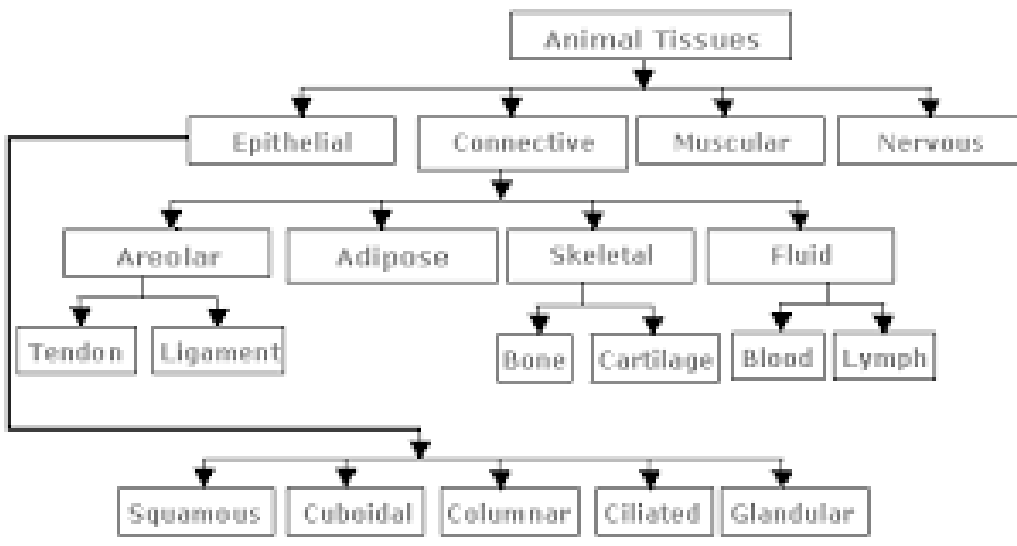


Chapter 7

Structural Organisation in Animals

- Cells of multicellular organisms are organised into tissues to carry out various functions.
- **Tissue:** A group of similar cells along with intercellular substances that perform a specific function
- **All complex animals consist of only four basic tissue types.**
- **Organ:** A group of similar and dissimilar tissues in a living organism that have been organized and adapted to perform a common specific function like heart, lung, kidney, stomach, etc.
- **Organ System:** A group of different organs that work together to perform a common function. Each performs a particular function in the body, and is made up of certain tissues.

7.1: Animal Tissues

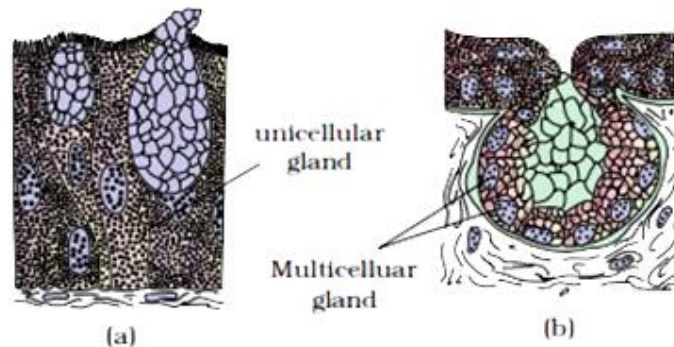
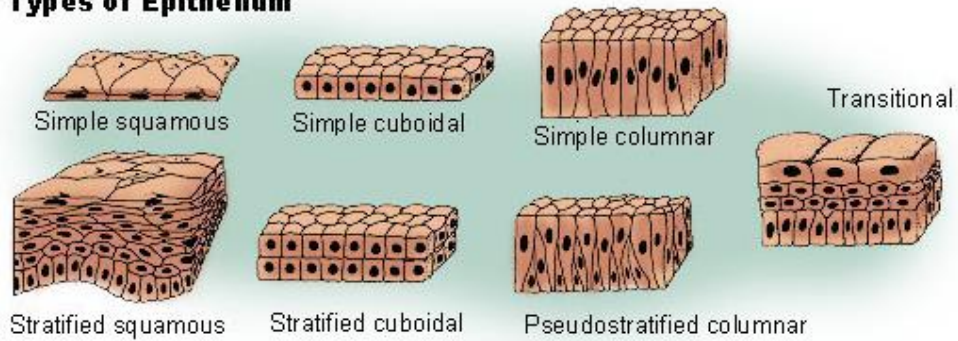


7.1.1: Epithelial Tissues:

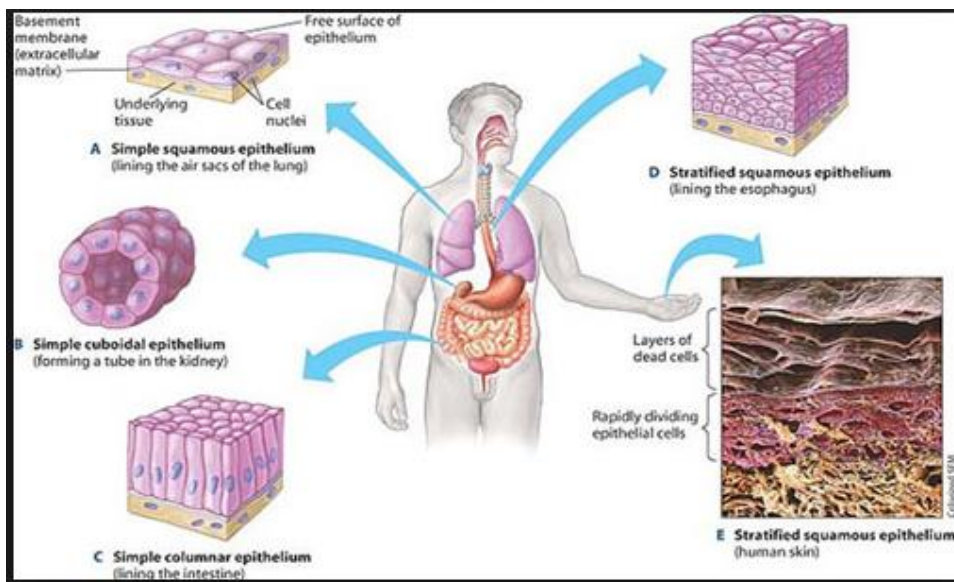
- They are tightly packed cells with little intercellular matrix
- One surface of this tissue is exposed to air or internal fluid
- The other surface of this tissue is attached to a basement membrane
- It covers the surface of the body and lines the internal organs and cavities
- It acts as a barrier against mechanical injury, pathogens and dehydration.
- It also provides a surface for absorption, excretion and transport of molecules.
- It is of two types- **Simple and Stratified epithelium.**
- **Simple epithelium:** composed of cells arranged end to end in a single layer. It is usually present as a lining for body cavities, ducts, and tubes.
- **Stratified or Compound Epithelium:** The compound epithelium consists of two or more cell layers and has protective function as it does in our skin.
- On basis of their structure simple epithelium is classified into three types- **squamous, cuboidal and columnar.**
- **Squamous epithelium:**
 - Flattened cells with irregular boundaries arranged to form a thin layer.
 - In surface view they appear polygonal.
 - They are also known as pavement epithelium because of the resemblance of its compact structure to tiles on floor.
 - It forms the delicate lining of cavities like mouth, oesophagus, nose, pericardium, alveoli, etc.
 - It also forms the lining of blood vessels
 - They are involved in functions like formation of a diffusion boundary.
 - It forms the covering of tongue and skin

- In skin, squamous epithelium is arranged in many layers to prevent wear and tear.
- **Cuboidal Epithelium:**
 - A layer of cube-like cells
 - Appear as squares in sections but on free surface they appear hexagonal.
 - It is found in kidney tubules, thyroid vesicles and in glands.
 - It forms the germinal epithelium in gonads
 - It is involved in absorption, excretion and secretion.
 - It also provides mechanical support
 - The epithelium of the proximal convoluted tubule in the nephron of a kidney has microvilli. Microvilli are finger-like projections on the surface of epithelial cells. They help in the process of absorption.
- **Columnar Epithelium:**
 - A layer of tall, slender cells
 - The nuclei are located at the base.
 - Free surface may have microvilli.
 - They are present in the lining of stomach and intestines
 - They help in secretion and absorption
- **Ciliated Epithelium:**
 - Cuboidal or columnar epithelium on whose surface fine, hair-like protoplasmic outgrowths are present.
 - It lines the body of nephrons, trachea and fallopian tubes.
 - The cilia move particles or mucus in a specific direction over the epithelium.
- **Glandular Epithelium:**
 - Cells that are modified for secretion. They may be columnar or cuboidal.
 - Unicellular: They are single and isolated glandular cells, like the goblet cells of alimentary canal
 - Multicellular: They are a cluster of glandular cells like the salivary gland.
 - Exocrine: Exocrine glands secrete products through ducts or tubes. These glands secrete saliva, mucus, earwax, oil, milk, digestive enzymes, and other cell products.
 - Endocrine: They do not have any ducts (ductless glands). Their products are called **hormones** and are directly secreted into the fluid bathing the gland.
- **Stratified or Compound Epithelium:**
 - They are made of more than one layer of cells, I.e., they are multi-layered.
 - They have limited role in secretion and absorption.
 - They mainly function in providing protection against mechanical and chemical stresses.
 - They are present on the dry surface of the skin, pharynx, the moist surface of the buccal cavity, inner lining of ducts of salivary glands and ducts of pancreas.
- **Junctions:** They are specialised structures that provide structural and functional links between individual cells.
- They are **tight, adhering and gap junctions**.
- **Tight junctions:** The specialised structures that prevent substance leak across a tissue
- **Adhering junctions:** The specialised structure that cements the neighbouring cells together.
- **Gap Junctions:** The specialised structures that help cells to communicate with each other. They connect the cytoplasm of adjoining cells and thus help in rapid transfer of ions, small molecules and big molecules.

Types of Epithelium



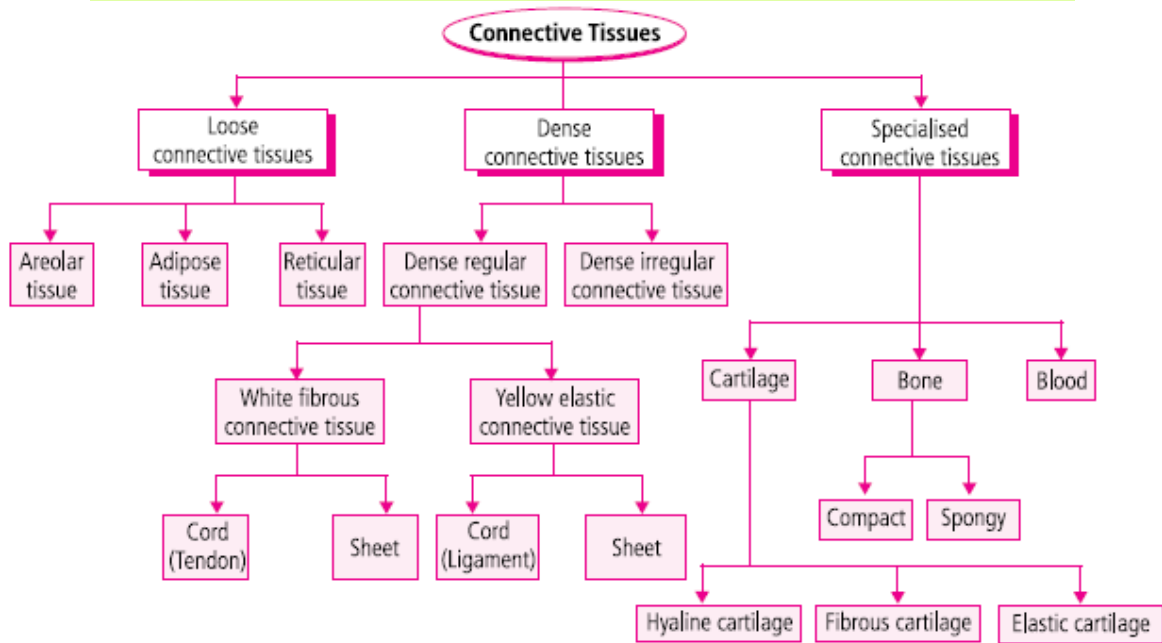
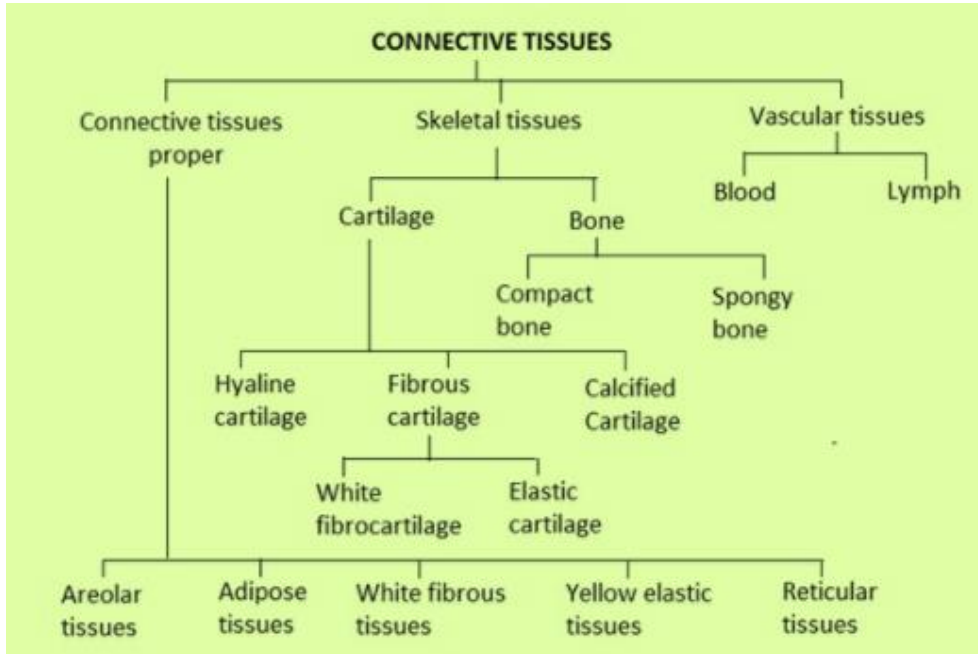
Glandular epithelium : (a) Unicellular
(b) Multicellular



7.1.2: Connective Tissue:

- The most abundant of all tissues in the body of complex animals are the different forms of connective tissue. They are also the most widely distributed.
- They are so called because they function specially in the linking and supporting of tissues/organs of the body.
- They are of different types, from soft to specialised.
- Connective tissue comprises of widely spaced cells embedded in a matrix.
- The nature of the matrix determines the function of the tissue.
- **In all connective tissues except blood, the cells secrete fibres of structural proteins called collagen or elastin.**
- The proteins provide strength, elasticity and flexibility to the tissue.

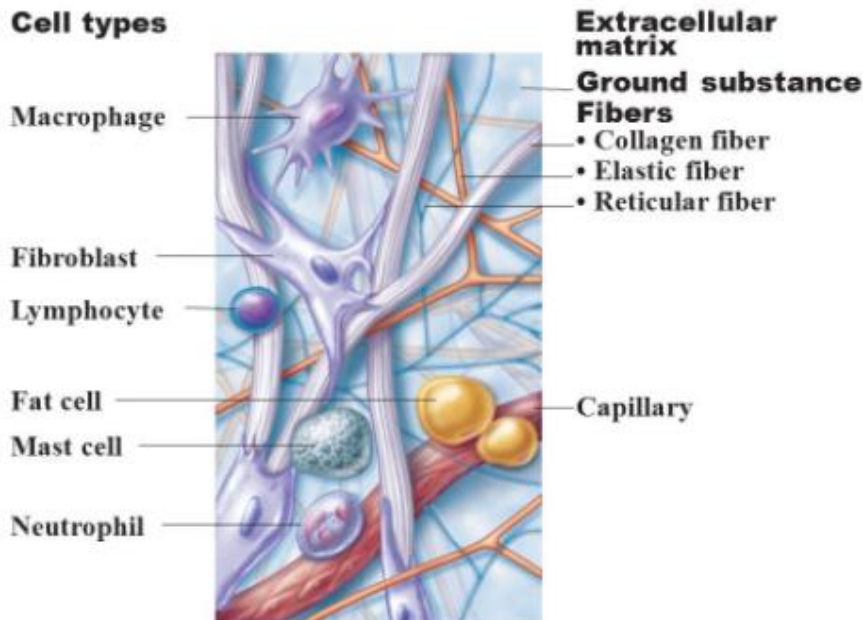
- The matrix or ground substance is formed by the accumulation of modified polysaccharides secreted by the cells.
- Three major types of connective tissue: **Loose connective tissue, dense connective tissue and specialised connective tissue.**
- Connective tissue can also be classified as: **Connective tissue proper, skeletal tissue and vascular or fluid tissue.**



Loose Connective Tissue:

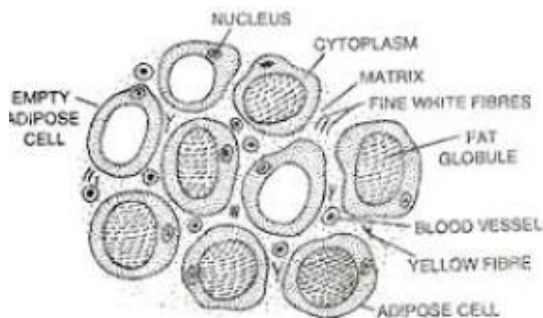
- Cells and fibres are loosely arranged in a semi-fluid ground substance.
- They are the **areolar, adipose and reticular tissue.**
- **Areolar Tissue:**
 - It is the most widely distributed connective tissue in the body.
 - This tissue fills spaces inside organs.
 - It is also found between skin and organs, around blood vessels, nerves and in bone marrow.
 - It often serves as a support framework for epithelium.

- It contains fibroblasts, macrophages and mast cells.
- Fibroblasts produce and secrete two types of fibres: inelastic white fibres and elastic yellow fibres.
- It holds various tissues together in an organ.
- It helps to repair body tissues after injury.
- The mast cells are concerned with allergy.



- **Adipose Tissue:**

- This tissue is located mainly beneath the skin.
- The cells are specialised to store fats.
- It consists of oval and round cells that are filled with fat globules, called as adipocytes.
- It provides insulation by preventing loss of heat from the body.
- It helps in the storage of excess energy in the form of fats.
- It forms a cushion-like shock absorber around the vital organs like heart, kidney, eye-balls, etc.



- **Reticular Tissue:**

- Cells in this tissue are star-shaped and form a network like structure.
- The fibres are made up of reticulin protein.
- It is present in the spleen, lymph nodes, tonsils, etc.
- It forms the lymphoid tissues in the body.
- Reticular tissue in the bone marrow helps in the formation of blood cells.

Dense Connective Tissue:

- Cells, fibres and fibroblasts are arranged compactly with very little matrix.
- Orientation of tissues may show regular or irregular pattern and are therefore called **dense regular and dense irregular tissues** respectively.
- **Dense regular connective tissues**: Many parallel bundles of fibres are contain the collagen fibres in between. Collagen fibres are present as rows. Examples: tendons and ligaments.
- **Tendons**: It is made up of white fibrous tissues. The fibroblasts are arranged almost continuously. It is tough and inelastic. It connects a skeletal muscle to bone.
- **Ligaments**: It is made up of yellow elastic tissue. The fibroblasts are scattered. It is a strong and yet elastic tissue. It connects a bone to another bone.
- **Dense irregular connective tissues**: In this the fibroblasts and fibres (mainly collagen) are oriented differently. These form the tissues present in the skin.

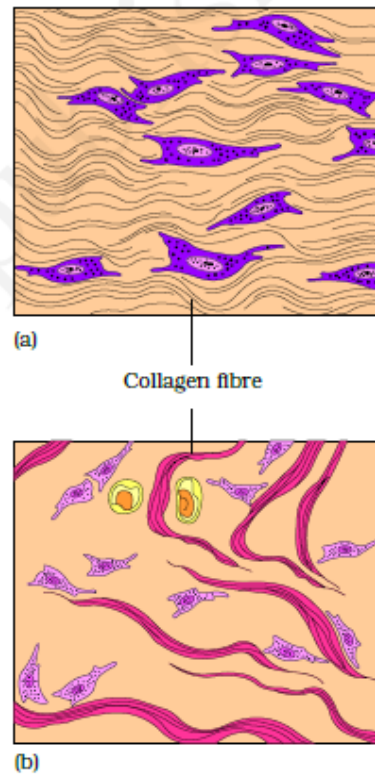
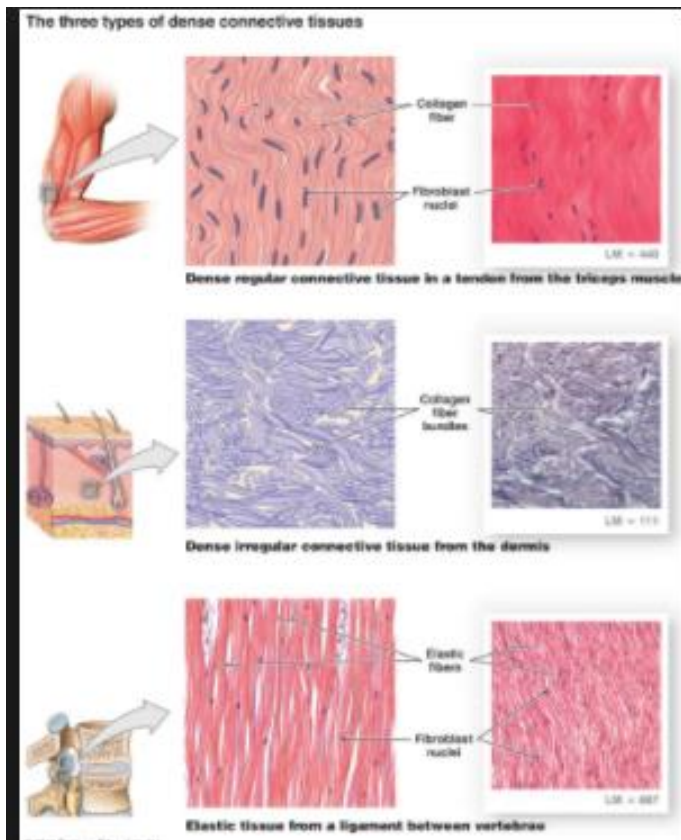


Figure 7.5 Dense connective tissue:
 (a) Dense regular
 (b) Dense irregular



Specialised Connective Tissue:

- Connective tissue that is specialised for specific function is called specialised connective tissue.
- It includes **bone, cartilage and lymph**.
- **Bone:**
 - It is a type of skeletal tissue.
 - It forms the supportive framework of the body.
 - It consists of a hard non-pliable matrix composed of calcium phosphate, calcium carbonate and a protein (ossein) along with collagen.
 - The matrix consists of longitudinal canals called Haversian canals.
 - The matrix is present in the form of layers called lamellae. The lamellae are present as crescentic rings around Haversian canals.
 - Within the lamellae ring shaped, fluid-filled spaces are present called as lacunae.
 - The bone cells or the **osteocytes** are present in the lacunae.
 - Bones support and protect softer tissues and organs.
 - Limb bones, such as the long bones of the legs, serve weight-bearing functions. They also interact with skeletal muscles attached to them to bring about movements.
 - The bone marrow in some bones is the site of production of blood cells.
- **Cartilage:**
 - It is also a type of skeletal tissue.
 - This tissue is elastic and strong but softer than bone.
 - The matrix is solid and pliable and resists compression.
 - Cartilage cells or **chondrocytes** are enclosed in small cavities within the matrix secreted by them.
 - The elasticity is due to the presence of protein chondrin.
 - Cells are widely spaced and the matrix is reinforced by fibres.
 - It forms the embryonic skeleton of vertebrates. Most of the cartilage is later replaced by bones.
 - Cartilage is seen in certain regions like the tip of nose, limbs and hands in adults, outer ear joints, etc. It is also found in the vertebral column between adjacent bones.
 - Cartilage forms the adult skeleton in sharks and rays.

- **Blood:**

- It is a fluid connective tissue composed of plasma and the blood cells.
- It is the main circulating fluid that helps in the transport of various substances.
- It is the softest connective tissue.
- Plasma is the fluid component consisting nearly 90% water. The remaining 10% is made up of proteins, salts, hormones and other materials meant for transport of digested food, gases, excretory products, etc.
- The blood cells include red blood cells (RBCs), white blood cells (WBCs) and platelets.

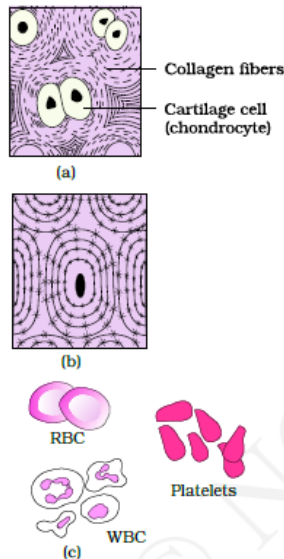
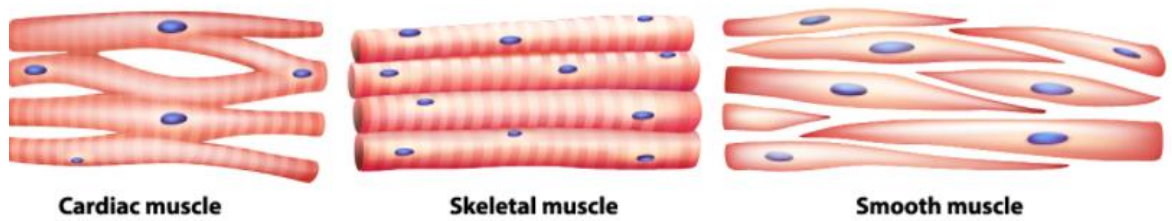


Figure 7.6 Specialised connective tissues : (a) Cartilage (b) Bone (c) Blood

7.1.3: Muscle Tissue:

- Muscular tissue has the unique ability to contract and relax and thereby perform mechanical work.
- Each muscle is made of many long cylindrical fibres arranged in parallel arrays.
- The fibres are composed of numerous fine fibrils called myofibrils.
- Muscle fibres contract when stimulated. They then relax and return in a co-ordinated fashion to their original uncontracted state.
- Their action causes the body or parts of body to move in order to adjust to the changes in the environment and to maintain the positions of the various parts of the body.
- Muscle cells are of three types: **skeletal, smooth and cardiac muscles**.
- **Skeletal Muscle:**
 - It is closely attached to skeletal bones.
 - They are striated and are bundled together in a parallel fashion.
 - A sheath of tough connective tissue encloses several bundles of muscle fibres.
 - They are also called as voluntary muscles as they are under the conscious control.
 - Cells are multinucleate and unbranched.
- **Smooth Muscle:**
 - The cells taper at both ends to form a spindle or fusiform shape.
 - They are non-striated.
 - They are held together by cell junctions and bundled together in a connective tissue sheath.
 - Cells are uninucleate.
 - They are also called as involuntary muscles as their function is not under conscious control.
 - They are found in the walls of internal organs such as stomach, intestine and blood vessels.

Types of Muscle

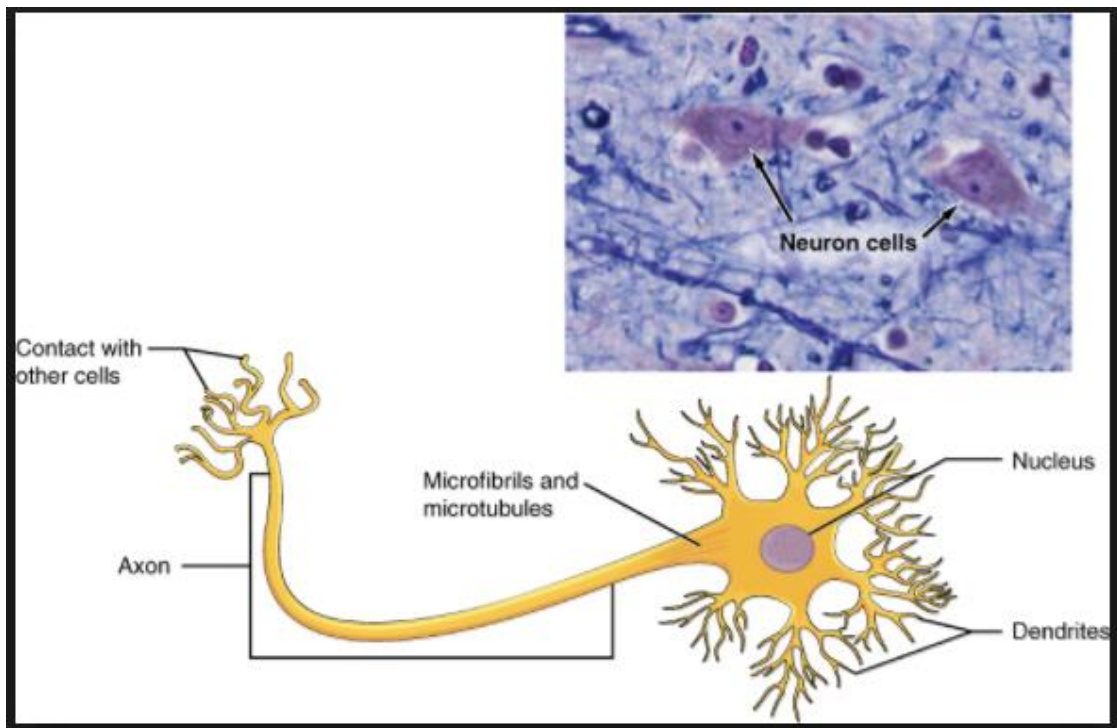


- **Cardiac Muscle:**

- It is a contractile muscle tissue present only in the heart.
- Cell junctions fuse plasma membranes of the cardiac muscle cells and make them stick together.
- Communication junctions or intercalated discs at some fusion points allow cells to contract as a unit. This means that when one cell receives the signal, its neighbouring cells are also stimulated to contract.
- They are involuntary muscles.
- They are uninucleate and branched.
- In these muscles rhythmic contraction and relaxation occurs throughout the life.

7.1.4: Neural Tissue

- Neural tissue is specialised for conduction of nerve impulses.
- It consists of densely packed cells called as the **neurons**.
- Neurons are present in the brain, spinal cord and the nerves.
- Neuroglial cells protect and support the neurons.
- Neuroglia make up more than one-half of the volume of neural tissue in our body.
- The neuron consists of three parts- **cyton, dendrites and axon**.
- **Cyton:** It is the cell body that contains a central nucleus and cytoplasm with characteristic deeply stained particles called as Nissl's granules.
- **Dendrites:** One to many short and branched cytoplasmic processes. They receive impulse from the receptor or another neuron and bring it to cyton.
- **Axon:** Single long process that conducts impulse away from cyton to another neuron.
- Nerve fibres may or may not be myelinated.
- When a neuron is stimulated an electrical impulse is generated which travels quickly along the plasma membrane. When this impulse reaches at the ends of the neuron, it triggers events that cause stimulation or inhibition of adjacent neurons.



7.2: Organ and Organ System

- The basic tissue types in the body organise in various manners to form organs. A group of such organs then associate with each other to form organ systems in the multicellular organisms.
- Organisation of the body into tissues, organs and organ systems is essential for more efficient functioning of the body. It also helps in better coordination of the activities of millions of cells constituting an organism.
- Each organ in our body is made of one or more type of tissues. For example, our heart consists of all the four types of tissues, i.e., epithelial, connective, muscular and neural.
- The complexity in organ and organ systems displays certain discernible trend and is called as evolutionary trend.

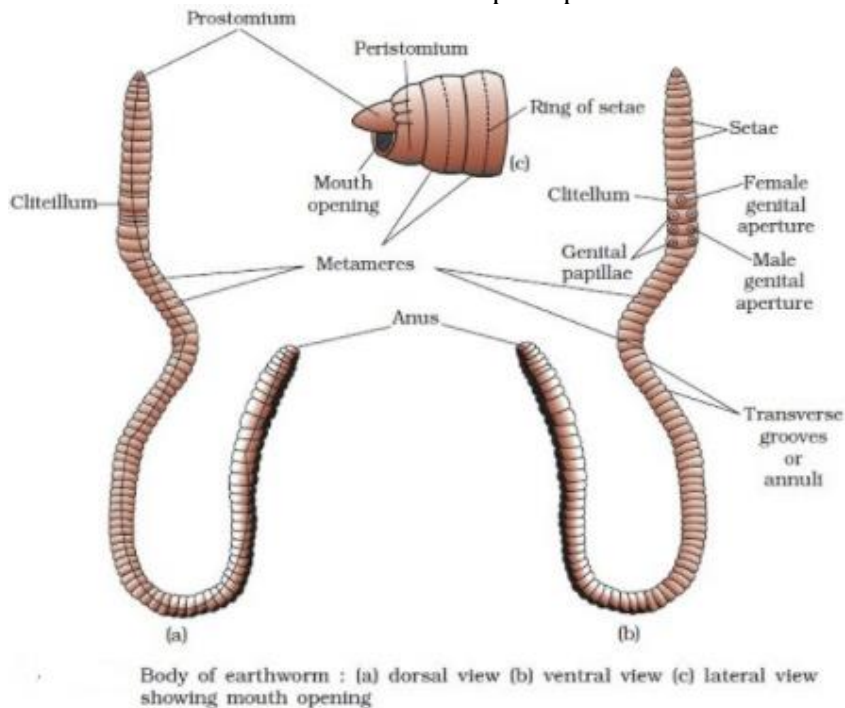
7.3: Earthworm

- It is a terrestrial invertebrate that is reddish brown in colour and lives in the upper layer of moist sand.
- They can be located by their faecal deposits called as worm casting.
- The common Indian earthworms are *Pheretima* and *Lumbricus*.

7.3.1: Morphology:

- Earthworms have a long cylindrical body. The body is divided into more than hundred short segments called as **metamers** which are similar (metameres about 100-120 in number).
- The dorsal blood vessel is represented by a dark median mid-dorsal line present on the dorsal surface of the body.
- The ventral surface is characterised by the presence of genital openings (pores).
- Anterior end includes the mouth and the **prostomium**. Prostomium is a lobe which serves as a covering for the mouth. It is used as a wedge to force open cracks in the soil into which the earthworm may crawl.
- The **prostomium** is sensory in function.
- The first segment of the body contains the mouth and is called **peristomium** (buccal cavity).
- A prominent dark band of glandular tissue called **clitellum** covers the segments 14-16 in a mature worm.
- The body is divided into three segments: **preclitellar, clitellar and postclitellar segments**.

- On the ventro-lateral sides of the intersegmental grooves four pairs of **spermathecal apertures** are present. i.e., they are present between the 5th-9th segments.
- The mid-ventral line of **14th segment** contains a **single female genital pore**.
- On the ventro-lateral sides of the **18th segment** a **pair of male genital pores** are present.
- Many tiny and minute pores called **nephridiopores** open on the surface of the body.
- **Nephridiopores:** A nephridiopore is part of the nephridium, an excretory organ found in many organisms, such as flatworms and annelids.
- Rows of S-shaped **setae** are present in each body segment. Setae are absent in the first, last and clitellum segments of the body. They are present embedded in the epidermal pits in the middle of each segment. Setae can be extended or retracted. Their principal role is in locomotion.



7.3.2: Anatomy

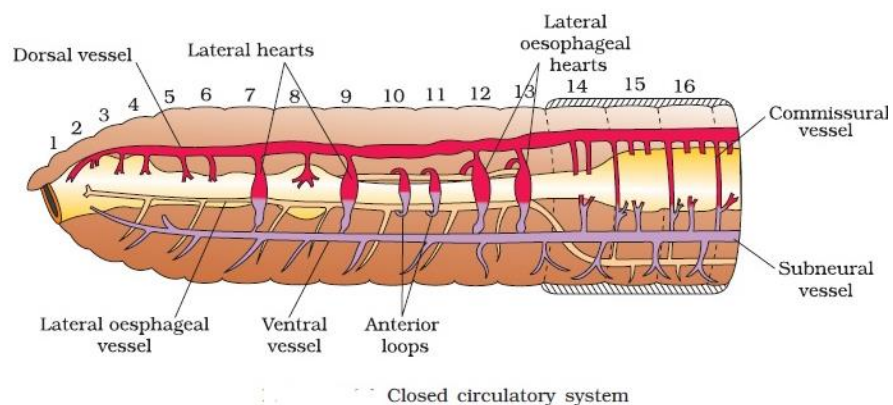
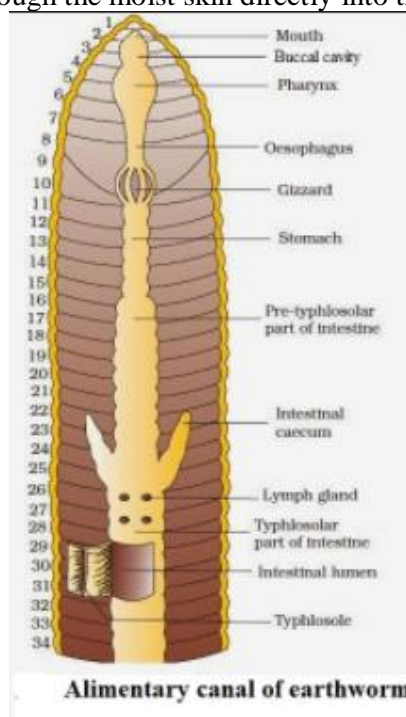
- The body wall of the earthworm is covered externally by a thin non-cellular **cuticle** below which is the **epidermis**, **two muscle layers (circular and longitudinal)** and an **innermost coelomic epithelium**.
- The **epidermis** is made up of a single layer of columnar epithelium which contains **secretory glandular cells**.
- **Digestive System:**
 - The alimentary canal is a straight tube and runs between first to last segment of the body.
 - A mouth present at the end opens into the **buccal cavity** (1-3 segments). This then leads into **muscular pharynx**. A small **oesophagus** is present between 5th-7th segments. It continues into a muscular **gizzard** (8-9 segments). It aids the grinding of the soil particles and decaying of leaves, etc.
 - The **stomach** is present between 9-14 segments. The earthworm feeds on decaying leaves and organic matter mixed with soil. **Calciferous glands** are present in the stomach. They neutralise the humic acid present in humus.
 - **Intestine** begins at the 15th segment and ends at the last segment. A pair of short and conical intestinal **caecae** project from the intestine on the 26th segment.
 - The characteristic feature of the intestine after 26th segment (except the last 23rd-25th segments) is the presence of internal median fold of dorsal wall called **typhlosole**. This increases the effective area of absorption in the intestine.
 - The alimentary canal opens to the exterior by a small rounded aperture called **anus**.

- The ingested soil is rich in organic matter. It passes through the digestive tract. In the digestive tract digestive enzymes breakdown complex food into smaller absorbable units. These simpler molecules are absorbed through intestinal membranes and are utilised.

- **Circulatory System:**

- *Pheretima* exhibits a **closed type of blood vascular system**, consisting of blood vessels, capillaries and heart.
- It shows closed circulatory system and therefore blood is confined to the heart and blood vessels.
- Contractions keep blood circulating in one direction.
- Smaller blood vessels supply the gut, nerve cord, and the body wall.
- **Blood glands** are present on the **4th, 5th and 6th segments**. They produce the cells of the blood and haemoglobin. Haemoglobin is dissolved in blood plasma.
- Blood cells are phagocytic in nature.

- Earthworms lack specialised breathing devices. **Respiratory exchange** occurs through moist body surface. Gases are exchanged through the moist skin directly into their blood stream.



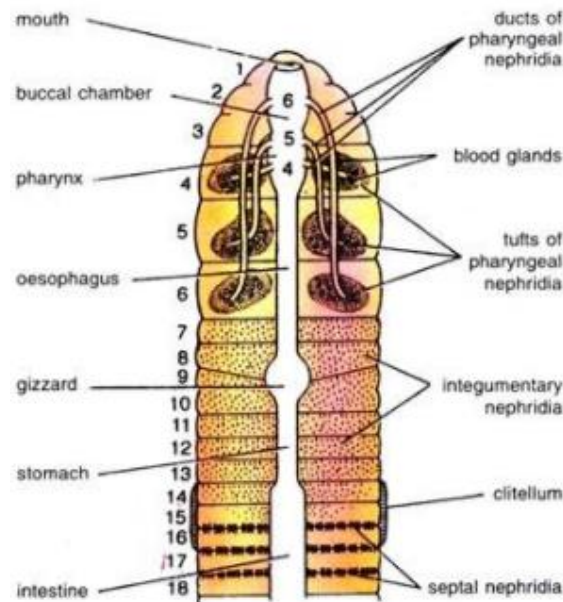
- **Excretory System:**

- The excretory organs in earthworm are called **nephridia** (sing.: *nephridium*). They are coiled tubules that are arranged segmentally. They. The three nephridial types are: **septal nephridia**, **integumentary nephridia** and **pharyngeal nephridia**.

- **Septal nephridia:** These are present on segment 15 at the last intersegmental septa. They are present on both the sides. They open into the intestine
- **Integumentary nephridia:** These are attached to lining of the body wall of segment 3 to the last that open on the body surface
- **Pharyngeal nephridia:** These are present as three paired tufts in the 4th, 5th and 6th segments.
- These different types of nephridia are basically similar in structure.
- Nephridia control and modulate the volume and composition of the body fluids.
- A nephridium begins as a funnel. It drains excess fluid from coelomic chamber. The funnel connects with a tubular part. This delivers the wastes into the digestive tube.

- **Nervous system:**

- It consists of ganglia that are arranged segmentally on the ventral paired nerve cord.
- The nerve cord bifurcates in the anterior region (3rd and 4th segments). It then encircles the pharynx. Finally it joins the cerebral ganglia from the dorsal side to form a nerve ring.
- The cerebral ganglia integrate sensory input along with other nerves in the nerve ring. They also command muscular responses of the body.



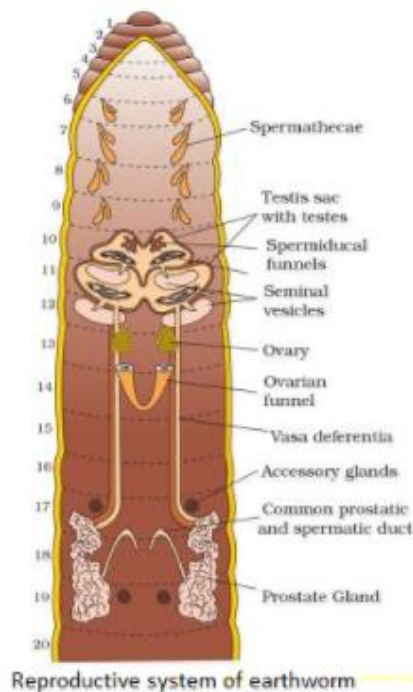
Pheretima. Different types of nephridia and general plan of their distribution.

- Sensory system possesses **organs sensitive to light and touch**. They are present as receptor cells. They distinguish the light intensities and help to feel the vibrations in the ground. Eyes are absent.
- Worms have specialised **chemoreceptors** (taste receptors) located in the anterior part of the worm which react to chemical stimuli.

- **Reproduction:**

- Earthworm is **hermaphrodite** (bisexual), i.e., testes and ovaries are present in the same individual.
- There are two pairs of testes present in the 10th and 11th segments. Their vasa deferentia run up to the 18th segment where they join the prostatic duct.
- There are two pairs of accessory glands. They are present in the 17th and 19th segments.
- The vasa deferentia is the common prostatic and spermatic duct. It opens to the exterior by a pair of male genital pores. These pores are present on the 18th segment on the ventro-lateral side.
- Four pairs of **spermathecae** are present. They are present in the segments from 6-9. One pair of spermatheca is present in each segment. They receive and store spermatozoa during copulation.
- **Spermathecae:** It is a sac or receptacle present in some female or hermaphrodite animals. In this sac sperm from the mate is stored until the eggs are ready to be fertilized.
- At the inter-segmental septum between the 12th and 13th segments a pair of ovaries is present.

- The ovaries open into ovarian funnels that are present beneath the ovaries. The ovarian funnels open into oviduct. They later join together and open on the ventral side to form single median female genital pore that is present on the 14th segment.
- During mating there is a mutual exchange of sperm between two worms.
- One worm finds another worm. Mating occurs when the worms juxtapose their gonadal openings opposite to each other. These gonadal openings are called **spermatophores**. They are used to exchange packets of sperms.
- The glands of clitellum produce cocoons. Into these cocoons mature sperm and egg cells are deposited along with the nutritive fluid.
- Fertilisation and development of ova takes place inside the cocoons. These cocoons are then released into the soil. The fertilized ova then falls off along with the cocoon from the worm. The worm embryos develop inside the cocoon.
- After approximately 3 weeks, each cocoon produces two to twenty baby worms. Four are produced on an average.
- Earthworm shows direct development of earthworms and there is no formation of larva.



- Earthworms are also called as ‘**friends of farmers**’. This is because they make burrows in the soil which makes it porous. This helps the developing plant roots to penetrate and respire.
- Earthworms are used for **vermicomposting**. In this method earthworms are used for breakdown of organic matter and soil thereby increasing soil fertility.
- They are used in fishing as bait.

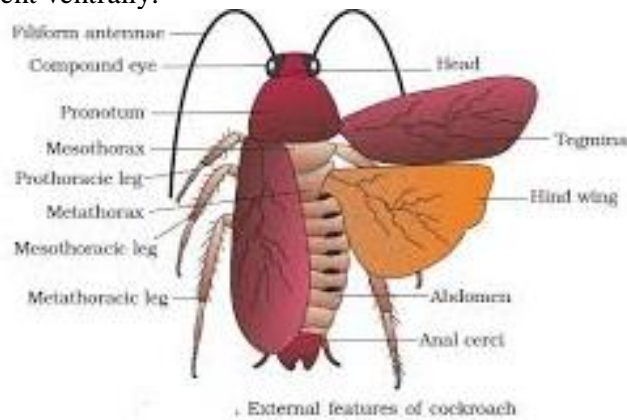
7.4: Cockroach:

- They are brown or black bodied organisms of Class Insecta in Phylum Arthropoda.
- In tropical regions brightly coloured cockroaches of red, yellow and green colour have been reported.
- They measure 0.-7-6 cm in length.
- They have long antenna, legs and a flat extension of the upper body wall that conceals their head.
- They are nocturnal omnivores.
- They live in damp places.
- They infest homes and are vectors of various diseases.

7.4.1: Morphology

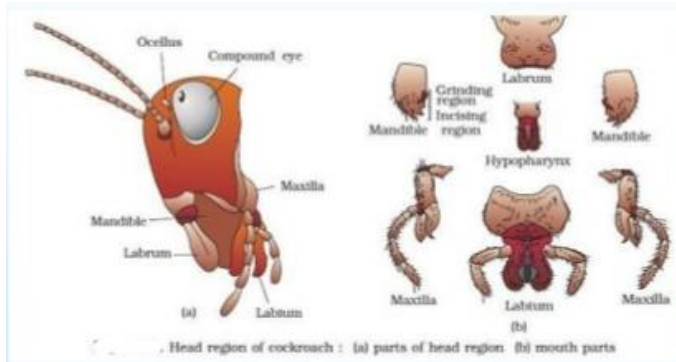
- The most widespread species of cockroach is *Periplaneta americana*.
- They are 33-54mm long.
- In males the wings are seen to extend beyond the abdomen.

- Their body is segmented with three distinct regions: **head, thorax and abdomen.**
- An exoskeleton covers the entire body. It is hard and made up of chitin.
- **Sclerites:** Hardened plates of exoskeleton in each segment that are joined to each other by thin and flexible articular membrane.
- **Arthroial membrane:** The thin and flexible membrane that joins the sclerites of each segment.
- **Tergites:** Sclerites present dorsally
- **Sternites:** Sclerites present ventrally.



- **Head:**
 - Triangular in shape and lies anterior at right angles to the longitudinal body axis.
 - Formed by the fusion of six segments.
 - Shows great mobility in all directions due to a **flexible neck.**
 - The head capsule bears a pair of **compound eyes.**
 - **Antennae** arise from membranous sockets that lie in the front of the eyes.
 - Antennae have sensory receptors that sense the changes in the environment.
 - Anterior end of the head bears mouth parts that have appendages specialised for **biting and chewing.**
 - The mouthparts consisting of a **labrum** (upper lip), a pair of **mandibles**, a pair of **maxillae** and a **labium** (lower lip). A median flexible lobe, acting as tongue (**hypopharynx**), lies within the cavity enclosed by the mouthparts.
- **Thorax:**
 - Consists of three parts- **prothorax, mesothorax and metathorax.**
 - The head is connected to the thorax by the **neck.**
 - The neck is a short extension of the prothorax.
 - Each thoracic segment bears a pair of walking legs
 - Two pairs of wings are present.
 - The first pair arises from mesothorax and the second pair arises from the metathorax.
 - **Tegmina:** The forewings or the mesothoracic wings of the cockroach. They are opaque, dark and leathery. They cover the hind wings when at rest.
 - **Hind wings:** They are the metathoracic wings. They are transparent, membranous and are used in flight.
- **Abdomen:**
 - Consists of **10 segments.**
 - **Females:** 7th sternum is **boat shaped**
 - 7th, 8th, and 9th sterna together form a **brood or genital pouch**
 - The **female gonopore, spermathecal pores and collateral glands** are present in the anterior part of the **brood.**
 - **Males:** **genital pouch or chamber** is present at the hind end of abdomen. 9th and 10th terga bind the genital pouch dorsally. The genital pouch is bound ventrally by the 9th sternum.
 - The dorsal part contains the **anus.** The **male genital pore** is ventral. The pouch also contains the **gonapophysis.**
 - A pair of short, threadlike anal styles are present in males. They are absent in females.

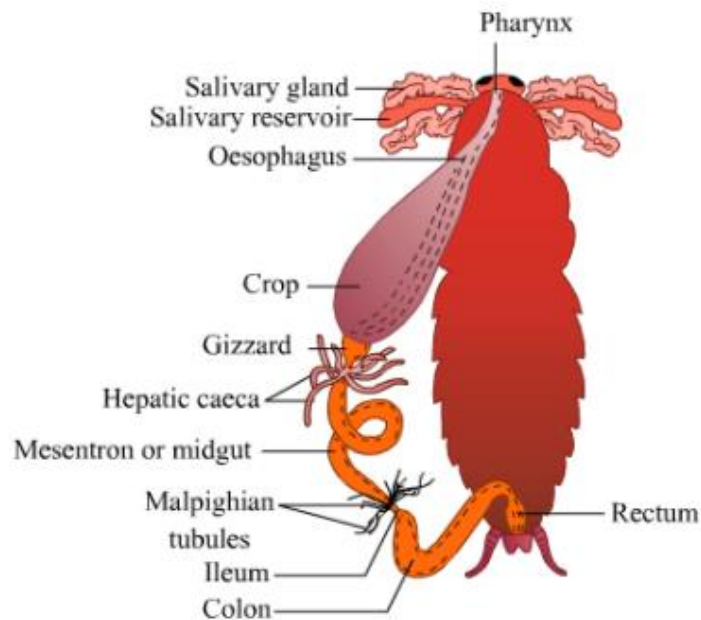
- **Anal cerci:** A pair of jointed filamentous structures borne on the 10th segment of both males and females.



7.4.2: Anatomy

- **Alimentary Canal/Digestive System:**

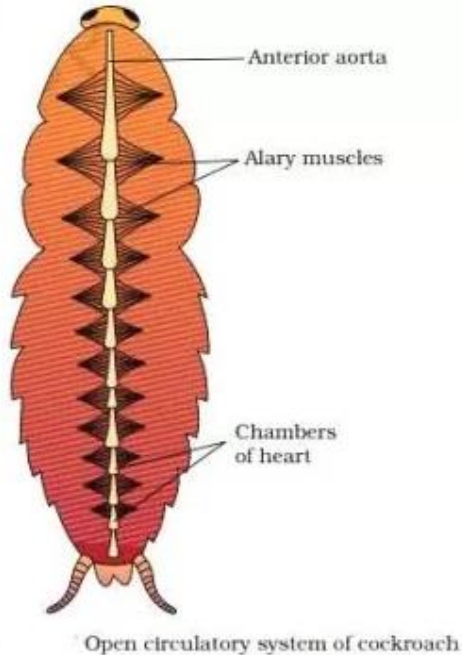
- Alimentary canal consists of three parts: **foregut, midgut and hind gut.**
- **Foregut:** It includes the following parts:
 - **Mouth:** It opens into a short tubular pharynx.
 - **Pharynx:** It leads to the narrow tubular oesophagus.
 - **Oesophagus:** A small tubular structure that opens into a sac like structure called as the crop.
 - **Crop:** A sac-like structure at the end of oesophagus. It is used for storing food.
 - The crop is followed by gizzard or proventriculus. It has an outer layer of thick circular muscles and thick inner cuticle forming six highly chitinous plate called teeth. Gizzard helps in grinding the food particles.
 - The entire foregut is lined by cuticle.
- **Midgut:** It consists of 6-8 blind tubules called hepatic or gastric caecae. It is present at the junction of foregut and midgut. It secretes digestive juice.
- **Malpighian tubules:** A ring of 100-150 yellow coloured thin filamentous tubules present at the junction of midgut and hindgut. They help in the removal of excretory products from the haemolymph.
- **Haemolymph:** It is a fluid, analogous to the blood in vertebrates that circulates in the interior of the arthropod body remaining in direct contact with the animal's tissues. It is composed of a fluid plasma in which hemolymph cells called hemocytes are suspended.
- **Hindgut:** It is broader than midgut. It is differentiated into ileum, colon and rectum. The rectum opens out through anus.



Alimentary canal of cockroach

• Blood Vascular System/Circulatory System:

- Cockroach shows the presence of an open circulatory system.
- Poorly developed blood vessels that open into central cavity called as the **haemocoel**.
- Visceral organs are present in the haemocoel. They are surrounded by and are in direct contact with the haemolymph.
- The haemolymph is colourless. It consists of plasma and haemocytes. Both plasma and haemocytes are colourless.
- **Heart:** It is made up of an elongated muscular tube that lies along mid dorsal line of thorax and abdomen. It consists of 13 funnel shaped chambers. Ostia are present on either side.
- Blood enters heart through ostia from sinuses. It is then pumped out anteriorly to sinuses again.
- **Ostia:** A pair of slit-like openings that are present in each chamber of heart at the posterior-end. It allows the entry of blood into the heart.



• Respiratory System:

- It is a network of tubes like trachea that ends at 10 pairs of small holes called **spiracles**. These spiracles are present laterally.
- **Spiracles:** Spiracles are external openings of the respiratory system seen in some animal species. They are found in insects, spiders and some species of fish and whales. The function of spiracles is to help oxygen to reach internal respiratory organs. The internal respiratory organs vary with animals, such as lungs in whales and tracheae in insects.
- **Tracheoles:** Thin branching tubes of trachea that carry oxygen from the air to all parts of the body. Exchange of gases takes place through diffusion.
- **Sphincters:** Muscle-like tissues that control the opening of spiracles.

• Excretory System:

- Excretion is performed by Malpighian tubules.
- Each tubule is lined by glandular and ciliated cells.
- They absorb nitrogenous waste products and convert them into uric acid which is excreted out through the hindgut. Therefore, this insect is called **uricotelic**.
- The fat body, nephrocytes and urecose glands also support the Malpighian tubules in excretion.

• Nervous System:

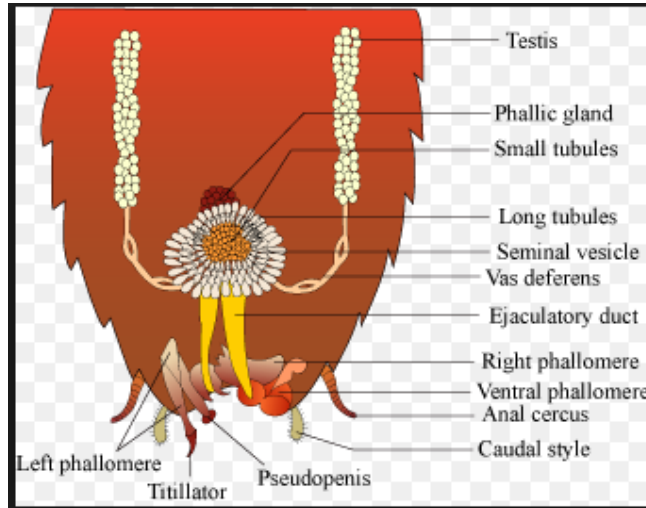
- It consists of a series of ganglia. These ganglia are fused and arranged segmentally. They are joined by paired longitudinal connectives on the ventral side.

- Three ganglia are present in the thorax. Six ganglia are present in the abdomen.
- The nervous system of cockroach is spread out in the entire body.
- The nervous system is divided between the head and the ventral (belly-side) part of its body. Therefore, if the head of a cockroach is cut off, it will still live for as long as one week.
- The **brain** is present in the head region and is represented by **supra-oesophageal ganglion** which supplies nerves to antennae and compound eyes.
- **Supra-oesophageal ganglion:** The supraesophageal ganglion is also called as the "arthropod brain" or "a microbrain". It is the first part of the central nervous system of arthropods, especially insects.
- **The sense organs:** Antennae, eyes, maxillary palps, labial palps, anal cerci, etc.
- **Compound eyes:** Present at the dorsal surface of the head. Each eye is made up of about 2000 hexagonal **ommatidia** (sing.: *ommatidium*).
- These ommatidia help a cockroach to receive several images of an object. This kind of vision is known as **mosaic vision**. It has increased sensitivity but less resolution. It is sensitive during night. Therefore, it is called as nocturnal vision
- **Ommatidia:** Units comprising the compound eyes of arthropods like insects, crustaceans and millipedes. (Singular: ommatidium). Each ommatidium consists of a cluster of photoreceptor cells that are surrounded by support cells and pigment cells. The outer part of the ommatidium is covered by a transparent cornea.

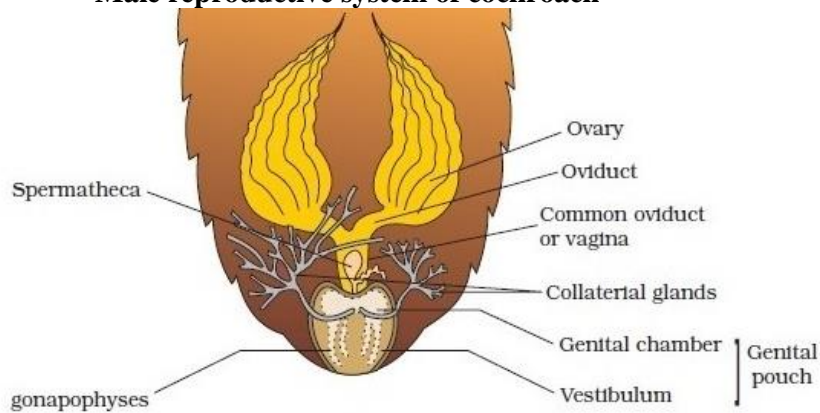
- **Reproduction:**

- Cockroaches are dioecious.
- Both sexes have well developed reproductive organs.
- **Male Reproductive System:**
- It consists of a pair of testes one lying in each lateral side between the 4th-6th abdominal segment.
- Vas deferens arises through each testis.
- Vas deferens opens into the ejaculatory duct through the seminal vesicles.
- The ejaculatory duct opens to the male gonopore.
- **Gonopore:** It is the opening of the ejaculatory duct in males. It is located ventral to anus.
- **Accessory reproductive gland:** Characteristic mushroom shaped gland present in the 6th-7th abdominal segments.
- The external genitalia are represented by **male gonapophysis or phallomere**
- **Phallomere:** These are chitinous asymmetrical structures surrounding the male gonopore.
- The sperms are glued together in the form of bundles and are stored in the seminal vesicles. These bundles are called **spermatophores**. They are discharged during copulation.
- **Spermatophores:** Bundles of sperms sticking together and released during ejaculation.
- **Female Reproductive System:**
- It consists of 2 large ovaries lying laterally in the 2nd-6th abdominal segments.
- Each ovary consists of a group of eight ovarian tubules. These ovarian tubules are called **ovarioles**. Each ovariole consists of a chain of developing ova.
- Oviducts of each ovary come together to form single median **oviduct**. It is also called as the **vagina**. It opens into the **genital chamber**. A pair of **spermatheca** opens into the genital chamber. It is present in the 6th segment.
- **Spermatheca:** a sac for storing sperms in the female reproductive tract present in various lower animals, especially insects.
- Sperms are transported as spermatophores.
- Fertilised eggs are enclosed in capsules called as **oothecae**.
- **Ootheca:** It is a large dark reddish to blackish brown capsule about 8mm long. They are laid or attached to a suitable surface. The surface should be near a food source and have relative high humidity.
- On an average 9-10 oothecae are produced by females. Each ootheca contains around 14-16 eggs.
- The development of eggs is **paurometabolous**.

- **Parametabolous development:** It is a form of incomplete metamorphosis where the development involves a nymph stage.
- **Nymph:** It is a stage in the incomplete metamorphosis of certain insects where the immature form resembles the adult in appearance but is smaller in size. The nymph grows by moulting to reach adult stage. The nymph stage just before the adult stage has wing pads but only adults have wings.
- Most cockroaches are wild and have no economic importance.
- Some are pests and destroy and contaminate food.
- They are also vectors of various bacterial diseases.



Male reproductive system of cockroach



Female reproductive system

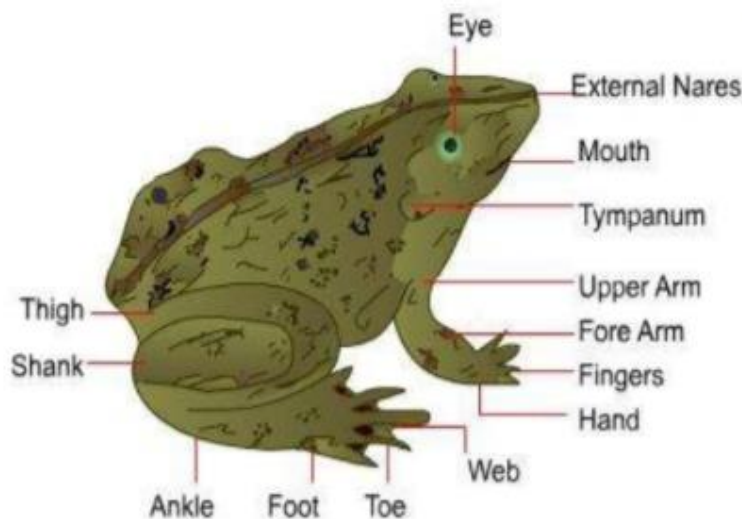
7.5: Frog

- Frogs are amphibious vertebrates. They can live on both land and freshwater.
- They belong to class Amphibia of Phylum Chordata.
- The most common Indian species is *Rana tigrina*.
- They are cold-blooded or **poikilotherms**.
- **Poikilotherms:** They are organisms whose body temperature varies with the environment. Therefore, they do not have a constant body temperature.
- **Camouflage:** The ability to change their body colour to blend with the surroundings and hide from their enemies.
- **Mimicry:** The protective colouration of the organism that blends with the environment and camouflages it from the enemy.
- **Aestivation:** The dormant state of organisms during summer. This helps the organism to survive the high heat of summer. It is also called as summer sleep. The metabolic and physiological activities of the organism at this stage are at their minimum.

- **Hibernation:** The dormant state of organisms during winter. This helps the organism to survive the extreme cold of winter. It is also called as winter sleep. The metabolic and physiological activities of the organism at this stage are at minimum.

7.5.1: Morphology:

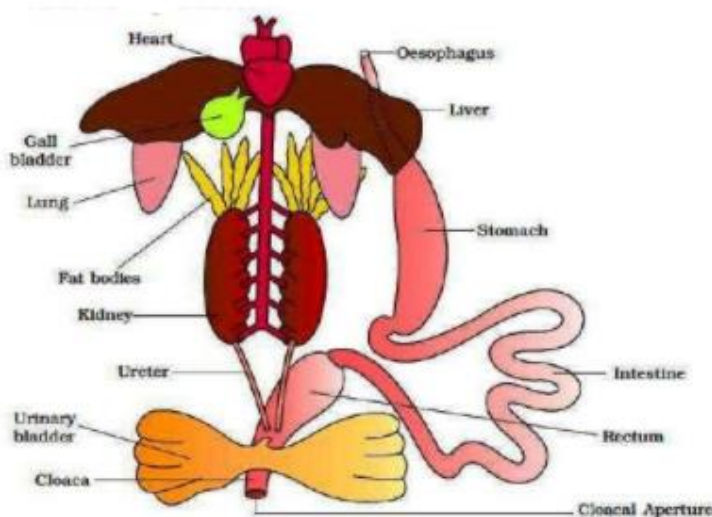
- The skin is smooth is slippery due to the presence of mucus. This helps to maintain the skin at moist conditions always.
- The colour of dorsal side of body is generally olive green with dark irregular spots. The ventral side is a pale yellow.
- The frog doesn't drink water. Instead it absorbs it directly through the skin.
- Body of a frog is divisible into **Head and Trunk**.
- Neck and tail are absent.
- A pair of nostrils is present above the mouth.
- Eyes are bulged and covered with a **nictitating membrane**.
- **Nictitating membrane:** It is a whitish or translucent membrane that forms an inner eyelid in birds, reptiles, and some mammals. It can be drawn across the eye to protect it from dust and keep it moist. In frogs this membrane protects the eyes while in water.
- **Tympanum:** A membranous structure on either side of the eye representing the ear. It receives sound signals.
- **Forelimbs and hindlimbs:** They help in walking, swimming, leaping and burrowing.
- **Hind limbs:** They are larger and muscular than forelimbs. They end in 5 digits.
- **Forelimbs:** They are smaller and less muscular than the hind limbs. They end in 4 digits.
- Feet have webbed digits to help in swimming.
- Frogs are dioecious.
- Male frogs are characterised by the presence of sound producing vocal sacs and a copulatory pad of the first digit of forelimbs.



7.5.2: Anatomy

- **Digestive System:**
 - It consists of an alimentary canal and digestive glands.
 - Alimentary canal is short as frogs are carnivores and the length of the intestine is reduced.
 - Mouth opens into buccal cavity that leads to oesophagus through pharynx.
 - Oesophagus is a short tube. It joins the stomach. The stomach continues into the intestine. The intestine opens into the rectum and finally opens into the outside through cloaca.
 - **Cloaca:** a common chamber at the end of the digestive tract. It is used for the release of both excretory and genital products in vertebrates (except most mammals) and certain invertebrates.
 - **Pancreas:** It is a digestive gland that produces pancreatic juice which contains digestive enzymes.

- **Bilobed tongue:** It helps to capture food.
 - **Stomach:** It secretes gastric juice and HCl. This helps in digestion of food.
 - **Chyme:** Partially digested food that is formed in the stomach.
 - Chyme is passed from the stomach into the duodenum
 - **Duodenum:** It is the first part of the intestine. It receives bile from gall bladder and pancreatic juice from pancreas through a common bile duct. Bile emulsifies fats and pancreatic juice digests proteins and carbohydrates.
 - Final digestion occurs in the intestine.
 - Digested food is absorbed by the numerous villi and microvilli.
 - **Microvilli:** These are the numerous finger-like projections extending from the inner wall of the intestine. They increase the surface area for absorption.
 - Undigested solid waste moves into rectum and passes out through cloaca.
- **Respiration in Water:**
 - In water they show **cutaneous respiration**.
 - In this the skin acts aquatic respiratory organ.
 - Dissolved oxygen in the water is exchanged through skin by diffusion.
 - **Respiration on Land:**
 - They show **pulmonary respiration**.
 - Buccal cavity, skin and lungs act as respiratory organs.
 - The lungs are a pair of elongated, pink coloured sac-like structures present in the upper part of the trunk region (thorax).
 - Air enters into the buccal cavity through the nostrils. It then enters the lungs.
 - During aestivation and hibernation respiration occurs through skin.



Diagrammatic representation of internal organs of a frog including the digestive system

- **Circulatory System:**
 - It is well developed and shows closed type circulatory system.
 - They also have a lymphatic system.
 - The blood vascular system involves **heart, blood vessels and blood**.
 - The lymphatic system consists of **lymph, lymph channels and lymph nodes**.
 - **Heart** is a muscular structure situated in the upper part of the body cavity. It has **three chambers** consisting of two atria and one ventricle. The heart is covered by a membrane called pericardium.
 - A triangular structure called **sinus venosus** joins the right atrium.
 - Major veins called **vena cava** supply blood to the heart.
 - The ventricle opens into **conus arteriosus**. It is a saclike structure present on the ventral side of the heart.
 - The blood from the heart is carried to all parts of the body by the arteries (**arterial system**).

- The veins collect blood from different parts of body to the heart and form the **venous system**.
- **Hepatic portal system:** Special venous connection between liver and intestine
- **Renal portal system:** Specialised venous connection present between the kidney and lower parts of the body.
- **Blood:** The blood consists of plasma and cells. The blood cells include **RBC (red blood cells) or erythrocytes, WBC (white blood cells) or leucocytes and platelets**.
- **RBC's** are nucleated and contain red coloured pigment haemoglobin.
- The lymph is different from blood. It lacks RBCs and few proteins.
- The blood transports nutrients, gases and water to the respective sites during the circulation.
- The circulation of blood is caused due to the pumping action of the muscular heart.

- **Excretory System:**

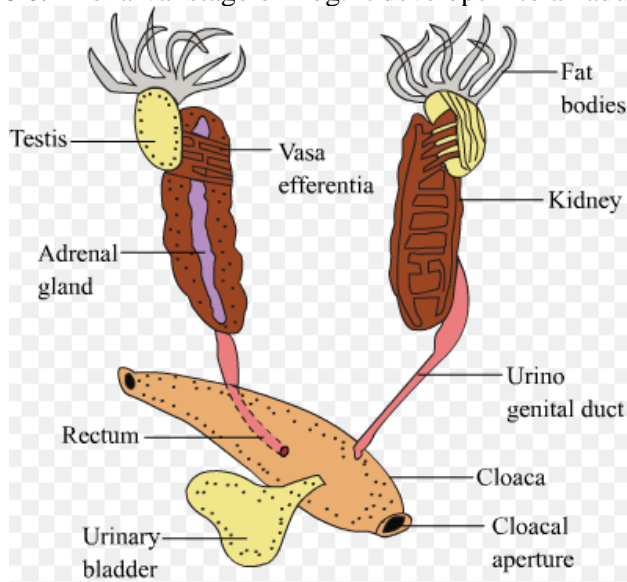
- It is the organ system responsible for the elimination of nitrogenous wastes from the body.
- It consists of a pair of **kidneys, ureters, cloaca and a urinary bladder**.
- **Kidney:** They are red, bean-like structures located in the posterior part of the body on either side of the vertebral column.
- The structural and functional unit of kidney is the **nephron**. Each kidney contains numerous such nephrons or **uriniferous tubules**.
- **Ureters:** They are tubular structures that arise from the kidney. They are urogenital duct and open into the cloaca.
- In females the oviduct and ureters open separately into cloaca.
- **Urinary bladder:** It is thin walled and present ventral to the rectum. The rectum also opens into the cloaca.
- **Ureotelic:** Animals that excrete nitrogenous waste in the form of urea. Frog is a ureotelic animal.

- **Control and Co-ordination:**

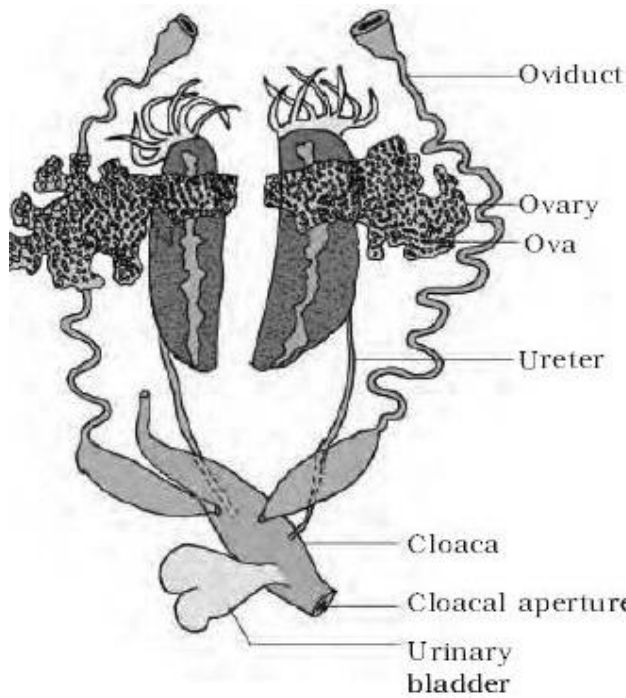
- It is highly evolved in frogs.
- It includes both **neural system and endocrine glands**.
- **Endocrine glands:** The secretory tissues which release various chemicals called as **hormones** that brings about chemical co-ordination in animals. The important endocrine glands in frog are pituitary, thyroid, parathyroid, thymus, pineal body, pancreatic islets, adrenals and gonads.
- **Nervous system:** It is organised into **central nervous system, peripheral nervous system and autonomic nervous system**.
- 10 pairs of cranial nerves arise from the brain.
- Brain is enclosed in a bony structure called as the **cranium or the brain box**.
- The brain is divided into **fore-brain, mid-brain and hind-brain**.
- **Forebrain:** It includes olfactory lobes, paired cerebral hemispheres and unpaired diencephalon.
- **Midbrain:** It is characterised by a pair of optic lobes.
- **Hind-brain:** It is made up of cerebellum and medulla oblongata. The medulla oblongata leaves through the foramen magnum and continues into spinal cord. The spinal cord is enclosed in the vertebral column
- **Sense organs:**
- Organs of touch: **sensory papillae**
- Organs of taste: **taste buds**
- Organs of smell: **nasal epithelium**
- Organs of vision: **eyes**
- Organs of hearing: **tympanum**
- Eyes and internal ears are well organised structures.
- The remaining (sensory papillae, taste buds, nasal epithelium) are cellular aggregations around nerve endings.
- **Eyes:** A pair of structure present in the orbit in skull. They are simple eyes with only one unit.
- **Ears:** External ears are absent. Tympanum can be seen externally. It is the organ for hearing as well as balance or equilibrium.

- **Reproduction:**

- They have well-organised male and female reproductive systems.
- **Male reproductive system:**
- It includes a pair of yellowish ovoid testes.
- They adhere to the upper part of the kidney by a double fold of the **peritoneum** called as the **mesorchium**.
- **Peritoneum:** It is the serous membrane lining the cavity of the abdomen and covering the abdominal organs.
- **Mesorchium:** It is the fold of peritoneum that attaches the testis to the upper part of the kidney.
- **Vasa efferentia:** They are 10-12 in number and arise from the testes. They enter the kidneys on the side and open into **Bidder's canal**.
- **Bidder's canal:** Bidder's canal is present inside kidney of frog. It receives sperms from testes via a number of vasa efferentia. It communicates with the urinogenital duct and opens into the cloaca.
- **Cloaca:** A small median chamber that is used to pass faecal matter, urine and sperms to the exterior.
- **Female Reproductive System:**
- It consists of a pair of ovaries situated near the kidneys.
- There is no functional connection between the ovaries and the kidneys.
- **Oviduct:** A tubular structure that connects the ovary and the cloaca. It opens separately into the cloaca.
- A mature female can lay around 2500-3000 eggs at a time.
- Fertilisation is external and occurs in water.
- Frog life cycle shows **complete metamorphosis** where the development includes a larval stage.
- **Tadpole:** The larval stage of frog. It develops into an adult after metamorphosis.



Male reproductive system of frog



Female Reproductive System of frog

- Frogs are beneficial for mankind because they eat insects and protect the crop.
- Frogs maintain ecological balance because these serve as an important link of food chain and food web in the ecosystem.
- In some countries the muscular legs of frog are used as food by man