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: 2010**

Instructions:

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

1. (a) Draw a large, well-labeled diagram of a chloroplast of higher plants.

Outer Membrane: The smooth outermost layer that encloses the chloroplast.

Inner Membrane: Lies just beneath the outer membrane, enclosing the stroma.

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

Stroma: The fluid-filled matrix inside the inner membrane, containing enzymes, ribosomes, and chloroplast DNA.

Thylakoids: Flattened, disc-like sacs within the stroma.

Granum (plural: Grana): Stacks of thylakoids.

Thylakoid Lumen: The internal space within a thylakoid.

Lamellae: Membranous structures connecting grana.

Chlorophyll: Pigment molecules embedded in the thylakoid membranes.

(b) How is the chloroplast's structure related to its function?

The structure of the chloroplast is intricately linked to its role in photosynthesis:
Double Membrane: The outer and inner membranes regulate the movement of molecules in and out of the chloroplast, maintaining an optimal internal environment.

Thylakoid Membranes: House chlorophyll and other pigments that capture light energy, initiating the light-dependent reactions of photosynthesis.

Grana: The stacked arrangement increases the surface area for light absorption and electron transport processes.

Stroma: Contains enzymes essential for the Calvin cycle (light-independent reactions), where carbon dioxide is fixed into glucose.

Chloroplast DNA and Ribosomes: Enable the chloroplast to produce some of its own proteins necessary for photosynthesis.

(c) i. What are lysosomes?
Lysosomes are membrane-bound organelles found in eukaryotic cells that contain hydrolytic enzymes capable of breaking down various biomolecules, including proteins, nucleic acids, carbohydrates, and lipids.

ii. Briefly elaborate on the roles of lysosomes in organisms.
Lysosomes serve several critical functions:

Intracellular Digestion: They degrade material ingested by the cell through endocytosis, breaking down macromolecules into their constituent parts for reuse.

Autophagy: Lysosomes digest obsolete or damaged organelles, helping to maintain cellular health by recycling cellular components.

Defense Against Pathogens: They can destroy invading microorganisms by fusing with phagosomes containing pathogens, leading to their degradation.

Programmed Cell Death (Apoptosis): Lysosomal enzymes can be involved in the controlled dismantling of cellular components during apoptosis.

2. Give an account of the features which have made insects the most successful group in the animal kingdom.

Insects are the most diverse and numerous group of animals on Earth, owing their success to several key features:

Exoskeleton: Composed of chitin, it provides protection, structural support, and prevents desiccation.

Small Size: Allows exploitation of diverse ecological niches and requires fewer resources.

High Reproductive Rate: Many insects produce large numbers of offspring, increasing the likelihood of species survival.

Metamorphosis: Complete metamorphosis (egg, larva, pupa, adult) reduces competition between life stages by allowing them to occupy different habitats and consume different resources.

Flight: The evolution of wings enables insects to escape predators, disperse to new environments, and access various food sources.

Diverse Feeding Strategies: Adaptations such as specialized mouthparts allow insects to exploit a wide range of food sources, from plant sap to other animals.

Sensory and Neural Adaptations: Highly developed sensory organs and nervous systems facilitate efficient navigation, communication, and response to environmental stimuli.

Social Structures: In species like ants and bees, complex social behaviors and division of labor enhance survival and reproductive success.

3. Figure 1 shows the results of an experiment set to find the effect of Na^+ ions on the production of action potentials in squid axons. The axons were bathed in different concentrations of isotonic seawater.

a. i. Which action potentials correspond with axons placed in normal, half, or one-third seawater?

The action potentials correspond as follows:
- The action potential labeled (p) represents axons placed in normal seawater.
- The action potential labeled (q) represents axons placed in half-strength seawater.
- The action potential labeled (r) represents axons placed in one-third seawater.

ii. Explain the effect of the different concentrations of seawater on the action potential.

The concentration of seawater impacts the ionic environment needed for generating action potentials:
- In normal seawater, the sodium ion concentration is optimal, resulting in a robust depolarization and a higher peak action potential.
- In half-strength seawater, sodium ion concentration is reduced, causing a weaker depolarization and a lower peak action potential as fewer sodium ions enter the axon.
- In one-third seawater, the sodium ion concentration is significantly reduced, resulting in a much smaller action potential due to a limited influx of sodium ions.

This demonstrates the critical role of extracellular sodium ions in generating and propagating action potentials.

b. i. Describe the ionic changes occurring across an axon membrane during a refractory period.

During the refractory period:
- In the absolute refractory period, sodium channels are inactivated, preventing any new action potential. Potassium channels remain open, allowing potassium ions to exit the axon, which helps repolarize the membrane.
- In the relative refractory period, some sodium channels recover from inactivation, but the membrane is hyperpolarized due to the continued efflux of potassium ions. A stronger-than-normal stimulus is required to initiate a new action potential.

ii. Explain, in terms of the resistance of the axoplasm and local circuits, why giant axons conduct impulses at greater velocities than fine axons.

Giant axons conduct impulses faster because:
- The resistance of the axoplasm is lower in larger-diameter axons, allowing ionic currents to flow more easily along the axon.

- The larger diameter enhances the efficiency of local current circuits, enabling quicker depolarization of adjacent membrane regions.
- The reduced resistance decreases ion leakage, preserving the amplitude of the action potential over longer distances.

As a result, giant axons are well-suited for rapid conduction, a vital adaptation in organisms like squid for rapid escape responses.

4. (a) Why is it necessary for pepsin to be secreted in an inactive state?

Pepsin is a potent proteolytic enzyme responsible for breaking down proteins in the stomach. To prevent it from digesting the very cells that produce it, pepsin is synthesized and secreted by the chief cells in the stomach lining in an inactive form known as pepsinogen. This zymogen form prevents the enzyme from digesting the cells that produce it. Once pepsinogen enters the acidic environment of the stomach, it undergoes a conformational change, activating into pepsin. This mechanism ensures that the active enzyme is only present in the stomach lumen, where it can safely perform its digestive functions without harming the gastric tissues.

(b) How is the small intestine (ileum) adapted to its function?
The ileum, the final section of the small intestine, is specialized for the absorption of nutrients. Its structure is intricately adapted to maximize this function:

Length: The ileum is approximately 2–4 meters long in humans, providing an extensive surface area for absorption.

Circular Folds (Plicae Circulares): These permanent transverse ridges slow the movement of chyme, enhancing contact time with the intestinal wall for optimal absorption.

Villi: The mucosal surface is covered with tiny, finger-like projections called villi, which further increase the surface area. Each villus contains a network of capillaries and a lymphatic vessel (lacteal) to transport absorbed nutrients into the body's circulation.

Microvilli: On the apical surface of the epithelial cells lining the villi are even smaller projections called microvilli, forming a "brush border" that dramatically amplifies the absorptive surface area and houses enzymes crucial for the final stages of digestion.

Thin Epithelium: The single layer of epithelial cells facilitates efficient nutrient diffusion into the blood and lymphatic vessels.

Rich Blood Supply: A dense network of blood vessels within the villi ensures rapid transport of absorbed nutrients into the systemic circulation.

Lymphatic Vessels (Lacteals): These structures are essential for the absorption of dietary fats and fat-soluble vitamins, transporting them into the lymphatic system before they enter the bloodstream.

Collectively, these adaptations enable the ileum to efficiently absorb nutrients, ensuring that the body receives the essential components required for energy and maintenance.

(c) The leaves of most green plants are well adapted to the process of photosynthesis. Discuss.

Leaves are the primary sites of photosynthesis in most green plants, and their structures are finely tuned to optimize this process:
Broad, Flat Surface (Lamina): Provides a large surface area to capture maximum sunlight.

Thin Structure: Minimizes the distance for gas diffusion, facilitating efficient exchange of carbon dioxide and oxygen.

Cuticle: A waxy, transparent layer covering the epidermis reduces water loss while allowing light penetration.

Upper Epidermis: Transparent cells that permit light to reach the photosynthetic tissues beneath.

Palisade Mesophyll: Located beneath the upper epidermis, this layer contains densely packed, chloroplast-rich cells oriented to maximize light absorption.

Spongy Mesophyll: Situated below the palisade layer, these irregularly shaped cells create air spaces to facilitate gas exchange and house chloroplasts for photosynthesis.

Stomata: Pores primarily on the lower epidermis regulate gas exchange and water vapor release. Guard cells surrounding each stoma control its opening and closing in response to environmental conditions.

Veins (Vascular Bundles): Comprising xylem and phloem, veins transport water and minerals to the leaf cells and distribute the synthesized sugars to other plant parts.

These structural features work in concert to ensure that leaves efficiently capture light energy, facilitate gas exchange, and synthesize the organic compounds necessary for the plant's growth and energy needs.

5. (a) Define guttation.
Guttation is the process by which certain vascular plants exude droplets of xylem sap from the tips or edges of their leaves. This typically occurs during the night or early morning when soil moisture levels are high, root pressure increases, and transpiration rates are low due to closed stomata. The exuded fluid emerges through specialized structures called hydathodes located at the leaf margins.

(b) How are xerophytes capable of surviving in their environments?

Xerophytes are plants adapted to thrive in arid environments with limited water availability. They possess a range of structural and physiological adaptations to minimize water loss and maximize water uptake:

Reduced Leaf Surface Area: Many xerophytes have small, narrow, or needle-like leaves, which decrease the surface area exposed to the atmosphere, thereby reducing transpiration.

Thick Cuticle: A waxy, thickened cuticle covers the leaf surface, acting as a barrier to water loss and reflecting sunlight to reduce leaf temperature.

Sunken Stomata: Stomata are often located in pits or grooves, which helps trap moist air and reduce the gradient for water vapor loss.

Leaf Hairiness (Trichomes): Some xerophytes have hairy leaves that create a microenvironment of higher humidity around the stomata, reducing transpiration rates.

CAM Photosynthesis: Crassulacean Acid Metabolism (CAM) allows these plants to open their stomata at night to minimize water loss, storing CO_2 for use during daylight hours.

Extensive Root Systems: Deep or widespread root systems enable xerophytes to access water from a larger soil volume, tapping into deep or distant moisture sources.

Water Storage: Succulent xerophytes store water in specialized tissues within their stems or leaves, providing a reservoir during drought conditions.

(c) Outline the different ways in which endothermic animals respond to cold and hot conditions.

Endothermic animals, or warm-blooded animals, regulate their internal body temperature through various physiological and behavioral mechanisms to cope with temperature extremes:

Responses to Cold Conditions:

Shivering Thermogenesis: Involuntary muscle contractions generate heat to raise body temperature.

Non-Shivering Thermogenesis: Metabolic heat production, particularly in brown adipose tissue, increases to warm the body without muscle activity.

Vasoconstriction: Narrowing of blood vessels near the skin surface reduces heat loss by limiting blood flow to the periphery.

Insulation: Thick fur, feathers, or fat layers provide physical barriers to heat loss.

Behavioral Adaptations: Seeking shelter, huddling together, or adopting postures that minimize exposed surface area help conserve heat.
Torpor or Hibernation: Some animals enter a state of reduced metabolic activity to conserve energy during prolonged cold periods.

Responses to Hot Conditions:

Vasodilation: Widening of blood vessels near the skin surface increases heat dissipation through enhanced blood flow.

Sweating or Panting: Evaporative cooling mechanisms, such as sweating in humans or panting in dogs, facilitate heat loss.

Behavioral Adaptations: Seeking shade, becoming nocturnal, or reducing activity levels during peak heat periods help avoid overheating.

Insulation: In some cases, fur or feathers can also protect against heat by shielding the skin from direct sunlight.

Burrowing or Seeking Water: Some animals retreat to cooler underground burrows or immerse themselves in water to lower body temperature.

6. Figure 2 shows two solutions which are separated by a partially permeable membrane. Study it carefully and answer the questions that follow.

a. Which solution has a higher concentration of water molecules?
Solution N has a higher concentration of water molecules because it has a lower solute concentration. The presence of more solvent (water) molecules is inversely related to the solute concentration in a solution.

b. Which solution is more concentrated?
Solution M is more concentrated because it has a higher concentration of solute molecules such as sugar or salt, which reduces the concentration of water molecules.

c. In which direction will osmosis occur?
Osmosis will occur from Solution N to Solution M. This is because water molecules move from a region of higher water concentration (lower solute concentration) to a region of lower water concentration (higher solute concentration) through a semi-permeable membrane.

d. Which of the two values of ψ is higher?
(i) -1000 kPa
(ii) -500 kPa
Solution N, with a ψ of -500 kPa, has a higher water potential than Solution M, which has a ψ of -1000 kPa. Water always moves from a region of higher water potential to a region of lower water potential.

e. Which solution has:
(i) higher ψ
Solution N has a higher ψ (water potential) because its solute concentration is lower.
(ii) higher solute potential
Solution M has a higher solute potential because its solute concentration is higher, leading to a more negative ψs (solute potential).

f. What is the relationship between ψs and ψ of a solution at atmospheric pressure?
The water potential (ψ) of a solution is determined by the solute potential (ψs) and pressure potential (ψp). At atmospheric pressure, ψ is equal to ψs because ψp is zero. Thus, the equation $\psi = \psi s + \psi p$ simplifies to $\psi = \psi s$.

7. (a) Give any four differences between meiosis and mitosis.

Meiosis and mitosis are two distinct types of cell division processes in living organisms. Here are four key differences between them:

- Purpose:
  Mitosis: Facilitates growth, tissue repair, and asexual reproduction by producing two daughter cells identical to the parent cell.
  Meiosis: Generates gametes (sperm and eggs) for sexual reproduction, resulting in four genetically diverse daughter cells with half the original chromosome number.

- Number of Divisions:
  Mitosis: Involves a single cell division, yielding two daughter cells.
  Meiosis: Comprises two consecutive divisions (meiosis I and meiosis II), producing four daughter cells.

- Chromosome Number in Daughter Cells:
  Mitosis: Daughter cells retain the same chromosome number as the parent cell (diploid in diploid organisms).
  Meiosis: Daughter cells possess half the chromosome number of the parent cell (haploid).

- Genetic Variation:
  Mitosis: Results in genetically identical daughter cells.
  Meiosis: Promotes genetic diversity through processes like crossing over and independent assortment.

(b) Explain the significance of meiosis in multicellular organisms.

Meiosis holds several vital roles in multicellular organisms:

Genetic Diversity: Through recombination and independent assortment, meiosis generates genetically unique gametes, enhancing variation within a species.
Chromosome Number Maintenance: By halving the chromosome number in gametes, meiosis ensures that fertilization restores the species-specific chromosome count, maintaining genomic stability across generations.
DNA Repair: Meiotic recombination facilitates the repair of DNA damages, preserving genomic integrity.

8. (a) Explain how artificial selection in plants and animals by humans supports organic evolution.

Artificial selection, practiced by humans, involves the intentional breeding of plants and animals to enhance desirable traits. This process mirrors natural selection and provides evidence for organic evolution in several ways:
Observable Trait Changes: Selective breeding leads to significant modifications in species over relatively short periods, demonstrating how selection pressures can drive evolutionary change.
Inheritance of Traits: The success of artificial selection relies on the heritability of traits, supporting the concept that genetic variations can be passed to offspring and influence evolutionary trajectories.
Speciation Events: Prolonged artificial selection can result in the emergence of new breeds or varieties that are reproductively isolated from their wild counterparts, illustrating mechanisms of speciation.

These outcomes of artificial selection underscore the principles of variation, inheritance, and selection that are foundational to the theory of organic evolution.

(b) How does adaptive radiation bring about speciation?

Adaptive radiation is an evolutionary process where a single ancestral species diversifies into multiple distinct species, each adapted to different ecological niches. This process contributes to speciation through several mechanisms:
Ecological Opportunity: When new habitats or resources become available, populations exploit these opportunities, leading to divergent selection pressures.
Morphological and Behavioral Divergence: Adaptations to specific environments result in variations in form and behavior, reducing competition among emerging species.
Reproductive Isolation: Over time, accumulated differences can lead to reproductive barriers, such as changes in mating behaviors or timing, ultimately resulting in the formation of new species.
A classic example of adaptive radiation is observed in Darwin's finches on the Galápagos Islands, where an ancestral finch species diversified into multiple species, each with unique beak shapes tailored to specific food sources.

9. Explain how a quadrat can be used to estimate population size with respect to three aspects of species distribution, namely: species density, species frequency, and species cover.

Quadrat sampling is a fundamental ecological method used to assess the distribution and abundance of species within a defined area. By placing a quadrat—a square or rectangular frame of known dimensions—

at various locations within a study site, researchers can collect data to estimate population size through different metrics: species density, species frequency, and species cover.

1. Species Density

Species density refers to the number of individuals of a particular species per unit area. To estimate species density using quadrats:

Procedure:

Randomly or systematically place the quadrat within the study area.

Count the number of individuals of the target species within the quadrat.

Repeat this process for multiple quadrats to obtain a representative sample.

Calculation:

Calculate the mean number of individuals per quadrat by summing the counts from all quadrats and dividing by the number of quadrats sampled.

Determine the area of a single quadrat.

Species density is then calculated as:

Species Density = Mean Number of Individuals per Quadrat/Area of Quadrat

This provides an estimate of the number of individuals per unit area in the study site.

2. Species Frequency

Species frequency measures how often a particular species appears within the sampled quadrats, indicating its distribution across the study area. To estimate species frequency:

Procedure:

Place the quadrat at various locations within the study area.

Record the presence or absence of the target species in each quadrat.

Repeat for multiple quadrats to ensure adequate sampling.

Calculation:

Count the number of quadrats where the species is present.

Calculate the total number of quadrats sampled.

Species frequency is then calculated as:

Species Frequency = (Number of Quadrats with Species Present/Total Number of Quadrats) x 100

This percentage reflects the likelihood of encountering the species within the study area.

3. Species Cover

Species cover estimates the proportion of the ground area within a quadrat that is occupied by a particular species, providing insight into its dominance and spatial arrangement. To assess species cover:

Procedure:

Place the quadrat over the vegetation in the study area.

Visually estimate the percentage of the quadrat area covered by the target species.

For increased accuracy, use a gridded quadrat divided into smaller units (e.g., 10x10 grid), counting the number of grid cells at least half-filled by the species.

Repeat for multiple quadrats to obtain a representative sample.

Calculation:

If using a gridded quadrat with 100 cells, each cell represents 1% of the total area.

Count the number of cells occupied by the species.

Species cover is then the total percentage of the quadrat area covered by the species.

This method provides a quantitative measure of the species' spatial occupation within the habitat.

By employing quadrat sampling to assess species density, frequency, and cover, ecologists can gain comprehensive insights into the abundance, distribution, and ecological significance of species within a given area.