**THE UNINTED REPUBLIC OF TANZANIA**

**MINISTRY OF EDUCATION AND CULTURE**

**ADVANCED CERTIFICATE OF SECONDARY EDUCATION EXAMINATION**

**133/2** **BIOLOGY 2**

**Time: 2:30 Hours** **ANSWERS** **Year: 2009**

**Instructions:**

1. this paper consists of six questions
2. answer five questions
3. Each question carries twenty marks.







***Prepared by: Maria Marco for TETEA***

1. (a) Distinguish bacterial cells from trypanosomes on the basis of the following features:

(i) Size of the cells
- Bacterial cells are generally smaller, ranging from 0.1 to 5 micrometers in size.
- Trypanosomes are larger, ranging from 20 to 30 micrometers in length.

(ii) Outer boundary material
- Bacterial cells are surrounded by a rigid cell wall made of peptidoglycan.
- Trypanosomes lack a cell wall and have a flexible pellicle made of microtubules under the plasma membrane.

(iii) Locomotive structures
- Bacterial cells move using flagella or pili.
- Trypanosomes use a single flagellum attached to an undulating membrane for movement.

(iv) Type of hereditary materials and their location
- Bacterial cells have circular DNA located in the nucleoid region, with no membrane-bound nucleus.
- Trypanosomes have linear DNA housed in a well-defined nucleus.

(v) Organelle for respiration
- Bacterial cells lack membrane-bound organelles and perform respiration on their plasma membrane.
- Trypanosomes have mitochondria where cellular respiration occurs.

(vi) Organelle for synthesis of protein
- Bacterial cells synthesize proteins using 70S ribosomes found freely in the cytoplasm.
- Trypanosomes use 80S ribosomes, both in the cytoplasm and attached to the endoplasmic reticulum.

(vii) Organelle for transport of lipids and proteins
- Bacterial cells lack membrane-bound organelles for transport; all processes occur in the cytoplasm.
- Trypanosomes have an endoplasmic reticulum and Golgi apparatus for the transport of lipids and proteins.

(viii) Ability to utilize atmospheric nitrogen
- Some bacteria, like nitrogen-fixing bacteria, can utilize atmospheric nitrogen through nitrogenase enzymes.
- Trypanosomes cannot fix nitrogen and rely on their host for nutrients.

(b) Draw a large, well-labeled diagram of a typical plant cell as seen under an electron microscope. Underline the labels for structures that differentiate it from a typical animal cell.

Description:
A typical plant cell, as observed under an electron microscope, exhibits various organelles and structures. Key components include:
i. Cell Wall: A rigid outer layer composed of cellulose, providing structural support and protection.

ii. Plasma Membrane: A semi-permeable membrane located just beneath the cell wall, regulating the movement of substances into and out of the cell.
iii. Nucleus: A membrane-bound organelle containing the cell's genetic material (DNA) and responsible for controlling cellular activities.
iv. Nucleolus: A dense region within the nucleus where ribosomal RNA (rRNA) synthesis occurs.
v. Cytoplasm: A gel-like substance filling the cell, in which organelles are suspended and various metabolic reactions occur.
vi. Chloroplasts: Organelles containing chlorophyll, responsible for photosynthesis.

vii. Large Central Vacuole: A prominent, membrane-bound sac occupying a significant portion of the cell's volume, involved in storage and maintaining turgor pressure.
viii. Mitochondria: Organelles responsible for energy production through cellular respiration.

ix. Endoplasmic Reticulum (ER):
- Rough ER: Studded with ribosomes; involved in protein synthesis and transport.
- Smooth ER: Lacks ribosomes; involved in lipid synthesis and detoxification processes.

x. Golgi Apparatus: A stack of membrane-bound sacs involved in the modification, sorting, and packaging of proteins and lipids for secretion or delivery to other organelles.
xi. Ribosomes: Small structures, either free-floating in the cytoplasm or attached to the rough ER, responsible for protein synthesis.
xii. Plasmodesmata: Channels between adjacent plant cells that allow for transport and communication.

Note: The underlined structures—cell wall, chloroplasts, large central vacuole, and plasmodesmata—are unique to plant cells and distinguish them from typical animal cells.

2. (a) (i) Define the term 'differentiation.'

Differentiation is the biological process by which unspecialized cells, such as stem cells, undergo specific changes to become specialized in structure and function. This process involves the selective activation and repression of genes, leading to the development of distinct cell types with unique roles within an organism.

(ii) What is the significance of differentiation in the organisms in which it occurs?

Differentiation is crucial for the development, growth, and maintenance of multicellular organisms. Its significance includes:
Formation of Specialized Tissues and Organs: Through differentiation, cells develop into various types, such as muscle cells, nerve cells, and blood cells, each performing specific functions necessary for the organism's survival.
Efficient Functioning: Specialized cells are adapted to perform their functions more efficiently than unspecialized cells, contributing to the overall efficiency of biological processes.
Developmental Processes: Differentiation is essential during embryonic development, guiding the formation of complex body structures from a single fertilized egg.

Regeneration and Repair: In adults, differentiation allows for the replacement and repair of damaged tissues, maintaining the integrity of the organism.

(b) Describe the structure of a:

(i) Mitochondrion
A mitochondrion is a double-membrane-bound organelle found in most eukaryotic cells, often referred to as the "powerhouse" of the cell due to its role in energy production. Its structure includes:
Outer Membrane: A smooth membrane that encloses the organelle, serving as a barrier between the cytosol and the mitochondrial environment.

Inner Membrane: Highly folded into structures called cristae, which increase the surface area for biochemical reactions involved in energy production.

Intermembrane Space: The region between the outer and inner membranes.

Matrix: The innermost compartment containing enzymes, mitochondrial DNA, and ribosomes, where the Krebs cycle occurs.

(ii) Chloroplast
Chloroplasts are double-membrane-bound organelles found in plant cells and certain algae, responsible for photosynthesis. Their structure includes:
Outer Membrane: A smooth membrane that encloses the organelle.
Inner Membrane: Encloses the stroma and the thylakoid system.
Stroma: A fluid-filled matrix containing enzymes, chloroplast DNA, ribosomes, and starch granules.
Thylakoids: Flattened, disc-like structures stacked into grana; the thylakoid membranes contain chlorophyll and are the sites of the light-dependent reactions of photosynthesis.

(c) Why are chloroplasts and mitochondria said to be 'cells within cells'?
Chloroplasts and mitochondria are often referred to as "cells within cells" due to several characteristics that suggest they originated from free-living prokaryotic organisms through an evolutionary process known as endosymbiosis:
Own Genetic Material: Both organelles contain their own DNA, which is circular and resembles bacterial DNA.
Ribosomes: They possess their own ribosomes, similar in size and structure to those found in bacteria.
Double Membranes: The presence of double membranes is consistent with the engulfing mechanism proposed in endosymbiotic theory.

Reproduction: They replicate independently within the cell through a process akin to binary fission, similar to bacterial division.

These features support the idea that mitochondria and chloroplasts were once independent prokaryotic organisms that entered into a symbiotic relationship with ancestral eukaryotic cells, eventually becoming integral components of modern eukaryotic cells.

3. (a) With the aid of a well-labeled diagram, describe the structure of the membranous labyrinth of the mammalian inner ear.

The membranous labyrinth is a complex system of fluid-filled membranous sacs and ducts located within the bony labyrinth of the inner ear. It plays a crucial role in the senses of hearing and balance. The membranous labyrinth is filled with endolymph and is surrounded by perilymph, which separates it from the enclosing bony labyrinth.

Components of the Membranous Labyrinth:

- Cochlear Duct (Scala Media):
  A spiral-shaped tube within the cochlea responsible for hearing.
  Contains the organ of Corti, which houses sensory hair cells that transduce sound vibrations into neural signals.

- Semicircular Ducts:
  Three loop-shaped structures (anterior, posterior, and lateral) oriented perpendicularly to each other.
  Detect rotational movements of the head (angular acceleration).
  Each duct has an enlarged region called the ampulla, which contains the crista ampullaris—a sensory organ that responds to head movements.

- Utricle and Saccule:
  Two interconnected sacs located within the vestibule.
  Detect linear movements and the position of the head relative to gravity (linear acceleration).
  Each contains a macula, a sensory region with hair cells embedded in a gelatinous layer topped with otoliths (calcium carbonate crystals) that enhance sensitivity to movement.

- Endolymphatic Duct and Sac:
  A narrow duct that connects the utricle and saccule to the endolymphatic sac.
  Involved in the regulation of endolymphatic fluid volume and pressure.

(b) What is the significance of the refractory period during nerve impulse transmission?

The refractory period is a critical aspect of nerve impulse transmission, ensuring proper signal propagation and neural function. Its significance includes:

- Unidirectional Propagation:
  The refractory period prevents the backward propagation of action potentials along an axon, ensuring that nerve impulses travel in a single direction—from the neuron's cell body toward the synaptic terminals.

- Regulation of Firing Frequency:
  By imposing a mandatory interval between action potentials, the refractory period limits the maximum frequency at which a neuron can fire. This regulation prevents the overstimulation of neurons and allows for the proper encoding of information.

- Discrete Impulse Generation:
  The refractory period ensures that each action potential is a separate, distinct event. This separation prevents the overlapping of action potentials, allowing the nervous system to transmit clear and discrete signals.

4. (a) Main Features of:

(i) Autotrophic Nutrition
Autotrophic nutrition is a mode of nutrition in which organisms synthesize their own organic molecules from simple inorganic substances. The main features include:
Energy Source: Autotrophs utilize external energy sources to drive the synthesis of organic compounds.
Photoautotrophs: Use light energy through photosynthesis (e.g., plants, algae).
Chemoautotrophs: Obtain energy from chemical reactions involving inorganic molecules through chemosynthesis (e.g., certain bacteria).
Carbon Source: Carbon dioxide ($CO_2$) is the primary carbon source for building organic molecules.

Examples: Green plants, cyanobacteria, and some protists.

(ii) Heterotrophic Nutrition
Heterotrophic nutrition is a mode of nutrition in which organisms obtain organic molecules by consuming other organisms or their by-products. The main features include:
Energy and Carbon Source: Heterotrophs rely on complex organic substances for both energy and carbon.

Modes of Consumption:
Holozoic: Ingest solid food particles (e.g., animals).

Saprophytic: Absorb nutrients from decomposing organic matter (e.g., fungi, certain bacteria).
Parasitic: Derive nutrients from a host organism, often causing harm (e.g., tapeworms, some protozoa).

Examples: Animals, fungi, and most bacteria.

(b) Components of:
(i) Pancreatic Juice

Pancreatic juice is a vital digestive fluid secreted by the pancreas into the duodenum. Its components include:
Digestive Enzymes:
Proteases: Such as trypsinogen and chymotrypsinogen, which are activated in the small intestine to digest proteins.
Pancreatic Amylase: Breaks down carbohydrates into simple sugars.
Pancreatic Lipase: Digests fats into fatty acids and glycerol.
Nucleases: Degrade nucleic acids into nucleotides.

Bicarbonate Ions ($HCO_3^-$): Neutralize the acidic chyme from the stomach, providing an optimal pH for enzyme activity.

(ii) Bile
Bile is a digestive fluid produced by the liver and stored in the gallbladder, released into the duodenum. Its components include:

Bile Salts: Emulsify fats, increasing their surface area for lipase action.
Bilirubin: A pigment resulting from the breakdown of hemoglobin, giving bile its characteristic color.
Cholesterol: Excreted from the body via bile.
Phospholipids: Assist in fat digestion and absorption.
Electrolytes: Maintain osmotic balance.

(c) Control of Pancreatic Juice Flow
The secretion of pancreatic juice is regulated by both hormonal and neural mechanisms:
Hormonal Control:
Secretin: Released by the duodenal mucosa in response to acidic chyme; stimulates the pancreas to secrete a bicarbonate-rich fluid to neutralize the acidity.
Cholecystokinin (CCK): Released in response to fats and proteins in the duodenum; stimulates the pancreas to secrete enzyme-rich pancreatic juice and causes the gallbladder to contract, releasing bile.

Neural Control:
Vagus Nerve (Parasympathetic Stimulation): Enhances pancreatic secretion during the cephalic and gastric phases of digestion, preparing the digestive system for food intake.

5. (a) List the ways in which a mammal obtains and loses water.

(i) Ways in which a mammal obtains water:

i. Drinking water and other fluids.
ii. Absorption of water through food (e.g., fruits, vegetables, and meat contain water).
iii. Metabolic water produced during cellular respiration when glucose and other nutrients are oxidized.

(ii) Ways in which a mammal loses water:
i. Excretion through urine.
ii. Evaporation through sweat to regulate body temperature.
iii. Water vapor lost during breathing (respiration).
iv. Loss of water through feces.

(b) Analysis of the glomerular filtrate and the urine of a mammal yielded the following mean daily values:

| Glomerular filtrate | Urine |
|---|---|
| Urea 60 g | 35 g |
| Water 180 $dm^3$ | 1.5 $dm^3$ |

(i) 150 $dm^3$ of water is reabsorbed by the proximal convoluted tubules. Calculate the percentage of water from the filtrate that is reabsorbed elsewhere.
Solution:
- Total water in the glomerular filtrate = 180 $dm^3$.
- Water reabsorbed by the proximal convoluted tubules = 150 $dm^3$.
- Water excreted in urine = 1.5 $dm^3$.

Water reabsorbed elsewhere = Total filtrate - Water reabsorbed by proximal tubules - Water in urine.
= 180 $dm^3$ - 150 $dm^3$ - 1.5 $dm^3$ = 28.5 $dm^3$.

Percentage of water reabsorbed elsewhere = (Water reabsorbed elsewhere ÷ Total water in filtrate) × 100.
= (28.5 ÷ 180) × 100 = 15.83%.
(ii) Name other regions of the nephron where further reabsorption of water takes place.

i. Loop of Henle (especially the descending limb).
ii. Distal convoluted tubule.
iii. Collecting ducts (under the influence of antidiuretic hormone).

(c) Discuss the causes and symptoms of three (3) common disorders of the urinary system in humans.

(i) Bladder infection (Cystitis):
Causes:
i. Bacterial infection, usually Escherichia coli.
ii. Poor hygiene or urinary retention.

Symptoms:

i. Frequent and painful urination.
ii. Cloudy or foul-smelling urine.
iii. Lower abdominal pain or discomfort.

(ii) Kidney stones (Renal calculi):
Causes:
i. High levels of calcium, oxalates, or uric acid in the urine.
ii. Dehydration or inadequate fluid intake.

Symptoms:
i. Severe pain in the back or side (flank).
ii. Blood in urine (hematuria).
iii. Nausea and vomiting.

(iii) Kidney failure:
Causes:
i. Chronic conditions like diabetes or hypertension.
ii. Severe dehydration or acute infections.

Symptoms:
i. Reduced or no urine output.
ii. Swelling in legs and ankles (edema).
iii. Fatigue, confusion, or shortness of breath.

6. (a) (i) At what age did the woman start ovulation? Explain your answer.
The woman likely started ovulation at puberty, which typically begins around the age of 12 to 14 years in most females. Ovulation begins when the hypothalamus signals the pituitary gland to release luteinizing hormone (LH) and follicle-stimulating hormone (FSH), which stimulate the ovaries to release eggs.

(ii) Estimate the time in years that ovulation would have continued in that woman.
To estimate the time ovulation continued:
- A typical woman ovulates from puberty (around 12–14 years) to menopause (around 50 years).
- Therefore, the total duration of ovulation would be approximately 36–38 years, assuming a consistent cycle.

(iii) How many potential sets of twins could this woman have produced and what type of twins would they be?
The number of potential sets of twins depends on the number of follicles containing two oocytes. According to the data:
- Seven follicles contained two oocytes.
- If all seven follicles matured and resulted in ovulation, and fertilization occurred, the woman could produce seven sets of fraternal (dizygotic) twins, as each oocyte could develop into a separate embryo.

(b) Name the process that accounts for the presence of two nuclei in some of the oocytes.
The process responsible for the presence of two nuclei in oocytes is meiotic division, specifically meiotic non-disjunction during meiosis I or II. This results in abnormal segregation of chromosomes, leading to two nuclei within an oocyte.

(c) What major change would happen to the fetal circulation if blood pressure was highest in the aorta?
If blood pressure in the aorta was abnormally high:
- It would affect the efficiency of oxygen and nutrient exchange in the placenta.
- The high pressure might reduce blood flow to the placenta, causing fetal hypoxia (low oxygen levels) and impaired growth, as the fetus relies on adequate placental circulation for development.
- Additionally, it could increase the workload on the fetal heart, potentially leading to developmental complications.

7. (a) Define the term translocation.
In genetics, translocation refers to a chromosomal abnormality where a segment of one chromosome breaks off and attaches to another chromosome. This can result in a rearrangement of genetic material, potentially leading to genetic disorders or diseases.

In botany, translocation is the process by which plants transport soluble products of photosynthesis, primarily sugars, from the leaves (where they are produced) to other parts of the plant, such as stems, roots, and developing fruits. This movement occurs through the phloem tissue and is essential for plant growth and development.

(b) Explain the factors that affect the rate of translocation.

The rate of translocation in plants is influenced by several factors:

- Rate of Photosynthesis: Higher photosynthetic activity increases the production of sugars in the leaves, leading to a greater concentration gradient between the source (leaves) and sink (areas of storage or growth). This gradient drives the translocation process.
  Rate of Cellular Respiration: Active regions of growth or storage (sinks) consume sugars through respiration. Increased respiration in these areas can enhance the sink strength, promoting a more rapid translocation of nutrients from the source.

- Environmental Factors:
  Temperature: Elevated temperatures can increase the rate of translocation by enhancing enzymatic activities related to loading and unloading of sugars in the phloem. However, excessively high temperatures may damage plant tissues and impede translocation.
  Water Availability: Adequate water supply maintains turgor pressure in the plant cells, which is crucial for the movement of sap through the phloem. Water stress can reduce turgor pressure, thereby slowing down or even halting translocation.

Nutrient Concentration: The availability of essential nutrients can affect the overall health of the plant and the efficiency of the translocation process. Nutrient deficiencies may impair phloem function and reduce the rate of translocation.

8. The origin of life on Earth has been a subject of profound inquiry, leading to the development of several theories that attempt to explain how life began. Here is a discussion of four prominent theories:

(a) Special Creation
The theory of special creation posits that life was created by a supernatural being or deity in its current form. This perspective is rooted in religious beliefs and suggests that life did not arise through natural processes but was intentionally created. It is not considered a scientific explanation, as it relies on faith-based doctrines and is not testable or falsifiable through empirical methods.
(b) Spontaneous Generation
Spontaneous generation is an outdated scientific theory that proposed that living organisms could arise from non-living matter spontaneously. For example, it was once believed that maggots could emerge from decaying meat. This theory was debunked through experiments by scientists such as Louis Pasteur in the 19th century, who demonstrated that life arises from existing life, leading to the principle of biogenesis.

(c) Cosmozoic Origin (Panspermia)
The cosmozoic theory, also known as panspermia, suggests that life originated elsewhere in the universe and was transported to Earth via meteoroids, comets, or cosmic dust. This hypothesis implies that life exists throughout the universe and can be spread between planets. Recent analyses of samples from the asteroid Bennu have revealed the presence of amino acids and nucleobases, essential components for life, supporting the idea that space rocks may have delivered the raw materials for Earth's early life.

(d) Naturalistic (Abiogenesis)
The naturalistic theory, often referred to as abiogenesis, proposes that life arose naturally from non-living chemical compounds on early Earth. Through a series of chemical reactions, simple molecules gradually formed more complex structures, eventually leading to the first living organisms. Experiments such as the Miller-Urey experiment in 1953 demonstrated that organic molecules could be synthesized from inorganic precursors under conditions thought to resemble those of early Earth. This theory is supported by scientific research and experiments that simulate early Earth conditions.

9. (a) What is population explosion?

Population explosion refers to a rapid and dramatic increase in the size of a population, typically characterized by high birth rates and declining death rates. This phenomenon often results in significant challenges related to resource management, urbanization, and environmental sustainability.

(b) Explain the consequences and control measures of population explosion with reference to the human species.

Consequences:

- Resource Depletion: A rapidly growing population can lead to the overconsumption of natural resources such as water, arable land, and fossil fuels, resulting in shortages and environmental degradation.

- Environmental Degradation: Overpopulation contributes to pollution, deforestation, loss of biodiversity, and climate change, as the increased demand for resources leads to habitat destruction and higher greenhouse gas emissions.

- Economic Strain: High population growth can strain economic systems, leading to unemployment, poverty, and inadequate public services such as healthcare and education.

- Health Issues: Overcrowding and insufficient healthcare resources can facilitate the spread of diseases, increase mortality rates, and reduce overall quality of life.

Control Measures:

- Family Planning: Promoting the use of contraceptives and providing access to reproductive health services can help individuals and couples control the number and spacing of their children, thereby reducing birth rates.

- Education: Improving access to education, particularly for women and girls, is associated with lower fertility rates, as it empowers individuals to make informed decisions about reproduction.
  Economic Development: Enhancing economic opportunities and reducing poverty can lead to lower birth rates, as families may choose to have fewer children when economic conditions improve.

- Healthcare Improvements: Reducing infant and child mortality through better healthcare can decrease the perceived need for larger families, thereby contributing to lower birth rates.

Implementing these measures requires comprehensive policies and international cooperation to address the multifaceted challenges posed by population explosion.