Uttar Pradesh Rajarshi Tandon Open University

Bachelor of Science

UGZY-104

Hemichordates & Chordates

COURSE INTRODUCTION

Hemichordates and Chordates

Hemichordates are worm like, marine animals, white chordates live in water, land and air. The hemichordata contains an epidermal nervous system, whereas chordata contains a central nervous system.

The entire syllabus divided into Block-I and Block-II.

The Block-I consists of 4 units (unit-1 to unit-4).

The Block-II consist of 4 units (unit-5 to unit-8).

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BLOCK

1

HEMICHORDATES & CHORDATES

UNIT-1

Hemichordata and Cephalochordata

UNIT-2

Urochordata

UNIT-3

Fish, Ambhibia and Reptilia

UNIT-4

General Characters and Classification of aves up to order with examples, Flying adaptations in Birds

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BLOCK INTRODUCTION

The Block-1 consists of 4 units (Unit-1 to Unit-4).

In Unit-1 you will study about hemichordata and cephalochordata. In this unit general characters of hemichordate, Affinities of *Balanoglossus*. In cephalochordata you will study about habit, morphology, anatomy and physiology of *Branchiostoma* in very detailed manner.

In Unit-2 you will study about Urochordata. In this unit classification of *Herdamina*, their habits, and morphology. There is also study of anatomy like respiratory system, mechanism of respiration, digestive system , excretory system, reproductive system, fertilization, development, tadpole larva, retrogressive metamorphosis are study in very detailed manner.

In Unit-3 you will study in detailed about *Scoliodon* in which its classification, its habits, morphology, skin, placoid scale, locomotion in *Scoliodon*, digestive system include alimentary canal and its associated gland and physiology of digestion. Respiratory system include respiratory organ and mechanism of respiration, blood vascular system include heart, arteries, veins and blood, nervous system include brain and spinal cord, sense organ include olfactory organ, optic organs, stato acoustic organ, lateral line organs like neuromast organs, pit organs, and ampulla of lorenzini, urinogenital system, reproductive organ, fertilization and development. In another section of this unit will have general character and classification of amphibian and reptile.

In Unit-4 you will study about general characters and classification of Aves. In another segment of this you will study in detailed of flying adaptations in birds including their body shape and structure, body covering of feathers, fore limbs modified into wings, beak, flexible neck and head, bipedal locomotion, flight muscle, air sacs and respiration, loss of weight, circulatory system, digestive system, ureotelic excretion, perching, endoskeleton, brain and single ovary.

Objectives

After studying this block you will be able to

- Basic knowledge about hemichordate and cephalochordate
- Describe the habit, morphology anatomy and physiology of *Branchiostoma*.
- Describe the classification and detailed study about morphology, anatomy, physiology and post embryonic development of *Herdmania.*
- Describe the classification and detailed study about morphology, anatomy, physiology *Scoliodon*.
- Explain about general character and classification of amphibian and reptilia.
- Explain general character and classification of aves.
- Explain about flying adaptation in birds.

- Explain about histology, comparative study of skin and skeleton
- Describe pectoral girdle, pelvic girdle, fore limb and hind limb of amphibia, reptilia, bird and mammal.

UNIT-1 HEMICHORDATA & CEPHALO-CHORDATA

Structure (A) Hemichordata

Structure (B) Cephalochordata

Structure (A) Hemichordata

1.1 INTRODUCTION

Hemichordata (Gr.hemi, half; chorde, cord) is an independent phylum of invertebrates and is close to Echinodermata. But for convenience of the comparative study to protochordates, the hemichordata is retained in subphylum chordate and is considered to be connecting link between non-chordata and chordata. Hemichordata are a small group of marine, solitary or colonial worm like, enterocoelous animals, most of which live in tubes. The body and enterocoelous coelom are divisible into three unequal regions; like proboscis, collar and trunk. In most forms one to several pairs of gill clefts lead from the pharynx to exterior. Nervous system is a network of nerve cells and fibres on the surface of the body, embedded in the epidermis. They have no bony tissue, but a buccal diverticulum is present in the preoral region, which is often regarded as a notochord.

Objectives :

- Classify the general characters of Hemichordata and Cephalochordata.
- Describe the morphology, anatomy, physiology of Branchiostoma.

1.2 GENERAL CHARACTERS OF HEMICHORDATA

- Exclusively marine, solitary or colonial, mostly tubicolous.

- Body soft, fragile, vermiform, unsegmented, bilaterally symmetrical and triploblastic.
- Body typically divided into 3 distinct regions, *viz.,* proboscis, collar and trunk.
- Coelom enterocoelous, usually divided into protocoel, mesocoel and metacoel, corresponding to 3 body regions.
- Body wall of a single layered, epidermis with mucous glands. No dermis.
- Digestive tube complete, straight or U –shaped.
- Foregut gives out a hollow buccal diverticulum into proboscis.
- Dorso-lateral pharyngeal gill slits, when present, one to several pairs. Ciliary filter feeders are present.
- Excretion by a single proboscis gland or glomerulus connected to blood vessels.
- Circulatory system simple and open, including a dorsal heart and two longitudinal vessels, one dorsal and one ventral.
- Nervous system primitive consisting mainly of a subepidermal nerve plexus. Dorsal collar nerve cord hollow.
- Reproduction mainly sexual. Sexes usually separate. Gonads one to several pairs.
- Fertilization external, in sea water. Development direct or indirect with a free swimming tornaria larva.

1.3 AFFINITIES OF BALANOGLOSSUS

The class Enteropneusta, to which *Balanoglossus* belongs, was established in 1870 by Gegenbaur. The name hemichordata was given by Bateson in 1885 and he include it with the chordata. Hyman in 1959, however gave independent phylum status to Hemichordata in the invertebrate. In establishing its phylogenetic position, *Balanoglossus* has been linked to several diverse groups, Annelida, Echinodermata and Chordata. It was also associated with a number of minor phyla like Nemertinea, Pogonophora and Phoronida but due to lack of evidence these relationship were rejected.

Affinities with Annelida

The relationship between Annelida and hemichordata was first established by Spengel (1893).

Similarities :

1. The habits of *Balanoglossus* like burrowing, ingesting mud extraction of nutrients from ingested mud and leaving the waste in the form of casting, and general body form suggests it to be an earthworm.
2. The proboscis of *Balanoglossus* and prostomium of Nereis are similar and preoral.
3. The collar of acron worm and the clitellum of earthworm are similar.
4. The blood vascular system of both the groups is similar – the heart is dorsal in position and the blood flows forward in the dorsal vessel and backward in the ventral vessel.
5. The tornaria larva of *Balanoglossus* and the trochophore larva of polychaete annelids are similar in being pelagic and ciliated and the having an apical plate, eye spots and well development alimentary canal.

Dissimilarities :

The two groups differ in the following characters.

1. Absence of gills and buccal diverticulum in Annelida.
2. Organisation of the nervous system – the nerve cord is tubular and dorsal in *Balanoglossus* and in Annelida the nerve cord is double, ventral and solid.
3. Nephridia of annelids are absent in *Balanoglossus*.
4. The tornaria larva of Balanoglossus differs from the trochophore larva of polychaete worms in the following characters.
   (i) Absence of nephrida in tornaria.
   (ii) Absence of preoral coelom in trochophore.
   (iii) The blastophore becomes the mouth in trochophore and anus in tornaria.

The differences between the two groups are greater as compared to the resemblances which are superficial and insignificant. It probably indicates a convergent evolution resulting from similar habits and habitat. In the light of these differences, therefore, the phylogenetic relationship between the two groups has been given up.

Affinities with Echinodermata

There is no similarity in the appearance of adults of both hemichordates and echinoderms so it is difficult to suspect and any relationship between them. The only anatomical similarity between them lies in the organization of the nervous system which is poorly developed and forms epidermal plexus. They have common habitat and power of regeneration. The mode of origin of coelom is enterocoelic in both.

The similarity between the two groups, however, is based on embryological evidence and the similarity between larval stages. The resemblance between young tornaria larva of *Balanoglossus* and young Auricularia and Bipinnaria larvae of

echinoderms is so great. Metschnikoff (1865) proved it to be the larva of Enteropneusta and thus established its relationship with the Echinodermata.

Larva resemblances:

1. The larvae are small, oval, transparent and pelagic.
2. The course of ciliated bands is identical.
3. The shape and division of the digestive tract is similar.
4. The cleavage pattern and formation of gastrula are similar.
5. The formation and arrangement of coelomic cavities is similar. The origin of coelom is enterocoelous and is divided into three regions which in hemichordates are called protocoel, mesocoel and metacoel and in echinoderms the exocoel, hydrocoel, protocoel, mesocoel and metacoel. The proboscis pore of Balanoglossus is comparable with the water pore of the echinoderms.
6. The heart vesicle of hemichordates is regarded homologous to the madreporic vesicle of the echinoderm larvae. In the adults, the heart vesicle is closely connected with the glomerulus in the hemichordates and the madreporic vesicle with axial gland in echinoderms, both these structures combine excretory and vascular function.
7. The blastopore becomes the larval anus.

Differences :

1. Absence of apical plate, eye spot and telotroch in bipinnaria.
2. The protocoel in echinoderm larva is paired but in tornaria it is single.

The great similarity in embryological development cannot be accidental or due to convergent evolution as believed by Fell (1963). It is likely that they have evolved from a common ancestor. The echinoderms have, however, deviated greatly from the common ancestral type while the hemichordates are closer to it.

Affinities with Chordata

The branchial apparatus of *Balanoglossus* shows a rough analogy with that of Italic Amphioxus. In fact, it has stimulated a search of additional chordate characters in *Balanoglossus*. Bateson (1885) was the first to identify the structure that he regarded as notochord, a characteristic feature of all chordates and included hemichordate in phylum Chordata in 1887.

Resemblances :

It resembles the chordates in possessing the three fundamental chordate characters.

1. **Notochord :** The buccal diverticulum of hemichordates has been regarded as the notochord by Bateson.

2. **Central nervous system :** The central nervous system of hemichordates and chordates shows a marked resemblance in structure and development. The dorsal position of the collar cord, its mode of construction and occasional presence of a neuropore in it, is comparable with the dorsal tubular nerve cord of the chordates.

3. **Pharyngeal gill slits :** The most striking line between the hemichordates and the chordates is the presence of pharyngeal gill slits which have the same general construction with tongue bars, synapticulae and M-shaped skeletal supports as those of Amphioxus. Hymen (1959) says that this relationship does not, however, justify the inclusion of the hemichordates in the phylum choradata.

Differences :

The differences are more than that of resemblances are as follows

1. The nervous system of hemichordates presents typically invertebrates pattern. It is intraepidermal in position, the main nerve cord in ventral and circumcentric connectives are present.
2. The coelomic regions characteristic of hemichordate are found in chordate.
3. The chordates are metamerically segmented, where as in hemichordates there is no trace of segmentation.
4. There is no post anal tail in hemichordates.
5. The blood vascular system is of invertebrate type.

From the above characters it can be concluded that the hemichordates are more like invertebrates in their general organization and morphology. It is likely that the groups Echinodermata, hemichordate and chordate, evolved from a common ancestor which is probably a dipleura larva. The echinoderms have deviated from the main ancestral stock while the hemichordates are closer to it. Thus the main ancestor gave rise to the hemichordate and chordate along the main line of evolution and the Echinodermata as a blind off shoot.

SAQs 1.

Complete the following sentences by inserting appropriate words in the blanks.

(i) ---------- is the mother of life.

(ii) *Balanoglossus* belongs to the group ---------.

(iii) Coelom in Balanogolssus is ----------.

(iv) Larval form of hemichordates is ----------.

Structure (B) Cephalochordata

1.4 CLASSIFICATION

Systemic position

Phylum : Chordata

Group : Acrania

Subphylum : Cephalochordata

Class : Leptocardii

Family : Branchiostomidae

Generic : *Branchiostoma*

1.5 DETAILED STUDY (HABITS, MORPHOLOGY, ANATOMY, PHYSIOLOGY) OF *BRANCHIOSTOMA*

Habits and Habitat

Branchiostoma is a marine animal commonly found in shallow waters, mostly in brackish or salty water, on the sandy coast. It lives in a double mode of life. Mostly it is buried in sand in an upright condition with only the anterior ends is protruding above the sand. At night or dusk, it comes out of the sand and swims actively by lateral undulating movements of its body caused by muscles. It swims vertically in water. *Branchiostoma* is a typical ciliary feeder. It feeds on planktonic micro-organisms brought along with a respiratory-cum-food water current which constantly enters the mouth placed on its projecting anterior ends and leaves through the atripore.

Morphology

Branchiostoma is a small elongated narrow and fish like animal with 5 to 8 cm in length. Body is whitish somewhat translucent, laterally compressed and pointed at both the ends, hence it is called “lancelet” which mean “a little lance”. The stream lined body is well suited for burrowing as well as swimming. The posterior end is more tapering and pointed than the anterior end.

A true head is degenerate and absent. The body is divided into two regions. The large anterior region constitutes the trunk, and a much shorter post anal posterior region is a tail. The anterior end of trunk projects in a front as a pointed snout or rostrum. The trunk bears three opening i.e. mouth, atripore and anus. At the anterior part below the rostrum is a tentaculated structure called oral hood formed by dorsal and lateral projections of the body. The mouth is a very wide anterio- ventral aperture, lying just infront of the ventral fin. The large atrial cavity surrounding the pharynx opens to outside through atripore. At the posterior end a small aperture i.e. anus lies asymmetrically to the left of mid ventral line at the base of caudal fin. The small posterior body region behind the anus is tail.

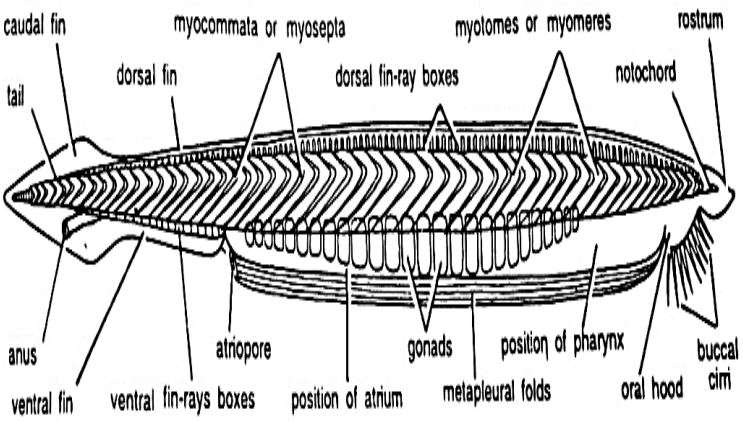


Fig 1.1 : *Branchiostoma* External feature

1The *Branchiostoma* bears three longitudinal median or unpaired fins dorsal, caudal and ventral. The dorsal fin runs as a low, mid dorsal fold along the entire length of trunk. It is continuous behind and joins a much broader caudal fin around the tail. The ventral fin runs mid-ventrally from caudal fin up to atripore along the posterior trunk region. It is slightly wider than dorsal fin. The dorsal and ventral fins are internally supported respectively by one and two rows of small rectangular fin rays boxes. Fin rays are not present in caudal fin. The paired fins are absent but running longitudinally along the ventro-lateral margins of the anterior two third part of trunk, from oral hood to atripore, are two hollow membranous metapleural folds. The two folds are connected by a horizontal fold of body wall called epipleur, which forms the floor of the atrial cavity inside. On each lateral side of body a series of shaped muscle bands called myotomes or myomeres are present.

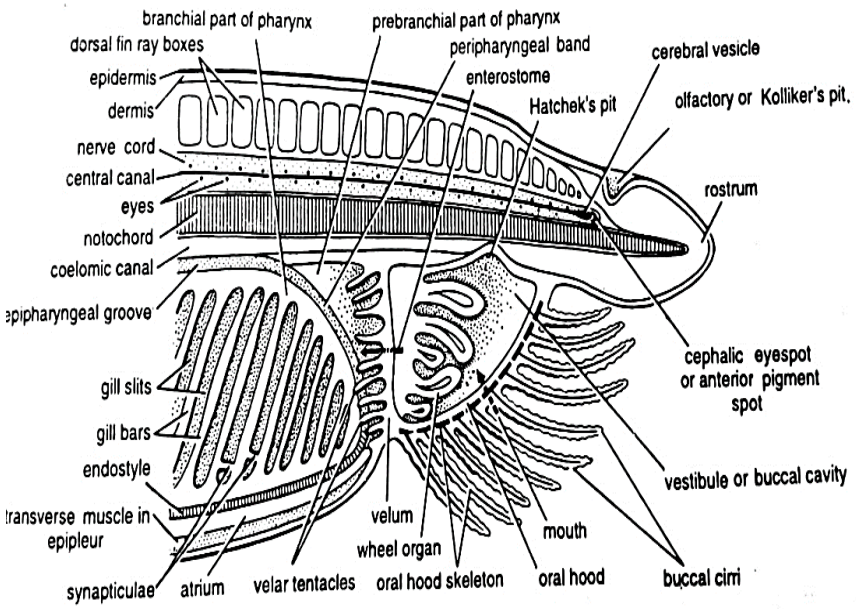


Fig 1.2 : *Branchiostoma* Enlarged L.S. of anterior end

Body wall

There is a thin, outermost, perforated cuticle, covering an epidermis which is made of a single layer of columnar epithelial cells. In between the epidermal cells are some sensory cells, but there are no glands or chromatophores. A thin layer of tough fibrous connective tissue forms a cutis below the epidermis. Below the cutis is a subcutis made of a gelatinous material containing fibres and cutaneous canals. The integument is made up of only protein. A dermis is absent.

Skeleton

In *Branchiostoma there* is no exoskeleton. The notochord is an elongated, narrow, cylindrical and rod like structure with tapering ends extending from the tip of snout to the tail end. It is formed of large alternate fibrous and gelatinous cells which make the notochord hard and turgid. The notochord is enclosed in a thick layer of connective tissue called notochordal sheath. The turgid cells and notochordal sheath give the notochord its stiff elasticity enabling it to prevent any shortening of the body when myotomes contract. Besides the notochord an endoskeleton function is performed by myocommata forming a layer around the myotomes, they form a system of strong septa throughout the length of the body; they serve for attachment of muscles. Dense fibrous connective tissue also ensheathes the central nervous system. In certain parts fibrous connective tissue is replaced by a gelatinous substance resembling soft cartilage. The oral hood is supported by such a ring made of pieces lying end to end, each pieces give out a rod forming the axis of an oral cirrus. Gill bars of the pharynx and endostyle are supported by a skeletal rod made of elastic, gelatinous substance. Dorsal fin is supported by a single row of fin rays. Whilist the ventral fin has a double row of supporting fin rays. There fin rays are made of connective tissue containing a gelatinous substance inside.

Coelom

The body cavity is a well developed coelom lined with somatic and splanchnic mesodermal epithelium, it contains a lymph like coelomic fluid. Behind the pharynx the coelom is a spacious cavity around the mid gut and hind gut, the intestine being suspended in the coelom by a dorsal mesentery, but it is reduced on the right side of the hind gut by a posterior extension of the atrium. Coelom also surrounds the mid gut diverticulum lying the atrium on the right side of the pharynx. But in the region of the pharynx the coelom is much reduced due to formation of gill-clefts, though in the larva it surrounds the pharynx all around except mid-dorsally. Thus in the pharyngeal region of the adult it is reduced to three types of spaces, a mid-ventral sub-endostylar coelom running longitudinally below the endostyle, two dorsal longitudinal canals lying above the pharynx and enclosing the brown funnels and vertical coelomic canals in the primary gill bars which connect the sub-endostylar coelom with a dorsal longitudinal canal on each side of the pharynx.

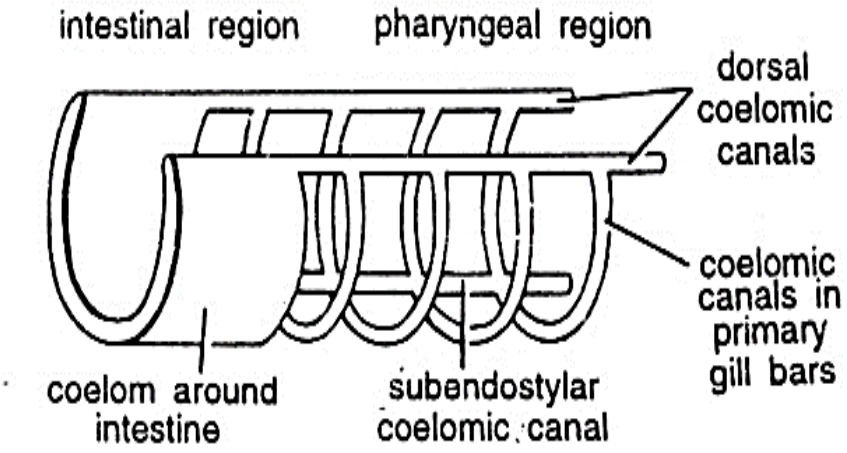


Fig 1.3 : *Branchiostoma* Diagrammatic representation of coelom

Atrium

Atrial cavity or atrium is a large body space lined by an atrial epithelium of ectodermal origin. It is formed by a pair of metapleural folds, one on either side above the gill slits of embryo, growing downwards and united ventrally by a transverse fold, thus enclosing an outside space lined by ectoderm within the body. In the adult, the atrium surrounds the pharynx and the intestine laterally as well as ventrally. It also extends back on the right side as a blind pouch which runs almost up to the anus. From near the hind end of the pharynx the atrium gives out two conical pouches, each projecting infront into the coelom on either side of the pharynx, theses pouches are brown funnels or atrio-coelomic canals. The atrium open externally by a small atripore which lies ventrally just in front of the ventral fin. The gill clefts of an adult *Branchiostoma* open into the atrium.

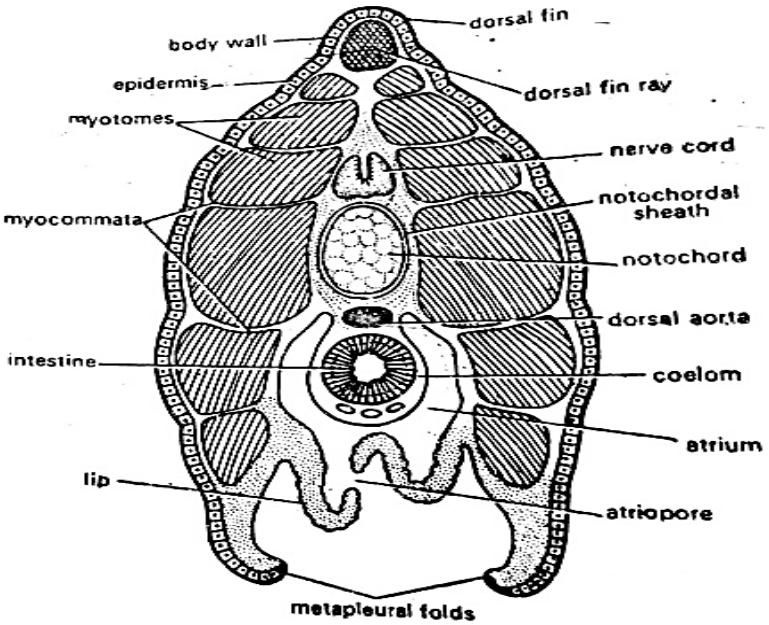


Fig 1.4 : *Branchiostoma:* T.S through atripore

Circulatory System

The circulatory system of *Branchiostoma* is of the closed type and is well developed. Blood is colorless due to lack of any respiratory pigment and corpuscles. Blood is found not only in blood vessels but also in lymph spaces as in metapleural folds and the dorsal and ventral fins. The main function of blood is transportation of food and excretory products rather than O_2 and CO_2 for gaseous exchanges.

Heart is lacking so that all blood vessels are muscular and contractile in nature. There is no structural difference between arteries and veins, but these names are being given due to their homologies with blood vessels of higher chordates.

Below the pharynx, is a contractile ventral aorta which pumps blood forwards by peristaltic contractions at the anterior end, the ventral aorta passes into two external carotid arteries. From the ventral aorta paired afferent branchial arteries arises and pass upwards in the pharyngeal wall on both sides, the afferent branchial arteries at their commencement have contractile dilations called bulbilli which also pump blood, then they pass through the primary gill bars as three branches and through the synapticula they give two branches to each secondary gill bar. They form vascular plexuses which supply nephridia. Blood is collected from the gill bars and nephridia by aortic arches or paired efferent branchial vessels. The efferent branchial vessels of each side open into a lateral dorsal aorta lying on the side of the epipharyngeal groove. The right lateral dorsal aorta is more dilated than the left one, each is continued in front into the rostrum as an internal carotid artery. The two lateral dorsal aorta unite behind the pharynx to form a median dorsal aorta lying between the notochord and intestine. The dorsal aorta gives out many small, paired parietal arteries to the body wall and the intestine where they form plexuses in lymph spaces, then it is continued backwards as a caudal artery into the tail.

From the lymph spaces of the intestine blood is collected into a sub-intestinal vein. For a greater part of its length the sub-intestinal is not a single vein but a plexus of small vessels, it runs below the intestine, and blood flows forwards in it. The blood from the tail is collected by a caudal vein which joins the plexuses of the sub-intestinal vein. The caudal vein is also joined to both posterior cardinal veins. Small vessels in the anterior part of the mid gut unite to form a short but wide hepatic portal vein which runs along the ventral border of the mid gut diverticulum and ramifies in its wall, thus forming a system which is not strictly comparable with, but which foreshadows the hepatic portal system of vertebrates. Small blood vessels from the mid gut diverticulum unite to form a short hepatic vein running along the dorsal border of the mid gut diverticulum. The hepatic vein enters a sac like sinus venous from which arises the ventral aorta.

A pair of parietal veins lying above the gut return blood from the dorsal body wall into the sinus venosus. Small paired transverse veins return blood to the ventral aorta.

In the body wall at the level of gonads on each side are an anterior cardinal and a posterior cardinal vein which receive blood through small segmental veins coming from the body wall, myotomes and gonads. The anterior and posterior cardinal veins of each side enter a ductus Cuvieri vein just behind the pharynx. The two ductus cuvieri passes inwards through the atrium to join the sinus venosus. A

renal portal and a true hepatic portal system are absent because of the absence of kidneys and a true liver.

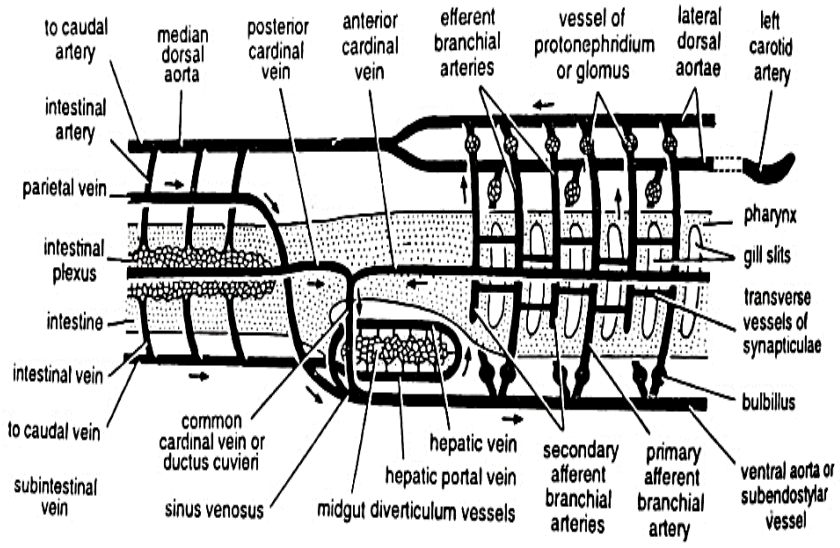


Fig 1.5 : *Branchiostoma* : Circulatory system

Digestive System

The digestive system consists of an alimentary canal and digestive gland.

Alimentary canal

The alimentary canal is a straight complete tube from mouth to anus. A mouth leads into an oral hood, the space enclosed by the oral hood is an ectoderm lined vestibule or buccal cavity, which is funnel shaped. At the back of the vestibule is a vertical velum having a hole in the middle known as enterostome. The edges of the velum bear 12 or more slender, ciliated velar tentacle, which normally project backwards forming a strainer. The enterostome lead into a pharynx. The pharynx is a large, laterally compressed sac with its walls perforated by more than 150 pairs of gill clefts, through which the pharyngeal cavity communicates with the atrial cavity. The gill slits bear no gills and their number increases with age of the animal on the posterior side of pharynx. Between the gill clefts the wall of the pharynx is known as gill bars or gill lamellae. The gill bars are of two types, primary gill bars and secondary gill bars or tongue bars, they alternate regularly and differ in their structure and mode of development. Both primary and secondary gill bars are covered on their external surface by sparsely ciliated ectodermal or atrial epithelium, but on inner anterior and posterior surface by endodermal pharyngeal epithelium, which is heavily ciliated. These cilia on the anterior and posterior endodermal surfaces of gill bars are long lateral cilia which propel water and the cilia on the inner endodermal surface of each gill bar form a long but narrow tract of frontal cilia which propel mucus.

The gill bars are supported internally by gelatinous skeletal gill rods, all gill rods are united dorsally, but ventrally their free ends are forked in the primary gill bars, and unforked or simple in the secondary gill bars. The primary gill bars are connected to each other by transverse junctions called synapticula which also contain gelatinous rods and blood vessel. In the pharynx, mid dorsally is a ciliated

epipharyngeal groove which lead into the opening of oesophagus at the posterior end of the pharynx. In the mid ventral wall of the pharynx is a shallow groove called endostyle. The endostyle is lined with four longitudinal tracts of gland cells which secrete mucus. The epipharyngeal groove and endostyle are joined to each other anteriorly by two ciliated peripharyngeal bands, each running on one side in the wall of pharynx just behind the velum.

The pharynx open posteriorly into a straight gut made of anterior narrow ciliated oesophagus followed by a wide mid gut which is continued into a narrow hind gut opening by an anus lying slightly to the left where the caudal fin begins. Arising ventrally from the junction of oesophagus and mid gut is a blind pouch called mid gut diverticulum which extends in front on the right of the pharynx. The mid gut diverticulum is often called liver or hepatic caecum, but it does not resemble a liver in structure or function. The mid gut diverticulum is a digestive gland and is comparable to a vertebrate pancreas. The entire gut is suspended from the body wall by a dorsal mesentery. The gut has a lining of epithelial cells and a thin covering of smooth muscles. The gut has several ciliated areas in its lining, there is a crescent shaped lateral tract of cilia in the mid gut which directs food into the mid gut diverticulum, there is a dorsal tract in the mid gut, between the mid gut and the hind gut is a large ciliated iliocolonic or iliocolic ring which churns foods. Mid gut enters into narrow hind gut and its terminal parts or rectum is heavily ciliated and open to outside by anus. The anus is a small circular aperture opens at the base of caudal fin a little left of the mid ventral line.

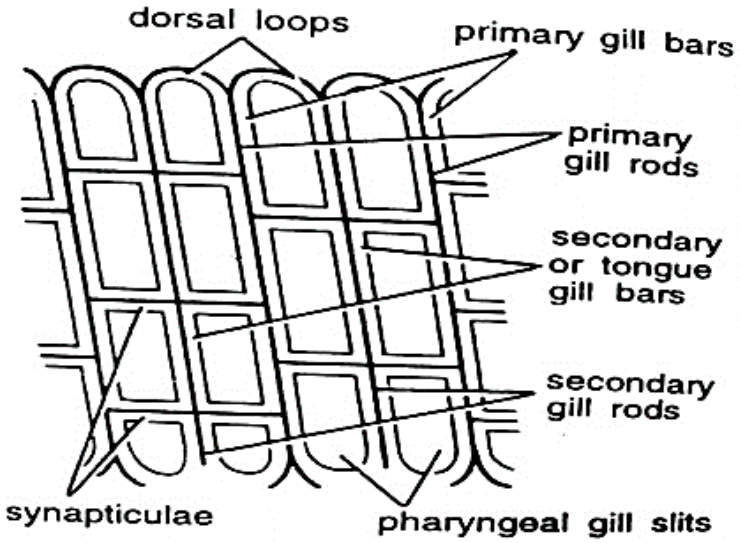


Fig 1.6 : *Branchiostoma* A part of pharyngeal wall

Digestive gland

The mid gut diverticulum or liver is a main digestive gland. It arises as a blind pouch from the ventral junction of oesophaguy and mid gut and extends forward into atrial cavity on the right side of pharynx up to one third of its length. Its zymogen cells secrete a number of digestive enzymes. The epithelial lining of intestine also contains numerous gland cells that secrete digestive enzyme.

Feeding

Branchiostoma is a microphagus animal feeding on diatoms, desmids, protozoans and other pelagic microscopic organism, suspended in sea water. *Branchiostoma* is a ciliary or filter feeder. The animal lead a sedentary life buried in sand and with only the anterior body end protruding out into water. The food particles are filtered from the current of water entering pharynx through mouth and goes to the pharynx from where it passes through gill clefts into an atrial cavity and then goes out through an aperture of the atrial cavity called atripore In feeding the oral hood is extended and oral cirri are turned inwards, they prevent sand from entering the mouth. The rotary movements of cilia of wheel organ direct water towards the pharynx, but some food particle fall out of the water current, they are mixed with mucus secreted by groove of Hatschek and passed back into the pharynx. When the main water current passes through the enterostome into the pharynx, mainly due to lateral cilia of gill bars, the suspended food particle fall on the gill bars where they get entangled in mucus secreted mainly by the endostyle and to some extent by the pharyngeal epithelium. Mucus secreted by endostyle is transferred to the ventral wall of the pharynx by its lateral rows of cilia, the median row of long endostylar cilia keeps supplying mucus to the lateral rows of cilia of endostyle, these cilia lash outwards throwing the mucus on the ventral wall of pharynx. The frontal cilia of gill bars beat along the length of the bars in such a way that they propel mucus from the ventral to the mid dorsal side of pharynx. In this way a stream of mucus with food particles passes from the lower side into epipharyngeal groove, many belts of mucus and food come up on each side of the pharynx along the frontal cilia, they all unite and pass as a cord into the epipharyngeal groove where the cilia beat backwards moving the cord of mucus and food into the oesophagus.

The peripharyngeal bands collect and pass to the epipharyngeal groove any food particles which fall out of the water current at the extreme anterior end of the pharynx. Food and mucus are not transferred from the endostyle into the peripharyngeal bands.

The cord of food and mucus passes down the gut by action of cilia, it is moved from the oesophagus into the mid gut where a lateral tract of cilia directs it into the mid gut diverticulum, from here the cord is returned again into the mid gut. The iliocolic or iliocolonic ring rotates the cord of food causing the food and enzyme to mix, then the cord of food is moved into the hind gut.

Digestion

Digestive enzymes are secreted by the epithelial cells of the gut and mid gut diverticulum, they are mixed with food as it passes along. Digestion starts in the mid gut and is continued in the hind gut. Beside this extracellular digestion, intracellular digestion also occurs in which food particles are taken into the epithelial cells of the hind gut and digested there. Some papillae on the floor of the atrium contain phagocytic cells which engulf food particles which may pass into the atrial cavity. Absorption of digested food takes place mostly in the hind gut and to lesser extent in the mid gut.

Respiration

In *Branchiostoma* special respiratory organ are lacking. In *Branchiostoma* some exchange of O_2 and CO_2 occurs between the water current and blood through

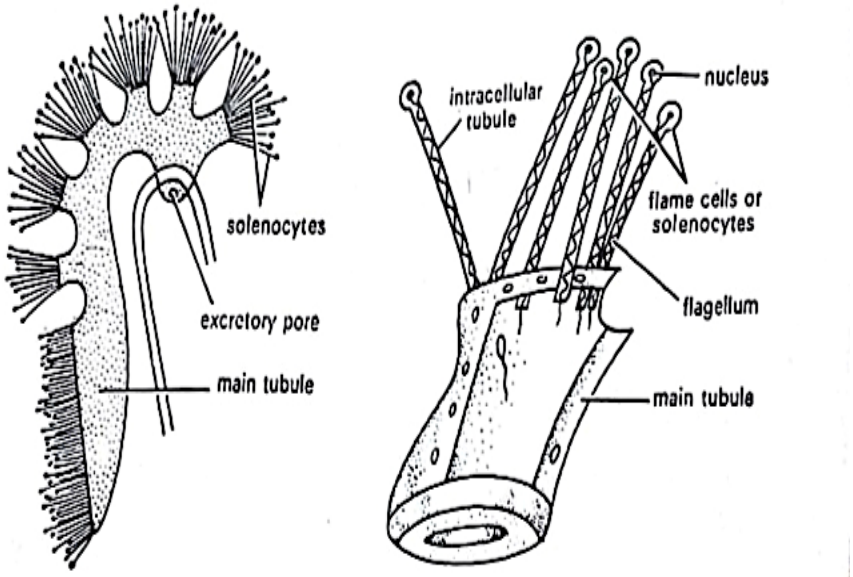
the gill cleft but this appears doubtful since the blood contain no respiratory pigment. It appears more probable that an exchange of gases occurs over the whole surface of the body and particular in the wall of atrium.

Excretory System

In *Branchiostoma* excretory organs are about 90 pairs of segmentally arranged nephridia which are of closed type called protonephridia, they lie above the gill clefts on each side corresponding to primary gill bars. Each protonephridium is a bent nephridial tube having groups of thin tubules ending in solenocytes. Each solenocyte has a round nucleated head leading into a thin tubule which contains a vibratile flagellum. The tufts of solenocytes project into the dorsal longitudinal coelomic canals and are bathed in coelomic fluid. The nephridia are also supplied with small blood vessels. The nephridial tube opens by nephridiopore into the atrium at the upper end of a gill cleft lying against a secondary gill bar. So on one end of the protonephridium lies in the coelom and the other ends open to the atrium. Protonephridia absorb nitrogenous waste from the blood sinuses and coelomic fluid by diffusion, and discharge it into the atrium.

Along the paired series of protonephridia there is a single large nephridium of Hatschek above the velum, slightly to the left of the notochord, it is like a protonephridium with a bent tube having numerous tubules ending in solenocytes. Its blind anterior end is in front of Hatschek pit, while the posterior end opens into the pharynx just behind the velum. The Hatschek's nephridium is associated with a network of fine blood vessels and each solenocytes is surrounded by a small coelomic sac, it absorbs nitrogenous waste.

In *Branchiostoma* kidneys and heart are lacking, the low blood pressure is sufficient for excretion by protonephridia.



A **B**

Fig 1.7 : *Branchiostoma* A : Entire nephridum B : A portion of nephridium

Nervous system

In *Branchiostoma* nervous system is very simple type. Brain is absent. The central nervous system consist of a hollow dorsal neural tube or nerve cord lying mid-dorsally just above the notochord. It starts behind the anterior end of notochord and its posterior part called spinal cord gradually tapers to end, just before the posterior end of notochord. A narrow central canal called neurocoel, run throughout the length of neural tube and filled with a cerebro-spinal fluid.

On the anterior end the central canal dilates into a cerebral vesicle or ventricle from its roof, arises a blind pouch called dorsal diverticulum. In the walls of cerebral vesicle some sense organs are found. From the anterior part of the neural tube arise two pairs of sensory nerves going to the oral hood, cirri and sense organs. The nerves arising from the nerve cord behind the cerebral vesicle are called spinal nerves. One pair of these arises on either side in each segment. Each spinal nerve has a dorsal root with afferent sensory fibres entering and ventral root made of several separate efferent motor fibres leaving the neural tube. The dorsal roots comes from the skin and ventral roots go to myotomes, but the dorsal and ventral roots do not unite to form a mixed spinal nerve. The dorsal roots also contain fibres running to the wall of the gut. The dorsal and ventral roots of pair do not originate at the same level, but the dorsal root of one side lies opposite the ventral root of the other side. The spinal nerve have no myelin sheath, are primitive.

In *Branchiostoma* there is an autonomic nervous system having two nerve plexuses in the smooth muscle of the wall of the intestine. These are connected to the neural tube by visceral nerves through the dorsal roots.

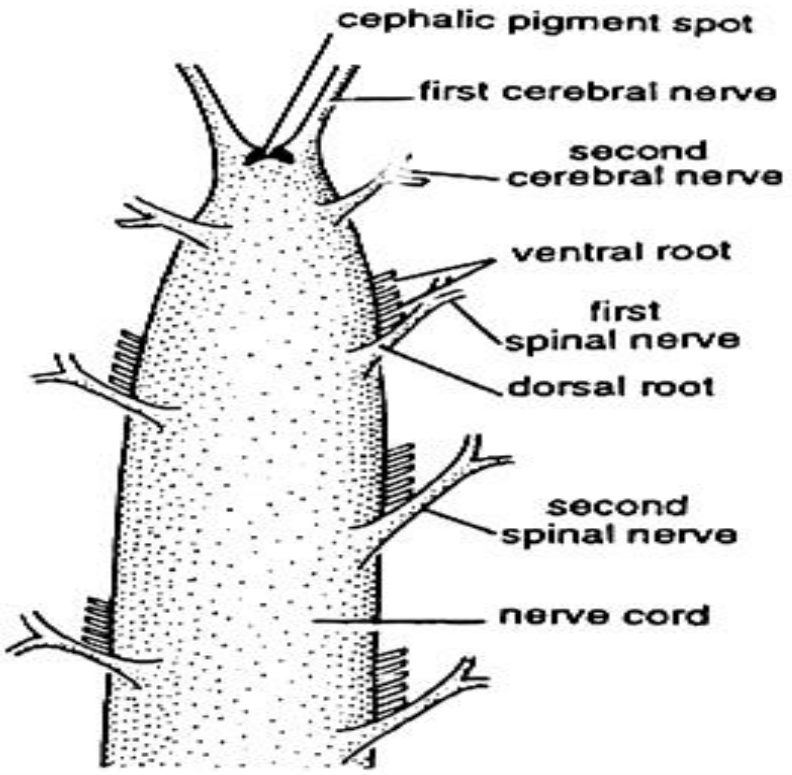


Fig 1.8 : *Branchiostoma*, Anterior part of central nervous system

Sense organs

Branchiostoma has simple and various types of sense organs or receptors.

(i) Eye spot or ocelli : The ocelli or eye spots are rows of black pigmented spot along the entire length of the neural tube, they are arranged in definite tracts and are sensitive to light. Each eye has a lens like photo sensitive cell with a striated apical border or vitreous body which secretes a pigmented cup. The photo sensitive cell receives one nerve fibre. The light sensitive eyes are responsible for orientation of the animal as it burrows in sand.

(ii) Pigmented spot : It is a large pigment spot on the anterior wall of cerebral vesicle. It lacks the structure of eye and has no sensory function. It is probably act as the thermo-receptor.

(iii) Infundibular organ : The infundibular organ is a depression in the floor of the cerebral vesicle. It is lined by long ciliated cells. The exact function is unknown but it is involved in detection of pressure in the cerebrospinal fluid, perceiving the shadow cast by cephalic pigment spot and in neurosecretion.

(iv) Kolliker's pit : Kolliker's pit or olfactory pit is a depression of ciliated ectodermal cells on the roof in the anterior region of cerebral vesicle. It marks the position of neuropore by which the neural tube open anteriorly in the larva, but the neuropore closes in the adult. It is probably not an olfactory organ since it has no specialized sensory cells, but is considered as olfactory chemoreceptor.

(v) Hats chek's groove : The pit and groove of hatschek present in the roof of oral hood are considered sensory organs of unknown functions.

(vi) Sensory cells and papillae : The sensory cells are distributed all over the epidermal especially on the dorsal side. The group of sensory cells or papillae are present on the oral cirri and velar tentacles. These are chemoreceptor and tactile organ.

Reproductive system

In *Branchiostoma* male and female are separate, but there is no sexual dimorphism, so both look identical. The gonads, either testes or ovaries lie in the ventro-lateral part of the body wall projected into the atrium. There are 26 pairs of testes or ovaries arranged metamerically, there being one pair in each of the segments 25 to 51, they begin from about the middle of the pharynx and run up to the anus on each side. Gonads are derived from the walls of the coelom and each is enclosed in a pouch of the coelom. There are no genital duct. When the gametes are matured the wall of the gonad burst and ova or sperms are escape into the atrium from which they escape through the atripore. Fertilization occurs in sea water.

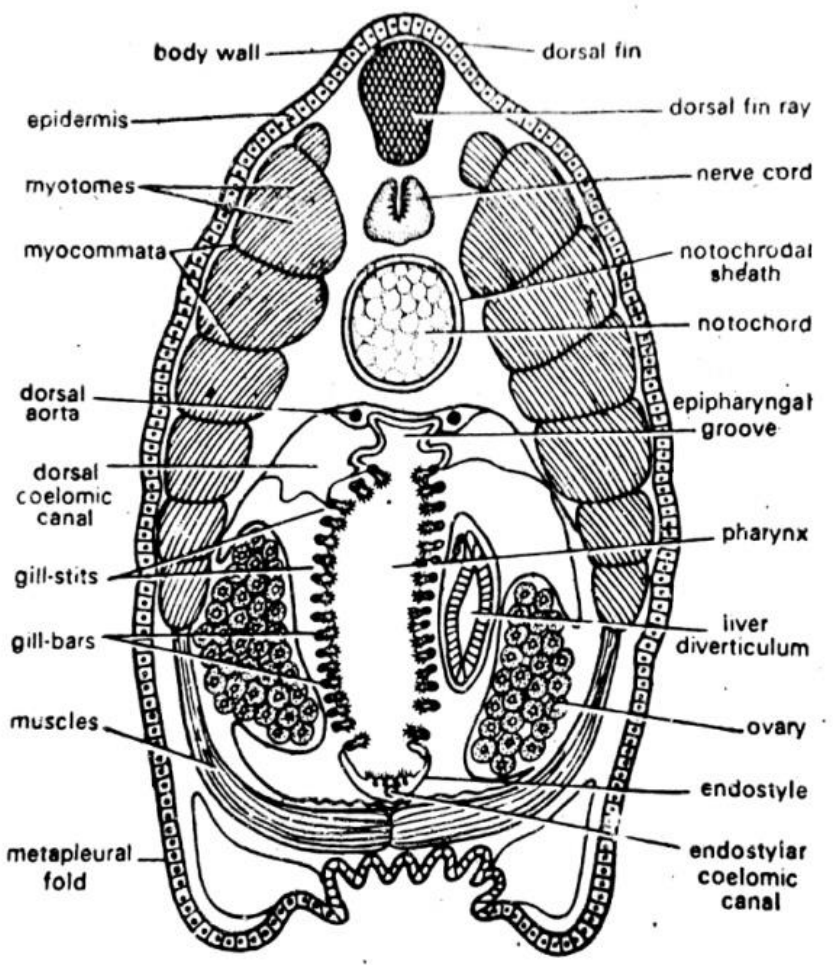


Fig 1.9 : *Branchiostoma* T.S passing through posterior region of pharynx showing gonads

SAQs 2.

Complete the following sentences by inserting appropriate words in the blanks.

(i) The coelom in *Branchiostoma* is ----------

(ii) Mouth in *Branchiostoma* is bordered by ----------

(iii) Liver in *Branchiostoma* is ----------

(iv) The thermoreceptor in *Branchiostoma* is ----------

1.6 SUMMARY

In this unit, hemichordata and cephalochordata are primitive chordate. They are more closely related to vertebrate than other group of living organism. It is suggested that the evolution of ancestral chordates has taken place in the auricularia larva farm of echinodermata by which it changed into an ancestral chordate. This phylogenetic relationship is unquestionable and it appears reasonable that echinodermata and hemichordates arose from a common ancestor and then the hemichordates gave rise to chordate.

In second part of this unit detailed study of habit, morphology, anatomy and physiology of Branchiostoma has been covered.

1.7 TERMINAL QUESTION

Q1. Explain general characters of hemichordata ?

Q2. Explain respiration in *Branchiostoma* ?

Q3. Describe Kolliker's pit of *Branchiostoma* ?

1.8 ANSWERS

SAQ 1 (i) Sea

(ii) Hemichordata

(iii) Enterocoel

(iv) Tornaria.

SAQ 2 (i) Enterocoelic

(ii) Oral hood

(iii) Midgut diverticulum

(iv)Cephalic pigments

TERMINAL QUESTION

1. The general character of hemichordates are as follows

   (i) Exclusively marine, solitary or colonial, mostly tubicolous.

(ii) Body soft, fragile, vermiform, unsegmented, bilaterally symmetrical and triploblastic.

(iii) Body typically divided into 3 distinct regions, *viz.*, proboscis, collar and trunk.

(iv) Coelom enterocoelous, usually divided into protocoel, mesocoel and metacoel, corresponding to 3 body regions.

(v) Body wall of a single layered, epidermis with mucous glands. No dermis.

(vi) Digestive tube complete, straight or U –shaped.

2. In *Branchiostoma* special respiratory organ are lacking. In *Branchiostoma* some exchange of O_2 and CO_2 occurs between the water current and blood through the cleft but this appears doubtful since the blood contains no respiratory pigment. appears more probable that an exchange of gases occurs over the whole surface of the body and particular in the wall of atrium.

3. Kolliker's pit or olfactory pit is a depression of ciliated ectodermal cells on the roof in the anterior region of cerebral vesicle. It marks the position of neuropore by which the neural tube open anteriorly in the larva, but the neuropore closes in the adult. It is probably not an olfactory organ since it has no specialized sensory cells, but is considered as olfactory chemoreceptor.

UNIT-2 UROCHORDATA

Structure : *Herdmania*

2.1 INTRODUCTION

The Urochordata or tunicate are widely distributed in marine water and are called sea squirts. They are found in all seas, shores and upto depth of more than two miles. In most of the urochordates, several chordates characters are lost in the adult but their chordate affinities are clearly observe in the gill clefts, a dorsal tubular central nervous system and a notochord is present in the tail region. During metamorphosis the chordate characters are lost except gill cleft do not open to the exterior, but into atrium. The body becomes surrounded by a coat called test or tunic. Due to sedentary life, ciliary feeding takes place, which result in simple and reduced of locomotory organs and neuro-sensory system. They have no metameric segmentation and also coelom is absent. They are hermaphrodite.

Objectives :

- Describe the habits, morphology, anatomy, physiology of Urochordata.
- Discuss the post embryonic development of Urochordata.

2.2 CLASSIFICATION

Phylum : Chordata
Subphylum : Urochordata
Class : Ascidiacea
Order : Pleurogona
Genus : *Herdmania*

2.3 DETAILED STUDY (HABITS, MORPHOLOGY, ANATOMY, PHYSIOLOGY AND POST EMBRYONIC DEVELOPMENT)

Habits & Habitat

Herdamina is a solitary marine animal and generally found at places where abundant polychaete fauna and chanks are present. They are usually found in coastal and deeper waters. They remain attached to the rocky substratum by a broad base or embedded in a sandy floor by its extended foot. Sometime it shows commensal on the shell of *Xancus*. The mollusca carries *Herdamina* from one place to another where it can get more food, oxygen and dispersal progenies also occur. The mollusca protected from its enemies due to presence of unpalatable taste of *Herdamina. Herdamina* is a ciliary feeder and feeds on planktons, microorganism etc. When *Herdamina* gets disturbed, the body contract and emits two jets of sea water with a considerable force through the branchial and atrial apertures. Hence the name sea squirt is given. It is bisexual. Fertilization is external. The development is indirect with a free swimming tadpole larva, which undergoes retrogressive metamorphosis.

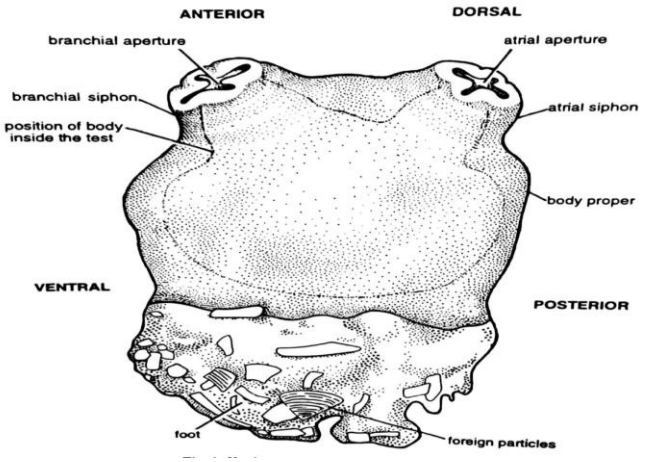


Fig 2.1 : *Herdmania* : External feature

Morphology

The animal is roughly oblong or may be slightly elongated because of massive foot. It is laterally compressed. Its size varies between 8–13 cms in length and 6-8 cms in breath, its thickness is about 4 cms. It is pink in color in living condition. The body of animal is enclosed within a thick protected test or tunic. Body is divided into a broad trunk and a foot. The foot is concave ventrally and attached to the substratum. Numerous foreign particles like stones, shell of molluscs, appendages of crustaceans, barnacles etc. are embedded in the foot. At the free upper margin of test there are two protuberances called branchial and atrial siphons each bearing a large opening the branchial aperture and atrial aperture respectively. The branchial aperture is larger measuring 2cms in diameter while the atrial aperture is small measuring 1.5 cm in diameter. Each aperture is broadered by four small lobe like projections of test called lips. The body is covered by a protective test which is usually opaque measuring 2-3 mm in thickness.

The branchial aperture marks the anterior end of the animal and the lower end diagonally opposite to it is the posterior end. The atrial siphon marks the dorsal side of the animal and opposite to it is ventral side. The body of *Herdamina* is covered by a thick, soft, leathery and translucent covering known as the test. The test is secreted by the ectoderm of mantle. It is wrinkled in appearance with a number of folds and depression running all over the surface. The inner surface is smooth and shinning. It wears off continuously from the outer surface and replaced from inside by the epidermis of mantle. The entire foot is made up of test only. The test is composed of gelatinous matrix having a polysaccharide, tunicin, protein and some inorganic substances.

Body wall

The body wall in *Herdamina* is known as mantle. The mantle secretes the test. The mantle is suspended inside the test and is attached only at the branchial and atrial apertures, where it form branchial and atrial siphons. It is not developed uniformly throughout the body, it is very thick, opaque and highly muscular in anterio- dorsoal region while thin transparent and nonmuscular in the ventro-posterior region of the body. The mantle encloses a large water filled cavity called atrium.

Coelom & Atrium

The true coelom is under –developed. The pericardial cavity surrounding the heart represents true coelom. A considerable part of visceral lies into a cavity formed of ectoderm and is known as atrium. It opens externally at the atrial aperture and is continuous throughout the body except in the anterior and mid-ventral part, where branchial sac is fused with body wall. Its median dorsal part is known as cloaca where rectum and genital ducts empty their contents. The remaining part surrounding the branchial sac or pharynx from the sides is called the peribranchial cavity.

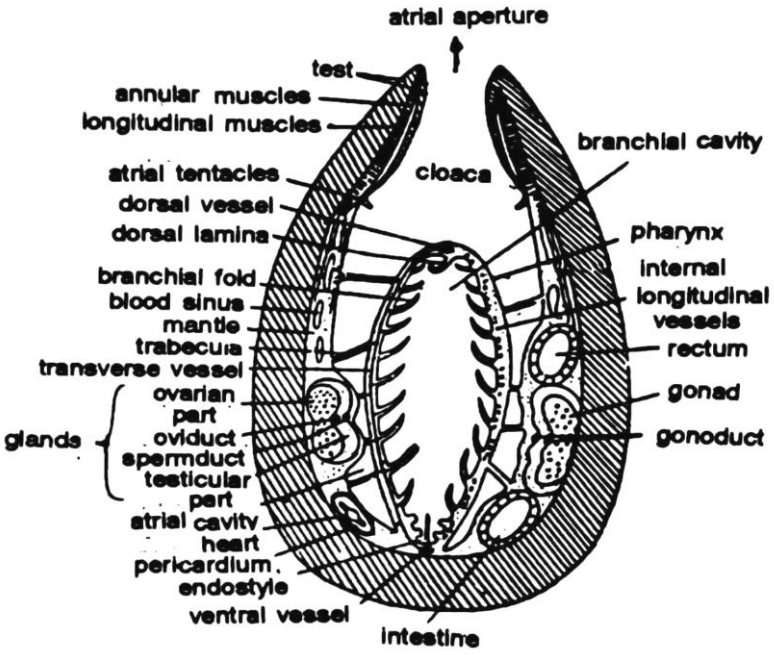


Fig 2.2 : *Herdamina:* Section of body

Digestive system

The digestive system includes the alimentary canal and digestive glands.

Alimentary Canal

The alimentary canal is coiled and complete, starting from mouth and terminating at the anus. It has following parts.

(i) Mouth : The mouth or branchial aperture lies on the top of branchial siphon. It is bordered by four lips formed by the test. These lips are contractile in nature. The mouth leads into buccal cavity.

(ii) Buccal Cavity : The buccal cavity lies in the branchial siphon. It is lined with the ectoderm and test. At the base of buccal cavity lies a strong branchial sphincter. Just above the sphincter lies the circlet of highly branched branchial tentacles. The tentacles are about 64 in number and are of four sizes, 8 are large, 8 are medium, 16 are small and 32 are smallest. Each tentacles is bipinnately branched, bearing several symmetrically paired lateral branches called tentaculets. Each tentaculets has a thin covering of a single layered epithelium enclosing a core of connective tissue containing nerve fibrils and blood sinuses. The tentacles working as a sieve sac and straining the water current passing into branchial sac. They also taste the quality of water and thus act as a chaemoreceptor. It leads into pharynx.

(iii) Pharynx : The pharynx is large sac like structure and it occupies the major part of atrial cavity. It is differentiated into a prebranchial zone and branchial sac.

(a) Prebranchial Zone : It is a small anterior region just behind the branchial sphincter. It is demarcated from the branchial sac by two circular, parallel ciliated ridges called anterior and posterior peripharyngeal bands. Between the bands there is a narrow ciliated peripharyngeal groove. The anterior peripharyngeal band is a completed ring while the posterior peripharyngeal band is incomplete, dorsally it is continuous with dorsal lamina or hyperpharyngeal groove of branchial sac and ventrally with endostyle. Just above the anterior peripharyngeal band on dorsal side there lies a swollen horse shoe shaped structure, dorsal tubercle.

(b) Branchial Sac : It is a large spacious structure. The lateral wall of the pharynx is perforated by several rows of gill slits or stigmata arranged in transverse rows, through these the cavity of the pharynx communicates with the atrial cavity. The edges of stigmata are beset with cilia which drive currents of water from the pharynx into the atrial cavity. The stigmata are not gill clefts but they are formed by subdivision of a few original gill clefts. Between the stigmata the wall of the pharynx has transverse and longitudinal bars containing blood

vessels, thus the pharynx appears like a basket. The inner surface of each lateral wall of branchial sac is raised into 9 to 10 longitudinal folds. These folds starting from behind the posterior peripharyngeal band and extending dorsally upto area which surround the opening of the oesophagus.

On the ventral side of pharynx there is a mid ventral longitudinal groove called endostyle or hypobranchial groove. It starts from the ventral margin of the posterior peripharyngeal band running centrally and terminating into a pit, a short distance from the oesopheageal opening on the dorsal side, but its wall extend upto the oesophageal opening as the retropharyngeal bands.

On the dorsal side of pharynx, a thin flap called hyperpharyngeal band or dorsal lamina hangs in the branchial sac. It starts anteriorly from the posterior peripharyngeal band and extends posteriorly upto the right lip of oesophageal opening. The dorsal lamina bears a row of 20-30 ciliated tongue like structure called languets.

The posterior most region of branchial sac has a small, circular oesophageal area behind the dorsal lamina, it has two semicircular lips guarding the oesophageal opening.

(iv) Oesophagus : The branchial sac posterior-dorsally lead into the oesophagus which is a very short, curved and thick walled tube opening into stomach. It bears four longitudinal ciliated grooves on its inner surface for the passage of food.

(v) Stomach : It is a wide, thin walled tube with almost smooth inner surface**.** It bears sphincters at each end. It is surrounded on either side by left and right lobes of liver.

(vi) Intestine : The stomach leads into intestine which is a thin walled "u" shaped tube consisting of a proximal limb and a distal limb. The proximal limb runs along the ventral side, than take a sharp turn to dorsal side to become the distal limb, leading into the rectum. The left gonad lodges between two limbs.

(vii) Rectum : It is the small terminal part of alimentary canal that curves dorsally to open in the atrial cavity by the anus. The rectal lining is made up of flagellated epithelium.

(viii) Cloaca : The atrial cavity or cloaca leads dorsally into the atrial siphon which opens to outside through the atria aperture.

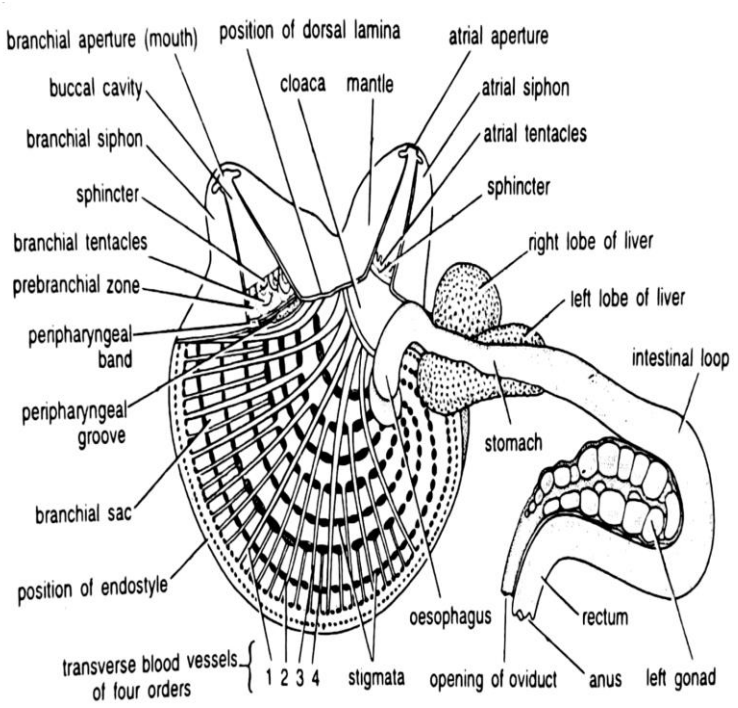


Fig 2.3 : *Herdmania* Alimentary Canal

Digestive gland :

The digestive glands are liver and pyloric gland which are associated with alimentary canal.

(i) Liver : The liver of *Herdmania* is a large dark brown coloured bilobed gland. Its left lobe is larger and right lobe is smaller. Both the lobes lie on either side of stomach. Each lobe is made up of a large number of tubules embedded in a connective tissue matrix and contains blood sinuses. It secretes a dark yellowish brown secretion which is poured in the stomach by 10 to 11 fine ciliated hepatic ducts open independently. The secretion contains amylase, protease and a mild lipase enzyme.

(ii) Pyloric gland : It consists of a large numbers of branching tubules in the wall of stomach and intestine. The tubules of gland open into a ducts and a number of ducts unite to form a single duct which open into the middle of proximal limb of intestine. The pyloric gland performs excretory organ as well as pancreas of higher vertebrates.

Food and feeding

The food of *Herdmania* is microscopic planktonic organism such as protozoans, algae, diatoms, fragments of decaying animals. The animal is ciliary or filter feeder. A continuous water current is set by the rapid beating of cilia of stigmata causes water to enter into the mouth and passing into the pharynx from where it goes out through the stigmata into the atrial cavity and then to the exterior through the atrial aperture. The current of water carries in minute organic food particles which pass into the pharynx, where they settle down on the pharyngeal walls. Gland cell of the endostyle secrete mucus. The mucus is lashed out

transversely from the endostyle by its cilia, at right angles to the endostyle. The food particle lying on the lining of the pharynx are caught in the mucus and generally transported upwards along the pharyngeal wall to dorsal lamina, in passing the food particle and mucus are rolled into a cylindrical mass. The dorsal lamina cilia convert the cylindrical mass into a string in the tube formed by curving upwards of languets, the food laden mucus string is carried into the oesophagius.

Digestion

In *Herdmania* liver secrete yellowish brown colour digestive enzyme like amylase split carbohydrate, protease splits protein and lipase splits fats. Bile pigment also present. Pyloric gland is an accessory digestive organ; it is probably pancreatic in nature. The food is completely digested in the proximal limb of intestine and absorption mainly takes place in mid intestinal part. The undigested food material is passed into rectum and is discharged into atrial siphon through anus. The liver also stores starch as reserve food material.

Respiratory System

The water current entering into the pharynx brings dissolved oxygen in sea water. The pharyngeal wall is highly vascular transversed by rich network of blood vessel and is also very thin enabling gaseous exchange. The Co_2 of blood diffuses into water and O_2 from water into blood. The respiratory surface is increased by longitudinal folds and papillae. The respiratory pigment of blood seems to be incapable of absorbing any oxygen. Then gaseous exchange also occurs in the vascular trabeculae of atrium. The test also provides a respiratory surface as it contains vascular ampullae and blood vessels.

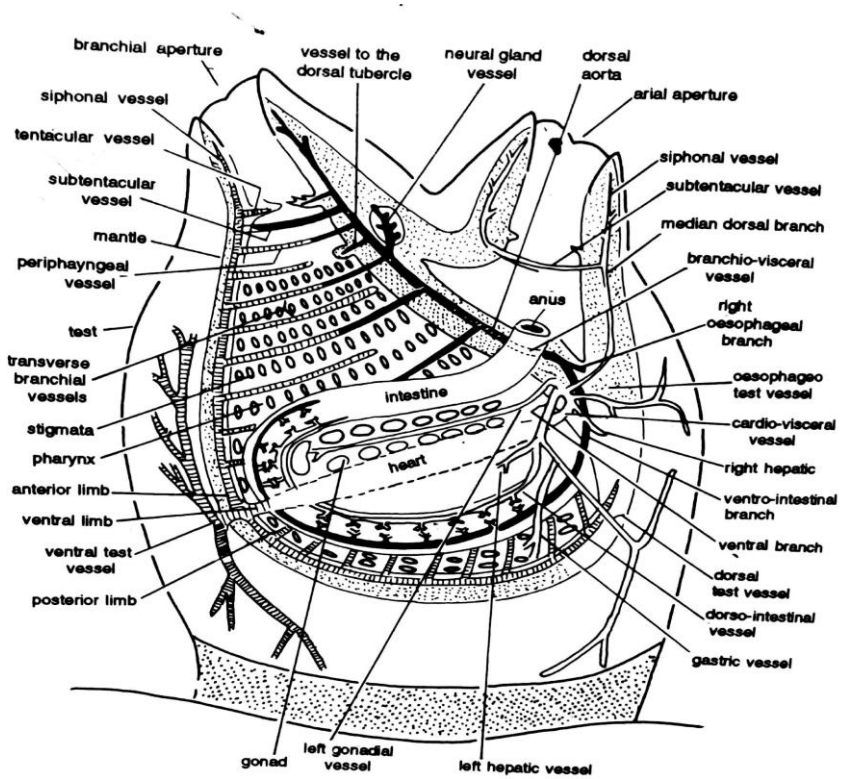


Fig 2.4 : *Herdmania* blood vascular system

Circulatory System

The circulatory system consists of heart, blood vessel and blood.

Heart

The heart is thin walled, tubular and contractile structure is situated in the pericardium, below the right gonad. The heart is internally composed of epithelium and externally by a striated muscular layer. There is no valve is present in heart to regulate the direction of blood flow. The pericardium is closed at both the ends and its cavity is filled with blood like fluid.

Blood vessels

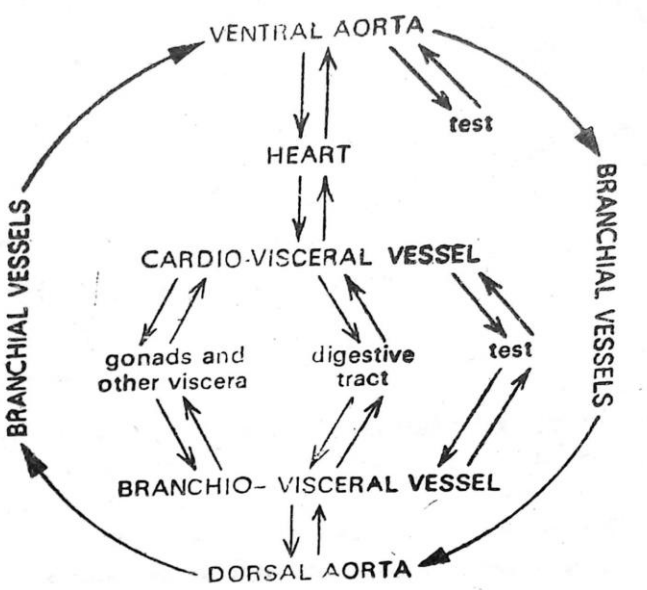
There are about four main blood vessels which are simultaneously, once serves as the arteries and at other movement these become the veins depending upon the direction of blood flow.

(1) **Ventral Aorta :** It is the largest vessel. Just after its emergence from the ventral side of heart, it gives rise three branches: an anterior limb, a posterior limb and ventral test vessel. Anterior limb runs forward and towards the branchial siphon it unites with peripharyngeal vessel. Just near their junction a short subtentacular vessel is given to siphon. Sub-tentacular vessel sends a tentacular branch in each branchial tentacle and about 6-8 siphonal vessels into branchial siphon. The posterior limb, at its extremity, gives off a small vessel to the oesophagus. Both anterior and posterior limbs of ventral aorta send numerous paired transverse branchial vessels in the branchial sac which run transversely in between the rows of stigmata. Their number ranges between 40 -56 pairs. Ventral aorta sends out blood into the test through a large ventral test vessel which arises from the junction of ventral aorta and heart.

(2) **Dorsal aorta :** This is a large vessel as thick as the ventral aorta. It runs to the dorsal wall of branchial sac just above the dorsal lamina. Anteriorly it gives out a short neural vessel to the neural gland and a small branch to the dorsal tubercle. After it joins the peripharyngeal, sub-tentacular vessels and 6-8 siphonal vessels. Posteriorly, it joins the branchio –visceral vessel. In the middle region it sends transverse branchial vessels that joins similar vessels coming from ventral aorta.

(3) **Branchio-visceral vessel :** The branchial and visceral vessels commonly originate from the posterior end of dorsal aorta. It gives rise two branches: (a) Right oesopheageal vessels supplies the blood to the right oesophageal lip and right liver lobe. (b)The ventro-intestinal vessel which runs along the ventral wall of intestine and supplies to left lip of oesophagus, left lobe of liver, stomach and intestine.

(4) **Cardio-visceral vessel :** The main cardio-visceral vessel curves and takes a turn from right to left and form 3 branches are median dorsal branches, left gonodial branches and ventral branch of cardio-visceral.



***Herdmania* Course of circulation**

Circulation

The peristaltic contraction or wave of the heart passes from one end of the heart to the other for several beats, then there is a short pause after which contractions begin again and pass in wave in the opposite direction, thus the flow of blood is alternately in opposite direction. This is a peculiar case of reversal in the flow of blood in *Herdmania*. When the heart beats dorso-ventrally the blood is driven into the ventral aorta from where it goes to the test and to the pharynx through the transverse vessel. The blood is oxygenated in the pharynx from where it goes to the dorsal aorta which enters the branchio-visceral vessel, from here the blood goes to the liver, gonads, oesophagus, stomach and intestine. The blood from these organs and the test is collected by the cardio-visceral and returned to the heart. But when the heart beats ventro-dorsally the blood goes to the branchio-visceral vessel which supplies the test and viscera, the blood from the viscera goes to the branchio-visceral vessel, dorsal aorta, transverse vessels, ventral aorta and then to the heart. Oxygenation of blood takes place both in the pharynx and the test.

Blood

The blood is slightly reddish and almost transparent fluid. It contains 8 types of corpuscles.

(1) Orange Cells: Theses are spherical, non-nucleated, uniformly granular.

(2) Signet Cells: It is also spherical and non-nucleated. It contain a large vacuole.

(3) Green Cells: These are also known as vanadocytes. They are spherical, non-nucleated, yellowish green colour. The cytoplasm is finely granular.

(4) Compartment Cells: These are non-nucleated, light yellow cells. Numerous vacuoles are present in cytoplasm.

(5) Eosinopihilous Cell : It contain an eccentric nucleus. The cytoplasm contain brown granules.

(6) Lymphocytes: They are oblong and small in size. They possess a large centrally placed nucleus.

(7) Macrophages : These are coarsely granular amoeboidal cells having blunt pseudopodia.

(8) Nephrocytes : These are vacuolated cells containing colloidal suspensions.

Nervous System

The nervous system is represented by a solid, elongated dorsal ganglion. It lies between the branchial and atrial siphons forming the central nervous system. It is pinkish in colour and almost equal to the gland. The peripheral nervous system is represented by five slender nerves, three arising from the anterior and two from the posterior end of ganglion. The anterior nervous supply to the branchial siphons and muscles. The posterior nerves encircle the base of atrial siphon and supply nerves to the muscles, epithelium of atrial siphon, test, gut and other viscera.

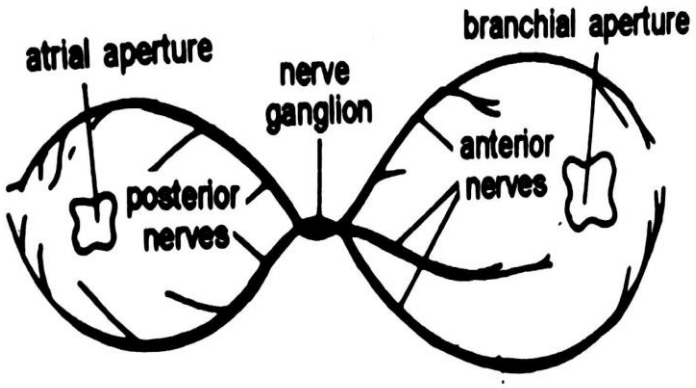


Fig 2.5 : *Herdmania* Nervous system

Sense Organ

In *Herdmania* receptors are poorly develops. These are as follows

(1) Tangoreceptors : These sensory cells are present in ampullae, tentacles and marginal cells of both the atrial and branchial siphon.These are being sensory to contact.

(2) Pigmented photoreceptors : These are bright red pigmented spots present in the siphonal lining and are considered to be sensitive to light.

(3) Olfactoreceptor : The branchial tentacles are richly supplied with nerve fibres, which are capable to taste the quality of water and size of food particles.

(4) Rheoreceptors : Theses are present on the apical margin of the siphon because they are sensitive to water currents.

(5) Thermoreceptors : These are cell lining of siphons are very sensitive to change in the temperature of water.

(6) Dorsal Tubercle : These are lying in the prebranchial zone, near the junction of dorsal lamina with the peripharyngeal bands. It has a broad base with two spirally coiled lobes, each lobe has three coils and its surface has ciliated cells. It is an olfactory and gustatory organ.

Excretory Organ

The excretory organ comprising by neural gland. It is a glandular mass of about the same size of nerve ganglion. It is brown and elliptical structure and remain embedded in the mantle just above the nerve ganglion. It contains some central tubules from which arise a few peripheral tubules. The central tubules open into a non ciliated canal whose anterior part is funnel shaped and ciliated. The funnel opens into the dorsal part of branchial sac at the base of dorsal tubercle. The excretory cells are nephrocytes of blood. These cells are brown in colour and contain xanthine and urate as excretory products when these cells are filled with excretory granules they pass into the lumen of neural gland. The neural gland also secrete a hormone which aids in oviposition and metamorphosis.

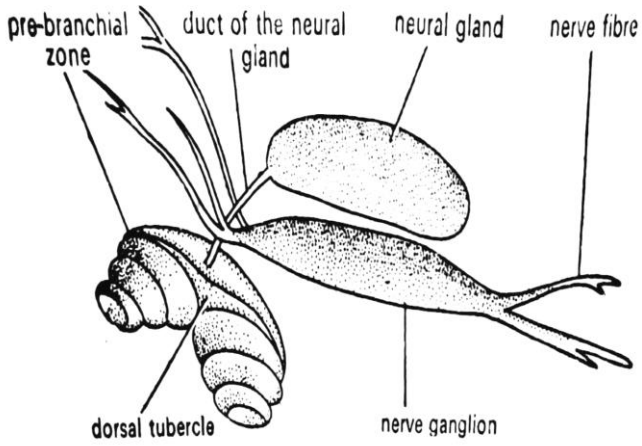


Fig 2.6 : *Herdmania* : Neural gland

Reproductive System

Herdmania is hermaphrodite, but cross fertilization occurs. The animal is protogynous i.e. the ovaries mature much before the testes. The two large gonads are embedded in the mantle, the left one lies in the loop of the intestine and the right one dorsal to the heart. Each gonad consists of twenty lobes arranged in two rows. The medium lobe is bigger in size and is bean shaped while the other lobes are rounded or oval. Each lobe has an outer, reddish testicular part which produce sperms and an inner pinkish ovarian part having ova. The ovarian parts of gonads are joined by narrow ductules to a thick oviduct, while the testicular parts are connected to a thin spermatic duct or vas deferens by ductules. The oviduct and vas deferens run parallel and open by their own apertures into the atrial cavity where ova and sperms are discharged. The sex cells pass out of the atrial siphon into the sea.

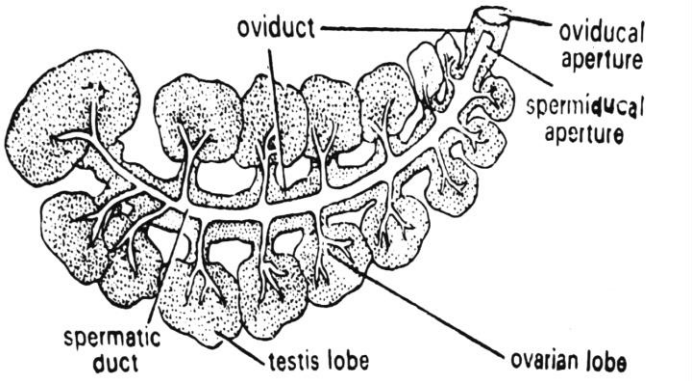


Fig 2.7 : *Herdmania* Gonad

Fertilization :

In *Herdmania* fertilization is external and it takes place in sea water. *Herdmania* is protogyny i.e. female gametes mature and discharged much before than the male gametes, so self fertilization does not occur. The mature ova of young individual and mature sperms of older individual are liberated in their cloaca, pass out through their atrial aperture into the surrounding sea water where cross fertilization occurs.

Development :

After half an hour of fertilization, the zygote undergoes holoblastic cleavage, which is unequal and thus formed a round blastula having a blastocoel. The upper smaller cells are micromeres or ectoderm and lower larger cells are macromeres or endoderm. The gastrulation takes place by emboly or invagination of macromeres, which result in the formation of archenteron cavity. The opening of archenteron is the blastopore.

After the gastrulation the embryo elongates and develops into a tailed larva. The tailed larva hatches from the egg and becomes free swimming. It has an oval body and a long laterally compressed tail and resemble like a tadpole of frog, hence it is called tadpole larva.

Tadpole Larva:

The tadpole larva of *Herdmania* has a short oval body and along tail. The entire body of tadpole is divided into two parts i.e. trunk and tail. The trunk is covered by a thin and transparent test, secreted by the ectoderm, which becomes flattened in the tail region and forms a tail fin. The tail is four times long as the trunk and is laterally compressed. At the anterior end of the trunk are three adhesive papillae made of ectodermal secretary cell, whose secretion helps in the attachment of the larva with the substratum during metamorphosis. The nervous system consists of an enlarged anterior part called sense vesicle or brain which is hollow. The sense vesicle is continued posteriorly into a solid, thick mass of nerve cells, called visceral ganglion, it is continued into the tail and lies mid dorsally. The sense vesicle contains a pigmented otocyst and two pigmented unequal ocelli as sense organs on the ventral side of the nerve cord lies and notochord which runs from the endoderm cells of the trunk to the end of the tail. The notochord persists only in the

tail region. In tadpole alimentary canal is fully developed and distinguished into pharynx, oesophagus, stomach and intestine. Mouth remains covered by test, so no feeding is possible. The pharynx has an endostlye and also some stigmata. An atrial cavity is formed around the pharynx and it opens to the exterior by an atrial aperture lying dorsally. The heart and pericardium have been formed in tadpole larva.

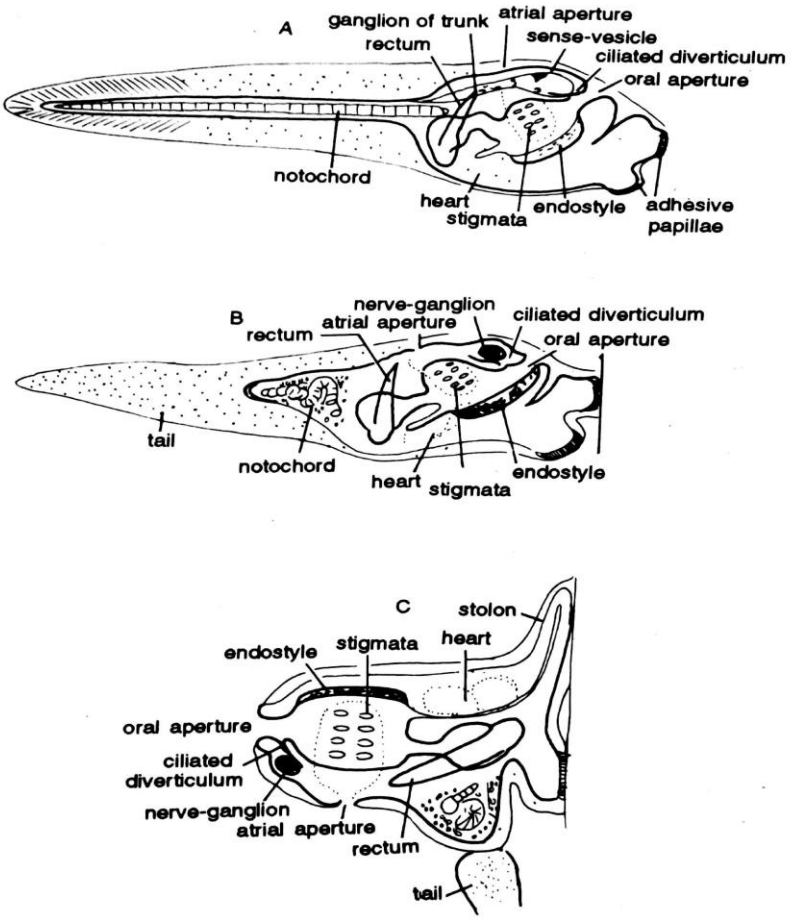


Fig 2.8 : *Herdmania :* Retrogressive metamorphosis

The ascidian tadpole larva, about 3 to 4 hours of nonfeeding and free swimming life, it sinks to the bottom and undergoes retrogressive metamorphosis.

Retrogressive Metamorphosis

The tadpole larva after about 3 to 4 hours of swimming it settles down to the bottom and becomes attached to some substratum stands in an upside down posture. In this attached condition (with the tail upward) the larva under goes the process of metamorphosis which is retrogressive type. In retrogressive metamorphosis certain advanced characters of the tadpole larva start degenerating and adult appears degenerated form. The following changes occur in metamorphosis are as follows.

(1) First of all the tail along with the caudal fin, muscles, notochord and nerve cord begins to reduce and finally disappears largely due to phagocytosis and partly due to loss.

(2) Four ectodermal ampullae arise from the trunk which firmly anchor the larva to the substratum.

(3) The region between the adhesive papillae and the mouth undergoes exceptional growth, while the dorsal region stops growing. This brings about a re-orientation of the body parts by which the mouth and siphons move upwards and the alimentary canal changes its position.

(4) The atrial cavity enlarges, the pharynx also increases in size and the stigmata increase in number by division.

(5) The stomach and intestine become longer and the appearance of lobes of liver can also be seen.

(6) Heart and circulatory system develops.

(7) The atrial and branchial siphons are developed at their respective apertures by the invagination of test.

(8) The central nervous system begins to decrease and it forms a small solid brain and a neural gland which come to lie upwards between the mouth and the atrial aperture.

(9) The sense organ (ocelli and statocyst) disappear completely.

(10) Gonads and vascular system are developed from the mesodermal cells of tadpole larva.

(11) When the changes are taking place, the portion between mouth and the point of attachment grows very rapidly. This growth brings about a dorso-posterior rotation of the body by nearly 180 degrees. This rotation brings the atripore and branchiopore at the free distal end of the body.

(12) The test encloses the entire animal, it increases in thickness and it may form a foot.

From the above characters, the tadpole, free swimming active larva with well developed sense organs, nervous system and notochord etc. changes into fixed and inert adult. Thus all the basic chordate characters like notochord, dorsal tubular nerve cord, are lost except the gill clefts. The adult does not appear as chordate. So this type of metamorphosis in which the adult, instead of acquiring advanced characters, loses them and become degenerate form is called retrogressive metamorphosis.

SAQs 1.

Complete the following sentences by inserting appropriate words in the blanks.

(i) Fertilization in *Herdmania* ----------.

(ii) Intestine of *Herdmania* is ----------.

(iii) Branchial sac is called ----------.

(iv) The aperture of siphons in *Herdmania* is guarded by ------.

2.4 SUMMARY

Herdmania are widely distributed in marine water. They are attached to the rocky sea bottom by a broad base. In *Herdmania* there is a peculiar characters in

metamorphosis in which their larva having pharyngeal gill slits, a dorsal tubular central nervous system and notochord continued to the tail are lost in adult except gill cleft, so the larva having advanced characters than adult, such metamorphosis is called retrogressive metamorphosis. The larva of *Herdmania* is geonegative and photopositive after metamorphosis it is photonegative and geopositive.

2.5 TERMINAL QUESTION

Q1 Describe the respiratory system in *Herdmania.*

Q2 Describe the excretory system in *Herdmania.*

Q3 Describe the changes in retrogressive metamorphosis.

2.6 ANSWERS

SAQ 1

(i) External and cross fertilization

(ii) U shaped

(iii) Branchial basket

(iv) 4 lips

TERMINAL QUESTION

1. The water current entering into the pharynx brings dissolved oxygen in sea water. The pharyngeal wall is highly vascular transversed by rich network of blood vessel and is also very thin enabling gaseous exchange. The Co_2 of blood diffuses into water and O_2 from water into blood. The respiratory surface is increased by longitudinal folds and papillae. The respiratory pigment of blood seems to be incapable of absorbing any oxygen. Then

gaseous exchange also occurs in the vascular trabeculae of atrium. The test also provides a respiratory surface as it contains vascular ampullae and blood vessels.

2. The excretory organ comprising by neural gland. It is a glandular mass of about the same size of nerve ganglion. It is brown and elliptical structure and remains embedded in the mantle just above the nerve ganglion. It contains some central tubules from which arise a few peripheral tubules. The central tubules open into a non ciliated canal whose anterior part is funnel shaped and ciliated. The funnel opens into the dorsal part of branchial sac at the base of dorsal tubercle. The excretory cells are nephrocytes of blood. These cells are brown in colour and contain xanthine and urate as excretory products when these cells are filled with excretory granules they pass into the lumen of neural gland. The neural gland also secrete a hormone which aids in oviposition and metamorphosis.

3. These changes are as follows

(1) First of all the tail along with the caudal fin, muscles, notochord and nerve cord begins to reduce and finally disappears largely due to phagocytosis and partly due to loss.

(2) Four ectodermal ampullae arise from the trunk which firmly anchor the larva to the substratum.

(3) The region between the adhesive papillae and the mouth undergoes exceptional growth, while the dorsal region stops growing. This brings about a re-orientation of the body parts by which the mouth and siphons move upwards and the alimentary canal changes its position.

(4) The atrial cavity enlarges, the pharynx also increases in size and the stigmata increase in number by division.

(5) The stomach and intestine become longer and the appearance of lobes of liver can also seen.

(6) Heart and circulatory system develops.

(7) The atrial and branchial siphons are developed at their respective apertures by the invagination of test.

UNIT-3 PISCES

Structure (A) *Scoliodon*

Structure (B) Amphibia & Reptilia

Structure (A) *Scoliodon*

3.1 INTRODUCTION

Pisces or fishes are cold blooded, aquatic, jaws bearing vertebrates that respire by gills. There are about 30,000 to 40.000 species of fishes differing widely from each other in shape, size, habits and habitat. They live in all seas, rivers, canals, lakes, dams, ponds and in almost every place where there is water. The fishes usually have stream lined body but some are elongated snake like and few are dorso-ventrally flattened. They have paired pectorals and pelvic fins and unpaired are dorsal anal and caudal fins.

Objectives :

- Describe the morphology, anatomy and physiology of Scoliodon.
- Classify the general characters and classification of Amphibia and Reptilia.

3.2 CLASSIFICATION

Phylum	:	Chordata
Group	:	ertebrata
Division	:	Gnathostomata

Super class	:	Pisces
Class	:	Chondrichthyes
Subclass	:	Selachii
Order	:	Squaliformes (Pleurotremata)
Family	:	Carcharinidae
Genus	:	*Scoliodon*

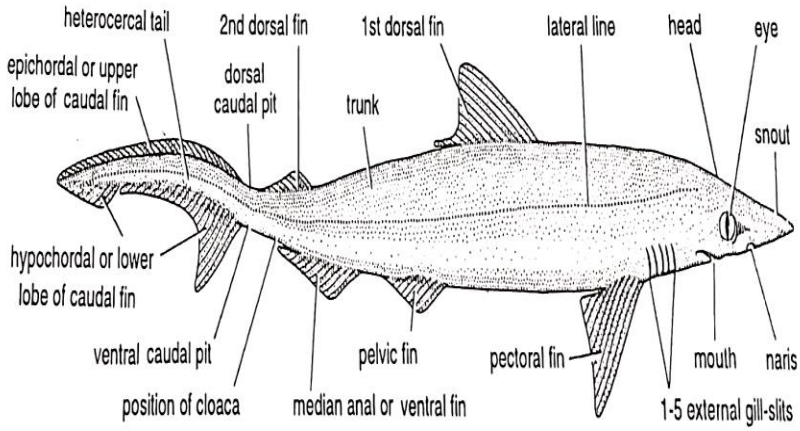


Fig 3.1 : *Scoliodon* External feature

3.3 STUDY OF HABITS, MORPHOLOGY, ANATOMY AND PHYSIOLOGY OF *SCOLIODON*

Habit and habitat

The *Scoliodon* is widely distributed in India, West Indies and Eastern coasts of South America and Atlantic oceans. The first appearance of *Scoliodon* is not clear known but some fossil record that it might evolved in the geological strata of lower Eocene to subsequent period. *Scoliodon* is marine like most sharks. It is carnivorous and predaceous feeding on crabs, lobsters, worms and fishes etc. It is a fast swimmer as the body is perfectly streamlined without having rigid projections. In *Scoliodon* both male and female are separated. Fertilization is internal. It is viviparous i.e. producing living young that develop in the uteri.

Morphology

Shape, size and color

Scoliodon has a long, lateral compressed spindle shaped body tapering at both ends. Its highly stream lined body reduces resistance to water, making movement easier and faster with minimum wastage of energy. A full grown individual measures about 60 cm in length. The color of body is dark grey above and pale white below, while the portions of the caudal fin are more or less dark. The coloration of body serves as a camouflage against predator in water.

Division of body

The body of *Scoliodon* is divisible into head, trunk and tail and there is no clear distinct boundaries between these regions.

(i) Head : The head is strongly compressed dorso-ventrally and is produced in front into a wedge shaped snout.

(ii) Trunk : The trunk is almost elliptical in transverse section. Its thickest part lying in front of the middle of the body. The trunk gradually taper behind into the tail.

(iii) Tail : The tail is laterally compressed and is bent upwards at a small angle. Such types of tail are commonly known as heterocerceal tail.

Skin

The skin or integument of *Scoliodon* consists of two layer i.e. outer epidermis and inner dermis.

(i) Epidermis : The epidermis is composed of many layer of stratified epithelial cells. The epithelial cells are ciliated at young stage and at adult are lost. The inner most layer of epidermis is made of columnar of polyhedral cells called stratum germinativum, which rest on a basement membrane. The stratum germinativum layer cell divide and give rise to new cells which move upward and become flattened and keratinized. Many epidermal cells become specialized into mucus secreting gland cells. Mucus lubricates the body surface.

(ii) Dermis : Below the epidermis is dermis, which consist of areolar connective tissue, mingled with smooth muscle fibres, blood capillaries, pigment cells and nerves. The outer layers containing few loose fibres from stratum laxum. The inner most layer is called subcutaneous layer, which is variable in the thickness and contain five fibres arranged in reticular fashion. The pigment cell or chromatophore or melanophores are grouped just below epidermis giving spotted appearance and darker color on dorsal side of body.

Placoid Scale

The skin of *Scoliodon* is very rough and due to the presence of minute, hard placoid scales, which is embedded in the skin in regular oblique rows and forming the exoskeleton.

The placoid scale consists of mainly two parts, the basal plate and the spine. The basal plate is diamond shaped and lies embedded in the skin. The basal plate is formed of a bone like loose trabecular calcified tissue called cement. The inner surface of basal plate bears an opening which leads into the pulp cavity. During life the pulp cavity is filled with vascular connective tissue called the pulp containing numerous odontoblasts, blood vessels, nerves and lymph channels. The trident spine projecting out of the skin and is backwardly directed and formed by one median and two lateral spines. The spine is composed of a hard calcareous substance called dentine. The dentine is traversed by minute nearly parallel canaliculi with delicate branches and is coated externally with a hard dense substance called enamel. The placoid scales are partly derived from dermis and

partly from the epidermis. The basal plate and dentine of spine are derived from mesoderm, while the enamel is secreted by the ectoderm.

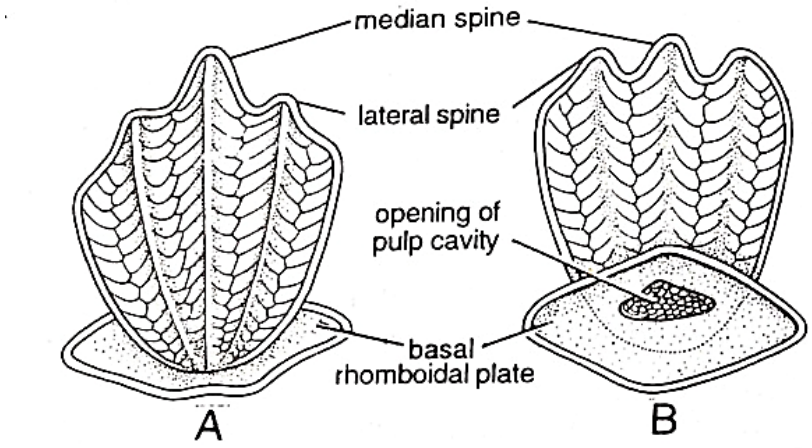


Fig 3.2 : *Scoliodon* Placoid scale (A) Dorsal view (B)Ventral view

Locomotion

The locomotion of *Scoliodon* has been explained by Breder (1926) and Gray (1933). They have shown their experiment by taking series of photographs at definite interval of time of a swimming fish against a back ground marked with a graduated scale. They have shown by a series of timed photographs the entire body of fish takes part in progression or swimming. The force which drives a fish through water is produced by longitudinal muscle fibres of myotomes, their contraction causes the body to bend. Waves of curvature or bending pass alternately on each side of the body from the head to the tail, because the myotomes contract one after the other from before behind. This bending is more noticeable behind the head region and especially in the tail, because of progressively greater transverse amplitude of the waves as they pass backwards. As one wave of contraction passes backwards on one side, it is followed by a similar second wave on the other side of the body. This contraction of successive myotomes causing waves of bending is called metachronal contraction. In metachronal contraction each segment or part of the body moves in a transverse direction to its path of swimming in such a way that it is bent at an angle or obliquely backward movement to push the water backwards. Thus the whole body operated as a single self propelling system and the fish is thrust forward.

The role of paired and median fins in swimming is to give stability to the fish and to maintain equilibrium, so that they enable the fish to keep a constant course or to change its course. The body is subjected to three forces while swimming in water, (a) rolling or turning sideways or deviating from the longitudinal path of motion, this is called drag, (b) pitching or deviating from a transverse plane is called lateral force (c) yawing or deviating from a vertical axis by raising or lowering the head is called lift.

The median dorsal fin keeps the fish steady in a horizontal plane. Equilibrium in a vertical plane is controlled by the movable pectoral fins, the smallest movement of these fins prevents yawing and restores the original direction of locomotion. The paired fins and caudal fin prevent pitching. The powerful

movements of the heterocercal tail not only give a forward thrust to the fish, but they also make the fish dive head downwards this is counter balanced by the paired fins, chiefly the pectoral fins. The pectoral fins lieu in front of the centre of gravity and act as elevators, forcing the head upwards. Hence the heterocercal tail and pectoral fins neutralize each others effects and maintain the fish in a constant plane. Turning is produced either by a wave of myotomal contraction only one side of the body or by asymmetrical braking with the pectoral fins.

Coelom

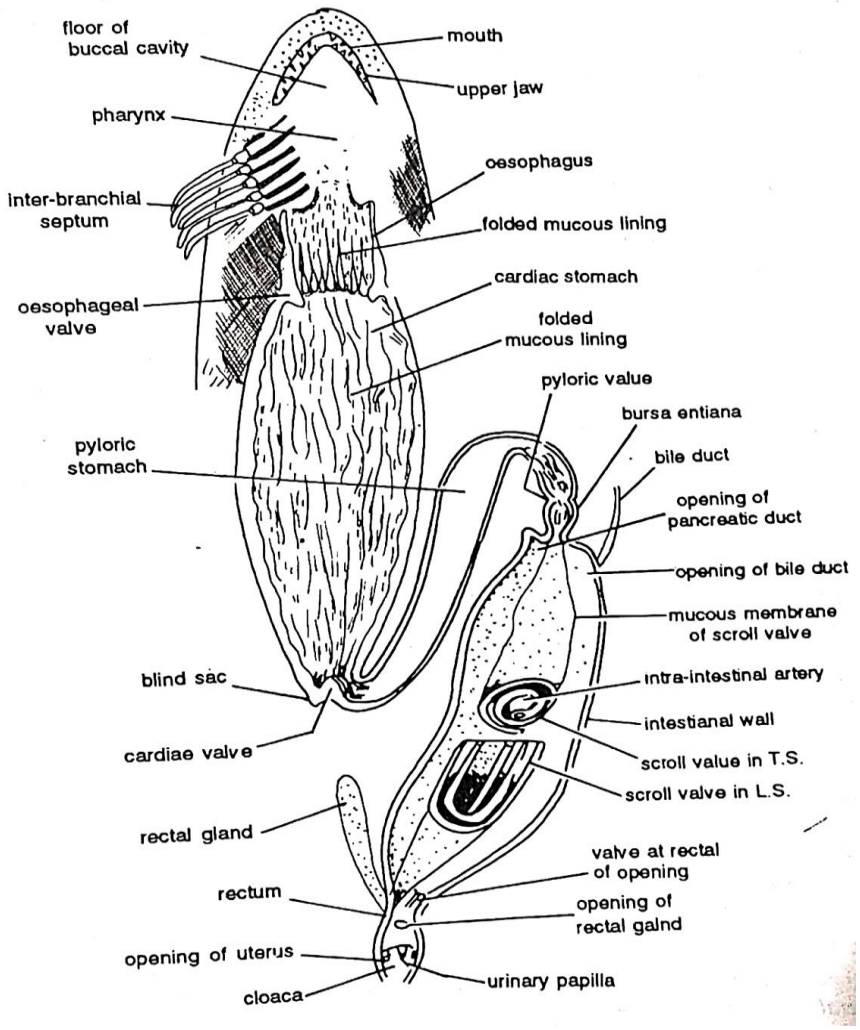


Fig 3.3 : *Scoliodon* Digestive system

The coelom of *Scoliodon* is spacious and is divided into two unequal cavities, the anterior small pericardial and the large posterior abdominal or perivisceral cavity, separate from each other by a membranous partition, the septum transversum. The pericardial cavity is comparatively smaller in size and triangular in shape and lies beneath the pharynx and surrounds the heart. It is enclosed between a tightly fitting smooth layer of peritoneum lining the outer wall of the cavity and the inner pericardial layer which adheres closely to the heart itself. The pericardial cavity contains a clear colourless fluid, the pericardial fluid. It communicates with the exterior through a pair of abdominal pores situated on

papillae, one on either side of cloacal aperture. The abdominal cavity is lined with the peritoneum and is also filled with a colourless coelomic fluid.

Digestive system

The digestive system of *Scoliodon* consists of alimentary canal and its associated gland.

Alimentary Canal

The alimentary canal consists of mouth, buccal cavity, pharynx, oesophagus, stomach and intestine.

(i) **Mouth :** The mouth of *Scoliodon* is a wide cresentic opening on the ventral side of the head. It is bounded by folds of integument sometimes called upper and lower lips. The mouth opens into the buccal cavity.

(ii) **Buccal cavity :** The mouth opens into a spacious dorso-ventrally flattened buccal cavity. The buccal cavity is lined with a thick mucous membrane. The mucous membrane is raised ventrally into a thick fold to form non muscular, non glandular non protrusible "tongue" which is internally supported by the flat basihyal cartilage. The teeth are oblique and have sharp more or less compressed cusps, the edges of which are smooth and non-serrated. The teeth are all alike in shape, homodont and borne in several parallel rows on the inner margin of the upper and lower jaws. The teeth are used to catch the prey and prevent its escape but not to crush or masticate it. If teeth are lost or destroyed they are replaced by other teeth several times (polyphydont). There are no glands in the buccal cavity but mucous cells are found which secrete mucous for the lubrication of food material.

(iii) **Pharynx :** The buccal cavity opens into the pharynx. The cavity of pharynx is lined with mucous membrane containing numerous dermal denticles. On the either lateral side of pharynx contains an oval pit of spiracles and five separate vertical internal gill slits of gill pouches. The spiracles are vestigial without gill lamellae and external apertures.

(iv) **Oesophagus :** The pharynx narrows posteriorly to form the short oesophagus. The oesophagus has thick muscular walls with an internal lining of mucous membrane raised into longitudinal folds.

(v) **Stomach :** The oesophagus widens posteriorly to form the large muscular stomach. The stomach is bent on itself and forms a J shaped structure. Its proximal limb is longer, wider and distensible and called cardiac stomach while distal limb is shorter and narrow and called the pyloric stomach. The oesophageal opening into cardiac stomach is guarded by an oesophageal valve formed by a circular fold of mucus membrane. The mucus lining of cardiac stomach also forms longitudinal fold like those of oesophagus. At the junction of cardiac and pyloric stomach is present a small blind outgrowth, blind sac as well as sphincter valve. The lining of pyloric stomach is mostly smooth, though and slightly folded distally. At the end of pyloric stomach is present a strong circular muscle band called pyloric

valve, guarding its opening into a small but thick walled muscular chamber the bursa entiana.

(vi) Intestine : The Bursa entiana continues into the intestine. The intestine is a wide tube running straight backwards into the abdominal cavity and opening posteriorly into the rectum. The internal surface of the intestine is increased by a characteristic fold of the mucus membrane, the scroll valve, having one edge attached to the inner wall of the intestine and the other rolled up longitudinally on itself into a scroll, making an anticlock wise spiral of about two and a half turns. It look like a watch spring. The scroll valve serves not only to increase the extent of the absorptive surface of the intestine but also prevents the rapid flow of food through the intestine. The rectum is the last part of the alimentary canal. The tubular rectal (caecal) gland opens dorsally into the rectum. The rectum leads into the cloaca into which the alimentary canal as well as the urinogenital duct opens.

Digestive Gland

There are 3 digestive gland in *Scoliodon* liver, pancreas and rectal gland.

(i) Liver : The liver is an elongated, yellowish gland consisting of two lobes which extend back along the greater part of the abdominal cavity. The two lobes are united anteriorly but remain apart posteriorly. The right lobe of the liver contain 'V" shaped thin walled sac, called gall bladder, which stores the bile secreted by the liver. The gall bladder communicates intestine through bile duct of about 3 cm long. Bile duct also receives branches from the lobes of liver. Liver produces bile, stores glycogen and fat and destroys worn out of blood.

(ii) Pancreas : It is a compact whitish or pale bilobed gland situated in the angle between cardiac and pyloric stomach. It consist of a longer dorsal lobe running parallel to the posterior part of cardiac stomach and a ventral lobe lying closely applied to the pyloric stomach. The pancreatic duct opens into the intestine just opposite to the opening of the bile duct.

(iii) Rectal or Caecal gland : The rectal or caecal gland is a short thick diverticulum arising from the dorsal wall of the rectum. It has a central cavity lined by cuboidal epithelial cells. It is highly vascular and composed of lymphoid tissue but discharge a fluid in the intestinal lumen.

Physiology of digestion

Food, feeding and physiology of digestion

The *Scoliodon* is predaceous carnivorous and feed mainly on other fishes, but the diet may also includes rock crabs, lobsters, and spider. The teeth are only meant to prevent the escape of prey from the mouth and it do not perform the function of mastication. The teeth are only used for tearing the food. There are no salivary gland present in mouth hence there is no digestion in the buccal cavity. The wall of the pharynx possesses numerous mucous glands which only help in the passage of food. The oesophagus has also no digestive function. The digestion only starts in the cardiac stomach. The mucous membrane of cardiac stomach secretes the gastric juice which contains pepsin and hydrochloric acid that convert proteins

into syntonin, proteoses and peptones. The gastric juice is not able to digest chitin. The pyloric stomach and scroll valve have no digestive activity of their own but they activate the pancreas. The pancreas secretes trypsin, amylopsin and lipase. As the semi-digested food enters the intestine it is acted upon by the bile and the pancreatic juice. The bile makes the food alkaline and thus helps the action of pancreatic juice. The trypsin acts on the remaining proteins, amylopsin converts starch into sugar and lipase turns fats into fatty acids. The digested food is absorbed into the blood over the extensive surface of the intestine and scroll valve. The undigested food is eliminated out through the cloacal aperture.

Respiratory system

In *Scoliodon* respiration is aquatic i.e. they respire by mean of gills, which are present in a series of gill pouches on either side of the pharynx. The water enters the mouth and after passing through the buccal cavity, pharynx, gill pouches and goes out through the gill slits after bathing the gills.

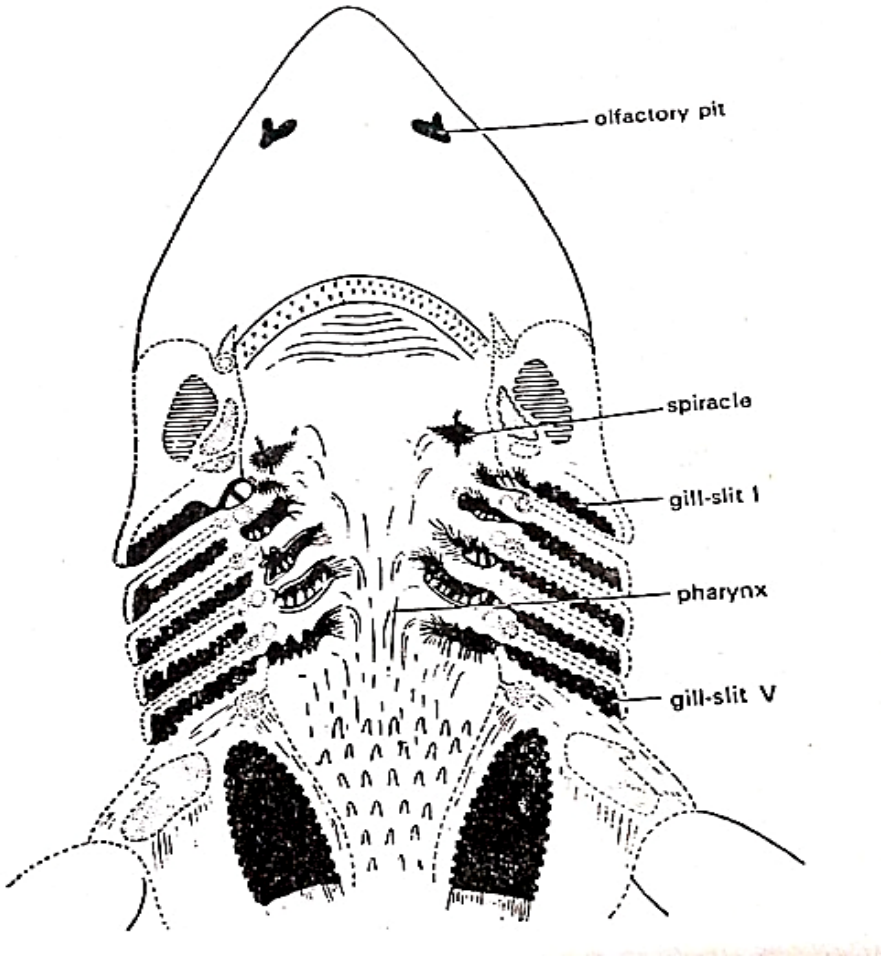


Fig 3.4 : *Scoliodon* Pharynx exposed to show gill pouches

Respiratory Organ

There are five pairs of lateral gill pouches situated in the lateral walls of the pharynx and are arranged in a series on either side. Each gill pouch is compressed

anterior–posteriorly and communicates with the cavity of the pharynx through a large internal brachial aperture and with the exterior through a narrow external branchial aperture or gill slit. The endodermal mucus membrane of gill pouch is raised into a series of horizontal folds to form lamelliform branchial lamellae. The branchial lamellae have a rich blood supply and they have a very thin covering membrane through which blood is exposed to sea water for an exchange of gases. Each gill pouch has two sets of gill lamellae, one on its anterior wall and the other on the posterior. Each set of lamellae is a half gill or hemibranch, so that gill pouch has two hemibranches. The gill pouches are separate from each other by muscular inter branchial septa of connective tissue. The inter branchial septa extend well beyond the branchial lamellae, then each bends posteriorly to protect the lamellae. Each gill receives blood from the afferent branchial vessels and passes it to the efferent branchial loop at the branchial vessels and passes it to the efferent branchial loop at the sides of arch. The blood is oxygenated when it passes through the network of capillaries and Co_2 is removed. Infront of hyoid arch or first internal gill slit there is an oval spiracle on either lateral side of pharynx. It has no gill lamellae or external branchial apertures hence it is regarded as vestigial gill pouch. The hyoid arch bears a hemibranch posteriorly. The first four branchial arches bear a holobranch each, the fifth branchial arch has no branchial lamellae, thus *Scoliodon* has nine hemibranch on each side.

Mechanism of Respiration

The floor of the bucco-pharyngeal cavity is depressed by hypo-branchial muscles and the mouth is opened, at the same time the visceral arches expand the wall of the pharynx, so that sea water containing dissolved oxygen rushes in through the mouth. Entry of water into external branchial apertures is prevented by an anterior fold of skin on each gill pouch. The bucco-pharyngeal floor is then raised and the mouth is closed, and contractions of the wall of the pharynx force the water into internal branchial apertures, the oesophagus being closed, and then into gill clefts, where it washes the branchial lamellae and goes out of the external branchial aperture. The flow of blood in branchial lamellae is from top towards the base, that is in a direction opposite to that of the water current. The blood comes in contact with highest concentration of water and lowest concentration of carbon dioxide. Thus an efficient exchange of O_2 band Co_2 takes place between the blood and sea water.

Physiology of Respiration

The sea water enters the gill pouches carries a large amount of dissolved oxygen. This oxygen passes by endosmosis through the thin membranous and permeable capillary walls into blood and carbon dioxide of the blood passes out by exosmosis, into the out0going water current. Thus the oxygen is conveyed to all parts of the body by the blood and the carbon dioxide is brought to the gills is also by blood.

Blood vascular System

The blood vascular system of *Scoliodon* consist of heart, arteries, veins and Blood.

Heart

The heart of *Scoliodon* is dorso ventrally bent, triangular, muscular, reddish brown in color. It is enclosed by a double layered membrane of which outer membrane is called pericardial membrane and inner is known as parietal membrane. In between these two layers a pericardial fluid is present which make the heart moist and also it prevent the shock. The heart of *Scoliodon* receive deoxygenated or venous blood only, which is pump into gills for oxygenation or aeration. Hence such type of heart is called venous or branchial heart. The heart consist of 4 chambers i.e. sinus venosus, atrium, ventricle and conus arteriosus.

(i) Sinus Venosus : The sinus venosus is a triangular thin walled chamber elongated transversely and lying along the base of the pericardial cavity. On both the lateral side of sinus venous receive venous blood through ductus cuvieri and on the posterior side it receive through a pair of hepatic sinus. The sinus venous open anteriorly into the auricle through the sinu-auriclar aperture, which is guarded by a pair of membranous valves, sinu-auricular valve, which prevent the back flow of the blood.

(ii) Auricle : The auricle is a large triangular sac, lying infront of the sinus venous and dorsally to the ventricle. Its walls are moderately muscular and thick than those of the sinus venous. It is triangular in shape, with its posterior angles produced into processes, which project laterally at the sides of the ventricle. It opens into ventricle through an auricle-ventricular aperture which is guarded by a bilabiate valve, which prevents the back ward flow of the blood.

(iii) Ventricle : The ventricle is the most prominent and pear shaped chamber of the heart. It has very thick muscular walls and is supported ventrally by the coracoids cartilage. The inner surface of the ventricle is produced into numerous muscular strands which give its a spongy texture. Chordae tendineae are attached to opposite walls to prevent ventricle for expanding beyond its capacity. The ventricle communicates dorsally with the atrium through the atrio-ventricular aperture and anteriorly with the conus arteriosus.

(iv) Conus arteriosus : The ventricle tapers anteriorly into a stout and muscular tube called conus arteriosus. The cavity of conus arteriosus contains two transverse rows of semi lunar valves to block the back flow of blood into ventricle. Each row has three valves, one dorsal and two ventro-lateral in position. A small accessory valve is also present on either side of each dorsal valve. Anterior valves are larger than the posterior ones. After perforating the anterior wall of pericardium the conus arteriosus continue forward as the ventral aorta.

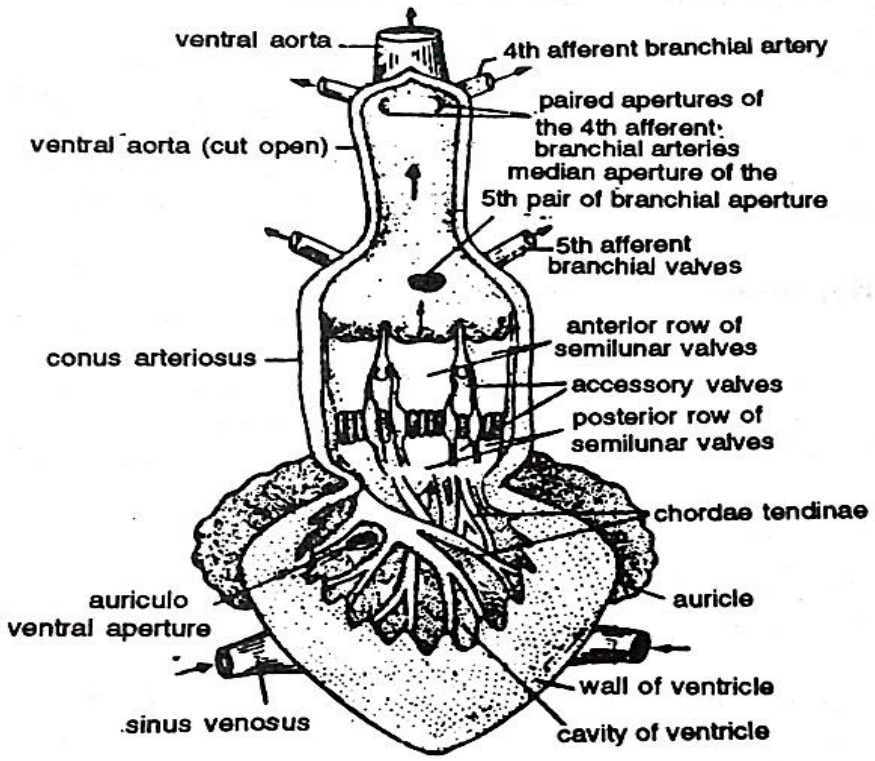


Fig 3.5 : *Scoliodon* : Heart dissected from ventral side to show internal structure

Working of heart

The heart of *Scoliodon* is of venous type because it only pump venous or deoxygenated blood. It has single circuit type of circulation i.e. only once time blood can pass through heart. In heart sinus venous and auricle are the receiving chamber while ventricle and conus arteriosus constitute the forwarding chamber of the heart. The rhythmic contraction and relaxation of cardiac muscle is called heart beat. The contraction is called systole and relaxation is called diastole. The initiation and wave of excitation or contraction starts from sinus venous, then reaches to the auricle, ventricle and ended at conus arteriosus. As the blood is filled in sinus venous, it contract and forcing the blood into auricle through sinu-auricular aperture. The valve prevent the back flow of blood. Now the auricle contracts and the blood reaches the ventricle through auriculo-ventricular aperture. Then ventricle contracts and passes the blood into conus arteriosus, from where it enters the ventral aorta. The venous or deoxygenated blood passes to the gills for aeration by afferent branchial vessels. The oxygenated blood is forced to different body parts by efferent branchial vessels and dorsal aorta. The venous blood is returned to the heart from different parts of the body, thus only the venous blood passes through the heart. During course of its circulation the blood passes through heart only once in its complete circuit. Thus the heart of Scoliodon is venous heart and the blood circulation is of single type of circulation.

Blood

The blood of *Scoliodon* consists of colorless plasma and corpuscles suspended in it. The corpuscles are of two types

(a) Red blood corpuscles or Erythrocytes: Theses are oval, in the shape and are nucleated bodies. It contain respiratory pigments i.e. hemoglobin.

(b) White blood corpuscles or Leucocytes: Theses are amoeboid in shape and are responsible for phagocytosis.

Nervous system

The nervous system of *Scoliodon* consists of three parts:

(i) Central nervous system : It includes brain and spinal cord.

(ii) Peripheral nervous system : It includes cranial and spinal nerves.

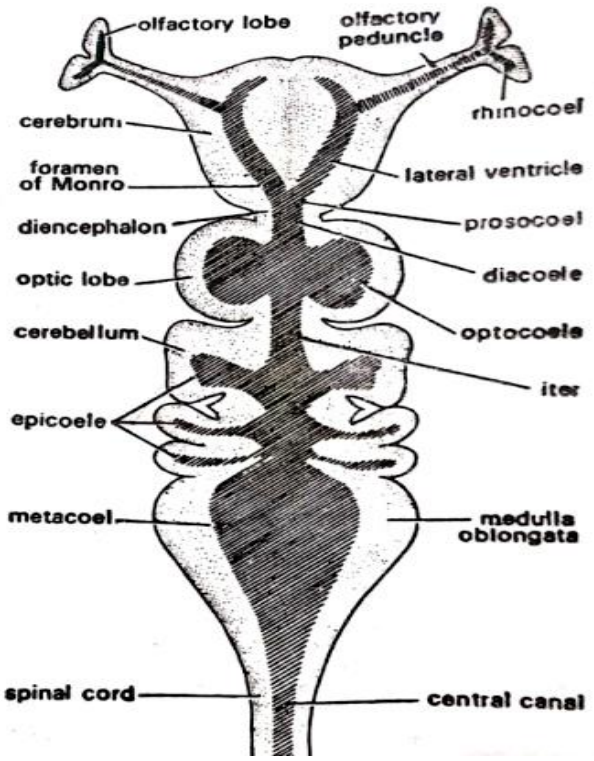


Fig 3.6 : *Scoliodon* Horizontal longitudinal section of the brain

Brain

The brain of *Scoliodon* is enclosed within the chondrocranium and it is divided into 3 parts i.e. fore brain, mid brain and hind brain.

Fore brain

It consists of two parts cerebrum and diencephalon. The cerebrum form the anterior part of the brain and is undivided mass of nervous tissue. There is no median groove to separate the cerebrum into right and left cerebral hemispheres. From either antero–lateral side of cerebrum arise a narrow but a stout olfactory stalk terminating into a large bilobed olfactory lobe. It lies immediately behind the large olfactory sac that opens to outside through the nostril or nares. The dorsal surface of cerebrum is quite smooth, but on its mid-ventral surface there is a small aperture called the neuropore, through which comes out a pair of delicate nerves called pre-

olfactory nerves. The cerebrum is continued posteriorly into the narrow diencephalon which is extremely short and is completely covered by the forward prolongation of the cerebrum. The roof of diencephalon is extremely thin and membranous which is highly vascular and is known as anterior choroid plexus. The posterior dorsal end of the diencephalon gives rise to a pineal stalk which end in a rounded knob like structure called pineal body. The floor of diencephalon gives off a hollow outgrowth, called infundibulum which projects downward and backward. The infundibulum possesses at its distal end a rounded structure called hypophysis. On either side of infundibulum lie the two lobi inferior, the distal end of each is continued into a glandular sac called sacccus vasculosus. Near the anterior end of diencephalon lies the optic chiasma which is formed by the crossing of the two optic nerves.

Mid brain

The mid brain consists of two optic lobes. The optic lobes are rounded swelling and are almost completely covered over dorsally by the cerebellum and ventrally by the infundibular outgrowths. The third cranial nerve arises from the floor of the mid brain, while the fourth cranial nerve arises from the roof between the optic lobes and the cerebellum.

Hind brain

The hind brain consists of two parts cerebellum and medulla oblongata. The cerebellum is large, elongated and well developed. It extends forwards up to the cerebrum and posteriorly covered the parts of medulla oblongata. The dorsal surface of cerebellum having irregular fold and it divide the cerebellum into three lobes by two transverse furrows. The median longitudinal furrow divide the cerebellum into right and left halves. The medulla oblongata is triangular in shape and forms the posterior part of the brain. From its anterior end arise a pair of hollow outgrowths, the corpora restiformia which lie on the dorso-lateral side of the medulla and are slightly overlapped by the cerebellum. The corpora restiformia of two sides are connected with the help of a band of nervous tissue. The floor and sides of the medulla oblongata are thick, while the roof is extremely thin and non-nervous and bears the posterior choroid plexus. The 5^{th}, 6^{th}, 7^{th}, 8^{th}, 9^{th} & 10^{th} cranial nerves arise from the medulla oblongata.

Cavities of brain

From the vertical and horizontal longitudinal sections of the brain reveals various cavities or ventricles of the brain. They are communicated with one another and are continuous with the central canal of spinal cord. These cavities contain a liquid called cerebro-spinal fluid. Each olfactory lobe contains a cavity called rhinocoel, which is communicated with the lateral ventricle behind. The lateral ventricles open into the large third ventricle behind, each by the foramen of Monro. The cavity of the third ventricle extends into the infundibulum of the pituitary body and also into the base of pineal stalk. The optic lobes possess optocoel within them. The fourth ventricle is the cavity of medulla into which also opens the cavity of the cerebellum. A common space connecting the third and fourth ventricle, into which also open the optocoel, is called the iter. Behind the fourth ventricle is continued into the central canal of the spinal cord and infront into the unusually wider iter or aqueductus sylvii.

Spinal cord

It starts from medulla oblongata and end almost to the end of tail. It is surrounded by pia matter only. It has a dorsal and ventral fissures, central canal and inner grey and outer white matters. The grey matter is arranged into dorsal and ventral horns. The dorsal horns are united to form a single broad region and appear as inverted 'T' shape.

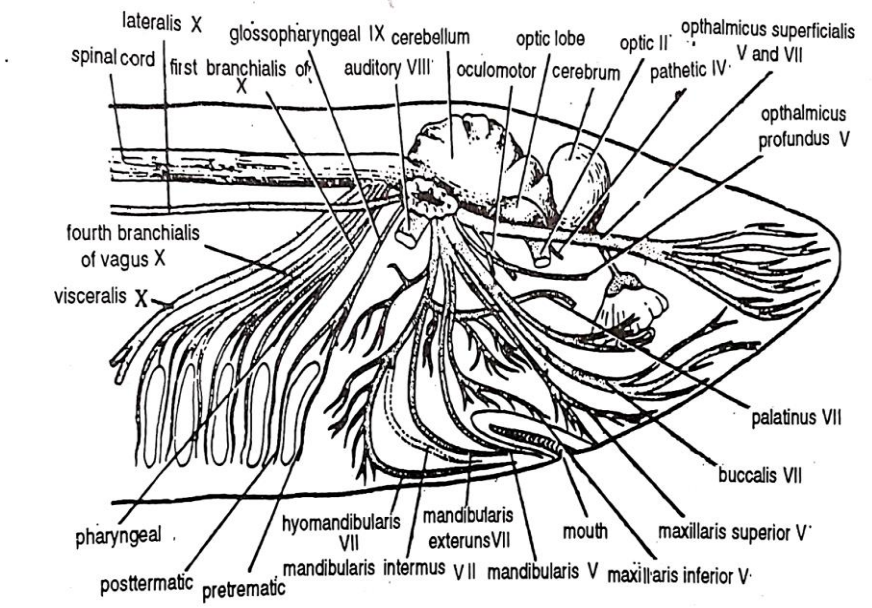


Fig 3.7 : *Scoliodon* Crainal nerves in right lateral view

Cranial nerve

In *Scoliodon* 10 pairs of cranial nerves arise from the brain. Beside this a pair of anterior terminal nerve also arises.

(i) Nerve 0 terminal or pre-olfactory : This nerve originate through the neuropore present on the ventral side of cerebrum and innervate the olfactory region. It is sensory in nature.

(ii) Nerve I or olfactory nerve : It arise from each olfactory lobe and innervate the olfactory sac of its side. It is sensory in nature.

(iii) Nerve II or optic nerve : It arise from optic thalamus. The nerve of each side crosses the other to form the optic chiasma. It innervates the retina of the eye. It is sensory in nature.

(iv) Nerve III or occulomotor nerve : It arise from the ventral surface of mid brain. It divided into 4 branches which supply to anterior, superior and inferior recti muscles and inferior oblique muscle of the eye ball. It is motor in nature.

(v) Nerve IV or trochlear nerve : It arises from the dorso-lateral surface of the mid-brain, posterior to optic lobes. It supplies the superior oblique muscle of the eyeball. It is a motor nerve.

(vi) Nerve V or trigeminal nerve: It arises from the sides of medulla oblongata. It divides into four main branches.

(a) Opthalmicus superficialis : It enters the eye orbit along with opthalmicus superficialis of VII nerve. It supplies the skin of snout. It is sensory in nature.

(b) Maxillarias : It divided into two main branches, maxillaries superior and maxillaries inferior. The maxillaries superior supply to the skin of the upper jaw. While maxillaries inferior supply to the posterior part of the upper lip.

(c) Mandibularis : It supplies the muscle of the lower jaw. It is mixed in nature.

(d) Opthalmicus profundus : It passes through the eye orbit and sends a branch to the eye ball and goes to the skin of the dorsal surface of the snout.

(vii) Nerve VI or Abducens nerve : It arises mid ventrally from medulla oblongata. It supply the posterior rectus muscle of the eye ball.

(viii) Nerve VII or facial nerve : It is a very large nerve and emerges from the medulla oblongata. It is mixed in nature and divided into four main branches.

(1) Opthalmicus superficialis : It supplies to the lateral line receptors and ampullae of Lorenzini.

(2) Ramus buccalis : It supplies the infra-orbital canal of the snout and associated groups of ampullae of Lorenzini.

(3) Ramus hyomandibular : It gives out a small branch to the lateral line receptors and then divides into 3 branches.

(a) Mandibularis externus : It supply to the mandibular canal.

(b) Mandibularis internus : It supply to the mucous membrane of the buccal floor.

(c) Hyoidean : It supply the muscles of the throat.

(4) Ramus palatines : It supply the roof of the buccal cavity and pharyngeal.

(ix) Nerve VIII or auditory nerve : It arises close to the origin of fifth and seventh nerves and divides immediately into two branches, the vestibular and saccular. It is sensory in nature.

(a) Vestibular : It supply to the membranous labyrinth.

(b) Saccular : It supply to cochlea.

(x) Nerve IX or glossopharyngeal nerve : It arises from the ventro-lateral surface of medulla oblongata. It runs obliquely backwards and divides into two branches and is mixed in nature.

(a) Pre-trematic : It runs along the anterior border of the first gill cleft and supplies the mucus membrane around the first gill-cleft and pharynx.

(b) Post- trematic : It runs along the posterior border of the first gill cleft supplying the muscles of the pharynx.

(xi) Nerve X or vagus nerve : It is very large nerve and arises from ventro-lateral margin of medulla oblongata behind ninth nerve. It is mixed in nature and it divided into three branches.

(a) Branchialis : It consists of four main nerves going around the second, third, fourth and fifth gill clefts. Each nerve consists of a pre-trematic and post-tematic branches. The branchial nerves branches supply the mucus membranes around the gill cleft and pharynx and also supply the branchial bundles.

(b) Visceralis : It is large nerve and run backward into the body cavity and supply the viscera including the alimentary canal, liver, lungs and heart.

(c) Lateralis : It arises from the dorsal side of the medulla and runs parallel but below the lateral line canal giving branches to the receptors of the lateral line along the length of the body.

Spinal nerves

There are several pairs of spinal nerves arises from spinal cord at regular intervals along its entire length. Each spinal nerve, originates by two roots, a sensory dorsal root and a motor ventral root. Dorsal root bears a ganglion. After piercing through the neural arch, both the roots unite outside to form a mixed spinal nerve. Each spinal nerve divides into three branches

(i) Ramus dorsalis : It supply the skin and muscles of the dorsal body wall.

(ii) Ramus ventralis : It supply the skin and muscles of the ventral body wall

(iii) Ramus communicans : It contain visceral sensory and motor fibres and joining the autonomic nervous system

A branchial plexus is formed at the level of pectoral girdle, but no plexus is formed in the pelvic region.

Autonomic nervous system

The autonomic nervous system consist of a paired series of irregularly arranged ganglia situated anteriorly in the dorsal wall of the posterior cardinal sinuses and posteriorly in the dorsal part of the kidney on each side of the mid-dorsal line. The first ganglia are small. The second or gastric ganglion is fairly large, being formed by the fusion of a number of ganglions. It lies immediately behind the post-branchial plexus. It is connected with numerous fibres from spinal nerves and gives off branches to the viscera. The succeeding ganglia are small. There is always at least one ganglion in each segment, but often there are two or three in a segment. Some time the ganglia of successive segments are joined by longitudinal

connectives, but there is no definite continuous chain. The posterior ganglia innervate the genital ducts, kidney, urinary sinus, intestine and rectum.

Sense organ (Receptor organs)

The receptor organs or sense organs in *Scoliodon* are as follows

(i) Olfactory organs

(ii) Optic or photoreceptor organs

(iii) Stato acoustic organ

(iv) Lateral line organs or neuromast

(iv) Ampullae of Lorenzini

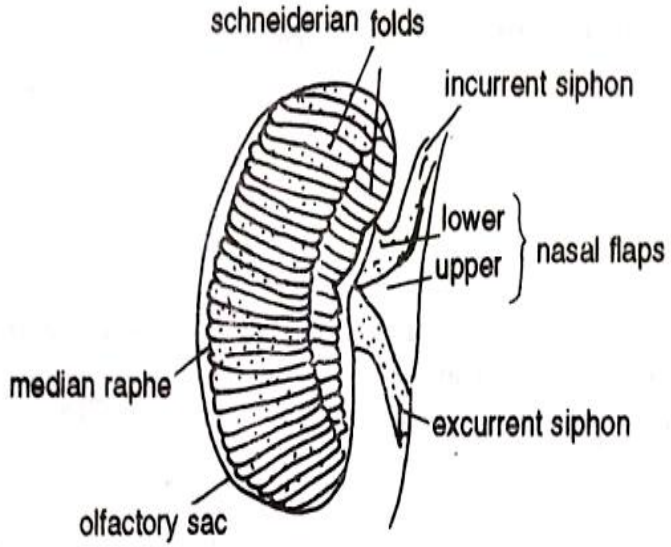


Fig 3.8 : *Scoliodon* Olfactory organ

(i) Olfactory organs : The olfactory organs of *Scoliodon* are a pair of blind sacs lying on the ventral side of the head infront of the mouth. Each sac is formed by an ectodermic invagination. Each olfactory sac is large, oval sac and is covered externally by a thin membrane and is lodged on each side in the cartilaginous olfactory capsule. The mucus membrane lining the inner wall of the olfactory sac is thrown into a double series of folds called Schneiderian fold. The schneiderian folds are many and are held in place by a median band of connective tissue, called median raphe. The olfactory epithelium consists of two types of cells, the olfactory receptor cells and supporting cells. The olfactory cells are connected with the fibres of the olfactory nerve which passes from each olfactory sac with olfactory lobe of its side of the brain.

Each external nostril is more or less completely divided into two, a lateral incurrent siphon and a median excurrent siphon by three nasal flaps. The median raphe of the schneiderian folds lies parallel to the long axis of the nasal aperture and therefore the current of water that enters through the

incurrent siphon is at first directed against the oval wall of the olfactory sac, then turns internally to the nasal valve in the direction of the median raphe and finally passes out through the median excurrent siphon. The current of water enters at the lateral end of the nasal aperture and thus takes a zig-zag course through the olfactory sac finally leaving by a mesial end of the nasal aperture. The great size of olfactory sacs in Scoliodon is highly developed sense of smell. The highly developed sense of smell enables them to detect foods.

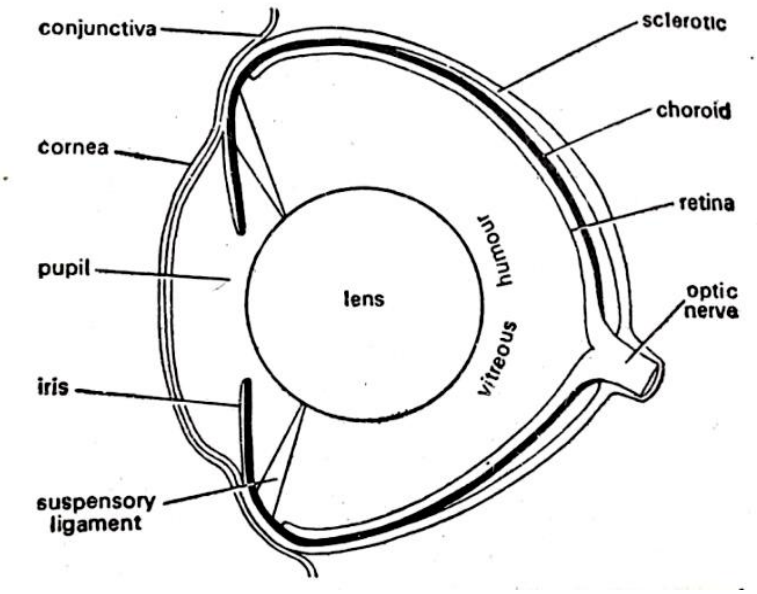


Fig 3.9 : *Scoliodon* V.S. of eyeball

(ii) Optic or photoreceptor organs : *Scoliodon* has a large paired elliptical eye are present one on either side of the head. It is held in orbit by recti and oblique muscle and also by cartilaginous optic pedicle. Each eye ball consists of three concentric layers, sclerotic, choroid & retina. The sclerotic layer is cartilaginous and opaque and form the outer protective layer of the eye. The sclerotic layer of the exposed part is transparent and known as cornea through which the light enters. The sclerotic layer is internally lined by a connective tissue coated layer called choroid. The choroid is richly supplied with blood vessels and is pigmented. In *Scoliodon* choroid layer contains cells with guanine crystals forming a light reflecting surface called tapetum lucidium. In the front part, choroid layer separates from sclerotic forming a circular curtain like iris around a vertical slit like pupil. The retina is the inner most layer of the posterior region of eye ball and forms its sensitive portion. It is made up of special nerve cell called rods, which are connected with the fibres of the optic nerve. Behind posterior surface of the iris is closely attached spherical crystalline lens which are held by a suspensory ligament with ciliary muscle. The crystalline lens divide the eye into two unequal chamber, each is filled with saline liquid, the aqueous humour, while the chamber behind the lens contain a jelly like mass fluid, the vitreous humour.

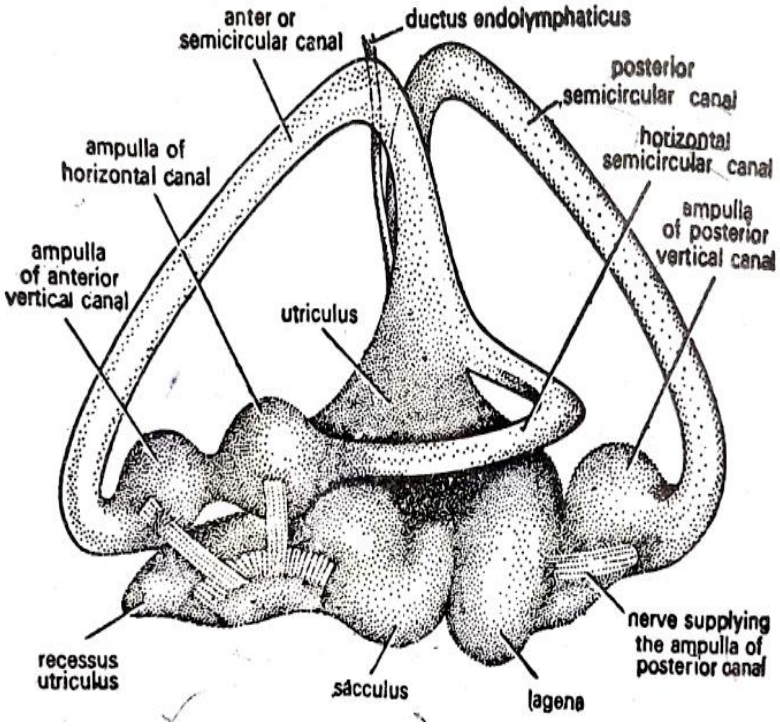


Fig 3.10 : *Scoliodon* Membranous labyrinth

(iii) Stato acoustic organ : In *Scoliodon* ear plays two very important functions i.e. static or balancing and hearing that is why it is called stato-acoustic organ. In *Scoliodon* there are no external ears or middle ear is present. It has only internal ears or membranous labyrinths. The internal ear of each side is in a closed ectodermal sac, the membranous labyrinth which is enclosed within the cartilaginous auditory capsule. The main body or vestibule of membranous labyrinth is laterally compressed and made of a dorsal utriculus from which projects a ventral and posterior lobe, the sacculus. A posterior outgrowth of sacculus is called lagena cochleae. The anterior outer growth of utriculus is known as recessus utriculi. From the vestibule arise three slender tubes called semicircular canals. The all three semi-circular canal arises at right angle to each other and ends of each bear a swelling or ampulla. The anterior vertical and horizontal canals arises from top of utriculus and open into the middle after forming their ampulla which lie anteriorly above the resessus utriculi. The posterior vertical canal originates dorsally from sacculus and opens by its ampulla posteriorly into lagena cochleae.

The interior of membranous labyrinth, including the semi-circular canals is filled with a fluid, the endolymph, which is sea water. The endolymph contains the calcareous bodies called otoliths. The space between the membranous labyrinth and the wall of the auditory capsule is filled with a perilymph which is actually the cerebro-spinal fluid. The perilymph space opens to the exterior by a large aperture, fenestra lying immediately behind the opening of the ductus endolymphaticus. The membranous labyrinth is innervated by the auditory nerve. In utriculus sacculus, recessus utriculi, legena cochleae as well as in the ampullae of

the semi-circular canals contains groups of delicate receptor cells bearing stiff hair. The stiff hairs of utriculus and sacculus called maculae while ampullae of semi-circular canals are called cristae.

The function of stato-acoustic organ are to maintains muscle tone, detect acceleration of speed and change of direction, controls orientation and equilibration with regard to gravity (balance) and detect low frequency vibrations of water.

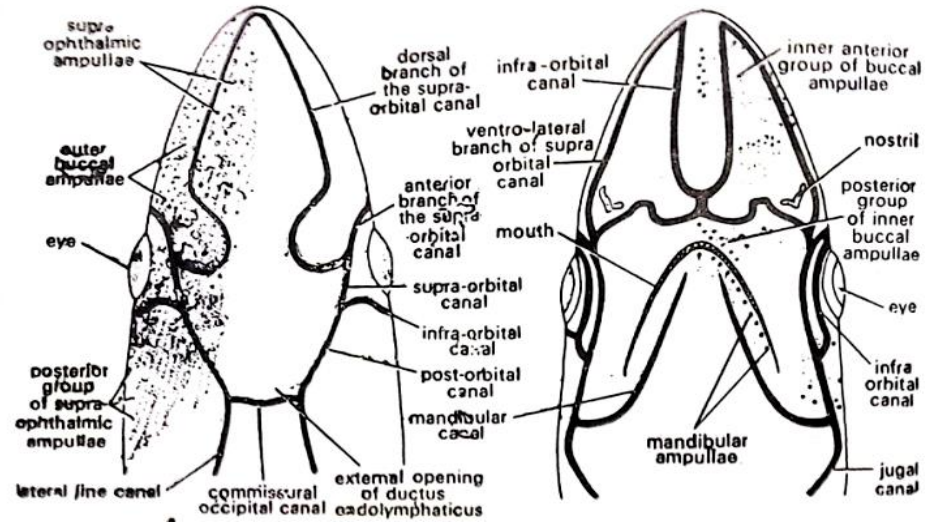


Fig 3.11 : *Scoliodon* Neuromast organs (A) Dorsal surface (B)Ventral surface

(iv) Lateral line organs or neuromast : It consist of three parts lateral line, neuromast organ and pit-organs.

(a) Lateral line : The lateral line lie in the lateral line canal on each side of the trunk and tail. Each lateral line canal lies within the skin running along the side of the entire body. In the head region two lateral canals above the head, then each lateral line canal runs forward as a post-orbital canal which divides into two branches, a supra-orbital canal above the orbit and an infra-orbital below the orbit, both run up to the snout. From the infra-orbital canal arises a jugal canal which runs back up to the first gill-cleft. The jugal canal gives off a mandibular canal to the lower jaw.

(b) Neuromast organs : The lateral line canals are lined with epithelium having many mucous gland cells which secrete mucous. The canals open at intervals on the surface by vertical tubes The canals are filled with fluid and mucus. In the lateral line canals contain a little groups of sensory receptor cell and supporting cell are called neuromast organs. Each receptor cell has a stiff sense hair at one end and a nerve fibre at the other end. The hairs of receptors of receptor cells are tipped with a heavy gelatinous substance. They are supplied with nerve fibre of facial, glosspharyngeal or lateralis branches of vagus nerves. The neruomast organ are rheo-receptors or current receptors. They can

perceive vibration of very low frequency and detect disturbance in water such as caused by the movements of other fibre.

(c) Pit organs : Pit organs are found on the dorsal and lateral surface of the head. They are embedded in pits. A pit-organ consists of a few neurosensory cells and supporting cells sunk into a small pit in the skin. They are also rheoreceptors as they respond to vibrations in the water.

(v) Ampullae of Lorenzini : These are found in clusters on the dorsal and ventral surfaces of the head or snout embedded below the skin but opening externally on the surface of the skin. Each ampullla has a pore opening on the surface, the pore leads into an elongated tubules, which ends in a radially septate ampullary sac lying deeply beneath the skin and free from it. Each ampullary sac consists of eight to nine radially dilated chambers arranged around a central core, the centrum. Two kinds of cells are found in the ampullae, the pear shaped gland cells which secrete the jelly filling the ampullary tubular and the pyramidal cells or sensory cells with sense hairs forming the receptor cells. The ampullae of Lorenzini are innervated by branches of the facial nerve. The ampullae of Lorenzini are arranged in groups and are named according to their position. The groups are

(a) Supra-opthalamic : This group lies around the supra-orbital canal.

(b) Outer buccal : These group lies between the supra-orbital and infra-orbital canals

(c) Inner buccal : These group lies beneath the infra-orbital canal.

The ampullae of Lorenzini were formerly regarded as neuromast organs but Sand (1938) has proved that these are thermo receptor organs. The changes in the temperature of water are carried to the brain through the ampullary receptors.

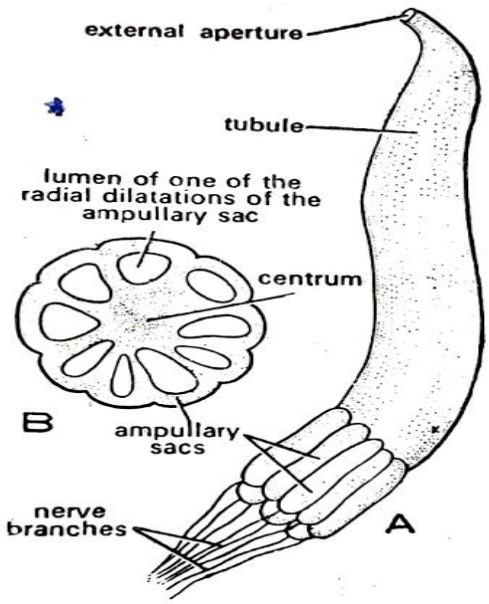


Fig 3.12 : *Scoliodon* (A)An ampullae of Lorenzini (B)Section of ampullary sac

Urinogenital System

In *Scoliodon* both excretory and reproductive organs are closely related, so both are dealt together under heading urinogential system. In *Scoliodon* both male and female are separated i.e. sexual dimorphism is observed. In male, the medial portions of pelvic fins are modified into claspers for transfer of spermatozoa during copulation. The claspers are absent in female.

Male Urinogenital system :

Excretory organs : The excretory organs in male consist of kidneys, ureters and urino-genital sinus. The kidney is of mesonephric type. In *Scoliodon* only one pair of kidney. Each kidney is a long flattened and ribbon like glandular structure lying dorsally to the peritoneum on either side of the median line. They extend through to the entire length of the body cavity from the root of the liver in front to the side of cloaca behind. Each kidney is differentiated into two parts i.e. anterior and posterior. The anterior part is reduced, non-excretory, narrower and takes the function of conveying genital product and hence called epididymis. The posterior part is greatly developed, excretory in nature, thicker and form the chief organ of excretion. In each kidney is made up of large no of coiled glandular urinoferous tubule. Each urinoferous tubule consist of Bowman's capsule enclosing the glomerulus and a coiled renal tubule. The large no of tubule unite to open into a common collecting tubule. All the collecting tubules of each kidney open into a thin walled common duct or ureter. On the posterior side both the ureter open into a wide chamber called urinogenital sinus. The urinogenital open into the cloaca through its aperture placed at the tip of a short urinogenital papilla.

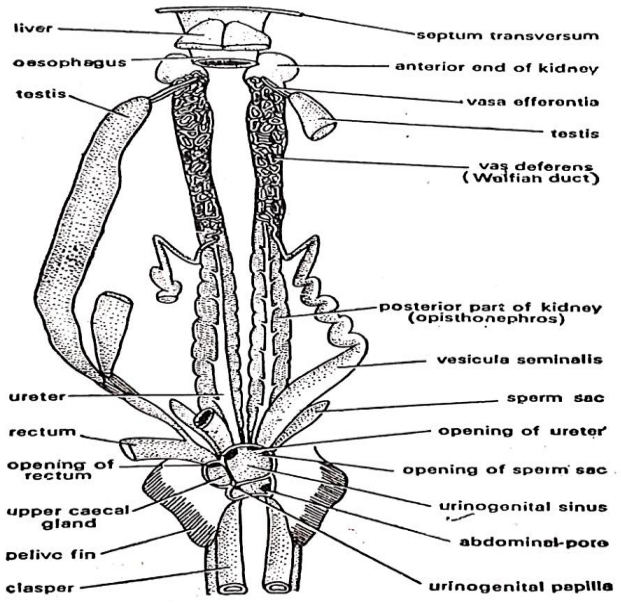


Fig 3.13 : *Scoliodon* Male urinogenital organs

Reproductive organs

The male reproductive organ in *Scoliodon* consists of a pair of testes, a pair of vas-deferens and a pair of seminal vesicles.

In *Scoliodon* two elongated testes lying one on either side of the middle line. Each testes extends from the base of the liver infront to the caecal gland behind. Each testes is attached to the dorsal body wall by mean of mesorchium and at the posterior side to the caecal gland by a non-glandular tissue. Each testes is consist of large no of seminiferous tubule. The sperms are develop from the germ cells of seminiferous tubule. These tubule unite to form median central canal. From each testis arises several thin tubular vasa-efferentia, which open into the anterior end of vas deferens. The vas deferens forms a narrow closely coiled tube occupying the greater part of the anterior section of the kidney but becomes very much enlarged posteriorly to form seminal vesicle. The seminal vesicles of both the sides open behind into a large triangular chamber, the urinogenital sinus, which open into the cloaca on an elevated urinogenital papillia. On either side of the urinogenital sinus lies a club shaped sperm sac. The function of sperm sac is unknown. During copulation the sperms pass into the claspers which are inserted into the cloaca of the female. The claspers are grooved elongations of the pelvic fins. The sperms from the cloaca pass into the claspers and are transferred to the female through them. On the ventral side of the body just beneath the skin there is a pair of elongated glandular and muscular sacs the siphons. These sacs extend anteriorly almost to the level of posterior region of the pectoral fins where they end blindly. Posteriorly these sacs extend as siphon tubes, each of which opens into the groove of clasper of its side. The siphons have no direct communication with the male urino-genital organs except they open into the groove of claspers. It is believed that sea water enters the siphons and it forces the sperms along the grooves of the claspers during copulation.

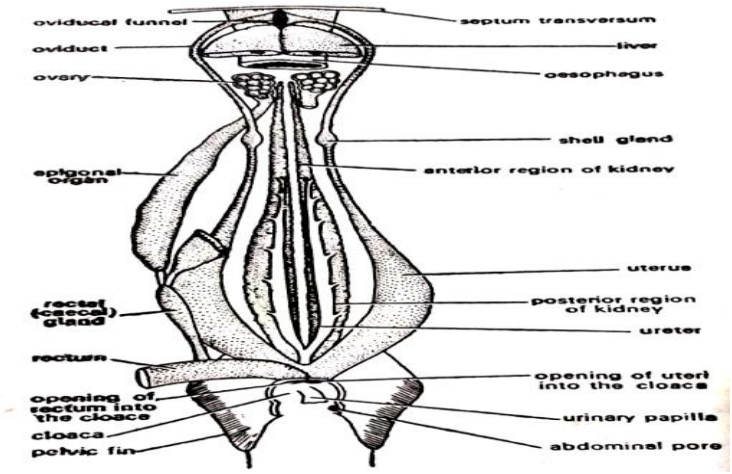


Fig 3.14 : *Scoliodon* Female urinogenital organs

Female urinogenital organ

In female each kidney also has two parts, an anterior part which is degenerate and reduced to a narrow strand which is non renal and non functional and abroad posterior part which contains masses of coiled called uriniferous tubules. The uriniferous tubules of posterior functional part open into along thin walled wolffian duct called ureter. The two ureter of either side unite to form a common ureter which opens into a urinary sinus. The urinary sinus is formed by the enlarged ends of the wolffian duct. The urinary sinus opens into the cloaca by an aperture on a urinary papilla.

The female excretory organ differ from the male organ in following

(1) There is no direct connection between the kidney and the genital organs.

(2) The anterior part of each kidney is extremely reduced.

(3) Both the ureter unites behind by a single median urinary aperture into the triangular chamber, the urinary sinus.

(4) The urinary sinus receives the ureters only and the genital ducts open directly intoi the cloaca.

Reproductive organs

The female reproductive system consists of a pair of ovaries, a pair of oviducts, shell gland and a pair of uteri.

The ovaries are situated one on either side of the vertebral column just behind the base of liver. They are suspended in the body cavity one on each side, by a fold of peritoneum, the mesovarium. From each ovary rounded follicles are projected and each follicle contain an ovum. The mature ova are shed into the abdominal cavity where they enter the oviduct. The two oviducts or mullerian ducts are large tubes extending the whole length of body cavity, they start from a single oviducal funnel near the septum transversum, then each oviduct runs backward and enlarged into structure called shell gland or oviducal gland in which the spermatozoa are stored during copulation. After shell gland oviduct dilates to form a sac like uterus. The uteri of both the sides unite to form a short vagina which opens into the cloaca by a large aperture. A fold of mucus membrane of this region separates the vagina from the cloaca, and acts as a value which closes the vagino-cloacal aperture during the development of the embryo within the uterus.

Reproduction

Copulation

In *Scoliodon* reproduction occur almost throughout the year. During copulation, the male twines around the female and one or both claspers of male are inserted into the cloaca of the female and are fixed in position by the erection of terminal pieces. The spermatic fluid is forced through the grooves of the claspers into the oviducts through the vagina.

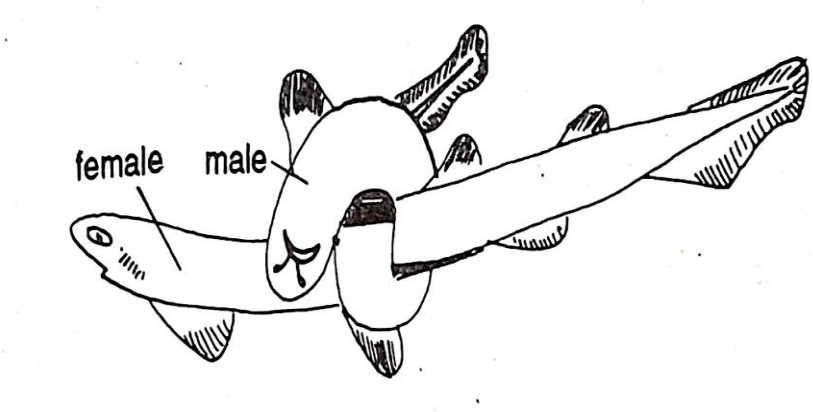


Fig 3.15 : *Scoliodon* : Copulation

Fertilization

In *Scoliodon* the fertilization is internal. Fertilization of mature eggs takes place in the section of the oviduct between the oviducal funnel and the shell gland.

Development

The *Scoliodon* is viviparous. The posterior region of the oviduct dilates into a very wide chamber, the uterus, which serve as a place for the development of the young. During breeding contained season the two uteri occupying the greater part of the abdominal cavity in which 3-7 embryos may be retained. The mucus lining of the uterus becomes divided into as many compartments and each of the compartments is filled with a fluid which completely surrounds the embryo and protect it.

In early stages of development each embryo is provided with a tubular yolkstalk which is connected at one end with the intestine of the embryo and at the other with a yolk sac containing yolk for the nourishment of the young. In later stages when the yolk is more or used up, the yolk sac becomes greatly folded and embedded in the uterine wall, thus forming a yolk sac placenta through which the embryo obtains its nourishment from the uterine tissue with the formation of the placenta the tubular connection of the yolk stalk with the intestine become finished, but the blood vessels are developed in the yolk stalk which thus becomes the placental cord attached to the embryo in the mid-ventral line at a point in level with the anterior edges of the pectoral fins. The other end of the cord ends in the fold of the yolk sac placenta which is usually attached close to the vaginal embryo, head of the embryo points forwards while the tail is bent on itself. Each embryo has its own placental cord and placenta. From the placental cord grow out numerous delicate tubular processes the appendiculae. Each appendiculum consists of several layers of epithelial cells surrounding a central core of loose connective tissue.

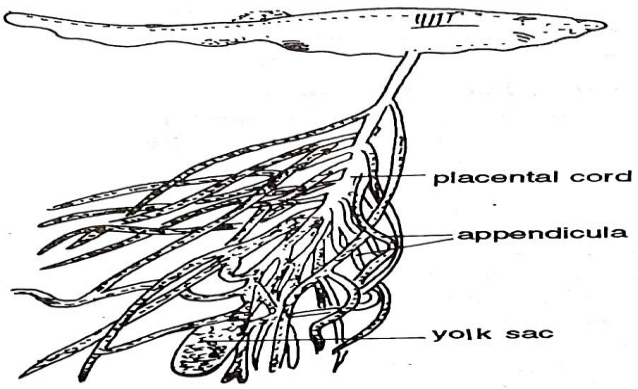


Fig 3.16 : *Scoliodon* Embryo with placenta

SAQs 1.

Complete the following sentences by inserting appropriate words in the blanks.

(i) Body in *Scoliodon* is covered by ----------.

(ii) The heart in *Scoliodon* receives ----------

(iii) The scroll valve is present in ----------

(iv) The swimming movement of *Scoliodon* is controlled by ---------

STRUCTURE (B) AMPHIBIA & REPTILIA

3.4 GENERAL CHARACTERS & CLASSIFICATION OF AMPHIBIA

Amphibia were the first animals that attempted a transition from aquatic to terrestrial mode of life. But they are not fully terrestrially adapted and however between aquatic and land habitats. That is why these animals are called as Amphibia (amphi=dual or double & bios=life). Structurally Amphibia are between the fish on one hand and reptiles on the other.

General Characters

(1) Aquatic or semi-aquatic (fresh water), air and water breathing, carnivorous, cold blooded oviparous, tetrapoda vertebrates.

(2) Head distinct, trunk elongated. Neck and tail may be present or absent.

(3) Limbs usually 2 pairs (tetrapods), some limbless. Toes 4-5 (pentadactyle) or less. Paired fins absent. Median fins, if present without fin rays.

(4) Skin soft, moist and glandular. Pigment cells (chromatophores) present.

(5) Exoskeleton absent. Digits clawless. Some with concealed dermal scales.

(6) Endoskeleton mostly bony. Notochord does not persist.

(7) Skull articulates with the atlas by two occipital condyles.

(8) Mouth large. Upper or both jaws with small homodont teeth. Tongue often protrusible. Alimentary canal terminates into cloaca.

(9) Respiration by lungs, skin and mouth lining. Larva with external gills which may persist in some aquatic adult.

(10) Heart 3 chambered (2 auricles & 1 ventricle). Sinus venous present. Aortic arches 1-3 pairs. Renal and hepatic portal systems well developed.

(11) Red blood corpuscles are biconvex, oval and nucleated.

(12) Kidney mesonephric. Urinary bladder large. Urinary duct open into cloaca. Excretion ureotelic.

(13) Lateral sense organs are present during some stages of development.

(14) Brain poorly developed. Cranial nerves 10 pairs.

(15) The eyes have eyelids. Nictitating membrane is well developed.

(16) Nostrils connected to buccal cavity. Middle ear with a single rod like ossicle, columbella.

(17) Ear consists of internal and middle ear. Tympanum cover the middle ear.

(18) Sexes separate. Male without copulatory organ. Gonoducts open into cloaca. Fertilization mostly external. Female mostly oviparous.

(19) Eggs with gelatinous covering, usually laid in water.

(20) Development indirect. Cleavage holoblastic but unequal. No extra embryonic membranes. Larva pass through an aquatic stage before metamorphosing into adult.

Classification

G. Kingsley Noble (1924) classify amphibian into six orders, in which 3 are extinct group and 3 are living group. So the class amphibian is classified into 2 subclasses in which one are extinct amphibian are placed and other are living amphibian.

Subclass –I Stegocephalia (Extinct)

- Skin with scale and bony plates.
- Skull with a solid bony roof, Leaving opening for eyes and nostril
- Limbs pentadactyle
- Permian to Triassic

Order –I Labyrinthodontia

- Distributed from Carboniferous to the Triassic period.
- These were crocodile or salamander like amphibians.
- The skull was completely roofed over with bones. The number of bones in the skull were more than those of recent forms.
- The teeth were enlarged and with greatly folded dentine in both the jaws.
- All the vertebrae consist of neural arches and intercentra. Further in all the forms except in stereospondyle, a pre-ossified pleurocentrum is present.

  Example : *Eryops, Capitosaurus*

Order – II Phyllospondyli

- They were distributed in Carboniferous to the Permian period.
- They were small, salamander like amphibians.
- The vertebrae were tubular with the notochord and spinal cord lying in one cavity.

- The Centrum was represented by the thick floor of each vertebral ring.
- The transverse processes were well marked with short ribs
- Cartilaginous pubis and coracoids.
- Three pairs of gills in long larval life resembles the urodela.

Example : *Ichthyostega*

Order –III Leposondyli

- They were distributed in Carboniferous to the Permian period.
- Each vertebrae was composed of a single piece. The neural arch continued with centrum.
- The ribs articulating with column intervertebrally. In some cases there was a secondary shift of ribs to the side of vertebra.

Example: *Diplocaulus, Sauropleura*

Subclass –II Lissamphibia(Living)

- Modern amphibian lacking dermal bony skeleton.
- Teeth small and simple.

Order –I Apoda or Gymnophiona

- Limbless, blind, elongated worm like, burrowing tropical.
- Tail short or absent, cloaca terminal.
- In some dermal scales embedded in skin which is transversally wrinkled.
- Skull compact, roofed with bone.
- Limbs girdles absent.
- Male have protrusible copulatory organs.

Example : *Ichthyophis, Uraeotyphlus.*

Order –II Caudata or Urodela

- Body with distinct head, trunk and tail.
- Limbs 2 pairs, usually weak, almost equal.
- Skin devoid of scales and tympanum.
- Gill permanent or lost in adult.
- Male without copulatory organ.

- Larva aquatic, adult like with teeth.

  Example : *Ambystoma, Salamandra, Necturus, Siren*

Order –III Salientia or Anura

- Specialized amphibian without tail in adults.
- Head and trunk are fused.
- Neck and tail are absent.
- Hind limbs usually adapted for leaping & swimming.
- Adult without gills or gill openings.
- Eyelids well formed. Tympanum present.
- Skin loosely fitting, scalesless, Mandibles toothless.
- Fertilization is usually external.

  Example : *Rana, Hyla, Rhacophorus*.

SAQs 2.

Complete the following sentences by inserting appropriate words in the blanks.

(i) The amphibian skin has ----------

(ii) Amphibia are ---------

(iii) Tailless amphibians are ----------

(iv) Salamander belongs to ----------

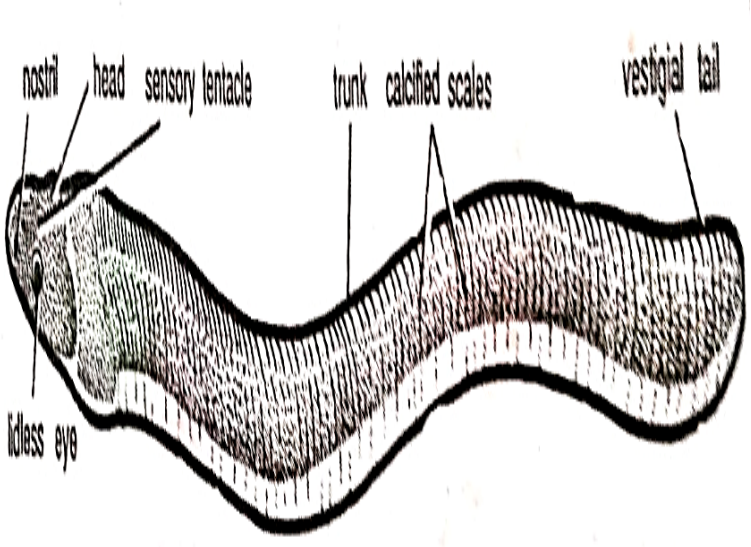


Fig 3.17 : *Ichthyophis*

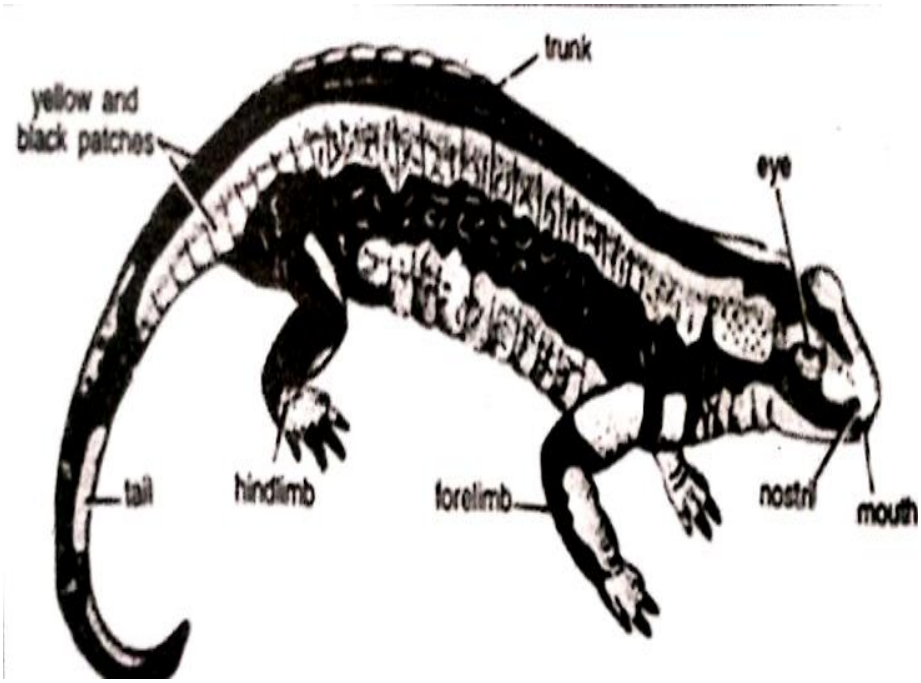


Fig : *Salamandra*

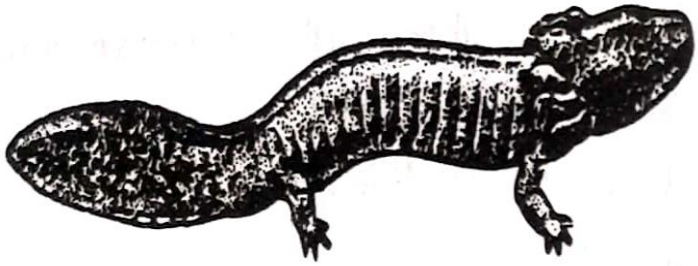


Fig: *Necturus*

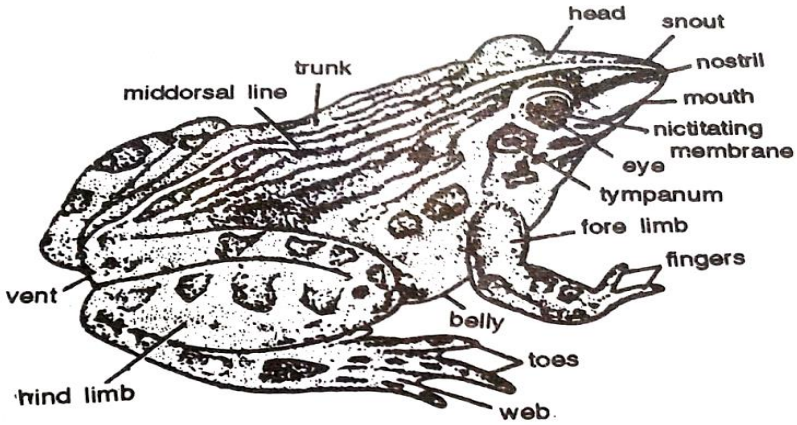


Fig 3.18 : *Rana*

3.5 GENERAL CHARACTERS AND CLASSIFICATION OF REPTILIA

The reptiles are the first class of vertebrates fully adapted for life in dry places on land. They have flourished and attained maximum development during the Mesozoic era. The characters of reptiles are in fact a combination of characters that are found in fish and amphibians on one hand and in birds and mammals on the other. Reptila refers to the mode of locomotion (creeping or crawling) and study of reptiles is called Herpetology.

General Characters

(1) Predominantly terrestrial, creeping or burrowing mostly carnivorous, air breathing, cold blooded, oviparous and tetrapodal vertebrates.

(2) Body is bilaterally symmetrical and divisible into 4 regions head, neck, trunk & tail.

(3) Limbs 2 pairs, pentadactyle. Digits provided with horny claws. Limbs are absent in snake and in some lizard.

(4) Body is provided with exoskeleton of scales, shields, plates or scutes.

(5) The skin is dry and without any gland.

(6) Endoskeleton bony. Skull with one occipital condyle.

(7) A characteristic T-shaped interclavicles is present.

(8) Mouth terminal, simple, conical teeth present on the jaws. In turtle teeth are replaced by horny beaks.

(9) Alimentary canal terminates in a cloacal aperture.

(10) Reptiles are carnivorous.

(11) Respiration by lungs.

(12) Heart with two auricle and incompletely divided ventricle, four chambered in crocodiles. The RBC are oval and nucleated.

(13) Brain is more developed than that of amphibians. Twelve pairs of cranial nerves present. Lateral line system is absent. Jacobson's organ present in the roof of the mouth.

(14) Kidneys metanephric. Excretion uricotelic.

(15) Sexes separate. Male with a pair of copulatory sac or hemipenis.

(16) Fertilization internal. Eggs lays on land. Development is direct. Young ones resemble the adults.

(17) Embryonic membranes (amnion, chorion, allantosis and yolk sac) are formed during development.

(18) No parental care.

Classification

The class reptilian can be divided into five subclasses on the basis of presence or absence of certain openings in the temporal regions of the skull.

Subclass –I Anapsida

Primitive reptiles with a solid skull roof. No temporal opening

Order – I Chelone

- Body short, broad and oval.
- Limbs clawed and/or webbed, or paddle like.
- Body is encased in a shell of rounded dorsal carapace and flat ventral plastron.
- Thoracic vertebrae and ribs usually fused with the carapace.
- Skull solid, quadrate immovable, sternum absent.
- 6 jaws without teeth, covered with horny sheath.
- Clocal aperture is longitudinal.
- Copulatory organ single.
- Marine forms are turtles, fresh water forms terrapins and land form tortoises.

Example : *Chelone, Testudo*

Subclass –II Euryapsida (**Extinct)**

Skull with a single dorso-lateral temporal opening on either side, bounded below by post-orbital and squamosal bones.

Subclass –III Parapsida (**Extinct)**

Skull with a single dorso-lateral temporal opening on either side bounded below by the supra-temporal and post frontal bones.

Order –I Protosauria

- From Permian to Triassic

Example: *Araeoscelis*

Order –II Plesiosaur

- From Triassic to Cretaceous

Example : *Pilosaurus, Plesiosaurus.*

Order –III Ichtyosauria

- From Triassic to Cretaceous

Example : *Mixosaurus, Ichthyosaurus*

Subclass –IV Synapsida (Extinct)

From Carboniferous to Permian, Skull with a single lateral temporal opening on either side bounded above by the post-orbital and squamosal bone

Order –I Pelycosauria

Example : *Varanosaurus, Dimetrodon.*

Order –II Mesosauria

Example : *Mesosaurus.*

Subclass –IV Diapsida

Skull with two temporal openings on either side separated by a bar of post-orbital and squamosal bone

Order –I Rhynchocephalia

- Body small, elongated, lizard like.
- Limbs pentadactyle, clawed and burrowing.
- Skin covered by granular scales and a mid-dorsal row of spines.
- Nasal opening separate, parietal foramen with vestigial pineal eye present. Quadrate is fixed.
- Vertebrae amphicoelus or biconcave. Numerous abdominal ribs present.
- Teeth acrodont.
- Cloacal aperture transverse.
- Heart incompletely 4 chambered.
- No copulatory organ in male.

Example : *Sphenodon* only living species.

Order –II Squamata

- Size small to medium, elongated.
- Limbs clawed, absent in snakes like and few lizards.
- Exoskeleton of horny epidermal scales, shields & spines.
- Quadrate movable.
- Vertebae procoelous.
- Ribs single headed.
- Teeth acrodont.
- Heart incompletely 4-chambered.
- Cloacal aperture is transverse.
- Male with eversible double copulatory organs.

Example : *Hemidactylus, Draco, Naga, Viper.*

Order –II Crocodilia

- Large sized carnivorous and aquatic reptiles.
- Tail long, strong and laterally compressed.
- Limbs short but powerful, clawed and webbed.
- Skin thick with scales bony plates and scutes.
- Quadrate immovable.
- Teeth numerous, thecodont lodged in sockets.
- Heart completely 4 chambered.
- Cloacal aperture is a longitudinal slit.
- Male with a median, erectile grooved penis.

Example : *Crocodylus, Alligator*

SAQs 3.

Complete the following sentences by inserting appropriate words in the blanks.

(i) Tuatara belongs to ----------

(ii) The age of reptiles ----------

(iii) The study of reptile is known as ----------

(iv) Reptiles are ----------

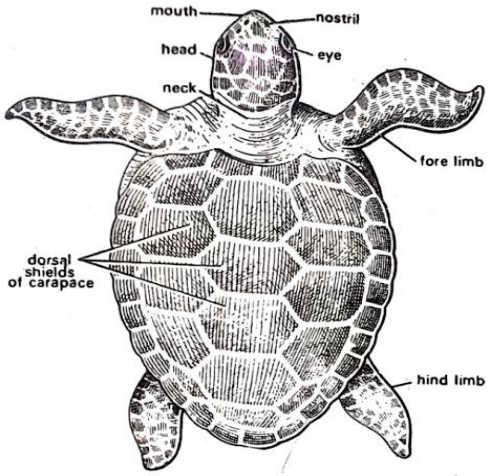


Fig : *Hemidactylus*

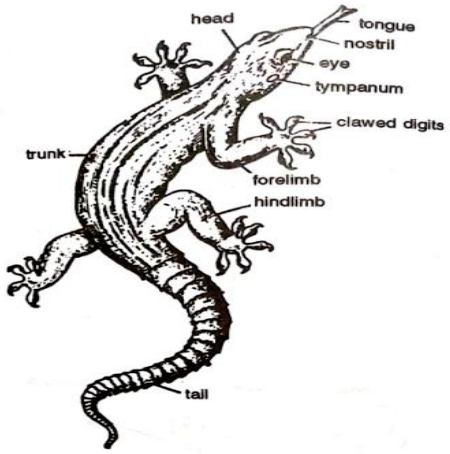


Fig : *Chelone*

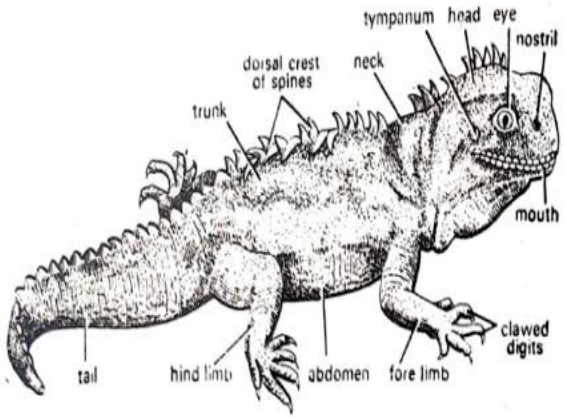


Fig : *Sphenodon*

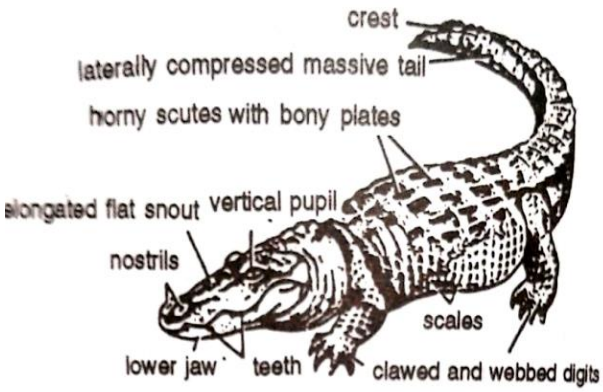


Fig : *Alligator*

3.6 SUMMARY

In this unit you will study the classification and detailed about habit, morphology, anatomical and physiological of *Scoliodon*. In this unit there is discussion have been done on skin, placoid scale, locomotion, coelom, digestive system and its physiology of digestion, respiratory organ and mechanism of respiration, heart, and its working, blood, in nervous system brain, spinal cord, cranial nerve, spinal nerve, autonomic nervous system, in sense organ olfactory organ, optic organ, stato-acoustic organ, lateral line organs, ampullae of lorenzini, excretory organ, male and female urino-genital system, male and female reproductive organ, reproduction, copulation, fertilization, and development

In this unit you will also study about the general characters and classification of amphibian and reptilian in detailed.

3.7 TERMINAL QUESTION

Q1. Explain the mechanism of respiration in *Scoliodon*.

Q2. Explain the general character of class amphibian.

Q3. Explain the general character of class reptilian.

3.8 ANSWERS

SAQ 1 (i) Placoid scales

(ii) only venous blood

(iii) *Scoliodon*

(iv) Hind brain

SAQ 2 (i) Glands

(ii) Cold blooded animal

(iii) Gymnophiona

(iv) Caudata

SAQ 3 (i) Rhynchocephalia

(ii) Mesozoic era

(iii) Herpetology

(iv) Carnivorous

TERMINAL QUESTION

Ans 1.

The floor of the bucco-pharyngeal cavity is depressed by hypo-branchial muscles and the mouth is opened, at the same time the visceral arches expand the wall of the pharynx, so that sea water containing dissolved oxygen rushes in through the mouth. Entry of water into external branchial apertures is prevented by an anterior fold of skin on each gill pouch. The bucco-pharyngeal floor is then raised and the mouth is closed, and contractions of the wall of the pharynx force the water into internal branchial apertures, the oesophagus being closed, and then into gill clefts, where it washes the branchial lamellae and goes out of the external branchial aperture. The flow of blood in branchial lamellae is from top towards the base, that is in a direction opposite to that of the water current. The blood comes in contact with highest concentration of water and lowest concentration of carbon dioxide. Thus an efficient exchange of O_2 band Co_2 takes place between the blood and sea water.

Ans 2.

- Aquatic or semi-aquatic (fresh water), air and water breathing, carnivorous, cold blooded oviparous, tetrapoda vertebrates.
- Head distinct, trunk elongated. Neck and tail may be present or absent.
- Limbs usually 2 pairs (tetrapods), some limbless. Toes 4-5 (pentadactyle) or less. Paired fins absent. Median fins, if present without fin rays.
- Skin soft, moist and glandular. Pigment cells (chromatophores) present.
- Exoskeleton absent. Digits clawless. Some with concealed dermal scales.
- Endoskeleton mostly bony. Notochord does not persist.
- Skull articulates with the atlas by two occipital condyles.
- Mouth large. Upper or both jaws with small homodont teeth. Tongue often protrusible. Alimentary canal terminates into cloaca.
- Respiration by lungs, skin and mouth lining. Larva with external gills which may persist in some aquatic adult.
- Heart 3 chambered (2 auricles & 1 ventricle). Sinus venous present. Aortic arches 1-3 pairs. Renal and hepatic portal systems well developed.

Ans 3.

- Predominantly terrestrial, creeping or burrowing mostly carnivorous, air breathing, cold blooded, oviparous and tetrapodal vertebrates.
- Body is bilaterally symmetrical and divisible into 4 regions head, neck, trunk & tail.

  Limbs 2 pairs, pentadactyle. Digits provided with horny claws. Limbs are absent in snake and in some lizard.
- Body is provided with exoskeleton of scales, shields, plates or scutes.
- The skin is dry and without any gland.
- Endoskeleton bony. Skull with one occipital condyle.
- A characteristic T-shaped interclavicles is present.
- Mouth terminal, simple, conical teeth present on the jaws. In turtle teeth are replaced by horny beaks.
- Alimentary canal terminates in a cloacal aperture.

UNIT-4 GENERAL CHARACTERS AND CLASSIFICATION OF AVES UP TO ORDER WITH EXAMPLES, FLYING ADAPTATIONS IN BIRDS

Structure :

4.1 INTRODUCTION

Birds constitute a well defined group of vertebrate animals. They are adopted for aerial mode of life. They have branched off from the reptiles. Both Reptiles and birds resemble each other in many respects, so Huxley placed them in two classes of vertebrate in a single superclass Sauropida. Although birds have many reptiles features but they are highly specialized than reptile. This made T. H. Huxley to state that birds are glorified reptiles.

Objectives :

- Describe the general characters and classification of birds.
- Explain the flying adaptation in birds.

4.2 GENERAL CHARACTERS

- The birds are feather covered, air breathing, warm blooded, oviparous, bipedal flying vertebrates.
- Body is more or less spindle shaped and divisible into four distinct regions head, neck trunk and tail.
- The jaws are elongated into a toothless beak or bill.
- Neck is long and flexible, tail is short and stumpy.

- Limbs are two pairs. Forelimbs are modified as wings for flying. The hinds limbs are adapted for walking, running, perching, swimming etc. They bear four clawed digits of which the first one or hallux is directed backwards and the remaining three infront.
- The birds has an epidermal exoskeleton represented by
  - Feathers forming a non conducting body covering for warmth.
  - Claws on the toes.
  - Sheaths on the beaks
- The skin is dry and devoid of glands except the oil or preen gland at the root of tail.
- Pectoral muscles of flight are well developed.
- The endoskeleton is bony. The bones are pneumatic or hollow and without bone marrow. This makes the body light. The bones are usually fused.
- The skull is smooth and monocondylic, bearing a single occipital condyle. Cranium large and dome like.
- Lower jaw consist of 5 to 6 bones and articulates with quadrate.
- Vertebral column short. Centra of vertebrate heterocoelous. Cervical vertebrae numerous, bear small cervical ribs. Some thoracic vertebrae fused together. A synsacrum results by fusion of posterior thoracic, lumber, sacral and anterior caudal vertebrae. Few tail vertebrae compressed laterally and the last 3 or 4 fused into a ploughshare bone, pygostyle.
- The sternum is large and bears a keel for the attachment of flight muscle.
- Ribs double headed or bicephalous and bear posteriorly directed uncinate process.
- Both clavicle and single interclavicles fused to form a “V” shaped bone called furcula or wish bone.
- The pelvic girdle is large, strong and fused with the synsacrum. The acetabulum is perforated.
- The heart is four chambered. Sinous venous and truncus arteriosus are absent. The right systemic arch only persists, the left one disappears. The RBC are nucleated.
- The lungs are compact, spongy and non-distensible and provided with thin walled air sacs.
- Larynx is without vocal cords. A sound box or syrinx is present.
- Kidney metanephric and 3 lobed. Ureter open into cloaca. Urinary bladder absent. Birds are urecotelic. Excretory substance of urates eliminated with faeces.

- Brain with greatly developed cerebellum, cerebrum and optic lobes. Cranial nerves twelve pairs.
- The eyes are surrounded by sclerotic plates and contain vascular pectin.
- The olfactory organs are poorly developed.
- The birds have 3 – chambered cloaca.
- Sexes separate. Sexual dimorphism well marked. Male has a pair of abdominal testes and a pair of sperm ducts. Male without copulatory organ except in ratitae, duck etc. The female has a single functional left ovary and oviduct.
- Fertilization internal, preceded by copulation and courtship. Female oviparous. Eggs large with much yolk and hard calcareous shell.
- Eggs develop by external incubation. Cleavage discoidal meroblastic. Development direct. Extra embryonic membrane (amnion, chorion, allantosis and yolksac) present.
- Newly hatched young fully formed (precocial) or immature (altrical).
- Parental care is well marked.

4.3 CLASSIFICATION OF AVES UP TO ORDER

The birds form a more homogenous group than any other class of vertebrates, therefore they fail to present prominent external features for their classification. There are about 9000 living species of birds. The class Aves is divided into two subclasses Archaeornithes and Neornithes.

Subclasses I: Archaeornithes

(Gr., *archios*, ancient + *ornithos*, bird)

1. Ancient and extinct birds that lived about 155 million year ago in the Mesozoic era.
2. Wings primitive, with little power of flight.
3. Tail long, tapering, with more than 30 vertebrae, lizard like, bearing two lateral rows of rectrices.
4. Each hand bearing three unfused and clawed fingers.
5. Skull with teeth in both jaws, embedded in sockets (alveoli).
6. Vertebrae amphicoelous.
7. Tail with 18 – 20 free caudal vertebrae, without pygostyle.
8. Sternum without a keel.
9. Carpals and metacarpals free.
10. Cerebellum small.

This subclass includes a single order

Order 1 : Archaeopterygiformes

Example : *Archaeopteryx lithographica,* from Jurassic of Bavaria Germany.

Subclasses II: Neornithes

(Gr., *neo*, modern + *ornithos*, birds)

1. Modern as well as extinct post Jurassic birds.
2. Wings usually well developed and adapted for flight, with few exceptions.
3. Tail short and reduced, caudal vertebrae 13 or even less, with rectrices arranged in a fan like manner.
4. Wing composed of 3 partly fused fingers without claws.
5. Teeth absent except in some fossil birds.
6. Vertebrae heterocoelous in living forms.
7. Few caudal vertebrae free. Rest fused into a pygostyle.
8. Sternum usually with a keel.
9. Distal carpals fused with matacarpals to form carpometacarpus.
10. Cerebellum large.

This subclass is divided into 4 super orders:

Super-order 1 : Odontognathae

(Gr., *odontos*, teeth)

1. Extinct, Upper cretaceous birds.
2. Jaws bear teeth, so advantageous for catching fish.
3. Brain of the avian type

This super order has 2 orders

Order 1. Hesperornithiformes

1. Large flightless marine birds.
2. Sharply pointed pleurodont teeth, present in grooves rather than in sockets.
3. Vertebrae amphicoelous.
4. Shoulder girdle reduced.
5. Sternum without a keel.

Example : *Hesperornis, Baptornis* .

Order 2. Ichthyornithiformes

1. Whether teeth were present is not a definite.
2. Neck vertebrae amphicoelous.

3. Shoulder girdle well developed.
4. Sternum with a well developed keel.

Example : *Ichthyornis, Apatornis.*

Super-order 2 : Palaeognathae or Ratitae

(Gr., *palaios* old + gnathos jaw; L., *ratis* raft)

1. Modern big-sized, flightless, running birds, without teeth.
2. Wings vestigial or rudimentary; feathers devoid of interlocking mechanism.
3. Rectrices absent or irregularly arranged.
4. Skull sutures remain distinct for long time.
5. Quadrate articulates by a single head with skull.
6. Sternal keel vestigial, absent or flat, raft-like.
7. Uncinate processes are vestigial or absent.
8. Tail vertebrae free. Pygostyle small or absent.
9. Pectoral muscle poorly developed.
10. Syrinx is absent.
11. Male has a large and erectile penis; female has a clitoris.

This has super order has 7 orders

Order 1: Struthioniformes

(Gr. *struthio,* ostrich + form)

1. Head, neck and legs sparsely feathered.
2. Feathers without after shaft.
3. Head comparatively small, neck long and flexible, beak short and broad.
4. Legs strongly developed, only two toes (third and fourth) present on each.
5. Pubic symphysis present.
6. Sternum without keel.
7. Pygostyle absent.

Example : *Struthio camelus* (ostrich) found in Africa and Arabia

Order 2: Rheiformes

1. Swift running birds.
2. Head, neck and thigh feathered.
3. Feathered aftershaft.
4. Legs bear 3 toes with claws
5. Sternum without keel.

6. Ischial symphysis present.

Example : *Rhea Americana* (rhea) of America

Order 3 : Casuariformes

1. Forelimbs greatly reduced.
2. Head bears a comb-like structure.
3. Neck and body densely feathered. Feathers with aftershaft nearly equal to shaft.

Example: Cassowaries of Australia and Emus of New Zealand

Order 4 : Apterygiformes

1. Feathers simple, hair –like or bristle-like.
2. Wings vestigial.
3. Long bill with nostrils near the tip

Example : Kiwis (*Apteryx*) of New Zealand

Order 5 : Dinornithiformes

1. Giant birds, become extinct nearly 700 years ago.
2. Wings almost absent,
3. Beaks short
4. Massive legs bearing four toes.
5. Sternum reduced and without keel.
6. Pectoral girdle completely absent

Example : *Dinornis* (moas) of New Zealand.

Order 6 : Aepyornithiformes

1. Recently extinct birds.
2. Wings vestigial or tiny.
3. Legs powerful, with four toes.
4. Sternum short, broad and without keel.
5. Coracoid, scapula and wings bones reduced or absent.

Example : *Aepyornis, Mulleornis* (giant elephant birds) of Africa and Madagascar

Order 7 : Tinamiformes

1. Small terrestrial birds, not flightless but essentially great runners (cursorial).
2. Sternum is keeled.
3. Pygostyle reduced.

4. Egg shells with high gloss.

Example : *Tinamus. Eudromia*

Super-order 3 : Impennae

1. Include aquatic flightless birds.
2. Wings paddle like.
3. Feet webbed.
4. Small scale like feathers covers the whole body.
5. Come ashore to breed.

This has only 1 order

Order 1 : Sphenisciformes

1. Modern, aquatic, flightless, with paddle-like wings or flippers.
2. Feet are webbed.
3. Feathers small, scale like, covering entire body.
4. Thick layer of fat beneath skin.
5. Nest in colonies or rocky islands or ice.
6. Bones are much compressed.

Example : Penguins (*Aptenodytes*) of Southern Hemisphere.

Super-order 4 : Neognathae or Carinatae

1. Most modern, usually small sized, flying birds.
2. Wings well developed, feathers with interlocking mechanism.
3. Rectrices present and arranged regularly.
4. Pterylae are regular.
5. Oil gland is present.
6. Skull is neognathous, that is vomer is short allowing palatines to meet.
7. Skull suture disappear very early.
8. Quadrate is double headed.
9. Sternum with a well developed keel.
10. Uncinate processes are present.
11. Pygostyle is present.
12. Scapula and coracoids meet at a right angle or acute angle.
13. Pectoral muscle large.
14. Male has no copulatory organ.
15. Young are altricious.

The super order Neognathae includes several orders. Only a few interesting orders are mentioned below with known examples. For convenience sake these orders have been grouped in six ecological groups on the basis of the habits.

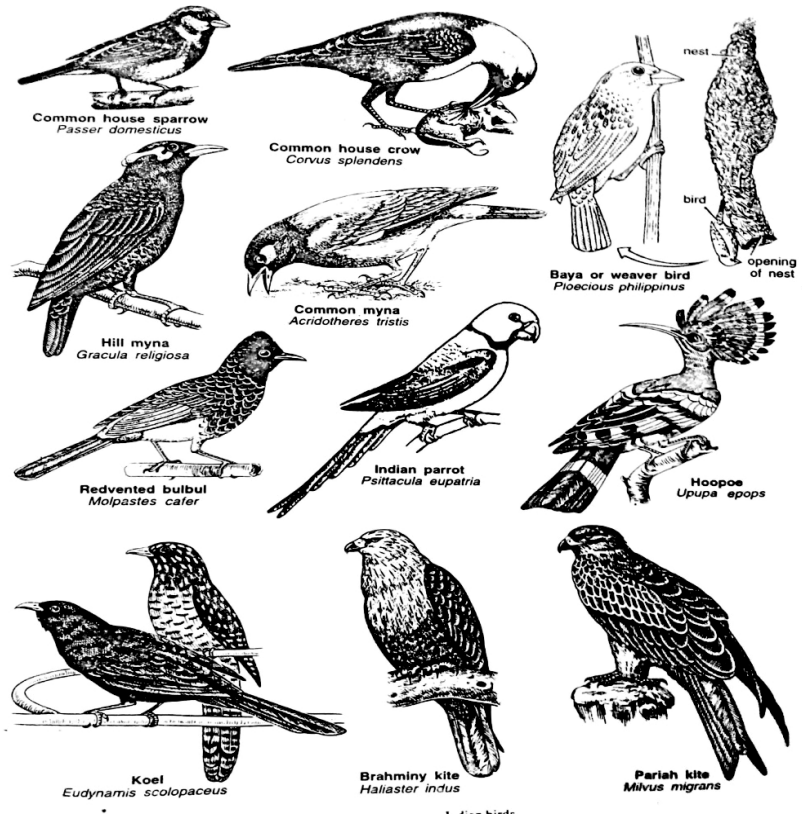


Fig 4.1 : Some common Indian Birds

Group A : Arboreal Birds

This group includes those birds which live in and around tree and shrubs. Majority of birds belong to this group.

Order 1 : Passeriformes

1. Largest order including half of the known species.
2. Toes three infront and one behind, adapted for perching.
3. Beaks adapted for cutting.

Example : Sparrow (*Passer domesticus*), Crow (*Corvus splendens*), Bulbul (*Molpestes*), Starlings (*Sturnus*), Larks (*Alauda*), Crossbill (*Loxia*). Finches (*Fringilla*).

Order 2 : Piciformes

1. Includes highly specialized wood - boring birds like woodpeckers, toucans, sap-suckers.
2. Bill is hard and powerful.

3. Tongue is long and protrusible.

4. Insectivorous.

Example : Yellow front pied wood pecker (*Dendrocopos mahrattensis*), Golden backed woodpecker (*Dinopium benaghalensis*).

Order 3 : Columbiformes

1. Includes doves and pigeons.

2. Beak usually soft and slender.

3. Crop large producing pigeon milk to feed youngs.

4. Fruit and grain rating birds.

5. Mostly good filers.

Examples : Blue rock pigeon (*Columba livia*)

Order 4 : Psittaciformes

1. Includes parrots, parakeets, cocatoos, macaws etc.

2. Beak stout, narrow, sharp edged and hooked at the tip.

3. Upper jaw movably articulated with the skull.

4. Feet zygodactylus that is two toes infront and two toes behind. Outer toe not reversible.

5. Have considerable memory.

6. Vegetarian.

7. Feathers green, blue, yellow or red.

Examples : Large Indian parakeet (*Psittacula eupatria*), Green parrot (*Psittacula lameri*)

Group B : Terrestrial birds

These birds are perfectly able to fly but spend most of their time walking or running on ground.

Order 5 : Galliformes

1. Include game birds with short powerful flight.

2. Feet usually massive adapted for scratching and running.

3. Beak short.

4. Feathers with aftershaft.

5. Graminivorous (grain eating).

6. Palatable.

Example : Jungle fowl (*Gallus*), Peacock (*Pavo cristatus*).

Order 6 : Cuculiformes

1. Include cuckoos.
2. The female usally lays eggs in the nests of other birds, only some species make their own nests.
3. Two toes infront and two behind, outer one reversible.
4. Tail long and beak moderate

Examples : Cuckoo (*Cuculus canorus*), Koel (*Eudynamis scolopaceous*)

Group C : Swimming and diving birds

Order 7 : Anseriformes

1. Include aquatic birds like ducks, geese and swans.
2. Beak broad and flattened covered with soft cornified epidermis, margins of beak bear many transverse horny ridges or lamellae. Tongue fleshly.
3. Tail usually short, with many feathers.
4. Legs short and feet webbed.

Example : Wild duck (*Anas*), Swan (*Cygnus*).

Order 8 : Coraciiformes

1. It include kingfishers.
2. Beak strong.
3. Third and fourth toe fused at the base.

Example : White breasted kingfisher (*Halcyon smyrnensis*), Hoopoe (*Upupa epops*).

Order 9 : Gaviiformes

1. It includes marine birds called loons.
2. Legs short, toes webbed.
3. Tail consists of 18 – 20 short stiff feathers.

Example : *Gavia* represented by four species.

Order 10 : Podicipediformes or Colymbiformes

1. Freshwater divers with legs placed for back on the body, feet lobed.
2. Tail with a tuft of down feathers.

Example : Rebes(*Podicipes*)

Order 11 : Procellariformes

1. It include sea birds.
2. Nostrils tubular.
3. Wings long and narrow.
4. Feathers compact and oily in texture.
5. Nest usually on islands.

Examples : Albatross (*Diomedea*)

Order 12 : Pelecanioformes

1. Fish eating and colonial. Nest is colonies on rocks.
2. Beak long, with wide gap for catching and swallowing the prey.
3. Nostril vestigial or absent.
4. Feet four toed and webbed.
5. Gular pouch present of the throat.

Example : Pelican (*Pelecanus*)

Group D : Shore birds and wading birds

This group also includes aquatic birds. They lives near the shore and rarelyswim or dive.

Order 13 : Charadriformes

1. The legs are long and slender, toes are webbed.
2. Beak mud probing.
3. Feathers dense and firm

Examples : Snipe (*Capella*), gull(*Larus*).

Order 14 : Ciconiiformes

1. Long legged marshy wading birds.
2. Neck long and snake like.
3. Beak javeline or pincer like for piercing aquatic prey (marine fishes)
4. Feathers decorative strong fliers.
5. Toes without web.
6. Young ones born naked.

7. Some areb migratory.

Examples : Flamingo (*Phonicopterus*), Stork (*Ciconia*).

Order 15 : Gruiformes

1. It includes crane like wading birds with long legs and partially webbed feet.
2. Beak heavy.
3. Omnivorous diet.

Examples : Common coot (*Fulica atra*)

Group E : Birds of Prey

Order 16 : Falconiformes

1. Diurnal and strong fliers.
2. Beak short and curved at the tip.
3. Feet with sharp curved claws adapted for grasping and holding the prey.

Examples : Common kite (*Milvus migrans*), hawk (*Astur badius*), king vulture (*Sarcogyps calvus*).

Order 17 : Strigiformes

1. Nocturnal birds with large rounded head.
2. Eyes large and directed infront. Each located in a disc of radial feathers.
3. Beak short.
4. Feet feathered upto the toes. Claws sharp, adapted for grasping prey.

Examples : Great horned owl (*Bubo bubo*).

Group F : Aerial Birds

This group includes birds which are generally on wings and have weak or vestigial perching feet.

Order 18 : Micropodiformes or Apodiformes

1. It includes small insectivorous birds.
2. Beak small and weak, with long tubular tongue.
3. Wings long and pointed.

Examples : Indian swift (*Micropodus*), humming birds (*Trochus*).

Order 19 : Caprimulgiformes

1. It includes shy, nocturnal and insectivorous.

2. Beak small and delicate.

3. Mouth wide, margined with long bristle like sensory feathers.

4. Feathers soft.

Examples : Goat sucker (*Caprimulgus*), night hawk (*Chordeiles*).

SAQs 1.

Complete the following sentences by inserting appropriate words in the blanks.

(i) The ---------- are modified into wings for flying.

(ii) Bones of birds are ----------.

(iii) Birds are ----------.

(iv) Heart no of birds have ---------- chambers.

4.4. FLYING ADAPTATIONS IN BIRDS

Young (1958) describe birds as the masters of air. The entire bodies of birds have been modified for flight. Birds are good fliers and the fastest of all animals. Infact, a birds is like a flying machine. It flies on the principle of an aeroplane, a heavier that air machine. The morphology, anatomy, physiology and embryology of birds are highly modified for flight. These are as follows :-

(1) Body shape and structure: Birds have stream lined, boat shaped or spindle shaped body which offers minimum resistance to the air while flying. The body is quite compact. It is light but strong dorsally and heavy ventrally. It helps in maintaining balance in the air.

The internal structures are well centralized. The attachment or wings high up on the thorax, the high position of light organs like lungs and air sacs and low and central position of heavy structures like muscles, sternum and digestive organs beneath the line of attachment of wings lowers the centre of gravity.

(2) Body covering of feathers: The feathers are characteristic features of birds. They fully cover the body. They perform following functions

(i) The feathers covering the body reduce friction.

(ii) The feathers are light so they reduce weight.

(iii) The feathers insulate the body and prevent loss of body heat. This enables the birds to tolerate extreme cold at height and maintain a constant body temperature.

(iv) The body feathers hold a blanket of air around the body and this helps in buoyancy.

(v) The wing feathers help in striking the air and tail feathers are used for lifting and steering.

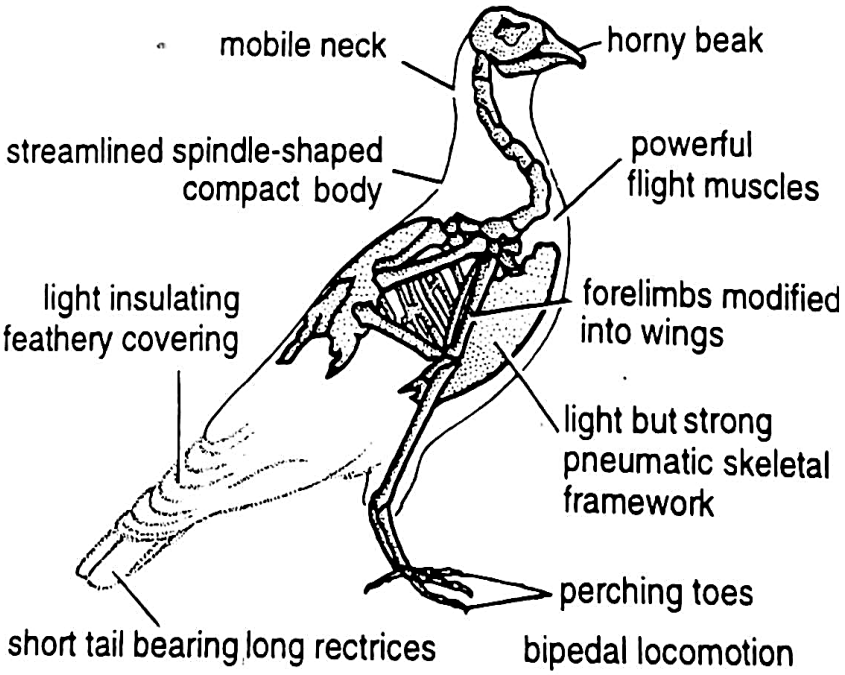


Fig 4.2 : Diagrammatic representation of flight adaptations

(3) **Fore limbs modified into wings:** The fore limbs have been converted into the unique and powerful organs i.e. wings, which are used for propulsion through the air. The convex upper surface and concave lower surface causes reduction in air pressure above and increases below and this helps in driving the birds forwards and upwards during flight.

(4) **Short Tail :** The short muscular tail bears a series of long, strong but light caudal feathers or rectrices arranged in a fan like manner and serves as a rudder for steering during flight to suddenly check flight and as a counter balance in perching.

(5) **Beak:** The conversion of forelimbs into wings is duly compensated by the presence of bill or beak. The mouth is drawn out into the horny beak. It is used for picking up food in nest building, for preening and for offence and defense.

(6) **Flexible neck and head :** The head is small and light and the neck is long and flexible. It can be retracted during flight, thus shorting the body axis. The flexible neck allows free movement of head which helps the beak in performing its functions easily.

(7) **Bipedal locomotion :** The forelimbs being no longer available, the hind limbs or legs anteriorly from the trunk to balance and to support the entire weight of the body and for locomotion on the ground or in water. Bipedal

is as characteristic of birds as flight, since flightless birds have all retained the habit of walking on two legs. The legs are also relatively stronger.

(8) Integument : The skin is quite loose. It allows free movement of flight muscles.

(9) Flight muscle : The wing is operated by a set of muscles called flight muscles. They are highly developed in flying birds and constitute nearly one sixth of total body weight. They are four set of flight muscles. The wings is depressed or lowered by an enormous pectoralis major muscles. It is elevated or raised by pectoralis minor muscle, the tendon of which passes through the foramen triosseum to be inserted dorsally on the head of humerus.

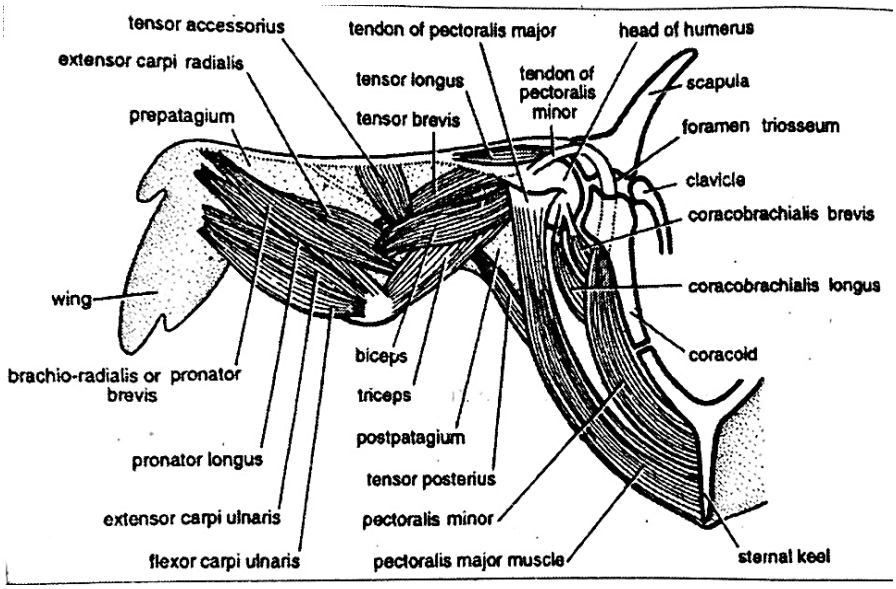


Fig 4.3 : Flight muscle of breast and right wing in ventral dissection

(10) Air sacs and respiration : The air sacs are thin walled, not muscular sac connected to the lungs. There are four paired and one unpaired air sacs. The paired air sac are cervical, anterior thoracic, posterior thoracic and abdominal and unpaired interclavicular air sac. They occupy the space between the internal organs and extend into the cavities of bones. They serve as reservoirs of air. In other vertebrates air is supplied to the lungs only once and that is during inspiration. But in birds during expiration also air is supplied to the lungs from the air sacs. Thus, in birds blood is oxygenated twice during a single breathing. This is called double oxygenation or double ventilation. Thus the respiratory system of birds is highly adapted to supply more oxygen to flight muscles. The air sacs also help in internal perspiration which helps in regulation of body temperature.

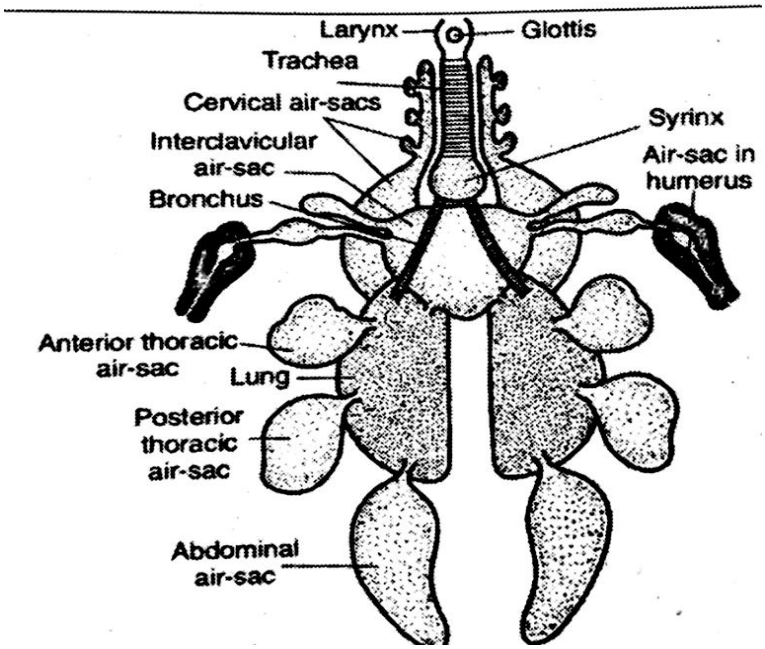


Fig 4.4 : Air Sacs Respiratory system of Pigeon

(11) Warm – bloodedness : Birds are warm blooded animals. The perfect aeration of blood is responsible for the high temperature of body (40^{o} – 46^{o}C) which is a necessity for flight requiring a great output of energy over a longer period.

(12) Loss of weight : For flight, less weight is very essential. This is achieved by the following features.

(i) Bones are pneumatic, i.e. they are provided with air sacs. The skeletal framework is light but strong.

(ii) Skull bones are thin and light and firmly fused together.

(iii) Thoracic ribs bear uncinate processes which provide compactness by concentrating the mass.

(iv) Absence of teeth.

(v) Absence of ovary and oviduct of right side in female.

(vi) Absence of urinary bladder.

(vii) Production of solid excretory waste.

(viii) Presence of feathers.

(13) Circulatory system : Active flight and warm bloodedness require high output of energy which require more oxygen. The circulatory system of birds is highly adapted for carrying more oxygen.

(i) The heart is relatively large and completely divided into four chambers.

(ii) Efficient double circulation of blood.

(iii)The blood contains high proportion of haemoglobin.

(14) Digestive system : Since metabolic rate is high birds require large amount of food and rapid digestion. Digestive system is compact but effective. Food eaten by birds is generally of high caloric value, easily digested and with minimum undigested waste. The rectum is short because of small amount of waste material which is voided at once.

(15) Urecotelic excretion : Birds do not have a urinary bladder, so they cannot store urine. The water of the excretory fluid is reabsorbed in the urinary tubules of kidneys and in the coprodaeum of cloaca. The result is the formation of a semisolid excreta, chiefly containing the insoluble uric acid and urates which are voided at once. These features help in reducing the unnecessary weight of the body.

(16) Perching : The hind limbs of a birds are well suited for an aboreal life. Their muscles are well developed and help in perching. As the bird settle down on the tree, the bending of legs exerts a pull on the flexor tendons which make the toes automatically to flex and to grip the perch. Thus the bird, in resting or sleeping, is automatically clamped to its perch.

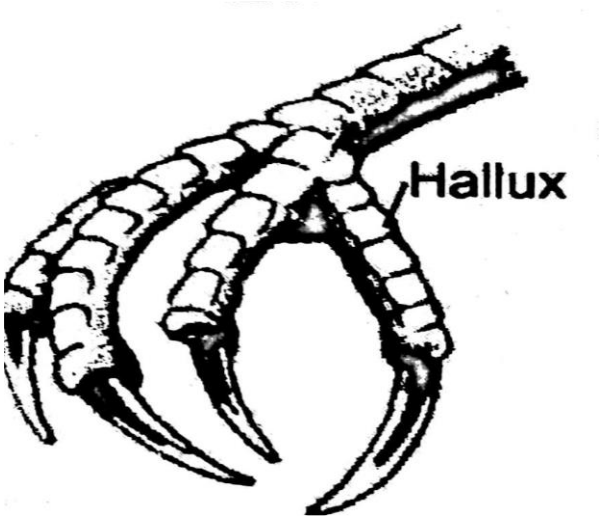


Fig 4.5 : Perching type of foot

(17) Endoskeleton :

(i) The heterocoelous cervical vertebrae offer great flexibility to the neck.

(ii) In the vertebral column about fourteen vertebrae are fused together to form a plate like structure called synsacrum. The vertebrae are one thoracic (last), six lumbar, two sacral and five caudal. It acts as a girder to support the entire weight of the body and also provides a firm fulcrum for the action of wings.

(iii) The shortening of caudal vertebrae and formation of pygostyle (fusion of last four caudals) provided stability in the air.

(iv) The fusion of pelvis with the synsacrum provides firm attachment to the legs, supports body weight during locomotion on the ground and counteracts the effects of shocks when the bird alights.

(v) The sternum bears a mid ventral ridge called keel or carina to which the flight muscles are firmly attached.

(vi) The clavicles of the pectoral girdle are fused ventrally to form a V – shaped furcula or merry thought bone or wish bone. It works like a spring between the two wings.

(vii) The mid ventral symphysis between the pubes and Ischia is absent. This results in a more posterior displacement of the viscera, shifting the centre of gravity towards the legs.

(18) Brain : Brains are much developed and convoluted cerebellum indicates the delicate sense of equilibrium and the great power of muscular co-ordination belonging to birds. The enormous development of corpus striata in the cerebrum also adds to the extra ordinary manoeuvreability to attain stability in flight.

(19) Single ovary : Presence of a single functional ovary of the left side in the female bird also leads to reduction of weight which is so essential for flight.

SAQs 2.

Complete the following sentences by inserting appropriate words in the blanks.

(i) Accessory organ for respiration in birds is ----------.

(ii) Birds are glorified ----------.

(iii) Nitrogenous waste product of birds is in the ---------- form.

(iv) Body of birds are spindle shaped and consist of ---------- regions.

4.5 SUMMARY

In this unit you have studies the general characteristic of class Aves. You will now know that how it has difference with other classes of vertebrate. In this unit you have studied variety of bird with their characters. You have also studied the flight adaptation in birds, how and each body parts of birds are modified for their flight adaptation.

4.6 TERMINAL QUESTION

Q1. Describe how the body shape & structures of birds are suitable for flight ?

Q2. Which modification in birds make their body weight light ?

Q3. Write general features of Aves ?

4.7 ANSWERS

SAQ 1 (i) Fore limbs

(ii) Pneumatic

(iii) Oviparous

(iv) Four

SAQ 2 (i) Air sacs

(ii) Reptiles

(iii) Uric acid

(iv) Four

TERMINAL QUESTION

Ans 1. Birds have stream lined, boat shaped or spindle shaped body which offers minimum resistance to the air while flying. The body is quite compact. It is light but strong dorsally and heavy ventrally. It helps in maintaining balance in the air.

The internal structures are well centralized. The attachment or wings high up on the thorax, the high position of light organs like lungs and air sacs and low and central position of heavy structures like muscles, sternum and digestive organs beneath the line of attachment of wings lowers the centre of gravity.

Ans 2. For flight, less weight is very essential. This is achieved by the following features.

(i) Bones are pneumatic, i.e. they are provided with air sacs. The skeletal framework is light but strong.

(ii) Skull bones are thin and light and firmly fused together.

(iii) Thoracic ribs bear uncinate processes which provide compactness by concentrating the mass.

(iv) Absence of teeth.

(v) Absence of ovary and oviduct of right side in female.

(vi) Absence of urinary bladder.

(vii) Production of solid excretory waste.

(viii) Presence of feathers.

Ans 3. These are as follows :

i. The birds are feather covered, air breathing, warm blooded, oviparous, bipedal flying vertebrates..

ii. Limbs are two pairs. Forelimbs are modified as wings for flying. The hinds limbs are adapted for walking, running, perching, swimming etc. They bear four clawed digits of which the first one or hallux is directed backwards and the remaining three infront.

iii. The skin is dry and devoid of glands except the oil or preen gland at the root of tail.

iv. The endoskeleton is bony. The bones are pneumatic or hollow and without bone marrow. This makes the body light. The bones are usually fused.

v. Sexes separate. Sexual dimorphism well marked. Male has a pair of abdominal testes and a pair of sperm ducts. Male without copulatory organ except in ratitae, duck etc. The female has a single functional left ovary and oviduct.

vi. Fertilization internal, preceded by copulation and courtship. Female oviparous. Eggs large with much yolk and hard calcareous shell.

Uttar Pradesh Rajarshi Tandon Open University

Bachelor of Science

UGZY-104

Hemichordates & Chordates

BLOCK

2

FUNCTIONAL ANATOMY OF CHORDATES

UNIT-5

Comparative Anatomy of Vertebrates

UNIT-6

Digestive System and Respiratory System

UNIT-7

Circulatory System and Urinogenital System

UNIT-8

Nervous System and Sense Organs

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BLOCK INTRODUCTION

The Block-2 consists of 4 units (Unit-5 to Unit-8).

In block-2 you have studied about diversity of chordates which includes general characters of hemichordate and affinities of *Balanoglossus*, classification and detailed study of *Branchiostoma*, classification and detailed study of *Herdmania*, classification and detailed study about *Scoliodon*, general characters and classification of amphibia and reptilia. You have also study about general characters and classification of aves, flying adaptation in birds. You have also study about tissue and its different types. In comparative study you have study about basic structure of skin and comparison of skin of protochordata, cyclostomata, fishes, amphibian, reptilian, birds and mammals. In comparative study of skeleton you have study about pectoral girdle, pelvic girdle, fore limb and hind limb of amphibian, reptilian, birds and mammals. The present block consists of 4 units (unit 5 to unit 8).

In Unit-5 you will study about different type of tissues like epithelial tissue, connective tissue, muscular tissue, nervous tissue and their different types. You will study about basic structure of skin and function and also skin in different chordates like protochordata, cyclostomata, fishes, amphibian, reptilian, birds and mammals. You will also study about comparative study of skeleton in which it includes somatic skeleton and visceral skeleton. In this segment you will study about pectoral girdle, pelvic girdle, fore limb and hind limb of amphibian, reptilian, birds and mammals.

In Unit-6 you will study about alimentary canal and digestive glands in cartilaginous fishes, Amphibia, Reptile, Aves and Mammal. In another segment of this unit consist of respiratory system which includes study of gills, gill slits and structure of true gill. You will also study about air sacs in birds in very detailed manner and its functions. You will also study about swim bladder, its different types and function of swim bladder.

In Unit-7 you will study about circulatory system which contains evolution of heart. In this segment you will study about various changes which take place in the heart of lower vertebrate to the higher vertebrate. You will also study about modification of aortic arches in *Amphioxus*, *Petromyzon,* pisces, amphibia, reptilian, aves and mammal. In another segment you will study about the evolution of kidney which includes different type of kidney like pronephros, mesonephros and metanephros. You will also study about evolution of urinogenital ducts include male and female genital duct.

In Unit-8 you will study about nervous system which includes basic structure of brain and its difference in cephalochordates, cyclostomes, elasmobranchs fishes, bony fishes, amphibian, reptile, aves, mammals. In another segment you will study about sense organs in which you will study about different types of receptors like exteroceptors, proprioceptors, interoceptors, mechanoreceptors, chemoreceptors, photoreceptors, thermoreceptors.

Objectives

After studying this block you will be able to

- Describe the alimentary canal and digestive glands in different vertebrates.
- Explain about gills, gill slits and structure of gill.
- Explain about air sacs in birds
- Describe evolution of heart in vertebrate.
- Describe modification of aortic arches.
- Explain about evolution of kidney
- Explain in very detailed about evolution of urinogenital duct.
- Describe the structure of brain and its different parts in different vertebrate animals.
- Explain different types of receptors like exteroceptors, proprioceptors, interoceptors, mechanoreceptors, chemoreceptors, photoreceptors, thermoreceptors.

UNIT–5 COMPARATIVE ANATOMY OF VERTEBRATES

Structure (A) Histology

Structure (B) Comparative study of Integument and Skeleton

5.1 INTRODUCTION

The word "Histology" is derived from two Greek words i.e. *histos* mean tissue and *logia* mean knowledge. Thus histology means knowledge of tissue or study of tissue and formation of organs by different tissues. Tissue is a group of cells having same embryonic origin, structure and functions. Tissues are unique in performing their specialized functions. In the body of organism, various tissues combine together in an orderly manner to form large functional unit called organ. Number of organs work in co-ordination and give rise to an organ system. Thus histology is defined as 'the branch of biology which deals with study of microscopic structure of tissue and organs with their functions'. It is also called microscopic anatomy because cell and tissues are studied with the help of microscope.

For the study of cells or tissue now a day there are various new techniques and sophisticated instruments are available in the field of histology. Thus advanced histological and histochemical methods including light microscope, electron microscope, immune-fluorescence technique, histo-autography, polarization microscopy, vital staining, supra-vital staining, radioautography, historadiography and other aids like tissue culturing and separation of cell organelles etc have revolutionized the older ideas of histology. However, the conventional approach with help of light microscope has been used for histological study of specific tissue or organs by following steps such as obtaining the tissue, fixation, dehydration, clearing, embedding, sectioning, staining and mounting.

Objectives :

- Describe the histology and comparative study of integument and Skeleton.

5.2. HISTOLOGY

The term tissue (Latin texere = to weave) was introduced by a **French surgeon Bichat (1771-1802),** Later it was introduced as a separate branch of biology as **"Histology"** by **Mayer**. During embryonic development, the embryonic cells first differentiate to form three primordial germinal layers like ectoderm, mesoderm and endoderm, It is from these layers that all the different types of tissue of adult body are derived. The important tissues are –

(A) Epithelial tissue : Formed from the cells of ectoderm, mesoderm and endoderm

(B) Connective tissue : Mainly formed from mesoderm and mesenchyme

(C) Muscular tissue : Formed from mesoderm

(D) Nervous tissue : Formed from ectoderm

(A) Epithelial tissue

The term epithelium was introduced by **Dutch Anatomist Ruysch (18th century)** to refer to the fact that these tissue grow upon other tissue (German word Epi = upon thelio =grows).

Occurrence – They occur as one or more layers of cells upon all external and internal exposed surfaces of body and various organs and forming protective covering sheets. The solid organs like tongue, kidney, liver, spleen etc. have externally epithelial coverings. The skin and wall of hollow organs like alimentary canal, various ducts and tubes, blood and lymph vessels etc. have external and internal epithelia coverings.

Function of Epithelia- These are as follows

(i) To protect the under lying tissues from dehydration, infection and mechanical and chemical damage is the primary role of epithelia.

(ii) Epithelia act as selective barrier, controlling the passage of all materials passing across the exposed surfaces they cover.

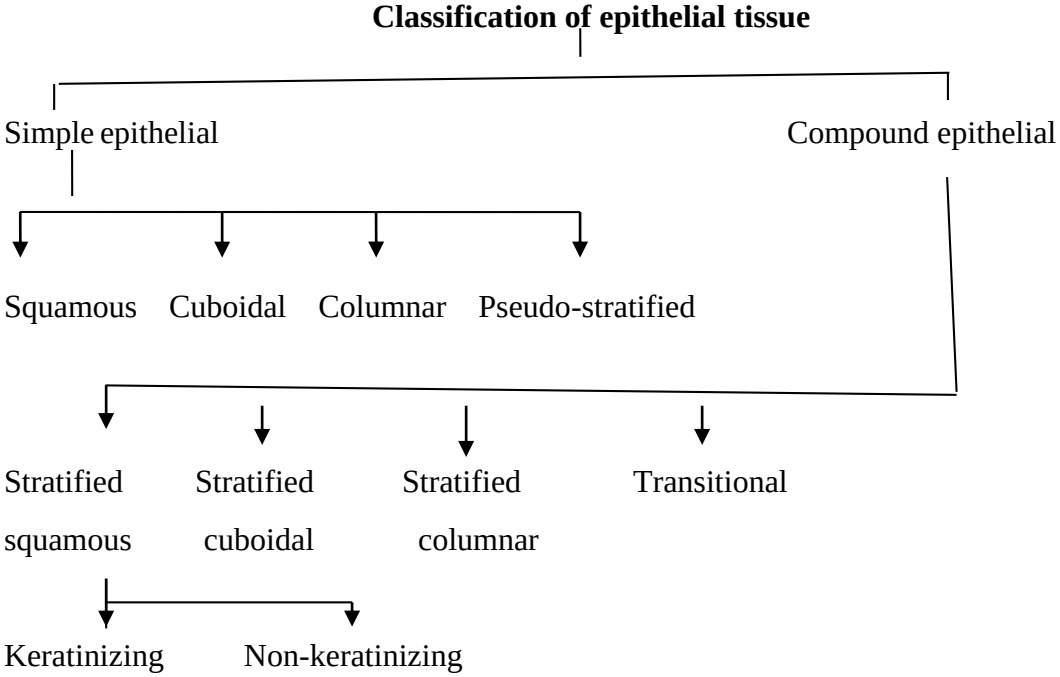
(iii) Ciliated epithelia (e.g. those of respiratory and genital passages) serve to conduct mucous or fluids in the ducts they line.

(iv) Epithelia of intestine and uriniferous tubules are absorptive.

(v) The epithelium of uriniferous tubules is specialized for urine formation for excretion.

(vi) Epithelia are highly regenerative, when damaged they regenerate more rapidly than tissues and thus facilitate rapid healing of wound.

Classification of epithelial tissue



(a) Simple epithelial- These consist of a single layer of cells (unilaminar) resting upon a basement membrane. These occur at surfaces where transfer of materials by secretion, absorption or diffusion etc. is more important a function than protection. On the basis of the shapes and structure of components of cell, the simple epithelial tissue are further classified into 4 subtypes squamous, cuboidal, columnar and pseudostratified.

(i) Simple squamous epithelial – The cells are polygonal in shape, thin, delicate and flat. The nucleus is centrally placed. These appear like tiles when viewed from above, thus are also called pavement epithelium. These are widely distributed in body i.e. they form lines of peritoneal, pleural and pericardial cavities of mesothelium, the heart and blood and lymph vessels, portion of uriniferous tubules and thyroid epithelium etc.

(ii) Simple cuboidal epithelium – This is formed of dice-like (isodiametric) square or cuboidal cells with almost equal height and width and central, spherical nuclei. Such cells are suited for an active role in secretion, absorption and excretion. Hence cuboidal epithelia form the lining of convoluted parts of uriniferous tubules in kidneys, ciliary body and choroid of eyes and thin bronchioles. In the distal convoluted tubules of nephrons, the cell bear microvilli (brush border). Lining of some glands (e.g. sweat glands of mammalian skin) and germinal epithelia are also cuboidal.

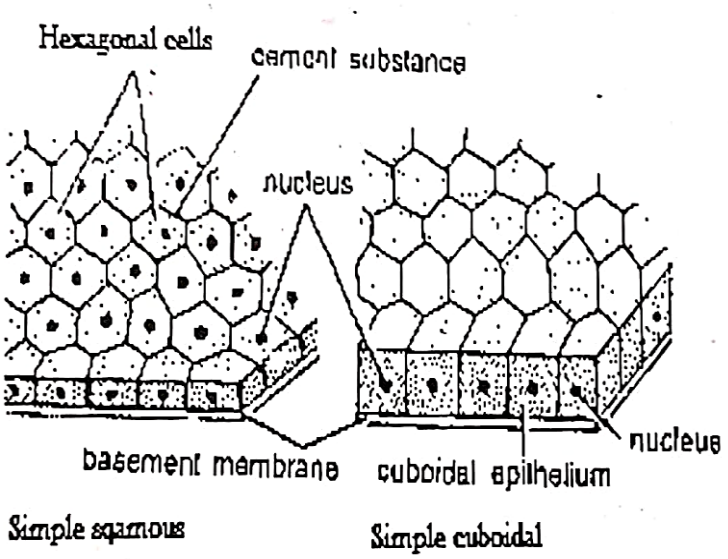


Fig 5.1 : Simple squamous and simple cuboidal epithelium

(iii) **Simple columnar epithelium –** The cells of columnar epithelia are tall and prismatic in shape. Their height exceeds their width. Their nuclei are basal and somewhat elongated. These cells hardly live for 2 or 3 days. Hence these are continuously formed by transformation of adjacent epithelial cells. Gut epithelium from stomach to anus is simple columnar. Absorptive cells of intestinal epithelium bear microvilli (brush border). Lining of gall bladder, bile ducts, stomach and large intestine are good examples of columnar epithelia. Simple columnar epithelia, forming the lining of uterine tubes, tympanic cavity, small bronchi of lungs, oviducts, ureters, and neurocoel cavity of brain and spinal cord are ciliated.

(iv) Pseudostratified columnar Epithelium – The epithelium appears like multilayered consisting of single layer but appear like multilayered. However, some cells are shorter than others. All the cells are rest on the same basement membrane, but not all of them extend to free surface. The nuclei lie at different levels, giving it a stratified appearance. Its cells may be columnar, rounded or fusiform, ciliated or non-ciliated. Usually the shorter cells lack cilia and secrete mucous to trap particles on their surface. The longer cells bear cilia, these cell forms the inner lining of the nose, trachea, larger bronchioles, excretory duct of parotid gland etc.

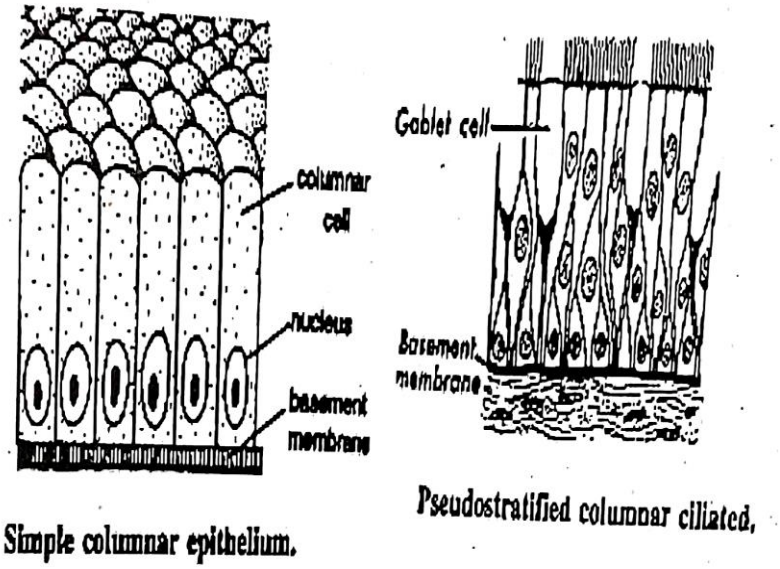


Fig 5.2 : Simple columnar epithelium and Pseudostratified columnar epithelium

(b) Compound epithelial – These consist of more than one layer cells (bilaminar or multilaminar) and occur at surfaces where protection is the main function. These are generally found where surface is exposed to drying by air (skin epidermis) or to chemical, microbial or mechanical (friction and abrasion), damage (cornea of eyes, inner surface of mouth, oesophagus, anal canal, vagina etc.) are covered by stratified epithelia. So there is a regular wear and tear of the cells of the exposed surface layer in these epithelia. So to make good this loss, true stratification of epithelia provides a complete basal (deepest) layer of continuously proliferating cells called germinative layer. The compound or stratified epithelial are classified into squamous, cuboidal and columnar and transitional types according to the shape of the cells of outer most surface layer.

(i) Stratified squamous epithelium – The cells of the superficial layers are flattened and scale like (squamous). They form main protective epithelium of the body and consist of many cell layers. The cells may be flattened, polyhedral or cuboidal and basal layer is of columnar type. The stratified squamous epithelia are of two type keratinizing and nonkeratinizing.

(a) Keratinizing squamous epithelia – Skin epidermis is of keratinizing type. In such types as the cell layers move towards the surface in it, an insoluble fibrous protein called keratin progressively accumulates in their cells. By the time a layer reaches the surface, its cells become squamous, lose their nucleus and become dead. Thus these cells actually become mere scales of keratin. Such a completely keratinized layer is water proof, it prevents outside water from entering into the skin as well as evaporation of water from underlying cells. It also protects the underlying tissues abrasion and infection.

(b) Nonkeratinizing stratified squamous epithelium – These occurs at surfaces subject to abrasion but protected from drying (wet-surface). These

are found in cornea of eyes, inner surfaces of eyelid and the lining of buccal cavity, lower part of pharynx, oesophagus, vagina and vestibule of nasal cavities. The squamous cells of surface layer do not lose their nucleus and keratin is either absent or much less in quantity. Such types of cells can be observed in the mucus scrapped from inner surface of our cheeks.

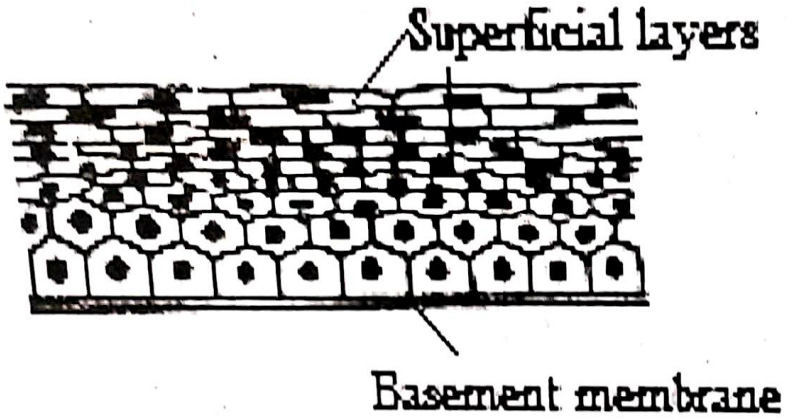


Fig 5.3 : Stratified squamous epithelium

(iv) Stratified cuboidal epithelium – These are found in conjunctiva of eyes, lining of ducts of sweat glands, female urethra and some part of anal canal. The cells of the outer most layer in this cases are cuboidal.

(v) Stratified columnar epithelium – These are found in some parts of larynx, pharynx and ducts of some large glands for e.g. parotid and mammary glands. The cells of the superficial layer are of columnar.

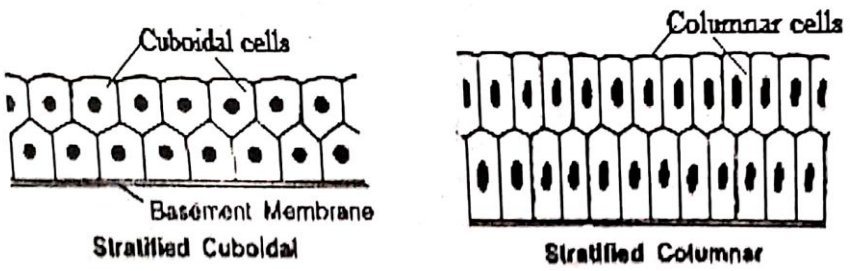


Fig 5.4 : Stratified cuboidal epithelium & stratified columnar epithelium

(vi) Transitional epithelium – The epithelial cells are soft and to a certain extent plastic, being able to adjust themselves to influences which increases or decreases the general surface area. Therefore, the arrangement of cells in different regions is variable e.g. in dilated bladder, epithelium consists of two or three layer of cells i.e. the superficial or outer cells are large cuboidal while lower or basal cells are smaller and irregular cubical. Where as in the contracted bladder, the epithelium becomes five or six layered, where the surface cells are large and cuboidal with condensed and dark cytoplasm. While the lower cells have rearranged themselves with reduction of surface area.

They overlap each other and have flask or pear shaped form. There is no distinguishable basement membrane and the division between epithelium and underlying connective tissue. The transitional epithelium is found only in the urinary system i.e. pelvis of kidney, ureter, bladder and a portion of urethra.

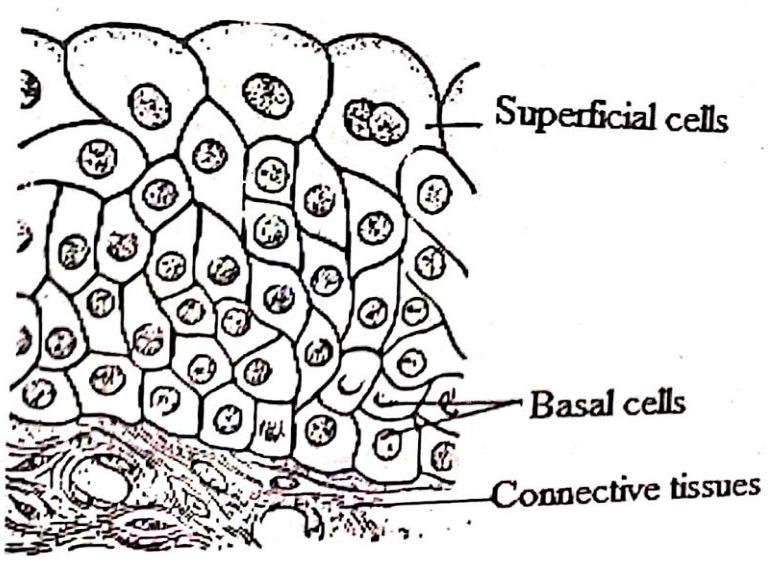


Fig 5.5 : Transitional epithelium

(B) Connective tissue

In contrast to the epithelial tissue, the adult connective tissues have relatively small number of cells or fibres and large amount of intercellular substance (ground substance), together constitute the matrix. These tissues are mainly for connection with other tissue together i.e. bind the muscle to skeleton. These are mesodermal in origin and lies under the epidermis, in the wall of tubular organs and inside the solid organs.

Connective tissues are broadly classified into 3 main types

(a) Connective tissue proper includes areolar, elastic, adipose, fibrous tissue etc.

(b) Skeletal connective tissue includes cartilages and bones

(c) Fluid connective tissue includes blood and lymph

(a) Connective tissue proper : Most of connective tissues arise from mesoderm. The connective tissue structure of early embryo (i.e. the umbical cord or wharton's jelly is a classical example of mucous connective tissue) is very much different from that of the adult connective tissues. The connective tissue is composed of several types of cells fibres and ground substance as described below

(i) Connective tissue cells : Following are some important cells

(a) ***Fibroblasts and Fibrocytes*** **–** These are the most numerous and largest cells of areolar connective tissue. They are flattened,

irregular with branching processes, a large ovoid nucleus and vacuolated cytoplasm. If they are young and active they are called fibroblasts and if they are old and inactive they are called fibrocytes. They synthesize the proteins (collagen, elastin and reticulin) that form the connective tissue fibres and secrete the mucopolysaccharides and proteins that form the amorphous ground substance. These cells play important role in healing of wounds, growth repair of tissues.

(b) ***Macrophage or Histiocytes*** **–** These are large, numerous and common cells of connective tissue. They are of two types, the fixed macrophages and wandering macrophages. The fixed macrophages remain at same place, and it lies along collagen fibres. The wandering macrophages are ovoid or rounded, but actively amoeboid and migrate from place to place. All macrophages are remarkably specialized for ingesting particulate matter by phagocytosis. They engulf and destroy debris of dead cells, bacteria and inert and harmful foreign particles by means of their lysosomal enzymes. Thus they play a role of scavenger and defense against infective microbes.

(c) ***Mast cells*** **–** They widely occurs in areolar and other connective tissues. They are numerous but comparatively small, spherical or oval cell. They mostly gathered along small blood vessels, lymphatics and nerves. Their cytoplasm is specially laden with granules. Occasionally these cells form short pseudopodia and slowly wander about in the body. They secrete three active substances heparin, histamine and serotonin. The heparin, a proteoglycan is an anticoagulant and it prevents coagulation of blood in blood vessels. Histamine is a protein acting as a vasodilator (widening of blood vessels) in inflammatory and allergic reactions. It also increases the permeability of small vessels. Serotonin is a protein. It acts as a vaso-constrictor to arrest bleeding and to increase blood pressure.

(d) ***Lymphocytes*** **–** These are the smallest, less numerous and spherical or ovoid cells resembling lymphocytes of blood and lymph. They actively move about by pseudopodia. Their function is to form and carry antibodies. They are seen in large number at the sites of inflammation.

(e) ***Plasma cells*** **–** These are usually small and rounded, superficially resembling lymphocytes, but are sluggishly amoeboid and short lived (only 2or 3 days). These are the most potential antibody forming cells of body. It is assumed that mature lymphocytes (B-lymphocytes) transform into plasma cells or proliferate to form plasma cells.

(f) ***Fat or Adipose cells*** **–** A few, large and spherical cells occur in areolar tissue, singly or in clusters around small blood vessels.

Each cell contains a large globule of fat surrounded by a thin peripheral layer of cytoplasm having a nucleus.

(g) ***Eosinophils*** **–** These cells closely resemble the eosinophilic leucocytes of blood. These probably play a phagocytic role in inflammatory and allergic reactions.

(ii) Fibrous connective tissue and ground substance : It include fibrous connective tissue & ground substance

(a) Fibrous connective tissue :- Thses are of three types as follows

(i) ***Collagenous fibres***- These are long, unbranched fibres of a soluble and shining collagen protein (tropocollagen). Some fibres are slender and straight, but most are coarse and wavy. The coarse fibres are bundles of slender fibres. Each slender fibre is a bundle of fine fibrils and a fibril is formed of microfibrils, which are aggregates of filamentous tropocollagen molecules. All collagen fibres are soft and flexible, but not elastic, and hence great tensile strength. These are colorless and hyaline, and hence called white fibres. If it is boiled in water, collagen (albuminous protein) changes into gelatin. The one third of body proteins in man is made up of collagenous fibres.

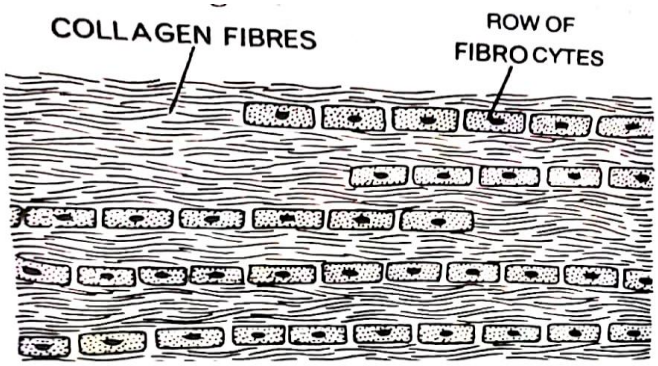


Fig 5.6 : Dense white fibrous connective tissue

(ii) ***Reticulin fibres***- These are delicate, freely branching and inelastic fibres of reticulin protein, found interwoven to form networks. These are very abundant in embryos, new-born and in healing and regenerating wounds. In areolar tissues of adults, these are mostly replaced by collagen fibres, but remain abundant in lymphoid and blood forming tissues and in the stroma of pancreas, liver etc. Chemically reticulin is also a type of collagen.

(iii) ***Yellow elastin fibres***- These are less numerous, thinner branched and of a pale yellow color and it is made up of elastin protein. These are very elastic and remain stretched due to tension in the areolar tissue. Elastin is probably the most resistant of all body proteins to chemical changes. Thousands of year old mummies still have their arteries intact due to well preserved elastin fibres.

(b) Ground substance :- It is amorphous and non-cellular substances in which the cells and fibres of connective tissues are embedded. It is a viscous or thin jelly like fluid having capacity for bonding large amount of water. This water serve medium for diffusion of gases and metabolic substances. The ground substances are composed of number of mucopolysaccharides of sulphated and non-sulphated type e.g. hyaluronic acid and chondriotin sulphate respectively. Hyaluronic acid is viscous fluid found in wharton's jelly, synovial fluid, humour of eye and many other parts of body. It probably plays a role in preventing spread of noxious agents in localized infection. Chondriotin sulphate is present in cartilages, bone, cornea, aorta, heart valves, umbilical cord and skin etc.

(iii) Areolar (Loose) connective tissue :- The Areolar connective tissue has a large amount of ground substance and contain almost all types of cells and fibres of connective tissue. It spreads extensively throughout the body like under the skin, and epithelia, in between and around muscles, nerves and blood vessels, in the sub-mucosa of respiratory and gastrointestinal tracts, between the lobes and lobules of compound glands, and in mesenteries. It also forms the internal histological frame work (stroma) of many solid organs. The primary function of areolar tissue is to bind parts together. Further by virtue of its looseness, it facilitates sliding movement of epithelia muscles and other parts, provides for rapid diffusion of materials and facilitates migration of wandering cells towards area of infection and repair.

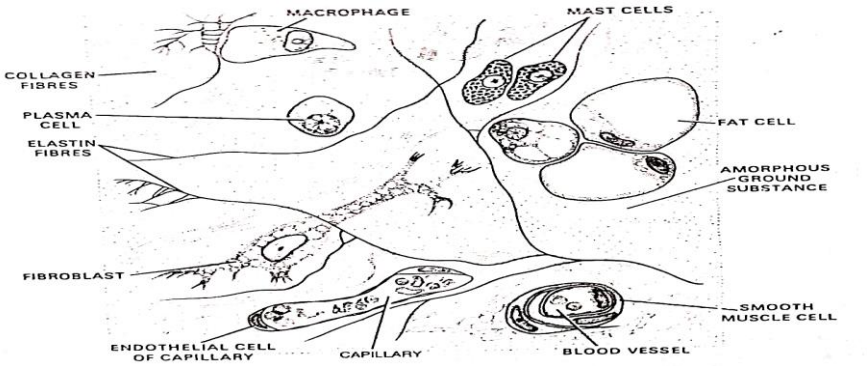


Fig 5.3 : Areolar connective tissue

(iv) Adipose or fatty connective tissue :- These are areolar tissue specialized for fat storage. These contain a high percentage of fat storing cells called adipocytes. Mast cells and eosinophils also occur. Adipose tissue can form anywhere, but some of its permanent sites are subcutaneous tissue beneath skin (Panniculus adiposus, blubber of whales and elephants, hump of camel and thick tail of Marino sheep), yellow bone marrow, around kidney and blood vessels and

mesenteries and fat bodies of frogs. About 10% to 15% of our body weight is of adipose tissue

The adipose tissue chiefly act as "food reserves" or "fat depots" for storage and metabolism of lipids. They also act as heat insulators and pressure, pull and push absorbers. There are two types of adipose tissue i.e. 'white adipose tissue' which appear opaque because presence of numerous fat cells, these are found in adults and 'brown adipose tissues' is reddish brown coloured due to presence of large number of blood vessels, these are mostly seen in developing fetus and infants.

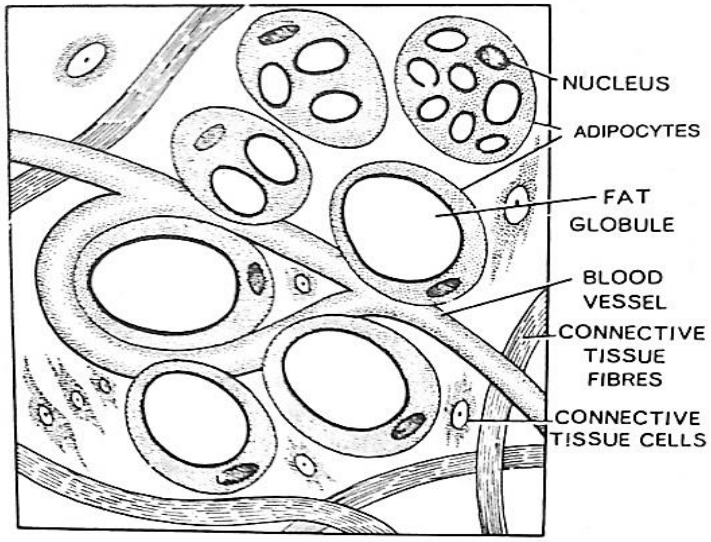


Fig 5.8 : Adipose connective tissue

(v) Dense connective tissue :- It is chiefly characterized by the close packing of its fibres. It occurs in the form of sheets, bands and cord like structure. The tendon and ligaments are example of this tissue.

(a) ***Tendon*** **:** They are specialized extensions of muscles, formed of parallel and are closely packed bundles of white (collagen) fibres. In these fibres only fibroblasts cellS are present. Tendon attaches muscle to bones and play important role in various movements.

(b) ***Ligaments*** **:** Structurally, ligaments are similar to tendon, but formed of bundles of yellow (elastic) fibres. They bind to different bones at the joints and play important role in preventing dislocation of bones as well as providing flexibility to joints.

(C) Muscular tissue

Muscle plays a very important role in the physiology of body. Muscle tissue is specialized for producing movement both of the body as whole and of the many parts with respect to one another. The muscle cells show great

development of the function of contractility and motility (movement).

Kinds of muscles :- The muscle fibres are categories into 3 types

(i) Striated or voluntary muscle

(ii) Unstriated or Involuntary muscle

(iii) Cardiac muscle

(i) Striated or voluntary muscle : Most of the muscles of the body are of voluntary type. This types of muscle bring about voluntary movements under the control of brain and hence they are called Involuntary muscles. These muscles are attached with the bone on their both ends and hence they are also called skeletal muscles, since movement of limbs and the body solely depend upon these muscles and hence these are also called somatic muscles. Each voluntary muscle fibre are 0.01 mm to 30cm long, slender, cylindrical, unbranched and multinucleated. Their covering envelope is called sarcolemma. It consists of an internal plasma membrane, middle fibrous layer like basement membrane and an external layer of glycoproteins. Inside the sarcoplasm is homogenous semifluid cytoplasm is present called sarcoplasm. Sarcoplasm contain all components of cells like mitochondria, golgi apparatus, endoplasmic reticulum, many oval and compressed nucleus, number of enzymes, glycogen granules and lipid droplet. It also contains three soluble proteins myoalbumin, myoglobin and myogen and also four contractile protein myosin, actin, tropomyocin and troponin.

The H.E.Huxley have elucidate the fine structure of striated muscle fibre. It appears alternate dark and light bands. The dark band or "A" band (Anisotropic band) appears dark due to presence of myocin filament. While the light band or "I" band (Isotropic band) appear light due to presence of actin filament. The "A" band contains about 120 Å thick and 1.8 μ long myosin filaments. The I band contains about 60 Å thick and 1.0 μ long actin filaments. In the middle of light band or I band, a dark line appears called "Z" membrane or Krause membrane. The distance between the two A line is called sarcomere. It is about 2.3 μ long in uncontracted mammalian striated fibres. There is also a light line appears in a dark or A band is called M line or Hensen's line. The middle region of A band is comparatively lighter but its terminal parts appear darker, because of an overlapping of ends of actin and myosin filaments. This middle lighter region is called "H" zone. In transverse section each myosin filament is surrounded by 6 actin filament and each actin filament is surrounded by 3 myosin filaments.

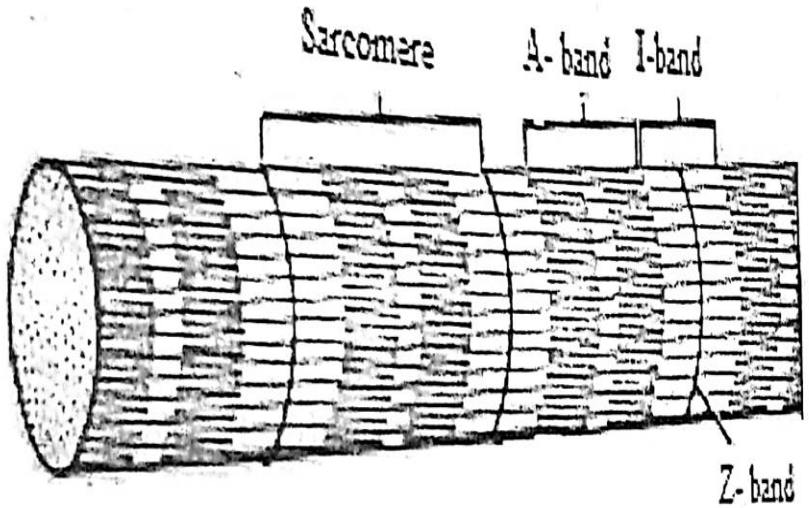


Fig 5.9 : Microscopic structure of striated myofibril

(ii) Unstriated or Involuntary muscle : These are called smooth, plain, nonstriated or unstriped muscles due to absence of striations. The involuntary muscles are simplest in structure, their fibres are shorter (0.02mm to 0.5mm long), thin spindle shaped, unbranched and uninucleate. These occur in the walls of hollow internal organs (alimentary canal, gall bladder, bile duct, respiratory tracts, uterus, urinogenital ducts, urinary bladder, blood vessels etc.) in capsules of lymph glands, spleen etc. In iris and ciliary body of eyes, skin dermis, penis and other accessory genitalia etc. There is no connection of these muscles with bone. Smooth muscles of skin dermis called arrector pilli muscles, are associated with hair roots and are responsible for goose flesh (erection of hair).

The contraction of smooth muscles is usually slow and sustained and independent of voluntary control. It usually occurs with a rhythm in accordance with the internal environmental and physiological conditions of the body. The animal usually does not even feel its occurrence. Thus smooth muscles are involuntary muscles of body.

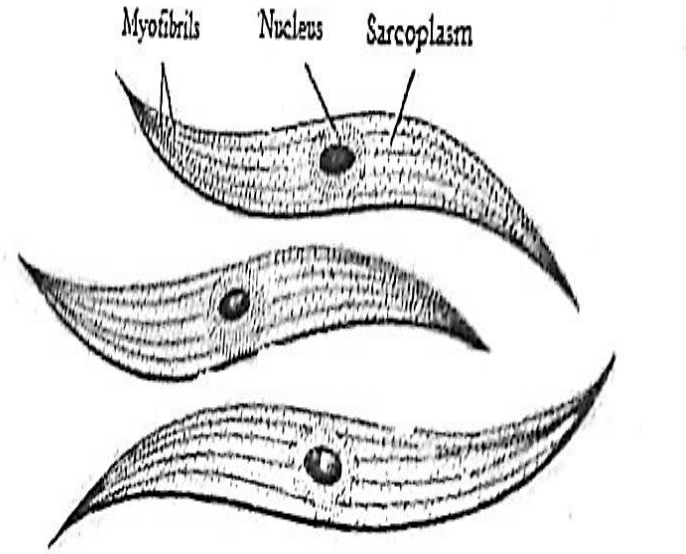


Fig 5.10 : Unstriated or Involuntary muscle

(iii) Cardiac muscle : These are especial types of muscles which are found in the wall of heart and hence called myocardium. Structurally these muscles resemble striated muscle but functionally independently of the voluntary control of brain. These are involuntary like the smooth muscles. The cardiac muscles or fibres are comparatively shorter and thicker, cylindrical, mostly uninucleate with a central nucleus, somewhat branched and covered by a sarcolemma. These are arranged in a lattice work, the fibres dividing then recombining and then spreading again. There are extensive gap junctions between the branches of neighboring fibres. The cardiac muscle fibres are joined mend to end, in a interdigitation, figure like process. These interdigitation appear as a disc like which is called intercalated disc, which is very strong and prominent.

The heart is composed of three types of cardiac muscles atrial muscle, ventricular muscle and a specialized self-excitatory and conducting muscle. The atrial and ventricular muscles respectively form the walls of atrium and ventricle of the heart. The mechanism of contraction and relaxation in the fibres of these muscles is like voluntary muscle fibres except that the duration of contraction is much longer in cardiac muscle fibres. The fibres of the self excitatory and conducting muscle of the heart are of three kind - nodal fibres, transitional fibres and Purkinje fibres. Being specialized for self-excitation and conduction of the excitation impulses these fibres lose contractility. The nodal fibres form one or two small, spongy nodes (S A & A V node) in the heart wall. The transitional fibres are slow conducting fibres which spread out from nodes and established connecting pathways between nodes and between

nodes and Purkinje fibres. The latter are fast conducting fibres which spread out into atrial and ventricular muscles in a definite pattern.

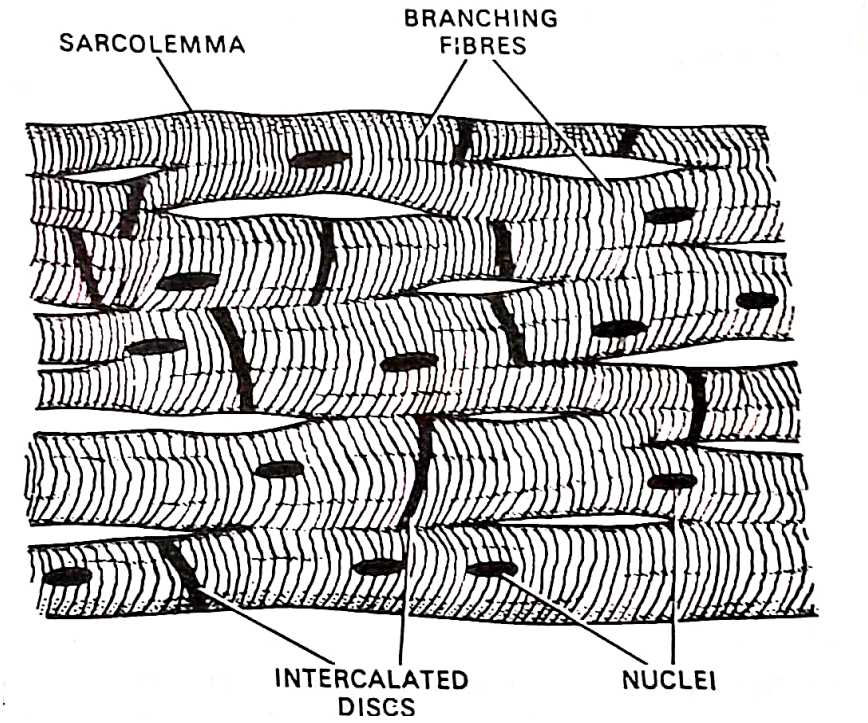


Fig 5.11 : Cardiac muscle fibres

(D) Nervous tissue

All organisms possess the property of changing their activities and behavior in accordance with change in surrounding environmental conditions are called stimuli and the relevant changes in the activities of organism are called their reactions or responses. This response property of organism is called irritability. As the complexity of body organization in highly evolved animal like human, there is separate specialized sensory or receptor cells for receiving stimuli, effectors cells for exhibiting responses and impulse conducting cells for receiving sensory impulses from receptors and transmitting or conducting these as response or motor impulses to effectors, differentiated.

These are highly excitable cells specialized for impulse conduction are called nerve cell or neurons. They arise from the neural plate of embryonic ectoderm and serve as the structural and functional units of nervous tissue. These are widely distributed, innervating every part of the body that respond according to stimuli.

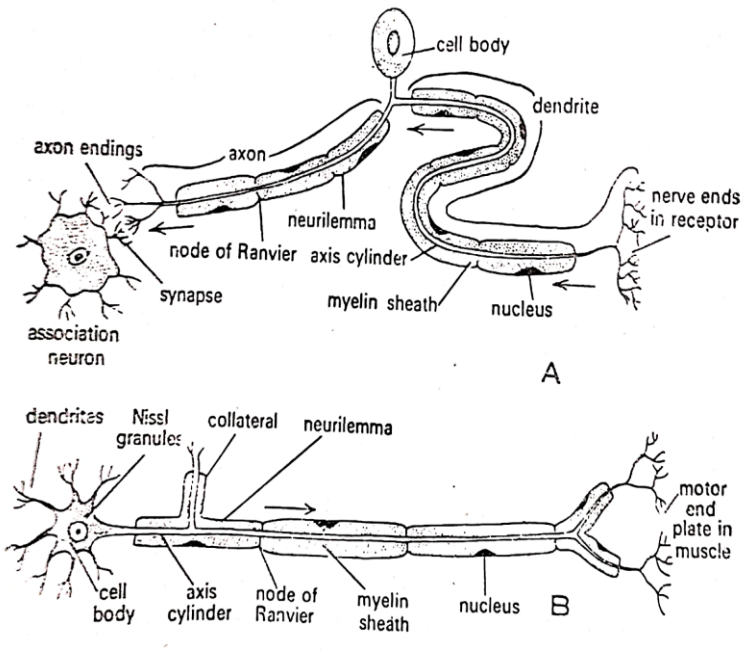


Fig 5.12 : Neuron A- sensory B- motor

Structure of nerve cells – The most important and diagnostic characteristic of nerve cells is that they bear one or more distinct and branched cytoplasmic processes. Their size may be from 0.1mm to several metres in length. Thus neurons with longer processes happen to be the longest cells in the body. Human nervous system has about 100 billion neurons. Majority of the neurons occur in the brain.

Each neuron arises in the embryo from a single neuroblast cells. The main cell body of neuron is called cyton or perikaryon or soma. The cytons are irregularly spherical or oval and contain abundant cytoplasm (neuroplasm), a large and central nucleus, mitochondria, golgi bodies, rough endoplasmic reticulum, ribosomes, lysosomes fat globules, pigment granules etc. Besides these presence of Nissl bodies and neurofibrils is characteristic to all neurons. The Nissl bodies are large and irregular masses of ribosomes and rough endoplasmic reticulum. In neurons centrosome are absent. So they never divide and remain in interphase throughout life.

From cyton, varying lengths of branches arises called neuritis. They are generally of two types i.e. dendrites and axon. The dendrites may be one to several but axon is always one. The dendrites are usually shorter and tapering processes, which generally start branching from near their bases, becoming bushy or dendritic. The Nissl bodies, neurofibrils and mitochondria etc. are present in these. Axon is usually a long process of uniform thickness and branched only terminally into slender branches called telodendria. These branches ended into a knobbed ends called end bulbs or axon terminals or buttons. Certain axon also gives out here and there twig like thin branches at right angles called collateral fibres. The axon is surrounded by a plasma membrane called axolemma and the cytoplasm present in it is called axoplasm. The axoplasm contains large amount of neurofibrils and mitochondria but Nissl bodies, golgi bodies, ribosomes, pigment granules, fat globules etc are absent. The part of the cyton from which axon arises is cone-shaped and rich in

molecules which are secreted in the cyton to be transferred to the axon is called axon hillock.

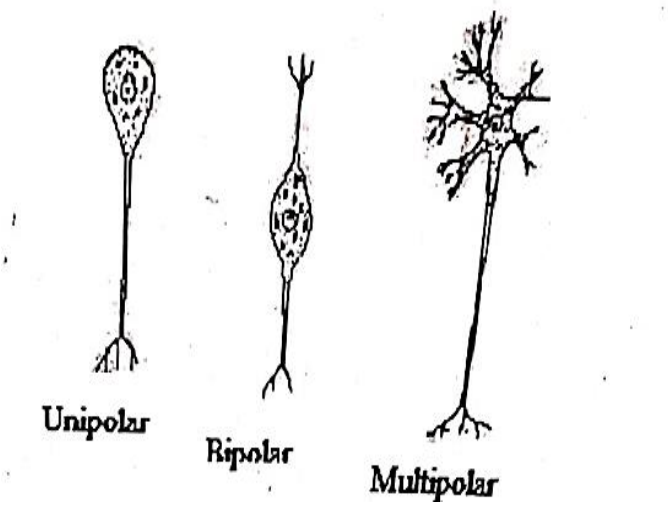
The functional difference between dendrites and axon is that, the dendrites are afferent processes, because they only generate and bring nerve impulses to the cyton from sensory receptors or other neurons, where as the axon is an efferent process because it conducts the nerve impulses away from the cyton to other neurons or effectors (muscles and glands). Dendrites occur only in the central and autonomic nervous system where as the axons occur in the entire nervous system.

Types of Neurons: - On the basis of the number and nature of their processes, neurons are of 3 types –

(i) **Unipolar Neurons –** In such types a single process emerges from the cyton and it soon bifurcates into a dendron and an axon. Most sensory neurons are of unipolar types, such neurons are common in invertebrates and vertebrate embryos. In adult vertebrates, the dorsal root ganglia of spinal nerves possess pseudo unipolar neurons.

(ii) **Bipolar neurons-** In such type they bear a single dendron and an axon at opposite poles of the cyton. These occur in retina of eyes, olfactory epithelium and cochlear ganglia.

(iii) **Multipolar neurons-** In such types they bear several dendrites and an axon. The motor neurons and inter neurons are multipolar types.



Types of neuron

Medullated and Non-medullated fibres - The axon are protected or enveloped one, two or three layer sheath. The axon of peripheral nervous system may have inner most layer of myelin sheath, middle sheath of Schwann calls or neurilemma and an outer most fibrous connective tissue sheath called endoneurial sheath or sheath of Henle or key-Retzius. The myelin sheath appears as a tube around the axon, which filled with a mixture of lipids and proteins called myelin. At regular intervals (about 1mm in humans), the neurilemma is constricted and the myelin sheath is interrupted. These interrupted portions are called nodes of Ranvier, and the distance between two nodes is called internodes. The sympathetic nerve does not have myelin sheath and hence are called non-myelinated or non-medullated

nerve fibres, while parasympathetic nerves are called myelin or medullated nerve fibres. Form electron microscopy it has been observed that myelin sheath consists merely of the plasma membrane of overlying Schwann cells wrapped around the axon several times in spiral fashion. Each internodal segment of the axon and its myelin sheath in the product of a single Schwann cell. At each internode the myelin is discontinued, but the two adjacent Schwann cells profusely interdigitate to maintain a functional continuity of neurilemma.

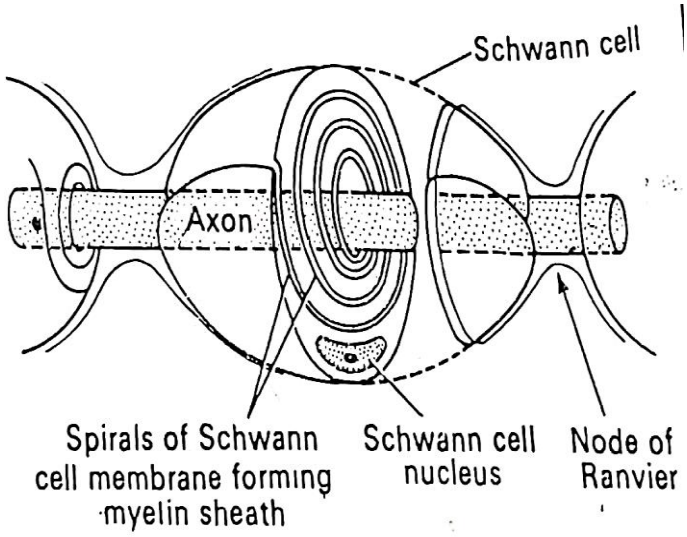


Fig 5.13 : Formation of myelin sheath by Schwann cells

SAQs 1.

Complete the following sentences by inserting appropriate words in the blanks.

(i) The process by which undifferentiated cells of a germ layer developinto specialized cells of tissue is called ----------.

(ii) ---------- muscle fibres of heart are fast conducting fibres

(iii) The brown adipose tissues are mostly found in ----------.

(iv) The nucleus and Nissl granules of nerve cell are located in -------- region of neuron.

Structure (B) Comparative study of Integument and skeleton

5.3 COMPARATIVE STUDY OF INTEGUMENT

The integument or skin is the outer most layer of the animal body. It forms a protective, elastic, water proof, secretion and heat regulation. The integument may be considered as a compound organ. Morphologically it is compound because it is structurally double, being made up in all vertebrates of epidermis and dermis or corium, embryonically its compound character is indicated by its derivation from two separate germ layers ectoderm from which the epidermis arises and the mesoderm from which dermis arises. Physiologically the integument is also a very

versatile organ. Since it performs a wide range of functions therefore it may termed as “Jack of all trade”.

The skin of all vertebrates is built with a same basic plan. The skin is formed of two distinct layers outer epidermis and inner dermis. The epidermis is an ectodermal in origin & consists of stratified squamous epithelium. The epidermis consists of several layers of epithelial cells. The dermis is mesodermal in origin and consist of cells, fibres (Mostly white collagen fibres), blood vessels and capillaries, nerve and smooth muscle fibres, cutaneous glands and receptor etc., all embedded in an amorphous and gelatinous colloid ground substance.

Epidermis

The epidermis is thick and exhibit maximum layer and cellular differentiation. It consists of five layers

(i) **Stratum germinativum –** The stratum germinativum consists of a single layer of columnar or cuboidal cells, each cell of which has short, thin cytoplasmic processes on its basal surface. These teeth like processes fit into pockets of the basal lamina and appear to anchor the epithelium to the underlying dermis. By absorbing nutrition from the blood capillaries of dermis, the cells of this layer continue growing and dividing by mitosis throughout life, forming new layers to make good loss of surface layer of stratum corneum.

(ii) **Stratum spinosum –** The stratum spinosum is several layers thick and is composed of irregular, polyhedral cells, slightly separated from each other. Toward the surface these cells become flattened. These cells are tightly held together by means of their interdigitating finger like cytoplasmic processes. So this layer provides firmness and rigidity to the epidermis. According to some authors the stratum germinativum and stratum spinosum are grouped together and called as malpighian layer. This malpighian layer is responsible for proliferation and for initiation of keratinization process. The malpighian layer also contains melanocytes, which produce the pigment melanin.

(iii) **Stratum granulosum –** The stratum granulosum also consists of six or seven layers above stratum spinosum. The cells of these layers are flattened. Their nuclei are denser and cytoplasm contains the basophilic and refractile keratohyaline granules.

(iv) **Stratum lucidum –** This layer is consisting of 2 to 3 layers of which the cells become flattened. In these the keratohyaline granules first dissolve and then transform into a substance eleidin, which renders the cells semitransparent, shiny and water proof. The nucleus under goes gradual disintegration. This layer act as “barrier layer” by preventing water and other fluids from diffusing across the epidermis.

(v) **Stratum corneum –** As the cell layer are pushed further outwards from stratum lucidium, their cells become still more flattened and scale like. Their eleidin containing cytoplasm loses all water and become hard and water-proof horny keratin, completing the process of keratinization or

cornification. The eight to ten layers of such dried, hard and flattened scale like dead cells, having interdigitate processes, form the stratum corneum. This stratum is thick in soles and palms, but relatively thinner in other parts of body.

In human soles and palms, the skin surface exhibits regular patterns of furrow (sulci cutis) and ridges (cristae cutis) used to make finger, hand foot prints.

Dermis

The dermis is about two to three times thicker than epidermis. All along the region of contact between epidermis and dermis, both are folded so that folds of epidermis interdigitate with those of dermis by providing a firm anchorage to the epidermis with dermis. The dermal folds are called dermal papillae. These are especially rich in blood capillaries and cutaneous receptors.

The dermis largely contains connective tissue fibres with a few cells, but abundant blood and lymph vessels and capillaries and nerve and smooth muscle fibers. It also contains roots of hair, cutaneous glands receptors. The connective tissue fibres are mostly collagen fibres. These occur in thick or thin, interwoven bundles extending in all directions. Some elastin fibres also occur. This dermis forms a strong and elastic covering over the body.

A thin layer of subcutaneous areolar connective tissue lies between dermis and underlying musculature of body wall. This tissue contains accumulations of fat cells (stratum adiposus). The fat serves as a shock absorber, "energy storing", depot and thermal insulator against external heat and loss of body heat. In man fat forms a continuous layer called paniculus adipose, which is responsible for symmetry of body shape and distinction in the shape of men and women.

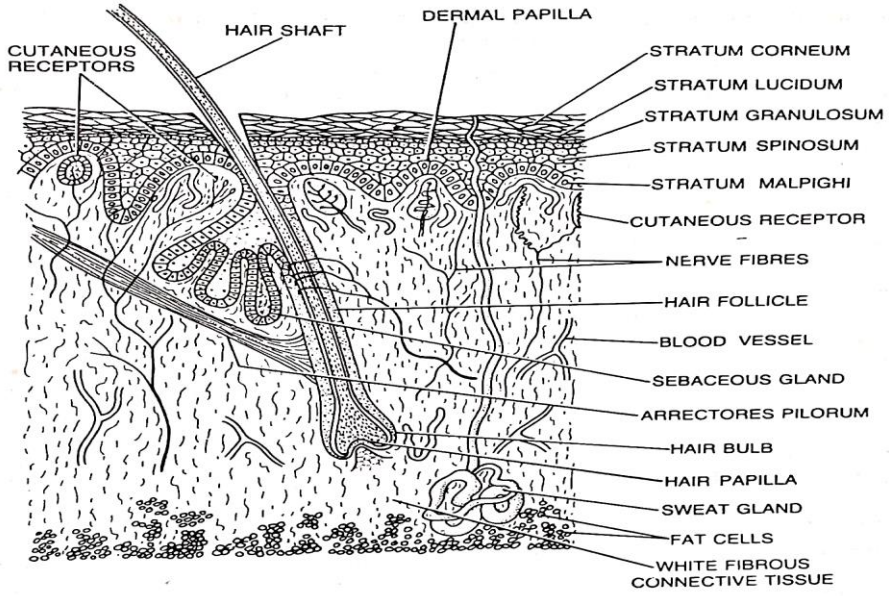


Fig 5.14 : V.S. of skin

Function of integument : - It perform various functions are as follows

(1) Protection against injury of many kinds, dermal endoskeleton, locomotion.

(2) Prevents loss of moisture.

(3) Reduces the harmful effects of UV radiation.

(4) Acts as a sensory organ.

(5) Helps to regulate temperature.

(6) Play a role in immunological surveillance.

(7) Synthesizes vitamin D_3 (cholecalciferol).

(8) It has cosmetic, social and sexual associations.

The fundamental structure of skin in all vertebrate are similar but they differ in different classes by the presence or absence of dermal bone, relative abundance of gland in a aquatic form and stratum corneum of epidermis in terrestrial form.

(1) Protochordata :- In Protochordata like *Balanoglossus* and *Branchiostoma* the skin is simple and lack keratin. The epidermis is made up of a single layer of columnar cells resting on a basement membrane. In larva it is ciliated but in adults are devoid of cilia. There are numerous unicellular epidermal gland cells secreting a thin cuticle in *Amphioxus.* In *Amphioxus* dermis is gelatinous.

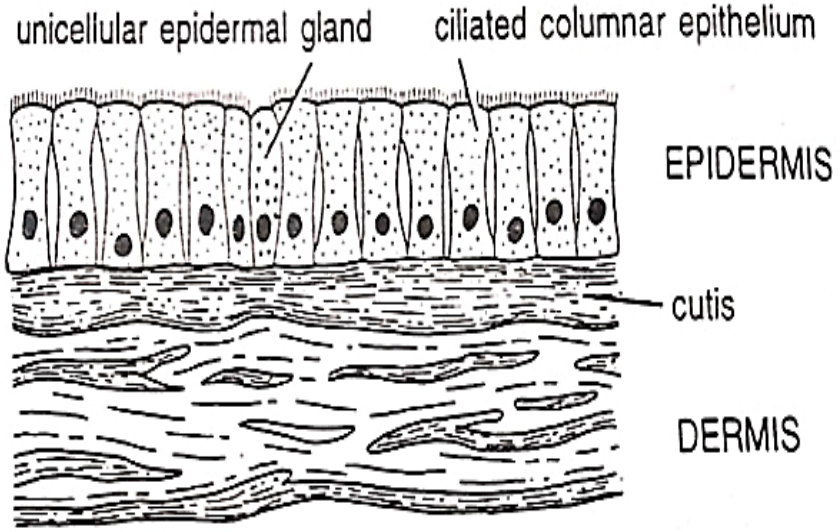


Fig 5.15 : V.S. of skin of young *Amphioxus*

(2) Cyclostomata :- The skin consist of epidermis and dermis. The epidermis is several layers in thickness. Keratinizing does not occur in the epidermis. The outer layer of the skin is shed from time to time and new cells are added by the division of cells present at the basal layer. The epidermis contain 3

types of secretory cells or *unicellular gland*, mucous gland secrete slime, elongated *club cells* help in sliminess, having cytoplasm and *granular cells* of unknown functions. Below the epidermis is a layer of collagen and elastin fibres form cutis. This layer also contains star shaped chromatophores bearing pigments in them. The dermis consists of connective tissue, muscle fibres and blood vessels.

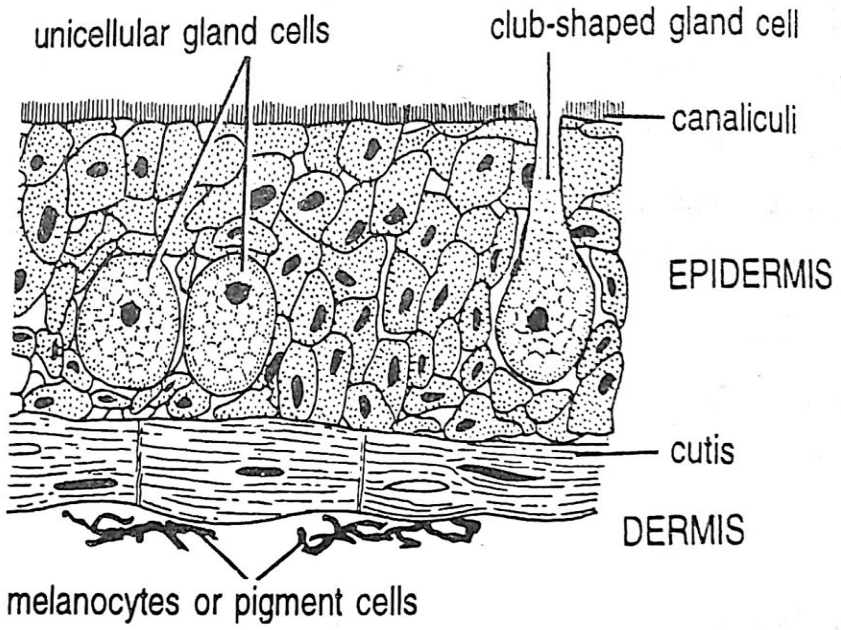


Fig 5.16 : V.S. of skin of larval cyclostomate

(3) Fishes : - In fishes epidermis has several layer of cells but there is no dead stratum corneum. The outer most cells are nucleated and living. Epidermis contain goblet shaped mucus gland cells, which secrete mucous make the skin slimy reducing friction. It also protects the skin from bacteria and fungi. It also assist in the control of osmosis. The epidermis rests on a delicate membrane. The dermis contains connective tissue, smooth muscles, blood vessels, nerve, lymph vessels and collagen fibres, it shows some degree of stratification but the connective tissue fibres are generally not arranged at right angle, almost all run parallel to the surface. The scales are embedded in the dermis, in elasmobranch have placoid scale which project above the surface, Chondrostei and Holostei have ganoid scales, while in Teleostei have cycloid and ctenoid scales. Many bony fishes shows brilliant colour are due to pigment cell called chromatophore and iridophores are present in dermis. If the chromatophore contain red, yellow or orange pigment are called lipophores. The iridophores contain crystals of guanine which produce white or silvery colour of fishes.

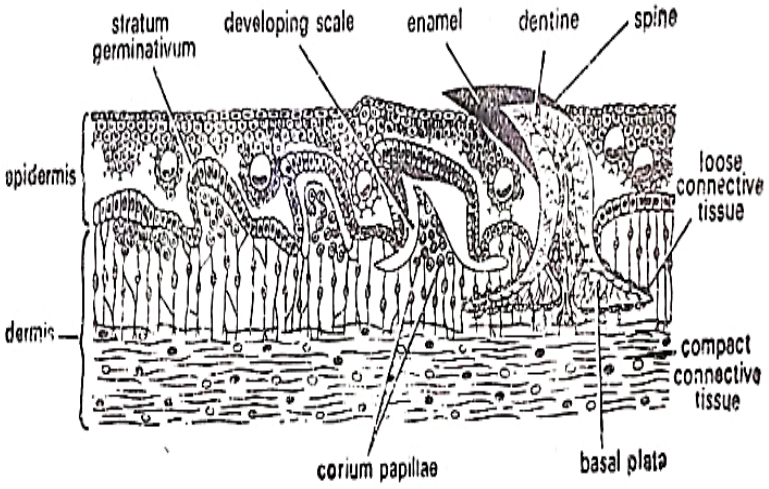


Fig 5.17 : V.S. of skin of *Scoliodon*

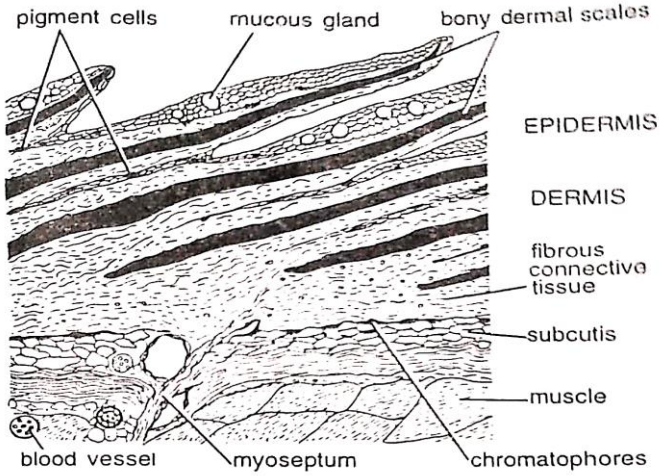


Fig 5.18 : V.S. of skin of Teleost fish

(4) Amphibian :- The epidermis has several layers of cells. The outer most layer is a stratum corneum, highly keratinized and are of dead cells which appears first in amphibian and marked for land appearance. This stratum corneum makes an adaptation to terrestrial life, it prevent the excess of water loss from the surface of body. The dermis is thin and is made up of two layers, an upper loose stratum spongiosum and a lower dense and compact stratum compactum. Connective tissue fibres run both vertical and horizontal. There are two kind of glands mucous gland and poison glands are present in dermis, they are derivative of the epidermis. The mucous gland produce mucous which not only forms a slimy protective covering but also helps in respiration. The poison glands produce a mild but unpleasant poison which is protective. The dermis also contains chromatophore having melanophore or lipophores type produce colour of skin.

The skin of amphibian are a important organ of respiration than lung it also enables the frog to respire under water for long period. During hibernation and aestivation skin is only organ of respiration.

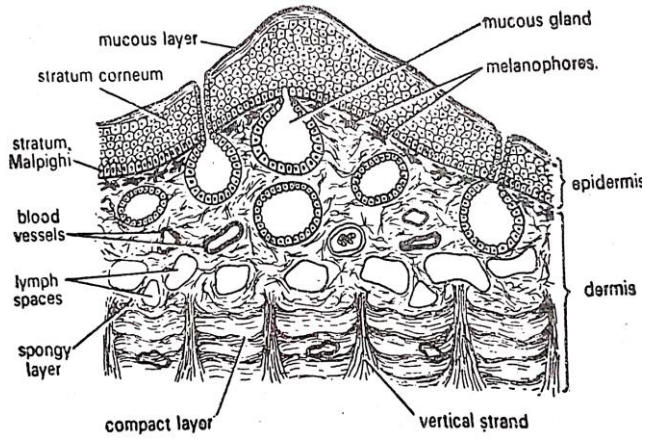


Fig 5.19 : V.S. of skin of Frog

(5) Reptilia : - The reptile are the first animal truly adapted for terrestrial mode of life. There are certain modifications in their skin for terrestrial life. The integument is thick and dry, which prevent the loss of water. It has no gland, only scent glands are present for sexual activity. The stratum corneum of epidermis is well adapted for terrestrial life. It is variously modified to form overlapping horny epidermal scales covering the body, spines, shields, scutes, plates, claws, horns, beaks rattle etc. forming the exoskeleton. Below the epidermal scales are dermal bony plates or osteoderms in tortoises, crocodile and some lizard.

The dermis is thick and has an upper and a lower layer, the upper layer has an abundance of chromatophores in snakes and lizard. The lower layer has bundle of connective tissue in which collagen fibre lie at the right angle.

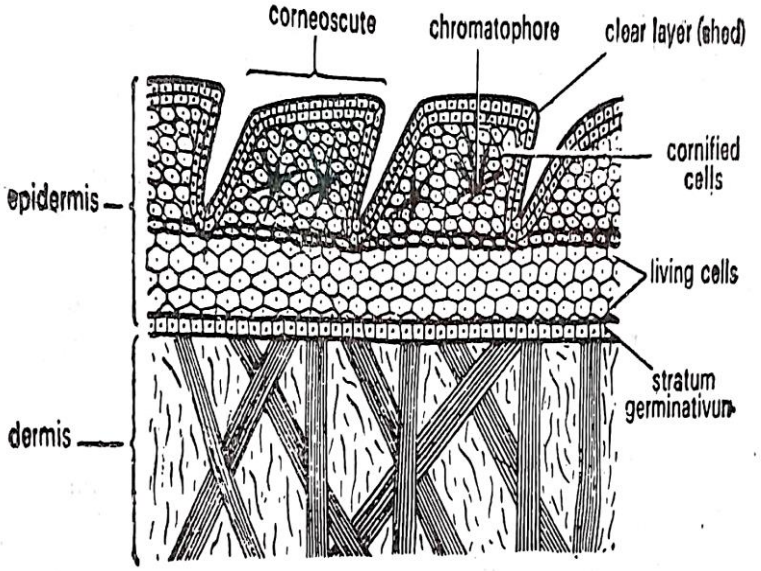


Fig 5.20 : V.S. of skin of *Uromastrix*

(6) Birds : - The integument in bird is thin, loose dry and devoid of glands, there is only uropygial or preen gland at the base of the tail, its oil is used for preening the feathers especially in aquatic birds. The epidermis is delicate, except on shanks and feet where it is thick and form epidermal feathers. The dermis is thin and has interlacing connective tissue fibres, abundant muscle fibres for moving feathers, blood vessels and nerves. The dermis form an upper and lower compact layers, between which is a vascular layer, the dermis also contain fat cells. Bird skin has no chromatophores. Melanocytes containing pigment migrate into the feathers and scales. Body colours are mainly due to reflection and refraction of light from feather.

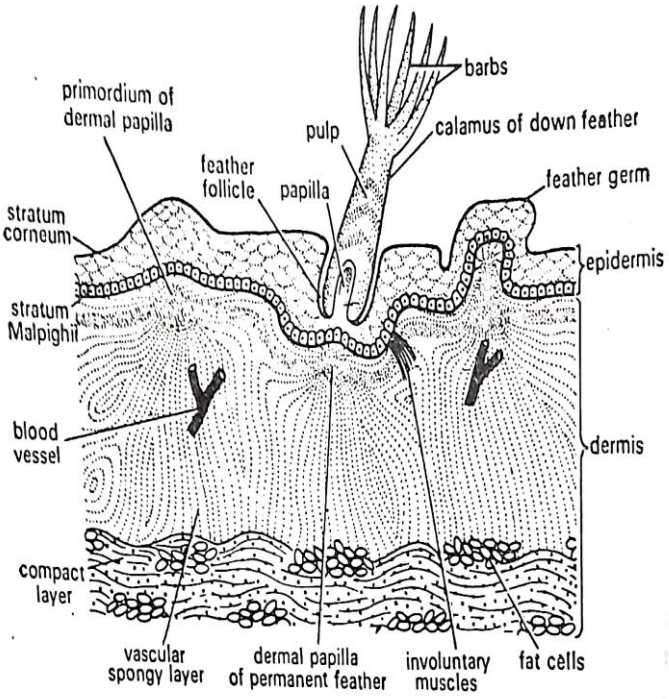


Fig 5.21 : V.S. of skin of *Pigeon*

(7) Mammals :- The skin of mammals is elastic, water proof and thickest of all vertebrates. Both epidermis and dermis layer are present. The epidermis layer consists of 5 layers from outside to inside is stratum corneum, stratum lucidium, stratum granulosum, stratum spinosum and stratum germinativum. The keratin is present in stratum corneum which causes hard, tough, water proof layer of skin. The germinativum layer form new cells continuously which move towards the surface and become flat and keratinized. This layer is sloughed off continuously and replaced by new cells. The keratin from the epidermis at ends of digits forms claws, nail or hoofs.

The dermis is well developed in mammals. The upper part of the dermis in contact with the epidermis is known as papillary layer which is made up of elastic and collagen fibres with capillaries in between. The greater lower part of the dermis is a reticular layer having elastic and collagen fibres. In both papillary and reticular layers there are blood vessels, nerves, smooth

muscles, certain glands, tactile corpuscles and connective tissue fibres extending in all directions. Below the dermis the subcutaneous tissue has a layer of fat cells forming adipose tissue which helps to maintain body heat. The skin colour in mammal is due to varying concentration of melanin pigment in basal layers of epidermis or due to pigment containing melanocytes located in dermis. The mammalian skin has variety of glands like sebaceous, sweat, mammary, lachrymal and scent gland.

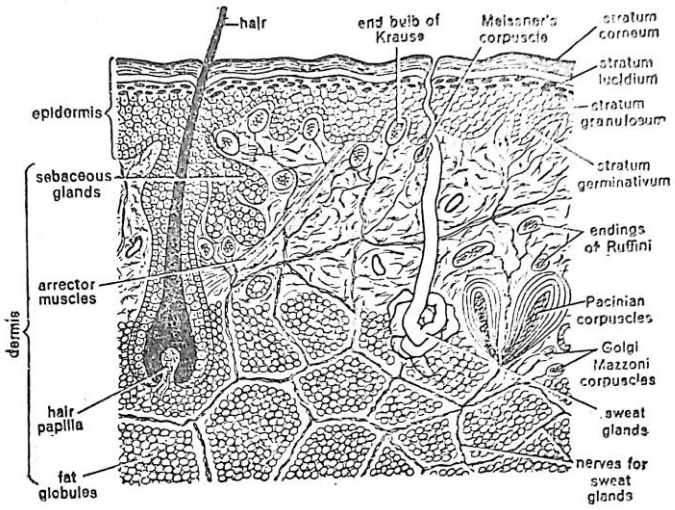


Fig 5.22 : V.S. of skin of Rabbit

SAQs 2.

Complete the following sentences by inserting appropriate words in the blanks.

(i) ----------is a dead and fully keratinized layer of epidermis.

(ii) A sebum is secretary product of ----- gland

(iii) Unicelluar glands secrete a protein -------

(iv) Claws are modified into nails which are characteristic of --------

5.4 COMPARATIVE STUDY OF SKELETON

In vertebrates the skeleton is made up of cartilage, bone or of both cartilage & bone, form a frame work of the body. The vertebrates shows the characteristic of endoskeleton. The endoskeleton support the body, it permit growth because it is living and grows in size with the rest of the body, it maintains a definite shape and form of an animal, it provides protection for delicate vital organs of the body and it furnishes a firm and adequate surface for attachment of muscles by means of tendons. There are joints in the endoskeleton so that movement of parts is possible. In transition from water to land levers in the form of limbs were provided which not only about locomotion, but also lift the body above the ground. The vertebral column becomes a rigid axis to support the heavy head and to resist the thrust exercised by the limbs.

5.5 SUMMARY

The endoskeleton of vertebrate body can be divided into two parts somatic and visceral skeleton.

(1) Somatic skeleton :- These are of two types

(a) Axial skeleton :- These include vertebral column, rib, sternum and most of the skull bone (neurocranium & dermatocranium)

(b) Appendicular skeleton :- These include girdles and limb bones.

(2) Visceral skeleton :- These are skeleton of pharyngeal wall (splanchnocranium).

Appendicular skeleton

The appendicular skeleton consists of skeletal elements of pectoral and pelvic girdles and of the appendages. The appendages are median and paired. The median appendages are found in fishes and aquatic tetrapoda and paired appendages are found in vertebrates except cyclostomes. In fishes the paired appendages are pectoral and pelvic fins, in tetrapoda they are fore and hind limbs.

Amphibia

***Pectoral girdle* :-** In Amphibia or frog the pectoral girdle is present in the thoracic region and provide attachment to the fore limbs and their muscles. It protect the inner softer parts of the thoracic. It consists of two similar halves united mid-ventrally and separated dorsally. Each half is divided into a dorsal scapular portion and a ventral coracoids portion. The scapular portion consists of supra-scapula and scapula. The supra-scapula is a thin cartilaginous plate on the dorsal side. The scapula is a flattened but thicker and stronger bony plate, having a glenoid cavity in postero-ventral corner into which articulate the head of humerous. The antero-ventral corner form a small cartilaginous acromian process.

The coracoids portion consists of clavicle, coracoids, precoracoid and epicoracoid. The clavicle and coracoids meet mid-ventrally with sternum and their counterparts of other side by a stripe of cartilage, the epicoracoid.

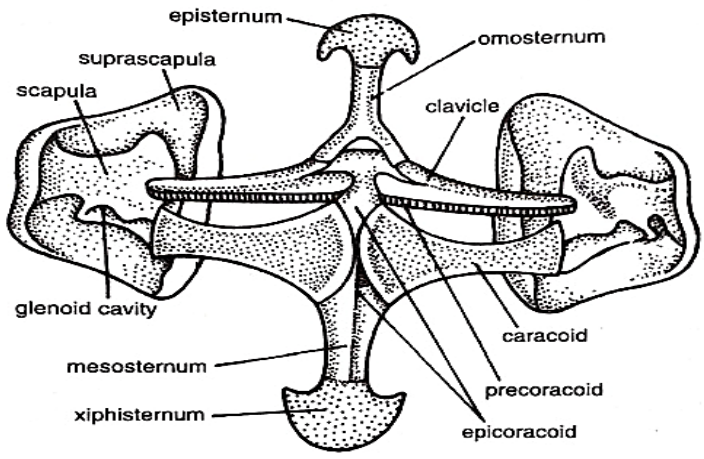


Fig 5.23 : Pectoral girdle of frog

***Pelvic girdle* :-** The pelvic girdle of frog lies in the posterior region of the trunk. It gives support to the hind limb. It is "V" shaped and composed of two similar halves. Each half is called os-innominatum. Each os-innominatum is composed of three bones ilium, pubis and ischium. The ilium is greatly elongated and forms the major part of the each half. It runs forwards to meet the transverse process of the ninth vertebrae. The ilium bears a prominent vertical ridge, iliac crest on its dorsal surface. The pubis is made much reduced, it is a triangular piece of calcified cartilage. The ischium is larger and slightly oval bone. The disc formed by the union of three bones contains a cup-shaped cavity, the acetabulum. In acetabulum the head of femur articulated.

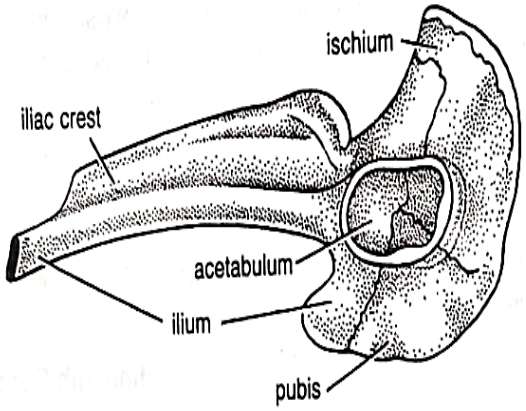


Fig 5.24 : Pelvic girdle of frog

Forelimb:- The bones of the fore-limb include humerus, radio-ulna and the bones of hand.

(i) Humerus :- It is short, stout and cylindrical bone with a slightly curved shaft. Its proximal end is known as head which fits into the glenoid cavity of pectoral girdle. Head is covered with calcified cartilage. The antero-ventral ridge below the head is known as deltoid ridge to which muscle are attached. The distal end forms a rounded trochlea with a condylar ridge on either side. Trochlea articulates with the groove of radio-ulna.

(ii) Radio-ulna :- It is compound bone of forearm of forelimb. It is formed by the fusion of radius and ulna bones. Its proximal end has a concavity for the trochlea of humerous and further projects into an olecranon process forming elbow joint. The distal portion of radio-ulna is somewhat flat having a groove divisible into an anterior (radial) part and a posterior (ulnare) part having facets for the proximal row of carpals.

(iii) Bones of hand : - The bones of wrist (carpus) are called carpals. Carpal bones are six in number and arranged in two rows of three each. The bones of the proximal row are called ulnare, intermedium (central) and radiale. These bones articulate with radio-ulna. The bones of distal row are called capitohamatum, trapezoid and trapezium. These bones articulate with metacarpals. Hand (manus) is provided with five rod-like slender metacarpals. First metacarpal is rudimentary. Hand bears four digits. Thumb is absent. The remaining four metacarpals are supported by bony

rod like phalanges. The first and second digits bear phalanges, third and fourth digits bear 3 phalanges each.

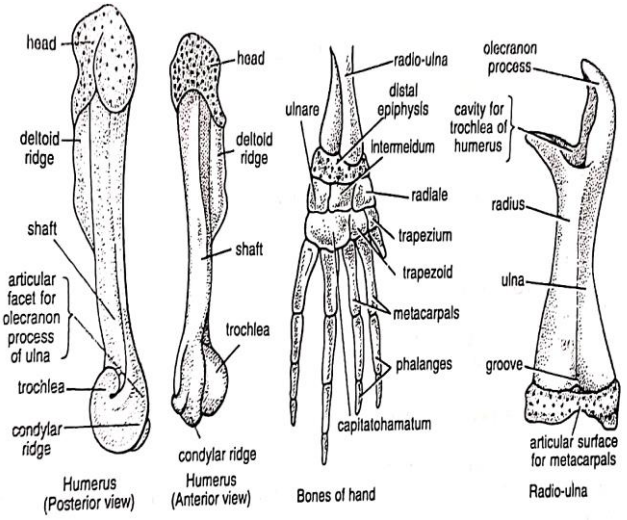


Fig 5.25 : Forelimb bones of frog

***Hind limb* :-** The bones of the hind-limb include femur, tibio-fibula, astragalus-calcaneum and bones of foot.

(i) Femur :- Femur is a long slender bone of thigh region of hind limb. Its shaft is slightly curved. The proximal swollen end is called head that fits into acetabulum of pelvic girdle forming ball and socket joint. The distal end forms a condyle which articulates with tibio-fibula. Head and condyle are covered by calcified cartilage.

(ii) Tibio-fibula :- Tibio-fibula is a large compound bone of the shank region of hind limb. It is formed by the fusion of inner tibia and outer fibula bones forming a single bone called the tibio-fibula. The proximal and distal ends are covered by cartilage. Near the proximal end tibia bears a cnemial or tibial crest. The proximal end articulates with femur and distal end articulates with astragalus-calcaneum.

(iii) Astragalus-calcaneum :- Astragalus-calcaneum is a compound proximal row of long bones of ankle of hind limb fused at their two ends with a wide gap in the middle. The inner bone is thinner and slightly curved called astragalus or tibiale and the outer bone is thicker and straight called calcaneum or fibulare. Their proximal and distal ends are covered by epiphyses of calcified cartilage.

(iv) Bones of foot :- Foot of frog is supported by five long and slender bones called metatarsals bearing five toes. First, second, third, fourth and fifth metatarsals bear 2,2,3,4 and 5 respectively. A small preaxial sixth toe composed of 2 or 3 bones is present on the inner side of the first toe or hallux. Preaxial sixth toe is called the prehallux or calcar and does not project from foot.

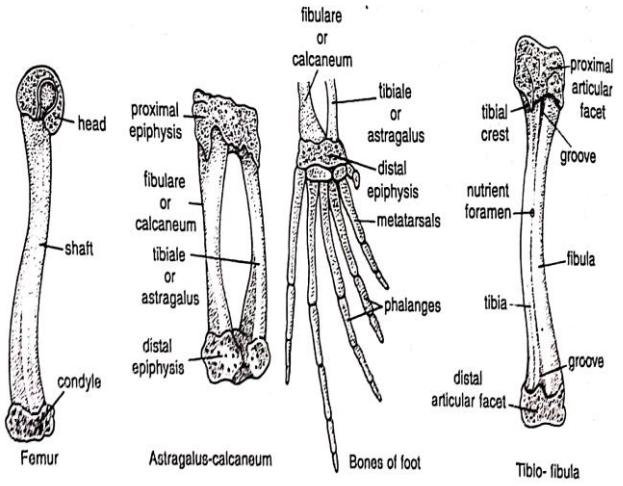


Fig 5.26: Hind limb bones of frog

Reptilia

***Pectoral girdle* :-** The pectoral girdle in reptile or *Varanus* is composed of two similar halves lying on either side of inter-clavicle and sternum. Each half of pectoral girdle consists of scapula, supra-scapula, coracoids and epicoracoid. Scapula is an oblong and flat bony plate which is narrow in the middle. Its outer broader end articulates with supra-scapula, while its inner narrow end unites with coracoids. The supra-scapula is more or less rectangular thin plate of calcified cartilage. It articulates ventrally or proximally with scapula and its distal or dorsal border is free and slightly curved inward. The coracoids is larger, flat fenestrated partly bony and partly cartilaginous. Two large fenestrate divide the bony coracoids part into outer procoracoid, middle mesocoracoid and inner coracoids proper that articulates with antero-lateral border of sternum. Epicoracoid is cartilaginous and irregular shaped arising from the anterior inner part of coracoids above the fenestrate. Epicoracoid of two sides abut medially with posterior stem of interclavicles. At the joint of scapula and coracoid along the ventral side is present a glenoid cavity for the articulation of head of humerous.

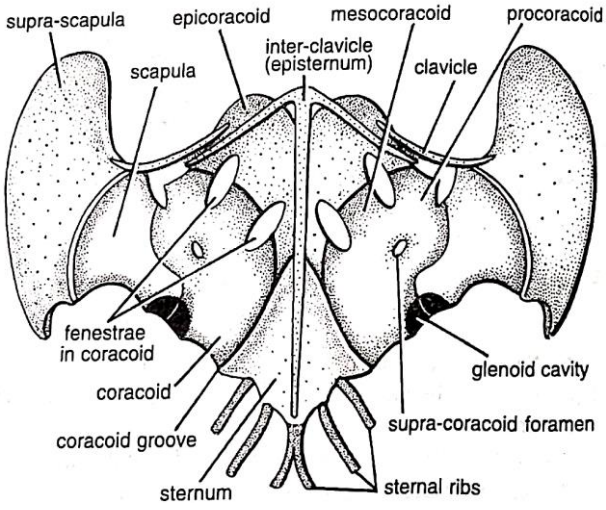


Fig 5.27 : Pectoral girdle of *Varanus*

Pelvic girdle :- The pelvic girdle consists two similar halves (os-innominata) meeting in the mid line by a vertical ligament. Each half is composed of ilium, pubis and ischium which are not fused with each other. Ilium is strong, compressed rod like bone directed upwards and backwards to articulated with the sacral vertebra. On outer side it is produced into a knob like pre-acetabular process in front of acetabulum and also contributes in the formation of about one third part of acetabulum. Pubis is a flat and slightly curved bone passes downwards and forwards to meet infront with its fellow of the other side in mid-ventral line at pubic symphysis. Between the anterior ends of two pubis infront of symphysis is present a nodule of calcified cartilage, the epipubis. Pubis also contributes to about one third of acetabulum. On the posterior end near its fusion with ilium and ischium it has an oval foramen for the abturator nerve. Just external and slightly posterior to the above foramen arises a small rod like process the prepubis which is directed outward. Ischium is flat and slightly curved bone, runs inwards to meet its fellow of the other side at the ischiatic symphysis. It articulates with pubis and ilium of its side. A small rod like piece of calcified cartilage hypoischium is present in between two ischia and passes backwards from ischiatic symphsis to give support to ventral wall of cloaca. Ischium also forms about one third of acetabulum which is a cup shaped cavity that provides articular surface for the head of femur. A wide space is present between pubis and ischium of both sides which is divided into two lateral ishio-pubis fenestrae by a median ligament.

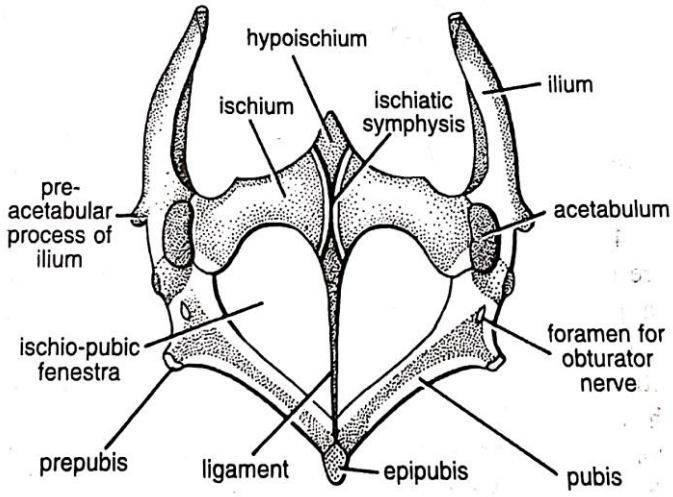


Fig 5.28 : Pelvic girdle of *Varanus*

Forelimb:- The bones of the fore-limb include humerus, radio-ulna and the bones of forehand.

Humerus :- It has an elongated shaft, whose both ends are expanded and covered by epiphyses of calcified cartilage Proximal end bears rounded head which fits into the glenoid cavity of pectoral girdle. A bicipital fossa is enclosed between medial process and head at proximal end. A prominent crest like deltoid ridge is present below the head. Distal end has a pulley like trochlea formed of two articular surfaces or epicondyles, radial condyle and ulnare condyle for radius and ulna respectively.

Radius and Ulna :- Radius(inner) and ulna(outer) are bones of forearm of the forelimb. Radius is slender and consists of a shaft, both ends of which are covered with epiphyses. At the distal end of radius is present a concave articular facet for carpus and preaxial styloid process. Ulna is relatively stouter. Its proximal end is produced into an upwardly directed olecranon process, whereas distally it bears a concave articular surface for carpus.

Bones of forefoot :- Carpus (wrist) consists of ten rounded polyhedral carpals arranged in two rows. Proximal row contains three carpals radiale, ulnare and intermedium. Distal row has five small carpals. Central lies in between two rows of carpals. Besides the above a pisciform is attached to the distal epiphysis of ulna on its post-axial side. Manus (hand) has five long metacarpals which bear five digits having 2,3,4,5, and 3 phalanges with terminal horny claw.

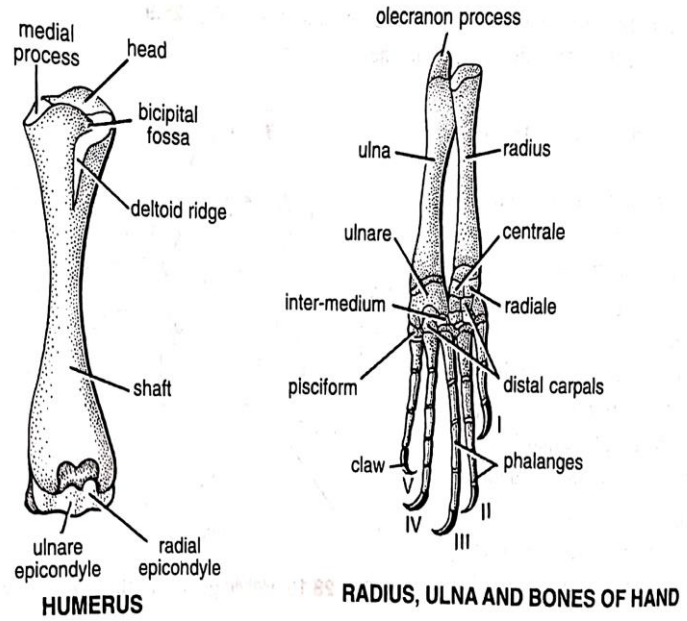


Fig 5.29 : Forelimb bones of *Varanus*

***Hind limb* :-** The bones of the hind-limb include femur, tibio-fibula, and bones of foot.

Femur :- Femur is stout bone of thigh having an elongated shaft and two epiphyses at both ends. Proximal end has a rounded head which fits into acetabulum of pelvic girdle. Proximal end also bears two tuberosities greater trochanter at postaxial side and lesser trochanter at preaxial side. Distal end is pulley shaped having two condyles for articulation with tibia and fibula.

Tibia-fibula :- Tibia is a stout bone and bear a longitudinal ridge, cnemial crest on the dorsal surface. Proximal end of tibia also bear two concave facets for articutaltion with condyles of femur. Fibula is relatively slender bone proximally articulating with femur. Distal ends of both tibia and fibula provide surface for the articulation with tarsals.

Bones of foot :- Tarsal contain five bones, two in the proximal row and three in distal row. Two tarsals of proximal row are suturally fused and articulate with tibia

and fibula. Distal row consists of three cuboid tarsals articulating with five metatarsals of toes. The number of phalanges in five toes is variable, first has 2, second has 3, third has 4, fourth has 5 and fifth has 3 phalanges. Terminal phalanx of each toe is clawed.

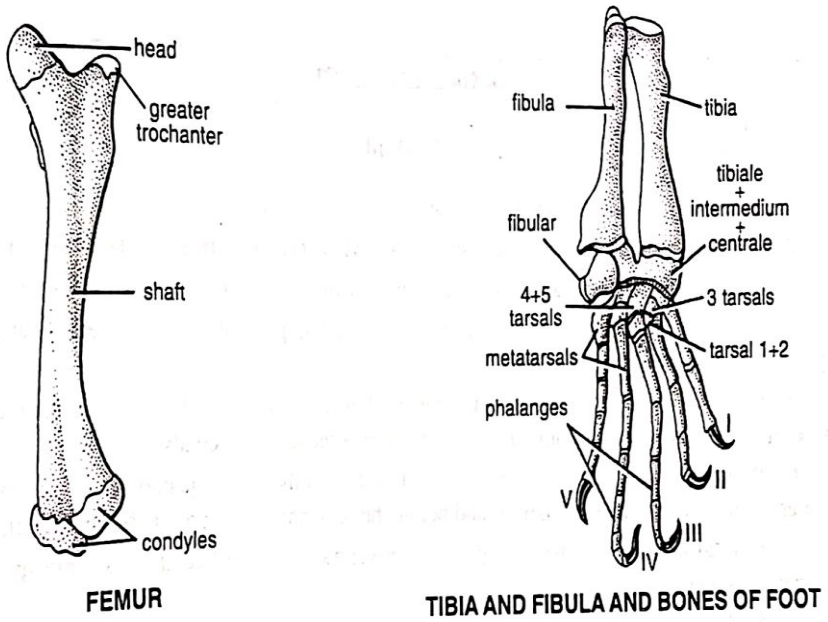
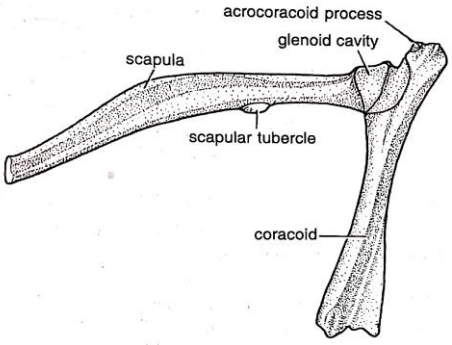


Fig 5.30 : Hind limb bones of *Varanus*

Aves or Fowl :

***Pectoral girdle* :-** The pectoral girdle is a very stout bony structure connected with the sternum on either side to support the wings. On either side it consists of a scapula, coracoids and a clavicle. Scapula is a long flattened sabre-shaped bone lying above the thoracic ribs and parallel to the vertebral column. The expanded anterior end of scapula is firmly united with the coracoid by a ligament. On its outer side it bears shallow depression forming a part of glenoid cavity and its inner surface is produced into an acromian process to provide articular surface to the clavicle and to form a part of foramen triosseum. The supra scapula is wanting. Coracoid is a stout straight bone directed downwards and articulates with the articular surface of coracoids on the antero-lateral edge of the sternum at the base of manubrium. The upper end of coracoid on its inner side articulates with the scapula and on its outer side it bears a deep cup-shaped depression completing the glenoid cavity. The upper end of coracoids is also produced into an acrocoracoid process directed upwards and inwards. Clavicles are a pair of slender curved bones connected by their expanded upper ends with the coracoid and scapula. Ventrally the two clavicles are fused with inter clavicle to form a laterally compressed disc. The forked bone thus formed is known as furcula or merry thought.



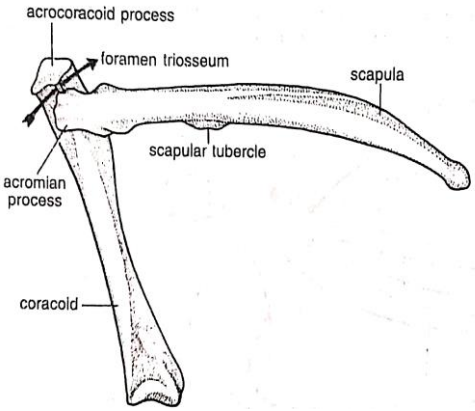


Fig 5.31 : Pectoral girdle of fowl (outer view

Fig: Pectoral girdle of fowl (inner view)

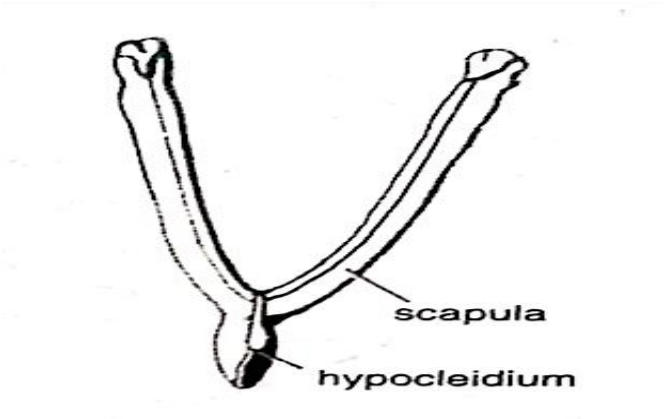


Fig 5.32 : Furcula of fowl

Pelvic girdle :- The pelvic girdle consists of two separate halves lying on either side of the synsacrum. Each half is known as os-innominatum. Each os-innominatum is composed of ilium, ischium and pubis. At the junction of three bones is present a concavity, the acetabulum which provides surface for the articulation of the head of femur. Ilium is an elongated and remarkably expanded bone extending both anterior and posterior to the acetabulum. The inner margin of ilium is fused with the synsacrum, whereas the outer surface of its anterior part is concave and posterior part is fused with ischium. On the outer surface above the acetabulum is a projection the antitrochanter which articulates with the great trochanter of femur. Ischium is also dorso-ventrally flattened bone projecting backwards behind the acetabulum and parallel to the posterior part of the ilium. Ischium is fused posteriorly with the ilium but separated anteriorly from it by an oval ilio-ischiatic foramen. Pubis is along slender bone directed backwards parallel to the outer margin of ischium with which it is usually fused. Behind the acetabulum the pubis and ischium are separated by a slit-like opening, the obturator foramen. Just in front and outside acetabulum the pubis gives off a short and blunt process, the prepubic process.

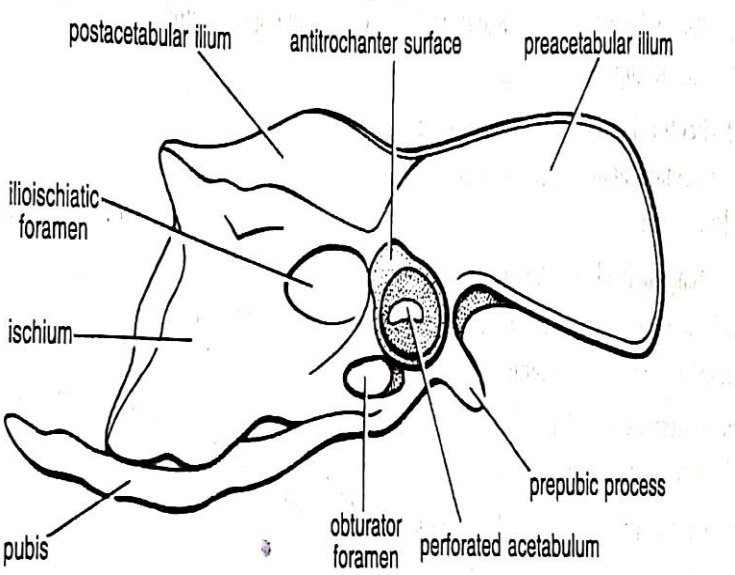


Fig 5.33 : Pelvic girdle of fowl (right half)

Forelimb:- The bones of the fore-limb include humerus, radius and ulna, carpometacarpus and phalanges.

Humerus :- Humerus is the bone of upper arm of fore limb. It is an elongated bone expanded at both the ends. The proximal end is expanded into smooth concave surface the head which fits into the glenoid cavity. The head is bordered by preaxial and postaxial tuberosites. From the preaxial tuberosity extends in front a short deltoid ridge. The postaxial tuberosity is larger and has a pneumatic foramen on the dorsal side of the proximal end. The distal end possesses a trochlear surface for the articulation with the radius and ulna.

Radius and ulna :- Radius and ulna are the bones of fore arm. Radius is a slender and straight bone. Proximally it has a cup-shaped articular surface for the trochlea of humerus. Distally it articulates with the carpus. Ulna is stouter and a larger than the radius and also slightly curved. Proximally it bears a small olecranon process and a large articular facet for the inner condyle of the humerus. Distally it articulates with the carpus and radius.

Carpometacarpus :- Carpometacarpus is the bone of manus. It is a compound bone formed by the fusion of three metacarpals with the distal row of carpals. The first metacarpal is very short and stumpy. The second metacarpal is strong and somewhat straight bone. The third metacarpal is represented by the thinner, slightly curved rod on the postaxial side and fused at both the ends with the second metacarpal.

Phalanges :- Three metacarpals bear three clawsless digits (fingers) which posses small rod like bones called phalanges. First digit or pollex is preaxial and consists of a single phalanx, second digit has two phalanges and third postaxial digit has a straight phalanx.

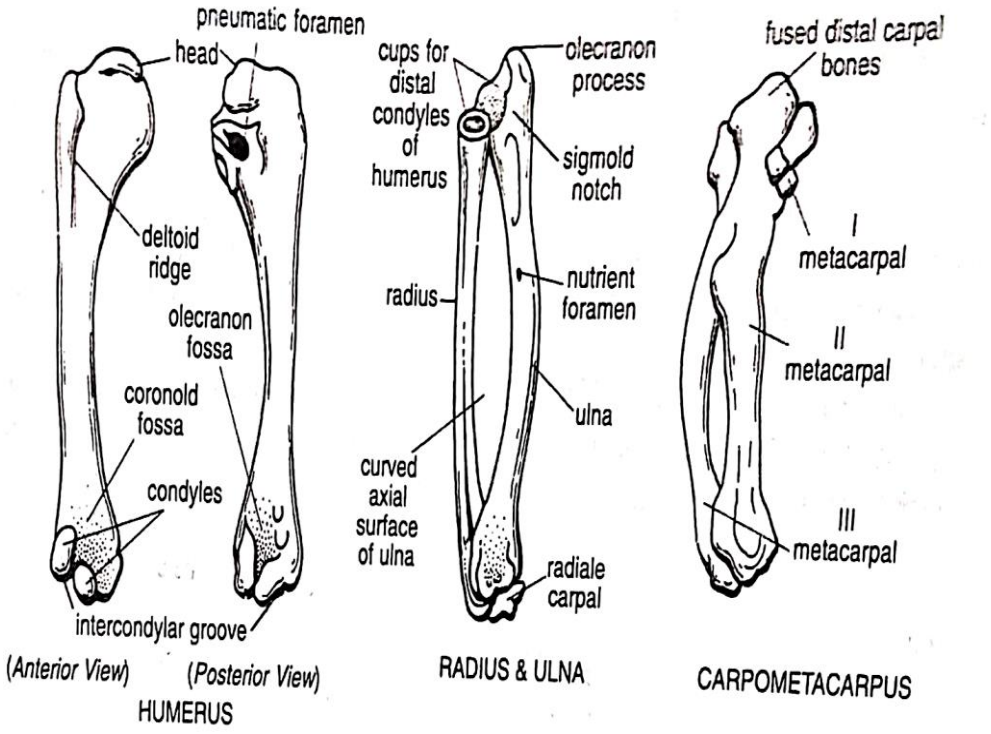


Fig 5.34 : Forelimb bones of fowl

***Hind limb* :-** The bones of the hind-limb include femur, tibiotarsus and fibula, tarso-metatarsus and phalanges.

Femur :- Femur is the bone of thigh of hind limb. It is short and powerful bone enlarged at both the ends. Proximally it is produced on the inner side into a rounded head which fits into the acetabulum. On the outer side of the head is an irregular process, the great trochanter. Between the great trochanter and head is the articular surface for the antitrochanter of ilium. Distally it has in front a deeply grooved surface for the patella which is a sesamoid bone forming the knee joint. Two prominent condyles are also present for the articulation with the tibia and fibula**.**

Tibiotarsus and fibula :- Tibiotarsus and fibula are the bones of shank of hind limb. Tibiotarsus is along and stout nearly straiught bone. It is formed by the fusion with the proximal row of tarsals. The proximal end of tibiotarsus is expanded and has on its anterior face an enemial crest and two articular surface for the condyles of femur. Distally it articulates with the tarso-metatarsus by a pulley like articular surface. The fibula is a slender bone closely applied to the outer surface of the tibiotarsus. Proximally it articulates with the femur.

Tarso-metatarsus : Tarso-metatarsus is a compound bone formed by the fusion of distal row of tarsals with the second, third and fourth metatarsals. It is a stout and long bone proximally articulating with the tibiotarsus and distally bearing three metatarsals each articulating with a corresponding digit. First metatarsal is a small irregular nodules of bone attached to the inner anti-posterior surface of tarso-metatarsus. Proximally it bears two cup-like for the articulation with the tibiotarsus. In male the tarso-metatarsus often bears a stout pointed. Spinous fighting spur.

Phalanges : These are small slender bones. Metatarsus carries four toes first or hallux is directed backward and has two phalanges and remaining three are directed forward. Second, third and fourth toes bear 3,4, and 5 phalanges respectively. Terminal phalanx of each toe has a horny claw.

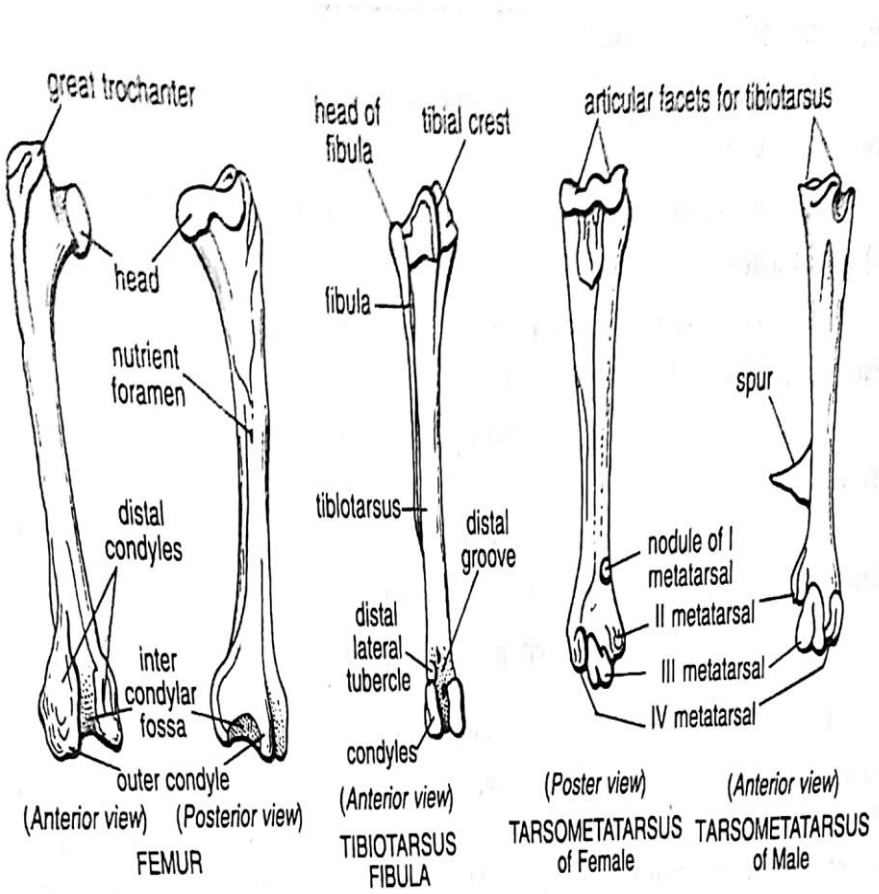


Fig 5.35: Hind limb bones of fowl

Mammals or Rabbit

***Pectoral girdle* :-** The pectoral girdle lies obliquely outside the ribs and is attached to the axial skeleton by muscles and ligaments. It consists of two similar halves which are separate due to the presence of thoracic ribs. Each half of the pectoral girdle composed of two bones i.e. scapula-coracoid and clavicle. The scapula-coracoid is a large flat and triangular bone whose apex is directed downwards and forwards terminating into a concave glenoid cavity for the head of humerus. Over it hangs the coracoids process. On the outer surface of scapula is present a vertical spine which runs downwards parallel to it and continued ventrally into a free downwardly directed acromian process from the posterior border of which arises a long backwardly projecting metacromian process. The supra scapula is a thin cartilaginous strip attached to the dorsal border of the scapula. The clavicle is a slender curved bone whose one end articulates with manubrium of sternum and the other end with acromian process of scapula.

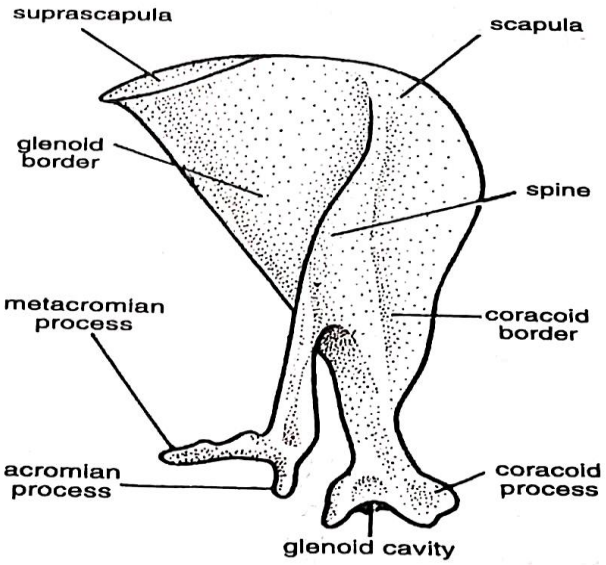


Fig 5.36 : Pectoral girdle of rabbit (Right half)

Pelvic girdle :- The pelvic girdle is also composed of two equal halves os-innominata. The two os-innominata united posteriorly with each other by a pubic symphysis and connected anteriorly with the sacrum. Each os-innominatum is made up of three pieces, the ilium, ischium and pubis. The ilium is a blade like bone running parallel to the vertebral column and bearing on its inner surface articular facet for sacrum. The ischium is stout and straight bone lying opposite to the ilium. At the point of union of ilium and ischium is present a concavity the acetabulum into which fits the head of femur. Pubis is the smallest bone of the three and becomes slightly transverse near the acetabulum. Between the pubis and ischium is present a cavity known as obturator foramen. On the inner side of the acetabulum between the ilium and ischium is present a small cotyloid bone. The posterior end of ischium carries an ischial tuberosity.

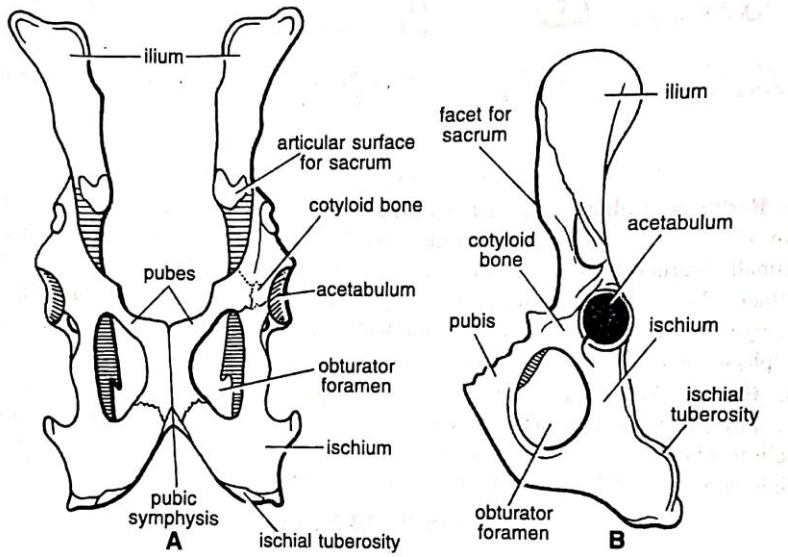


Fig 5.37 : Pelvic girdle of rabbit (A) Complete girdle in ventral view (B) Left half

Forelimb:- The bones of the fore-limb include humerus, radius and ulna, and bones of hand.

Humerus :- Humerus is the bone of upper arm of fore limb. It is elongated and expanded at the proximal end forming a rounded knob like head. Head fit into the glenoid cavity of pectoral girdle. Greater and lesser tuberosities are present at the side of the head. A prominent deltoid ridge is present below the head on the preaxial side. Distal end bears a pulley like trochlea and olecranon fossa. Above the trochlea is a supra-trochlea foramen. Distally it articulates with the radius and ulna.

Radius and ulna :- Radius and ulna are almost equal in size, slender and curved and applied to each other. Radius is elongated and slightly curved forward. Proximally it articulates with the trochlea of humerus and distally with the bone of wrist. Ulna is longer than radius. Proximally ulna projects beyond radius to form the olecranon process and a deep sigmoid notch for the articulation with the trochlea of humerus. Distally the ulna narrows considerably and articulates with the carpus.

Bones of hand :- The wrist bones or carpals are 9 small bones arranged in two lateral rows. Proximal row has three carpals called radiale, ulnare and intermedium. The radiale is situated below the radius, ulnare below the ulna, while the intermedium is situated between them. The distal row consists of trapezium and trapezoid situated below the radiale, centrale and magnum situated below the intermedium and unciform situated below the ulnare. The unciform is actually fused two carpals. Besides these, a sesamoid pisiform is present on the ventral side of carpus. The bones of the palm or manus are five long metacarpals which support the five digits having 2, 3, 3, 3, 3 phalanges respectively. The terminal phalanx of each digit bears a horny claw.

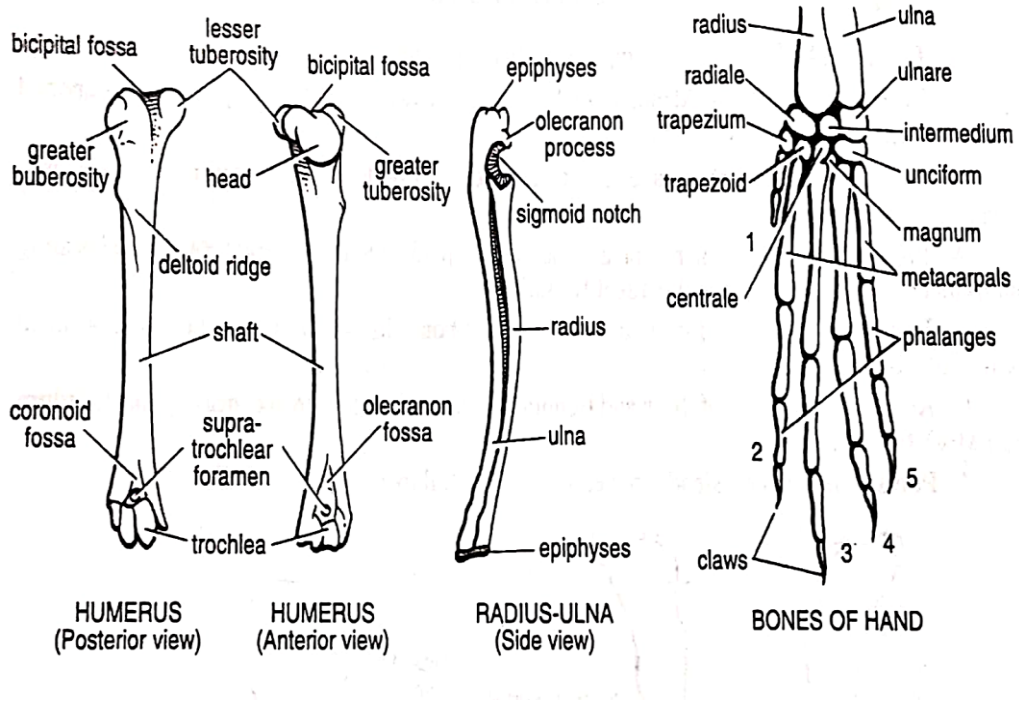


Fig 5.38 : Forelimb bones of rabbit

Hind limb **:-** The bones of the hind-limb include femur, tibio-fibula, and bones of foot.

Femur :- Femur is the bone of thigh region. It is an elongated and stout bone. It consists of a cylindrical shaft and enlarged proximal and distal ends. The proximal ends bears a rounded head which fits into the acetabulum of pelvic girdle. Below the head there are three projections, the anterior greatest trochanter, the third trochanter lies below the greatest trochanter, while the lesser trochanter is just below the head. Distal end bears two large condyles separated by a intercondylar notch. The condyles articulate with the tibia.

Tibio-fibula :- Tibio-fibula is the bone of shank of hind limb. It is made up of two bones of unequal size. Tibia is a stout and a straight bone. The proximal end of tibia is enlarged and bears two oval surfaces on its upper end for the articulation with condyles of the femur. A prominent enemial crest is present near the proximal end. Distal end of tibia articulates with the tarsal bone. Fibula is a slender bone fused distally with the tibia.

Bones of foot :- The ankle is formed of six tarsus arranged in three rows. The first proximal row is formed of two tarsals, a tibiale and intemedium, both fused to form the astragulus located on the preaxial side. The other largest is the calcaneum which is produced into a process behind its articulation with the tibia-fibula. The astragalus bears a pulley like surface for articulation with tibia. The middle row has a single bone, the centrale, just in front of astragalus. The distal row has three tarsals which are mesocuneiform, ectocuneiform and cuboid. The bones of sole or foot are 4 long metatarsals (the first is absent). Four digits or toes are only present, each formed of three phalanges. The last phalanx of each digit is provided with a claw. Hallux is absent.

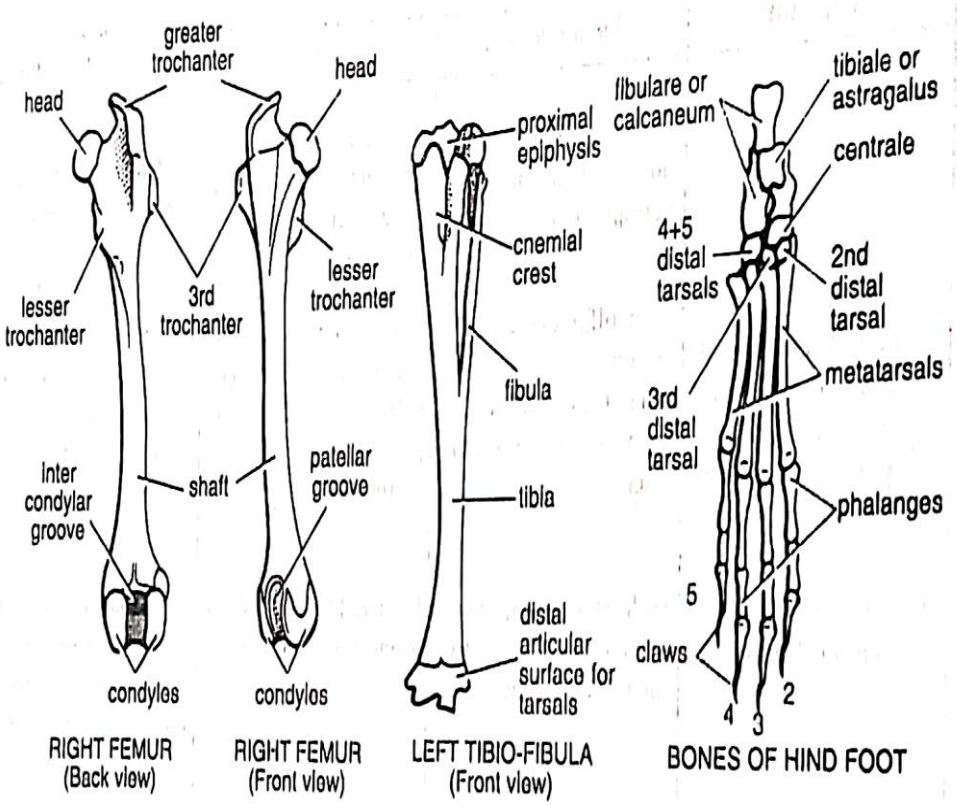


Fig 5.39 : Hind limb bones of rabbit

SAQs 3.

Complete the following sentences by inserting appropriate words in the blanks.

(i) The glenoid cavity is found in -------

(ii) Astragalus and calcaneum are bones of which part of frog ----------

(iii) A deltoid ridge characteristic of ----------

(iv) Ilium, ischium and pubis meet at one point in rabbit to form---------

5.5 SUMMARY

In this unit you will be study the basic structure of epithelial tissue, connective tissue, muscular tissue, nervous tissue and its different types.

In other segment you have study about the basic structure of skin and in different group of animals from protochordata up to mammals.

In last segment you have study about the pectoral girdle, pelvic girdle, forelimb and hind limb of amphibian, reptilian, aves and mammals.

5.6 TERMINAL QUESTION

Q1. Explain Areolar connective tissue in brief.

Q2. Explain the skin of Bird.

Q3. Explain the pelvic girdle of rabbit

5.7 ANSWERS

SAQs 1.

(i) Histogenesis

(ii) Purkinje

(iii) Infant

(iv) Cyton

SAQs 2.

(i) Stratum corneum

(ii) Sweat

(iii) Mucin

(iv) Primates

SAQs 3.

(i) Pectoral girdle Bones

(ii) Hind limb

(iii) Humerus

(iv) Acetabulum

TERMINAL QUESTION

Ans 1. The Areolar connective tissue has a large amount of ground substance and contain almost all types of cells and fibres of connective tissue. It spreads extensively throughout the body like under the skin, and epithelia, in between and around muscles, nerves and blood vessels, in the sub-mucosa of respiratory and gastrointestinal tracts, between the lobes and lobules of compound glands, and in mesenteries. It also forms the internal histological frame work (stroma) of many solid organs. The primary function of areolar tissue is to bind parts together. Further by virtue of its looseness, it facilitates sliding movement of epithelia muscles and other parts, provides for rapid diffusion of materials and facilitates migration of wandering cells towards area of infection and repair.

Ans 2. The integument in bird is thin, loose dry and devoid of glands, there is only uropygial or preen gland at the base of the tail, its oil is used for preening the feathers especially in aquatic birds. The epidermis is delicate, except on shanks and feet where it is thick and form epidermal feathers. The dermis is thin and has interlacing connective tissue fibres, abundant muscle fibres for moving feathers, blood vessels and nerves. The dermis form an upper and lower compact layers, between which is a vascular layer, the dermis also contain fat cells. Bird skin has no chromatophores. Melanocytes containing pigment migrate into the feathers and

scales. Body colours are mainly due to reflection and refraction of light from feather.

Ans 3. The pelvic girdle is composed of two equal halves os-innominata. The two os-innominata united posteriorly with each other by a pubic symphysis and connected anteriorly with the sacrum. Each os-innominatum is made up of three pieces, the ilium, ischium and pubis. The ilium is a blade like bone running parallel to the vertebral column and bearing on its inner surface articular facet for sacrum. The ischium is stout and straight bone lying opposite to the ilium. At the point of union of ilium and ischium is present a concavity the acetabulum into which fits the head of femur. Pubis is the smallest bone of the three and becomes slightly transverse near the acetabulum. Between the pubis and ischium is present a cavity known as obturator foramen. On the inner side of the acetabulum between the ilium and ischium is present a small cotyloid bone. The posterior end of ischium carries an ischial tuberosity.

UNIT–6 DIGESTIVE SYSTEM AND RESPIRATORY SYSTEM

Structure (A) Digestive System

Structure (B) Respiratory System

Structure (A) Digestive system

6.1 INTRODUCTION

The digestive tract or alimentary canal in vertebrates develops from embryonic archenteron. It refers to an internal tube. The ectodermal invaginations form an anterior stomodaeum and a posterior proctodaeum which become the lining of the two ends of the digestive tract. The stomodaeum becomes the adult buccal cavity and the proctodaeum forms either a small part near the anus or it gives rise to an external portion of the cloaca. The digestive tract is differentiated for different functions. Its different parts are mouth, buccal cavity, pharynx, oesophagus, stomach, small intestine, large intestine and cloaca. The chief accessory organs associated with the alimentary canal are tongue, teeth, oral glands, pancreas, liver, gall bladder. There are various modifications of alimentary canal in different vertebrates as lengthening of various parts by looping or coiling, formation of diverticula or enlargements (e.g. crop, caecum, stomach compartments) and development of internal folds like spiral valve, villi, typhosole, papillae, rugae.

Objectives :

- Describe briefly the alimentary canal and digestive glands in vertebrates.
- Explain the gills, air sacs and swim bladder.

6.2 BRIEF ACCOUNT OF ALIMENTARY CANAL AND DIGESTIVE GLANDS IN VERTEBRATES

Cartilaginous fishes (*Scoliodon*)The mouth is present on the ventral side of head. It lead to open into spacious dorso-ventrally compressed buccal cavity. The sharp

similar (homodont) and backwardly directed teeth present in several rows on skin of both jaw. Teeth are modified placoid scales and replaced by new once (polyphydont) during life. Teeth are used for grasping the prey. The buccal cavity opens into the pharynx. On either side of pharynx contains an oval pit of spiracles and five separate vertical internal gill slits of gill pouches. The pharynx narrows posteriorly to form the short oesophagus. The oesophagus has thick muscualar walls with an internal lining an of mucus membrane raised into longitudinal folds. The oesophagus opens into stomach by oesophageal valve. The oesophagus moves backwards and open and into a large muscular and U-shaped stomach. Its proximal limb is longer, wider and called cardiac stomach. The distal limb is shorter and narrow called pyloric stomach. At the junction of cardiac and pyloric stomach is a small blind outgrowth called blind sac and a sphincter valve is present. At the end of pyloric stomach is present a strong circular muscle band called pyloric valve, guarding its opening into a small but thick walled muscular chamber, bursa entiana.The bursa entiana open into the intestine. The intestine is a wide tube. The internal surface (mucus membrane) of intestine become folded anticlock wise into a longitudinal spiral or scroll of about two and a half turns. This is called spiral or scroll valve. The scroll valve serve not only to increase the extent of absorptive surface of the intestine but also

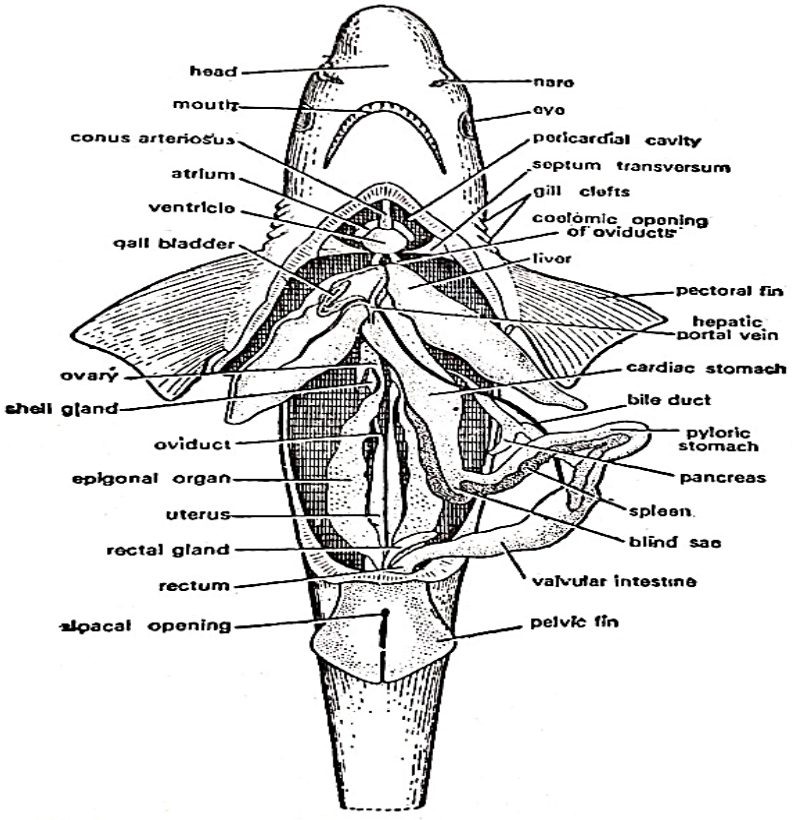


Fig 6.1 : *Scoliodon* : Internal viscera showing parts of digestive system

prevents the rapid flow of food through the intestine. The intestine open into rectum. The rectum is a short and narrow tube opening behind through anus into the ventral cloaca.

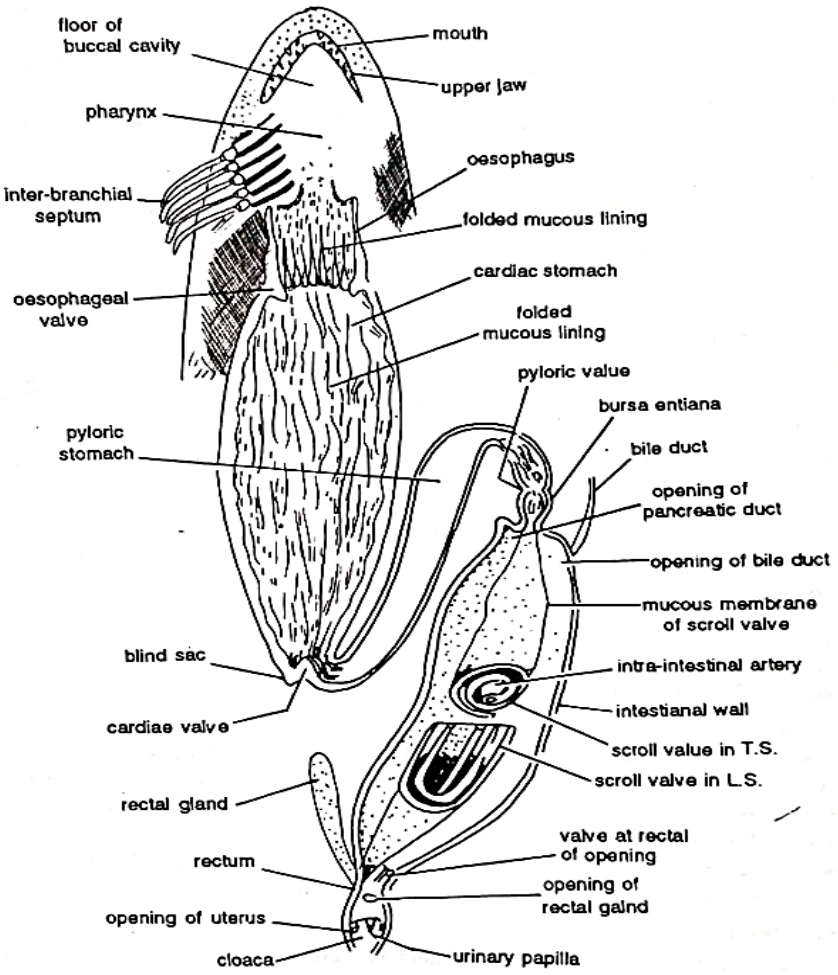


Fig 6.2 : *Scoliodon* : Dissection of digestive system

Digestive glands:

Salivary glands *:-* Absent

Liver *:* The liver is a large bilobed yellow or mustard coloured gland occupying a considerable length and space of the abdominal cavity. The liver has two lobes i.e. right and left lobes. A "V" shaped gall bladder storing bile over the right lobe of liver is present. The bile duct or *ductus choledochus* carries bile into the intestine and opens into the dorsal wall. The liver produces bile, store glycogen and fat.

Gastric glands : These are microscopic to submicroscopic occur in the wall of stomach. They secrete gastric juice for digestion for food.

Pancreas *:* The pancreas is a compact whitish or pale bilobed gland is present in between the cardiac and pyloric stomach. A pancreatic duct runs through the whole length of the gland and opens into the intestine. Pancreas secretes pancreatic juice.

Intestinal glands : These glands are also lie in the wall of intestine. They secrete succus entericus.

Caecal or rectal gland *:* It is a small finger like body attached by its duct to the dorsal side of rectum into which it open. Its function is unknown.

Amphibia (Frog) :

The mouth is present at the anterior end, it opens into a broad cavity called buccal cavity, which lies in between the two jaws, the upper and lower jaw. The upper jaw is fixed while the lower jaw is movable ups and down vertically. The teeth are present only on upper jaws. They are small, conical and backwardly pointed teeth present on premaxillae and maxillae bone of jaw. The roof of bucccal cavity also contain and two groups of vomerine teeth. The teeth are meant to hold the prey. The teeth are similar (homodont), not present in socket (acrodont) and are replaced several time during life cycle (polyphydont). The floor of mouth cavity contain a large, muscular sticky tongue. Its anterior end is attached to the inner border of lower jaw. Its posterior end is free and bifid which can be flicked out and retracted suddenly after capturing the prey with its slimy surface. The buccal cavity narrows behind as the pharynx which open into oesophagus through gullet. The oesophagus is short, wide, muscular and highly distensible tube. Its mucus epithelial lining is folded longitudinally and contain some mucus glands. The oesophagus open into stomach. The stomach is a large long, broad and slightly curved bag or tube. It is divided into two parts. The anterior broad cardiac part and posterior short narrow pyloric part. The pyloric end of stomach is slightly constricted and it open into intestine is guarded by a circular ring called pyloric valve. The intestine consists of two parts, the small intestine and a large intestine. The small intestine is a long, coiled a narrow tube of about 30 cm long. It has two parts a small anterior duodenum and a much longer posterior ileum. The ileum open into large intestine or rectum, which is short wide tube 4 cm long, open into cloaca by anus guarded by an anal sphincter. The cloaca is a small terminal sac into which open the anus and urino-genital aperture. The cloaca open to outside by the cloaca aperture lying at the hind end of the body.

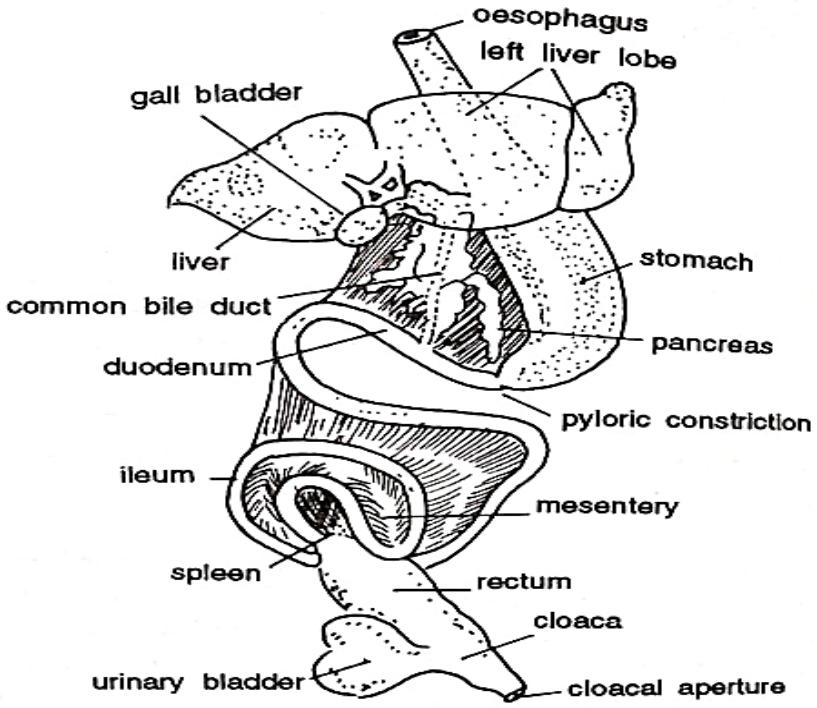


Fig 6.3 : Frog : Digestive system

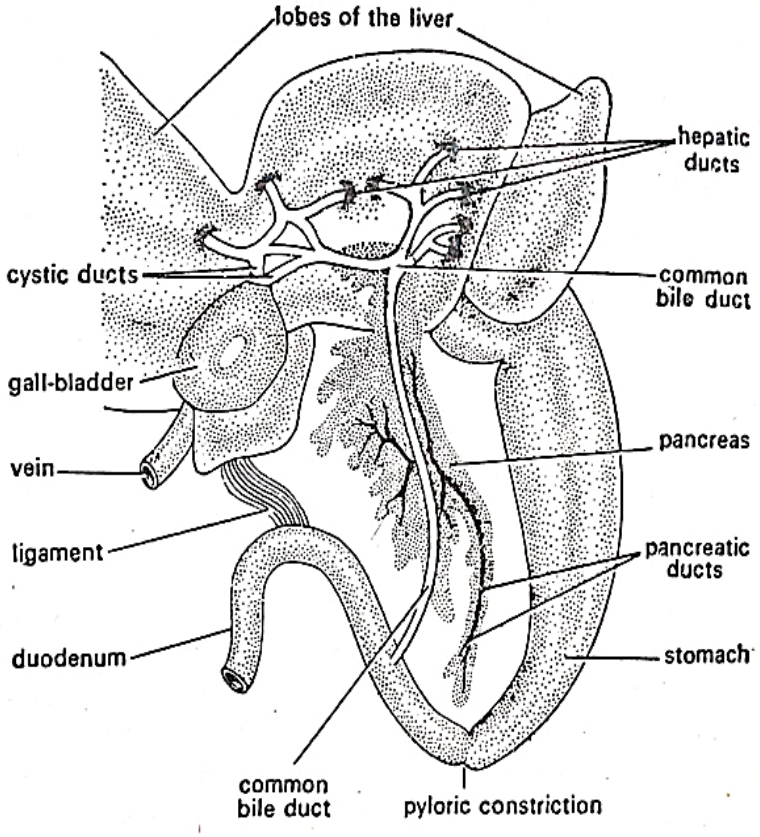


Fig 6.4 : Frog: Digestive organ and gland

Digestive glands:

Salivary glands *:-* Absent

Liver *:* It is large, dark red colour gland present in the anterior body part. In frog liver consist of 3 lobes right, left and median. At the junction of two lobes of liver, there lies a thin walled greenish, spherical sac called gall bladder.

Gastric glands : These are microscopic to submicroscopic occur in the wall of stomach. They secrete gastric juice for digestion for food.

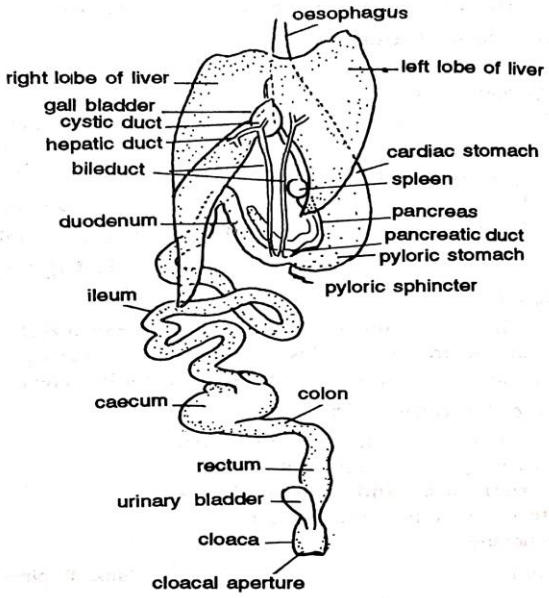
Pancreas *:* It is irregular, elongated whitish gland situated in a thin mesentery between the stomach and duodenum. It produces pancreatic juice which is carried into bile duct through several pancreatic ducts and finally poured into duodenum by hepatopancreatic duct.

Intestinal glands : These glands are also lie in the wall of intestine. They secrete intestinal juice.

Reptile(*Uromastix*)

The mouth open in a fairly a wide gaps bounded by the upper and lower immovablie and muscular lips. The mouth open into the buccal cavity. The buccal cavity is narrow infront but broad posteriorly. It is lined with mucus membrane and contains teeth, tongue and internal nares. The teeth are present on the premaxillae and

maxillae of upper jaw and dentaries of lower jaw. They are acrodont. The tongue is anteriorly narrow end is free and notched (bifid) at the tip and protrusible. The posterior broad end is fixed and widely bifurcated. The buccal cavity open into the pharynx. The pharynx open into oesophagus. The oesophagus open into a long, cylindrical, sac like structure called stomach. The stomach appears U-shaped differentiated into two parts anterior part is cardiac stomach and posterior is pyloric stomach. The pyloric stomach open into a small intestine, which is long, narrow and coiled tube. The small intestine is divided into duodenum and ileum. The ileum open into the large intestine. The large intestine is differentiated into anteriorly thin walled colon and posteriorly thick walled rectum. The anterior part of colon is dilated into a blind pouch the caecum. An ileo-colic valve is present internal at the junction of ileum and caecum. The function of colon is the formation of faeces and absorption of water. The colon open into the rectum, which is short, tubular and thick walled and serve to store the faeces. The rectum open into the cloaca which open to the exterior by the cloacal aperture. The cloaca is divisible into 3 chambers, the proctodeum, urodaeum,and coprodaeum. The division of cloaca into chambers serves for re-absorption of water both from the faeces and urine.



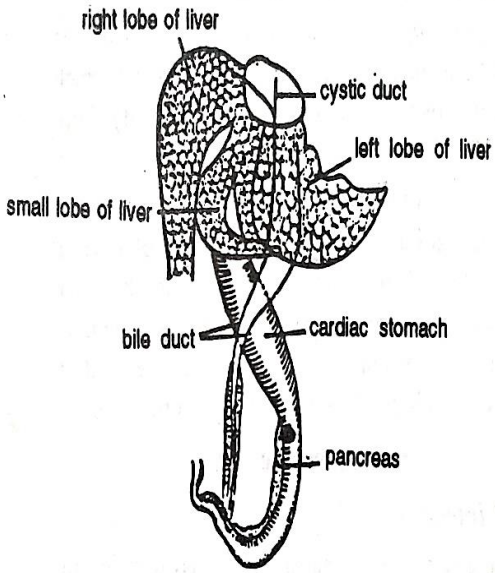


Fig 6.5 : *Uromastix*. Alimentary canal **Fig: *Uromastix*. Digestive gland**

Digestive glands:

Salivary glands *:-* According to keith a few salivary gland open into the buccal cavity and secrete mucus.

Liver : It is a large, trilobed gland, dark red in colour. The three lobes of liver are the right lobe, the left lobe and small lobe, the dorsal lobe. The right lobe is narrow and long which extends posteriorly upto the right gonad. The left lobe is attached to the upper side of left lobe. A sub-rounded gall bladder is situated on the ventral side at the junction of right and left lobes of liver.

***Gastric glands* :** They secrete gastric juice for digestion for food.

Pancreas : It lies between the stomach and duodenum. It is a long narrow band like whitish gland.

Intestinal glands : These glands occur in the mucosa of small intestine in the form of simple crypts of lieberkuhn. They secrete intestinal juice.

Aves (Pigeon)

The mouth opening is a wide, slit, bounded by upper and lower horny beaks having no teeth. The mouth opens into the buccal cavity. The buccal cavity has a large, narrow, triangular and pointed tongue at its floor. The buccal cavity posteriorly opens into pharynx. The pharynx open into oesophagus. The oesophagus is a long, wide, distensible thick walled tube. At the base of neck the oesophagus dilated into a large, thin walled bilobed, elastic and non grandular sac called crop. The crop enables the bird to store quickly eaten food for later digestion, it is specially large in graminivorous (grain eating) birds such as pigeons, finches, bunting, parrots. The grain is macerated in it. In both sexes of pigeon the crop produce "pigeon milk" especially during the breeding season. It is formed by the degeneration of epithelial cells lining the crop. The pigeon milk contain water, protein, fat and ash. After leaving the crop the oesophagus again become thick walled and narrow tube and open into stomach. The stomach is differentiated into an anterior proventriculus and a posterior gizzard. The proventriculus is a small, thick walled, tubular and glandular structure which is hardly broader than the oesophagus. Its thick mucus lining secrete gastric juice. The proventriculus open into gizzard. The gizzard is large, hard and laterally compressed. The walls of gizzard have thick muscle radiating from two tendons. The lumen is lined by an epithelium which is thick, tough horny and yellow or green in color. The cavity of gizzard always contains small stones or girt swallowed by the bird. These stone help the gizzard in grinding the food. The gizzard open into small intestine, opening of which is guarded by pyloric valve or pylorus (In carnivorous bird the gizzard is not so muscular). The small intestine is differentiated into duodenum and ileum. The duodenum arises from the dorsal side of gizzard so that the pyloric opening of gizzard into duodenum lies close to the cardiac opening of proventriculus into gizzard. The duodenum open into ileum. The ileum is a long & coiled tube. Its inner epithelium lining is thrown into numerous minute figure like processes or villi, which greatly increases its area of secretion and absorption. The ileum open into large intestine. The large intestine is differentiated into 2 parts. The anterior is rectum and posterior is cloaca. At the junction of ileum and rectum, a pair of small, conical blind pouches the rectal or colic caeca is present, which is probably absorb some water from food. The rectum is guarded by an anal sphincter. The rectum open into a three chamber compartment, the anterior coprodaeum into which rectum is open, a short middle urodaeum into which urinary and genital duct open and proctodaeum which open to the outside by the cloacal aperture. A small glandular, blind pouch of lymphatic, the bursa fabricii lies on the dorsal side of the cloaca. It is lined with endoderm and open into the proctodaeum. In a young bird it forms lymphocytes and probably it produces antibodies and protects against local infection but it atrophies in the adult before sexual maturity. It is also called cloacal thymus.

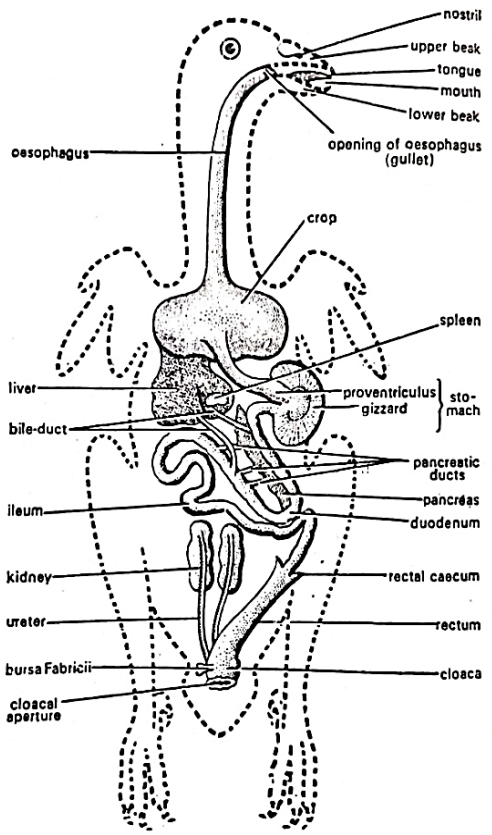


Fig 6.6 : Pigeon. Alimentary canal

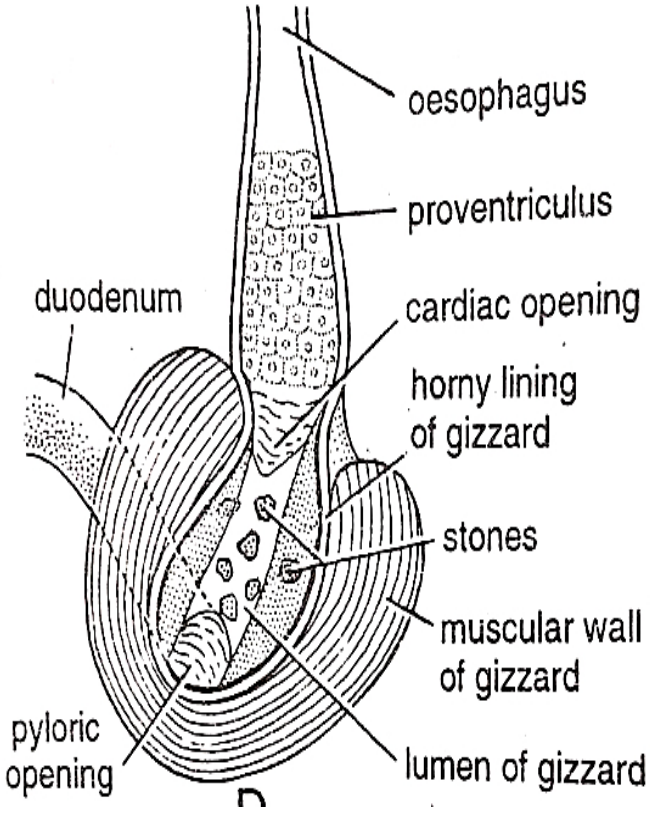


Fig 6.7 : Pigeon. Stomach in sagittal section

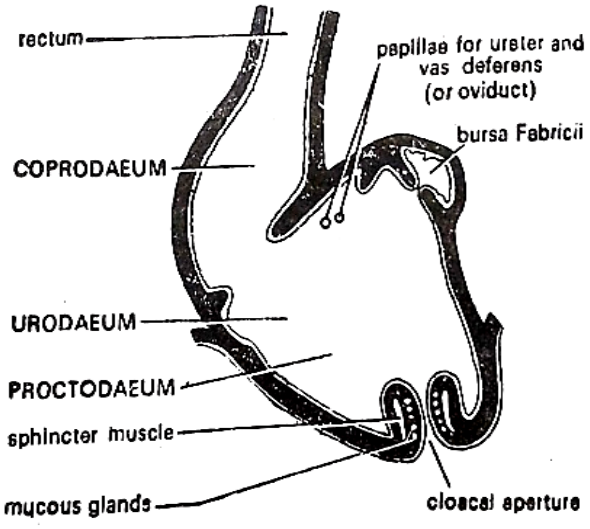


Fig 6.8 : Pigeon Cloaca in section

Digestive glands:

Buccal glands :- Pigeon has no salivary gland in the buccal cavity, but has two sub-lingual glands and a pair of mucus glands near the corners. These glands are the only buccal glands which secrete mucus to moisten the food and the amylase enzyme. The tongue also bears few mucus glands.

Liver : The liver of pigeon is large , compact, dark red, bilobed, containing a large right lobe and a small left lobe. From each lobe of the liver arises a bile duct, reach of which opens into the duodenum. There is no gall bladder in the pigeon. . The liver secretes bile juice.

Gastric glands **:** They secrete gastric juice containing peptic enzyme for digestion for food.

Pancreas : Between two limb of the duodenum is a compact, reddish digestive gland, the pancreas. Pancreas produces three separate pancreatic ducts which pour the pancreatic secretions containing many enzymes into the duodenum.

Intestinal glands : They secrete intestinal juice.

Mammal (Rabbit)

The mouth is small transverse aperture situated at subterminally at the tip of the snout. The mouth is bounded by two mobile and muscular lips. The mouth opens into a narrow, vertical, slit like space, the vestibule. It is bounded externally by the lips and cheeks and internally by the gums of jaws. Mucous glands are found in its lining. The vestibule open into buccal cavity. The roof of the buccal cavity is formed from palate, side by cheek and floor by throat. The anterior end of palate is hard and formed by premaxillae, maxillae and palatine bone is called hard palate. The lower surface of hard palate bear prominent transverse ridge called palatal rugae. The hard palate is followed by soft, fleshy, smooth soft palate. It posterior end hang down freely into pharynx as a small flap called uvula. The upper & lower jaws bear teeth which are present on the premaxillae, maxillae and dentary bone. The teeth are thecodont, heterodont and diphyodont. The buccal cavity open into a

short narrow chamber called pharynx. The pharynx open into a long, narrow elastic and muscular tube called oesophagus. The oesophagus move down and after piercing the diaphragm it open into a sac like stomach. The stomach is situated on the left side in the anterior part of the abdominal cavity. The stomach is consist of 3 parts cardiac, fundic & pyloric. The cardiac stomach into which open oesophagus. The opening is guarded by oesophageal valve. The opening of pyloric stomach into duodenum is guarded by a circular pyloric sphincter valve. The cardiac & pyloric opening are close to each other. The pyloric open into the small intestine. The small intestine consists of 3 parts duodenum, jejunum & ileum. The pyloric open into duodenum which is U shaped loop. Behind its jejunum and which is followed by ileum. The distal end of ileum is dilated to form a sac like structure called sacculus rotundus. It opens into the caecal valve direct the food content into the caecum before passing into the colon. The caecum is about 20 inches long thin walled diverticulum which has pouch like spiral constriction. The caecum lead into a blind ending finger like tube, about four inches long and thick walled known as vermiform appendix.

The ileum open into the large intestine. It consists of two part colon and rectum. The ileum open into the colon. The colon is wide, tube of about 45 cm long and bear longitudinal muscle band, taeniae. The wall of colon at the sides of taeniae are constricted at regular intervals to form pocket like pouches, haustra. The colon open into rectum. Rectum is a long and at interval it is swollen to form rounded structure and finally open outside by the anus.

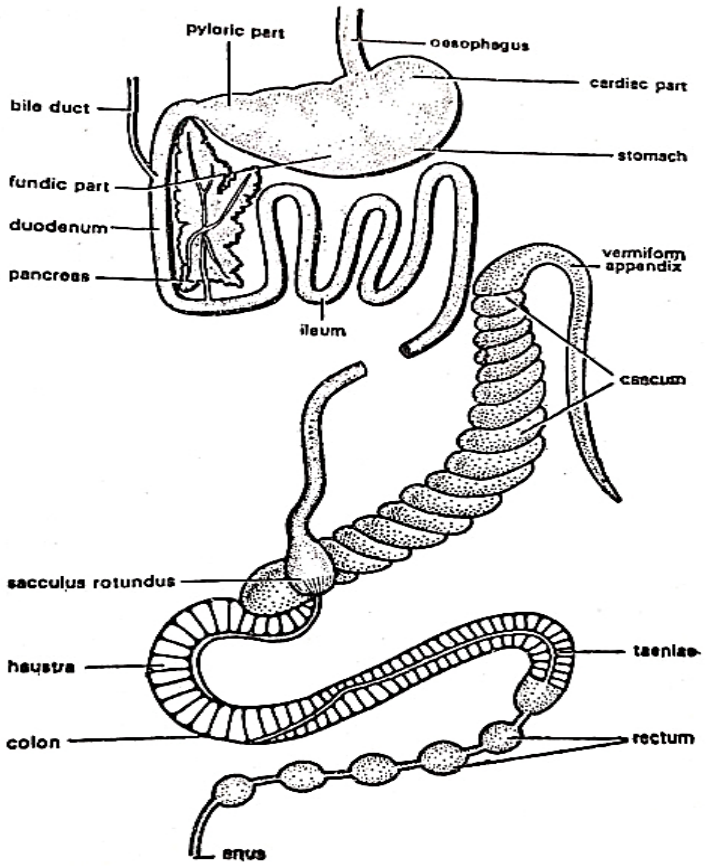


Fig 6.9 : Rabbit. Alimentary canal

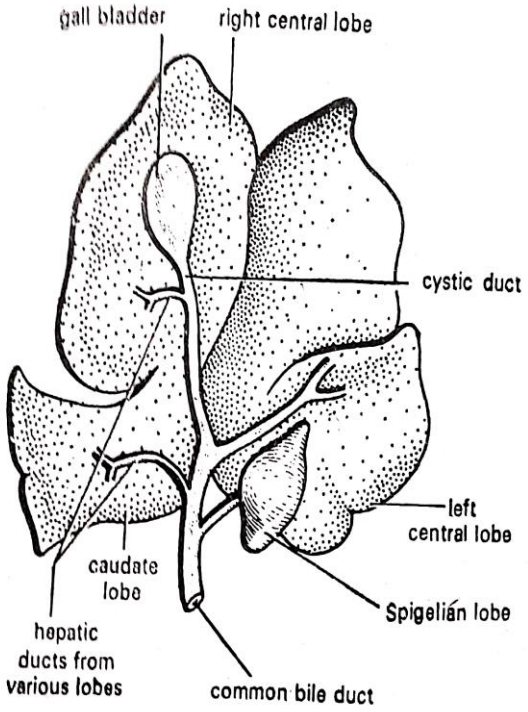


Fig 6.10 : Rabbit Liver lobes and gall bladder

Digestive glands:

***Mucus gland* :** The mucus gland is found throughout the mucus lining of the digestive tract. They are mainly found in the lining of the vestibule. They secrete mucin. The mucin lubricates the food and food passage.

Salivary gland :- Four pairs of salivary gland are found, parotid glands, infra-orbital glands, submandibular or submaxillary glands, sub lingual glands. Saliva is secreted by these salivary glands which contain slippery mucin and watery ptyalin. Ptyalin helps in the digestion of starch. The salivary glands are stimulated to produce saliva by reflex actions caused due to the presence of food in the buccal cavity.

Liver : It is reddish- brown in colour. It consist of 5 lobes The three lobes on left are a small Spigelian, left lateral and left central while 2 lobe on right side are right caudate and right central. From each of the five lobes, the hepatic ducts arise. An elongated dark green thin walled gall bladder is situated more or less between the right and left lobes. A large cystic duct arises from the gall bladder and united with the hepatic ducts to form a common bile duct or *ductus choledochus* which opens in the proximal limb of duodenum. The opening of common bile duct is guarded by a sphincter muscle, the sphincter of oddi.

Pancreas : It is irregular shape laying in the fold between the stomach and duodenum. It has two kinds of functional cells exocrine cell and endocrine cells or *islets of langerhans*. The exocrine cells secrete three digestive juice amylopsin, trypsin, and steapsin. The endocrine cell secretes two principal hormones insulin and glucogon.

Intestinal glands : They secrete intestinal juice.

SAQs 1.

Complete the following sentences by inserting appropriate words in the blanks.

(i) The ---------- is the largest lobed gland in the body

(ii) Non muscular tongue is found in ----------.

(iii) In many ruminants the stomach has ---------- chamber.

(iv) A gall bladder is the storage of ---------- secreted by the hepatic cells.

Structure (B) Respiratory system

6.3 BRIEF ACCOUNT OF GILLS AND AIR SACS AND SWIM BLADDER

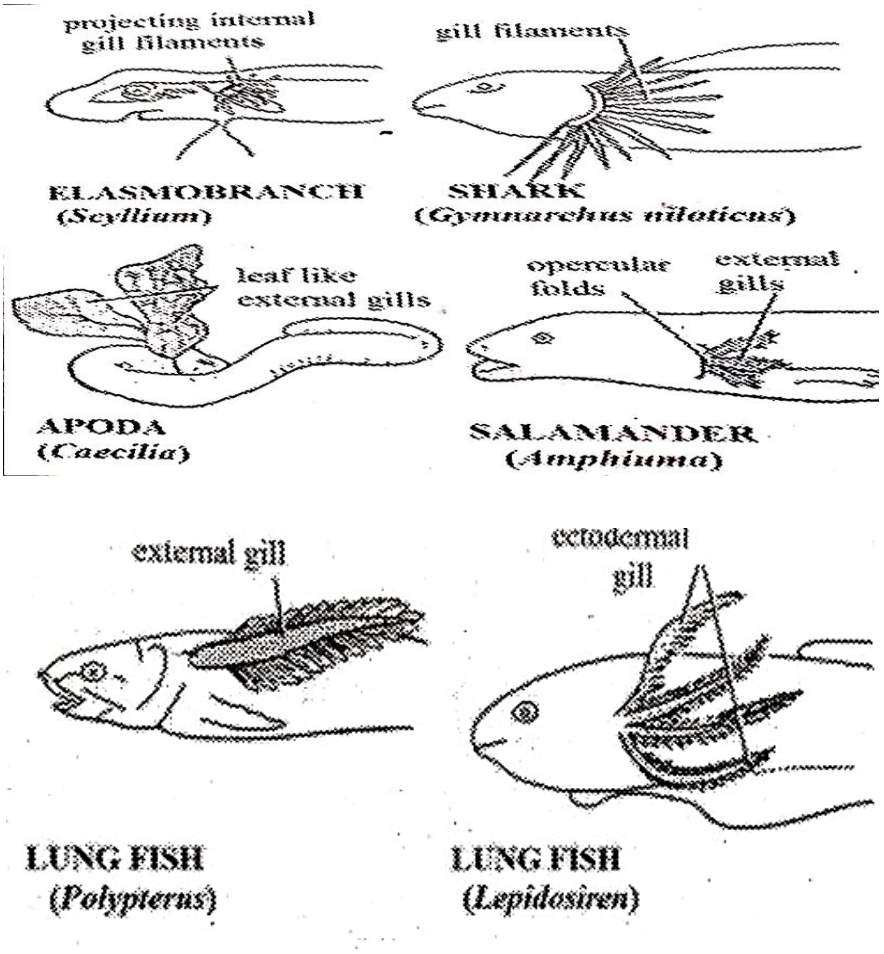
In a living cell exchange of gases through the respiratory surface i.e. to obtain O_2 and give off Co_2 for oxidation of organic substance (glucose) to produce energy is called respiration. The exchange of gases takes place at two places i.e. respiratory organ (lung or gill) and in tissues. During internal respiration or tissue respiration exchange of O_2 and Co_2 occurs between blood and tissues (cells) of the body. During external respiration, gaseous exchange takes place between blood and external environment (in aerial respiration within lungs and in aquatic respiration within water and gills surface). The system designed for the exchange of gases of O_2 and Co_2 between the organism and its environment is termed the respiratory system.

Gills

Fishes and amphibians used gills for their aquatic respiration. Amniotes do not utilize gills at any time in their embryonic or adult life. Besides exchange of gases at the surface of gills salt are also eliminated from the gills surface in marine teleosts. Gills are of two types on the basis of their position i.e. external gills and internal gills. In some animals both internal and external gills are present.

(1) External gills :- The external gills are formed as branching outgrowths from the exposed outer epithelium of gill arches and not from that of pharyngeal pouches. They are ectodermal in origin and usually temporary organs found only in larval stages hence called larval gills. External gills are rare in fishes, but some are found in some larval forms of lampreys, *Polypterus* has one pair external gills. Dipnoi (*Lepidosiren*) have four pairs of filamentous external gills attached to the outer edges of the branchial arches. In some tailed amphibians, external gills and gill slits are retained throughout life, but in some tailed and all tailless amphibians they are lost during metamorphosis and hence called larval gills. External gills are in direct contact with water and an exchange of gases occurs through their surface epithelium. Later an operculum arises and covers these gill clefts and gills externally in tadpoles so that the gills become enclosed in an opercular chamber lined with ectoderm. These external gills soon

degenerate and a new set of gills called internal gills develop from same visceral arches. In *Amphiuma* gills are absorbed but gill slits remain. Gills assume various shapes being pectinate, bipinnate, dendritic or leaf like. Each gill consists of a narrow main central axis bearing double row of filaments. These are richly vascularised by aortic arches.



Figc 6.11 : External gills of fishes

(2) Internal gills or true gills :- Fishes are characterized by the presence of internal gills. These are placed in the gill slits and attached to the visceral arches. In amniotes embryonic pharyngeal pouches do not communicate to the outside through gill-slits in the adults. Gills are not found in them.

Gill slits : - In embryo, the pharyngeal cavity is connected to the outside by series of lateral opening known as pharyngeal clefts or gill slits. The gill slits are present in the adult of cyclostomes, fishes and certain amphibians but become abolished in higher vertebrates. The number of gill slits is 6 – 14 pairs in cyclostomes, 5 – 7 pairs in sharks and rays and 4 pairs in most bony fishes. The gill slits are separates from one another by partitions called visceral or gill arches.

Gill slits of bony fishes are covered by operculum while operculum is absent in cartilaginous fishes. In sharks gill slits are laterally situated while in ray they are ventrally placed. A pair of spiracle is present in elasmobranch

anterior to first gill which corresponds to vestigial primitive first gill slit. The spiracle are absent or lost in bony fishes.

Structure of true gill

The gills are developed on the walls of gill pouches or gill arches. A gill is formed of two rows of a series of gill filaments or gill lamellae develop from the epithelium covering the interbranchial septum on both sides. Interbranchial septum extends outwards from the cartilaginous arch. A single row of gill filaments on one side of interbranchial septum forms a half gill called a hemibranch or demibranch. An interbranchial septum, with two hemibranchs (anterior and posterior) forms a complete gill or holobranch. Gill filaments are richly supplied with blood capillaries and it is here that exchange of gases with water take place.

Sharks and rays have generalized structure of gills. In higher bony fishes the interbranchial septum is lacking so that the hemibranches on the anterior and posterior part of each branchial arch are no longer separated from one another.

The gill aperture also no longer open separately to the outside. Instead, the gills are enclosed in a single chamber and covered externally by a large bony operculum which opens and closes posteriorly to permit water to pass to the outside. In most bony fishers there are four pairs of functional gills.

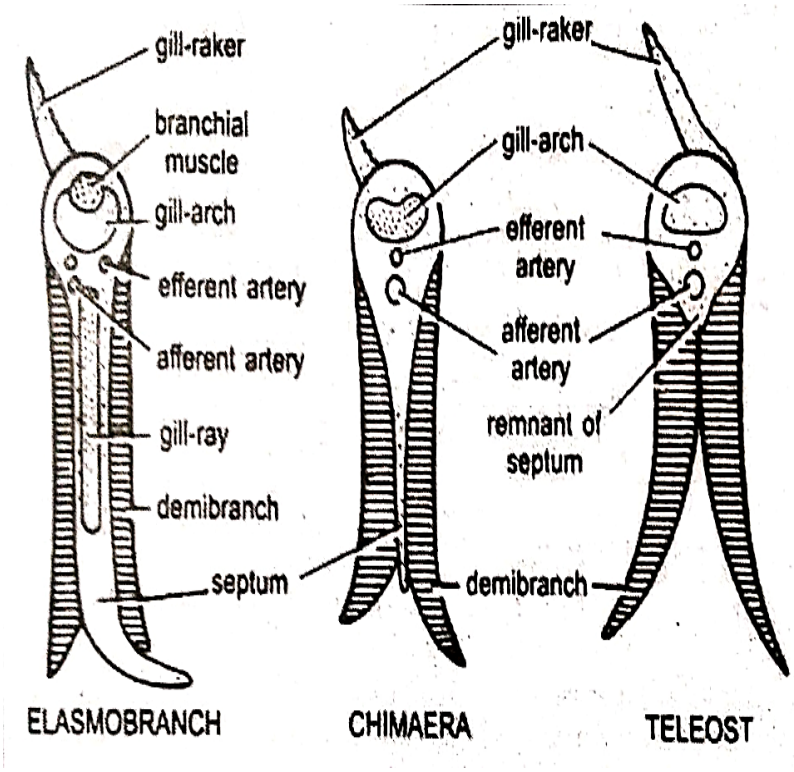


Fig 6.12 : Types of internal gills in fishes

Air Sacs

The respiratory tract of bird consists of following parts starting from external nares which open into nasal chamber. This open inside to the pharynx by internal nares. Through the glottis it opens into trachea. The anterior part of the trachea is called

larynx. It is not the sound box (compare to other it is sound box). The trachea leads to open into syrinx a some swollen structure which is the sound box of the bird. It is provided with internal and external tympanic membrane. After that the trachea divide into two branches called bronchi. This enters into the lung.

The lung of pigeon is bright red color, it is small, compact, inelastic, highly vascular and have no capable of expansion (other vertebrate the lung can store air). Lung cannot store air. They are solid, spongy and lie in the pleural cavity. From the dorsal and dorso-lateral side it is not covered by the peritoneal membrane. Only from the ventral side it is covered called pleuro or pulmonary aponeurosis and muscle attached with it is called costpulmonary membrane.

After entering the bronchi into the lung it does not divide and only lose the cartilaginous ring and called primary bronchus and it move toward the posterior end and is called mesobronchus it divide and give it gives the tertiary bronchi nor parabronchi. The lung parenchyma has hexagonal area which are surrounded by parabronchi and they have interlacing blood vessel and a system of air capillary. The air capillary is joint by parabronchi. The air capillaries have a vascular respiratory surface from which the gaseous exchange take place (compare to the vertebrate that they have alveoli for the respiratory surface but in bird has no alveoli). From the lung many air sac are arises.

From the mesobronchi secondary bronchi develop. In each lung 5 secondary bronchi develop which does not divide into tertiary bronchii develops. It passes through the wall of lung and their mucus membrane is dilated and form large air sac. The air sac are large, thin walled non-muscular, non-vascular and do not increase the respiratory surface. From the secondary bronchi of air sac arise the recurrent bronchi which connect the air sac to the parabronchi. So the pure air goes to the air capillary from air sac. There are 5 air sacs.

(i) **Inter clavicular air sac :-** It is in the median, somewhat triangular and connect the two lung by the secondary bronchi. It is present in between the angle of two limb of the furcula. From the inter-clavicular air sac two tubular like outgrowth, one of which enter into the cavity of humerus through the pneumatic foramen.

(ii) **Cervical air sac :-** This is a pair and arise from the anterior end the lung and goes the cervical region. It is on the dorsal side of the neck and along side of vertebral column. It gives out minor saccula branches to the neck.

(iii) **Anterior thoracic air sac : -** It arise from the anterior side and on the ventral side of the lung.

(iv) **Posterior thoracic air sac : -** It arise from the posterior side of the lung.

(v) **Abdominal air sac : -** It is large and arises from the distal end of the lung, it somewhat cover the intestine and abdominal portion.

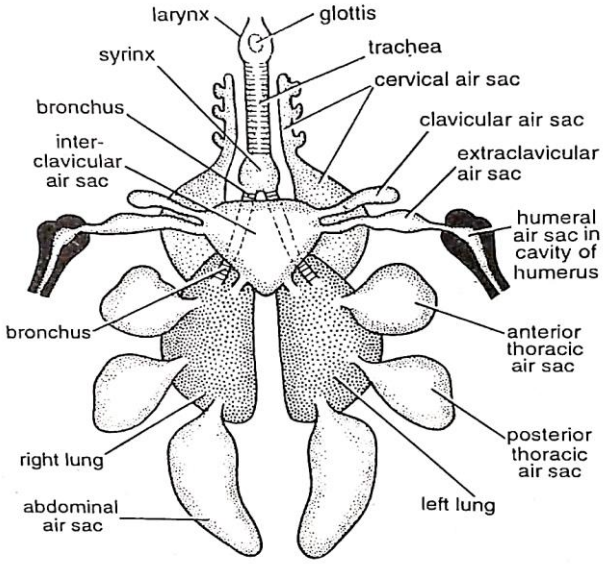


Fig 6.13 : Air sacs in Pigeon

Function of air sac

The air sacs are not respiratory organs. They lack blood capillaries so no exchange of gases takes place. They simply serve as reservoir of gases. It perform following functions

(a) **Lightness :** The air sacs probably act as balloons to provide lightness and buoyancy to the body, probably they reducing the specific gravity of the body, due to the contained warm air.

(b) **Flight :** Their association with flight is also confirmed by the fact that the best fliers amongst birds possess the most highly developed air sacs.

(c) **Accessory respiratory organs** : The air sacs principally function as the accessory breathing organs. Their smooth lining is without capillaries and does not take part in gaseous exchange. But they serve as reservoirs and take part in the movements of air during respiration. They take care of the residual or dead air, thus ensuring a complete renewal of air in the lungs at each breath. At each expiration, they acts as bellows forcing their air out through the lung, thus leaving no dead space or unrespired air in the lungs. It is claimed that the anterior air sacs e.g. interclavicular, cervical and anterior thoracic etc. expiratory and they are more active during flight. The posterior air sacs e.g. posterior thoracic and abdominal are inspiratory, they are more active when the bird is not flight.

(d) **Temperature regulation :** The birds have no sweat glands so air sacs help in temperature regulation. They acts as a cooling device by loosing body heat through internal evaporation or perspiration, that is water vapours diffuse from the blood into the cavities of air sacs and pass out through the lungs resulting in loss of body heat.

(e) Balancing during flight : The air sacs help in flight and also maintain proper centre of gravity during flight. This is possible because the air sacs are properly arranged on either sides of the body.

Swim Bladder

Swim bladder is a accessory respiratory organs. It is special respiratory structure present in addition to gills in some tropical fresh water fishes. Swim bladder is a sac like structure present between the gut and the kidney. It is also called as gas bladder or air bladder. It is generally develop in response to certain environmental conditions and enable the fish to tolerate oxygen deficiency or to sustain life out of water for short period. They are rarely present in marine fishes. The accessory respiratory organ are generally present in fishes living in shallow stagnant fresh water or hill stream fishes. The swim bladder lies dorsal to the alimentary canal beneath the vertebral column and kidney but outside the coelom. It arises as an outgrowth from the dorsal or lateral walls of the foregut and opens into the oesophagus by a pneumatic duct which is short and wide in lower teleosts and long and narrow in other. In specialized teleost it may be lost during the course of development. Air bladder is present in almost all bony fishes except few bottom dwellers in which it has lost. It is absent in elasmobranchs. The air bladder is filled with a mixture of gases like oxygen, carbon dioxide and nitrogen.

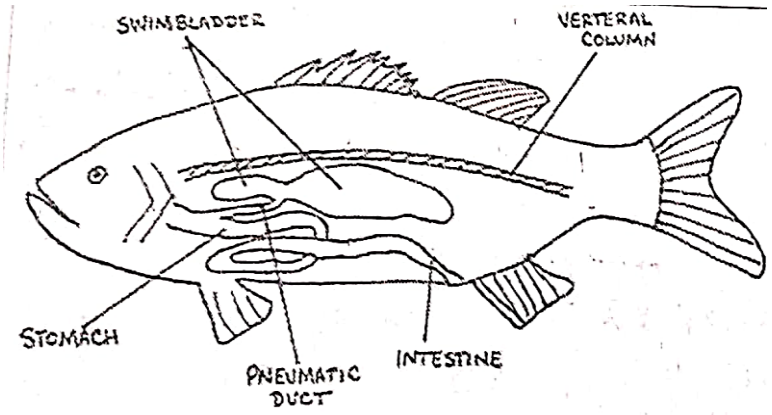


Fig 6.14 : Swim bladder in fish

The swim bladder varies greatly in structure, position, mode of development and functions in different groups of fishes are as follows.

(i) Chondrostei : In *Polypterus* is one of the most primitive bony fish and has the most primitive type of air bladder. It is in the form of a bilobed sac i.e. left lobe is smaller and the right lobe is larger with smooth walls. It opens ventrally into the oesophagus by a single duct.

(ii) Dipnoi or lung fishes : The air bladder is bilobed and equal in size. The walls are thick, highly vascular and alveolar. They open ventrally into the oesophagus by a single duct e.g. *Protopterus* and *Lepidosiren*. In *Neoceratodus* the air bladder is single lobed lying dorsal to the gut but open ventrally into the oesophagus by a narrow pneumatic duct. The walls are highly vascular and alveolar.

(iii) Holostei : In *Amia* and *Lepidosteus* the air bladder is single lobed, lies dorsal to the gut and opens dorsally into the oesophagus. The walls are thick, vascular and alveolar.

(iv) Teleostei : The air bladder in higher bony fishes is concerned mainly with hydrostasis and play little or no role in respiration. It is of two types physostomous and physoclistous.

(a) Physostomous : It is open type of air bladder, found in generalized teleost. It is of open type because it remains connected with the oesophagus by a pneumatic duct which opens dorsally as in *Amia* and *Lepidosteus*. The air bladder is single lobed with smooth and non-vascular walls. An intermediate stage is found in the teleost *Erythrynus* in which the pneumatic duct opens laterally into the oesophagus.

(b) Physoclistous : It is closed or ductless type of air bladder, found in more specialized teleosts. It is called ductless or closed type because the pneumatic duct is lost. The air bladder is single lobed, oval, thin walled, gas filled sac extending along the whole lengthy of the body cavity.

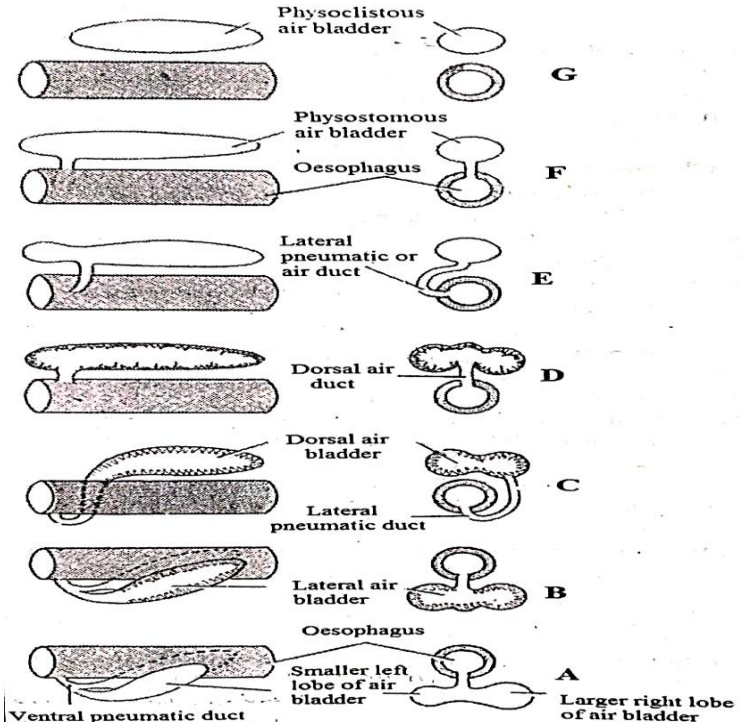


Fig 6.15 : Swim bladder in fishes

(A)*Polypterus* and *Clamoichlthytes*, (B)*Polypterus* and *Lepidosiren*

(C)*Neoceratodus*, (D)*Amia* and *Lepidosteus*, (E)*Erythrynus*, (F)Generalised teleost and *Acipenser*, (G) Specialized teleost

Functions of Swim bladder

The swim bladder of fishes perform a number of functions. These are as follows :-

(1) Hydrostatic organ : - The swim bladder serves as an important hydrostatic organ in fishes. By adjusting the amount of air inside it makes the density of fish more or less equal to that of its environment. So that it may swim with minimum effort. The fish becomes completely weightless in water and is kept in a state of equilibrium so that it is able to maintain itself in position with very little effort. Fish with well developed swim bladder, swim easily in mid-water as compared to those having a small or no swim bladder.

When the fish move from one depth to another, a decrease or increase in the volume of the swim bladder take place and there is a change in the density of the fish. This is compensated by a increasing or reducing of the gas inside the gas bladder. In case of physostomi fishes excess gas can be passed out through the pneumatic duct. Air can also be gulped in at the surface and forced into the bladder through the duct. In physoclistic, the gas is secreted or absorbed through bladder wall with the help of a gas secreting complex consisting of a retia mirabilia and the gas gland.

(2) Respiratory function :- The swim bladder act as lung or oxygen store house. In certain teleost fishes like *Megalops, Chirocentrus, Erythrinus, Umbra,* the gas bladder work like a lung. These fishes live in swamps or pools where carbon dioxide tension is high and that of oxygen is low. These teleosts come to the surface, swallow air and pass it back to the air bladder which is highly vascular. It appears that the lung like function has been reacquired in these teleosts as a special adaptation for living in foul water.

Swim bladder can also be used for storing oxygen to be used in emergency. In many fishes like *Cyprinus carpio, Carassius auratus* the amount of oxygen stored in the bladder would enable the fish to survive for s few minutes only, the swim bladder may be more important in deep water fishes where the amount of oxygen stored is much higher . Studies have shown that in fishes living nearer the surface the gas in the swim bladder is very much like air, while in those living at greater depths, oxygen forms a major components upto 75% in some species. In such a circumstance the swim bladder may be important as oxygen store.

(3) Sensory function :- When the fish is subjected to pressure changes by moving into different depths of water, compression or rarefaction of the enclosed air take place. This leads to deformation of the wall of the swim bladder which functions as a pressure receptor like barometer, hydrophone or manometer. It has been suggested that swim bladder act as a sense organ enables a fish to maintain a steady depth. If the fish moves above or below a certain depth at which it is in equilibrium, changes in the tension of the bladder wall lead to compensatory swimming movements and the fish returns to the original level.

(4) Auditory function : - Air bladder serves to transmit sound waves to the ear especially in the Ostariophysi, more efficiently than in the species in which a connection with the ear is missing.

(5) Sound production :- The swim bladder act as important part in sound production. It may act as a resonator for the sound produced by neighbouring organs as in Ballistidae or Trigger fishes. Sound is also

produced when the gas is released through the pneumatic ducts as in eel. In some species gas bladder wall vibrates due to an elastic spring apparatus or by the action of muscles attached directly to the wall e.g. in Scianidae, Triglidae and in toad fish. It has been concluded that sound produced by fishes serves for communication especially during the breeding season and may also be used for offence.

SAQs 2.

Complete the following sentences by inserting appropriate words in the blanks.

(i) ---------- are used for aquatic respiration found in fishes and amphibians.

(ii) The swim bladder is present inn almost all bony fishes and functions as a ----------

(iii) The swim bladder is filled with mixture of ----------

(iv) There are ---------- air sacs in modern birds.

6.4 SUMMARY

In this unit you will be study about the alimentary canal and digestive gland of different vertebrate animals like Cartilaginous fishes, Amphibian, Reptilia, Aves and mammal and you will also observed the difference in their structures.

In respiratory segment you will study about the structure and function of gills in fishes, Air sacs in birds and swim bladder in fishes in detailed.

6.5 TERMINAL QUESTION

Q1. Describe the liver of vertebrates.

Q2. Describe Pancreas in vertebrates.

Q3. Describe swim bladder in fish.

6.6 ANSWERS

SAQ 1

(i) Liver

(ii) Fish

(iii) four

(iv) Bile

SAQ 2

(i) Gills

(ii) Hydrostatic organ

(iii) Oxygen, carbon dioxide and nitrogen gases

(iv) 9

TERMINAL QUESTION

Ans 1. The liver is the largest lobed gland in the body, suspended by a double layer of peritoneum from the transverse septum or its representative. A gall bladder is for storage of bile secreted by the hepatic cells, lies in the liver and drains into the duodenum through common bile duct formed by the union of cystic duct and hepatic duct. A gall bladder is not indispensible and is lacking in many birds and mammals.

A liver is present in all vertebrate. In cyclostomes, it is small, single lobed (lampreys) and two lobed in hag fishes. It is bilobed in elasmobranchs, two or three lobed in bony fishes, amphibians, reptiles and birds and many lobed in mammals. Liver is long, narrow and cylindrical in fishes, urodeles and snakes.

It is short, broad and flattened in birds and mammals. A gall bladder and bile duct are present in larval cyclostomes but they are absent in the adult. Fishes, amphibians and reptiles generally have a gall bladder, but it is lacking in many birds. Most mammals have a gall bladder, but it is absents in cetacean and ungulate. The liver secretes watery, alkaline bile but have no enzymes. It neutralizes the acidity of food entering the duodenum. It aids in the digestion of fats.

Ans 2. Pancreas is present in all vertebrate and is second largest gland. Pancreas arises as one or two ventral diverticula from liver bud, and one dorsal diverticulum

from embryonic duodenum. It is endodermal in origin from embryonic archenteron. Distal portion of diverticula divide to from acinous type glands, one dorsal pancreas and one ventral pancreas. Both may persist as in fishes, but more generally the two unite to form a single gland in tetrapods. Proximal portion of diverticula form pancreatic ducts all of which may persist. But usually the ducts undergo reduction or fusion, so that only one or two pancreatic ducts remain as in mammals. The ducts open into duodenum separately or jointly or one of them may unite with the common bile duct.

Pancreas plays a dual role. It is partly exocrine secreting digestive enzymes through pancreatic ducts into duodenum and partly endocrine secreting hormones such as insulin. Pancreas is absent in lancelet. In lampreys, some teleosts, lungfishes and lower tetrapods, it is distributed diffusely in liver. In elasmobranchs and higher tetrapods, pancreas is well defined and compact.

Ans 3. Swim bladder is a accessory respiratory organs. It is special respiratory structure present in additional to gills in some tropical fresh water fishes. Swim bladder is a sac like structure is present between the gut and the kidney. It is also called as gas bladder or air bladder. It is generally develop in response to certain environmental conditions and enable the fish to tolerate oxygen deficiency or to sustain life out of water for short period. They are rarely present in marine fishes. The accessory respiratory organ are generally present in fishes living in shallow stagnant fresh water or hill stream fishes. The swim bladder lies dorsal to the alimentary canal beneath the vertebral column and kidney but outside the coelom. It arises as an outgrowth from the dorsal or lateral walls of the foregut and opens into the oesophagus by a pneumatic duct which is short and wide in lower teleosts and long and narrow in other. In specialized teleost it may be lost during the course of development. Air bladder is present in almost all bony fishes except few bottom dwellers in which it has lost. It is absent in elasmobranchs. The air bladder is filled with a mixture of gases like oxygen, carbon dioxide and nitrogen.

UNIT–7 CIRCULATORY SYSTEM AND URINOGENITAL SYSTEM

Structure (A) Circulatory system

Structure (B) Urinogenital system

Structure (A) Circulatory System

7.1 INTRODUCTION

The circulatory system is the transport system which carries oxygen and nutrient to the tissue of the body and removing the waste from them. The circulatory medium is nothing but a liquid connective tissue known as the blood. The blood is circulated throughout the body through artery and vein. Arteries are the blood vessel which carries the blood from the heart to the different part of the body likewise the vein which carries the blood from different part of the body to the heart. The circulation is being maintained by the central pumping station known as Heart.

In **1628 Willium Harvey** wrote a paper known as "**Matu de cordis**" which mean the motion of the heart in other word the circulatory medium. The circulatory system is mesodermal in origin. The heart keeps the blood in constant motion it is modified artery as well as the vein. The origin of heart is bilateral but it is unilateral in position e.g. mammal mostly. Heart in all vertebrate lies in ventral side. By the process of the differential growth & migration of the cells, many scattered mesenchyme or vascular cells appear in between the mesodermal plate & below the pharynx. Later these scattered cells form a pair of endothelial tube. In case of the bony fish, reptile & bird the endocardial tube is formed by the fusion of two vitelline veins, while in mammals the endocardial tube is formed from a single endothelial tube. The endocardial tube form the inner most lining or wall of the heart. Splanchnic mesoderm become more active so much that it descent below the endocardiual tube. Finally they fuse one another. At the same time the splanchnic mesoderm grow on dorsal side and fuses with other enveloping (covering) the whole endocardial tube. Later the splanchnic mesoderm form the muscular middle

layer myocardium and outer thin wall known as epicardium of the heart. Thus the cardic tube is made up of three layers, outer most thin layer - epicardium, middle more muscular myocardium and inner endocardium. The epicardium & myocardium are formed by splanchnic mesoderm while the endocardium is formed by the mesenchyme cell or the vascular cell. The cardial tube which is growing with in a limited space and fixed at two ends by a pericardium takes a turned of 'S'-shaped and develop into 4 compartment. The 1st which receive the blood is thin wall elastic compartment is known as sinus venosus. The sinus venosus opens into a 2nd little muscular chamber atrium which is muscular & contractile. In between this compartment develop thin walled structure known as valve. The atrium open into the 3rd compartment which is muscular compartment known as ventricle. The ventricle opens into a 4th compartment known as conus arteriosus or bulbus arteriosus which finally open into ventral aorta. The atrium and ventricle are the permanent chambers of the heart but the sinus venous and conus arteriosus are the temporary (accessory) compartment of the heart. The fishes are 2 chamber heart, amphibia, reptile are 3 chamber heart while crocodile, bird and mammal are 4 chamber heart.

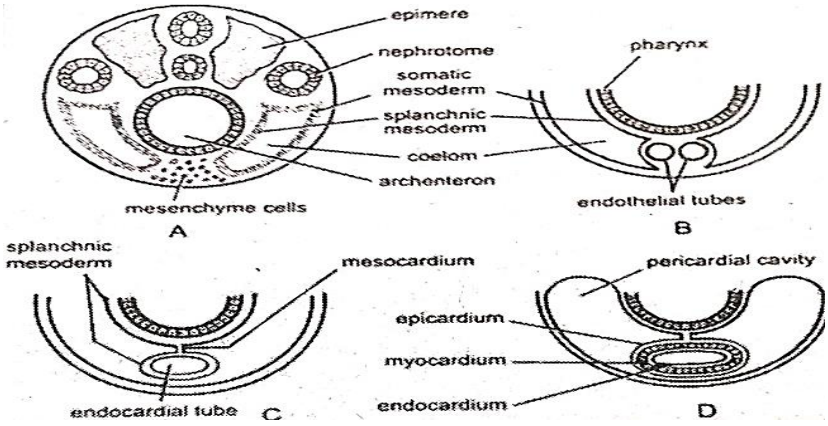


Fig : Various stages showing the development of heart

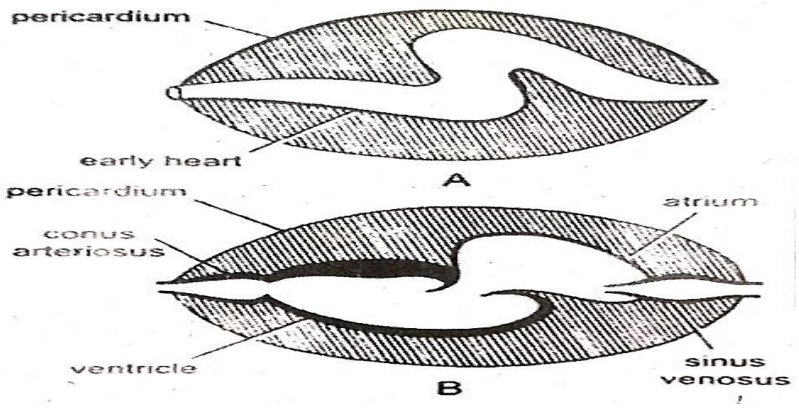


Fig 7.1 : Stage A & B showing the formation of chamber in heart

Objectives :

- Explain the evolution of heart and aorticarches in vertebrates.
- Describe the kidney and evolution of Urinogenital ducts.

7.2. EVOLUTION OF HEART AND AORTIC ARCHES IN VERTEBRATES

Evolution of Heart

Evolution of heart in vertebrate mean that various change which takes place in the heart of lower vertebrate to the higher vertebrate is known as Evolution of heart in vertebrate. The heart is in anterior region but due to the development of neck the heart shift or situated in the thoracic region. In all vertebrate heart is situated on ventral side. Evolution of heart in different animal are as follows

(a) Protochordata :- In *Amphioxus* the ventral aorta below the pharynx is contractile enough to send the blood forward therefore the ventral aorta of *Amphioxus* mask disposition of the heart of higher vertebrate which means the primitive condition of the heart of all the vertebrates is tubular and below the pharynx.

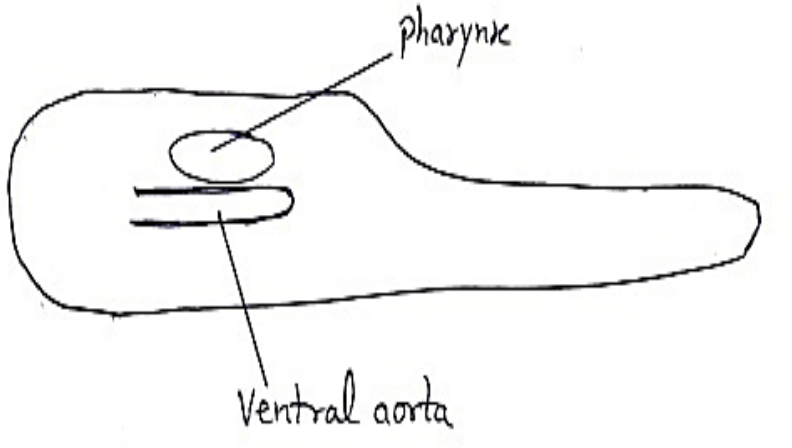


Fig 7.2 : Anterior region of *Amphioxus*

(b) Cyclostomes (*Petromyzon*) :- In cyclostomes the heart is primitive, two chamber and venous(Branchial). The heart consist of 4 compartments the thin walled sinus venous which is elastic and a receiving chamber. The sinus venosus receives the blood through lateral blood vessels known as ductus cuvieri and form the posterior region through hepatic vein or omphalomesentric veins. The sinus venosus open into a little muscular and elastic atrium through an opening known as sino-auricular aperture guarded by a pair of sino-auricular valves. The valve does not allow the backward flow of blood. The sinus venosus and atrium are receiving compartment of the heart. Atrium open into a muscular contractile ventricle through an opening known as atrio-ventriculo aperture guarded by atrio-ventricular valve. The ventricle open into or reduce into a muscular conus arteriosus. The conus arteriosus open into a ventral aorta. All these compartment are covered by a thin walled pericardium.

(c) *Scoliodon* or cartilaginous fishes :- In *Scoliodon* the heart is venous, dorsi-ventrally bent muscular tube consist of the various compartments. The sinus venosus is triangular, elastic situated transversely on the dorsal side of the

heart. The sinus venosus is situated at the base of pericardium. Sinus venosus is the receiving chamber receives the blood through ductus cuvieri from the posterior side. The atrium is dorsal, little muscular and receive the blood from the sinus venosus through sino-atrial aperture guarded by sino-atrial valve. The atrium open into ventricle which is ventral very muscular and contractile. The inner wall of the ventricle is provided with strands and ridges which gives ventricle a spongy texture. The flow of blood from atrium to ventricle is almost automatic or mechanical because the atrium lies above the ventricle. The atrium open into the ventricle through atrio-ventricular aperture guarded by atrio-ventricular valve. The ventricle is the forwarding chamber of the heart. The conus arteriosus is well developed, muscular and contractile. The inner wall of the conus arteriosus is provided with 2 row of semi-lunar valve and each row consists of 3 semi-lunar valve. The median valve is ventral and the others are ventro-lateral in position. On each side of the median valve is a pair of a small valve known as miniature or accessory valve. Conus arteriosus is the forwarding compartment opens into the ventral aorta carrying venous blood.

***(Note-** The intensity of curvature of heart is maximum in the higher vertebrate i.e. the atrium which was posterior in lower vertebrate become anterior in the higher vertebrate while the ventricle which was anterior in lower vertebrate has become posterior in higher vertebrate)*

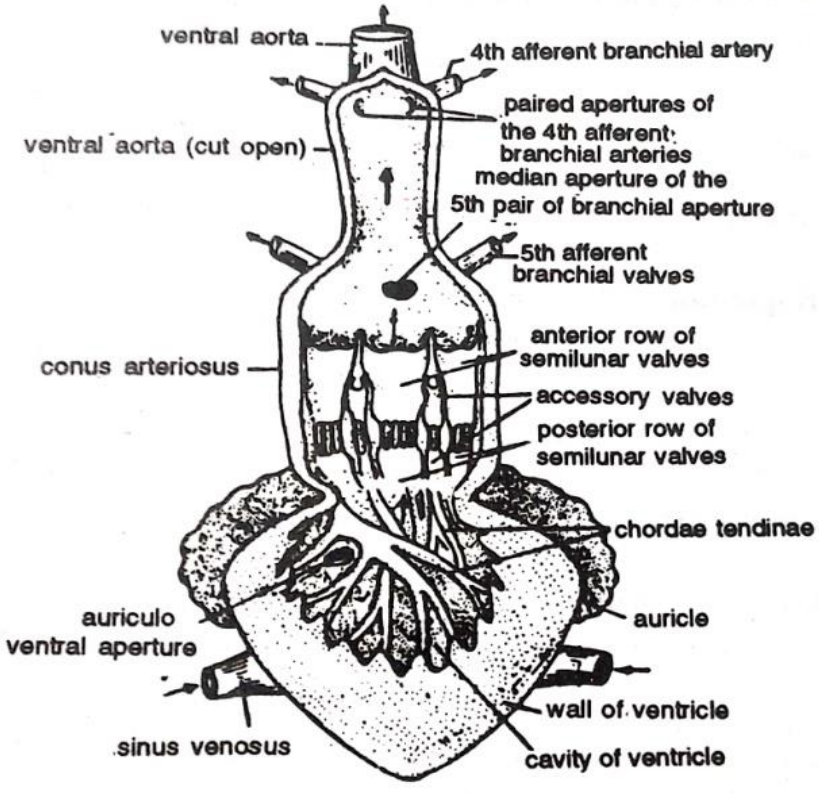


Fig 7.3 : Internal structure heart of *Scoliodon*

(d) **Bony fishes :-** The heart in case of bony fish is two chamber consist of 4 part i.e. elastic thin wall sinous venosus, little muscular and elastic atrium, muscular and contractile ventricle but conus arteriosus is very muscular like a bulb which is non- contractile and known as bulbous arteriosus.

(e) **Dipnoi** :- As soon as the lung breather introduce which influences the structure of heart and especially the atrium. The atrium divide incompletely by an inter-auricular septum living an opening known as foramen of ovale due to which the right and left auricle communicate with each other. There is a change in which a pulmonary vein develops bringing oxygenated blood from the air bladder (lung) to the left auricle. The heart is not venous but consist of oxygenated and deoxygenated blood which is known as pulmonary heart.

(f) **Amphibia or tetrapoda :-** The presence of different types of respiration like gills, lung, bucco-pharyngeal and skin influences the structure of heart like the intensity of heart curvature is maximum, the sinous venosus and conous arteriosus are reduced.

In Anura (frog) the sinous venosus is reduced and dorsal in position. It opens into the right auricle. The opening of which is guarded by sino-auricular valve. Sinous venous is elastic and thin walled and known as the receiving chamber of the venous blood. The auricles are completely divided by inter-auricular septa, dividing into a large right auricle and small left auricle. The left auricle receive the oxygenated blood through pulmonary vein opening of which is without valve. The heart is 3-chambered 2 auricles and 1 ventricle. The ventricle is muscular, contractile which receive blood from the auricle. The inner wall of the ventricle is provided with strand and ridges which are known as columnea carneae. The auricle open into the ventricle through a auriculo-ventricular aperture which is guarded by two pairs of flap like auriculo-ventricular valve. This valve is attached to the wall of ventricle by thread like structure called chordae tendineae. The conus arteriosus or truncus arteriosus reduced but well developed. The inner wall of conus arteriosus have spiral valve which is attached on dorsal side but free on ventral side. It divides the conus arteriosus in proximal pylangium and distal synangium,. The right cavity on the side of spiral valve is known as cavum aorticum and left is known as cavum pulmocutaneum. The distal portion of conus arteriosus as well as ventral aorta split into 2-trunck and each splitting dividing into 3 artery known as carotid, systemic and pulmocutaneous artery.

In urodela those having gill breather, heart is two chamber like fish and the conus arteriosus is without spiral valve but in lung breather urodela the atrium is completely divided by inter-auricular septum like dipnoi and conus arteriosus is without spiral valve.

In Apoda the atrium is completely divided by inter-auricular septum. The conus arteriosus is without spiral valve.

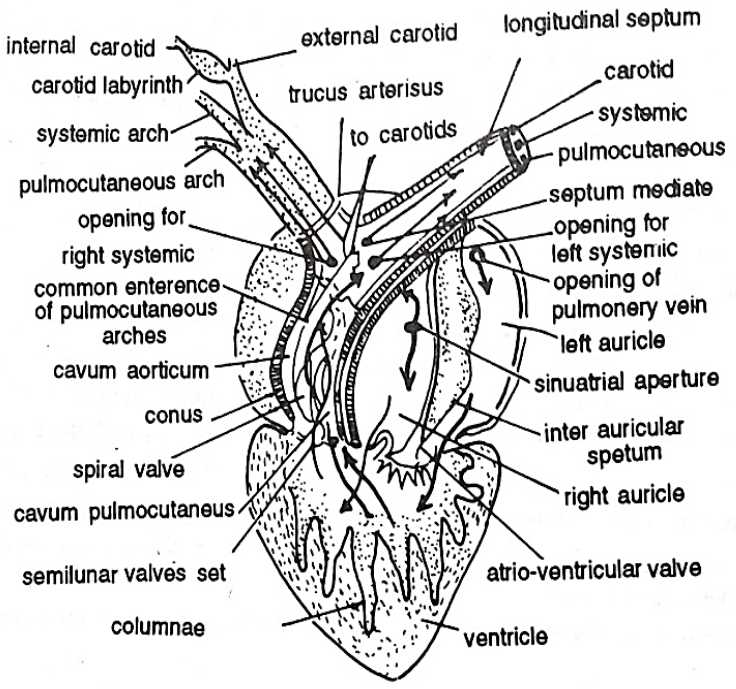


Fig 7.4 : Internal structure heart of Frog

(g) Reptila :- In Amniota the heart is much more muscular and large in size. It is mostly situated in thoracic cavity in mid ventral line except mammal. The blood vessel come closure to the heart i.e. vein they open more or less into the auricle because sinus venosus will disappear in the higher vertebrate. From ventricle arise arteries because the conus arteriosus has also disappeared. Most of the reptiles are lung breathing (Pulmonary respiration) except aquatic turtle, which respire by mean of lung and as well as by cloaca which has a decided influences on the structure of the heart. The heart in reptile is 3 chambered as well as 4 chambered. In *Uromastrix* has 3 chambered heart but the ventricle incompletely divided by inter-ventricular septum which arises from the apex of ventricle. In crocodile the heart is 4 chambered with 2 auricles and 2 ventricles.

In *Uromastrix* the sinus venous is bilobed and reduced and opens into the right auricle. The opening is guarded by valve. The pulmonary vein brings oxygenated blood and open into left auricle. The right auricle is always bigger then left auricle. The inner wall of right auricle with interlacing muscle which is known as musculi pectinati. The right and left auricle open into ventricle by atrio-ventriculo aperture guarded by valve. The ventricle is muscular which is incompletely divided by an interventricular septum arising from the apex. This interventricular septum divide the ventricle into a large cavity on the right side which is known as cavum dorsale and smaller on the left side is known as cavum pulmonale. The trunous arteriosus disappear and split and which arises directly from the ventricle. The opening of each is guarded by 3 semi-lunar valve. The right systemic which is also known as carotico-systemic arises from the left ventricle carrying oxygenated blood. From the right ventricle arises 2 aortic arches the inner

aortic arches is known as left systemic aortic arches because it travel to supplies the left side. The right and left aortic arches while communicate with each other by a common opening known as Foramen of Panizzae. From the outer side of the right ventricle arises 3rd aortic arch known as pulmonary aorta carrying de-oxygenated blood to the lung. The heart of lower reptile but the ventricle is incompletely divided, but in higher reptile like crocodile the heart is 4 chambered i.e. 2 auricles and 2 ventricles.

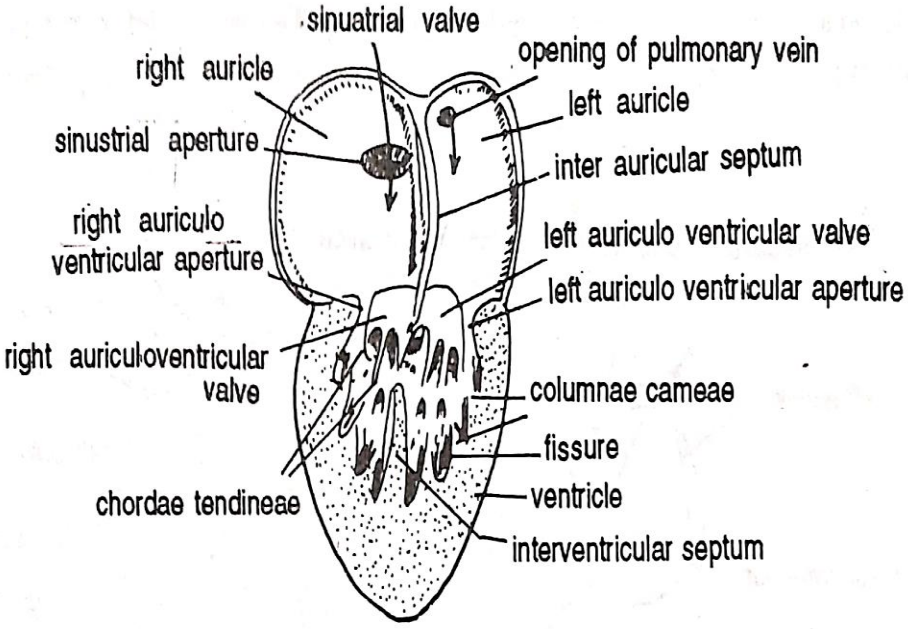


Fig 7.5 : Internal structure heart of *Uromastrix*

(h) Aves or Bird :- For the 1st time complete double circulation is observed. It is also known as closed circulation. This is due to complete pulmonary respiration. The heart in Aves is more muscular, compact and large in size. It is situated in the mid ventral region of the thoracic. The heart is covered by pericardium. The right auricle is larger then left auricle. The auricle and ventricle are demarked by a groove known as coronary sulcus or coronary groove. The sinus venosus disappear or fuses or incorporated with the right auricle. In the right auricle open 2- pre-cava and 1-post cava. The opening of the posterior vena cava is guarded by a valve known as eustachian valve. The right auricle opens into right ventricle which is guarded by a single valve monocuspid valve. The right ventricle is less muscular and is smaller then left ventricle because the left ventricle has to pump pure blood throughout the body. The left auriculo-ventriculo opening is guarded by bicuspid valve. The inner wall of the ventricle becomes thicker & muscular known as papillary muscle. The truncus arteriosus disappear and split in 2 aortic arches (*in reptile it split in 3 aortic arch*). The one which arises from the right ventricle is known pulmonary aorta carrying de-oxygenated blood to the lung. The opening of which is guarded by 3 semi-lunar valve. From the left ventricle arises the right systemic aorta carrying oxygenated blood to the body. It is also known as right carotico-systemic. In bird the left systemic is absent.

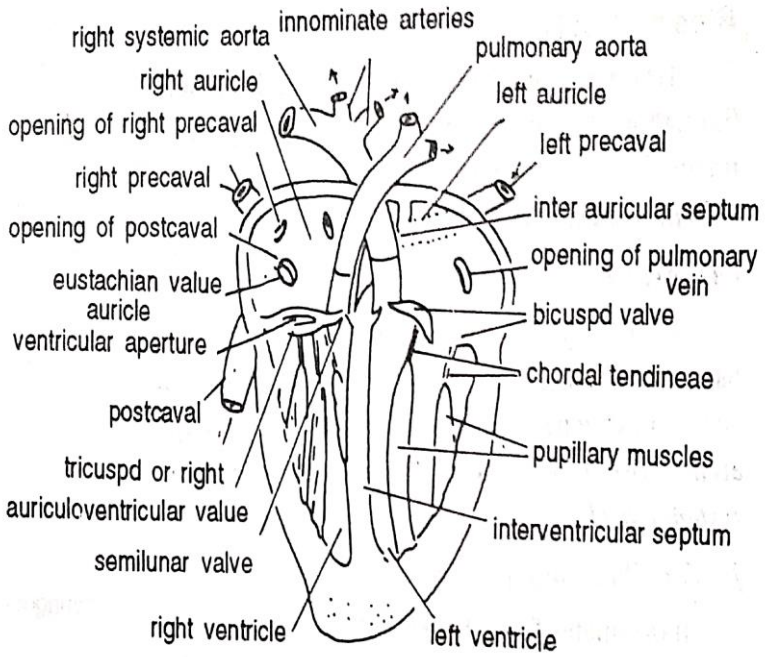


Fig 7.6 : Internal structure heart of *Columba*

(i) **Mammal :-** The heart of mammal is much more muscular compact and large in size. It is more or less pear shaped. It is mostly situated on the mid ventral line of the thoracic cavity. The mammalian heart is 4 chambers with 2 auricles & 2 ventricles. The sinus venosus and conus arteriosus are reduced. In human there is only one pre-caval vein and one post-caval vein. The pulmonary artery arises from right ventricle and a cartico-systemic arch arises from left ventricle. The heart is made up of 3 layer outer epicardium, middle myocardium and inner endocardium. The middle layer is much more muscular and made up of cardiac muscle. The cardiac muscles are of involuntary type. The right auricle is larger then left auricle. The eustachian valve is present at the post-caval vein. The mammalian heart supplies the blood to its own wall by coronary system. In the right auricle open a coronary sinus bringing the deoxygenated blood from the muscle of heart. The opening of which is guarded by coronary or Thebesian valve. In the left auricle open through pulmonary vein bringing oxygenated blood from the lung. The wall of left ventricle is much more muscular then right ventricle. The right auriculo-ventriculo opening is guarded by a tricuspid valve, which is the characteristic of mammalian heart. The left auricle-ventricle opening is guarded by a bicuspid or Mitral valve. The inner wall of the ventricle is well developed in a muscular structure known as papillary muscle. The pulmonary arch and carotico-systemic arch having 3-semi-lunar valve, which make the flow of blood from ventricle to arteries. From the cartico-systemic arches also arises coronary artery carrying oxygenated blood into the muscle of heart. Where the pulmonary arch crosses the cartico-systemic arches, the two arches are connected by

ductus arteriosus or botalli artery. Later this is blocked by ligament arteriosum and prevents the mixing of oxygenated and de-oxygenated blood.

In the right auricle there is sino-auricular node (S-A node) is present near the pre-caval vein. The other node is atrio-ventricular node (A-V node) is also present at the base of inter-auricular septum in the right auricle. From A-V node a bundle of muscle arises known as A-V bundle or Bundle of His. This give rise to fibres called fibres of Purkinje and distribute into the wall of ventricle.

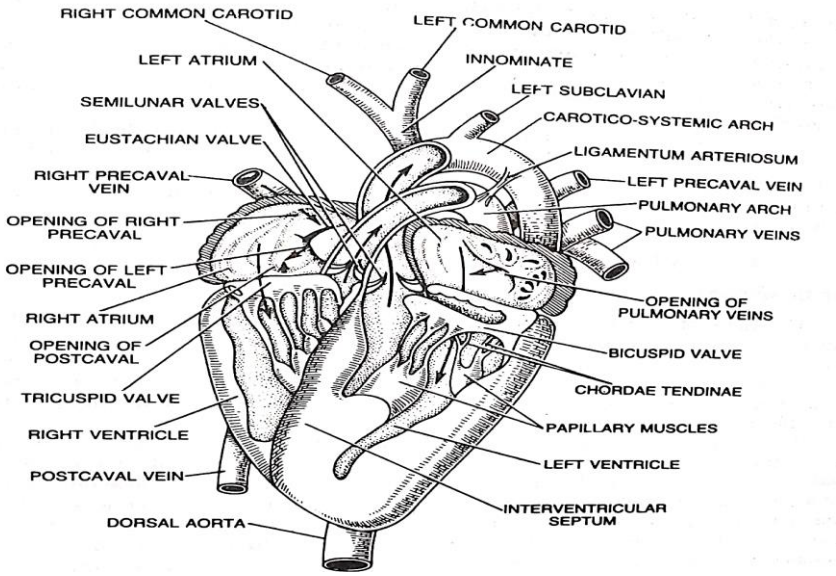


Fig 7.7 : Internal structure heart of Rabbit

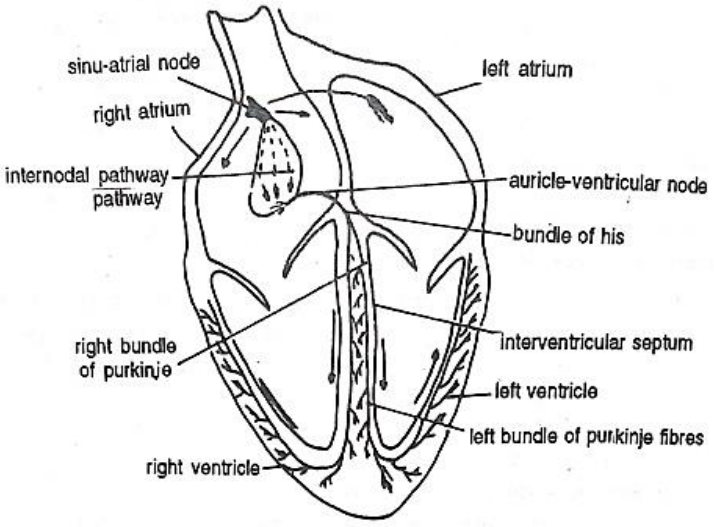


Fig 7.8 : Conduction of heart of Rabbit

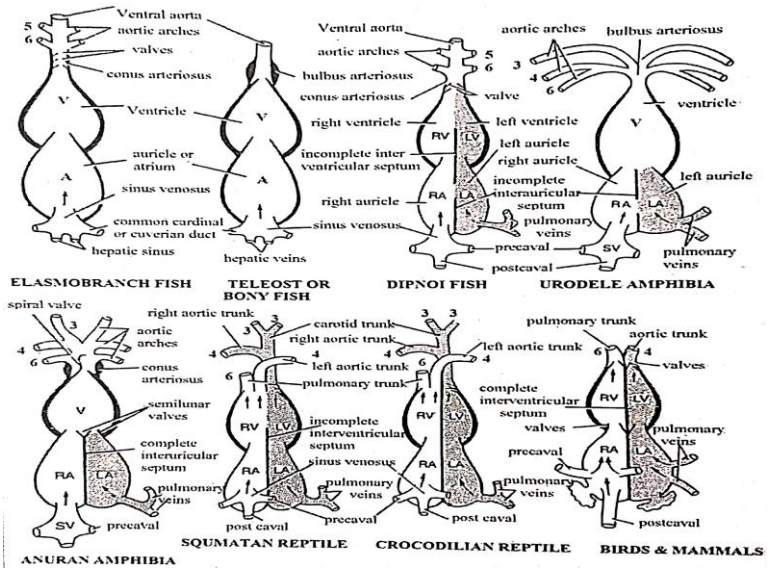


Fig 7.9 : Evolution of heart in different classes of vertebrates

Aortic arches in vertebrates

In all vertebrates the ventral aorta develops below the pharynx. It moves anteriorly and divided into two part which passes upward and backward on the dorsal side of the pharynx as lateral dorsal aorta or radix. The two lateral dorsal aorta behind the pharynx unit to form a single median dorsal aorta, which continue behind into the tail region as caudal arteries. The branches from these main arterial channels supply all parts of the vertebrate body. In the mean time connection between the ventral aorta and dorsal aorta is brought by usually 6 pairs of aortic arches. The 1st pair of aortic arches is known as mandibular aortic arch. The 2nd is hyoid arches and rest are known as 3rd, 4th, 5th & 6th aortic arches. Each aortic arch consists of ventral afferent branchial artery carrying venous blood to capillaries in the gill and dorsal efferent branchial artery taking arterial blood from the gill. All the efferent branchial arteries of same side join to form lateral dorsal aorta or radix which extend into the head as the internal carotid artery.

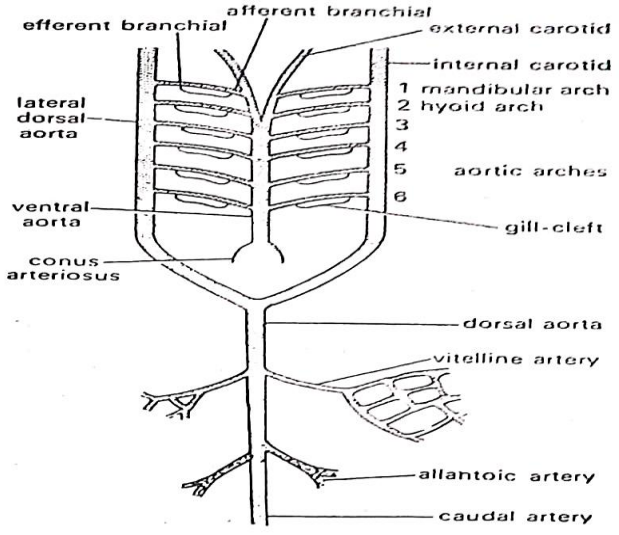


Fig 7.10 : Basic pattern of aortic arches and arteries

Modification of Aortic arches

In branchiostoma (*Amphioxus*) 60 pairs of aortic arches are present. In *Petromyzon* 7 pairs of aortic are present. There is a progressive reduction in the number of aortic arches from lower vertebrate to higher vertebrate. The position of aortic arches are varying. The position of the aortic arches in gill breather found in pharyngeal region while in the case of lung breather it is found in thoracic region. The different type of respiration influences the structure of heart as well as aortic arches as follows.

(a) Gill or branchial breathing vertebrate

(b) Gill as well as lung breather

(c) Pulmonary breather or lung breather

Pisces

In *Scoliodon* I^{st} aortic arch disappear, only II^{nd}, III^{rd}, IV^{th}, V^{th} & VI^{th} aortic will remain. In bony fishes I^{st} & II^{nd} aortic arches disappear, only III^{rd}, IV^{th}, V^{th} & VI^{th} aortic arches are remain. In dipnoi (lung fishes) I^{st} & II^{nd} aortic arches disappear, only III^{rd}, IV^{th}, V^{th} & VI^{th} aortic arches are present. In dipnoi as gill are poorly developed, so the pulmonary artery arises from the efferent part of VI^{th} aortic arches on each side and supplies blood to air bladder or lung. The VI^{th} aortic arch is complete because a connection develop into pulmonary artery and dorsal aorta. This connection is called ductus arterious

Tetrapoda

In tetrapoda as true internal gill is absent so that aortic arches does not break up into afferent and efferent arteries. The I^{st} and II^{nd} aortic arches also disappear.

Amphibia

Urodela :- In Urodela (tailed amphibian) external gill are present along with lungs. I^{st} & II^{nd} aortic arches disappear, only III^{rd}, IV^{th}, V^{th} & VI^{th} aortic arches are present and of which V^{th} aortic arch is reduced or absent. The aortic arches are not broken by gill into afferent and efferent because branching arising from IV^{th}, V^{th} & VI^{th} aortic arches into the external gills. The III^{rd} aortic arch form carotid arch, IV^{th} form systemic arch. The lateral dorsal aorta between III^{rd} & IV^{th} aortic arches are known as ductus caroticus. From the VI^{th} aortic arches a pulmonary artery grow on each side taking blood to a lung, the portion of the VI^{th} aortic arch between the pulmonary artery and lateral dorsal aorta is known as ductus arteriosus (duct of botalli).

Anura :- In Anura (tailless) amphibian the I^{st}, II^{nd}, V^{th} aortic arches disappear. The lateral dorsal aorta between III^{rd} & IV^{th} disappear. The connection between the pulmonary artery and lateral dorsal aorta i.e. ductus arteriosus is also disappear. So the VI^{th} aortic arches become the pulmonary artery.

Reptilia :- In Reptilia only III^{rd}, IV^{th} & VI^{th} aortic arches are present. As there is partially separation of ventricle into two part, the distal portion of conus arteriosus and entire ventral aorta is split into 3 vessel i.e. two aortic or systemic and one pulmonary artery. The right systemic arches arising from left ventricle giving oxygenated blood to the carotid arch (III^{rd}) to send into head. The left systemic

arising from right ventricle. The pulmonary artery arises from right ventricle carrying de-oxygenated blood to lung for purification. The ductus carotricus and ductus arteriosus absent. But ductus caroticus is present in certain snake and lizard (*Uromastrix*) and ductus arteriosus is present in some turtles. Both ductus caroticus and ductus arteriosus is present in sphenodon.

Aves :- In bird IIIrd, IVth &VIth aortic arches are present. In bird as there is complete division of ventricle into right and left ventricle. The conus arteriosus and ventral aorta have split to form two vessel, right systemic aorta arising from left ventricle and pulmonary aorta arising from right ventricle. The left systemic arch form the left subclavian artery and rest will disappear. The IIIrd form carotid, IVth form systemic and VIth aortic arch form the pulmonary artery.

Mammal :- In mammal IIIrd, IVth & VIth aortic arches are present. In mammal conus arteriosus & ventral aorta split into two vessels i.e. (i) only left systemic arch is present and it arise from left ventricle. The right systemic form an innominate and right subclavian artery (ii) a pulmonary artery from the right ventricle. The ductus arteriosus degenerate, but it persist in a reduced form on the left side as thin ligamentum arteriosum.

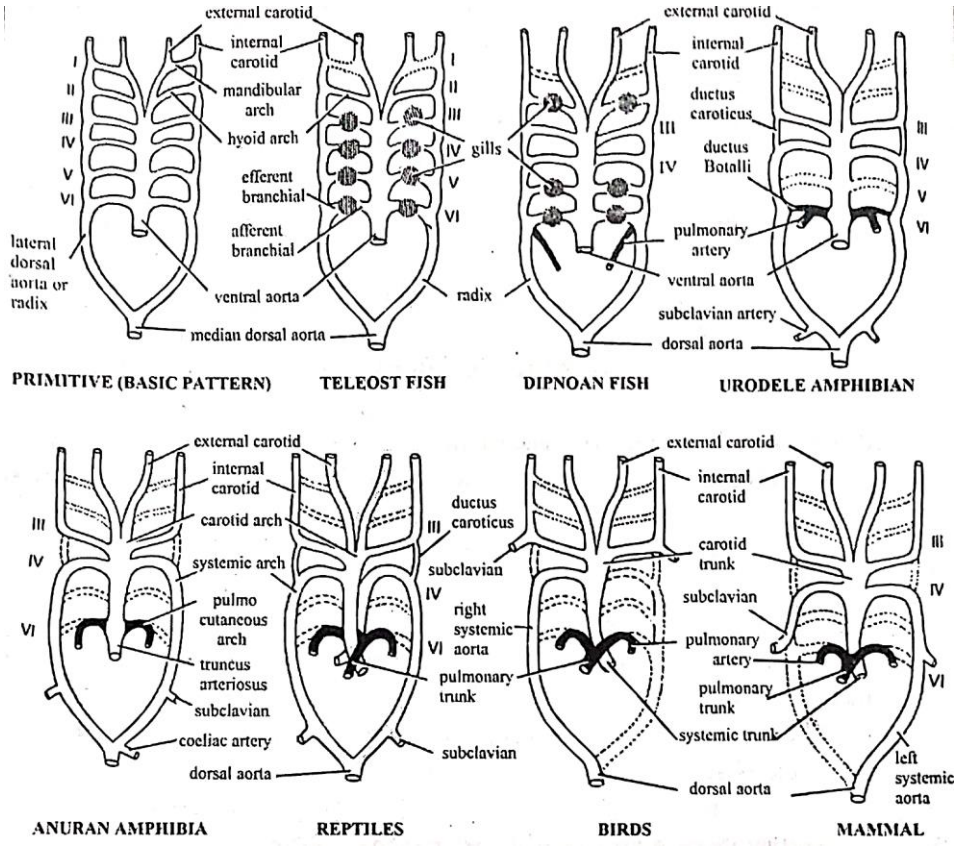


Fig 7.11 : Modification of aortic arches in vertebrates

SAQs 1.

Complete the following sentences by inserting appropriate words in the blanks.

(i) The heart is an unpaired organ but its origin is ----------

(ii) In most fishes, the heart is ---------- chamber.

(iii) Sinus venosus in frog is formed by the union of ----------

(iv) In all tetrapoda the ---------- arches disappear.

Structure (B) Urinogenital System

7.3 SUCCESSION OF KIDNEY AND EVOLUTION OF URINOGENITAL DUCTS

The end products of metabolism are waste substances like carbon dioxide, urea, ammonia, uric acid, pigment, creatinine and some inorganic salts. Carbon dioxide is removed through the skin and gills or lungs, but the others are excreted through the kidney. Kidney is situated on the roof of abdominal cavity in pelvic region and attached to the dorsal wall of the body cavity and ventrally the kidney is covered by coelomic epithelium. Each kidney consists of a mass of uriniferous tubules or renal tubules and opens into a duct ureter or urinary duct, which runs behind to open into the cloaca.

The excretory system consists of paired tubules opening on one hand to the coelom and on the other side into a longitudinal duct. The coelomic opening is in the form of a ciliated funnel is known as peritoneal funnel. The funnel leads into a narrow neck, which widens to form a thin walled chamber, the bowman's capsule. On one side of bowman's capsule is pushed in by a bunch of afferent and efferent arterioles of the vascular system which form the glomerulus. The bowman's capsule and glomerulus are collectively called malpighian body. In different group of vertebrates these are present in varied form. The variations are mainly co-related with different environmental condition.

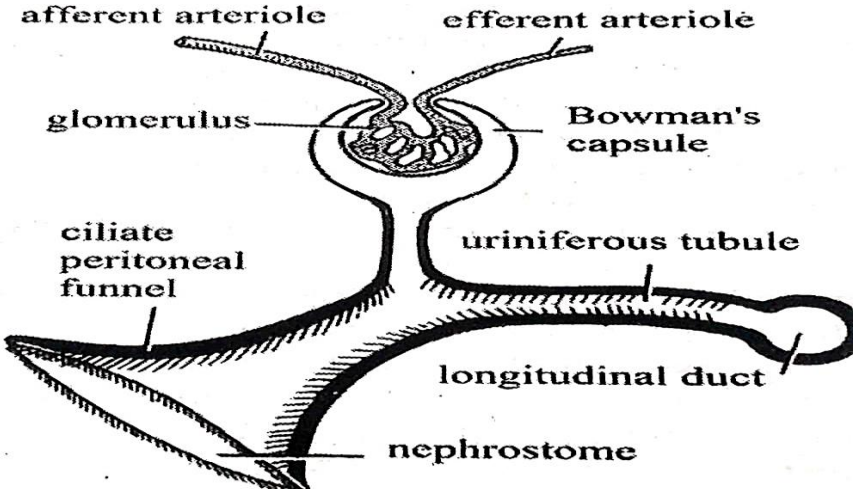


Fig 7.12 : Structure of an embryonic kidney tubule

Development:

Each uriniferous tubules develops from a special mass of mesoderm that lies between the dorsal somite and ventrally unsegmented lateral plate. This special mass of mesoderm is called mesomere or nephrotome and the cavity which contain

is called nephrocoel. Internally the nephrocoel communicate with dorsal myocoel and ventrally splanchocoel. Soon the nephrocoel become cut off from the somite above but its connection with the body cavity persist as the peritoneal funnel. In meanwhile from the lateral wall of nephrotome arise a diverticulum that grows outwards the ectoderm forming the glandular tubule ultimately. The diverticulum are blind at first, elongated send backward and fuses at their distal ends to form the longitudinal duct, which goes freely backward, between the ectoderm and somatic wall of the coelom and extend upto the embryonic cloaca. The kidney tubules which are formed in anterior region are called head kidney or pronephron. Later behind the pronephros is another type of kidney arise called mesonephros. In aminota there is also a kidney formed behind the mesonephros is called metanephros which is adult kidney and is functional kidney.

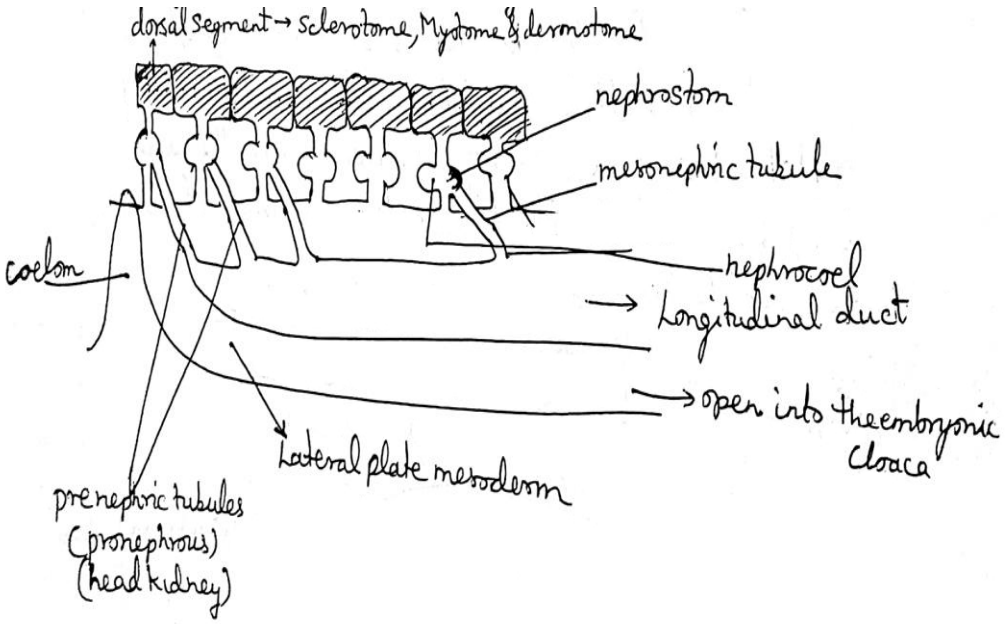


Fig 7.13 : Origin & Development of nephric tubule

Ancestral Kidney

Primitive vertebrate possess a pair of archinephric kidney or holonephros, which contain a pair of archinephric duct located on the dorsal side of the cavity and extending the length of coelom. Each archinephric duct secreted the opening of series of segmentally arranged tubule. Each tubule open on one hand into the coelom by independent ciliated funnel, nephrostome and on the other into the archinephric duct. It is presumed that the various kidneys of present day might have been derived from archinephric type of kidney. The occurrence of archinephric kidney in the larva of *Myxine* and some apodon amphibians support this view.

In present day vertebrates the uriniferous tubules develop anterio-posteriorly in two or three stages in succession, these stages are pronephros, mesonephros and metanephros. All these stages have been evolved from the original archinephros.

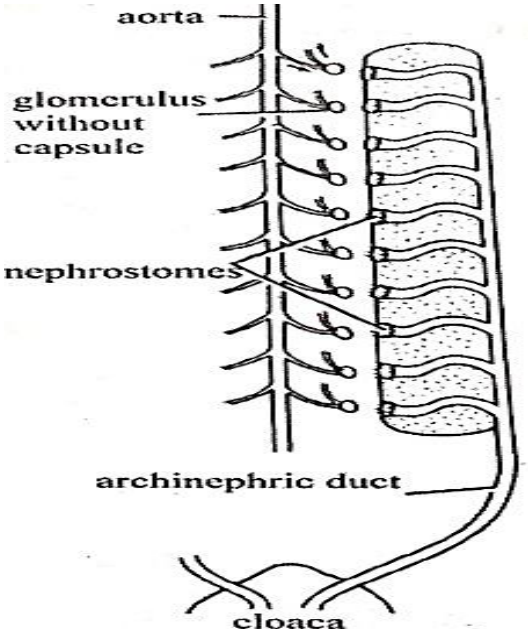


Fig 7.14 : Primitive ancestral vertebrate kidney or archinephros

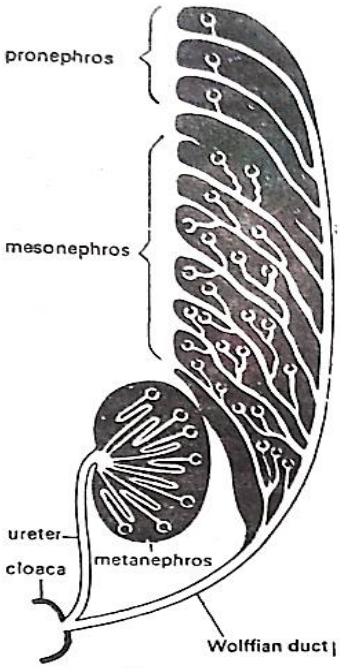


Fig 7.15 : A plan of pronephros, mesonephros and metanephros

Pronephros

The first kidney tubules formed in the anterior most part of the nephrostome is called pronephros, which is also the first kidney phylogenetically speaking. It is formed in the anterior end of the body and consists of 3-15 pair of (3 pair in larval kidney of frog, in human embryo -7 pair, in chick embryo-12 pair) tubule in each. One pair in each segment. The tubules of each pronephros open into a common pronephric duct which grow back to enter the embryonic cloaca. Usually the pronephric tubules do not have individual glomeruli but a single large glomerulus in which a formation of large pronephric chamber, in this chamber a

large single glomerulus called glomus is situated. So this is not covered by bowman's capsule and it is called external glomeruli (compare to internal glomeruli which is surrounded by bowman's capsule).

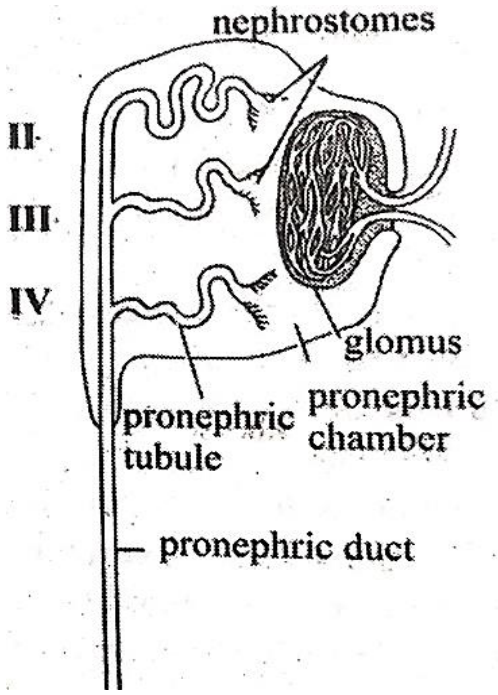


Fig 7.16 : Pronephric kidney

A pair of pronephric appear in all vertebrate embryo but they become functional kidney only in some cyclostomes and embryo of all anamniotes, in others they degenerate during development but the pronephric duct persist. In those vertebrates in which pronephric become adult kidneys, they are called head kidneys e.g. *Myxine* and some teleosts.

Mesonephric

Mesonephros develop from the intermediate mass of nephrotome just behind the pronephric region. These kidney tubules arise from the nephrogenous tissue in the similar fashion as the pronephric tubules. These tubule opening into the pre-existing pronephric duct. Early the tubule are segmental in fashion i.e. one pair tubule contain in each segment. Later the secondary and tertiary nephric tubule develop in the mesonephric by the budding, with that result the segmental nature is all lost. The no of the tubules gradually increase. Later mesonephric tubules may have no peritoneal funnel, even the connection of the primary mesonephric tubules is cut off. Each and every mesonephric tubule acquire its individual internal glomeruli, Hence the nitrogenous waste is directly drawn into the mesonephric tubules. Mesonephros originally extend to 35 – 37 somite in *Squirlus*. In frog 6^{th} - 11^{th} myotomic segment are involved in the development. Mesonephros is the functional adult kidney of fishes and amphibian. They also form the kidney of embryo of amniotes in which they degenerate at the time of hatching or born, when the function is taken up by metanephros.

The mesonephros of anamniotes is not exactly equivalent to that of amniotes embryo. In anamniotes the mesonephros extends through the length of the coelom behind the pronephros and is formed from the entire nephrotome left behind the nephros. While in amniotes embryos the mesonephros is formed only from the middle part of the nephrotome and it does not extend through the length of the coelom hence the term opisthonephros (opistho mean behind) is used for the kidney of all adult anamniotes.

In elasmobranch and upto some extend in amphibian the embryonic mesonephric duct split up longitudinally upto anterior end of the mesonephros forming 2-separate duct opening separately in cloaca. The duct which remain connected with the mesonephros is known as wolffian duct, where as the duct remain connected with degenerate pronephros is known as mullerian duct. In female the mullerian duct form the oviduct carrying ova to cloaca but in male the mullerian duct degenerate along with degenerating pronephros. In male some of the anterior mesonephric tubule lose their excretory function and going across mesorchium established connection with gonad forming vasa efferentia, carrying sperm to urino-genital duct. In anamniotes and amniotes the mullerian duct is form different. The invagination form in the peritoneum covering ventro-lateral part of the kidney form the rudiment of mullerian duct which run backward as duct to open cloaca or its derivates.

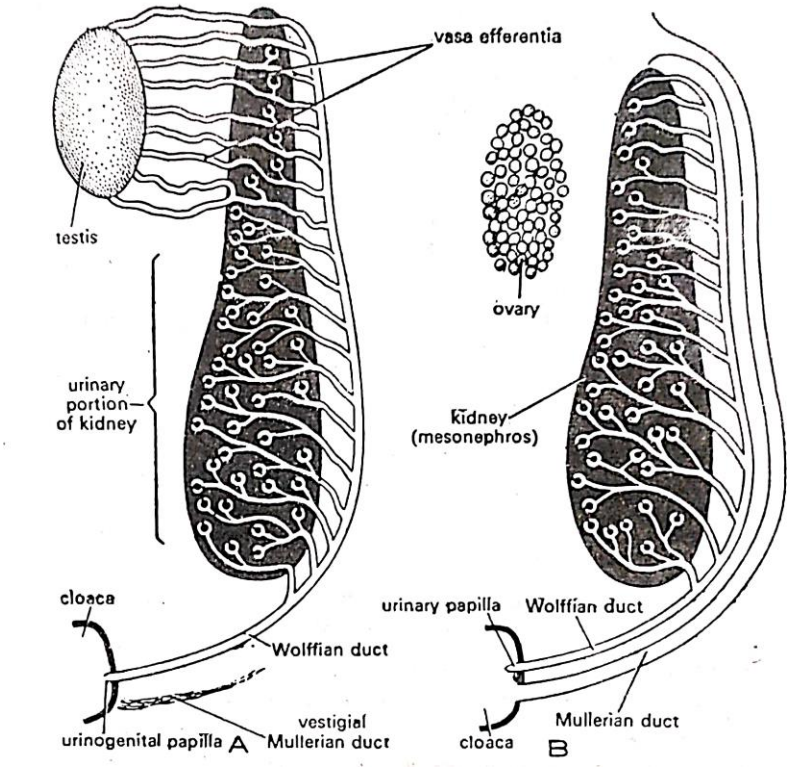


Fig: Development of mesonephric kidney and genital ducts in anamniote

(A) Male (B) Female

Metanephros

Metanephros is the functional adult kidney of amniotes i.e. reptile, bird and mammal. Metanephros develop from the caudal end of nephrogenic mesoderm. As

metanephros develop quite late when all the traces of segmental arrangement is lost. It is not possible to say that how many segments take part in its formation. While in the nephrogenic mesoderm a diverticulum arises from the caudal end of the embryonic mesonephric duct known as metanephric bud. The diverticulum grows dorsally into the caudal end of nephrogenic mesoderm. In so going it carries a cap of tissue at anterio-lateral. The metanephros tissue is displace laterally during development. From the distal end of diverticulum later on form metanephric duct or ureter. Metanephric duct grows into the nephrotome or nephrogenic mesoderm where it divides into branches. The branches form collecting tubule. As soon as the collecting tubule is form nephrotome gives rise to metanephric tubule. Simultaneously open into collecting tubule. Later on caudal portion of the embryonic duct (mesonephric duct) merges into the wall of cloaca. So that metanephric duct or ureter now open directly into cloaca or its derivative or may urino-genital sinus. The metanephric tubule do not acquire a peritoneal funnel at any stage of development. Each nephros has its individual internal glomerulus. The metanephros starts function at the time of hatching or birth when mesonephros degenerates.

In female mesonephric duct also degenerate along with the mesonephros but in male mesonephros degenerate but mesonephric duct is retain along with some anterior mesonephric tubule. The mesonephric duct form the spawn duct or vasa-deferens and the anterior mesonephric tubule which loses excretory function and established with testis giving rise vasa-efferentia. The mullerian duct that develops in amniota in each sex is retain. In female forming oviduct while in male it degenerate. The metanephric duct form a sole excretory duct carrying urine to cloaca or its derivatives.

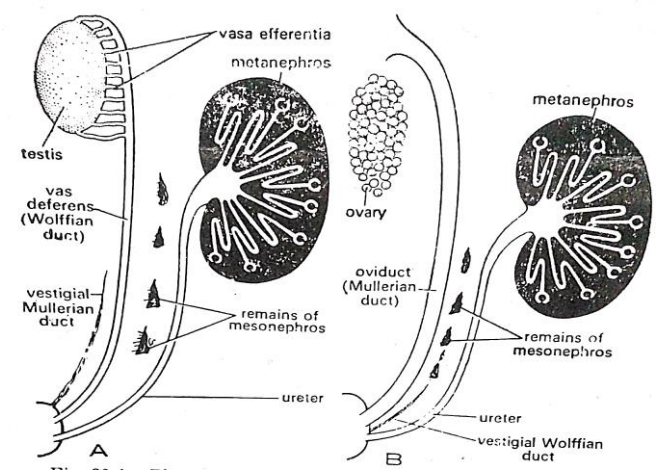


Fig 7.18 : Development of metanephric kidney and genital ducts in amniotes

(A) Male (B) Female

Evolution of Urinogenital ducts

Male Genital ducts

In cyclostomes gonads are unpaired and genital duct are absent. Testes are paired in other vertebrates and are usually found attached to the kidneys.

In anamniotes the anterior portion of the mesonephric kidney comes to serve the male genital system and the posterior part as renal organ. The mesonephric kidney of adult anamniotes has an anterior genital portion and a posterior renal portion. The mesonephric duct is a urinogenital duct in male, it serves both as a urinary duct for urine and as a vas deferens for sperms. But in many elasmobranchs (e.g. *Scoliodon*) special accessory urinary ducts are formed, one for each kidney to drain urine for kidney to cloaca and the mesonephric duct is only genital in function and is a vas deferens. The anterior genital part of kidney with a part of mesonephric duct forms the epididymis.

In amphibians testes are paired and are connected directly or by way of mesonephric tubules to the archinephric duct which in turn opens into the cloaca.

In male amniotes the adult functional kidneys are metanephric, each has its own ureter for conducting urine, hence, the persistent mesonephric duct is taken by the testis and becomes an entirely genital vas deferens.

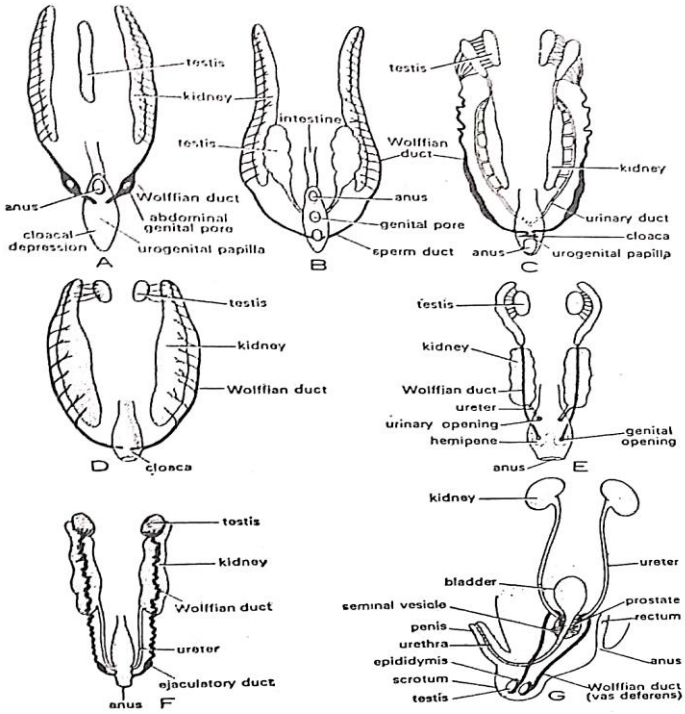


Fig 7.19 : Reproductive and urinary ducts of male vertebrates

A-Cyclostome, B- Teleost, C-Elasmobranch, D-Amphibia,

E- Reptile, F- Bird, G- Mammal

Female Genital ducts

The ovary are not connected with the kidneys and also with their genital ducts in most vertebrates, hence ova pass into the coelom after being discharged.

In female anamniotes acoelomic funnel is formed from the nephrotome, the funnel grows back to form a groove on each side. The groove become closed to form a tube known as oviduct or mullerian duct which lies on the outer side of the mesonephric duct and runs backwards to join the cloaca. A mullerian duct also appears in the male, but it is suppressed by androgen and it soon becomes vestigial.

Thus, there are two ducts on each side in female anamniotes a mullerian duct acting as an oviduct and a mesonephric duct serving as a ureter. But in most elasmobranchs the original pronephric duct splits longitudinally to form two ducts, one becoming the mesonephric duct for urine and other forming an oviduct for ova which appropriates one or more peritoneal funnels to form its opening into the coelom.

In female amniotes the development of mesonephric and mullerian ducts is the same as in anamniotes, but the adult kidneys are metanephroi, each with its own ureter, hence mesonephros and its duct degenerate leaving only vestiges. The mullerian duct acts as an oviduct and the metanephric duct as the ureter on each side.

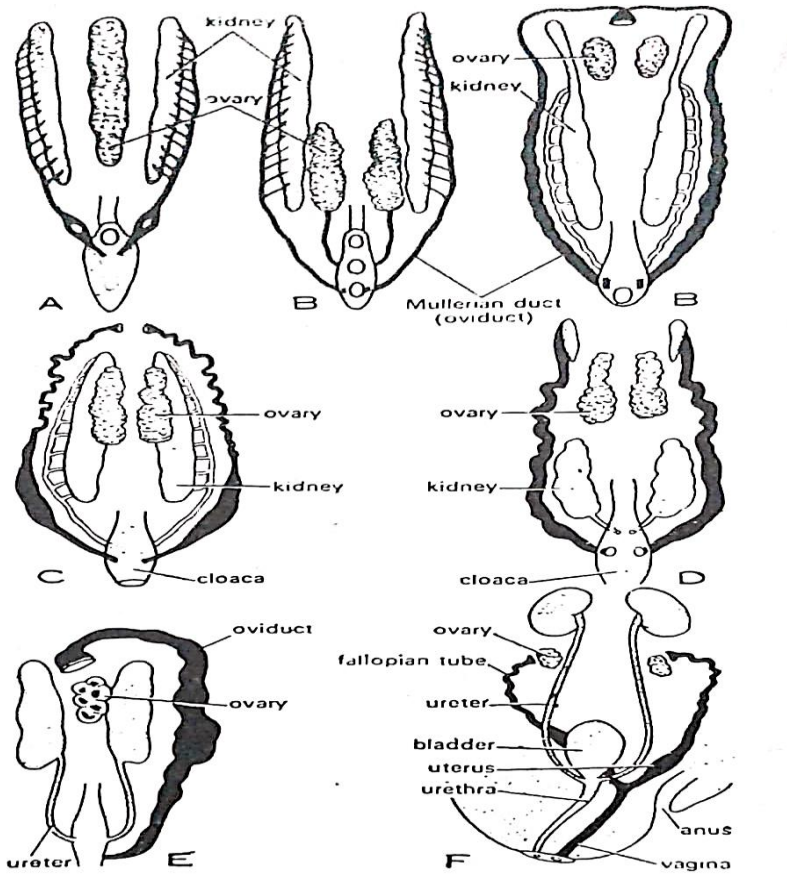


Fig 7.20 : Reproductive and urinary ducts of female vertebrates

A-Cyclostome, B- Teleost, B-Elasmobranch, C-Amphibia,

D- Reptile, E- Bird, F- Mammal

SAQs 2.

Complete the following sentences by inserting appropriate words in the blanks.

(i) Hypothetical primitive kidney is----------

(ii) Functional unit of kidney is----------

(iii) ----------is also called head kidney

(iv) Oviduct in vertebrates is modified into ----------

7.4 SUMMARY

In this unit you will be study about the evolution of heart and aortic arches in different vertebrate animals like cartilaginous fishes, amphibian, reptilia, aves and mammal and you will also observed the difference in their structures of heart.

In other segment i.e. succession of kidney and evolution of urinogenital ducts you will study about the how the kidney has evolved and how the different types of kidney i.e. pronephros, mesonephros and metanepohros are formed and along with this the urinogenital duct are formed in male and female.

7.5 TERMINAL QUESTION

Q1. Explain the structure of Aves heart.

Q2. Explain the structure of aortic arches in Pisces.

Q3. Explain pronephros kidney.

7.6 ANSWERS

SAQs.1

(i) Bilateral

(ii) Two

(iii) 2 pre-cavals and 1 post-caval

(iv) First and second aortic

SAQs.2

(i) Archinephros

(ii) Nephron

(iii) Pronephros

(iv) Mullerian duct

TERMINAL QUESTION

Ans 1. The heart in Aves is more muscular, compact and large in size. It is situated in the mid ventral region of the thoracic. The heart is covered by pericardium. The right auricle is larger then left auricle. The auricle and ventricle are demarked by a groove known as coronary sulcus or coronary groove. The sinus venosus disappear or fuses or incorporated with the right auricle. In the right auricle open 2- pre-cava and 1-post cava. The opening of the posterior vena cava is guarded by a valve known as eustachian valve. The right auricle opens into right ventricle which is guarded by a single valve monocuspid valve. The right ventricle is less muscular and is smaller then left ventricle because the left ventricle has to pump pure blood throughout the body. The left auriculo-ventriculo opening is guarded by bicuspid valve. The inner wall of the ventricle becomes thicker & muscular known as papillary muscle. The truncus arteriosus disappear and split in 2 aortic arches (*in reptile it split in 3 aortic arch*). The one which arises from the right ventricle is known pulmonary aorta carrying de-oxygenated blood to the lung. The opening of which is guarded by 3 semi-lunar valve. From the left ventricle arises the right systemic aorta carrying oxygenated blood to the body. It is also known as right carotico-systemic. In bird the left systemic is absent.

Ans 2. In *Scoliodon* I^{st} aortic arch disappear, only II^{nd}, III^{rd}, IV^{th}, V^{th} & VI^{th} aortic will remain. In bony fishes I^{st} & II^{nd} aortic arches disappear, only III^{rd}, IV^{th}, V^{th} & VI^{th} aortic arches are remain. In dipnoi (lung fishes) I^{st} & II^{nd} aortic arches disappear, only III^{rd}, IV^{th}, V^{th} & VI^{th} aortic arches are present. In dipnoi as gill are poorly developed, so the pulmonary artery arises from the efferent part of VI^{th} aortic arches on each side and supplies blood to air bladder or lung. The VI^{th} aortic arch is complete because a connection develop into pulmonary artery and dorsal aorta. This connection is called ductus arterious

Ans 3. The first kidney tubules formed in the anterior most part of the nephrostome is called pronephros, which is also the first kidney phylogenetically speaking. It is formed in the anterior end of the body and consists of 3-15 pair of (3 pair in larval kidney of frog, in human embryo -7 pair, in chick embryo-12 pair) tubule in each.

One pair in each segment. The tubules of each pronephros open into a common pronephric duct which grow back to enter the embryonic cloaca. Usually the pronephric tubules do not have individual glomeruli but a single large glomerulus in which a formation of large pronephric chamber, in this chamber a large single glomerulus called glomus is situated. So this is not covered by bowman's capsule and it is called external glomeruli (compare to internal glomeruli which is surrounded by bowman's capsule).

A pair of pronephric appear in all vertebrate embryo but they become functional kidney only in some cyclostomes and embryo of all anamniotes, in others they degenerate during development but the pronephric duct persist. In those vertebrates in which pronephric become adult kidneys, they are called head kidneys e.g. *Myxine* and some teleosts.

UNIT–8 NERVOUS SYSTEM & SENSE ORGANS

Structure (A) Nervous system

Structure (B) Sense Organs

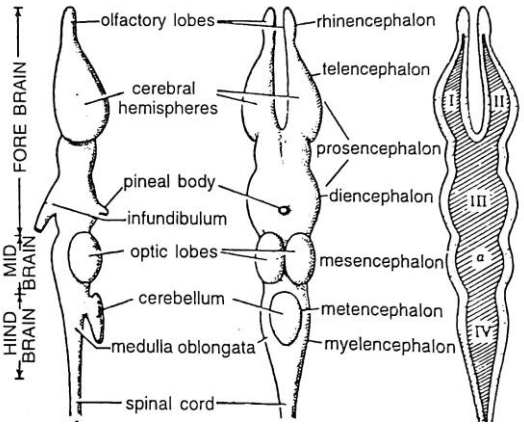
Structure (A) Nervous System

8.1 INTRODUCTION

The brain is a soft and delicate organ of nervous tissue. It is develop from the anterior thickened end of the neural tube. It undergoes differential growth and acquires two constrictions which divide it into three lobes termed the primary cerebral vesicles. The primary cerebral vesicles are a fore brain or prosencephalon, a mid brain or mesencephalon and a hind brain or rhombencephalon. They further subdivided into 5 sub divisions. The fore brain or prosencephalon is divided in two subdivision telencephalon and diencephalon. The telencephalon consists of two parts rinencephalon and cerebral hemisphere. The diencephalon consists of 3 parts epithalamus (roof), thalamus (side) and hypothalamus (floor). The mesencephalon or mid brain has no sub division and its ventral wall form thick crura cerebri (floor). The hind brain or rhombencephalon is divided in two sub division metencephalon and myelencephalon. The metencephalon form the cerebellum and myelencephalon form medulla oblongata. The various parts of the adult brain in different vertebrates are formed by modification i.e. by thickening and folding of these 5 sub division. The adult brain has a series of cavities called ventricles which are in continuation with the central canal of the spinal cord and filled with a cerebro-spinal fluid.

Objectives :

- Explain the comparative account of brain.
- Describe the sense organs.



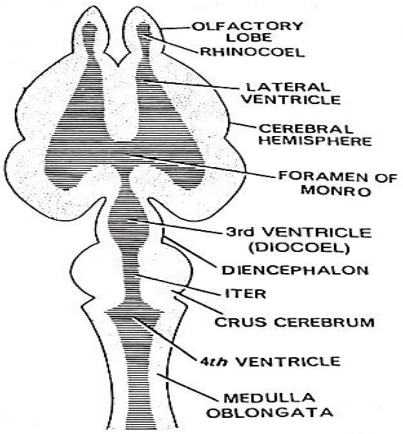


Fig 8.1 : Basic structure of brain in vertebrate **Fig :Cavities in brain**

8.2. COMPARATIVE ACCOUNT OF BRAIN

The brain of all vertebrates are built in same architectural plan. But they differ in form of different vertebrates in accordance with their habits and behavior of the animals. These are as follows:

(1) **Cephalochordates :-** In *Amphioxus* brain does not consist of fore brain, mid brain and hind brain. Instead, the so called brain is made of anterior prosencephalon or cerebral vesicle with a single enlarged ventricle. It is lined with cilia and long filamentous processes of ependymal cells.

(2) **Cyclostomes :-** In cyclostomes brain is very primitive. The subdivision are not well marked. The two olfactory lobes are large, but cerebral hemispheres are quite small. The cavities of cerebral hemisphere or lateral ventricle are rudimentary. The pineal apparatus and parapineal or parietal body are well developed in *Petromyzon* but absent in *Myxine*. Pineal apparatus is connected to epithalamus made of two habinulae ganglia. The two optic lobes are imperfectly differentiated. The medulla oblongata is very well developed while cerebellum is small transverse dorsal band. From the hypothalamus of diencephalon bear a hypophysis or pituitary body attached by infundibulum stalk.

(3) **Fishes :-** The brain of fishes is more advanced than that of cyclostomes. The subdivision of brain are more pronounced than their primitive relations.

(a) ***Elasmobranchs fishes:-*** In elasmobranchs fishes i.e. *Scoliodon* olfactory organs are enormous in size so that olfactory lobe of brain are large, attached to cerebrum by short but stout olfactory tracts or peduncles. The optic lobes and pallium are relatively moderate in size. The mid brain cavity (III ventricle) is quite large and extends into optic lobes. A thin walled vascular sensory organ called saccus vasculosus is attached to pituitary and connected by fibre tracts with cerebellum. The pineal apparatus is well developed. Cerebellum is especially large due to active swimming habit. To assist cerebellum in the maintenance

of equilibrium, ruffle like restiform bodies are present at the anterio-lateral angle of medulla oblongata.

(b) ***Bony fishes :-*** In bony fishes brain is more specialized than elasmobranchs. In perch, olfactory lobes, cerebral hemisphere and diencephalon are smaller while optic lobes and cerebellum are larger than in a shark. Some bony fishes have restiform bodies. The anterio-lateral sides of medulla oblongata show unusual bulging or vagal lobes. Parapineal body is absent in modern teleosts.

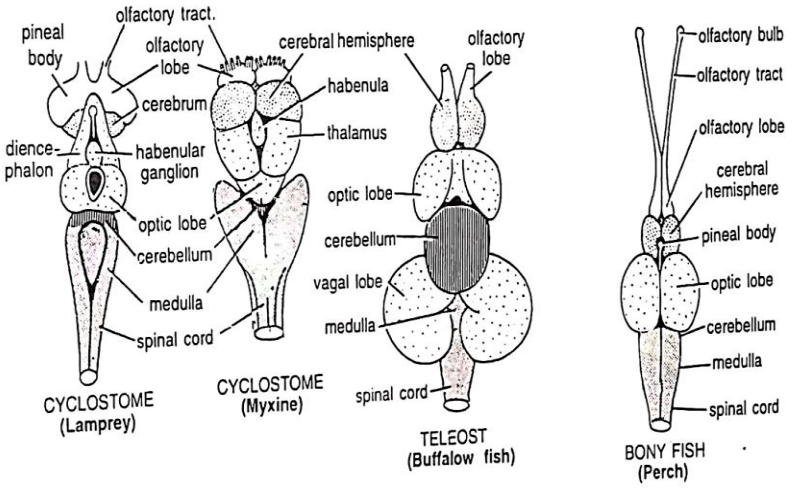


Fig 8.2 : Comparative anatomy of brains of vertebrates

(4) **Amphibian :-** The brain of frog is more advanced than fishes. The olfactory lobes are smaller and larger optic lobes indicate a greater reliance on sight rather than smell. Corpus striatum receives greater number of sensory fibres projected forward from thalamus than in fishes. The two cerebral hemisphere shows a greater development in accordance with more complex activities of locomotion, hibernation, breeding etc. However optic lobes are probably the dominant co-ordinating centres in amphibian brain. The wall of mid brain thickened and reduce the lumen into a narrow passage called aqueduct. The poor development of cerebellum, a mere transverse band, shows relative decrease in muscular activity. Medulla oblongata is also small. A small pineal body is present in all modern amphibians.

(5) **Reptile :-** Due to complete terrestrial mode of life the reptilians brain shows advancement in size proportion to that of amphibians. In reptile the telencephalon increases to become the largest region of brain. The two long olfactory lobes are connected to cerebral hemisphere which are larger than in amphibians because of greater thickness and enlargement of corpora striata. A fine vomeronasal nerve from the organ of Jacobson goes to the olfactory bulbs. Parapineal body or parietal eye is still found in *Sphenodon* and some modern lizards, but is vestigial or absent in other reptiles. A pair of auditory lobes is found posterior to optic lobes which are not hollow. The III ventricle is reduced to a narrow cerebral aqueduct. Cerebellum is pear shaped and larger than in amphibians.

(6) **Aves :-** The Avian brain is relatively larger than in lower forms, but in shape it is short, broad and rounded. The olfactory bulbs are small and degenerate due to poorly developed organs of smell. The two cerebral hemispheres are larger, smooth and project posteriorly over the diencephalon to meet the cerebellum. Pallium is thin but corpus stratium is greatly enlarged, making lateral ventricle small and vertical. The IIIrd ventricle is also narrow due to great development of thalami. Optic lobes on mid brain are conspicuously developed in co-relation with keen sight, but they are somewhat laterally displaced. The cerebellum is large extending forward, it has a large central vermis with transverse groove forming folds and ridges and two lateral lobes or flocculi due to many activities involving muscular co-ordination and equilibrium such as flight and perching. The cerebellum extends far backwards covering a large part of the medulla oblongata.

(7) **Mammals :-** The brain reaches its highest development in mammals with better integration and mastery over the environment. The mammalian brain is relatively larger than in other vertebrates. The cerebral hemispheres of Prototheria are smaller and smooth like reptiles. They are larger but smooth in Metatheria. In higher mammals (Eutheria) cerebral hemispheres becomes greatly enlarged and divided into lobes with thick cerebral cortex of grey matter. In mammals such as rabbit, surface of cerebral hemispheres is relatively smooth with few fissures. In others, such as man and sheep, surface is immensely convoluted with a number of elevations (gyri) separated by furrows (sulci). This folding increases the surface cortex or gray matter containing nerve cells, resulting in greater intelligence without adding to the size of brain. The two hemisphere are jointed internally by a transverse band of fibres, the corpus callosum, not found in other vertebrates or even in prototheria and metatheria.

Olfactory lobes are relatively small but clearly defined and covered by the hemispheres. Diencephalon and midbrain are also completely covered by the cerebral hemispheres. Characteristic of mammals are 4 almost solid optic lobes, called corpus quadrigemina, on the roof of mid brain. The IIIrd ventricle or iter of mid brain is laterally compressed vertical passage called cerebral aqueduct.

Cerebellum is also large, conspicuously folded and may overlie both mid brain and medulla oblongata. Usual folds are a median vermis, two lateral flocculi and their mushroom like projections, the paraflocculi. The other chief topographical features of mammalian hind brain include the pyramids carrying voluntary motor impulses from higher centres, pon varoli with crossing or decussating fibres connecting opposite sides of cerebrum and cerebellum, and the trapezoid body of transverse fibres relaying impulses for sound. Hind brain contains centres for the regulation of digestion, respiration and circulation.

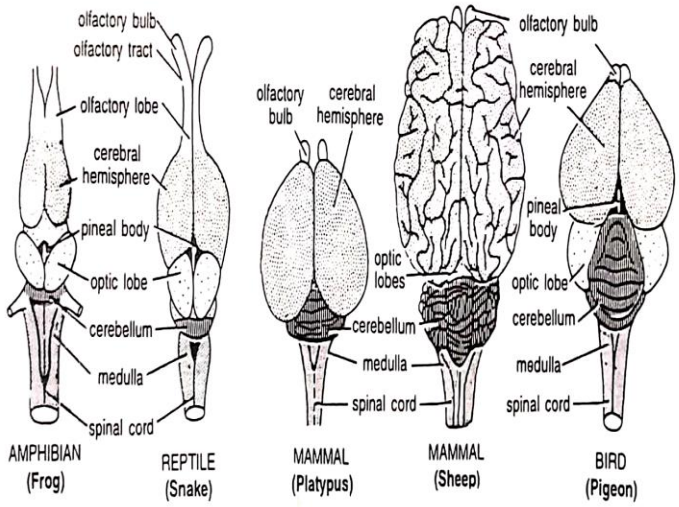


Fig 8.3 : Comparative anatomy of brains of vertebrates

SAQs 1.

Complete the following sentences by inserting appropriate words in the blanks.

(i) The primitive brain is found in ----------.

(ii) The olfactory lobe of ------- is small due to poor sense of smell.

(iii) Cerebellum is well developed due to active ---------- habit in fish

(iv) The number of gyri on brain surface is concerned with ---------

Structure (B) Sense Organs

8.3 TYPES OF RECEPTORS

Each organism are always influences from their surrounding environment. Any changes in the external or internal environment that stimulate the organism is called stimuli and the organs which receive these changes or stimuli are called receptors or sense organs. The receptor or sense organs receives the information and change it into nerve impulses and transmit to the brain or spinal cord, where they are interpreted as ensations and respond in appropriate manner or in other words receptor is a specialized cell or group of specialized cells that receives the stimuli and act as biological transducer to transform the stimulus energy into electrochemical energy as nerve impulse.

A vertebrate has receptors or sense organs for touch, smell, taste, sight and hearing which are stimulated by the external environment are termed as external receptors or exteroceptors. There are many other sense organs found in the body which detect temperature, pain, hunger, thirst, fatigue and muscle position are internal receptor or interoceptors. The sense organs or receptors are classified in many ways.

(1) General and special receptors :- The general receptor are very minute sense organs that are distributed widely upon or within the body skin. The special receptors are like tongue, nose, ears and eyes. They are mainly

concentrated in small areas particularly on the cephalic end of the body and they respond to a particular type of stimuli.

(2) According to location :- These are of various types

(a) ***Exteroceptors*****:** These are those receptors which receives environmental stimuli from outside the body and supply information about the surface of the body (touch, pressure, taste heat etc.) These include eyes, nose, ears, taste buds and cutaneous sense organs.

(b) ***Proprioceptors*****: -** These are stretch receptors present in the muscles, joints, tendons, connective and skeletal tissues. They supply information about the kinesthetic sense of equilibrium and orientation. They act like pressure gauges and are responsible for maintenance of body posture.

(c) ***Interoceptors*** **: -** They lie in various internal organs and provide information about the internal body environment such as Co_2 concentration, blood composition, pain and fullness etc. They are responsible for maintaining an appropriate internal body environment.

(3) According to stimuli :- Receptors are also classified on the basis of the stimulus to which they are sensitive

(a) ***Mechanoreceptors***: - These are stimulated by touch and pressure (skin), vibrations or sound and Stato-acoustic organ (ear).

(b) ***Chemoreceptors*** **:-** These are sensitive to smell, that is chemical substances or odours in air (nose) and to taste, which is substances in solution (tongue).

(c) ***Photoreceptors*** **:-** Thses are sensitive to light waves or sight (eyes).

(d) ***Thermoreceptors*** **:-** They are sensitive to heat and cold (skin).

(e) ***Nerve ending*** **:-** They are sensitive to pain (skin).

(4) According to somatic and visceral receptors : - Exteroceptors and proprioceptors are also called somatic receptors and interoceptors are also called visceral receptors.

(1) Mechanoreceptors:-There are various types of mechanoreceptors.

(a) ***Tactile receptors*** **(*Tangoreceptor*) :-** The tactile receptors are branched naked sensory terminal lying upon hair follicles. Most of them are tapering but some are terminally expanded into knob or disc. They become excited when hairs come in contact with an object. The profusely branched tactile terminals of myelinated and non-myelinated sensory nerve fibres are abundantly occur in dermal papillae of skin. In the skin of lips, nipples, penis, palms, soles, fingertip etc. the branching is generally encapsulated by adjacent connective tissue forming a cylindrical tactile corpuscle.

The **Merkel's disc**, a tactile receptor occurs in epidermis of hairless skin and hair follicles of man, pig and certain other mammals.

The **Pacinian corpuscle**, a tactile receptor occur in deeper layer of skin dermis of palms, soles, fingers, external genitals, nipples, arms, neck, joints etc. These are oval, spherical or irregularly coiled and very characteristic in structure. The capsule of each comprises about 30 concentrically arranged lamellae of flattened cells, and the core has a single sensory nerve fibre terminating in an expanded end bulb. The corpuscle become excited by vibrations and pressure of strong and sustained contact. The skin of glans penis in males and clitoris in females possesses a special type of bulb like tactile corpuscles called genital corpuscle.

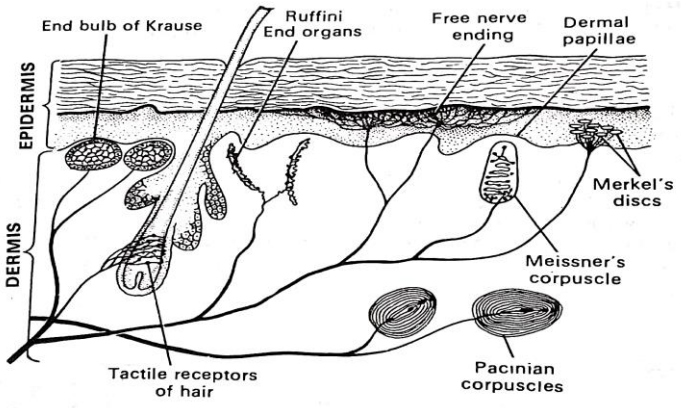


Fig 8.4 : Various cutaneous (general) receptors of Rabbit's skin

(b) ***Pain receptors*** **(*Algesireceptors*) :-** These are branched and naked terminal scattered in the epidermis and dermis of skin. These are responsible to detect pain. Beside pain these are also sensitive to itching and burning.

(c) ***Rheo receptors*** **: -** Rheoreceptors or detectors of low vibrations in water are present fishes and aquatic amphibian. These are also known as lateral line sense organs. Two lateral line sense organs, each with a series of lateral line organs or neuromasts constitute rheoreceptors.

These are located within lateral line canals divisible into (a) a trunk and tail and (b) a head or cephalic canal. The lateral line canals lie in the dermis or deeper and covered by the skin bearing numerous pores.

A neuromast is a group of sensory cells with supporting cells. Each sensory cell has a hair projecting outside through the pore. A mass of gelatinous material, the cupula, secreted by the neuromast cells encloses the tips of the cells.

The sense organs are innervated by the facial nerve and the lateralis branch of the vagus. The organs detect low vibrations in water and enable the fish to move correctly in turbid water and also in darkness.

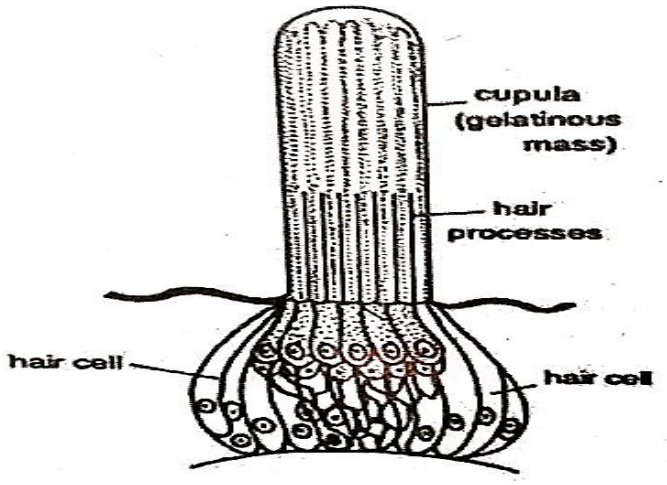


Fig 8.5 : Neuromast sensory organ -Fish

(d) ***Stato-acoustic organ*** **(ear):**The ear has two functions i.e. equilibrium and hearing hence it is called stato-acoustic organ. The mammalian ear is divided into 3 parts i.e. external ear, middle ear and internal ear. All the 3 parts are concerned with hearing while internal ear are only concerned with equilibrium.

(i) ***External Ear :-*** It consist of two parts. The outer ear is known as pinna, is the visible immovable, skin covered cartilaginous projection from the side of the head. The pinna leads to a narrow, about 25 mm long auditory canal running towards the middle ear. The walls of auditory canal are lined with skin containing hairs, oil glands and wax glands. The hairs, oil and wax prevent dust particles and small things like insects from entering and damaging the ear drum.

(ii) ***Middle Ear*** **:** Middle ear is in the form of an air filled chamber called tympanic cavity. This cavity is enclosed in a flask shaped bone called tympanic bulla. The tympanic cavity is connected with pharynx by a tubular passage is known as Eustachian tube. The tympanic cavity start from the tympanic membrane or ear drum and end in the wall between middle ear and internal ear by two opening covered by thin membranes. The upper opening is called fenestra ovalis and lower is called fenestra rotundus. In the middle ear cavity contain a chain of three little bone or ossicles extending between the tympanic membrane and the fenestra ovalis. These bones are malleus, incus and stapes. The malleus is attached to the incus and incus is attached to stapes and this stapes is attached to the fenestra ovalis. These bones are suspended in there respective position from the tympanic cavity by means of elastic ligaments.

(iii) ***Internal Ear :-*** The inner ear is the essential part containing the sensory cells from which impulses pass to the brain *via* the auditory nerve. It is a much complicated and delicate structure,

comprising membranous walled sac and canals are called membranous labyrinths. It is hollow and contains a lymph like fluid called endolymph. It is deeply embedded in the periotic bone of skull called bony labyrinth. The space between the membranous labyrinth and bony labyrinth is filled with another fluid called perilymph.

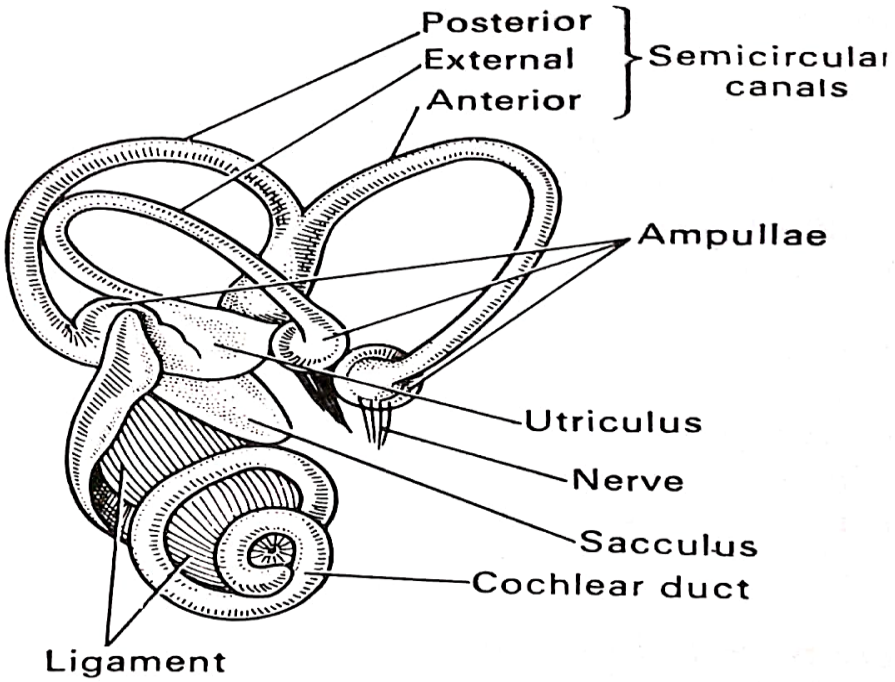


Fig: Membranous labyrinth

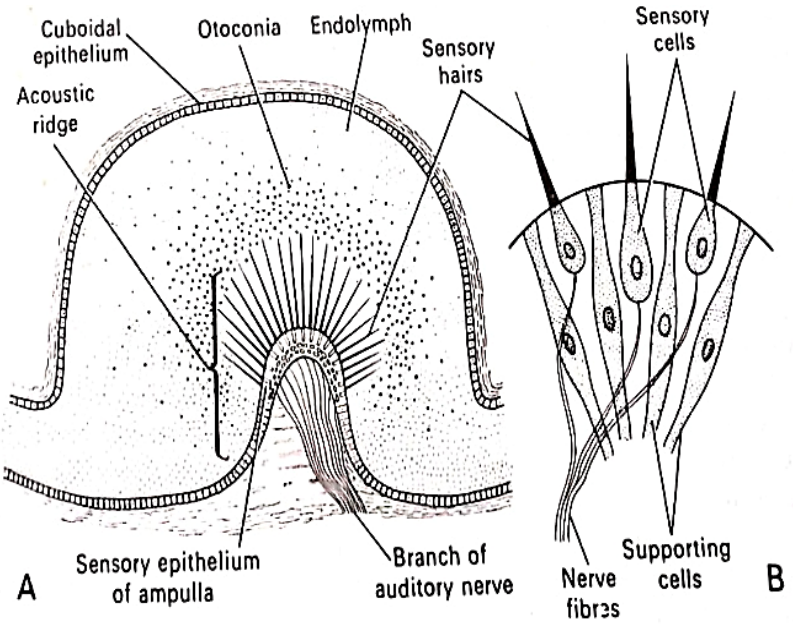


Fig 8.6 : (A) V.S. of theampulla of semic (B) Enlarged part of sensory epithelium of crista

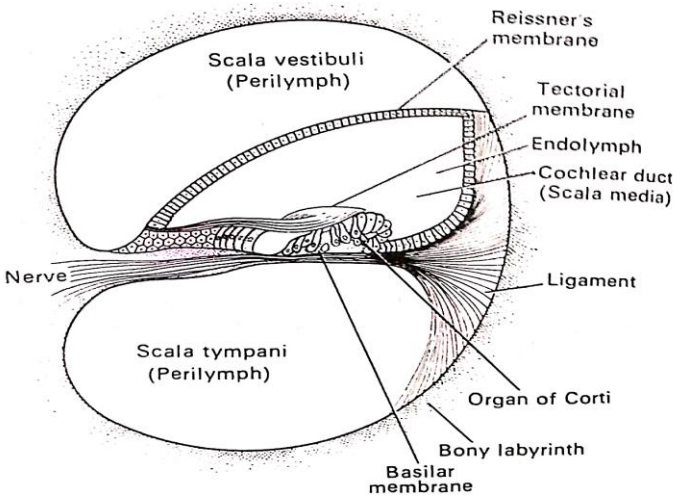


Fig: T.S of cochlear apparatus

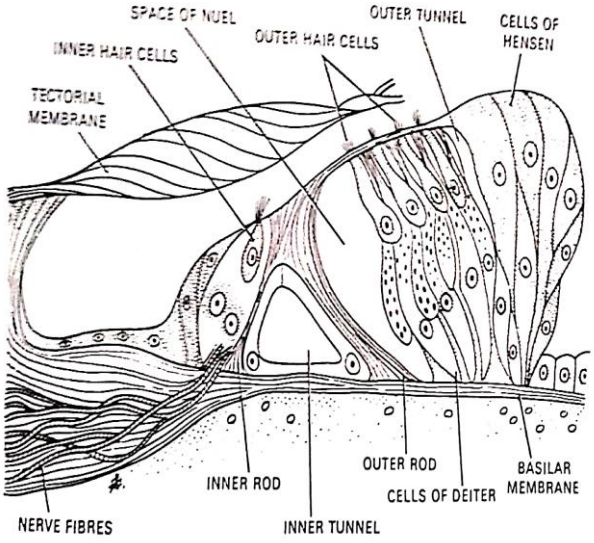


Fig 8.7 : Enlarged diagram of organ of corti

Membranous labyrinth :-

It is divided into 3 parts, the sac like utriculus and sacculus (i.e. body proper), semicircular canals and cochlea.

(a) Utriculus & sacculus :- The body proper is further differentiate into an upper larger chamber, utriculus and smaller lower chamber sacculus. The two chambers are connected together by a small narrow sacculo-utricular duct. From sacculus gives off a small slender endolymphatic duct ending blindly into an endolymphatic sac. Both in utriculus and sacculus has a special group of sensory cells called macula with fine projecting hairs. The hairs are embedded in jelly also contain particles of calcium carbonate called otoliths. These sensory parts are called macula utriculi and maculi sacculi of utriculus and sacculus respectively. These help the animal to maintain the body posture. The bony labyrinth surrounding the utriculus is known as vestibule.

(b) ***Semicircular canals :-*** From the utriculus, three long and narrow semicircular canal arises at the right angle to each other and they back again open into utriculus. These are called anterior vertical, posterior vertical and horizontal semicircular canal. The distal end of each semicircular canal duct that open back into the utriculus is enlarged to form a small ampulla. Each ampulla has a group of sensory hair cells called crista. The hairs are embedded in a cone of jelly that may distributed by movements of the endolymphs. The cristae send information to brain about the accelerating and rotational movements.

(c) ***Cochlea :-*** From the sacculus, a long much coiled, tubular structure arises called cochlea duct. It is spirally coiled like watch spring. The part of bony labyrinth enclosing the cochlear duct is also similarly coiled and is called cochlear canal. They are the organ of hearing. In cross section the cochlear apparatus is divided into three flattened longitudinal space or chamber are called scalae. The upper chamber is called scala vestibule and the lower chamber is called scala tympani. Both these chamber are filled with perilymph. In between these two chambers, there is another chamber called scala media or cochlear duct and is filled with endolymph and closed at its tip. The ventral wall or floor of scala media is thickened called basilar membrane. The dorsal wall or roof is thinner, sloping and called vestibular or Reissner's membrane. At the apex of cochlear duct, scala vestibuli and scala tympani communicate by a narrow junction called helicotrema. All along its median longitudinal line, the floor of scala media i.e. basilar membrane is thickened inwards bulging into endolymph as a sensory ridge called the organ of corti i.e. organ of hearing or phonoreceptors. It consists of a few longitudinal rows of columnar sensory cells separated by columns of supporting cells (cells of Hensen), basal cells (cells of Deiter) and small fluid spaces. The fluid of spaces is endolymph and is called cortilymph. Each sensory cell bears a number of sensory hair "stereocilia" at its free end, and is innervated by a fibre of the cochlear branch of auditory nerve. A thin gelatinous ribbon like sheet of connective tissue called tectorial membrane overhangs the hair cells in close contact with their tiny hairs. The hair cells and tectorial membrane collectively form the organ of corti.

Working of ear

The mammal ear has two function i.e. balancing or equilibrium and hearing

(i) **Equilibrium :-** The mammal can perceive differences in the orientation of their bodies by responding to gravity and maintain their equilibrium. The maculae of utriculus and sacculus and the cristae of semicircular canals of the membranous labyrinth form the organs of equilibrium (balance & posture).

The maculae are special groups of sensory cells with fine projecting hairs in contact with a jelly with embedded particles of $CaCo_3$ or otoliths which are heavier than the surrounding endolymph. If the head is tilted, the otoliths bend the hairs to the side. As a result of this stimulation, the brain responds by causing appropriate muscles to contract thus bringing the head back to its normal position. Besides responding to the posture of the head and body

(static equilibrium). This apparatus also responds to linear acceleration that is straight line rapid forward or backward movements of the head, which are non-rotational.

The cristae are sensory organs in the ampullae of semicircular canals. They are similar to maculae but lack the otoliths. They respond only to the change in the direction or rotational movement of the head. When the head is turned in a particular direction, the endolymph because of its inertia does not move as fast as the head thus bending the hairs in opposite directions. So that the brain is informed about the particular rotational movement.

(ii) **Hearing :-** The cochlea of the ear are the organ of hearing. The sound waves collected by pinna and travelling down the external auditory canal, strike and cause the tympanic membrane or the ear drum to vibrate. From tympanic membrane, the vibrations are transmitted mechanically across the middle ear through ear ossicles (malleus, incus & stapes) and fenestra ovalis into the perilymph of the inner ear. Due to lever action of the ear ossicles and due to smaller size of membrane covering the fenestra ovalis than the tympanic membrane. The force of vibrations received by the perilymph is increased many fold. The vibrations in the perilymph pass through the scala vestibule of cochlea, cross the scala media to reach the scala tymphani and escape through fenestra rotundus back into the middle ear. The direct passage of vibrations from the perilymph of scala vestibule to perilymph of scala tympani *via* helicotrema at the apex of the spiral is said to be negligible. The increase or decrease in the pressure on the membrane of the fenestra ovalis, make it to move into or out of the perilymph of scala vestibule. Since liquids do not compress, the perilymph of scala tymphani in turn causes the elastic membrane of fenestra rotundus to bulge out or in sympathetically with the increase or decrease in pressure. Thus the membrane of fenestra rotundus serve as a pressure relief valve. This arrangement prevents loss of perilymph from closed chambers as well as retains full vigour of vibrations until they are delivered to the sensory cell. The alternating pressure changes in the perilymph set the endolymph and the basilar membrane into sympathetic undulations. The vibrations cause the tectorial membrane floating in endolymph of scala media to brush the processes of sensory hair cells of the organ of corti. The nerve impulses produced are carried through cochlear branch of the auditory nerve to the brain where these are interpreted as sound. The sound analysis by cochlea is a very complex, the sound vibration having different frequencies stimulate different parts of the basilar membrane. Higher notes (frequencies) seem to stimulate shorter fibres forming the basal part, while lower notes stimulate the longer fibre forming the apical part.

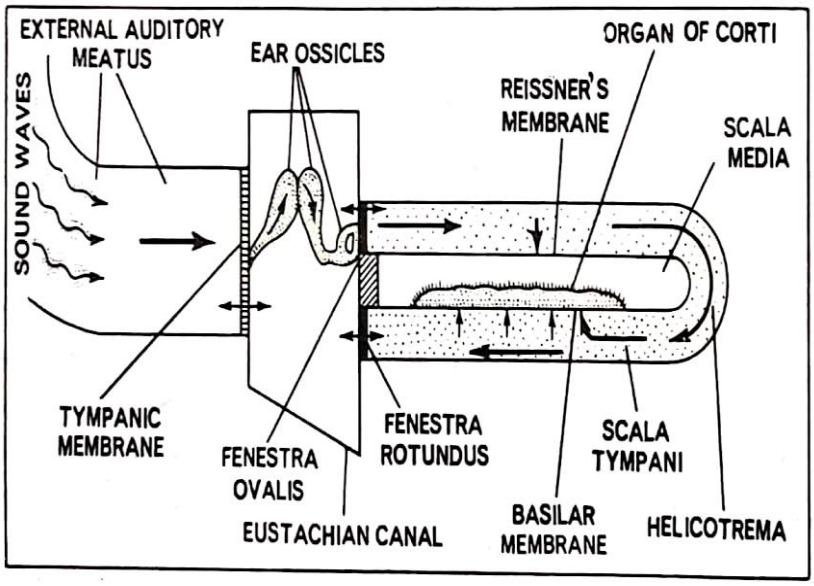


Fig 8.8 : Passage of sound vibrations in the process of hearing in a mammal

(2) Thermoreceptors :- These are those receptors which are responsible for sensitive to temperature variation. They are present in all vertebrates and scattered all over the body. The dermal papillae of hairless skin like conjunctive of eyes, external genitalia etc., the hair follicles in skin of forearms and mucous membrane of anus possesses small, spherical or oval bulb like receptors called **end bulbs of krause**. These corpuscles are excited by cold and hence also called frigidoreceptors.

The receptors are sensitive to heat i.e. caloreceoptors are spindle shaped called **end organs of Ruffini**, having two or more intertwining and encapsulated dendrites of sensory neuron occur in the deeper layers of dermis.

(3) Electroreceptor :- Electroreceptor are sensory cells which can detect changes in the electric field of the surroundings. The fishes like electric ray or electric eel can generate electric impulses exceeding 500 volts.

These are believed to be a part of the electric guidance system. It is presumed that with their specific electric organs the fishes create a pulsating electric field around them and any object in the surroundings with a different electrical conductivity than that of the water will disturb the field. With their special receptor cells these fishes can be detect the disturbance in the electric field and alter their course in water.

(4) Photoreceptors :- It is of two types of photoreceptors organs or eyes are found in vertebrates

(a) ***Pineal eyes*** :- The pineal eyes of cyclostomes can possibly distinguish light and darkness. It is a round capsule with a lens formed of elongated cells at the anterior wall and the posterior wall resembles a retina made of an inner layer of rod-like visual elements and an outer layer of nerve fibres. In reptiles the nerve degenerate in the embryo and the eye lost its function.

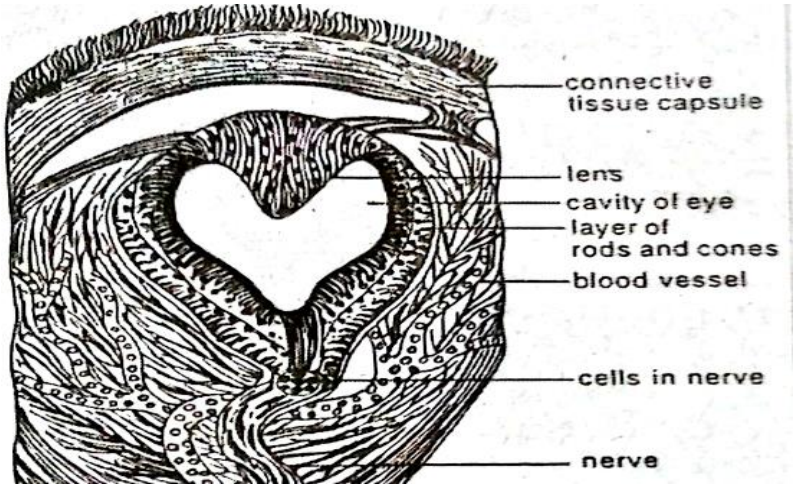


Fig 8.9 : Pineal eye (vertical section) – *Sphenodon*

(b) ***Image forming eye*** **: -**The vertebrates eyes are camera type eye, which are adapted to see under water, in bright light, in dim light and in darkness.

Eyes: In mammals the wall of eye ball consist of three concentric layer i.e. outermost sclerotic, middle choroid and inner most retina

(a) ***Sclerotic*** **:-** It is the outermost thick and tough, non vascular covering around the eyeball. The posterior 2/3 part of eyeball is opaque and lie in eye orbit is called sclerotic coat or sclera. The remaining 1/3 part is small anteriorly exposed, transparent through which light enter is called cornea. It bulges out slightly and its external surface is intimately covered with a thin, transparent epidermal layer, conjunctiva. It is supplied with free nerve ending and blood capillaries and is continuous with the epidermis lining the eyelids.

(b) ***Choroid*** **:-** The choroid is much thinner connective tissue layer heavily pigmented and richly vascular. It consists of three part i.e. choroid, ciliary body and iris. The choroid is the main part of eye ball and adhered to the sclerotic. It is formed of a highly vascular soft connective tissue containing few fibres, a dense network of blood capillaries and numerous branched pigment cells. The choroid lines only the posterior region of sclera. Anteriorly nearly the junction of sclera and cornea, the choroid enlarges to form the cilary body. It contains ciliary muscles and projects into vascular fold called ciliary processes, which secrete the aqueous humour.

Infront of the ciliary body where choroid get separated from cornea, the choroid appear like curtain. This curtain like structure is called iris. It is visible from outside as an opaque brown disc, perforated in the centre by around hole called pupil. The iris contains two sets of smooth muscles circular and radial. The pigmented iris prevents the light from entering the eye except through the pupil. The pupil can be constricted or dilated due to action of iris muscles thus regulating the amount of light entering the eye.

(c) ***Retina*** **:-** The retina is the innermost transparent layer sensitive to light. It consist of an outer non-nervous pigment layer closely applied with the choroid and the inner nervous layer containing two main types of sensory cells, rods and cones. These are stimulated by light and they generate electric impulses and relay the information to the brain by way of the optic nerve. The inner nervous layer of retina consist of receptive layer of rods and cones, synapsis, bipolar neurons, synapsis, unipolar ganglion cell and layer of nerve fibres which converge to form optic nerve.

The rods are more sensitive to dim light (low intensity) so rods are used to see in night. The cones are sensitive to light of high intensity so they are more suited for day vision and they produce a sharp image with fine detail. The cones are sensitive to lights of relatively narrow frequency bands so that they are associated with appreciation of colour.

The distribution of rods and cones within the retina is not uniform. The cones are more concentrated toward the centre, while rods are more numerous toward the periphery. The spot where all the nerve fibres converge and the optic nerve formed leaves the eye, there are no retinal cells present and so no image is formed. This spot is called the blind spot. Near it lies the yellow spot or fovea centralis marked by a slight depression along the optical or visual axis. It is point of principal focus or brightest image, because it has only cones and no rods.

Lens :- A crystalline solid and biconcave lens is present just behind the pupil. It is composed of concentrically arranged layers of transparent fibres, enclosed within a thin transparent elastic lens capsule. It is held in position by suspensory ligaments which are radially fibres connecting the lens capsule with the ciliary processes.

Chambers :- The iris, lens and its suspensory ligaments divide the internal cavity of eye into two unequal compartments. Between the lens and the cornea is the smaller anterior aqueous chamber. It is filled with a clear lymph like watery fluid, the aqueous humour. It is secreted continuously by the ciliary body and drained through canal of schlemm at the base of the cornea. Aqueous humour nourishes cornea and lens and maintains intraocular pressure. An imbalance in the intraocular pressure lead to a disease called glaucoma in which retina is injured.

Between the lens and the retina is the larger posterior vitreous chamber. It is filled with a gelatinous secretion called vitreous humour. A narrow hyaloids canal runs through the vitreous humour obliquely from the region of blind spot upto the middle of the posterior face of the lens.

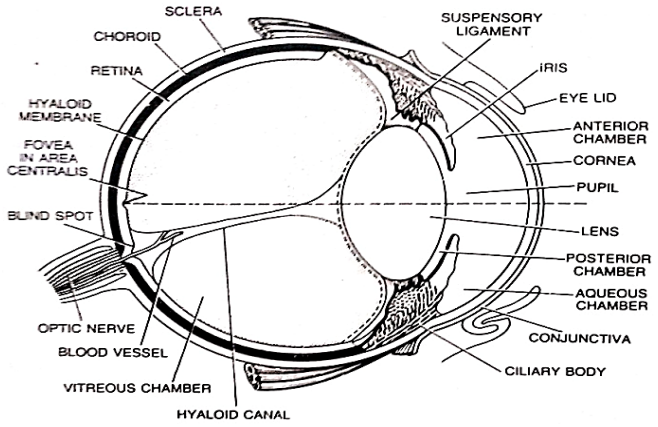


Fig 8.10 : Diagrammatic V.S. of mammalian eye

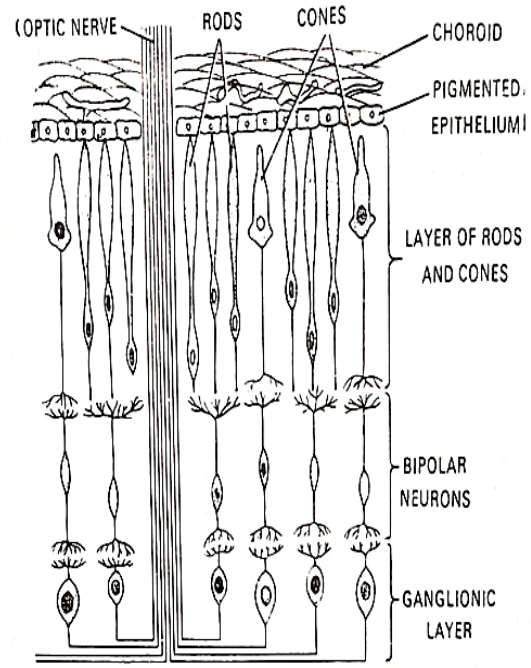


Fig 8.11 : Diagrammatic structure of the retina

(5) **Chemoreceptors :** The chemoreceptor or organs of chemical sense consist of olfactory organs and organs of taste (gustatory). Both these organs are stimulated only by substances in solution, the medium for dissolving substance is water for aquatic animals and mucous for land animals. The olfactory organs can respond to a low concentration of the dissolved substance, where as organs of taste need a higher concentration of the dissolved substance for a response. The olfactory receptors can detect objects from a distance while gustatory receptors are active only in contact with the substance.

(a) ***Olfactory receptors*** **:** The olfactory receptors are located in the posterior part of the nasal cavity. The olfactory receptor or olfactory epithelium have a lining of olfactory mucous membrane or Schneiderian membrane made up of olfactory cells sensitive to smell.

The one end of the cell responds to the chemical stimuli while the other end is continuous with a neuron. The nerve fibres join to form the olfactory nerve, which passes directly to the olfactory lobe of the brain. It is believed that substances containing volatile particles when dissolved in the fluid of the nasal cavity, releases the volatile particle, which stimulate the receptor cells. This initiate impulses, which are transmitted to the site of smell in the brain.

In many air breathing vertebrates (amphibians, reptiles, mammals) an off shoot of the olfactory organ separated from it, forms a distinct sac lined by sensory epithelium and innervated by the olfactory and trigeminal nerve. It opens into the mouthy and known as Jacobson's organ.

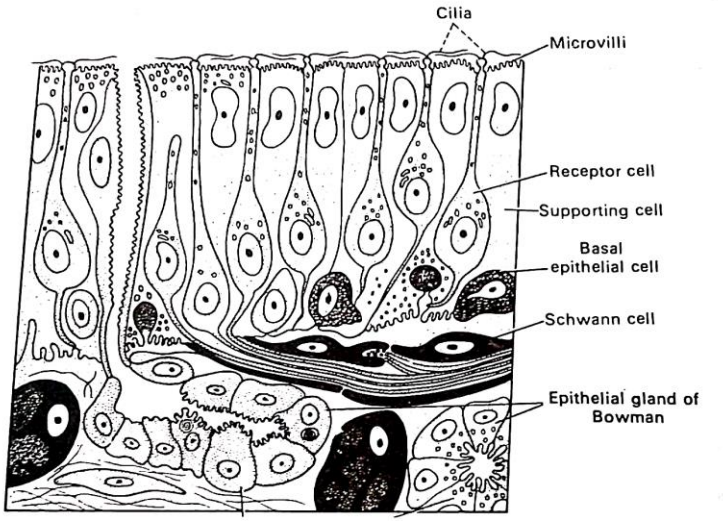


Fig 8.12 : Diagram showing the structure of olfactory epithelium

(b) ***Gustatory receptors*** **:-** The sense organs for taste are bud like structure, known as taste buds.

In fishes the taste buds are numerous and located in the mouth cavity, pharynx, skin of the head, tentacles, branchial chambers and in some cases, scattered on whole surface of the body. In mammals, the buds are located on the papillae in the tongue and soft palate.

The taste buds are derived from the epithelium and oval in shape. Each bud contains two types of narrow cells, the taste cells and supporting cells. The free ends of the taste cells bear microvilli. The bud is in communication with the surroundings through a minute pore and many microvilli project into the pore. The taste bud is innervated by glossopharyngeal nerve.

A taste cell may be connected with only one neuron or more than one. The taste cells are stimulated by substances in solution. Sweat, sour, salt and bitter are four basic tastes. Some buds are specific while others may be stimulated by more than one taste. This makes the detection and processing of information in the tongue very complex. But the messages finally transmitted to the brain are different tastes.

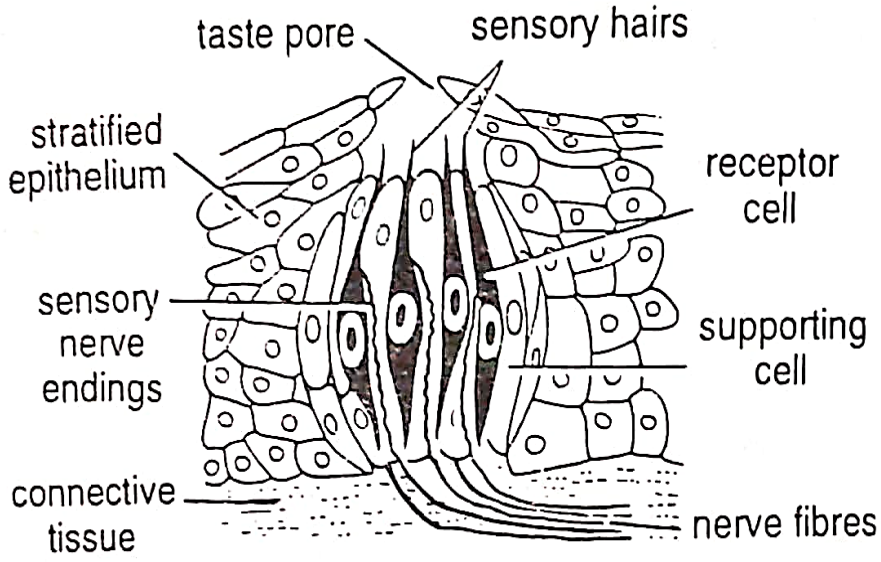


Fig 8.13 : A taste Bud

SAQs 2.

Complete the following sentences by inserting appropriate words in the blanks.

(i) Thermo receptors are sensitive to ----------

(ii) Chemoreceptor are sensitive to ----------

(iii) Exteroceptor and proprioceptors are also called ---------

(iv) ---------- are stimulated by touch and pressure, vibrations or sound and balance

8.4 SUMMARY

In this unit you will be study the basic structure of brain in different vertebrate animals like cephalochordate, cyclostomes, cartilaginous fishes, bony fishes amphibian, reptilia, aves and mammal and you will also observed the differences in their structures of brain.

In other segment you have study about the types of receptors present in our body like Mechanoreceptors, Chemoreceptors, Photoreceptors, Electroreceptor, Thermoreceptors, Stato-acoustic organ and other type of receptors in vertebrates.

8.5 TERMINAL QUESTION

Q1. Explain the structure of brain of elasmobranches fishes.

Q2. Explain the structure of Avian brain.

Q3. Explain about Rheoreceptors.

8.6 ANSWERS

SAQs.1

(i) Cyclostomes

(ii) Birds

(iii) Swimming

(iv) Intelligence

SAQs 2.

(i) Heat & cold

(ii) Smell

(iii) Somatic receptors

(iv) Mechanoreceptors

TERMINAL QUESTION

Ans 1. In elasmobranchs fishes i.e. *Scoliodon* olfactory organs are enormous in size so that olfactory lobe of brain are large, attached to cerebrum by short but stout

olfactory tracts or peduncles. The optic lobes and pallium are relatively moderate in size. The mid brain cavity (III ventricle) is quite large and extends into optic lobes. A thin walled vascular sensory organ called saccus vasculosus is attached to pituitary and connected by fibre tracts with cerebellum. The pineal apparatus is well developed. Cerebellum is especially large due to active swimming habit. To assist cerebellum in the maintenance of equilibrium, ruffle like restiform bodies are present at the anterio-lateral angle of medulla oblongata.

Ans 2. The Avian brain is relatively larger than in lower forms, but in shape it is short, broad and rounded. The olfactory bulbs are small and degenerate due to poorly developed organs of smell. The two cerebral hemispheres are larger, smooth and project posteriorly over the diencephalon to meet the cerebellum. Pallium is thin but corpus stratium is greatly enlarged, making lateral ventricle small and vertical. The IIIrd ventricle is also narrow due to great development of thalami. Optic lobes on mid brain are conspicuously developed in co-relation with keen sight, but they are somewhat laterally displaced. The cerebellum is large extending forward, it has a large central vermis with transverse groove forming folds and ridges and two lateral lobes or flocculi due to many activities involving muscular co-ordination and equilibrium such as flight and perching. The cerebellum extends far backwards covering a large part of the medulla oblongata.

Ans 3. Rheoreceptors or detectors of low vibrations in water are present fishes and aquatic amphibian. These are also known as lateral line sense organs. Two lateral line sense organs, each with a series of lateral line organs or neuromasts constitute rheoreceptors.

These are located within lateral line canals divisible into (a) a trunk and tail and (b) a head or cephalic canal. The lateral line canals lie in the dermis or deeper and covered by the skin bearing numerous pores.

A neuromast is a group of sensory cells with supporting cells. Each sensory cell has a hair projecting outside through the pore. A mass of gelatinous material, the cupula, secreted by the neuromast cells encloses the tips of the cells.

The sense organs are innervated by the facial nerve and the lateralis branch of the vagus. The organs detect low vibrations in water and enable the fish to move correctly in turbid water and also in darkness.

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ROUGH WORK