   | 45                           | 4                              |
| Cellular cholesterol-to-phospholipid ratio               | 1:1                          | 1:4                            |
| Intracellular water volume                               | Normal                       | Low/decreased                  |
| Proportion of cells stalled in S-phase of cell cycle (%) | <2                           | 68                             |

**Task:**

- Explain how the organic serum caused the observed symptoms in affected patients.
- Evaluate the biological safety of each of the proposed interventions.

**KING FAHAD ISLAMIC INSTITUTE - BUSEGA**

**Item 1.6**

At Kigoma Senior Secondary School, students were housed in newly renovated dormitories with poor ventilation. After several weeks, students complained of frequent headaches, persistent fatigue during sports activities, and slow recovery from minor skin injuries. Following the complaints, occupational health experts from Makerere University School of Biomedical Sciences carried out physiological, microscopic, and molecular investigations and obtained the results shown in the table 1.6.

**Table 1.6:** Effects of poor dormitory air quality on cellular structure, respiration, and cell division

| Parameter                                                      | Normal Students | Affected Students |
|----------------------------------------------------------------|-----------------|-------------------|
| Cytochrome c oxidase activity (%)                              | 100             | 25                |
| ATP production in muscle cells (%)                             | 100             | 35                |
| Mitochondrial density in skeletal muscle cells (per unit area) | 18              | 7                 |
| Mitotic activity in skin epithelial cells (%)                  | 100             | 40                |

The investigators further detected high concentrations of carbon monoxide released from the poorly maintained dormitory heating equipment. They recommended improving dormitory ventilation, replacing faulty heating systems, and conducting regular indoor air quality monitoring.

**Task:**

- Examine how the data obtained from the students is related to their complaints and the conclusions reached by the investigators.
- Weigh up the effectiveness of the recommendations proposed by the scientists.

**STANDARD HIGH SCHOOL ZZANA**

## 2. Plant Physiology and Adaptation

### Item 2.1

In the lowland areas of Nakasongola District, farmers recently started growing tomato plants which are  $C_3$  plants for commercial markets. Some farmers grew their tomato plants in open fields while others grew theirs in greenhouse structures. The farmers who grew tomato plants in open fields complained to the agricultural officer about low crop yields compared to the farmers that grew their tomatoes in green houses. The agricultural officer observed that tomato plants grown in open fields had smaller hairy leaves, and smaller fruits compared to those in greenhouses.

Further investigation of environmental conditions and plants from open space and green house revealed the following data shown in **Table 2.1**.

**Table 2.1:** Environmental Conditions Affecting Tomato Growth in Open Field and Greenhouse Systems

| Condition  | Temperature | Amount of water | Stomatal opening | Hormone levels |
|------------|-------------|-----------------|------------------|----------------|
| Open field | 34°C        | low             | Mostly closed    | ABA high       |
| Greenhouse | 26°C        | High            | Mostly open      | ABA low        |

#### Task:

- Explain how the table data obtained relates to the farmers' complaint.
- Evaluate the effectiveness of using a greenhouse to improve crop yields and assess the effectiveness of the survival strategies exhibited by plants growing under open-field conditions.

KISOZI HIGH SCHOOL

### Item 2.2:

In Kyotera District, Mr. Kato and other maize farmers depend on seasonal rainfall for crop production. During the previous growing season, they planted a mixture of maize varieties in fields that experienced prolonged dry conditions and high temperatures. After harvest, farmers complained of low grain yield, premature leaf wilting, and poor seed germination from harvested grain.

Following the complaints, plant physiologists from the National Agricultural Research Organization (NARO) conducted investigations and obtained the measurements shown in **Table 2.2**.

**Table 2.2:** Effects of drought stress on photosynthesis and plant development

| Parameter                                   | Well-watered field | Drought stressed field |
|---------------------------------------------|--------------------|------------------------|
| Soil moisture (%)                           | 32                 | 9                      |
| Average stomatal aperture ( $\mu\text{m}$ ) | 15                 | 4                      |
| Photosynthetic rate (relative units)        | 100                | 35                     |
| Germination percentage of harvested seeds   | 95                 | 48                     |

The scientists further observed reduced guard cell turgidity and recommended irrigation scheduling, planting drought-tolerant varieties, and applying mulches to conserve soil moisture.

#### Task

- Explain how the data obtained by the scientists is related to the farmers' complaints.
- Assess the effectiveness of the recommendations proposed by the physiologists.

HENRY KASULE MEMORIAL HIGH SCHOOL KAKIRI

### Item 2.3

In Kapchorwa District, Ms. Chemutai manages a coffee plantation located on the slopes of Mount Elgon. In recent years, farmers complained of poor bean development, reduced aroma quality, and low yield. They also observed that some sections of the plantation exposed to direct sunlight throughout the day performed worse than partially shaded areas.

Following the complaints, plant physiologists from Uganda Coffee Development Authority (UCDA) carried out investigations and obtained the measurements shown in **Table 2.3**.

**Table 2.3:** Effects of light exposure on photosynthesis and coffee bean development

| Parameter                                   | Partially Shaded | Full Sun |
|---------------------------------------------|------------------|----------|
| Average stomatal aperture ( $\mu\text{m}$ ) | 14               | 6        |
| Net photosynthetic rate (relative units)    | 100              | 55       |
| Aroma oil concentration (%)                 | 8.5              | 3.2      |
| Mature bean weight (g/100 beans)            | 180              | 95       |

The scientists recommended maintaining shade trees, conserving soil moisture through mulching, and selecting varieties adapted to local climatic conditions.

**Task:**

- Examine how the data obtained from the coffee plantation is related to the farmers' complaints.
- Justify the effectiveness of the recommendations proposed by the scientists.

**KAKUNGULU MEMORIAL SCHOOL****Item 2.4**

A commercial vegetable farmer in Lira grows two leafy crops: a broad-leaved temperate vegetable (Crop P) and a tropical indigenous vegetable (Crop Q).

However, over the past 3 years, Lira region has been struck with a severe heat wave and drought. The farmer has now noticed a strange phenomenon among his crops. Crop P would severely wilt by 1:00 PM every day, with its leaves drooping completely, and its overall yield dropped drastically in over one month. Crop Q, however, maintained stiff leaves throughout the day and had an exceptionally high yield. Concerned about this the farmer took samples of the leaves to an agricultural laboratory. The laboratory tested the internal chemistry of the leaves at 1:00 PM. The results are detailed in Table 2.4.

**Table 2.4:** Physiological leaf responses of temperate and tropical vegetables under heat and drought stress

| Physiological Parameter at 1:00 PM            | Crop P (Temperate)                                | Crop Q (Tropical Indigenous)                 |
|-----------------------------------------------|---------------------------------------------------|----------------------------------------------|
| Endogenous Absciscic Acid (ABA) concentration | 150 $\mu\text{g/g}$ fresh weight (Extremely high) | 15 $\mu\text{g/g}$ fresh weight (Normal/Low) |
| Stomatal pore size                            | Completely closed                                 | Partially open                               |
| Enzyme affinity for Oxygen                    | High                                              | Zero                                         |

The physiological parameters measured are confusing to both the farmer and the lab technician. The lab technician wants to rescue the cultivation of the high-value Crop P and he is proposing the following implementations.

- Installing high-pressure irrigation arrays programmed to spray the canopy of Crop P continuously daily.
- Spraying the leaves of Crop Q with a synthetic chemical anti-transpirant designed to force complete stomatal closure during the morning hours.
- Constructing low-cost plastic greenhouse tunnels and continuously pumping in artificially generated, high-purity carbon dioxide into the

**Task:**

- Analyze the results and data carefully to explain the difference in the activity and yield of the two crop varieties; what caused the problems of severe wilting and drastic drop in overall yield of crop P?
- Evaluate the practical sustainability of each of the implementations proposed.

**VIENNA HIGH SCHOOL KABOWA****Item 2.5**

A commercial farmer in the Doho Rice Scheme usually grows a lowland rice variety in the paddies. Hoping to maximize carbohydrate yield for animal feed, the farmer attempts to intercrop the rice with a high-yielding maize variety. A month after planting, heavy rains cause the fields to remain deeply waterlogged for three weeks. The farmer observed that the rice thrives and continues to grow rapidly, while the maize becomes severely stunted, its leaves turn yellow, and the root system begins to rot.

Plant physiologists analyzed the structures of the lowland rice and the maize to investigate the cause of the difference in survival and the results are summarized in Table 2.5.

**Table 2.5:** Showing adaptations of lowland rice and maize under waterlogged conditions

| Parameter                                    | Lowland Rice | Maize              |
|----------------------------------------------|--------------|--------------------|
| Root tissue Ethylene concentration (nl/g/hr) | 45.2         | 2.1                |
| Root Aerenchyma (air space) volume (%)       | 40           | 5                  |
| Soil oxygen concentration around roots (%)   | Reduced      | Reduced            |
| Bundle sheath PEP carboxylase activity       | 0            | Only 15% of normal |

After the above observations, agricultural officers proposed the following interventions:

- Digging shallow drainage channels in the maize field.
- Use timed planting by targeting the non-rainy seasons.
- Apply moderate artificial nitrogen fertilizers

**Task**

- Analyze the physiological and anatomical data to explain why the maize becomes severely stunted, its leaves turn yellow, and the root system begins to rot.
- Evaluate the proposed interventions on how they could improve crop survival in the Doho Rice Scheme.

**SAVIOUR HIGH SCHOOL KIBOGA**

## SECTION B

### Part I: Analysis of animal systems and behaviours in adapting to environmental changes for health, survival, and welfare

**Item 3.1**

Tere a Canadian athlete travelled to Kapchorwa to train for an upcoming international marathon. In preparation for the travel, he was vaccinated against malaria. On one hot afternoon, he went for training, shortly, he started sweating, his heart rate increased and blood vessels showed all over his skin. He also complained about having a mild headache.

The doctor at the training center hospital examined him and made the following observations; The doctor explained that the mild headache was due to malaria but he will recover without treatment. He also advised him to take a cold shower, and to exercise.

**Table 3.1:** Showing responses of an athlete during training in hot conditions

| Parameter                                 | Tere's results | Reference range |
|-------------------------------------------|----------------|-----------------|
| Body temperature                          | 39°C           | 37°C            |
| Sympathetic nerve impulse firing rate (%) | 80             | 21-37           |
| Memory B-lymphocyte cells (%)             | 90             | 40-60           |
| Number of active sweat glands (%)         | 90             | 10-30           |

**Task:**

- Explain how the observations made are related to Tere's sweating, heart rate and blood vessels showing on the skin.
- Evaluate the doctors advise in treating Tere's symptoms.

**ABUBAKAR SWIDIQ S.S KYANJA**

**Item 3.2**

In Bukedea District, St. Agnes Girls' School uses water from a nearby swamp for irrigation and cleaning. A textile and agro-processing facility upstream discharges untreated waste into the swamp. The community reported allergic skin reactions among students, students experiencing dizziness and irregular heartbeat during physical activity.

Following the complaints, public health experts from the Ministry of Health carried out investigations and obtained the measurements shown in the **Table 3.2**.

**Table 3.2:** Physiological and environmental effects of contaminated swamp water

| Parameter                          | Clean water | Contaminated water |
|------------------------------------|-------------|--------------------|
| pH of the water                    | 7.0         | 4.2                |
| Oxygen dissociation efficiency (%) | 96          | 65                 |
| Histamine concentration (mg/L)     | 0.4         | 7.5                |
| Synaptic transmission speed (ms)   | 90          | 42                 |

Experts concluded that effluents were acidic, and interfered with neuronal coordination. They recommended neutralization of waste, medical antihistamine treatment, and installation of wastewater treatment systems.

**Task:**

- Explain how the data relates to allergic reactions, dizziness and heartbeat irregularities.
  - Evaluate the effectiveness of the recommendations.
- MUWANGUNZI HIGH SCHOOL KYENGERA**

**Item 3.3**

In Masaka District, Kijjabwemi village uses River Nabajuzi for irrigation, livestock watering, and domestic use. A sugar factory upstream releases heated wastewater into the river. Farmers reported livestock showing rapid breathing, increased heart rate, and fish displaying erratic movement before dying. Environmental health experts from NEMA carried out investigations and obtained the measurements shown in the Table 3.3.

**Table 3.3:** Effects of Heated Effluent on Biological Systems

| Parameter                          | Normal river | Affected river |
|------------------------------------|--------------|----------------|
| Water temperature (°C)             | 24           | 44             |
| Oxygen dissociation efficiency (%) | 97           | 72             |
| ADH secretion level                | Normal       | Elevated       |
| Neural impulse speed (ms)          | 10           | 30             |

The officials recommended cooling of effluent, construction of buffer reservoirs, and strict regulation of industrial discharge.

**Task:**

- Explain how the data relates to the reported livestock rapid breathing, increased heart rate, and fish displaying erratic movement before dying.
  - Evaluate the effectiveness of the recommendations.
- IGANGA HIGH SCHOOL**

**Item 3.4**

After attending a 6-hour outdoor music festival characterized by extreme noise levels and heavy alcohol consumption, an 18-year-old student named David was admitted to the school's sickbay. He presented with severe disorientation, inability to walk in a straight line, profound dehydration, and persistent complaints of a constant "ringing" in his ears. These symptoms raised concern about the combined effects of alcohol intake and prolonged exposure to loud noise.

The university nurse assessed David's condition and compared his vital signs and sensory parameters with those of a healthy, sober student who had not attended the concert. The findings highlighted significant physiological and sensory disturbances in David, and the results were summarized in Table 3.4.

**Table 3.4:** Showing effects of alcohol and noise exposure on an athlete

| Parameter                                       | David (Post-Concert & Alcohol)     | Healthy Student |
|-------------------------------------------------|------------------------------------|-----------------|
| ADH Concentration in Blood (pg/mL)              | 0.8                                | 4.5             |
| Heart rate (beats/min)                          | 98                                 | 75              |
| Sensory Hair Cell Integrity in Cochlea          | 35% damaged                        | 0% damaged      |
| Endolymph fluid dynamics in Semicircular Canals | Highly turbulent/Altered viscosity | Normal flow     |

Following his admission, the medical team proposed to give him isotonic saline solution intravenously, oral rehydration salts or plain distilled water and place him in a quiet rehabilitation environment. The attending doctor however later advised that David should quit alcohol to avoid long term complications.

**Task:**

- Explain how variation of David's parameters from those of a healthy student led to his presentation of severe disorientation, inability to walk in a straight line, profound dehydration, and complaints of a constant "ringing" in his ears.
- Evaluate the medical team's proposal in helping David.

**ST. JAMES S.S BUDDO**

**Item 3.5**

A team of researchers from the coastal city of Mombasa (altitude 15m) travelled to the Rwenzori Mountains (altitude 4,500m) for a month-long biodiversity survey. They were guided by a local guide who has lived on the mountain slopes his entire life.

During the first week, one of the coastal researchers, Chevonne, experienced severe dizziness, excessive urination, and muscle cramps, while the local guide, Masereka, remained completely unaffected. The expedition's medical officer recorded their physiological parameters during a steep climb at 10°C, as shown in Table 3.5.

**Table 3.5:** Physiological adaptations to high altitude in coastal and mountain residents

| Parameter                             | Chevonne (Coastal Resident) | Masereka (Local Guide) |
|---------------------------------------|-----------------------------|------------------------|
| Blood oxygen saturation (%)           | 81                          | 94                     |
| ADH levels in blood (pg/mL)           | 1.2                         | 4.5                    |
| Core body temperature (°C)            | 36.8                        | 37.1                   |
| Red blood cell count (cells/ $\mu$ L) | $4.8 \times 10^6$           | $6.5 \times 10^6$      |

Following the incident, the medical officer suggested to offer Chevonne a highly concentrated glucose solution and offer 100% oxygen therapy via nasal prongs. The escort nurse also suggested that Amina should just have some rest for some time while at the mountain before continuing with the survey.

**Task:**

- Analyze the physiological mechanisms responsible for Chevonne's observed symptoms.
- Evaluate the suggestions being offered by the medical officer and nurse in helping improve the health of Chevonne.

**ST. ELIZABETH GIRLS SEC. SCHOOL - MITYANA**

**Item 3.6**

During the dry season in Murchison Falls National Park, a team of wildlife researchers and tourists became stranded for several hours near a rocky grassland zone after unexpectedly disturbing a large swarm of African honey bees. Two individuals, Leah and Daniel, sustained multiple bee stings. Within minutes, Leah developed severe facial swelling, difficulty in breathing, dizziness, and extreme pain. Daniel developed only localized swelling and intense pain around the sting sites.

The park emergency response officer rushed the two victims to a clinic where immediate first aid was administered. Leah received an intramuscular adrenaline injection, while Daniel was given an ice-cold compress placed over the swollen regions. Fifteen minutes later, clinicians compared the physiological responses of the two individuals with healthy baseline values as shown in Table 3.6.

**Table 3.6:** Physiological responses to bee stings and treatment compared to healthy baseline

| Parameter                                                 | Daniel (After Ice-cold Compress) | Leah (after Adrenaline) | Healthy Baseline |
|-----------------------------------------------------------|----------------------------------|-------------------------|------------------|
| Blood Histamine concentration (ng/mL)                     | 4.2                              | 16.0                    | 0.3 - 1.0        |
| Heart rate (beats/min)                                    | 84                               | 110                     | 70-80            |
| Action potential frequency in sensory pain receptors (Hz) | 25                               | 45                      | 0-5              |
| Rate of sweating (ml/hr)                                  | 42                               | 95                      | 30               |

Both victims however are complaining of intense pain which did not reduce even with the first aid given but the pain intensity is higher for Leah than for Daniel. The attending nurse therefore proposes to administer antihistamine drugs.

**Task:**

- Explain how Leah and Daniel were affected by the honey bees.
- Evaluate the effectiveness of the different first aid measures given to the victims and how the nurse's new proposal would bring about a change.

**ONWARDS AND UPWARDS**

**Item 3.7**

The Black Coffee Twig Borer (*Xylosandrus compactus*) is causing severe damage to Robusta coffee plantations in Mukono District, leading to significant yield losses. In an attempt to control the pest without using chemical insecticides, agricultural researchers are testing a mating disruption technique that involves releasing synthetic female pheromones to interfere with normal male mating behavior.

Male twig borers were placed in a controlled flight tunnel and exposed to varying concentrations of the synthetic pheromone to determine how sensory reception in the antennae influences their behavior. electrical activity in antennal chemoreceptors and subsequent flight responses were recorded under different stimulus levels. Results are summarized in **Table 3.7**.

**Table 3.7:** Male twig borer responses to pheromone concentrations

| Pheromone concentration (ppm) | Antennal receptor potential amplitude (mV) | Sensory neurone action potential frequency (Hz) | Male behaviour observed                    |
|-------------------------------|--------------------------------------------|-------------------------------------------------|--------------------------------------------|
| 0.0                           | -70                                        | 0                                               | Random flight                              |
| 0.5                           | -45                                        | 40                                              | Directed flight toward source              |
| 5.0                           | -20                                        | 120                                             | Frantic circling, failure to locate source |
| 50.0                          | -15                                        | 150                                             | Dropping                                   |

**Task**

- Analyze the data collected and explain the effect of the pheromones on the neural and behavioral responses observed in the male twig borer. Assess the complete cessation of flight observed at 50.0ppm pheromone concentration.
- Evaluate the effectiveness of pheromone-based behavioral disruption as an integrated pest management strategy for coffee farmers. Propose and evaluate other better strategies that could help the coffee farmers in Mukono.

**KING FAISAL BBUYE ISLAMIC S.S**

## **Part II: Inheritance, Evolutionary trends and ecological dynamics**

**Item 4.1**

Mataba cattle farm has been the leading beef producing farm in Mbarara district for the last 10 years. This is partly attributed to the two pure varieties of grasses **A** and **B** grown on the farm that provide food for the cattle.

Of recent, the farm is facing a problem of lack of feeds due to prolonged drought and attack by pests in the rainy season that destroys the grasses. However, the farm manager noticed that variety **A** was resistant to drought but not the pest while **B** was resistant to pests but not drought.

At the beginning of the rainy season, they sprayed the pests using a pesticide but people complained about food poisoning after eating the meat. This prompted officers from national agriculture organization (NARO) to carry out investigations and the patients were examined.

The following observation were made:

- Drought resistance was controlled by a dominant allele **D** in variety A while pest resistance was controlled by a dominant allele **R** in variety B
- There was a significant reduction in the number of cattle.

Further analysis of the meat is shown in **Table 4.1**.

**Table 4.1:** Pesticide residue levels in grass, meat, and patients from Mataba cattle farm

| Parameter                | Grass | Meat | Patients |
|--------------------------|-------|------|----------|
| Amount of pesticide(ppm) | 200   | 300  | 800      |

The officers recommended controlled breeding of the two grass varieties, irrigation and use biological pest control to improve feed production and food security.

**Task:**

- Using a genetic cross explain how the two grass varieties can be improved and how pesticide use led to people's complaints.
- Evaluate the effectiveness of the officers' recommendation to improve feed production and food security.

**LUKWANGA S.S**

**Item 4.2**

In Mbale District, near the slopes of Mount Elgon, a community practices mixed farming and also harvests insects such as caterpillars and locusts as a protein source. The area includes forest patches undergoing rapid deforestation. Farmers reported grumbles of unpredictable rainfall leading to poor crop germination, reduced insect availability affecting food security, and emergence of abnormal crop traits such as dwarf maize plants and irregular leaf patterns.

Following the complaints, evolutionary ecologists from Makerere University conducted investigations and recorded the results in **Table 4.2**.

**Table 4.2:** Effects of land-use change on plant genetics and insect population dynamics

| Parameter                              | Forested area | Deforested area |
|----------------------------------------|---------------|-----------------|
| Frequency of dwarf allele (d) in maize | 0.2           | 0.7             |
| Insect metamorphosis success (%)       | 90            | 45              |
| Species richness index                 | 8.5           | 3.2             |
| Soil moisture content (%)              | 35            | 12              |

Researchers recommended reforestation of buffer zones, conservation of insect breeding habitats, and controlled selective breeding of crops to stabilize allele frequencies and improve resilience.

**Task:**

- Explain how the results relate to genetic variation in maize, insect development, and ecosystem instability.
- Evaluate the effectiveness of the recommended interventions in restoring ecological balance and genetic stability.

**ENTEBBE GIRLS SCHOOL**

**Item 4.3**

In Gulu District, communities collect wild edible insects such as grasshoppers and termites for food security. Recently, a pesticide intensive farming system was introduced nearby to control crop pests. Farmers reported decline in edible insect populations, increased pest resistance to pesticides, and reduced soil fertility affecting crop productivity.

Following the complaints, evolutionary biologists and environmental toxicologists from Gulu University conducted investigations and obtained the data shown in **Table 4.3**.

**Table 4.3:** Effects of pesticide use on insect evolution, soil ecology, and crop productivity

| Parameter                                              | Low pesticide use area | High pesticide use area |
|--------------------------------------------------------|------------------------|-------------------------|
| Resistant allele frequency in pests                    | 0.2                    | 0.85                    |
| Edible insect population density (per m <sup>2</sup> ) | 150                    | 40                      |
| Soil nitrogen content (%)                              | 1.8                    | 0.6                     |
| Crop yield index                                       | 80                     | 45                      |

Researchers concluded that there was strong selection pressure from pesticides, and reduced soil microbial activity. They suggested integrated pest management, reduction of chemical pesticide use, and promotion of ecological farming practices to restore biodiversity and genetic balance.

**Task:**

- Explain how the data relates to pest resistance evolution, decline in edible insects, and reduced soil fertility.
- Evaluate the effectiveness of the proposed interventions in restoring genetic diversity, ecological stability, and agricultural productivity.

**BOSTON HIGH SCHOOL**

**Item 4.4**

In Soroti District, a cattle-keeping and crop-farming community relies on a nearby lake that also supports diverse fish species and aquatic insect larvae. Recently, a new irrigation scheme diverted water from the lake for large-scale farming. Farmers reported reduced fish catches affecting protein supply, poor crop performance due to saline irrigation water, and increased algal blooms causing foul smell and water discoloration.

Following the complaints, ecological geneticists and aquatic biologists from the Fisheries Research Institute conducted investigations and obtained the results in **Table 4.4**.

**Table 4.4:** Effects of water diversion on fish genetics, plant growth, and aquatic ecology

| Parameter                    | Natural lake | Irrigated lake |
|------------------------------|--------------|----------------|
| Oxygen concentration (mg/L)  | 8            | 2              |
| Fish genetic diversity index | 0.78         | 0.32           |
| Algal biomass (mg/L)         | 15           | 90             |
| Crop yield index             | 85           | 40             |

They suggested controlled water abstraction, reduction of fertilizer runoff, and conservation of breeding fish populations to maintain genetic diversity and ecosystem balance.

**Task:**

- Explain how the data relates to reduced fish populations, poor crop yields, and water quality deterioration.
- Evaluate the effectiveness of the recommendations in addressing ecological degradation and genetic loss.

**BUDDO CHRISTIAN S.S**

**Item 4.5**

In Namutumba District, farmers cultivate rice in wetlands that also serve as breeding grounds for mosquitoes and dragonflies. Recently, a nearby agro-processing plant began discharging warm effluent into the wetland. Farmers reported complaints of reduced rice yields, increased mosquito populations causing malaria outbreaks, and disappearance of predatory insects affecting ecological balance.

Following the complaints, environmental physiologists and geneticists from the Ministry of Agriculture, Animal Industry and Fisheries conducted investigations and obtained the data is shown in **Table 4.5**.

**Table 4.5:** Effects of industrial discharge on plant physiology, insect populations, and wetland ecology

| Parameter                                          | Upstream wetland | Polluted wetland |
|----------------------------------------------------|------------------|------------------|
| Rice root mitotic index (%)                        | 98               | 35               |
| Mosquito larval survival (%)                       | 40               | 85               |
| Dragonfly population density (per m <sup>2</sup> ) | 60               | 15               |
| Water temperature (°C)                             | 22               | 38               |

The officers concluded that there was high temperature and toxic effluents, and they recommended installation of effluent cooling systems, biological mosquito control using predators, and restoration of wetland vegetation to stabilize genetic and ecological processes.

**Task:**

- Explain how the data relates to rice growth defects, insect population shifts, and wetland ecological imbalance.
- Evaluate the effectiveness of the proposed solutions in restoring ecosystem stability and agricultural productivity.

**VERONA HIGH SCHOOL MUTUNDWE****Item 4.6**

Lake Victoria has for many years been affected by the rapid spread of water hyacinth (*Eichhornia crassipes*), which blocks fishing routes and lowers oxygen levels in water. To reduce the weed, fisheries authorities introduced *Neochetina* weevils as biological control agents because both larvae and adults feed on the water hyacinth.

Initially, the weevil population increased and the weed coverage declined. However, a few years later, a fungal disease outbreak severely reduced the weevil population, leading to rapid re-expansion of the water hyacinth in several parts of the lake. Researchers later discovered that some weevils possessed a recessive allele, *r*, which gives resistance to the fungal pathogen, while the dominant allele, *R*, leaves the weevils susceptible to infection.

A district fisheries research team monitored changes in the weevil population and water hyacinth biomass for four years after the fungal outbreak. The data collected are shown in Table 4.6.

**Table 4.6:** Impact of fungal disease on weevil survival and water hyacinth biomass in Lake Victoria

| Year | Total Weevils Sampled | Number of Surviving Susceptible Weevils | Water Hyacinth Biomass (tons/ha) |
|------|-----------------------|-----------------------------------------|----------------------------------|
| 2022 | 10,000                | 6,400                                   | 15.2                             |
| 2023 | 8,500                 | 4,335                                   | 28.5                             |
| 2024 | 6,000                 | 2160                                    | 45.0                             |
| 2025 | 5,500                 | 1,045                                   | 55.3                             |

In order to save the local fishing economy, the fisheries department are planning on the following course of action.

- Spraying the entire lake surface with a strong chemical fungicide to completely kill off the fungal pathogen and protect the remaining weevils.
- Hiring local youth to manually harvest and pull the water hyacinth out of the lake.
- Encouraging fish farming and stop reliance on the lake for fishing.

**Task:**

- Apply the Hardy-Weinberg principle to determine the change in frequency of the resistance allele (*r*) from 2022 to 2025. Evaluate how the resulting genetic and population changes affect ecosystem balance in Lake Victoria.
- Evaluate the course of action being planned by the fisheries department and recommend accordingly.

**SUMAYYA GIRLS HIGH SCHOOL NSANGI****Item 4.7**

In the Doho Wetlands in Butaleja District, integrated rice-fish farming supports local food security. However, farmers have increasingly applied persistent organochlorine pesticides to combat rice pests. Recently, local *Oreochromis niloticus* (Nile Tilapia) populations have suffered massive die-offs from Epizootic Ulcerative Syndrome (**EUS**). Fisheries geneticists discovered that fast growth rate (**G**) is dominant over slow growing, resistant tilapia with slow-growing, susceptible tilapia yielded an unexpected distribution of offspring as shown below.

- Fast-growing, **EUS** resistant - 415
- Slow-growing, **EUS** susceptible - 405
- Fast-growing, **EUS** susceptible - 90
- Slow-growing, **EUS** resistant - 93

To study the overall effect of the persistent organochlorine pesticides on the water ecosystem, ecologists investigated Trophic Energy and Pesticide Residues in different organisms as seen in Table 4.7.

**Table 4.7:** Trophic energy flow and organochlorine residue accumulation in Doho wetland rice–fish ecosystem

| Organism                   | Net Energy Assimilation (kJ/m <sup>2</sup> /year) | Mean Organochlorine Residue (mg/kg) |
|----------------------------|---------------------------------------------------|-------------------------------------|
| Phytoplankton & Rice Algae | 85000                                             | 0.05                                |
| Zooplankton                | 8100                                              | 0.65                                |
| Small Juvenile Tilapia     | 760                                               | 4.80                                |
| Mature Nile Tilapia        | 68                                                | 38.50                               |

**Task:**

- Analyze the data provided and describe the inheritance pattern that led to the observed offsprings and explain the pattern of energy flow and pesticide distribution across the organisms.
- Propose and evaluate sustainable intervention policies for the Doho community that addresses both genetic stock enhancement and wetland ecological stability to guarantee long-term food security.

**LIVING HOPE CHRISTIAN HIGH SCHOOL**

**Item 4.8**

A newly established tea processing plant has for several years discharged untreated effluent into River Mpanga. The local fishermen reported declining fish catches, foul-smelling water and gradual disappearance of some aquatic insects near the factory outflow over the years. The concern raised led to ecologists investigating the population dynamics of selected aquatic organisms at different distances from the outflow as they believed these organisms had varying tolerance to industrial discharges. The surveys conducted revealed that, over the years, sections nearest the outflow became dominated by chironomid larvae, while the mayfly larvae remained restricted mainly upstream regions. The investigational data are summarized in Table 4.8.

**Table 4.8:** Impact of industrial effluent on aquatic organism populations in River Mpanga

| Distance from outflow (km) | Mayfly nymph density (per m <sup>2</sup> ) | Chironomid larvae density (per m <sup>2</sup> ) | Algal biomass (g/m <sup>2</sup> ) | Fish biomass (kg/ha) |
|----------------------------|--------------------------------------------|-------------------------------------------------|-----------------------------------|----------------------|
| -2 upstream                | 350                                        | 20                                              | 15                                | 120                  |
| 0 outflow                  | 0                                          | 850                                             | 180                               | 5                    |
| 5 downstream               | 15                                         | 500                                             | 120                               | 25                   |
| 15 downstream              | 180                                        | 80                                              | 45                                | 85                   |

In order to restore River Mpanga, district environmental officers proposed the following interventions:

- Installation of an effluent treatment plant before wastewater enters the river.
- Restoration of riverbank vegetation.
- Controlled restocking of native fish species.

**Task:**

- Analyse the provided information to explain the impact of the processing plant on the water ecosystem and how this led to observed evolutionary changes.
- Evaluate the water restoration strategies being proposed by the district environmental officers.

**JANAN SCHOOL BOMBO**

## P530/2 BIOLOGY PAPER 2 (PRACTICAL)

### 1. Comparative Observational investigation: Biological structures and Microscopy

#### Item 1.2.1

At the end of the first term, Peter left his leather suitcase in the dormitory and went home for the holidays. On returning for the second term, he opened the suitcase and a rat jumped out. The suitcase was torn, with cockroaches hiding among his books and partly eaten potato crisps inside. Disturbed, Peter reported the matter to the warden, who referred it to the headteacher.

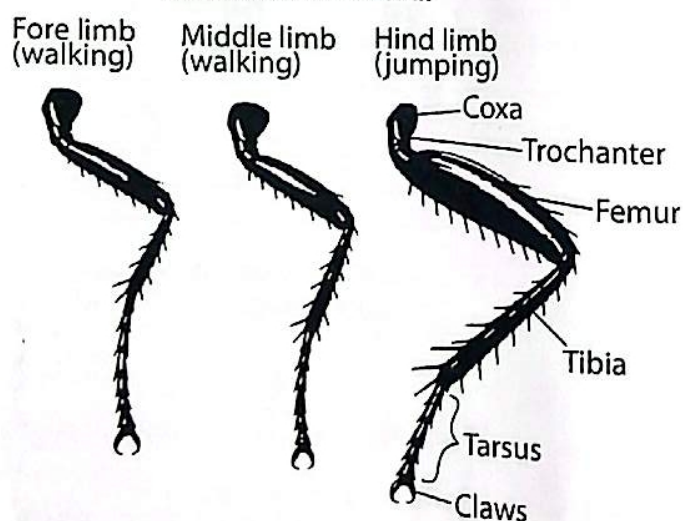
The headteacher called a pest control expert, who fumigated the dormitory and set traps that caught several rats. To help students understand the biology of the infestation, the headteacher invited the biology teacher to explain during assembly.

Using a trapped rat and charts of cockroach mouthparts and limbs, the teacher showed how both animals feed on potato crisps because the tissues store food visible under a microscope. He explained that the rat escaped quickly due to the size and efficiency of its locomotory structures. To illustrate, he displayed drawings of cockroach limbs, the cockroach heart, and a table of limb measurements.

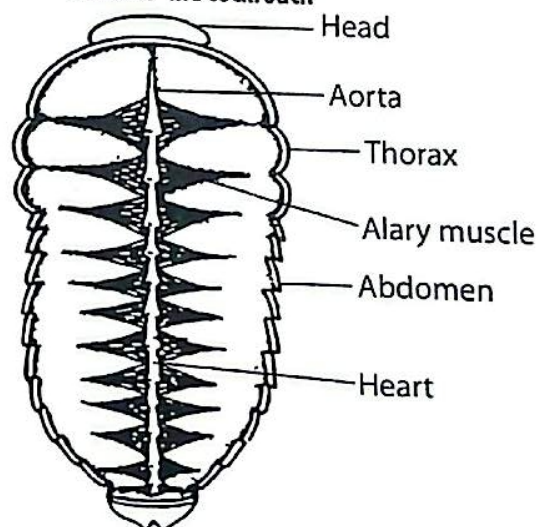
**Table 1.2.2:** Showing the relative length and thickness of limbs.

| Limb Type   | Relative Length (cm) | Relative Thickness (mm) |
|-------------|----------------------|-------------------------|
| Fore limb   | 1.5                  | 1.5                     |
| Middle limb | 2.0                  | 2.0                     |
| Hind limb   | 2.8                  | 3.0                     |

**A drawing showing structures of the fore, middle and hind limbs of a cockroach**



**A drawing showing structure of the heart of the cockroach**



The headmaster and students were not convinced and needed a detailed explanation so as to completely eliminate rats and cockroaches from the dormitory.

You are provided with a rat (specimen X), a potato tuber (specimen Y), and other apparatus to help the headmaster and students interpret the message of the biology teacher to their satisfaction.

- Observe the locomotory structures of the rat and dissect it to display the transport structures supplying the limbs. Draw and label these structures, and explain the teacher's findings.
- Using a microscope, draw and label three representative structures of the stem of specimen Y to show why the crisps were described as dietary food for rats and cockroaches.
  - From your drawings, explain why the observed structures are considered dietary food for these pests.

### Item 1.2.2

A researcher at a Ugandan university investigated the factors influencing the survival of rats in grassland and newly metamorphosed common toads that dispersed from an adjacent wetland into the same grassland habitat over a four-months period. During the investigation, the researcher observed that the survival rate of common toads was drastically lower than that of the rats.

The researcher hypothesized that the observed difference in survival rates of the two animals was partly associated with differences in the relative length of their digestive organs and dietary differences.

Field observations showed that both animals fed largely on invertebrates found in the grassland. However, the rats also fed on wild starch-rich tubers similar to specimen C whereas the adult common toads remained entirely carnivorous. The tubers similar to specimen C contain specialized food-storage structures that can be identified microscopically after staining with a suitable reagent. These observations indicate adaptations to survival.

To further investigate these adaptations, the researcher obtained data from a freshly killed common toad, he recorded it in table 1 and he intended to collect corresponding data from a freshly killed rat (specimen E). However, the investigation was never completed.

**Table 1.2.2:** Showing length of digestive organs of a toad and a rat

| Parts of digestive system                                         | Toad | Rat |
|-------------------------------------------------------------------|------|-----|
| Stomach (length in mm)                                            | 48   |     |
| Ileum (length in mm)                                              | 150  |     |
| Hind gut (length in mm)<br>(Measured from end of small intestine) | 58   |     |

The researcher also made drawings of the measured structures for a toad. To complete the investigation, there is need to compare data for the two animals together with drawings for the rat. You are therefore required to complete the investigation by obtaining data from specimen E together with making drawings. You are provided with a freshly killed rat labelled E,

#### Task:

- Obtain data from specimen E and complete table 1.  
(Your responses should include a procedure for carrying out the dissection)
- Provide microscopically obtained evidence to support of the nutritional advantage of this food source the rats have over toads in the grassland.
- Analyze the findings from this whole investigation (your data and the researcher's data), to justify the differences in the survival abilities of the common toad and specimen E (rat).

## 2. Scientific investigations

### Item 2.2.1

Farmers in eastern Uganda are adopting new agricultural practices by introducing the water lily as a commercial cash crop. This interest is based on the fact that the underground stem, known as the rhizome, acts as a storage organ for food that can be consumed by people. During a community meeting, one farmer noted that although the water lily is an aquatic plant, not all lakes in the region are suitable for its growth. He suggested that they seek guidance from an agricultural officer to understand the proper methods of planting the crop.

The agricultural officer explained that the suitability of different lakes depends on the concentration of salts in the water, which influences the nature of the water and the growth of the plant. He advised the farmers to collect water samples from various lakes and pour measured amounts into large graduated basins. In each basin, they should plant water lily specimens, record the initial length of the rhizome using a thread for accuracy, and cover the basins partially to reduce water loss.

The officer emphasized that the farmers should monitor growth weekly by measuring the length of the rhizome in each basin and recording the water volume. These observations would help them determine which lakes provide the most favorable conditions for cultivating the water lily.

To save time, the officer also suggested a laboratory method. Cylinders of Irish potato tuber tissue, each 5 cm long and cut using a cork borer of 0.5 cm diameter, could be placed in the different water samples. This would simulate plant tissue response and reduce the investigation time by about forty minutes.

### Task

You have been provided with an Irish potato tuber stem, water samples labeled **A, B, C, D, E, and F** collected from different lakes, a cork borer, and other necessary apparatus. Carry out an investigation to help the farmers determine which water samples are most suitable for planting the water lily.

### Item 2.2.2

Joan is piloting a project in which she intends to generate and use the gas for study in a school laboratory. She produces the gas by the catalytic breakdown of solution **P** under constant temperature. She was advised to use an enzyme which is obtained from plant extracts.

Joan obtains her enzyme from extract **C** which is obtained by mixing 4 g of peeled and crushed Irish potato with 50 cm<sup>3</sup> of distilled water, the mixture is stirred and decanted.

However, she first needs to find out whether the extracts on market labelled as **A** and **B** could produce more gas per unit time than her local extract **C**.

To further increase the rate of gas production, Joan was advised by experts to add an enzyme activator in her set up. Currently there are two types of enzyme activators on the market; activator **X** and **Y**, and she needs to be guided on which one increases gas production in her case.

You are provided with a sample of solutions **P**, enzyme activators **X** and **Y**, enzyme extracts **A** and **B** then specimen **C** from which Joan prepared her enzyme extract **C**. Joan needs guidance on how to select the appropriate materials for her gas production.

### Task:

Design and carry out an investigation then use your findings to give appropriate advice to Joan in form of a report. (Your response should be in form of a scientific report).

**END**

*We extend our heartfelt wishes to all learners for great success in the forthcoming UNEB examinations. May your dedication and hard work open doors to rewarding futures in Medicine, Surgery, Nursing, Dentistry, and other Biology-related fields. Continue to pursue excellence with confidence, and may your aspirations be fulfilled – Biology Department, Buddo Secondary School.*