

UPSC MAINS ZOOLOGY OPTIONAL PAPER-1: MODEL ANSWER 2025

Que 1. a. Metagenesis

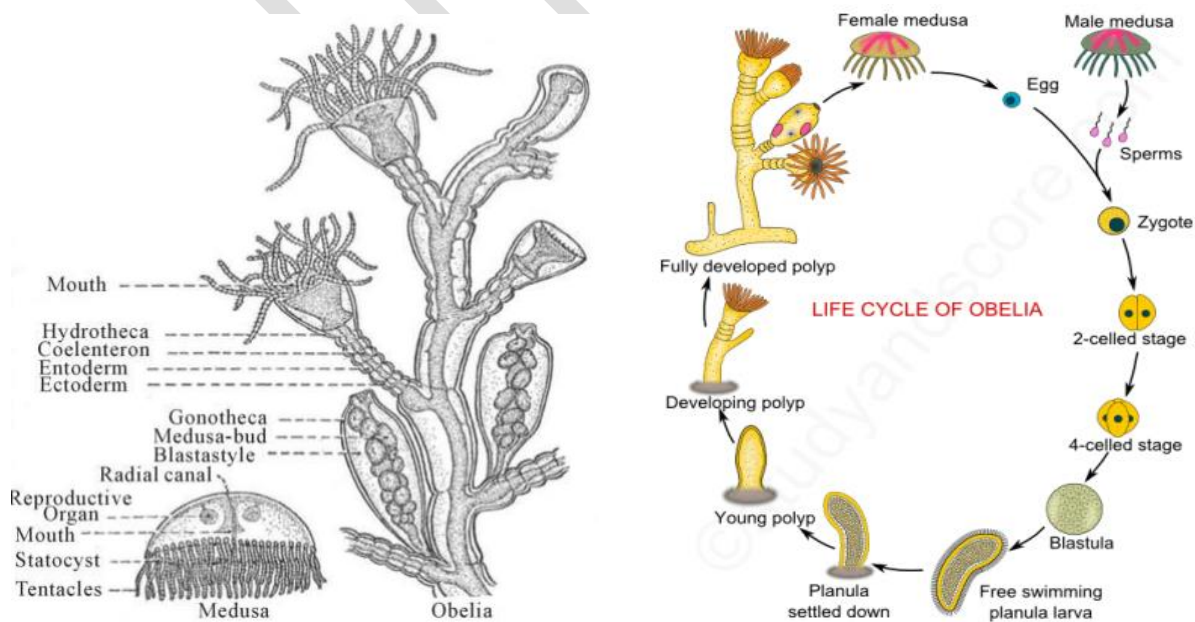
Metagenesis is a type of biological phenomenon where an organism's life cycle alternates between two forms of reproduction, i.e., where a diploid asexually reproducing generation alternates with a sexual haploid generation. It is a specific type of alternation of generation except for the alternation between haploid asexual and diploid sexual stages. It is commonly seen in some Cnidarians such as Obelia.

Metagenesis in Obelia

In Cnidaria (Obelia), two types of individuals exist, namely a polyp and a medusa.

Polyp: The tube-like zooid is called a polyp. The polyp reproduces asexually. It is sessile and attaches to a substrate at the aboral end. It has a cylindrical body called the column. Its mouth is surrounded by food-gathering tentacles. This form reproduces asexually by budding.

Medusa: The umbrella-like zooid is called a medusa. The medusa is dioecious, meaning each medusa has reproductive organs of only one sex and they are free-swimming. The gonads (testis or ovaries) are four in number and lie on the sub-umbrella. Its shape is like an inverted bowl. The tentacles hang from its margins, which help in active swimming.



These two forms, polyp and medusa alternate successively where the polyp reproduce asexually to form a large number of medusa, each medusa reproduce sexually by the union of eggs and sperms to form zygote. The zygote grows into larva, which fix itself to a substrate and finally form a new polyp.

Fertilization: The sperm and ova when fully formed are set free in water by rupture of the outer wall of the gonad. Sometimes the flagellated sperms swim about in water and fertilize the ova present in female medusae. The fertilization takes place in water. As medusa is the motile form, it performs two important functions for the colony namely reproduction and dispersal of the gametes.

Planula larva-The fertilized egg undergoes cleavage which is equal and holoblastic, forming Blastula and develop into embryo. The embryo is set free from the egg membrane as a free -swimming larva called the planula. The larva swims about for some time and brings about wide distribution of the species.

Development- After the free-swimming life the planula larva loses its cilia and settles down on the bottom of the sea, gets attached to the substratum by its broader end and undergoes metamorphosis. The narrow portion beyond their origin becomes the hypostome. Soon an aperture, the mouth, is formed at the end of the hypostome. The young hydranth closely resembles a simple polyp like hydra and is called hydrula which undergoes repeated asexual budding to gives rise to complex Obelia colony.

Metagenesis is one of the significant process in the development as in Obelia, as it maximizes reproductive success through allowing organisms to reproduce both asexually (for rapid population growth in favorable conditions) and sexually (to introduce genetic variation and adapt to changing environments), Enables polymorphism, which leads to different life stages, or polymorphs, each with a specialized form and function, such as the sessile polyp and the free-swimming medusa and Promotes genetic diversity as the sexual phase increases genetic variation within the population, which is crucial for long-term survival and adaptation.

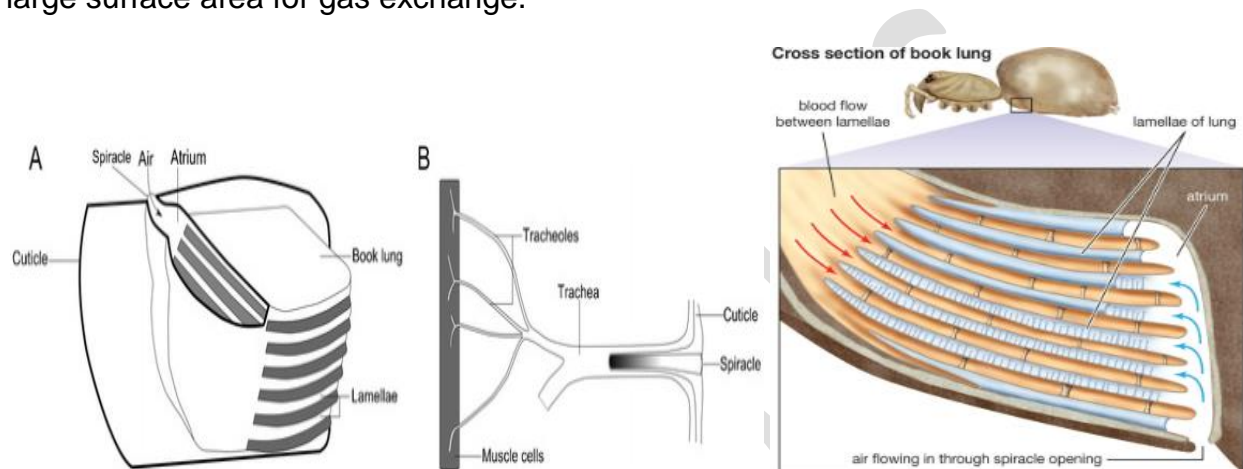
b. Book lungs

Respiration is a vital process for all living organisms, enabling the exchange of gases necessary for cellular functions. Among the various respiratory adaptations found in the animal kingdom, *book lungs* represent a fascinating structure unique to certain arachnids, particularly spiders and scorpions. These specialized organs enable terrestrial respiration, an essential adaptation for survival in dry environments. The name “book lungs” is derived from their distinctive appearance, resembling the pages of an open book when viewed under a microscope.

Structure of Book Lungs

Book lungs are internal respiratory organs located within small cavities on the ventral (underside) side of the arachnid's abdomen. Typically, spiders possess one or two pairs of book lungs, while scorpions usually have four pairs.

Each book lung consists of a series of thin, flat, leaf-like folds called *lamellae*. These lamellae are arranged parallel to one another, much like the pages of a book, creating a large surface area for gas exchange.



External Structure

1. **Spiracle (Stigma):**
 - A small slit-like opening on the **ventral surface** of the abdomen.
 - It connects the exterior air to the internal **pulmonary chamber**.
 - Often guarded by fine hairs or lips to prevent dust entry and water loss.
2. **Pulmonary Chamber (Atrium):**
 - The space just inside the spiracle.
 - Leads into the **lamellar chamber**, where gas exchange occurs.

Internal Structure

Inside the pulmonary chamber is the **book lung proper**, which consists of **numerous thin, parallel lamellae (plates)** — hence the “book” analogy.

1. Lamellae (Leaf-like Plates):

- Each book lung contains **about 100–150 thin, flat lamellae**.
- These are arranged parallel to one another like pages in a book.
- The lamellae are **alternately air-filled and blood-filled**.

Each lamella consists of:

1. **Cuticular lining** — thin, non-chitinized layer.
2. **Epithelial cells** — provide structure and secretion.
3. **Hemolymph sinus** — space for blood flow.

The membranes separating air and blood are extremely thin to facilitate diffusion.

2. Air Lamellae:

- Spaces between adjacent lamellae through which **air circulates**.
- Air enters via the spiracle and flows between the lamellae.

3. Blood Lamellae:

- Each lamella contains a **blood sinus**.
- The hemolymph (blood) flows through these lamellae and is separated from air by a **very thin epithelial membrane**.
- **Gas exchange** (oxygen uptake and carbon dioxide release) occurs across this membrane by diffusion.

4. Ventral and Dorsal Walls:

- The lamellae are attached alternately to the **ventral wall** and **dorsal wall** of the pulmonary chamber.
- The arrangement maximizes the surface area for gas exchange within a small space.

How they Work- Book lungs work through passive diffusion of gases between air and hemolymph. Air enters through a small ventral opening called the spiracle into the pulmonary chamber. From there, it moves between thin air-filled lamellae arranged like book pages. Adjacent to each air lamella is a blood-filled lamella containing circulating hemolymph. Oxygen from the air diffuses across the thin membrane into the blood, while carbon dioxide diffuses out. The oxygenated hemolymph is then carried by the pulmonary vein to the heart for distribution throughout the body.

Book lungs are a remarkable evolutionary adaptation that exemplifies how arachnids have successfully transitioned from aquatic to terrestrial life. Their unique structure — a series of lamellae resembling book pages — provides a large surface area for gas exchange while conserving moisture, enabling spiders and scorpions to thrive in diverse and often harsh environments.

c. Paedomorphosis

Garstang proposes the term paedomorphosis in 1928. The paedomorphosis (Gk. pais, child; morphe, form) is the retention of ancestral juvenile characters in the late

developmental stages of descendants. The affected individuals are called paedomorphic. But Kardong, 2002 refers to Paedomorphosis as an individual which is larval in anatomy but it becomes sexually mature. The phenomenon of attainment of sexual maturity leading to reproduction in an arrested larval stage (pre-adult stage) is called Paedogenesis (pais; child; morphe form). The term first used by Von Baer (1866). It is commonly seen in urodeles, amphibians.

Types of Paedomorphosis: There are two types of paedomorphosis found in urodeles.

i. Obligatory Paedomorphosis:

Some species of urodeles or larval stages always remain mature permanent larval stages. They do not metamorphose at any time. The developing tissues fail to respond to the thyroid hormone (T_4), when in other forms the tissues respond to the thyroid hormone and metamorphose into adult. In obligatory paedomorphosis, the genes for transformation during metamorphosis have become suppressed. eg. Amphiuma of United States have no external gills but larval gill-slits. They have vestigial limbs but without eyelids.

ii. Facultative Paedomorphosis:

It can be induced by manipulating Thyroid function and depends on environmental factors and physiology of the larval developmental stages. Larva does not metamorphose into adult in certain specific natural condition and attains sexual maturity. But metamorphosis can take place after artificial treatment or suitable natural conditions. e.g., some species of Ambystoma of north western part of U.S.A. and Triturus exhibit paedomorphosis. The larvae become sexually mature and breed but they can metamorphose and change into adults when the available conditions are changed.

Factors

Environmental factors

- **Food abundance:** Ample food can lead to the retention of larval features.
- **Temperature:** Low temperatures can halt or slow down the metamorphic process.
- **Iodine availability:** Insufficient iodine in the diet can lead to the production of faulty hormones, preventing metamorphosis.

- **Aquatic environment:** Permanently stable aquatic habitats, especially deep, cool, and permanent lakes, may favor paedomorphosis, as the terrestrial environment may be less hospitable.

Intrinsic factors

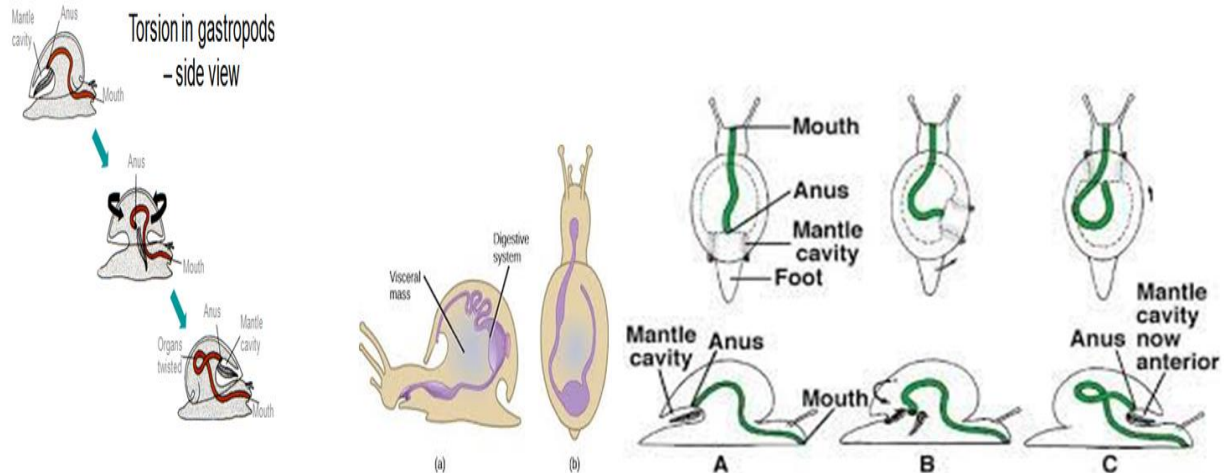
- **Hormonal regulation:**
- **Thyroid gland:** Insufficient production of thyroid hormones, which are crucial for metamorphosis, can cause paedomorphosis.
- **Pituitary and hypothalamus:** Underactivity in this system can lead to low production of thyroid-stimulating hormone (TSH), which in turn reduces thyroid hormone production.
- **Other hormones:** Hormones like insulin can also inhibit metamorphosis.
- **Tissue insensitivity:** Larval tissues may become unresponsive to the hormonal signals that trigger metamorphosis.
- **Calcium concentration:** High calcium levels can inhibit metamorphosis in some species, such as the axolotl.

Paedomorphosis in amphibians allows for the **occupation of new aquatic niches**, evolutionary innovation, better survivability and adaptability, the **generation of new body plans**, and the **escape from developmental constraints** by enabling a sexually mature adult to retain juvenile traits.

d. Torsion and detorsion in gastropods.

Torsion (twisting) is one of the developmental process of animals of Gastropods, Molluscas, where rotation of visceral organs in anticlockwise direction through an angle of 180° on the rest of the body during larval development.

Site of Torsion- Only visceral mass, undergo rotation through 180 degree, whereas head and foot remain fixed. Actual site of torsion is neck behind head-foot, through which oesophagus, rectum, aorta, visceral nerve loop and shell muscle pass.



How Torsion Occurs?

Before torsion, larva is quite symmetrical, mantle cavity faces backwards and downwards, alimentary canal is straight and anus opens posteriorly.

A ventral flexure of the body results in the looping of alimentary canal and approximation of mouth and anus, which lead to the coiling of shell and visceral mass, and such shell is called exogastric.

Ventral flexure is followed by a lateral torsion, so that dorsal or exogastric shell becomes or endogastric. Lateral torsion is probably due to arrest of growth on one side and active extension on the other.

Generally, growth of the right side becomes retarded so that mantle cavity and pallial complex gradually pass round to right side, and so to the anterior side, which lead to greater growth of visceral sac towards the left. On the contrary, it is due to muscular contractions. There is pullof retractor muscles in the larva, running from velar lobes to the shell, which are absent on the left side. This contraction of muscle lead to rotation or torsion. In which actual twisting of larval neck occurs which bring to anticlockwise rotation of everything between head and anus, at angle of 180 degree around a vertical axis passing in dorso-ventral direction.

Effects of Torsion- studied by Spengel

- Changes in relative position of anus, ctenidia and renal orifices projecting forward, and auricle lie in front of ventricle
- Mantle cavity displacement from posterior position, which further open behind the head and associate part shifted forwards.

- Alimentary canal become coiled, which was originally straight and both side of opening comes one side of the body.
- Long, uncoiled pleura-visceral nerve connectives become twisted into a figure of 8.
- Loss of bilateral symmetry to asymmetrical animal, anus is displaced towards right side of pallial cavity.

Detorsion- It is characteristic feature of group of Euthyneura. Detorsion is a process, in which changes occurred in the torsion process in the animal body reverses, either completely or partially, which lead to moving back of pallial complex towards the posterior end along the right side, ctenidia pointing backwards, auricle move behind the ventricle and visceral loop becomes untwisted and symmetrical again. This all lead to the reestablishment of secondary external symmetry.

Detorsion may occur in the following steps- Detorsion in Opisthobranchs (e.g., Sea slugs, Aplysia)

.Steps:

1. During early development, normal **180° torsion** occurs.
2. Later, a **secondary reverse rotation of about 180°** takes place.
3. As a result, the **mantle cavity shifts from the anterior to the posterior end**.
4. The **anus, ctenidium, and renal aperture** are repositioned posteriorly.
5. One ctenidium is often **lost**, and bilateral symmetry is partially restored.
6. The **streptoneurous nervous system becomes euthyneurous** (untwisted).
7. Shell becomes **reduced or absent**, eliminating the need for torsion-related protection.

Result:

Opisthobranchs exhibit **almost complete and maximum detorsion** and greater body symmetry

Detorsion in Pulmonates (e.g., Snails, Slugs like Pila)

.Steps:

1. Normal torsion of **180°** occurs during larval life.
2. During later development, a **partial reverse rotation (90°–120°)** takes place.
3. The mantle cavity shifts **from the anterior region toward the right side** of the body.
4. The **ctenidium is lost** and replaced by a **pulmonary sac (lung)**.
5. The anus opens near the **right side**, reducing fouling of the head.
6. The nervous system becomes **partially euthyneurous**.
7. Here the pallial complex is shifted but no chiasmoneury, as a result of shortening of visceral commissure.

Result:

Pulmonates show **incomplete detorsion** with reduced asymmetry.

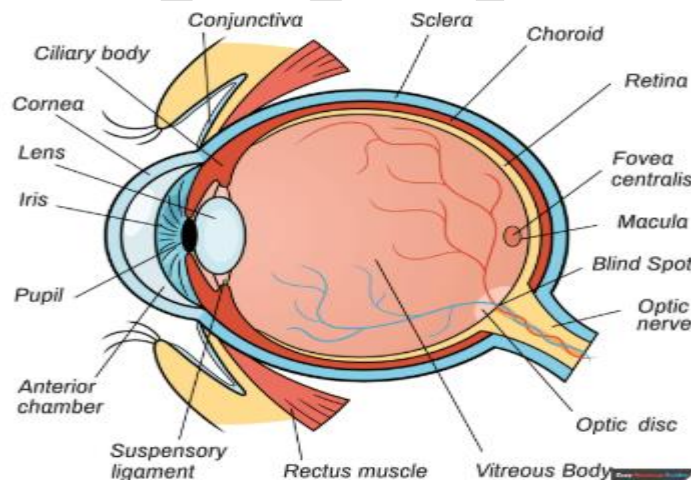
In Eolis, there is veliger larva with a coiled visceral hump that undergoes torsion but adult does not show any evidence of it, and the pallial complex is posteriorly placed in adult

Conclusion- Torsion and detorsion is a gradual process, which shows important evolutionary modifications, important for survival, as torsion (180° twist of visceral mass in gastropods) is significant for defense (head retracts first) and sensory advantage (head samples water/sediment) while detorsion leading to shell loss for streamlined, more streamlined body, worm-like forms, showing evolution adapting to torsion's downsides.

Que. 1. e. Draw a well-labelled diagram of human eye and write its functions.

Ans. The human eye is a highly specialized sensory organ responsible for the **sense of vision**. Its main function is to **receive light rays**, convert them into **nerve impulses**, and transmit these impulses to the brain, where visual perception occurs.

Structure of Human eye.



Function of Eye

1. Reception of Light

The eye receives light reflected from objects through the **cornea**, which is the transparent anterior part of the eye.

The cornea allows maximum light entry and begins the process of refraction.

2. Regulation of Light Entry

The **iris** regulates the amount of light entering the eye by controlling the size of the **pupil**.

- In bright light, the pupil constricts to reduce light entry.
- In dim light, the pupil dilates to allow more light to enter.

This protects the retina from excessive light and improves vision in varying light conditions.

3. Refraction of Light

Light rays are refracted by the **cornea, aqueous humour, lens, and vitreous humour**. These refractive media bend the light rays so that they are focused precisely on the retina.

4. Formation of Image

A **real, inverted, and diminished image** of the object is formed on the **retina**, particularly on the **fovea centralis**, which is the region of sharpest vision.

5. Accommodation for Near and Distant Vision

The **lens** changes its curvature with the help of **ciliary muscles** to focus objects at different distances.

- For near vision, the lens becomes thicker.
- For distant vision, the lens becomes thinner.

This ability is called **accommodation**.

6. Photoreception

The retina contains two types of photoreceptor cells:

- **Rods** – responsible for vision in dim light (scotopic vision).
- **Cones** – responsible for vision in bright light and color vision (photopic vision).

These cells convert light energy into electrical impulses.

7. Color Vision

Color vision is mediated by **cones**, which are of three types, sensitive to red, green, and blue wavelengths.

The combined stimulation of these cones allows the perception of different colors.

8. Visual Acuity

The eye provides **sharp and detailed vision**, especially through the **fovea centralis**, which contains a high density of cones and no rods.

9. Transmission of Visual Impulses

The electrical impulses generated in the retina are transmitted through the **optic nerve**, which serve as the communication cable to the **visual cortex of the brain**.

The brain interprets these impulses as visual images.

10. Binocular Vision and Depth Perception

Both eyes work together to provide **binocular vision**, which helps in:

- Depth perception
- Judging distance
- Three-dimensional vision

11. Circadian Rhythm

- The eye helps regulate the body's internal clock, as it is the primary and specialized set of photoreceptors with Intrinsic Photosensitive Retinal Ganglionic Cells (IPRGCs) which detect the ambient light, and manage, as they contain unique photopigment called melanopsin which triggers an electrical signals. The axon of these cells form a direct pathway to brain.

The development of human eye shows a great evolutionary and functional significance, functioning like a sophisticated camera to capture detailed images of our environment. It's vital for daily life, Information Gathering, as a primary way we perceive surroundings supporting, required for complex development of life, non-verbal communication, safety, detects threats, aids navigation, and supports activities, and overall quality of life, making it a key example of advanced biological adaptation.

Que. 2. a. Describe the comparative anatomy of digestive system in vertebrates. (20 marks)

Ans. The alimentary canal is formed early during embryonic development and is lined with the endoderm, except the mouth and rectum, which have an ectodermal lining. It includes series of organs involved in the digestion of food eaten, absorption of digested food and expulsion of undigested residue. Digestive system includes alimentary canal and associated glands.

Comparative anatomy- The digestive tract of vertebrates include the following parts: I. Mouth and Oral Cavity • Teeth • Tongue • Oral Glands II. Pharynx III. Oesophagus IV. Stomach V. Intestine VI. Glands Associated with the Digestive System • Liver • Pancreas • Gall Bladder and bile duct

1. Mouth and Oral Cavity- Mouth is the anterior opening that leads into the oral cavity, which consist teeth, tongue and oral glands.

- In amphioxus , true mouth is located at the end of the vestibule perforating the velum. In cyclostomes (Lamprey), the mouth is a circular opening at the vertex of buccal funnel.
- In gnathostomes, generally the mouth is terminal. However, in elasmobranchs and sturgeons, the mouth is ventral.
- In fishes, the mouth margins of amphibians and most reptiles have small lips. • In turtles, the lips of birds and a few mammals have been transformed into a horny beak like structure or bill.
- In mammals, the mouth is bounded by muscular lips. • The mammalian mouth is specialised to serve as suckling and masticatory organ (with muscular cheeks).

Fishes have a very short oral cavity, while tetrapods have longer oral cavities. • In a majority of fishes, the nasal cavities do not open into the oral cavity by internal nares. • In crossopterygians (lobe-finned fish) and amphibians, the internal nares open into the oral cavity, • In reptiles and birds, the oral cavity is separated from the nasal passage by palatal folds. • In mammals, the nasal passage has been completely separated from the oral cavity due to the formation of a bony secondary palate.

Teeth- Two types of teeth occur in vertebrates. 1. Epidermal teeth (horny projections of stratum corneum) e.g Cyclostomes Other examples are conical projections from lips of tadpole of some species of frogs. 2. True teeth (occur in all vertebrates except agnathans, sometoades, modern birds etc.) Its comparative account are as follows:-

- **Cyclostomes** :- True teeth are absent. The epidermal teeth are present on the lining of buccal funnel .
- **Fishes** :- Dentation in fishes is of Acrodont, Polyphyodont and Homodont. Teleosts have sharp teeth attached to jaw bones.
- **Amphibians** :- The larval anurans have epidermal teeth, serrated (saw like) whereas adult amphibians have true teeth. The dentation in amphibians is of acrodont, polyphyodont and homodont type.
- **Reptiles** :- Homodont and polyphyodont type of dentation. Lizards have acrodont and Crocodiles have thecodont dentations. The poison fang of snakes are modified maxillary teeth bearing of poison duct.
- **Birds** :-Modern birds lacks teeth.
- **Mammals** :- Thecodont type of dentitions is rule in mammals. Whales and Sirenians have monophyodont condition . Echidna has no teeth at any stage of life. • In mammals, teeth are thecodont, heterodont and diphyodont

. • Teleosts have sharp teeth attached to jaw bones. True teeth are found in all vertebrates (except cyclostomes, sturgeons, some toads, sirens, turtles and birds). • In fishes, amphibians and most reptiles, teeth are acrodont, homodont and polyphyodont. • In mammals teeth show variation as in human teeth are thecodont (embedded in jaw bones, with blood supply), heterodont (4 types i.e. incisor, canine, premolar and molar), and diphyodont (milk teeth and permanent teeth).

Tongue- The tongue is nonmuscular and non glandular in fishes. Taste buds also absent • Some anurans are tongueless while in others, a muscular tongue is present with few taste buds present and is mainly used to capture pray. • In snakes and some lizards, the tongue is well developed and bifid but in turtles and crocodiles tongue is poorly developed. • In birds the tongue is well developed and have few taste buds. • In mammals the tongue is well developed and taste buds are present on the tongue.

Oral glands- In vertebrates, a great variety of oral glands are found that secrete a variety of substances such as saliva, poison (lizards, snakes and mammals) and anticoagulant (vampire bats). •Salivary gland is absent in fishes and amphibians. • A few mucus secreting salivary glands are present in the buccal cavity of reptiles such as Uromastix (Spiny-tailed lizard). • In snakes the labial glands are present in a row in the upper and lower jaws. The posterior labial glands of the upper jaw is modified as the poison gland in the poisonous snakes. • Buccal glands of birds such as pigeon probably secrete mucus but they are not salivary glands. • Buccal gland of vampire bats produce

anticoagulant. • In mammals salivary glands of different kinds found which open into buccal cavity by separate ducts. They secrete saliva containing an enzyme Ptyalin.

In the buccal cavity of humans, three pairs of salivary glands are present, viz., parotid, sublingual and submaxillary.

Pharynx- It is the region of foregut between the oral cavity and the oesophagus. It is divided into three parts, viz., nasopharynx, oropharynx and laryngopharynx .

Cyclostomes:- In lampreys , the pharynx lies below oesophagus as separate blind pouch communicating with gills.

Fishes :- In fishes, pharynx plays an important role in respiration. In cartilaginous fishes pharyngeal lateral wall has internal gill clefts.

Tetrapods:- the pharynx is the cross road between food and respiratory passage. In tetrapods, it is the site of openings of auditory (Eustachian) tube. In male Frog, a pair of opening of vocal sac is present.

Oesophagus - The oesophagus is a distensible muscular tube connecting the pharynx and the stomach. It does not take part in digestion. The oesophagus is very short in neckless vertebrates (fishes and amphibians).

Cyclostomes:- In lampreys, Oesophagus starts directly from buccal cavity lined by numerous folds.

Fishes:- It is very short in fishes, as neck is absent. Sharks and Latimeria have a large oesophagus. The oesophagus is long in Polypterus

Amphibians:- In anurans, esophagus is very short and consists of little more than constricted area of alimentary canal and is ciliated.

Reptiles:- The Oesophagus is longer than anamniotes. In snakes the longitudinal folds in the walls permit distension during swallowing of large objects.

Birds:- The oesophagus is very long as neck is very long in birds lined by horny papillae in grain eating birds e.g. Pigeons and birds of prey. Oesophagus is dilated to form large thin walled distensible sac called crop, act as a temporary site of food storage and in pigeon crop has crop gland and these glands on stimulation secrete Pigeons milk

Mammals :-In mammals,the length of oesophagus varies with the neck . In human, at each end of the esophagus, the muscularis becomes slightly more prominent and forms two sphincters—the upper esophageal sphincter (UES), which consists of skeletal muscle, and the lower esophageal (cardiac) sphincter (LES), which consists of smooth muscle and is near the heart.

Stomach :- The sack like muscular enlargement of digestive tract between oesophagus and intestine is called stomach. It is the most dilated part of alimentary canal. It serves as storage and macerating site for ingested food and secretes digestive enzymes . The shape of the stomach is according to the shape of body. It may be Tubular 'J' shaped, and 'U' shaped or Transverse sac like. In embryos of vertebrates, the stomach is a straight tube-like structure. • In certain fishes, long-bodied amphibians, lizards and snakes, the stomach is cigar-shaped. The anterior end of the stomach connected to oesophagus is called cardiac end and the part connected to intestine is called pyloric end. The main part of stomach is called body.

Cyclostomes :- in cyclostomes, Stomach is poorly developed. It is simply enlargement at posterior end of oesophagus.

Fishes:- Ture stomach first appears in elasmobranch. Here it is “J” shaped. In some deep fishes, the stomach is so distensible, so that it can hold prey larger than themselves. In amphibians, the stomach is long and lacks fundus

Amphibians:- The typical amphibians stomach is called curved, Dilated Part of alimentary canal. It is present on left side of the body In amphibians, the stomach is long and lacks fundus. In salamanders the stomach is like a straight tube .

Reptiles :- In most of reptiles (snake and lizard) long spindle shaped stomach is present. In crocodilians, stomach is similar to that of birds. In tested , stomach is U shaped. The stomach of Uromastix is U-shaped, having thick muscular walls and the gastric glands found in the mucous lining of stomach.

Birds :- The stomach of birds is highly specialized to crush the food, and has no or very less storage capacity.The stomach is differentiated into two regions:- The anterior portion, small glandular region ventriculus continous with oesophagus and posterior distal muscular region called gizzard, help in grinding the food, as teeth are absent in Jaws.

Mammals :- Stomach of mammals show greatest modifications. It may be simple sac or divided into cardiac, fundic and pyloric regions. The inner wall of the stomach contains gastric glands in which the following three types of secretory cells are found: (a) Chief cell - Pepsinogen and prorennin (b) Oxyntic cell - HCl (c) Mucus cell – Mucus. In monotremes (egg laying mammal), the stomach is in the form of a sac-like structure and is without any gastric glands. • In ruminants, the stomach has four chambers, viz., the rumen, reticulum, omasum and abomasum. In cud chewing mammals or ruminants stomach has four well defined chambers omasum are claimed the modifications of oesophagus and serve as reservoirs of food and last chamber abomasums represent true stomach.

Small and Large Intestine- It is the most important part of digestive tract and undergoes several modifications in vertebrates. It is a long tube like part between stomach and anus and cloaca. The length of intestine depends on the feeding habits. It is shorter in carnivores and longer in herbivores.

- **Cyclostomes**: The cyclostomes have straight intestine. There is no demarcation between small and large intestine. The intestine opens into anterior end of cloacal depression.
- **Fishes** :- In cartilaginous fishes the small intestine is smaller than stomach and contains a scroll valve. The large intestine is a short passage between small intestine and anus. There is present rectal gland at the junction of small and large intestine. The intestine is relatively straight and short and not differentiated into large and small intestine in cartilaginous and primitive bony fishes (lung fish and sturgeon). However, the intestines of cartilaginous fishes have a spiral valve. Caecum is lacking. Distal end of the intestine forms a short, narrow rectum which opens into cloaca. Rectum receives a tubular rectal gland of unknown function.
- **Amphibians**:- The intestine of amphibian is comparatively longer and coiled than that of fishes. The intestine is differentiated into a coiled small intestine and a short straight large intestine. Duodenum is a straight tube, forms “U” with stomach, and receives hepato-pancreatic duct. True villi in the ileum is absent. Caecum and rectal gland is lacking. It contains urinogenital apertures and bursa Fabrici.
- **Reptiles** :- The small intestine is long coiled and of uniform diameter. The large intestine is wide straight and opens into cloaca.
- **Birds** :- The birds have comparatively longer small intestine than lower vertebrates due to herbivorous habit in most of the birds. The large intestine is short and straight and

opens out as cloaca. Ileocolic caeca is present at the junction of small and large intestine .

- **Mammals** :- In mammals the intestine is better developed than other vertebrate .The small intestine is differentiated into three regions : Duodenum ,Jejunum, and Ileum. Large intestine is shorter and wider than small intestine and is differentiated into two regions : colon and rectum .At the junction of Ileum and colon ileocolic valve is present. Rectum opens out as anus except in monotreme where cloaca is present.In the wall of small intestine there are present large number of villi and glands .

In many bony fishes and mammals (except monotremes), the urinogenital and anal openings are separate. • Vermiform appendix is absent in Fishes, amphibians, reptiles and birds but present in mammals.

DIGESTIVE GLANDS The digestive glands associated with the alimentary canal secrete several juices which aid in digestion . Some of the glands are present in alimentary canal are salivary gland whereas some glands like liver and pancreas are appended to alimentary canal..

Glands of oral cavity : Glands of oral cavity basically secrete secretions which help in ingestion of food .In land vertebrates these glands secrete mucus which moistens the food . Oral glands- In vertebrates, a great variety of oral glands are found that secrete a variety of substances such as saliva, poison (lizards, snakes and mammals) and anticoagulant (vampire bats). •Salivary gland is absent in fishes and amphibians

- **Cyclostomes** : - A pair of salivary gland lie below the tongue.They secrete an anticoagulant called lampherdin .
- **Fishes** :- The only gland present in buccal cavity of fishes are mucous glands. Amphibians :- In aquatic amphibians like urodels only mucous glands are present like fishes .
- **Reptiles** :- In reptiles lingual , sublingual and labial glands are present . In Gila monster modified sublingual glands are poison secreting gland. In poisonous snakes the modified posterior labial gland of upper jaw is poison gland . A few mucus secreting salivary glands are present in the buccal cavity of reptiles such as Uromastix (Spiny-tailed lizard). • In snakes the labial glands are present in a row in the upper and lower jaws.

- **Birds** :- In birds well developed sublingual gland opens at the floor of buccal cavity. Buccal glands of birds such as pigeon probably secrete mucus but they are not salivary glands
- **Mammals** :- Mucous glands minute and numerous are located on palate and tongue of mammals. In man there are three pairs of the glands namely parotid, submaxillary and sublingual. The parotid gland lies below external auditory meatus and their secretions are brought by Stensen's duct. The submaxillary gland lie in the posterior region of lower jaw and their secretions are brought by Wharton's duct. The sublingual glands lie under tongue and their secretions are brought by Bartholin's duct. Buccal gland of vampire bats produce anticoagulant.

LIVER : - It is the largest gland of the body .it is present in all vertebrates .it is primarily a digestive gland although it serves many other functions . Liver develops as an outgrowth of the endodermal wall of the archenteron called as liver diverticula differentiates into two parts: anterior part forms large glandular mass of liver and its bile ducts while posterior part give rise to gall bladder and cystic duct. The comparative anatomy of liver in different vertebrates is as follows :- Cyclostomes:- The liver of cyclostomes is very small .it is bilobed in hagfish and single lobed in lampreys . Fishes :- The liver of fishes is many lobed and large .Gall bladder is generally present except in sharks . Amphibians:- The liver is large in proportions to body size and many lobed .Gall bladder is present. Birds :- Many lobed liver is found in birds .Gall bladder is absent in most of them . Mammals :- In mammals liver is many lobed .Basically two main lobes are further divided into many smaller lobes .In man and rabbit there are five lobes .Gall bladder is lacking in some mammals like rodents

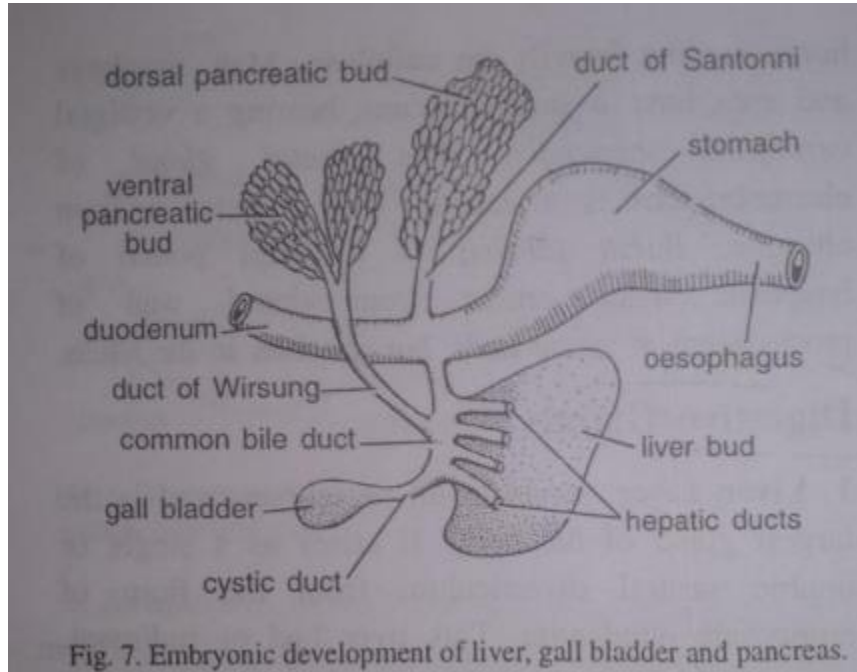


Fig. 7. Embryonic development of liver, gall bladder and pancreas.

PANCREAS :- It is the second largest digestive gland of the body .It is heterocrine gland their secretions form pancreatic juices and contain enzymes .it is the exocrine part formed of acini. The endocrine part is formed of groups of small cell called Islets of Langerhans . The comparative anatomy of pancreas in vertebrates is as follows :

Cyclostomes :- The hag fish have very small pancreas near bile duct . In lampreys pancreas is absent. Fishes :- Elasmobranchs have well defined pancreas having dorsal and ventral lobes . Amphibians ,Reptiles and Birds :- A well defined ,compact pancreas is present in the loop between duodenum and the stomach . Mammals : - The pancreas is lying between duodenum and ileum in rabbit and in v fold of duodenum in most of the mammals .There are two pancreatic ducts .The ventral duct joins bike duct near ampulla .The dorsal duct enter duodenum directly . In few mammals pancreatic bladder is present to store pancreatic juice .

Comparative anatomy of vertebrate digestive systems reveals evolution driven by diet, showing adaptations like gizzards for grinding, multi-chambered stomachs for fermentation (ruminants), and specialized beaks/tongues, all highlighting how structure links to environment, nutrient processing efficiency, and survival, from basic tubular forms to complex specialized organs for diverse food sources, ecological success, functional relationships links morphology (shape, glands, muscle) to function (storage, secretion, absorption, mixing), showing how stomach size/shape varies with food intake.

Que.2.b. Give an illustrated account of reproduction in sponges.

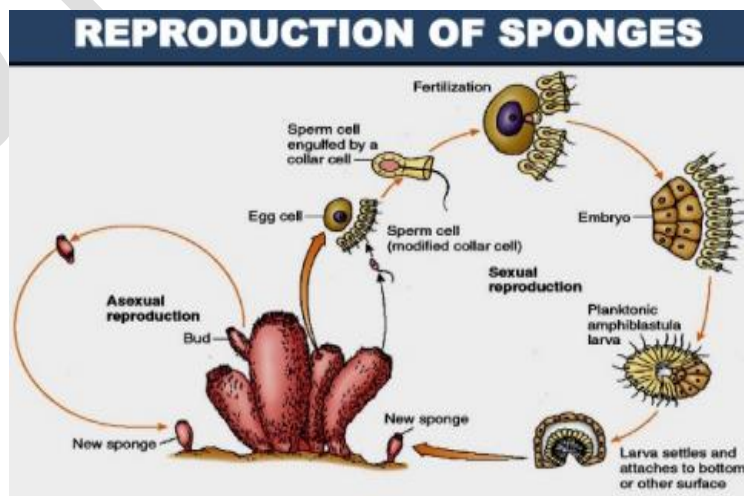
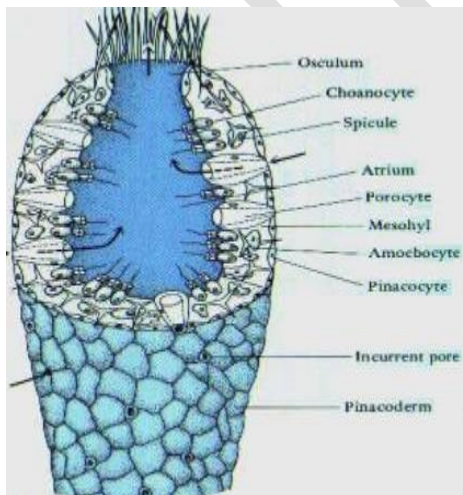
Ans. Sponges are multicellular organisms with sessile aquatic habitat, of the phylum Porifera meaning pore bearing animals having specialized cells. Sponges reproduce both asexually and sexually and they also possess the power of regeneration due to which it is almost impossible to kill a sponge. Their sexual reproduction is similar to higher animals even though their body organization is primitive type.

Reproduction in sponges- Sponges reproduce both asexually and sexually

Asexual Reproduction-

Regeneration- Sponges possess a remarkable ability of regeneration. A piece cut from the body of a sponge is capable of growing into a complete sponge. If a sponge is cut into small pieces and squeezed through a fine silken mesh to separate cells, the separated amoebocytes will reunite and in a few days will develop canals, flagellated chambers and skeleton and grow up into a new sponge. It also helps in regenerating lost parts.

Budding & Branching In budding, numerous archaeocytes gather near the surface resulting in a small outgrowth on the pinacoderm. The bud thus formed grows outward to produce a small individual, which either remains attached with the parent individual or gets detached and attached to a nearby rock to grow into an independent colony. Stolon of the sponge grows by branching and secondary branching and many small vertical buds grow out of it.



Fission & Fragmentation In some sponges multiplication takes place by developing a line of fission and throwing off parts of the body which later can develop into a new sponge. Sponges can break into several pieces along several lines of weakness and

breaking into fragments that are capable to tide over unfavourable environmental conditions and grow into complete sponges in the following favourable season.

Reduction bodies- Many fresh water and marine sponges disintegrate in adverse environmental conditions particularly in winter, leaving small rounded balls called reduction bodies. Each body consists of an internal mass of amoebocytes, covered externally by a pinacoderm and spicules. When favourable conditions return, these reduction bodies grow into complete new sponges.

Gemmules Fresh water sponges such as Spongilla as well as some marine forms such as Ficulina, Suberites, and Tethya possess the remarkable ability to produce specialised bodies called gemmules, which survive during unfavourable conditions and germinate to produce new sponges. For gemmule formation, archaeocytes laden with food material in the form of glycoprotein or lipoprotein get aggregated into a mass. Amoebocytes surround the central mass of archaeocytes and secrete a thick hard chitinous inner layer and an outer membranous layer over it. Scleroblasts secrete amphidisc spicules between the inner and outer membranes. A fully formed gemmule is a small hard ball having a mass of food laden archaeocytes enclosed in a double layered tough envelope with amphidisc spicules in between. There is a small opening the micropyle through which the cells come out during development in favourable conditions. In autumn fresh water sponges die and disintegrate, leaving behind a large number of gemmules, which remain viable throughout the winter. Same thing happens during summer when water available is low. In favourable conditions with abundance of water the gemmules begin to hatch and their living contents escape through micropyles and develop into new sponges by collecting themselves together.

SEXUAL REPRODUCTION Sexual reproduction involves formation of sperms and ova. The sex cells arise either from archaeocytes or choanocytes. Although most sponges are hermaphrodite but crossfertilization is the rule because eggs and sperms are produced at different times. Oocytes are produced inside the body and remain inside mesogloea waiting for fertilization. In sperm formation, archaeocyte and trophocyte cells are involved and in demospongiae choanocytes form sperms and leave the body of sponge through osculum in large numbers. Sperms from water enter the body of another sponge through canal system and reach the flagellate chambers, where choanocytes trap them. Acting as nurse cells, choanocytes transport the sperm body without tail to the mature ova that wait in the mesogloea. The sperm nucleus then fuses

with the nucleus of ovum, ensuring internal fertilization. Further development of organism in sexual reproduction occurs through larval stage as

Sponges use diverse reproductive strategies—cloning for speed, sexual reproduction for adaptation, genetic diversity and regeneration with totipotent cells for resilience also allows repair and rapid population growth and survival in harsh conditions make them persistent organisms, ensures survivability and highly successful organisms, and shows both ecological and evolutionary significances.

Que.2.c. Describe the general features, distribution and social organization in termites.

Ans. Termites are **eusocial insects** commonly known as **white ants**, though they are not true ants. They belong to the **order Isoptera** (now placed under **Blattodea**) and are well known for their **complex social organization, division of labour**, and ability to digest **cellulose**.

General features of Termites

- **Habitat-** □ Terrestrial insects living in **colonies**. Found in soil, wood, tree trunks, or constructed nests (mounds) and they prefer warm, humid conditions.
- **Body Structure:** Termites generally have soft bodies, typically pale in color (white or light brown), although some species can be darker. Their bodies are divided into a head, thorax, and abdomen.
- **Antennae:** They possess moniliform (bead-like) antennae, which are crucial for tactile sensing and chemical communication within the colony.
- **Mouthparts:** Termites have chewing mouthparts, specifically mandibulate type, which are well-developed for gnawing wood, soil, or other food sources.
- **Eyes:** Most worker and soldier termites are blind or have vestigial eyes, relying on chemical and tactile cues. Reproductive alates (kings and queens) typically have well-developed compound eyes.
- **Wings:** Reproductive forms (alates or swarmers) possess two pairs of membranous wings of equal size, which they shed after their nuptial flight. This characteristic (isoptera, meaning "equal wings") differentiates them from ants, whose forewings are larger than their hindwings.
- **Caste System:** A defining feature is their polymorphic caste system, comprising reproductives (king, queen, secondary reproductives), soldiers, and workers, each with distinct morphology and functions. Castes are morphologically distinct. Queen shows extreme abdominal enlargement (physogastry).
- **Digestive System:** Termites feed mainly on cellulose. They achieve this primarily through symbiotic microorganisms (protozoa named Trichonympha and bacteria) residing in their hindgut, which break down cellulose into digestible sugars.

- **Trophallaxis:** They practice trophallaxis, the transfer of food or liquid among colony members, which is vital for nutrient distribution and for transferring symbiotic microorganisms to newly molted or hatched termites.
- **Development-** □ Undergo incomplete (paurometabolous) metamorphosis. Development: egg → nymph → adult.

Distribution of Termites

Termites are widely distributed across the globe, with a preference for warm and humid climates. Their presence is most prominent in tropical and subtropical regions, but they can also be found in temperate zones.

- **Global Reach:** They are found on every continent except Antarctica. The highest diversity and density of termite species occur in tropical rainforests and savannas of Africa, South America, and Australia.

Ecological Distribution

- Soil-dwelling termites
- Wood-dwelling termites
- Mound-building termites

Habitat Diversity: Termites inhabit a wide range of habitats, from dense forests and grasslands to deserts and urban environments. Their ability to construct complex nests allows them to thrive in diverse ecological niches

Environmental Factors: Their distribution is largely influenced by temperature, humidity, and the availability of cellulose-rich food sources. Cold climates limit their survival, while arid regions often see them adapting to subterranean lifestyles to access moisture.

Major Regions

- **Africa:** Home to some of the largest and most complex termite mounds, especially by species like *Macrotermes*.
- **Australia:** Rich in endemic termite species, including those that build elaborate magnetic mounds. It includes the most primitive living termite, *Mastotermes darwiniensis*
- **South America:** Abundant in rainforests, contributing significantly to wood decomposition.
- **Asia:** Particularly prevalent in Southeast Asia and India, where they are both ecological engineers and significant agricultural and structural pests. In India Common in forests, grasslands, agricultural fields, and human dwellings
- **North America:** Predominantly found in warmer southern states, with species like the subterranean termite *Reticulitermes flavipes* being common.

Social Organization of Termites: The detailed account of termites was published first in the Royal Society of London in 1781 by Henry Smeathman. The account was based on African termites. A typical colony possesses nymphs (semimatured young's), workers, soldiers and reproductive individuals of both sexes. A termite colony includes two major castes— sterile castes and reproductive castes

A. Sterile castes: They are incapable of reproduction and include usually workers and soldiers.

(i) **Workers:** They are sterile of both sexes and developed from the fertilized eggs. They constitute major numbers in a colony and occupy 80%-90% of the total number. They are small-sized individuals measuring about 6 to 8 mm in length which bear chewing mandibles and usually lack of eyes. They have no wings (apterous). They feed upon the wood or fungus products. Workers perform all the duties for the colony except reproduction. The most numerous caste, performing the majority of the colony's tasks including foraging for food, caring for the young and queen, building and repairing the nest, and grooming other colony members.

(ii) **Soldiers:** They are developed from the unfertilized eggs. They are wingless and larger than the workers. Soldiers are more or less pigmented and possess large head and stout, powerful mandibles. They constitute 5-8% in number in a colony. Soldiers for food rely on workers. They maintain the defense of the colony.

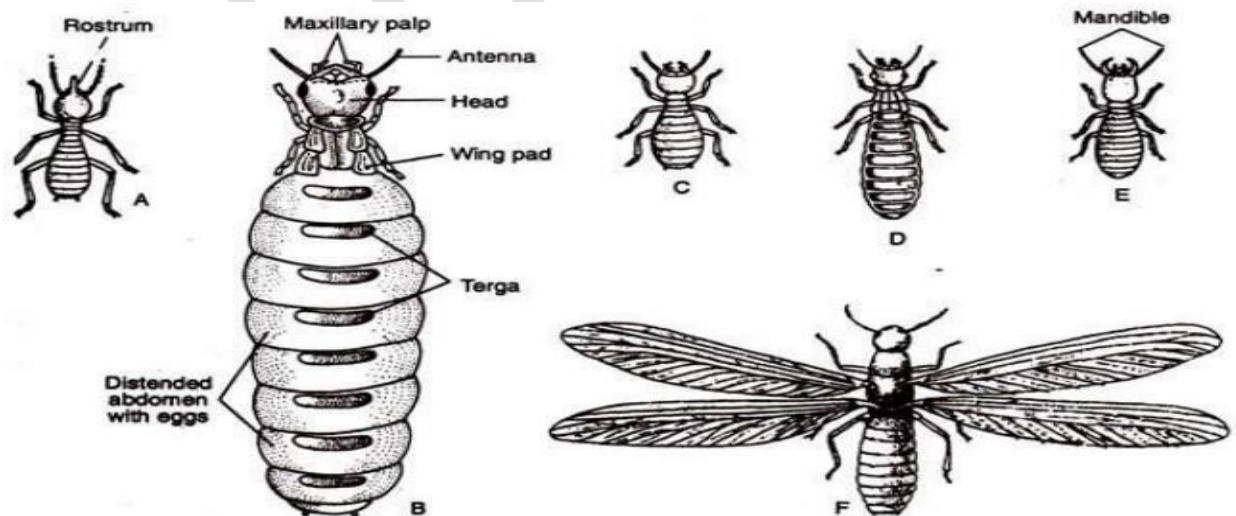


Fig. 18.91: Different forms in a termite colony. A. Nasute, B. Queen or female. C. Worker. D. Male. E. Soldier. F. Winged male.

B. Reproductive castes: These are fertile and are characterised by the presence of the eyes. From the functional point of view, the reproductive castes are of three types:

1. **Macropterous** or large winged or primary reproductive forms. These sexually matured males and females have two pairs of wings longer than the body and convert kings and queens. The royal pair or the sexually active males and females of social insects are the original founders of the colony.

- ❖ King: Usually there is a single king in a colony. It is smaller than the queen. Its function is to mate intermittently and provide sperm to the queen.
- ❖ Queen: The queen is also a single in a colony which is largest in size measuring 60- 80 mm in length. It lays eggs after mating and can lay more than 1000 eggs per day. Both king and queen live in a special chamber, called nuptial chamber.

2. **Brachypterous** neotenic or short winged or substitute reproductive forms: When the primary or original king or queen dies or gets old, its place is taken by the sexually mature male or female but in nymph form. To replace them, the nymphs of the suitable sex (male or female) attain maturity by special feeding without further moulting and become the substitute queen. The substitute reproductives are characterized by the presence of short pad-like wings, ocelli and rudimentary compound eyes and small reproductive organs. The substitute reproductives vary in number in different species within colony.

3. **Apterous** neotenic reproductives or wingless forms or replacement reproductives: If queen dies in some adverse conditions or gets old, the apterous neotenic reproductives are produced. In some primitive subterranean species, like *Reticulitermes flavipes*, *Reticulitermes mallei*, the nymphs or ergates (workers) are without wings and possess less developed eyes, and reproductive organs become a functional reproductive in the colony with one or two moults.

Termites are highly organized eusocial insects with specialized castes performing distinct roles. Termites, with their unique general features, widespread distribution, and highly sophisticated social organization, represent a significant component of many terrestrial ecosystems. Their ecological roles as decomposers and soil engineers are indispensable, contributing to nutrient cycling and soil aeration. However, their destructive potential as pests necessitates continuous research into sustainable management strategies. Understanding their biology and social dynamics is crucial for both preserving their beneficial roles and mitigating their detrimental impacts on human infrastructure and agriculture, highlighting the delicate balance of their existence. Their

ability to digest cellulose, complex social structure, and wide distribution make them ecologically significant as well as economically important pests.

Que.3.a. Describe the mechanism of parental care in amphibians with suitable examples. (20 marks)

Parental care refers to any form of behavior exhibited by parents that enhances the survival and well-being of their offspring. It involves various actions taken by parents to provide protection, nourishment, and support to their young, increasing the likelihood of their survival to reproductive age. Amphibians show the diverse methods of parental which refers to the **behavioural and structural adaptations** shown by parents to **protect eggs, larvae** and young ones to increase their chances of survival.

Methods of Parental Care in Amphibians

Protection by nests, nurseries or shelters: Amphibians have evolved countless interesting methods to give protection to their defenceless eggs and larvae from predators.

1. Selection of site. Many amphibians lay eggs in protected, moist microhabitats on land. Many tropical frogs and toads lay eggs on land near water. Many tree frogs lay their eggs not on land but on leaves and branches overhanging water. Species of Phyllomedusa, Rhacophorus, Hylodes, etc. glue their eggs to foliage hanging over water. Many tree frogs deposit eggs in water that accumulates in epiphytic tropical plants such as Rhacophorus malabaricus in India.

2. Defending eggs or territories. Protection of young ones, eggs and larva through direct and indirect methods as guarding of territory from external intruding factors such as Males of green frog *Rana clamitans* and other species maintain territories and attack small intruders to defend eggs. Male or female even guards the eggs. In *Mantophryne robusta*, the male actually sits over and holds with hands the elastic gelatinous.

3. Foam nests. According to Mallick, Mallick and Das (1980), *Polypedates* (= *Rhacophorus*) *maculatus*, secretes a jelly-like secretion with eggs from time to time which is beaten by the cross-wise movement of the hind-limbs of the female partner, resulting in a formation of a small frothy mass. The frothy mass looks like an irregular ball. Many amphibians convert copious mucous secretions into nests for their young. In the Japanese tree frog, *Rhacophorus schkgeli*, the mating couple digs a hole or tunnel into which eggs are left in a frothy mass to avoid desiccation. During rains, hatching

tadpoles are washed down the slopping tunnel into pond or river water for further development. The female of South American tree frog, *Leptodactylus mystacinus*, stirs up a frothy mass of mucus, fills it in holes near water and lays eggs in them which provide moisture and slimy covering to young ones.

Frothing of water: Some anurans just after the laying of the eggs, the surrounding water is made frothy by the wriggling movement of hind limbs, so that the eggs are prevented from desiccation and also can escape the sight of enemies. Both males and females participate in this process

4. Mud nests in amphibians are specialized nurseries, often built by male frogs like the Brazilian *Hyla faber* (Ferreiro frog) or *Nyctibatrachus kumbara*, who dig holes in shallow water or mud, using the excavated mud to form a protective wall, creating a safe, water-filled basin for eggs and tadpoles, shielding them from predators and dehydration.

5. Tree nests. The South American tree frog, *Phyllomedusa hypochondrales*, lays eggs in a folded leaf nest with margins glued together by cloacal secretion. The tadpoles when formed fall straight into water below. Another tree frog, *Hyla resinifictrix*, lines a shallow tree cavity with bees wax obtained from the hives of certain stingless bees. Female lays eggs when this cavity is filled with rain water. Here, the young develop relatively free from predators.

6. Gelatinous bags in amphibians are protective structures, often made of secreted jelly, that hold and shield eggs, preventing desiccation (drying out) and hiding them from predators, seen in species like tree frogs that create foam nests, salamanders building nests in plant shoots, or frogs like *Phrynilaxalus biroi* laying eggs in transparent, sausage-shaped bags in streams. *Salamandrella keyserlingi*, a small aquatic salamander also deposits 50 to 60 small eggs in a gelatinous bag which is fastened to aquatic plants.

[II] Direct carrying by parents:

1. Coiling around eggs- Some of the amphibians female, or sometimes the male, wraps their body around a clutch of eggs, often in damp soil or burrows, to guard them from predators and keep them moist until they hatch. Females amphibians like caecilians (like *Ichthyophis*) and the Congo eel (*Amphiuma*) and in males like the giant salamander (*Megalobatrachus*), males perform this guarding duty.

Eggs glued to body. Many amphibians, instead of remaining with the eggs, carry the eggs glued to their body for protection until hatching, ensuring embryos develop in a

safer, moist spot away from aquatic predators, with some even showing physiological exchange. In the dusky salamander, *Desmognathus fuscus*, female carries the string of eggs coiled around her neck, until they have hatched.

Carrying larva from one place to other: In *Arthroleptis*, the larvae are attached to the males and are carried from one pond to the other. At the time of danger they are kept inside the buccal cavity

Eggs in back pouches. In one group of tree frogs - called marsupial frogs or toads the female carries the eggs on her back, either in an open oval depression, a closed pouch or in individual pockets. The eggs develop into miniature frogs before they leave their mother's back. In the Brazilian tree toad, *Hyla goeldii* or *Cryptobatrachus evansi*, the posterior part of the back of female forms a sort of incipient brood pouch in which the eggs remain exposed.

Organs as brooding pouches. Male of the terrestrial South American Darwin's frog, *Rhinoderma darwinii*, pushes at least two fertilized eggs into his relatively large vocal sacs. Here, they undergo complete development to emerge out as fully formed froglets. In West African tree frog, *Hylambates breviceps*, the female carries eggs in her buccal cavity. In *Arthroleptis*, it is the male who keeps the larvae in his mouth. The only known case of gastric incubation in vertebrates is found in the Australian frog, *Rheobatrachus silus*. The female keeps the eggs in her stomach. The tadpoles are expelled through mouth after metamorphosis.

6. Viviparity. Some anurans are ovoviviparous. They retain eggs in the oviducts and the females give birth to living young. African toads, Nectophrynoidea and Pseudophryne give birth to little frogs. The European Salamander, *Salamandra salamandra* produces 20 or more small young while the Alpine salamander, *S. atra* gives birth to one or two fully developed young.

Parental care provide the significant role in overall development of amphibians as increased survival **as** the primary benefit for the survival rate of eggs and young, which face heavy predation and desiccation in aquatic/terrestrial environments, habitat Provision as safe nurseries (foam nests, mud nests, leaf clutches) or guide young to water, overcoming dispersal challenges defense from predators by Guarding eggs and larvae from fish, insects, and other amphibians protects them until they're independent, nutritional support, overcoming environmental risks by ensuring eggs and tadpoles

survive droughts or find water, essential for species that don't lay thousands of eggs and help in enhancing fitness by investing resources and energy.

Que. 3 b. Describe the different stages of life cycle of *Pheretima* with the help of suitable diagrams. (15 marks)

Answer. The life cycle of ***Pheretima posthuma*** (the common Indian earthworm) is a fascinating process that involves several distinct stages: mating, cocoon formation, fertilization, and development. Since earthworms are **hermaphrodites** (monoecious), each individual possesses both male and female reproductive organs, but they still require a partner for cross-fertilization.

1. The Juvenile (Immature) Stage

The main non-reproductive stage of *Pheretima* is the **juvenile stage**.

- **Appearance:** Juveniles look like miniature versions of the adult (often paler in color), but they **lack a clitellum**.
- **Segments 14–16:** In a non-reproductive worm, segments 14, 15, and 16 look identical to the rest of the body segments. They are not yet swollen or covered by the dark, glandular band of tissue.
- **Development:** Earthworms have **direct development**, meaning they hatch directly from cocoons as small worms without passing through a larval stage. Therefore, the juvenile is the only significant "non-reproductive" growth phase.

2. Copulation (Mating)

Mating usually occurs during the rainy season at night or in the early morning.

- Two earthworms lie in a "head-to-tail" position with their ventral surfaces touching.
- They align so that the male genital pores of one worm are opposite the **spermathecal pores** of the other.
- During this process, they exchange sperm, which is stored in each other's spermathecae. This exchange lasts about an hour.

3. Cocoon Formation

After mating, the **clitellum** (the thick, glandular band on segments 14–16) becomes very active.

- The clitellar glands secrete a viscous fluid that hardens upon exposure to air, forming a membrane-like tube around the clitellum.
- As the worm starts to wiggle backward, the tube slides forward toward the head.

- **Collection of eggs and sperm:** As the tube passes over the female genital pore (segment 14), it collects eggs. As it continues forward over the spermathecal pores (segments 6–9), it collects the "stored" sperm from the partner.

4. Fertilization and Deposition

Once the tube slides off the head of the worm, the ends of the tube constrict and seal, forming a small, lemon-shaped structure called a **cocoon** (or egg case).

- **Fertilization:** Unlike humans, fertilization in *Pheretima* is **external**, occurring inside the cocoon after it has been shed into the soil.
- The cocoons are usually deposited in moist, dark soil to prevent desiccation (drying out). They are yellowish-brown and only a few millimeters in size.

5. Embryonic Development

The development of the embryo happens entirely within the cocoon.

- *Pheretima* exhibits **direct development**, meaning there is **no larval stage**.
- The zygote undergoes cleavage and eventually forms a tiny, fully-formed worm.
- Each cocoon typically contains several eggs, but usually, only **one to few** embryos survive and successfully develop due to competition for the nutrient-rich albumen inside the cocoon.
- The developmental period usually lasts between **2 to 3 weeks**, depending on the temperature and moisture of the soil.

6. Hatching and Maturity

- **Hatching:** When development is complete, tiny, colorless "juvenile" earthworms crawl out of the cocoon. They are essentially miniature versions of the adults but lack the clitellum.
- **Growth:** The juveniles feed on organic matter in the soil and grow rapidly.
- **Sexual Maturity:** After about **6 to 10 weeks**, the worm develops a clitellum and functional reproductive organs, becoming a sexually mature adult ready to begin the cycle again.

Earthworm stages (Egg/Cocoon, Hatchling, Juvenile, Adult) are significant as they represent key transformations for growth, survival, and reproduction, with the **cocoon** protecting eggs, **hatchlings** being miniature, vulnerable versions, **juveniles** rapidly growing and developing, and **adults** maturing to facilitate sperm exchange and cocoon production, all crucial for continuing the species and vital for soil health (aeration, nutrient cycling) through their feeding and burrowing activities.

Que.3.c. Discuss the various modes of nutrition in protozoa. (15 marks)

Ans. Nutrition is the process of ingestion, digestion, assimilation and egestion of food to provide energy for various vital activities of life. Protozoa, being a highly diverse group of single-celled eukaryotes, exhibit several distinct modes of nutrition to survive in various aquatic and parasitic environments. Their nutritional strategies range from plant-like self-feeding to complex animal-like ingestion.

1. Holozoic (Zootrophic) Nutrition

This is the most common "animal-like" mode of nutrition. The protozoan ingests solid food particles (such as bacteria, algae, or smaller protozoa) and digests them internally.

- **Mechanism:** Food is captured using specialized structures like **pseudopodia** (in *Amoeba*) or **cilia** (in *Paramecium*).
- **Digestion:** Once captured, the food is enclosed in a **food vacuole**, where enzymes break it down.
- **Examples:** *Amoeba*, *Paramecium*.

2. Holophytic (Autotrophic) Nutrition

This is a "plant-like" mode where the organism synthesizes its own organic food from inorganic substances using sunlight.

- **Mechanism:** These protozoa contain **chlorophyll** or other pigments within chromatophores/chloroplasts to perform photosynthesis.
- **Examples:** *Euglena* (in the presence of light), *Volvox*.

3. Saprozoic (Saprotrophic) Nutrition

Saprozoic protozoa absorb dissolved organic nutrients directly from their environment through the cell membrane via osmosis or diffusion.

- **Mechanism:** This is also known as **osmotrophy**. It is common in organisms living in environments rich in decaying organic matter.
- **Examples:** *Chilomonas*, *Entamoeba histolytica* (which can absorb nutrients from the host's gut).

4. Parasitic Nutrition

Parasitic protozoa live within or on a host organism and derive their nutrients at the host's expense.

- **Food Robbers (Commensals):** Feed on undigested food in the host's gut without necessarily causing harm (e.g., *Opalina*).
- **Pathogenic:** Feed on the host's living tissues or blood (e.g., *Plasmodium*, which causes malaria). They may obtain their food in holozoic manner in *Entamoeba histolytica* or

saprophytically by absorbing liquid or assimilable food as in Plasmodium and Trypanosoma. Thus they exhibit two ways of food uptake:

- (1) By phagotrophy-In this method, the parasites feed on host tissue by holozoic method. It is exhibited by Nyctotherus and Balantidium.
- (2) By osmotrophy-In this method, parasitic protozoa feed saprophytically and obtain liquid food by diffusion as for example, Trypanosoma and Entamoeba.

5. Mixotrophic Nutrition

Some protozoa can utilize more than one mode of nutrition depending on environmental conditions.

- **Example:** *Euglena* is a classic example. It behaves as a **holophyte** (autotroph) in sunlight but can switch to **saprophytic** (heterotroph) nutrition in the dark by absorbing organic matter.

6. Pinocytosis ("Cell Drinking")

This is a specific mechanism for ingesting liquid food.

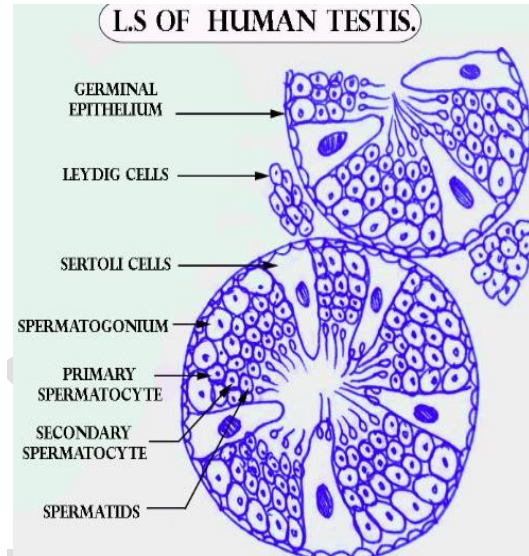
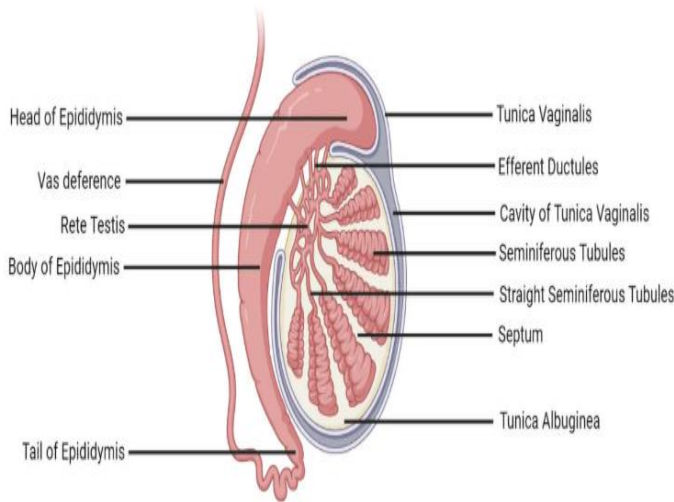
- **Mechanism:** The cell membrane invaginates to form tiny channels that pinch off as small vesicles (**pinosomes**) containing fluid and dissolved nutrients.
- **Examples:** *Amoeba proteus* has been observed performing this when exposed to certain salts or proteins.

The significance of diverse nutrition in protozoa lies in their **ecological flexibility, survival in varied habitats, and role in nutrient cycling**, enabling them to thrive as producers (holophytic), consumers (holozoic, saprophytic), or parasites (parasitic), with mixotrophy combining methods for adaptability, showing how these strategies support life from photosynthesis to exploiting hosts. These varied strategies allow protozoa to occupy diverse ecological niches, from ocean depths to parasitic hosts, showcasing remarkable evolutionary adaptability and ecological impact.

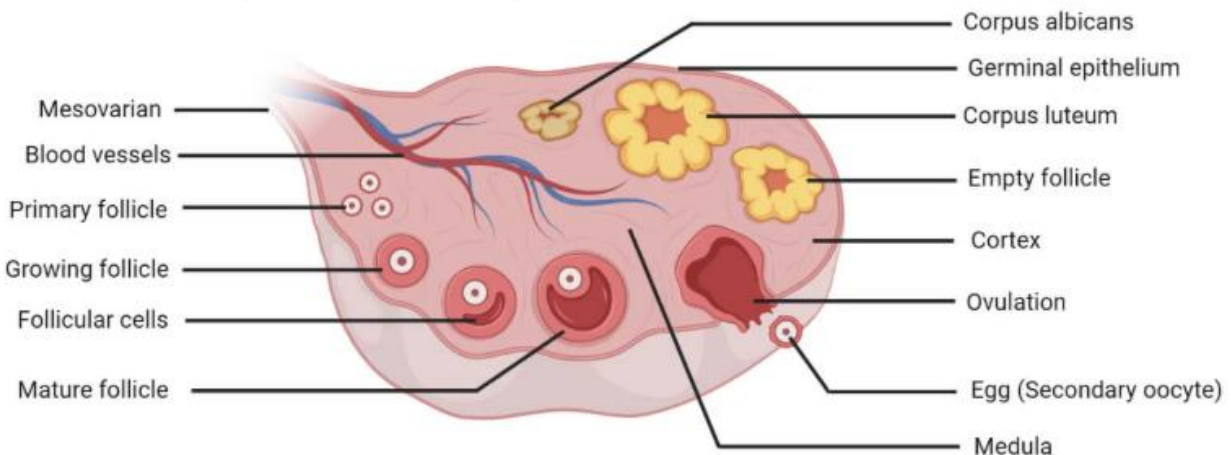
Que.4.a. Draw a well-labelled diagram of testis and ovary in mammals, and discuss the functions of their hormones. (20 marks)

Ans. The reproductive organs in mammals are specialized biological structures designed to ensure the continuation of a species through sexual reproduction. These systems are characterized by **sexual dimorphism**, meaning the male and female of the same species possess distinct anatomical structures and physiological roles. The development

Male Reproductive System: Testis



Female Reproductive System: Ovary



Male reproductive hormones

In male mammals, the reproductive system is governed by a precise hormonal loop known as the **Hypothalamic-Pituitary-Gonadal (HPG) axis**. This system ensures that sperm production and male physical characteristics are maintained at optimal levels.

Testosterone- Primary source is Leydig cells (interstitial cells).

- **Sexual & Reproductive Health:** Develops male sex organs, maintains sex drive (libido), supports erections, and is essential for sperm production (spermatogenesis).

- **Physical Characteristics:** Determines male hair patterns (facial, body), deepens the voice, influences fat distribution, and promotes muscle growth and strength.
- **Bone Health:** Helps maintain strong bones and bone density.
- **Energy & Mood:** Contributes to energy levels, sense of well-being, and can affect mood.
- **Blood Production:** Stimulates the production of red blood cells, leading to higher hematocrit levels in men

Inhibin- Source- Sertoli cells

- **Negative Feedback on FSH:** When sperm production is adequate, inhibin signals the pituitary to reduce FSH, preventing overproduction and slowing down spermatogenesis.
- **Marker of Testicular Function:** Inhibin B levels correlate directly with testicular volume and sperm count, making it a valuable diagnostic tool for male infertility and testicular disorders.
- **Supports Spermatogenesis:** While it inhibits FSH, inhibin's presence indicates healthy Sertoli cell function, which is vital for nurturing sperm development.

Female Reproductive Hormones- Female mammals typically follow an **estrous cycle** (or a menstrual cycle in higher primates) where hormone levels fluctuate significantly to prepare for potential fertilization. Major hormones-

Estrogen (Estradiol)

Reproductive & Sexual Health

- **Menstrual Cycle:** Regulates ovulation and thickens the uterine lining for potential pregnancy.
- **Fertility:** Makes cervical mucus more sperm-friendly during fertile windows.
- **Libido:** Supports sexual arousal and comfort during intercourse.
- **Reproductive Organs:** Develops and maintains the uterus, vagina, and fallopian tubes.

Physical Development & Maintenance

- **Puberty:** Triggers breast growth, body shape changes (curves), and pubic/armpit hair.

- **Bone Health**: Helps maintain bone density, protecting against osteoporosis.
- **Skin**: Promotes skin elasticity, hydration, and collagen production, preventing dryness.
- **Muscles**: Contributes to muscle mass and strength.
- **Progesterone** – source- Corpus luteum; It is also ‘hormone of pregnancy’
- **Menstrual cycle**-After ovulation, it thickens the uterine lining (endometrium) to prepare for a potential fertilized egg. If pregnancy doesn't occur, progesterone levels drop, causing menstruation.
- **Pregnancy Support**: It maintains the uterine lining, nourishes the embryo, and helps form the placenta, reducing miscarriage risk. It also keeps the uterus calm to prevent premature contractions.
- **Fertility Treatments**: Used in IVF to help embryos implant and support early pregnancy

Other Important Roles:

- **Mood & Sleep**: Has a calming effect, helps stabilize mood, and can improve sleep quality.
 - **Estrogen Balance**: Counteracts some effects of estrogen, like preventing excessive uterine lining growth, which is important in menopause.
 - **Metabolism**: Helps regulate insulin levels, potentially impacting weight and blood sugar.
 - **Bone Health**: Stimulates bone-building cells (osteoblasts)
- Relaxin Source**- Produced mainly by the ovaries (corpus luteum) and placenta during pregnancy, and by the endometrium (uterine lining). Relaxin is a crucial hormone in females, primarily known for preparing the body for childbirth by relaxing pelvic ligaments, softening the cervix, and inhibiting early uterine contractions, but it also aids in early pregnancy by promoting embryo implantation, placental growth, and expanding maternal blood volume, while also influencing the menstrual cycle and potentially fighting fibrosis in conditions like endometriosis.

In mammals, reproductive organs and hormones are vital for species survival. The **testes** produce sperm and **testosterone**, which drives male traits and fertility. The **ovaries** produce eggs, **estrogen**, and **progesterone**, which regulate reproductive cycles and maintain pregnancy. Together, these systems facilitate fertilization, support

fetal development (gestation), and ensure the successful birth and nourishment of offspring.

Que. 4.b. Give an illustrated account of skull types in reptiles. (15 marks)

Ans. Reptile represent the first class of vertebrates fully adapted for life in dry place on land. The characters of reptiles are in fact a combination of characters that are found in fish and amphibians on the one hand and in birds and mammals on the other. Reptilian skulls are traditionally classified into five major types based on the presence, number, and position of **temporal fenestrae** (openings) in the post-orbital region of the skull. These openings serve to lighten the skull and provide increased surface area and space for the expansion of powerful jaw muscles.

Types of Skull in reptiles

1. Anapsid Skull

The **Anapsid** condition is considered the most primitive (plesiomorphic) state. The skull has a solid roof of dermal bone behind the eye orbits, with no temporal openings.

- **Characteristics:** Completely roofed temporal region; extremely strong but heavy.
- **Examples:** Primitive "stem" reptiles (e.g., *Captorhinus*, *Seymouria*) and modern **Turtles/Tortoises** (though modern molecular evidence suggests turtles may be "secondary" anapsids that lost their openings).

2. Diapsid Skull

The **Diapsid** skull is characterized by two temporal fenestrae on each side of the skull—one upper (**supratemporal**) and one lower (**infratemporal**).

- **Characteristics:** The two openings are separated by a bony bar formed by the postorbital and squamosal bones. This design allows for a very light skull and highly specialized jaw kinetics.
- **Examples:** Most living reptiles including **Lizards, Snakes, Crocodiles, and Tuatara**, as well as extinct **Dinosaurs** and Pterosaurs.

3. Synapsid Skull

The **Synapsid** skull possesses a single temporal opening located low on the skull, below the junction of the postorbital and squamosal bones.

- **Characteristics:** This "lower" opening is bordered ventrally by the zygomatic arch (jugal and squamosal). This lineage eventually led to the evolution of mammals.

- **Examples:** Extinct "mammal-like" reptiles such as **Pelycosaur**s (e.g., *Dimetrodon*) and **Therapsids**.

4. Euryapsid Skull

The **Euryapsid** skull has a single temporal opening, but unlike the synapsid, it is located **high** on the skull, above the postorbital and squamosal bones.

- **Characteristics:** It is widely believed that euryapsids evolved from diapsid ancestors by the secondary closure or loss of the lower temporal opening.
- **Examples:** Extinct marine reptiles like **Plesiosaurs** and **Placodonts**.

5. Parapsid Skull

The **Parapsid** skull is often considered a variant of the euryapsid condition, featuring a single high opening. However, it is distinguished by the specific bones bordering the fenestra.

- **Characteristics:** In this type, the opening is bordered by the parietal, postfrontal, and supratemporal bones, with the squamosal bone often excluded from the margin.
- **Examples:** Extinct dolphin-like marine reptiles known as **Ichthyosaurs**.

Reptilian skull diversity is crucial for understanding their evolution and ecological success, driven by adaptations for different diets and lifestyles, mainly through temporal fenestrae (openings) that lighten the skull and anchor powerful jaw muscles for diverse feeding, from crushing to grasping large prey, with classifications like anapsid, synapsid, and diapsid forming evolutionary trees and explaining unique features in turtles, crocodiles, snakes, and lizards, also show structural and weight efficiency.

Que.4.c. Explain the types and significance of migration in fishes.

Ans. Migration involves movement of animals on a larger scale and duration for a particular reason. Fish migration is a remarkable biological phenomenon where fish move in large numbers from one habitat to another in a regular, periodic cycle. These journeys can range from a few meters to thousands of kilometers and are driven by fundamental needs such as reproduction, feeding, and survival

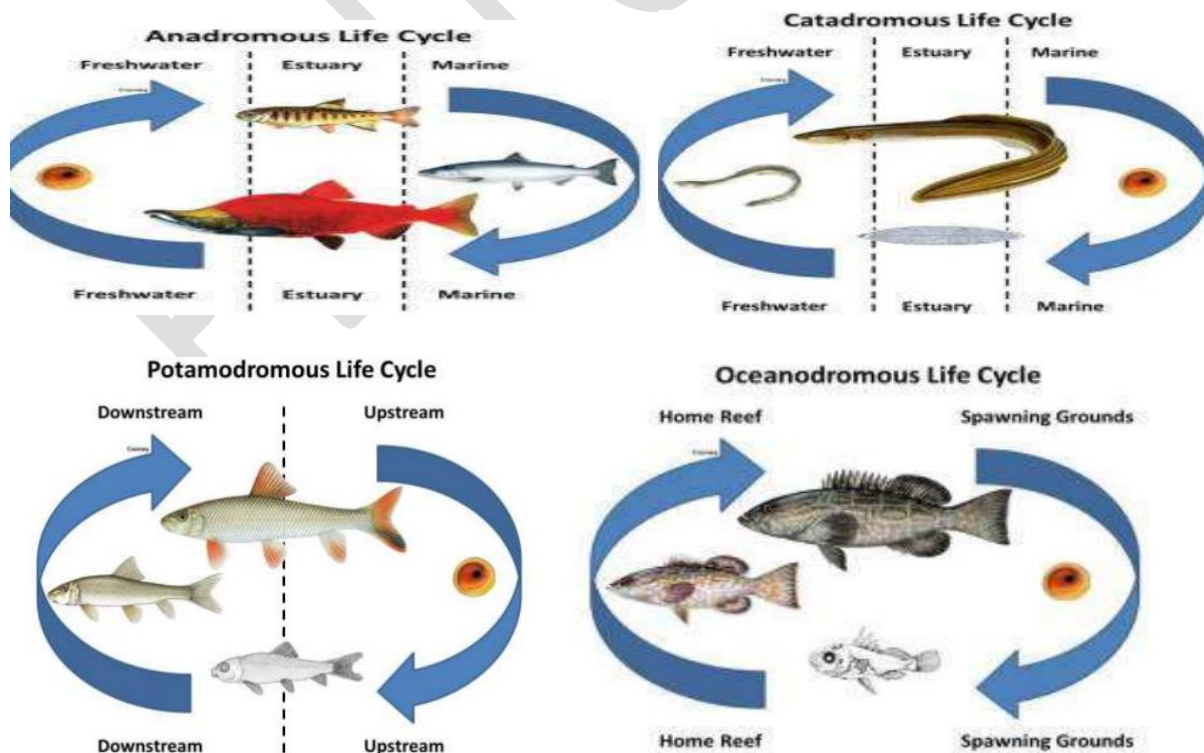
Types of Migration Based on Habitat (Myers' Classification)

In 1949, George S. Myers classified migratory fish into several distinct categories based on the environments they traverse.

1. Diadromous Migration

This is the most well-known type, involving movement between saltwater (sea) and freshwater (rivers/lakes).

- **Anadromous:** Fish live in the sea but migrate to freshwater to spawn. After spawning, the adults often die (e.g., Pacific Salmon) or return to the sea.
 - **Example: Atlantic Salmon, Hilsa, and Sea Lamprey.** Salmon migrate for breeding during winter from sea to river. While migrating, some physiological changes occurs: – stops feeding during journey. – changes colour from silver to dull reddish brown. – gonads mature. They select suitable spawning ground and make a saucerlike nest in which female lays eggs and male releases smelt over them. Juvenile larva hatched out from the egg known as Alevins (a newly hatched salmon when still attached to the yolk sac). Alevins then transform into a juvenile fish called parr and metamorphose into adult when return to the sea
- **Catadromous:** Fish live in freshwater but migrate to the sea to spawn.
 - **Example: Freshwater Eels (Anguilla species).** They travel from rivers to the Sargasso Sea to breed. Both European eel (*Anguilla* or *Anguilla vulgaris*) and the American eel (*Anguilla rostrata*) migrate from the continental rivers to Sargasso Sea off Bermuda in south Atlantic for spawning, crossing Atlantic Ocean. Before and during migration some physiological changes occur in their bodies: Deposit large amount of fat in their bodies which serves as reserve food during the journey
- **Amphidromous:** Fish move between fresh and salt water at some stage of their life cycle, but **not** for the purpose of breeding. It is usually for feeding or refuge.
 - **Example: Hawaiian Gobies and Mountain Mullet.**



2. Potamodromous Migration

These migrations occur entirely within freshwater systems (rivers or lakes). It is fresh water migration of fishes from one habitat to another for feeding or spawning.

Characteristics: Movement is typically from large rivers or lakes into smaller upstream tributaries to find suitable spawning gravel or oxygen-rich water. **Example: Common Carp, Catfish,** and some species of **Trout**.

3. Oceanodromous Migration

It is the migration of fish within sea in search of suitable feeding and spawning ground. Fish are born near spawning grounds, then drift on ocean currents as larvae before settling as juveniles to grow into adults before migrating back to spawning grounds. □

Characteristics: Fish travel vast distances following ocean currents or temperature gradients to reach feeding or spawning grounds. **Example: Tuna, Mackerel, Clupea Cod,** and **Herring**.

4. Latitudinal migration: ▪ it is the migration of fish from north to south and vice-versa. ▪ It is a climatic migration. ▪ Eg. Sward fish migrate north in spring and south in autumn.

5. Vertical migration: ▪ it is a daily migration of fish from deep to the surface and vice-versa for food, protection and spawning. ▪ E.g. Sward fish usually move vertically downward to greater depth for food. **6. Shoreward migration:** ▪ it is the migration of fish from water to land. However, it is a temporary migration. ▪ E.g. Eel migrate from one pond to another pond via moist meadow grass.

Significance Migration is an evolutionary adaptation that offers several critical advantages:

1. **Reproductive Success:** It allows fish to deposit eggs in specialized environments (like oxygen-rich mountain streams) that provide the best chance for larval survival, far from the predators of the adult habitat.
2. **Optimal Feeding:** By moving between habitats, fish can exploit "blooms" of food (like plankton or small forage fish) that occur seasonally in different geographic areas.
3. **Survival from Extremes:** It enables species to avoid lethal environmental conditions, such as freezing temperatures or low-oxygen "dead zones."
4. **Genetic Diversity:** Large-scale migrations often lead to the mixing of different populations, which enhances the genetic health and resilience of the species.
5. **Ecosystem Nutrient Transfer:** Migratory fish act as "biological conveyors." For instance, when salmon die after spawning in rivers, their bodies bring vital marine nutrients (Nitrogen and Phosphorus) to inland forest ecosystems.
6. **Economic significance- Fisheries and Livelihoods:** Many commercially important fish species are migratory (e.g., salmon, tuna, Hilsa, eels). Understanding and managing their migration patterns is vital for sustainable fisheries, providing food security and supporting the livelihoods of millions globally.

Fish migration is vital for **species survival** and **ecological balance**. It ensures reproductive success by reaching optimal spawning grounds and maximizes growth through seasonal feeding. Critically, it facilitates **nutrient cycling**, as fish transport marine minerals to inland ecosystems. This movement maintains genetic diversity, supports commercial fisheries, also important role in recreational phenomenon, and one of the major attraction in tourism and local economy, and allows species to escape lethal environmental extremes like temperature shifts or drought.

SECTION-B

Que.5.a. Biodiversity hot spots

Ans. In 1988, British ecologist Norman Myers published a seminal paper identifying 10 tropical forest "hotspots." Biodiversity hotspots are specific biogeographic regions that are both extremely rich in unique biological life and under immediate threat of destruction. The concept was first introduced by British ecologist **Norman Myers** in 1988. Currently, there are 36 biodiversity hotspots in the world. Most of them occur in tropical forests.

Criteria to qualify as Biodiversity hotspot

- **Endemism:** It must have at least 1,500 vascular plants as endemics (> 0.5% of the world's total) — i.e. it must have a high percentage of plant species found nowhere else on the planet. A hotspot, in other words, is irreplaceable.
- **Threat Level:** It must have lost 70% or more of its original natural vegetation. In other words, it must have only 30% or less of its original natural vegetation.

Biodiversity hotspot in India- Globally, there are **36** recognized biodiversity hotspots. **India** is home to four of them, showcasing its status as a "megadiverse" nation

1. The Himalayas- The Himalayan hotspot is a massive mountain range that contains the world's highest peaks and spans several countries.

- **Location:** Extends across North and Northeast India, covering states like Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, and Arunachal Pradesh.
- **Specific Features:** It acts as a transition zone between the Palearctic (Eurasian) and Indo-Malayan realms. It is the source of major rivers like the Indus, Ganga, and Brahmaputra.
- **Climatic Conditions:** Ranges from **subtropical** in the foothills to **tundra/arctic** at high altitudes. It experiences heavy monsoon rainfall in the east and dry, cold conditions in the west.
- **Flora:** Over 10,000 plant species. Key flora include **Rhododendrons, Deodar cedar, Orchids**, and alpine meadows (Bugyals).
- **Fauna:** Iconic species include the **Snow Leopard, Red Panda, Himalayan Tahr, Musk Deer**, and the **Himalayan Griffon vulture**.

2. Western Ghats (and Sri Lanka)- Also known as the **Sahyadri Mountains**, this hotspot is one of the "hottest hotspots" in the world due to its high level of endemism per unit area.

- **Location:** Runs parallel to the western coast of India through the states of Gujarat, Maharashtra, Goa, Karnataka, Tamil Nadu, and Kerala.
- **Specific Features:** These mountains are older than the Himalayas. They intercept the southwest monsoon, making them a major watershed for peninsular India.
- **Climatic Conditions: Tropical monsoon climate.** High rainfall (2,000–8,000 mm) leads to humid, evergreen conditions.
- **Flora:** Home to unique **Shola forests** (high-altitude stunted forests) and **Myristica swamps**. Prominent plants include *Impatiens* and *Strobilanthes kunthiana* (Neelakurinji).
- **Fauna:** High endemism in amphibians (65%). Notable animals include the **Lion-tailed Macaque**, **Nilgiri Tahr**, **Malabar Large-spotted Civet**, and the **Purple Frog**.

3. Indo-Burma- This is one of the largest hotspots, but only a portion of it lies within India.

- **Location:** In India, it covers the **Northeastern states** (excluding the Assam plains) including Manipur, Mizoram, Nagaland, and Tripura. It extends into Myanmar, Thailand, and Vietnam.
- **Specific Features:** Known for its "limestone karst" landscapes and several of Asia's largest river deltas. It is a region where new large mammals are still being discovered (like the Saola in Vietnam).
- **Climatic Conditions:** Primarily **tropical and subtropical**. It is characterized by heavy seasonal monsoon rains and high humidity.
- **Flora:** Rich in **bamboo**, **gingers**, and **orchids**. It features a mix of wet evergreen and deciduous forests.
- **Fauna:** Home to the **Hoolock Gibbon** (India's only ape), **Clouded Leopard**, **Golden Langur**, and numerous rare hornbill species.

4. Sundaland (Nicobar Islands)- While most of this hotspot covers Southeast Asian islands like Sumatra and Borneo, the **Nicobar Islands** in India are a vital part of it.

- **Location:** The **Nicobar Islands** in the Bay of Bengal (The Andaman Islands are generally considered part of Indo-Burma).
- **Specific Features:** Comprised of unique island ecosystems, including extensive coral reefs and mangroves that act as a bridge between the Indian and Pacific Oceans.
- **Climatic Conditions: Equatorial climate**—hot and wet throughout the year with minimal seasonal temperature variation.
- **Flora:** Features **Giant Mangroves**, tropical evergreen rainforests, and the world-famous **Rafflesia** (found in the wider hotspot).
- **Fauna:** Notable endemic species include the **Nicobar Megapode** (a mound-building bird), the **Crab-eating Macaque**, and the **Giant Robber Crab**.

However, they face severe **challenges**. The primary threat is **habitat fragmentation** due to urbanization and agriculture, as these areas have already lost 70% of their original vegetation. Other critical pressures include invasive species, poaching, and climate-induced shifts that push specialized endemic species toward extinction. There is need to tackle such challenges as Biodiversity hotspots are of immense **significance** as they harbor over 50% of the world's plant species and 43% of terrestrial vertebrates within just 2.4% of Earth's land. These regions act as vital "carbon sinks" for climate regulation, natural pharmacies for medicine, and essential providers of ecosystem services like water purification and pollination for billions of people. Addressing the threats and implementing effective conservation strategies can safeguard these crucial natural treasures.

Que. 5.b. Navigation in birds

Ans. Navigation in birds is one of the most remarkable phenomena in the natural world. It involves a "map and compass" system where birds determine where they are (map) and then which direction to fly (compass) to reach a distant destination. Avian navigation is a biological masterpiece, blending sensory precision with instinctive endurance

Types of Navigation

1. The "Map and Compass" Concept- To navigate successfully, a bird requires two distinct pieces of information:

- **The Compass:** Tells the bird which way is North, South, East, or West.
- **The Map:** Tells the bird its current location relative to its goal (e.g., "I am 500 miles North of my wintering grounds").

2. Types of Navigation Mechanisms

A. Celestial Navigation (The Sun and Stars)

Many birds use the position of heavenly bodies to orient themselves.⁷

- **Sun Compass:** Diurnal (day-flying) birds use the sun's position.⁸ Since the sun moves across the sky, birds have an **internal biological clock** (circadian rhythm) to compensate for the time of day.⁹
 - *Example: European Starlings* can maintain a constant direction by adjusting their angle to the sun as it moves.¹⁰
- **Star Compass:** Nocturnal (night-flying) migrants use constellations.¹¹ They don't just look at one star; they observe the rotation of the night sky around the Celestial Pole (Polaris in the North).¹²
 - *Example: Indigo Buntings* learn the "center of rotation" of the stars to find North.¹³

B. Magnetic Navigation (Magnetoreception)

Birds possess a "sixth sense" that allows them to detect the Earth's magnetic field.¹⁴

- **Inclination Compass:** Unlike a human compass that points to "Magnetic North," birds often sense the **dip** (angle) of magnetic field lines relative to the Earth's surface. This helps them distinguish between "poleward" and "equatorward."
- **Mechanism:** Scientists believe birds have light-sensitive proteins called **cryptochromes** in their eyes that allow them to "see" magnetic fields.¹⁵
 - *Example: European Robins* rely heavily on magnetic cues, especially when the sky is overcast.¹⁶

C. Visual Landmarks (Piloting)

This is the simplest form of navigation, often used for shorter distances or the final stages of a journey.

- **Topographical Features:** Birds follow coastlines, mountain ranges, rivers, and even man-made highways.¹⁷
 - *Example: Hawks and Eagles* often follow mountain ridges to take advantage of updrafts while using the ridge as a visual guide.¹⁸

D. Olfactory Navigation (Smell)

Recent research shows that some birds, particularly seabirds, use an "odor map" to navigate over featureless oceans.

- *Example: Procellariiforms (like Albatrosses and Shearwaters)* can detect chemical gradients in the air to find their way back to specific nesting burrows.

3. Categories of Navigational Ability

Biologists often categorize bird navigation into three levels of complexity:

| Type | Description | Example |
|----------------------------------|--|---|
| Type I: Piloting | Finding the way using familiar landmarks. | Pigeons recognizing local buildings. |
| Type II: Orientation | The ability to fly in a constant compass direction (vector navigation). | Young songbirds on their first migration. |
| Type III: True Navigation | The ability to return to a goal after being displaced to a completely unfamiliar location. | Manx Shearwaters released 3,000 miles from home. |

PROBLEMS OF NAVIGATION –

- Migratory birds use land marks like mountains, hills, rivers, valleys etc. for identification of route.
- Birds navigates through responses to the earth's magnetic field.
- Birds may be guided by position of sun in day and by moon and stars during night.
- Birds learn by experience and guide themselves.
- Migration is the inherent nature of the birds which as a result of hereditary accumulation reaches the offspring.

The ability of birds to navigate is vital for global biodiversity and ecosystem stability. It enables species to exploit seasonal resources, escape harsh climates, and optimize breeding success. Beyond biology, studying these pathways is crucial for conservation; protecting "migratory corridors" ensures the survival of species that bridge distant continents. Furthermore, bird navigation inspires breakthroughs in human technology, particularly in developing autonomous systems and biomimetic sensors that mimic their extraordinary efficiency.

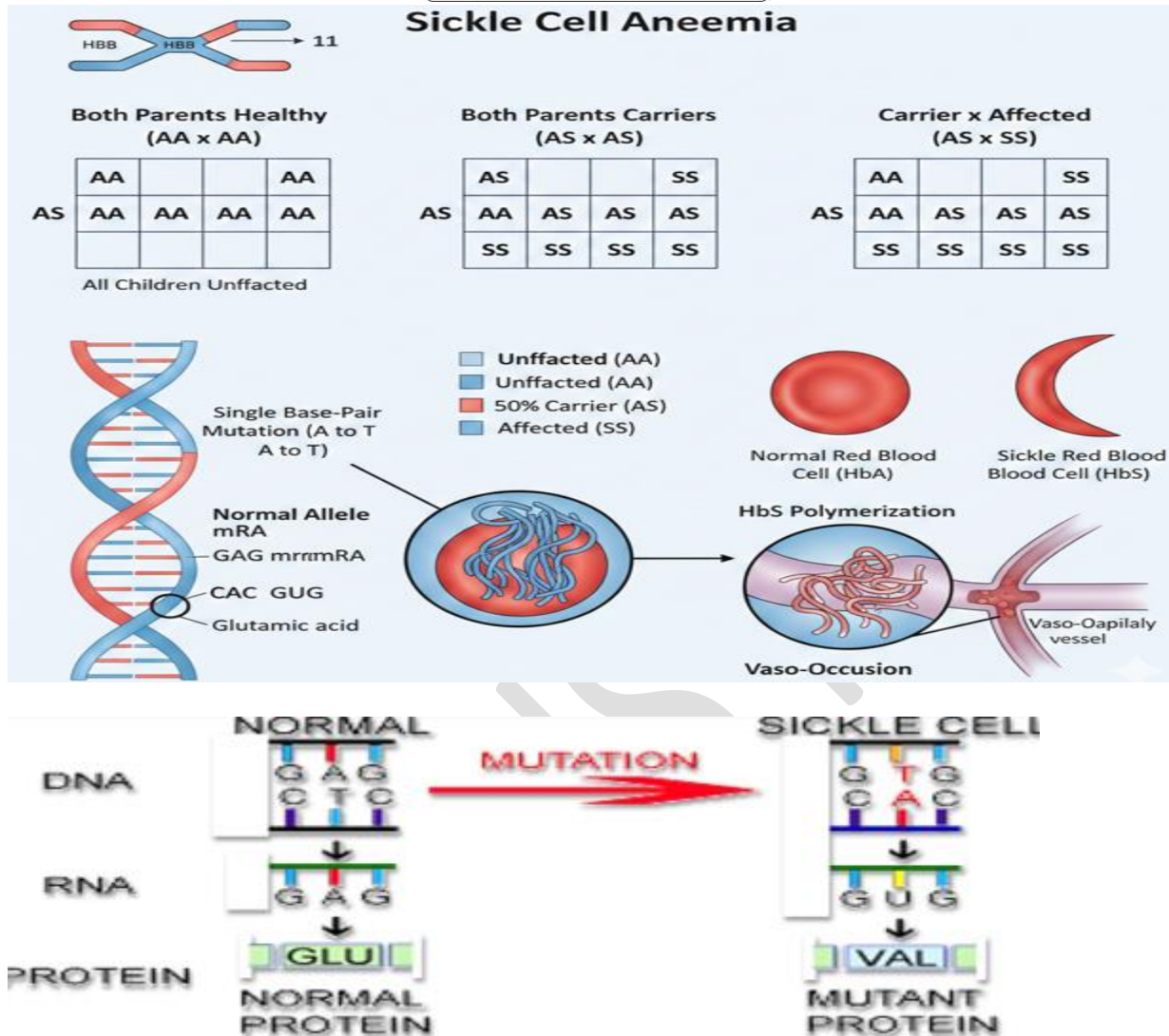
Que.5.c. Sickle cell anaemia

Ans. Sickle cell anaemia is a hereditary blood disorder that affects the structure and function of red blood cells. It is the most common and severe form of **Sickle Cell Disease (SCD)**. Each year about 300 000 infants are born with major haemoglobin disorders – including more than 200 000 cases of sickle-cell anaemia in Africa. India contributes significantly to the global SCD burden, with estimates suggesting over 42,000 newborns annually are affected.

Causing Factor: The Genetic Basis

Sickle cell anaemia is caused by a specific **genetic mutation** in the *HBB* gene, which provides instructions for making the beta-globin protein in hemoglobin (the oxygen-carrying part of the blood).⁷

- **Point Mutation:** A single "letter" change in the DNA (specifically, a substitution of thymine for adenine) causes the amino acid **glutamic acid** to be replaced by **valine** at the sixth position of the beta-globin chain.
- **Mechanism:** When oxygen levels are low, this abnormal hemoglobin (called **Hemoglobin S** or **HbS**) clumps together into long, stiff fibers, distorting the cell into a sickle shape.
- **Inheritance:** It is an **autosomal recessive** condition. This means a child must inherit two copies of the sickle cell gene (one from each parent) to have the disease (HbSS). If they inherit only one copy (HbAS), they have the **Sickle Cell Trait** and are usually healthy carriers.



How does this Impact?

The nature of GLU is polar, charged and hydrophilic in nature while the Valine is Non polar, uncharged and hydrophobic amino acid.

It is Non Conservative and mis-sense type of mutation. It is also example of Transverse and Point mutation

It causes one of the most lethal effect in the protein structure and now it try to get away from the aqueous environment which leads to reduction in surface area and protein becomes fold. This ultimately reduces the Oxygen binding capacity of Haemoglobin

Symptoms and Signs

Symptoms typically appear around **5 to 6 months of age** and vary significantly between individuals.

- **Anaemia:** Fatigue, pale skin, and shortness of breath due to the lack of oxygen-carrying cells.

- **Pain Crises (Vaso-occlusive Crises):** Sudden, sharp, or throbbing pain in the chest, abdomen, joints, or bones caused by blocked blood flow.
- **Dactylitis:** Painful swelling of the hands and feet, often one of the first signs in infants.
- **Frequent Infections:** Sickle cells can damage the **spleen**, which is vital for fighting bacteria, making patients more vulnerable to pneumonia and meningitis.
- **Delayed Growth:** Shortage of healthy red blood cells can slow growth in children and delay puberty.
- **Jaundice:** Yellowing of the eyes and skin due to the rapid breakdown of red blood cells and the buildup of bilirubin.

Managing sickle cell anaemia requires a dual focus on medical innovation and public health policy. **Treatment** has evolved from basic pain management to life-altering therapies like **hydroxyurea**, chronic blood transfusions, and curative **bone marrow transplants** or **CRISPR gene editing**. Governments worldwide are taking critical **steps** by implementing universal **newborn screening**, funding specialized clinics, and launching awareness campaigns to reduce the disease burden. These combined efforts are essential for improving the quality of life and longevity of affected individuals.

Que.5.d. **Circadian rhythms**

Ans. The term "circadian" comes from the Latin *circa*, "around", and *diem* or *dies*, "day", meaning literally "approximately one day". The nature of the rhythms is thus endogenous and innate and driven by an endogenous clock. Such self-sustained oscillations with a period of about one day are called "circadian rhythms". One of the most dramatic features of the world in which we live is the cycle of day and night. Circadian rhythms are natural, internal processes that regulate the sleep-wake cycle and repeat roughly every **24 hours**. Often called the "body clock,"

The Master Clock: How It Works

The primary control center for circadian rhythms in mammals is a tiny region in the brain called the **Suprachiasmatic Nucleus (SCN)**, located in the hypothalamus.

- **Input (Light):** The SCN receives direct information about light levels from the eyes via the optic nerve.
- **The Response:**
 - * **In Light:** The SCN signals the brain to suppress **melatonin** (the sleep hormone) and increase **cortisol** to promote alertness.
 - **In Dark:** The SCN signals the pineal gland to release melatonin, lowering body temperature and blood pressure to prepare for sleep.
- **Molecular Level:** Every cell has its own "molecular clock" driven by specific **clock genes** (like *PER*, *CRY*, and *CLOCK*). These genes create a 24-hour loop of protein production and degradation

Mechanism of Circadian Rhythm:-Three components are believed to be operative for circadian rhythm.

(a) An Oscillator: As circadian rhythm is also observed in acellular organisms, it is probably that the oscillator of biological clock resides in the cell. Three theories have been put forward for the precise identification of the clock in the cell:

- **The plasma membrane:** As the permeability of plasma membrane changes periodically at different times in 24 hours, Giese (1989) is of the opinion that the physiology is changed in circadian way.
- **The nucleus:** As rhythm is absent in prokaryotes, it is supposed that the clock might be in the nucleus and acts by changing levels of macromolecular synthesis.
- **Geophysical variables:** Some geophysical variables are believed to be responsible for the changed function of a cell membrane or nucleus or both.

(b) A Receptor: Certain receptors are responsible for the input to the oscillator. These may be in the form of photo-receptors present either in the eyes or pineal gland or in the brain itself.

(c) A Coupling Device: It is believed that the device that couples the receptor to the oscillator is chemical in nature. Experiments conducted by Truman and Riddiford (1990) with two species of silkworm has revealed that the eclosion (emergence) of moths is controlled by a hormone (chemical) in the brain which can be used to induce eclosion in another species of silkworm. Thus, the coupling device is not species specific

Circadian rhythm is a fundamental homeostatic system influencing behavior and physiology of animals. After birth there is progressive maturation of the circadian system with day-night rhythms. Suprachiasmatic nucleus is responsible for the control of circadian rhythms in peripheral tissues, acting through neural and humoral signals like melatonin. Biological rhythms are controlled endogenously by self-contained circadian clocks.

Que.5.e. **Biome**

Ans. **Frederic E. Clements** first used the term "biome" (1916). A **biome** is a large geographical region characterized by a specific climate, soil type, and a distinct community of plants (**flora**) and animals (**fauna**) that have adapted to that environment. Biomes are essentially the world's major habitats, defined primarily by abiotic factors like temperature and precipitation

Types of Biomes- **R.H. Whittaker (1970s):** Developed a widely used scheme plotting mean annual temperature and precipitation to map major world biomes.

Tropical Rainforest⁴

- **Location:** Equatorial regions (Amazon Basin, Congo Basin, Southeast Asia).
- **Climate:** Hot and humid year-round (20C to 34C); high rainfall (200–600 cm annually).
- **Speciality:** Highest biodiversity on Earth; "Nature's Pharmacy" due to medicinal plants.
- **Flora:** Tall evergreen trees with buttress roots, lianas (vines), orchids, and ferns.

- **Fauna:** Monkeys, jaguars, toucans, sloths, and a vast array of insects and colorful frogs.

B. Savanna (Tropical Grassland)

- **Location:** Africa, South America, and northern Australia.
- **Climate:** Warm year-round (24°C to 29°C); distinct wet and dry seasons.
- **Speciality:** Frequent fires are common, maintaining the grassland and preventing thick forests.¹³
- **Flora:** Tall grasses, scattered umbrella-shaped Acacia trees, and Baobabs.
- **Fauna:** Large grazing herds (zebras, wildebeests, giraffes) and predators (lions, cheetahs, hyenas).

C. Desert

- **Location:** Subtropical belts (Sahara, Arabian) and rain shadows (Gobi, Atacama).
- **Climate:** Extreme temperature fluctuations (scorching days, freezing nights); very low rainfall (<25cm).
- **Speciality:** Animals and plants have extreme water-conservation adaptations.
- **Flora:** Cacti, succulents, and creosote bushes with waxy coatings to reduce water loss.
- **Fauna:** Camels, fennec foxes, scorpions, and Gila monsters.

D. Temperate Deciduous Forest

- **Location:** Eastern North America, Western Europe, and Eastern Asia.
- **Climate:** Four distinct seasons; moderate rain and snow (75–150 cm).
- **Speciality:** Trees undergo "dormancy" by shedding leaves in autumn to survive winter.
- **Flora:** Broadleaf trees like Oak, Maple, Beech, and Hickory.
- **Fauna:** White-tailed deer, black bears, squirrels, and migratory songbirds.

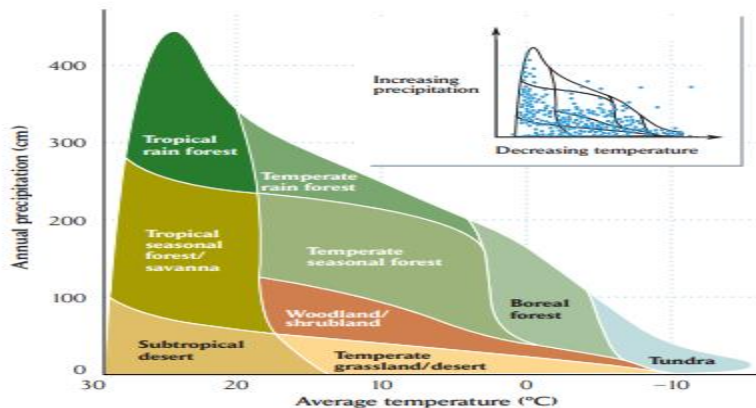
E. Taiga (Boreal Forest)

- **Location:** Subarctic regions of North America (Canada/Alaska) and Eurasia (Russia/Scandinavia).
- **Climate:** Short, moist summers and long, very cold, snowy winters.
- **Speciality:** The largest terrestrial biome; dominated by "conifers" (cone-bearing trees).
- **Flora:** Needle-leaf evergreen trees like Spruce, Pine, and Fir.
- **Fauna:** Moose, wolves, lynx, siberian tigers, and grizzly bears.

F. Tundra

- **Location:** Arctic Circle and high mountain tops (Alpine Tundra).
- **Climate:** Extremely cold and windy; very low precipitation; presence of **permafrost** (frozen soil).²¹

- **Speciality:** Known as a "treeless plain" because roots cannot penetrate the frozen ground.²²
- **Flora:** Lichens, mosses, dwarf shrubs, and grasses.
- **Fauna:** Arctic foxes, polar bears, caribou, snowy owls, and lemmings.



Biomes serve as the planet's vital life-support systems, maintaining global equilibrium through essential ecosystem services. They act as massive carbon sinks that regulate the climate, provide diverse habitats that safeguard Earth's genetic library, and drive the water and nutrient cycles necessary for all life. Beyond biological stability, biomes supply the fundamental resources—food, freshwater, and raw materials—that sustain human civilization and economic development across the globe.

Que.6.a. **Define air pollution. Explain the types, sources, consequences and control measures of air pollution.**

Of the world's **30 cities with the worst air pollution**, 17 are in India. The capital, New Delhi, has the poorest air quality among capital cities globally, with concentrations of particulate matter (PM_{2.5}) nearly 10 times higher than the **World Health Organization** guidelines. Air pollution is the contamination of the atmosphere by harmful chemical, physical, or biological agents that alter the natural characteristics of the air.

Types of Air Pollutants

Air pollutants are generally classified into two main categories based on how they enter the atmosphere:

- **Primary Pollutants:** These are the substances emitted directly from an identifiable source into the atmosphere in a harmful form. These pollutants retain the same chemical form they had at the point of emission. *Examples:* Carbon Monoxide (CO), Sulfur Dioxide (SO₂), Nitrogen Oxides (NO_x), and Particulate Matter (PM).
- **Secondary Pollutants:** are not emitted directly. Instead, they form when primary pollutants undergo chemical reactions with each other or with natural atmospheric components like water vapor and sunlight. A classic example is **Ground-level Ozone**

(O₃), which forms when nitrogen oxides react with volatile organic compounds in the presence of heat and sunlight. *Examples:* Ground-level **Ozone** (O₃) and **Smog** (a mixture of smoke and fog).

Sources of Air Pollution

The sources can be broadly divided into human-made (anthropogenic) and natural categories:

A. Anthropogenic Sources (Human-made)

- **Burning of Fossil Fuels:** Power plants and industries burn coal and oil, releasing large amounts of SO and CO₂
- **Vehicular Emissions:** Cars, trucks, and buses release ¹⁸SO₂, ¹⁹NO_x, and fine particulate matter due to fuel combustion.²⁰
- **Agricultural Activities:** Ammonia is a common byproduct of fertilizers and livestock waste. Insecticides and pesticides also release hazardous chemicals.
- **Mining and Construction:** These activities release massive amounts of dust (PM10) and chemicals into the air.

B. Natural Sources

- **Volcanic Eruptions:** Release ash, smoke, and sulfurous gases.
- **Forest Fires:** Generate vast quantities of smoke and carbonaceous particles.
- **Dust Storms:** Carry fine particles across thousands of miles.

Consequences of Air Pollution

The impact of air pollution is felt across human health, ecosystems, and the global climate.

- **Human Health:** Causes respiratory diseases (asthma, COPD, lung cancer), cardiovascular issues (heart attacks, strokes), and even cognitive decline.
- **Acid Rain:** SO₂ NO_x mix with water droplets to form acidic rain, which damages crops, kills aquatic life, and corrodes buildings/monuments.
- **Ozone Layer Depletion:** Chemicals like Chlorofluorocarbons (CFCs) destroy the stratospheric ozone layer, allowing harmful UV rays to reach Earth.
- **Global Warming:** Greenhouse gases (like CO₂ and methane) trap heat, leading to rising temperatures, melting glaciers, and rising sea levels.

Control Measures

Efforts to reduce air pollution require action at individual, industrial, and governmental levels:

- **Technological Interventions:**

- **Electrostatic Precipitators (ESPs):** Used in industries to remove dust/ash from smoke.
- **Catalytic Converters:** Installed in vehicles to convert toxic gases into less harmful ones.
- **Scrubbers:** Use liquid sprays to "wash" sulfur and other gases out of industrial exhaust.
- **Policy and Regulation:** Governments set emission standards (like Bharat Stage or Euro norms) and establish "Green Belts" around industrial zones.
- **Renewable Energy:** Shifting from coal to solar, wind, and hydroelectric power reduces the primary source of carbon emissions.
- **Individual Actions:** Using public transport, carpooling, practicing **Afforestation** (planting trees), and avoiding the open burning of waste.

Curing air pollution is vital to prevent millions of premature deaths, respiratory diseases, and environmental degradation that currently costs India over **1.3% of its GDP**. To combat this, the government has intensified the **National Clean Air Programme (NCAP)**, aiming for a **40% reduction** in particulate matter by 2026. Key steps include enforcing **BS-VI emission standards**, promoting electric vehicles, and implementing the **Graded Response Action Plan (GRAP)** to manage emergency pollution spikes.

Que.6.b. Define pheromones. Discuss the role of pheromones in alarm spreading in animals with suitable examples.

Ans. The first pheromone discovered was "Bombykol" (10,12-hexadecadien-1-ol), the silk moths sex pheromone, by Adolf Butenandt (1959). The term "Pheromone" (Gr. Pheroin = to transport and hormone = to stimulate) was introduced by Peter Karlson and Martin Luscher. **Pheromones** are chemical signaling molecules secreted by an organism into the external environment to elicit a specific physiological or behavioral response in other members of the same species. Unlike hormones, which act internally, pheromones are "ectohormones" that facilitate communication across distances.

Classification of pheromones on the basis of the nature of the action.

- i) Releaser pheromones: the pheromones that elicit the "releaser" reaction fall under this category. A releaser response is an immediate and reversible response operated directly through the central nervous system, e.g. recognition, or through rapidly acting neurohumoral channels, as exemplified by the milk-ejection reflex.
- ii) Primer pheromones: The exteroceptive response implicating the anterior pituitary gland. This type is slow to develop, demanding prolonged stimulation which initiates a chain of physiological effects in the recipient.
- iii) Pheromones of imprinting: Stimulation at a critical period during development may result in a permanent modification of behavior in the adult.

Role of pheromones in alarm spreading in animals

Alarm pheromones serve to rapidly disperse a group of insects usually as a response to predation. These kinds of pheromones are usually of short duration and the dispersed individuals usually reform aggregations

How they work The "alarm" is rarely a single static message; instead, it is often a **graded response**

Chemical Messengers: Pheromones are released chemicals that trigger specific reactions in other members of the same species (conspecifics).

Rapid Dispersal: They are often volatile, spreading quickly through air or water, allowing for fast communication of danger.

Coordinated Response: A few individuals releasing pheromones can start a chain reaction, synchronizing the group's reaction

1. Aggressive Recruitment (Social Insects)

In species like bees and wasps, the alarm pheromone is a call to arms.³

- **The Honeybee Example:** When a bee stings, it releases **isopentyl acetate**.⁴ This chemical serves as a beacon. Instead of fleeing, nestmates become highly agitated and fly toward the highest concentration of the scent. This leads to a "mass stinging" event that can drive away much larger predators, including mammals.⁵

2. Coordinated Escape (Aquatic Environments)

In the underwater world, visual cues can be blocked by silt or darkness, making chemical signals paramount.

- **The Fish "Schreckstoff" Effect:** Many fish (like minnows) have "club cells" in their skin that contain an alarm substance. This substance is only released when the skin is broken (indicating a predator strike).
- **The Response:** Nearby fish don't just swim away randomly; they engage in **area avoidance** or form a **tight shoal**, making it harder for the predator to pick a single target.

3. Dispersal and "Drop-off" (Hemiptera)

For stationary insects like aphids, the goal isn't to fight, but to vanish.

- **The Aphid Example:** When an aphid is pierced by a ladybug's mandibles, it secretes **(E)-beta-farnesene** from its cornicles.
- **The Response:** Neighboring aphids, which are usually immobile while feeding on plant sap, will immediately withdraw their stylets and drop off the leaf to the ground. This "falling rain" of aphids is a classic example of pheromone-induced dispersal.

Pheromones are crucial for alarm spreading in animals, acting as rapid chemical messengers that signal danger, enhancing survival by triggering immediate group responses like flight (aphids), aggression (ants, bees), or seeking shelter (fish). They create a chain reaction, synchronizing defense, dispersing individuals from threats, and

enabling coordinated attacks, significantly boosting collective survival chances through fast, efficient intraspecific communication.

Que.6.c. What is DNA fingerprinting? Explain the mechanism and applications of DNA fingerprinting in forensic science.

Ans. **DNA Fingerprinting** (also known as DNA profiling or genetic fingerprinting) is a method or chemical test that used to identify individuals based on their unique DNA characteristics by showing the genetic makeup of a person or other living things. Developed by **Sir Alec Jeffreys** in 1984, it relies on the fact that while 99.9% of DNA is identical among humans, the remaining 0.1% contains unique variations called **polymorphisms**.

Principle- The **principle of DNA fingerprinting** is based on the fact that while 99.9% of the DNA sequence is identical among all humans, the remaining **0.1%** contains specific regions that are highly variable and unique to every individual (except identical twins). This 0.1% variation is primarily found in the non-coding regions of DNA (often called "junk DNA"), and it forms the scientific foundation for genetic identification.

1. DNA Polymorphism

The core principle is **DNA polymorphism**. Polymorphism refers to variations at the genetic level that arise due to mutations. While mutations in coding genes might affect a person's health or appearance, mutations in non-coding DNA simply accumulate over generations without affecting survival. These variations in DNA sequences across the population allow scientists to distinguish one person from another.

2. Satellite DNA and Repetitive Sequences

When human DNA is separated using a technique called **density gradient centrifugation**, it splits into two groups:

Bulk DNA: Forms the major peak (the 99.9% identical part).

Satellite DNA: Forms smaller, separate peaks. This consists of highly repetitive sequences where a small stretch of DNA is repeated many times in a row.

3. VNTRs (Variable Number Tandem Repeats)

Tandem Repeats: These are short sequences of nucleotides (e.g., GATA-GATA-GATA) that repeat one after another.

Variability: The **number of repeats** varies significantly between individuals. For example, at a specific location on a chromosome, Person A might have 10 repeats, while Person B has 25.

Inheritance: These repeats are inherited from parents. A child will have a combination of repeat numbers—half from the mother and half from the father—making the overall pattern unique.

4. The "Barcode" Effect

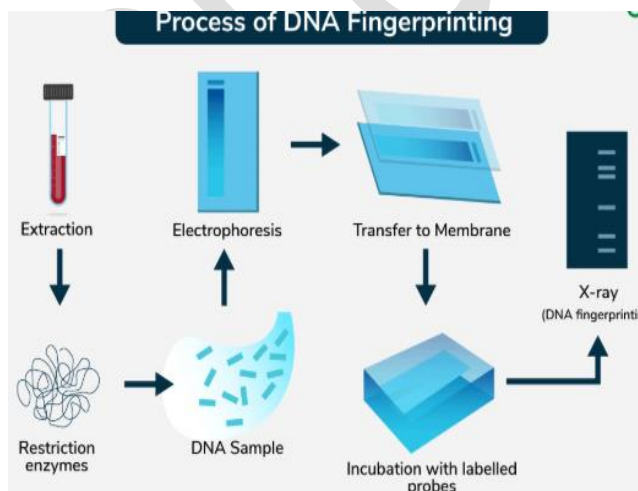
Because these VNTRs are spread across many different chromosomes, the probability of two unrelated people having the exact same number of repeats at every single location is virtually zero (roughly **1 in 30 billion**). When these fragments are separated

by size on a gel, they create a unique pattern of bands—much like a digital barcode—which serves as the individual's "DNA Fingerprint."

Mechanism of DNA Fingerprinting (Step-by-Step)

The process involves several precise laboratory steps to convert a biological sample into a visible "barcode" of DNA bands.

1. **Sample Collection:** Biological evidence (blood, saliva, hair follicles, skin cells, or semen) is collected from the crime scene and the suspects.
2. **DNA Extraction:** DNA is isolated from the cell nucleus using chemicals and centrifugation to break open cell membranes and remove proteins/fats.
3. **DNA Amplification (PCR):** If the collected sample is too small, the **Polymerase Chain Reaction (PCR)** is used to create millions of copies of the specific DNA sections being studied.
4. **Restriction Digestion:** The DNA is treated with **Restriction Endonucleases** (molecular scissors) that cut the DNA at specific sequences, resulting in fragments of various lengths.
5. **Gel Electrophoresis:** The DNA fragments are placed on an agarose gel and subjected to an electric field. Since DNA is negatively charged, it moves toward the positive electrode.
 - *Smaller fragments move faster and further; larger ones stay closer to the start.*
6. **Southern Blotting:** The separated DNA fragments are transferred (blotted) from the fragile gel onto a sturdy nylon or nitrocellulose membrane.
7. **Hybridization:** Radioactive or fluorescent **DNA Probes** (short sequences complementary to the VNTRs) are added to the membrane. They bind only to the specific matching sequences on the membrane.
8. **Autoradiography:** An X-ray film is exposed to the nylon membrane. The radioactive probes create dark bands on the film, producing the final "DNA Fingerprint" or banding pattern.



Applications in Forensic Science

DNA fingerprinting has revolutionized criminal investigations by providing near-absolute certainty in identification.

- **Criminal Identification:** By comparing the DNA profile from a crime scene (e.g., a drop of blood) with a suspect's DNA, investigators can definitively link or exclude a person from a crime.
- **Exonerating the Innocent:** It is used to re-examine old evidence, which has led to the release of many individuals who were wrongfully convicted before DNA technology existed.
- **Paternity and Kinship Testing:** Since children inherit half of their VNTRs from each parent, DNA fingerprinting is the gold standard for solving parental disputes and identifying family lineages.
- **Identification of Remains:** In cases of natural disasters, war, or severe accidents where bodies are unrecognizable, DNA from teeth or bones is compared with samples from surviving relatives to identify the deceased.
- **Wildlife Forensics:** It helps track poaching activities by identifying the origin of animal parts (like ivory or skins) and monitoring illegal trade in endangered species.

DNA fingerprinting is a powerful tool for identifying individuals based on unique DNA sequences. It is widely used in criminal investigations, paternity testing, and other forensic applications to match DNA samples from known and unknown individuals. The technique is also valuable in zoological, botanical, and agricultural studies. It is a crucial method for solving crimes and determining biological relationships. Its applications extend to personal identification, diagnosing hereditary disorders, and even breeding programs, showcasing its versatility and importance in various scientific fields.

Que.7.a. **What is Student's t-test and its significance in biological research? Write the formula of t-test and its various steps using simple data.**

Student's t-test is a fundamental statistical tool used to determine if there is a significant difference between the means (averages) of two groups. Developed by **William Sealy Gosset** (who published under the pseudonym "Student"), it is especially valuable when sample sizes are small (typically $n < 30$) and the population standard deviation is unknown.

Significance in Biological Research

In biology, variation is natural (e.g., no two plants grow at the exact same rate). The t-test helps scientists distinguish between **true biological effects** and **random chance**.

- **Comparing Treatments:** Determining if a new drug significantly lowers blood pressure compared to a placebo.
- **Ecological Variations:** Testing if the average leaf size of a plant species differs between a sunny and a shaded habitat.

- **Genetic Studies:** Comparing gene expression levels between healthy and diseased tissues.
- **Agricultural Research:** Assessing if a specific fertilizer leads to a higher crop yield than the standard one.
- **Validation of experimental treatment-**
 - **Drug Efficacy:** In medicine, an **Independent t-test** is used to compare a "treatment group" (receiving a new drug) against a "control group" (receiving a placebo). If the t-statistic is high enough, researchers can confidently say the drug works.
 - **Agricultural Trials:** Comparing the yield of crops using a new organic fertilizer versus a standard chemical one.

The Formula for t-test

The most common version, the **Independent Two-Sample t-test**, is calculated using the formula:

| | |
|--|--|
| <p>One-Sample T-Test</p> $t = \frac{\bar{x} - \mu}{\frac{s}{\sqrt{n}}}$ <p> \bar{x} = observed mean of the sample μ = assumed mean s = standard deviation n = sample size </p> | <p>Two-Sample T-Test</p> $t = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$ <p> \bar{x}_1 = observed mean of 1st sample \bar{x}_2 = observed mean of 2nd sample s_1 = standard deviation of 1st sample s_2 = standard deviation of 2nd sample n_1 = sample size of 1st sample n_2 = sample size of 2nd sample </p> |
|--|--|

Steps to Perform a t-test (Using Simple Data)

Steps to Calculate T Value One Sample T-Test

To perform the One Sample T-test, the steps listed below are generally followed:

Step 1: State a null hypothesis and an alternative hypothesis. The null hypothesis assumes that the sample mean and the known population mean (μ) are equal, while the other assumes that the sample mean is different from the population mean.

Step 2: Define values for the level of significance (α) and the degree of freedom (df). The degree of freedom equals ($n - 1$) for this case.

Step 3: Calculate the t-value using the formula stated above by putting all the known values of the sample mean (\bar{x}), sample standard deviation (σ), the population mean (μ), and the sample size (n).

Step 4: Determine the associated p-value with the t-value using a t-distribution table.

Step 5: Compare the p-value to the level of significance. If the p-value is less than the level of significance, reject the null hypothesis and conclude that the sample mean is significantly different from the population mean. Otherwise, conclude that there is no significant difference between the sample mean and the population mean.

T Test for Independent Samples

The steps listed below are generally followed to perform this test:

Step 1: State a null hypothesis and an alternate hypothesis. The null hypothesis assumes that the means of the two groups are equal ($\bar{x}_1 = \bar{x}_2$), while the other assumes that the means of the two groups are significantly different ($\bar{x}_1 \neq \bar{x}_2$).

Step 2: Define the values for the level of significance (α) and the degrees of freedom (df). The degree of freedom equals ($n_1 + n_2 - 2$) in this case.

Step 3: Calculate the t-value from the formula defined above after obtaining the required data related to each group.

Step 4: Find the critical t-value from a t-distribution table with the corresponding degrees of freedom and level of significance.

Step 5: If the calculated t-value is greater than the critical t-value, then reject the null hypothesis. This indicates that there is a significant difference between the means of the two groups. Otherwise, the null hypothesis is not rejected. And, this suggests that there is no significant difference between the means of the two groups.

Student's t-test is an essential statistical bridge that validates experimental claims by distinguishing biological signals from random noise. Whether assessing drug efficacy in medicine, crop yields in agriculture, or quality standards in industry, it ensures that observed differences are statistically significant. By providing a rigorous basis for decision-making, it remains a cornerstone of reliable scientific inquiry.

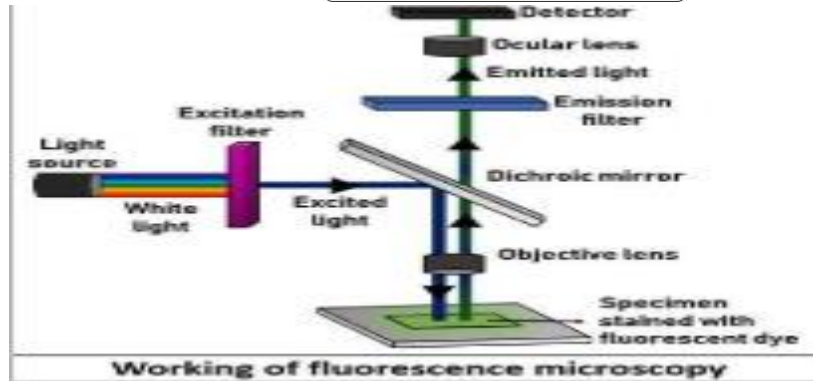
Que.7.b. Explain the principle, instrumentation and applications of fluorescence microscope.

Ans. A Fluorescence Microscope is a specialized optical microscope that uses fluorescence and phosphorescence instead of, or in addition to, reflection and absorption to study properties of organic or inorganic substances. It allows for the visualization of specific cellular components with high sensitivity and contrast.

Principle of Fluorescence Microscopy

The fundamental principle is based on the **fluorescence phenomenon**, where certain molecules (fluorophores) absorb light of a specific wavelength and subsequently emit light of a longer wavelength.

1. **Excitation:** A specimen labeled with a **fluorophore** is illuminated with high-intensity "excitation light" of a shorter wavelength (higher energy), typically UV or blue light.
2. **Energy Absorption:** The electrons in the fluorophore absorb photons and jump to a higher energy state (excited state).
3. **Stokes Shift:** During the brief period in the excited state, some energy is lost as heat. When the electrons return to their ground state, they emit the remaining energy as "emission light" of a **longer wavelength** (lower energy). This shift in wavelength is known as the **Stokes Shift**.
4. **Signal Separation:** The microscope uses specialized filters to separate the relatively weak emitted fluorescence from the much brighter excitation light, so that only the fluorescing structures are visible against a dark background.



Instrumentation

Most modern fluorescence microscopes use the **Epi-fluorescence** design, where the excitation and emission light travel through the same objective lens.

- **Light Source:** Provides intense, multispectral light. Common sources include **Mercury or Xenon arc lamps, LEDs, or Lasers** (for confocal microscopy).
- **Excitation Filter:** Placed in the light path before the specimen. It selectively allows only the specific wavelength required to excite the fluorophore to pass through.
- **Dichroic Mirror (Beamsplitter):** A specialized mirror tilted at **45°**. It reflects shorter excitation wavelengths toward the specimen while allowing longer emission wavelengths to pass through toward the detector.
- **Objective Lens:** Acts as both a condenser (focusing excitation light onto the sample) and a light gatherer (collecting the emitted fluorescence).
- **Emission Filter (Barrier Filter):** Positioned before the eyepiece or camera. It blocks any residual reflected excitation light and allows only the specific emitted fluorescence to reach the eye/detector.
- **Detector:** Typically a **CCD/CMOS camera** or a **Photomultiplier Tube (PMT)** that captures the fluorescent signal to create a digital image.

Applications

Fluorescence microscopy is a cornerstone of modern cell biology and medical diagnostics.

- **Immunofluorescence:** Using fluorescently labeled antibodies to detect and localize specific proteins or antigens within cells (e.g., diagnosing rabies or syphilis).
- **Live Cell Imaging:** Tracking the movement and interactions of proteins in real-time using genetic tags like **Green Fluorescent Protein (GFP)**.
- **Diagnostic Microbiology:** Identifying specific pathogens (like *Mycobacterium tuberculosis*) in clinical samples using specialized fluorescent stains.
- **Genetics (FISH): Fluorescence In Situ Hybridization** is used to visualize specific DNA sequences or genes on chromosomes to detect genetic disorders.
- **Cell Viability:** Using "live/dead" stains to determine the health and ratio of living vs. dead cells in a population.

Fluorescence microscopy is indispensable for visualizing the "invisible" dynamics of animal life and various uses. However, major challenges include **photobleaching**, where fluorophores lose their glow, and **phototoxicity**, where intense excitation light damages live tissues. It enables researchers to map **neural circuits** in organisms like *C. elegans*, track **embryonic development** in *Xenopus*, and study gene expression using **GFP tags** in *Drosophila*. Furthermore, it is critical for diagnosing animal diseases—such as rabies—by detecting viral antigens with high specificity and sensitivity.

Que. 7.c. Describe the different species suitable for prawn culture with emphasis on the methods of prawn cultivation.

Ans. Prawn culture, or prawn farming, is a major branch of aquaculture. While the terms "prawn" and "shrimp" are often used interchangeably, in commercial aquaculture, "prawn" usually refers to freshwater species, while "shrimp" refers to marine species, focused on breeding, raising, and harvesting prawns and shrimp in controlled environments like ponds or tanks for commercial purposes, offering a vital protein source and significant export income, with methods ranging from extensive (low-tech, natural) to intensive (high-tech, controlled feeding/water) systems for both freshwater and marine species.

1. Species Suitable for Culture

Selecting the right species depends on salinity, climate, and market demand.

Freshwater Species

- **Macrobrachium rosenbergii (Giant River Prawn):** The most popular freshwater species globally. It is known for its large size, high growth rate, and ability to thrive in turbid waters.
- **Macrobrachium malcolmsonii (Monsoon River Prawn):** Primarily cultured in South Asia, it is the second-largest freshwater species.

Marine and Brackish Water Species

- **Penaeus monodon (Giant Tiger Prawn):** Recognized by its tiger-like stripes. It grows very large and has high market value but is susceptible to viral diseases.
- **Litopenaeus vannamei (Whiteleg Shrimp):** The most widely cultured species globally due to its high stocking density tolerance and resistance to many diseases.
- **Penaeus indicus (Indian White Prawn):** Well-suited for traditional farming in Indian coastal regions.

Methods of Prawn Cultivation

Prawn cultivation involves several stages, from hatchery to harvest. The methods are categorized based on intensity.

A. Traditional (Extensive) Culture

- **Location:** Low-lying coastal areas or "pokkali" fields.
- **Method:** Natural tides bring in prawn seeds. There is no supplemental feeding or aeration.
- **Yield:** Low, as it relies entirely on the natural productivity of the ecosystem.

B. Semi-Intensive Culture

- **Pond Preparation:** Ponds are drained, limed (to manage pH), and fertilized to promote the growth of natural food (plankton).
- **Stocking:** Hatchery-reared seeds (Post-Larvae or PL) are stocked at moderate densities (10–20 per m²).
- **Management:** Regular water exchange and supplemental high-protein pellet feed are provided. Aerators are used to maintain dissolved oxygen.

C. Intensive Culture

- **System:** Small, often concrete or plastic-lined ponds.
- **Stocking:** Very high density (above 50 per m²).
- **Technology:** Requires sophisticated automated feeders, 24/7 aeration, and strict "Biosecurity" to prevent disease outbreaks.
- **Biofloc Technology:** A modern intensive method where waste is recycled into protein-rich microbial flakes, reducing the need for water exchange.

Methods of Prawn Culture

The cultivation of prawns (specifically the **Giant River Prawn** or **Tiger Prawn**) is a meticulous process that requires balancing water chemistry, nutrition, and biology. The transition from a microscopic larva to a marketable adult takes approximately **4 to 6 months**.

Step 1: Site Selection and Pond Construction

The success of a prawn farm begins with the right location.

- **Soil Quality:** Clayey-loam soil is preferred as it holds water effectively without excessive seepage.²
- **Topography:** A gentle slope is ideal to allow for complete drainage during harvest.³
- **Water Source:** Proximity to a pollution-free water source (estuaries for marine prawns or rivers for freshwater prawns) is essential.
- **Pond Design:** Rectangular ponds (0.5 to 1.5 hectares) are easiest to manage.

Step 2: Pond Preparation

Before introducing prawns, the "home" must be sterilized and fertilized.

- **Drying:** The pond bottom is dried until the soil cracks to kill pathogens and oxidize organic waste.⁴
- **Liming:** Agricultural lime (CaCO_3) is applied to neutralize soil acidity and maintain a pH between **7.5 and 8.5**.
- **Fertilization:** Organic or inorganic fertilizers are added to stimulate the growth of **Phytoplankton** and **Zooplankton**, which serve as natural food for young prawns.

Step 3: Seed Selection and Acclimatization

Prawn "seeds" are usually purchased at the **Post-Larvae (PL)** stage from hatcheries.

- **Quality Check:** Healthy PL should be active, uniform in size, and have a full gut.
- **Acclimatization:** This is the most critical sub-step. The bags containing PL are floated in the pond water to equalize the temperature. Then, pond water is slowly added to the bags to adjust the salinity and pH levels gradually. This prevents **osmotic shock**.

Step 4: Stocking.

- **Density:** For semi-intensive farming, **10–25 PL per square meter** is standard.
- **Time:** Stocking should be done during the cooler parts of the day (early morning or late evening) to reduce stress.

Step 5: Feed Management

Prawns are bottom feeders and require high-protein diets.

- **Types of Feed:** Farmers use pelletized feed containing fish meal, soybean meal, and vitamins.
- **Frequency:** Feeding occurs 2–4 times a day. Check-trays (submerged nets) are used to monitor how much the prawns are eating; if the tray is empty, the feed is increased; if feed remains, it is decreased to prevent water pollution.

Step 6: Water Quality and Health Monitoring

- **Aeration:** Paddle-wheel aerators are used at night (when oxygen is lowest) to dissolve oxygen into the water.
- **Water Exchange:** Periodic exchange of 10–20% of the water helps remove ammonia and excess waste.
- **Sampling:** Every 15 days, a few prawns are caught to check their growth rate and screen for signs of disease (like White Spot Syndrome).

Step 7: Harvesting and Post-Harvest

When the prawns reach the desired market size (30g to 100g depending on the species), they are harvested.

- **Method:** The pond is slowly drained, and a bag net is attached to the outlet sluice. Remaining prawns are collected manually.
- **Chill Killing:** Harvested prawns are immediately placed in **slush ice (0°C)**. This preserves the texture, prevents bacterial growth, and ensures a high market price.

Prawn culture is significant for providing high-value protein, boosting economies through exports (especially for species like *Macrobrachium rosenbergii* or Scampi), utilizing vast freshwater resources, creating rural livelihoods, and offering a sustainable alternative to declining wild fisheries, contributing to global food security and economic growth as increasing export revenue, boosting local economy and employment, effective resource utilization through controlled, high-yield farming techniques.

Que. 8.a. What do you mean by infectious and communicable diseases? Mention the causative agent and means of spread of filaria. Also describe the symptoms, diagnosis, treatment and preventive measures of filaria.

Ans. Infectious and communicable diseases are illnesses caused by pathogens (viruses, bacteria, fungi, parasites) that can spread, but "communicable" specifically means it spreads *directly* from person-to-person or animal-to-person, while "infectious" is a broader term for any germ-caused illness, including those not easily passed, like tetanus. All communicable diseases are infectious, but not all infectious diseases are communicable. They spread via air, contact, vectors (insects), or contaminated sources, with common examples including flu, COVID-19, strep throat, and malaria.

1. Major Agents of Infectious Diseases (The Pathogens)

These are the biological entities that invade the body and cause tissue damage or physiological dysfunction.

Bacteria: Single-celled prokaryotes that cause diseases like **Tuberculosis, Cholera, and Strep throat**. They often produce toxins that damage cells.

Viruses: Microscopic genetic material (DNA or RNA) encased in protein. They require a host cell to replicate. Examples: **Influenza, COVID-19, and HIV**.

Fungi: Multi-cellular or unicellular organisms that cause infections like **Ringworm and Athlete's foot**, typically affecting the skin or respiratory system.

Protozoa: Single-celled eukaryotes that often have complex life cycles. Examples: **Plasmodium (Malaria) and Amoeba**.

Helminths (Parasitic Worms): Large, multicellular organisms. Examples: **Tapeworms and Filarial worms (Elephantiasis)**.

Prions: Misfolded proteins that cause neurodegenerative diseases like **Mad Cow Disease**.

2. Major Agents of Communicable Diseases (The Transmission Routes)

Communicable diseases are defined by how the infectious agent moves through a population. The "agents" here are the methods of transfer.

Airborne/Droplet Agents: Spread through respiratory secretions when an infected person coughs or sneezes (e.g., **Measles, Common Cold**).

Water/Foodborne Agents: Spread through the ingestion of contaminated resources (e.g., **Typhoid, Hepatitis A**).

Vector Agents: Living organisms that carry the pathogen from one host to another without getting sick themselves. **Mosquitoes:** Malaria, Dengue, Filaria. **Ticks:** Lyme disease. **Fleas:** Bubonic Plague.

Direct Contact Agents: Spread through skin-to-skin contact or exchange of bodily fluids (e.g., **Ebola, Syphilis**).

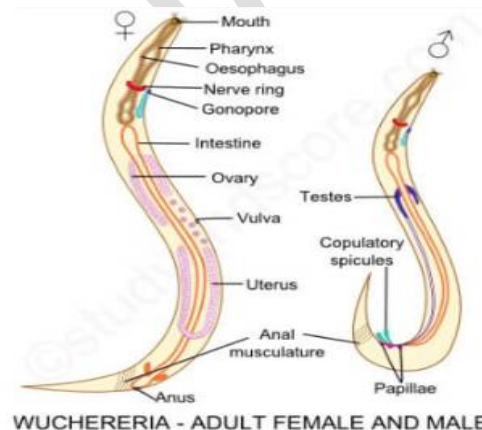
Fomites: Inanimate objects (doorknobs, towels, needles) that harbor pathogens and transfer them to a new host.

Causative agent of Filaria-

In 1709, Clarke called elephantoid legs in Cochin as Malabar legs. The discovery of microfilariae (mf) in the peripheral blood was made first by Lewis in 1872 in Calcutta.

Filariasis is caused by the nematode worm, either *Wuchereria bancrofti* or *Brugia malayi* round, coiled and thread-like parasitic worms belonging to the family filaridea. In India, 99.4% of the cases are caused by the species - *Wuchereria bancrofti* whereas *Brugia malayi* is responsible for 0.6% of the problem.

| Organism | Vectors | Disease produced |
|-----------------------------|---|---------------------------------------|
| <i>Wuchereria bancrofti</i> | Culex Mosquitoes | Lymphatic filariasis |
| <i>Brugia malayi</i> | Mansonia Mosquitoes | Lymphatic filariasis |
| <i>Brugia timori</i> | Anopheles mosquitoes Mansonia mosquitoes | Lymphatic filariasis |
| <i>Onchocerca volvulus</i> | Simulium flies | Subcutaneous nodules; River blindness |



Means of Spread (Transmission)

The disease is transmitted through the bite of infected mosquitoes (vectors), primarily of the **Culex**, **Anopheles**, and **Aedes** genera.

The Detailed Transmission Cycle

The spread occurs through a series of interlocking steps:

A. Ingestion of Microfilariae

When a mosquito bites an infected human, it ingests **microfilariae** (immature, microscopic larvae) present in the person's bloodstream. In many regions, these larvae exhibit **nocturnal periodicity**, meaning they migrate to the surface blood vessels only at night to coincide with the biting habits of the mosquitoes.

B. Development inside the Mosquito

Once inside the mosquito, the microfilariae undergo a biological transformation. Over a period of **10 to 14 days**, they shed their sheaths and develop into **third-stage (L3)**

infective larvae. During this time, the mosquito is not yet capable of spreading the disease, but it acts as an incubator.

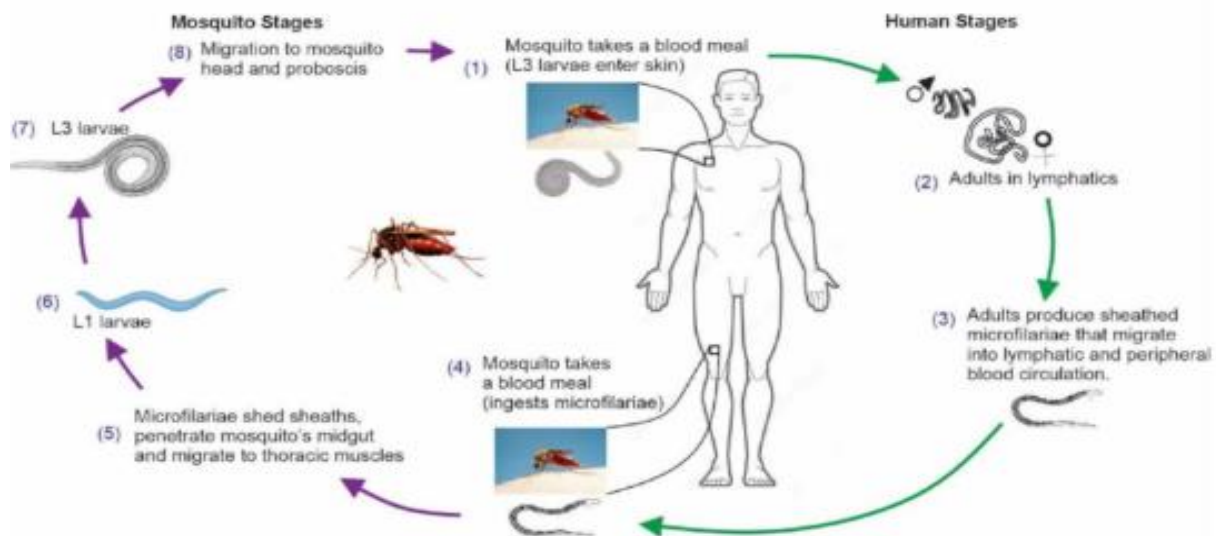
C. Infection of a New Host

When the infected mosquito bites a healthy human, the L3 larvae are deposited on the surface of the skin. They do not enter through the bite wound itself but rather crawl into the puncture site or other tiny skin abrasions.

D. Migration to the Lymphatic System

Once they enter the human body, the larvae migrate to the **lymphatic vessels**. Here, they mature into adult worms over several months. These adult worms mate and produce millions of new microfilariae, which enter the bloodstream, waiting for the next mosquito bite to continue the cycle.

Wuchereria bancrofti



Factors Affecting the Spread

- **Environmental Sanitation:** Stagnant water, open drains, and poor waste management provide ideal breeding grounds for the Culex mosquito.
- **Population Density:** High-density living allows for a rapid "bite-and-spread" cycle between infected and healthy individuals.
- **Climate:** Warm, humid tropical and subtropical conditions are necessary for both the mosquito's survival and the development of the parasite inside the vector

Symptoms

The disease often starts without symptoms (asymptomatic phase), but over years, it causes:

- **Lymphedema:** Severe swelling of the legs, arms, or breasts due to fluid accumulation.

- **Elephantiasis:** Thickening and hardening of the skin and underlying tissues (resembling an elephant's hide).
- **Hydrocele:** Swelling of the scrotum in men.
- **Filarial Fever:** Frequent episodes of high fever, chills, and headache.

Diagnosis

Microscopic Examination: Identifying microfilariae in a "blood smear." Since these larvae are "nocturnally periodic," blood must be collected at night (usually between 10 PM and 2 AM).

Antigen Test: Rapid diagnostic kits that detect specific parasite proteins in the blood.

Ultrasonography: Used to detect the "filarial dance sign"—the movement of live adult worms in the lymphatic vessels.

Treatment

- **Chemotherapy:** The World Health Organization (WHO) recommends **Mass Drug Administration (MDA)** using a combination of **Albendazole** with **Diethylcarbamazine (DEC)** or **Ivermectin**. These drugs kill the microfilariae and stunt the adult worms.
- **Surgical Intervention:** Surgery may be required for hydrocele or to reduce severe tissue mass in elephantiasis

Preventive Measures:

- ✓ **Vector Control:** Using mosquito nets (ITNs), insect repellents, and wearing long-sleeved clothing.
- ✓ **Environmental Sanitation:** Eliminating stagnant water where mosquitoes breed.
- ✓ **Morbidity Management:** For those already infected, strict hygiene (washing the affected area with soap and water) prevents secondary bacterial infections that worsen the swelling.
- ✓ **Preventive Chemotherapy:** Participating in annual MDA programs in endemic areas to clear the parasite from the community.

Filariasis has been a major public health problem in India next only to malaria. Currently, more than 1.4 billion people in 83 countries are at risk of being infected. Globally, an estimated 25 million men suffer with genital disease and over 15 million people are afflicted with lymphoedema. Eliminating lymphatic filariasis can prevent unnecessary suffering and contribute to the reduction of poverty.

Que.8.b. **Give an illustrated account of carbon cycle with suitable diagram.**

Ans. The carbon cycle is a biogeochemical cycle where different forms of carbon compounds are cycled through the Earth's various systems like the atmosphere, biosphere, hydrosphere, and geosphere. The **Carbon Cycle** is the process by which carbon atoms continuously travel from the atmosphere to the Earth

and then back into the atmosphere. Carbon is the backbone of life, and its movement is essential for maintaining Earth's temperature and supporting biological functions.

Step 1: Carbon Entry into the Atmosphere

Carbon exists in the atmosphere primarily as **Carbon Dioxide**. It enters the atmosphere through several pathways:

- **Respiration:** Plants and animals break down glucose for energy, releasing CO₂ as a byproduct.
- **Combustion:** Burning of fossil fuels (coal, oil, gas) and wood releases stored carbon.
- **Decomposition:** When organisms die, decomposers (bacteria and fungi) break down their bodies, releasing carbon back into the air or soil.

Step 2: Carbon Absorption by Producers (Photosynthesis)

This is the primary way carbon is removed from the atmosphere.

- **Process:** Green plants, algae, and cyanobacteria absorb CO₂ from the air.
- **Transformation:** Using sunlight and water, they convert CO₂ into **Glucose** C₆H₁₂O₆ a carbon-based sugar that serves as food.
- **Formula:** $6\text{CO}_2 + 6\text{H}_2\text{O} + \text{Light} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$

Step 3: Carbon Transfer through Food Chains

Carbon moves from "producers" to "consumers."

- **Ingestion:** When animals eat plants, the carbon stored in plant tissues is transferred to the animal's body.
- **Higher Trophic Levels:** When a predator eats a herbivore, the carbon moves further up the food chain. This carbon is used to build proteins, fats, and DNA.

Step 4: The Oceanic Carbon Cycle

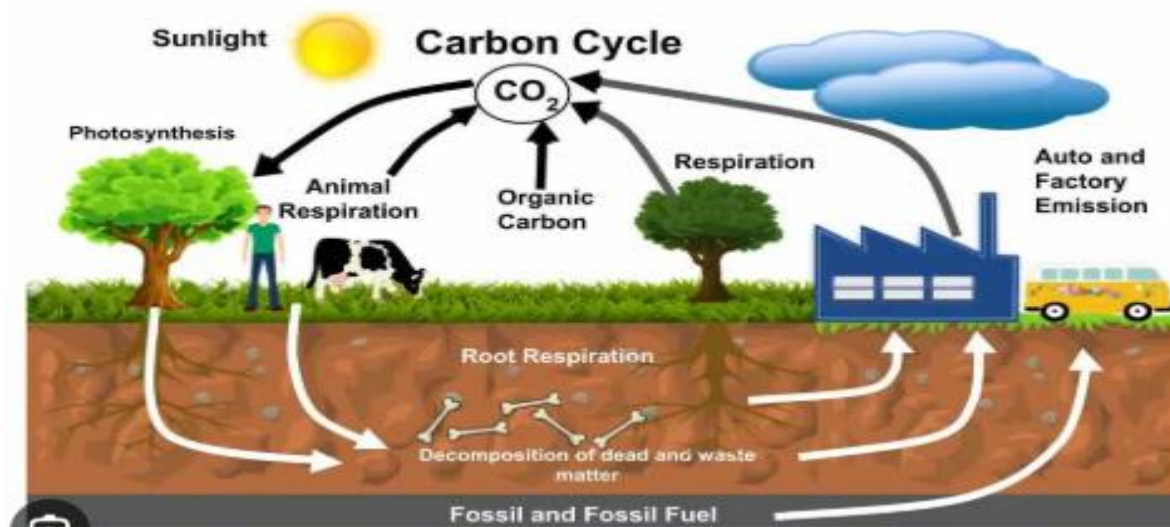
The ocean is the largest "carbon sink" on Earth.

- **Diffusion:** CO₂ dissolves directly from the atmosphere into the ocean water.
- **Marine Life:** Phytoplankton use this carbon for photosynthesis. Marine organisms like corals and shellfish use carbon to form **Calcium Carbonate** shells.
- **Sedimentation:** When these organisms die, their shells sink to the ocean floor, eventually forming limestone rock.

Step 5: Long-term Storage (Fossilization)

Not all carbon is recycled immediately.

- **Formation of Fossil Fuels:** Over millions of years, dead organic matter buried under high pressure and heat transforms into coal, oil, and natural gas.
- **Geological Storage:** Carbon can be trapped in rocks and sediments for millions of years until it is released via volcanic eruptions or human mining.



Step 6: The Return Loop

The cycle completes when carbon is released back into the atmosphere through the methods mentioned in Step 1 (respiration, decay, or burning), restarting the process.

Carbon Cycle Significance

- The carbon cycle is important as it balances the amount of carbon on Earth which allows the planet to remain hospitable for life.
- Carbon is an essential element for all living beings, and its movement through different systems helps to understand different biological factors and factors that influence them.
- Carbon dioxide is an essential gas of the atmosphere that protects the Earth from the sun's harmful rays. However, the increased amount of carbon dioxide causes the insulation of Earth, increasing the temperature of the Earth. Understanding the movement of carbon dioxide through different ecosystems helps to understand the climate and the onset of global warming.
- The carbon cycle is also tied to the availability of other elements and compounds like oxygen and sulfur.
- The carbon cycle enables the flow of energy through the food chain. Carbon compounds carry the solar energy trapped from producers to consumers to decomposers.
- The decomposition or the mineralization process works as a natural waste removal system.
- Different carbon-containing gases like carbon dioxide and methane also affect the Earth's climate.

The cycle moves more than 10^{15} to 10^{17} grams of different carbon forms in a year. Deforestation and urbanization results in the loss of green plants throughout the world, which causes a further increase in the carbon dioxide amount in the atmosphere. The increase in carbon dioxide in the atmosphere increases the greenhouse effect causing noticeable warming of the earth's surface. To improve the carbon cycle, we must prioritize **reforestation**, **soil carbon sequestration**, and transitioning to **renewable energy** to reduce excess emissions. Its significance lies in stabilizing **global**

temperatures, preventing ocean acidification, and maintaining the vital balance of gases necessary for the survival of all living organisms.

Que.8.c. **Describe the phenomenon of sexual conflict and selfishness in studying animal behaviour with suitable examples.**

Ans. In the study of animal behavior, **sexual conflict** and **selfishness** are two evolutionary concepts that challenge the idea of "nature in harmony." These phenomena arise because individuals are driven to maximize their own fitness, often at the expense of their partners or group members.

Sexual conflict Sexual conflict in animal behavior is the clash between males and females' evolutionary interests, where traits benefiting one sex's reproduction can harm the other, leading to "arms races" in mating behaviors, parental care, or resource use. Driven by different reproductive investments (e.g., males wanting many mates, females wanting quality care), this conflict results in males evolving manipulative tactics (like forced copulation) and females evolving counter-adaptations (like resistance), shaping unique sexual strategies and potentially speciation. **Geoff Parker** first introduced this concept, highlighting how traits beneficial to one sex can be detrimental to the other.

A. Inter-sexual Conflict (The Battle of the Sexes)

This occurs when one sex develops traits to manipulate the other.

- **The Example of Bedbugs (Traumatic Insemination):** Male bedbugs possess a needle-like reproductive organ used to pierce the female's abdomen to inject sperm directly into the body cavity. This bypasses the female's reproductive tract. While this ensures the male's paternity, it causes physical trauma, shortens the female's lifespan, and increases her risk of infection.
- **Toxic Semen in Fruit Flies:** In *Drosophila melanogaster*, male seminal fluid contains proteins that increase the female's egg-laying rate and decrease her desire to re-mate with other males. However, these proteins are toxic and reduce the female's overall longevity.

Interlocus Sexual Conflict: Involves coevolutionary battles between genes expressed differently across sexes, such as over mating behaviours or fertilization control. It often results in an antagonistic coevolutionary arms race, where an adaptation in one sex is countered by a maladaptation in the other.

Intralocus Sexual Conflict: Occurs when a single gene or locus has sexually antagonistic effects, benefiting one sex but harming the other. This can lead to different optimal trait values for males and females that are genetically correlated.

Sexual conflict can manifest at various stages of reproduction, from initial courtship to parental care:

- **Forced Copulation and Female Resistance:** Males may evolve aggressive tactics to coerce females into mating, which can be detrimental to female fitness (e.g., physical harm, increased predation risk, reduced foraging). Females, in turn, evolve counter-adaptations to resist these attempts.
- **Water Strider (*Gerris incognitus*):** Male water striders have evolved grasping structures to force copulation. Females have developed abdominal spines and erratic swimming behaviours to make forced mating more difficult and costly for males.
- **Northern Elephant Seals:** Large male elephant seals often use their massive body weight to pin down and bite females, inflicting severe injuries (e.g., broken ribs, internal bleeding) to force mating.
- **Harmful Seminal Fluid Components:** In many species, male ejaculate contains substances that manipulate female physiology or behaviour, often to the male's advantage but at a cost to the female.
- ***Drosophila melanogaster* (Fruit Fly):** Male fruit flies' seminal fluid proteins (SFPs) increase female egg-laying rates and reduce their receptivity to remating (beneficial for the male's paternity). However, these SFPs also shorten the female's lifespan, imposing a direct cost. Females have evolved resistance tactics to these male manipulations.
- **Infanticide:** In some species, males kill the offspring of other males to bring females into estrus sooner, thereby accelerating their own reproductive opportunities. This is a severe cost to female reproductive success.
- **Lions (*Panthera leo*):** When a new coalition of male lions takes over a pride, they often kill existing cubs that are not their own. This causes the nursing lionesses to stop lactating and become fertile again, allowing the new males to sire their own offspring. Female lions have evolved counter-strategies such as polyandrous mating (mating with multiple males) to confuse paternity and deter infanticide.
- **Hanuman Langurs:** Similar to lions, male Hanuman langurs taking over a troop may commit infanticide to hasten female receptivity.
- **Parental Care Conflict:** Both sexes may attempt to reduce their investment in parental care, shifting the burden to their partner to maximize their own future reproductive output.
- **Birds:** In many bird species, there is a conflict over which sex provides more care, or how much care is given to offspring. One partner might 'desert' to seek new mating opportunities, leaving the other to bear the full cost of raising the young.

Selfishness in Animal Behavior

Selfishness describes behaviors that increase the fitness of the individual performing the action while decreasing the fitness of the recipient. In an evolutionary sense, "selfish" behavior is favored because genes that promote individual survival and reproduction are more likely to be passed on.

A. Infanticide

- **Lion Prides:** When a new coalition of male lions takes over a pride, they often kill the existing cubs. This is "selfish" because it stops the females from lactating and brings them back into estrus (fertility) sooner. The new males can then sire their own offspring immediately, rather than waiting for another male's cubs to grow up.

B. Brood Parasitism

Some species "steal" the parental care of others to avoid the costs of nesting.

- **The Cuckoo Bird:** The female cuckoo lays her eggs in the nests of other bird species (the hosts). The cuckoo chick often hatches first and instinctively pushes the host's eggs out of the nest. The host parents then spend all their energy raising a chick that is not their own, while the biological cuckoo parents save energy for more egg-laying.

C. The "Selfish Herd" Theory

Proposed by W.D. Hamilton, this theory suggests that animals join groups not to "help" the group, but to reduce their own individual risk of predation. By staying in the center of a herd, an individual uses its neighbors as a living shield, forcing those on the edges to take the greatest risk.

- **Adélie Penguins:** When a group of Adélie penguins approaches the water's edge, individuals may push others into the water first to test for predators, exhibiting selfish behaviour by exposing others to danger while assessing their own safety.
- **Fish Schools:** In fish schools attacked by predators, individual fish will try to get into the centre of the school, increasing their chances of survival at the expense of those on the periphery.

Sexual conflict and selfishness are fundamental concepts in understanding animal behaviour, revealing the intricate and often harsh realities of evolutionary processes. While sexual conflict highlights the inherent tension between the reproductive interests of males and females, driving dynamic coevolutionary arms races, selfishness underscores the pervasive drive of individuals to propagate their own genes, even at the cost of others. These phenomena are not mutually exclusive; indeed, many instances of sexual conflict are rooted in selfish strategies employed by one sex against the other. Together, they demonstrate that much of animal behaviour is a result of individuals striving to maximize their fitness in a world of limited resources and competing interests, profoundly shaping species' social structures, reproductive strategies, and evolutionary trajectories.