unit II.
Puei Sie
Zoology — II

4 Pisces

Pisces may be defined as *ectothermic* (except order *Thunniformes*) cold blooded aquatic vertebrates having *jaws, gills, fins* and *skin* covered in scales (*Misra*, 1969; *Collins Dict*, 1983). The study of fishes is called *Ichthyology* (G.*ichthys*, fish+*logos*, study).

General Characters

Pisces includes all *fishes*.

1. *Fishes* are *cold blooded* aquatic vertebrates having *jaws, gills, fins* and *scales*.
2. They are *chordates* because the embryos develop a *notochord*.
3. They are *vertebrates* because they contain a *vertebral column*.
4. The brain is enclosed in a *cranium*. So they are *Craniata*.
5. They have *jaws*. So they are included in *Gnathostomata*.

Fig.4.1:Scoliodon(shark),atypical fish.

6. Respiration is carried out by *gills*.
7. The appendages are in the form of *fins*.
8. The nostrils do not open into the pharynx.
9. The jaws are hinged.
10. The *scales* are *dermal* in origin and are in the form of placoid scales, ganoid scales,

cycloid and ctenoid scales.

11. The notochord is replaced by vertebrae.

12. ***Lateral line sense*** organ is present.

13. The eyes are suited to vision in water. Eyelids and tear glands are absent.

14. The ***heart*** is ***'S'*** shaped and ***two chambered*** with one ***auricle*** and one ***ventricle*** and receives only venous blood. It is a ***venous heart.***

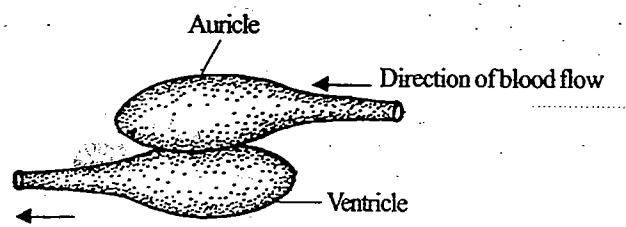

Fig.4.2: Heart of fishes:

15. The alimentary canal is well developed with the ***stomach*** and the ***pancreas.***

16. Skeleton is less massive than that in terrestrial vertebrates.

17. Visceral skeleton (skeleton of pharyngeal wall, associated with the gills) is well developed.

18. Absence of a fleshy muscular tongue.

19. ***Cerebrum*** is primarily an olfactory centre.

20. The integument contains ***mucous glands.***

21. The ***kidneys*** are ***mesonephros.***

22. The ***cranial nerves*** are ***ten pairs.***

23. The sexes are ***separate.***

24. Fertilization is ***external*** or ***internal.***

25. Some fishes are ***oviparous*** or ***ovoviviparous*** and some others are ***viviparous.***

Eg. *Shark, Mullet, Tilapia, Eel,* etc.

Classification in Brief

Fishes are *cold blooded aquatic vertebrates having jaws, gills, fins* and *scales.*

Fishes are included in the phylum ***Chordata*** because the embryos develop a notochord.

They contain a vertebral column. So they are included in ***Vertebrata.***

The brain is enclosed in a cranium. So they are included in ***Craniata.***

They have jaws. So they are included in ***Gnathostomata.***

The fishes are included in ***three classes***, namely

Class 1. Placodermi
Class 2. Chondrichthyes } *Class : Pisces*
Class 3. Osteichthyes

The three classes of fishes are also together called class ***Pisces.***

Class ***Placodermi*** includes ***extinct fishes***. They were called ***plate-skinned fishes*** because the body was covered by a ***bony armour***. They were the ***first fishes***. Eg. *Coccosteus.*

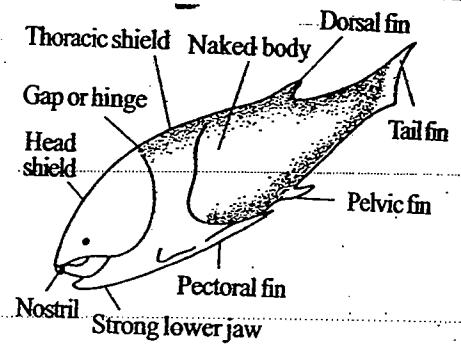

Fig.4.3: Devonian placoderm: Coccosteus.

Class ***Chondrichthyes*** includes ***cartilaginous fishes***. (***Chondros,*** cart; ***ichthys,*** fish).

Chondrichthyes is characterized by:

1. Cartilaginous skeleton.
2. Placoid scales.
3. Heterocercal caudal fin and.
4. Claspers in male.

The class ***Chondrichthyes*** is divided into 2 subclasses, namely:

Subclass 1. Elasmobranchii

Subclass 2. Holocephali.

- ***Elasmobranchii*** is characterized by ***plated gills.*** Eg. *Scoliodon (shark), Pristis, Narcine, Torpedo,* etc.

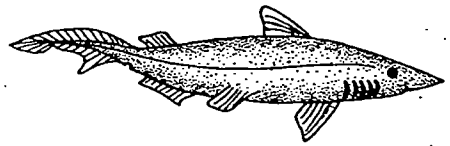

Fig.4.4: Scoliodon (shark) - lateral view.

- ***Holocephali*** means ***entire head.*** It includes *Chimaera.* It is intermediate between Chondrichthyes and Osteichthyes.

Class ***Osteichthyes*** includes ***bony fishes*** (***Osteon,*** bone; ***ichthys,*** fish).

Osteichthyes is characterized by:

1. Bony skeleton.
2. Ganoid or cycloid or ctenoid scales.
3. Operculum covering the gills.
4. Homocercal or diphycercal caudal fin.
5. Air bladder.

Class ***Osteichthyes*** is divided into 3 subclasses, namely

Subclass 1. Acanthodii

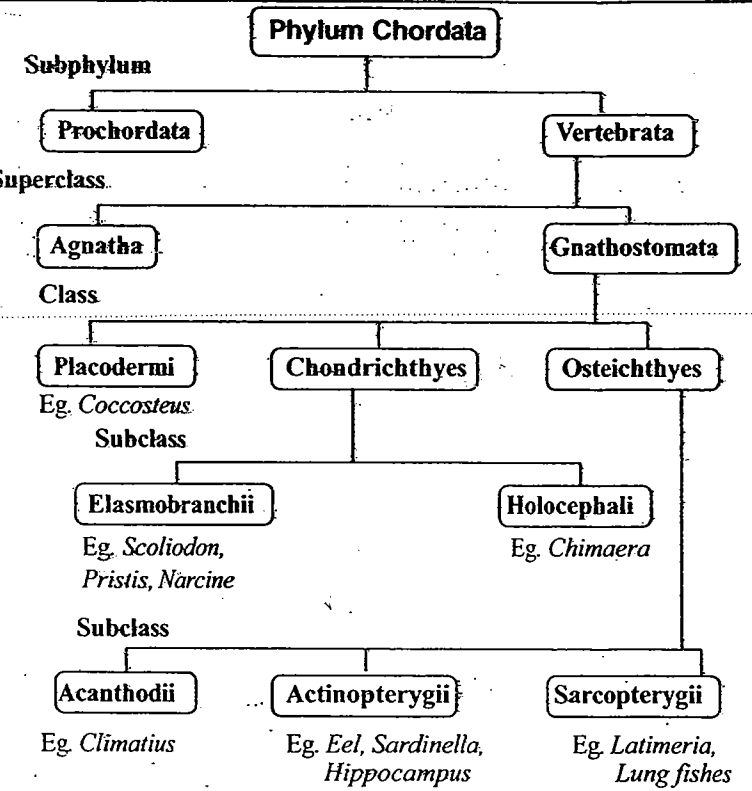

Fig.4.5: Synoptic classification of fishes.

Subclass 2. Actinopterygii
Subclass 3. Sarcopterygii

• ***Acanthodii*** means ***spine***-like. They have a series of ***lateral fins*** supported by ***spines***. includes ***Climatius***. It was the ***first freshwater fish***. It had ***ganoid scales***.

• ***Actinopterygii*** includes ***ray-finned*** fishes. Most of the modern fishes are included in ctinopterygii. The order ***Teleosteii*** is the largest group. Eg. *Eel, Sardinella, Hippocampus, xocoetus*, etc.

• The subclass ***Sarcopterygii*** includes the ***fleshy finned fishes***. Eg. *Latimeria, lung shes*, etc.

Placoderms

Placoderms were the ***first fishes***.
Placoderms is a class of ***Gnathosto-mata***.
They were ***extinct fishes***.
They were called ***plate skinned fishes*** as they had a ***bony armour***. They are called ***rmoured fishes***.

They lived during ***Mesozoic era***.
They were the ***first jawed - Vertebrates***.
Males had ***claspers***.
They had ***paired fins*** and ***caudal fins*** were ***heterocercal***.
They had 5 pairs of gill slits. Eg. *Climatius*.
A ***spiracle*** was present.

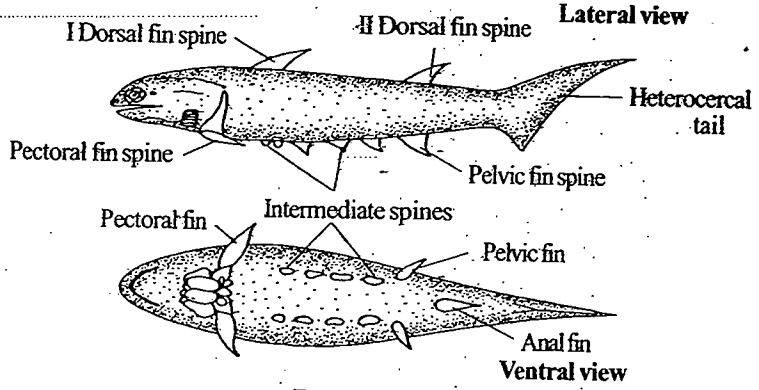

Fig.4.6: Climatius.

Chondrichthyes

Chondrichthyes are ***cartilaginous fishes***.
They were ***marine***.
They had ***placoid scales***.
The ***mouth*** is ventral. The tail is ***heterocercal***.
Gill clefts are ***5 pairs***.
Gills ***without operculum***.
Two ***spiracles*** are present.
Hyostylic jaw suspension.
No air bladder.
5 pairs of aortic arches.
Heart has a ***conus arteriosus***.
Nostrils do not open into the mouth.
Kidney is ***pronephros***.
The intestine has a ***scroll valve***.
Males have a pair of ***claspers***.
Fertilization is ***internal***.
They are ***ovoviviparous***. Eg. *Sharks, skates, rays*.

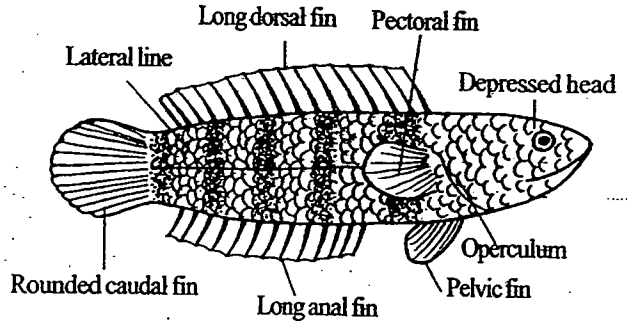

Fig.4.25: Ophiocephalus punctatus.

4. The body is large and covered with ***thick scales***.
5. Its dorsal and ventral fins are long.
6. The caudal fin is rounded.
7. The ***pectoral*** and ***pelvic fins*** are present.
8. ***Accessory respiratory*** organs are present. Hence it can live for a long time out of water.
9. It is ***carnivorous,*** feeding on ***tadpoles, frogs*** and ***small fishes***.
10. When ponds dry up it burrows in the mud and hides and comes out when water ollects in the rainy season.
11. The male constructs a nest out of weeds during the breeding season. The female lays its ggs in the nest and the male fertilizes them. Both the male and the female take care of the oungones.
12. It can live for a long time outside water. Hence it is called a ***live fish***.

Detailed Study

1. Shark

Scoliodon sorrakowah

Phylum : *Chordata*
Subphylum : *Vertebrata*
Superclass : *Gnathostomata*
Class : *Chondrichthyes*
Subclass : *Elasmobranchii*

Scoliodon is a cartilaginous fish. Hence it is included in the class ***Chondrichthyes***. *oliodon* is commonly called ***Indian dog fish*** or ***shark***. In tamil, it is called '***Chura Meen***'.

The common species are:

Scoliodon sorrakowah = S.laticaudas
Scoliodon dumerilli
Scoliodon palasorrah
Scoliodon walbeehmi

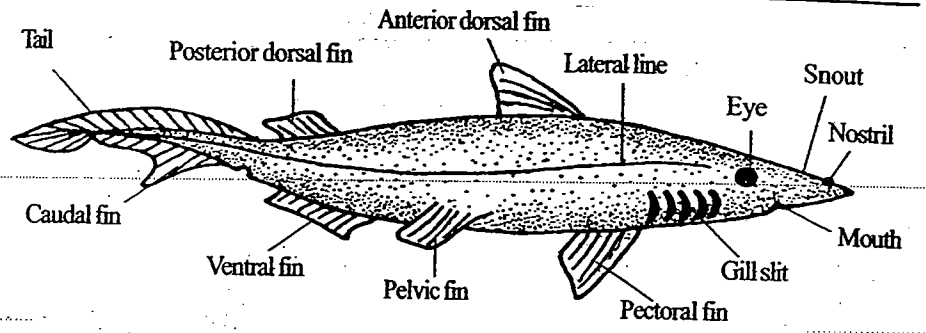

Fig.4.26: Scoliodon (shark) - lateral view.

Scoliodon is a ***marine fish***. It is a fast swimmer. It is carnivorous in habit. The sexes are separate. Fertilization is ***internal*** and development is ***direct***. It is viviparous and giving birth to youngones.

Scoliodon is elongated, spindle-shaped and laterally compressed. Both ends are pointed. It reaches a length of about 60 cm.

Shark ***exhibits counter shading***, an adaptation. The dorsal and lateral sides are dark grey in colour. The ventral side is white in colour. This helps the shark to escape from the enemies.

When an enemy looks shark from above, the dark grey merges with the dark background of the bottom. When an enemy looks from below, the white underside of the shark merges with the lighted background of the atmosphere.

On either side of the body, a faint line extends from the head to the tail. This line is called ***lateral line***. It marks the presence of ***lateral line sense organ*** inside the body.

The skin is rough and the roughness is due to the presence of innumerable backwardly directed ***spine***-like structures called ***placoid scales***.

The body is divisible into three regions, namely ***head, trunk*** and ***tail***.

The head is present at the anterior end. It is dorso-ventrally flattened. Anteriorly, it is produced into a pointed ***snout***.

The head contains a ***mouth*** on the ventral side. It is a ***crescentic*** opening. It is bounded by two jaws, namely an ***upper jaw*** and a ***lower jaw***. Each jaw has one or two rows of teeth.

Infront of the mouth, two ***slit***-like openings are situated on the ventral side. They are called ***nares*** or ***nostrils***. They are used exclusively as an olfactory organ and not as a respiratory organ.

Two prominent ***eyes*** are present on the sides of the head at a place between the mouth and nares.

Each eye is protected by three eyelids, namely an ***upper eyelid***, a ***lower eyelid*** and a ***nictitating membrane*** or ***third eyelid***. The upper and lower eyelids are immovable.

The nictitating membrane is thin, transparent and ***movable***. It lies along the lower side and can be drawn over the eye to cover it, when required.

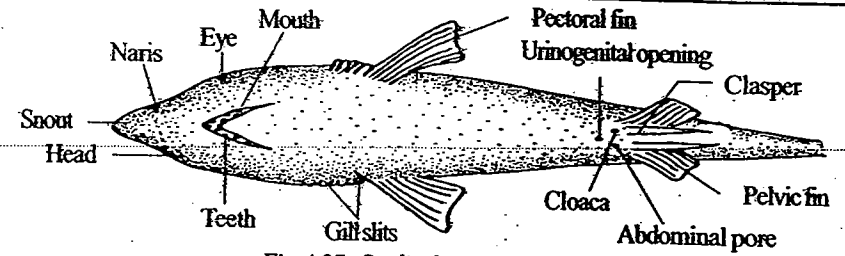

Fig.4.27: Scoliodon - ventral view.

The head and snout, on the dorsal side, contain numerous groups of pores called ***ampullary ores***. They are the external openings of ***ampulla of Lorenzini***.

Five pairs of vertical ***slit***-like openings are present on the sides of the head behind the eyes. hese openings are called ***external gill slits*** or ***external branchial apertures***. They open to the pharynx.

The ***trunk*** extends from the last gill slit to the cloacal aperture. The trunk is laterally mpressed. It contains ***fins*** and ***cloacal aperture***.

The trunk has an anterior ***median dorsal fin***, a pair of ***pectoral fins*** behind the head and air of ***pelvic fins*** infront of the tail.

The cloacal aperture lies between the pelvic fins.

The tail is the posterior region and it extends behind the cloacal aperture. It constitutes out half of the length of the trunk. It is also laterally compressed like the trunk. It is slightly nt upwards. Such an upturned tail is called ***heterocercal tail***.

The tail bears three fins, namely a ***posterior median dorsal fin***, a ***caudal fin*** and a ***ntral fin***.

Fins

Fins are specialized locomotory organs of fishes. *Fins are **flap-like outgrowths of the** dy wall directed backwards and supported by rods and fin rays.*

Shark has two types of fins. They are ***median fins*** or ***unpaired fins*** and ***paired fins*** or ***eral fins***.

1. Median Fins or Unpaired Fins : Median fins are located along the median line of body. They are unpaired and are arranged individually.

Shark has three types of median fins, namely two ***dorsal fins***, a ***caudal fin*** and a ***ventral***

One dorsal fin lies along the median line about the middle of the body. It is called ***anterior rsal fin*** or ***first dorsal fin***. It is ***triangular*** in shape.

The ***second dorsal fin*** lies just infront of the tail. It is called ***posterior dorsal fin***. It is ***ctangular*** in shape.

The heterocercal tail is surrounded by a ***caudal fin***. The caudal fin is formed of two lobes, mely a dorsal ***epichordal lobe*** and a ventral ***hypochordal lobe***.

The hypochordal lobe has a notch dividing it into a large anterior part and a small posterior rt. In the root of the caudal fin, there is a ***caudal pit*** on both the dorsal and ventral sides.

The ventral side has a ***ventral fin*** infront of the caudal fin.

2. Paired Fins or Lateral Fins: Paired fins occur in pairs on the lateral sides of the body, especially in the trunk region. As they are present on the lateral sides, they are also called ***lateral fins***.

Shark has two types of lateral fins, namely ***pectoral fins*** and ***pelvic fins***. These fins correspond to the fore limbs and hind limbs of higher vertebrates.

The pectoral fins are large and triangular in shape. They are located just behind the gill slits.

The pelvic fins are smaller and are subtriangular. They are located on the ventral side at the junction of the trunk and tail on either side of the cloacal aperture.

In the male, each pelvic fin bears on its inner edge, a rod-like structure called ***clasper***. Each clasper has a groove on its dorsal surface leading into a cavity at its base.

Placoid Scales

The skin of shark contains thousands of ***spine-like*** structures called ***placoid scales***. They form the ***exoskeleton***. They are ***dermal*** in origin.

Each placoid scale has a ***basal plate*** and a ***spine***. The spine is a ***trident***. It is formed of ***dentine***.

The dentine is externally coated with ***enamel***. It encloses a cavity called ***pulp cavity***.

It is filled with ***pulp*** containing numerous ***odontoblasts, blood vessels, nerves,*** etc.

The basal plate is ***diamond-shaped***. It has an opening in the centre to open into the pulp cavity.

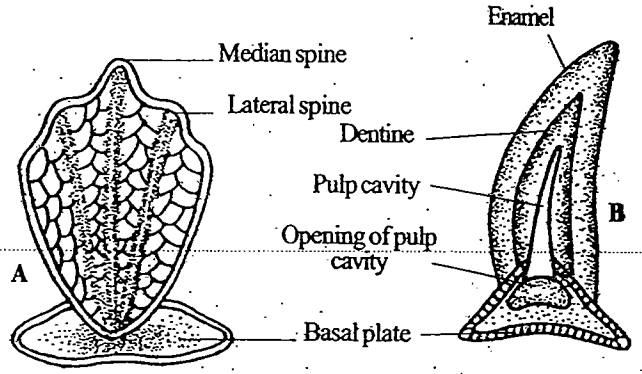

Fig.4.28: Shark - A. Placoid scale (Entire); B. Placoid scale (L.S).

Digestive System

The digestive system includes the ***alimentary canal*** and the ***digestive glands***.

Alimentary Canal

The alimentary canal starts with the mouth. The mouth is ***crescent***-shaped and it is located on the ventral side of the head. It is bounded by upper and lower jaws.

The jaws are provided with one or two rows of teeth. The teeth are ***homodont*** and ***polyphyodont***. The teeth are not used for mastication; but for catching and preventing the escape of prey.

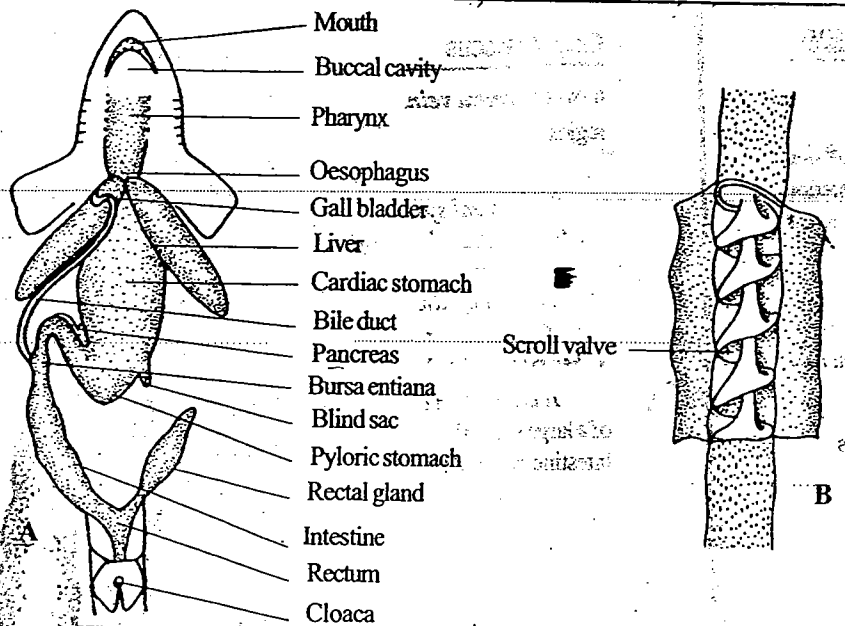

Fig.4.29: Shark-A. Digestive system; B. Spiral valve.

The mouth leads into the ***buccal cavity***. The buccal cavity contains a ***tongue***. The buccal ty opens into the pharynx.

The pharynx receives the openings of a pair of ***spiracles*** and five pairs of gill pouches on ides. The pharynx is followed by a narrow ***oesophagus***.

The oesophagus opens into the ***stomach***. It is J-shaped. The stomach has two regions, ely an anterior, wide ***cardiac*** stomach and a posterior, narrow ***pyloric*** stomach. These two eparated by a short ***blind sac***.

The distal end of pyloric stomach is slightly dilated to form a sac called ***bursa entiana.***

The stomach leads into the ***intestine***. The intestine is lined with mucous membrane. The ous membrane is folded to form a ***scroll valve.***

One edge of the scroll valve is attached to the inner wall of the intestine and the other edge led up on itself longitudinally making an anticlockwise spiral of about two and a half folds. In a cross section, it looks like a watch spring. It has two functions: a. ***It increases the of absorption***. b. ***It prevents the rapid flow of food through the intestine.***

The intestine leads into the ***rectum*** which opens into the ***cloaca***. The rectum contains a ***t gland.***

estive Glands

Shark has two digestive glands, namely the ***liver*** and the ***pancreas***.

Liver: Liver is located at the junction of oesophagus and cardiac stomach. The liver is ed of two lobes. The two lobes are united anteriorly and free posteriorly.

The right lobe contains the ***gall bladder***. A bile duct arises from the gall bladder and it opens into the intestine.

The liver has three functions: 1. ***It secretes bile***, 2. ***It stores glycogen and fat***, 3. ***It destroys worn out RBC***.

Pancreas: The pancreas is located in the loop of the stomach. It is ***bilobed***. The ***pancreatic duct*** arising from the pancreas opens into the intestine opposite to the bile duct.

Physiology of Digestion

Shark is ***carnivorous***, feeding on fishes, crustaceans, molluscs, etc. The teeth prevent the escape of prey. Digestion starts in the stomach and is completed in the intestine. Absorption occurs in the intestine. The scroll valve helps absorption.

Respiratory System

The respiratory system is formed of five pairs of ***gill pouches***. They are located on the lateral wall of the pharynx.

They open into pharynx by an ***internal branchial aperture*** and to the outside by the ***external branchial aperture.***

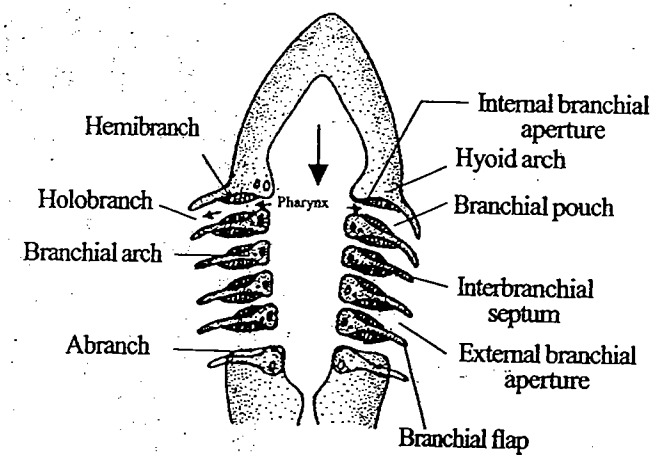

Fig.4.30: Shark - Respiratory system.

The mucous membrane of gill pouches is produced into a series of leaf-like structures called ***branchial lamellae***. They are highly vascularized.

Each gill pouch has two sets of branchial lamellae; one is on its anterior wall and the other is on its posterior wall.

The lamellae of one side of each gill pouch constitute a ***demibranch*** or ***hemibranch***. Two hemibranchs constitute a ***holobranch***.

The gill pouches are separated by ***interbranchial septa.*** An interbranchial septum is nothing but a part of the pharyngeal wall located in between the gill pouches.

Each interbranchial septum is supported by a ***cartilaginous rod*** called ***visceral arch.*** The visceral arches at their inner end bear comb-like ***gill rakers*** to protect the internal branchial aperture.

The visceral arch lying infront of the first gill pouch is called ***hyoid arch***. The hyoid arch rs only one gill on its posterior surface. Hence it is a ***hemibranch***. The remaining posterior hes are called I, II, III, IV and V ***branchial arches***.

The last branchial arch is without any gills. Hence it is an ***abranch***. The remaining four nchial arches bear four ***holobranchs***. Hence shark has nine hemibranchs on each side.

In shark, the gill lamellae are attached to the entire length of the interbranchial septum; nce the gills are called ***lamelliform***.

etween the mandibular arch and the hyoid arch there is a pit in the inner wall of the pharynx. s called ***spiracle***.

In shark, it has no lamellae and no opening to the exterior. It is a ***vestigial gill***. In other smobranchs, it is a functional gill having lamellae and an opening to the exterior.

echanism of Respiration

The respiration in shark is ***aquatic***. The ***gills*** are the respiratory organs. During respiration mouth is opened and the buccal and pharyngeal cavities are enlarged. Water is drawn in ough the mouth.

The water enters the gill pouches through the internal branchial apertures. The entry of d particles into the gill pouches is prevented by the gill rakers.

From the gill pouches, the water passes out through the external branchial apertures after shing the branchial lamellae. The O_2 from the water diffuses into the blood and the CO_2 fuses into the water.

Circulatory System

The circulatory system comprises the ***heart, blood, arteries*** and the ***veins***.

Blood

The blood is ***reddish*** in colour. It has a liquid component called ***plasma*** and ***cellular nponents***. The cellular components include ***RBC, WBC, platelets,*** etc.

Heart

The heart is the ***muscular pumbing organ*** of the circulatory system.

The heart is located beneath the pharynx. It is a conical ***muscular organ***. It is enclosed in wo layered sac called ***pericardium***. Between the two layers of pericardium is a narrow ice called ***pericardial cavity*** filled with a ***pericardial fluid***.

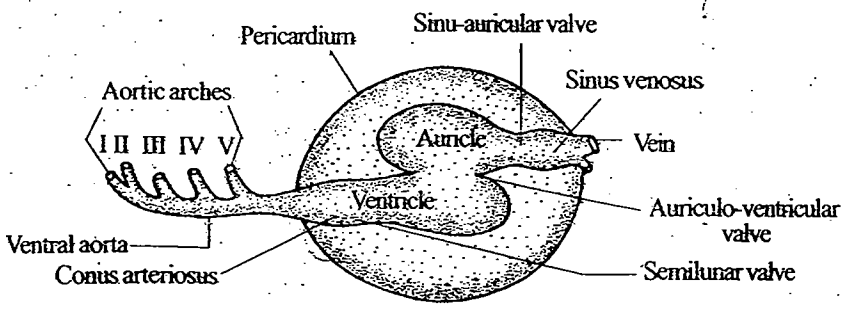

Fig.4.31: Heart of Scoliodon - Lateral view.

The pericardial fluid protects the heart from shocks and provides free movement to the heart during contraction.

The heart is formed of ***two chambers***, namely an ***atrium*** (auricle) and a ***ventricle.***

The atrium is triangular in shape. It is thin walled. It opens into the ventricle by the ***auriculo-ventricular aperture*** guarded by the ***auriculo-ventricular valve.***

The ***ventricle*** is ***thick walled.*** The inner surface of the ventricle has numerous muscular strands called ***chordae tendinae.*** Anteriorly the ventricle leads into a tubular structure called ***conus arteriosus.***

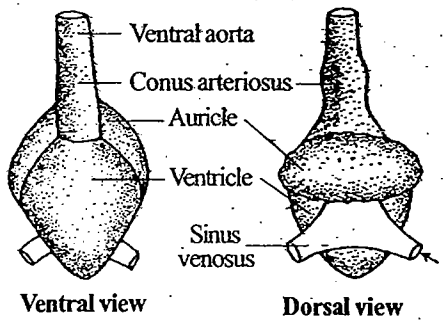

Fig.4.32: Heart of Scoliodon.

The conus arteriosus is provided with two transverse rows of ***semilunar valves.*** The conus continues forwards in the form of a tube called ***ventral aorta.***

The atrium receives blood from a sac called ***sinus venosus.*** The sinus venosus is ***thin walled.*** It receives venous blood. The sinus venosus opens into the atrium by the ***sinu-auricular aperture.*** It is guarded by the ***sinu-auricular valves.*** These valves prevent the flow of blood from the atrium into the sinus venosus.

The heart of shark contains only ***deoxygenated blood.*** Hence it is called ***venous heart*** or ***branchial heart.***

As the sinus venosus and conus arteriosus are not considered as true chambers, the heart of shark is called ***two-chambered heart.***

Arterial System

Arterial system includes a system of blood vessels called ***arteries.*** They carry the blood from the heart and supply it to the various parts of the body. It is a blood ***distributing system.***

The conus arteriosus of the heart runs forward in the form of a tube called ***ventral aorta.*** It runs forward beneath the pharynx upto the hyoid arch. Here it divides into two branches called ***innominate arteries.***

Each innominate artery again divides into two branches called ***I*** and ***II afferent branchial arteries.*** They supply blood to the ***hyoid arch*** and ***I branchial arch*** respectively. Behind the innominate arteries, the ventral aorta gives out three more pairs of branches called ***III, IV***

afferent branchial arteries and they supply blood to the *II, III* and *IV* branchial respectively.

he blood from the gill is collected by nine *efferent branchial arteries*. The first eight join in pairs to form *branchial loops* around the first four gill pouches. The ninth artery ng the anterior surface of the fifth gill pouch.

he four loops are interconnected by three longitudinal connectives called *synapticula*. rth loop is connected to the 9th efferent branchial artery by another *synapticulum*.

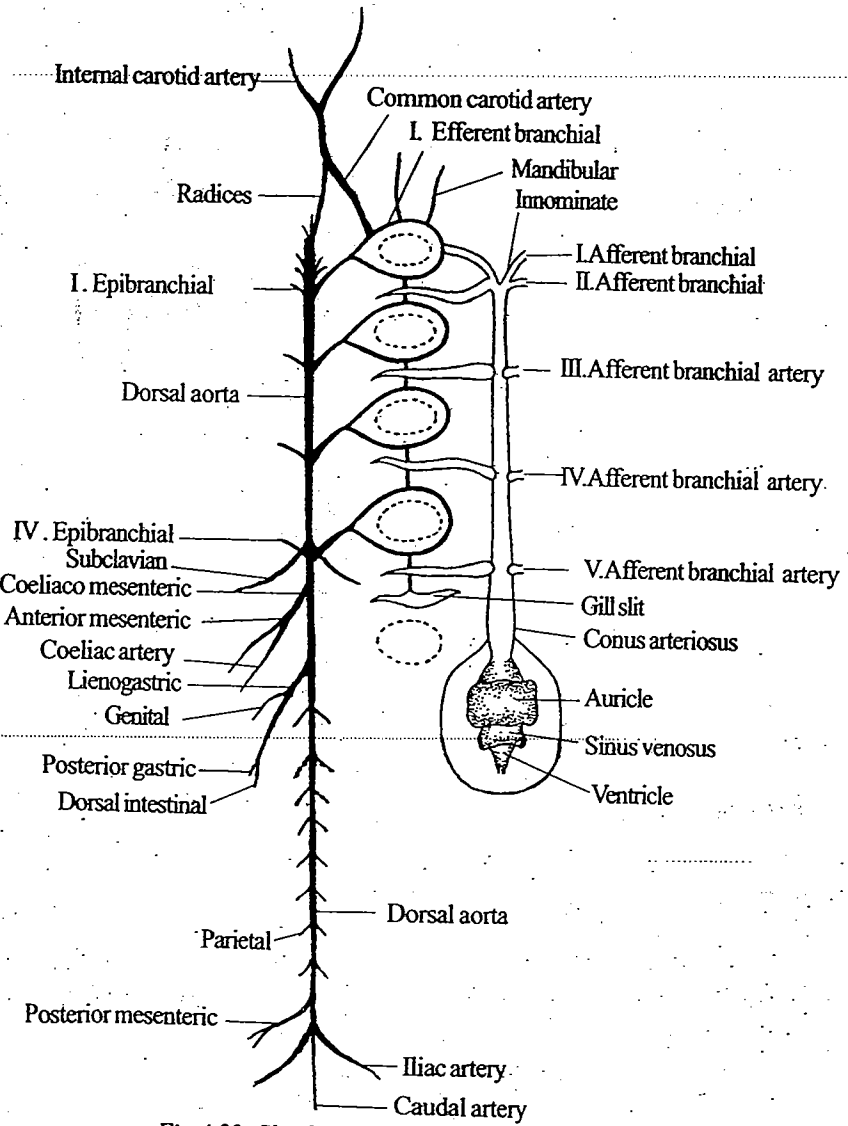

Fig.4.33: Shark - Arterial system.

From each loop arises a large vessel called ***epibranchial artery***. The epibranchial arteries of the two sides run towards the mid-dorsal line where they open into a median longitudinal vessel called ***dorsal aorta***.

The head receives blood mainly from the first branchial loop. From this loop three branches arise. They are the ***common carotid artery,*** the ***hyoidean artery*** and the ***mandibular artery***. The common carotid also receives a small branch called ***radix*** from the dorsal aorta.

The ***common carotid artery*** divides into ***internal carotid artery*** and ***external carotid artery.*** The internal carotid artery supplies blood to the brain.

The external carotid artery divides into branches like ***orbital artery, buccal artery, maxillonasal artery*** and ***rostral artery.***

The ***hyoidean artery*** divides into an ***ophthalmic artery*** and a ***cerebral artery***. They supply blood to the eye and brain.

The ***mandibular artery*** supplies blood to the lower jaw.

The dorsal aorta gives out the following branches:

1. Radices: Radices are a pair of arteries arising from the anterior end of dorsal aorta and are connected with common carotid arteries.

2. Buccal arteries: A few pairs of buccal arteries arise from the anterior end of the dorsal aorta and supply blood to the roof of buccal cavity.

3. Subclavian arteries: They arise from the junction of dorsal aorta and the last epibranchial arteries. They supply blood to the ***pectoral fins***.

4. Coeliaco mesenteric artery: It arises from the dorsal aorta just behind the last epibranchials. It soon divides into a ***coeliac artery*** and an ***anterior mesenteric artery.***

5. Lieno-gastric artery: It arises from the dorsal aorta a little behind the coeliaco mesenteric artery. It supplied blood to gonads, stomach, intestine, spleen, etc.

6. Posterior mesenteric artery: It supplies blood to the posterior part of gonads and the rectal glands.

7. Parietal arteries: Several pairs of ***parietal*** arteries arise throughout the length of the dorsal aorta. They supply blood to the muscles, vertebral column, spinal cord, kidneys, gonads, etc.

8. Iliac arteries: These are paired arteries supplying blood to the pelvic fins.

9. Caudal artery: It is the posterior continuation of dorsal aorta supplying blood to the tail.

Venous System

Venous system is a system of veins which carry blood from the various parts of the body to the heart. It carries ***deoxygenated blood***. It is a ***blood collecting system.***

The sinus venosus receives the blood through two pairs of large vessels, namely one pair of ***ductus Cuvieri*** and another pair of ***hepatic sinus***.

Each ***ductus cuvierius*** is formed by the union of five main veins, namely

the ***anterior cardinal sinus***

the ***inferior jugular sinus***

the ***posterior cardinal sinus***

*e **lateral abdominal sinus** and*
*e **subclavian vein.***

he anterior cardinal sinus collects the blood from the dorsal side of the head. The inferior veins collect the blood from the floor of buccal cavity and the pharynx. The posterior l sinus starts as a median vessel in between the kidneys. It receives a number of ***renal*** om the kidneys. Then it divides into two branches. The branches open into the ***ductus i.***

he subclavian vein *receives* blood from the pectoral fin. The lateral abdominal veins are along the sides of the body. Posteriorly the two lateral abdominal veins are connected by

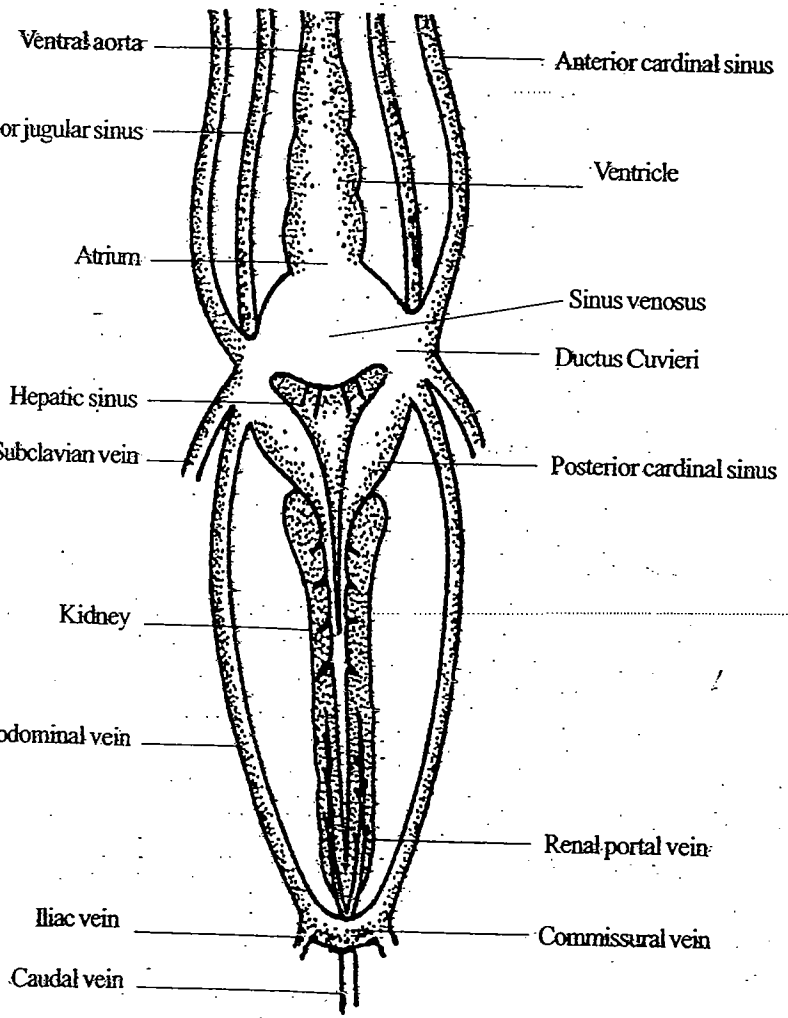

Fig.4.34: Shark - Venous system.

a ***commissural vein.*** Posteriorly each abdominal vein receives an ***iliac vein*** from the pelvic region.

Portal Systems

The portal system is formed of a system of veins which carry blood from one organ to another organ other than heart.

There are two types of portal system in vertebrates. They are:

1. The hepatic portal system

2. The renal portal system.

1. Hepatic Portal System

It is a system of veins carrying blood from the digestive system to the liver. It is formed of a large vein called ***hepatic portal vein*** which collects blood from the digestive system (stomach, intestine, rectum) through small veins.

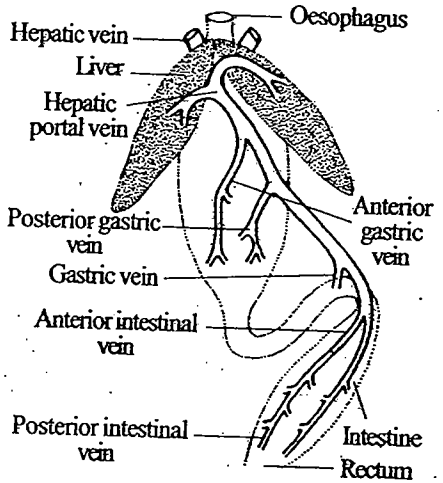

Fig.4.35: Hepatic portal system.

The hepatic portal vein divides into two branches and each branch enters the liver. In the liver, the hepatic portal veins break into capillaries and supply the liver. Small capillaries collect blood from the liver and they join together to form ***hepatic sinuses.*** They open into the ***ductus Cuvieri.***

2. Renal Portal System

It is a system of veins carrying blood from the tail to the kidney.

From the tail a ***caudal vein*** arises. It divides into two ***renal portal veins.*** They enter the kidney and divide into small branches called ***afferent renal veins.*** Blood is collected from the kidney by the ***efferent renal veins.*** The efferent renal veins of each kidney join together to form a ***posterior cardinal sinus.*** The two posterior cardinal sinuses open into the ***ductus Cuvieri.***

Nervous System

The nervous system of *Scoliodon* consists of 3 parts. They are,

1. Central Nervous System: It includes ***brain*** and ***spinal cord.***

2. Peripheral Nervous System: It includes ***cranial nerves*** and ***spinal nerves***.

3. Autonomic Nervous System: It includes ***sympathetic*** and ***parasympathetic*** nerves.

Brain

Brain is the centre of the nervous system. It is the control centre for all actions of the nal.

The brain is enclosed in a brain case called ***cranium***. The cranium is made up of ***cartilage***. ow the cranium, the brain is covered by a thin, vascular membrane called ***meninx primitiva***.

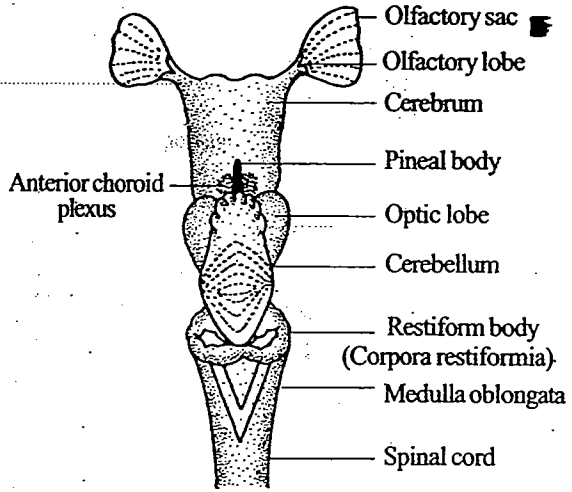

Fig.4.36: Scoliodon: Brain - dorsal view.

The brain consists of three main divisions, namely

1. Forebrain or *Prosencephalon*

2. Midbrain or *Mesencephalon*

3. Hindbrain or *Rhombencephalon.*

Forebrain

The forebrain is the anterior region of the brain and it is called ***prosencephalon***. The forebrain sists of three parts, namely ***olfactory lobes, cerebrum*** and ***diencephalon***.

The anterior end of the brain has a pair of ***bulb***-like structures called ***olfactory bulbs*** or ***ctory lobes***. The olfactory lobes are concerned with ***smell***.

The olfactory lobe is connected to the brain by an ***olfactory tract*** or ***olfactory peduncle***. h olfactory lobe is closely attached to the ***olfactory sac***.

The anterior region of the brain is called ***cerebrum***. It is formed of two ***cerebral nispheres***. The cerebral hemispheres are the seat of ***memory, intelligence*** and ***sciousness***.

Each cerebral hemisphere encloses a cavity called ***lateral ventricle***. The two lateral tricles found in the cerebral hemispheres are called ***I*** and ***II ventricles***. Posteriorly they n into the III ventricle by an Y-shaped opening called ***foramen of Monro***.

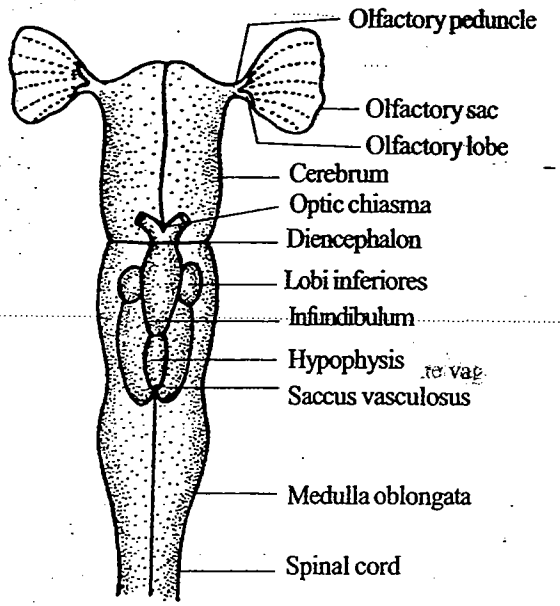

Fig.4.37: Scoliodon : Brain -ventral view.

The roof of the lateral ventricles remains thin and is called ***pallium***. The floor of the lateral ventricles remains thick and is called ***corpus striatum*** (Pl. ***corpora striata***).

Diencephalon is the posterior part of the forebrain. It encloses a cavity called ***III ventricle*** or ***diocoel***. The III ventricle communicates with the IV ventricle through ***iter***.

The lateral walls of the ***III*** ventricle are thickened and are called ***thalami***. The roof is called ***epithalamus***.

The floor of the ***III*** ventricle is called ***hypothalamus***.

The roof of the ***III*** ventricle bears a stalk called ***pineal stalk***. The pineal stalk ends in a ***pineal body*** or ***pineal gland*** or ***epiphysis***.

The floor of the diencephalon has a cross formed by the crossing of the two optic nerves. This cross is called ***optic chiasma***.

Behind the optic chiasma, the diencephalon has a down growth called ***infundibulum***. On the sides of infundibulum, there are two lobes called ***lobi inferiores***.

Posteriorly, the infundibulum is attached to an oval body called ***hypophysis***. The infundibulum and hypophysis together form an endocrine gland called ***pituitary gland***. Pituitary gland is the ***master of endocrine glands***.

The dorsal side of hypophysis has a vascular sac called ***saccus vasculosus***. Saccus vasculosus is peculiar to fishes and it acts as a ***pressure receptor***.

2. Midbrain

The midbrain is the middle region of the brain and it is called ***meseneephalon***. It consists of two main parts, namely ***optic lobes*** and ***crura cerebri***.

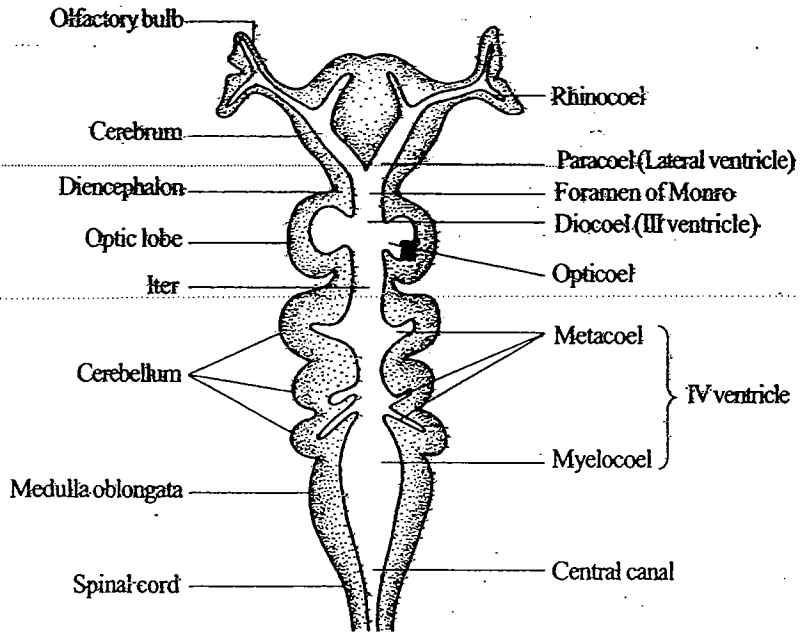

Fig. 4.38: Scoliodon - Brain in vertical section showing the ventricles.

Shark has a pair of large rounded swellings on the dorsal side of the midbrain. They are d ***optic lobes*** or ***corpora bigemina***. Optic lobes control ***vision.***

The ventral side of the midbrain has thick bands of nerve fibres running antero-posteriorly ecting the forebrain with the hindbrain. These thick bands of nerve fibres are called ***crura ri.***

The midbrain encloses a narrow canal called ***iter*** or ***aqueduct of Sylvius***. It connects the ***ntricle*** with the IV ventricle.

indbrain

Hindbrain is the posterior region of the brain and it is called ***rhombencephalon***. It consists o parts, namely ***cerebellum*** and ***medulla oblongata***.

Cerebellum is a large, elongated and rhomboidal structure. Anteriorly it covers the optic and posteriorly it covers the medulla oblongata. Its dorsal surface is thrown into numerous ular folds. Cerebellum controls ***muscular co-ordination***.

Medulla oblongata is the posterior part of the brain. Anteriorly it is broad and posteriorly ers into the spinal cord.

The antero-dorsal end of medulla oblongata bears a pair of hollow outgrowths called ***corpora formia*** or ***restiform bodies*** or ***auricular lobes***. These lobes correspond to the floccular of birds and mammals.

The medulla oblongata encloses a wide cavity called ***IV ventricle***. It is communicated the ***III*** ventricle through iter.

Commissures: The right and left halves of the brain are connected by transverse bands of fibres called ***commissures***.

The vertebrate brain has three kinds of commissures. They are ***anterior commissure, dorsal commissure*** and ***posterior commissure***.

Ventricles of Brain: The cavity enclosed by the brain is called ***ventricle***. There are four ventricles in the brain. They are, ***I, II, III*** and ***IV*** ventricles.

I and II ventricles are located inside the ***cerebrum***. They are also called ***lateral ventricles***. III ventricle lies inside the ***diencephalon***. It communicates with I and II ventricles by two openings called ***foramen of Monro***.

The IV ventricle is present inside the ***cerebellum***. III and IV ventricles are connected by a narrow canal called ***iter*** or ***aqueduct of Sylvius*** lying in the midbrain. The ventricles are filled with ***cerebrospinal fluid***.

Spinal Cord

Spinal cord is the posterior elongation of the brain. It remains in the ***neural canal of vertebral column***. It is a long tube with uniform diameter. It extends from the medulla oblongata to the end of the tail.

The spinal cord is covered by a membrane called ***meninx primitiva*** which is continuous with that of the brain.

The spinal cord has a narrow cavity at its centre called ***central canal***. Anteriorly the central canal opens into the IV ventricle and posteriorly it remains closed. The central canal is filled with ***cerebrospinal fluid.***

On the dorsal side the spinal cord has a median depression called ***sulcus***. The ventral side has a deep ***median groove*** called ***ventral fissure***.

The central canal is surrounded by ***grey matter***. It has the shape of a triangle in transverse section and the apex of the triangle is facing upwards. The grey matter is surrounded by the ***white matter***.

The spinal cord conducts the sensory and motor impulses to and from the brain. It is also a centre for ***local*** and ***spontaneous reflex actions***.

Cranial Nerves

The nerves arising from the brain are called ***cranial nerves***. Shark has 11 pairs of cranial nerves. They are the following:

1. "O" Nerve or Terminal Nerve

This nerve is named as ***zero nerve*** because it was discovered long after the other 10 cranial nerves were numbered. It originates from the olfactory sac, extends along the olfactory peduncle and enters the cerebrum. It is a somatic ***sensory nerve***.

2. I Nerve or Olfactory Nerve

It starts from the nasal sac and ends in the olfactory lobe. It is a somatic ***sensory nerve.***

3. II Nerve or Optic Nerve

It starts from retina of the eye and joins the diencephalon. The two optic nerves cross on the floor of the diencephalon to form the ***optic chiasma***. The optic nerves are ***somatic sensory***.

4. III Nerve or Oculomotor Nerve

It emerges from the ventral surface of the midbrain and innervates the ***superior rectus, inferior rectus, internal rectus*** and ***inferior oblique muscles*** of the eyeball. It is a somatic ***motor nerve***.

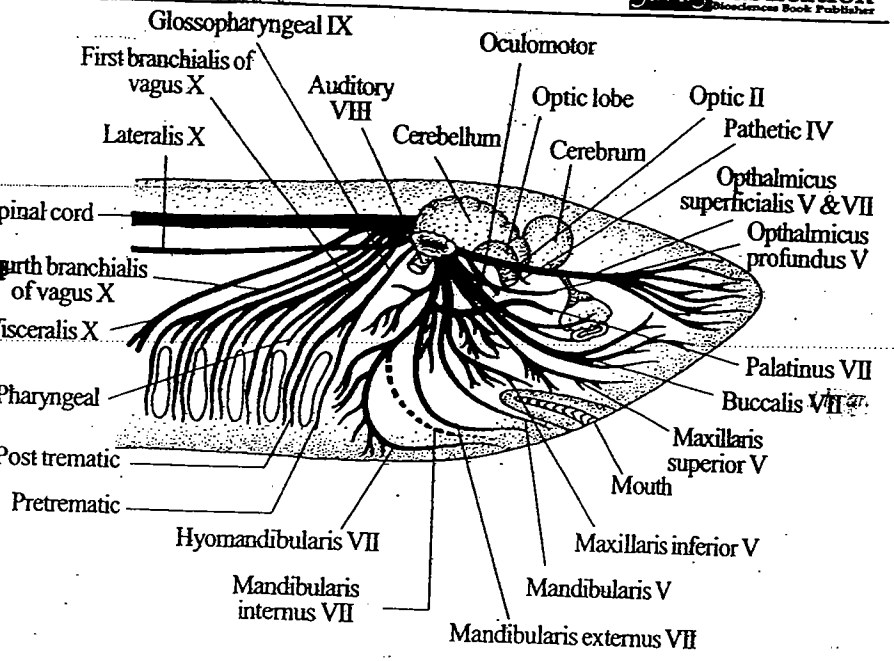

Fig.4.39: Scoliodon - Cranial nerves

V Nerve or Pathetic or Trochlear Nerve

It begins from the dorsal surface of the midbrain and supplies the ***superior oblique muscle*** he eyeball. It is a somatic ***motor nerve***.

/ Nerve or Trigeminal Nerve

It leaves the brain at the sides of the anterior part of the medulla oblongata beneath the ***ous restiformia***. It is a mixed nerve, having somatic ***sensory*** and somatic ***motor fibres***. It s a large ***Gasserian ganglion*** soon after its origin and divides into three branches:

a. Ophthalmic Nerve or Ophthal-micus: It again divides into two, namely ***ramus thalmicus superficialis*** and ***ramus ophthalmicus profundus***. The former, extends along pper border of the orbit and supplies the skin of the snout infront of the ***olfactory capsule***. a ***sensory branch***. The ramus ophthalmicus profundus enters the orbit, where it gives off a ler ciliary nerve to the eyeball. It then enters the cranium, which it again leaves to innervate kin on the dorsal surface of the snout. It is a mixed nerve.

b. Maxillary Nerve or Maxillaris: It is the main branch of the trigeminal. It runs along the buccalis branch of the facial nerve for a short distance and then divides into branches upply the skin of the upper jaw, upper lip and lower eyelid and teeth of the upper jaw. It is sory nerve.

c. Mandibular Nerve or Mandi-bularis: It runs along the side of the maxillaris for a distance and then runs to the lower jaw to innervate its skin and muscles. It is a mixed

7. VI Nerve or Abducens (Abducent) Nerve

It arises from the ventral side of the medulla oblongata near its middle part and is distributed to the external rectus muscle of the eyeball. It sends a small branch to the nictitating membrane. It is a somatic ***motor nerve***.

8. VII Nerve or Facial Nerve

It arises from the side of the medulla oblongata just behind the trigeminal nerve. It is a mixed nerve, having ***somatic sensory***, ***visceral sensory*** and ***visceral motor fibres***. It divides into five branches:

a. Ophthalmicus superficialis: It runs along the upper border of the orbit and supplies the lateral line sense organs on the upper surface of the snout. It is a sensory branch.

b. Buccalis: It runs for a short distance alongside the maxillaris of the fifth nerve and then separates to get distributed to the lateral line sense organs of the maxillary region. It is a ***sensory nerve***.

c. Mandibularis externus: It innervates the lateral line sense organs of mandibular region. It is a ***sensory nerve***.

d. Hyomandibularis: It sends several fine branches to the lateral line sense organs of the mandibular region and a ***mandibularis internus branch*** to the mucous membrane of the buccal cavity. Then it goes to the muscles of the throat as the ***hyoidius nerve***. It is a ***mixed nerve***.

e. Palatinus: It branches off from the hyomandibularis, extends forwards and supplies the roof of the pharynx and roof of the buccal cavity. It is a sensory nerve.

The facial nerve has a ***geniculate ganglion***, where the hyomandibular branches off.

9. VIII Nerve or Auditory Nerve

It is very short and bears an ***acoustic ganglion*** on it. It is formed by the union of two nerves: ***vestibular*** and ***saccular*** coming from the balancing and hearing portions of the ear respectively. The nerve joins the brain at the side of the medulla oblongata just behind the fifth and seventh nerves. It is a somatic sensory nerve.

10. IX Nerve or Glossopharyngeal Nerve

It arises from the side of the medulla oblongata near its hind end. It bears a ***petrosal ganglion*** near its origin, passes backwards and downwards to the region of the first gill slit, where it divides into three branches:

i. Pharyngeal Branch: It supplies the receptors present in the mucous membrane of the pharynx. It is a sensory branch.

ii. Pretrematic: It innervates the hemibranch infront of the first gill slit. It is also a sensory branch.

iii. Post-trematic: It is distributed to the hemibranch behind the first gill slit and visceral muscles. It is a mixed branch.

The ninth nerve is mixed, having visceral sensory and visceral motor fibres.

11. X Nerve or Vagus or Pneumogastric Nerve

It emerges from the medulla oblongata close to the ninth nerve and has a very wide distribution (***vagus*** = wandering). It is a ***mixed*** nerve, having ***somatic sensory***, ***visceral sensory*** and ***visceral motor fibres***. It divides into 3 main branches. They are the following:

i. Branchialis: It consists of four nerves that pass backwards and downwards to the region e second, third, fourth and fifth gill slits. Each of these four nerves sends a ***pharyngeal branch*** e roof of the pharynx, a ***pretrematic branch*** to the hemibranch infront of the respective gill slit ***post-trematic branch*** to the hemibranch behind the respective gill slit. These three branches nble in nature with the corresponding branches of the ninth nerve. The branchialis is a mixed e.

ii. Visceralis: It enters the trunk and innervates the alimentary canal and the heart. It is a d nerve.

iii. Lateralis: It runs backwards deep in the lateral body wall and innervates the lateral line e organs. It is a sensory nerve.

The vagus nerve bears a ***lateralis ganglion*** at the base of the lateralis branch and a ***lar ganglion*** at the base of other branches.

Spinal Nerves

Scoliodon has a large number of spinal nerves, there being a pair of them in each body ent. All of them are similar in origin and distribution.

Each spinal nerve arises from the grey matter of the spinal cord by two roots: a ***dorsal*** and ***ntral***. The dorsal root bears a ***dorsal root ganglion*** in its course. The ventral root is out a ganglion. The two roots emerge from the neural canal through separate ***foramina*** and e outside the vertebral column to form the spinal nerve. The ventral root is ***purely motor***, but orsal root is ***not purely sensory***, because some visceral motor fibres pass out via dorsal also. The spinal nerves formed by the union of dorsal and ventral roots are mixed.

Each spinal nerve divides into ***dorsal*** and ***ventral rami***. The dorsal ramus supplies the and muscles of the dorsal part of the body. The ventral ramus innervates the skin and cles of the ventral and lateral parts of the body. A few anterior spinal nerves are represented e ventral roots only. These are termed the ***spino-occipital nerves***. Fibres from these es join to form a ***hypobran-chial nerve*** on either side to supply the ventral part of the gill n. ***Cervico-branchial*** and ***lumbo-sacral*** plexuses are formed by union of some of the l nerves in connection with the pectoral and pelvic fins.

Autonomic Nervous System

The sympathetic chain of cartilaginous fishes, uniquely among vertebrates, does not extend he head. Otherwise it conforms to the typical gnathostome pattern. Parasym-pathetic system ot yet been clearly recognized.

Sense Organs

Shark has the following sense organs: 1. ***Olfactory sacs***, 2. ***Eyes***, 3. ***Ear***, 4. ***Lateral line e organs*** (Neuromast organs) and 5. ***Ampullae of Lorenzini***.

1. Olfactory Sacs

The shark has two olfactory sacs located inside the nostrils. They are ***chemoreceptors***. y feel the sense of ***smell***. They open to the exterior by ***external nostrils***.

2. Eyes

The eyes are ***photoreceptors***. Shark has ***two eyes***. They are located on the sides of the head in the ***orbits***.

The eye is in the form of a hollow ball called ***eye ball***. Its wall is formed of three coats, namely an outer ***sclerotic coat***, a middle ***choroid coat*** and an inner ***retina***.

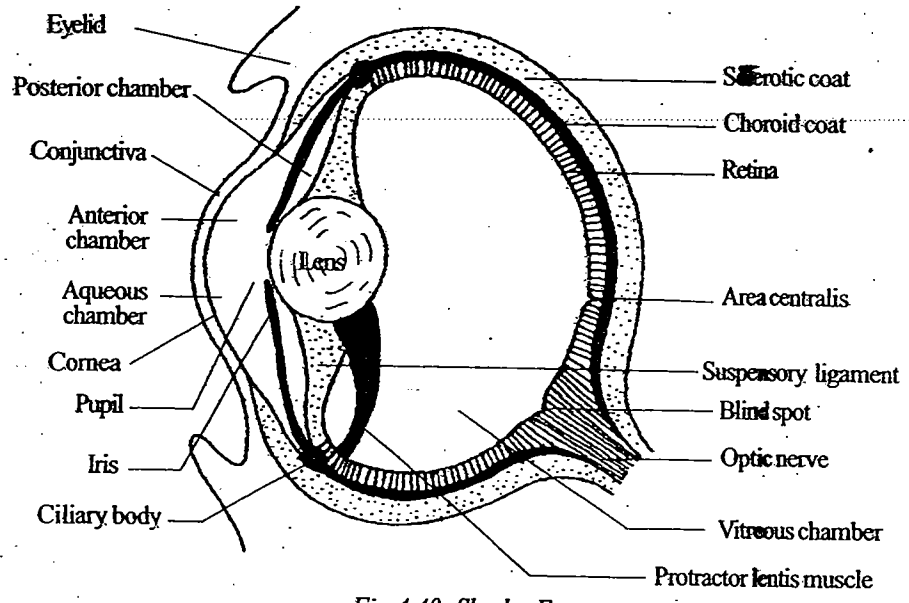

Fig.4.40: Shark - Eye .

Sclerotic coat is the outer covering. It is ***cartilaginous***. Anteriorly it remains as a transparent membrane called ***cornea***. The cornea is covered by a thin membrane called ***conjunctiva***.

The ***choroid coat*** is the middle layer. It is formed of ***blood vessels*** and ***pigment cells***. The inner surface of the choroid coat contains a layer of cells having light reflecting ***guanine crystals***. This layer is called ***tapetum lucidum***. They reflect the light back to the retina.

Anteriorly the choroid forms a circular disc called ***iris***. The centre of the iris has a slit called ***pupil***.

A ***lens*** is located in the pupil.

At the junction of the iris and the choroid there is a nonpigmented, non- vascular thickened area called the ***ciliary body***. The inner surface of the ciliary body is thrown into radiating folds called ***ciliary processes***.

The lens is attached to the ciliary process by a gelatinous ***suspensory ligament***. The lower side of the lens is attached to the ciliary body by a muscle called ***protractor lentis muscle***.

Retina is the innermost layer. The retina contains photosensitive cells called ***rods***; ***cones are absent***. Hence fish is ***colour blind***. From the rods nerve fibres arise.

All the nerve fibres converge towards the posterior side of the eyes and come out with the me of *optic nerve*. The point of the retina from where nerve leaves the eye is called *blind ot*. The blind spot is free from rods; so this area cannot form any image and hence the name.

The eye is protected by three eyelids, namely the *upper eyelid*, the *lower eyelid* and the *ctitating membrane*.

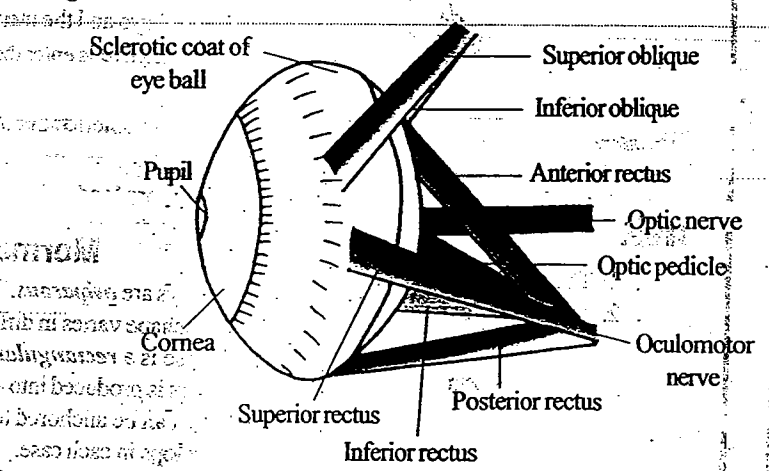

Fig. 4.41 : Scoliodon - Eye and muscles

The nictitating membrane is a special outgrowth of the anterior region of the lower eyelid. an cover the eye fully.

The eye encloses cavities filled with a transparent gelatinous fluid called *humour* (humor). e cavity lying between cornea and iris is called *anterior chamber*.

The small cavity lying between the lens and the iris is called *posterior chamber*. These two mbers are filled with a thin watery liquid called *aqueous humour*. Hence these two chambers collectively called *aqueous chambers*.

The large cavity lying between the lens and the retina is called *vitreous chamber* * and it is ed with a jelly like material called *vitreous humour*.

The eyes are kept in position in the orbit by *6 muscles* and an *optic pedicle* which is tilaginous.

The eye muscles are the following

1. *Superior oblique musele*
2. *Inferior oblique muscle*
3. *Superior rectus muscle*
4. *Inferior rectus muscle*
5. *Anterior rectus muscle*
6. *Posterior rectus muscle*

These muscles bring about the movement of eye ball.

Vitreous chamber is not the posterior chamber of eye.*

The eyes have a *monocular vision*. The two eyes are independent in vision. They cannot discriminate between colours. They are *colour blind*. The eyes are adapted for vision in dimlight.

3. Ears

Ears are the organs of *equilibrium* and *hearing*. The shark has two ears. The external and the middle ears are absent. Only internal ears are present in the shark.

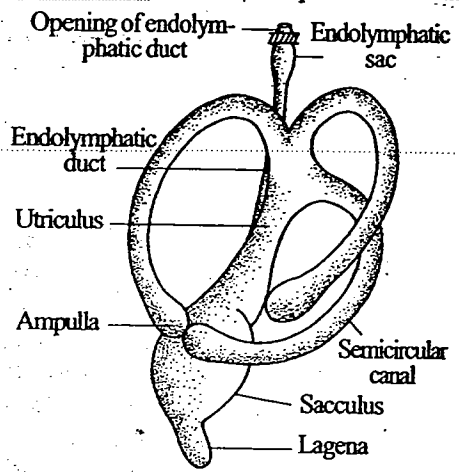

Fig.4.42: Scoliodon - Internal ear.

The internal ear is called *membranous labyrinth*. It is enclosed in a *cartilaginous labyrinth*. There exists a space inbetween the *membranous labyrinth* and the *cartila-ginous labyrinth*. It is called *perilymphatic space*. The membranous labyrinth is filled with *endolymph*.

The *membranous labyrinth* has two chambers, namely a dorsal *utriculus* and a ventral *sacculus*. The sacculus gives out a small projection from its ventral side, called *lagena*.

A small canal arises from the dorsal side of the *sacculus* called *endolymphatic duct*. It runs upwards and dilates to form a sac called *endolymphatic sac*. It opens to the outside on the dorsal side.

The utriculus has three *semicircular canals*. Both ends of the canal open into the utricu-lus. One end of each tube becomes dilated to form a sac called *ampulla*.

One duct is *horizontal* and the other two are *vertical* in position.

The inner ear is provided with *six sensory patches*. Of these, three are in the ampullae and they are called *cristae*. The other three are in *utriculus*, *sacculus* and *lagena* and they are called *maculae*.

4. Lateral Line Sense Organs (Neuromast Organs)

The lateral line sense organs are *rheoreceptors* of fishes. They detect the *water current*. They are in the form of two canals embedded in the dermis, one on each side of the body. They extend from the head to the tail.

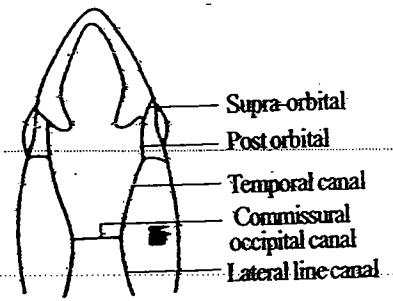

Fig.4.43: Scoliodon - Lateral line canal branches in the head.

In the head region, they are highly branched. Just behind the head, the two lateral canals are joined dorsally by a ***commissural occipital canal***. Then each canal runs forward as the ***temporal canal***. Each temporal canal divides into many branches.

The canals are filled with ***mucous***. They open to the exterior by ***vertical tubes***. The tubes are lined with ***epithelial cells***. There are many ***mucous gland cells*** secreting ***mucous***.

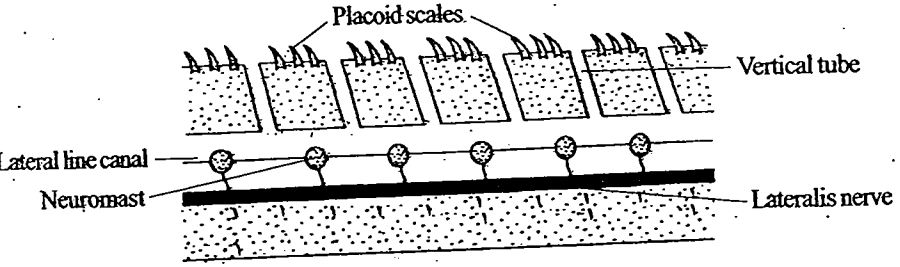

Fig.4.44: L.S. of lateral line.

There are groups of sensory cells called ***neuromasts***. Each neuromast is made up of a group of ***sensory receptor cells*** and ***supporting cells***.

Each sensorycell has a ***sensory hair*** at its inner surface and a ***nerve fibre*** at its outer surface. The nerve fibres are connected to the ***lateralis nerve***.

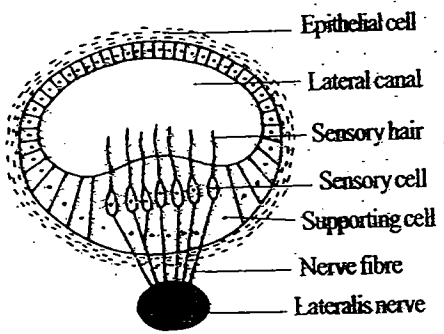

Fig.4.45: Shark - T.S. of lateral line through a neuromast.

The sensory hairs are tipped with a gelatinous substance in the form of a cup called ***cupula***.

Functions

The neuromast organs detect the ***vibrations in water***. This helps the fish to move in darkness and turbid water. It also helps the fish to detect the enemies.

5. Ampullae of Lorenzini

These are ***thermoreceptors*** of shark. They are present in groups in the head. They are embedded in the skin.

Each ampulla of Lorenzini has an elongated tube called ***tubule*** filled with ***mucous***. The outer end opens to the exterior by an ***aperture*** and the inner end has a dilated ***ampullary sac***.

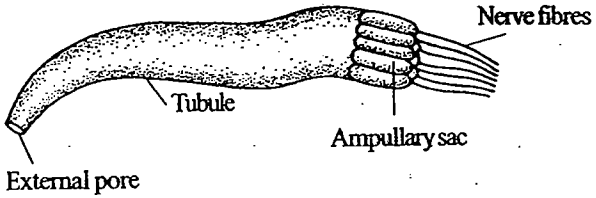

Fig.4.46: Shark - Ampulla of Lorenzini.

Each ampullary sac has 8 - 9 chambers arranged around a central core called ***centrum***. The ampullary sac is lined with two types of cells, namely ***gland cells*** and ***sensory cells***. The gland cells ***secrete mucous***. The sensory cells are connected to ***nerve fibres***.

Urinogenital System

The urinogenital system includes two systems, namely the ***excretory system*** and the ***reproductive system***.

Excretory System

The excretory system includes a pair of ***kidneys***, a pair of ***ureters*** and an ***urinogenital sinus***.

*The kidney is a **mesonephros***. It is long and flattened. It extends from the cloaca to the oesophagus. It has two distinct parts, namely a ***slender*** anterior part and a ***thicker*** posterior part.

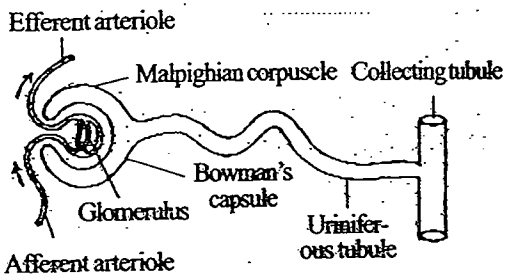

Fig.4.47: A nephron.

In the male, the anterior part is called ***genital kidney***. This part is rudimentary and functionless in the female. The posterior part is called ***renal kidney***. It carries out the ***excretory*** function.

The kidney is formed of thousands of tubules called ***uriniferous tubules*** or ***nephron***. One end of each uriniferous tubule has a ***Malpighian corpuscle***. It is formed of a cup-like structure called ***Bowman's capsule*** and a network of capillaries called ***glomerulus***. The other end is connected to a ***collecting tubule*** which receives many uriniferous tubules.

The collecting tubules open into the ureter. The ureters of the two kidneys open into an urino-genital sinus which inturn opens to the cloaca.

Reproductive System

In shark, the sexes are separate. It exhibits ***sexual dimorphism***.

In the male, the inner margins of the pelvic fins bear a pair of copulatory organs called ***claspers***. They are absent from the females.

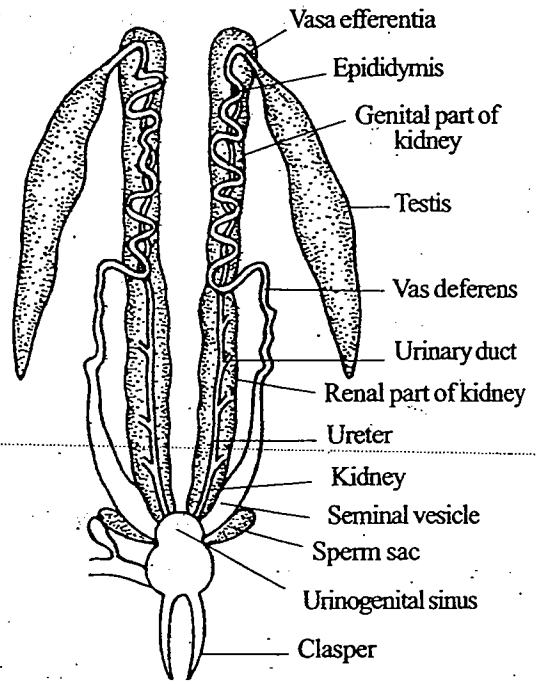

Fig.4.48: Scoliodon - Male urinogenital system.

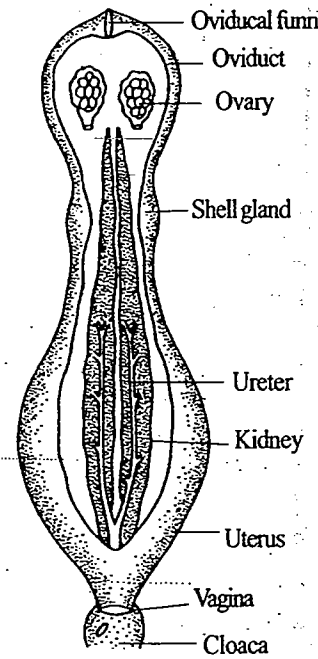

Fig.4.49: Scoliodon-Female urino genital system.

Male Reproductive System

The male has two ***testes***. They are elongated. They are attached to the dorsal body wall by a membrane called ***mesorchium***.

From each testis arise several ***vasa efferentia***. The vasa efferentia open into a ***vas deferens***. It remains much coiled in the genital kidney. This is called ***epididymis***. It comes out of the kidney and posteriorly it dilates to form a sac called ***seminal vesicle***.

The seminal vesicles open into the ***urinogenital sinus*** which inturn opens into the ***cloaca***. Two ***sperm sacs*** of unknown function are attached to the ***urinogenital sinus***.

Female Reproductive System

It consists of a pair of ***ovaries, oviducts, shell glands*** and ***uteri***. The ovaries are located behind the oesophagus.

They are attached to the dorsal body wall by a membrane called ***mesovarium***.

The ***oviducts*** are long and they open into the body cavity by ***oviducal funnels*** near the oesophagus. Near the middle the oviduct has a sac called ***shell gland*** to store spermatozoa.

Posteriorly, the oviduct dilates to form a sac-like ***uterus***. The two uteri join together to form a ***vagina***. The vagina opens into the cloaca.

Copulation and Fertilization

Mature males and females take part in copulation. During copulation, the claspers are introduced into the cloaca of the female.

The sperms are introduced into the vagina. Fertilization is ***internal*** and occurs in the oviduct.

Development

In the case of *Scoliodon*, fertilization is ***internal***.

The fertilized egg develops inside the uterus of the mother and the mother gives birth to youngones.

The embryo is nourished by the yolk stored in the egg and the mother gives mainly protection. This type of development is called ***ovoviviparous***.

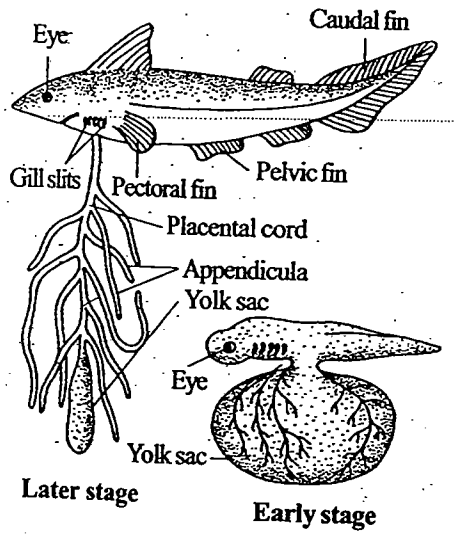

Fig.4.50: Yolk sac placenta of Scoliodon.

About 3-7 embryos develop inside the uterus. The yolk of the developing embryo is closed in a sac called ***yolk sac***.

The yolk sac gets connected with the gut of the embryo by a tubular ***yolk stalk***. When the lk is used up, the reduced yolk sac gets attached to the uterine wall of the mother. This tissue nnection between the embryo and the uterus is called ***yolk sac placenta.***

In the mean time, blood vessels enter the ***yolk sac*** by way of the ***yolk stalk***. Now the yolk alk is called ***placental cord.***

Nutritive materials are transferred through the placental cord.

The placental cord sends numerous slender tubular outgrowths called ***appendicula*** into e uterine wall to absorb more food.

Mermaids purse

Some sharks and rays are ***oviparous***. Their fertilized egg is laid in an egg-case called ***Mermaids purse***. Its shape varies in different species.

In ***Scyllium***, the purse is a ***rectangular box***.

Each of its four corners is produced into a long tendril-like ***thread***. With the help of these threads, the egg-case can be anchored to sea weeds.

Usually one egg develops in each case.

The young one is hatched in 6 to 9 months.

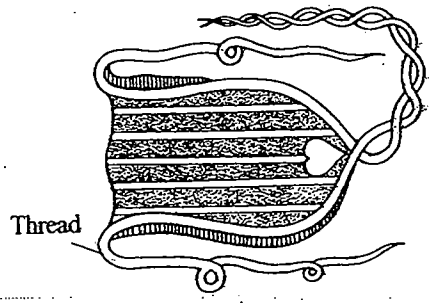

Fig.4.51: A mermaid's purse.

Endoskeleton

'Endoskeleton' refers to the hard parts present inside the body. It forms the ***internal frame work***. In shark, it is formed of ***cartilage*** and not of bones.

The endoskeleton has the following functions:

1. It gives ***shape*** to the ***animals.***
2. It protects the internal organs like the ***brain, heart, lungs***, etc. and
3. It helps in the ***attachment*** of ***muscles*** to itself.

The endoskeleton is broadly divided into two groups namely,

a. Axial skeleton

b. Appendicular skeleton.

Endoskeleton

Axial skeleton	***Appendicular skeleton***
Eg. *Skull, Vertebral column* and *Sternum*	Eg. *Girdles* and *supporting elements of fins*

Axial skeleton lies in the long axis of the body. It includes the ***skull, vertebral column*** and the ***sternum.***

The appendicular skeleton lies in the transverse axis and it includes the ***girdles*** and ***supporting elements of fins.***

Skull

1. The skull is an ***axial skeleton.***
2. The skull of shark is ***cartilaginous.***

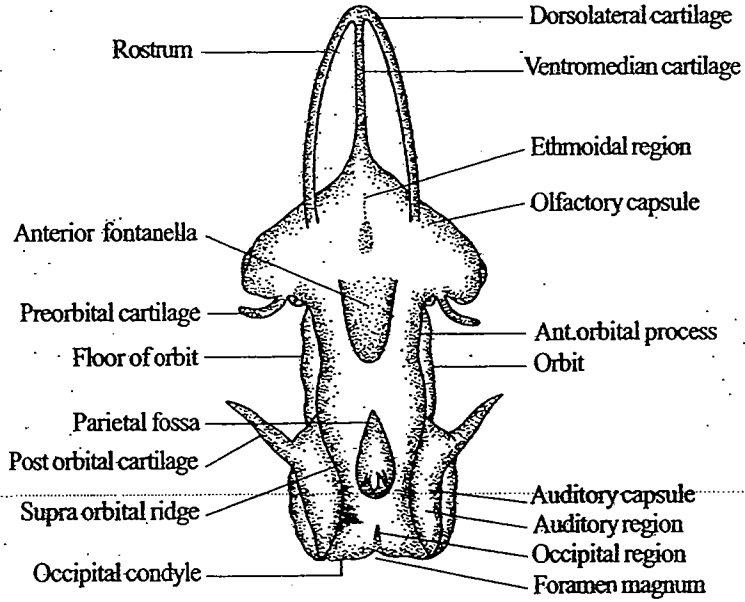

Fig.4.52: Scoliodon : Skull - Dorsal view.

3. The skull is ***dicondylic*** as it contains two ***occipital condyles***.
4. It is ***hyostylic.***
5. It is ***violin*** shaped.
6. The skull consists of a ***cranium*** and ***visceral skeleton***.
7. The cranium is the ***brain case***. It consists of 4 regions, namely ***occipital, auditory, orbital*** and ***olfactory (ethmoidal)*** regions.
8. The posterior region is called the ***occipital*** region. It has a large opening called ***foramen magnum***. The brain is connected to the spinal cord through this opening.

5 Amphibia

Amphibia may be defined as ***ectothermic*** *vertebrates typically living on land and breeding in* ***water;*** *they are having a smooth or rough skin rich in glands which keep it* ***moist;*** *if scales are present, they are* ***hidden*** *in the skin* ***(Noble, 1931; Collins Dict., 1983).***

The term ***'Amphibia'*** refers to a ***double life*** (***Amphi***=double; ***bios***=life). The amphibians live both in ***water*** and on ***land***.

They are the first group of vertebrates living on land. They came from water. They are not fully adapted for the life on land. A part of their life is carried out in water. So they lead an ***amphibious life.***

They originated from fishes. Structurally, amphibians are intermediate between fishes and reptiles. Eg. *Frogs, toads, caecilians,* etc.

General Characters

Amphibians possess the following general characters:

1. Amphibians are ***cold blooded vertebrates*** with ***dual life.***
2. They contain a ***cranium*** around the brain. So they are called ***Craniata.***
3. They have ***jaws.*** Hence they are included in the superclass ***Gnathostomata.***
4. They are ***tetrapods*** having 4 limbs.
5. The embryos do not develop an ***amnion.*** Hence they are called ***anamniota.***
6. All amphibians are ***freshwater forms.*** There are no marine amphibians.
7. The skin is ***moist, glandular*** and without outer scales.
8. The limbs are ***pentadactylous*** (having 5 digits).

9. The skull possesses two *occipital condyles*.

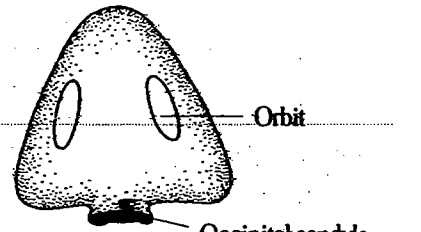

Fig.5.1: Skull of frog showing two occipital condyles.

10. The heart is *3-chambered* consisting of *2 auricles* and *one ventricle*.

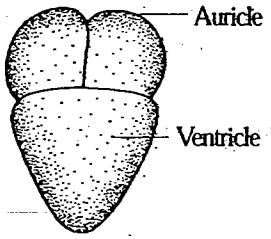

Fig.5.2: Three chambered heart of Amphibia.

11. Three pairs of *aortic arches* are present.
12. The RBCs are *nucleated*.
13. The respiratory organs include *gills, lungs, skin* and *buccopharynx*.
14. The kidney is a *mesonephros*.
15. They contain *10 pairs* of *cranial nerves*.

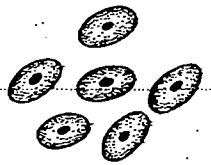

Fig.5.3: Nucleated RBC of Amphibia.

16. The ear consists of *middle ear* and *internal ear*. External ear is absent. The middle ear contains a single ear bone called *columella auris*.

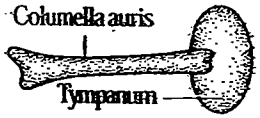

Fig.5.4: Columella auris of Amphibia.

17. The sexes are separate with *sexual dimorphism*.
18. Amphibians are *oviparous* i.e. laying eggs.
19. Fertilization is *external*.
20. The development is *indirect*. A *tadpole larva* is included in the life history.
21. Metamorphosis commonly takes place in them.

Classification of Amphibia

Amphibians are *cold blooded* vertebrates living both in water and land.

Amphibians are *Chordates* as they develop a notochord in the embryonic stage.

They are *vertebrates* because they contain a *vertebral column*.

They have a cranium around the brain. So they are included in the group *Craniata*.

They have *jaws*. So they are included in the superclass *Gnathostomata*.

They do not develop an amnion. So they are included in *anamniota*. They have 4 limbs. So they are included in the group *Tetrapoda*.

Class Amphibia is divided into *three subclasses*, namely:

1. *Labyrinthodontia* - *Extinct*
2. *Lepospondyli* - *Extinct*
3. *Lissamphibia* - *Extant*

Subclass.1. Labyrinthodontia

Labyrinthodontia is also called *Stegocephalia*. It includes extinct amphibia. They had *labyrinthodont teeth* and *complex vertebrae*. They were *aquatic*.

Labyrinthodontia is divided into three orders, namely:

1. *Ichthyostegalia*.
   Eg. *Ichthyostega*
2. *Temnospondyli*.
   Eg. *Eryops*.
3. *Anthracosauria*
   Eg. *Gephyrostegus*

Subclass.2. Lepospondyli

Lepospondyli includes extinct amphibia. They had *ring*-like vertebrae. Eg. *Diplocaulus*.

Subclass.3. Lissamphibia

Lissamphibia includes modern living amphibia like frogs, toads, etc.

Lissamphibia is subdivided into 3 orders based on the presence or absence of tail or limbs. They are:

1. *Anura*
2. *Urodela*
3. *Apoda*

Anura includes *tailless, jumping* amphibians. Eg. *Rana tigerina, Rana hexadactyla, Bufo, Rhacophorus*.

Urodela includes *tailed* amphibians. Eg. *Necturus, Ambystoma, Salamandra*, etc.

Apoda includes *limbless* amphibians. Eg. *Ichthyophis.*

Labyrinthodontia

Labyrinthodontia is an extinct group of amphibians. They were also called *Stegocephalia.*

They were *aquatic.*

They had *labyrinthodont tooth.* The wall of the pulp cavity showed complex *infoldings.*

he surface of the tooth had *serrations.*

They had dermal scales.

The vertebrae were complex with a *neural arch,* an anterior *intercentrum* and a posterior *eurocentrum.*

The common examples are *Ichthyostega, Eryops,* etc.

Anura

Anura are *tailless jumping* amphibians (*An* - No; *oura* - tail). It includes *frogs* and *toads.*

The skin is *moist, glandular* and without scales.

Four *pentadactyl limbs* are present. Hind limbs are larger.

The vertebral column is made up of *9 vertebrae* and an *urostyle.*

Tympanum is present. *Vocal cords* are present.

Development is *indirect* with a *tadpole* larva.

Eg. *Rana tigerine, Rana hexadactyla, Bufo, Rhacophorus,* etc.

Urodela

Urodela are *tailed* amphibians (*Oura* - tail, *delos* - visible).

The body is long. The skin is *scaleless.*

Tympanum is absent.

Four *pentadactyl limbs* are present. The limbs are equal in size. Vocal cords are absent.

Vertebrae are *numerous* upto *90.*

Development is *direct* or indirect.

Some urodeles exhibit *neoteny.*

The common urodeles are *Salamandra, Necturus, Ambystoma,* etc.

Apoda

Apoda are *limbless amphibians* (*A* - without; *podos* - foot).

The body is *snake-like* with *naked skin.* Hence apoda is also called *Gymnophiona* (*ymnos* - naked, *Ophioneosa* - of a snake).

They are *blind* and hence called *caecilians.*

The body is long. The skin is embedded with minute *scales.*

Tympanum is absent.

Vertebrae are numerous upto 275.

Vocal cords are absent.

Development is *indirect.*

They are *burrowing* in habit.

They exhibit *parental care.*

They exhibit *discontinuous distri-bution.*

Eg. *Ichthyophis.*

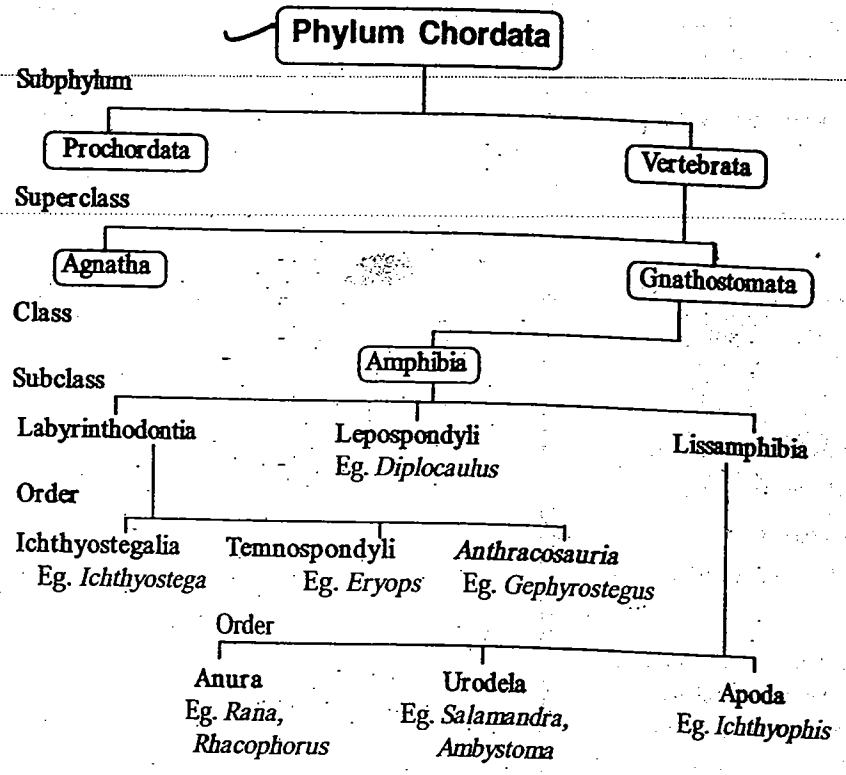

Fig.5.5: Synoptic classification of Amphibia.

Detailed Classification

Extinct Amphibians

The extinct amphibians are included in the subclasses *Labyrinthodontia* and *Lepospondyli.*

Subclass 1: Labyrinthodontia (Folded teeth)

(G. *labyrinthos,* tortuous passage + *odontos,* tooth)

1. This is an extinct subclass of Amphibia comprising the late *Palaeozoic* and *Triassic solid-skulled* amphibians with *complex vertebrae* (*Colbert,* 1969).
2. Aquatic or semi-aquatic forms.
3. Strong *conical* teeth with *striations.* These resemble the teeth of Rhipidistian crossopterygians. In cross section, both groups show the *labyrinthodont* pattern of complex *infoldings of the walls of pulp cavity.*
4. Some had dermal scales.
5. All were fish-eating.

The hand inturn is divisible into three regions, namely a *wrist (carpus)*, a *palm (metacarpus)* and the *fingers*.

The bones of the wrist are called *carpals*. There are six carpals. They are arranged in two

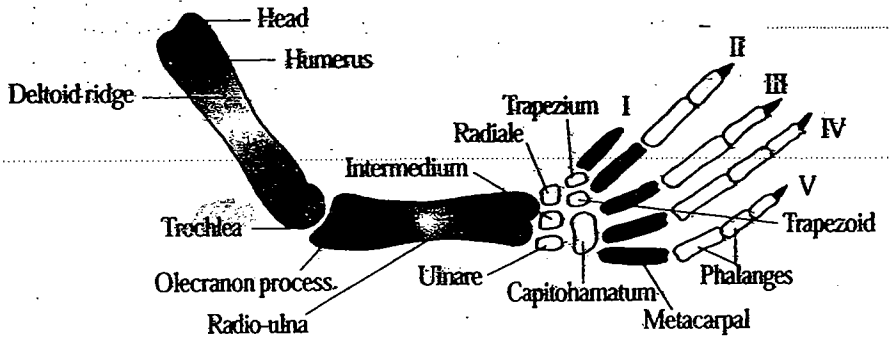

Fig.5.82: Frog - Fore limb.

rows of three each. The proximal row consists of three carpals, namely *ulnare, intermedium* and *radiale*. The ulnare articulates with the *ulna* and the radiale articulates with the *radius*. The carpals of the distal row are named as *capitohamatum, trapezoid* and *trapezium*.

The palm is supported by five *metacarpals*.

There are four digits having *phalanges*. The first digit is absent. The phalangial formula is 0,2,2,3,3.

Hind Limbs

The hind limb is made up of three regions, namely *thigh*, *shank* and *foot*.

The thigh is supported by a single bone called *femur*. The anterior end of the femur is

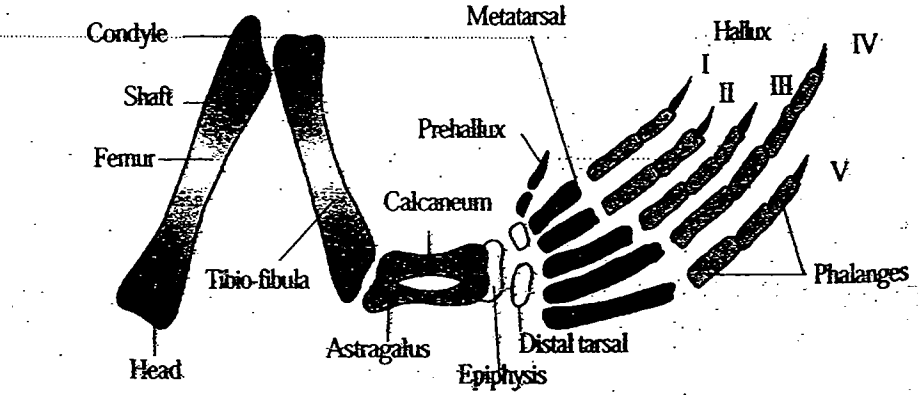

Fig.5.83: Frog - Hind-limb.

rounded to form the *head* which articulates with the *acetabulum* of the pelvic girdle. The posterior end forms the *condyle*. The main stem is called *shaft*.

The *shank* consists of a single bone called *tibio-fibula*. It is formed by the fusion of two bones, namely *tibia* and *fibula*. The tibia has a *cnemial crest*.

The foot in turn is divisible into three regions, namely an *ankle (tarsus)*, an *instep (metatarsus)* and the *toes*.

The ankle consists of *5 tarsal* bones. The tarsal bones are arranged in two rows. The proximal tarsals include *astragalus (tibiale)* and *calcaneum (fibulare)*. These two bones are very long and are united at their ends but separated in the middle region. The distal tarsals are composed of two small bones.

The instep is composed of *five metatarsals*.

There are five *digits* or *toes*. There is an additional digit called *pre-hallux* or *calcar* and it lies on the inner side of the *big toe* or *hallux*. The pre-hallux has two small bones.

The phalangial formula is 2,2,3,4,3.

The digits are *webbed*.

General Topics

Parental Care in Amphibia

The nursing of eggs and embryos by the parents is called parental care. It is well developed in *Amphibia*.

1. Nests

The parents construct a nest into which the eggs are laid. Four types of nests are encountered.

a. Mud Nests

i. Hyla faber: Female makes a nest in the mud in shallow waters. The female lays eggs about 2 days after nest building.

ii. Heptadactylus ocellatus: It builds small mud bunds near the edge of the pond water and spawns in that enclosure.

iii. Rhacophorus schlegeli: (Arboreal frog of Japan): The female makes a spherical hole of 6-9 cm wide in mud-banks of ponds.

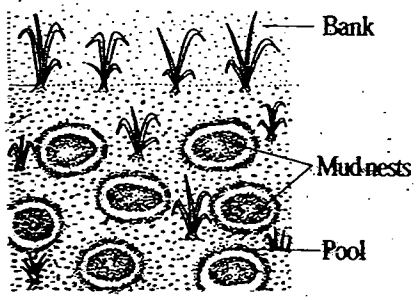

Fig.5.84: Mud nests of Hyla faber.

iv. Desmognathus fucus: It is an urodele amphibian. It constructs an underground burrow and protects her eggs.

b. Tree Nests

i. Phyllomedusa deposits the egg in the leaf nests. The leaf nests are constructed by folding the margin of the leaves.

Leaf margins are glued together by cloacal secretion. These leaf nests are seen in the branches of trees overhanging the water. After hatching the larvae jump into the pond.

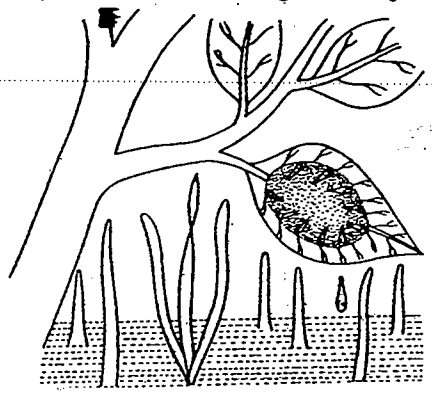

Fig.5.85: Leaf nest of Phyllomedusa.

ii. Triton constructs the nest using the shoots of trees.

iii. *Chiromantis:* The female deposits the eggs on the foamy mass on various kinds of trees either between roots or in a nest formed by gluing together several leaves. The larvae are probably washed down into the water by *rain*.

iv. Hyla resinfictrix: Collects bees wax from the hives of certain stingless bees and applies it on the inner surface of a shallow cavity on the tree. When this cavity is filled with rain water, the female lays eggs. Here these eggs develop into tadpoles and are free from predators.

c. Foam Nests

Rhacophorus schlegeli is a *Japanese tree frog*. It digs a hole or tunnel and lays eggs here. In a frothy mass to avoid desiccation. During rains hatching tadpoles are washed down the dropping tunnel into the pond or river for further development.

Leptodactylus mystracinus, the *South American tree frog* (female) digs a hole near water and fills it with a frothy mass of mucous. The eggs are laid on this.

d. Gelatinous Bags

Phrynixalus birol secretes a *sausage*-shaped transparent gelatinous membranous bag and it lays its eggs in it.

Salamandrella keyserlingi lays its eggs in a gelatinous bag which is fastened to aquatic plants.

2. Direct Caring by the Parents

Some species of amphibians directly care their eggs and youngones:

1. *Desmognathus fucus:* It is a *tailed amphibian*. The male carries the eggs around

the neck in the form of a string.

2. *Dendrobatus:* They carry their tadpoles on their back, to which they are attached by a peculiar secretion.

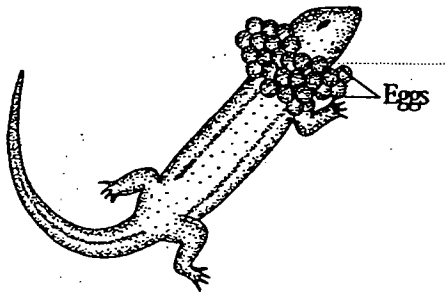

Fig.5.86: Desmognathus fucus with eggs on the neck.

3. *Phyllobatus:* Male carries its tadpoles on its back. The youngones get fixed themselves by means of their suckers. The tadpoles are carried from one pond to another.

4. *Alytes obstetricans* (Mid-wife toad): The males of this toad show a peculiar type of parental care. This toad is abundant in *France* and *Italy*.

Several males collect around a female. One of the males becomes successful to grasp round the waist of the female.

The male then lubricates the cloacal region of the female where upon the female discharges the eggs. The eggs are fertilized.

Fig.5.87: Mid wife toad.

After fertilization the eggs are wrapped round the back of the thigh of the male and the male withdraws himself into a hole near the pond. Now and then the male carries the egg to the water to moisten them. When the eggs are nearly ready to hatch, he takes them to the water where the larvae come out and further development and metamorphosis take place.

5. *Hyla goeldii:* The female carries the eggs on its back.

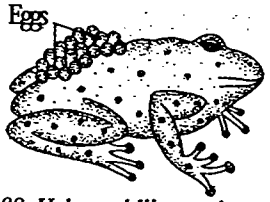

Fig.5.88: Hyla goeldii carrying eggs.

6. ***Pipa pipa***: In this species, the skin on the dorsal side has small pockets into which the eggs are placed.

7. ***Pipa dorsigera***: In this species, small cutaneous pits develop on the dorsal skin of the female. The male places the eggs on these small pits. Each pit has an operculum which covers the pit. The partition between the pits is highly vascular.

The larvae develop inside these brood pits. The developing larvae attain a vascular tail. Physiological exchange of materials between the developing larva and the mother occur in this animal. The tadpole larva comes out of the pit in about 80 days.

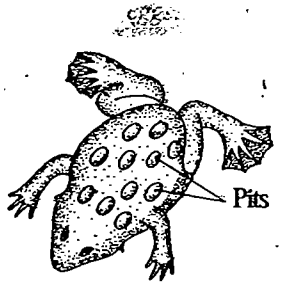

Fig.5.89: Pipa showing dorsal pits.

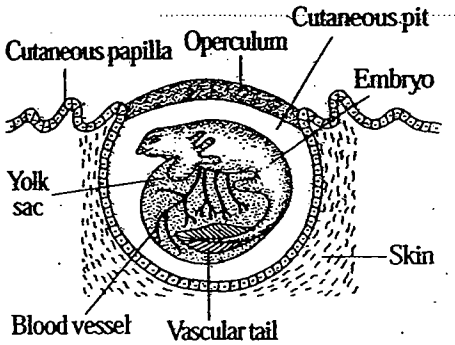

Fig.5.90: Pseudoplacentation in Pipa dorsigera.

8. ***Rhinoderma darvini***: In this frog, the vocal sac of the male opens by 2 slits one on either side of the tongue. During breeding season the vocal sacs enlarge and the eggs are put into them.

The eggs remain in the vocal sacs upto hatching or even upto the completion of metamorphosis.

9. ***Nototrema marsupium*** **(Marsupial toad)**: The eggs are deposited in a pouch on the back with one opening at the posterior end.

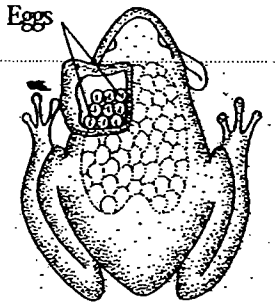

Fig.5.91: Nototrema marsupium with brood pouch.

10. ***Ichthyophis***: It is a burrowing, limbless amphibian (apoda) coils around the egg mass until they are hatched.

The female takes the eggs into the water shortly before hatching.

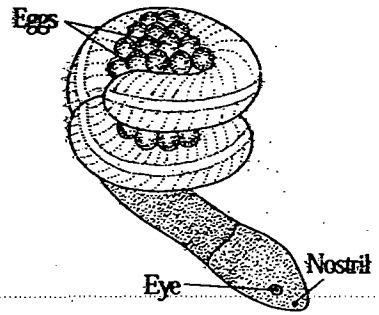

Fig.5.92: Ichthyophis glutinosa coiling around eggs.

11. **Ovoviviparity**: Some amphibians are *ovoviviparous*. The females retain their eggs in the oviduct and they give birth to youngones.

Eg. *Toads* like *Nectophrynoides* and *Pseudophryne*, salamanders like *Salamandra salamandra* and *S.atra* and apodans like *Typhlonectes, Geotrypetes, Dermophis*, etc.