1. (a) Define the following terms (any three): (3)

    - (i) **Operculum:** A bony flap that covers and protects the gills of bony fishes (Osteichthyes), allowing for continuous ventilation of the gills without constant swimming.
    - (ii) **Preen gland:** Also known as the uropygial gland, it is a sebaceous gland located at the base of the tail in most birds that produces an oily, waxy substance used for preening, waterproofing feathers, and maintaining feather health.
    - (iii) **Diastema:** A gap or space between teeth, often found in herbivores between the incisors and premolars, which allows for the manipulation of food by the tongue and cheeks.
    - (iv) **Stomochord:** A short, hollow, diverticulum of the foregut found in hemichordates (e.g., acorn worms). It was initially thought to be homologous to the notochord but is now considered a supportive structure that stiffens the proboscis.
    - (v) **Opisthoglyphous fangs:** Refers to a type of dentition in snakes where the fangs are located towards the rear of the upper jaw, typically grooved rather than hollow, and used to inject venom into prey after it has been grasped.

(b) Differentiate between the following terms (any two): (4)

- (i) **Physostomous and Physoclistous swim bladder.**
    - **Physostomous swim bladder:** This type of swim bladder retains a pneumatic duct that connects it to the esophagus, allowing the fish to gulp air to inflate the bladder or burp gas to deflate it for buoyancy control.
    - **Physoclistous swim bladder:** This type of swim bladder lacks a pneumatic duct and is a closed sac. Gas exchange for buoyancy control occurs through a specialized vascularized structure called the gas gland, which secretes gas into the bladder, and a reabsorptive area called the oval body.

- (ii) **Tornaria and Tadpole larvae.**
  - **Tornaria larvae:** This is the characteristic planktonic larval stage of some hemichordates (e.g., acorn worms). It is transparent, ciliated, and resembles the bipinnaria larva of echinoderms, suggesting a phylogenetic link between these groups.
  - **Tadpole larvae:** This is the aquatic larval stage of amphibians (e.g., frogs, toads). It is typically limbless, possesses gills for respiration, a lateral line system, and a tail for propulsion, and undergoes metamorphosis to transform into the adult terrestrial form.
- (iii) **Altricious and precocious birds.**
  - **Altricious birds:** These are birds whose young hatch in a helpless, undeveloped state, often naked or with sparse down, blind, and unable to fend for themselves. They require extensive parental care, including feeding, brooding, and protection, for an extended period. Examples include passerine birds (songbirds) and raptors.
  - **Precocious birds:** These are birds whose young hatch in a relatively mature and mobile state, with downy feathers, open eyes, and the ability to walk or run shortly after hatching. They require less parental care and can often feed themselves or follow their parents to find food. Examples include chickens, ducks, and ostriches.

(c) Give the function of the following (any four): (4)

- (i) **Nuptial pads:** Glandular thickenings on the digits or forelimbs of male amphibians, particularly frogs and toads, that develop during the breeding season. Their function is to provide a firm grip on the female during amplexus (mating embrace), aiding in the successful fertilization of eggs.

- (ii) **Buccal funnel:** A circular, suctorial mouth present in jawless fish like lampreys. Its function is to attach to the host fish or substrate, allowing the lamprey to feed as an ectoparasite by rasping flesh or to anchor itself.
- (iii) **Jacobson 'organ:** Also known as the vomeronasal organ, it is a chemosensory organ found in the palate of many tetrapods, especially reptiles (like snakes and lizards) and some mammals. Its function is to detect non-airborne chemical cues (pheromones, prey trails) by transferring chemical particles from the tongue to the organ, providing a sense of "smell-taste."
- (iv) **Keel:** A prominent, ventral ridge or extension of the sternum (breastbone) in birds. Its function is to provide a large surface area for the attachment of the powerful flight muscles (pectorals), which are essential for flapping wings and enabling flight.
- (v) **Crop:** A muscular pouch, typically an expansion of the esophagus, found in many birds (e.g., pigeons, chickens) and some insects. Its function is to store and soften food before it passes into the stomach, allowing for rapid consumption and later digestion. In some birds, it also produces "crop milk" for feeding young.
- (vi) **Weberian ossicle:** A series of small bones that connect the swim bladder to the inner ear in certain teleost fishes (e.g., carp, catfish). Their function is to transmit vibrations from the swim bladder, which acts as a resonator, to the inner ear, thus enhancing the fish's sense of hearing and sound perception.

(d) Give the scientific names and classify upto order (any two): (4)

- (i) **Australian Lung fish**
  - Scientific Name: *Neoceratodus forsteri*
  - Order: Ceratodontiformes
- (ii) **Hagfish**

- Scientific Name: *Myxine glutinosa* (common hagfish example, many species exist)
- Order: Myxiniformes

- (iii) **Duck billed platypus**
  - Scientific Name: *Ornithorhynchus anatinus*
  - Order: Monotremata
- (iv) **Flying lizard**
  - Scientific Name: *Draco volans* (a common example, many species exist)
  - Order: Squamata

2. (a) Compare and discuss the characteristics of modern-day living agnathans. (8)

Modern-day living agnathans include two distinct groups: **Hagfishes (Myxiniformes)** and **Lampreys (Petromyzontiformes)**. Despite both being jawless, they exhibit significant differences:

- **Hagfishes (Class Myxini/Myxinoidea):**
  - **Body Form:** Eel-like, slimy bodies with a naked, scale-less skin.
  - **Jaws:** Completely jawless. Possess a muscular mouth with keratinized teeth on a movable tongue-like structure for rasping flesh.
  - **Notochord:** Persists throughout life as the primary axial support; vertebrae are rudimentary or absent.
  - **Gills:** Possess 5-16 pairs of gill slits, which open directly to the outside or into common external openings. Gill pouches are connected to the pharynx by afferent and efferent branchial ducts.

- **Eyes:** Rudimentary eyes, often covered by skin, suggesting poor vision.
- **Lateral Line System:** Absent or poorly developed.
- **Osmoregulation:** Unique among vertebrates, hagfishes are isosmotic with seawater, meaning their internal salt concentration is similar to that of the surrounding seawater. This minimizes osmotic stress.
- **Habitat:** Strictly marine, primarily deep-sea scavengers and predators of invertebrates.
- **Pores:** Possess numerous large slime glands along their body, which secrete copious amounts of protective and defensive mucus when disturbed.
- **Reproduction:** Dioecious (separate sexes), but some species are hermaphroditic. Fertilization is external. They lay large, yolky eggs with hooks for attachment.

- **Lampreys (Class Petromyzontida/Petromyzontia):**
  - **Body Form:** Eel-like bodies with a naked, scale-less skin.
  - **Jaws:** Completely jawless. Possess a large, suctorial buccal funnel lined with horny teeth and a rasping tongue.
  - **Notochord:** Persists throughout life. Possess small, cartilaginous vertebral elements (arcualia) overlying the notochord.
  - **Gills:** Possess 7 pairs of distinct, pouch-like gill slits, which open independently to the outside.
  - **Eyes:** Well-developed eyes, indicating better vision than hagfishes.
  - **Lateral Line System:** Present and well-developed, sensing water movements.

- **Osmoregulation:** Anadromous life cycle, spending part of their life in freshwater and part in saltwater. They are osmoconformers in saltwater (maintaining internal osmolality close to seawater but still regulating ions) and osmoregulators in freshwater (actively taking up salts and excreting dilute urine).
- **Habitat:** Mostly freshwater, with some species migrating to the sea as adults. Many are parasitic, attaching to fish and feeding on blood and body fluids. Some are non-parasitic.
- **Slime:** Do not produce copious amounts of slime like hagfishes.
- **Reproduction:** Dioecious. Spawn in freshwater; larvae (ammocoetes) are filter feeders that live buried in sediment for several years before metamorphosing into adults.

Comparison and Discussion:

Both groups share the fundamental agnathan characteristics of being jawless, possessing a persistent notochord, and lacking paired fins. However, their evolutionary paths have diverged significantly, leading to distinct adaptations. Hagfishes represent a more primitive lineage, evident in their rudimentary eyes, more generalized osmoregulation (isosmotic), and extensive slime production for defense. Lampreys, while still primitive, show advancements such as cartilaginous vertebral elements, better-developed eyes, a lateral line system, and a complex osmoregulation strategy adapted to both freshwater and marine environments. Their parasitic lifestyle in adulthood also distinguishes them from the scavenging nature of hagfishes. These differences highlight the diverse adaptations within the earliest vertebrate lineages.

(b) Describe osmoregulation by teleost fishes in sea and freshwater? How does shark maintain their osmoregulation? (7)

Osmoregulation by Teleost Fishes:

- **Freshwater Teleosts (Hyperosmotic Regulators):**

- **Challenge:** Freshwater is hypotonic to the fish's body fluids, meaning water tends to move into the fish by osmosis, and salts tend to diffuse out.
- **Water Balance:** They do not drink water. Excess water that enters their bodies is efficiently excreted as a large volume of very dilute urine, produced by well-developed glomeruli in their kidneys.
- **Salt Balance:** To counteract salt loss, they actively absorb ions (like Na^+, Cl^-) from the surrounding water through specialized chloride cells in their gills. Some salt is also obtained from food.

- **Marine Teleosts (Hypoosmotic Regulators):**
  - **Challenge:** Seawater is hypertonic to the fish's body fluids, meaning water tends to move out of the fish by osmosis, and salts tend to diffuse in.
  - **Water Balance:** They constantly drink seawater to replace water lost by osmosis.
  - **Salt Balance:** To excrete the excess salts ingested with seawater, they possess specialized chloride cells in their gills that actively pump out Na^+ and Cl^- ions. Their kidneys produce a small volume of concentrated urine with minimal salts, primarily excreting divalent ions (like Mg^{2+}, SO_4^{2-}).

How Sharks Maintain Osmoregulation (Osmoconformers with Ion Regulation):

Sharks (Chondrichthyes) employ a unique osmoregulatory strategy that differs significantly from teleosts. They are often described as osmoconformers because their internal osmotic concentration is similar to or slightly higher than that of seawater, but they are also ion regulators.

- **Urea and TMAO Retention:** Sharks retain high concentrations of urea and trimethylamine N-oxide (TMAO) in their blood and other body fluids. Urea is a nitrogenous waste product that is typically toxic at high concentrations, but TMAO acts as a chemical chaperone that counteracts the denaturing effects of urea on proteins, allowing sharks to tolerate high internal urea levels.

- **Osmotic Balance:** The combined osmotic effect of urea, TMAO, and inorganic salts (though kept at lower concentrations than seawater) raises the internal osmotic pressure of the shark's body fluids to be slightly hyperosmotic or isosmotic to the surrounding seawater. This minimizes the osmotic loss of water from their bodies.
- **Salt Excretion:** Despite being iso-osmotic, sharks still face the problem of salt influx from the seawater. They deal with this by:
  - **Rectal Gland:** A specialized salt-excreting gland located in the rectum that actively secretes a concentrated fluid rich in NaCl into the gut, which is then expelled.
  - **Kidneys:** Their kidneys excrete small amounts of divalent ions and regulate levels of other ions.
  - **Gills:** Gills are less permeable to salts compared to marine teleosts and also play a role in some ion exchange.
- This strategy allows sharks to conserve water and avoid dehydration in their marine environment without needing to constantly drink large amounts of seawater or excrete highly concentrated urine like marine teleosts.

3. (a) Explain various characteristic features which help bird to adapt to aerial mode of life. (8)

Birds are exquisitely adapted for flight, exhibiting a suite of unique anatomical and physiological features:

- **Feathers:**
  - **Lightweight and Strong:** Made of keratin, providing lift and thrust.

- **Aerodynamic Shape:** Contour feathers streamline the body, reducing drag.
- **Insulation:** Down feathers provide excellent insulation, maintaining high body temperature necessary for flight.
- **Flight Feathers:** Remiges (wing feathers) and rectrices (tail feathers) are specifically structured for flight, controlling lift, thrust, and steering.
- **Preening:** Allows for maintenance of feather structure and waterproofing.

- **Wings:**
    - **Modified Forelimbs:** Forelimbs are modified into wings, providing the primary surface for lift and propulsion.
    - **Airfoil Shape:** The wing's cross-sectional shape (convex upper surface, flatter lower surface) creates an airfoil, generating lift as air flows over it.

- **Skeletal Adaptations:**
    - **Lightweight and Strong Bones:** Bones are often hollow (pneumatic) with internal struts, making them strong yet lightweight.
    - **Fusion of Bones:** Many bones are fused (e.g., synsacrum, pygostyle, carpometacarpus, tarsometatarsus) to provide rigidity for flight and withstand the stresses of powered flight.
    - **Keel (Carina):** A prominent, deep keel on the sternum provides a large surface area for the attachment of powerful flight muscles (pectoralis and supracoracoideus).
    - **Coracoid:** Strong, strut-like coracoid bones brace the shoulder joint against the sternum, preventing collapse during the powerful downstroke.

- **Muscular System:**
  - **Large Flight Muscles:** Pectoralis major (downstroke) and supracoracoideus (upstroke, via the triosseal canal) are highly developed, making up a significant portion of the bird's body mass.
  - **Efficient Muscle Fibers:** Flight muscles are rich in mitochondria and myoglobin, allowing for sustained aerobic activity.
- **Respiratory System:**
  - **Highly Efficient Lungs:** Birds have a unidirectional airflow system with parabronchi and air capillaries, allowing for continuous gas exchange during both inhalation and exhalation.
  - **Air Sacs:** A series of thin-walled air sacs (anterior and posterior) extend throughout the body and into pneumatic bones. They act as bellows to move air through the lungs, rather than directly participating in gas exchange. This ensures a constant supply of fresh air over the respiratory surfaces.
- **Digestive System:**
  - **High Metabolic Rate:** To support high energy demands of flight.
  - **Rapid Digestion:** Possess a crop for temporary food storage, a proventriculus (glandular stomach) for chemical digestion, and a gizzard (muscular stomach) for mechanical grinding of food.
  - **No Teeth:** Birds lack teeth, reducing head weight. Food is ground in the gizzard.
  - **Rapid Excretion:** Short digestive tract and ability to excrete feces and urine together as uric acid (a semi-solid paste) minimize retained waste weight.
- **Circulatory System:**

- **Four-Chambered Heart:** A fully divided four-chambered heart ensures complete separation of oxygenated and deoxygenated blood, allowing for highly efficient oxygen delivery to muscles.
- **High Blood Pressure and Heart Rate:** To meet the demands of flight.

- **Excretory System:**
  - **Uric Acid Excretion:** Excrete nitrogenous waste as uric acid, which is less toxic and requires less water for excretion than urea, conserving water and reducing body weight.
  - **No Urinary Bladder:** Absence of a urinary bladder further reduces body weight.
- **Sensory Organs:**
  - **Acute Vision:** Large eyes with excellent visual acuity are crucial for navigation, spotting prey, and avoiding obstacles during flight.
  - **Good Hearing:** Well-developed hearing for communication and navigation.
- **Reproduction:**
  - **Internal Fertilization and Hard-shelled Eggs:** Embryonic development occurs externally, freeing the female from carrying developing young, which would add weight during flight.

(b) A classic example of adaptive radiations can be seen in mammalian locomotory appendages. Explain with examples. (7)

Adaptive radiation is the evolutionary process where a single ancestral species or group of species rapidly diversifies into many new forms, each adapted to a specific ecological niche. The mammalian locomotory appendages, particularly the pentadactyl limb, provide a classic and compelling example of such radiation, demonstrating how a common basic structure can be modified to suit a wide array of specialized functions. The ancestral mammalian limb was likely suited for generalized quadrupedal locomotion (walking/running). Over millions of years, this basic plan has been profoundly modified through natural selection to enable diverse modes of locomotion:

- **Walking/Running (Cursorial Adaptation):**
  - **Characteristics:** Limbs adapted for speed and efficiency in terrestrial locomotion. Elongation of distal limb elements (metacarpals, metatarsals, phalanges), reduction in the number of digits, and development of hooves or pads.
  - **Examples:**
    - **Horses (Equidae):** Highly specialized for running, with only one functional digit (the third digit) ending in a hoof. The limb bones are elongated and fused for rigidity and power.
    - **Deer (Cervidae) and Antelopes (Bovidae):** Two functional digits (third and fourth) with hooves, adapted for swift running and agility.
    - **Dogs (Canidae) and Cats (Felidae):** Digitigrade locomotion (walking on toes), allowing for increased stride length and speed.
- **Climbing (Arboreal Adaptation):**
  - **Characteristics:** Limbs adapted for grasping, climbing, and navigating complex three-dimensional arboreal environments. Retention of five digits, often with opposable thumbs/toes, flexible joints, and development of claws or prehensile tails.
  - **Examples:**

        - **Primates (e.g., Monkeys, Apes):** Highly mobile shoulders and elbows, opposable thumbs and big toes for grasping branches, and long, flexible digits.
        - **Sloths (Folivora):** Long, curved claws for hanging inverted from branches.
        - **Tree Kangaroos (Macropodidae):** Strong forelimbs with large claws for climbing.

- **Flying (Aerial Adaptation):**
    - **Characteristics:** Forelimbs modified into wings for sustained flight.
    - **Examples:**
        - **Bats (Chiroptera):** The most dramatic modification. The ulna is reduced, and the metacarpals and elongated phalanges support a thin membrane (patagium) that forms the wing. The thumb remains free for grasping.

- **Swimming (Aquatic Adaptation):**
    - **Characteristics:** Limbs modified into flippers or paddles for efficient propulsion through water. Reduction of outer digits, webbing between digits, and overall flattening/broadening of the limb.
    - **Examples:**
        - **Whales and Dolphins (Cetacea):** Forelimbs are modified into paddle-like flippers, with shortened and flattened limb bones and increased phalangeal numbers (hyperphalangy) in some. Hind limbs are vestigial or absent.
        - **Seals, Sea Lions, and Walruses (Pinnipedia):** Limbs are modified into flippers for propulsion (hind limbs in seals, forelimbs in sea lions).

        - **Manatees and Dugongs (Sirenia):** Forelimbs are flippers, hind limbs are absent.

- **Digging/Burrowing (Fossorial Adaptation):**
    - **Characteristics:** Short, robust limbs with strong claws, adapted for excavating soil.
    - **Examples:**
        - **Moles (Talpidae):** Short, powerful forelimbs with broad, shovel-like paws and large claws, used for digging extensive tunnel systems.
        - **Badgers (Mustelidae):** Strong forelimbs with long, robust claws for digging burrows.

This remarkable diversity in mammalian locomotory appendages, all derived from a common ancestral pentadactyl limb, underscores the power of adaptive radiation in filling diverse ecological niches and is a testament to the versatility of evolutionary processes.

4. (a) Give an elaborative account of parental care in amphibians. (9)

Parental care in amphibians is highly diverse and spans a wide range of strategies, from no care at all to elaborate behaviors protecting eggs and larvae. These behaviors are crucial for increasing offspring survival rates in often challenging environments.

- **No Parental Care:**
    - The most common strategy, particularly in anurans (frogs and toads), is to lay a large number of eggs in water and then abandon them. The hope is that sheer numbers will ensure some survival against predation and environmental fluctuations.
    - **Example:** Many species of pond frogs and toads simply deposit eggs as masses or strings in water bodies and leave.

- **Egg Guarding and Protection:**

- **Laying Eggs in Protected Locations:** Many species choose specific microhabitats to deposit eggs to protect them from predators or desiccation.
    - **Gelatinous masses:** Some frogs lay eggs in foamy masses or gelatinous strings that deter predators and prevent desiccation.
    - **Leaf nests:** Some tree frogs lay eggs on leaves overhanging water, with tadpoles dropping into the water upon hatching (e.g., *Hyla* species).
    - **Buried eggs:** Some terrestrial salamanders and caecilians lay eggs underground or under logs, providing moisture and protection.
- **Direct Guarding:** One or both parents remain with the eggs to guard them from predators, keep them moist, or even aerate them.
    - **Male or female guarding:** In some species, the male (e.g., many hylids, some dendrobatids) or female (e.g., *Desmognathus* salamanders) remains coiled around or near the egg clutch.
    - **Nest building:** Some frogs build simple nests or mud walls around their eggs (e.g., some *Physalaemus* species).

- **Transporting Eggs/Larvae:**
    - **On the Back:**
        - **Poison Dart Frogs (Dendrobatidae):** Females (or sometimes males) carry individual tadpoles on their backs to small water-filled phytotelmata (e.g., bromeliad axils), where they deposit them and may even feed them with unfertilized eggs.

        - **Pipa pipa (Surinam Toad):** Eggs are embedded in the spongy dorsal skin of the female, where they develop and hatch directly into froglets, bypassing the free-swimming larval stage.
    - **In Vocal Sac/Mouth:**
        - **Darwin's Frog (*Rhinoderma darwinii*):** Males brood eggs in their vocal sacs until metamorphosis.
        - **Gastric Brooding Frogs (*Rheobatrachus* spp. - now extinct):** Females swallowed fertilized eggs, and tadpoles developed in their stomach, with gastric acid secretion inhibited. Froglets then emerged from the mouth.
    - **Wrapped Around Legs:**
        - **Midwife Toads (*Alytes obstetricans*):** The male wraps strings of eggs around his hind legs and carries them until they are ready to hatch, at which point he deposits them in water.

- **Direct Development (Avoiding Aquatic Larval Stage):**
    - In many terrestrial and arboreal species, the larval stage is bypassed entirely, and eggs hatch directly into miniature adults. This is a form of parental care in the sense that it protects the vulnerable larval stage from aquatic predators and desiccation.
    - **Example:** Many species of lungless salamanders (Plethodontidae) and direct-developing frogs (e.g., *Eleutherodactylus* species) lay eggs on land, and tiny froglets or salamanderlings emerge. This often requires the parent to keep the eggs moist.
- **Feeding of Young:**

- **Trophic Eggs:** In some poison dart frogs, the female returns to the phytotelmata and deposits unfertilized eggs as food for her developing tadpoles.
- **Skin Feeding:** The caecilian *Boulengerula taitana* exhibits dermatophagy, where the young feed on a specially developed, lipid-rich outer layer of their mother's skin.

These diverse strategies highlight the evolutionary pressures on amphibians to overcome challenges of desiccation, predation, and limited resources, ultimately increasing the fitness of their offspring.

(b) Explain plate tectonic theory and comment on the fauna of Australian realm. (6)

Plate Tectonic Theory:

Plate Tectonic Theory is a unifying theory in geology that explains the large-scale motion of Earth's lithosphere. The lithosphere, which includes the Earth's crust and the uppermost part of the mantle, is broken into a number of large and small plates (tectonic plates). These plates are in continuous, slow motion relative to each other, driven by convection currents in the underlying, viscous asthenosphere (part of the mantle).

Key aspects of the theory include:

- **Earth's Layers:** The Earth's interior is divided into layers: the solid inner core, liquid outer core, mantle (lower mantle and asthenosphere), and the lithosphere (crust and rigid upper mantle).
- **Plate Boundaries:** Interactions between plates occur at their boundaries, leading to most of the Earth's seismic and volcanic activity, and mountain building. There are three main types of plate boundaries:
    - **Divergent Boundaries:** Plates move apart, leading to the creation of new crust (e.g., mid-ocean ridges, rift valleys).

  - **Convergent Boundaries:** Plates move towards each other, resulting in subduction (one plate sliding beneath another) or collision (two continental plates colliding, forming mountain ranges).
  - **Transform Boundaries:** Plates slide horizontally past each other, causing earthquakes (e.g., San Andreas Fault).
- **Continental Drift:** The theory incorporates the concept of continental drift, originally proposed by Alfred Wegener, explaining that continents have moved over geological time. The supercontinent Pangea broke apart, and its fragments drifted to their current positions.

Fauna of the Australian Realm (Zoogeographical Realm):

The Australian realm, which includes Australia, New Guinea, and surrounding islands (east of Wallace's Line), is renowned for its highly distinctive and unique fauna, a direct consequence of its long geological isolation resulting from plate tectonics.

- **Isolation and Endemism:** Australia separated from the supercontinent Gondwana around 80-100 million years ago and drifted in isolation. This prolonged isolation prevented the influx of many groups of mammals that evolved later on other continents, particularly placental mammals. This allowed ancient lineages to diversify without significant competition, leading to an exceptionally high degree of endemism (species found nowhere else on Earth).
- **Dominance of Marsupials:** The most striking feature of Australian fauna is the dominance and incredible adaptive radiation of marsupials. While placentals diversified elsewhere, marsupials filled almost all ecological niches in Australia that are occupied by placentals on other continents. Examples include:
  - **Herbivores:** Kangaroos, wallabies, koalas, wombats.
  - **Carnivores:** Tasmanian devils, quolls (and formerly the thylacine).

        - **Insectivores:** Bandicoots, numbats.
        - **Gliders:** Sugar gliders, gliders.
    - **Monotremes:** Australia is also home to the world's only living monotremes (egg-laying mammals): the platypus and echidnas. These are even more ancient mammalian lineages, representing a direct link to early mammalian evolution.
    - **Avian Diversity:** The realm boasts a rich and unique avian fauna, including flightless birds like the emu and cassowary, a remarkable diversity of parrots, cockatoos, kookaburras, and birds of paradise (in New Guinea).
    - **Reptiles and Amphibians:** A high diversity of reptiles, including numerous venomous snakes, lizards (e.g., monitor lizards, geckos), and crocodiles. Amphibian diversity is also significant, with unique frog families.
    - **Lack of Native Placental Mammals (with exceptions):** Historically, native placental mammals were largely absent, with the exception of bats (which could fly to the continent) and a few rodent species (likely arrived by rafting or later dispersal). The dingo, a placental carnivore, was introduced relatively recently by humans.
    - **Vulnerability:** The distinctiveness of Australian fauna makes it particularly vulnerable to introduced species (e.g., foxes, rabbits, cats, cane toads) that compete with or prey on native species, leading to significant conservation challenges.

In essence, plate tectonics, by isolating the Australian landmass, created a unique evolutionary laboratory, resulting in a biological realm characterized by unparalleled endemic marsupial and monotreme diversity.

5. (a) Write a detailed note on origin of Tetrapods. (7)

The origin of tetrapods, the four-limbed vertebrates, from fish ancestors represents one of the most significant evolutionary transitions in vertebrate history, marking the colonization of land. This transition occurred during the Devonian Period, often referred to as the "Age of Fishes."

- **Ancestral Group: Lobe-finned Fishes (Sarcopterygians):**
  - Tetrapods did not evolve from ray-finned fishes (Actinopterygii), but from a group of lobe-finned fishes, the Sarcopterygians.
  - Key features of sarcopterygians that predisposed them to land life include:
    - **Fleshy, Muscular Fins:** Their fins had a central bony axis with muscles, unlike the thin, ray-supported fins of ray-finned fish. This structure was homologous to the limb bones of tetrapods (humerus/femur, radius/ulna/tibia/fibula).
    - **Lungs/Swim Bladder:** Many had primitive lungs or a vascularized swim bladder, allowing them to gulp air from the surface, an adaptation crucial for survival in oxygen-poor shallow waters. Coelacanths and lungfishes are modern-day sarcopterygian survivors.
- **The Devonian Environment:**
  - The late Devonian was characterized by fluctuating water levels, periods of drought, and warm, shallow, oxygen-depleted waters. This created selective pressure favoring fish that could survive short periods out of water or move between drying pools.
  - Abundant terrestrial arthropods provided a new food source on land.
- **Key Transitional Fossils:**

- **Eusthenopteron (Fish-like Sarcopterygian):** Possessed a typical fish body, but its paired fins showed a bone pattern strikingly similar to the basic tetrapod limb.
- **Panderichthys (More Tetrapod-like Fish):** Flattened skull, dorsally placed eyes, and more robust pectoral fins with a clear humerus-like bone. Lacked dorsal and anal fins, and had a more crocodile-like head.
- **Tiktaalik roseae (The "Fishapod"):** Discovered in 2006, this fossil is a crucial intermediate. It had fish-like scales, fins, and gills, but also tetrapod-like features: a flattened skull, dorsally placed eyes, a mobile neck (lost opercular bones), and a robust rib cage (supporting internal organs out of water). Most importantly, its pectoral fins had a wrist-like structure and distinguishable elbow, wrist, and digit-like elements, indicating it could prop itself up and potentially "walk" on shallow substrates.

- **Acanthostega and Ichthyostega (Early Tetrapods):** These are among the earliest known true tetrapods.
    - **Acanthostega:** Primarily aquatic, with internal gills and a tail fin, but had eight distinct digits on each limb and a robust skeleton, suggesting it could move on land for short periods. Its limbs were more paddle-like, suited for navigating shallow water.
    - **Ichthyostega:** More robust limbs with seven digits on the hind limb, stronger ribs, and a pelvis attached to the vertebral column, indicating better terrestrial locomotion than Acanthostega, though still largely aquatic.
- **Tulerpeton:** An early tetrapod with six digits per limb, suggesting that the five-digit pattern (pentadactyly) characteristic of most modern tetrapods evolved later through reduction.

- **Evolutionary Scenario:**
    - It is now widely accepted that limbs with digits evolved in an aquatic environment, initially for propulsion and maneuvering in shallow, vegetation-rich waters, or for propping the body off the substrate.
    - The ability to breathe air and move on rudimentary limbs provided a survival advantage during periods of low oxygen or when moving between drying ponds.
    - Over time, these features became more refined, leading to increasingly terrestrial forms. The transition was not a single event but a gradual process involving a mosaic of fish and tetrapod features in intermediate forms.

The origin of tetrapods highlights a classic example of evolution acting on existing structures (lobe fins) to adapt to new environmental pressures, leading to a major diversification of vertebrates on land.

(b) Briefly explain the poison apparatus and biting mechanism in snakes. (8)

Poison Apparatus in Snakes:

The poison (venom) apparatus in venomous snakes consists of specialized glands and teeth (fangs) adapted for producing and delivering venom.

1. **Poison Glands:**
    - These are modified salivary glands, typically located on either side of the head, behind and below the eyes.
    - They produce a complex mixture of proteins, enzymes, and other bioactive compounds (venom) that act as a potent cocktail for prey immobilization and digestion.
    - The gland itself is surrounded by muscles that contract to squeeze venom out during a bite.
2. **Fangs:**

- Highly specialized, enlarged teeth designed for injecting venom. They are typically hollow or grooved.
- Based on fang morphology and location, venomous snakes are classified into:
  - **Proteroglyphous:** Short, fixed, hollow fangs located at the front of the maxilla. Found in cobras, mambas, sea snakes (Elapidae).
  - **Solenoglyphous:** Long, hollow, erectile fangs located at the front of the maxilla. These fangs can rotate forward when the mouth opens and fold back when the mouth closes. Found in vipers, rattlesnakes (Viperidae).
  - **Opisthoglyphous:** Grooved fangs located at the rear of the maxilla. Found in rear-fanged snakes like boomslangs and hognose snakes (some Colubridae). They typically need to chew to introduce venom effectively.
  - **Aglyphous:** Lacking specialized fangs (non-venomous or mildly venomous snakes).

Biting Mechanism in Snakes:

The biting mechanism varies depending on the type of fangs, but the general principle involves coordination of jaw movements and venom injection.

1. **Proteroglyphous (Fixed-Fanged) Biting (e.g., Cobras):**
   - The fangs are relatively short and permanently erect at the front of the mouth.
   - The snake opens its mouth wide, and the fangs are exposed.
   - It strikes and typically holds onto the prey for a short period, allowing venom to flow down the fangs by capillary action or muscle contraction around the gland, entering the wound.
   - The bite often results in puncture wounds.

2. **Solenoglyphous (Hinged-Fanged) Biting (e.g., Vipers):**
   - This is the most advanced and efficient biting mechanism.
   - When the snake is about to strike, powerful muscles pull the quadrate bone forward, which in turn pushes the pterygoid and ectopterygoid bones.
   - This lever system rotates the maxilla (which is greatly reduced and bears only the fang) forward, swinging the long fangs into a striking position, perpendicular to the jaw.
   - As the fangs penetrate the prey, jaw muscles contract, and muscles surrounding the venom glands contract, forcefully injecting venom through the hollow fangs into the deep tissues of the prey.
   - The fangs then retract as the mouth closes. This allows for deep penetration and rapid venom delivery. Vipers often perform a quick strike and release.

3. **Opisthoglyphous (Rear-Fanged) Biting (e.g., Boomslang):**
   - The grooved fangs are located towards the back of the upper jaw.
   - To inject venom, these snakes often need to grasp and chew their prey, allowing the venom to flow along the grooves of the fangs and into the wound. This makes their bites less efficient at venom delivery compared to front-fanged snakes, and deep penetration is often required.

In all cases, the primary purpose of the venom apparatus and biting mechanism is to immobilize, subdue, and often initiate digestion of prey, playing a crucial role in the snake's feeding strategy.

6. Write short notes on any three of the following: (15)
   - (i) **Wallace and Weber line**

- The **Wallace Line** and **Weber Line** are significant biogeographical boundaries in Southeast Asia, marking distinct faunal divisions that highlight the influence of geological history and plate tectonics on species distribution.
- **Wallace Line:** Proposed by Alfred Russel Wallace, it runs through the Malay Archipelago, specifically between Borneo and Sulawesi, and between Bali and Lombok. To the west of the line (Sunda Shelf region), the fauna is largely Asian in character, reflecting a historical land connection during glacial periods when sea levels were lower (e.g., tigers, elephants, rhinoceroses). To the east of the line, the fauna is more Australasian, characterized by marsupials, monotremes, and unique bird groups. The line represents a deep oceanic trench that remained a barrier to dispersal even during periods of low sea level, thus acting as a strong filter for terrestrial species.
- **Weber Line:** Proposed by Max Carl Weber, this line runs slightly further east than the Wallace Line, often placed between Sulawesi and New Guinea, and west of the Australian continental shelf. It attempts to define a boundary where the balance of Asian and Australian fauna is approximately equal, or where Australasian fauna begins to dominate more strongly. It recognizes that some "Wallacean" islands (like Sulawesi) have a mixed fauna, indicating some degree of dispersal across the Wallace Line over geological time.
- Both lines illustrate the profound impact of past land bridges and deep-sea channels on the distribution and evolution of biodiversity in a region of complex tectonic activity.

- (ii) **Origin of chordates**
  - The origin of chordates is a complex and highly debated topic in evolutionary biology, but generally involves understanding their relationship to other deuterostomes and the evolution of their defining characteristics. Chordates belong to the

superphylum Deuterostomia, which also includes echinoderms (e.g., starfish) and hemichordates (e.g., acorn worms). Molecular evidence strongly supports a close phylogenetic relationship between chordates and hemichordates, grouped as Ambulacraria.

- The earliest known chordate fossils, like *Pikaia* from the Burgess Shale (Cambrian period), already show some chordate features. However, the precise evolutionary steps leading to the five defining chordate characteristics (notochord, dorsal hollow nerve cord, pharyngeal slits, post-anal tail, and endostyle/thyroid gland) from a non-chordate ancestor are still being elucidated.

- **Key Hypotheses/Concepts:**

  - **Dipleuruloid Ancestor:** A common hypothesis suggests that the ancestor of deuterostomes was a small, ciliated, bilateral animal, similar to the dipleurula larva of echinoderms.

  - **Auditory Larval Theory:** Proposed that a sessile, filter-feeding adult ancestor (perhaps resembling a tunicate-like organism) developed a free-swimming, tadpole-like larva that retained ancestral features. Over time, this larva became sexually mature and the adult sessile stage was lost (neoteny), leading to the evolution of free-swimming chordates. This theory explains the apparent "retrograde metamorphosis" in tunicates, where the larva has chordate features but the adult is sessile.

  - **Filter-Feeding Predisposition:** Pharyngeal slits, initially for filter feeding in ancestral deuterostomes, became elaborated in early chordates for efficient feeding, and then adapted for respiration in fish.

- **Notochord Evolution:** The notochord likely evolved as a skeletal support for burrowing or swimming.

- Early chordates were likely small, soft-bodied, marine filter-feeders, living in shallow waters. The appearance of features like the notochord and muscle blocks (myomeres) facilitated more efficient swimming, eventually leading to the active lifestyle of vertebrates. The fossil record, particularly from the Cambrian explosion, provides crucial insights into these early forms, bridging the gap between invertebrates and the diverse chordate phylum.

- (iii) **Retrogressive metamorphosis**
  - Retrogressive metamorphosis is a unique type of metamorphosis observed in certain animal groups, most notably tunicates (subphylum Urochordata). In typical metamorphosis (e.g., insects, amphibians), the larval stage is less developed and less complex than the adult form, and metamorphosis involves a progression towards a more complex adult. However, in retrogressive metamorphosis, the free-swimming larva possesses more advanced chordate characteristics than the sessile adult, and metamorphosis involves a degeneration or simplification of these features.
  - **Example: Ascidian Tadpole Larva:**
    - The tadpole larva of an ascidian (sea squirt) is free-swimming and exhibits all five chordate hallmarks: a notochord in the tail, a dorsal hollow nerve cord, pharyngeal slits, a post-anal tail, and an endostyle. Its primary function is dispersal.
    - Upon settlement, the larva attaches to a substrate by its adhesive papillae. It then undergoes a dramatic transformation:
      - The tail and notochord are resorbed.

- The dorsal hollow nerve cord degenerates into a simple ganglion.
- The pharyngeal slits persist and enlarge for filter feeding, and the endostyle develops further.
- The adult ascidian becomes a sessile, sac-like, filter-feeding organism that bears little resemblance to its chordate larva, appearing more invertebrate-like.

- This phenomenon is significant because it suggests that the ancestral chordate might have been a free-swimming, tadpole-like creature, and the sessile adult tunicate represents a secondary, specialized adaptation. It highlights the plasticity of developmental pathways and provides insights into possible evolutionary pathways of early chordates.

- (iv) **Sphenodon**

  - *Sphenodon punctatus*, commonly known as the **tuatara**, is a fascinating reptile endemic to New Zealand. It is the sole surviving genus of the order Rhynchocephalia (or Sphenodontia), an ancient lineage of reptiles that flourished during the Mesozoic Era alongside dinosaurs. Due to its unique characteristics and evolutionary distinctiveness, it is often referred to as a "living fossil."
  - **Key Features and Significance:**
    - **Ancient Lineage:** Tuataras represent the most basal extant lineage within the Lepidosauria, making them the closest living relatives of snakes and lizards, yet they branched off much earlier and retain many primitive reptilian features.
    - **Parietal Eye:** They possess a well-developed parietal (third) eye on the top of their head, which has a retina,

lens, and cornea, though it is covered by opaque skin in adults. It is light-sensitive and thought to be involved in regulating circadian rhythms and thermoregulation.

- **Unique Dentition:** They have acrodont dentition (teeth fused to the top of the jawbone) and a distinctive double row of teeth in the upper jaw that fits over a single row in the lower jaw, creating a shearing action for processing food.
- **Slow Metabolism and Long Lifespan:** Tuataras have a very slow metabolism, are active at lower temperatures than most reptiles, and have an exceptionally long lifespan, often living over 100 years.
- **Cold Tolerance:** They are unusual among reptiles in being active at relatively low temperatures (even below 7°C), allowing them to co-exist with seabirds.
- **Conservation Status:** Tuataras are highly protected and are found only on a few offshore islands of New Zealand, having been driven to extinction on the mainland by introduced predators (rats, stoats). Their conservation is crucial due to their unique evolutionary position.

- Studying the tuatara provides invaluable insights into the ancestral characteristics of reptiles and the early evolution of amniotes.