1. (a) Define the following (any 4):
    - (i) Biodiversity
        - Biodiversity, or biological diversity, refers to the variety of life on Earth at all its levels, from genes to ecosystems, and the ecological and evolutionary processes that sustain it. It encompasses the diversity of species, genetic diversity within species, and the diversity of ecosystems and habitats. It is a measure of the health of biological systems.
    - (ii) Hormogonia
        - Hormogonia are short, motile filaments of cells formed by some filamentous cyanobacteria (blue-green algae), such as Nostoc and Oscillatoria. They are specialized structures involved in asexual reproduction and dispersal, breaking away from the main filament to establish new colonies. They are capable of gliding motility and can develop into new full-length filaments.
    - (iii) Mycelium
        - A mycelium is the vegetative part of a fungus or fungus-like bacterial colony, consisting of a mass of branching, thread-like hyphae. It is typically found underground or within the substrate on which the fungus grows. The mycelium is responsible for nutrient absorption from the environment.
    - (iv) Strobilation
        - Strobilation is a form of asexual reproduction seen in some cnidarians, particularly scyphozoans (jellyfish), and also in some tapeworms (cestodes). In cnidarians, it involves the transverse fission of a polyp into a stack of immature medusae (ephyrae), which then develop into

adult medusae. In tapeworms, it refers to the formation of proglottids, segments that contain reproductive organs and are budded off from the scolex.

- (v) Ametabola
  - Ametabola refers to insects that undergo little or no metamorphosis during their life cycle. These insects hatch from eggs resembling miniature adults, and they grow larger through a series of molts, but they do not undergo a pupal stage or dramatic morphological changes. Examples include silverfish and springtails.
- (vi) Madreporite
  - The madreporite is a porous, button-like or sieve-like plate on the aboral (upper) surface of echinoderms, such as starfish and sea urchins. It serves as the opening for the water vascular system, allowing water to enter and exit the system. It filters seawater and helps maintain the internal pressure of the water vascular system, which is crucial for locomotion, feeding, and gas exchange.

(b) Fill in the blanks:

- (i) Common name of Selaginella is **Spikemoss** or **Clubmoss**.
- (ii) The main pigment in red algae is **Phycoerythrin**.
- (iii) **Radula** is present in molluscs for feeding.
- (iv) **Cnidocytes** or **Nematocysts** type of cells are present in cnidarians for defense.

(c) Match the following:

- (i) Nostoc - (b) Heterocyst
- (ii) Symbiosis - (a) Lichens

- (iii) Appendiculate - (d) Marchantia (specifically referring to the antheridiophore of Marchantia which can have appendiculate features)
- (iv) Vascular cryptogams - (c) Pteridophytes

(d) Differentiate between the following:

- (i) Male & Female Ascaris
  - **Male Ascaris:**
    - Typically smaller in length (2-4 cm).
    - Posterior end is curved ventrally (hook-shaped).
    - Possesses a pair of copulatory spicules near the cloaca, used during mating.
    - No vulva.
  - **Female Ascaris:**
    - Generally larger in length (20-35 cm).
    - Posterior end is straight and conical.
    - Lacks copulatory spicules.
    - Possesses a distinct vulva located approximately one-third of the body length from the anterior end.
- (ii) Polyp & Medusae
  - **Polyp:**
    - Sessile (immobile) or largely sedentary form.
    - Cylindrical body shape with a mouth and tentacles facing upwards.
    - Attached to a substrate at its base.

- Typically reproduces asexually by budding or fission.
- Examples: Sea anemones, Hydra, colonial corals.

- **Medusa:**
  - Free-swimming (motile) form.
  - Bell-shaped or umbrella-shaped body with a mouth and tentacles hanging downwards.
  - Propels itself by rhythmic contractions of the bell.
  - Typically reproduces sexually by producing gametes.
  - Examples: Jellyfish.

2. (a) With the help of labelled diagrams explain the development of male and female gametophytes in Selaginella.
   - (As per instructions, I cannot make schematic diagrams. I will describe the development.)
   - **Development of Male Gametophyte (Microgametophyte) in Selaginella:**
     - Selaginella is heterosporous, producing two types of spores: microspores and megaspores.
     - Microspores are produced in microsporangia, which are borne on microsporophylls.
     - Each microspore is the mother cell for the male gametophyte. The development of the male gametophyte begins while the microspore is still within the microsporangium.
     - The microspore nucleus divides to form a small, non-functional prothallial cell and a large antheridial initial.

  - The antheridial initial undergoes further divisions to form a jacket (sterile) layer and an inner mass of androgonial cells.
  - These androgonial cells develop into biflagellate antherozoids (sperms).
  - At maturity, the male gametophyte, still contained within the microspore wall, is released. It consists of the prothallial cell, the jacket cells, and the antherozoids.
  - Upon release, and in the presence of water, the microspore wall ruptures, releasing the antherozoids, which are capable of swimming towards the female gametophyte.

- **Development of Female Gametophyte (Megagametophyte) in Selaginella:**
  - Megaspores are produced in megasporangia, which are borne on megasporophylls.
  - Each megaspore is the mother cell for the female gametophyte. The development of the female gametophyte also begins while the megaspore is still within the megasporangium (endosporic development).
  - The megaspore nucleus undergoes repeated free nuclear divisions, forming a large number of nuclei within the megaspore wall.
  - Cell wall formation then occurs around these nuclei, primarily at the apical end of the megaspore, leading to the formation of cellular tissue.
  - A small cushion-like prothallus (female gametophyte) is formed, which often protrudes slightly from the ruptured megaspore wall.

- Archegonia (female sex organs) develop on this prothallus, typically at the apical end. Each archegonium contains a single large egg cell.
- In some species, the megaspore is retained within the megasporangium even after fertilization, a step towards seed habit.
- The mature female gametophyte contains archegonia with egg cells, ready for fertilization by the swimming antherozoids.

(b) Give a detailed account of life cycle of pork tapeworm.

- The pork tapeworm, *Taenia solium*, is a parasitic flatworm that causes taeniasis (in humans) and cysticercosis (in humans or pigs). It has a complex life cycle involving two hosts: humans as the definitive host and pigs as the intermediate host.
- **1. Adult Tapeworm in Human Intestine (Definitive Host):**
  - Humans become infected by ingesting raw or undercooked pork containing infective larvae called cysticerci.
  - Upon ingestion, the cysticercus excysts in the human small intestine, and its scolex (head) attaches to the intestinal wall using suckers and hooks.
  - The scolex then buds off proglottids (segments), and the tapeworm grows to several meters in length.
  - The adult tapeworm is hermaphroditic, with each mature proglottid containing both male and female reproductive organs. Self-fertilization or cross-fertilization between proglottids occurs.
  - Gravid proglottids (filled with thousands of eggs) detach from the tapeworm and are passed in the human feces.

- **2. Eggs in Environment:**
    - The gravid proglottids may release eggs either before or after being passed in feces. The eggs are microscopic and highly resistant, capable of surviving in the environment for days to months.
- **3. Ingestion by Intermediate Host (Pig):**
    - Pigs become infected by ingesting food or water contaminated with human feces containing these eggs.
- **4. Larval Development in Pig Muscle (Intermediate Host):**
    - Once ingested by a pig, the eggs hatch in the pig's intestine, releasing an oncosphere (hexacanth embryo).
    - The oncosphere penetrates the intestinal wall and enters the bloodstream.
    - It then disseminates throughout the pig's body, preferentially migrating to striated muscles (e.g., tongue, diaphragm, ham, shoulder).
    - In the muscles, the oncosphere develops into a cysticercus (also known as a "bladder worm"), which is a fluid-filled cyst containing an invaginated scolex. This process takes approximately 2-3 months.
    - Pigs infected with cysticerci are said to have "measly pork."
- **5. Human Infection (Cycle Continues):**
    - The life cycle completes when humans consume raw or undercooked "measly pork" containing viable cysticerci, restarting the cycle.
- **Human Cysticercosis (Accidental Intermediate Host):**

  - A critical aspect of *T. solium* life cycle is that humans can also act as accidental intermediate hosts. If a human ingests *T. solium* eggs (either from contaminated food/water or through autoinfection from their own intestinal tapeworm), the eggs hatch in the human intestine.
  - The oncospheres then penetrate the human intestinal wall and disseminate throughout the body, just as they would in a pig.
  - These oncospheres develop into cysticerci in various human tissues, including muscles, subcutaneous tissue, eyes, and most dangerously, the brain (neurocysticercosis). Neurocysticercosis is a major cause of acquired epilepsy in many parts of the world.
- The life cycle highlights the importance of proper sanitation, thorough cooking of pork, and treatment of infected individuals to break the transmission chain.

3. (a) With the help of suitable diagram illustrate the water vascular system in asteroidea.
   - (As per instructions, I cannot make schematic diagrams. I will describe the system.)
   - The water vascular system, also known as the ambulacral system, is a unique and defining characteristic of echinoderms, including asteroids (starfish). It is a hydraulic system of fluid-filled canals and tube feet that plays crucial roles in locomotion, feeding, gas exchange, and sensory perception.
   - **Components of the Water Vascular System in Asteroidea:**
     - **Madreporite:** This is the external opening of the system, located on the aboral surface (upper side) of the central

disc. It is a sieve-like plate that filters seawater entering the system.

- **Stone Canal:** From the madreporite, water passes into the stone canal, a short, S-shaped, vertical canal. Its walls are often reinforced with calcareous rings, and it connects the madreporite to the ring canal.
- **Ring Canal (or Circular Canal):** This circular canal encircles the mouth in the central disc. It connects to the stone canal and gives rise to the radial canals.
- **Tiedemann's Bodies:** These are usually 9 small, glandular bodies or pouches attached to the ring canal on the inner side (ambulacral side). Their exact function is debated, but they are thought to be involved in producing amoebocytes (phagocytic cells) for the coelomic fluid and filtering fluid in the water vascular system.
- **Polian Vesicles:** These are balloon-like, contractile sacs also attached to the ring canal. They function as reservoirs for the fluid in the water vascular system and may help regulate internal pressure. The number of Polian vesicles varies among species.
- **Radial Canals:** From the ring canal, five radial canals extend along the length of each arm, running within the ambulacral groove on the oral surface.
- **Lateral Canals:** Short, paired lateral canals (also called podial canals) branch off alternately from the radial canals into the ambulacral groove of each arm. Each lateral canal supplies a single tube foot.
- **Tube Feet (Podia):** Each lateral canal ends in a tube foot. A tube foot consists of a muscular ampulla (a bulb-like sac) located inside the arm, and a slender, cylindrical

podium (the external part) that typically ends in a suction cup.

- **Functioning:**
  - The system operates through hydrostatic pressure. Contraction of the ampulla forces water into the podium, extending it. When the podium touches a surface, the suction cup adheres. Contraction of the longitudinal muscles in the podium then pulls the animal forward, and water is drawn back into the ampulla, detaching the cup.
  - This coordinated action of thousands of tube feet allows starfish to move slowly, cling tightly to surfaces, and exert powerful forces to open bivalve shells. The system also plays a role in respiration and waste excretion.

(b) Write short notes on the following (any 3):

- (i) Vesicular Arbuscular Mycorrhiza (VAM)
  - Vesicular Arbuscular Mycorrhiza (VAM), now more commonly referred to as Arbuscular Mycorrhiza (AM), represents the most widespread type of endomycorrhizal association, forming a symbiotic relationship between fungi (specifically from the phylum Glomeromycota) and the roots of about 80% of all land plants.
  - **Structure and Formation:** The fungal hyphae grow both intercellularly (between root cells) and intracellularly (penetrating into cortical root cells). Inside the root cells, the hyphae form specialized structures:
    - **Arbuscules:** These highly branched, tree-like structures are formed within the plant cell walls (but outside the plasma membrane). They are the primary sites of nutrient exchange between the fungus and the plant.

        - **Vesicles:** These are oval-shaped, lipid-rich storage organs formed inter- or intracellularly, serving as nutrient reserves for the fungus.
    - **Mutualistic Relationship:**
        - **Benefits to the Plant:** The fungal hyphae extend far into the soil, vastly increasing the surface area for nutrient absorption, particularly for relatively immobile nutrients like phosphorus and certain micronutrients (e.g., zinc, copper). The fungi can also enhance water uptake, provide protection against root pathogens, and improve plant tolerance to environmental stresses (e.g., drought, salinity).
        - **Benefits to the Fungus:** In return, the fungus obtains carbohydrates (sugars) and lipids synthesized by the plant through photosynthesis, as fungi are heterotrophic and cannot produce their own food.
    - **Ecological Importance:** VAM plays a crucial role in nutrient cycling in ecosystems, plant establishment in disturbed lands, and sustainable agriculture by reducing the need for synthetic fertilizers.
- (ii) Economic importance of Lichens
    - Lichens, symbiotic associations between a fungus (mycobiont) and an alga or cyanobacterium (photobiont), have several economic and ecological importance:
        - **Pioneer Species:** They are often pioneer organisms, colonizing barren environments like bare rock. Their ability to secrete acids helps in weathering rocks, initiating soil formation, which is crucial for ecological succession.

- **Food Source:** Some lichens are a significant food source for animals in harsh environments, particularly reindeer and caribou in arctic and subarctic regions (e.g., "reindeer moss," *Cladonia rangiferina*). Humans also consume certain lichens in some cultures, though they can be unpalatable or toxic.
- **Dye Production:** Historically, lichens were a primary source of natural dyes (e.g., litmus, orchil). Litmus, a pH indicator, is still widely used in laboratories.
- **Medicinal Uses:** Some lichens have been traditionally used in folk medicine for their antimicrobial, anti-inflammatory, and antioxidant properties. Certain lichen compounds (e.g., usnic acid) have known antibiotic activity.
- **Perfumes and Cosmetics:** Lichens like oakmoss (*Evernia prunastri*) are used as fixatives in perfumery and cosmetics due to their long-lasting fragrance.
- **Bioindicators of Air Quality:** Lichens are extremely sensitive to air pollution, especially sulfur dioxide. Their absence or altered growth forms in an area can serve as an early indicator of air pollution, making them valuable bioindicators.
- **Nitrogen Fixation:** When the photobiont is a cyanobacterium (e.g., Nostoc), the lichen can fix atmospheric nitrogen, contributing to nitrogen enrichment in nutrient-poor environments.

- (iii) Female sex organ of Polysiphonia

- Polysiphonia is a genus of red algae (Rhodophyceae) characterized by its complex life cycle and specialized reproductive structures. The female sex organ in Polysiphonia is the **carpogonium**.
- **Structure:** The carpogonium is a single, flask-shaped cell that functions as the female gamete. It is borne on a specialized, short branch called the **carpogonial branch**, which typically consists of 3-4 cells. The carpogonium itself has two distinct parts:
    - **Basal swollen part:** This contains the female nucleus (egg).
    - **Elongated, receptive apical part (trichogyne):** This is a slender, hair-like extension of the carpogonium that protrudes above the thallus surface. Its primary function is to receive the non-motile male gametes, called spermatia.
- **Fertilization:** When spermatia (released from antheridia, the male sex organs) are carried by water currents and come into contact with the sticky surface of the trichogyne, they adhere. The wall between the spermatium and the trichogyne dissolves, and the male nucleus migrates down the trichogyne to fuse with the female nucleus in the basal part of the carpogonium, leading to fertilization.
- **Post-fertilization Development:** Following fertilization, a complex sequence of events occurs, involving the development of a diploid carposporophyte, which produces carpospores. This intricate post-fertilization development is a characteristic feature of red algae.

- (iv) Vegetative structure of Rhizopus

- *Rhizopus* is a common genus of fungi belonging to the Zygomycetes (now often placed in Mucoromycota), famously known as "bread mold." Its vegetative structure is typical of many filamentous fungi and is characterized by a rapidly growing, coenocytic mycelium.
- **Mycelium:** The main body of *Rhizopus* is a cottony, white or grayish mycelium. This mycelium is composed of a network of hyphae.
- **Hyphae:** The hyphae of *Rhizopus* are:
    - **Coenocytic:** This is a defining feature, meaning the hyphae are aseptate (lack cross-walls or septa). The cytoplasm, containing multiple nuclei, is continuous throughout the hyphal network. This allows for rapid nutrient flow and growth.
    - **Branched:** The hyphae are extensively branched, forming a large surface area for absorption of nutrients from the substrate.
    - **Hyaline:** The hyphae are generally transparent or colorless.
- **Specialized Vegetative Hyphae:** *Rhizopus* also possesses specialized vegetative hyphae that anchor the fungus and absorb nutrients:
    - **Rhizoids:** These are root-like, branched hyphae that grow downwards into the substrate (e.g., bread). They secrete digestive enzymes and absorb the digested nutrients. They provide anchorage for the sporangiophores.
    - **Stolons:** These are horizontal, arching aerial hyphae that connect groups of rhizoids. They grow rapidly across the surface of the substrate and

periodically produce new rhizoids and sporangiophores where they touch the substrate, allowing for rapid colonization.

- This efficient and extensive vegetative structure allows *Rhizopus* to rapidly colonize and decompose organic matter.

4. (a) Discuss key factors responsible for the biodiversity crisis/loss.

   - The biodiversity crisis, or the rapid decline in the variety of life on Earth, is a multifaceted problem driven by a complex interplay of human activities. The key factors responsible for biodiversity loss are often summarized by the acronym HIPPO (Habitat loss, Invasive species, Pollution, Population, Overharvesting), with climate change being an increasingly significant additional factor.

   - **1. Habitat Loss and Fragmentation:** This is widely considered the leading cause of biodiversity loss.
     - **Conversion:** Natural habitats are converted for agriculture (croplands, pastures), urbanization, industrial development, infrastructure (roads, dams), and resource extraction (mining, logging).
     - **Fragmentation:** Remaining habitats are broken into smaller, isolated patches, which reduces population sizes, limits gene flow, increases edge effects (e.g., increased predation, altered microclimates), and makes species more vulnerable to extinction.
     - **Degradation:** Even if not completely lost, habitats can be degraded by pollution, altered hydrological regimes, or unsustainable resource use, rendering them unsuitable for many species.
   - **2. Invasive Alien Species:**

    - The introduction of non-native species (intentionally or accidentally) into new ecosystems can have devastating effects.
    - Invasive species can outcompete native species for resources, prey on native species, introduce diseases, alter habitats, or disrupt food webs, leading to declines or extinctions of native populations.
- **3. Pollution:**
    - Pollution of air, water, and soil by various chemicals and waste products harms organisms and degrades ecosystems.
    - **Chemical Pollution:** Pesticides, industrial chemicals, heavy metals, plastics, and pharmaceuticals can directly poison organisms, disrupt their physiology, or accumulate in food chains (biomagnification).
    - **Nutrient Pollution:** Excess nutrients (nitrogen, phosphorus) from agricultural runoff and sewage lead to eutrophication of aquatic ecosystems, causing algal blooms, oxygen depletion (dead zones), and loss of aquatic life.
    - **Light and Noise Pollution:** Can disrupt animal behaviors (e.g., migration, reproduction) and impact ecosystem function.
- **4. Climate Change:**
    - Global warming, driven by greenhouse gas emissions, is rapidly altering environmental conditions beyond the adaptive capacity of many species.
    - **Temperature Changes:** Shifting temperature regimes affect species' physiological processes, distribution, and

phenology (timing of life events like flowering or breeding).

- **Altered Precipitation Patterns:** Changes in rainfall lead to droughts or floods, impacting water availability and habitat integrity.
- **Extreme Weather Events:** Increased frequency and intensity of storms, heatwaves, and wildfires directly destroy habitats and kill organisms.
- **Ocean Acidification:** Increased CO_2 absorption by oceans leads to acidification, which severely impacts marine organisms with calcium carbonate shells or skeletons (e.g., corals, molluscs).
- **Sea Level Rise:** Threatens coastal habitats and low-lying areas.

- **5. Overexploitation/Overharvesting:**
  - Unsustainable harvesting of wild populations (hunting, fishing, logging, collection for pet trade or traditional medicine) can deplete species to critically low levels, leading to local extinctions or overall population collapse.
  - Examples include overfishing of many fish stocks, poaching of endangered animals (e.g., rhinos, elephants), and unsustainable logging of forests.
- **6. Human Population Growth and Consumption:**
  - Underlying all these direct drivers is the expanding human population and its increasing per capita consumption of resources. More people and higher consumption rates place greater demands on natural resources and lead to more waste and habitat conversion.

- These factors often interact synergistically, exacerbating the impact on biodiversity. Addressing the biodiversity crisis requires a multi-faceted approach, including habitat protection, sustainable resource management, pollution control, climate action, and addressing underlying socio-economic drivers.

(b) Describe the thallus structure and reproduction in Nostoc.

- *Nostoc* is a genus of filamentous cyanobacteria (blue-green algae) commonly found in freshwater, soil, and on moist rocks. It forms colonies that are often visible as gelatinous, globular, or flattened masses.
- **Thallus Structure (Colonial and Filamentous):**
  - **Colony:** The most characteristic feature of *Nostoc* is its macroscopic, gelatinous colony. This colony is irregular in shape, typically spherical or flattened, and can be small or several centimeters in diameter. It is embedded in a thick, mucilaginous (gelatinous) sheath, which provides protection from desiccation and UV radiation. The mucilage helps the colony retain water and gives it a characteristic slippery feel.
  - **Filaments:** Within this gelatinous matrix, numerous unbranched filamentous trichomes (chains of cells) are embedded. Each trichome consists of a single row of cells.
  - **Vegetative Cells:** These are typically spherical or barrel-shaped, photosynthetic cells that make up the majority of the trichome. They contain photosynthetic pigments like chlorophyll *a*, phycocyanin, and phycoerythrin (giving them a bluish-green to brownish color).
  - **Heterocysts:** Interspersed along the trichome are larger, thick-walled, transparent cells called heterocysts. These are specialized cells for atmospheric nitrogen fixation.

They lack photosystem II, preventing oxygen production (which inhibits nitrogenase, the enzyme for nitrogen fixation) and creating an anaerobic environment necessary for nitrogen fixation.

- **Akinetes:** Under unfavorable conditions (e.g., drought, nutrient depletion), some vegetative cells can differentiate into larger, thick-walled, resistant spores called akinetes. These are resting spores that can survive harsh conditions and germinate when favorable conditions return.

- **Reproduction in Nostoc:**
  - **1. Asexual Reproduction:** This is the primary mode of reproduction.
    - **Fragmentation:** The most common method. The entire colony can fragment into smaller pieces, each capable of developing into a new colony.
    - **Hormogonia Formation:** This is a specialized type of fragmentation. Short, motile fragments of the trichome, consisting of a few vegetative cells, are called hormogonia. These break away from the main filament and, being motile (by gliding), can disperse to new locations and develop into new colonies. This is particularly common in young cultures.
    - **Akinete Germination:** When conditions become favorable, the resistant akinetes can germinate, releasing new vegetative cells that grow into a new trichome and eventually a colony.
  - **2. Sexual Reproduction:** True sexual reproduction (involving fusion of gametes) is **absent** in *Nostoc* and all

cyanobacteria. Their genetic recombination mechanisms are different from eukaryotic sexual reproduction.

(c) Discuss the process of pearl formation in molluscs with the help of suitable diagrams.

- (As per instructions, I cannot make schematic diagrams. I will describe the process.)
- Pearl formation is a natural defensive mechanism of certain molluscs, primarily bivalves (like oysters and mussels), to encapsulate and neutralize an irritant within their shell. The process results in the formation of a lustrous, hard gem called a pearl.
- **The Irritant:** Pearl formation is typically triggered when a foreign irritant, such as a parasite, a grain of sand, or a piece of shell, enters the mollusc's mantle cavity and becomes lodged near the mantle tissue. It's a common misconception that a single grain of sand is the primary cause; parasites are more often the natural trigger.
- **Mantle Tissue Response:**
  - The mantle is the fleshy layer of tissue that lines the inside of the mollusc's shell and is responsible for secreting the shell material.
  - When an irritant lodges in the mantle, the epithelial cells of the mantle tissue, which are responsible for secreting nacre (mother-of-pearl), are stimulated.
  - These epithelial cells proliferate and surround the irritant, forming a "pearl sac" or "pearl cyst" around it. This pearl sac effectively isolates the foreign object from the mollusc's soft body.
- **Nacre Deposition:**

    - The cells of the pearl sac then begin to secrete concentric layers of nacre around the irritant. Nacre is composed of microscopic hexagonal platelets of aragonite (a crystalline form of calcium carbonate, $CaCO_3$) cemented together by a flexible organic matrix (conchiolin, a protein).
    - Each layer of nacre is incredibly thin and translucent. The iridescent luster (orient) of a pearl is due to the diffraction and interference of light passing through these multiple translucent layers.
  - **Growth of the Pearl:**
    - Over time (from months to several years), successive layers of nacre are deposited, gradually increasing the size of the pearl. The shape of the pearl depends on the shape of the initial irritant and its position within the mollusc. Spherical pearls, the most valuable, form when the irritant is perfectly rounded and free to move within the pearl sac.

  - **Types of Pearls:**
    - **Natural Pearls:** Formed naturally without human intervention when an irritant accidentally enters the mollusc.
    - **Cultured Pearls:** Produced by human intervention, where a small bead (nucleus) and a piece of mantle tissue from another mollusc are surgically inserted into the gonad or mantle of the host mollusc. The mollusc then forms a pearl sac around the inserted nucleus and secretes nacre around it. This process mimics the natural formation.
  - The formation of a pearl is a testament to the mollusc's remarkable biological defense mechanism, transforming a potential threat into a valuable gem.

5. (a) Give an illustrative account of the sporophyte of Marchantia.

- (As per instructions, I cannot make schematic diagrams. I will describe the sporophyte.)
- *Marchantia* is a common genus of liverworts (Bryophytes), and its life cycle is characterized by a dominant gametophytic generation and a sporophyte that is entirely dependent on the gametophyte for nutrition and support. The sporophyte of *Marchantia* is short-lived and relatively simple in structure compared to higher plants.
- **Location and Dependence:**
  - The sporophyte develops within the archegonium on the underside of the female gametophyte's specialized reproductive stalk, the archegoniophore. It remains permanently attached and nutritionally dependent on the gametophyte throughout its life.
- **Structure of the Mature Sporophyte:** The mature sporophyte of *Marchantia* typically consists of three distinct parts:
  - **1. Foot:**
    - This is the basal, bulbous or conical part of the sporophyte embedded within the tissue of the female gametophyte.
    - Its primary function is absorption. It consists of parenchymatous cells that act as a haustorium, absorbing nutrients, water, and minerals from the gametophyte to support the developing sporophyte.
  - **2. Seta:**
    - This is a short, colorless, stalk-like structure connecting the foot to the capsule.

- It is generally short and does not elongate significantly in *Marchantia* as it does in some other bryophytes (like mosses). It provides a connection and perhaps limited transport between the foot and the capsule.

- **3. Capsule (Sporangium):**
  - This is the terminal, spherical or oval-shaped part of the sporophyte, where meiosis occurs and spores are produced.
  - **Capsule Wall:** It has a single-layered wall that is initially green (photosynthetic) but later turns brown as it matures.
  - **Archesporium:** Inside the capsule, the sporogenous tissue (archesporium) differentiates into two types of cells:
    - **Spore Mother Cells (Sporocytes):** These diploid (2n) cells undergo meiosis to produce numerous haploid (n) spores.
    - **Elaters:** These are sterile, elongated, spindle-shaped cells with hygroscopic (water-absorbing) spiral thickenings in their walls. They are sensitive to changes in humidity. When the capsule wall ruptures at maturity, the elaters twist and untwist due to changes in moisture, aiding in the dispersal of spores by scattering them.

- **Dehiscence and Spore Dispersal:**
  - At maturity, the capsule wall ruptures irregularly (or by longitudinal slits in some species). The twisting

movements of the elaters help to effectively disperse the tiny, lightweight spores into the air.

- Each haploid spore, upon landing in a suitable moist environment, germinates to form a new haploid gametophyte, completing the life cycle.

(b) Give a detailed description of the five kingdom classification given by R.H. Whittaker.

- R.H. Whittaker proposed the Five Kingdom Classification system in 1969, which became widely accepted for its comprehensiveness and clarity in organizing biological diversity. This system primarily classified organisms based on their cell structure (prokaryotic vs. eukaryotic), mode of nutrition (autotrophic vs. heterotrophic), and body organization (unicellular vs. multicellular). The five kingdoms are Monera, Protista, Fungi, Plantae, and Animalia.
- **1. Kingdom Monera:**
  - **Cell Type:** Prokaryotic (lacking a true nucleus and membrane-bound organelles).
  - **Body Organization:** Unicellular, though some may form colonies or filaments.
  - **Cell Wall:** Present, composed of peptidoglycan (murein).
  - **Mode of Nutrition:** Diverse, including autotrophic (photosynthetic like cyanobacteria, chemosynthetic like nitrifying bacteria) and heterotrophic (saprophytic, parasitic).
  - **Examples:** Bacteria (e.g., *Escherichia coli*, *Bacillus subtilis*), Archaea (e.g., methanogens, halophiles), Cyanobacteria (blue-green algae, e.g., *Nostoc*, *Anabaena*).

- **2. Kingdom Protista:**
  - **Cell Type:** Eukaryotic (possessing a true nucleus and membrane-bound organelles).
  - **Body Organization:** Predominantly unicellular, but some are colonial or simple multicellular (without specialized tissues).
  - **Cell Wall:** Present in some (e.g., algae), absent in others (e.g., protozoa).
  - **Mode of Nutrition:** Varied, including autotrophic (photosynthetic, e.g., diatoms, Euglena, Volvox), heterotrophic (ingestive, e.g., Amoeba, Paramecium), and saprophytic (absorptive, e.g., slime molds).
  - **Examples:** Amoeba, Paramecium, Euglena, Diatoms, Dinoflagellates, Slime molds. (This is a very diverse and somewhat polyphyletic group).

- **3. Kingdom Fungi:**
  - **Cell Type:** Eukaryotic.
  - **Body Organization:** Mostly multicellular filamentous (hyphae forming mycelium), but some are unicellular (e.g., yeasts).
  - **Cell Wall:** Present, composed of chitin (unlike plant cell walls made of cellulose).
  - **Mode of Nutrition:** Strictly heterotrophic, primarily saprophytic (decomposers, absorbing nutrients from dead organic matter), but some are parasitic or symbiotic (e.g., mycorrhizae, lichens). They obtain nutrients by secreting digestive enzymes externally and then absorbing the digested molecules.

    - **Examples:** Mushrooms, molds (e.g., *Rhizopus*, *Penicillium*), yeasts (*Saccharomyces*), puffballs.
- **4. Kingdom Plantae:**
    - **Cell Type:** Eukaryotic.
    - **Body Organization:** Multicellular, with specialized tissues and organs.
    - **Cell Wall:** Present, composed primarily of cellulose.
    - **Mode of Nutrition:** Primarily autotrophic (photosynthetic), synthesizing their own food using sunlight.
    - **Examples:** Algae (multicellular forms), Bryophytes (mosses, liverworts), Pteridophytes (ferns), Gymnosperms (conifers), Angiosperms (flowering plants).
- **5. Kingdom Animalia:**
    - **Cell Type:** Eukaryotic.
    - **Body Organization:** Multicellular, with highly specialized tissues, organs, and organ systems.
    - **Cell Wall:** Absent.
    - **Mode of Nutrition:** Strictly heterotrophic, primarily ingestive (consuming other organisms or organic matter), followed by internal digestion.
    - **Examples:** Sponges, Cnidarians, Worms, Insects, Fish, Amphibians, Reptiles, Birds, Mammals.
- **Significance:** Whittaker's system was a significant improvement over earlier two or three-kingdom classifications by recognizing the distinct evolutionary pathways and nutritional strategies of fungi and prokaryotes. While subsequent molecular studies have led to further refinements (e.g., the three-domain system and multiple supergroups within

Eukaryota), the five-kingdom model remains a foundational concept in biology education due to its clear and logical framework.

6. Discuss the following (any three):

   - (i) Structure of gemma cup of Marchantia

     - The gemma cup is a distinctive asexual reproductive structure found on the dorsal surface of the thallus of certain liverworts, most notably *Marchantia*. It plays a crucial role in vegetative propagation, allowing for rapid and efficient dispersal of new individuals genetically identical to the parent plant.

     - **Structure:**

       - **Cup-shaped Receptacle:** The gemma cup is a crescent-shaped or circular, cup-like depression embedded in the dorsal surface of the thallus. Its margin is typically lobed or toothed.

       - **Wall:** The wall of the gemma cup is composed of parenchymatous cells, similar to the thallus tissue.

       - **Gemmae:** Within the gemma cup, numerous small, multicellular, green, disc-shaped, or oval structures called gemmae (singular: gemma) are produced. Each gemma is a propagule capable of developing into a new plant.

         - Each gemma is bilaterally symmetrical and has two notches (indented growing points) on opposite sides.

         - It is attached to the base of the gemma cup by a short stalk.

- The gemmae contain chlorophyll and are thus photosynthetic.

- **Mucilage Hairs:** Unicellular or multicellular mucilage hairs are present at the base of the gemma cup. These hairs secrete mucilage, which swells upon absorbing water, helping to detach the gemmae from their stalks and facilitating their dispersal.

- **Dispersal:** When raindrops fall into the gemma cup, the force of the impact dislodges the gemmae, propelling them out of the cup and onto the surrounding substrate. The mucilage also helps in this process. If a gemma lands in a favorable, moist environment, each notch (growing point) develops into a new thallus, effectively cloning the parent plant. This efficient method allows *Marchantia* to colonize new areas rapidly.

- (ii) Canal system in Sycon
  - The canal system, or aquiferous system, is a defining characteristic of sponges (phylum Porifera). It is a complex network of canals and chambers through which water flows, facilitating feeding, gas exchange, and waste removal. *Sycon* (also known as *Scypha*) is a common example of a syconoid sponge, representing an intermediate level of complexity in its canal system.
  - **Structure and Water Flow in Sycon (Syconoid Type):**
    - **Incurrent Canals:** Water enters the sponge body through numerous small pores on the outer surface called dermal ostia (or incurrent pores). These ostia lead into radially arranged incurrent canals. The incurrent canals are lined by pinacocytes (flat epithelial-like cells).

- **Prosopyles:** The incurrent canals do not open directly into the radial canals. Instead, they lead to specialized openings called prosopyles, which are small pores that connect the incurrent canals to the radial canals.
- **Radial Canals (Flagellated Canals):** These are radially arranged chambers that constitute the main part of the syconoid canal system. They are lined by choanocytes (collar cells), which are unique flagellated cells characteristic of sponges. The beating of the flagella of choanocytes creates a current that draws water into the radial canals.
- **Apopyle:** From the radial canals, water passes through larger openings called apopyles into the central cavity, the spongocoel.
- **Spongocoel:** This is the large central cavity of the sponge. In syconoid sponges, the spongocoel is lined by pinacocytes, not choanocytes.
- **Osculum:** Finally, water exits the spongocoel and leaves the sponge body through a single, large opening at the top called the osculum.

- **Function:**
  - **Feeding:** As water flows through the radial canals, the choanocytes filter out microscopic food particles (bacteria, detritus) from the water using their collar-like microvilli, which trap the particles before they are engulfed by phagocytosis.
  - **Gas Exchange:** Oxygen diffuses from the water into the sponge cells, and carbon dioxide diffuses from the cells into the water.

        - **Waste Removal:** Metabolic wastes are carried out of the sponge by the water current.
        - **Reproduction:** Gametes (sperm) are released into the water current, and larvae develop within the system before being expelled.
    - The efficiency of the canal system in *Sycon* is enhanced compared to the simpler asconoid type by increasing the surface area for choanocytes, thereby improving feeding and water flow.
- (iii) Alternation of generation in Ectocarpus
    - *Ectocarpus* is a genus of brown algae (Phaeophyceae) that exhibits a classic example of isomorphic alternation of generations. This means that both the diploid sporophyte generation and the haploid gametophyte generation are morphologically similar (isomorphic), making it difficult to distinguish them purely by their appearance, although they differ in their chromosome number and reproductive structures.
    - **Life Cycle Stages:**
        - **1. Diploid Sporophyte (2n):**
            - The sporophyte is typically filamentous and branched, resembling the gametophyte.
            - It bears two types of sporangia:
                - **Unilocular sporangia:** These are single-chambered sporangia where meiosis occurs, producing numerous haploid (n) meiospores (zoospores). These meiospores are motile (flagellated) and, upon germination,

directly develop into new haploid gametophytes.

- **Plurilocular sporangia:** These are multi-chambered sporangia that produce diploid (2n) zoospores (mitospores) by mitosis. These mitospores, upon germination, develop into new diploid sporophytes. This allows for asexual propagation of the sporophyte stage.

- **2. Haploid Gametophyte (n):**
  - The gametophyte is also filamentous and morphologically similar to the sporophyte.
  - It bears **plurilocular gametangia** (multi-chambered reproductive structures).
  - These gametangia produce numerous haploid (n) motile gametes (zoogametes). In some species, these gametes are isogamous (morphologically similar), while in others, there might be slight differences (anisogamous).
- **3. Fertilization:**
  - Male and female gametes are released from the gametophyte's plurilocular gametangia.
  - Fertilization occurs when a male gamete fuses with a female gamete, forming a diploid (2n) zygote.
- **4. Development:**
  - The zygote then germinates and develops into a new diploid sporophyte, completing the life cycle.

- **Isomorphic Nature:** The key feature is that both the sporophyte and gametophyte are free-living and visually indistinguishable, highlighting an evolutionary step where both generations have maintained similar vegetative complexity, unlike the heteromorphic alternation found in many other algae and land plants.

- (iv) Sol-gel Theory

  - The Sol-gel theory, also known as the Sol-gel concept of amoeboid movement, is a classical explanation for how amoeboid cells (like *Amoeba proteus* and white blood cells) move. It proposes that the cytoplasm within the cell undergoes reversible transformations between a gel-like (more viscous, solid-like) state and a sol-like (less viscous, liquid-like) state, which drives the formation and extension of pseudopods (false feet) and subsequent cell movement.
  - **Mechanism:**
    - **1. Plasmasol (Sol) and Plasmacol (Gel):** The cytoplasm is differentiated into two regions: the inner, more fluid **endoplasm** (plasmasol) and the outer, more viscous **ectoplasm** (plasmagel or plasmacol). The plasmagel is formed by a network of actin filaments (a type of microfilament) cross-linked by various actin-binding proteins.
    - **2. Pseudopod Extension:** At the leading edge of the amoeba, the plasmagel at the anterior end temporarily weakens and converts into plasmasol. This decreases the viscosity at the front.
    - **3. Contraction at Posterior End:** Simultaneously, the plasmagel at the posterior end of the cell contracts. This contraction, often attributed to the

interaction of actin and myosin filaments (similar to muscle contraction), pushes the more fluid plasmasol forward into the extending pseudopod.

- **4. Conversion at Anterior End:** As the plasmasol flows into the pseudopod, it comes into contact with the plasma membrane. Here, the plasmasol undergoes gelation, converting back into plasmagel at the sides and tip of the pseudopod, thus solidifying the new structure.
- **5. Attachment and Retraction:** The tip of the pseudopod adheres to the substrate, and the contraction at the posterior end continues, pulling the rest of the cell body forward. As the cell moves, the plasmagel at the posterior end converts back to plasmasol, allowing for continuous flow.

- **Molecular Basis:** While the sol-gel theory provides a macroscopic description, the underlying molecular basis involves the dynamic assembly and disassembly of the actin cytoskeleton, regulated by various proteins like actin-binding proteins (e.g., gelsolin, filamin) that control the cross-linking and severing of actin filaments, thereby mediating the sol-gel transitions.
- **Limitations:** While influential, the sol-gel theory has been refined and supplemented by more detailed models (e.g., cortical pulling model, actin polymerization at the leading edge) that emphasize the direct role of actin polymerization in pushing the membrane forward and the complex interplay of various cytoskeletal proteins in generating force and movement. However, the fundamental concept of cytoplasmic streaming driven by changes in cytoplasmic viscosity remains relevant.