Simple permanent tissues consist of similar types of cells. They are classified into parenchyma, collenchyma and sclerenchyma. A complex permanent tissue is a group of more than one type of tissues having common origin and working together as a unit to perform a function. These tissues are concerned with transportation of water, minerals and nutritions. Xylem and phloem are complex permanent tissues.

Three types of tissue systems are found in plant organs like root, stem and leaf. Epidermal tissue system is represented by the epidermis and the associated organs like cuticle, hairs, stomata etc. Ground tissue system is made up of hypodermis, cortex, endodermis, pericycle, and pith while vascular tissue system consists of xylem and phloem.

In most of the dicotyledons, after completion of the primary growth, further increase in girth takes place due to formation of secondary tissues. The secondary growth involves lateral meristems like vascular cambium and cork cambium.

The lengthwise growth of roots and stems is due to apical meristem and this type of growth is known as primary growth. The secondary growth involves lateral meristem like vascular cambium and cork cambium. These are the secondary tissues responsible for growth in breadth or girth.

Exercise

1. Put a dark colour in a given circle for correct answer :

(1) The tissue in which cells are having property of cell divisions is known as :

(A) Permanent tissue ◯ (B) Meristematic tissue ◯

(C) Xylem ◯ (D) Phloem ◯

(2) The meristem which is responsible for the linear growth in the plant is :

(A) Lateral meristem ◯ (B) Apical meristem ◯

(C) Vascular cambium ◯ (D) Cork cambium ◯

(3) Which of the following is primary meristem ?

(A) Intercalary meristem ◯ (B) Lateral meristem ◯

(C) Vascular cambium ◯ (D) Cork cambium ◯

(4) Which of the following tissues possesses dead thick walled cells ?

(A) Parenchyma tissue ◯ (B) Collenchyma tissue ◯

(C) Sclerenchyma tissue ◯ (D) Meristematic tissue ◯

(5) In which type of tissue the inner wall of cell shows the deposition of pectin ?

(A) Parenchyma tissue ◯ (B) Collenchyma tissue ◯

(C) Sclerenchyma tissue ◯ (D) Meristematic tissue ◯

(6) Which of the following tissues provides elasticity and flexibility to the organs ?

(A) Parenchyma tissue ◯ (B) Collenchyma tissue ◯

(C) Sclerenchyma tissue ◯ (D) Meristematic tissue ◯

(7) Which of the following is the living component of xylem ?

(A) Tracheid ◯ (B) Xylem Vessel ◯

(C) Xylem parenchyma ◯ (D) Xylem fibre ◯

(8) Which of the following is the dead component of phloem ?

(A) Sieve cell ◯ (B) Companion cell ◯

(C) Phloem parenchyma ◯ (D) Phloem fibre ◯

(9) Casparian strips can be seen in the endodermis of

(A) Dicot root ◯ (B) Monocot stem ◯

(C) Monocot leaf ◯ (D) Dicot stem ◯

(10) The collenchymatous hypodermis can be seen in

(A) Monocot root ◯ (B) Monocot stem ◯

(C) Dicot stem ◯ (D) Dicot leaf ◯

(11) The sclerenchymatous hypodermis can be seen in

(A) Dicot stem ◯ (B) Monocot stem ◯

(C) Dicot root ◯ (D) Dicot leaf ◯

(12) In which plant organ stele is radial, alternate and polyarch ?

(A) Monocot stem ◯ (B) Monocot root ◯

(C) Dicot stem ◯ (D) Dicot root ◯

(13) In which plant organ stele is radial, alternate and tetrach?

(A) Monocot stem ◯ (B) Monocot root ◯

(C) Dicot stem ◯ (D) Dicot root ◯

(14) Bulliform cells are found in

(A) Dicot leaf ◯ (B) Monocot leaf ◯

(C) Dicot stem ◯ (D) Monocot stem ◯

2. Answer in short :

(1) Define meristematic tissue

(2) Define complex permanent tissue

(3) What is spring wood ?

(4) Why dicot leaf is known as dorsiventral leaf ?

(5) Define : Radial and collateral types of vascular bundles.

3. Do as directed :

(1) Differentiate between collenchyma and Sclerenchyma

(2) Differentiate between Heart wood and Sap wood

(3) Give reason : Bulliform cells are present in the maize leaf

(4) Give reason : Collenchyma tissue is considered as living mechanical tissue

(5) Differentiate between isobilateral leaf and dorsiventral leaf

(6) Write properties of meristematic tissues

(7) Name the regions which form ground tissue system

(8) Give location and functions of Casperian Strips.

(9) Give location and functions of vascular cambium

(10) Give location and functions of lateral meristem

4. Long answer questions :

(1) Describe the structure and functions of various components of xylem.

(2) Describe the types of simple permanent tissues

(3) Explain the structure and functions of various components of phloem.

(4) Explain the different types of tissue systems found in the various organs of plants.

(5) How the vascular cambium is responsible for secondary growth ? Explain.

(6) Explain the internal structure of monocot root.

(7) Describe the internal structure of dicot stem with the help of labelled diagram.

(8) Explain the internal structure of monocot leaf.

(9) Describe the internal structure of dicot leaf.

(10) Explain, with labelled diagram, the stele of dicot root.

Naturalist Jaikrishan Indraji

Naturalist Jaikrishan was born in Girnara Brahmin caste in Lakhapat village of Kachcch on the day of Aso sudh dasham (Vijayadashmi) in Sanwat 1905. His father's name was Indraji Thakar. During his childhood he had an abnormal interest in physical exercise which was proved worth during his frequent visits to jungle. He spent his adolescence in Mathura.

In his Dec. 22, 1929 issue of "Navjivan" Pujya Gandhiji wrote about Jaikrishan Indraji that "many times he wandered in Barda Dungar for the search of plants. He made herbaria of many plant specimens in his own house. He was having tremendous interest in the identification of plants and hence, I always considered him as an ideal student".

Shri Jaikrishan didn't receive any degree in Science from any university but he worshipped science. He was an avid follower of science and inspired the generation of students to follow the path of science. Day and night he worshipped Botany. In a real sense he was the Linnaeus of Gujarat. He was also a great lover of nature and books.

Under the guidance of Pandit Bhagwanlalbhai he first started identifying flowering plants and as per his direction he read the book of botany written by Hucker and came to know the scientific names of plants. After that he came in contact with Dr. Sakharm Arjun (Botanist) who introduced Jaikrishan to Dr. Mc Donald (Botany Teacher). Many other European friends have appreciated his amazing knowledge of Botany and helped him. He learnt the properties of dynamism and regularities from them. In the beginning he was writing about the plants in monthly magazine "Vaidh Kalpataru". Later on he wrote books like "Vanspatishastra" and "Kachchh Ni Jadi Butti".

Many rare books of English literature were in his home library and some of those books were gifted to him by his British friends. The Volumes of the Hucker were his most favourite. The life of Jaikrishan was for the people. The early half of his life was spent in the study of botany while the later half was spent in worshipping god . Lotus was his favourite flower.

This great soul breathed his last in Bhuj on Magsar Sudh Bij of Sanwat 1968.

4

Animal Tissue

As you have studied that body organization process remains dynamic where multicellularity resulted with complexity due to which there was need for division of labour and coordination. As a result, group of cells structurally and functionally became similar and organised into tissues. Its sequential formation is as follows :

Complex body
↑
Organ Systems
↑
Organs
↑
Tissues
↑
Cells

The present chapter is aimed to understand various types of tissues in animals in general. Animals contain four basic types of tissues. Each basic tissue has its own characteristics and distinguished appearance. These basic tissues are :

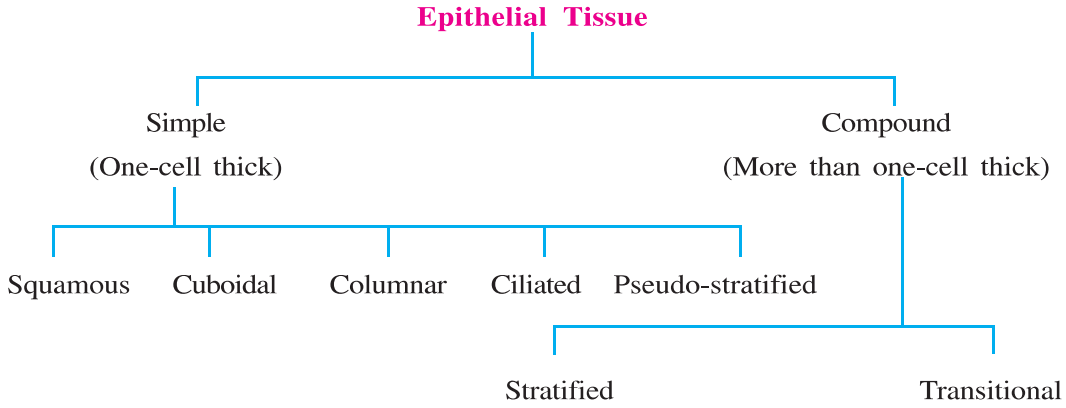
(1) Epithelial tissue (2) Connective tissue (3) Muscular tissue (4) Nervous tissue

(1) Epithelial tissue : The epithelial tissue is highly specialised to perform the functions of protection, absorption and secretion. It covers the external surface of the body and internal free surfaces of many organs. According to the function the cells, arrangements are different. As for example, the skin and most of the organs are covered by an epithelial membrane for protection whereas some of the epithelial surfaces are absorptive or secretary also.

In an epithelial tissue, the cells are arranged very close to each other with very little extracellular material or matrix which is a product of these epithelial cells. Their cells rest on

a non-cellular basement membrane. The lining of the skin, alimentary canal, blood vessels, digestive glands, respiratory organs etc. are covered by epithelial tissue. Based on the structure and function, epithelial tissues are divided into two main groups: covering epithelia and glandular epithelia.

The different types of epithelial tissue are as follows :



(A) Simple Epithelium : The cells in a simple epithelium are arranged in a single layer. The intercellular matrix does not occur. Various kinds of simple epithelia can be described on the basis of the form of the cells.

(i) Squamous epithelium : The cells of this kind of epithelium are extremely thin and flat. All the cells are arranged edge to edge and form delicate lining or covering. They are joined by cement material. In surface view, this tissue seems to be composed of flat tiles like that of a pavement. It is because of this appearance it is often known as the pavement epithelium. Cells are thin, flat and polygonal and with prominent round or oval nucleus in the centre. Its main function is protection of the underlying tissue. The outermost layer of skin of frog is made up of squamous epithelium. It forms the inner lining of lung alveoli, lining of blood vessels, Bowman's Capsules of the kidney, peritoneum of body cavity, etc.

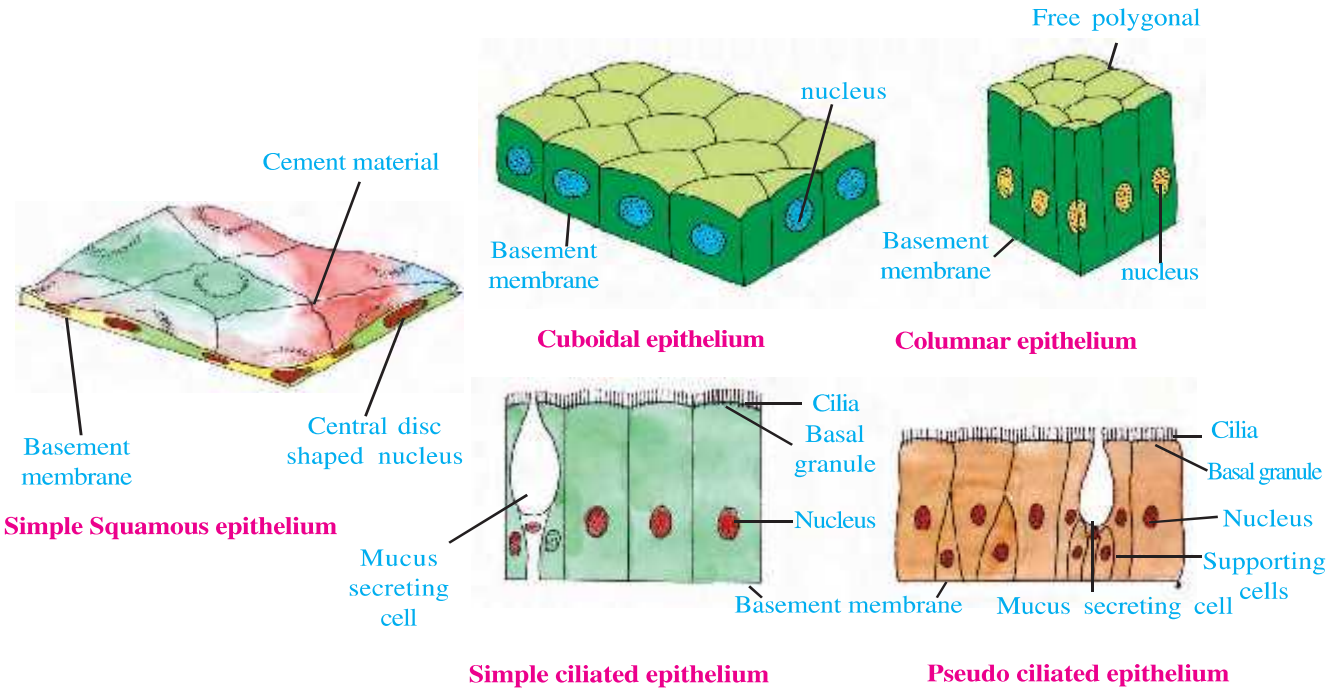
(ii) Cuboidal epithelium : The cuboidal cells are square in vertical sections; they are polygonal in horizontal section. In addition to protection, these cells participate in secretion (gastric juice, hormones, etc), excretion and absorption. The cells of absorptive surfaces often bear microvilli on their free ends. e.g. proximal tubules of kidneys, salivary glands, pancreatic ducts, thyroid gland and ovary.

(iii) Columnar epithelium : Cells of this type of epithelium are elongated and are placed side by side like tall pillars. Their inner ends are generally narrow but free ends are broad having polygonal surface. The function of columnar epithelium is secretion or absorption. The simple columnar epithelium forms the lining layer of the mucous membrane of the stomach, intestine, gall bladder and of the urinogenital organs and their ducts.

(iv) Ciliated epithelium : This is merely a modification of the columnar epithelium. Cells bear thin protoplasmic processes on their free surfaces called cilia (as per diagram). Hence an epithelium is known as ciliated epithelium. Cilia are furnished with extremely delicate vibrating hair-like protoplasmic processes. The function of the cilia is to move

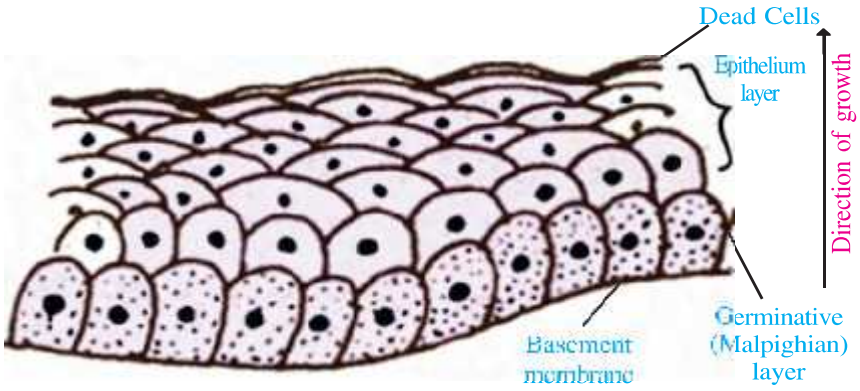
particles, free cells and mucus in a specific direction. They are present in auditory tube, uriniferous tubule, respiratory tract, etc.

(v) Pseudo-stratified epithelium : It is the simple columnar epithelium in which the regular arrangement of the cells is distorted. The cells of this type of epithelium are also twisted with respect to each other giving a false appearance. Cells are arranged in single layer, but appear multi-layered. This type of epithelium is present in the inner linings of trachea, large bronchi and helps to remove mucus.



(B) Compound epithelium : There are only two kinds of compound epithelia which are made of several layers of cells. These are (i) stratified and (ii) transitional. The stratified epithelium appears where there is much wear and tear, such as in the epidermis of skin, the lining of the mouth cavity, the tongue, oesophagus and vagina of mammals. It provides a durable covering to these organs. The cells forming the different layers of this epithelium are not all of the same kind. Due to erosion the cells towards the surface becomes flat and are removed, whereas the lower cells by division go on adding new cells towards upper surface. It consists of more than one layer of cells and gives a stratified appearance. The lower layer of cells arranged on the basement membrane is called germinative layer or malpighian layer. The main function of this type of epithelium is protection to underlying tissues. In stratified cuboidal epithelium, the superficial cells are cuboidal in shape. Such tissue is present in the inner surface of larger salivary gland and pancreatic ducts. Further stratified squamous epithelia are of two types: (i) stratified squamous non-keratinised and (ii) stratified squamous keratinised. When the surface cells contain insoluble protein (keratin), the tissue is called keratinised epithelium.

Another special type of compound epithelium is the transitional epithelium. The transitional type occurs within the passages of the excretory organs.



Stratified epithelium

(2) Connective tissue : The connective tissue is the group of cells and matrix containing of intercellular substance secreted by cells themselves. Cells are quite widely spaced. The connective tissue named so, because its chief function is to connect together the other tissues of the body.

The functions of the tissue are :

(i) to connect up structures,

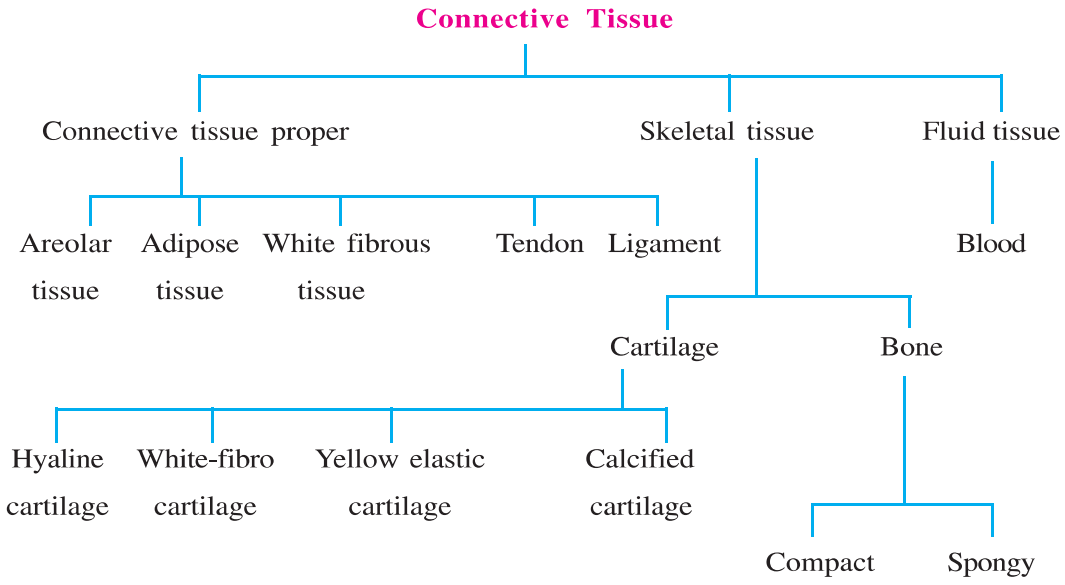
(ii) to form packing around organs,

(iii) to replace tissues which have been destroyed by injury,

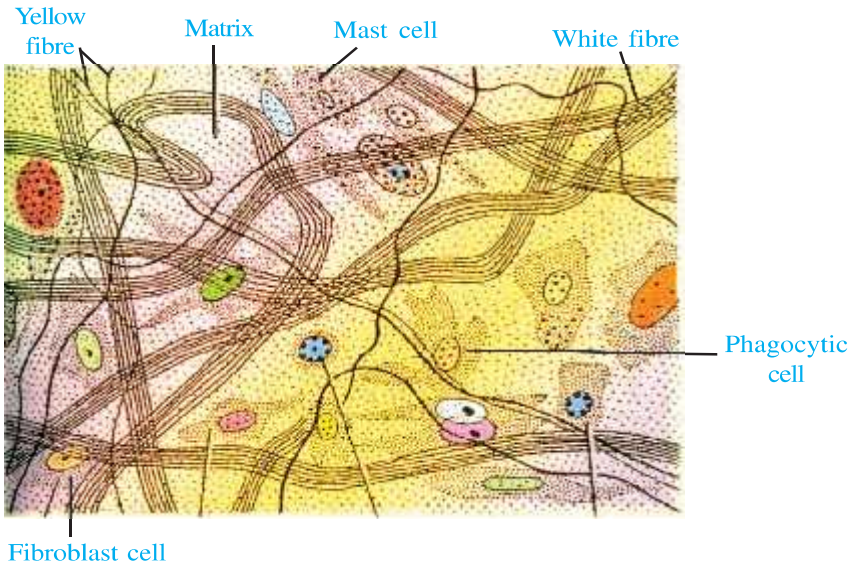
(iv) to combat foreign toxins and

(v) to form a supporting framework (Skeleton in function).

Connective tissues fall into the following three main groups :



(A) Connective tissue proper : The term connective tissue obviously denotes a tissue which connects parts of the body together. It includes five types: (i) areolar (ii) adipose (iii) white fibrous (iv) tendon and (v) ligament.

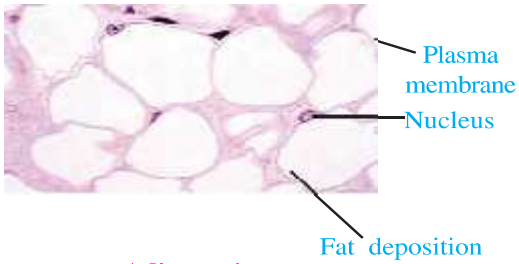


Areolar tissue

Areolar tissue

This is the simplest and the most widely distributed connective tissue. It is also called loose connective tissue. It is made up of fibres and cells. There are two types of fibres: White fibres are wavy, unbranched and are arranged in bundles. Yellow fibres are few in number, more slender than the white fibres and are not arranged in bundles. They are single fibres branched and joined with one another to form a delicate network. The white fibres are formed of a substance called protein collagen. The yellow fibres are made of elastin.

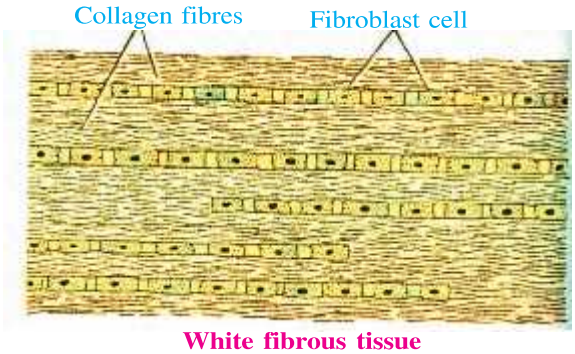
Mainly types of cells found in ground substance are fibroblast, macrophages (histocytes) and mast cells. Of these fibroblasts are the main cells of the tissue. They synthesize two kinds of proteins – collagen and elastin. The other chief type of cell is phagocytic cell or histocyte. It is able to move and ingest foreign particles, and is thus called macrophage. Thus these cells help in the defense of the body. The mast cells are also irregular in shape and large in size. They contain three active substances: heparin, histamine and serotonin.



Adipose tissue

Adipose tissue

The adipose tissue differs little from areolar tissue except that it contains a much higher percentage of fat cells (adipocytes); which constitute the principal components of this tissue. Besides adipocytes, it contains fibroblasts, macrophages, collagen fibre and elastic fibres. The adipose tissue occurs in abundance in the subcutaneous tissue; here it helps to conserve the body heat. Mainly tissues present beneath the skin, around kidneys and in mesenteries and bone marrow.



White fibrous tissue

White fibrous tissue

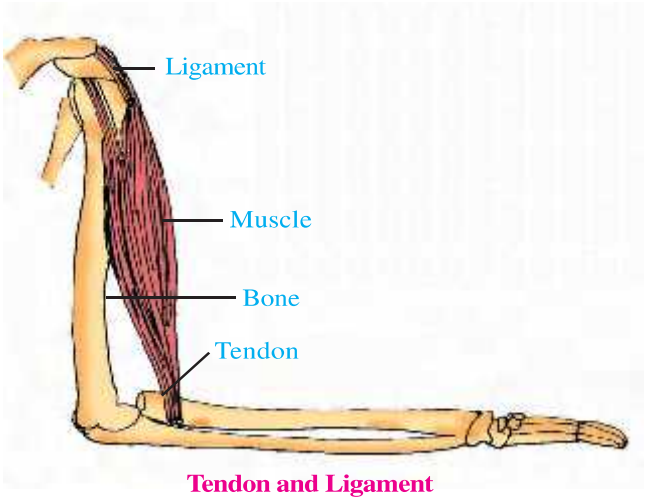
It occurs in tendons, which are elastic cords and connect muscles to the connective tissue sheath which surrounds the bone. White fibres are arranged compactly and parallel in bundles. This kind of tissue is found in places where great strength with limited flexibility is desirable. This kind of tissue is mainly present in the periosteum of the bones and perichondrium of cartilage. They are also seen at the joint between cranium bones and make them immovable.

Tendon :

It is strong fibrous connective tissue. It is composed of bundles of collagen fibres (matrix). A few flat and elongated fibroblast cells lay between the fibre bundles.

Ligament :

The ligament connects the joints and holds them in position. It is a dense fibrous connective tissue. It contains matrix as ground substance. Matrix has yellow elastin fibres. They are branched fibres. Fibroblast lie scattered between the fibres.



Tendon and Ligament

(B) Skeletal tissue : The tissue includes cartilage and bones which form the endoskeleton of the vertebrate body. These two tissues mainly provide material for the attachment of the muscles.

Cartilage :

The cartilage is a specialised connective tissue. It differs from the soft generalised connective tissue for its matrix which is solidified. The cartilage is quite distinct in its structure, physical properties, vascularisation and the pattern of growth and regeneration.

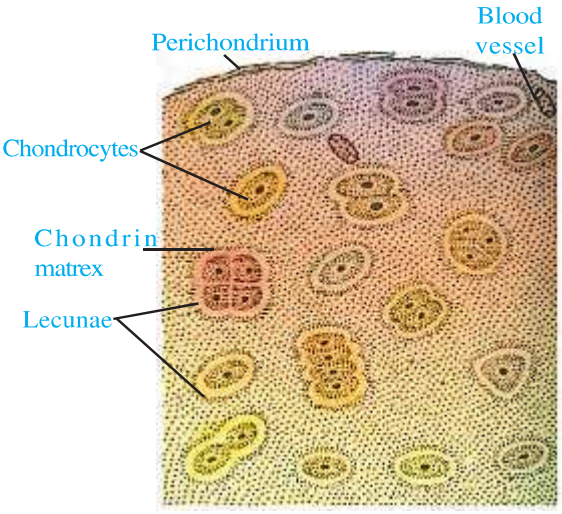
The cartilages are classified into the following four types.

(i) Hyaline cartilage

(ii) White fibro cartilage

(iii) Yellow elastic fibro cartilage

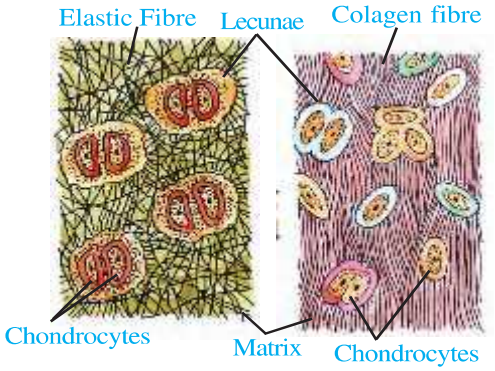
(iv) Calcified cartilage (cellular cartilage)



Hyaline Cartilage

Hyaline cartilage

The word hyaline is derived from the Greek work "hylos" which means "glass", and the hyaline cartilage was so named because in the gross, it appears as a clear bluish coloured glassy surface. Its matrix is clear, homogeneous translucent and laking fibres. It is present in larynx, trachea, sternum, hyoid and ribs etc. The cartilage cells are chondroblasts, which secrete chondrin lie in groups of two, four or eight in fulfilled space called lacunae. It is always covered by a tough fibrous membrane; the perichondrium. It contains blood vessels from which nutritive substances diffuse through the cartilage.



White fibro cartilage **Yellow elastic cartilage**

White fibro-cartilage

White fibro-cartilage

It consists of dense white fibrous tissue arranged in bundles (bundles of collagen fibres) with cartilage cells between the bundles. The cartilage cells are usually ovoid in shape and are surrounded by matrix. It is typically found in the intervertebral discs, which binds the vertebrae in mammals.

Yellow elastic cartilage

Yellow elastic cartilage

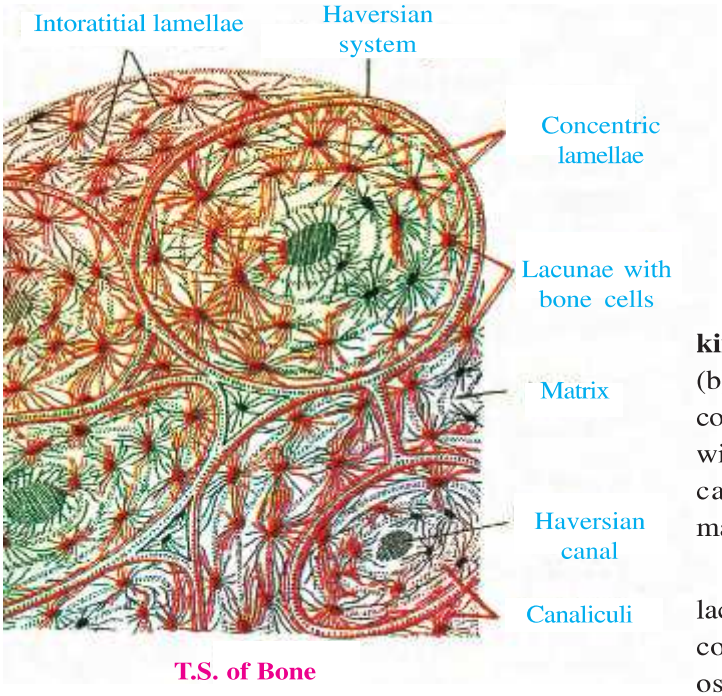
This is similar to fibrous cartilage except for yellow elastic fibres. It has elastin. This type of cartilage is found in the pinna, tips of nose, epiglottis and in certain other regions.

Calcified Cartilage

It differs from the hyaline type in having its matrix impregnated with lime salts. It is seen in a normal stage in the development of cartilage during early embryonic life but it is also found in a permanent tissue in the external ears of many mammals. It occurs in the pubis of frogs, in supra scapula and at the head of humerus and femur.

Bone

The bone is a specialized connective tissue. Some of the features of this tissue are as follows :



T.S. of Bone

- It is highly vascular
- It is mineralized
- It is constantly changing
- It is hard and rigid
- It is resilient
- It has a regenerating capacity
- It has a canalicular system

The mature bone is composed of two kinds of tissues : (a) the compact bone and (b) spongy. The ground substance or the matrix, composed of protein called ossein is impregnated with various inorganic salts of lime, namely, calcium phosphate, calcium carbonate, magnesium phosphate and calcium fluorides.

In adult bone flat irregular spaces called lacuna occurs in the solid matrix. Each lacuna contains a flat bone cell or osteocyte. An osteocyte has an irregular shape and long cytoplasmic process. These processes extended into minute canals radiating from each lacuna. The lacunae are in communication with one another by fine canalicules.

In a long dried bone of frog, large number of lamellae are present in a ground substance. In the center there is a narrow cavity of the bone. It contains a tissue known as the bone marrow which is yellow in colour. It is composed of adipose tissue, blood

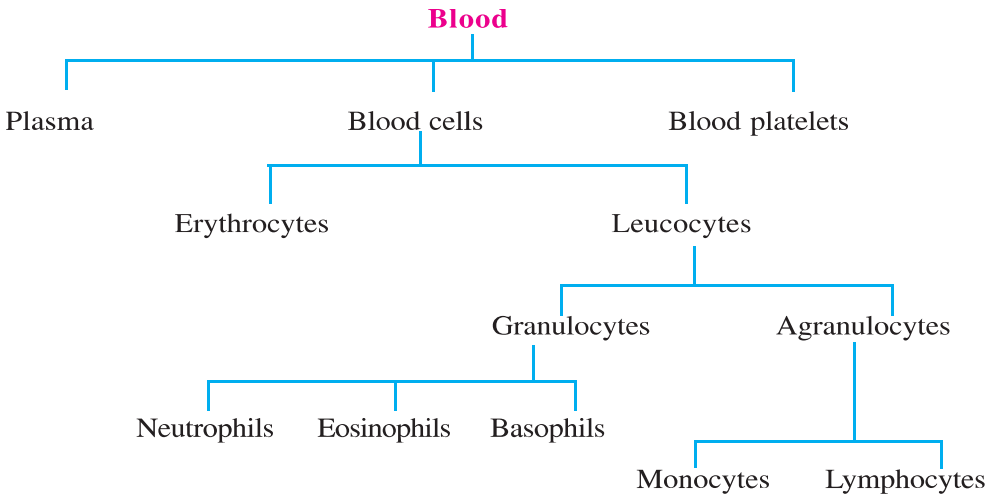
vessels, etc. The bone increases in thickness by the addition of successive layers to the outside as well as to the innerside.

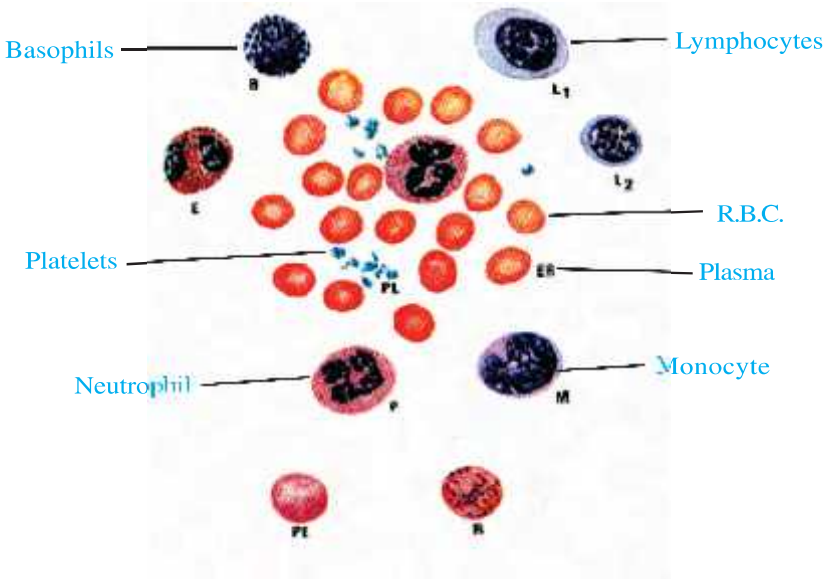
In mammalian bones many column like structures are seen called Haversian system. In each Haversian system, several concentric layers (lamellae) of bony matrix encircle a longitudinal central canal (Haversian canal). This canal carries blood vessels and nerves.

Spongy bones are found in vertebrae, ribs, skull, etc. It contains red bone marrow, which is the seat for formation of erythrocytes and granulocytes.

(C) Fluid tissue : Blood : The blood is an opaque turbid fluid. It is a fluid connective tissue. Its fluid is the intercellular substance or matrix. The fluid part of the blood is known as plasma. The blood cells are of two types: Red and white. The fragments of cytoplasm that are present in the blood are called platelets. Its cells are quite distinct from other connective tissue cells, both in structure and function. Blood differs from other connective tissues in that the secretion of the matrix is not entirely by blood cells and moreover, the new blood cells are not formed by the division of the pre-existing corpuscles.

The composition of blood is shown in the chart below :

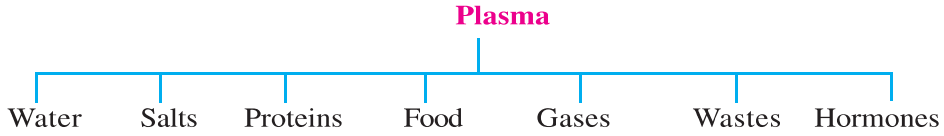




Blood connective tissue

Plasma

This is the fluid matrix or intercellular substance of blood. It is almost colourless having faint yellow tinge. It contains essentially seven classes of substances:



It is also rich in sodium and chloride ions. It also contains potassium, calcium, magnesium, phosphate, bicarbonate and many other ions. It contains many crystalloids and colloids. The colloids of plasma include plasma proteins (including prothrombin and immunoglobulins). It contains usually 80 % water. In addition to these there are metabolic waste products such as urea, uric acid, ammonia, carbon dioxide and water. Various hormones are also present in it. The plasma also contains protective substances such as antitoxins, agglutinins, lysine, etc. and blood proteins like fibrinogen, prothrombin, albumins and globulins.

In adult humans normal blood sugar level after 2 hrs of meal is 90-120 mg per 100 ml of blood. Cholesterol in humans normally ranges from 140 to 260 mg per 100 ml of serum. Except required components for blood clotting of plasma is known as serum.

Erythrocytes

They are also called Red Blood Corpuscles (RBCs). Under normal condition the blood of adult male contains 4,100,000 to 6,000,000 erythrocytes per cubic millilitre, while that of adult female contains 3,900,000 to 5,500,000 per cubic millilitre.

The normal human erythrocyte is a biconcave disc. The red colour of erythrocytes is due to the presence of haemoglobin, a red coloured pigment which is a conjugated protein made up of globin and Fe^{+2} (ferrous) containg haeme. It has high affinity for oxygen. The shape and size of RBC's vary in different animals. The cells are nucleated in all vertebrates, except mammals. Erythrocytes participate in transporting carbon dioxide from tissue to lungs. Erythrocytes have an average life span of about 120 days.

Leucocytes

Leucocytes are also known as White Blood Corpuscles (WBCs). They are small nucleated semi transparent cells devoid of haemoglobin. The leucocytes are capable of changing their shape and moving independently through the intercellular spaces among the tissues. The numbers of WBCs in adult humans are $7.5 \pm 3.5 \times 10^3$ per cubic millimeter of blood. The number of these cells depends upon the condition of the body. During infection of the body they generally increase in number. They are known as phagocytes because they feed on the bacteria and broken down tissue cells by engulfing particles. WBCs are of two types, granulocytes (with granules in cytoplasm) and agranulocytes (without granules). On the basis of staining characteristics of cytoplasm granules and shape of nucleus, granulocytes are of three types.

(1) Neutrophils : The neutrophil whose granules stain weakly with both the acidic and basic stain. Neutrophils have many lobed nucleus.

(2) Eosinophils (Acidophil) : Their granules which stain by acidic dyes such as eosin. Eosinophils are large in size and with bilobed nucleus.

(3) Basophils : The basophil the granules of which stain by basic dyes such as methylene blue. Basophils has 'S' shaped nucleus.

The agranular leucocytes are classified into two groups : **(1) Monocytes (2) Lymphocytes. Monocytes** are the largest leucocytes and its nucleus is kidney shaped. **Lymphocytes** have large and rounded nucleus.

Blood Platelets

Platelets are relatively small non-nucleated oval disc. They are also known as thrombocytes because they secrate thromboplastin. They are especially concerned with the clotting of blood. They are made in the bone marrow.

General Functions

The general functions of blood are summarised here under.

(1) Transport of oxygen
(2) Transport and Removal of carbon dioxide
(3) Transport of food materials
(4) Transport of waste matter
(5) Clotting of blood
(6) Transport of hormones, antitoxins, etc.
(7) To neutralise the toxins
(8) Equalization of body temperature
(9) Disposal of cell wreckage

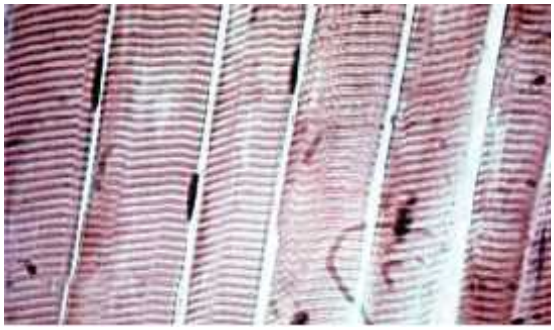
Muscular tissue : It consists of cellular elements in the form of fibres of varying lengths. It has almost no intercellular substances. All muscular tissues have great contractility. There are three types of muscular tissue.

Muscular Tissue

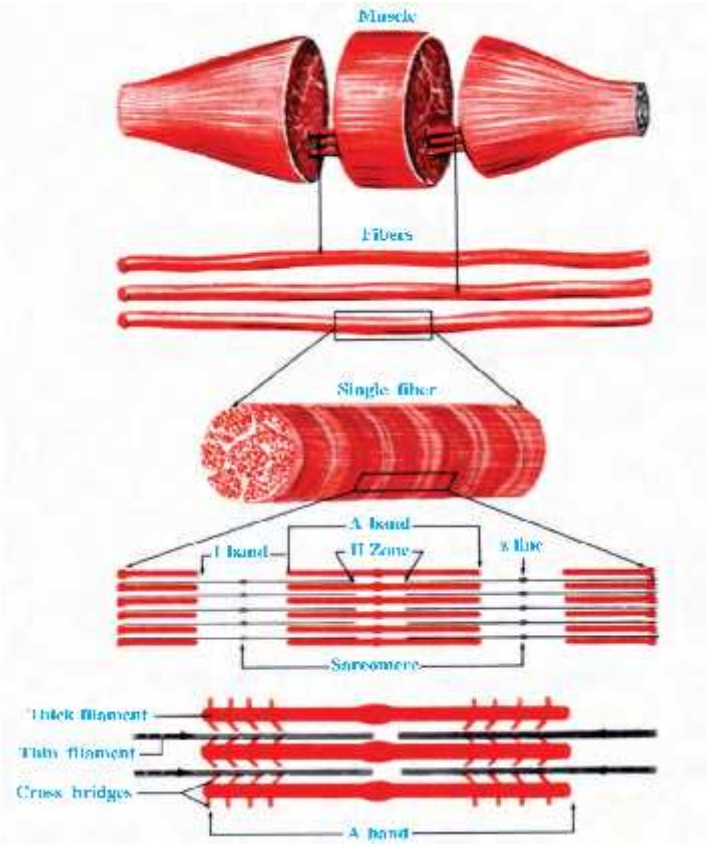
Skeletal muscle	Unstriated	Cardiac muscle
or	or	
Striated	Smooth	
or	or	
Striped	Plain	
or	or	
Voluntary	Involuntary muscle	

Skeletal Muscle

The muscle fibers are the units of skeletal muscle. Each muscle fibre is a single thin and elongated cell provided with many nuclei. The muscle fibres are arranged in bundles (fasciculi). In higher animals, these are found associated with the skeleton through tendon. They are attached to bones by tendons.



Skeletal Muscle

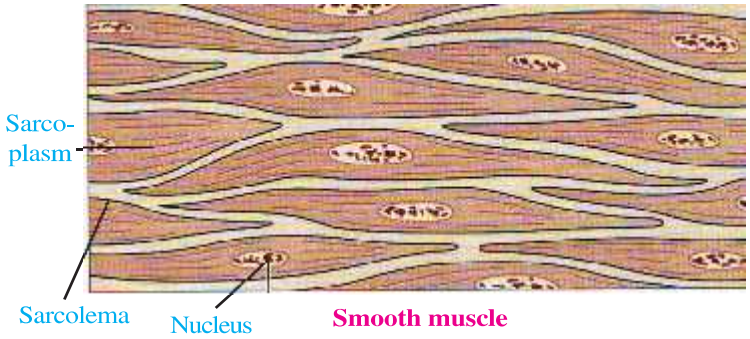


Ultrastructure of striated muscle

Muscle fibers can be contracted as desired. Therefore, they are also called voluntary muscles. Because of their appearance they are called striated or striped muscle.

The cytoplasm (sarcoplasm) of each fibre contains large number of myofibrils. Each fibre has an extensive sheath, the sarcolemma. The muscle fibres show cross or transverse striations of alternating light and dark brands. The darker bands are called 'A' bands; the lighter bands are called 'I' bands. The dark bands or 'A' discs are separated from one another by light bands or J-discs, each of which is itself crossed by Krause's membrane or Z-disc. Each portion between two successive Z-disc is termed as sarcomere. There are two types of filaments: thick filaments and thin filaments. Thick filaments occupy the 'A' band, the central portion of the sarcomere. Thick and thin filaments overlap for some distance within the 'A' band. The thin filaments run between and parallel to the thick filaments and have one end attached to the 'Z' line. Thin filaments being absent in the middle of 'A' band, this part appears light or less dark and is known as 'H'band (Hensen's zone). The thick filaments are made up of the protein myosin. Thin filament is composed of the proteins actin, tropomyosin and troponin.

Smooth Muscle :



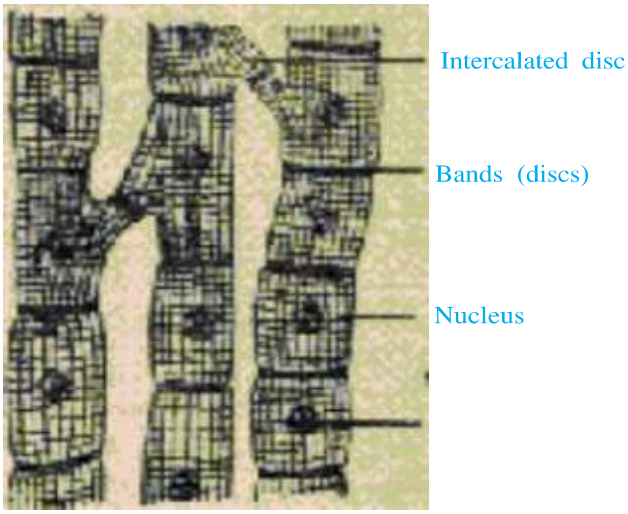
Smooth muscle

The smooth, plain, non-striated, unstriped or involuntary muscle differs considerably from the skeletal and cardiac muscles, both in its structure and physiological properties. The smooth muscle is made up of mononucleate spindle shaped cell. It has granular sarcoplasm around its nucleus. The rest of the cytoplasm has large number of extremely fine myofibrils. They have the property of contraction. These muscles always receive their nerve supply from the autonomous nervous system. These muscles are present in alimentary canal, iris, etc.

Cardiac Muscle

With the light microscope, the heart muscle appears as network of branching and anastomosing cylinders. The spaces between the cardiac muscle cells are occupied by the

endomysium. The endomysium contains fibroblasts, collagen and reticular fibres. Each cell of cardiac muscle shows striation with 'A', 'I', 'Z' and 'H' bands. At the ends of the cardiac muscle cells, there are prominent cross striations called intercalated discs. These discs are thicker than 'Z' discs. It differs from skeletal muscles due to reticulated pattern of fibres. These muscles are capable of contracting rhythmically and are immune to fatigue. There is rich blood supply.



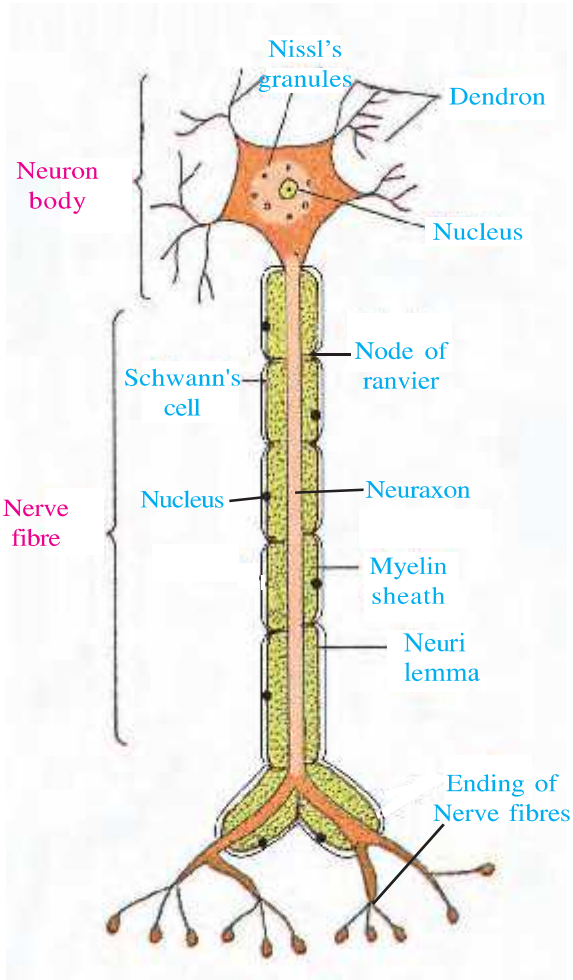
Cardiac muscle

Nervous tissue : Nervous tissue is composed of two types of cells (a) neurons and (b) neuroglia. The neurons form the most important elements of the nervous system. Neurons have long processes which transmit nerve impulses. The glial cells have short processes and they support and protect neurons.

Neuron cells are specialised for reception, integration, transformation and onward transmission of information. Typically each neuron consists of a cell body and branching fibres. Amongst the fibres one of the processes called the axon is long and conducts nerve impulses away from the cell body (efferent) and it ends in a number of small branches on muscle fibres, gland cells or other neurons. The remaining processes conduct nerve impulses towards the cell body (afferent) and are called dendrites or dendrons.

The number of processes arising from a cell body is variable and forms the basis of the morphological classification into three types: unipolar, bipolar and multipolar. In the unipolar neuron the cell body has a single process giving rise to both dendrite and axonal branches. In bipolar neuron, there is a process at each end of the cell body. Out of which one is afferent and opposite to it is efferent. In multipolar neurons, there are more than two processes.

The cytoplasm of the cyton contains a large and spherical nucleus. There are large numbers of dark particles called Nissl's granules in a cytoplasm.



Neuron (Nerve Cell)

The nerve fibres may be surrounded by two concentric sheaths. The inner is known as medullary or myelin sheath. It is surrounded by a transparent cellular outer sheath, the neurilemma. The neurilemma sheath is made up of single layer of flat expanded Schwann's cells. Each myelinated nerve fibre shows constrictions at regular intervals called nodes of Ranvier. The nerve endings of axon are not in direct physical contact with nerve endings of dendrites of another neuron. This physical gap is called synapse. Nerve impulses pass between neurons through the synapse with the help of a hormone Acetylecholine called Neurotransmitters.

Summary

Tissue is the group of cells having similar structure and function. Animals contain four basic types of tissues which are: epithelial tissue, connective tissue, muscular tissue and nervous tissue. Based on structure and function, epithelial tissues are divided into two main groups: covering epithelium and glandular epithelium. Covering epithelia are different types such as squamous, cuboidal, columnar, ciliated, pseudo-stratified, stratified and transitional. They perform different functions: protection, absorption and secretion.

The connective tissues are the group of elements or matrix of intercellular substance secreted by cells themselves. They fall into three main groups: connective tissue proper, skeletal and fluid tissue (blood). Connective tissues proper are of five types : areolar, adipose, white fibrous, tendon and ligament. Skeletal tissue includes cartilage and bones which form the endoskeleton of the vertebrate body. The cartilages are classified into the following four types: hyaline, white fibrous, yellow elastic fibro cartilage and calcified cartilage (cellular cartilage).

Blood is a fluid connective tissue. It is an opaque turbid fluid which is a intercellular substance or matrix (plasma). It is composed of plasma, blood cells and blood platelets. Blood cells are erythrocytes and leucocytes. There are five types of leucocytes: neutrophils, eosinophils, basophils, monocytes and lymphocytes.

Muscular tissue consists of cellular elements in the form of fibres of varying lengths. They have great contractibility. There are three types of muscular tissue: skeletal muscle, unstraited or plain muscle and cardiac muscle.

The nervous tissue is composed of two types of cells (a) neurons and (b) neuroglia. The neurons form the most important elements of the nervous system. They transmit nerve impulses. Neuron cells are specialized for reception, integration, transformation and onward transmission of information. Neuron has two or more processes extending from it. One of the processes carries impulses away from the cell body and is called the axon. Other processes carry nerve impulses towards the cell body and are called dendrites. There is a physical gap between the nerve endings of axon and dendrites called synapse.

Exercise

1. Put a dark colour in a given circle for correct answer :

(1) Specialized tissue which performs the functions of protection, absorption and secretion.

(A) Neuron ◯ (B) Striped muscle ◯

(C) Blood ◯ (D) Epithelial tissue ◯

(2) Bowman's capsule has which type of epithelium ?

(A) Cuboidal epithelium ◯ (B) Squamous epithelium ◯

(C) Columnar epithelium ◯ (D) Pseudo-stratified epithelium ◯

(3) Which cell secrets heparin and histamine ?

(A) Mast Cell ◯ (B) Neuron ◯

(C) Monocytes ◯ (D) Squamous epithelium cell ◯

(4) The cartilage typically found in the vertebrae in mammals ?

(A) Calcified ◯ (B) Yellow elastic ◯

(C) White fibro ◯ (D) Hyaline ◯

(5) In which tissue Haversian system is present ?

(A) Connective tissue ◯ (B) Blood ◯

(C) Cartilage ◯ (D) Bone ◯

(6) How many erythrocytes are present in adult man ?

(A) 3900000 to 5500000 ◯ (B) $7.5 \pm 3.5 \times 10^3$ ◯

(C) 4100000 to 6000000 ◯ (D) $3.5 \pm 7.5 \times 10^3$ ◯

(7) By which protein the thick filament of striped muscle is made up of ?

(A) Actin ◯ (B) Myosin ◯

(C) Actin and Myosin ◯ (D) Tropo myosin ◯

(8) The distance between two 'Z' disc is termed as .....

(A) Synapse ◯ (B) Sarcolemma ◯

(C) Sqrocomere ◯ (D) Sarcoplasam ◯

(9) The spaces between the cardiac muscles are occupied by

(A) Endomysium ◯ (B) Sarcolemma ◯

(C) Granular sarcoplasam ◯ (D) Sarcoplasam ◯

(10) In which tissue medullary sheath is present ?

(A) Epithelial ◯ (B) connective ◯

(C) Muscle ◯ (D) Nervous ◯

2. What is tissue ? Give a general chart of different tissues with their sub types.

3. Give functions of different tissues.

4. Distinguish between :

(a) Simple and compound epithelial tissue

(b) Cartilage and bone

(c) Erythrocytes and leucocytes

(d) Striated muscle and unstriated muscle

5. Match the terms in Column A with those in Column B.

A		B	
(1)	Axon	(1)	Cardiac muscle
(2)	Z-disc	(2)	Bilobed nucleus
(3)	Eosinophils	(3)	Thromboplastin
(4)	Endomysium	(4)	Kidney shaped nucleus
(5)	Pseudo stratified epithelium	(5)	Striped muscle
(6)	Transitional epithelium	(6)	Compound epithelium
(7)	Blood platelets	(7)	Nervous tissue
(8)	Monocytes	(8)	Simple columnar epithelium

6. Name the tissue which performs the following functions :

(a) Absorption and secretion

(b) Helps to remove mucus

(c) Ingest foreign particles

(d) To conserve body heat

(e) Transportation of O_2 and CO_2

(f) Blood clotting

(g) Transmit nerve impulses.

7. What are the cellular components of blood ?

8. Describe the ultrastructure of striped muscles fibre.

9. Describe different types of simple epithelial tissue.

10. Write short note on :

(1) Leucocytes

(2) Columnar epithelium

(3) Adipose tissue

(4) Cardiac muscle

(5) Neurons

11. Draw a sketch diagram and label only :

(1) Different types of leucocytes

(2) Neuron with myelinated axon

(3) Areolar connective tissue

(4) Different types of simple epithelial tissue

5

Animal Morphology and Anatomy - I
(Earthworm and Cockroach)

In earlier chapter we have understood organization of body, and in which cells form tissue, tissues form organ, and organs form an organ systems. e.g. digestive system, respiratory system, circulatory system, excretory system, reproductive system and nervous system. These systems coordinate with each other to perform various complex physiological functions, which keep body in living state. Thus many cells unite to form multicellular body. In our body organ like heart consists of four different kinds of tissues, such as epithelial tissue, connective tissue, muscular tissue and nervous tissue. As required for adaptation the organs and organ systems evolved more complex organizations. Thus study of various systems in two or three animals can be made to understand evolutionary stages. With this aim the curriculum on earthworm, cockroach and frog has been included in present chapter. The morphology and internal organization in the body and various systems and physiological processes run by them, can be studied. We will understand systems with diagram when required. Let's start with the earthworm.

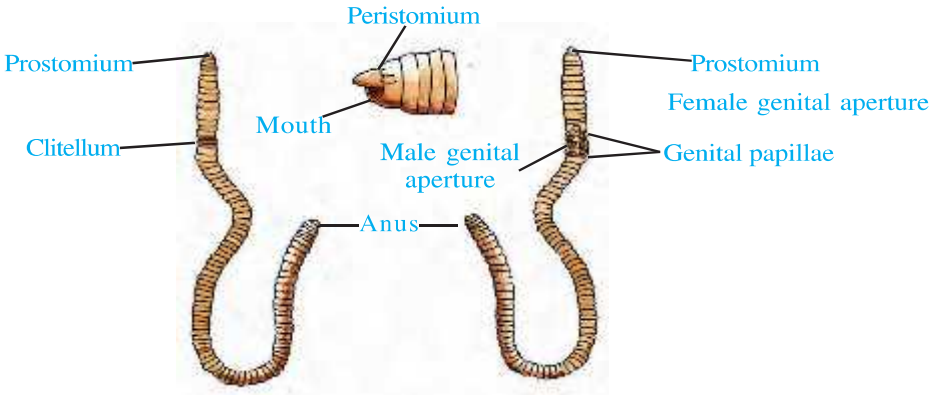
Earthworm

Earthworm is a typical coelomate animal of annelida phylum. In our country, *Pheritima posthuma* is found commonly. Earthworm is a reddish brown terrestrial invertebrate that inhabits on the upper layer of the moist soil. During day time it lives in burrow and eat the soil. Whatever the soil it consumes with food is excreted as worm castings and with the help of these castings earthworms can be traced.

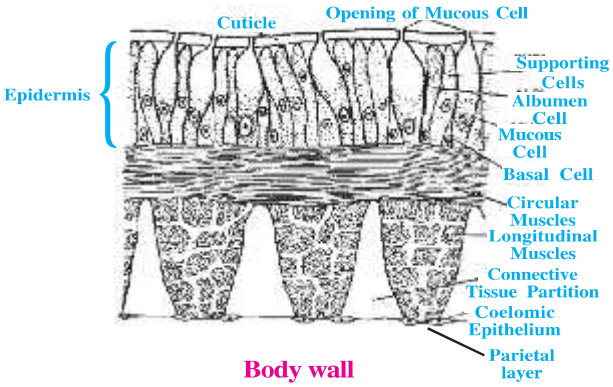
Morphology

Earthworm is cylindrical, a little bit long and thin. It's body is divided into small segments which are approximately 100 to 120 in number. The dorsal surface of the body is marked by a dark median mid dorsal line along the longitudinal axis of the body. The ventral surface is distinguished by the presence of genital pores. Anterior end consists of the mouth and the prostomium, a lobe which serves a wedge to force open cracks in the soil into which the

earthworm may crawl slowly further. The prostomium is a sensitive organ. The first segment is called the peristomium in which mouth is found. In a mature earthworm, 14 to 16 segments are covered by a dark band of glandular tissue called clitellum. Thus the body is divided into three prominent areas preclitellar, clitellar and postclitellar segments. Four pairs of spermathecal apertures are found on the ventro-lateral sides between segments 5/6, 6/7, 7/8, 8/9 in the intersegmental grooves. A single female genital pore is present in the mid-ventral line of the 14th segment. A pair of male genital pores is present on the ventro-lateral sides of the 18th segment. Number of minute pores called nephridiopores, get opened on the surface of the body which are found in all the segments except the first, last and clitellum. In the midst of each segment a circle of setae is found. These setaes are made of chitin and help in locomotion.



Earthworm – dorsal view **Earthworm – ventral view**



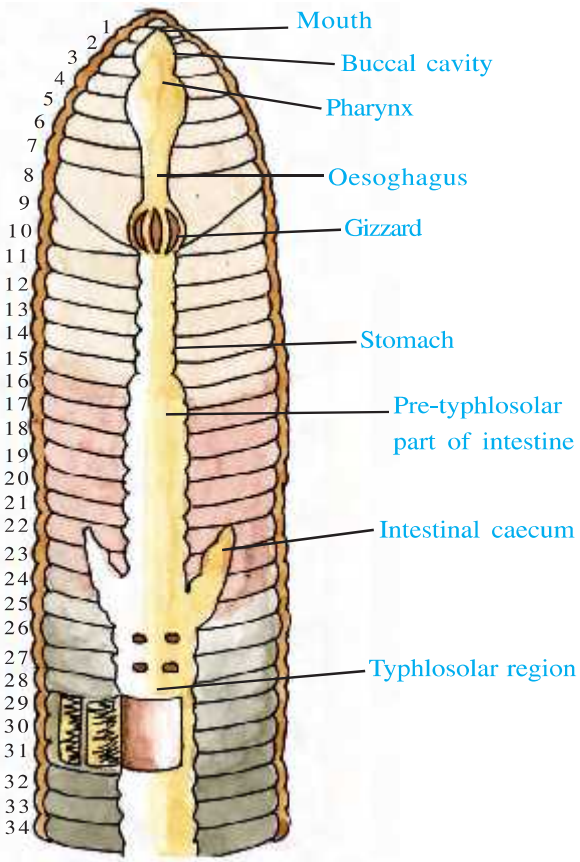
Body wall

The body wall of the earthworm consists of cuticle, epidermis, circular muscles, longitudinal muscles and parietal layer. Cuticle is a thin layer secreted from epidermis. The epidermis is made up of a single layer of columnar supporting cells and oblong gland cells which secrete albumin and mucus. Sensitive cells are found in groups. They bear cilia which takes inspiration from external stimulation.

Digestive System

The alimentary canal is a straight tube and runs between first to last segment of the body. A terminal mouth opens into the buccal cavity which spreads to 1 - 3 segments. Because of the contraction of muscles joining body wall, buccal cavity protrudes out of the body and accepts the food. The pharynx, muscular tube found after buccal cavity is extended upto fourth segment. A small narrow tube like oesophagus is extended from 5 to 7 segments which opens into muscular gizzard of the 8th segment. The wall of this gizzard is thick and there are thick layers of circular muscles. The internal surface of it made up of columnar cells covered with cuticle. Due to the contraction of circular muscles gizzard grinds the soil particles and decaying leaves like a grinder. The stomach is extended from 9th to 14th segment. Calciferous glands, found in stomach, neutralize the humic acid present in humus. Intestine starts from the 15th segment

and continues till the last segment. A pair of short and conical intestinal caecum projects from the intestine on the 26th segment, which secrets enzyme of carbohydrate digestion. In the intestine between 26 to 95 segment is the presence of internal median fold of dorsal wall called typhlosole. Due to this fold there is an increase in the area of absorbtion. Last 23 - 25 segments are without typhlosole and hence it is called post typhlosole. The alimentary canal opens to the exterior by a small rounded aperture - anus. The ingested organic rich soil passes through alimentary canal and digestive enzymes breakdown complex food into smaller absorbable units.

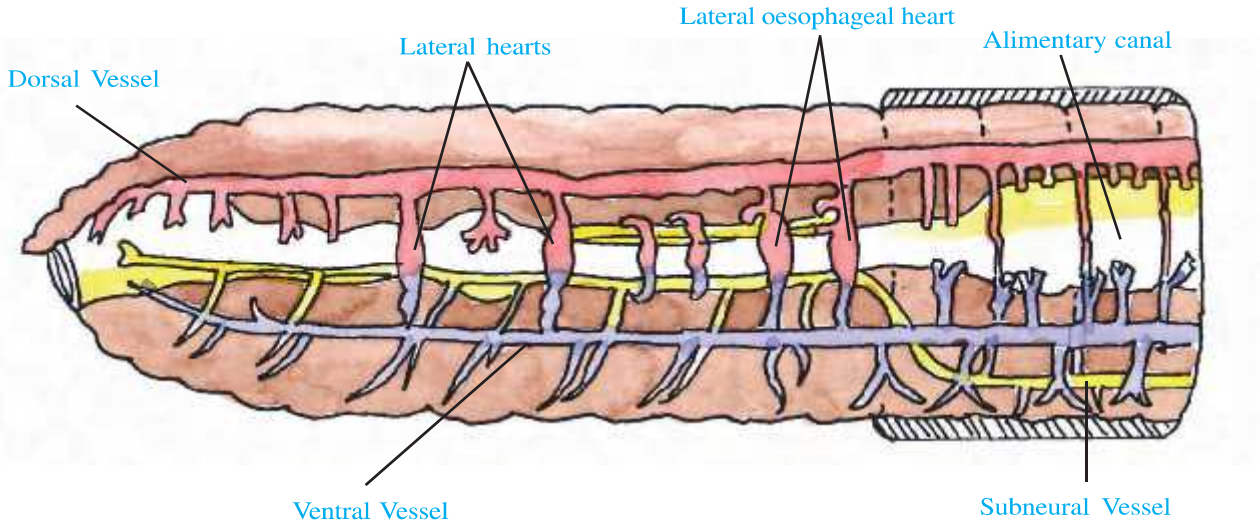


Digestive system of Earthworm

Circulatory System

In earthworm closed type of circulatory system is found. In circulatory system blood vessels, capillaries and heart are included. Due to closed circulatory system, blood is confined to the heart and blood vessels. Due to contraction, blood circulates into one direction and smaller blood vessels supply blood to the gut, nerve cord and the body wall. Blood glands are present on the 4th, 5th and 6th segments. Its function is to produce blood cells and haemoglobin which is dissolved in blood plasma. Blood cells are of phagocytic type.

In earthworms there is absence of specialized breathing device. Respiratory exchange occurs through moist body surface and oxygen gets mixed into blood stream.



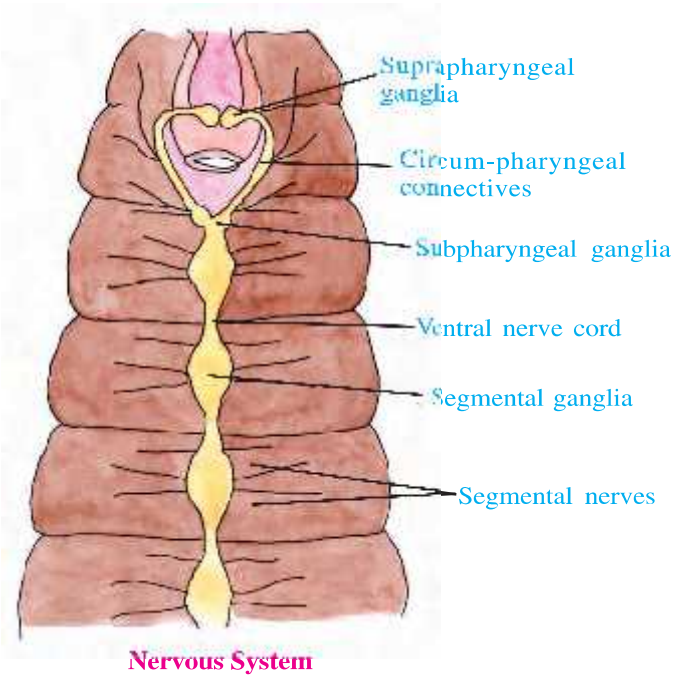
Circulatory System of Earthworm

Excretion

In excretory organs segmentally arranged coiled tubules called nephridia are found in every segment. They are of three types, septal nephridia from 15th segment to the last segment, found on both the sides of intersegmental septa which open into intestine. Integumentary nephridia attached to the lining of the body wall from segment 3 to all. All these nephridia open into external surface of the body through minute pores. Pharyngeal nephridia, present as three paired tufts in the 4th, 5th, and 6th segments. These nephridia discharge their waste into alimentary canal. These all three types of nephridia are basically similar in structure. These nephridia regulate the volume and composition of the body fluids. With the help of nephrostome they absorb the excretory waste from coelome and discharge the wastes through a pore to the surface in the body wall and into the digestive tube.

Nervous System

Nervous system is ganglionated. Nerve ganglia are formed by gathering the nerve cells of any segment. One pair of nerve ganglia is found at the ventral surface of each segment after the fifth segment, which is known as ventral nerve cord. One pair of ganglia is found at the posterior part of ventral side of third segment which is called subpharyngeal ganglion. At the dorsal side of pharynx in the third segment one pair of Suprapharynegeal ganglion is found. These ganglions are connected with sub-pharyngeal ganglion by circumpharyngeal connective. These pairs of connective and sub pharyngeal ganglion connected with Suprapharyngeal ganglion and formed nerve ring. Suprapharyngeal ganglion and other nerves of rings compiles the information and reacts immediately by making the body muscles to implement it. In earthworm specific sensory organs like eyes are not present. Only sensory cells of the body wall perform as a sensory receptor organs. These cells are inspired by the intensity of light, vibrations of the land etc. Some of the sensory cells are inspired by chemical instigators.

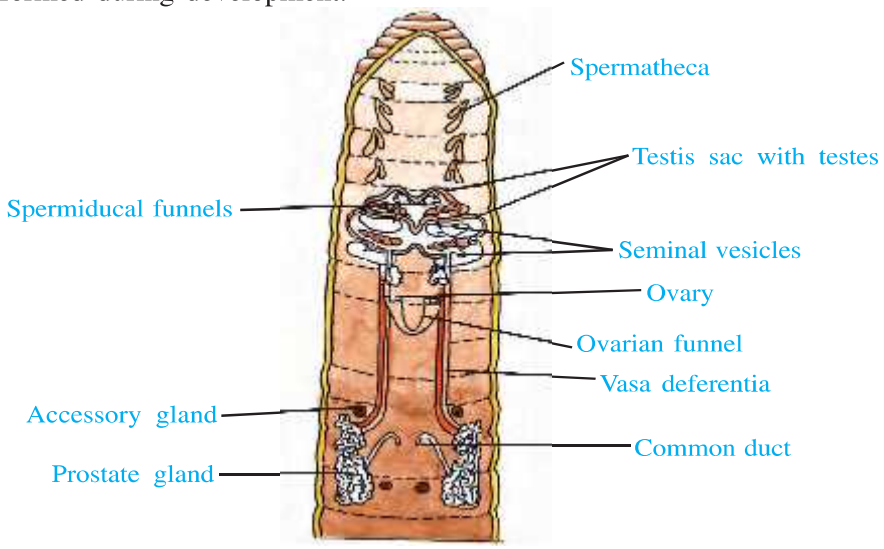


Nervous System

Reproductive System

Earthworm is hermaphrodite (bisexual) i.e. testes and ovary both are present in same animal. Two pairs of testes are found in the 10th and 11th segments. Their vasa deferentia run up to the 18th segment where they join the prostate duct. Two pairs of accessory glands are present, one pair each in the 17th and 19th segment. Common prostate and spermatic duct opens to the exterior by a pair of male genital pores on the ventro-lateral side of the 18th segment. One pair of spermathecae is located in segment 6, 7, 8 and 9 each. One pair of ovaries is attached at the inter-segmental septum of 12/13. Ovaries are small and their front part form oviducal funnels. Ovarian funnels are present beneath the ovaries which continue into oviduct, join together and open on the ventral side as a single median female genital pore on the 14th segment. During mating two earthworms come together and get

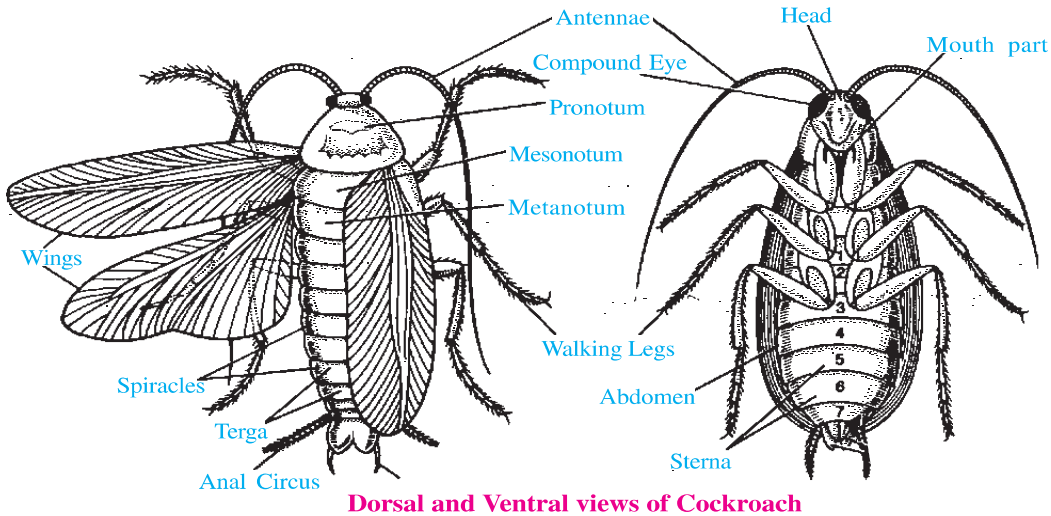
arranged into juxtaposing directions. Thus the mouth region of one faces the anus of the other. Male genital opening of one comes in contact with opening of the spermathecae of another earthworm. In this situation released sperm cells enter into the spermathecae of companion animal. Thus animals get separated after exchanging the sperms. After short time the secretion of clitellum gland forms white cocoon. In this cocoon eggs are released. Due to the contraction of body wall the cocoon slips towards the anterior end. When cocoon slipping towards the anterior end and passes through spermathecal region. Then the sperm stored in spermatheca enter into cocoon. This cocoon contains the egg cells of same animal and sperm cells of another animal with nutritive fluid. Both the ends of the cocoon are sealed when it comes out of the body. In this cocoon eggs are fertilized and resulted into zygote. After three weeks in cocoon, baby earthworms are coming out. The development of earthworm is direct. There is no larva formed during development.



Reproductive System

Earthworms are known as friends of farmers because they make burrows in the soil and thus they provide life giving gas for respiration to the developing plant roots. To increase fertility of soil earthworms are breeded which is called vermicomposting. In addition to this, earthworms as bait are used in fishing.

Cockroach :



Dorsal and Ventral views of Cockroach

Cockroach is included in class Insecta of phylum Arthropada. Generally cockroach is brown or black bodied insect, however in tropical regions, they have been reported to be bright yellow, red and green coloured. It is nocturnal and omnivores that live generally in warm and humid places all over the world. Cockroaches are quite common in kitchens, bathrooms, gutters and hotel kitchens.

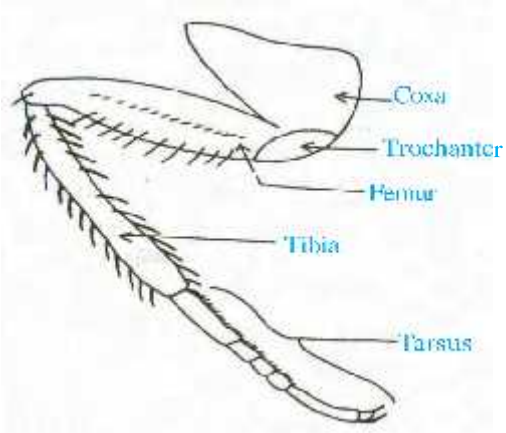
Morphology

The common species of cockroach is *Periplaneta americana*. They are about 25 to 45 mm long and 8 to 12 mm broad. The size of male is slightly bigger. The entire body is protected by a hard chitinous exoskeleton. The body is externally segmented. There is no internal segmentation. In each segment exoskeleton has hardened to thin and flexible articular membrane. The body of the cockroach is divisible into three distinct regions : (1) Head (2) Throax (3) Abdomen

(1) Head : Head is triangular in shape and lies anteriorly at right angle to the longitudinal body axis. It is formed by the fusion of six segments. It is attached to thorax through a flexible neck. So that it can move easily in all the directions. A pair of sessile, kidney shaped compound eyes occur on head. At the anterior end of head, mouth is located. Sensitive mouth parts are associated with mouth. They are concerned with collection of food and its chewing. The mouthparts consist of a pair of mandibles, a pair of first maxillae, labium and labrum. In the cavity surrounded by mouth parts occurs a muscular, folded structure called hypopharaynx. Salivary glands open at its basal region.

(2) Thorax : Thorax consists of three parts : (1) Prothorax (2) Mesothorax (3) Metathorax

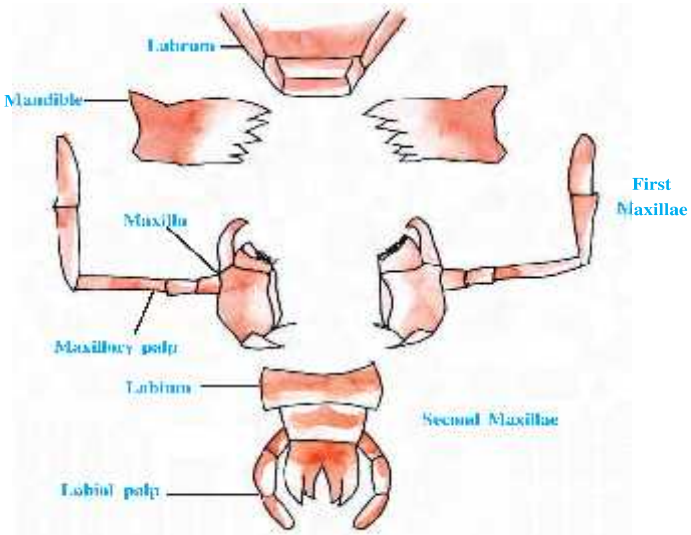
One pair of walking legs arise from ventral side of each segment. Each walking leg is made up of five segments. The first segment is called coxa, the second is trochanter, the third is femur, the fourth is tebia and fifth segment is tarsus. The first pair of wings develops from the dorsal side of mesothorax. These wings are horny and protective. The second pair of wings develops from the dorsal side of metathorax. It is bilobed and transparent. This pair is used for flying.



Walking leg

(3) Abdomen : Abdomen is made up of ten segments in both male and female. Each segment has a dorsal tergum, a ventral sternum and lateral pleurae. The terga of eight and ninth segments are covered under the tergum of seventh segment. The tenth tergum possesses a median groove. Anus occurs under it. A pair of anal cerci is associated with the tenth tergum. Anal cerci are photoreceptor structures. In male cockroach, a pair of anal styles

develop from ninth sternum. In female cockroach, the eighth and ninth sterna jointly form a genital pouch. The male genital opening occurs in mid-ventral region of ninth segment. The female genital opening opens in the eighth segment.



Mouth parts of Cockroach

Anatomy : (Internal Structure)

Body Wall :

The body wall of cockroach is made up of three main layers. The outermost layer is of cuticle. It forms exoskeleton. The layer under it is epidermis. It is formed of a single layer of columnar epithelial cells. On the innermost side, a basement membrane occurs.

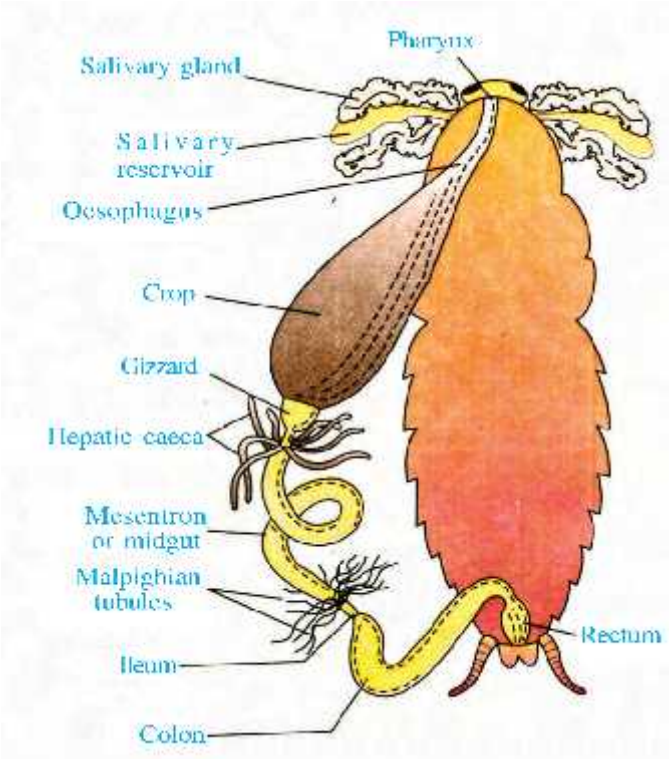
Alimentary Canal :

The alimentary canal of cockroach is complete.

Mouth is located at the anterior end of head. Mouthparts adapted for gathering and cutting food are arranged surrounding the mouth.

The tubular region following the mouth is called - pharynx. Then onwards, the alimentary canal is divided into three regions named foregut, midgut and hindgut. The cavities of foregut and hindgut are lined with cuticle. On the lateral side of the alimentary canal, a pair of salivary glands are found. Each salivary gland consists of two secreting lobes and two reservoirs.

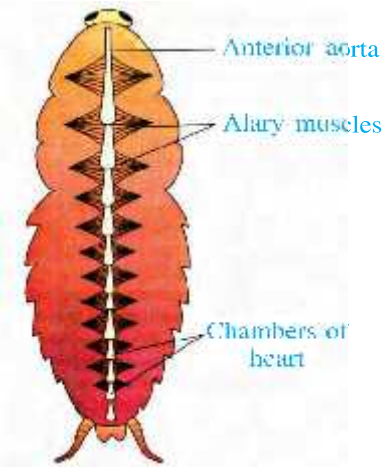
Oesophagus is narrow, tubular structure which follows the pharynx. It enlarges at its posterior end into a 'crop'. Crop opens into a muscular 'gizzard'. Six chitinous teeth occur inside the gizzard. At the posterior end of gizzard, a sieve-like structure made up of chitinous teeth is located. The region of alimentary canal upto gizzard constitutes the foregut. Gizzard opens into the midgut. Eight blind hepatic caeca occur in the midgut. Midgut opens into the hindgut.



Digestive system of Cockroach

At the junction of midgut and hindgut about 150 yellowish, thread like malpighian tubules open. They are excretory units. The proximal region of hindgut is called ileum. It is slightly narrow. The following region is some what coiled. The middle region is called colon. The bag-like posterior end region of hindgut is called rectum. It is folded inside. Rectum opens to the outside through anus. Anal opening is located under the tergum of 10th abdominal segment.

Cockroach is omnivorus animal. Cockroach searches food with help of antennae. In salivary gland saliva is prepared by secretory lobes. Mucus present in saliva makes food wet. The enzyme amylase affect the starch of food and digestion begins. Now food enters into crop and digestion proceeds further. Now food enters into gizzard where it cuts down into small pieces with the help of hard chitinous teeth, and the food enters the midgut. Columnar cells of midgut hepatic caeca secrete enzymes. Various proteolytic enzymes convert protein unit into amino acids. Through lipase fatty acid and glycerol are produced from lipid. Amylase produces the sugar from starch.



Blood Circulatory system of Cockroach

Blood vascular system

Blood vascular system of cockroach is an open type. It means during circulation blood enters into the body cavity instead of blood vessels. Thus body cavity acts as a haemocoel and organs of the body and tissues are directly connected with the blood. The haemolymph is mostly composed of plasma and uncertain shaped cells. The heart is made up of thirteen units. Three units occur in thoracic region and ten occur in the abdominal region. Anterior end of the heart is slightly narrow and posterior end is broad. Two valved openings occur between two nearby units. They are called ostia. The cells of haemolymph are of two types. Proleucocytes of smaller size and phagocytes of larger size. Blood from sinuses enters heart through ostia and is pumped anteriorly to sinuses again.

Respiratory system

Branched tubes known as trachea are main components of respiratory system. The branches of tracheal tubes are spread throughout the body. Terminal branches of tracheal tubes are called tracheoles which carry oxygen to entire body. The trachea have direct contact with the air in atmosphere through pores known as spiracles. Ten pairs of spiracles occur. Two pairs of spiracles occur in thoracic region and eight pairs of spiracles occur in the abdominal region. The walls of spiracles are framed from chitinous bristles. Chitinous bristles work as filter and prevents water and other waste substances entering into the respiratory system. Oxygen gets entered into the tracheas through spircales and from there it comes in contact of tissue fluid and gets dissolved in it. The tissues of body use this dissolved oxygen to get energy to work. The carbon dioxide produced consequently gets dissolved in tissue fluid generally which comes out through exhaling.

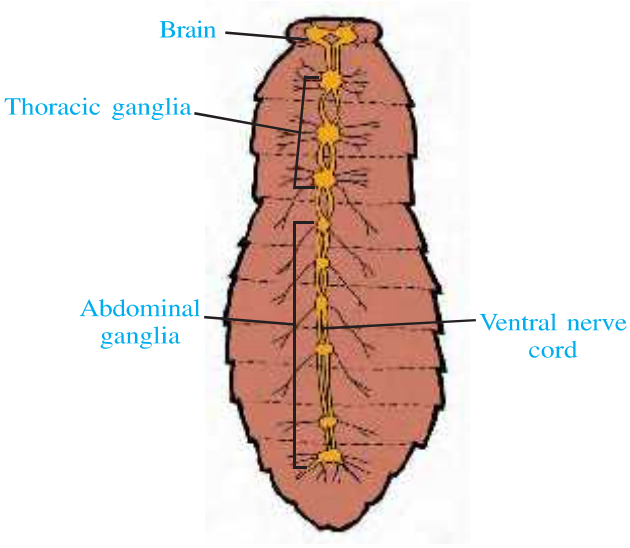
Excretory organs and process of excretion

At the junction of midgut and hindgut about 150 yellowish long, thin and hollow malpighian tubules open. They are main exceretory units. These blind tubules always float in the haemolymph. 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, cockroach

is a uricotelic animal. Excretory substances enter into the hindgut having large amount of water. This water is absorbeded by the wall of hindgut.

Nervous System

Nervous system is made up of paired ganglia, nervecords and nerves. Supraoesophageal formed by the fusion of three ganglia, which is known as brain, are located on oesophagus. They are connected with subeosophageal gangilia through circum-oesophageal commisures. Thus a nerve ring is formed. Suboeosephageal ganglion innervate the mouth parts. Three ganglia occur in the thorax region and the six ganglia occur in abdominal region. Each ganglion is made up of fusion of two ganglia. Thus, nervous system of cockroach is spread throughout the body.

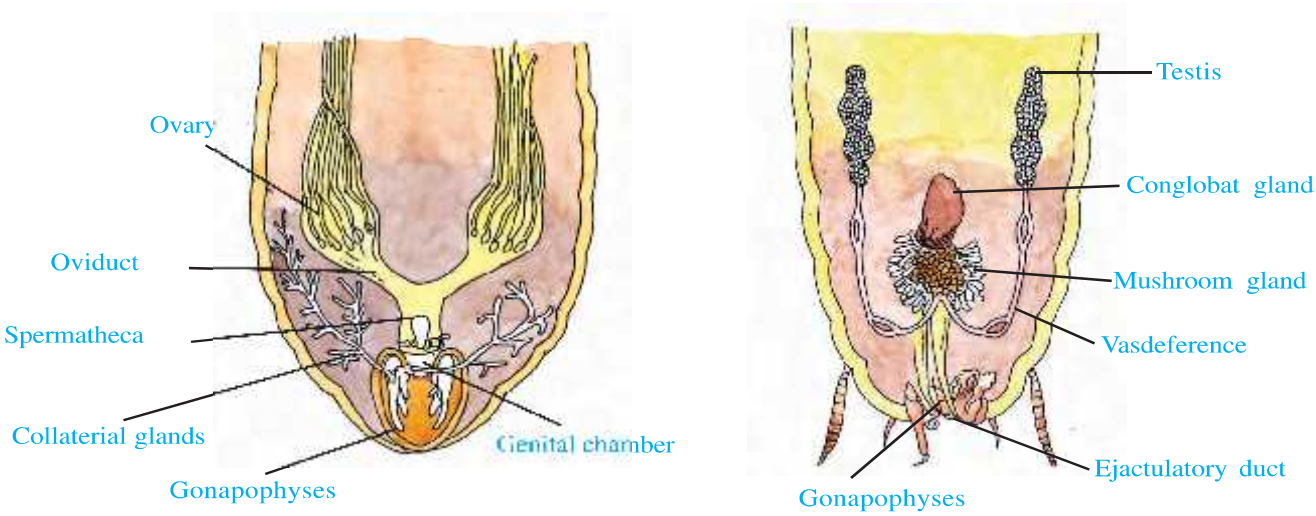


Nervous system of Cockroach

Amongst sense organs in cockroach, antennae, eyes, maxillary palps, tarsus of walking legs and anal cercus are included. The compound eyes are situated at the dorsal surface of the head. Each eye consists of about 2000 hexagonal ommatidium. With the help of several ommatidium a cockroach can receive several images of an object. This kind of vision is known as mosaic vision.

Reproductive system

Cockroaches are unisexual animals and both sexes have well developed reproductive organs. **Male reproductive system** consists of a pair of testis lying one on each lateral side in the 4 to 6 abdominal segments. From each testis arises a thin vas deferens, which opens into ejaculatory duct through seminal vesicle. The ejaculatory duct opens into male gonopore situated ventral to anus. A mushroom shaped gland occurs in segments 6 and 7. It is an accessory reproductive gland. At the end of the abdomen, chitinous gonapophysis are located which form external reproductive organs. The sperm are stored in the seminal vesicles and are glued together in the form of bundles called spermatophores which are discharged during copulation. In the **female reproductive system**, two ovaries lying laterally in the 2 to 6 abdominal segments. Each ovary is formed of a group of eight ovarian tubules or ovarioles, containing a chain of developing ova. Oviducts of each ovary unite into a single median oviduct known as vagina which opens into the genital chamber. A pair of spermatheca is present in the 6th segment. During copulation ovum come in the genital chamber, where they fertile by sperms. A dark brown coloured ootheca is formed by the group of fertilized eggs. Each ootheca has 14 to 16 eggs. Cockroach is developed through nymphal stage (or young insect). The nymphs look very much like adults. The nymph grows by moulting about 6 to 7 times to reach the adult form.



Male and Female reproductive systems of Cockroach

Summary

Earthworm and Cockroach show characterstic features in segmentation, symmetry and body organization. Earthworm is a burrowing and terrestrial animal while cockroach found in kitchens, hotel and laterines, where plenty of food is available. Earthworm exhibits true segmentation, while cockroach's body is segmented and divided into head, thorax and abdomen, segments of the body bares jointed appendages. The alimentary canal is complete in both the animals. The blood circulatory system is closed type in earthworm while in cockroach it is of open type. Earthworm is devoid of special respiratory organs, the exchange of gases take place through body wall. The respiratory system of cockroach consists of trachea which open outside through the spiracles. The excretory organs are nephredia in earthworm while in cockroach its consists of malpighian tubules. Nervous system is well developed in both earthworm and cockroach. Earthworm is a hermaphrodite animal while cockroach is dioecious. i.e. sex are separate. The earthworm exhibits cross fertilization and development takes place in cocoon, secreted by glands of clitellum. Development is direct, there is no larval forms. In cockroach fertilization is internal. Female cockroach produces ootheca, bearing the developing embryos. The young ones, called nymphs.

Exercise

1. Put a dark colour in a given circle for correct answer :

(1) The body of an earthworm is divided into how many segments ?

(A) 100 - 120 ◯ (B) 50 - 70 ◯

(C) 150 - 200 ◯ (D) 1000 - 2000 ◯

(2) Which cells are found in the epidermis of earthworm ?

(A) Gland cells and sensory cells ◯

(B) Supporting cells and gland cells ◯

(C) Supporting cells, gland cells, sensory cells and basal cells ◯

(D) Only sensory cells ◯

(3) Cockroach belongs to which class of Phylum Arthropoda ?

(A) Crustacean ◯ (B) Arachnida ◯

(C) Insecta ◯ (D) Myriapoda ◯

(4) Body of cockroach is divided into :

(A) Two parts ◯ (B) Four parts ◯

(C) Three parts ◯ (D) Five parts ◯

(5) In which segments does the clitellum found in *Pheretina posthuma* ?

(A) 12th, 13th and 14th ◯ (B) 13th, 14th and 15th ◯

(C) 14th, 15th and 16th ◯ (D) 15th, 16th and 17th ◯

(6) In earthworm one pair of male gential apertures is found in ventro lateral side of which segments ?

(A) 19 ◯ (B) 17 ◯

(C) 18 ◯ (D) 15 ◯

(7) The abdomen of cockroach is made up of :

(A) 10 segments ◯ (B) 8 segments ◯

(C) 9 segments ◯ (D) 7 segments ◯

(8) How many chitinous teeth are present in the cavity of gizzard ?

(A) 5 ◯ (B) 6

(C) 3 ◯ (D) 4 ◯

(9) In which segments typhlosole region is found ?

(A) 26 to 95 segments ◯ (B) Last 25 segments ◯

(C) 15 to last 15 segments ◯ (D) First 25 segments ◯

(10) In earthworm which segments possess blood gland ?

(A) 4th, 5th and 6th segments ◯

(B) 7th, 8th and 9th segments ◯

(C) 1st, 2nd and 3rd segments ◯

(D) 9th, 10th and 11th segments ◯

(11) Heart of cockroach is made up of :

(A) 12 units ◯ (B) 10 units ◯

(C) 11 units ◯ (D) 13 units ◯

(12) How many spiracles are present in cockroach ?

(A) 10 pairs ◯ (B) 8 pairs ◯

(C) 9 pairs ◯ (D) 6 pairs ◯

(13) How many types of nephridia are found in earthworm ?

(A) Three types ◯ (B) Two types ◯

(C) One type ◯ (D) Four types ◯

(14) In which segments, the testis lie in earthworm ?

(A) 10th and 11th segments ◯ (B) 12th and 13th segments ◯

(C) 13th and 14th segments ◯ (D) 15th and 16th segments ◯

2. Describe the following :

(1) Internal structure of body wall of earthworm

(2) Head of cockroach with mouth parts

(3) "Alimentary canal of earthworm" – Explain with diagram.

(4) Walking legs of cockroach

(5) External features of earthworm

(6) "Digestive system of cockroach" – Explain with diagram.

(7) Different types of nephridia of earthworm

(8) Respiratory system of cockroach.

(9) "Nervous system of earthworm" – Explain with diagram.

(10) Excretion and excretory process in cockroach

(11) Male reproductive organs of earthworm

(12) Female reproductive organs, process of copulation and cocoon formation

(13) Male reproductive system of cockroach

(14) Female reproductive system of cockroach, process of copulation and cocoon formation.

6

Animal Morphology and Anatomy - II
(Frog)

Frog is a member of class Amphibia. The class amphibia includes all those animals which live in fresh water as well as on land habitat. They are the first tetrapods which evolve from fish-like ancestors. They are characterized by their outstanding features and thus stand in between the fishes and reptiles. The systematic position of frog is as under:

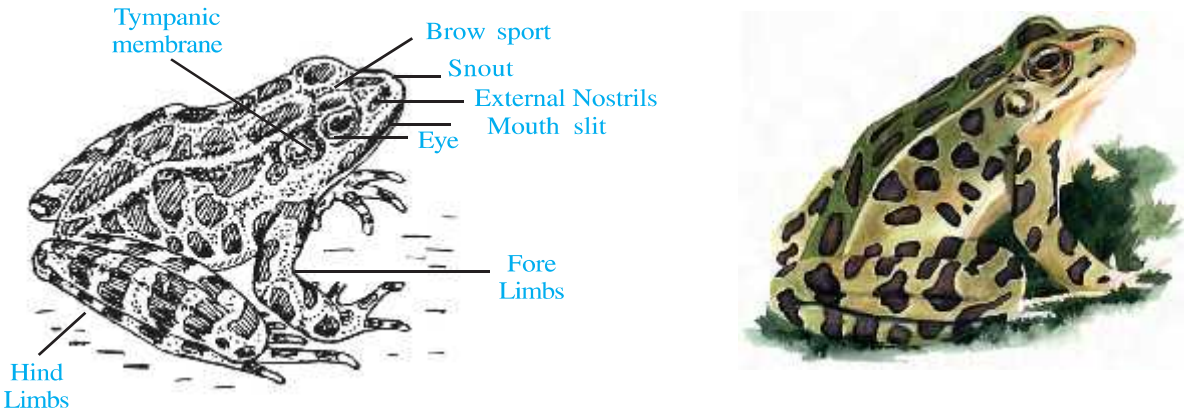
Systematic position

Phylum	:	Chordata
Subphylum	:	Vertebrata
Division	:	Gnathostomata
Class	:	Amphibia
Order	:	Anura
Genus	:	*Rana*
Species	:	*tigrina*
Binomial nomenclature	:	*Rana tigrina L.*

The common Indian bull frog *(Rana tigrina L.)* generally lives in or near the water. The dormant life during winter and summer known as hibernation and aestivation respectively. It is carnivorous which feeds on small animals. There are many natural enemies of frog such as snakes, some birds, man etc. Frog has capacity to change the skin colour according to the environment and this helps frog to escape from enemies.

External Morphology

The size of the frog varies in the same species depending upon the age of the individual. Frog has streamlined body which helps them to swim in water.

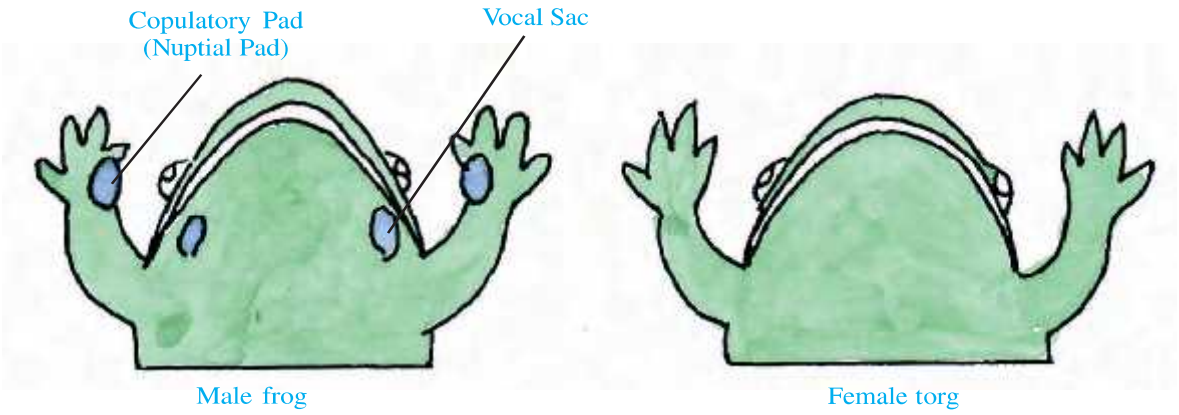


External morphology of Frog

The colour of the body at the dorsal side is green with black spots but ventrally it is lighter. The body is divided into two parts, head and trunk. The true neck and tail are absent. The anterior most part of the head is snout with two nostrils and laterally proputed eyes. On the mid dorsal line, in between two eyes there is browsport. Mid ear is represented by tympanic membrane. On the ventral side wide mouth is seen. The trunk bears two pairs of limbs; fore limbs are shorter with four digits while hind limbs are larger with five toes. Toes of hind limbs are connected by webs, which helps the animal in swimming.

Rana tigrina exhibits external sexual dimorphism, the phenomenon where two sexes (male and female) are morphologically different. During breeding season frog exhibits following characters.

Male	Female
• Two vocal sacs are present	• Vocal sacs are absent
• Nuptial pad present in the index finger	• Nuptial pad is absent
• The skin shows dark yellow colour during breeding season.	• Skin colour is not changed.
• The abdominal region narrow and flat.	• The abdominal region is broad and buldged.

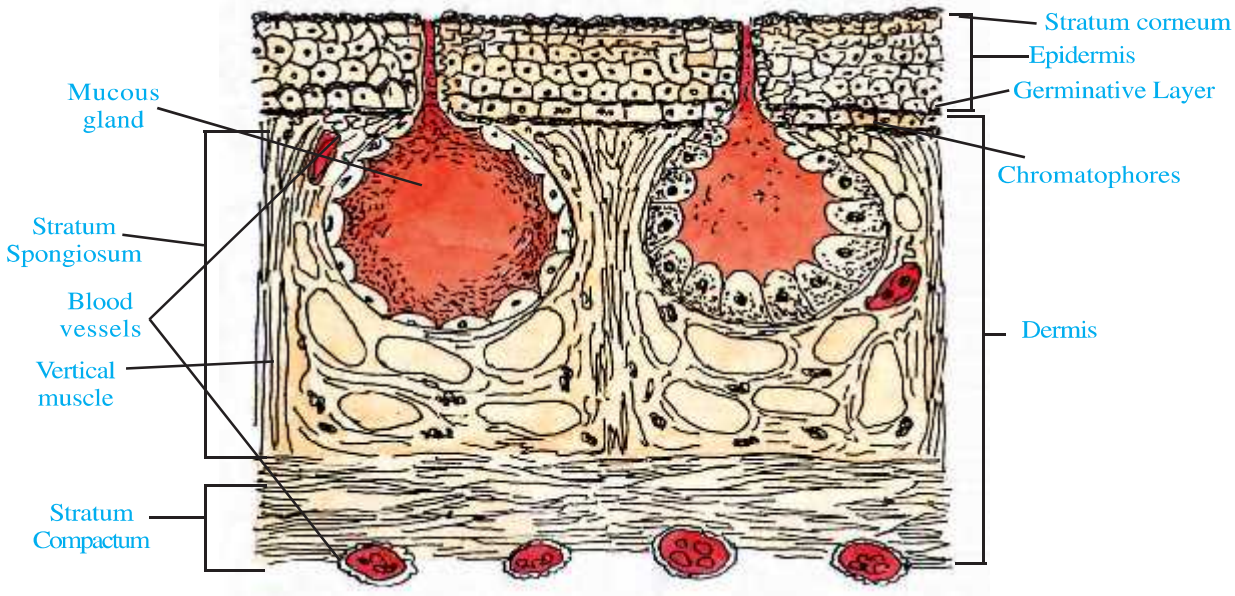


Sexual Dimorphism in Frog

Skin

The skin of frog is moist, smooth, slimy and without any exoskeleton. It consists of two layers, namely an outer epidermis and an inner dermis. The epidermis formed of several layers of epidermal cells. It is further divided into two layers, outer stratum corneum and inner stratum germinativum. Stratum cornium formed of a single layer of cells. This layer is dead and shed periodically. Stratum germinativum is formed of columnar cells. New cells are formed from this layer.

Dermis is the inner layer of skin. It is differentiated into two layers, outer stratum spongiosum and inner stratum compactum. The stratum spongiosum consists of loose network of connective tissue, blood vessels and mucous glands. Superficial part of this layer contains chromatophores. The stratum compactum is made by dense connective tissue, smooth muscle fibers, nerves and blood vessels.



Vertical section of the skin of Frog

Functions of the skin

(1) It gives definite shape and texture to the body.

(2) It protects the body against foreign bodies and fungi.

(3) It acts as a chief respiratory organ.

(4) It acts as an important sensory organ.

(5) The frog never drinks water but absorbs water through skin.

Anatomical Structure

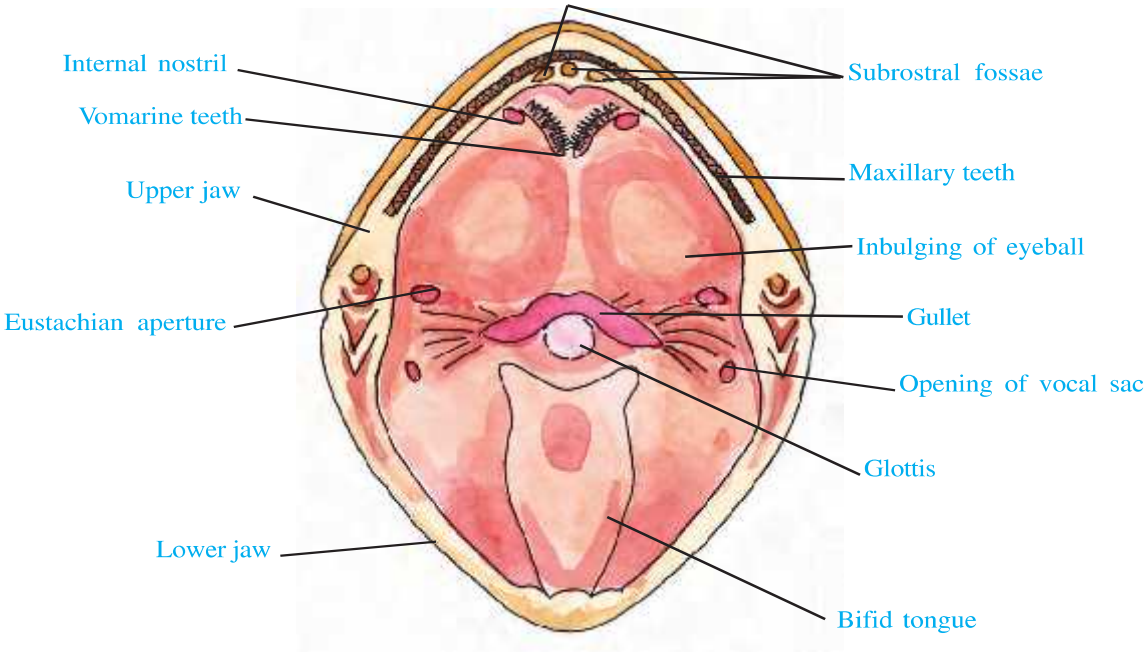
Frog has clear body cavity and different types of organ systems such as digestive system, skeleton system, circulatory system, respiratory system, urinogenital system and nervous system are seen in it.

Digestive System

The digestive system of frog mainly includes the alimentary canal and digestive glands. Alimentary canal starts from the mouth and ends at cloaca. The alimentary canal includes buccal cavity, pharynx, oesophagus, stomach, intestine, rectum and cloaca.

Alimentary Canal

Mouth is wide opening located at the anterior end of the head. It is bounded by the upper and lower jaws. A single row of teeth is present in the upper jaw. Mouth leads into a wide and broad cavity called buccal cavity which lies in between two jaws. The buccal cavity contains, maxillary teeth, vomerine teeth, internal nostrils, inbulging of eye-ball, eustachian apertures, opening of vocal sacs (only in male) and bifid tongue. The internal nostrils are a pair of openings located near the vomerine teeth. They serve in respiration. Behind the vomerine teeth there are two inbulging areas on the roof of the buccal cavity known as eye-balls. A pair of eustachian apertures lies on the roof of the buccal cavity, almost at the angles of the jaws. The eustachian apertures connects the pharynx with the middle ear and help in keeping the air pressure equal on both the sides of tympanic membrane. The two vocal sacs are present only in male frog and they open into buccal cavity, near the lateral surface of lower jaws. The bifid tongue is soft, slimy and fleshy. It is attached by its anterior end and is free at the posterior end. The free end of the tongue is bifid.

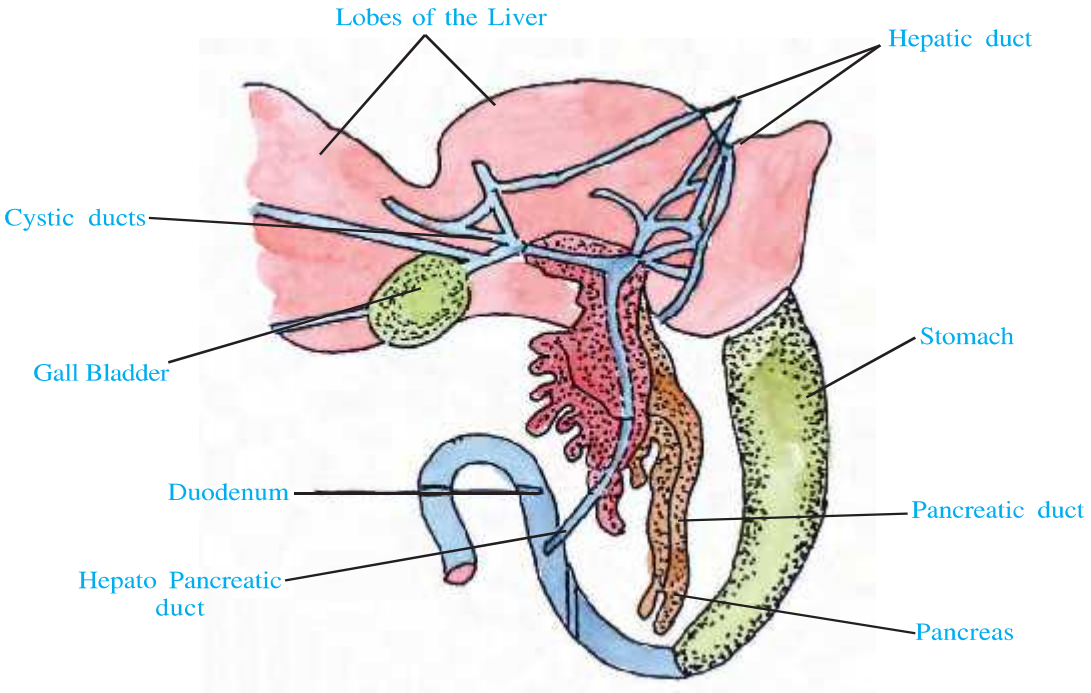


Open Bucco - Pharyngeal Cavity of Male Frog

The posterior end of the buccal cavity is the pharynx due to absence of neck. There is no demarcation between the buccal cavity and the pharynx. Hence, both the structures sometimes are collectively known as a bucco-pharyngeal cavity.

The oesophagus is a short, wide, muscular and highly distensible tube leading in to the stomach. The stomach lies on the left side in the body cavity. It is a large, broad and slightly curved chamber. It is formed of two regions, large broder anterior part is called cardiac stomach and posterior narrow part is called pyloric stomach. Its mucous epithelium contains multicellular gastric glands secreting the pepsinogen enzyme, diluted hydrochloric acid and mucus. Posterior end of pyloric stomach contains pyloric sphincter valve. The stomach is an organ for temporary food storage churning and partly digestion of proteins. The pyloric stomach leads to the small intestine.

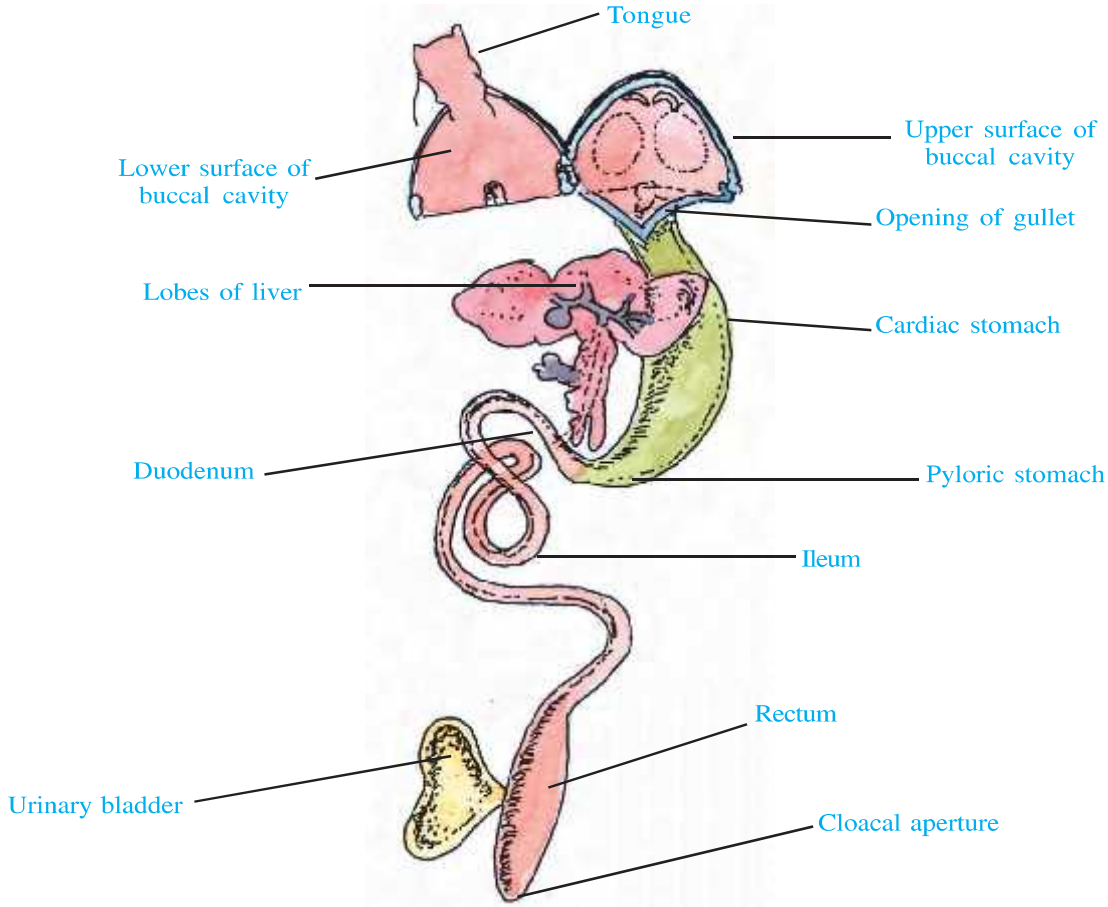
The small intestine is divided into anterior duodenum and a posterior ileum. Duodenum runs ahead parallel to stomach forming a U-shaped structure. It receives the hepatopancreatic duct from liver and pancreas which brings bile and pancreatic juice. The coiled ileum is the longest part of alimentary canal. Digestion and absorption of digested food occur in the small intestine.



Connectivity of Liver and Pancreas

The ileum leads to the large intestine. Anterior is a short, wide tube, running straight and opens into the cloaca. Its function is the re-absorption of water and the preparation and storage of faeces.

Cloaca is the small terminal sac like part. The term cloaca is used to denote the end part of the large intestine which opens into the rectum and the urinogenital apertures. Cloaca opens outside by the vent or cloacal aperture located at the posterior end of body.



Digestive tract of Frog

Digestive glands

The organ in which food does not enter but its secretion helps in physiological process of digestion are called digestive gland which includes Liver and Pancreas.

Liver

Liver is the largest gland found in the frog. It is a dark brown coloured gland located close to the heart and lungs. Liver is divided into two lobes and the left is again sub divided so it appears trilobed. A gall bladder lies between the right and left (lateral) lobes. The liver secretes greenish liquid called bile which contains bile salts and bile pigments like bilirubin and biliverdin is stored in gall bladder. The bile is transported to gall bladder by small hepatic ducts. Cystic ducts from gall bladder and hepatic ducts from liver combine to form a common bile duct. The bile duct passes through the pancreas and receives numerous pancreatic ducts. Now the bile duct is called heptopancreatic duct. It opens into the duodenum. Bile has no digestive enzymes, it only emulsifies fat so that liver is not truly a digestive gland.

Pancreas

It is the exocrine and endocrine pale yellow colored gland. It is situated at the junction between the stomach and duodenum. The pancreas produces pancreatic juice which contains

various enzymes which helps in digestion of proteins, carbohydrates and fats. In between the Pancreatic lobule groups of cells are found which are known as **islets of Langerhans.** These cells endocrine in nature which secretes hormones like **insulin and glucagon** directly into blood vessels. Insulin and glucagon maintain level of glucose in blood.

Digestion in Frog

Frog is a carnivorus animal. Generally it feeds on insects, worms, crustaceans, molluscs etc. The prey is captured by rapid action of its prehensile tongue. If prey is large, it is gripped with jaws, and prevented from escape. The prey is swallowed. The mucus helps in swallowing. The digestion of captured prey takes place in the stomach, duodenum and intestine. The physiology of digestion in different organs, enzymatic action and role of hormone in it are summarized in following table :

Table 1

Physiology of Digestion

Organs involving in digestion	Enzymes, Hormones and other substances	Function
Buccal cavity	No digestion	Prevent the escape of the prey
Tongue		Captured prey and put it into buccal cavity
Gullet		Helps in swallowing prey due to its slimy surface
Oesophagus	Mucus secretion from mucus secreting gland	-Prey undergoes physical changes due to constant peristaltic movement of wall -Prey easily passes toward stomach through it
Stomach	Secretion of Gastric juice from gastric gland (1) Gastrin (H)	-Stimulate gastric gland.
	(2) Diluted HCl (0.4%)	-Kills microbes from food -Provides acidic medium to activate enzyme Pepsinogen
	(3) Inactive Pepsinogen (E)	-Inactive Pepsinogen + HCl $\longrightarrow$ Active Pepsin -Protein + Pepsin $\longrightarrow$ Peptones or Proteoses
	(4) Mucus	- Lubricates the wall
	The liquefied semi digested acidic food is now called **Chyme.**	

Liver (Digestive gland)	Secretion of bile juice Contains Bile Salts.	-Greenish alkaline fluid which neutralized the acidity of chyme -Emulsifies fats -Activates pancreatic Lipase
Pancreas (Digestive gland)	Secretion of pancreatic juice (1) Inactive Trypsinogen (E) Inactive Chymotripsinogen (E) Procarboxypeptidase (E) (2) Enterokinase (co-enzyme)	Alkaline juice Inactived Trypsinogen + Enterokinase ⟶ Active Trypsin; which activates other inactive enzyme.
	(3) Trypsin (E)	Peptons or proteoses + Trypsin ⟶ Peptides and Amino acids
	(4) Amylase (E)	Polysacharide + Amylase ⟶ Maltose
	(5) Lipase (E)	Emulsified Fats + Lipase ⟶ Fatty acid + Glycerol
Duodenum	(1) Enterogastrone (H)	Reaches stomach and stop production of gastric juice
	(2) Cholecystokinin (H)	Contracts Gall bladder and releases bile juice into duodenum
	(3) Secretin (H) (4) Pancreozymin (H)	Combine effect is to stimulates pancreas to secrete pancreatic juice into duodenum
	(5) Enterocrinin (H) (6) Deokinin (H)	Stimulates Intestine to secrete Intestinal juice
Intestine	Secretion of Intestinal juice (1) Erepsin or Peptidases (E)	 Peptides + Erepsin ⟶ Amino acids
	(2) Maltase (E)	Maltose + Maltase ⟶ Glucose + Glucose
	(3) Sucrase or Invertase (E)	Sucrose + Sucrase or Invertase Glucose + Fructose
	(4) Lipase (E)	Lipid + Lipase ⟶ Fatty acids + Glycerol

*** Note :** Here E = Enzymen and H = Hormone

Absorption

Absorption is a process in which the digested food is taken into blood. Mainly this process takes place into duodenum and ileum. The walls of these organs are folded with villi which increase the absorptive surface. Water, mineral, salts and other nutrients in solution are directly absorbed through the epithelial lining and then they pass into blood capillaries.

Adsorption of digested food and egestion

As the food passes downwards in the alimentary canal the water and the digested products are absorbed whereas the indigested food, debries epithelial cells, leucocytes, bile pigments and large number of bacteria form faeces are removed time to time through cloacal opening.

Respiratory System

Respiration is a process in which living organisms obtain oxygen for oxidation and CO_2 is removed regularly from the body. Organs involved in respiration are known as respiratory organs. Frog as an amphibian animal exhibits three types of respiration i.e. (i) Cutaneous respiration or respiration through skin, (ii) Bucco-pharyngeal respiration and (iii) Pulmonary respiration or respiration through lungs. Generally frog respires through skin, but when the need of oxygen is greater it respires through bucco-pharyngeal cavity and lungs.

(1) Cutaneous respiration

This type of respiration takes place through the skin, so it is known as cutaneous respiration. The skin of frog is suitable for respiration due to following characters:

- Skin remains moist due to mucus, secreted by the mucous glands.
- Skin is permeable for gases.
- Skin is very thin.
- Skin has rich blood supply through blood capillaries.

Due to above characters, the oxygen from water or air diffuses into blood and carbon dioxide diffuses from the blood into surrounding medium of water or air through the skin. This type of respiration takes place in both media, water as well as on land. So when frog lives in any habitat, either water or land, it respires through skin.

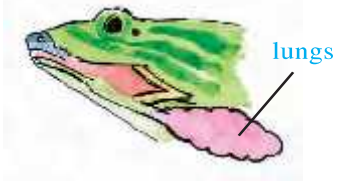
(2) Bucco-pharyngeal respiration

Respiration takes place through the buccal cavity and the pharynx then it is called bucco-pharyngeal respiration. It is a terrestrial respiration. Both the organs are lined with thin mucus, permeable to gases and rich with blood vessels. Lowering and raising of the floor of the buccal cavity bring the bucco-pharyngeal respiration, during the course of which the air is constantly sucked into the buccal cavity and is drawn out through the external and internal nares. When the floor of the buccal cavity is lowered, the air enters the buccal cavity through the nostrils or the nares. During this respiration gullet remains closed.

(3) Pulmonary respiration

Respiration takes place through lungs in terrestrial habitat is called pulmonary respiration. The system consists of respiratory tracts and lungs. There are two respiratory tracts, each respiratory tract starts from an external nostril. It opens into the bucco-pharyngeal cavity. Bucco-pharyngeal cavity leads into a sac called laryngotracheal chamber through glottis. This laryngotracheal chamber opens into lungs.

Pulmonary aspiration



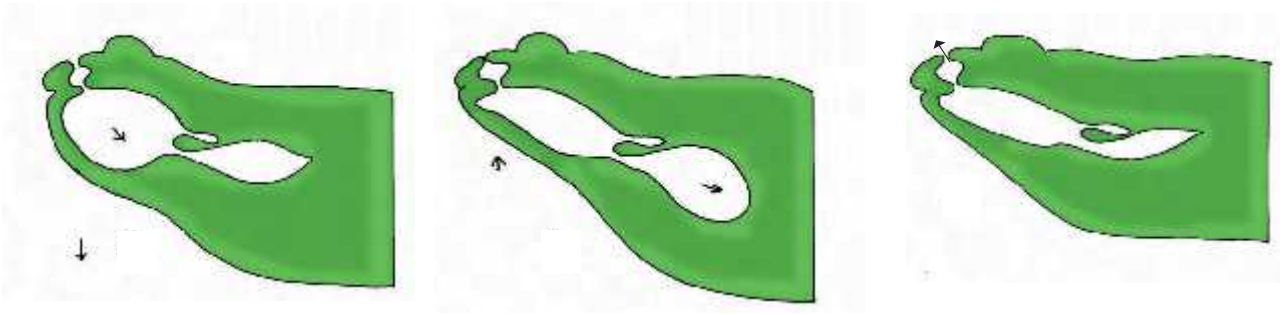
Pulmonary expiration

The entire process of pulmonary respiration is completed in three steps : (1) Aspiration, (2) Inspiration and (3) Expiration.

(1) Aspiration : The entry of the gases into the bucco-pharyngeal cavity is called aspiration.

(2) Inspiration : The gases pass through the bucco-pharyngeal cavity to lungs is called inspiration, during this process diffusion of oxygen occurred.

(3) Expiration : The passage of impure air from the lungs to the outside of the body is called expiration.



Aspiration Inspiration Expiration

Pulmonary respiration in frog

Circulatory System

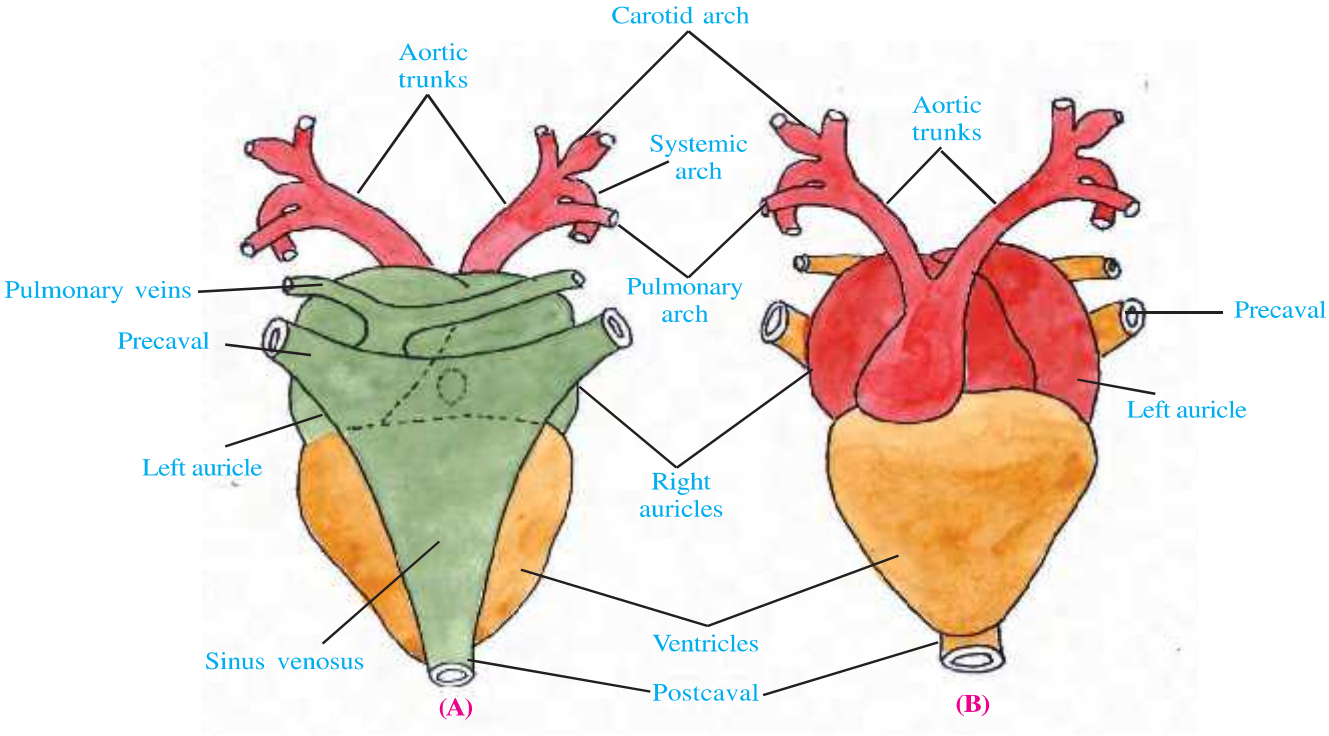
Frog as a vertebrate animal has closed type of circulatory system. This system has four main components i.e. blood, heart, arteries and veins.

Blood is a red coloured liquid connective tissue. It is composed of blood cells (corpuscles) and blood plasma. Blood corpuscles are of three types (1) Red Blood Corpuscles (RBCs) - nucleated and contain hemoglobin, (2) White Blood Corpuscles (WBCs) - colourless and nucleated and (3) Platelets - nucleated. The blood plasma is a liquid in nature and consists of mainly water and salts (see blood as a tissue in Chapter 4).

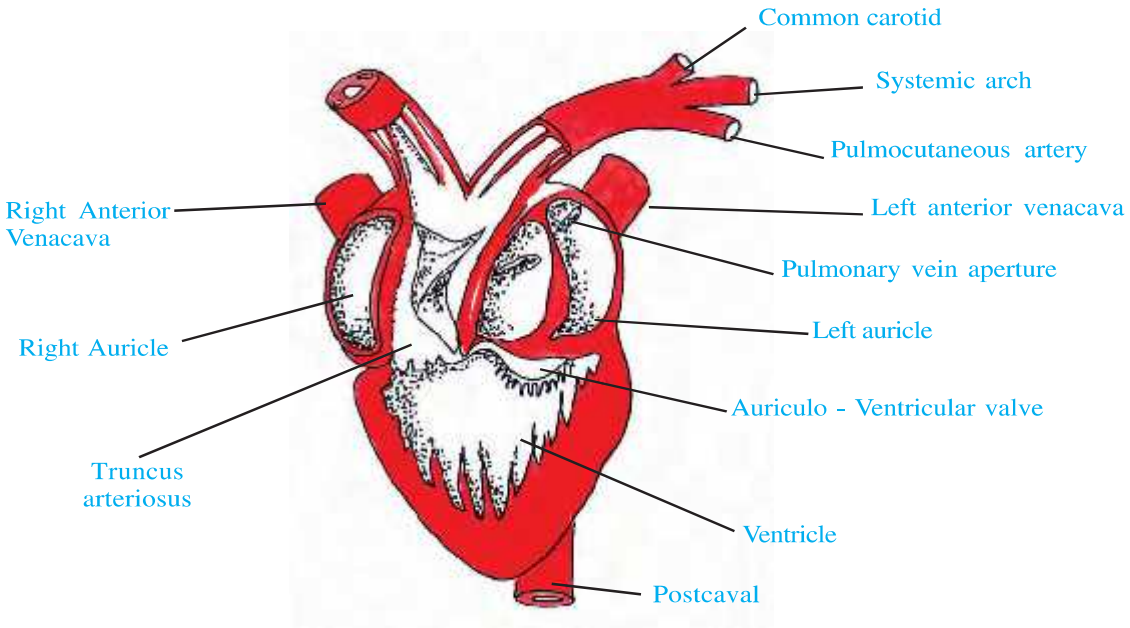
The heart is protected inside a double walled bag called pericardium. In between these walls pericardium fluid is present. The heart is located in the anterior region of coelom. It is muscular, conical and three chambered (two auricles and one ventricle) pulsative organ. On the dorsal side of heart sinus venosus is located, which collects deoxygenated blood from various parts of the body and empty up into right auricle through sinu-auricular aperture.

The left auricle receives oxygenated blood from lungs through a common pulmonary vein. The blood from both auricles enter the ventricle through a single opening called auriculo-

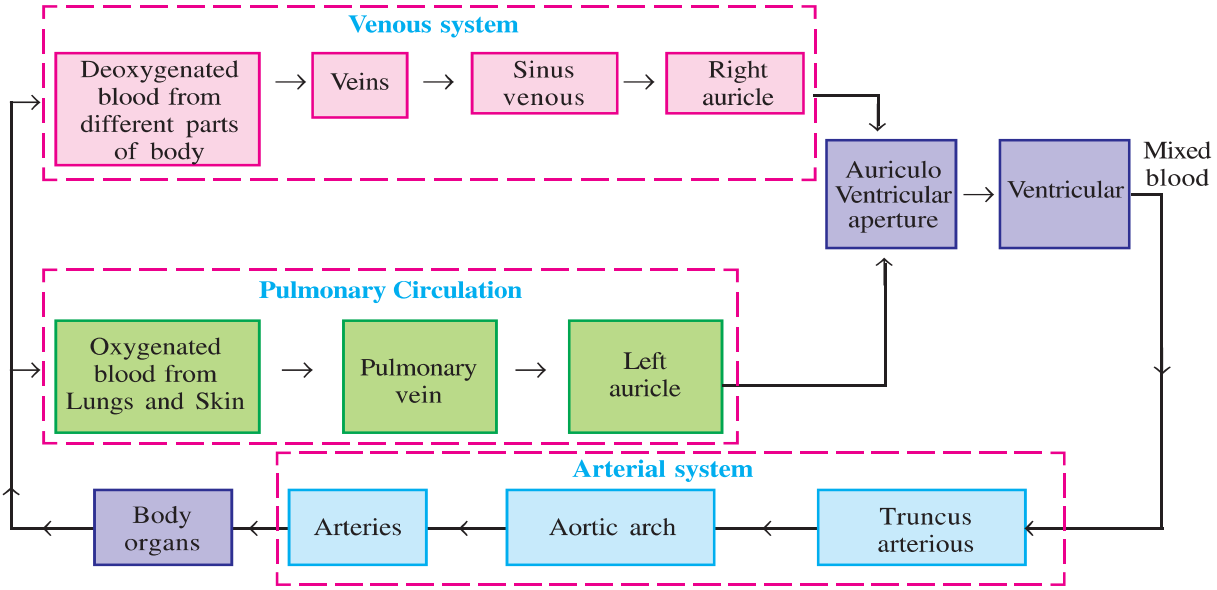
ventricular aperture. Thus, oxygenated blood from left auricle and deoxygenated blood from right auricle is mixed in ventricle. As a result in frog, mixed blood is circulated through arterial system. The ventricle contracts and forces the blood into truncus arterious from where it enters into arterial system.



Structure of Heart : (A) Dorsal view (B) Ventral views

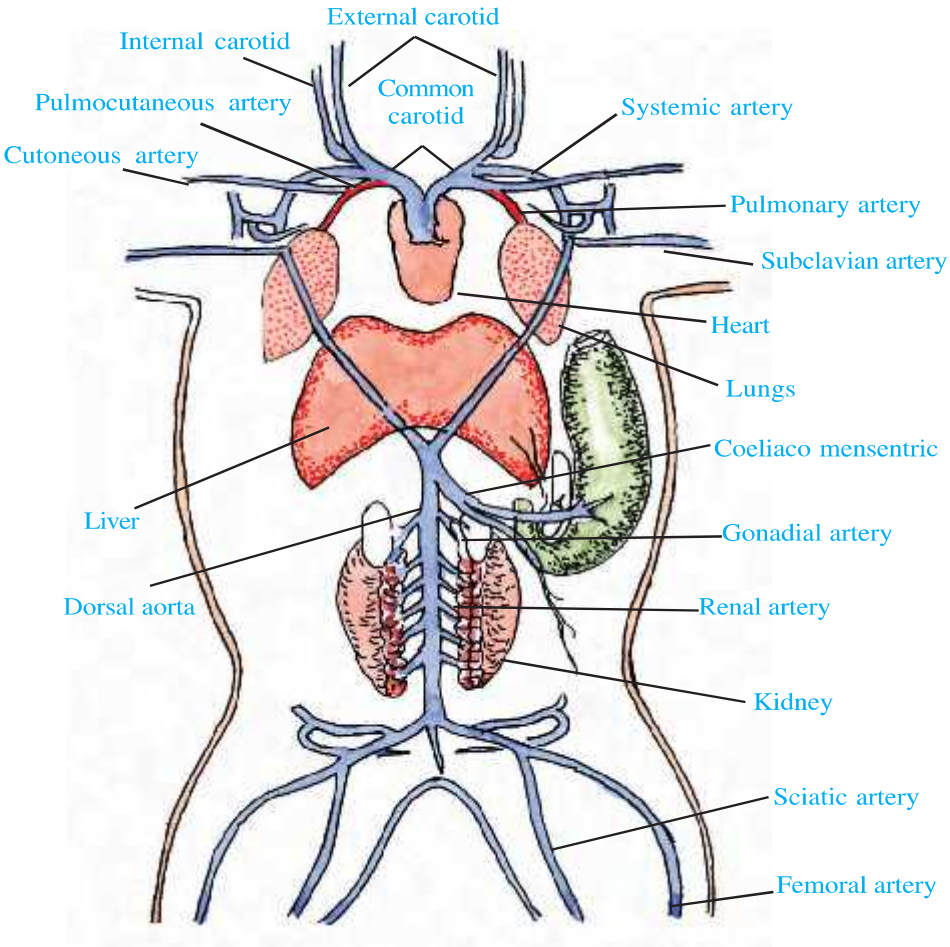


Verticle section of the Heart of Frog



Flow of blood in the frog

The arterial system, supplies blood from heart to different parts of the body. The system starts from truncus arteriosus and supplies mixed blood through aortic arteries.



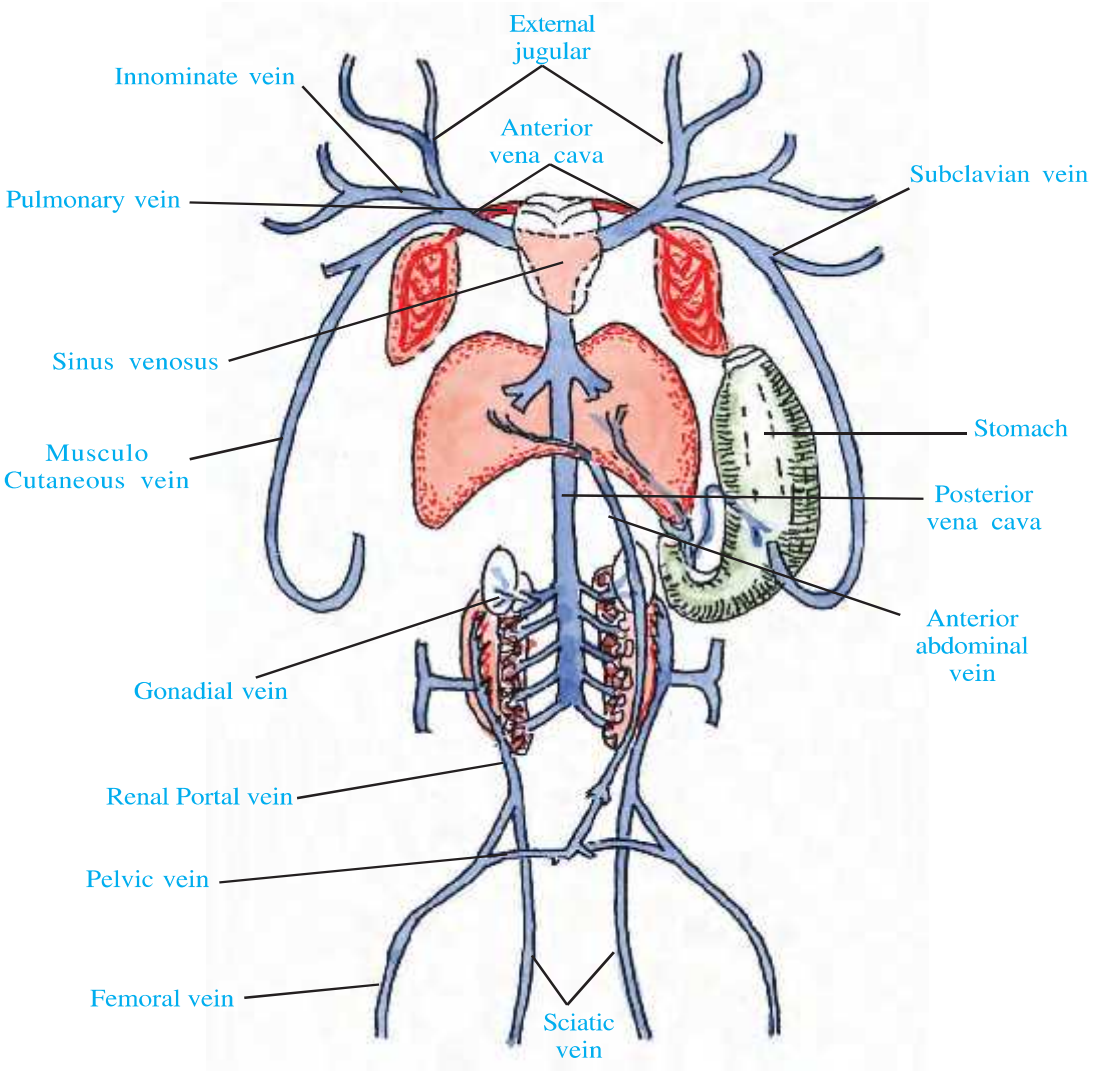
Arterial system of Frog

(1) carotid arch : external carotid and internal carotid arteries supply blood to head region. **(2) Systemic arch :** Unites to form a dorsal aorta. It supplies blood to posterior region through various arteries such as Coeliaco-mesenteric artery (supply blood to alimentary canal), gonadial artery (supply blood to gonads), renal artery (supply blood to kidneys) and iliac artery (supply blood to hind limbs). **(3) Pulmocutaneous artery :** Supplies blood to lung and skin.

The venous system brings blood from different parts of the body to heart. Collected impure blood from all the parts of the body is empty up into sinus venosus through three cavals (two pre-cavals and one post

caval). Each pre-caval receives blood from both sides through external jugular, innominate and sub-clavian veins. These veins drain impure blood from different organs like tongue, lower jaw, head, brain, fore limb etc. while cutaneous vein and the branches of sub-clavian veins exceptionally carries oxygenated blood. Renal veins emerging from two kidneys open into posterior vana cava which passes through right lobe of liver and opens in to sinus venosus, which bring blood from kidneys, gonads and liver through different veins.

Generally arteries and veins divided to form capillaries. Vertebrate animal like frog exhibits a special type of vein arrangement called Portal system. Veins gerenrally collect deoxygenated blood from various organs but some veins before entering into the heart enter into some organs (liver & kidney) and divide into many capillaries such veins are known as portal veins they form portal system. Frog has two types of portal systems **(1) Renal portal system :** In this system blood vessels carries blood from the hind limbs to the kidneys and **(2) Hepatic portal system :** It collects blood from the digestive tract and supplies blood to the liver.



The venous system of Frog

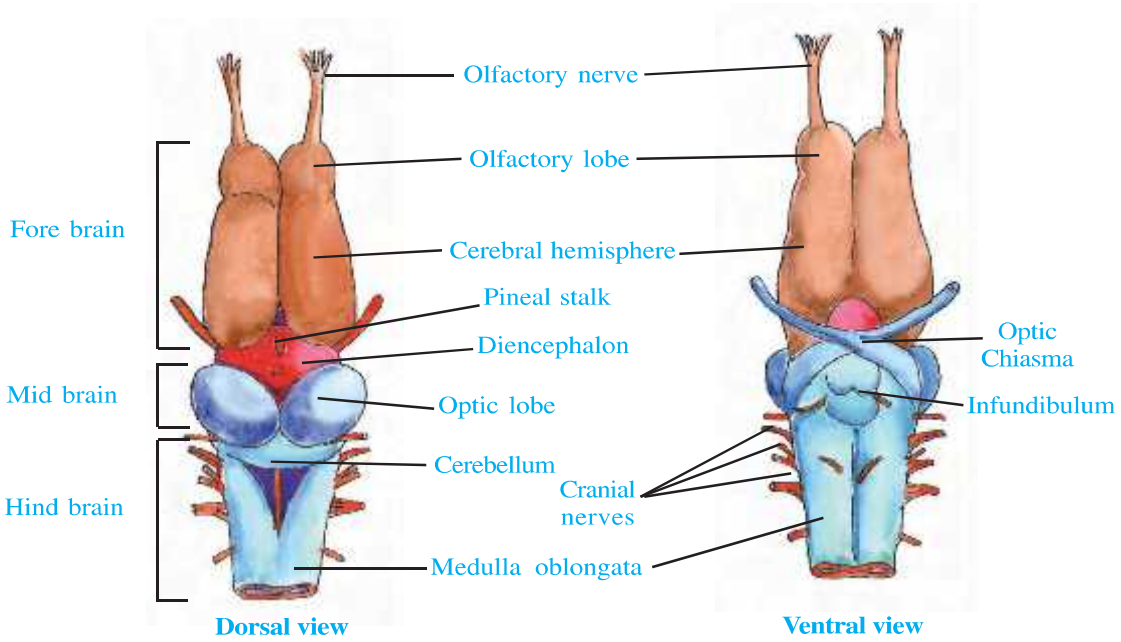
Nervous system

In frog the nervous system is located on the dorsal side of the body as found in all vertebrates. It is divided into two sections. (1) Voluntary nervous system and (2) Involuntary nervous system.

The regulation of voluntary nervous system is under the willingness of animals. Voluntary nervous system divides into central and peripheral nervous system. Central nervous system consists of brain and a spinal cord. Brain is situated in the head and protected within the cranium. Which divided into three regions : fore brain, mid brain and hind brain. Fore brain includes a pair of olfactory lobes, a pair of cerebral hemispheres and diencephalons. On the ventral side of diencephalons one hollow, bilobed and pouch like part is located, which is known as infundibulum. Pituitary gland is attached to the broad posterior end of it. It is master endocrine gland controlling various physiological activities, animal growth and development. The mid brain includes of two large oval and obliquely arranged optic lobes. While hind brain is composed of cerebellum and medulla oblongata. The medulla oblongata continues as the spinal cord in the vertebral column. Spinal cord forms the voluntary central nervous system in the trunk region and terminates in the hollow cavity of urostyle of a vetebral column as a filum terminale.

The peripheral nervous system is formed by cranial nerves and spinal nerves arising from brain and spinal cord respectively. In frog 10 pairs of cranial nerves from brain and 9 pairs of spinal nerves from spinal cord arise.

Involuntary or autonomous nervous system is associated with the controlling of involuntary activity of animal. It has two sections: sympathetic nervous system and parasympathetic nervous system. They perform complementary functions to each other. For example, the sympathetic nervous system accelerates the heart beat while parasympathetic nervous system deaccelerates the heart beat.

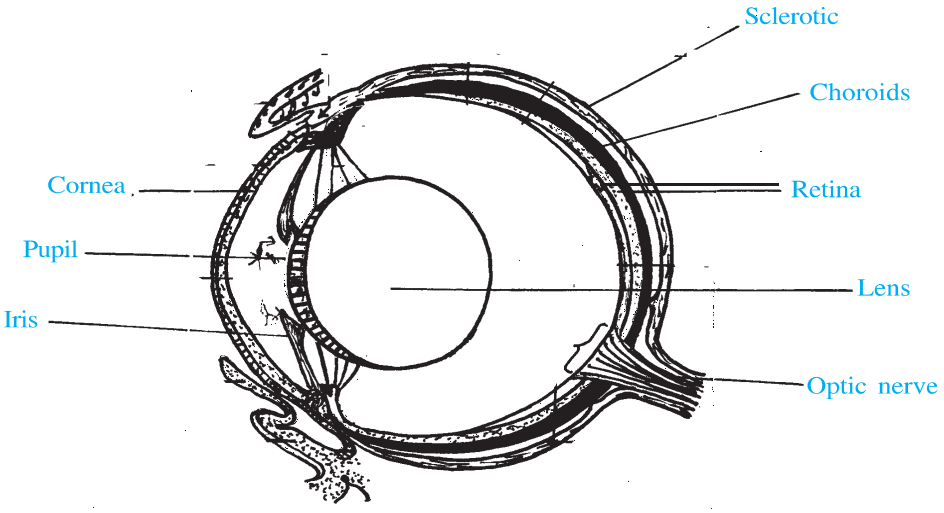


Brain of Frog

Five kinds of sense organs are found in frog: touch sensory, taste sensory, smell sensory, sight sensory and sound sensory. Of these, eye and ears are well organized structures. Other kinds of sense organs are constituted by specialized groups of cells, connected at near nerve endings. Tactile structures occur in skin. The tongue possesses taste receptors. In the lining of olfactory chambers, smell sensory structures are located.

Two eyes are located in the orbits. The wall of the eyeball is made up of three layers. The outer layer is sclerotic, the middle layer is choroids and the inner layer is retina. Towards the outerside a transparent cornea occurs in the eyeball. On its inner side, the choroids coat forms an iris. In the centre of iris, an aperture known as pupil occurs. Behind iris, the lens is arranged.

The ear consists of an inner ear and a middle ear. External ear is absent. The internal ear is also called membraneous labyrinth. It is located in a fluid-filled auditory capsule. Middle ear is an air-filled chamber which possesses the tympanic membrane at its outer end.



Ventral Section of Frog's eye

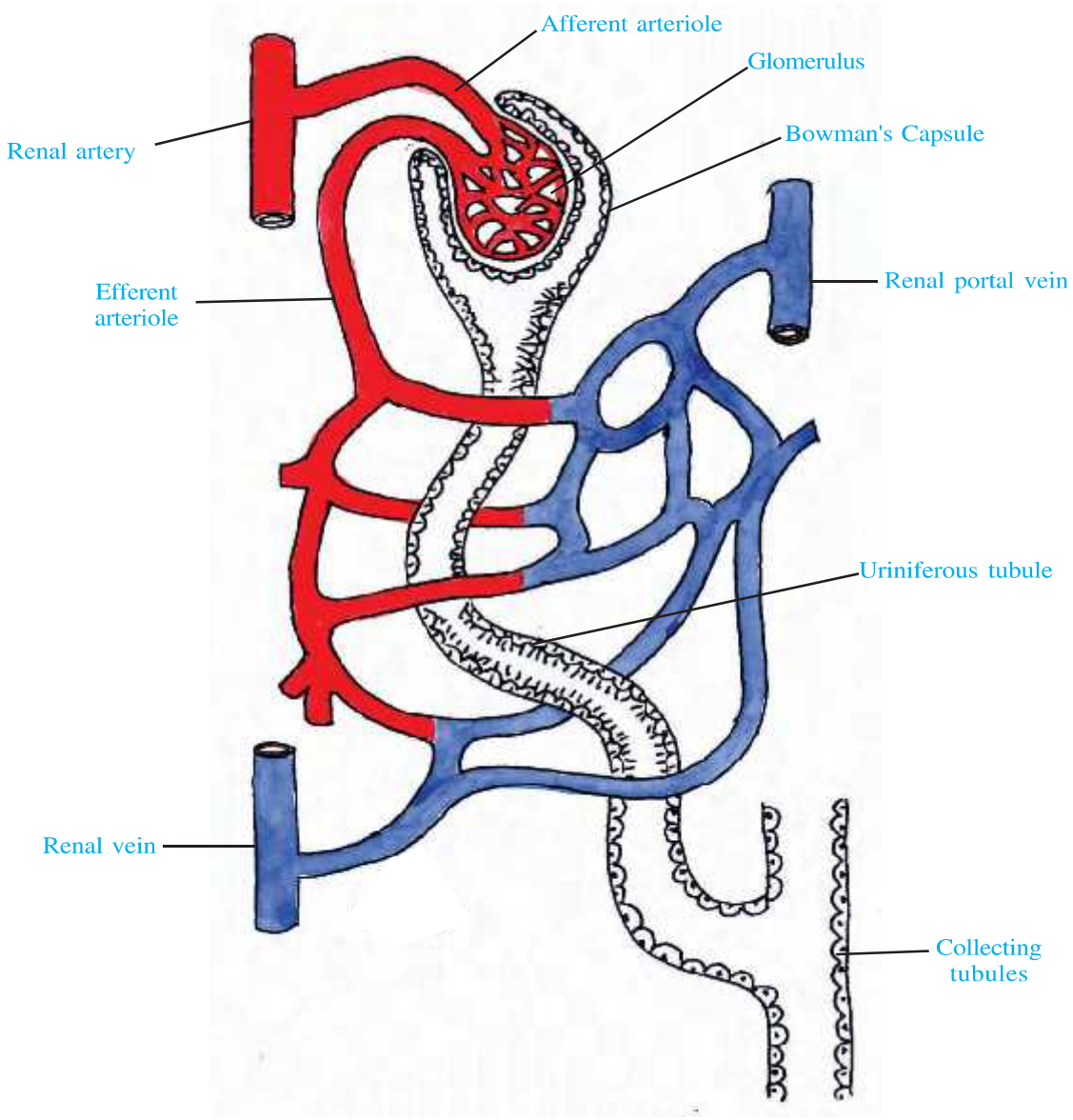
Over and above the nervous system, we also find an endocrine regulatory system made of endocrine glands. Which includes pituitary glands located in brain, thyroid gland in throat region, adrenal gland sunk in kidneys and gonads (testis and ovary). Islets of Langerhans of Pancreas also secretes hormones. Hormones are chemical regulators.

Urinogenital system

The urinogenital system comprises the excretory and the reproductive organs. The excretory system is closely associated with the genital system in male but they are separated in female. So here, we discuss this system separately.

In frog, a pair of kidneys act as main excretory organs. They are arranged on lateral sides of vertebral column in posterior part of the body. Kidneys are flat, oblong and brown in colour. A large number of uriniferous tubules occur in each kidney as units of excretion called Nephrons. Each uriniferous tubule possesses a double walled bowl like structure at its anterior end called Bowman's Capsule. Glomerulus is located within the Bowman's

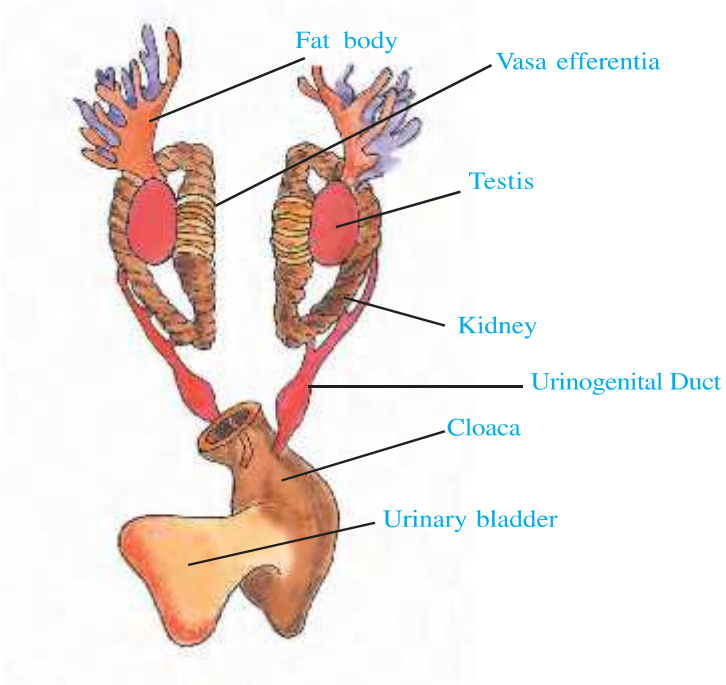
capsule which jointly called malpighian body. The process of urine formation begins here. The liquid urine formed in kidneys, is transported through ureters. Ureters come out from posterior lateral ends of kidneys. They transport urine towards cloaca. A bilobed, thin walled urinary bladder is associated with cloaca. Urinary bladder stores urine. When it is filled up, it contracts and discards urine through the cloacal aperture. The main excretory substance in urine is urea. In male frog, transport of sperms also occurs through the ureters, hence, the ureters are called urinogenital ducts.



Excretory unit of Frog

Reproductive System

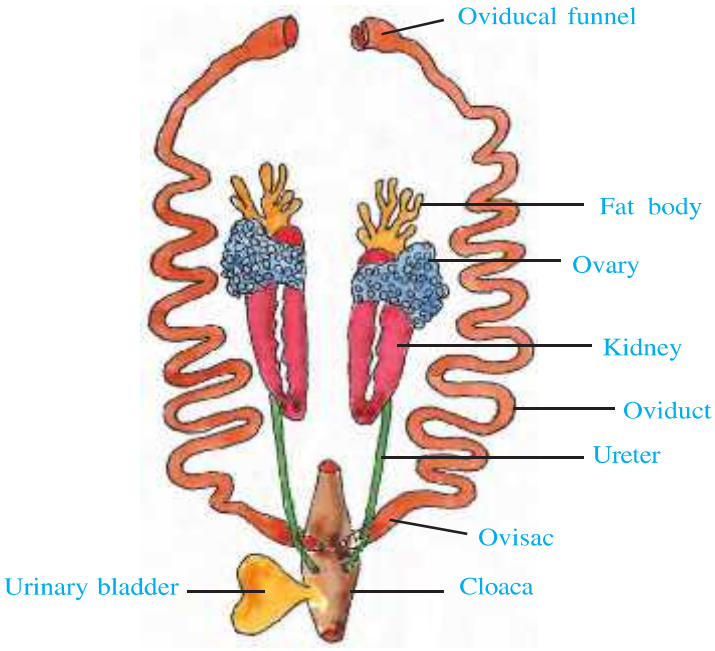
Frog is a unisexual animal. The male reproductive organs includes a pair of testes, vasa efferentia, Bidder's canal and urinogenital ducts. Each testis is located at the antero-lateral part of the kidney. It is oval-shaped, small and yellowish in colour. It remains connected to the kidney by mesorchium. The sperms produce in testes are transported to Vasa efferentia, Bidder's canal and finally, it is transported by urinogenital ducts to cloaca.



Male urinogenital system

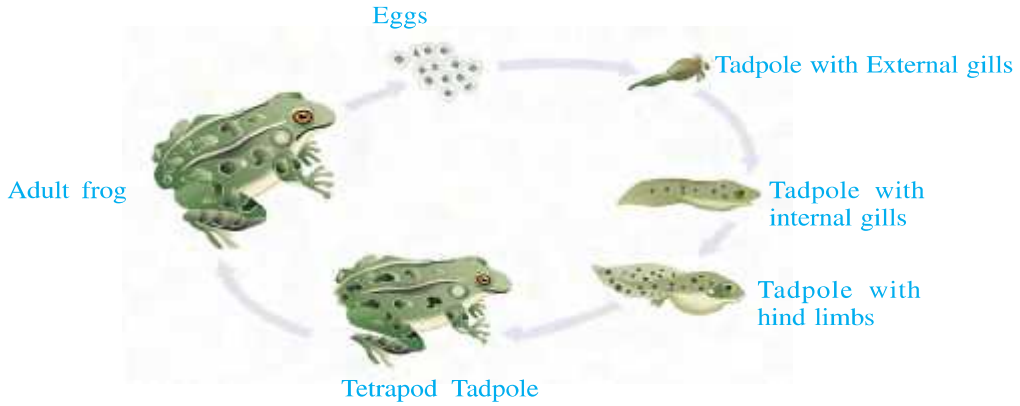
The reproductive organs of female frog includes a pair of ovaries, a pair oviducts and ovisac. Ovaries enlarge during the breeding season and produce ova. Each ovary is located at antero-lateral region of kidney. It is attached through mesovarium. Each oviduct begins as an oviducal funnel. It is a highly coiled structure which terminates into an ovisac and opens into the cloaca. The female frog releases large number of ovums in water.

The fat bodies situated at anterior end of kidney also act as accessory reproductive organs which supply energy during formation of gonadial cells.



Female urinogenital system

The breeding season of frog is monsoon, when it exhibits external and cross-fertilization. The medium of fertilization is water. Embryonic development is incomplete, external and metamorphosis type. So, instead of baby frog, the larval form of tadpole comes out from the egg. The tadpole passes through different forms like tadpole with external gills, internal gills, hind limbs, tetrapod tadpole etc. and it gets converted into baby frog.



Metamorphosis in Frog

Summary

Frog is a member of class Amphibia. The class amphibia includes all those animals which live partly in fresh water as well as on land habitat. *Rana tigrina,* the common **Indian bull frog** generally lives in or near the water. Frog has capacity to change the skin colour according to the environment and this helps frog to escape from enemies.

The body is divided into two parts, head and trunk. The head bears anterior snout, two large eyes, brow spot, tympanum and two nostrils. The trunk bears two pairs of limbs : fore limbs and hind limbs. Rana tigrina exhibits sexual dimorphism. The skin of frog is moist, slimy and without any exoskeleton. It acts as a chief respiratory organ. Frog has clear body cavity, in which, different types of organ systems accommodate, such as digestive system, circulatory system, respiratory system, urinogenital system and nervous system. The digestive system of frog mainly includes the alimentary canal and digestive glands. Alimentary canal starts from mouth and ends in cloaca. In between, it consists of the buccal cavity, pharynx, oesophagus, stomach and intestine. Other than the gastric gland (stomach) and intestinal gland (small intestine) two glands namely liver and pancreas are also associated with the alimentary canal. Frog is a carnivorus animal. The mucus helps in swallowing. The digestion of captured prey takes place in stomach, duodenum and intestine. Absorption is a process in which the digested food is taken into blood. Mainly this process takes place into duodenum and ileum. Faeces are removed time to time through the cloacal opening.

Respiration is a process in which living organisms obtain oxygen for oxidation and during this process CO_2 is removed regularly from the body. Frog as an amphibian animal exhibits three types of respiration, i.e. (i) cutaneous respiration or respiration through skin, (ii) bucco-pharyngeal respiration and (iii) pulmonary respiration or respiration through lungs.

Frog as a vertebrate animal has closed type of circulatory system. This system has four main components, i.e. blood, heart, arteries and veins. Blood is a red coloured liquid connective tissue. It is composed by blood cells (corpuscles) and blood plasma. Heart is muscular, conical and three chambered (two auricles and one ventricle) pulsative organ.

The arterial system, supplies blood from heart to different parts of body. The arterial system starts from truncus arteriosus and supplies mixed blood to various arteries.
The venous system brings blood from different parts of body to heart. Collected impure blood from all the parts of the body brings into sinus venosus. Vein collects deoxygenated blood from various organs and supply it in definite organs instate of heart is called portal vein. Frog has two types of portal systems : (i) Renal portal system and (ii) Hepatic portal system.

As in all vertebrates, in frog also the nervous system is located on the dorsal side of the body. It is divided into two sections : (i) Voluntary nervous system and (ii) Involuntary nervous system. Voluntary nervous system has two divisions: central nervous system and peripheral nervous system. Central nervous system consists of brain and a spinal cord. The peripheral nervous system is formed by cranial nerves and spinal nerves arising from brain and spinal cord respectively. Involuntary or autonomous nervous system is associated with the controlling of involuntary organs of the animal body. Five kinds of sense organs are found in frog : touch sensory, taste sensory, smell sensory, sight sensory and sound sensory.

The urinogenital system comprises the excretory and the reproductive organs. In frog, a pair of kidneys act as main excretory organs.

Frog is a unisexual animal. The male reproductive organs occur as a pair of testes, vasaefferentia Bidder's canal and urinogenital ducts. And the reproductive organs of female frog are a pair of ovaries, one pair oviducts and ovisac. In frog, cross-fertilization occurs, it is external. The medium of fertilization is water.

Exercise

1. Put a dark colour in a given circle for correct answer :

(1) Give scientific name of Indian Bull Frog ?

(A) *Rana silvetica* ◯ (B) *Rana tigrina* ◯

(C) *Rana asqulenta* ◯ (D) *Rana cylophyletis* ◯

(2) Which of the following enzymes digests carbohydrate ?

(A) Amylase ◯ (B) Lipase ◯

(C) Trypsin ◯ (D) Pepsin ◯

(3) Bidder's canal is formed to transport .....

(A) Sperms ◯ (B) Ova ◯

(C) Urine ◯ (D) Sperms and Urine ◯

(4) Sinus venous opens in which part of heart ?

(A) Right auricle ◯ (B) Left auricle ◯

(C) Ventricle ◯ (D) Auricle and Ventricle ◯

(5) How many pairs of cranial nerves are found in frog?

(A) 09 pairs ◯ (B) 10 pairs ◯

(C) 12 pairs ◯ (D) 11 pairs ◯

(6) In which part of alimentary canal of frog complete digestion of protein takes place ?

(A) Rectum ◯ (B) Stomach ◯

(C) Duodenum ◯ (D) Large Intestine ◯

(7) Which type of fertilization is seen in frog ?

(A) Self and internal fertilization ◯

(B) Cross and external fertilization ◯

(C) Self and external fertilization ◯

(D) Cross and internal fertilization ◯

(8) Which organ of frog collects faeces, urine and gametes ?

(A) Rectum ◯ (B) Urino-genital duct ◯

(C) Urinary bladder ◯ (D) Cloaca ◯

(9) Which part of alimentary canal produces chyme ?

(A) Stomach ◯ (B) Duodenum ◯

(C) Rectum ◯ (D) Large intestine ◯

2. Answer in short :

(1) Write phylum, subphylum and division of frog.

(2) Write a scientific name of frog

(3) What is Aestivation ?

(4) Which jaw has maxillary teeth in buccal cavity of frog.

(5) Name two parts of stomach of frog ?

(6) Write location of brow spot.

(7) In which part of body glottis opens ?

(8) In which part of stomach pyloric valve is located ?

(9) What is secreted by liver ?

(10) Hepato-pancreatic duct is a formed by the combination of which ducts ?

(11) Write location of Islets of Langerhans.

(12) Which hormone converts blood glucose into glycogen ?

(13) Name the enzymes which digesting protein ?

(14) Write functions of Cholecystokinin.

(15) Which are the three steps of pulmonary respiration ?

(16) What is portal vein ?

(17) Write location of pituitary gland.

(18) How many pairs of cranial nerves are present in frog ?

(19) Write a function of Cloaca.

(20) What is chemical conduction ?

(21) Write location of Infundibulum.

3. Answer in brief :

(1) Classify frog from phylum to species.

(2) What is sexual dimorphism ? Give comparison of sexual dimorphism of frog.

(3) Give brief information of habitat and food of frog.

(4) Write functions of skin.

(5) Give only chart of blood circulation in heart of frog.

(6) Write differences : Urinogenital system of male frog and Urinogenital system of female frog.

4. Write a short note :

(1) Internal structure of skin

(2) Buccal cavity of frog

(3) Alimentary canal of frog

(4) Digestive gland of frog

(5) Digestion of protein

(6) Inspiration and expiration

(7) Portal system

(8) Autonomous nervous system

(9) Urinary tract of frog

5. Answer the question as per instruction :

(1) Write external features of frog in detail.

(2) What is digestion ? Explain digestion process in the stomach of frog.

(3) Explain digestion in duodenum.

(4) Explain Cutaneous and Bucco-pharyngeal respiration in frog.

(5) Explain pulmonary respiration in frog.

(6) Describe with figure : Heart of frog.

(7) Explain : Venous system of frog.

(8) Explain in short : Sense organs of frog.

6. Draw only labelled diagram :

(1) L.S. of frog skin

(2) Alimentary canal of frog

(3) Open buccal cavity of frog

(4) L.S. of frog heart

(5) Venous system of frog

(6) Dorsal and ventral views of frog brain

(7) Urinogenital system of male frog

(8) Urinogenital system of female frog

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