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: 2007**

Instructions:

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

1. (a) What are enzymes?

Enzymes are biological catalysts that accelerate chemical reactions in living organisms. They are typically proteins, though some RNA molecules also exhibit catalytic properties. Enzymes function by lowering the activation energy required for reactions, thereby increasing the reaction rate without being consumed in the process. They are highly specific, each facilitating a particular reaction or set of reactions, and operate under optimal conditions of temperature and pH.

(b) Write an essay on enzymes using the following headings:

(i) Allosteric Inhibitors
Allosteric inhibitors are molecules that bind to an enzyme at a site distinct from the active site, known as the allosteric site. This binding induces a conformational change in the enzyme's structure, reducing its activity by altering the shape of the active site or its overall dynamics. Unlike competitive inhibitors, which directly compete with the substrate for the active site, allosteric inhibitors modulate enzyme activity indirectly. This form of regulation allows for fine-tuning of metabolic pathways, as the binding of an allosteric inhibitor can decrease the enzyme's affinity for its substrate or reduce its catalytic efficiency. An example of allosteric inhibition is the regulation of phosphofructokinase by ATP in glycolysis; when ATP levels are high, it binds allosterically to phosphofructokinase, decreasing its activity and thus slowing down the glycolytic pathway.

(ii) Negative Feedback Inhibition
Negative feedback inhibition is a regulatory mechanism wherein the end product of a metabolic pathway inhibits an enzyme involved earlier in the pathway. This process helps maintain homeostasis by preventing the overaccumulation of the final product. When the concentration of the end product reaches a certain threshold, it binds to an allosteric site on the enzyme, causing a conformational change that reduces the enzyme's activity. As a result, the production of the end product decreases. A classic example is the inhibition of the enzyme threonine deaminase by isoleucine in the biosynthesis of isoleucine. When isoleucine levels are sufficient, it binds to threonine deaminase, inhibiting its activity and thus reducing the production of more isoleucine.

(iii) Non-Competitive Irreversible Inhibition
Non-competitive irreversible inhibition occurs when an inhibitor binds to an enzyme at a site other than the active site, forming a covalent bond that permanently inactivates the enzyme. This binding alters the enzyme's structure, rendering it incapable of catalyzing reactions, regardless of substrate concentration. Unlike reversible inhibitors, the effects of irreversible inhibitors cannot be overcome by increasing substrate levels.

Examples:

i. Aspirin: Aspirin (acetylsalicylic acid) irreversibly inhibits the enzyme cyclooxygenase (COX) by acetylating a serine residue in its active site. This inhibition prevents the formation of prostaglandins and

thromboxanes, molecules involved in inflammation and platelet aggregation, respectively. As a result, aspirin is effective as an anti-inflammatory and antithrombotic agent.

ii. Ricin: Ricin is a potent toxin derived from castor beans that acts as an irreversible inhibitor of ribosomes. It enzymatically removes specific adenine residues from ribosomal RNA, leading to the inactivation of ribosomes and cessation of protein synthesis. This action is lethal to cells, making ricin a highly dangerous substance.

2. (a) Explain how Plasmodium is adapted to its mode of life.

Plasmodium, the protozoan parasite responsible for malaria, has evolved several adaptations to thrive within both its mosquito vector and human host:

Complex Life Cycle: Plasmodium undergoes a complex life cycle involving both sexual reproduction in Anopheles mosquitoes and asexual reproduction in humans. This dual-host cycle enhances its transmission and survival.

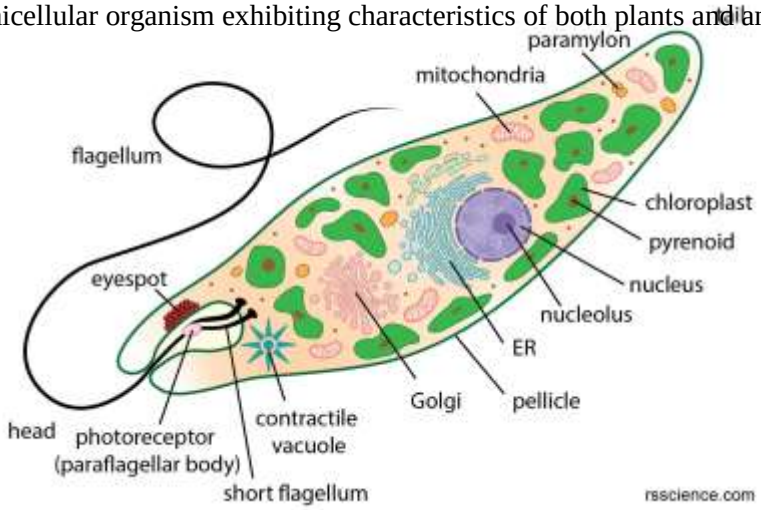
Antigenic Variation: The parasite can alter the proteins expressed on the surface of infected red blood cells, helping it evade the host's immune system.
Intracellular Habitat: By residing within liver cells and red blood cells, Plasmodium is shielded from direct immune attacks, allowing it to multiply undetected.

Manipulation of Host Behavior: Infected mosquitoes exhibit increased feeding persistence, enhancing the likelihood of parasite transmission to humans.

Nutrient Acquisition: Plasmodium digests hemoglobin within red blood cells to obtain amino acids necessary for its growth and reproduction.

(b) Draw a well-labelled diagram of Euglena and explain how it resembles both plants and animals.

Euglena is a unicellular organism exhibiting characteristics of both plants and animals:



Plant-like Features:
Chloroplasts: Euglena contains chloroplasts with chlorophyll, enabling it to perform photosynthesis and produce its own food in the presence of light.
Paramylon Granules: It stores energy in the form of paramylon, a carbohydrate similar to starch found in plants.

Animal-like Features:
Flagellum: Euglena possesses a flagellum, a whip-like structure that allows it to move actively, a trait common in many animal cells.
Pellicle: Instead of a rigid cell wall, Euglena has a flexible pellicle made of protein strips, providing protection while allowing shape changes, akin to some animal cells.
Phagocytosis: In the absence of light, Euglena can ingest food particles from the environment, displaying heterotrophic behavior typical of animals.
These dual characteristics enable Euglena to adapt to varying environmental conditions, switching between autotrophic and heterotrophic modes of nutrition as needed.

3. (a) Explain how the activities of many glands of the vertebrate animal are regulated.

In vertebrate animals, the activities of many glands are regulated through a complex interplay between the nervous and endocrine systems, primarily via feedback mechanisms and hierarchical control centers. The hypothalamus and pituitary gland play central roles in this regulatory network.

Hypothalamic-Pituitary Axis:
The hypothalamus, located in the brain, serves as a critical link between the nervous and endocrine systems. It synthesizes and secretes releasing and inhibiting hormones that regulate the anterior pituitary gland's function. In response, the anterior pituitary releases tropic hormones that act on peripheral endocrine glands, stimulating them to produce specific hormones. This hierarchical system ensures precise control over various physiological processes.

Feedback Mechanisms:
Hormonal regulation often involves feedback loops, predominantly negative feedback, to maintain homeostasis. In a typical negative feedback loop, the end product of a hormonal pathway inhibits its own production by suppressing the activity of upstream regulators. For example, the hypothalamus releases corticotropin-releasing hormone (CRH), prompting the anterior pituitary to secrete adrenocorticotropic hormone (ACTH), which in turn stimulates the adrenal cortex to produce cortisol. Elevated cortisol levels then inhibit the release of both CRH and ACTH, thus modulating the pathway's activity.

Autonomic Nervous System Influence:
The autonomic nervous system (ANS) also regulates glandular activity, particularly through its sympathetic and parasympathetic branches. For instance, the sympathetic nervous system can stimulate the adrenal medulla to release catecholamines (epinephrine and norepinephrine) during stress responses, while the parasympathetic system influences functions such as salivary secretion.

Local Regulation:
Some glands possess intrinsic regulatory mechanisms. For example, the pancreas regulates insulin and glucagon secretion in response to blood glucose levels, ensuring tight control over energy metabolism.
Through these integrated systems, vertebrate animals maintain physiological balance, adapting to internal changes and external stimuli effectively.

(b) Why are the sound receptor cells of the ear called mechanoreceptors?
Sound receptor cells in the ear, known as hair cells, are classified as mechanoreceptors because they detect and transduce mechanical vibrations into electrical signals. Located within the cochlea of the inner ear, these cells possess hair-like projections called stereocilia. When sound waves enter the ear, they cause the tympanic membrane (eardrum) to vibrate. These vibrations are transmitted through the ossicles of the middle ear to the oval window, creating fluid waves within the cochlea. The resulting fluid movement leads to the deflection of the stereocilia on hair cells. This mechanical deflection opens ion channels, allowing ions to flow into the cells, generating an electrical signal that is transmitted to the brain via the auditory nerve. Thus, hair cells convert mechanical energy from sound waves into neural impulses, embodying the function of mechanoreceptors.

4. (a) Describe the roles of the pancreas and liver in digestion and metabolism of the end products of digestion.
The pancreas and liver are vital accessory organs in the digestive system, each playing distinct roles in digestion and the metabolism of nutrients.

Pancreas:

Digestive Functions:
Enzyme Secretion: The pancreas produces pancreatic juices containing enzymes such as amylase, lipase, and proteases (e.g., trypsin and chymotrypsin). These enzymes are released into the duodenum, the first segment of the small intestine, where they facilitate the breakdown of carbohydrates, fats, and proteins, respectively.
Bicarbonate Production: Pancreatic juices also contain bicarbonate ions, which neutralize the acidic chyme entering the duodenum from the stomach, creating an optimal pH environment for enzymatic activity.

Metabolic Functions:

Hormone Production: The pancreas contains clusters of cells known as the islets of Langerhans, which secrete hormones like insulin and glucagon into the bloodstream. These hormones are crucial for regulating blood glucose levels.

Liver:
Digestive Functions:
Bile Production: The liver produces bile, a substance stored in the gallbladder and released into the small intestine. Bile contains bile salts that emulsify fats, breaking them into smaller droplets to enhance the efficiency of pancreatic lipase in fat digestion.

Metabolic Functions:
Nutrient Metabolism: After absorption, nutrients are transported to the liver via the hepatic portal vein. The liver processes these nutrients by:
Glycogenesis: Converting excess glucose into glycogen for storage.
Gluconeogenesis: Producing glucose from non-carbohydrate sources when needed.
Lipoprotein Synthesis: Synthesizing lipoproteins to transport lipids through the bloodstream.
Amino Acid Processing: Deaminating excess amino acids and converting the resulting ammonia into urea for excretion.
Detoxification: The liver detoxifies various metabolites and drugs, rendering them harmless and facilitating their excretion.

Through these coordinated functions, the pancreas and liver ensure the efficient digestion of food and the proper metabolism of nutrients essential for the body's energy and biosynthetic needs.

(b) How is the small intestine adapted to its role of absorption?
The small intestine is uniquely adapted to maximize the absorption of nutrients through several structural and functional features:

Length: The small intestine is approximately 6 meters long in adults, providing an extensive surface area and sufficient time for nutrient absorption.

Circular Folds (Plicae Circulares): The inner lining of the small intestine has permanent transverse folds that slow the movement of chyme, enhancing contact time with the intestinal wall for absorption.

Villi: Covering the folds are tiny, finger-like projections called villi, which further increase the surface area available for absorption. Each villus contains a network of capillaries and a lymphatic vessel (lacteal) to transport absorbed nutrients into the body's circulation.

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

Thin Epithelium: The epithelial layer of the villi is one cell thick, minimizing the diffusion distance for nutrients into the blood and lymphatic vessels.

Rich Blood Supply: A dense network of blood vessels in the villi rapidly transports absorbed nutrients to the liver and other tissues, maintaining a concentration gradient that facilitates diffusion.

Lacteals: Specialized lymphatic vessels within the villi absorb dietary fats and fat-soluble vitamins, transporting them into the lymphatic system before they enter the bloodstream.

5. Explain the following observations as fully as possible:

(a) Succulent plants can be found in both deserts and salt marshes.
Succulent plants are adapted to environments where water availability is limited or inconsistent. In deserts, water scarcity is due to low precipitation and high evaporation rates. Succulents in these regions store water in their fleshy tissues, allowing them to survive prolonged dry periods.
In salt marshes, although water is abundant, the high salinity creates osmotic challenges that make it difficult for plants to absorb water. Succulents in these habitats, known as halophytes, have evolved mechanisms to manage salt stress. For instance, some halophytic succulents, like Salicornia species, accumulate salts in their vacuoles, which helps maintain osmotic balance and allows them to thrive in saline conditions.
Thus, the presence of succulents in both deserts and salt marshes illustrates their remarkable adaptability to environments where water is either scarce or not readily available due to osmotic constraints.

(b) Marine teleosts (bony fish) excrete large quantities of ions, especially Na^+, Cl^-, Mg^{2+}, and SO_4^{2-}.
Marine teleosts live in seawater, which has a higher ion concentration than their internal body fluids. To maintain osmotic balance, these fish drink seawater and absorb the water along with dissolved ions. Excess ions, particularly monovalent ions like Na^+ and Cl^-, are excreted primarily through specialized cells in the gills known as ionocytes. Divalent ions such as Mg^{2+} and SO_4^{2-} are less efficiently excreted by the gills and are primarily eliminated via the kidneys. The kidneys produce urine rich in these divalent ions to prevent their accumulation and maintain ionic homeostasis.

(c) Animals that live in dry habitats tend to have much longer loops of Henle than animals that live where water is freely available.
The loop of Henle in the nephron of the kidney plays a crucial role in concentrating urine. In arid environments, conserving water is essential for survival. Animals adapted to such habitats often have elongated loops of Henle, which create a steeper osmotic gradient in the renal medulla. This adaptation allows for the production of highly concentrated urine, minimizing water loss. In contrast, animals in water-abundant environments have shorter loops of Henle, as the need for water conservation is less critical.

(d) Eating a very salty meal leads to reduced urine output.
Consuming a high-salt meal increases the osmolarity of the blood. In response, the body releases antidiuretic hormone (ADH), which acts on the kidneys to promote water reabsorption. This mechanism helps dilute the elevated salt concentration in the bloodstream. Consequently, urine output decreases as the kidneys conserve water to restore osmotic balance.

6. With reference to flowering plants and mammals, give an account of the importance of transport, providing specific examples.

Transport systems are essential in both flowering plants and mammals, ensuring the distribution of vital substances necessary for survival, growth, and reproduction. Despite differences in their structures and mechanisms, these systems perform analogous functions in maintaining homeostasis.

Transport in Flowering Plants

Flowering plants possess specialized vascular tissues that facilitate the movement of water, minerals, and nutrients:

- Xylem: This tissue transports water and dissolved minerals absorbed from the soil by the roots to various parts of the plant, including stems and leaves. The unidirectional flow in the xylem is driven by transpiration—the evaporation of water from leaf surfaces—which creates a negative pressure pulling water upward. This process is crucial for maintaining cell turgor, facilitating photosynthesis, and transporting essential minerals.
- Phloem: Phloem tissue is responsible for the bidirectional movement of organic compounds, primarily sucrose, produced during photosynthesis in the leaves to other parts of the plant, such as roots, stems, and developing flowers or fruits. This process, known as translocation, ensures that energy is available where needed for growth, storage, and reproduction.

Specific Example:

Fruit Development: During the development of fruits, the phloem transports sugars from the leaves to the growing fruit tissues, providing the necessary energy and building blocks for growth.

Transport in Mammals

Mammals have a closed circulatory system that efficiently distributes gases, nutrients, hormones, and waste products throughout the body:

- Blood Circulation: The heart pumps oxygenated blood through arteries to various tissues, delivering oxygen and nutrients essential for cellular metabolism. Deoxygenated blood and metabolic waste products are then carried back to the heart through veins and subsequently transported to the lungs and excretory organs for elimination.
- Lymphatic System: This auxiliary system transports lymph—a fluid containing white blood cells, proteins, and fats—helping to maintain fluid balance, absorb fats from the digestive tract, and provide immune defense.

Specific Example:

Oxygen Transport: Red blood cells contain hemoglobin, a protein that binds oxygen in the lungs and releases it in tissues requiring oxygen for aerobic respiration, a process vital for energy production.

Comparative Importance of Transport Systems

In both flowering plants and mammals, transport systems are fundamental to:

Nutrient Distribution: Ensuring that all cells receive the necessary nutrients to perform their functions.

Waste Removal: Transporting metabolic waste products to excretory organs for elimination, preventing toxic accumulation.

Signal Transmission: Distributing hormones and signaling molecules that regulate growth, development, and responses to environmental stimuli.

7. The diagram below shows the process of sperm formation in a mammalian testis.

(a) Explain why cells A and B are genetically identical.
Cells A and B are genetically identical because they are produced through mitosis, a type of cell division where the parent cell divides to form two daughter cells with identical DNA. This ensures that the genetic material in the daughter cells is a precise copy of the parent cell's genetic material.

(b) Describe two ways in which cell division causes cells C and D to be genetically different.
i. Crossing Over. During meiosis, homologous chromosomes exchange genetic material in a process called crossing over. This results in recombinant chromosomes that have different combinations of genes.
ii. ndependent Assortment. During meiosis I, homologous chromosomes are distributed randomly into daughter cells, leading to genetic variation in cells C and D.

(c) Briefly describe how the process of gamete formation in an ovary leads to a smaller number of large gametes to be produced in a female mammal
In the ovary, gamete formation occurs through oogenesis. During this process, a primary oocyte undergoes meiosis to form one large ovum and smaller polar bodies. The polar bodies degenerate, leaving one large gamete. This ensures that the ovum has sufficient cytoplasm and nutrients to support early embryonic development.

(d) Both testis and ovary contain a large number of blood vessels. Other than cell division, what specific function of these organs is associated with these blood vessels?
The blood vessels in the testis and ovary supply oxygen and nutrients to support the development of gametes and remove waste products. Additionally, they transport hormones such as testosterone in males and estrogen and progesterone in females, which regulate reproductive processes.

8. (a) What do you understand by the term organic evolution?

Organic evolution refers to the gradual and continuous process by which living organisms undergo genetic and phenotypic changes over successive generations, leading to the emergence of new species and the diversity of life observed today. This process involves alterations in the genetic composition of populations in response to environmental changes, resulting in adaptations that enhance survival and reproductive success.

(b) Explain how the following processes lead to organic evolution.

(i) Genetic recombination.
Genetic recombination is a process that occurs during sexual reproduction, particularly in meiosis, where genetic material is exchanged between homologous chromosomes. This shuffling of genes results in offspring with unique combinations of alleles, contributing to genetic diversity within a population. Such diversity provides a broader range of traits upon which natural selection can act, facilitating adaptation to changing environments and driving evolutionary change.

(ii) Mutation.
Mutations are changes in the DNA sequence of an organism's genome. They can occur spontaneously or due to environmental factors and may affect a single nucleotide or larger segments of a chromosome. Mutations introduce new genetic variations by altering gene activity or protein function, which can lead to different traits in an organism. These variations can be beneficial, neutral, or harmful. Beneficial mutations may confer advantages that enhance an organism's fitness, increasing the likelihood of survival and reproduction. Over time, such advantageous mutations can spread through a population, contributing to evolutionary change.

(iii) Natural selection.
Natural selection is the process by which individuals with traits that confer a survival or reproductive advantage are more likely to survive and reproduce, passing those advantageous traits to subsequent generations. Over time, this leads to an increase in the frequency of beneficial traits within a population, while less advantageous traits may diminish. Natural selection acts on the genetic variation within a population, shaping the evolution of species by favoring adaptations that enhance fitness in a given environment.
(iv) Geographic isolation.
Geographic isolation occurs when populations of a species become physically separated by barriers such as mountains, rivers, or distances. This separation prevents gene flow between the isolated populations, allowing them to evolve independently. Over time, genetic differences accumulate due to mutations, natural selection, and genetic drift. These differences can lead to reproductive isolation, where members of the separated populations can no longer interbreed even if they come into contact again, resulting in the formation of new species. This process, known as allopatric speciation, is a significant mechanism by which biodiversity increases.

9. (a) Define the following:

(i) Carrying capacity.

Carrying capacity refers to the maximum number of individuals of a particular species that an environment can sustainably support over time, given the availability of resources such as food, water, shelter, and other necessities. When a population exceeds its carrying capacity, resource depletion can lead to environmental degradation and a subsequent decline in population size.

(ii) Population.

In ecological terms, a population is defined as a group of individuals of the same species inhabiting a specific geographic area at a given time. These individuals interact with each other and share a common gene pool.

(iii) Environmental resistance.

Environmental resistance encompasses the combined factors that limit the growth of a population within an ecosystem. These factors can be biotic, such as predation, disease, and competition, or abiotic, such as adverse weather conditions, limited space, and nutrient deficiencies. Environmental resistance prevents populations from exceeding the carrying capacity of their environment.

(b) The population size of doves in a certain area was estimated to increase from 20 doves in 1960 to 100 doves in 1962. The female dove can produce two offspring per year. From this information:

(i) Calculate the carrying capacity of that area.

To estimate the carrying capacity, we can use the logistic growth model, which describes how a population grows more slowly as it approaches its carrying capacity (K). The logistic growth equation is:

Where:

is the population size at time ,
is the initial population size,
is the intrinsic rate of increase,
is the time elapsed,
is the carrying capacity.

Given:
doves (initial population in 1960),
doves (population in 1962),

years.

First, we need to calculate the intrinsic rate of increase (). The intrinsic rate of increase can be estimated using the exponential growth formula:

Solving for :

Now, using the logistic growth equation to solve for :

Simplifying the exponent:

Substituting back:

This simplification suggests that the carrying capacity is significantly larger than the current population size, making it difficult to estimate accurately with the given data. Therefore, based on the provided information, we cannot precisely determine the carrying capacity of the area.

(ii) Calculate the intrinsic rate of increase.

The intrinsic rate of increase was calculated in part (i) as approximately 0.8047 per year.

(iii) What will happen if the population increase is almost equal to carrying capacity?

As a population approaches its carrying capacity, the growth rate slows due to increased competition for limited resources such as food, space, and mates. This deceleration continues until the population size stabilizes around the carrying capacity, where the birth rate equals the death rate, resulting in zero population growth. If the population exceeds the carrying capacity, it may lead to resource depletion, environmental degradation, and a subsequent decline in population size until balance is restored.