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: 2014**

Instructions:

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

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1. (a) Describe the structural adaptations of Entamoeba spp.

Entamoeba species exhibit several structural adaptations that facilitate their survival and pathogenicity:

(i) Pseudopodia Formation: Entamoeba cells extend lobose pseudopodia, which are temporary, foot-like projections of the cell membrane. These structures aid in locomotion and the engulfment of food particles through phagocytosis.

(ii) Cyst Formation: To endure harsh environmental conditions outside the host, Entamoeba forms cysts. These cysts are characterized by a carbohydrate-rich wall composed of chitin and chitin-binding proteins, providing resistance to desiccation and other adverse factors.

(iii) Anaerobic Metabolism: Entamoeba species possess reduced or absent mitochondria, known as mitosomes, enabling them to thrive in low-oxygen environments such as the human gastrointestinal tract.

(iv) Surface Lectins: These proteins on the parasite's surface facilitate adherence to host cells, a critical step in colonization and invasion.

(v) Proteolytic Enzymes: Entamoeba secretes enzymes that degrade host tissues, aiding in invasion and nutrient acquisition.

(b) Explain the advantages of algae to human beings and other living things.

Algae offer numerous benefits to humans and ecosystems:

(i) Oxygen Production: Through photosynthesis, algae contribute significantly to global oxygen levels, supporting aerobic life forms.
(ii) Nutritional Value: Algae are rich in essential nutrients, including proteins, vitamins, minerals, and omega-3 fatty acids. Species like spirulina and chlorella are consumed as dietary supplements, offering health benefits such as improved cardiovascular health and antioxidant properties.

(iii) Environmental Benefits: Algae can sequester carbon dioxide, aiding in climate regulation. Additionally, certain algae can remove pollutants from water bodies, contributing to environmental cleanup efforts.

(iv) Biofuel Production: Algae can be cultivated to produce biofuels, offering a renewable energy source that can reduce reliance on fossil fuels.

(v) Aquaculture Support: In aquaculture, algae serve as a primary food source for various marine organisms, supporting the cultivation of fish, mollusks, and crustaceans.

2. (a) Account for the general characteristics of the Phylum Apicomplexa.

The Phylum Apicomplexa comprises a diverse group of obligate intracellular parasites known for their unique structural and reproductive features:

(i) Apical Complex: Apicomplexans possess a specialized structure called the apical complex at the anterior end of the cell. This complex includes organelles such as rhoptries, micronemes, and dense granules, which facilitate host cell invasion.

(ii) Obligate Parasitism: All members are obligate parasites, infecting a wide range of hosts, including humans, animals, and even other protists. They rely entirely on their hosts for survival and reproduction.

(iii) Complex Life Cycles: Apicomplexans exhibit intricate life cycles involving both asexual and sexual reproduction, often across multiple host species. These cycles typically include stages such as sporozoites, merozoites, and gametocytes.

(iv) Lack of Locomotory Organelles: Unlike some other protists, apicomplexans lack cilia or flagella in their mature forms. Instead, they move by gliding motility, a process driven by the actin-myosin motor complex beneath the cell membrane.

(v) Apicoplast Presence: Many apicomplexans contain a non-photosynthetic plastid called the apicoplast, believed to be derived from an ancestral algal endosymbiont. The apicoplast is involved in essential metabolic pathways, such as fatty acid and isoprenoid synthesis.

(b) Describe the life cycle of Plasmodium falciparum and the effects it causes to its host.

Plasmodium falciparum, the causative agent of the most severe form of human malaria, has a complex life cycle involving both human and mosquito hosts:

(i) Mosquito Stage:
Sporozoite Development: The life cycle begins when an infected female Anopheles mosquito bites a human, injecting sporozoites present in its salivary glands into the bloodstream.

(ii) Liver Stage (Exo-erythrocytic Schizogony):
Hepatic Infection: Sporozoites travel to the liver and invade hepatocytes (liver cells). Within these cells, they undergo asexual replication, forming schizonts containing thousands of merozoites.
Merozoite Release: After maturation, the liver cells rupture, releasing merozoites into the bloodstream.

(iii) Blood Stage (Erythrocytic Schizogony):
Erythrocyte Invasion: Merozoites invade red blood cells (erythrocytes), where they develop into ring-stage trophozoites. These trophozoites mature into schizonts, which then rupture the red blood cells to release more merozoites, perpetuating the cycle.

Gametocyte Formation: Some merozoites differentiate into sexual forms called gametocytes, which circulate in the bloodstream.

(iv) Transmission to Mosquito:
Gametocyte Uptake: When another mosquito bites the infected human, it ingests gametocytes. Within the mosquito's midgut, gametocytes mature into male and female gametes, fuse to form zygotes, and develop into ookinetes.
Sporozoite Formation: Ookinetes penetrate the midgut wall, forming oocysts. These oocysts produce sporozoites, which migrate to the mosquito's salivary glands, ready to infect a new human host, thus completing the cycle.

Effects on the Human Host:
The blood stage of P. falciparum is responsible for the clinical manifestations of malaria:
Fever and Chills: The synchronous rupture of infected red blood cells releases merozoites and toxins into the bloodstream, triggering cyclical fevers and chills.

Anemia: Destruction of red blood cells leads to a decrease in hemoglobin levels, causing anemia and associated fatigue.

Cerebral Malaria: In severe cases, infected red blood cells adhere to cerebral blood vessels, leading to impaired blood flow, brain swelling, and potentially fatal outcomes.

Organ Failure: The parasite can cause sequestration of infected erythrocytes in vital organs, leading to complications such as renal failure, pulmonary edema, and hypoglycemia.

3. (a) A father with blood group A and a mother of blood group B (both heterozygous) have four children. What is the probability that the children will have blood group A?

To solve this, we will use a Punnett square to determine the possible genotypes and phenotypes.

Parental Genotypes:
- Father: AO (heterozygous for blood group A)
- Mother: BO (heterozygous for blood group B)

Gametes:
- Father: A and O
- Mother: B and O

Punnett Square:

	B	O
A	AB	AO
O	BO	OO

Genotypes and Phenotypes:
- AB: Blood group AB (1/4 or 25%)
- AO: Blood group A (1/4 or 25%)
- BO: Blood group B (1/4 or 25%)
- OO: Blood group O (1/4 or 25%)

Probability of Blood Group A:
The genotype for blood group A is AO. Therefore, the probability is 25% or 1/4.

(b) In the experiment conducted on pure-breeding varieties of oats, one with black-hulled grains and the other with white-hulled grains, the offspring (F1) all had black-hulled grains. When F1 generation were crossed, the F2 generation had the following phenotype:
- 418 black-hulled grains
- 106 grey-hulled grains
- 36 white-hulled grains
Use the Punnett square to show the gametes, genotype and phenotypes in each generation and suggest the genetic ratio.

Explanation of Dominance:
- Black-hulled grains are dominant (B).
- White-hulled grains are recessive (b).
- Grey-hulled grains appear due to incomplete dominance.

Parental Genotypes (P):
- Parent 1: BB (Black-hulled, pure breeding)
- Parent 2: bb (White-hulled, pure breeding)

Gametes:
- Parent 1: B
- Parent 2: b

F1 Generation:
- All offspring are Bb (Black-hulled, heterozygous).

F2 Generation (F1 x F1 Cross):

F1 Gametes:
- B and b for each parent.

Punnett Square:

	B	b
B	BB	Bb
b	Bb	bb

Genotypes in F2:
- BB: Black-hulled (1/4 or 25%)
- Bb: Grey-hulled (2/4 or 50%)
- bb: White-hulled (1/4 or 25%)

Phenotypes in F2:
- Black-hulled: 418
- Grey-hulled: 106
- White-hulled: 36

Genetic Ratio:
The ratio is 12:3:1, confirming that black is dominant, and grey results from incomplete dominance in heterozygotes.

Conclusion:
This experiment confirms Mendelian inheritance principles, with slight modifications for incomplete dominance in grey-hulled grains.

4. (a) Elaborate Mendel's work in genetics by considering his successes and failures.

Gregor Mendel, often referred to as the "father of modern genetics," conducted pioneering experiments that laid the foundation for our understanding of heredity.

Successes:

(i) Formulation of the Laws of Inheritance:
Through meticulous experimentation with pea plants (Pisum sativum), Mendel established two fundamental principles:
Law of Segregation: Each individual possesses two alleles for a given trait, which segregate during gamete formation, ensuring that each gamete carries only one allele.

Law of Independent Assortment: Genes for different traits assort independently of one another during gamete formation, leading to various trait combinations.

(ii) Methodical Experimental Design:
Mendel's approach was characterized by:
Controlled Cross-Pollination: He carefully controlled the breeding of pea plants to study specific trait inheritance.
Selection of Discrete Traits: Focusing on traits with clear, contrasting forms (e.g., tall vs. short plants) allowed for straightforward analysis.
Quantitative Analysis: Mendel applied statistical methods to analyze his data, providing a mathematical basis for his conclusions.

Failures and Limitations:
(i) Limited Scope of Traits:
Mendel selected traits that exhibited clear dominant-recessive patterns. This focus excluded traits influenced by:
Incomplete Dominance: Where heterozygous individuals display an intermediate phenotype.
Codominance: Where both alleles are fully expressed in the phenotype.

(ii) Overlooked Linkage:
Mendel's Law of Independent Assortment assumes that genes are unlinked. However, he did not account for:
Genetic Linkage: Genes located close together on the same chromosome tend to be inherited together, violating independent assortment.

(iii) Lack of Immediate Recognition:
Despite the significance of his findings, Mendel's work was largely ignored during his lifetime due to:
Limited Communication: His research was published in a relatively obscure journal, limiting its dissemination.
Scientific Context: The scientific community of his time was not prepared to integrate his findings into existing paradigms.

In summary, while Mendel's experiments were groundbreaking and established the core principles of inheritance, they did not encompass the full complexity of genetic phenomena. Subsequent research has expanded upon his work, incorporating concepts like genetic linkage, polygenic inheritance, and environmental influences on gene expression.

(b) Show the probability of having haemophiliac children when a carrier haemophiliac woman marries a normal man.

To answer this, we need to understand that haemophilia is a sex-linked recessive trait carried on the X chromosome. Men have one X and one Y chromosome (XY), while women have two X chromosomes

(XX). A carrier woman has one normal X chromosome and one defective X chromosome (Xh), while a normal man has one normal X chromosome and a Y chromosome (XY).
Parental Genotypes:
- Carrier haemophiliac woman: XhX
- Normal man: XY
Gametes Produced:
- Woman: Xh, X
- Man: X, Y

Punnett Square for the Cross:

	X	Y
Xh	XhX	XhY
X	XX	XY

Genotypes and Phenotypes of Offspring:
i. XhX: A female carrier (50% probability of being a carrier like the mother).
ii. XX: A normal female (25% probability of being normal).
iii. XhY: A haemophiliac male (25% probability of having haemophilia).
iv. XY: A normal male (25% probability of being normal).

Summary of Probabilities:
- Probability of having a haemophiliac child (male with haemophilia): 25%
- Probability of having a normal child (male or female): 50%
- Probability of having a carrier female: 25%

Explanation:
Haemophilia primarily affects males because they only have one X chromosome, and a defective X chromosome leads to the disorder. Females require two defective X chromosomes to have haemophilia, which is extremely rare. A carrier female can pass the defective gene to her sons (causing haemophilia) or to her daughters (making them carriers).

5. (a) Explain how mitosis is significant in living organisms.

Mitosis is a fundamental process in living organisms, playing a crucial role in various biological functions:

(i) Growth and Development:
Mitosis enables organisms to grow by increasing the number of cells. Starting from a single fertilized egg, mitotic divisions lead to the development of a multicellular organism, forming various tissues and organs.

(ii) Tissue Repair and Regeneration:
When tissues are damaged due to injury or wear and tear, mitosis facilitates the replacement of lost or damaged cells, maintaining tissue integrity and function.

(iii) Asexual Reproduction:
In certain organisms, mitosis serves as a means of asexual reproduction, producing genetically identical offspring. Examples include binary fission in bacteria and vegetative propagation in plants.

(iv) Maintenance of Chromosome Number:
Mitosis ensures that each daughter cell receives an exact copy of the parent cell's chromosomes, preserving the species-specific chromosome number across generations of cells.

(v) Cellular Replacement:
Regular turnover of cells, such as skin cells and blood cells, is achieved through mitosis, ensuring the continuous renewal of these cell populations.

(b) With reference to housefly and grasshopper, describe in detail the process of metamorphosis in each.

Metamorphosis is the biological process by which insects develop from immature forms into adults. Houseflies and grasshoppers undergo different types of metamorphosis:
Housefly (Musca domestica): Complete Metamorphosis (Holometabolism)
Houseflies experience complete metamorphosis, consisting of four distinct stages: egg, larva, pupa, and adult.

(i) Egg:
Female houseflies lay up to 500 eggs in several batches over a few days, typically on decaying organic matter. The white eggs are about 1.2 mm in length and hatch within a day under optimal conditions.

(ii) Larva (Maggot):
Upon hatching, larvae emerge as legless, white maggots. They feed on the organic material where the eggs were laid, undergoing rapid growth and molting several times over three to five days.

(iii) Pupa:
After reaching full size, larvae seek a dark, dry place to pupate. Inside the puparium, the maggot transforms into a pupa, a stage during which it undergoes significant reorganization to develop adult structures. The pupal stage lasts from a few days to several weeks, depending on environmental conditions.

(iv) Adult:
The adult housefly emerges from the puparium, ready to reproduce shortly after emergence. Adults typically live for two to four weeks, during which they continue the reproductive cycle.

Grasshopper: Incomplete Metamorphosis (Hemimetabolism)

Grasshoppers undergo incomplete metamorphosis, involving three stages: egg, nymph, and adult.

(i) Egg:
Female grasshoppers lay eggs in soil or plant material, where they remain dormant until favorable conditions prompt hatching.

(ii) Nymph:
Hatching produces nymphs that resemble miniature adults but lack fully developed wings and reproductive organs. Nymphs undergo multiple molts, known as instars, gradually developing adult features with each successive molt.

(iii) Adult:
After the final molt, the grasshopper reaches adulthood, characterized by fully developed wings and functional reproductive organs. Adults are capable of flight and reproduction, completing the life cycle.
In summary, houseflies undergo complete metamorphosis with a distinct pupal stage facilitating a transformation from larva to adult, while grasshoppers experience incomplete metamorphosis,

6. Describe how mammals are adapted to warm environments.

Mammals inhabiting warm environments have evolved a range of physiological, behavioral, and morphological adaptations to regulate their body temperature and maintain homeostasis:

(i) Evaporative Cooling Mechanisms:
Sweating: Many mammals possess sweat glands that secrete moisture onto the skin's surface. The evaporation of this sweat dissipates heat, effectively cooling the body. This mechanism is particularly prominent in humans and horses.
Panting: Species with fewer sweat glands, such as dogs and certain rodents, utilize panting to regulate temperature. Rapid breathing increases airflow over moist surfaces in the respiratory tract, promoting evaporative heat loss.

(ii) Behavioral Adaptations:
Nocturnal Activity: To avoid the intense heat of the day, some mammals, like desert rodents, are primarily active during the cooler nighttime hours.
Seeking Shade or Burrowing: Many mammals retreat to shaded areas, burrows, or dens during peak temperatures to minimize heat exposure. For instance, the fennec fox utilizes underground burrows to stay cool in the desert environment.

(iii) Morphological Adaptations:
Large Appendages: Some mammals have evolved larger ears or limbs that facilitate heat dissipation. Elephants, for example, have extensive ear surfaces rich in blood vessels; by flapping their ears, they enhance heat loss.

Reduced Insulation: In warmer climates, mammals may exhibit shorter, sparser fur to decrease insulation and promote heat loss. Conversely, they may shed thicker winter coats seasonally to adapt to rising temperatures.

(iv) Physiological Adaptations:
Vasodilation: Expansion of blood vessels near the skin surface increases blood flow, allowing more heat to be released into the environment. This process helps in cooling the body during elevated temperatures.
Concentrated Fat Storage: Some desert mammals, like camels, store fat in specific body areas (e.g., humps). This localization prevents the insulating effect of widespread fat distribution, aiding in heat dissipation across other body regions.

(v) Efficient Water Conservation:
Concentrated Urine and Dry Feces: To minimize water loss, many desert-dwelling mammals produce highly concentrated urine and dry feces. This adaptation reduces the need for water intake, which is scarce in arid environments.
Metabolic Water Production: Some species rely on water generated through metabolic processes, reducing dependence on external water sources. For instance, the kangaroo rat derives sufficient water from the oxidation of seeds it consumes.

7. (a) Describe the two types of competition and briefly explain why intraspecific competition is density dependent.

In ecological contexts, competition refers to the interaction between organisms or species that vie for the same limited resources within an environment. The two primary types of competition are:

(i) Intraspecific Competition:
This occurs when individuals of the same species compete for resources such as food, space, mates, or light. For example, trees of the same species in a dense forest may compete for sunlight and soil nutrients. Intraspecific competition is density dependent because as the population density increases, the availability of resources per individual decreases, intensifying competition. This can lead to reduced growth rates, lower reproductive success, and increased mortality within the population.

(ii) Interspecific Competition:
This occurs when individuals of different species compete for the same resources in an ecosystem. For instance, lions and hyenas may compete for prey in the same habitat. Interspecific competition can influence the population dynamics and distribution of the competing species, potentially leading to competitive exclusion or niche differentiation.

(b) Explain six ways in which excess intraspecific competition is avoided among organisms in the ecosystem.

Organisms have evolved various strategies to mitigate excessive intraspecific competition, ensuring better survival and reproductive success:

(i) Territoriality:
Many animals establish and defend territories to secure exclusive access to resources such as food, mates, and nesting sites. By maintaining territories, individuals reduce direct competition with conspecifics. For example, male songbirds often defend specific areas during the breeding season to attract females and ensure sufficient resources for their offspring.

(ii) Resource Partitioning:
Individuals may exploit different resources or utilize the same resources in varying ways or times to minimize competition. For instance, caterpillars of the same butterfly species might feed on different parts of a plant or at different times of day, reducing overlap in resource use.

(iii) Social Hierarchies:
In some species, social structures establish dominance hierarchies, where dominant individuals have priority access to resources, while subordinates may access them later or utilize alternative resources. This reduces constant aggressive interactions and allows for more orderly resource distribution. An example is the pecking order observed in chicken flocks.

(iv) Dispersal Mechanisms:
To alleviate local competition, many species have developed dispersal strategies where individuals move away from their birthplace to establish new territories or colonies. Plants may produce seeds with structures that facilitate wind or animal dispersal, ensuring offspring grow at a distance from the parent plant.

(v) Life Cycle Variation:
Some organisms exhibit variations in their life cycles that reduce competition among conspecifics. For example, certain insect species have larval stages that occupy different ecological niches than the adult stages, minimizing resource overlap between generations.

(vi) Phenotypic Plasticity:
Organisms may alter their behavior, morphology, or physiology in response to environmental conditions, allowing them to utilize different resources or habitats when competition is intense. For instance, some fish can change their diet based on the availability of prey, reducing direct competition with conspecifics.
These strategies enhance the ability of species to coexist by reducing the negative impacts of intraspecific competition, thereby promoting population stability and ecological balance.

8. Elaborate how primary and secondary ecological successions take place.

Ecological succession is the process by which the structure of a biological community evolves over time. This process can be categorized into two main types: primary succession and secondary succession.

Primary Succession:

Primary succession occurs in lifeless areas where there is no soil or initial vegetation. This can happen in environments such as newly formed volcanic islands, areas exposed by retreating glaciers, or regions where a lava flow has solidified. The stages of primary succession include:

Nudation: The creation of a bare, uninhabited environment due to events like volcanic eruptions or glacial retreats.
Colonization by Pioneer Species: Hardy organisms such as lichens and certain algae are the first to colonize these barren areas. These pioneer species can survive in harsh conditions and begin the soil formation process by breaking down the substrate.
Soil Formation: As pioneer species decompose, they contribute organic matter, leading to the gradual development of soil. This newly formed soil allows mosses and small plants to establish themselves, further enriching the soil as they die and decompose.
Arrival of Intermediate Species: With improved soil conditions, grasses, ferns, and shrubs can take root, outcompeting the pioneer species and altering the habitat.
Establishment of a Climax Community: Over time, the ecosystem reaches a stable state known as the climax community, characterized by mature trees and a diverse array of plant and animal life. The specific composition of this community depends on the regional climate and environmental conditions.

The entire process of primary succession can span hundreds to thousands of years, given the initial absence of soil and organic material.
Secondary Succession:

Secondary succession takes place in areas where a disturbance has destroyed an existing community but left the soil intact. Such disturbances include wildfires, hurricanes, floods, or human activities like farming and logging. The stages of secondary succession are:

Disturbance: An event removes the existing vegetation and possibly displaces animals, but the soil remains, often enriched with nutrients from decaying plant matter.
Colonization by Pioneer Species: Weedy and fast-growing plants, such as grasses and certain herbs, quickly occupy the disturbed area. These species stabilize the soil and prevent erosion.
Establishment of Intermediate Species: As conditions improve, shrubs and young trees begin to grow, creating habitats for various animal species and leading to increased biodiversity.
Development of a Climax Community: Eventually, the area matures into a climax community similar to the one that existed before the disturbance, assuming no further disruptions occur.

Secondary succession progresses more rapidly than primary succession because the presence of existing soil and seed banks accelerates the recovery process.

In summary, both primary and secondary successions are natural processes that lead to the development and maturation of ecosystems. While primary succession starts from a barren landscape without soil, secondary succession begins in areas where a disturbance has reset an existing ecosystem, but the soil remains.