# CONTENTS

# SYLLABUS

## B. Sc. (Part II) Zoology

## PAPER – I : CHORDATA (SC-122)

**UNIT-1 :**

Chapter 1 : Urochordata General characters and classification.

Chapter 2 : Herdmania Morphology and anatomy, Blood Vascular system and Reterograssive Metamorphosis.

Chapter 3 : Ceaphalochordata General characters and classification.

Chapter 4 : Amphioxus Morphology and Anatomy.

Chapter 5 : Cyclostomata Comparison between Petromyzon and Myxine.

**UNIT-2 :**

Chapter 6 : Gnathostomata General characters of Pisces and outline classification.

Chapter 7 : Amphibia : General characters and classification, Paedogenesis in Assolatal larva.

Chapter 8 : Reptilia General characters and classification, Poisonous and nonpoisonous snakes.

Chapter 9 : Aves General characters and classification, Flight adaptations in birds.

Chapter 10 : Salient features and affinieties of Prototheria, Metatheria and Eutheria.

# UNIT 1

# CHORDATA

## STRUCTURE



## LEARNING OBJECTIVES

After going through this unit you will learn :

- Chordata fundamental, Chordata characters features. Classification of chordata.

## 1.1. INTRODUCTION TO CHORDATA

Phylum chordata (Gr. *Chorde* = cord and *ata* = bearing) was created by **Balfour** in 1880. It refers to a common characteristic feature, that is, a stiff, supporting rod-like structure along the back, called the **notochord** (Gr., *noton* = back; L., *Chorda* = cord). It is found in all the members of the phylum chordata at some stage of their lives. The animals belonging to other group, the **nonchordata** have no notochord or backbone. The phylum chordata includes fishes, amphibians, reptiles, birds and mammals. It also includes tunicates and lancelets which are said to be protochordates (primitive chordates).

Chordates species are about 49,000. Subphyla Urochordata and Cephorlochordata include about 2,500 species. Among chordate, fishes are most numerous about 25,000 species. Others are amphibians about 2,500 species, reptiles about 6,000, birds about 9,000 and mammals about 4,500. Their size varies from medium to large. The gigantic blue whale (*Balaenoptera musculus*) is 35 metres long and 120 tons in weight, whale shark (*Rhineodon typus*) is 15 metres long. Philippine qoby (*Pandaka*) is the smallest fish measuring about 10 mm long.

Chordates are distributed in all types of habitats such as terrestrial, deserts, fresh and marine waters and inthe air, and from poles to the equator. Fishes, amphibians and reptiles are cold-blooded animals and are not able to survive in very hot and cold climates of Arctic and Antartic regions. Birds and mammals are warm-blooded animals and can survive in every type of climates. Their body temperature remains constant.

All fishes are aqatic (fresh water or marine), amphibians are terrestrial as well as aquatic, but no one is marine, reptiles (fresh water as well as marine). Birds are exclusively terrestrial (aereal) and mammals are terrestrial and also aquatic in habit freshwater and marine.

### Three Fundamental Chordate Characters

All the chordates possess three unique characteristics at some stage in their llife history. These three morphological features are :

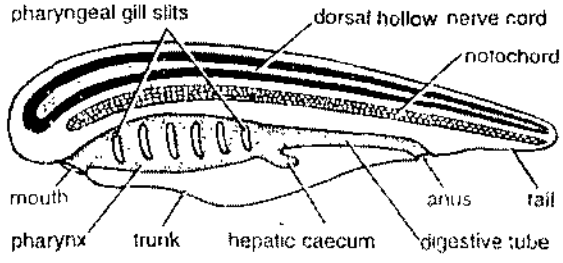



**Fig. 1. A chordate showing three fundamental chordate features (diagrammatic).**

1. A dorsal hollow (tubular) nerve cord.
2. A longitudinal supporting rod-like notochord.
3. A series of pharyngeal gill slits.

**1. Dorsal hollow nerve cord :** In chordates, central nervous system is always dorsal, hollow (tubular) and lies dorsal to the notochord extending lengthwise inthe body. The nerve cord (**neural tube**) is derived from the dorsal ectodermal neural plate of the embryo and encloses a canal, called **neurocoel.** In vertebrates, the anterior region of nerve cord enlarges to form the **crebral vesicle** or **brain** that is enclosed in the bony or cartilagiuous cranium. The posterior part of nerve cord forms the **spinal cord** which remains protected within the vertebral column.

**2. Notochord :** The notochord or **chorda dorsalis** is an elongated rod-like flexible structure extending throughout the length of the body. It lies beneath the nerve cord and above the alimentary canal. It is derived from the endoderm (roof of the embryonic archenteron). It is formed of large vacuolated notochordal cells having gelatinous matrix and surrounded by outer fibrous and inner elastic sheaths. In adult vertebrates, it is surrounded or replaced by the vertebral column.

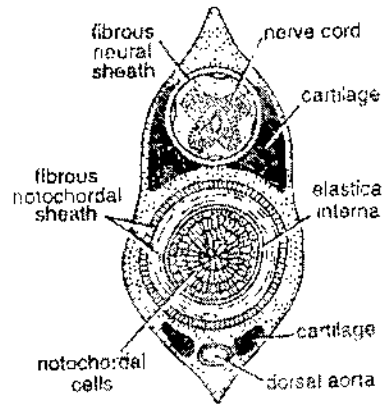



**Fig. 2. T.S. of young dogfish showing notochord.**

**3. Pharyngeal gill slits :** In all chordates, at some stage of life cycle, a series of paired lateral **gill slits** or visceral lefts perforate the pharyngeal wall of the gut. Water entering the pharynx through mouth passes out from the pharynx through the above slits or pouches and, thus bathes the gills for respiration. These are found in *Amphioxus,* fishes and certain amphibians and remain functional through out life. But in higher vertebrates, they disappear or become modified in the adults which respire through lungs. These above characters were also present in the ancestral chordates.

## 1.2. CLASSIFICATION OF CHORDATA

The **phylum chordata** has been divided into two main groups on the basis of the cranium :

**1. Craniata :** Cranium is present. They also have jaws, vertebral column and paired appendages (two pairs), coelom schizocoelic, notochord covered or replaced by vertebral column, skull wall developed, pharyngeal gill slits persist or disappear, heart chambered, kidneys meso-metanephridium, sexes separate.

**2. Acraniata :** They do not posses cranium, jaws, vertebal column and paired appendages. Exclusively marine, coelom enterocoelic, notochord persistent. pharyngeal gill slits present. Heart not chambered, kidneys protonephridia, sexes separate or united, development indirect. The acraniates are more primitive than the craniates and hence they are commonly called **protochordates.**

**Protochordates** are marine, triploblastic coelomates, having notochord either in a part of the body or in the entire body, either persists throughout the life or only in the larval state (ascidians). They lack cranium, jaws, vertebral column and paired appendages. But the gill slits are permanently present in the pharynx.

### Characters of Protochordates

1. They are marine, solitary or colonial.
2. The epidermis is single-layered.
3. The bony skeleton is lacking. The basement membrane is some times thickened to form the supporting structures.
4. The pharynx possesses gill slits which are lined with cilia and supporting branchial skeleton.

5. The notochord extends throughout the length of the animal in cephalochordates, in urochordates it is present only in larval stage in the tail region only, whereas in hemichordates, the presence of notochord is not yet proved. The buccal diverticulum is supposed to be the notochord.

6. **Feeding** is muco-ciliary type. The endostyle and the dorsal lamina in the pharynx help in the transference of the food particles.

7. The circulatory system includes a simple, tubular heart, vessels and sinuses.

8. The nervous system is primitive, but in cephalochordates it is relatively more developed. In urochordates, in adults it is represented only by a simple ganglion, the nerve ganglion, but in larval forms it is dorsal, hollow and tubular, **a chordate character**. In hemichordates, it is intraepidermal.

9. Excretory organs are nephridia in cephalochordates, neural gland in urochordates and glomerulus in hemichordates.

10. Reproduction by both the processes, sexual and asexual. The development is either direct or indirect with larval stage.

## • 1.3. GROUP CRANIATA

The group craniata is also called subphylum vertebrate, which has a distinct head and cranium. Craniata or vertebrata is divided into Aqnatha and Gnathostomata.

**1. Aqnatha** (Gr. *a* = not; *gnathos* = jaw) lack true jaws and paired appendages. They include a small number of primitive but specialized fish-like forms, the extinct ostracoderms and living cyclostomes.

**2. Gnathostomata** (Gr., *gnathos* = jaw; *stoma* = mouth) possess true jaws and paired appendages.

Agnatha and Gnathostomata are now considered as groups or super-classes of a subphylum vertebrata.

**Gnathostomata** includes two super-classes : Pisces and Tetrapoda. Pisces (L., *piscis* = fish) includes all the fishes, while Tetrapoda (Gr., *tetra* = four; *podos* = foot) includes four-legged land vertebrates, *e.g.*, amphibians, reptiles, birds and mammals.

Vertebrata is also divided into two groups : Amniota and Anamniota. **Amniota** includes classes Reptilia, Aves and Mammalia. They possess amnion (embryonic membrane) during development. **Anamniota** do not possess embryonic membrane, amnion during development. It includes cytostomes, fishes and amphibians.

## • 1.4. GENERAL CHARACTERS OF PHYLUM CHORDATA

1. Chordata are aquatic, aerial or terrestrial and free living.
2. Body bilaterally symmetrical and metamerically segmented.
3. Tail is **postanal** projecting behind the anus at some stage of life cycle. Adults may or may not be tailed.
4. Exoskeleton often present, *e.g.*, in fishes, reptiles, birds and mammals.
5. Body **triploblastic,** *i.e.*, three germ layers ectoderm, mesoderm and endoderm present.
6. Coelom **enterocoelic** (derived from enteron) or **schizocoelic** (derived by the splitting of mesoderm).
7. **Notochord** present at some stage of life.
8. Endoskeleton cartilaginous or bony living and jointed. In *Amphioxus*, it is absent.
9. Pharyngeal gill slits present at some stage of life cycle. They may be functional or non-functional.
10. Digestiv system with digestive glands complete.

## • TEST YOURSELF

1. Give the main features of phylum chordata.
2. Distinguish between (i) Acrania and craniata, and (ii) Agnatha and Gnathostomata.
3. Write down the general charactrs of phylum chordata.

UNIT

# 2

# UROCHORDATA

## STRUCTURE

- General characters of Urochordata.
- Classification. Three classes of Urochordata. Larvacea, Ascidiacea and Thaliacea.
- Characters of all three classes with examples.
- Two orders or class of Larvacea are Endostylophora and Polystylophora.
- Class Ascidiacea, its characters and its two orders; Pleurogona and Enterogona and their characters.
- Order Enterogona has two suborders : Phlebobranchia and Aplonsobranchia.
- Class Thaliacea, characters and its three orders : Hemimyaria, Cyclomyaria and Prosomida. Their characters and examples.
  - Summary
  - Student Activity
  - Test Yourself

## LEARNING OBJECTIVES

After going through this unit you will learn :

- General characters of Urochordata and its classification with examples.

## 2.1. GENEREAL CHARACTERS

1. Urochordates are exclusively marine found in all the seas, solitary or aggregated in groups, colonial.

2. Sedentary (mostly fixed), some pelagic or free-swimming.

3. Body of ädults unsegmented without paired appendages and without tail.

4. Body is covered over by test or tunic composed of cellulose-like tunicin, with branchial and atrial openings.

5. Coelom absent. Atrial cavity present, opening outside through atrial aperture.

6. Pharynx large with endostyle and perforated by numerous stigmata or gill slits.

7. Heart is ventral, simple, tubular and periodically reverses the direction of blood flow. Blood vascular system open.

8. Nervous system is reduced to small dorsal ganglion in the adult. In larval stages dorsal tubular nerve cord present.

9. Excretory organ is neural gland.

10. Hermaphrodite. Fertilization external and cross. Development indirect with a free swimming larva having all primary chordate characters.

## 2.2. CLASSIFICATION OF UROCHORDATA

Subphylum Urochordata has been divided into three classes :

1. Larvacea
2. Ascidiacea
3. Thaliacea

### Class. 1. Larvacea

1. Small, solitary, free swimming, pelagic and neotenic larva-like forms having persistent tail, notochord and nerve cord.

2. Test is large forming a temporary house which is renewed again and again.
3. Pharynx possesses only two gill slits opening outside directly.
4. Atrium and atrial aperture absent.
5. Hermaphordite No metamorhosis in the development.

Class Larvacea or Appendicularia includes two orders :

### 1. Endostylophora

1. House bilaterally symmetrical with separate inhalent and exhalent apertures.
2. Pharynx with endostyle.

Examples. *Appendicularia, Oikopleura.*

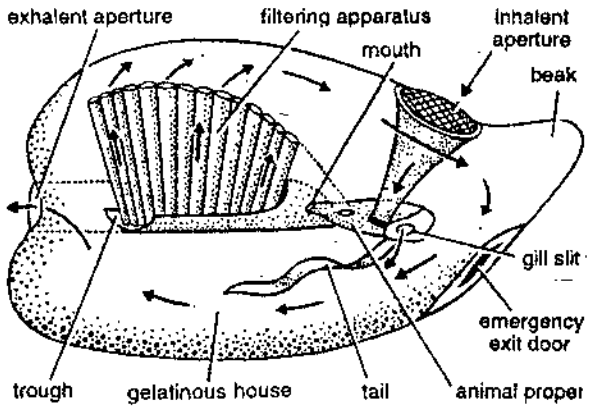



**Fig. 1. *Oikopleura***

### 2. Polystylophora

1. House biradially symmetrical with single aperture.
2. Pharynx without endostyle and peripharyngeal bands.

Example. *Kowalevskia*

### Classs. 2. Ascidiacea

1. Mostly fixed, solitary or colonial.
2. Test permanent, well developed and thick
3. Pharynx large having numerous gill slits, opening into the atrial cavity. Atrium opens dorsally by atriopore.
4. Nervous system represented by a single ganglion.
5. Excretory organ is subneural gland.
6. Hermaphrodite and larva are free swimming and well develoed.
7. Larva undergoes retrogressive metamorphosis losing tail, nerve cord and notochord. Adult sessile.

Class Ascidiacea is divided into two orders :

1. Pleurgona
2. Enterogona

### Order. 1. Pleurogona

1. Body compact and undivided.
2. Neural gland dorsal to nerve ganglion.
3. Gonads two or more embedded in the mantle.
4. Pharynx with numerous gill slits.
5. Larva with otolith

Examples, *Herdmania, Cynthia, Molgula* and *Botryllus.*

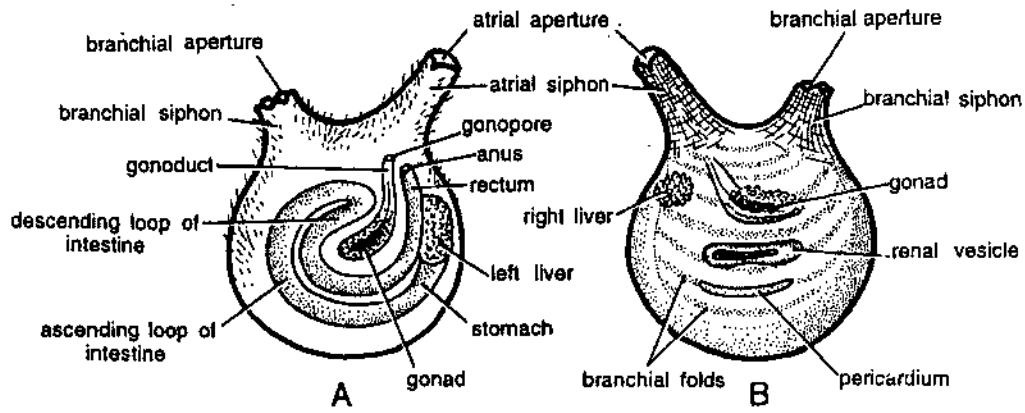



Fig. 2. *Molgula.* A–Left View. B–Right view.

## Order. 2. Enterogona

1. Fixed and colonial
2. Body sometimes divided into thorax and abdomen.
3. Neural gland ventral to nerve ganglion.
4. Gonad one lying in or behind intestinal loop.
5. Larva with ocelli and otolith (sense organ).

It is divided into two suborders :

## Suborder. 1. Phlebobranchia

1. Pharynx with internal longitudinal blood vessels.
2. Budding rare.

Examples. *Ascidia, Ciona, Phallusa, Corella.*

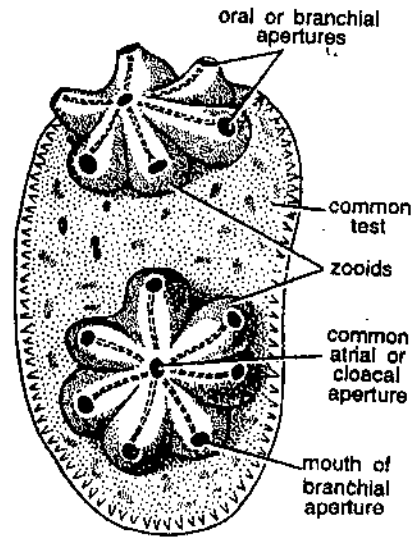



Fig. 3. *Botryllus.* Showing groups of zooids.

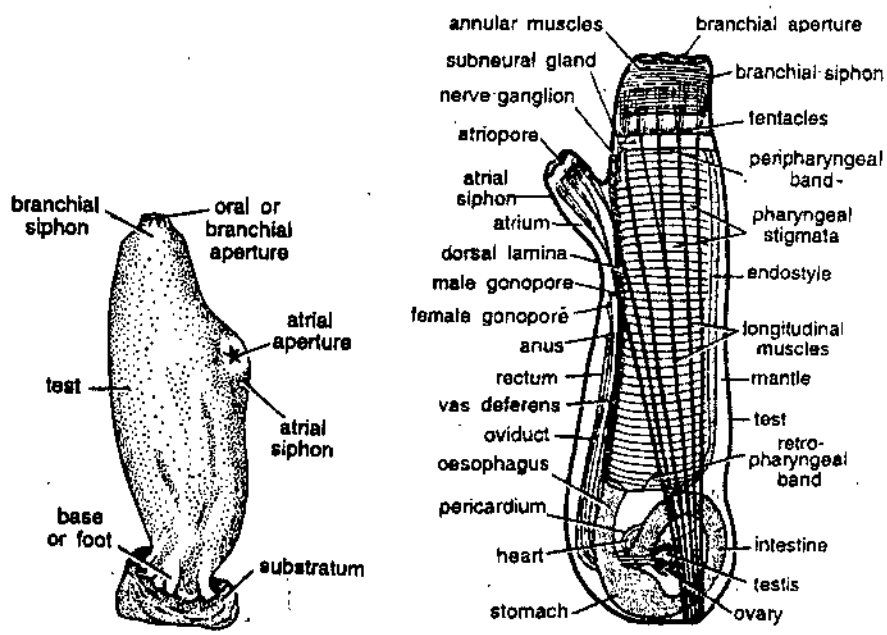



Fig. 4. (A) *Ascidia,* (B) *Ciona.*

## Suborder. 2. Aplonsobranchia

1. Body elongated with distinct abdominal region.

2. Pharynx without longitudinal blood vessels.

3. Budding common.

Examples. *Clavelina, Didemnum.*

### Class. 3. Thaliacea

1. Free living and pelagic. Solitary or colonial.

2. Body cask-shaped, opening at both ends.

3. Test permanent, thin and transparent. Body with circular muscle bands.

4. Pharynx possesses two large or many small gill slits.

5. Adult without notochord, nerve cord, and tail

6. Sexes united. Larval form present or absent.

7. Asexual budding from stolon.

8. Alternation of generation exists in the life history.

Class Thaliacea is divided into three orders :

### Order. 1. Hemimyaria or Salpida or Desmomyaria

1 Body cylindrical.

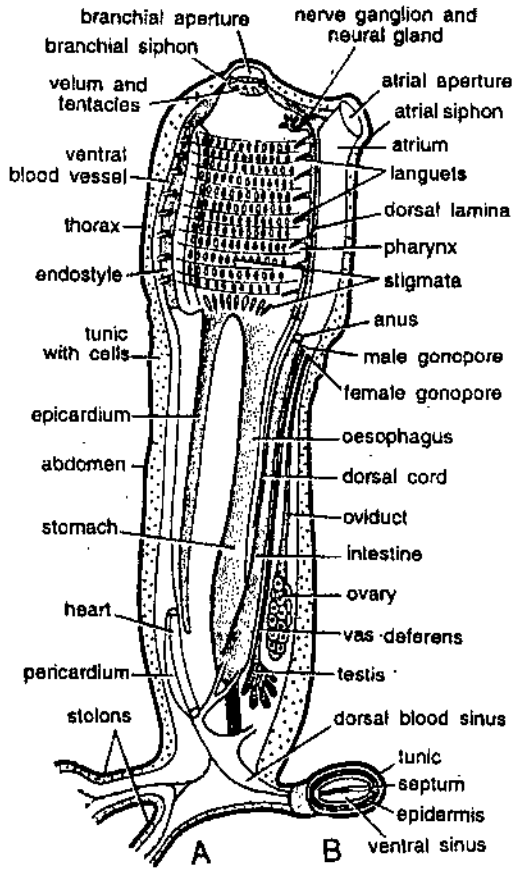



Fig. 5. *Clavelina*. A single zooid.

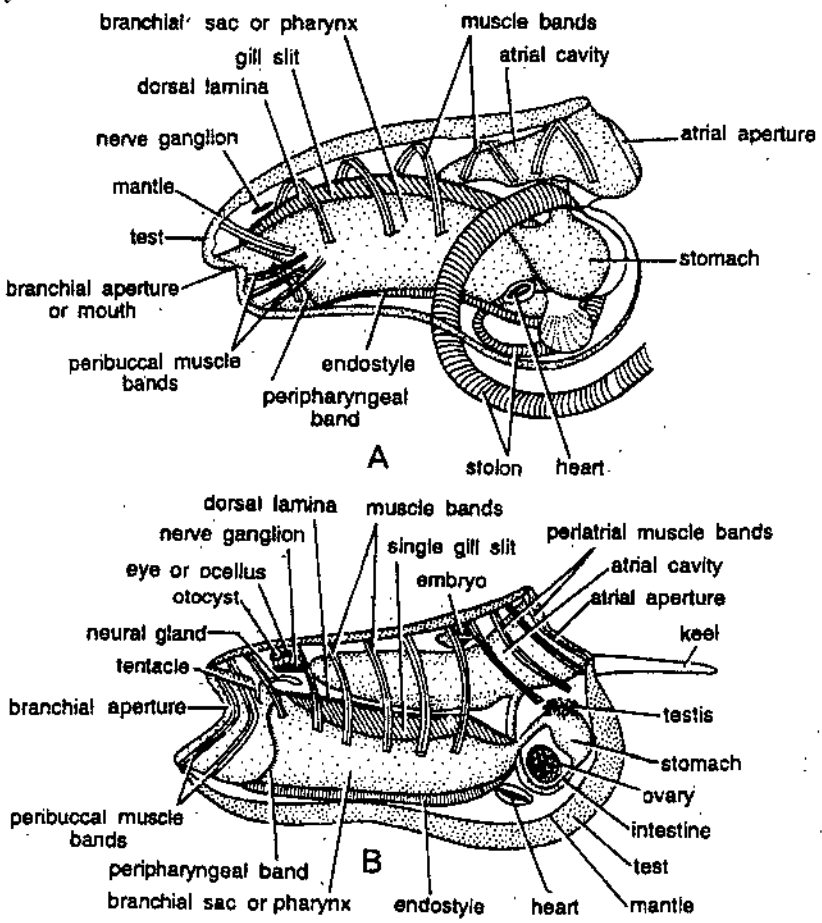



Fig. 6. *Salpa*. A–Oozooid. B–Blastozooid.

2. Pharynx communicates freely with atrium through a pair of lage gill slits.
3. Circular muscle bands incomlete ventrally.
4. Embryo is united to the parent for a time by a placenta.
5. No tailed larva during development.

Example. *Salpa.*

### Order. 2. Cyclomyaria or Doliolida

1. Body barrel-shaped..
2. Circular muscle bands complete except *Auchinia.*
3. Pharynx bears two rows of small stigmata.
4. Hermaphrodite (sexes united). Sexual generation is always polymorphic.
5. A tailed larva with notochord during development.

Example. *Doliolum.*

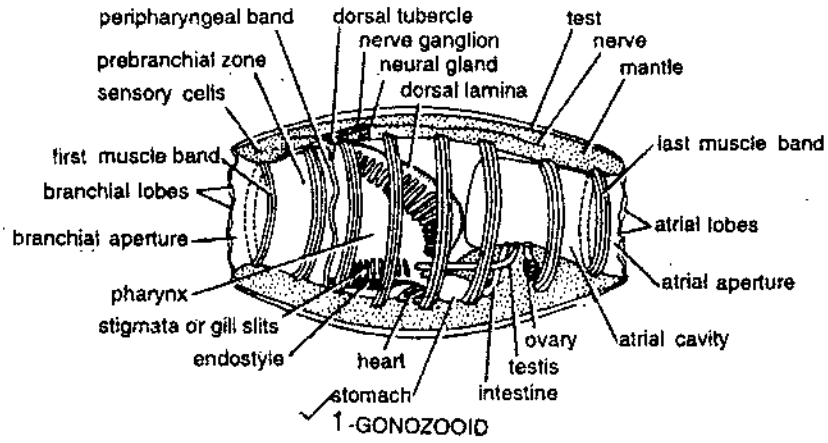



**Fig. 7. *Doliolum.* Gonozooid.**

### Order. 3 Pyrosomida

1. Colony tubular, closed at one end and phosphorescent.
2. Zooids (individual animals) embedded in a common test of colony.

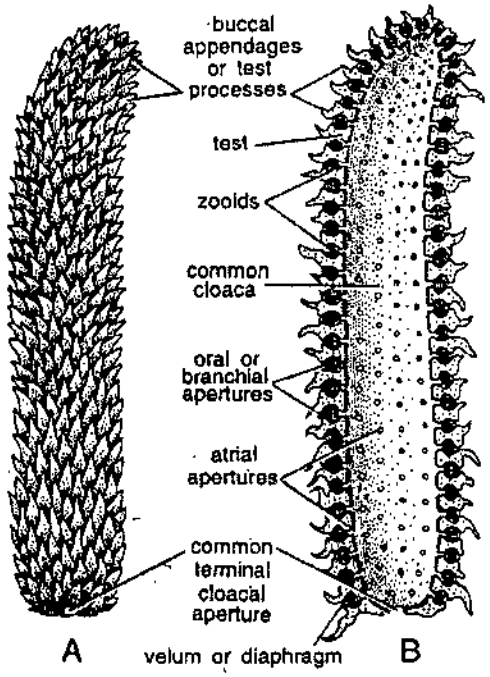



**Fig. 8. *Pyrosoma.* A–entire colony. B–L.S. of colony**

3. Atrial aperture regulated by muscle bands.
4. Gill slits numerous in each zooid.
5. No free swimming larval stage.

Example. *Pyrosoma.*

## • STUDENT ACTIVITY

1. Write down the classification of subphylum Urochordata.

2 Describe three classes of Urochordata with examples.

## • VERY SHORT ANSWER QUESTIONS

1. **Write down the name of excretory organ of Urochordates.**

   **Ans.** Excretory organ in urochordates is neural gland, present just below the nerve ganglion.

2. **In which class of Urochordata test is temporary ?**

   **Ans.** In class Larvacea *test is large temporary house that is renewed again and again.*

3. **In which classes gill slits are only two ?**

   **Ans.** Two gill slits are found in animals of class Larvacea and order Hemimyaria of class Thaliacea.

4. **Write down the differences between two orders of Class Ascidiacea.**

   Ans.

| Pleurogona | Enterogona |
|---|---|
| 1. Body undivided into thorax and abdomen | 1. Body some times divided into thorax and abdomen |
| 2. Neural gland dorsal to nerve ganglion. | 2. Neural gland ventral to nerve ganglion. |
| 3. Gonads two or more. Ex. *Herdmania.* | 3. Gonad one. Ex. *Ascidia, ciona*, etc. |

5. **Name the three orders of Class Thaliacea.**

   **Ans.** Orders : Hemimyaria, Cyclomyaria and Pyrosomida.

6. **Write down the differences between three orders of Class Thaliacea.**

| | Hemimyaria | Cyclomyaria | Pyrosomida |
|---|---|---|---|
| 1. | Body cylindrical | Body barrel-shaped | Body tubular |
| 2. | Circular muscle bands incomplete ventrally | Circular muscle bands complete. | Colonial, zooids embedded in a common test. |
| 3. | Gill slits two, large | Gill slits in two rows and small | Gill slits numerous in each zooid of the colony |
| 4. | — | — | *Phosphorescent.* |

7. **Write down the class and order of *Pyrosoma*.**

   **Ans.** *Pyrosoma* belongs to class Thaliacea and order Pyrosomida.

UNIT

# 3

# HERDAMANIA

## STRUCTURE

- *Herdmania* is world wide in distribution and has 12 species, out of which four are found in Indian ocean.
- Body of *Herdmania* is oblong and laterally compressed and found fixed over the hard substratum (rocky) of the sea.
- Body of *Herdmania* is entirely covered by test except two apertures : Branchial (anterior) and atrial (dorsal) apertures. Body of *Herdmania* is divisible into large antero-dorsal body proper and postero-ventral narrow foot composed of only hard test.
- All the viscera are lodged within the body proper of *Herdmania* -Blood vascular system of *Herdmania* includes pericardium and heart, blood vessels and blood.
- Pericardium and heart lies just below the right gonad.
- Pericardium is non-contractile and closed, while heart is contractile and enclosed within the pericardium.
- Major blood vessels arise from the heart are ventral vessel and cardio-visceral vessel.
- Digestive systm, Nerous system Excretory system, Receptors and Reproductive system of *Herdmania*.
- Tadpole larva of *Herdmania* undergoes degeneration of certain advanced characters transforming itself into a fixed, degenerate adult.
- Adult *Herdmania* only possesses stigmata and endostyle in the pharynx which indicated its chordate nature.
  - Summary
  - Student Activity
  - Test Yourself

## LEARNING OBJECTIVES

After going through this unit you will learn :

- *Herdmania's* morphology, anatomy, digestive, blood vascular, excretory systems, receptors and reproductive system

## • 3.1. *HERDMANIA*

### History :

The genus *Rhabdocynthia* was first established by **Herdman**. The same above genus was named as *Herdmania* by **Lahille** in 1888. **Herdman** in 1906 also designated *Rhabdocynthia* as *Herdmania* on the basis of close similarities in both the genus. Later, **Hartmeyer** in 1910 also established the identity of *Rhabdocynthia* of Herdman and *Herdmania* of Lahille. Therefore, the name *Herdmania* is very common and accepted as a valid genus by the foremost ascidiologists of the world. The Tamil fisherman call it *undapasi* (*unda* = round, *pasi* = weed) due to its general appearance or *mulaikanna* (*mulai* = breast, *Kanna* = fats) showing two feat like projecting siphons (branchial and atrial) at the free end of the animal.

### Distribution :

*Herdmania* is a marine animal. **S.M. Dass** collected four species of *Herdmania* during his investigation of Tuticorin in the Gulf of Manaar and these are *H. pallida, H. ceylonica, H. Mauritiana* and *H. ennurensis* from a depth of five to twelve fathoms extending upto ten miles from the sea-shore. They are found attached to the rocky shelf, which is covered over by sand and dead shells etc. along with polychaete fauna and the chanks (molluscs), which feed on polychaete worms. *Herdmania* is the commonest

monascidian found in groups (10–12) of various ages, though it is solitary and each is attached to the substratum separately by means of a foot (the postero-ventral end of the body). *Herdmania* is worldwide in distribution and found in all the seas except the Arctic. Geographical distribution of various spcies of *Herdmania* is given below :

1. **Indian Ocean** : *H. pallida, H. ceylonica, H. mauritiana* and *H. ennurensis.*
2. **Australian Seas** : *H. mollis, H. subfusca, H. tenuis* and *H. complanata.*
3. **Pacific Ocean** : *H. pallida, H. papietensis* and *H. pyriformis.*
4. **Atlantic Ocean** : *H. pallida, H. momus* and *H. pyriformis.*
5. **Malayan Seas** : *H. pallida* and *H. rosea.*
6. **West Indies** : *H. pallida.*
7. **Gaph** : *H. sacciformis.*
8. **Antarctic** : *H. draschii.*

## External Features

**Colour** : The colour of the body of a fresh specimen is pink with a reddish tint due to the presence of scattered areas of blood-capillaries and bright red vascular ampullae situated in the superficial layers of the test.

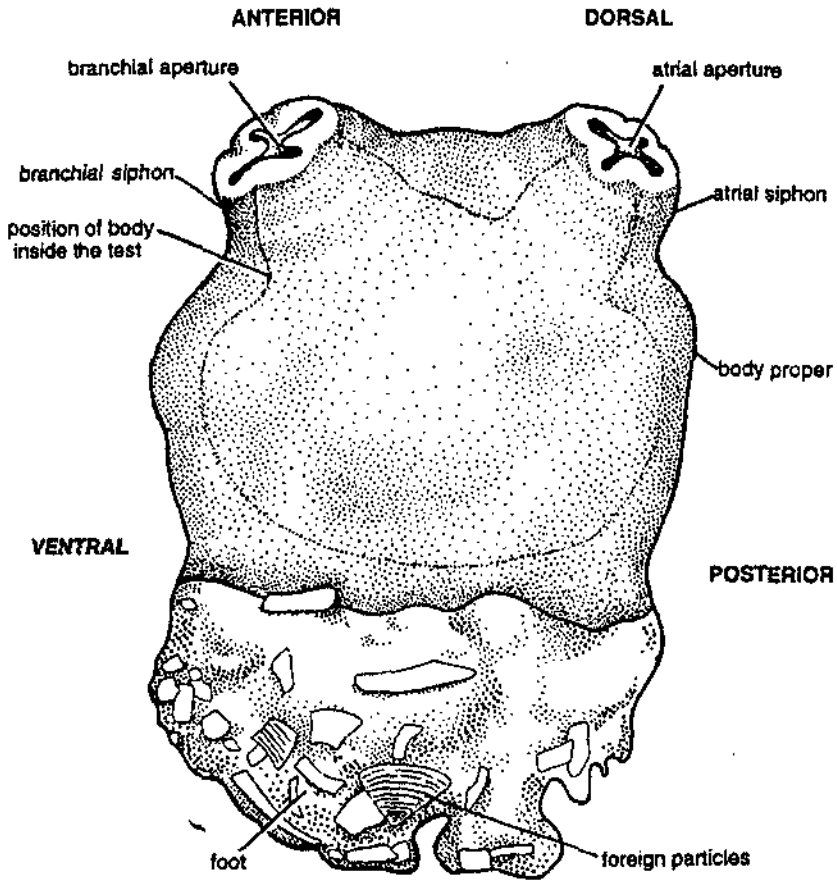



**Fig. 1. Morphology (external features) of *Herdmania*.**

**Size** : The average size of an adult is about 9.5 cms long, 7 cms broad and 4 cms thick, but it may vary upto 13 × 8 × 4.5 cms.

### Morphology

The body of *Herdmania* is roughly oblong. Its attached end is narrow and the free end is broad that bears two external apertures the **branchial** and the **atrial apertures.** Its body may be divided into a broad **trunk** and a **foot.**

**Foot :** It varies in shape according to the nature of the substratum which the animal inhabits. If the substratum is of fine sand the foot is oval in shape having smooth surface and the test is quite hard in consistency. When the substratum is of coarse sand and broken shell-pieces, the foot is irregular in outline and more or less soft in consistency. If the animal is attached to a rock or a mollusc shells, there is no foot, it is merely attached by a broad flat base. The foot may attain a length of 3 to 4 cms. With the foot are attached numerous foreign objects like broken parts of the mollusc shell branches, crustaceans and pebbles etc.

**Trunk :** It is the free part on the top of which lies two protuberances, the *branchial* and **atrial siphons.** The branchial siphon is smaller than the atrial siphon. The branchial siphon is always directed outwards, while the atrial siphon is always directed upwards. The branchial siphon bears branchial aperture directed more or less laterally and surrounded by four projecting lips. Like wise, the atrial siphon also bears an upright atrial aperture and also surrounded by four lips. The branchial aperture is larger than the atrial and its lips are also thicker than the later. Along the margin of each aperture and the lips run a bright red line.

**Test :** The entire body of the animal is covered by a soft and leathery **test**, which is opaque in adult animals. The general surface of the test is corrugated all over with shallow and fairly deep lines running in a criss-cross manner. The test also lines the branchial and atrial siphons internally.

**Orientation of the body :** The branchial aperture marks the anterior end of the animal and the opposite end attached to the substratum is its posterior end. Similarly the atrial aperture indicates the dorsal side of the body and its opposite side, which is partly attached to the substactum is the ventral side.

**Structure of the test :** Test covring the entire body except branchial and atrial apertures is leathery, about 4 to 8 mms. thick and regarded as an exoskeleton. It is largely made up of a substance called **tunicine,** which is identical in composition and behaviour with cellulose (vegetable substance). It gives the animal a definite form and forms the foot at the posteroventral region of the body, where it is 1 to 3 cms thick. The test in a living animal is continually worn at the surface and reformed by the formation of tunicine by the ectodermal cells lining the inner surface of the test and also by the mesoderm cells which migrate into the test through the walls of the test vessels and the end vesicles.

**Histologically** the test is composed of an ectodermal epithelial layer and below it a clear wavy matrix in which are embedded a large number of **cells, interlacing fibrils, minute spicules,** and branching and anastomosing **vascular tubes.**

### 1. Test Cells

These are of six different kinds as given below :

(i) **Large eosinephilous cells :** These are spherical or ovoid in shape and are stained bright red with cosin. Nucleus is large and vesicular.

(ii) **Small cosinophilous cells:** These are smaller than that of the above cells, the nucleus is excentric. Thes are more abundant in the inner half of the test.

(iii) **Amoeboid cells :** These are of irregular shape with large nucleus. These are very few in number.

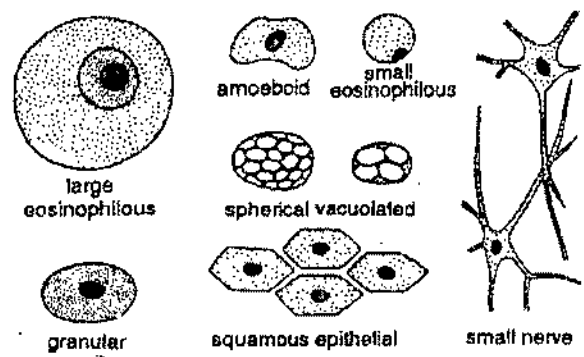



**Fig. 2. *Hirdmania.* Various types of Test Cells.**

(iv) **Spherical vacuolated cells :** These are ovoid in shape having a large number of small vacuoles. Nucleus is usually absent.

(v) **Granular cells :** These are oblong granular cells with large nuclei. These are found concentrated round the nerve cells and nerve fibrils. These cells are receptor cells (tactila in nature).

(vi) **Small nerve cells :** Each nerve cell possesses a large nucleus and two to six processes. These processes austomose with each other. These cells take the Methylene blue stain.

## 2. Vascular tubes

A large number of branching and *anastomosing vascular tubes are* found ramifying through out the test. From these tubes numerous branches are given off towards the surface, which end in a large vesicle, called the **vascular ampullae** or **terminal knobs.** These ampullae seem to be red patches on the external surface of the test. These ampullae are rounded, ovoid or pear-shaped and covered over by red pigmented flattened polygonal cells supplied with nerve fibrils. The vascular ampullae with these polygonal cells form tactile centres over the test. The vascular tubes are connected with the vascular system.

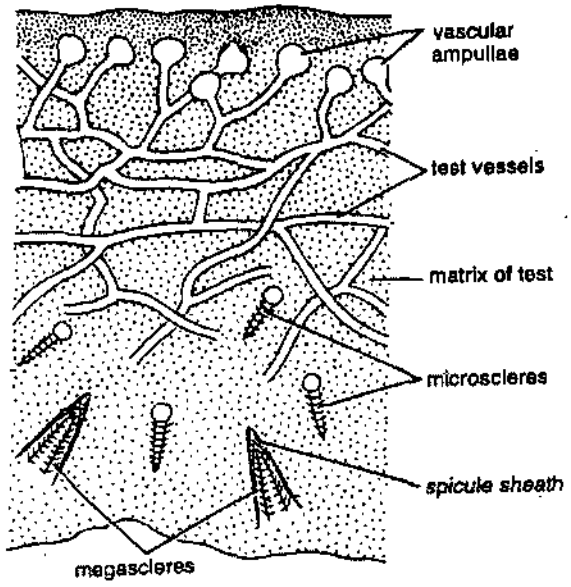



**Fig. 3. *Herdmania*. V.S. of test showing vascular tubes, ampullae and spicules.**

## 3. Spicules

The spicules are found scattered in the test. These give support to the various organs, firmly attaches the test with the mantle and make stiff to the walls of the blood vessels, preventing their collapse. These are calcareous in nature and are of two types : microscleres and megascleres.

(i) *Microscleres :* These are very small in size consisting of a rounded knob and an elongated tapering body. The knob is generally smooth, but the body bears a large number (5 to 20) of rings of spines. The average size of the microscleres vary from 50 μ to 8 μ.

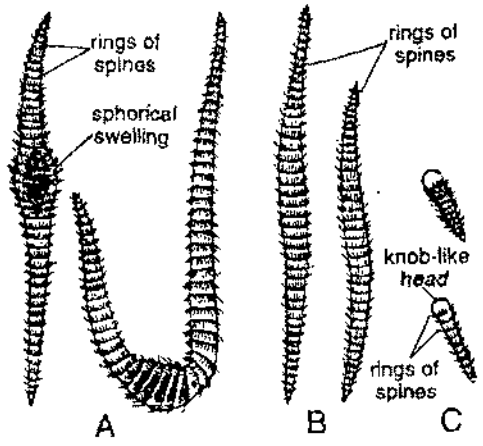



**Fig. 4. *Herdmania*. Different types of spicules**

(ii) *Megascleres :* These are very large in size varying from 1.5 mm to 2.5 mm. and are of two types :

**(a) Spindle-shaped megascleres :** These are found scattered in all the tissues of the body. These are abundant in the mantle, stomach, gonads and at the base of the siphons. Each is enclosed in a sheath of connective tissue. In the posterior half of the test these form sheath round the blood vessels. Each spicule bears twenty to sixty annular rings of spines directed upwards.

**(b) Pipette-shaped megascleres :** These are larger than that of the above, measuring about 3.5 mm. These are either straight or U or V-shaped. Each spicule bears a spherical swollen structure in the middle and is provided with a large number of annular rings of spines and enclosed in a connective tissue sheath. These are abundant in the mantle, gonads and the liver lobes.

## The Mantle and the Atrial Cavity

The mantle (body wall) lies beneath the test, completely surrounds the body of the animal except at the branchial and atrial apertures. The mantle is thick and musclar in the antero-dorsal region, and thin and almost transparent in the postero-ventral region. It encloses the large atrial (peribranchial) cavity which is continuous

throughout the animal except in the anterior and ventral regions. In these regions (anterior and ventral) the wall of the atrial cavity is fused with the mantle, dividing the atrial cavity into right and left halves and both the halves are continuous dorsally opening outside through the **atrial aperture.**

At the anterior and dorsal ends of the body the mantle is prolonged, forming two **siphons** : the **atrial** and the **branchial siphons.** Both are short tubes, leading into the atrial and branchial apertures respectively.

**Histologically** the mantle consists of three layers : outer ectoderm, middle mesoderm and inner ectoderm layers. The **outer ectoderm** layer lies just beneath the test. It consists of a single layer of flattened hexagonal epithelial cells. The ectoderm of the vascular ampulae, bases of the two siphons and the intersiphonal region is bright red in colour due to the presence of small red pigment bodies in the cytoplasm of the cells.

The **middle mesoderm layer** is thick and consists of connective tissue, muscles innervated by nerve fibres and numerous blood sinuses. The muscles are only confined in the antero-dorsal half of the body. These muscles are of two types : annular muscles and longitudinal muscles. These are of non-striated type.

*Annular muscles* form the circular rings around each siphon. These muscles constrict the siphons. Besides these muscles, there is a strong circular band of muscles (sphincter muscles) at the base of each siphon. These muscle constrict the base of each siphon, closing the internal opening.

*Longitudinal muscles* run lengthwise, thickened in the middle of the body and tapers towards the siphonal apertures. Their contraction constricts the entire body lengthwise.

The **inner ectoderm** is like that of the outer ectoderm.

### Anatomy of *Herdmania*

*Herdmania* or sea squirt body lodges all the internal organs and the foot attaches the animal to some hard substratum.

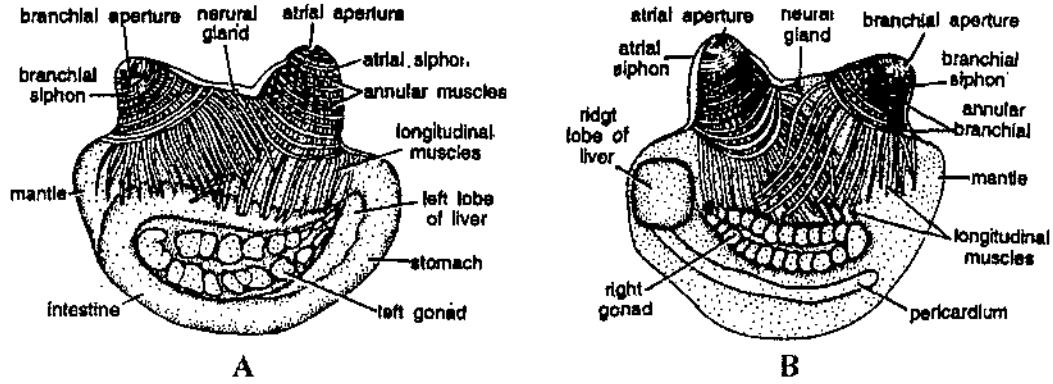



**Fig. 5. Inner view of *Herdmania*. A–From left side B–From right side.**

Beneath the test lies a transparent mantle (body wall) composed of outer ectoderm and inner ectoderm of flattened epithelial cells, and middle layer of parietal mesoderm having connective tissue and muscles innervated by nerve fibres and numerous blood sinuses. Branchial and atrial openings lead to respective siphons at the base of which circlet of delicate and branched tentacles are present, which project into the lumen. Branchial siphon leads directly into a large sac-like pharynx or branchial sac. Atrial siphon leads into a large spaceous atrial cavity which is continuous throughout the body except at the antero-ventral regions of the body where walls of branchial sac fuse with the mantle.

**Aligmentary canal.** Alimentary canal comprises branchial siphon opening outside by branchial aperture, large pharynx, short oesophagus, stomach and u-shaped intestine, opening by anus into the atrial cavity. Branchial sac is laterally perforated by a large number of gill slits and also possesses anteriorly a pair of ciliated circular

peripharyngeal bands separated from each other by a ciliated peripharyngeal groove. This groove is continuous with the dorsal lamina and endostyle present respectively on the roof and floor of the branchial sac. **Stomach** is surrounded by a bilobed liver.

**Nervous system.** It is poorly developed and consists of a single elongated ganglion lying in the intersiphonal region. Five nerves arise from this, three towards the anterior side and two towards the posterior side. Above the nerve ganglion lies the **neural gland** *(excretory organ)*.

**Circulatory system.** It includes the heart and blood vessels. Heart is ventral, simple, tubular and enclosed in a pericardial sac. It lies just below the right gonad. **Blood vessels** are ventral aorta, dorsal aorta, branchiovisceral vessel and cardio-visceral vessel and their branches.

**Receptor organs.** Receptor organs are the receptor cells in the test, ocelli found on the margins of siphon and around the vascular ampullae, branchial tentacles and dorsal tubercle present in the branchial region of pharynx

**Reproductive organs.** Gonads are two, one lies on the left side within the intestinal loop and the other lies on the right side located on the dorsal side of the pericardium. Each gonad consists of 10 to 25 distinct lobes and each lobe comprises outer testicular and inner ovarian zones. The ducts of the two zones open separately into a common vas deferens and oviduct respectively, both open into the atrial cavity.

### Blood Vascular System

Blood vascular system of *Herdmania* is well developed and includes heart and pericardium, blood vessels and blood.

### Blood

The blood of *Herdmania* is slightly reddish and almost transparent, having colourless plasma and a large number of pigmented corpuscles and a few colourless amoeboid leucocytes. The blood corpuscles are of eight different kinds :

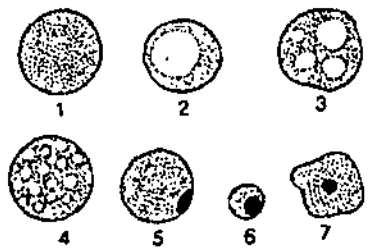



**Fig. 6. *Herdmania*. Different kinds of blood corpuscles**

1. **Orange corpuscles** : These are large, spherical non-nucleated cells of about 11 mu in diameter. Their protoplasm is orange pigmented.

2. **Signet corpuscles** : These are colourless, spherical and non-nucleated cells, having a single lare vacuole.

3. **Green corpuscles** : These are spherical, non-nucleated and yellowish green cells, having four to five large and small vacuoles. Their green colour is due to **Vanadium** – a green pigment. These cells have a peculiar property to extract vanadium from the sea water.

4. **Compartment coruscles** : These are non-nucleated large cells of about 13 mu in diamter. Each cell possesses a large number of small vacuoles.

5. **Eosinophilous corpuscles** : These are brown pigmented cells, having a large excentric nucleus.

6. There are a number of very small size (4 to 5 mu) ovoid or oblong cells, having a large central nucleus. The cytoplasm is brown pigmented.

7. **Leucocytes** : These are colourless amoeboid cells with a larg central nucleus.

8. **Nephrocytes** : These are vacuolated cells having colloidal suspension or large granules or intracellular calculi that contain purine bases.

## • 3.2. THE PERICARDIUM AND THE HEART

The **pericardium** is a closed tube which is about 7 cm long and 3 mm in diameter. It is situated on the right side of the body attached with the mantle. Its walls are thick, non-contractile and lined by a single layer of simple squamous epithelium. The pericardial sac is filled with colourless pericardial fluid having corpuscles more or less similar to those found in the blood.

The **heart** is enclosed within the pericardium. It is a cylidrical contractile tube which is attached along its entire length with the wall of the pericardium by means of a thin connective tissue flap. The cardiac wall is thin and convaluted, and composed of a single layer of epithelial cells surrounded by a thin layer of striated muscle fibres. The heart has no valve internally, but a peculiar pear-shaped body is present in between heart and the pericardium, which moves doroso-ventrally and ventro-dorsally to set the flow of blood in both the directions.

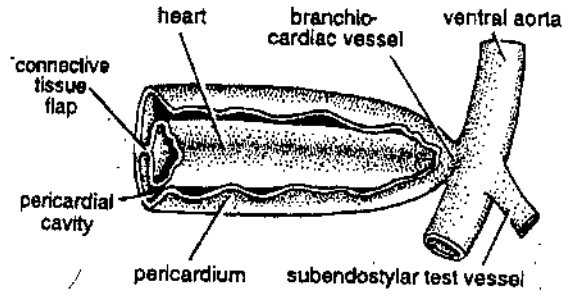



**Fig. 7. *Herdmania*. Heart and pericardium**

At each end of the heart is present an excitation centre which is responsible for initiating the heart beats (**Skramlik,** 1930). The heart beats seem to be neurogenic. The wave of contraction moves in longitudinal direction from dorsal to the ventral and vice versa. When the heart contracts from the dorsal to the ventral, the pear-shaped body is moved up towards the dorsal end and when the wave of contraction moves from the ventral to the dorsal side, it is shot up towards the ventral end. It presses the wall of the heart to prevent the flow of blood. In *Herdmania* the wave of contraction of the heart proceed in one direction for about two to three minutes. Then suddenly the contraction stops for a few seconds, the pear-shaped body moves towards the opposite end and then the wave of contraction takes the reverse path. the heart beats from dorsal to ventral are about 35 to 45 and from ventral to dorsal are 20 to 30.

**Blood vessels.** Major blood vessels are ventral aorta, dorsal aorta, branchio-visceral vessel and cardio-visceral vessel.

**1. Ventral aorta.** Ventral vessel or subendostylar vessel arises from the ventral end of the heart. In the beginning it gives out a **ventral test vessel** supplying blood to the ventral side of the test and then bifurcates into an anterior and a posterior **hypobranchial vessels** running below the endostyle. These two branches give off paired **transverse vessels** (40 to 56 pairs) to the branchial sac between rows of stigmata and fine branches to the endostyle and mantle. Anterior hypobranchial vessel joins with two circular vessels at the base of branchial siphon : a **peripharyngeal**

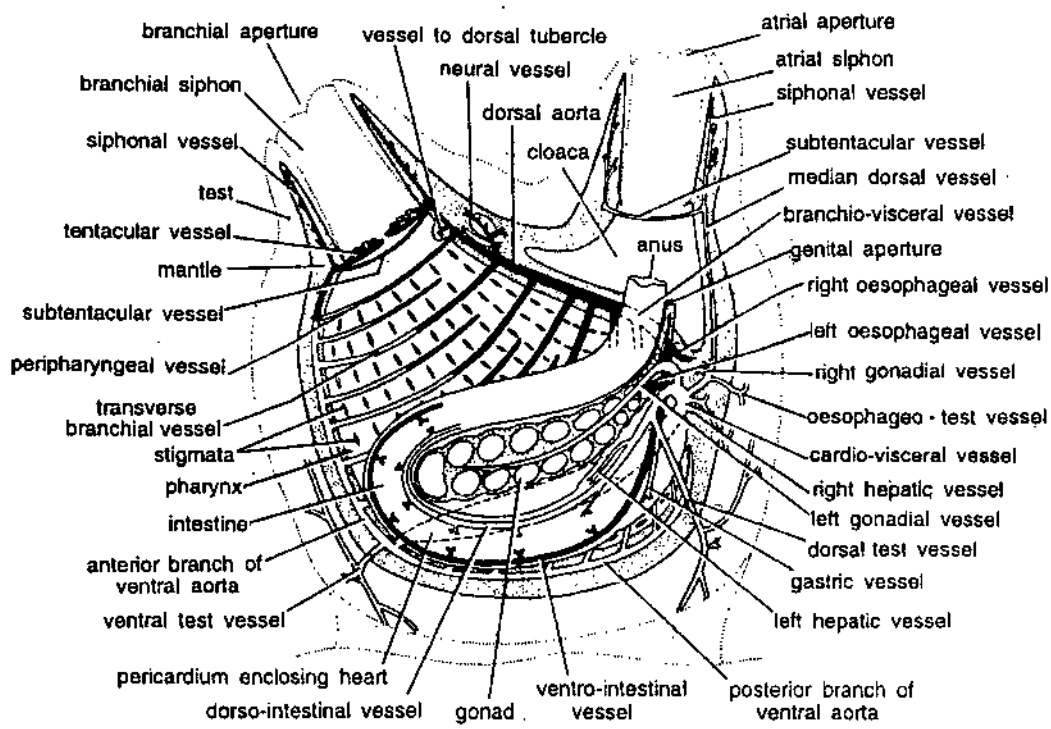



**Fig 8. *Herdmania*. Heart and blood vessels.**

**vessel** running below the peripharyngeal groove and a **subtentacular vessel** running below the bases of branchial tentacles. Subtentacular vessel gives off tentacular branch to each tentacle and siphonal vessels into the branchial siphon. Posterior branch of ventral aorta gives out a fine branch to oesophageal area.

**2. Dorsal aorta.** It runs just above the dorsal lamina in the dorsal wall of branchial sac. It is not connected with the heart but connected with the ventral vessel through 5 to 7 pairs of transverse vessels of the branchial sac, and peripharyngeal and subtentacular vessels. A neural vessel also arises from this that goes to the neural complex. Anterior end of dorsal aorta also gives off a small branch to dorsal tubercle and 6 to 8 siphonal vessels into the mantle of branchial siphon.

**3. Branchio-visceral vessel.** It is a small vessel arising from the posterior end of dorsal aorta, and divides into two branches on the postero-dorsal part of branchial sac : 1. **Right oesophageal vessel** runs on the right side of the branchial sac and supplies blood to the oesophagus and right lobe of liver. 2. **Ventro-intestina vessel** runs on the left side of branchial sac and supplies blood to the left liver lobe, oesophagus, stomach, intestine, rectum and left gonad.

**4. Cardio-visceral vessel.** It arises from the dorsal end of heart. It immediately gives off a **right hepatic branch** to the right lobe of liver and **oesophageal test branch** to the oesophagus and test.

The **dorsal main vessel** gives off a test vessel, left oesophageal and right gonadial to oesophagus and right gonad. It then extends dorsally to form a circular subtentacular vessel at the base of atrial siphon and a few siphonal vessels to the wall of atrial siphon. **Left gonadial vessel,** (middle branch) to the left gonad and **main ventral branch** soon divides into a **dorso-intestinal vessel** to left liver lobe, stomach and intestine, a **gastric vessel** to stomach and **a dorsal test vessel** to test.

**Blood**. Slightly red blood is transparent and hypertonic to sea water. It contains a few colourless amoeboid leucocytes, 6 or 7 types of coloured corpuscles (orange, yellowish brown or yellowish green) which are with or without nucleus and nephrocytes having vacuoles. There is no distinction between blood and tissue fluids due to absence of capillaries.

**Course of circulation.** Heart of *Herdmania* has no valves to regulate the flow of blood. Flow of blood is maintained by peristaltic waves and the small pear-shaped body lying in the heart and pericardium. At regular intervals reverse peristalsis occurs that change the direction of blood flow. Regularly arteries and veins change their roles as blood flow changes the direction.

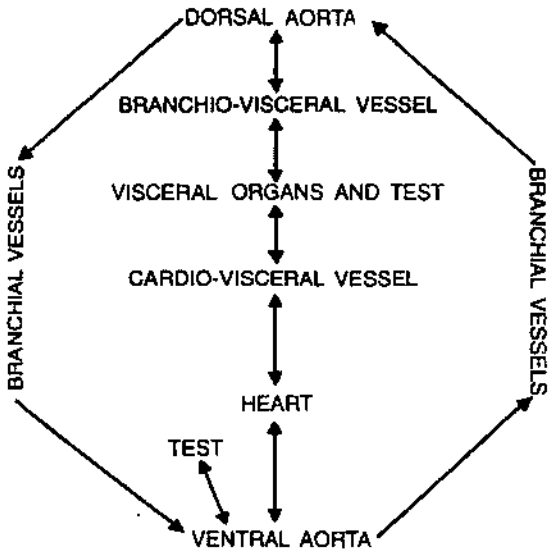



**Fig. 9. *Herdmania*. Course of blood circulation.**

When heart beats **ventro-dorsally,** its **oxygenated blood** collected through ventral aorta from branchial sac and test, is pushed into **cardio-visceral vessel** for distribution into different viscera and test. The deoxygenated blood from viscera and

test is collected by the branchio-visceral vessel which enters into dorsal aorta and then into transverse branchial vessels for oxygenation again.

When heart beats **dorso-ventrally,** the deoxygenated blood collected through cardio-visceral vessel from viscera is pumped into ventral aorta which is then sent into transverse branchial vessels, peripharyngeal vessels, subtentacular vessel and test vessel for oxygenation. This oxygenated blood is then enters the dorsal aorta for distribution again in viscera through branchio-visceral vessel. From viscera the deoxygenated blood is collected by cardio-visceral vessel which is then enters the heart to undergo the cycle.

## Digestive System

The digestive tract of *Herdmania* consists of a narrow tubular buccal cavity (branchial siphon), a large sac-like branchial sac (pharynx), a short oesophagus, a stomach, an intestine and terminal rectum, which opens into the atrial cavity through anus.

The quadrangular **branchial aperture** (mouth) leads into a small tubular branchial siphon (buccal cavity). The branchial aperture is guarded by four flaps or lips provided with annular muscles. The branchial siphon is lined by the test, which is the inpushing of the outer test. Outer to it is the infolded ectoderm (epidermis). The remaining parts of the tract except the atrial siphon is lined by the endoderm. At the base of the branchial siphon, *i.e.,* at the junction of the ectoderm and the endoderm, is present a ring of tentacles, which are of differnt sizes and are branched. The tentacles are innervated and are supposed to act as testing organs. These tentacles are curved inwords, forming a sieve or strainer over the aperture leading to branchial sac. This tentacular sieve allows the water current with minute food particles to pass into the branchial sac.

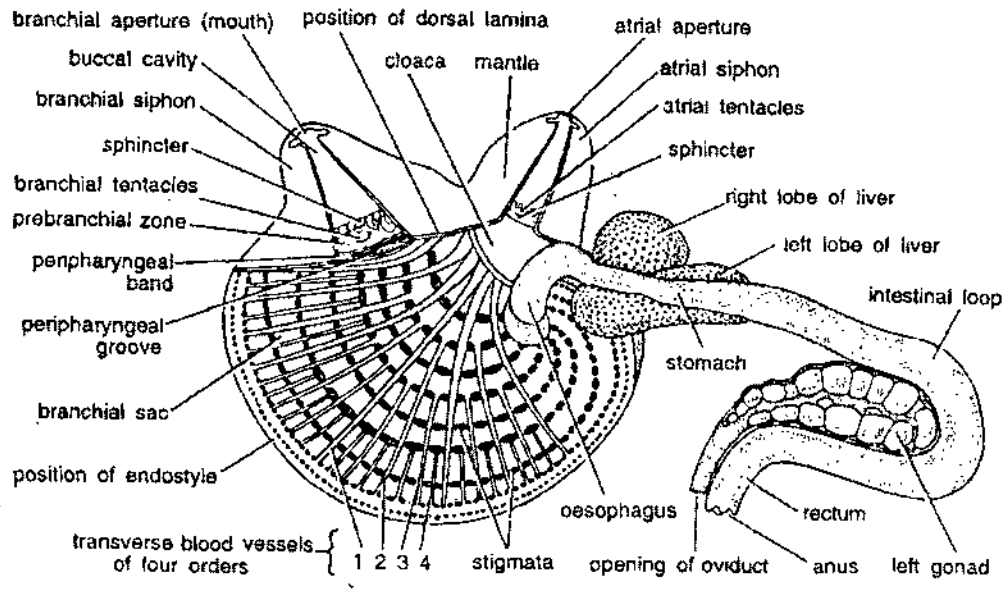



**Fig. 10. *Herdmania*. Digestive tract seen from the left side.**

The branchial siphon leads into the **branchial sac,** which is divided into an anterior short, smooth and non-ciliated **prebranchial zone** and a posterior, large, perforated sac-like part, which is shelf-like zone beneath the tentacular circlet is separated from the proper branchial sac by a pair of parallel ciliated ridges, called the **peripharyngeal bands.** The bands are separated by a ciliated **peripharyngeal groove.** The anterior peripharyngeal band is complete, but the posterior band is incomplete in the mid-dorsal and mid-ventral line. The peripharyngeal groove communicates with the **dorsal lamina** mid-dorsally and with the **endostyle** mid-ventrally. On the dorsal side in the probranchial zone lies a hemispherical **dorsal tubercle** (sensory organ).

The **branchial sac** occupies a greater part of the body, lying within the atrial cavity. The lateral walls of the branchial sac are perforated by a large number of apertures, the **stigmata,** which are about 4,000,000. These stigmata are internally lined by cilia. Through these stigmata water passes out from the branchial sac into the atrial cavity. The inner wall of the branchial sac is produced into twenty broad longitudinal folds, projecting into the cavity of the sac. The folds originate from just behind the posterior peripharyngeal band and extend upto the outer margin of the **oesophageal area.** The oesophageal area surrounds the oesophageal opening and does not possess the stigmata and blood vessels. The oesophageal opening is guarded by two semi-circular lips.

**Dorsal lamina :** The dorsal lamina is a thin flap-like structure lying in mid-dorsal wall of the branchial sac. Its edges gives off a row of twenty to thirty short, conical tentacle-like ciliated ougrowths, called the **languets.** They vary in size, the largest one lies towards the posterior side and they gradually decrease in size towards the anterior side. The dorsal languets are curved towards the right side. They together form a tube-like structure through which mucous chord along with food particles passes towards the oesophageal opening. The connective tissue possesses the blood sinuses and nerve fibres.

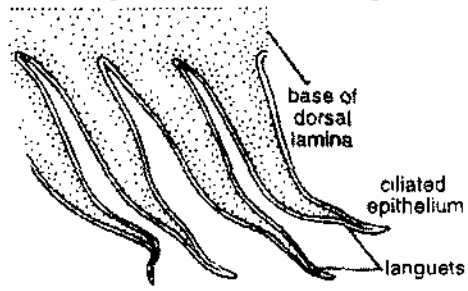



**Fig. 11. Structure of a part of dorsal lamina**

**Endostyle :** The endostyle (hypopharyngeal groove) is a mid-ventral groove in the branchial sac. It is a glandular ciliated groove which extends from the posterior peri-pharyngeal band upto the oesophageal opening. The endostyle is ridged on both the sides. Towards the posterior side these ridges are small. The endostyle is lined with four longitudinal rows of glandular epithelium, *i.e.*, two rows on either side of the midventral line bearing long cilia. On either side in between two rows of glandular epithelium is found a ciliated non-glandular part. The glandular epithelium secretes mucous, which entangles food particles brought into the branchial sac. The endostyle of *Herdmania* is homologous which the hypopharyngeal groove of *Amphioxus*. The oesophageal opening lying in the posterior region of the branchial sac is surrounded by circular, non ciliated and smooth oesophaeal area, which is devoid of stigmata. All the branchial folds converge at the outer margin of this area. It is provided with two broad lips enclosing the opening. The right lip is wider than the left and dorsally continuous with the dorsal lamina. While postero-vntrally the lips are in free contact with the endostyle. The **oesophagus** is a short, narrow curved tube. Its inner wall contains four longitudinal grooves lined by ciliated epithelium. The food ladden mucous chord moves thorugh these grooves.

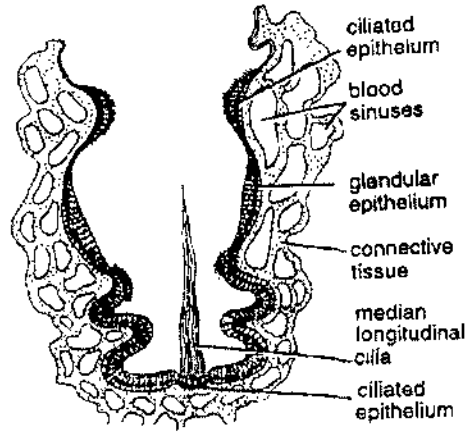



**Fig. 12. T.S. of endostyle.**

The **stomach** is a much wider tube then the oesophagus. It is thin-walled and its inner surface is smooth. The stomach is surrounded by two lobes of the liver, which opens into the stomach through ten or eleven ducts. The wall of the posterior half of the stomach contains ramifications of pyloric glands. The wall of the stomach consists of tall epithelial cells whih are nucleated and their granular cytoplasm possess four to five vacuoles. The submucosa of the posterior part of the stomach possesses numerous irregular pyloric ampullae lined with large cuboidal cells.

The stomach is followed by a long ⊂-shaped **intestine.** The proximal limb runs horizontally close to the ventral margin of branchial sac, which turns towards the dorsal side and after running for a short distance it again becomes horizontal. The distal limb of the intestine is parallel to the proximal limb and leads into the rectum. In

between the two limbs of the intestine lies a lobulated gonad. The intestinal epithelium is relatively thin having large cells with large nuclei and two to three vacuoles in each cell. The connective tissue is loose having numerous blood spaces and pyloric tubules.

The **rectum** is the hindermost part of the alimentary canal. The rectal epithelium is provided with flagella-like process. The connective tissue is richly vascularised.The rectum opens in the atrial cavity through **annus** (rectal orifice). The anus is guarded by four lips.

### Digestive glands

In *Herdmania* there are two digestive glands, situated in the gastric region.

**1. Liver :** The liver is chocolate coloured bilobed structure surrounding the stomach. The left lobe is larger than the right. The left lobe consists of five or more small lobules, while the right lobe of liver is small and ovoid in shape. Both the liver lobes show papillated surface. The left liver lobe pours its secretion in the stomach through nine openings and the right lobe has only two openings. Hence there are eleven openings in the stomach.

The liver is composed of highly branched caeca and connective tissue having blood sinuses. The minute branches of the caeca join to form the ductules, which further unite to form the main ducts, which are eleven in number. The caeca end blindly inthe form of minute papillae on the entire surfac of the liver. The caeca are lined with tall, vacuolated glandular cells having nuclei at their base. The cells possess dark refractory granules which are discharged in the lumen of caecum. The ducts are lined with ciliated cells, which probably propel the liver secretion. Liver has three kinds of cells, namely the ciliated, the secretory and the absorptive (**Berril**).

**2. Pyloric gland :** The pyloric gland is situated in the walls of the posterior half of the stomach. It is a much branched organ and its tubules ramifly in the walls of the stomach and the intestine. These tubules unite to form a single duct, which opens in the intestine. The ampullae of the gland are lined by large polygonal glandular cells and the tubules are lined with small cells. Its secretion is probably pancreatic in nature.

### Food and Feeding

The **food** consists of micro-organisms, such as protozoans, small pieces of decaying animals, zooplanktons etc.

The **feeding** is of **ciliary** type. Due to the continuous lashing movement of the cilia of the stigmata, water along with food particles enter in the branchial siphon through branchial aperture and then enter the branchial sac. From the branchial sac, the water passed out through the stigmata into the atrial cavity and then to the exterior through the atrial aperture. The food particles enter with the water adhere to the pharyngeal walls. Simultaneously the glandular cells of the endostyle secrete mucous which is lashed out transversely (at right angles to the endostyle) by endostyle cilia. Food particles lying on the walls of the branchial sac are caught by the mucous and transported towards the dorsal lamina. The languets of the dorsal lamina collect the mucous and enroll it into a cylindrical mass in the tube formed by the languets with the base of the dorsal lamina. The food ledden cord is carried backwards into the oesophageal opening.

### Physiology of Digestion

Digestion of food takes place in the stomach and in the proximal part of the intestine. The liver secretes a yellowish brown digestive fluid in the stomach. It contains a mixture of **amylase, protease** and weak **lipase.** Bile pigments are also present. Pyloric gland is probably pancreatic in nature and serve an accessory function in digestion. The liver stores carbohydrates in the form of starch. The absorption of food takes place in the middle part of the intestine. The excreta is forcibly expelled out into the atrial cavity and from there to the exterior through atrial aperture.

### Respiration

The main organ of respiration is the branchial sac. The test bearing a large number of **vascular ampullae** also subserve the function of respiration. The atrium bearing **vascular trabeculae** also act as respiratory organ.

The branchial sac is provided with numerous (80 to 130) **longitudinal blood vessels** which run within and in between the longitudinal folds and approximately equal number of **transverse blood vessels** – running on the outer surface of the sac. These later vessels intercross the longitudinal vessels resulting into a large number of square-shaped areas arranged in rows. These areas are called **stigmatic areas** and each area possesses about 4 to 6 **stigmata.** Besides these above vessels there are numerous **interstigmatic vessels** traversing in between two adjacent stigmata and are connected with the transverse vessels. Similarly there are fine **intrastigmatic blood vessels,** which traverse through all the stigmata and are connected with the longitudinal vessels. Thus, the total stigmata are about 40,00,000 and these are bounded by ciliated epithelium

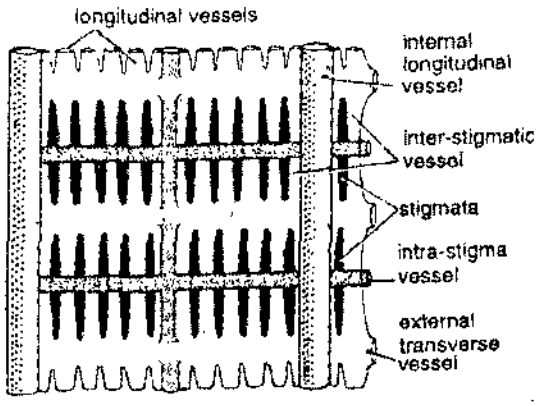



**Fig. 13. *Herdmania.* Diagram showing the plan of branchial vessels and the stigmata.**

Due to ciliary movement of the stigmatic cilia a powerful water current is produced, flowing continuously from branchial aperture towards the branchial sac and then into the atrial cavity through the stigmata. An exchange of gases takes place directly through the semipermeable membrane of the blood vessels. The presence of the blood spaces in the tissues of branchial sac and the hollow papillae on the inner surface of the branchial sac also facilitate the rapid gaseous exchange. In different tunicates the shape of the stigmata varies. It may be slit like, circular, ovoidal or spirally coiled.

## Nervous System

The nervous, excretory and the associated receptor organs are collectively called the **neural complex.** The **nervous system** in tunicates is poorly *developed. It consists of a single elongated* ganglion (brain) situated in the mid-dorsal line of the body in between the two siphons.

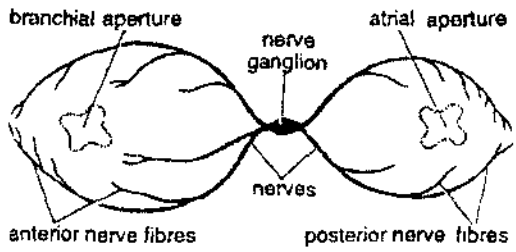



**Fig. 14. *Herdmania.* Nervous system.**

In *Herdmania,* the nerve ganglion is an elongated solid pinkish structure, which is about four mm long and one mm thick. It is placed on the ventral side of the neural gland. **Histologically** it consists of a large central zone of loose **fibrous matrix** having bipolar and multipolar nerve cells, and an outer covering of large **ganglion cells** having large nuclei.

It gives off three anterior nerves towards the branchial siphon and two posterior nerves towards the atrial siphon. The anterior nerves give branches to the branchial tentacles, branchial muscles. inner epithelium of the branchial siphon, test and the branchial sac. While the posterior nervs innervate sphincter muscles of the atrial siphon, inner epithelium of the siphon, test, gut and other viscera. These five nerves and their branches form the peripheral nervous system.

## Excretory System

In *Herdmania,* the **neural** or **subneural gland** is the excretory organ. It is oval or ellipsoidal in shape, light brown in colour and lies just above the nerve ganglion in between the two siphons. It is slightly imbedded in the mantle. It is about 4 mm long and 1 mm thick. It consists of a number of profusely

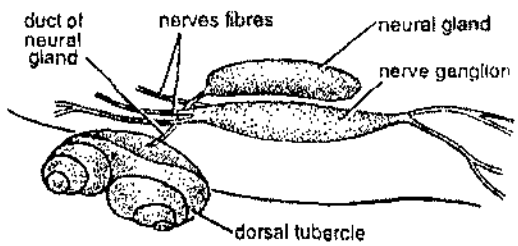



**Fig. 15. *Herdmania.* Neural complex.**

branched tubules towards the dorsal side which open into a long non-ciliated canal of the neural gland. From the anterior end of the gland arises a duct which opens into the antero-dorsal region of the branchial cavity by a ciliated funnel-shaped opening. This opening lies in the middle of the two spirally coiled lobes of the dorsal tuberele. The canal of the neural gland is lined with a single layer of non-ciliated oval cells with large nuclei. The remaining part of the neural gland is composed of closely packed small nucleated cells, whose cytoplasm possesses dark coloured granules. These granules contain **xanthine** and **urate** excretory particles.

The **nephrocytes** found in the blood act as carriers of nitrogenous wastes. The xanthine and urate particles are deposited in these cells. Later these cells are extruded into the lumen of the neural gland and finally thrown into the branchial cavity. **Julin** believed that the neural gland is homologous to the hypophysial cerebri of the higher vertebrates. **Das** (1956) proved that the neural gland secretes certain hormone which control oviposition in mature ascidians and also the rate of development and metamorphosis in the larva. Hence, it proves that the neural gland is homologous to the vertebrate pituitary gland.

### Receptors

In *Herdmania*, the receptors are poorly developed. The different kinds of sensory structures are given below :

**1. Tangoreceptors :** These are specially modified epithelial cells found scattered in the non-vascular epidermal layer of the test specially of the siphons. These cells cover the vascular ampullae and the tentacles. These receptor cells are provided with nerve fibres and hence act as **tactile organs.**

**2. Olfactoreceptors :** The tentacles found at the base of the branchial siphon are provided with nerves. These tentacles Judge the size and the chemical nature of the food particles entering the branchial cavity with the incurrent water.

**3. Photoreceptors :** There are red pigmented squamous epithelial cells found on the margins of the atrial and branchial siphons, and on the vascular ampullae. These cells act as **ocelli** in the absence of true eyes and are sensitive to light.

**4. Thermoreceptors :** These are present in between the cells lining the branchial siphon. These respond to various changes in the temperature of the water entering in the siphon.

**5. Dorsal tubercle :** It is olfactory (to smell) and gustatory (to taste) in function. It is situated in the branchial sac near the Junction of the peripharyngeal band with the dorsal lamina. It consists of a broad concave hemispherical base from which arises two

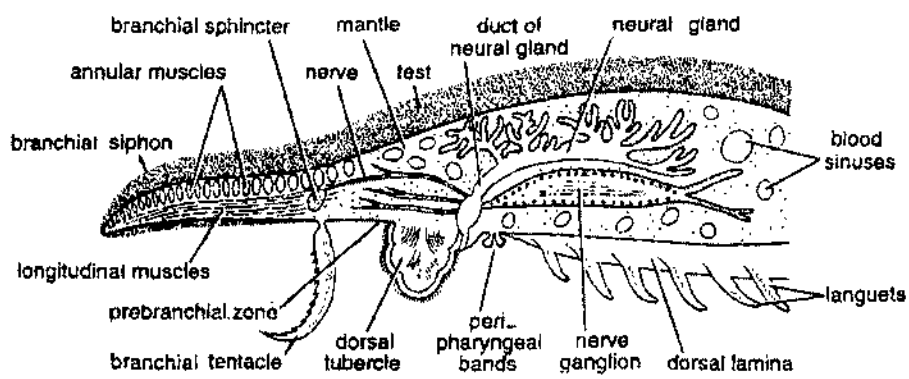



**Fig. 16. *Herdmania.* L.S. of body through neural complex.**

spirally coiled conical lobes. Each conical lobe possesses a spirally coiled ciliated channel which makes three loops. The ciliated channels of the two lobes unit at the base in between the two lobes. There is a funnel-shaped shallow ciliated opening of the neural gland in the centre.

The entire surface of the tubercle is covered by a single layer of tall ciliated epithelial cells provided with nerves. The interior of the tubercle contains loose connective tissue having numerous blood sinuses.

## Reproductive System

*Herdmania* is **hermaphrodite.** It bears two large gonads, which are situated on the left and the right side of the body. The left gonad lies within the loop of the intestine, while the right gonad is situated towards the dorsal side of the pericardium. Each gonad in adult animal is about 3 to 4 cms long and 1 cm wide.

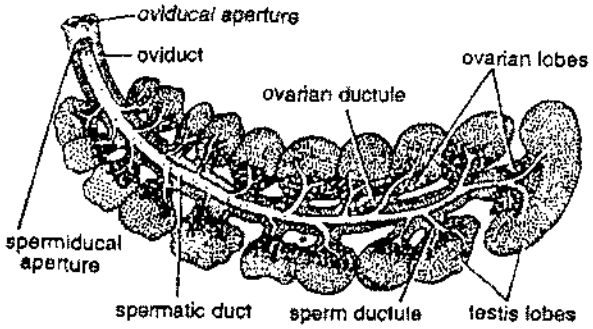



**Fig. 17. *Herdmania*. Left gonad seen fromits inner face.**

Each gonad consists of 10 to 25 distinct lobes, which are arranged in two rows, one on either side of a longitudinal axis in which lie the two **gonoducts** (genital ducts). The posterior most lobe is large and unpaired. The lobes gradually decrease in size towards the atrial side. The gonoducts to which the lobes communicate open into the atrial cavity.

Each lobe of the gonad is hermaphrodite. The outer part of each lobe is called the **testicular region** and it is brick red in colour. While the inner part is called the **ovarian region** and it is pinkish in colour. The ovarian parts of all the lobes of a gonad are united with a **oviduct** by a number of short **ovarian ductules.** The oviduct opens into the atrial cavity at the base of the atrial siphon and a short distance behind the rectal orifice. The narrow **spermatic duct** (vas deferens) running along the inner or branchial side of the oviduct also receives a number of (*i.e.*, equal to lobes of the gonad) narrow **sperm ductules.** Each sperm ductule is formed by the union of a number of fine branches, which profusely rebranched to form the closely packed **spermatic caeca.** The spermatic caeca are lined with spermatogonial cells which give rise to sperms. The spermatic duct also opens in the atrial cavity on a small papilla, a short distance behind the oviducal aperture. Both the gonoducts are internally lined by ciliated epithelium. The ovarian part of the gonad mature earlier than the testicular past (protogynous condition).

## Gometes

**Spermatozoon :** In *Herdmania*, the sperms are of three different types. Each sperm is very minute, about 4 mu in length, having an acrosome (beak), a head with nucleus, neck or middle piece and a long tail. The three types of sperms are as follows :

(a) The acrosome and the head are of equal length.

(b) The acrosome is three times the length of the neck.

(c) The middle piece (neck) is three times the length of the acrosome.

**Ovum :** The ovum is about 0.30 mm. in diameter with a small quantity of granulated yellowish yolk. The ovum is surrounded by two membranes, called the otuer chorion and the inner chorion. These are formed by the inner follicle cells. Follicle cells are found attached with the outer chorion. In between the two chorion layers the space is filled with interchorional fluid. The ovum has its own **vitelline membrane.** Its nucleus is large and excentric in position with a prominent nucleolus. Around the ovum beneath the inner chorion is found the pervitelline fluid in which are found floating isolated and also clumps of follicle cells. Follicle cells are also found attached with the vitelline membrane. During early development the embryo remains with in the chorionic membranes.

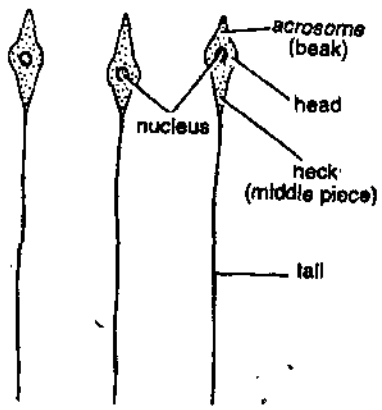



**Fig. 18. *Herdmania*. Structure of sperm**

## Fertilization

In *Herdmania,* self fertilization does not occur due to protogynous condition. Fertilization is external occurring in sea water. Before fertilization the primary oocyte shows three distinct areas namely :

1. An outer or peripheral transparent layer of cytoplasm having few yellow pigment.

2. Central greyish yolky cytoplasm.

3. The area of germinal vesicle near the presumptive animal pole of the egg.

The sperm enters the primary oocyte near the presumptive vegetal pole. Normally single sperm enters the ovum, but in exceptional cases several sperms may enter the ovum and they remain in the perivitelline space. As soon as the sperm enters the ovum through the vegetative pole, the movement of cytoplasm occurs and it forms four distinct areas :

1. The **yolky area** formed at the vegetal pole.

2. The **gray crescent.**

3. A clear cytoplasmic and yellow crescent.

4. A concentrated homogeneous cytoplasmic zone at the animal pole of the egg.

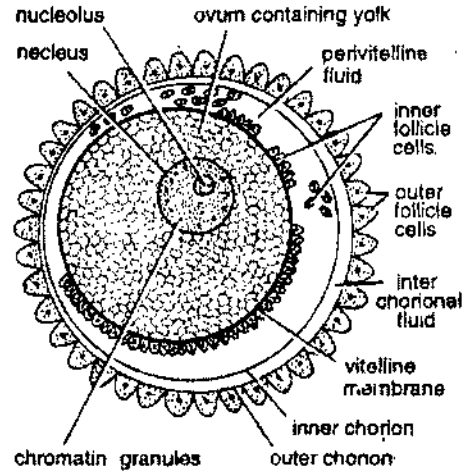



**Fig. 19. *Herdmania*. Structure of ovum**

## 3.3. RETROGRESSIVE METAMORPHOSIS IN *HERDMANIA*

### Development of *Herdmania*

*Herdmania* is hermaphrodite, still self-fertilization does not take place, because ova mature and discharged earlier than the sperms of the same animal. Hence fertilization is of cross-type and external takes place in sea water.

**Cleavage** is holoblastic and complete. The fate of blastomeres is predetermined. **Morula** is a solid ball of cells. **Coeloblastula** (blastula) has a single-layered flat embryo having a fluid filled blastocoel that is formed at 64 cells stage. **Gastrulation** by emboly or invagination forming archenteron opening outside by blastopore. Later blastopore closes and develops a rudiment of tail. Embryo elongates forming a tailed larva.

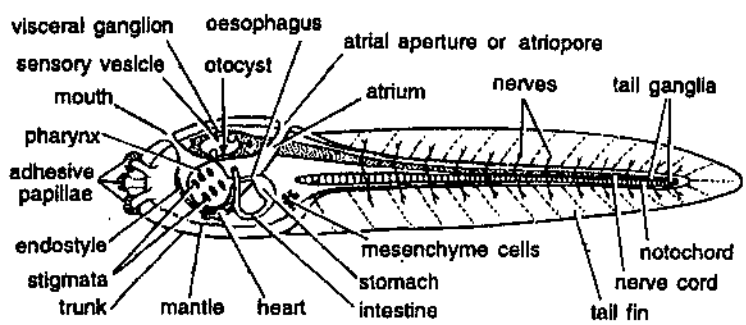



**Fig. 20. *Herdmania*. Tadpole larva in left lateral view.**

About 8 hours of fertilization, a fully formed larva hatches out and it becomes free-swimming. It's larva resembles to a small tadpole and hence it is called **tadpole larva.** Tadpole larva is transparent, about 1.2 mm long and 0.2 to 0.3 mm wide and highly motile. It's entire body is covered by a thin test and shows two distinct regions : a short oval **anterior trunk** or head and a long **posterior tail.**

## 3.4. RETROGRESSIVE METAMORPHOSIS

In retrogressive metamorphosis the active free-swimming larva having advance characters like axial notochord, dorsal neural tube and special sense organs, are transformed into an inert, sedentary and simple adult, which has only a pharynx, with stigmata and endostyle, which indicate its chordate nature. This type of metamorphosis which shows degeneration (retrogression) from larva to adult is called as **retrogressive metamorphosis.**

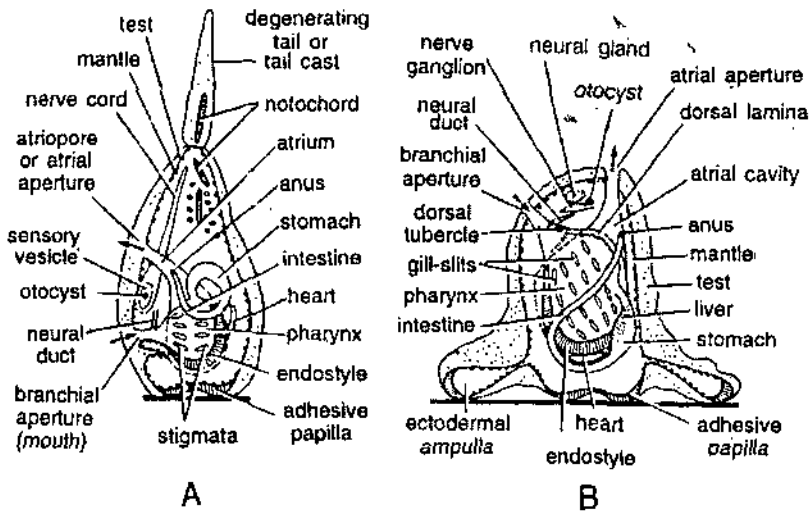



**Fig 21. *Herdmania* Figures showing retrogressive metamorphosis. A— Attached larva showing degeneration of tail. B— Young adult (side view)**

Retrogressive metamorphosis of the tadpole of *Herdmania* shows two types of changes : retrogressive and progressive.

### Retrogressive changes

1 **Loss of tail.** Tadpole larva of *Herdmania* loses its tail gradually including its notochord, nerve cord and muscles. These tissues are autolyses and resorbed by the metamorphosing larva.

2. Sensory vesicle in the brain breaks down. It's anterior part forms the neural gland, whereas its posterior part with the trunk ganglion forms the nerve ganglion and nerves of the adult.

3. Adhesive papillae disappears.

4. Anterior region between point of attachment (adhesive papillae) and mouth rapidly grows, shifting mouth through 90°. Thus, in the adult branchial and atrial apertures represent the anterior and dorsal sides of the larva.

### Progressive changes

1 After the loss of tail, trunk becomes pear-shaped and four large ectodermal ampullae grow out of its four corners to attach the tadpole with the substratum. These ampullae also serve as a respiratory organs because blood-like fluid circulates through them. Two more smaller ectodermal ampullae also appear dorso-laterally.

2. Sensory vesicle with its sense organs (ocelli and otocyst) degenerate. Adult neural gland is formed by the neural tube and trunk ganglion forms the nerve ganglion of the adult. Both lie middorsally between mouth and atriopore.

3. Pharynx enlarges, stigmata increase in number and vascularised by blood vessels. Stomach also enlarges, intestine becomes U-shaped and liver is formed. Atrial cavity becomes spaceous

4. Circulatory system with heart and pericardium develops and gonads with gonoducts appear from larval mesoderm

5. Test covers the entire animal and becomes thick, tough and vascular. It also forms the foot, which attaches the animal with the substratum

### Significance of *Herdmania* tadpole

The tadpole larva possesses chordate characters, such as notochord in the tail region and dorsal tubular nerve cord, which do not found in the adult. Thus, tadpole larva provides the clue for including *Herdmania* into the chordate.

## • SUMMARY

- *Herdmania* is world-wide in distribution.

- *Herdmania* is sedentary found attached with rocky substratum of the sea.
- Entire body of *Herdmania* is covered by test or tunic. Its body is oblong or rectangular and divisible into anterior broad body proper and posterior narrow foot attached with the substratum.
- Beneath the test lies the transparent mantle.
- Free end of body proper bears two apertures. Branchial and atrial apertures which lead into branchial and atrial siphons respectively. Blood vascular system includes heart and pericardium, blood vessels and blood.
- Heart is enclosed in an elongated transparent pericardium. Heart is also attached along its entire length with the pericardium.
- Pericardium is non-contractile and heart is contractile and its both ends are open.
- Major blood vessels are ventral aorta arising from the ventral end of the heart, dorsal aorta runs just above the dorsal lamina in the dorsal wall of branchial sac, branchio-visceral vessel arises from the posterior end of the heart.
- Blood is transparent and slightly reddish and has colourless amoeboid leucocytes, 6 or 7 types of coloured, non-nucleated corpuscles and nephrocytes.
- Heart at regular intervals beat dorso-ventrally and ventro-dorsally.
- Alimentary canal of *Herdmania,* consists of branchial siphon, branchial sac, oesophagus, stomach, intestine and rectum, Branchial sac is perforated by about 4,000,000 stigmata. It also bears a dorsal lamina and endostyle. Rectum opens into the atrial cavity through anus. Branchial sac is also acts as respiratory organ. Excretory organ is the neural gland.
- *Herdmania* undergoes retrogressive metamorphosis during development.
- Its active free swimming larva possesses some chordate characters axial : notochord, dorsal neural tube and special sense organs.
- During retrogressive metamorphosis active larva transforms into innert, sedentary simple adult bearing pharynx with numerous stigmata and endostyle which indicate its chordate nature.

## • STUDENT ACTIVITY

1. Describe the blood vascular system of *Herdmania.*

2. Describe the digestive system of *Herdmania.*

3 What is retrogressive metamorphosis ? Discuss it in *Herdmania* in detail.

4. Describe the digestive system of *Herdmania*.

## • SHORT ANSWER QUESTION

1. **Write the name of body covering of *Herdmania*.**
   **Ans.** Body covering of *Herdmania* that protects its body is test or tunic composed of tunicin.
2. **Write the positions of branchial and atrial apertures in *Herdmania*.**
   **Ans.** Branchial aperture lies at the anterior end and atrial aperture is located at the dorsal end of the body proper of *Herdmania*
3. **What is the position of foot in *Herdmania* ?**
   **Ans.** Foot is only composed of hard tunic and postero-ventral in position.
4. **What is the position of heart and pericardium in *Herdmania* ?**
   **Ans.** Pericardium encloses the heart and lies just below the right gonad.
5 **Name the major blood vessels of *Herdmania*.**
   **Ans.** Ventral aorta, dorsal aorta, branchio-visceral vessel and cardio-visceral vessel.
6. **Name the vessels which arise from the dorsal and ventral ends of the heart of *Herdmania* ?**
   **Ans.** Cardiovisceral vessel arises from the dorsal end of the heart and ventral vessel arises from the ventral end of the heart of *Herdmania*.
7. **What is the function of nephrocytes found in the blood of *Herdmania* ?**
   **Ans.** Nephrocytes are excretory cells and they collect waste products mainly xanthine and urate particles from the various organs and tissues of the body They are discharged into the lumen of neural gland and finally into the pharynx.
8. **What is the name of larva of *Herdmania* ?**
   **Ans.** Larva of *Herdmania* is called tadpole larva, because it resembles the frog's tadpole in shape..
9. **Define retrogressive metamorphosis.**
   **Ans.** Tadpole larva of *Herdmania* is an active, free swimming and bears certain chordate characters like notochord, dorsal neural tube and special sense organs and during this type of metamorphosis it loses these structures and becomes an inert sedentary simple adult. Thus, larva degenerates into an adult.
10. **Where endostyle and dorsal lamina of *Herdmania* is located ?**
    **Ans.** Dorsal lamina is found inthe mid-dorsal leaf of Branchial sac and endostyle is a midventral groove inthe branchial sac.
11. **Name the excretory organ of *Herdmania*.**
    **Ans.** Neural gland.

## • TEST YOUR MEMORY

1. What do you know about its morphology and anatomy ?
2. What do you know about the nature of blood vascular system of *Herdmania* ?
3. What is the nature of pericardium and heart of *Herdmania* ?
4. What are the major blood vessels of *Herdmania* and which arise directly from the heart ?
5. How the blood flow in the heart of *Herdmania* is regulated ? Since there are no valves in the heart to regulate the flow of blood ?
6. Difference between retrogressive and progressive metamorphosis.
7. What are the advanced characters found in the larva of *Herdmania* ?

UNIT

# 4

# CEPHALOCHORDATA : GENERAL CHARACTERS AND CLASSIFICATION

## STRUCTURE

- Cephalochordata subphylum includes a single class Leptocardii. *Branchiostoma* and *Asymmetron* are its two genera.
- Cephalochordata are marine animals found buried in the sand with its tail end.
- Body is divisible into trunk and tail, head is absent. Fish-like in appearance, without paired appendages, but median fins are present. Enterocoetic coelom. Excretory organs protonephridia. Interelationship of protochrodates.
  - Summary
  - Student Activity
  - Test Yourself

## LEARNING OBJECTIVES

After going through this unit you will learn :

- General characters of cephalochordata; habit and habitat of Amphioxus, its external features and skeletons; position of coelom in Amphioxus; Digestive tract, blood vascular system, excretory system of Amphioxus Inter-relationship of protochordates.

## 4.1. CHARACTERS OF CEPHALOCHORDATA

1. Marine, inhabits shallow waters. Buried in sand or mud with only anterior end projecting above the sand.

2. Body small, slender, fish-like, metameric and transparent.

3. Body has trunk and tail and head is absent.

4. Paired appendages absent, but median fins are present.

5. Muscles dorso-lateral, segmented myotomes.

6. Epidermis single layered and no exoskeleton.

7. Coelom entercoelous, reduced, present only in the pharyngeal region.

8. Notochord is persistant and extends through out the length of the body, ventral to the notchord.

9. Pharynx large having numerous gill slits which open into the atrial cavity. Ciliary feeders.

10. No respiratory organs. Respiration through general surface of the body.

11. Circulatory system closed and without heart and respiratory pigment. Hepatic portal system is present.

12. Excretory organs protonephridia with solenocytes.

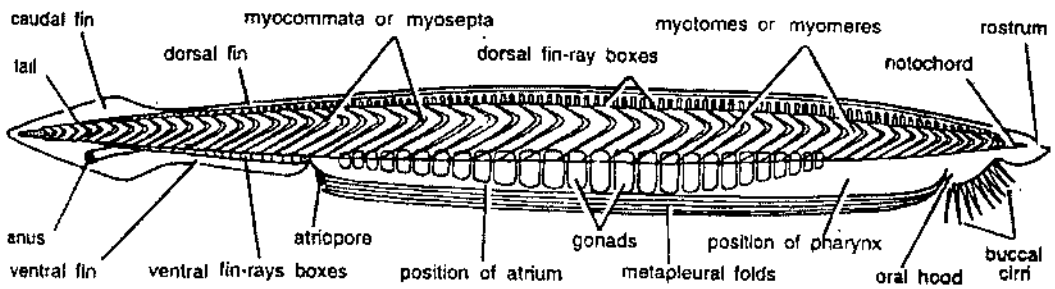



Fig. 1. *Branchiostoma*. (right side view).

13. Sexes separate. Gonads numerous metamerically arranged. No gonoducts.

14. Fertilization external and development indirect with a free-swimming larva.

Cephalochordata includes two genera-*Branchiostoma* and *Asymmetron*, belonging to the class Leptocardii.

*Branchiostoma* is regarded as a primitive chordate. It retains several primitive chordate characters as relics from its ancestors. Its primitive characters are as follows :

1. Like echinoderms body, its body also is asymmetrical. It regarded to have a common ancestory with chordates.

2. Absence of head, and paired limbs.

3. Epidermis one cell-thick and dermis is absent.

4. Coelom enterocoelous arises as lateral pouches of larval archenteron.

5. Myotomes (muscles) are metamerically arranged.

6. Notochord persists throughout life. Endoskeleton not developed.

7. Alimentary canal straight. Jaws absent, pharynx large, perforated by gill slits. Endostyle present. Liver is represented by a midgut diverticulum.

8. Blood vascular system is simple without heart. No distinction between arteries and veins. Hepatic portal system is primitive.

9. Respiratory organs and respiratory pigments are absent.

10. Excretory organs are protonepridia which are not coelomoducts.

11. Neural tube is hollow lying above the notochord. Specialized brain is absent and dorsal and ventral roots of spinal nerves are separate and dorsal roots without ganglia. (Brain poorly developed).

12. Sensory organs simple and paired. Ocelli or simple eye spots, cephalic pigment spot, infundibular organ, Kollicker's pit and Hatschek 's groove are the sensory organs.

13. Gonads are in several pairs, segmentally arranged and without gonoducts...

14. Eggs small almost without yolk.

## • 4.2. CLASSIFICATION

Cephalochordata (Subphylum) includes a single class Leptocardii having a single family Branchiostomidae. It includes two general *Branchiostoma* and *Asymmetron*. *Asymmetron* has unpaired gonads on the right side of the body and metapleural folds are asymmetrical.

## • STUDENT ACTIVITY

1. Write down the general characters of subphylum Cephalochordata.

_____

_____

_____

_____

_____

_____

## • SHORT ANSWER QUESTIONS

1. **Write the names of two genera of Cephlochordata.**

   **Ans.** Its two genera are *Branchiostoma* and *Asymmetron*.

2. **What is the main difference between *Branchiostoma* and *Asymmetron* ?**

   **Ans.** In *Asymmetron* gonads are unpaired and in *Branchiostoma* these are paired..

UNIT

# 5

# AMPHIOXUS : MORPHOLOGY AND ANATOMY

## STRUCTURE

- Morphology of *Amphioxus* includes its outer features.
- Anatomy of *Amphioxus* includes its various systems or organs like digestive respiratory, blood vascular, excretory, nervous, sense organs and reproductive systems.
  - Summary
  - Student Activity
  - Test Yourself

## LEARNING OBJECTIVES

After going through this unit you will learn :

- Habit and habitat of *Amphioxus*. External features of *Amphioxus*, Skeletal structures, Coelom, Anatomy Digestive, Blood vascular, Excretory systems and inter-relationship of protochordates.

## • 5.1. THE CEPHALOCHORDATA *AMPHIOXUS*

The caphalochordates possess the notochord in the ntire length of the body. The cephalochordata includes a few small fish-like forms, the lancelets which are commonly called *Amphioxus* and *Asymmetron*. It includes about sixteen species, which are arranged in two closely allied genera under the single family, **Branchiostomatidae. Pallas** (1778) first discovered the lancelet from the Northern coast of Norway and regarded it as mollusc (slug) and he named it as *Limax lancelotus*. Later **O.G. Costa** (1834) correctly diagnosed it as a lower vrtebrate on the basis of perforated pharynx and named it as *Branchiostoma*. The name *Amphioxus* was given by **Yarrel** (1836). The anatomy of Amphioxus was first described by **Johannes Muller** in 1841.

### Habit and Habitat

*Amphioxus* is a marina animal found in shallow waters burrowing in the sand with its tail end. Its anterior end protrudes out of the sand. It swims freely at night and swimming is done by lateral undulations of the body. The oral cirri and the wheel organ remain in constant motion to produce the feeding currents back to the mouth and thence to the buccal cavity. Since *Amphioxus* feeds upon microscopic organisms present in sea water, it is sensitive to light though its eye spots are poorly developed The sexes are separate but not distinguishable externally.

*Amphioxus* is found on the sandy shores of the tropical and warm temperate oceans of the world, such as Atlantic ocean, Indian ocean, West Indies, China seas, Mediterranean sea, Bay of Naples. *Amphioxides* (Amphioxididae) is a permanently pelagic in habit. It differs from *Amphioxus* in the absence of oral cirri and atrial cavity, the branchial slits open directly on the exterior in an unpaired ventral row. No adult form has been found out, but larger specimens have a single row of gonads. *Dolichobranchus indicus* has been recently discovered. Its snout is comparatively larger than the *Amphioxus*, in other details it is similar to that of later.

### External Features

*Amphioxus* is about three to six cm in length. It is slender, some what transluscent, laterally compressed and pointed at both ends. The colour of the animal is dark red or reddish brown. The anterior or head end is slightly thicker, called the **rostrum** and its venral surface is expanded to form the **oral hood.** The mouth is an oval aperture situated in the oral hood and the edges of the oral hood around the mouth bear twenty

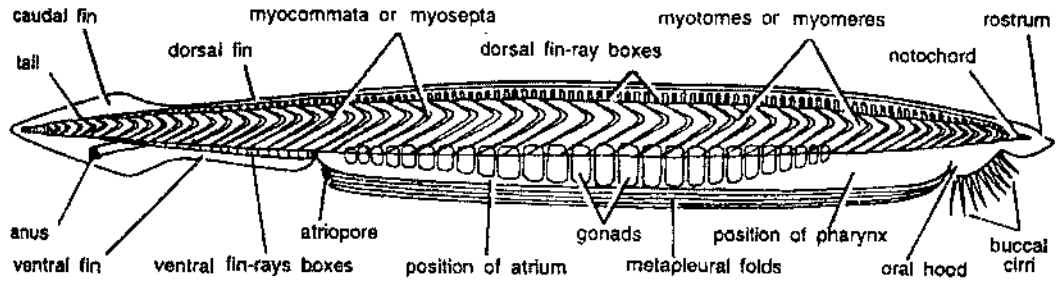



**Fig. 1. External structure of *Amphioxus*.**

to twenty two hair-like, sensory and stiff processes, which are called **oral cirri** or ciliated buccal tentacles. These cirri bear marginal sensory papillae (receptor organs for taste). The anterior two third part of the ventral surface is flattened. The lateral edges of this flat area are projected ventrally to form the **metapleural folds.** These arise from just behind the mouth and terminate in the middle line posteriorly behind a median opening the **atriopore.** From behind th atriopore the **ventral fin** extends back wards and surrounds the pointed posterior end of the body as **caudal fin.** The caudal fin extends forward along the median dorsal surface of the body upto the anterior end as **dorsal fin.** Hence in *Amphioxus* the unpaired fins (ventral, dorsal and caudal fins) are present and the paired fins are absent. The anus is placed at the back of the ventral fin. Behind the anus is the tail part which is surrounded by the caudal fin. The tail part bears the notochord and the extension of the neural tube.

**Fins :** The dorsal fin is supported by a single series of fin rays and the ventral fin by a double series of fin rays. Fin rays are short rods of connective tissue, continuous with the investment of the neural canal and separated from one anothr by small cavities, the **lymph spaces**. Fin rays are not found in the anterior and posterior parts of the dorsal fin, and in the ventral part of the caudal fin. The fins of *Amphioxus* are structurally different from that of fishes.

### Musculature

The longitudinal muscles on either side of the body are divided into a series of "V"-shaped segments placed one behind the other. These segments are called **myotomes.** There are 60 myotomes on either side of the body, but their number varies in different species from 50 to 85. The segmentation is externally marked by a number of "<" shaped grooves, the apex (pointed end) is being directed forward. The "<" shaped grooves of one side do not correspond to those of the other side. Each myotome (myomere) is enclosed in a sheet of fibrous connective tissue, called **myocomma.** The myotomic muscle fibres are of striated type and are inserted at each end into the myocommata. or myocomma. With in mycomma is also present the **myocoel.** The myotomes are very thick on the dorsal side and enclose the nerve cord and notochord.

Beneath the atrium is present a sheet of transverse muscle, which runs across the floor of the atrial cavity. It is not segmented. Its contraction compresses the atrial cavity due to which its contents are expelled out.

*Amphioxus* swims with the help of the alternate contraction and expansion of the myotomic muscles due to which the animal moves in transverse motion.

## • 5.2. SKELETAL STRUCTURES

In *Amphioxus*, the main skeletal structures are the notochord, skeleton of the oral hood, gill bars and endostylar plates.

**Notochord :** The notochord is the main supporting structure extending through out the length of the body just bneath the neural tube and above the alimentary canal. It extends anteriorly beyond the cerebral vesicle as the notochordal process. The notochord in early embryos is formed of vacuolated cells filled with fluid secretion and their nuclei are displaced to one side, either to dorsal or to ventral. This notochord is surrounded by a sheath of fibrous connective tissue, the **notochordal sheath.** Later the vacuolated cells take the form of regularly arranged alternating flattened plates of fibrous and homogneous gelatinous matter, and an **elastic interna** layer is formed beneath the notochordal sheath.

**Skeleton of Oral hood :** The oral hood is supported by a gelatinous ring resembling soft cartilage. It is made of pieces lying end to end. Each gelatinous piece gives out a rod forming the axis of an oral cirrus.

**Gill bars and endostylar plates :** The skeleton of the gill bars and endostyle is made of elastic gelatinous material.

### Coelom

**Coelomic in larval forms :** In the young larva of *Amphioxus* there are five coelomic spaces, viz. a median anterior **"head cavity"**, a pair of antero-lateral **"collar cavities"** and a pair of more **posterior longitudinal grooves.** In later larva these coelomic spaces give rise to the segmental myotomes and a ventral large coelomic space surrounding the digestive tract and separates it from the body wall.

**Coelom in adult animal** : In the adult animal, the coelom is somewhat restricted due to the development of the atrium.

**Coelom in pharyngeal region** : Above the pharynx, on either side of the epipharyhgeal groove is present a **dorso-coelomic canal.** Each canal gives off a ventral diverticula which pass through the primary gill bars of the pharyngeal region and finally units with the median **endostylar coelom.** The dorso-coelomic canals and the median endostylar coelom unit with each other behind the pharynx to form a narrow coelomic space, which surrounds the stomach and gives off a forward extension around the hepatic caecum.

**Coelom in the region of intestine** : In the intestinal region, behind the atriopore, the coelom extends posteriorly towards the left side of the intestine.

On the right side of the intenstine in the extension of the atrium upto the anus. Towards the dorsal side of the intestine, the coelom is restricted due to dorsal mesentery by which intestine is suspended.

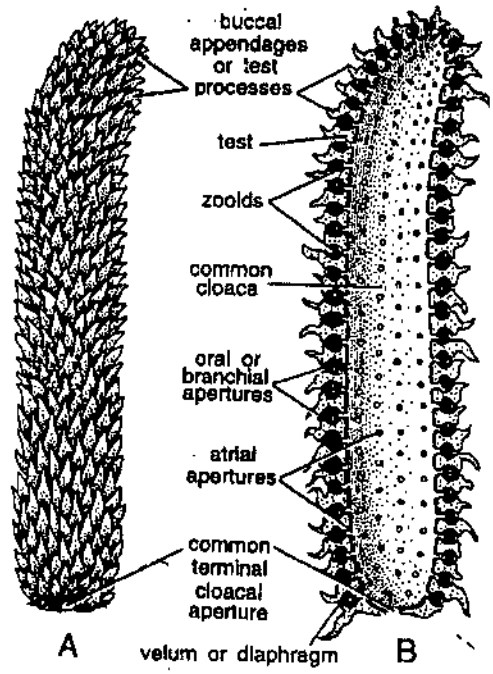



Fig. 2. *Amphioxus.* Median sagital section of notochord

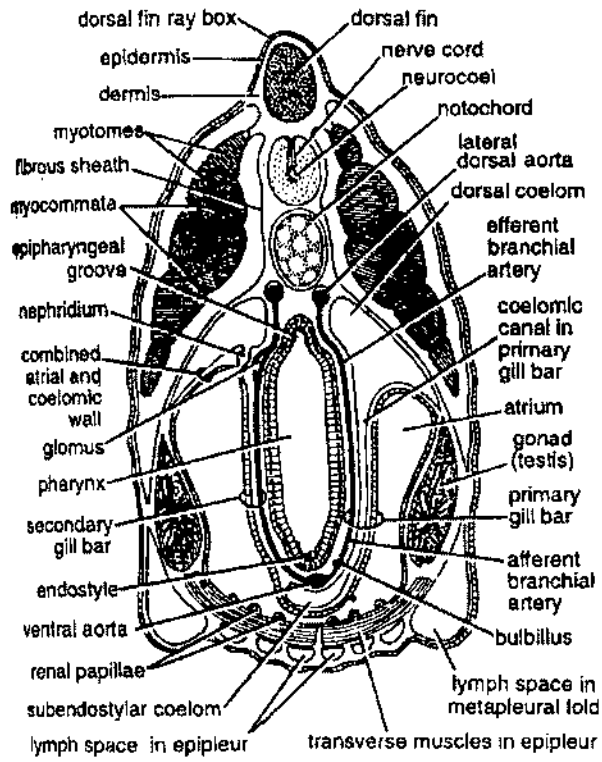



Fig. 3. *Amphioxus.* T.S. of pharyngeal region, passing on the right through a primary and on the left through a scondary branchial lamella

The coelom is lined by coelomic epithelium and filled with lymph-like fluid.

## • 5.3. MORPHOLOGY OF AMPHIOXUS

### Body Wall

**Skin** consists of an outer single columnar epithelial cells layer, called the epidermis that rests on basement membrane. It is externally covered by thin chitin-like **cuticle.**

In the epidermis are also found sensory cells. Gland cells and pigment cells are absent. Beneath the epidermis lies a thin, tough, fibrous connective tissue layer, called the **cutis** and below it is present a thick spongy **subcutis** formed of gelatinous matrix having nerve fibres, and blood vessels.

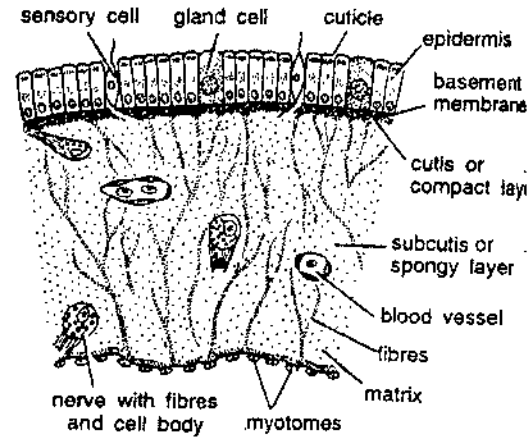



Fig. 4. *Amphibioxus.* V.S. of body wall

Beneath the skin is found muscles which are metamerically arranged throughout the body arranged in V-shaped muscle blocks or segments called **myotomes.** Apex of the V lies anteriorly. Myotomes are enveloped in a thin connective tissue layer and separated from each other by connective tissue partitions, called myosepta or myocommata. Muscle fibres in each myotome are of striped type and are arranged longitudinally.

Beneath the muscle lies a thin layer of **parietal peritoneum**.

## 5.4. ANATOMY OF *AMPHIOXUS*

### Skeleton

*Amphioxus* has no exoskeleton but endoskeleton is found in the form of notochord, fin-ray boxes, oral ring and gill rods.

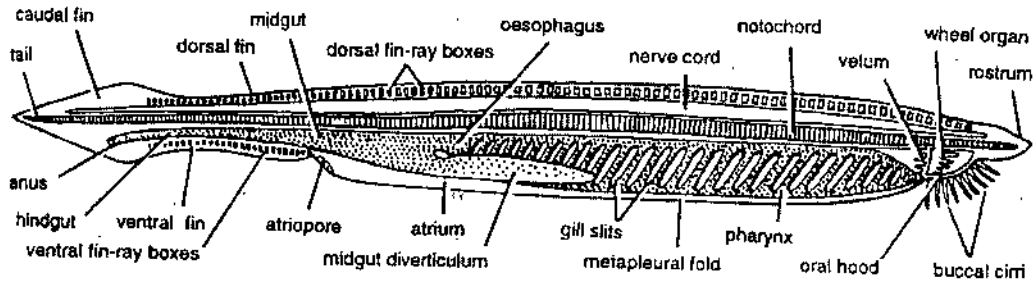



Fig. 5. General anatomy of *Amphioxus.*

**Notchord (Chorda dorsalis).** Notochord is an elongated narrow cylindrical rod-like structure. It is tapering at both ends and extends from tip of the snout upto the tail end. It lies in between the dorsal nerve cord and the gut. In adults, it is formed of a linear series of alternate disc-like fibrous and gelatinous plates. Notochord is externally surrounded by a tough fibrous connective tissue, called the **notochordal sheath**, which is covered by a thin elastic membrane.

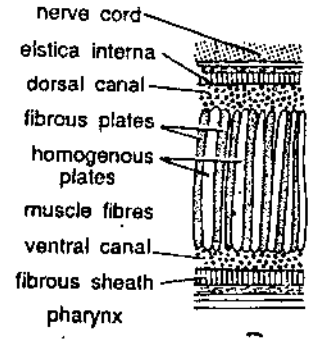



Fig. 6. *Amphioxus.* L.S. of notochord.

**Fin-ray boxes.** These support the fins. Fin-rays are composed of modified connective tissue containing gelatinous substance.

**Oral ring.** It supports the oral hood and its cirri. Oral ring is made of separate rod-like pieces located at the base of oral cirri. From each piece rod-like prolongation extends into each cirrus to give it a support.

**Gill rods.** Gill rods give support to the gill bars of gill slits. Each gill rod is made up of gelatinous substance and is of two types : primary rod and secondary rod. Primary gill rod is bifurcated ventrally, while secondary rod is single. Dorsally each rod is united with each other. Gill bars also get support from the cross bars, called **synapticulae.**

**Coelom.** Coelom in *Amhioxus* is true lined with somatic and splanchnic layers of mesoderm and filled with a lymph-like coelomic fluid. It is enterocoelic in origin. Coelom is a large cavity around intestine, which hangs in it by a dorsal mesentery. On

the right side of hind-gut, coelom is reduced due to the posterior extension of atrial cavity and extends beyond atriopore upto the anus. Reduced coelom is also found around pharynx. In higher chordates coelom is not found in the pharyngeal region. In pharyngeal region, a pair of dorsal longitudinal coelomic canals are present one on either side above the pharynx enclosing the **brown** funnels. A mid-ventral longitudinal **subendostylar coelomic canal** runs below the endostyle. Through the primary gill bars run the vertical coelomic canals, which unite with the subendostylar coelomic canal. Small coelomic spaces are also found within the gonads, called the **gonocoel** and around the mid-gut (liver diverticulum).

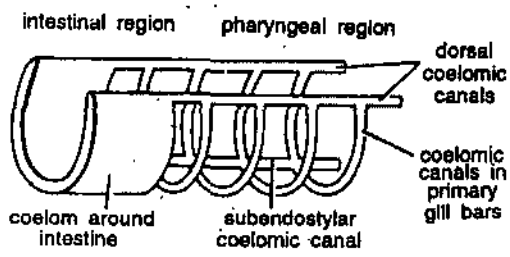



**Fig. 7. *Amphioxus*. Coelom (diagrammatic).**

**Atrium.** Atrium (atrial cavity) is a large space lined by atrial epithelium of ectodermal origin. Atrium surrounds the pharynx and intestine on the lateral and ventral sides. Gill slits open into the atrium, and atrium opens to outer side through a small mid-ventral aperture the **atriopore** located just infront of ventral fin. On the posterior side, atrium extends behind the atriopore as a blind pouch on the right side of intestine upto anus. On the anterior side, atrium extends into each dorsal coelomic canal on either side of pharynx, forming the **brown funnel** (atriocoelomic canal). Function of brown funnel is not known.

**Digestive Organs.** Digestive organs are alimentary canal and digestive glands.

**Alimentary Canal.** In *Amphioxus,* alimentary canal is a straight tube lined by ciliated epithelium, extending from mouth to anus.

**Mouth** is a large oval opening at the antero-ventral end of the trunk and bordered by a frill-like membrane, the **oral hood.**

**Oral hood** is a membranous projection of the anterior end of trunk. The free edge of the oral hood surrounding the mouth is produced to form a circlet of 12 to 20 **oral cirri** or tentacles. The edge of oral hood and oral cirri are supported by a gelatinous stiff rods. The oral cirri form a sieve over the mouth to check entry of larger particles with food current.

Oral hood encloses a large funnel-shaped **buccal cavity** and mouth opens into this cavity. Buccal cavity is lined by ciliated epithelium.

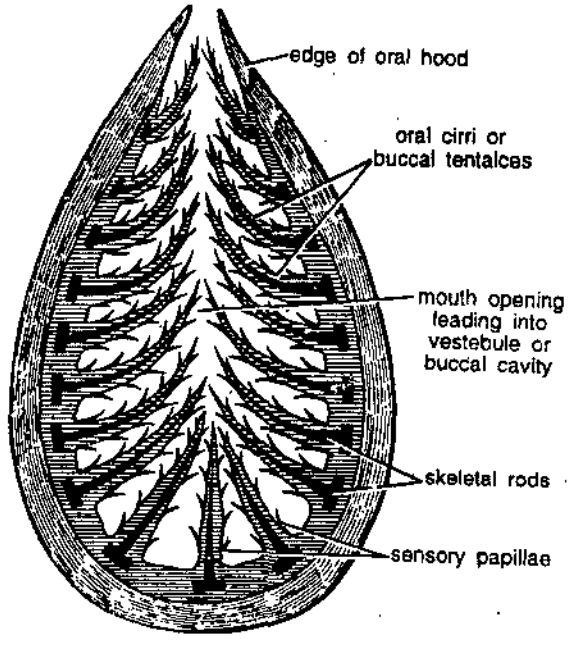



**Fig. 8. *Amphioxus*. Oral hood**

**Wheel organ.** Epithelium of the buccal cavity is produced to form 6 to 8 broad finger-like projections, which are collectively known as **wheel organ** or **Muller organ.** Each projection bears a groove covered by cilia. The median dorsal finger is relatively larger and it also bears a groove, that terminates anteriorly into a depression. This groove is called **Hatschek's groove** and **Hatschek's pit** or pre-oral pit respectively. These are lined by glandular epithelium, secreting mucous, which help in separating the food particles from the water current entering the buccal cavity. The beating of cilia of the wheel organ produces a current of water from mouth back to the pharynx.

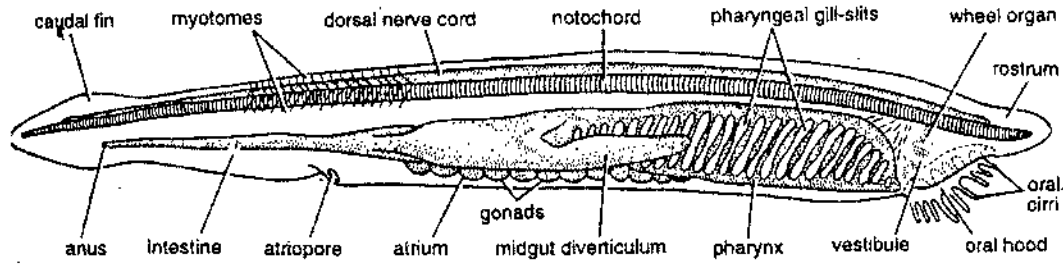



**Fig. 9. *Amphioxus.* Dissected animal in left-lateral view showing gut.**

Buccal cavity leads into the pharynx through a small opening, the **enterostome,** situated centrally in a membranous partition, the **velum.** The edge of the velum are prolonged into a circle of 10 or 12 upto 16 in some species, simple ciliated and sensory **velar tentacles.** These tentacles also form a sieve-like structure over the enterostome.

**Pharynx** is a large spacious and laterally compressed part of the alimentary canal. It occupies one-half anterior part of the trunk. It is enclosed within the atrium except dorsal part. Lateral walls of pharynx are perforated by a large number (150 to 200 on either side) of obliquely placed narrow gill slits or branchial apertures. These gill slits open into the atirum or peribranchial cavity. The space between adjacent gill slts is called **gill bar** or **branchial lamella.** A gill bar is formed of ciliated epithelium covering both ectodermal and endodermal surfaces and encloses a mesodermal core having fibrous connective tissue, blood vessels and a supporting gelatinous skeletal rod. Atria or outer surface of gill bars is sparsely ciliated, whereas endodermal surface is covered by long and dense cilia. Cilia of lateral sides of gill bars are, called **lateral cilia** and of the inner or pharyngeal sides are called **frontal cilia.**

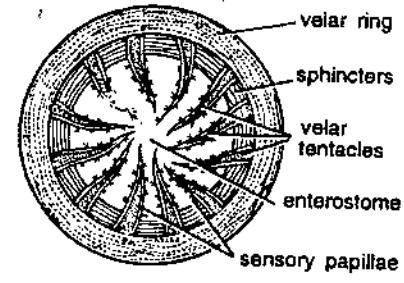



**Fig. 10. *Amphioxus velum.* L.S. of anterior end (right lateral view).**

**Gill bars** are of two types, primary and secondary, which regularly alternate with each other and differ in structure. The skeletal rod of primary gill bar is called **primary skeletal** rod, whereas skeletal rod of secondary gill bear is **secondary gill** rod.

Skeletal rod in primary gill bar is forked ventrally, while in secondary bar it is simple. Primary gill rod contains a coelomic canal and blood vessel, communicating dorsally and ventrally with other parts of that cavity. In secondary gill rod coelomic canal is lacking. These two types of bars are transversally connected at frequent intervals by transverse branchial bars or synapticulae. These bars are also supported by skeletal rods and contain blood vessels.

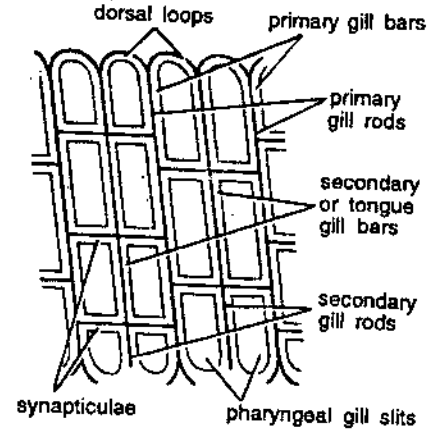



**Fig. 11. *Amphioxus.* Pharyngeal wall (A part).**

**Endostyle.** Along the mid-ventral line (floor) of pharynx runs a shallow groove, the **endostyle** or **hypopharyngeal groove.** It is lined by five longitudinal tracts of ciliated epithelium alternating with four longitudinal tracts of mucous secreting glandular epithelium. Cilia of the median tract are longer. At the anterior end, the ciliated tracts of the endostyle diverge to the right and left to encircle the front of the pharynx as the **peripharyngeal bands.** These two bands run obliquely upwards and backwards along the lateral walls of pharynx and unite dorsally to form the **epipharyngeal** or **hyperpharyngeal groove.** It runs backwards upto the oesophageal opening along the roof of pharynx.

**Oesophagus.** Pharynx posteriorly opens into a short and narrow oesophagus. It is internally lined by ciliated epithelium and leads into a slightly enlarged midgut.

**Midgut.** From the proximal end of the midgut arises a blind **midgut diverticulum,** which extends forward on the right side of the pharynx in the atrio-pharyngeal cavity. It is also internally lined by ciliated epithelium arranged in several tracts. The inner right lateral side of midgut has a crescentic lateral ciliary tract. Its cilia beat downward pushing food into divericulum. Midgut diverticulum seceretes digestive juice. Midgut is followed by a ciliated **ilio-colic ring,** whose cilia rotates the mucous cord containing food.

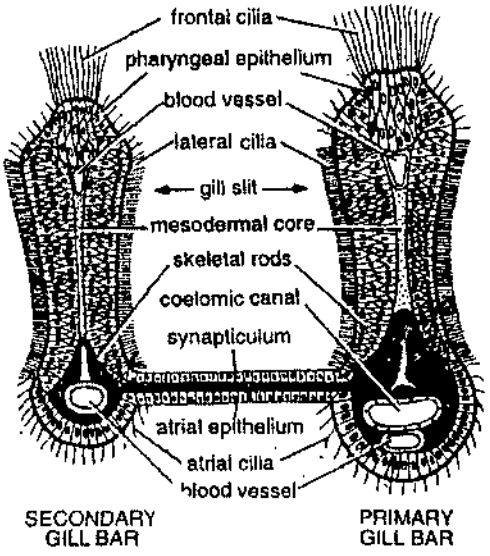



**Fig. 12. *Amphioxus.* Structure of primary and secondary gill bars- in T.S.**

**Hind gut.** Mid gut leads into a narrow hind gut, which is also internally possesses ciliary tracts. It tapers backwards leading into the terminal rectum. It is also internally ciliated and opens exterior through anus. **Anus** is situated at the base of caudal fin, slightly on the left side of the mid-ventral line. Anus is sphinctered.

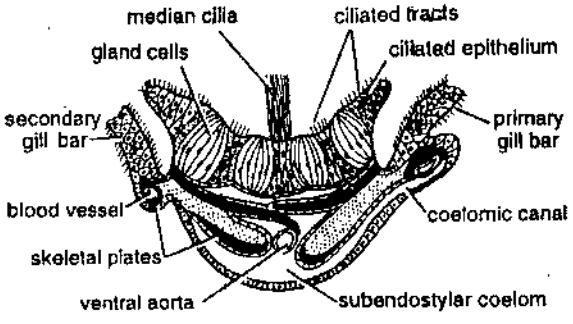



**Fig. 13. *Amphioxus.* T.S. of endostyle.**

**Digestive Glands**

Mid-gut diverticulum is also called **liver,** is the only digestive gland. It secretes a number of enzymes, *viz.,* amylase, protease and lipase.

**Blood Vascular System**

Blood vascular system of *Amphioxus* is of closed type and well developed. Blood is colourless due to absence of any respiratory pigment and corpuscles.

**Heart** is not found in *Amphioxus.* Blood vessels are muscular and contractile. Only dorsal aorta is lined by endothelium. Arteries and veins are similar in structure.

**Sinus venosus.** Sinus venosus is small and thin-walled sac. It is present just below the mid-gut diverticulum. Blood from the entire body enters the sinus venosus through a number of veins and then pumped into the **ventral aorta.**

**Ventral aorta.** Ventral aorta extends forward from sinus venosus and runs mid ventrally in the wall of pharynx below the endostyle in the subendostylar coelom. Blood flows in it anteriorly. It gives off a number of paired lateral **afferent branchial arteries** running through each primary gill bar of pharynx. Each afferent branchial artery at the base of gill bar forms a tiny bulb called **bulbillus** or **bulbule.** Bulbuli are pulsatile and helps in circulating the blood. Blood vessels of primary gill bars are connected with the blood vessels present in secondary gill bars through **transverse vessels** running in synapticulae.

Afferent vessels dorsal to the pharynx are called **efferent branchial vessels,** which open into **lateral dorsal aorta** of that side. Each efferent vessel gives off a small capillary network, called **nephric glomerular sinus** (glomus) in the nephridium.

**Dorsal aorta.** Right and left dorsal aorta running on dorso-lateral side of pharynx, continue forward as **internal carotid arteries,** which supply blood to the oral hood region.

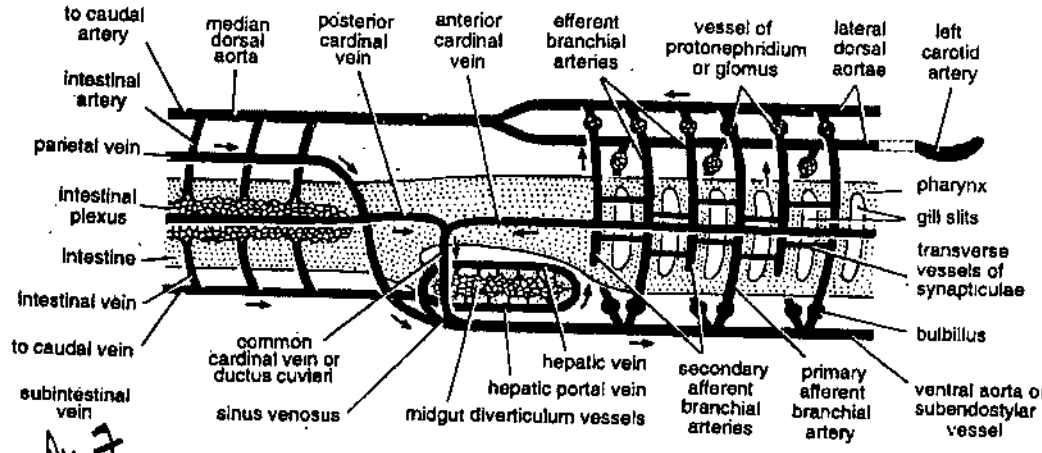



**Fig. 14. *Amphioxus*. Blood vascular system (right lateral view).**

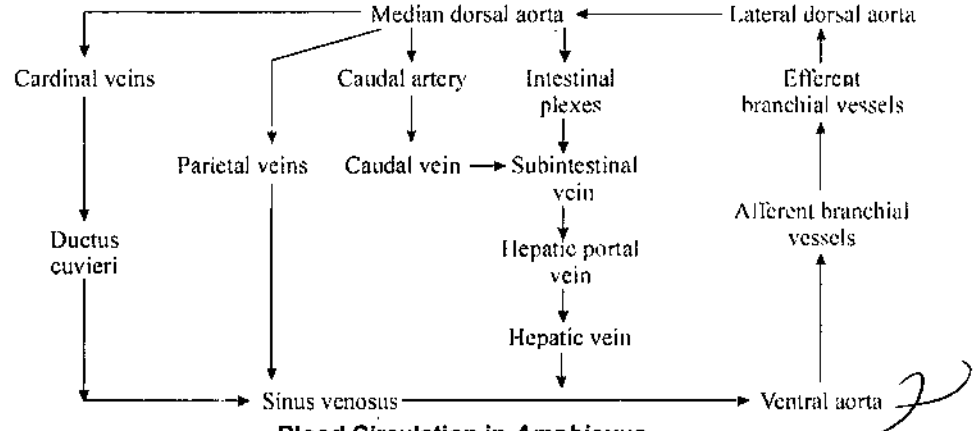
Both these lateral aortae behind the pharynx unite to form a single **median dorsal aorta** that runs posteriorly above the intestine and enters the tail as **caudal artery**. Blood flows backward in the lateral dorsal aortae and median dorsal aorta. Branches from these vessels enter into myocoel, lymph space between myotomes and body wall. Median dorsal aorta also gives off several **intestinal arteries** in the wall of intestine where they form **plexus** (capillary network).

**Sub-intestinal vein.** It runs below the intestine in the form of a plexus. It collects blood from the tail region through **mid-ventral caudal vein** and from intestine through **lateral intestinal veins.** Blood flows in it anteriorly.

**Hepatic portal system.** Sub-intestinal vein runs anteriorly as **hepatic portal vein.** It runs ventrally along the midgut diverticulum into which it breaks up in a capillary network. Blood from midgut diverticulum is collected by **hepatic vein** that runs along its dorsal side and anteriorly joins with the **sinus venosus.**

**Cardinal veins.** Blood from ventro-lateral regions of the body is collected on either side by an **anterior** and a **posterior cardinal vein.** Both these unite behind the pharynx forming a **common cardinal vein** or **ductus Cuveri.** Both these run down through atrium and join the sinus venosus..

**Parietal veins** (paired) collect blood from the dorsal body wall and run above the intestine and then run ventrally to join the sinus venosus.




**Blood Circulation in *Amphioxus*.**

## Lymphatic system

Lymphatic spaces (sinuses) are present inside fins and metapleural folds. These are filled with colourless blood having no leucocytes. Lymph is not found in *Amphioxus*.

## Excretory Organs

In *Amphioxus*, the excretory organs are **protonehridia,** which are ectodermal in origin. (In vertebrates the kidneys are mesodermal in origin).

**Protonephridia.** These are simple, closed, ciliated sac-like thin-walled tubules. There are 90 to 100 pairs of nephridia which are segmentally present on dorso-lateral

pharyngeal wall. Above each gill slit, on both sides are present one **nephridium.** Each nephridium is a small bent tube with horizontal and vertical limbs. Horizontal limb lies over the secondary gill bar in the dorsal coelomic canal and opens by a ciliated **nephridopore** in the atrial cavity. Vertical limb runs parallel to the primary gill bar within its coelom and terminate blindly. The anterior dorsal side of the nephridial tube possesses numerous short branches, each

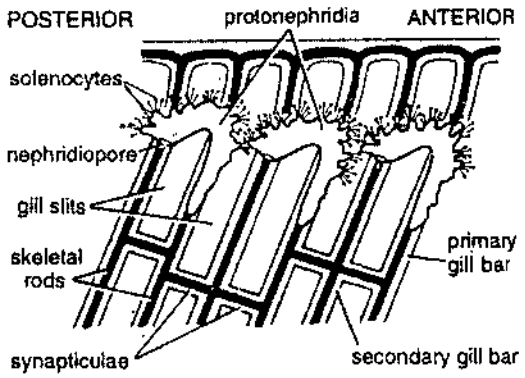



**Fig. 15. *Amphioxus.* Position of nephridia in pharynx.**

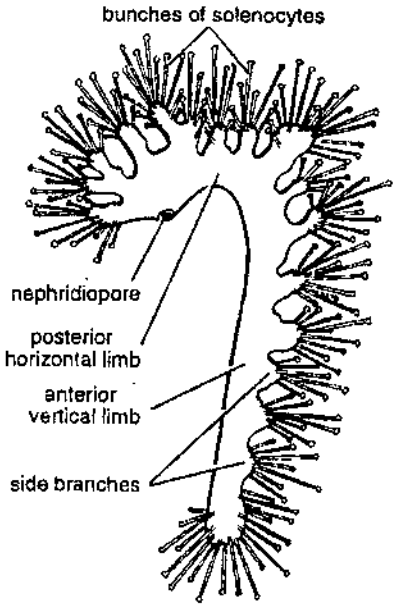



**Fig. 16. *Amphioxus.* A protonephridium and solenocytes.**

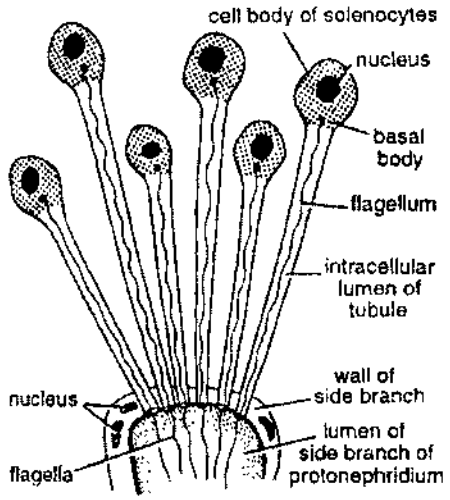



**Fig. 17. *Amphioxus.* Enlarged solenocytes**

of which receives a tuft of **flame cells** or **solenocytes.** A single nephridium has about 500 solenocytes. Tuft of solenocytes project into the dorsal coelomic canal bathed in coelomic fluid. They are well supplied with blood capillaries of afferent branchial vessels.

**Solenocyte.** Each solenocyte is 50 μm long and consists of a tiny rounded cell with a large nucleus and an intra-cellular long hollow tubule, opening into the side branch of the nephridial tubule. In the flame cell, is present a long vibratile flagellum arising from the basal body in the cell. It extends through the tubule and projects freely into the cavity of nephridium. Flame cells are infact modified coelomic epithelial cells and are quite similar to podocytes lining the renal capsule of vertebrates. Therefore they are also called **cryptopodocytes.** Flagella serve to drive the fluid into the body of nephridium.

**Hatschek's nephridium.** It is a large nephridium, which lies on the roof of the oral hood, near the left dorsal blood vessel. Its structure is similar to that of paired nephridia. Anteriorly it ends blindly near the Hatschek's pit and posteriorly it opens into the prebranchial sac of pharynx.

**Nerve Cord.** It lies dorsally just above the notochord and is hollow. Its anterior end terminates in the rostrum behind the anterior end of notochord. Its anterior end is slightly enlarged to form the **cerebral vesicle** (brain). Its posterior part gradually tapers and ends before the posterior end of notochord. Its narrow central canal, the **neurocoel** is filled with **cerebro-spinal fluid.** It dilates within cerebral vesicle and forms its ventricle. Its roof gives off a pouch-like blind dorsal diverticulum that extends

posteriorly for a short distance. **Cerebral vesicle** contains a pigment spot in its anterior wall and an infundibular organ over its floor.

**Pigment spot** is supposed to protect the ocelli from frontal stimulation by light and supposed to act as **thermoreceptor.**

**Infundibular organ** contains a pach of tall columnar ciliated epithelial cells. Its function is not known

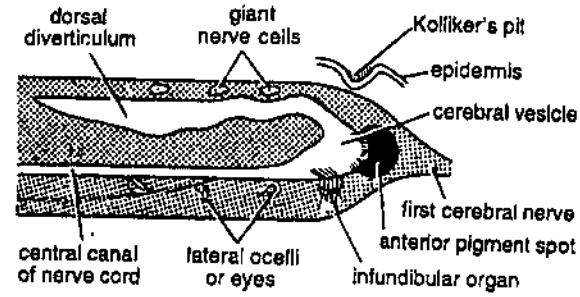



**Fig. 18. *Amphioxus.* Anterior part of nerve cord in V.L.S.**

Nerve cord gives off paired nerves, two pairs arise from the cerebral vesicle (**cerebral nerves**) and nerves arising behind the cerebral vesicle are **spinal nerves,** one pair in each segment. Each pair of spinal nerves has separate dorsal and ventral roots, which do not unite with each other, unlike vertebrates.

**Sense organs** are eye spots or **ocelli,** pigment spot, infundibular organ, Kollicker's pit, Hatschek's groove, sensory cells and papillae and free nerve endings

**Eye spots** are distributed on the ventro-lateral sides of nerve cord. These are light sensitive organs (**photoreceptors**).

**Pigment spot** present on the anterior wall of cerebral vesicle.

**Infundibular organ** lies at the floor of cerebral vesicle.

**Kollicker's pit** is a depression on the roof in the anterior part of cerebral vesicle.

**Hatschek's groove** is present in the roof of oral hood.

**Sensory cells** are found scattered all over the epidermis especially on dorsal side, over oral cirri and velar tentacles.

### Reproductive organs

Male and female animals are separate. Sexual dimorphism is not found.

**Gonads.** There are about 27 pairs of gonads, which are matamerically arranged in two rows, *i.e.,* one pair in each segment from 25 to 51. Gonads are present ventro-laterally beneath the myotomes from middle of pharyngeal region to the atriopore. Each gonad is a hollow sac slightly bulging into the atrial cavity. Gonoducts are absent.

## • 5.5. INTER-RELATIONSHIP OF PROTOCHORDATES

The diverse morphological features present in protochordata (Hemichordata, Urochordata and Cephalochordata) at first cast doubtfull relationships among these three subphyla. However, resemblance like filter feeding mode, notochord, gill stlits and some embryological features in these above phyla, bring them very near to each other. The lower chordata, based on the location of the notochord, is divided into three subphyla.

1. **Hemichordata :** Notochord occurs in the anterior region of the body.

2. **Urochordata :** Notochord is restricted only to the tail in the larval stage and is absent in adults.

3. **Cephalochordata :** Notochord extends in the entire length of the body.

### Resemblances on the basis of notochord

The notochord of hemichordates is not structurally like that of the notochord of urochordates and cephalochordates, since it is a hollow structure arises from the roof of the buccal tube and also lacks the notochordal sheath. While the notochord of urochordates and cephalochordates is solid, composed of tall vacuollated cells and enveloped by notochordal sheath. Hence the notochord of hemichordates (**Bateson** 1885) is actually a preoral extension of the buccal tube (**Silen**, 1950 and **Hyman**).

Developmentally also, it is different from the notochord of urochordates and cephalochordates, in which it arises from the roof of the archentron.

The function of the notochord is to give support to the body. It is lacking in hemichordates.

Hence, on the basis of presence of notochord, the hemichordates are not related to the urochordates and cephalochordates. But the later two groups are closely related to each other.

### Resemblances on the basis of gill slits

All the three subphyla possess the branchial sac. The branchial sac of Hemichordata is more closely resembled to Cephalchordata than Tunicata. Its mode of development is also identical with that of *Amphioxus*.

The gill slits present on the lateral walls of the branchal sac are U-shaped in Hemichordata and straight oval, slit-like in *Amphioxus*. In both, these are dorso-venrally directed. The area between the two limbs of the U-shaped gill slits of Enteropneusta is called the tongue bar and the area between the successive gill slits is called the **interbranchial septum** (gill bar). In Cephalochordata, similar primary and tongue bars are also present.

**Branchial skeleton :** In both, Enteropneusta and Cephalochordata, the branchial bars possess the branchial rods – tongue rods in tongue bars and primary gill rods in primary gill bars. These two types of skeletal rods in both the groups are connected at intervals by few transverse rods or synapticules. Thus, the Entropneusta and Cephalochordata, both are closely resembled with each other in the presence of gill slits and branchial skeleton.

In urochordata also, the branchial sac possesses a large number of gill slits, but these are devoid of branchial skeleton.

### Resemblances on the basis of hypopharyngeal groove

The hypopharyngeal groove (endostyle) is present in the ventral wall of the pharynx of Urochordata and Cephalochordata, but absent in Hemichordata.

### Mode of feeding

Mode of feeding in all the three subphyla is similar (**muco-ciliary**).

### Resemblances on the basis of development

The Enteropneusta resembles with the *Amphioxus* as regards development of the central nervous system; mode of formation of body cavities and the presence of numerous gonads.

The class Pterobranchia of Hemichordata does not resemble in any respect with the *Amphioxus*. But the pterobranchs resemble with the enteropneusts in their body regionation. However, the differences between these two classes of Hemichordata are more striking, in that the pterobranchs have a disproportionate size of the trunk due to large trunk cavity; central nervous system in the skin of the collar and having a pair of gill slits in *Cephalodiscuss*. While *Rhabdopleura* is devoid of gill slits. These features suggest that pterobranchs have diverged away from the ancestors of enteropneusts in remote past.

The relationship between Urochordata and Cephalochordata seems to be more closer than that of between Hemichordata and Cephalochordata. In this relationship the Amphioxus tail is more advanced and already set on the path of vertebrate evolution.

The relationship between Urochordata and *Amphioxus* are rather fundamental : the formation of nervous system and the notochord; presence of endostyle, epipharyngeal groove and peripharyngeal bands and ciliary or filter feeding mode. Ciliary mode of feeding is also found in Enteropenusta, ammocoete larvae of cyclostomes and the larvae of amphibians.

In fact the protochordates are characterized by such a mechanism, which is certainly evolved as a result of their mode of life.

The ascidians were once regarded as degenerated animals due to loss of various morphological features during a transition period of largva to adult. These are now regarded as essentially primitive in habits and the tadpole larvae have evolved as a dispersal phase in the life history of animal. These tadpole larvae could have checked their metamorphosis and continued to grow into a sexually mature swimming chordate from which vertebrates would have been evolved. This is strongly reflected in *Amphioxus*, in which various changes occur in the position of gill slits and other organs during its development. These changes are supposed to b the relics of the changes that might have occurred during metamorphosis in a hypothetical ascidian ancestor.

According to many authorities, the appendicularians are merely primitive tunicates and a degenerate offshoot of vertebrate stalk. According to another view, the appendicularians are neotenic, which have retained a tail, and lost the cloaca and converted the test into an appendicularian house.

*Amphioxus* is considered as a degnerate member of Agnatha, due to the absence of – skull, true brain, heart, auditory and ophthalmic organs, kidneys and pharynx surrounded by atrium. However, *Amphioxus* have acquired certain specialisations such as : multiplication of gill slits and mytomes; asymmetry of various organs; simplification of brain; absence of eyes and optic capsules, exoskeleton and generative ducts. Here *Amphioxus* can also be considered as a specialised vertebrate. In contrast to it, the presence of true nephridia with flame cells give no support to the above hypothesis. The unchanging situation of *Amphioxus* since Silurian times suggests that Amphioxus arose as a result of the practice of neoteny and paedogenesis.

## • SUMMARY

- *Amphioxus* is a small, fish-like animal, laterally compressed and pointed at both ends.
- It possesses three primary chordate characters : notochord, dorsal tubular nerve cord and pharyngeal gill slits.
- *Amphioxus* body is divisible into anterior large trunk and posterior post-anal part is the tail.
- *Amphioxus* has three unpaired fins : dorsal over the trunk, caudal around tail and ventral beneath the trunk from caudal fin upto atriopore.
- Its body wall or skin consists of outer single cells layer epidermis, externally covered by cuticle, cutis beneath epidermis and subcutis.
- Its coelom is enterocoelic and lined with somatic and splanchnic mesoderm layer. Coelom in pharyngeal region is reduced.
- Atrium or atrial cavity surrounds the pharynx and intestine on lateral and ventral sides. Gill slits of pharynx open into the atrium.
- Its alimentary canal is straight extending from mouth upto anus. Mouth lies at the antero-ventral end of oral hood surrounded by a circlet of oral cirri.
- Wheel organ is present in the buccal cavity. It is also called Muller organ.
- Pharynx is a large spacious part of the alimentary canal and bears a large number of gill slits on either lateral walls of pharynx; endostyle in the floor of pharynx.
- Mid-gut proximally bears a midgut diverticulum, which secretes digestive enzymes.
- *Amphioxus* has no heart. No distinction between arteries and veins. Sinus venosus is a thin-walled sac lies below the midgut diverticulum. Ventral aorta lies anterior to sinus venosus and extends mid-ventrally in the wall of pharynx beneath the endostyle.
- Dorsal aortae are two runs on dorso-lateral sides of pharynx and behind pharynx both unite to form the median dorsal aorta. Hepatic portal vein is present ventrally along the midgut diverticulum. Cardinal veins are anterior and posterior cardinal veins and common cardinal vein or ductus cuvieri.
- Excretory organs are paired ectodermal protonephridia like polychaetes. Nerve cord is simple and hollow dorsal to notochord. Its slightly enlarged anterior part is called cerebral vesicle and posterior part is spinal cord.

## • STUDENT ACTIVITY

1. Describe the morphology or external features of *Amphioxus*.

2. Describe the blood vascular system or digestive system of *Amphioxus*.

## • VERY SHORT ANSWER QUESTIONS

1. **Name the fins of *Amphioxus*, wheather they are paired.**
   **Ans.** *Amphioxus* has unpaired fins : dorsal, caudal and ventral fins.
2. **What are myotomes ?**
   **Ans.** These are V-shaped muscle blocks or segments, each muscle block is enclosed in a thin connective tissue layer.
3. **What is the characteristics of epidermis in protochordates ?**
   **Ans.** In protochordates epidermis is single layered (not striated).
4. **Write the name of endoskeleton of *Amphioxus*.**
   **Ans.** Notochord is cylindrical, rod-like structure lies mid-dorsally above the gut.
5. **Write the function of oral or buccal cirri.**
   **Ans.** Oral cirri are present around the mouth arising from the margin of oral hood and form a sieve over mouth to prevent entry of large particles with food current.
6. **What is wheel or Muller organ ?**
   **Ans.** Epithelial lining of oral hood is projected to form 6 to 8 ciliated finger-like structures in the buccal cavity. Their cilia beat to set up a whirling water current to sweep it into mouth.
7. **What is the function of Hatschek's groove and Hatschek's pit ?**
   **Ans.** Both these structures are ciliated and glandular and secrete mucous.
8. **What is enterostome ?**
   **Ans.** Enterostome is an aperture in the velar membrane that leads into pharynx behind.
9. **What is the function of endostyle ?**
   **Ans.** Endostyle is found along the floor of pharynx and it is a shallow groove lined by ciliated and glandular epithelium. It secretes mucous and push the food cord from pharynx into oesophagus.
10. **What is the name of digestive gland in *Amphioxus*.**
    **Ans.** Digestive gland of *Amphioxus* is midgut diverticulum which is also called liver. It secretes amylase, protease and lipase enzymes.
11. **Where gill slits open in *Amphioxus* ?**
    **Ans.** Gill slits open into the atrium that encloses pharynx from its ventro-lateral sides.
12. **Write the name of excretory organs in *Amphioxus*.**

**Ans.** 90 to 100 pairs of protonephridia arranged metamerically on dorso-lateral pharyngeal wall above the gill slits. Hatsck's nephridium in the roof of oral hood.

**13. Where Reissner's fibre is found ?**

**Ans.** Reissner's fibre arises from the inner side of infundibular organ that extends posteriorly inside the neurocoel.

**14. Where Kollicker's pit is found ?**

**Ans.** It is a depression on the roof in the anterior region of cerebral vesicle. It is lined by ciliated ectodermal cells. It is olfactory chaemoreceptor.

**15. What is the number of gonads in *Amphioxus* ?**

**Ans.** 26 to 27 pairs of gonads arranged metamerically in two rows, one pair in each segment from 25 to 51.

UNIT

# 6

# CYCLOSTOMATA : COMPARISON BETWEEN PETROMYZON AND MYXINE

## STRUCTURE

- General characters of Cyclostomata.
- Comparison between *Petromyzon* and *Myxine*.
  - Summary
  - Student Activity
  - Test Yourself

## LEARNING OBJECTIVES

After going through this unit you will learn :

- General characters of cyclostamata, differences between *Petromyzon* and *Myxine* and external features of *Petromyzon*.

Cyclostomata (*Cyclos* : circle +*Stoma* = mouth) is the only Class of the Subphylum **Agnatha,** which includes about 50 species of the living jawless forms.

## • 6.1. GENERAL CHARACTERS OF CYCLOSTOMATA

1. Body is eel-like in form and elongated.

2. Paired fins are absent. Median fins with cartilaginous fin rays. Tail diphycercal, *i.e.,* caudal fin is divided into two equal lobes by the extending vertebral column.

3. Skin is devoid of scales, slimy due to unicellular mucous glands and smooth.

4. Mouth is suctorial, rounded and devoid of functional jaws. Mouth is provided with a few horny teeth and rasping tongue. Rasp away flesh and suck out blood of host fish. Stomach is absent and intestine with a typhlosole.

5. Endoskeleton is cartilaginous. Notochord persistent. neural arches over ntochord imperfect.

6. There is a row of 6 to 14 gill slits on each side of pharynx, which may be exposed in *Petromyzon* and concealed in *Myxine*.

7. Heart two – chambered. No conus and renal portal system. Blood with nuclear erythrocytes and leucocytes. **Poikilothermous** (cold-blooded).

8. A pair of mesonepheric kidneys and ducts leading to urino-genital papilla.

9. Brain is three-lobed with very small cerebellum and sense organs. Cranial nerves 8 to 10 pairs.

10. Nasal opening is single and a median olfactory organ is present. Semicircular canals single or double. Lateral line canal is present.

11. Sexes separate or united. Gonad single without gonoduct.

12.Fertilization is external. Development direct or with a larval stage.

**Ammocoetes** larva of cyclostomes strikingly resembles with *Amphioxus*.

### *Petrmyzon*

#### External Features

*Petromyzon* (lamprey) has an elongated body having three regions : head, trunk and tail, which are not clear. Head and trunk are cylindrical, and the tail is laterally compressed. Body surface is without exoskeleton, slimy due to the secretions from

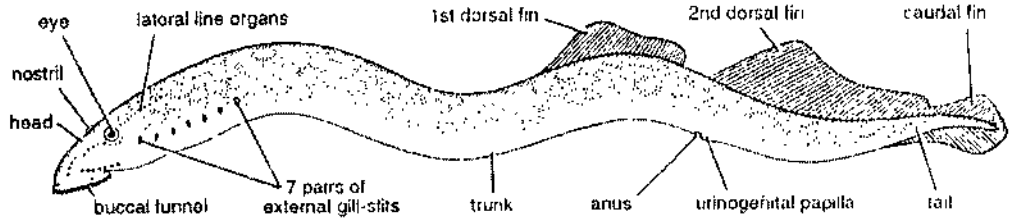



**Fig. 1. Sea lamprey**

epidermal glands *Petromyzon marinus* (sea lamprey) is about one meter long and *Lampetra flaviatilis* (common fresh water lamprey) is about 90 cm long.

**Paired appendages** are absent, but **median fins** are present. Median fins include two unequal **dorsal fins,** first and second located near the posterior end of the body. Other median fin is the **caidal fin** around the tail. Its upper lobe is continuous with the second dorsal fin. The fins are supported by thin cartilaginous rods, the **fin rays.** These rays are usually fused with the membranous sheath that surrounds the **notochord** and neural tube. In *Lampetra planeri* the female have an **anal fin,** but in males, it is reduced to a **copulatory papilla.**

**Buccal funnel.** Head bears a ventrally directed large cup-like **sucker** or **buccal funnel,** which is surrounded by a marginal membrane that is privided with numerous short small projections, called the **oral fimbriae** or **papillae.** These help the fish to attach with a fish. In between the papillae are present the longer **sensory cirri.** Within the buccal funnel are present radiating rows of conical horny epidermal **teeth.** The teeth in the upper and lower sides of the mouth fuse to form large **tooth plates,** called **supra oral** and **infra oral tooth plates** respectively. At the apex of the buccal funnel is present a small circuar **mouth opening. Mouth** is surrounded by concentric rows of **lateral teeth.** Immediately below and behind the mouth projects the **tongue,** which bears large horny teeth.

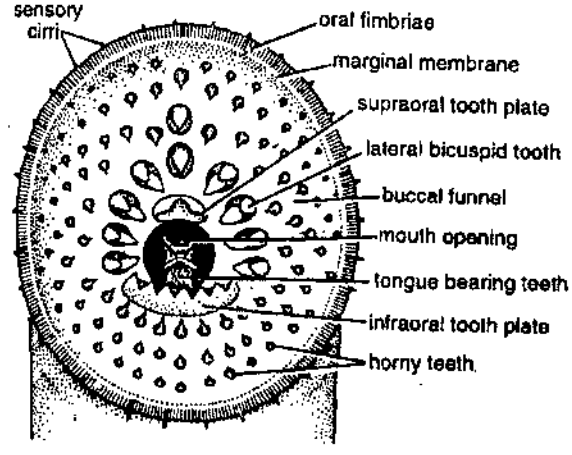



**Fig. 2. *Petromyzon.* Buccal funnel (ventral view)**

On the lateral sides of head are present large **eyes,** which lacks eyelids, but are covered by a transparent area of skin. Over the head, between the eyes is present a single mid-dorsal **nostril** or **nasohypophyseal aperture.** Behind the nostril is present a transparent area of skin that indicates the position of the **pineal organ.** On either lateral sides of the head, behind the eyes, are present **seven external gill slits** arranged in a longitudinal row. On the ventral side, at the junction of trunk and tail is present a depression, the **cloaca.** A **urinogenital papilla** having at its tip a minute urinogenital aperture protrudes through the cloaca. Within cloaca, infront of urinogenital papilla is present the **anus.**

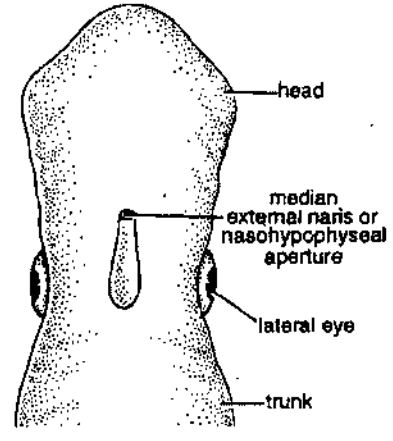



**Fig. 3. *Petromyzon.* Dorsal view of head**

Along each lateral sides of body and below the head are present numerous **sensory pores** of lateral line system.

## Comparison Between *Petromyzon* and *Myxine*

| | Characters | *Petromyzon* (Lampreys) | *Myxine* (Hagfish) |
|---|---|---|---|
| 1. | **Habitat** | Fresh water as well as marine. External parasite. | Marine, burrowing in sand. Internal parasite. |
| 2. | **Body** | Stout, about one metre long. | Feeble, under one metre. |
| 3. | **Fins** | Well developed, dorsal fin notched | Poorly developed, dorsal fin single or absent. |
| 4. | **Skin** | Slimy | Slimy |
| 5. | **Nostril** | Single on head between eyes. | Single and terminal. |
| 6. | **Eyes** | Paired, large and functional. | Paired, degenerated and covered by thick skin. |
| 7. | **Pineal eye** | Present | Absent |
| 8. | **Mouth** | Present at the apex of buccal funnel and ventral in position. Oral ring cartilaginous. | Terminal at the anterior end of indistinct head. Oral ring absent. |
| 9 | Buccal funnel (Sucker) | Large ventrally directed cup-like depression. | Absent. |
| 10. | **Sensory oral tentacles** | Absent | Three or four pairs. |
| 11. | **Tongue** | Tongue lies below and behind the mouth and bears large horny teeth. | Tongue well developed and bears smaller teeth. |
| 12. | **Salivary glands** | Present and secretes an anticoagulant. | Absent. |
| 13. | **Pharynx** | Ends blindly as a respiratory tube with internal and external gill apertures. | Pharynx continued into oesophagus. |
| 14. | **Gill pouches and external gill slits** | 7 Pairs | Six pairs gill pouches and gill slits one pair. |
| 15. | **Intestine** | With a typhlosole (spiral fold). | With longitudinal folds. |
| 16. | **Branchial region and basket** | Well developed and large. | Small and poorly developed. |
| 17. | **Neural arches** | Small rod-like on either side of nerve cord. | Absent. |
| 18. | **Pericardial sac** | Thick walled supported by a cartilaginous plate. | Thin walled not supported by a cartilage. |
| 19. | **Ductus Cuvieri** | Single on right side. | Two one on either side. |
| 20. | **Aortic arches** | Seven pairs supplying blood to 7 pairs of gill pouches. | Six pairs supplying blood to 6 pairs of gill pouches. |
| 21. | **Kidneys** | Mesonephric | Pronehros as well as mesonephros. |
| 22. | **Urinogenital sinus** | Present in which urine is conveyed through ureter. | Absent |
| 23. | **Brain and cranial nerves** | Primitive, ten pairs of cranial nerves. | Primitive, 8 pairs of cranial nerves. |

| | | | |
|---|---|---|---|
| 24. | **Spinal nerves roots** | Dorsal and ventral roots separate. | Dorsal and ventral roots united. |
| 25. | **Nasophypohyseal duct** | Ends blindly | Opens into pharynx. |
| 26. | **Semicircular canals** | Only two | Single |
| 27. | **Sexes** | Separate | United, gonads hermaphroditic. |
| 28. | **Eggs** | Small, naked without shell. Segmentation holoblastic. | Large enclosed in a horny shell. Segmentation meroblastic. |
| 29. | **Development** | Indirect with a ammocoete larva that undergoes metamorphosis. | Direct without larva and metamorphosis. |
| 30. | **Breeding** | Anadromous-ascend fresh-water rivers, streams for spawning. | Spawn on the floor of ocean. |

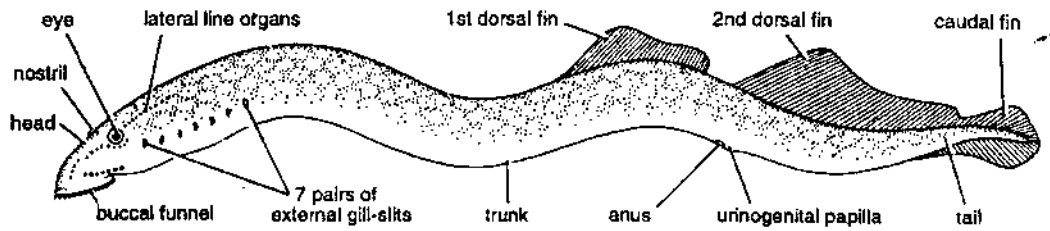



**Fig. 4.** ***Petromyzon***

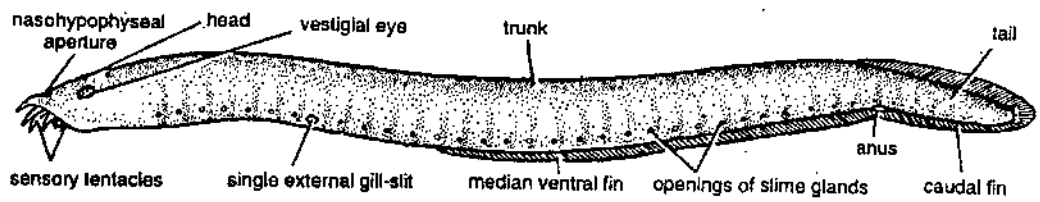



**Fig. 5.** ***Myxine.***

## • STUDENT ACTIVITY

1. Give characters of Cyclostomata.

2. Compare the characters of *Petromyzon* and *Myxine*.

3. Write down the external features of Petromyzon.

UNIT

# 7

# GNATHOSTOMATA : GENERAL CHARACTERS OF PISCES AND OUTLINE CLASSIFICATION

## STRUCTURE

- Meaning of Gnathostomata, and its characteristics.
- Pisces (Superclass) is divided into three classes : Placodermi, Chondrichthyes (cartilaginous fishes) and Osteichthyes (bony fishes). Placodermi includes primitive earliest jawed fishes with bonyhead shield articulated with trunk shield. Example. *Climatius.*
- Cartilaginous fishes possess cartilaginous endoskeleton, whereas bony fishes have bony endoskeleton.
- Gnathostomata (*Gr. Gnathos* = jaw; *Stomata* = mouth). Jawed vertebrates having true jaws and paired fins. It includes all the fishes under Superclass Pisces and all the four-footed vertebrates under Superclass Tetrapoda.
- Pisces are exclusively aquatic, whereas tetrapods are aquatic or terrestrial.
- Pisces have fins in place of limbs, whereas tetrapods have paired pentadactyle limbs.
- Pisces have moist and scaly skin, whereas tetrapods have dry and cornified skin.
- Pisces respire by gills (aquatic respiration), whereas tetrapods respire by lungs (aerial respiration).
- Superclass Pisces (L., piscis = fish) are true jawed vertebrates. It includes all the fishes which are aquatic and have paired fins for swimming and gills for respiration.
- **Scoliodon.** External features, Scales, digestive, respiratory, blood vascular systems and cranial nerves.
  - Summary
  - Student Activity
  - Test Yourself

## LEARNING OBJECTIVES

After going through this unit you will learn :

- General characters of Pisces and its classification. *Scolidon* : External features, placoid scales, digestive system respiratory organs, venous heart, cranial nerves and urinogenital systems.

## • 7.1. GENERAL CHARACTERS OF PISCES

1. Marine or freshwater, cold-blooded and oviparous (egg laying) or ovoviviparous (egg laying as well as give birth to young ones).

2. Body spindle-shaped (boat-shaped) and divisible into head, trunk and tail. Neck is not found, but present in tetrapods.

3. Presence of paired fins (pectoral and pelvic) and median fins (dorsal and caudal) for movement. Fins are supported by true dermal fin rays.

4. Exoskeleton in the form of scales, denticles or bony plates.

5. Endoskeleton cartilaginous or bony. Notochord is replaced by vertebrae.

6. Presence of myotomes (muscles arranged into segments) with separate dorsal and ventral parts.

7. Alimentary canal ends into anus or cloaca.

8. Respiration by gills. Gill slits 5 to 7 pairs which are naked or covered by operculum.

9. Heart two chambered (single auricle and ventricle) and venous type. Sinus venosus, hepatic and renal portal system present. Red blood corpuscles nucleated. Cold blooded or poikilothermous.

10. Kidneys mesonephric (middle part of intermediate mesoderm. posterior to pronephros degeneration develops the mesonephros). Excretion ureotelic, *i.e.*,excertion of urea in the urine.

11. Brain with five parts (forebrain having telencephalon and diencephalons, midbrain and hindbrain having two divisions, *e.g.*, metencephalon and myelencephalon). Crainial nerves 10 pairs. Pre-olfactory, olfactory, optic, oculomotor, trochlear, trigeminal, abducens, facial, auditory, ossopharyngeal and vagus or pneumogastric.

12. Nasal sacs do not open into mouth cavity. Tympanic cavity and ear ossicles are absent. Internal ear has three semicircular canals. Lateral line system is present and includes lateral lines, neuromast organs and pit organs.

13. Sexes separate. Gonads paired and gonoducts open into cloaca.

14. Fertilization internal in elasmoranchs (dogfish) or external in bony fishes. Oviparous (sharks and rays) or ovo-viviparous like dogfish. Foetal membranes absent.

## • 7.2. CLASSIFICATION OF PISCES

**Muller** in 1844 classified the lower chordates (cyclostomes, pisces and amphibians). He divided fishes into six subclasses. Dipnoi, Teleostei, Ganoiae, Elasmobranchi, Marshipobranchi and Leptocardii. He kept cyclostomes in Mashipobranchi and cephalochordates in Leptocardii. **Berg** (1940) recognized seven classes of Pisces : Pterichthys, Coccostei and Acanthodii are extinct fishes, and Elasmobranchii, Holocephali, Dipnoi and Teleostomi are living fishes. Teleostomi includes two subclasses Crossopterygii and Actinopterygii.

**Romer** (1959) included Elasmobranchii and Holocephali into a single class Chondrichthyes which includes all cartilaginous fishes. Whereas Dipnoi and Teleostomi are kept in class Osteichthyes. The later class is divided into two subclasses : Sarcopterygii and Actinopterygii. Superclass Pisces is divided into three classes : Placodermi that includes all the extinct jawed – fishes, chondrichthyes and Osteichthyes.

**Dipnoi** (order) belongs to the subclass **Sarcopterygii** of Osteichthyes and are also called **lung fishes,** because they respire through gills and also by lungs – Order Dipnoi includes two suborders : **Monopneumona** (have single lung), *e.g., Neoceratodus* found in Australia, and **Dipneumona** having two lungs, *e.g., Protopterus* (African) and Australian *Lepidosiren.*

**Class Chondrichthyes** is also called **Elasmobranchii** includes sharks, rays, skates and chimaeras. Pelvic fins bear claspers in male. Tail heterocercal. Skin with placoid seales. Endoskeleton cartilaginous, mouth ventral, teeth are modified placoid scales. Intestine with spiral valve. 5-7 pairs of gills. Gill slits not covered. Kidneys opisthone phric. Cloaca present. It includes two subclasses :

**1. Selachii.** It includes two orders. Squaliformes or Pleurotremata that includes sharks, *e.g.,* dogfishes (*Scoliodon, Chiloscyllium, Mustelus*), spiny dogfish (*Squalus*), Stegostoma, (Zebra shark), hammer – headed *Sphyrna, Rhineodon* (whale shark). These possess 5 to 7 pairs lateral gill slits and spiracles small. Tail heterocercal.

**2. Rajiformes** or **Hypotremata.** Gill slits 5 pairs ventral. Body dorso-ventrally flat. Pectoral fins large, fused to the sides of head and body. Spiracles large. Examples, Skates and rays. *Raja* (skate), *Trygon* (stingray), *Torpedo* (electric ray), *Myliobatis* (eagle ray), *Pristis* (sawfish).

**3. Holocephalii.** Single gill opening on either side covered by operculum, spiracles absent, cloaca and scales are also absent. Single nasal opening. Lateral line system with open groove. Examples *Chimaera* (ratfishes).

### Class. Osteichthyes.

Tail homocercal. Skin with dermal scales; ganoid or cycloid or ctenoid type. Some without scales. Sturgeons have cartilaginous endoskeleton. Claspers absent. Cloaca absent. Gills four pairs covered by operculum. Air or swim bladder present. Aortic arches four pairs. It includes marine as well as fresh water fishes like carp, perch, bass,

trout, catfish, sucker etc. Marine fishes are tarpon, meckerel, tuna, sailfish, barracula, flying fish etc. **A.S. Romer** (1966) has divided the class into two subclasses. Sarcopterygii and Actinopterygii.

**1. Subclass. Sarcopteryggii.** Paired fins lobed or leg-like. Dorsal fins two. Olfactory sacs usually connected to mouth cavity by internal nostrils (choanae). These are called lobed-finned or air breathing fish. It includes two orders.

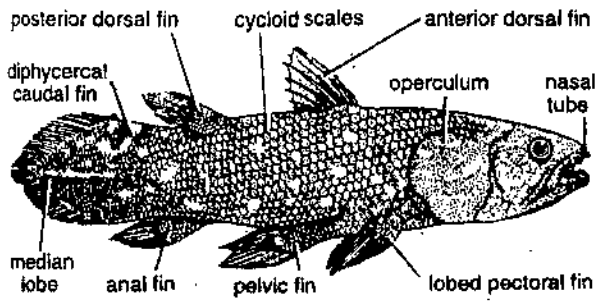



**Fig. 1.** ***Latimeria.***

**Order. 1. Crossopterygii.** Lobate paired fins and caudal fin 3-lobed. Spiracles present. Air bladder vestigial. Example, Extinct fishes. Living genus *Latimeria.*

**Order. 2. Dipnoi.** Median fins continuous and form diphycercal tail. Spiracles absent. Air bladder single or paired and lung like. Examples. Lung fishes. *Neoceratous, Protopterus* and *Lepidosiren.*

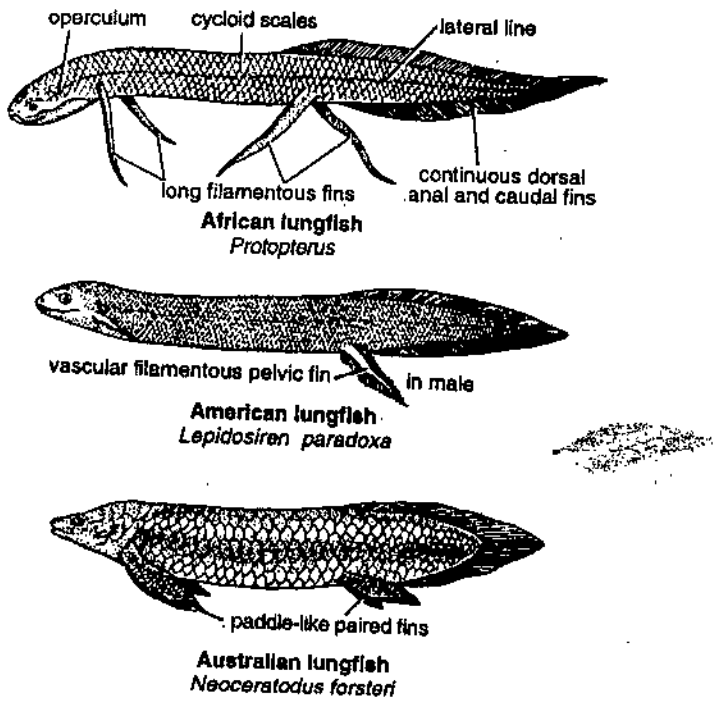



**Fig. 2.** ***Lung fishes.***

**Subclass. Actinopterygii.** Caudal fin without epichordal lobe, which is present in Sarcopterygii. Olfactory sacs not connected to mouth cavity. Ray-finned fishes. It includes three super orders : **Chondrostei, Holostei** and **Teleostei.**

### Three Superorders

| | Chondrostei | Holostei | Teleostei |
|---|---|---|---|
| 1. | Mouth opening large | Mouth opening small. | Mouth opening small and terminal. |
| 2. | Scales usually ganoid. | Scales ganoid or cycloid. | Scales cycloid, ctenoid or absent. |
| 3. | Caudal fin heterocercal. | Caudal fin heterocercal. | Caudal fin mostly homocercal. |
| 4. | Primitive ray-finned fish | Intermediate ray-finned fish. | Modern ray-finned fishes. Swim bladder usually present. |

| | | | |
|---|---|---|---|
| | It includes two orders : | It includes two orders: | It includes 15 orders : |
| | **Order 1. Polypteriformes.** Scales rhomboid ganoid. Pectoral fins lobed. Skeleton ossified. Example, *Polypterus* (Bichir) | **Order 1. Amiiformers.** Thin overlapping cycloid scales. Dorsal fin long. Example, *Amia* (Bowfin). | **Order 1. Clupeifomes.** Pelvic fins abdominal. Air bladder opens into pharynx. Weberian apparatus absent. Example. *Clupea* (Herring), *Salmo* (Salmon), *Sardinops* (sardine), *Esox* (pike), *Notopterus* (chital). |
| | **Order 2. Acipenseriformes.** Scaleless except bony scutes. Skeleton largely cartilaginous. Examples. *Acipenser* (sturgeon), *Polyodon* (paddlefish). | **Order 2. Semionotiformes.** Rhomboid ganoid scales in oblique rows. Example. *Lepidosteus* (Garpike). | **Order 2. Scopeliformes.** Deep sea fishes having phosphorescent organs, Mouth wide, air bladder absent. Example. *Harpodon* (Mumbai duck). |
| | | | **Order 3. Cypriniformes (Ostariophysi).** Air bladder opens into pharynx. Body may be naked and when scales present they are without bony plates. Third and fourth vertebrae are not fused (Cyprini). In siluri second, third, fourth and fifth vertebrae fused. Examples. *Cyprinus* (carpio), *Labeo* (rohu), *Catla, Botia, Carassius*, (Goldfish), *Clarius* (Magur), *Saccobranchus* (Singhi), *Wallago* (Lach), *Mystus* (Tengra), Electric eel (*Electrophorus*). |
| | | | **Order 4. Anguiliformes.** Body long, snake-like. Scales absent or vestigial, Dorsal and anal fins confluent. Air bladder opens into pharynx. Example. *Anguilla* (Fresh-water eel), |
| | | | **Order 5. Beloniformes.** Pectoral fins large and located high on body. Pelvic fins abdominal. Examples. *Exocoetus, Cypselurus* (Flying fish), *Hemirhamphus, Belone* (garfish). |
| | | | **Order 6. Syngnathiformes.** Snout tubular having suctorial mouth. Air bladder closed. Males possess brood pouch. Examples *Hippocampus* (Sea horse), *Syngnathus* (Pipe fish), *Fistularia* (Flute fish). |
| | | | **Order 7. Ophiocephaliformes (Channiformes).** Depressed head having plate-like scales. Air bladder without duct. Accessory respiratory organs present. Example. *Channa* (Snake head fish). |
| | | | **Order 8. Symbranchiformes.** Body eel-like or snake-like. Gill slits join forming transverse ventral slit. Paired fins and air bladder absent. Examples. *Amphipnous, Symbranchus* (Eel). |

| | | | |
|---|---|---|---|
| | | | **Order 9. Mastacembeliformes.** Body eel-like elongated. Dorsal, caudal and anal fins united. Examples. *Mastacembelus, Macrognathus* has separate caudal fin. |
| | | | **Order 10. Perciformes.** Dorsal fins two. Air bladder without duct. Example. *Anabas* (Climbing perch). |
| | | | **Order 11. Scorpaeniformes.** Head and pectoral fins large. Gills covering have spines. Example. *Pterois* (Scorpion fish). |
| | | | **Order 12. Pleuronectiformes.** Body flat lying on one side over bottom. Head asymmetrical, both eyes on dorsal side. Air bladder absent. Examples. *Pleuronectes, Synaptura* (Flat fishes). |
| | | | **Order 13. Echeneiformes.** First dorsal fin modifies into oval adhesive disc or sucker. Air bladder absent. Example. *Echeneis* (Remora)- Suckerfish. |
| | | | **Order 14. Tetraradontiformes.** Sharp beak having strong jaws. Scales often spiny. Some fishes swallow water and inflate. Examples. *Tetrodon* (Globefish), *Ostracion* (Trunk fish). |
| | | | **Order 15. Lophiiformes.** First dorsal flexible spine has a bulb-like tip overhead. It lures prey into wide mouth. Phosphorescent organs present. Examples. *Lophius* and *Antennarius* (Angler fishes). |

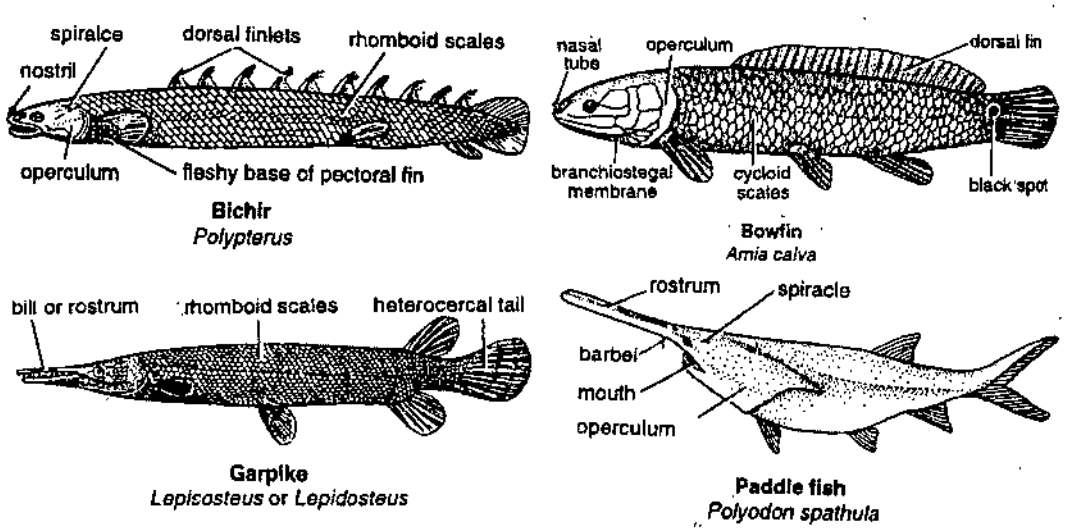
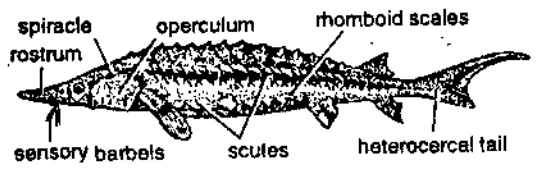
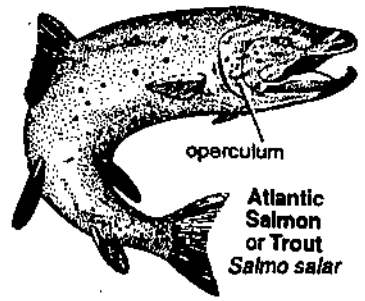


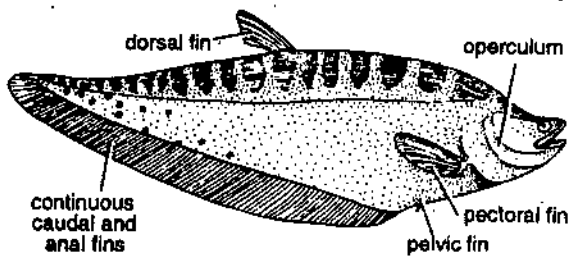

**Fig. 3. Fishes of Subclass Actinopterygii (continued)**




**Sturgeon**
*Acipenser*

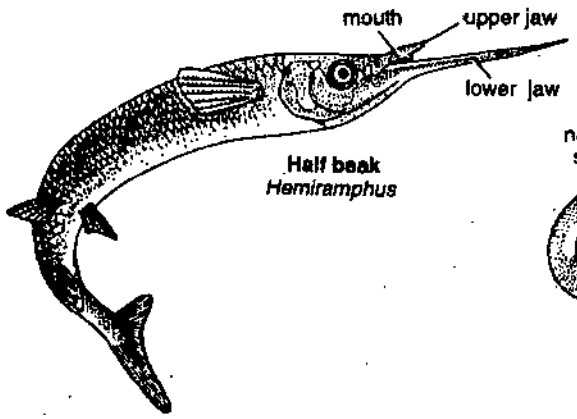



**Atlantic Salmon or Trout**
*Salmo salar*

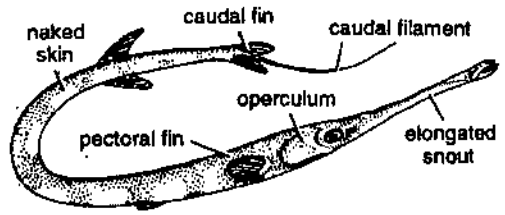



**Catfish or Chital**
*Notopterus chitala*

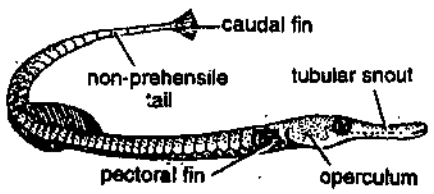

**Freshwater eel**
*Anguilla*



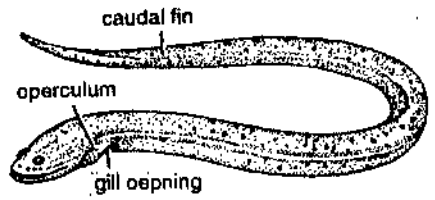

**Half beak**
*Hemiramphus*



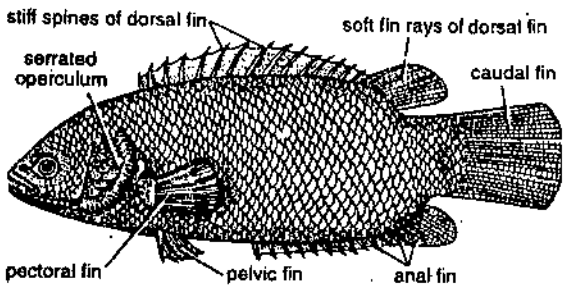

**Flute fish**
*Fistularia*



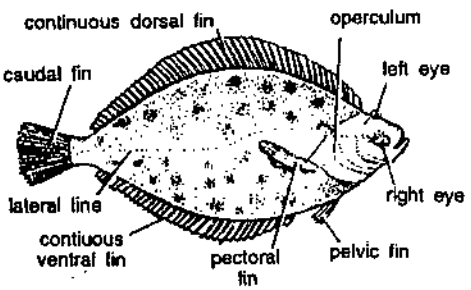

**Pipe fish**
*Syngnathus*



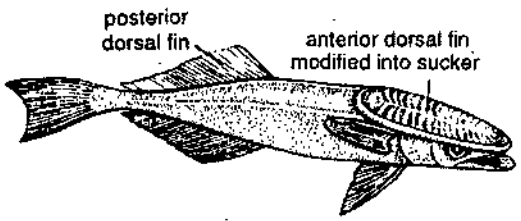

**Cuchia eel**
*Amphipnous cuchia*



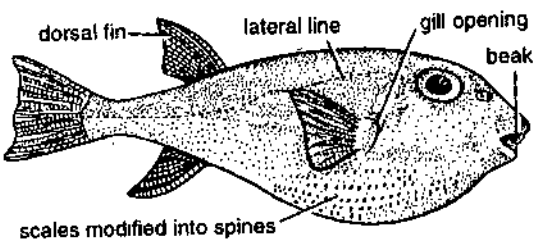

**Climbing perch**
*Anabas tesludineus*



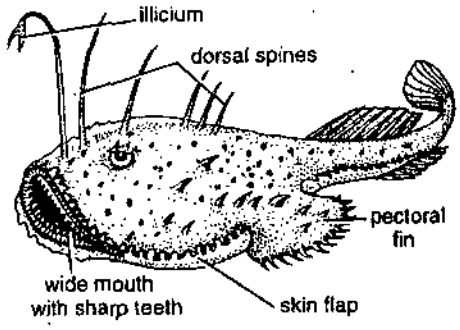

**Flat fish**
*Pleuronectes*




**Sucker fish**
*Echeneis* (= *Remora*)




**Globe fish or Puffer**
*Tetrodon*




**Angler fish**
*Lophius piscatorius*

## • 7.3. *SCOLIODON* (DOGFISH)

### External Features

**Shape and Size.** *Scoliodon* has long, spindle-shaped and laterally compressed body, which tapers at both the ends. It varies in length and the full grown specimen may be as long as two feet. The body is divisible into **head, trunk** and **tail,** however thedemarcation between them is not complete. The fish is dark-grey above and pale-white below.

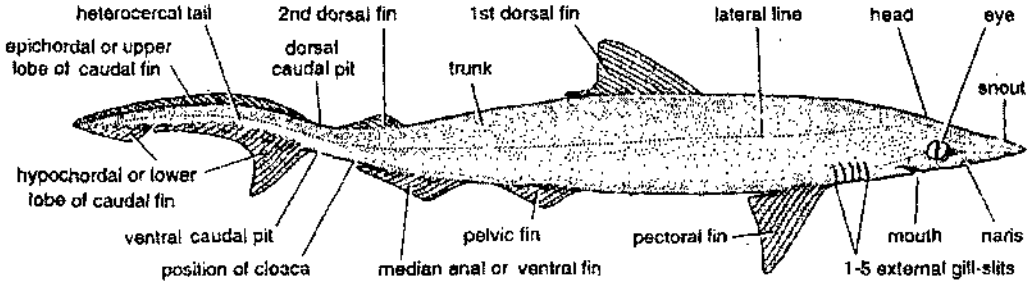



**Fig. 4. *Scoliodon*. Lateral view.**

**Head.** The **head** is dorso-ventrally compressed and is produced infront into a well developed **snout.** The ventral crescentic **mouth** is bounded by upper and lower jaws, bearing backwardly directed teeth. A pair of large circular **eyes** are found at the lateral sides of the head with upper and lower movable eye-lids. The eye is also provided with a movable thin nictitating membrane, which covers and protects the eye in danger. The pupil is narrow and vertical. Behind each eye is present an spiracle opening, which has no connection with the pharynx. It is a non-functional gill slit. Infront to the mouth, on the ventrtral side of the head there are present obliquely placed **nostrils,** one on each side opening into olfactory organs. The internal nostrils are absent. Besides there are five **gill slits** on each side behind the eyes. The gill slits communicate internally with the pharynx via gill pouches containing gills. Besides, head also possesses the openings of **lateral line canal** and scattered groups of **ampullary pores.**

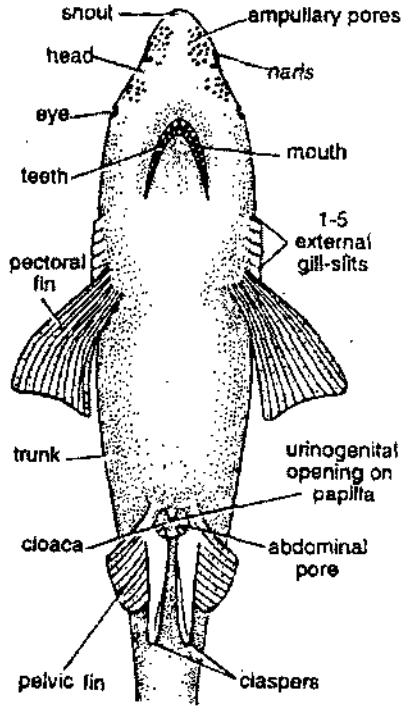



**Fig. 5. *Scoliodon*. Ventral view of the body of male fish**

**Trunk.** The trunk is the largst part of the body, which is thickest in the middle. It is elliptical and gradually tapers behind into the **tail.** The important structures of trunk mainly includes **fins. Fins** may be paired or unpaired. The paired fins include **pectoral**

and **pelvic fins** whereas the unpaired fins comprise **dorsal, ventral** and **caudal fins.** These fins are actually the extensions of the skin, which remain supported by cartilaginous rods and fin rays. The **pectoral fins** are more or less triangular in shape, being attached to the ventro-lateral margins of the body behind the gill slits. The **pelvic fins** are comparatively much smaller and are ventral in position. They lie on each side of the cloacal aperture. The **dorsal fins** are two in number. The first dorsal is roughly triangular and situated dorsally in the middle of the body. The second dorsal is still smaller and is found atttached in the mid way between the first dorsal and the tail. The ventral fin is situated ventrally just behind the **cloacal aperture.**

**Tail.** The tail is long, laterally compressed and is bent upwards. It is surrounded by a caudal fin with a reduced dorsal lobe and well developed ventral lobe. The ventral lobe is again differentiated into short anterior and long posterior parts. Such tail is called **heterocercal.** At the root of the tail, there are shallow pits, both on the dorsal and ventral surfaces. These are called the **caudal pits** and are characteristic of genus *Scoliodon.*

The general surface of the body is rough due to the presence of **placoid scales,** which are arranged in oblique rows. A lateral line runs along each side of the body. The **cloacal aperture** is situated onthe ventral surface surrounded by pelvic fins. The abdominal pores lie on papillae, situated on each side of the cloaca.

### Structure of Placoid Scale of Dogfish

The **placoid scales** or **dermal denticles** or **shagreen** are the scales of *Scoliodon* found embedded in the skin, but their spines are well projected above the body wall and backwardly directed. These are closely set and are arranged in oblique transverse rows. Each placoid scale consists of a **basal plate** and a **tri-radiate spine.**

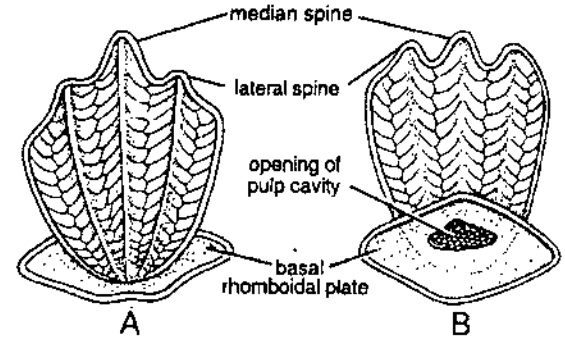



**Fig. 6. Placoid scale of *Scoliodon*. (A) dorsal view, (B) ventral view.**

**Basal plate.** It is rhomboidal in shape formed of hard cement-like substance. It is embedded in the skin and perforated in the centre on the under surface for the passage of blood vessel, nerves and onnective tissue fibres. This opening leads into the cavity of the tri-radiant spine, called the **pulp cavity.** The pulp cavity is filled with mesenchyme cells, blood vessels, nerve fibres and connective tissue fibres forming the pulp.

**Spine.** It is tri-radiate and well-projected above the skin and backwardly directed giving roughness to the body wall. Each spine is composed of **dentine** and externally covered over by hard enamel-like substance, the **vitrodentine** or **fibrodentine.** The dentine is traversed by fine, nearly parallel canals, called the **canaliculi.**

### Development of Placoid Scale

The development of placoid scales is dermal. The msenchyme cells of the dermis gather beneath the epidermis at certain places, which grow and sush the epidermis a little above, forming a small **dorsal papilla.** These mesenchyme cells are, called as **odontoblasts** or **scleroblasts.** Cells of **stratum germinativum** (basal cells of the epidermis) overlying or investing the dermal papilla form the **enamel organ,** which later divides into an **outer** and **inner enamel layer.** The cells of the inner layer of enamel organ are called the **ameloblast,** which form the **vitrodentine** or **enamel.** The mesenchyme cells of the dermal pulp opposite to that of ameloblast secrete the **dentine.** It is pierced by fine canals, called the **canaliculi** into which fine processes of scleroblasts extend. The middle part of the papilla remain soft and vascular forming the **pulp cavity.** The mesenchyme cells at the base of the papilla form the bony **basal plate.** In this way there is formed a pointed, enamel-tipped spine of dentine, which

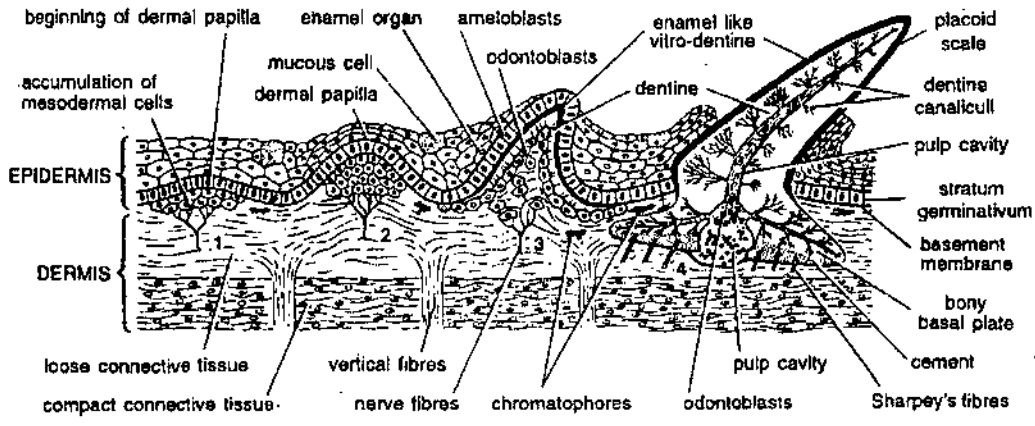



**Fig. 7. *Scolidon*. Development of placoid scale**

later pushes through the epidermis and protrudes backwards on the surface of the body, but it is firmly fixed in the skin by the basal plate. The centre of the under surface of the basal plate is perforated for the entrance of blood vessels, which pass through cellular pulp in the axis of spine. The single spine becomes trident due to subsequent accessory spines developed at their bases or from the surface of the basal plate.

Old placoid scales being continuously replaced by the new ones. Thus, the placoid scale is partly derived from the dermis and partly from the epidermis. The basal plate and the dentine of the spines are derived from the dermis and the enamel is formed by the lower cells of the epidermis.

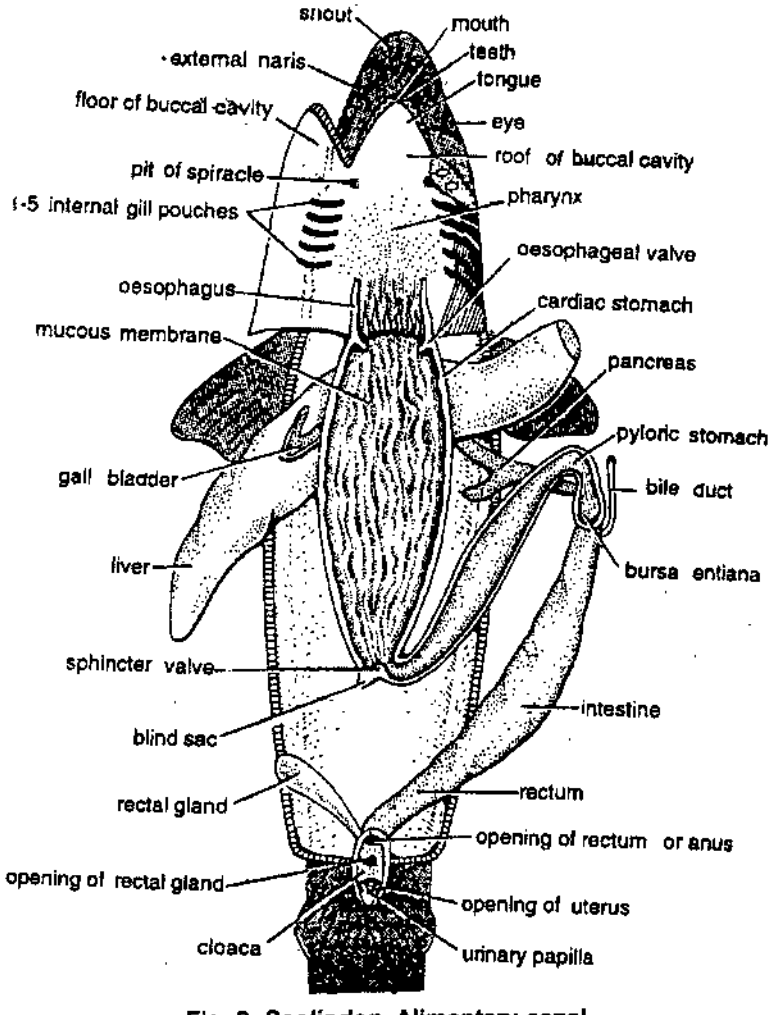



**Fig. 8. *Scoliodon*. Alimentary canal.**

## Digestiv System of Dogfish

### Food

*Scoliodon* is carnivorous and voracious feeder. It feeds on small pelagic animals, molluscs, crustaceans, fishes and marine mammals. It directly swallows its food without mastication. Hence, teeth are merely used to catch the prey and prevent it to escape from the mouth cavity.

### Alimentary Canal

Alimentary canal of *Scoliodon* comprises the mouth, buccal cavity, pharynx oesophagus, stomach, intestine and rectum.

**Mouth. Mouth** is crescentic opening lying on the ventral surface of the head and leads into a spacious **buccal cavity** which is dorso-ventrally compressed. It is lined with a thick mucous membrane which bears teeth in the region of jaws. The **teeth** are oblique, sharp, homodont, and are arranged in several rows at the inner margins of both the jaws. These are not mesticatory in function, but are used for catching and preventing the escape of prey. In the floor of the buccal cavity, the mucous membrane is modified into a **tongue,** which is non-muscular and devoid of glands.

**Pharynx.** Buccal cavity passes into the **pharynx,** which is perforated by large number of **dermal denticles.**

**Oesophagus.** The pharynx is followed by short **oesophagus** leading to stomach.

**Stomach.** The **stomach** is 'J'-shaped and is sharply divided into two parts with a blind sac at the junction. The anterior part is called the **cardiac stomach,** which extends upto the hind end of the body cavity. The posterior part is the **pyloric stomach,** which lies by the side of the cardiac stomach. The cardiac stomach is rich in mucosal longitudinal folds, which are wanting in the pyloric stomach.

**Intestine.** The pyloric stomach passes into the **intestine** and the junction of the two is marked by the thick walled muscular chamber, the **brusa entiana.** The intestine possesses a **scroll valve.** It prevents the rapid flow of food in the region and also increase the absorptive surface of the intestine. The **rectum** is short and possesses a rectal or caecal gland. The rectum finally opens in the cloaca.

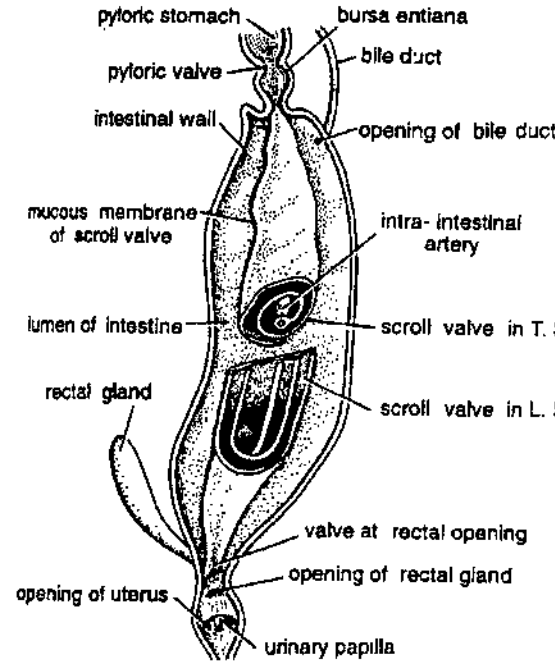



**Fig. 8. Dogfish. Intestine cut open to show scroll valve.**

### Digestige Glands

There are two digestive glands *iz.*, **liver** and **pancreas.**

**1. Liver.** The most of the abdominal cavity is filled with elongated, yellowish liver. It is bilobed and the two lobes are united anteriorly. Liver secretes the **bile,** which is collected first into V-shaped **gall bladder** found embedded in the right lobe of liver and then poured into the intestine through **bile duct.** The bile duct opens just above the commencement of scroll valve.

**2. Pancreas.** The pancreas is also biolobed gland found situated in between the two arms of the stomach, *i.e.*, cardiac and pyloric. The pancreatic duct carry its secretion and opens into the intestine just opposite the opening of the bile ducts.

### Digestion of Food

Dogfish feeds on other small aquatic animals *e.g.*, crabs lobsters, including other fishes. The swallowed prey finally comes in the cardiac stomach, where it is acted upon by the **gastric juice** secreted by the mucosa of the stomach. The gastric juice contains **hydrochloric acid** and **pepsin.** The hydrochloric acid destroys the bacterias coming along with the food, saves the food from contamination, dissolve hard parts of the prey and activate the inactive **pepsinogen** into active **pepsin**, which reacts in acidic medium. Pepsin acts on proteins of the food and convert them into **peptones** and **proteoses**. Pyoric stomach does not secrete the gastric juice so the partly digested food enters the intestine. In the intestine the semidigested food is acted upon by the **pancreatic** and **bile juices.** The bile makes the food alkaline and activates the pancreatic juice. The pancreatic juice contains **trypsin, amylopsin** and **lipase** enzymes.

(i) **Trypsin** digest the remaining part of the proteins.

(ii) **Amylopsin** splits insoluble starch into soluble glucose etc.

(iii) **Lipase** acts upon fat.

The digested food is absorbed by the intestine and the scroll valve surface. The undigested **food** is thrown out through cloaca.

### Respiratory Organs of Dogfish

**Gill-pouch** : In *Scoliodon,* respiratory organs comprise five pairs of branchial pouches, situated on either side of head, behind the eyes. They are separated from one another by mans of fibro-muscular **interbranchial septa.** The branchial pouches open to the exterior by narrow **external branchial apertures,** whereas towards the inner side they open into the pharynx by wide internal opening, **internal branchial apertures.** The external branchial apertures are usually, called the gill or branchial slits. The mucous membrane lining the branchial pouches is thrown into a series of horizontal folds, called **gill** or **branchial lamellae,** which are richly supplied with blood capillaries. Thus, each gill pouch has two sets of gill lamellae, an anterior and a posterior. Each forming a **hemibranch** or **demibranch** (half gill). The two demibranchs with inter branchial septum, branchial arch and branchial rays form a **holobranch** (complete gill).

*Gills. In Scoliodon, there are four holobranchs and one hemibranch. A hotobranch* consists of a branchial arch and two hemibranchs attached on its both sides. Thus there are 9 pairs of hamibranchs. First hemibranch is borne on the hyoid arch and the remaining 8 on both sides of first four branchial arches. The fifth branchial arch is devoid of gills.

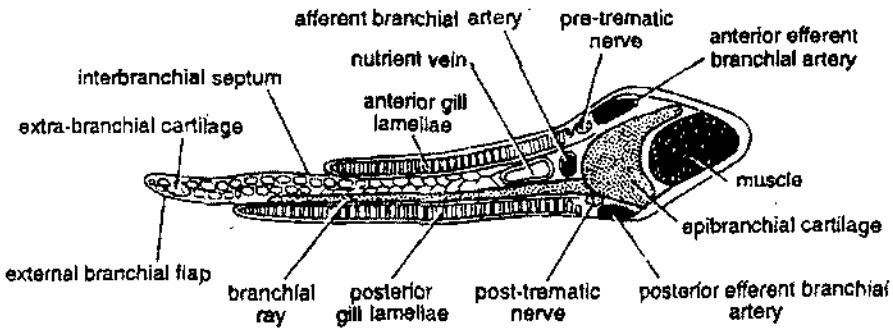



**Fig. 9. *Scoliodon.* Section of a holobranch.**

**Spiracles.** Bsides the gill pouches, there is one pair of **spiracles,** lying between mandibular and hyoid arches. It is in the form of a rudimentary pouch devoid of gill lamellae. It communicates with the pharynx by a narrow opening, but its external opening is closed and not reaches the surface.

### Mechanism of Respiration

Water enters the bucco-pharyngeal cavity through mouth, enters the branchial pouches, bath the gills and finally goes out through the external gill slits. This current

of water is maintained by the movement of the pharyngeal wall. The gills are well supplied with the blood contained in the blood capillaries coming from the **afferent branchial vessels** and leaving the gills through the **efferent branchial vessels.** As the water passes through them, gaseous exchange takes place. The oxygen dissolved in water is diffused into the blood of gills and the carbon dioxide from blood diffuses out in to the water. The whole mechanism can be explained as follows :

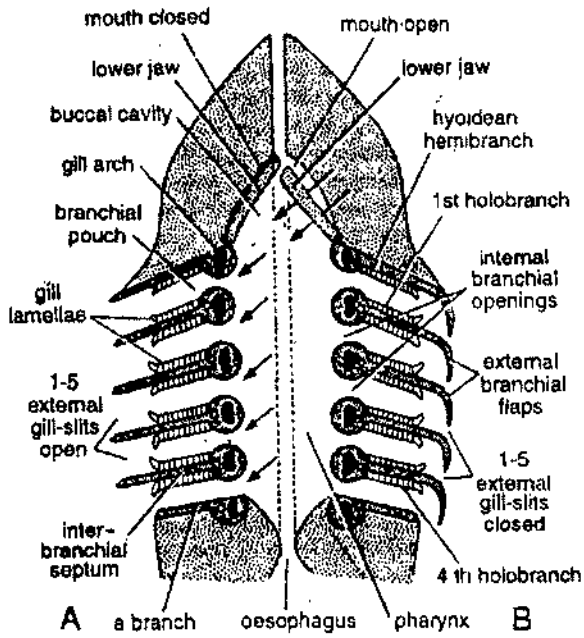



**Fig. 10. *Scoliodon*. Breathing mechanism. A–Expiration B–Inspiration**

**Inspiration** : 1. Due to the contraction of the **hypo-branchial muscles,** the floor of buccal cavity is depressed, thereby the volume of buccal cavity increases. The external gill openings being closed.

2. The mouth opens at the same time and water rushes into the buccal cavity.

3. Pharyngeal cavity enlarges due to the expansion of gill arches. It is followed by the contraction of the **hypo-branchial muscles.** Thus, water enters the pharynx.

**Expiration.** During expiration mouth closes by the contraction of **adductor muscles** and the pharynx contracts thereby the water rushes into the gill pouches and bathes the gillamellae. Gill lamellae are richly supplied with blood capillaries, so gaseous exchange takes place in this region.

### Venous Heart of Dogfish

Heart acts as a force pump for circulatory system. It receives non-aerated blood from different parts of the body and then forces it to various organs. In fishes, the heart contains only impure blood, because it receives the blood from various organs and which is non-aerated, then it forces to gills through afferent branchial vessels for aeration. The aerated blood from the gills is supplied to the various parts of the body. Such hearts which only contain venous blood are calld **"venous hearts"** or **"branchial hearts".**

### Heart of *Scoliodon*

*Scoliodon* possesses a venous heart, which is bent on itself. It lies just posterior to visceral arches enclosed in the pericardial cavity. It is surrounded by pericardium, the **pericardial fluid** which protects the heart. The heart comprises four chambers, *viz.,* the **sinus venosus,** the **atrium,** the **ventricle** and the **conus arteriosus.** The former two are the blood receiving chambers, whereas th lattr two are the blood forwarding chambers.

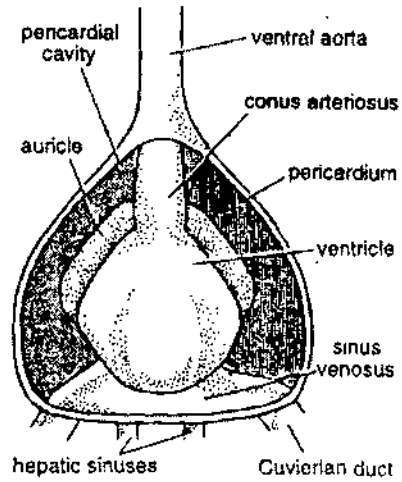



**Fig. 12. *Scoliodon*. Internal structure of the heart**

**Sinus venosus.** The sinus venosus is a triangular, thin, walled tubular chamber, which lies transversely along the base of the pericardial cavity. Into it opens the two pairs of veins, *i.e.,* a pair of lateral **ductus cuvieri** and a pair of posterior **hepatic sinuses** drawing the venous blood of the body. The sinus opens anteriorly into the atrium through **sinuatrial aperture** guarded by a pair of membranous valves.

**Atrium.** The atrium is a large, triangular sac with thick muscular walls. It lies dorsal to ventricle into which it opens through **atrio-ventricular aperture** guarded by a bilabiate valve.

**Ventricle.** The ventricle is a thick-walled muscular chamber. Its inner surface is thrown into numerous muscular strands, the **chordae tndinae,** which give spongy texture to its surface.

**Conus arteriosus.** The ventricle opens anteriorly into muscular tubular conus arteriosus, which extends upto the apex of the pericardium. The conus contains two transerse rows of semilunar valves, the anterior and posterior rows. Each row consists three valves one median dorsal and two ventro-lateral. On either side of median dorsal valve is present a miniature or **accessory valve.** All valves are held in position by muscular ligaments, which arises from the wall of the conus and are inserted over the anterior and porterior ends of valves. The conus leads to the ventral aorta.

### Course of Circulation

These valves which are present at diffrent places in the heart *regulate the flow of* blood only in one direction. The heart is contractile and the wave of contraction starts from the sinus venosus and proceeds onward with the result the blood contained moves onward. Finally when ventricle and conus contract, the blood leaves the heart and rushes to the ventral aorta, which carry it to the gills for aeration.

## Cranial Nerves of Dogfish

In *Scoliodon*, there are II pairs of cranial nerves, which arise from the different regions of the brain. These are as follows :

**0. Terminal** or **preolfactory.** It is also called zero nerves arising from the ventral side of the cerebrum through neuropore and terminate into the olfactory mucous membrane. It bears a ganglion inthe middle.

It is **Sensory.**

**1. Olfactory.** Each olfactory nerve arises from the olfactory epithelium and ends in the olfactory lobe of the brain.

It is somatic **sensory** in nature.

**2. Optic.** Optic nerves arise in the form of band from the optic lobes and then crosses each other beneath the diencephalon and infront of infundibulum forming **optic chaisma**. It terminates in the retina.

It is also **somatic sensory** in nature.

**3. Occulomotor.** It arises from the ventral side of the midbrain and supplies four eye muscles, *i.e.,* inferior oblique, inferior rectus, superior rectus and internal rectus. It is **somatic motor** in nature.

**4. Trochlear.** It arises from the dorsal side of the midbrain and innervates the superior oblique muscles of the eye.

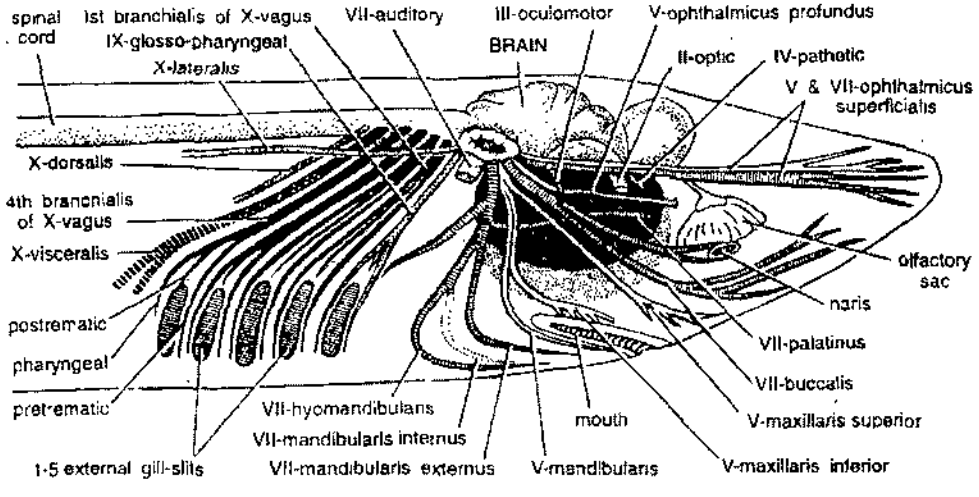



**Fig. 13. *Scaliodon*. Cranial nerves (lateral view).**

It is also **somatic motor** in nature.

**5. Trigeminal.** It emerges from the antero-lateral side of the medula below the corpora restiformia, and divides into 3 branches :

**(i) Ophthalmicus. Ophthalmicus superficials** along with a similar branch of the VII runs forward along the upper border of the orbit and innervates the skin, dorsal side of the head and snout. It is a superficial branch. **Ophthalmicus profundus,** a deep branch also runs forward behind the eye ball giing a **ciliary** branch to the eye and then proceeds onward supplying to the skin of dorsal and lateral sides of the snout.

It is **somatic sensory** in nature.

**(ii) Maxillary.** It is the main branch of trigeminal and came outside the cranium along with VII cranial nerve. It immediately divides into **maxillaris** and **mandibularis** branches.

**Maxillaris** divides into **maxillaris superior,** which runs parallel to the buccalis of VII and inervates the skin of the upper jaw, and **maxillaris inferior** supplies the posterior part of the upper lip.

It is **somatic sensory** in nature.

**6. Abducens.** It arises from the ventral side of the medulla and innerates the external rectus muscles of the eye ball. It is **somatic motor** in nature.

**7. Facialis.** It arises from the sid of the medulla just behind trigeminal and after emerging from the cranium immediately divides into 4 branches :

**(i) Ophthalmicus superficialis** runs along the similar branch of the fifth cranial nerve on the dorsal side of the orbit. It innervates the lateral line organs and the ampullary organs of the snout. It is **somatic sensory** in nature.

**(ii) Buccalis** runs across the floor of the orbit along with maxillaris of Vth and innervates the lateral line organs of the snout. It is **somatic sensory** in nature.

**(iii) Hyomandibularis** runs backward and outward above the hyomandibular cartilage and gives off three branches : **mandibularis externus** supplying the mandibular canal of the lateral line system and it is **somatic sensory; mandibularis internus** supplies mucous membrane of the buccal caity and it is **visceral motor** in nature; and **hyoidean** innervates the muscles of the roof of the buccal caity and pharynx. It is **visceral sensory** in nature.

**(iv) Palatinus** arises along with the hyomandibularis and runs forward along the floor of the orbit, terminating in the roof of the buccal cavity. It gives off a small branch of the roof of the pharynx. It is **visceral sensory** in nature.

**8. Auditory.** It also arises from the sides of the medulla near to the Vth and VIIth cranial nerves. It immediately divides into (a) **vestibular branch** and (b) **Saccular branch** innervating the membranous labyrinth. It is **somatic sensory** in nature.

**9. Glossopharyngeal.** It emerges from the ventro-lateral side of the medulla behind the sixth carnial nerve and runs obliquely backwards along floor of the auditory capsule into the region of first gill slit. Here it divids into **pretrematic** (small) and **post trematic** (large) and a small median **pharyngeal** branch supplying to pharynx. It is **visceral sensory.** Pretrematic is visceral sensory and runs along the anterior border of the first gill cleft while the post trematic is visceral sensory and visceral motor runs along the posterior border of the first gill slit.

**10.1 Vagus** (pneumogastric). It arises from the side of the medulla close to glossopharyngeal. It is a **mixed nerve.** It divides into three branches :

**(i) Lateralis** runs backward along the whole length of th body under the lateral line canal behind the gill slits. It innervates the lateral line organs and is **somatic sensory** in nature.

**(ii) Branchialis** divides into four **branchial nerves** innervating 2nd, 3rd, 4th and 5th gills. Like glossopharygneal, each branchial nerve divides into pre- and post-trematic and pharyngeal branches having the same types of fibres.

**(iii) Visceralis** is visceral sensory and viscral motor running backward into the body cavity and innervates the heart and alimentary canal etc.

## Urinogenital System of Dogfish

In *Scoliodon* the excretory and generative organs are closely associated and thus, they are studied under **urinogenital system.** The system can be described under two heads :

1. Urinary system, and
2. Gnital system.

## Urinary System

The urinary system composed of a pair of **opisthonephric kidneys,** *i.e.,* nephric tubules, which develop from the middle and posterior nephrotomes to form the opisthonephric kidney. The **kidneys** are paired, elongated ribbon like structurs, which extend from the base of the liver to the cloaca on either side of the mid-dorsal line. Each kidney is divisible in two parts, *viz.,* anterior slender portion and posterior thick portion. The anterior portion, sometimes called as **epididymis** or organ of Leydig or **Leydig's gland** and is mainly meant for transporting the sperms. It is non-renal in function and its urinary tubules are extremely thin. The **posterior portion** is the functional kidney and is typical in structure. It includes connective tissue in which are found embedded numerous **urinary tubules.** Each urinary tubule consists of a **peritoneal funnel** opening in coelom, **Bowman's capsule** enclosing the **glomerulus** and **renal tubule.** Renal tubules possess an special urea sbsorbing segment, which reabsorbs urea from glomerular filtrate. The renal tubules open into common collecting tubules, which in the posteror part of kidney open into ureter, while in anterior part of kidney open into **wolffian duct.** The ureters open separately in the **urinogenital sinus.**

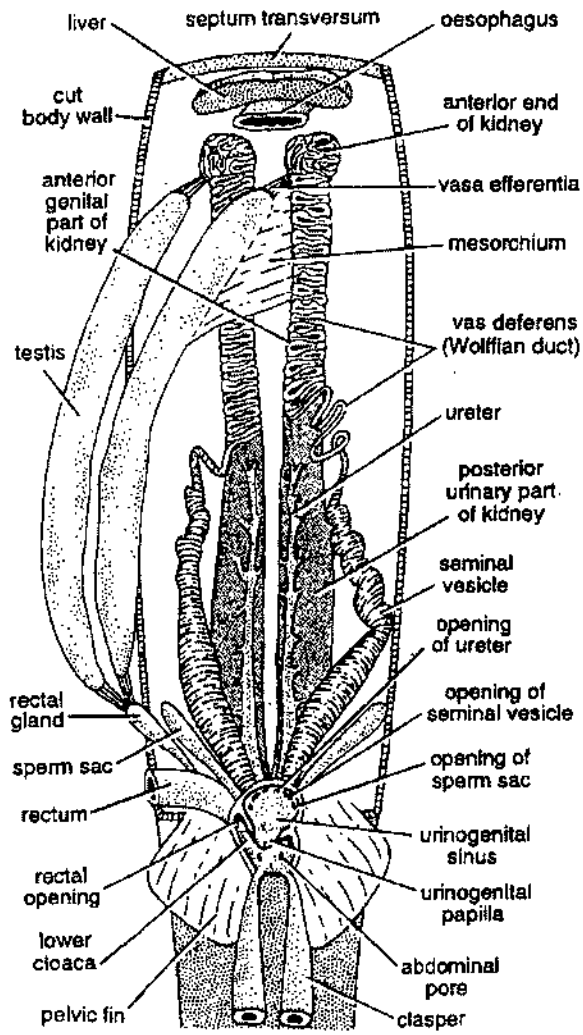



**Fig. 14. *Scoliodon.* Male urinogenital system**

## Genital System of Male

The male genital system comprises :

1. A pair of testes
2. A pair of vasa deferentia
3. A pair of seminal vesicle
4. Urinogenital sinus.
5. Sperm sacs,
6. Claspers.

**1. Testes** are white, elongated paired structures, which extend fromthe base of the liver to the **rectal glands.** The testes are attached with the rectal glands by means of

non-glandular tissue. The testes are suspended in the abdominal cavity with the dorsal body wall by means of **mesorchia.** Each testis is connected anteriorly with the kidney of its own side by means of minute ducts, called **vasa efferentia.**

**2. Vas deferens :** The *vasa efferentia* open into greatly coiled part of the **Wolffian duct** which act as **vas deferens.** The vas deferens runs along the ventral surface of the genital part of the kidney. The vas deferens enlarges behind into a sac-like **seminal vesicle** in which the ripe sperms are stored.

**3. Seminal vesicles.** The **seminal vesicles** of the two sides open posteriorly into a large **urino genital sinus** which opens into the cloaca through an aperture located at the top of the **urinogenital papilla.** A pair of blind **sperm sac** is given out from the ventral wall of the urinogenital sinus.

**4. Claspers.** A pair of **claspers** arise from the cloaca which are grooved towards their inner sides. Their inner opening into the cloaca is called the **apopyle** and their distal opening is called the **hypopyle.** They receive the sperms through apopyle and discharge them into the cloaca of female thrugh hypopyle. At the time of copulation, both come closer and act as penis.

Besides these, a pair of elongated sacs, the **siphons** are present on the ventral side of the body beneath the skin. Siphons extend anteriorly upto the pectoral fin and there they terminate blindly, but posteriorly they communicate with the apopyle of the claspers. Their walls are highly muscular and being filled with sea water. At the time of copulation their walls contract and the sea water is forcibly pushed into the grooves of clasper so that sperms are transferred into the cloaca of female.

## Female Urinogenital system of dogfish (shark)

### Urinary System

In female shark, there is no direct connection between the kidney and the ovaries. The kidneys are narrow, thread-like and rudimentary anteriorly, but thick and functional posteriorly. The **Wolffian ducts** are absent. The **ureters** only carry the urinary secretion and join before opening into the urinary sinus. Urinary sinus opens behind into the cloaca through an aperture found at the tip of the **urinary papilla.**

### Genital Organs

The female genital organs of shark are : (1) a pair of ovaries, (2) a pair of oviducts, (3) vagina.

**Ovaries.** There are a pair of **ovaries** situated one on either side of the vertebral column behind the liver. They are suspended into the abdominal cavity by a fold of peritoneum, the **mesovarium.** The size of the ovaries differ according to the season and age. During breeding season they enlarge very much. A long tubular strand of non-glandular tissue, called the **epigonal organ** connects each ovary with the **rctal gland.**

**Oviducts. Oviducts** are paired and independent ducts, which extend from **septum transversum** (found at the

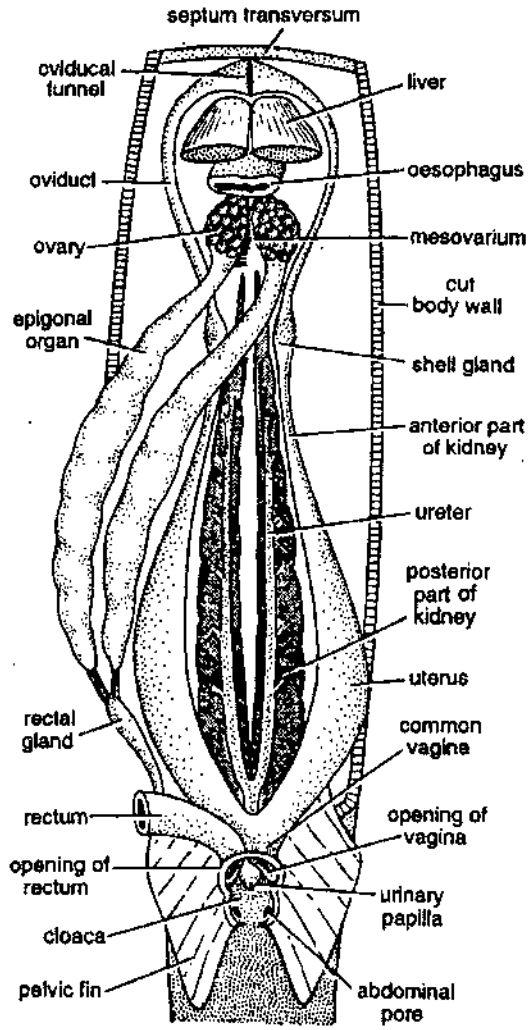



**Fig. 15.** ***Scoliodon.*** **Urinogenital system of female**

base of the liver separating the abdominal caity from the pericardial cavity) to the cloaca. At the anterior end, each oviduct enlarges to form **oviducal funnel,** which lie close to each other in the middorsal line infront of ovaries. Behind the ovaries, each oviduct dilates to form **shell gland,** probably of no significance. Further behind, the oviducts enlarge as **uteri,** where embryos develop. The uteri unite to form a **vagina,** which opens into the **cloaca** by single large median aperture.

The shark (*Scoliodon*) is **viviparous.**

## • STUDENT ACTIVITY

1. Give general characters of the Pisces and Classification of Chondrichthyes.

2. Write down the classification of Osteichthyes.

3. Describe the digestive system of *Scoliodon.*

4. Describe the structrue of gill and mode of respiration in *Scoliodon.*

5. Write down the names of cranial nerves, their origin and nature of *Scoliodon.*

## • VERY SHORT ANSWER QUESTIONS

1. **Give the names of fishes of Dipnoi.**
   **Ans.** *Neoceratodus, Protopterus* and *Lepidosiren.*
2. **In which class sharks, rays, skates and chimaeras are included ?**
   **Ans.** These fishes are kept in class Chondrichthyes.
3. **In which group cartilaginous endoskleton is found ?**
   **Ans.** Cartilaginous endoskeleton is found in fishes belonging to Chondrichthyes.
4. **Give the position of Chimaera in Super class Pisces.**
   **Ans.** *Chimaeras* are kept in Chondrichthyes (Elasmobranchii).
5. **Write the name of living fish of the order Crossopterygii.**
   **Ans.** *Latimeria* is the only living fish of the order Crossopterygii.
6. **What are the two classes of super class Pisces ?**
   **Ans.** Superclass Pisces includes Chondrichthyes and Osteichthyes.
7. **Write down the name of fish belonging to the subclass Holocephalii.**
   **Ans.** *Chimaera* (rat fishes) is included in Holocephalii
8. **Write down the name of fishes in which gill slits are ventral.**
   **Ans.** Skates and rays (*Raja, Trygon, Torpedo, Pristis*) possess the ventral gills.
9. **Write down the zoological names of porcupine and globe fish.**
   **Ans.** *Diodon* is the porcupine fish and *Tetrodon* is the globe fish.
10. **Write down the zoological name of scorpion fish.**
    **Ans.** *Pterois* is the scorpion fish.

11. **In which fish first dorsal fin is modified into sucker ?**
**Ans.** In *Echeneis* first dorsal fin is modified into flat, oval sucker.
12. **In which fish both the eyes are located on one side (dorsal) of head ?**
**Ans.** flat fishes *Pleuronectes* and *Synaptura* have both the eyes on dorsal side of head.
13. **What type of scales are found in *Scoliodon* ?**
**Ans.** Placoid scales.
15. **What is the function of seroll valve in *Scoliodon* ?**
**Ans.** Scroll valve in the intestine increases the absorptive surface of the intestine.
16. **What is a holobranch ?**
**Ans.** Complete set of gills on both sides of gill arch is called holobranch.
17. **Why *Scoliodon* heart is called venous heart ?**
**Ans.** *Scoliodon* heart receives only venous blood from the entire body which is pumped into gills for aeration, hence venous heart is found in cyclostomes and in other fishes also.
18. **How much chambers are found in the heart of dogfish ?**
**Ans.** Two chambers, one auricle and a ventricle.
19. **How much cranial nerves are found in dogfish ?**
**Ans.** 10 pairs of cranial nerves and a pair of terminal nerves called "O".
20. **What are claspers ?**
**Ans.** In male dogfish, medial portions of pelvic fins are modified into claspers for transfer of sperms during copulation.
21. **What is the type of Kidneys are found in dogfish ?**
**Ans.** Flat, ribbon-like mesonephric kidneys.

# UNIT 8

# AMPHIBIA

## STRUCTURE

- General characters of Amphibia.
- Classification of Amphibia.
- Axolotl larva.
- Paedogenesis in Axolotl.
- Parental care in Amphibia.
  - Summary
  - Student Activity
  - Test Yourself

## LEARNING OBJECTIVES

After going through this unit you will learn :
- Classification of Amphibia, Axolotl larva,
- Paedogenesis in Axolotl, Parental Care in Amphbia

Amphibians are transition forms of chordates which changed their mode of life, from aquatic to terrestrial. But all are not terrestrial, some forms are aquatic and some inhabit land environment. The name amphibian indicates double mode of life, *i.e.*, aquatic and terrestrial. Amphibia, Gr. *Amphi* = double + *bios* = life.

## • 8.1. GENERAL CHARACTERS OF AMPHIBIA

1. Amphibians are aquatic or freshwater aquatic or aerial breathing forms. These are cold-blooded. Carnivorous and oviparous tetrapod vertebrates.

2. Body divisible into head and trunk. Neck and tail is not found in all amphibians.

3. They are tetrapods and a few limbless. Toes 4 to 5. Paired fins absent and median fins if present, they are without finrays.

4. Skin moist and glandular and chromatophores (pigment cells) present.

5. Exoskeleton not found but in some hidden dermal scales are present.

6. Endoskeleton largely bony. Skull dicondylic.

7. Alimentary canal ends in a cloaca. Jaws with homodont teeth and tongue protrusible.

8. Respiration by moist skin, mouth cavity and lungs. External gills persist in some aquatic adults and larvae possess external gills.

9. Heart three chambered (2 auricles and one ventricle), sinus venosus also present. Aortic arches usually three pairs. Hepati and renal portal systems present.

10. Kidneys mesonephric, urinary bladder large and urinary ducts open into cloaca. Excretion ureotelic.

11. Cranial nerves 10 pairs and poorly developed brain.

12. Nostrils communicate with buccal cavity, Columella (rod-like ossicle) present. Lateral line system present in larval forms and aquatic adults.

13. Sexes separate, male with copulatory organ and gonoducts open into cloaca. Fertilization usually external. Development indirect with larval form. Segmentation holoblastic and unequal.

## • 8.2. CLASSIFICATION OF AMPHIBIA

Classification of Amphibia is based on G. Kingsley Noble (1924). He classified it in 3 orders of extinct forms and three orders of living forms. Adam Sedgwick placed all extinct forms in a Subclass Steocephalia and all living forms in Subclass Lissamphibia.

### Subclass 1. Stegocephalia (Extinct)

1. Limbs with five toes.
2. Skin with scales and bony plates.
3. Skull with solid bony roof having opening for nostrils and eyes.
4. Permian to Triassic.

It includes three orders :

### Order 1. Labyrinthodontia

1. Stem Amphibia. Freshwater or terrestrial.
2. Teeth large with folded dentine.

Example. *Erops.*

Fig. *Erops.*

Fig. 1. *Eryops*, a fossil labyrinthodont.

### Order 2. Phyllospondyli

1. Salamander-like, Head large and flat.
2. Notochord and spinal cord enveloped in a common cavity.
3. Vertebrae tubular.

Example. *Ichthyostega* (*Branchiosaurs*).

### Order 3. Lepospondyli

1. Eel-like or small salamander like.
2. Vertebrae cylindrical and ribs articulate intervertebrally.
3. Supposed to be ancestor of modern Gymnophiona.

Example. *Diplocaulus.*

### Subclass 2. Lissamphibia (Living amhibians)

Dermal bony skeleton absent. Teeth simple and small.

### Order 1. Gymnophiona (Apoda)

1. Blind, limbless elongated worm-like burrowing forms.
2. Tail absent or short.
3. Dermal scales embedded in skin due to which skin seems to be transversaly wrinkled.
4. Skull small with bony roof.
5. Limbs and girdles absent. Males possess protrusible couplatory organs.

Example. *Ichthyophis, Uraeotyphlus.*

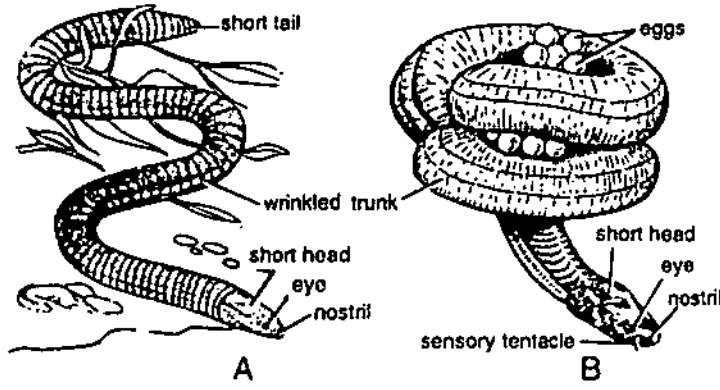



Fig. 1. *Ichthyophis.* A–Male. B–Female with eggs.

### Order 2. Urodela or Caudata

1. Tailed amphibians, with paired weak limbs.
2. Skin scaleless and tympanum absent.
3. Gills permanent or lost in adults.
4. Males have no copulatory organs.
5. Larvae adult like aquatic and have teeth.

It is divisible into five suborders.

### Suborder. 1. Cryptobranchoidea

1. Primitive, permanently aquatic.
2. Adults have no eyelids and gills.
3. Fertilization external.

Examples. *Cryptobranchus, Megalobatrachus*

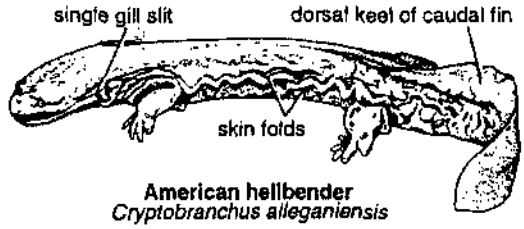



Fig. 2. *Cryptobranchus.*

### Suborder 2. Ambystomatoidea

1. Adults terrestrial and with eyelids.
2. Vertebrae amphicoelous.
3. Fertilization internal.

Example. *Ambystoma.*

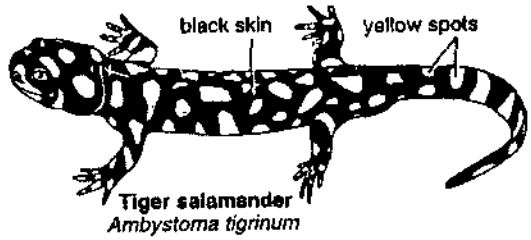



Fig. 3. *Ambystoma.*

### Suborder 3. Salamandroidea

1. Teeth on palate and prevomers.
2. Vertebrae opisthocoelous.
3. Fertilization internal.

Examples. *Triton, Triturus, Salamandra, Amhiuma, Desomognathus, Plethodon.*

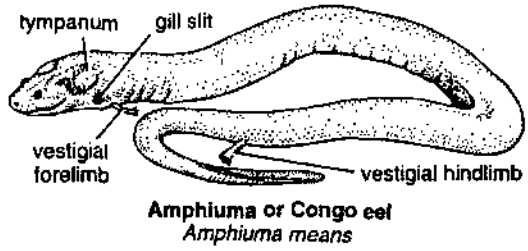



Fig. 4. Amphiunea.

### Suborder 4. Proteidae

1. Aquatic, bottom dwellers and without eyelids.
2. Adults have 3 pairs of external gills and two pairs of gill slits.
3. Skull cartilaginous.

Example. *Proteus, Necturus.*

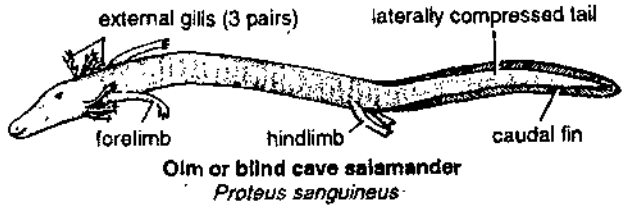



Fig. 5. *Proteus.*

### Suborder 5. Meantes

1. Aquatic, forelimbs small and hindlimbs lacking.
2. External gills 3 pairs.
3. Eyelids absent and jaws with horny covering.

Examples. *Siren, Pseudobranchus.*

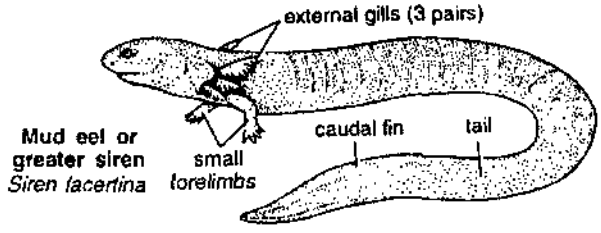



Fig. 6. Siren.

### Order 3. Salientia or Anura

1. Tailless amphibians. Hindlimbs large for leaping and swimming.
2. Adults without gills and gill slits.
3. Eyelids and tympanum present.

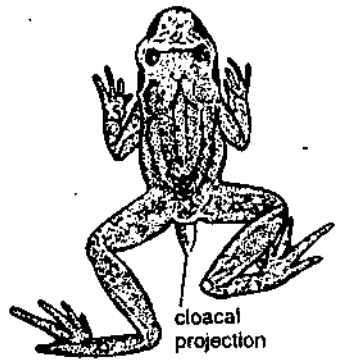
4. Skin scaleless.

5. Ribs absent or reduced. Vertebral column small with 5 to 9 presacral vertebrae and a urostyle.

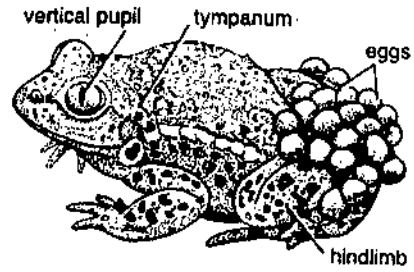
6. Fertilization external.

It is divided into 5 suborders.

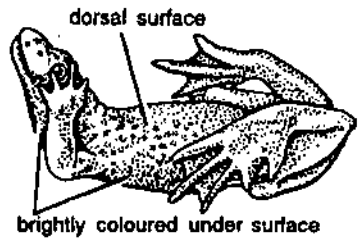
| Amphicoela | Opisthocoela | Anomocoela | Procoela | Diplasiocoela |
|---|---|---|---|---|
| Vertebrae amphicoelous. Presacral 9. | Vertebrae opisthocoelous | Vertebrae procoelous. Upper jaw with teeth. | Vertebrae procoelous. Presacral 5 – 8. | Vertebrae procoelous First 7 and 8th amphicoelous, sacral ($9^{th}$) anteriorly convex and bears 2 condyles posteriorly. |
| Ribs free. | Ribs free. | Ribs absent. | Free ribs absent. | Ribs absent. |
| Ex. *Leopelma, Ascaphus.* | Ex. *Alytes, Pipa, Xenopus, Bombinator.* | Ex. *Pelobates, Scaphiopus.* | Ex. *Bufo, Hyla, Rhinoderma, Gastrotheca, Dendrobates.* | Ex. *Rana, Rhacophorus.* |



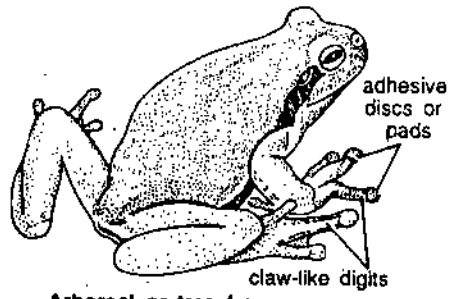

**Male American bell toad**
*Ascaphus truei*



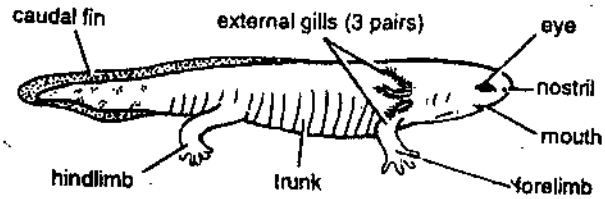

**Mid-wife toad**
*Alytes obstetricans*



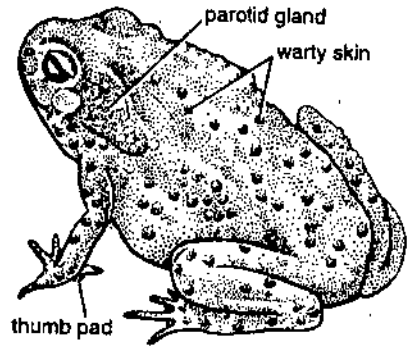

**fire-bellied toad**
*Bombinator igneus*
(lateral view)




**Arboreal or tree frog**
*Hyla arborea*

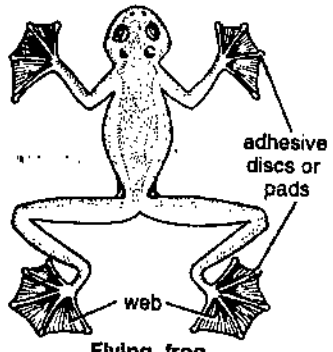



**Axolotl larva of**
*Ambystoma tigrinum*




**Common Indian toad**
*Bufo melanostictus*

### Paedogenesis in Axolotl larva



Flying frog
*Rhacophorus*

**Paedogenesis** (paedomorhosis) is the development of gonads in laval or preadult animal. **Neoteny** is the retention of embryonic or larval features in the adult. Paedogenesis and neoteny are shown by *Ambystoma* or *Amblystoma*. *Ambystoma maxicanum* is found in Xochimilco lake in Mexico and *Ambystoma tigrinum* is found in Colorado, North America. They commonly develop through gilled aquatic larval stages and then undergo metamorphosis to change into adult air-breathing terrestrial forms.

However, under certain conditions, larvae do not metamorphose and retain their gills in aquatic habitat and become sexually mature. This sexually mature larval stage with external gills is called **axolotl.**

The environmental conditions which are responsible for the absence of metamorphosis in these animals are abundance of food, cold temperature or insufficient iodine. When axolotl experimentally treated with thyroxine in which iodine is present, they lose their gills, lungs develop and they become adult air-breathing *Ambystoma.*

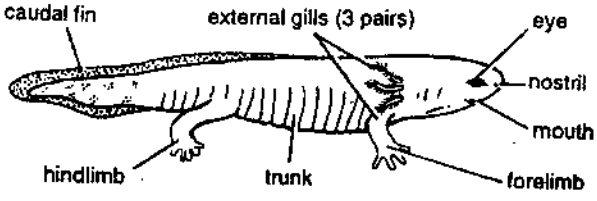


**Fig. 8. Axolotl larva of *Ambystoma tigrinum.***

## • 8.3. PARENTAL CARE IN *AMPHIBIA*

The animals have the tendency to care their eggs or young ones and this brooding tendency or habit of the parents is an instinct or inherent character found almost in all the groups of animal kingdom. This brooding habit or **parental care** in Amphibia seems to have independently developed and it is exhibited by various sub-classes of Amphibia. The following type of parental care is exhibited by Amphibians :

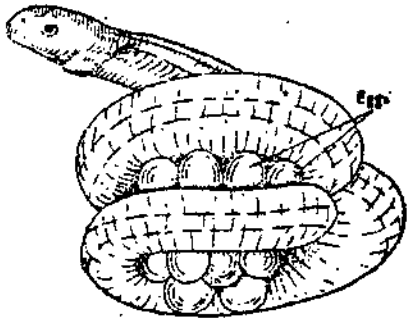


**Fig. 9. *Ichthyophis***

**1. Nursing of the eggs by the parents.** Most amphibians, which lay their eggs in the water abondon them after fertilization, but among those, which deposit large-yolked eggs, the female frequently remains with the eggs. *Ichthyophis glutinosa* lay their eggs in a shallow excavation near water and coils herself around the egg mass to protect them from ground burrowing animals. She takes the eggs into the shallow water shortly before time of hatching. Similarly *Amphiuma* an aquatic form, lay its eggs under logs on land. *Ambystoma opacum* deposits its eggs on land and **curl** around them. In these cases the damp body of the parent assumes the eggs sufficient moisture and their dermal secretions prevent fungus growth over the eggs.

**Fig. 10. *Pipa.***

**Fig. 11. *Alytes male***

**2. Carrying of eggs by the parents :** In certain frogs, the female's body become variously modified to brood the eggs. Such as *Pipa* carry the eggs in indiidual sacs on the back until the young hatch is fully developed; male *Alytes* (mide wife toad) carry the jelly covered eggs around its hind limbs until they hatch; female *Hylodes lineatus* carries the eggs glued by glatinous matter on the back; *Hyla geoldii* also keeps the eggs inside a dorsal pouch; in *Rhacophorous reticulats* about 20 eggs are found attached on the belly of the female.

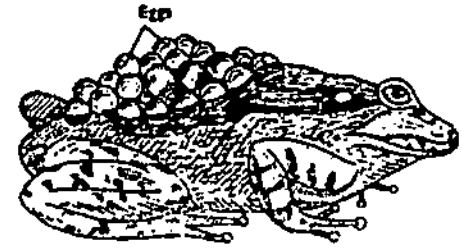



Fig. 12. *Hyla geoldi.*

In some Amphibia, the eggs are nursed in special pouches. Such as, in female *Nototrema*, there is a pouch on the back in which the eggs are kept, until these are hatched as tadpoles or metamorphosed frog; the female *Gastrotheca* (marsupial frogs) possess a single sac on her back to carry th eggs; in male *Rhinoderma drwini* the eggs are kept in the immense vocal sacs extending over the whole ventral surface, where they hatch as tadpole; *Hylambates* keeps the eggs inside the mouth for hatching.

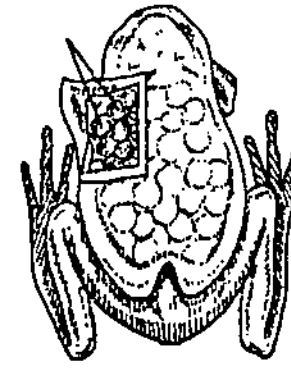


Fig. 13. *Nototrema*

**3. Construction of nests and nurseries.** This is another device for protecting the eggs and tadpole larvae. The females of various frogs and toads construct nest of leaves or other materials in which the eggs are deposited and in which the youngs are developed. Female *Hyla jaber* (Brazilian tree frog) digs a basin like aquarium of some depth inthe shallow pools and smoothens its walls by rubbing its body over it. The parents watch the eggs from a distance hiding in the neighbourhood of nest. *Leptodactylus* make a cup-like cavity under the stones or inside rotten trunks. *Hylodes martinicensis* attaches the foamy egg mass on the under side of leaves, where they undergo development. One species of *Rhacophorus* digs a hole in the flooded rice field just above the water level, where the eggs are deposited, which are covered with foam and froth. Similarly *R. malabaricus* attaches its eggs to the leaves overhanging the water. Male *Hellbender* makes nest on the river bottom guarding the eggs with in the nest until they are hatched.

*Triton, Salamandrella* and newts lay their eggs in nests made of leaves or in gelatinous bags attached to some object below the water level.

In several species, the tadpoles are carried about by the female adhering to her dorsal surface by suckers or by a viscid secretion. *Dendrobates tribittatus, Phyllobates bicolor* transfer their tadpoles from dry pools to those filled with water.

**4. Viviparous amphibians :** Certain species of Amphibia are viviparous and they give birth to the young ones instead of eggs. For example, *Salamandra atra* and *Spelespis fuscus* etc.

Thus, the parental care is an instinct. **Whitman** (1899) beleived that its utility is to give the rest to the parent following oviposition. In case of males, it is merely their tendency to remain near their calling stations.

## • STUDENT ACTIVITY

1. Write down the general characters of class Amphibia.

_____

_____

_____

_____

_____

_____

_____

2. Classify the class Amphibia giving examples of each order and suborder.

3. Discuss parental care in Amphibia.

## • VERY SHORT QUESTIONS

1. **What type of respiration is found in amphibians ?**
   Ans. Some amphibians respire by gills (aquatic respiration) and some respire by lungs.
2. **Write down the type of excretion in amphibians.**
   Ans. Excretion in amphibians is ureotelic.
3. **In which subclass extinct amphibians are placed ?**
   Ans. Extinct amphibians are kept in subclass Stegocephalia.
4. **Caecilians are placed in which order ?**
   Ans. Caecilians are kept in order Gymnophiona (Apoda).
5. **Axolotl belonged to which animal ?**
   Ans. It is neotinous larva of *Ambystoma*.
6. **Which amphibian carry thir eggs on its back ?**
   Ans. *Nototrema* (= *Gastrotheca*) female carry its eggs on her back covered by a skin flap that opens posteriorly infront of cloacal aperture.
7. **Write down the name of limbless amphibians.**
   Ans. *Ichthyophis* and *Uraeotyphlus*.
8. **Write the name of amphibian who retain gills throughout life.**
   Ans. *Necturus, Proteus, Siren.*
9. **Name the amphibian which has very weak limbs.**
   Ans. *Amphiuma.*

UNIT

# 9

# REPTILIA : GENERAL CHARACTERS AND CLASSIFICATION

## STRUCTURE

- General characters of Class Reptilia.
- Classification of Class Reptilia.
- Comparison of Lacertilia and Ophidia.
- Poisonous and Non-poisonous snakes.
  - Summary
  - Student Activity
  - Test Yourself

## LEARNING OBJECTIVES

After going through this unit you will learn :

- Classification of Class Reptillia, Comparison of Lacertilla and Ophidia, Poisonous and Nopoisonous snakes.

## • 9.1. GENERAL CHARACTERS OF REPTILIA

Reptiles are adapted for life in dry places on land. They possess characters found in fish and amphibians on one hand and in birds and mammals on the other hand.

Reptilia (L., repere or reptum = to creep or crawl). Thus, its name shows their mode of locomotion. Study of reptiles is called **Herpetology** (Gr., herpeton = reptiles).

1. Mostly terrestrial, creeping or burrowing, carnivorous, air-breathing, cold-blooded oviparous vertebrates.

2. Body divisible into head, neck, trunk and tail.

3. Two pairs of limbs pentadactyle and digits with horny claws. Snakes and few lizards like *Ophisaurus* (limbless lizard) are limbless.

4. Horny epidermal scales, shields, plates and scutes are their exoskeleton.

5. Skin dry, cornified and have no glands.

6. Alimentary canal ends in a cloaca. Jaws with simple conical teeth. but in turtles (Chelonia) horny beaks are found in place of teeth.

7. Bony endoskeleton. Skull has one occipital condyle (monocondylar). Interclavicle T-shaped.

8. In lizards, snakes and turtles heart 3-chambered, but in crocodiles 4-chambered. Sinus venosus formed by the union of precavals and postcaval. Arches are three. III, IV and V, two aortic or systemic and one pulmonary. Red blood corpuscles nucleated.

9. Respiration by lungs.

10. Kidneys metanephric and excretion uriocotelic (excretory product is uric acid).

11. Brain well developed in comparison to Amphibia and cranial nerves 12 pairs.

12. Absence of lateral line system. Jacobson's organs present in the roof of mouth cavity, *i.e.*, in between roof off mouth cavity and nasal cavities. These organs are absent in adult crocodiles.

13. Sexes separate, male with copulatory organ.

14. Fertilization internal, mostly oviparous, but vipers (pitless and pit vipers are viviparous. Eggs meroblastic covered with leathery shells. Embryonic membranes present during development. Young like adults.

## • 9.2. CLASSIFICATION OF REPTILIA

Class Reptilia is divided into five subclasses on the presence and absence of temporal openings in the skull; Anapsida, Euryapsida, Parapsida, Synapsida and Diapsida.

### Subclass 1. Anapsida

It includes primitive reptiles having skull roof solid, no temporal openings. It includes a single order Chelonia or Testudinata.

### Order 1. Chelonia (Testudinata)

Chelonia (Gr., chelone = turtle : L., testudo = turtle).

1. Short, broad and oval-shaped body.

2. Limbs 2 pairs, clawed and/or webbed, paddle-like in soft-shelled turtle and terrapins.

3. Body enclosed in a strong shell-dorsal carapace and ventral plastron formed of dermal bony plates. Thoracic vertebrae and ribs fused to carapace.

4. Skull anapsid, *i.e.*, without temporal foramen. Nasal opening single and parietal foramen is absent. Quadrate is immovable. Sternum absent.

5. Jaws with horny sheath. Teeth absent.

6. Heart incompletely 4-chambered. Ventricle partly divided.

7. Simple single copulatory organ.

Examples. Marine turtles, freshwater terrapins and terrestrial tortoises. *Chelone, Chrysemys, Testudo, Trionyx, Dermochelys.* **Subclasses** Euryapsida,, Parapsida and Synapsida are extinct.

### Subclass 5. Diapsida

Skull with two temporal openings on either side of skull separated by a bar of postorbital and squamosal bones. It includes three orders : Rhynchocephalia, Squamata and Crocodilia.

### Order 1. Rhynchocephalia

1. Body lizard–like small and elongated.
2. Limbs two pairs pentadactyle, clawed and burrowing.
3. Skin with granular scales and a mid-dorsal row of spines.
3. Skull with two temporal openings on either side of skull (diapsid). Nasal openings separate, parietal foramen with vestigial pineal eye. Quadrate fixed.
4. Vertebrae amphicoelous (biconcave). Abdominal ribs numerous.
5. Teeth acrodont (teeth attached at the summit of the jaw bone).
6. Cloacal aperture transverse (In Rhynchocephalia it is a longitudinal slit–like).
7. Heart incompletely four chambered, *i.e.*, ventricle incompletely divided. Copulatory organ in male absent.

Example. *Sphenodon punctatum* (tuatara) of New Zealand. This is the only living species.

### Order 2. Squamata

1. Body small, elongated or slender, narrow snake-like.

2. Limbs paired pentadactylous, clawed in lizards and absent in few lizards and snakes..

3. Exoskeleton of horny epidermal scales, shields and spines.

4. Skull diapsid and quadrate movable.

5. Procoelous vertebrae (centrum concave anterior and convex posterior) and ribs with single head.

6. Heart incompletely four chambered.

7. Copulatory organ in male eversible and double (hemipenes). Hemipenes are hollow nodule like and eversible present mid-ventrally behind the cloacal aperture at

the base of tail. Order Squamata is divided into two suborders. Lacertilia or Sauaria and Ophidia or Serpentina. Later suborder includes snakes and the first one includes lizards.

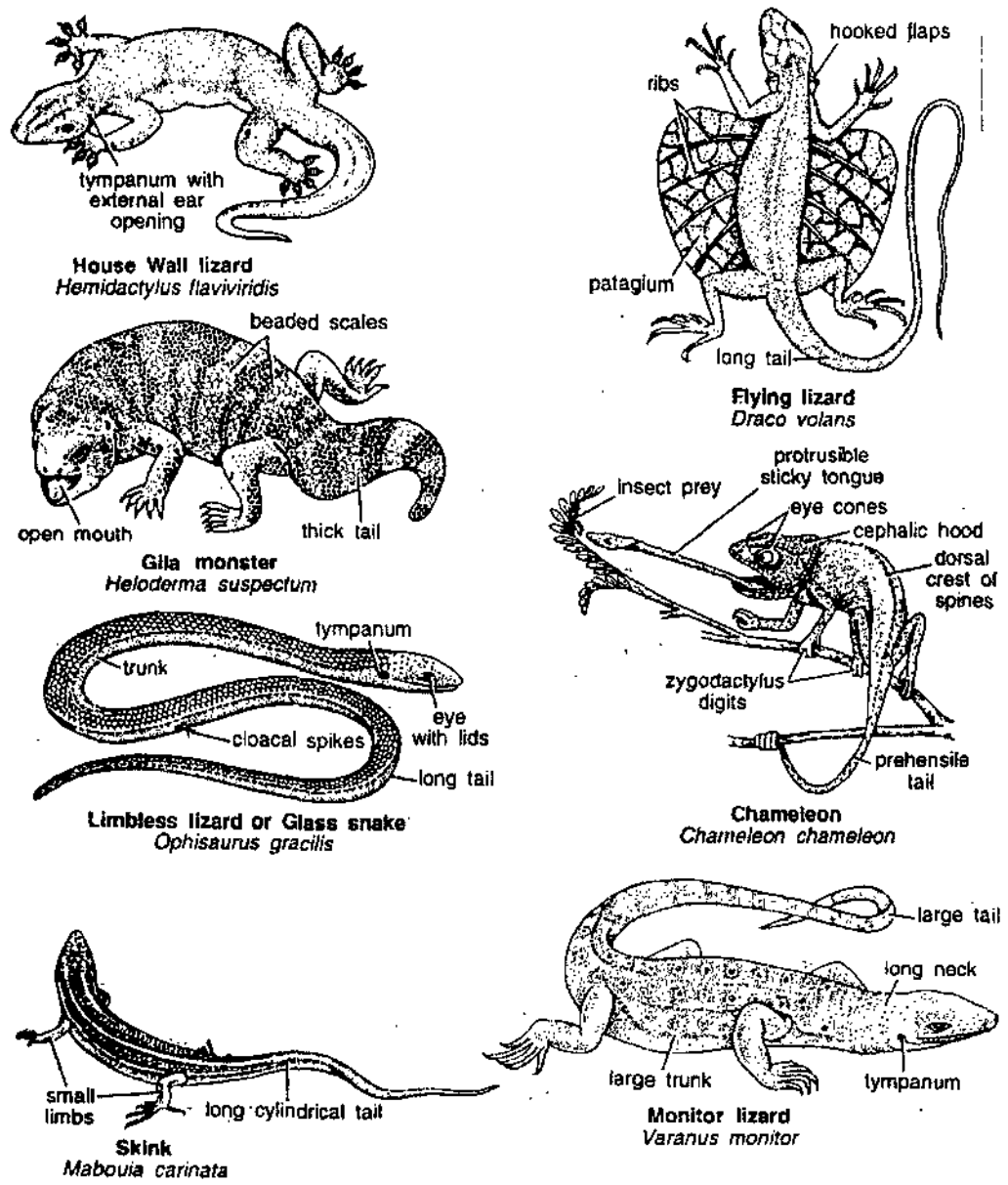



**Fig. 1. Some common lizards.**

| Lacertilia | Ophidia |
|---|---|
| Body elongated. | Body slender and narrow. |
| Paired limbs and girdles well developed. | Limbs and girdles absent. In boa, python etc. hind limbs and pelvic girdle vestigial. |
| Eyelids movable and nictitating membranes present. | Eyelids fixed and nictitating membranes absent. |
| Ear openings and tympanum present. | Ear openings and tympanum absent. |
| Skull : Maxillae, palatines and pterygoids fixed. | These skull bones feebly movable which help in biting mechanism. |
| Both rami of mandible anteriorly united. | Both rami of mandible joined by an elastic ligament which allow them to separate during swallowing of prey. |
| Premaxillae have conical teeth. | Premaxillae toothless. |

| | |
|---|---|
| Sternum, episternum present. | Absent. |
| Jugal present. | Absent. |
| Tongue rarely extensible. | Tongue slender, bifid and extensible. |
| *Both the lungs are equal in size.* | *Left lung small in size.* |
| Cerebral hemispheres short. | Cerebral hemispheres elongated and project between the eyes. |
| Cranial nerves 12 pairs. | Cranial nerves 10 pairs. |
| Examples. *Calotes, Hemidactylus, Uromastix, Varanus, Chamaeleon, Draco, Heloderma*, etc. | Examples. *Typhlops, Python, Boa, Eryx, Naja, Bungarus, Vipera, Hydrophis, Crotalus*, etc. |

### Order 3. Crocodilia

1. Aquatic, large carnivorous reptiles.
2. Body long, cylindrical, depressed and head elongated into flat snout having nostrils at its tip.
3. Tail massive and laterally compressed used for swimming purpose.
4. Limbs short but strong, pentadactyle, clawed and webbed.
5. Skin thick, leathery with horny scutes supported by dermal bony plates.
6. Cloaca is a longitudinal slit. A pair of musk glands are present in the cloaca.
7. Nostrils, eyes and ear openings are placed high on head. At the time of diving nostrils are closed by valves, nictitating membranes are drawn over eyes and ear openings are closed by skin flaps.
8. Teeth thecodent placed in sockets.
9. Lungs enclosed within pleural cavities and are separated from the body cavity by a muscular diaphragm.
10. Heart 4 –chambered –2 auricles and 2 ventricles.
11. In male copulatory organ grooved.
12. Oviparous.

Examples. *Crocodylus porosus* is the largest about 8 to 9 feet long lives in salt water or estuaries. *Crocodylus palustris* (maggar) is a fresh water crocodile, *Gavialis gangeticus* (gharial) live in Gangaes and Brahamputra, *Alligator* found in China and N. America.

### Identification of Poisonous and Non-poisonous Snakes

| Body structures | Characters | Nature : Poisonous or Non-poisonous | Snakes |
|---|---|---|---|
| Tail | Tail laterally compressed, oar-like. | Poisonous | Sea snakes, *Hydrophis*. |
| | Tail cylindrical, tapering. | Poisonous or non-poisonous Study further. | Land snakes |
| Belly scales or ventrals | (a) Belly scales small and continuous with dorsals. | Non-poisonous | |
| | (b) Ventrals do not cover the entire belly, *i.e.*, not fully broad. | Non-poisonous | Pythons |
| | (c) Ventrals broad fully covering the belly. | Examine other characters. | |

| | | | |
|---|---|---|---|
| Head scales, loreal pit and sub-caudals. | (a) Head scales small, triangular head and no loreal pit. **Subcaudals** double in *Vipera russelli* (Russel's viper) and **subcaudals** single in *Echis carinata*, both are pitless viper. | Poisonous. | Pitless viper. Russel's viper. |
| | (b) Head scales small and a loreal pit is present between nostril and eye. | Poisonous | Pit vipers. *Lachesis* found in South India and *Ancistrodon* (Himalayan pit viper). |
| | (c) Head having large shields. No loreal pit. | Examine further. | |
| **Vertebrals, infralabial** and supralabial. | (a) Vertebrals large and hexagonal, fourth infralabial largest. | Poisonous | Krait-*Bungarus*, common krait found in India. |
| | (b) Vertebrals not large, third supralabial touches eye and nostril. | Poisonous | |
| | (i) Neck with hood and spectacle mark. | Poisonous | Cobra-*Naja* found in India, King cobra or hamdadryad- *N. hanah or, N. bungarus* |
| | (ii) Coral spots on belly. Hood absent. | Poisonous | Coral snakes- *Hemibungarus*, *Callophis* are found in India. *Micrurus* found in USA having bands of black, red and yellow colour. |
| | (c) No such above characters | Non-poisonous. *Typhlops*, *Uropeltis*, *Ptyas* (dhaman); *Eryx* (sand boa). | |

Aug 4

## Non-Poisonous snakes

Blind snake (*Typhlops vermicularis*), *Uropeltis grandis* (rough tailed snake), *Ptyas* or *Zamenis* (dhaman or rat snake), *Tropidonotus quincunciatus* (pond snake), Python (*Python molurus*), *Dryophis* (whip snake), *Dendrophis* (tree snake), *Eryx johnii* (sand boa or double-headed snake), etc.

## Poisonous snakes

*Naja naja* (Indian cobra), *Naja hannah* (king cobra), *Bungarus caeruleus* (Krait), *Vipera russelli* (Russel's viper), *Ancistrodon* or *Agkistrodon himalayanus* (Himalayan pit viper), *Lachesis strigatus* common in South India, *Crotalus horridus* (rattle snake of North America) possessing a rattle at the end of tail, *Hydrophis* (sea snake), etc.

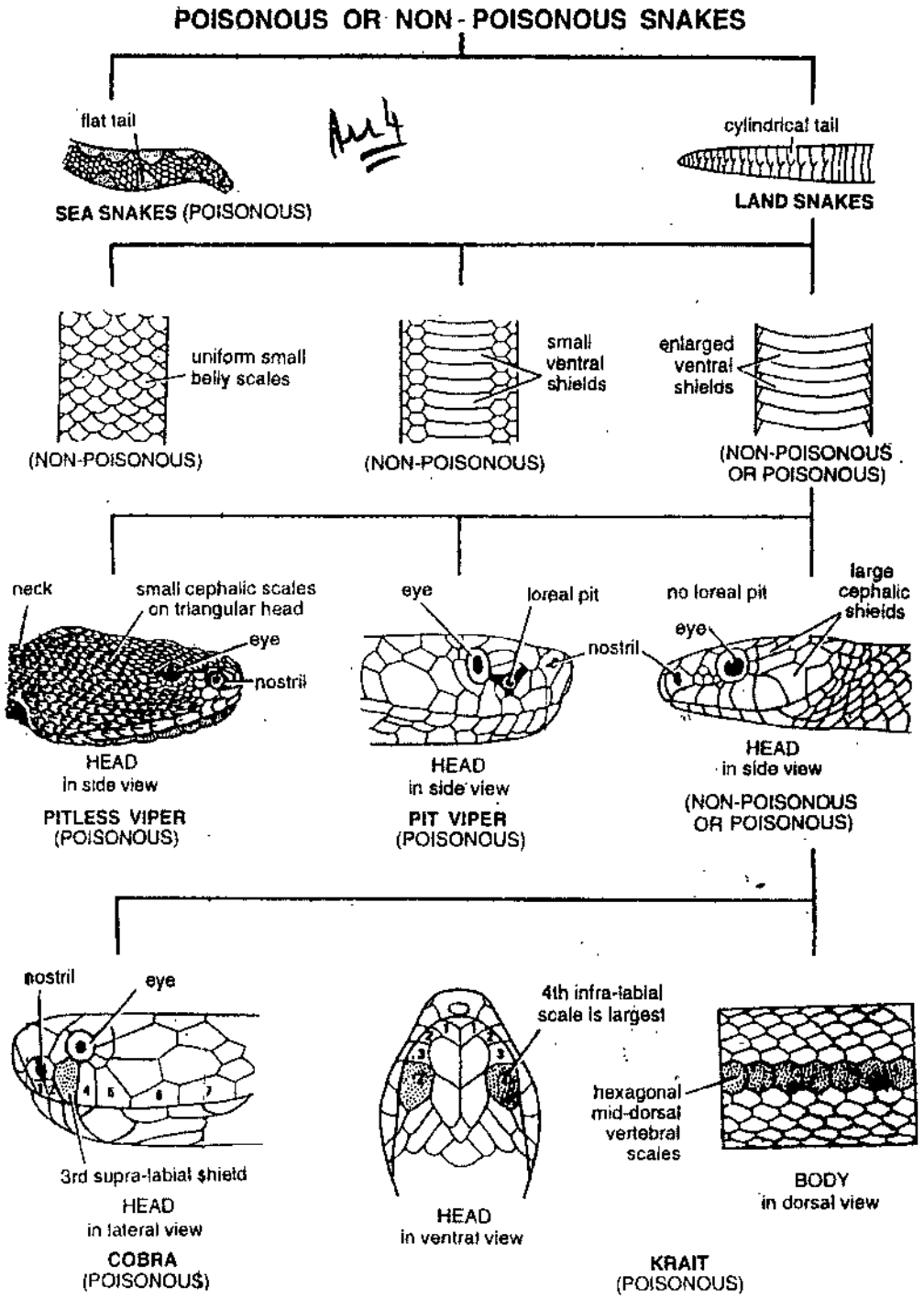



**Fig. 2. Identification of poisonous and non-poisonous snakes.**

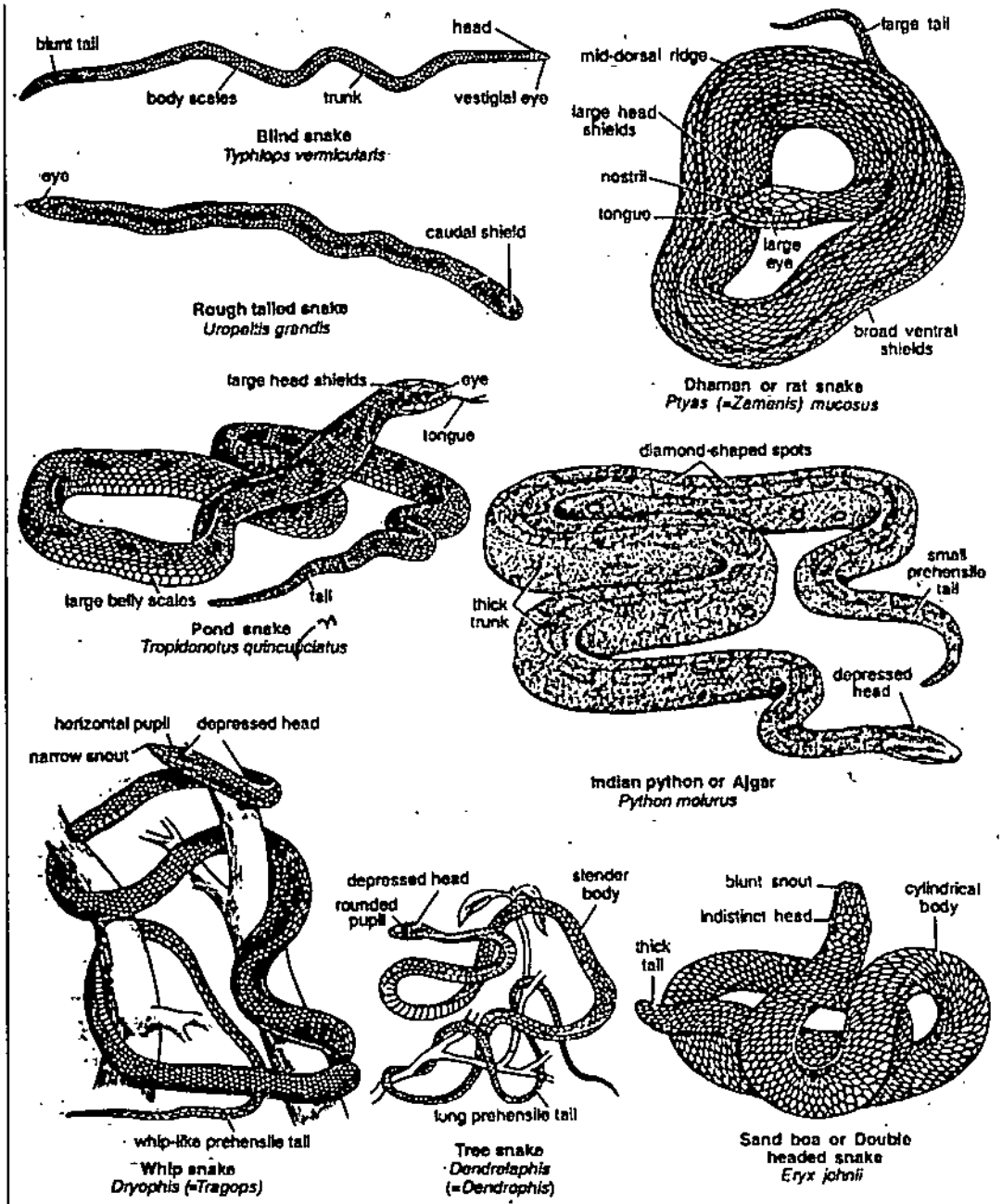



Fig. 3. Some non-poisonous snakes

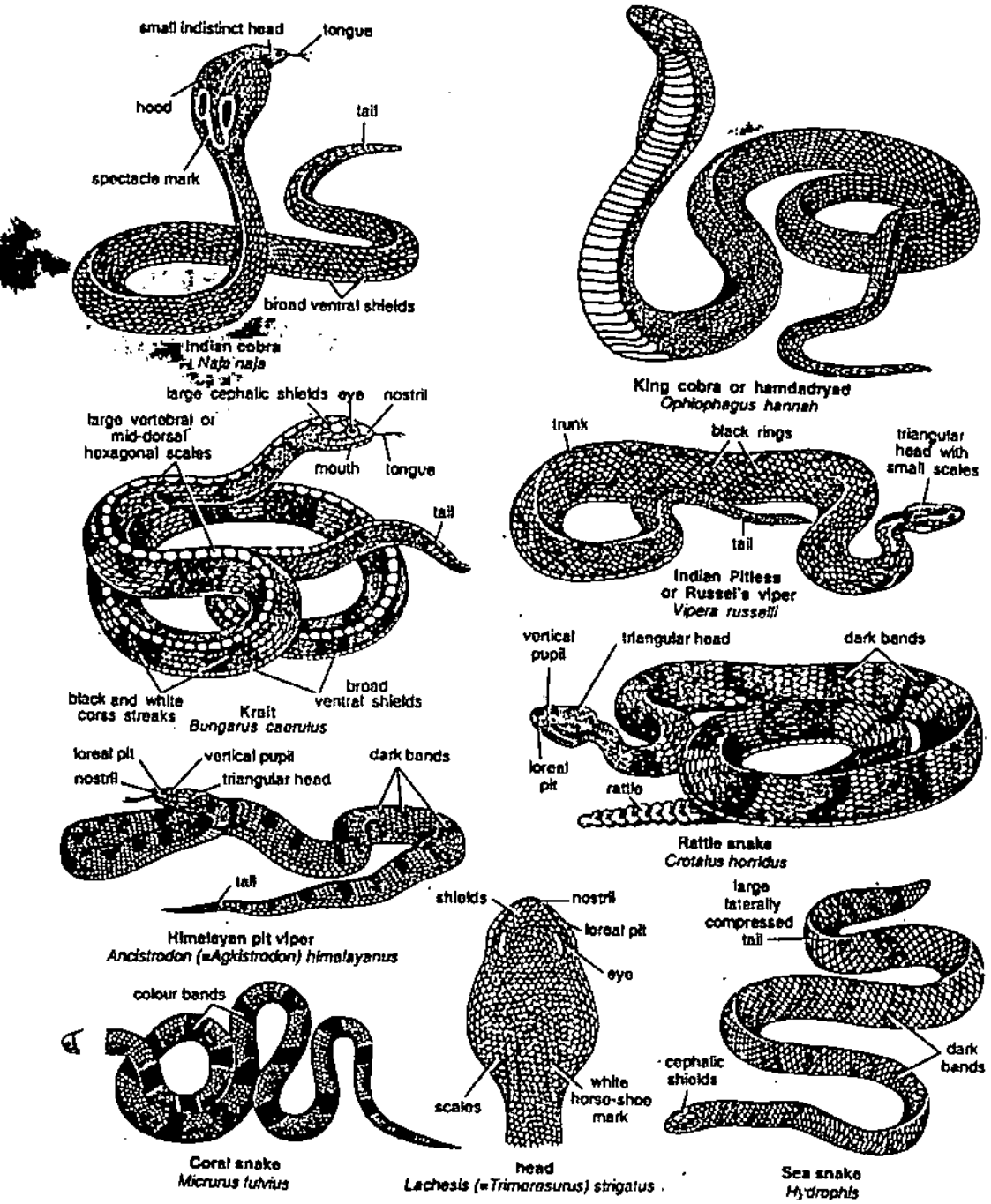



**Fig. 4. Some poisonous snakes**

## Jaw muscles help in biting mechanism

Movement of these skull bones is assisted by a number of muscles, which are given below :

(i) **Diagastric muscles** arises from the junction of squamosal and quadrate and attached with the posterior end of lower jaw. They open and close the jaws.

(ii) **Sphenopterygoid muscles** extend in between the dorsal surface of pterygoid and basal orbitosphenoidal region.

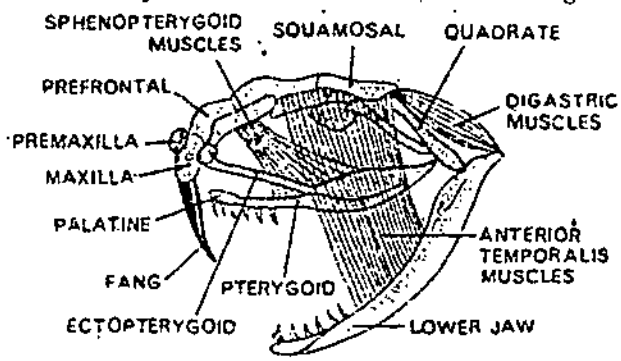



**Fig. 11. Diagram depicting the biting mechanism of a poisonous snake, when striking.**

(iii) **Temporalis muscles** found in between the lower jaw and sphenoidal region. Besides these, with the poison glands are associated the **mandibularis constrictor muscles** or **masseter muscles.**

### Bitting Mechanism of Poisonous Snakes

At rest when the mouth is closed, the **quadrate** lies in line with the long axis of the skull and the **maxilla** remains bent backward with the result the fangs remain directed backwardly and lie along the roof of the mouth.

When the snake strikes, the mouth is opened first. The jaw is lowered by the contraction of **masseters muscles,** there by the ventral end of quadrate moves forward. This pushes the pterygoids forward and bent the pterygo-palatine. The *forward movement of pterygoid is conveyed to the maxilla through the transpalatine* and causes the former to rotate through about 90° in such a way that the surface to which fangs are attached is carried forwards and ventral wards. Thus the fangs become errect and ready to strike. After siezing the rey, the lower jaw is raised by the action of **anterior temporalis muscles.** Consequently the prey is pressed against the fangs which penetrate deep in the prey. Side-by-side the poison glands are pressed, the venom flows in poison ducts then in the grooves or canals of the fangs. Finally it is injected into the prey by fangs which act as hypodermic syringe.

## • 9.3. STRUCTURE OF REPTILIAN *UROMASTIX* HEART

Reptiles to which lizards (*e.g., Uromastix*) belong are first truely terrestrial vertebrates in which respiration takes place wholly by means of lungs. Therefore, the animal has two streams of blood *viz.,* oxygenated and deoxygenated streams, which pass through the heart. This resulted in certain advancements in the structure of heart of the reptiles to avoid the mixing of blood from different parts of the body and then forces it to the various organs. Thus, it acts as a pulsatile station and controls the activity of the circulatory system.

### Heart of *Uromastix*

The heart of *Uromastix* lies in the anterior part of the body cavity in the mid-ventral line in the **pleuroparietal cavity** just below the sternum. It is enclosed in a thin **pericardium,** filled with **pericardial fluid.** The heart consists of four chambers *viz.,* dorsal **sinus venosus,** two ventro-anterior **auricles** and one ventro-posterior **ventricle.**

**Sinus venosus.** The sinus venosus is thin-walled triangular sac situated dorsally over the right auricle and it is formed by the confluence of the three cavals (2 precavals and 1 postcaval). It is differentiated externally into right and left halves. It receives the *deoxygenated blood of the body. It opens by a transverse oval slit into the right auricle,* which is called **sinu-auricular aperture** guarded by two flap-like mascular valves projecting into the lumen of right auricle.

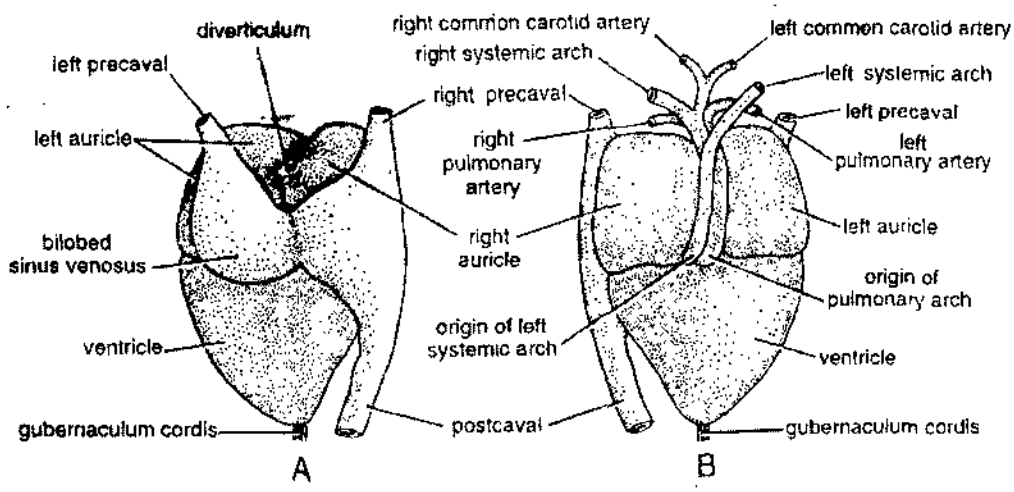



***Fig. 5. Uromastix.* External features of heart. A–Dorsal view. B–Ventral view.**

**Auricles.** The auricles are two, which are completely separated from each other by the **interauricular septum.** The right auricle s large. The inner surface of auricles are raised into a network of muscular ridges, called **musculi pectinati.** Into the right auricle opens the sinus venosus. The sinu-auricular aperture is guarded by a pair of **semilunar valves.** The anterior valve is larger than the posterior one. The **pulmonary** vein opens into the left auricle by an oblique aperture, which is not guarded by any valve. The valves and oblique nature of the opening prevent the flow of blood back to sinus venosus and pulmonary vein respectively, when auricles contract. The two auricles open by a single **auriculo-ventricular aperture** into the ventricle. The aperture is guarded by a pair of flap-like valves projecting into the lumen of the ventricle. Due to the continuation of inter-auricular septum into the ventricle, the auriculo-ventricular aperture becomes divided into right and left parts. This makes the separate openings for the two auricles. The valves are connected with the wall of ventricle by **chordae tendineae,** the muscular strands. These valves prevent the backward flow of blood, when ventricle contracts.

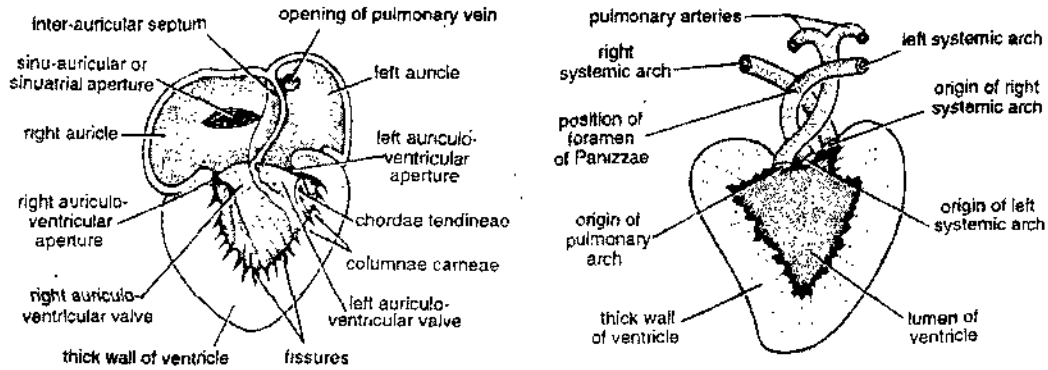



**Fig. 6. *Uromastix.* A–Internal structure of the heart in ventral view. B–Origin of aortic arches from ventricle.**

**Ventricle.** The ventricle is conical with thick muscular and spongy walls. Its lumen is partially divided into two chambers by **inter-ventricular septum** or **muscular ridge.** The left dorsal chamber is larger and is called **cavum dorsale,** where as the right ventral chamber is small and is called **cavum pulmonale.** The cavum dorsale is further sub-divided by **myocardial trabeculae** into a left **cavum arteriosum** and a right **cavum venosum.**

**Conus and ventral aorta** split up into three arches *viz.*, **pulmonary, left** and **right systemic arches.** The pulmonary and left systemic arch arise from cavum pulmonale and the right systemic arch originates from cavum dorsale. Soon the left systemic arch crosses on the right side and right systemic arch to the left side. Thus, two systemics cross each other and at the crossing lies the **foramen of panizzae** through which both systemics are in communication. Opening of each of these three arches is guarded by a valve.

## • 9.4. COURSE OF BLOOD CIRCULATION IN HEART

The deoxygenated blood from the sinus venosus and the oxygenated blood from the lungs enter the right auricle through sinu-auricular aperture and left auricle through pulmonary veins respectively. Now both the auricles contract (systole) simultaneously, while the ventricle diastole (relax). Thus, the blood from the auricles enter the ventricle through auriculo-ventricular aperture. The valves present at the sinu-auricular aperture check the backward flow of blood. The blood from the right auricle fills in the large cavum pulmonale and small cavum dorsale is being filled from the blood of left auricle.

Now the ventricle contracts (systole) and the auricles relax (diastole) and hence the blood from the ventricle is pumed from cavum pulmonale into the pulmonary and left systemic and from cavum dorsale into the right systemic arch. This time auriculo ventricular valves check the backward flow of blood from ventricle to auricles.

**COURSE OF CIRCULATION**

| | |
|---|---|
| **Lungs** | **Sinus venosus** |
| ↓ through pulmonary aperture | ↓ through sinu-auricular aperture |
| Left auricle | Right auricle |
| ↓ *through auriculo-ventricular aperture* | ↓ *through auriculo-ventricular aperture* |
| **Cavum dorsale of ventricle** | **Cavum pulmonale of ventricle** |
| ↓ | ↓ |
| **Right systemic arch** | **Pulmonary and left systemic arch.** |

## • 9.5. ARTERIAL SYSTEM OF LIZARD

In lizard, the conus arteriosus and ventral aorta split upto the base, forming three separate trunks, *i.e.*, **pulmonary** and **right** and **left systemics.**

(In frog, truncus arteriosus is found originating from the ventricle, which after running obliquely over the heart divides into two branches, each of which sub-divides into dorsal carotid, middle systemic and ventral (lower) pulmonary). **In lizard,** the **carotid** arises from the right systemic arch.

The following are the main arteries in lizard :

**1. Pulmonary aorta.** It arises from right side of the ventricle, **cavum pulmonale,** which divides to form **right** and **left pulmonary arteries,** entering the lungs of its own side.

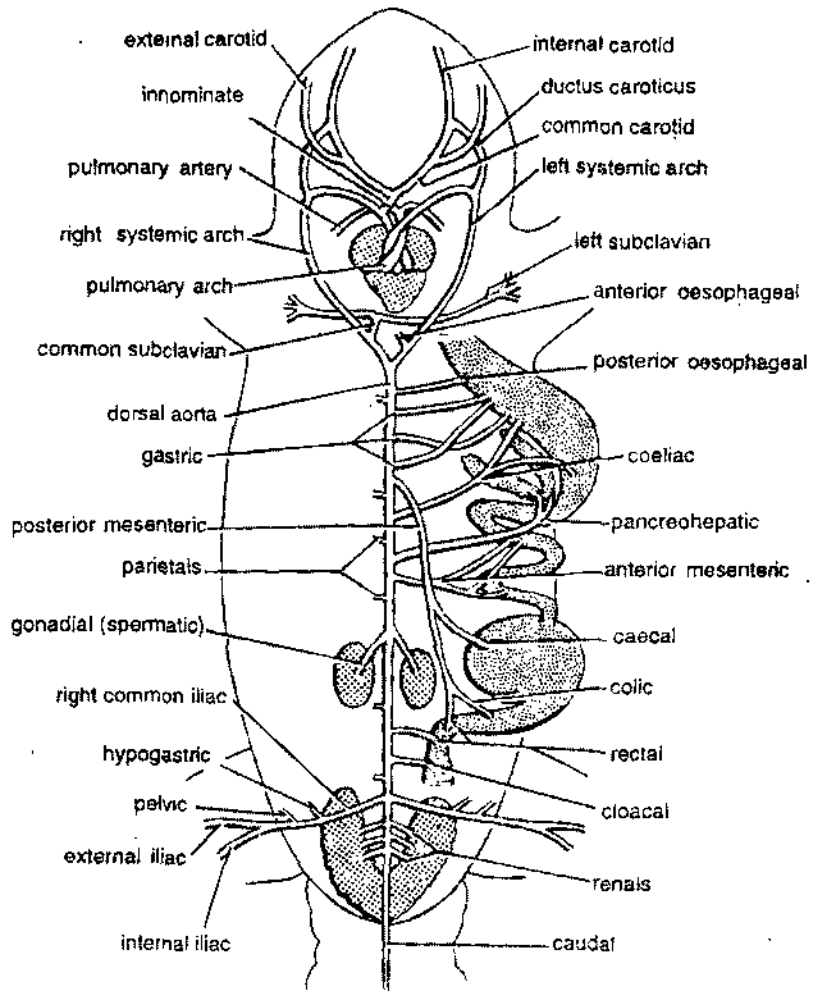



**Fig. 7. *Uromastix*. Arterial system**

**2. Systemic aorta.** These are two, the **right systemic aorta** arises from the left side of the ventricle (**cavum dorsale**) and beyond the heart it turns to the right side, while the **left systemic aorta** arises from the right side of the ventricle and then curves to the left side. Both the systemic aortae cross each other and where they came in contact with each other, each is perforated by **foramen of Pannizae.** Thus, the blood of these two aortae communicate with each other. The two systemics run backward and then unites behind the heart forming **median dorsal aorta,** which runs backward in the mid line upto the tail-beneath the vertebral column.

**Right systemic arch** gives rise the following arteries :

**(i) Innominate artery** or **carotis primaria** after arising from right systemic divides into right and left **carotid arteries.** Each carotid artery further divides into **external carotid** artery supplying the muscles of the buccal cavity and tongue, and **internal carotid artery** supplying blood to the brain and sense organs. It is also connected with the systemic of its side by **ductus caroticus.**

In frog **carotid artery** arises from each of the sub-division of truncus ateriosus and has no connection with the systemics. Systemic aortae are also originate like carotids and they do not cross each other.

**(ii) Common sub-clavian artery.** Soon after emergence it divides into right and left sub-clavian arteries, supplying blood to the limbs and girdles of their side.

**(iii) A pair of parietal arteries** supplying to body wall.

From the left systemic arch arises an **anterior oesophageal artery,** running to oesophagus.

**Dorsal aorta :** It gives of the following arteries :

### Left systemic arch

**1. Parietal arteries** are about 15 pairs, supplying vertebral column and its muscles.

**2. Oesophageal artery** to the oesophagus.

**3. Gastric arteries** to the stomach.

**4. Posterior mesenteric** runs backward and supplies to the intestine, caecum and colon.

**5. Caeliac artery** supplies to the stomach and spleen.

**6. Anterior mesenteric** runs backward and supplies to the intestine, caecum and colon.

**7. Gonadial arteries** are one pair supplying to th gonads.

**8. Iliac arteries** are also paired going to the hind limbs. Each divides into an **external** and **internal iliacs** suplying to thigh and lower part of legs respectively.

**9. Renal arteries** are three pairs going to kidneys.

**10. Caudal artery :** After giving off these arteries, the dorsal aorta enters the tail as **caudal artery**.

## • 9.6. VENOUS SYSTEM OF *UROMASTIX*

Venous system of *Uromastix* resembles to that of frog and it is most primitive amongst all lizards. It includes three great veins, *i.e.*, **two precavals,** draining blood from the anterior part of the body and the **post caval** bringing blood from the posterior region of the body, and both pour it into the vsinus vnosus. Besides these, there are two **pulmonary veins,** draining the lungs and pouring into the left auricle.

Here we take the different vein's in the following orders :

1. Precavals.
2. Post caval.
3. Renal portal system and anterior abdominal vein.
4. Hepatic portal system.
5. Pulmonary veins.

**1. Precavals.** Right and left precaval veins, each of which receives the following veins before entering the sinus venosus :

**(i) Common jugular** formed by the union of *(a)* **external jugular,** which is itself formed by the union of **maxillary vein** bringing blood from the upper jaw and face, and **mandibular vein** draining the lower jaw, and *(b)* **internal jugular vein,** which is formed by the union of **cerebral vein** from the brain and **orbital vein** from the orbital region of head. Both external and internal jugular veins unite at the level of tympanum forming common **jugular vein,** which runs through the neck, where it is enlarged to form **jugular sinus.**

**(ii) Sub-clavian vein** is formed by the union of **scapular** from the shoulder, **brachial** from the forelimb and **axillary** from the armpit and thorax. It then unites with the **jugular sinus at** its posterior end.

**(iii) Intercostal vein** drain's blood from the muscles of thorax and skin.

All these three, after uniting, form the **precaval**, which receives **laryngotracheal vein** close to the sinus venosus. Both the veins drain the larynx and the tongue and join with each other by 4 or 5 transverse **tracheal loops.**

**2. Post caval.** It drains the blood from the posterior region of the body. From the kidneys the blood enters the thin-walled **renal sinus** found in the centre of the kidneys. Two **efferent renal veins** run forwards from the sinus and each receives blood from the dorsal body wall by a few small veins. At the level of gonads both the efferent renal veins are joined together by a **commissural vein.** Commissural vein receives a pair of **genital veins** from the gonads. The right efferent renal vein extends forward beyond the gonads and runs through the right lobe of the liver, where it receives two **hepatic veins** and finally runs forwards as **post caval** entering into the sinus venosus.

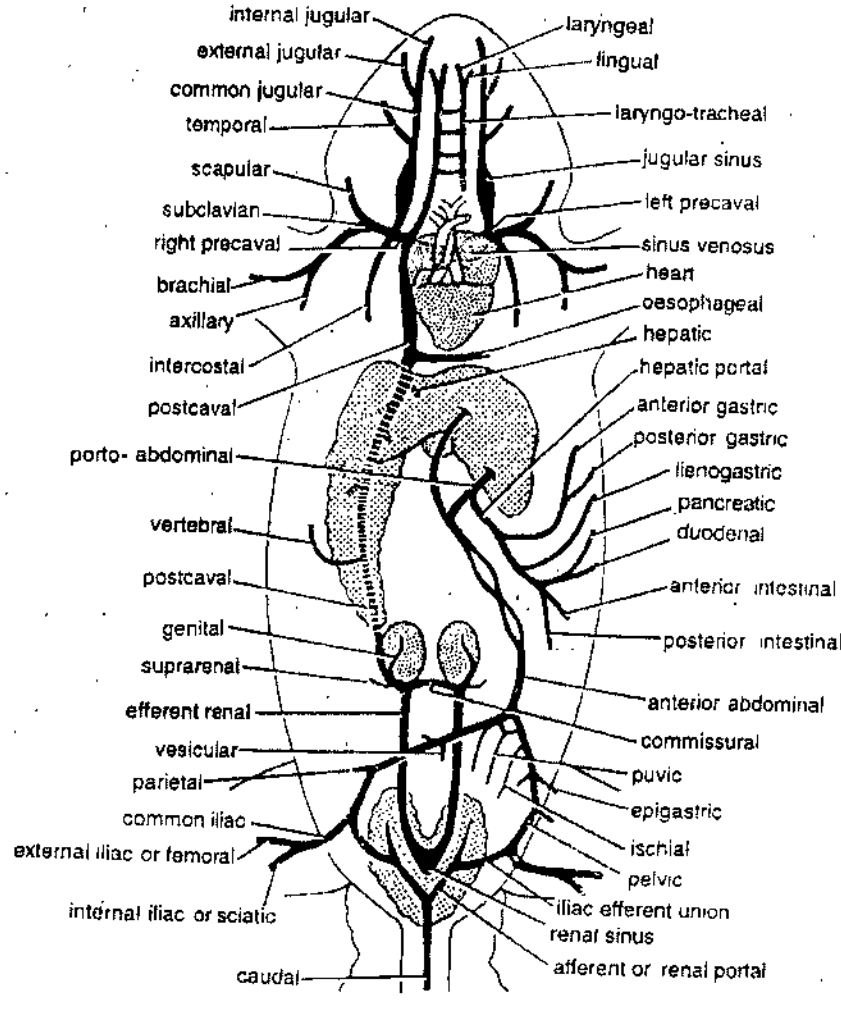



**Fig. 8. *Uromastix*. Venous system.**

**3. Renal portal system and anterior abdominal vein.** The **caudal vein** from the tail region after entering into the abdominal cavity bifuracates and each enters the kidney as **renal portal** or **afferent renal vein.** These veins also receive the **cloacal** and **rectal veins** from the cloaca and rectum respectively. Hence, very small quantity of blood enters the renal portal system. Most of the blood from the posterior part of the body enters the anterior abdominal vein.

**Anterior abdominal vein.** The blood from each limb is collected by **internal iliac** and **external iliac,** which join in the body cavity to form **common iliac** lying one on each side of the kidney. **Each common iliac** gives a branch joining with the afferent renal vein and the main branch runs forward as **pelvic vein.** Both the pelvic veins join with each other in front of the kidney to form the **anterior abdominal vein.** Pelvic vein of either side receives an **ischial vein** from lumbar and sacral regions, an **epigastric vein** from the dorsal body wall and a median **pubic vein,** which is connected to both the pelvic veins anteriorly are not fused along their whole length but remain separated from each other and one of them enters the left lobe of the liver directly and the other receives **hepatic portal vein** and then enters the liver lobe as **porto-abdominal vein.**

**4. Hepatic portal system.** It drains the blood from the gut. A number of veins such as **anterior** and **posterior gastric** from the stomach; **lienogastric** from the spleen and stomach; **duodenal** from the duodenum, **anterior intestinal** from ileum and **posterior intestinal** from caecum, colon and rectum unite to from an **hepatic portal vein.**

### Urinogenital System of *Uromastix*

In vertebrates, the excretory organs and the generative organs usually remain associated with each other, specially in the male. As such these two organs are studied under urinogenital system. In a lizard, *i.e., Uromastix,* this association is marked in the posterior region.

### Excretory system

Excretory system in Uromastix includes :

1. A pair of kidneys.
2. A pair of ureters.
3. Unpaired urinary bladder.

**Kidneys.** In *Uromastix,* the **kidneys** are **metanephric** in origin and form the main excretory organ. They are paired, chocolates-coloured structure found in the pelvic region of the body cavity, one on each side of the vertebral column. Each kidney comprises two lobes, *i.e.,* anterior broad and posterior narrow lobes. The **posterior lobes** of the two kidneys are fused in the mid-line and the **anterior lobes** are free and diverge from each other. Thus, the kidneys appear to be V-shaped.

**Ureter.** It arises from the ventro-lateral surface of each kidney, runs behind and finally opens separately in a special compartment of the cloaca, the **urodaeum.** In male, the ureter recieves the **vas deferens** of its own side before opening into the cloaca.

**Urinary bladder.** It is a median thin-walled sac, which opens into the urodaeum ventrally. It is meant for storing the urine.

### Reproductive system

In *Uromastix,* the sexes are separate but the sexual dimorphism is not well marked.

### Male Reproductive Organs

The male reproductive organs comprises :

1. A pair of testes.
2. A pair of vas deferens and epididymis.
3. A pair of copulatory sacs.

**Testes.** The testes are paired oval structures, placed asymmetrically in the body cavity anterior to the kidneys. Testes are suspended in the body cavity with the help of double fold of peritoneum called **mesorchium.** The right testis is situated just behind the tip of right lobe of the liver, where as the left one lies liittle further back.

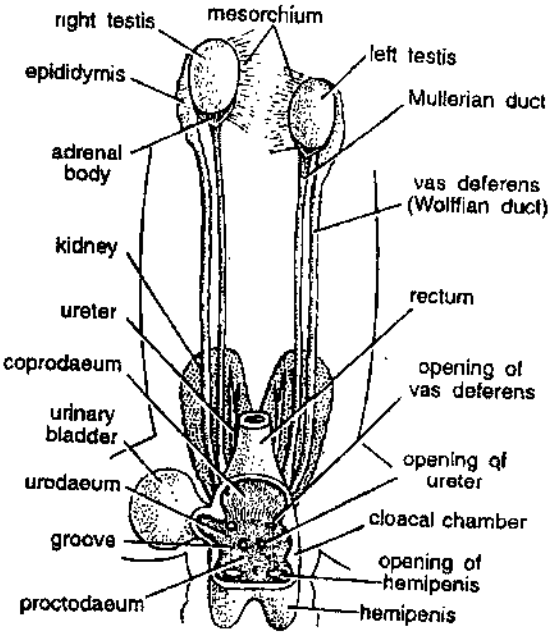



**Fig. 9. *Uromastix*. Male urinogential system.**

**Vas deferens and epididymis.** From each testis a number of delicate **vasa efferentia** pass through mesorchium and enter the epididymis. **Epididymis** is the remnant of mesonephros and the vasa efferentia are the outgrowth of mesonephric uriniferous tubules. Epididymis is found on the outer side of each testis, which is formed of convoluted mass of vasa efferentia. Each epididymis continues behind as a narrow convoluted **vas deferens,** which runs along the ventral surface of the kidney of its own side. It is a persistent Wolffian or mesonephric duct. Vas deferens joins the ureter before opening into the cloacal chamber. Thus, in male, the urinary and genital openings are not separate, but these open by a common openings.

**Copulatory sacs** or **hemipenes** are two eversible hollow sacs found in the urodaeum and are formed by evagination of the cloacal wall. They open into the posterior corners of the cloaca and is attached to the vertebral column by means of **retractor muscles.** It is made up of erectile vascular tissue and when everted become hard and cylindrical. It bears a groove, which starts from the urinogenital opening. During copulation any one of the hemipenis is inserted into the cloaca of the female and the sperms are passed on to the female urodaeum.

## Female Reproductive Organs

Female reproductive organs consists of :

1. A pair of ovaries.
2. A pair of oviducts.

**Ovaries.** The ovaries are white oval or irregular in shape and are suspended in the body cavity with the help of **mesovarium.** They are comparatively nearer to the kidneys but are asymmetrically placed like that of testes. The right ovary is some what anterior to the left one. From the surface of each ovary are projected round protuberances, called the follicles, each of which possesses an ovum.

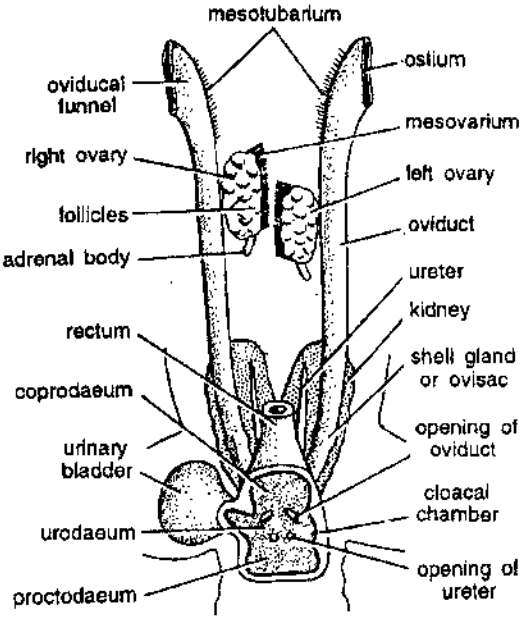



**Fig. 10. *Uromastix*. Urinogenital system of female.**

**Oviducts** are thin walled with broader anterior ends there by forming **oviducal funnels.** The opening of each oviducal funnel faces outwards not towards the inner side as is usual. Each runs behind, first along the outer border of the ovary than along the ventral surface of the kidney of its own side. In the kidney region, each dilates to form

**shell gland** or **ovisac** meant for storing the eggs. It finally oppens independently into the posterior part of the cloaca. In female the genital and urinary ducts open separately into the cloaca. The copulatory sacs are very small and insignificant.

**Cloaca.** In lizards, the cloaca is divisible into three chambers.

(i) **Coprodaeum** is the anterior most chamber having the opening of rectum.

(ii) **Urodaeum** is the middle chamber having the openings of ureters, urinary bladder and genital ducts.

(iii) **Proctodaeum** is the posterior chamber opening exterior by clocal opening.

## • SUMMARY

- Reptiles are mostly terrestrial, creeping like lizards and snakes, some of which also live in water.
- They are air breathing, cold-blooded and oviparous.
- Except snakes, other reptile's limbs are pentadactylous, with clawed digits, but *Ophisaurus* (lizard) is limbless. Body of reptiles is covered by scales, shields, plate and scutes. Except crocodiles, reptiles heart is three chambered-2 auricles and one incompletely divided ventricle.
- Reptiles possess Jacobson's organ (sense organ) in the roof of mouth cavity.
- Class Reptilia is divisible into five subclasses; Anapsida and Diapsida includes living reptiles, whereas other three subclasses. Euryapsida, Parapsida and Synapsida includes extinct reptiles. *Sphenodon punctatum* (tuatara) of New Zealand is the only living species of the order Rhynchocephalia.
- Order Squamata includes the lizards and snakes.
- Cotylosauria were the stem reptiles belonged to upper Carboniferous to upper Triassic, which resembled the labyrinthodont Amphibia from which they had evolved.
- Poinous snakes have fangs, while non-poisonous snakes lack the fangs. Lizards and snakes are uricotelic, *i.e.*, excrete uric acid.

## • STUDENT ACTIVITY

1. Classify Reptilia upto orders giving important characters and examples.

2. Write down the general characters of Class Reptilia.

3. Describ the structure of heart of *uromastix* and course of blood circulation.

4. Describe the arterial or venous system of a lizard.

5. Differentiate between poisonous and non-poisonous snakes.

6. Describe the biting mechanism of poisonous snake.

## • VERY SHORT ANSWER QUESTIONS

1. **Write down the name of limbless reptilia.**
   **Ans.** Limbless lizard (Reptile) is *Ophisaurus* and snakes.
2. **Write down the habitat of turtles, terrapins and tortoises.**
   **Ans.** Turtles are marine, terrapins are freshwater and tortoises are terrestrial.
3. **Write down the name of giant land tortoise found on Galapagos islands in Pacific Ocean and islands of Indian Ocean.**
   **Ans.** *Testudo abingdoni.*
4. **Write down the name of lizard found in New Zealand.**
   **Ans.** *Sphenodon punctatum* is the only living species found in New Zealand. Its common name is Tuatara or Hatteria.
5. **What do you know about the habits and habitat of *Sphenodon* ?**
   **Ans.** *Sphenodon* is burrowing living in small hole or burrows in rocks, and nocturnal in habits. It feeds on worms, insects, spiders, molluscs and fish.
6. **Write down three names of poisonous snakes.**
   **Ans.** *Naja naja* (cobra), *Bungarus caeruleus* (Krait) and *Vipera russelli* (Russel's viper).
7. **What type of snakes giving below :**

**Ans.** *Uropeltis* (rough tailed snake), *Ptyas* (dhaman), *Tropidontus* (pond or grass snake), *Dendrophis* (tree snake), *Hydrophis* (common Indian sea snake), *Crotalus* (rattle snake).

| | | |
|---|---|---|
| *Uropeltis* | – | Non-poisonous |
| *Tropidontus* | – | Non-poisonous |
| *Dendrophis* | – | Non-poisonous |
| *Hydrophis* | – | Poisonous |
| *Crotalus* | – | Poisonous |

8. **In which snake, hood and spectacle mark is found ?**

**Ans.** *Naja naja* (cobra) possesses the hood and spectacle mark.

9. ***Write down the names of viviparous snakes.***

**Ans.** *Vipera russelli* (pitless viper) and *Ancistrodon* (pit viper) are viviparous.

10. **How much chambers are found in the heart of lizards ?**

**Ans.** Lizard's heart is three chambered – two auricles and one incompletely divided ventricle. In crocodiles, heart is four chambered, 2 auricles and 2 ventricles.

11. **What is gubernaculum cordis ?**

**Ans.** It is a small cord that attaches apex of heart with the pericardium.

UNIT

# 10

# AVES : GENERAL CHARACTERS AND CLASSIFICATION, AND FLIGHT ADAPTATION IN BIRDS

## STRUCTURE

- General characters of birds or Aves.
- Classification of birds.
- Subclass **Archaeornithes** – Includes extinct birds like Archaeopteryx.
- Subclass **Neornithes** – Includes extinct as well as modern flying birds.
- Extinct birds are kept in Super order Odontognathae and order Hesperornithiformes and Ichthyornithiformes. Super order Palaeognathae includes flightless birds, like ostrich, rhea, cassowaries, penguins, kiwis, moas, elephant birds.
- Super order Neognathae or Carinatae includes all the flying modern birds.
- Flight adaptations in birds.
- Types of feathers, flight muscles, perching muscles, digestive, circulatory, respiratory and urinogenital systems of pigeon.
  - Summary
  - Student Activity
  - Test Yourself

## LEARNING OBJECTIVES

After going through this unit you will learn :

- Characteristic features of Aves and their classification *Archaeopteryx*. Flight adaptations in birds. Structure and types of feathers. Flight nucleus and Perching neuscles. Digestive organs, Respiration in pigeon and urinogenital organs

## • 10.1. GENERAL CHARACTERS OF BIRDS (AVES)

Class Aves (birds) is a homogeneous group among vertebrates. Birds are feather-clad, air-breathing, warm-blooded, oviparous and bipedal flying vertebrates.

1. Body is roughly spindle or boat-shaped and divisible into head, neck, trunk and tail. Beak or bill is toothless formed by the prolongation of jaw bones. Neck is long and flexible. Tail short and stumpy.

2. Limbs two pairs, forelimbs are modified into wings and hind-limbs with 4-clawed toes and are large and adapted for walking, running, perching, scratching, food capturing, swimming or wading. First (hallux) toe is directed backward.

3. Body is covered by epidermal and horny feathers, which keep the body warm, and scales found over the legs.

4. Skin is dry having no glands except oil or preen gland found at the root of tail.

5. Endoskeleton ossified, light in weight, strong and without epiphysis. Long bone like limb bones are hollow (pneumatic) and without bone marrow.

6. Skull monocondylic (single occipital condyle) like reptiles. Lower jaw (mandible) have 5 or 6 bones and articulate with quadrate.

7. Vertebral column short, vertebrae heterocoelous (saddle-shaped). Cervical (neck) vertebrae bear small cervical ribs. Second to fifth thoracic vertebrae, fused together. Synsacrum is formed by the fusion of last thoracic vertebra, lumbar vertebrae, 2 sacral vertebrae and seven caudal vertebrae. It gives support to ilia bones of pelvic girdle. Free caudal vertebrae are 4 to 5 and the last 4 or more caudal vertebrae fused to form plough-shaped pygostyle bone.

8. **Sternum** large with vertical mid-ventral keel for the attachment of flight muscles.

9. **Ribs** double headed, bicephalous and have uncinate processes directed backwardly.

10. Furcula (wish bone) is formed by the fusion of 2 clavicles and an interclavicle.

11. **Girdles.** Pelvic girdle large formed by the fusion of large ilia, ischia and a thin slender and curved pubes. Acetabulum perforated.

Pectoral girdle. Its each half is formed of three bones : a large coracoid, a thin scapula and a slender clavicle.

12. **Forelimb bones.** Humerus, radius and ulna, and carpo-metacarpus bone of palm formed by the fusion of distal row of carpals and three metacarpals.

**Hind limb** bones are femur, tibio-tarsus and fibula, tarsals whose proximal row is fused with tibia and distal row fused with metatarsus. Tarso-metatarsus of foot is formed by the fusion of distal row of tarsals and second, third and fourth metatarsals.

13. **Alimentary canal.** Oesophagus dilated into a crop for food storage, stomach divided into anterior glandular proventriculus and muscular gizzard. Cloaca three chambered : anterior coprodaeum, middle urodaeum and posterior proctodaeum.

14. **Heart** four-chambered. Sinus venosus and truncus arteriosus absent. Only right aortic arch is present. **Renal portal system** vestigial and red blood corpuscles nucleated.

15. **Lungs** compact, spongy and non-distensible and continuous with thin-walled air sacs. Larynx lacks vocal cords. **Syrinx** is the sound producing organ.

16. **Kidneys** metanephric and three – lobed. Urinary bladder absent. Urecotelic, *i.e.*, excretory product is uric acid.

17. **Brain.** Cerebrum, cerebellum and optic lobes well developed. Cranial nerves 12 pairs.

18. **Middle ear** has a single ossicle. Eyes possess nictitating membranes, sclerotic plates and a vascular pecten. **Sclerotic plates.** 10–12 overlapping bony plates form a ring which provides strength to the sclerotic coat of the eye. **Pecten** is a comb-like structure that projects into the cavity of eye ventral to the blind spot where optic nerve enters the eye ball.

19. **Sexes** separate and sexual dimorphism well marked. Female has a single left ovary and oviduct.

20. **Fertilization** internal. Eggs macrolecithal, *i.e.*,having large amount of yolk, and enveloped by calcareous shell.

21. **Cleavage** meroblastic and discoidal. Extra-embryonic membranes present during development.

22. Newly hatched young is either fully developed (**precocial**) or immature (**altricial**). Precocial young is fully clad with wet feathers and is able to move and feed.

## • 10.2. CLASSIFICATION OF BIRDS

There are 34 orders, out of which 27 orders are of living birds and 7 orders of fossil birds (**Wetmore,** 1960). Here only economic groups have been described. Birds (Aves) is divided into two Subclasses. **Archaeornithes** and **Neornithes.**

### Subclass 1. Archaeornithes

Extinct birds of Jurassic period, about 155 million years ago. They possessed primitive wings having little power of flight. Tail long and tapering having more than 30 tail vertebrae (lizard-like) with lateral rows of tail feathers. Skull with teeth in both jaws, vertebrae amphicoelous, sternum without keel, carpals and metacarpals free (in living birds distal carpals remain fused with metacarpals to form carpometacarpus), thoracic ribs slender without uncinate process (lizard-like), abdominal ribs present (lizard-like).

It includes a single **order-Archaeopterygiformes.** Example. *Archaeopteryx lithographica* discovered from Jurassic period from Bavaria, Germany. Its specimen is kept in British museum and Berlin museum.

### Subclass 2. Neornithes

It includes modern as well as extinct birds. Wings well developed with few exceptions like order **Hesperornithiformes** having no keeled sternum, flightless marine birds (*Hesperornis, Enaliornis, Baptornis* etc.) and order **Ichthyornithiformes** having keeled sternum, example. *Ichthyornis* and *Apatornis*. Both orders belong to **Super order Odontognathae.** Tail short with 13 or less caudal vertebrae, provided with tail feathers arranged in a fan-like manner, wing formed of 3 partly fused clawed fingers, teeth absent on jaws, vertebrae heterocoelous (saddle-shaped centrum), pygostyle present (formed by the fusion of last few caudal vertebrae), sternum with keel, carpometacarpus present (formed by the fusion of distal carpals and metacarpals), thoracic ribs with uncinate processes, and abdominal ribs absent.

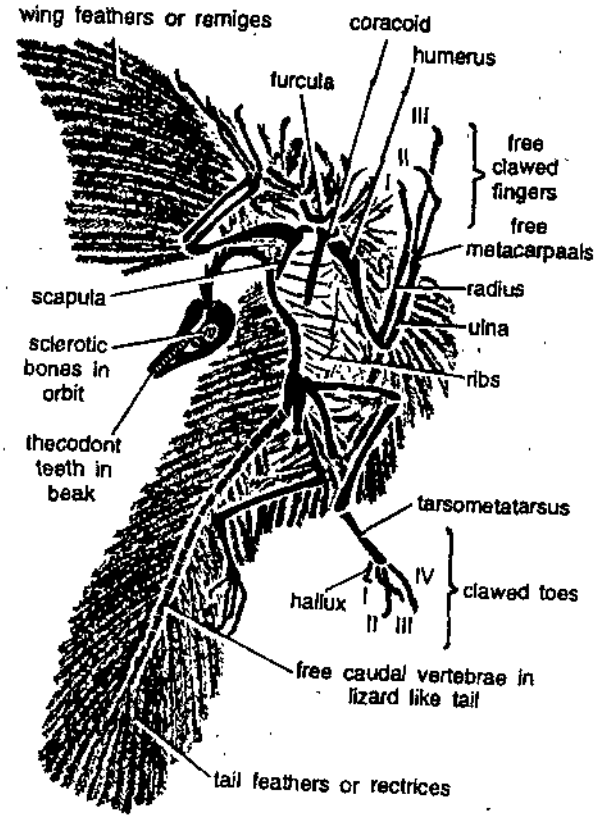



**Fig. 1.** ***Archaeoteryx lithograhica.*** **Fossil.**

### Subclass 2. Neornithes

It includes modern and extinct post jurassic birds. Wings well developed with few exceptions. Tail short with 13 or less caudal vertebrae and rectrices. Wing with 3 partly fused clawless fingers. Teeth absent except in fossil birds. Few caudal vertebrae free and rest fused to form pygostyle with keel. Abdominal ribs absent and thoracic ribs with uncinate processes.

This subclass is divisible into 4 Superorders : Odontognathae, Palaeognathae (Ratitae), Impennae and Neognathae (Carinatae).

### Superorder 1. Odontognathae

Extinct upper cretaceous birds, jaws with teeth for catching fish. It includes two orders :

1. **Hesperonithiformes** (Examples, *Hesperornis, Enaliornis* etc.). They lack keeled sternum.

2. **Ichthyornithiformes.** sterunm with keel. Example. *Ichthyomis.*

### Superorder 2. Palaeognathae or Ratitae

It includes large flightless running birds having no teeth in jaws. Wings vestigial (rudimentary), tail feathers absent or arranged irregularly. Oil gland at the base of tail is absent except Tinamus and Kiwi. Sternal keel vestigial or absent or flat. Tail vertebrae free and pygostyle absent or small. Pectoral muscles (flight muscles) poorly developed, syrinx (sound producing organ) well-developed, male has erectile penis and young precocious.

This super order includes 7 orders. : Struthioniformes, Rheiformes, Casuariformes, Apterygiformes, Dinornithiformes, Aepyornithiformes and Tinamiformes.

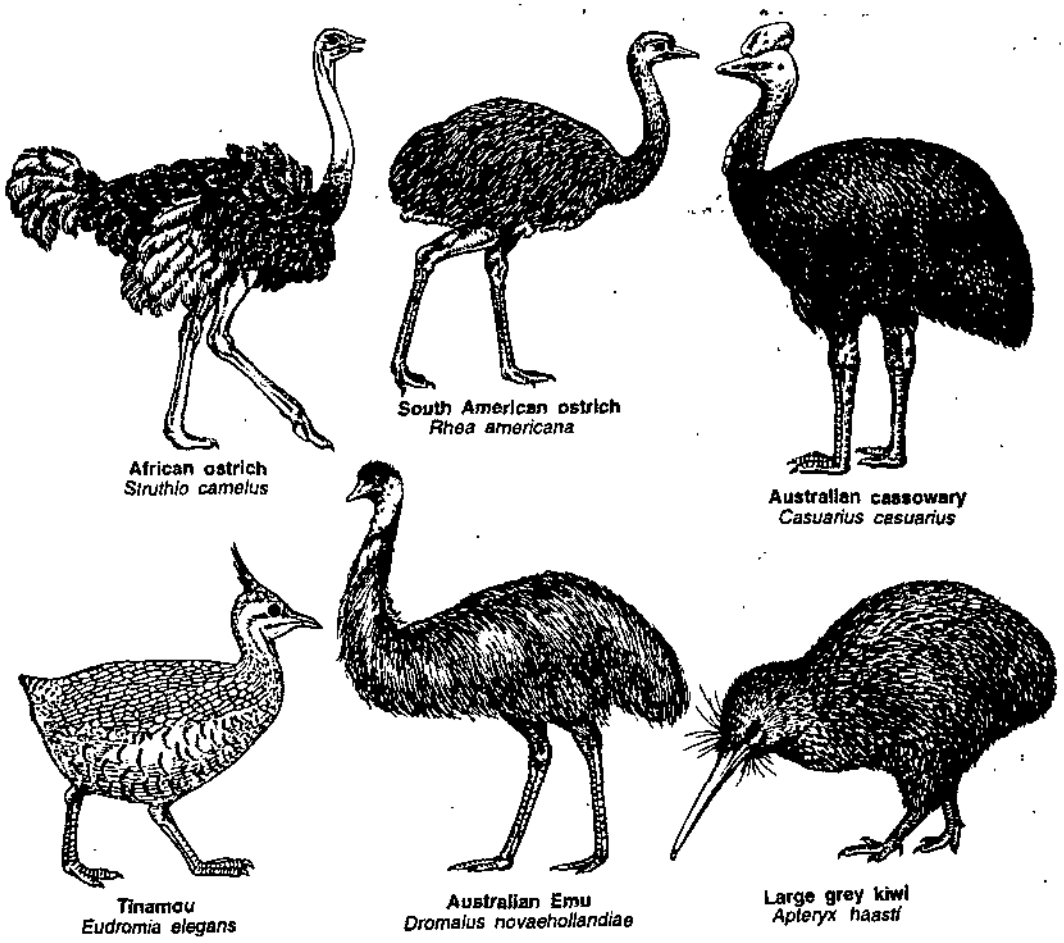



**Fig. 2. Common flightless birds.**

### Order 1. Structhioniformes

Flightless terrestrial birds with strong legs having two toes (3rd and 4th), sternum without keel, pygostyle absent, head, neck and leg sparsely feathered. Example. *Struthio camelus* (ostrich) found in Africa and western Asia.

### Order 2. Rheiformes

Legs bear 3 clawed toes, sternal keel absent, and head and neck are partly feathered. Example. *Rhea americana* (American ostrich).

### Order 3. Casuariformes

Head bears a comb-like structure, and neck and body densely feathered. Examples. *Casuarius* (cassowaries) found in Australia and New Guinea and *Dromaeus* (emus) of New Zealand

### Order 4. Apterygiformes

Wings vestigial, feather simple, hair-like or bristle-like and long bill having nostril near tip. Example. *Apteryx* (kiwis) of New Zealand.

### Order 5. Dinornithiformes

Wings absent, beak short and massive, legs with 4 toes. Giant extinct birds. Example. *Dinornis maximus* (moas) of New Zealand.

### Order 6. Aepyornithiformes

Wings tiny, legs strong with 4 toes. Recently extinct. Examples. *Aepyornis* and *Mulleornis* (giant elephant birds of Africa and Madagascar.)

### Order 7. Tinamiformes

Small terrestrial, running birds. Sternum keeled and pygostyle reduced. Example. *Tinamus* (tinamous).

### Super order 3. Impennae

Aquatic, flightless modern birds having paddle-like wings (flippers), feathers small covering entire body and beneath skin is found thick layer of fat. Feet webbed. Example. *Aptenodytes* (penguins) of southern hemisphere.

### Super order 4. Neognathae (Carinatae)

Modern flying birds. Wings well developed, feathers with interlocking mechanism, tail feathers present which are regularly arranged, oil gland present at the root of tail, sternum with keel, ribs with uncinate processes, pygostyle present, pectoral muscles large, male without copulatory organ, and young altricious.

It includes several orders, but a few are described here, which are economically important.

### Order 1. Passeriformes

This includes about half the known species of birds. Their feet are adapted for perching and beaks are used for cutting. Examples. *Passer domesticus* (common house

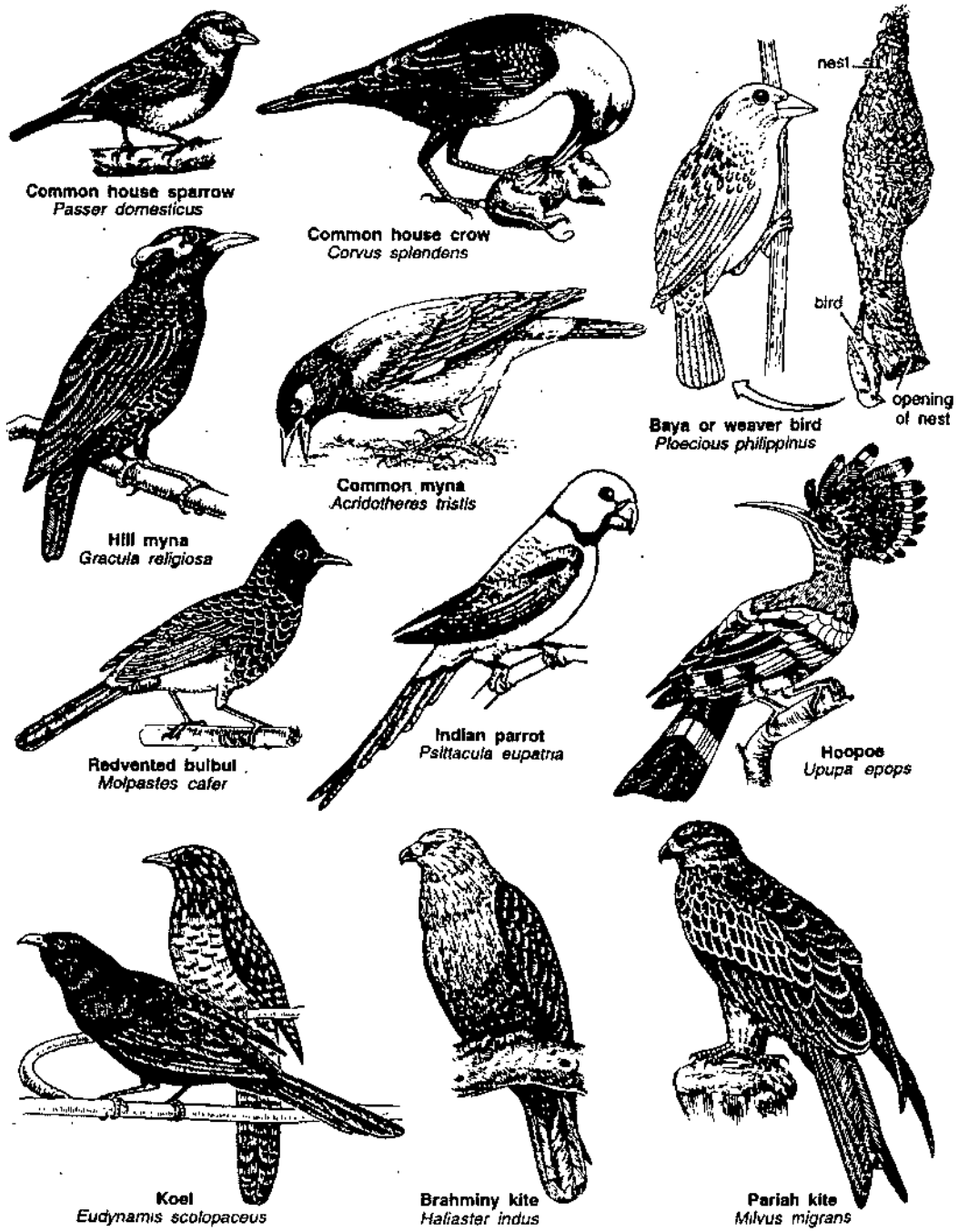



**Fig. 3. Few common Indian Birds.**

sparrow), *Corvus slpendens* (house crow), *Corvus macrorhynchos* (jungle crow), *Acridotheres tristis* (common myna), *Ploceus philippinus* (weaver bird or baya), *Muscicapa* (fly catchers), *Molpestes* (bulbuls), etc.

### Order 2. Piciformes

Beak is long straight or short and stout or strong and wedge-shaped and tongue is long and protrusible. Toes zygodactylous with curved claws. Examples. Wood peckers, toucans, barbets and honey suckers. *Dendrocopus mahrattensis* (yellow fronted pied wood-pecker), *D. brunneifrons* (Himalayan woodpecker), *Dinopium benghalensis* (golden-backed woodpecker).

### Order 3. Columbiformes

It includes pigeons and doves. Body compact, beak stout or slender, that is swollen and hardened at the decurved tip. Youngs born altricious. Examples. *Columba livia* (blue rock pigeon), *Crocopus* (green pigeon), *Carpophaga aenea* and *C. cuprea* are pigeons of South India, *Streptopelia risoria* (ringed turtle dove), *Streptopelia chinensis* (spotted dove), etc.

### Order 4. Psittaciformes

It includes gorgeously coloured parrots. Beak is short, stout with strongly arched movable maxilla and truncated mandible. Toes zygodactylous. Examples. *Palaeoornis torquatta* (rose ringed parkeet), *Psittacula* (green love bird), *Psittacula krameri* (green parrot), etc. All these above birds are arboreal.

## Terrestrial Birds

These are flying birds and are able to walk or run on ground.

### Order 5. Galliformes

It includes grouses, quails, pheasants and turkeys, etc. Beak is short, feet are adapted for perching, scratching and running. Youngs born precocious. Examples. *Gallus* (red jungle fowl), *Pavo cristatus* (pea fowl), *Cotrunix cotrunix* (quail), *Phasianus* (pheasants), *Perdix hodgsoniae* (partridge), etc.

### Order 6. Cuculiformes

It includes cuckoos and plantain eaters. Beak is moderate and tail is long. Feet zygodactylous and are not adapted for grasping. Cuckoos lay their eggs in the nest of crows for incubation and rearing. Youngs born altricious. Examples. *Eudynamis honorata* (Indian koel), *Centropus sinensis* (crow pheasant), Cuckoo (*Cuculus canorus*), etc.

## Swimming and Diving Birds

### Order 7. Anseriformes

It includes aquatic birds like geese, swans and duck. Margins of the beak are edged both above and below by horny lamellae. Presence of an evaginable penis. Examples. *Anas* (wild duck or mallard), *Anser indica* (bar headed goose), *Cygnus* (swan), etc.

### Order 8. Coraciformes

It includes kingfishers, horn bills and hoopoes, etc. In kingfishers head bears a crest and long stout beak and youngs born altricious. Examples. *Halcyon smyrnensis* (white breasted kingfisher), *Ceryle rudis* (pied kingfisher), *Dichoceros bicornis* (Great hornbill), *Upupa epops* (hoopoe), *Merops* (bea eaters), etc.

### Order 9. Gaviiformes

It includes loons (*Gavia*), marine birds. There are four species of *Gavia*.

### Order 10. Colymbiformes or Podicipediformes

Aquatic birds with webbed or lobed toes. In *Colymbus* beak is strong, straight, acute and compressed, while in grebes beak is moderate, often decurved, slender in *Aechmphorus* or stout in *Podilymbus*. Examples. *Colymbus* (diver), *Podicipes* (grebes), etc.

### Order 11. Procellariformes

It includes petrels, albatroses, fulmars and shearwaters. These are oceanic birds having extreme powers of flight-soaring type. Examples. *Diomedea* (albatross), *Gymodroma* (petrel), *Procellaria* (petrel), *Puffinus* (shear water). *Priofinus* (night hawk), etc.

### Order 12. Pelecaniformes

It includes pelicans, cormorants, etc. Aquatic birds well adapted for diving and fishing. Toes webbed. Presence of gular pouch on throat except tropical birds. Examples. *Pelecanus* (pelican), *Phalacrocorax* (cormorant), *Sula* (solan goose), etc.

## Shore birds and Wadding birds

### Order 13. Charadriiformes

It includes plovers, sand pipers, snipes, etc. Long wading legs, toes webbed and beak mudprobing. In jacanas, all the four digits are very long to walk on floating vegetation.

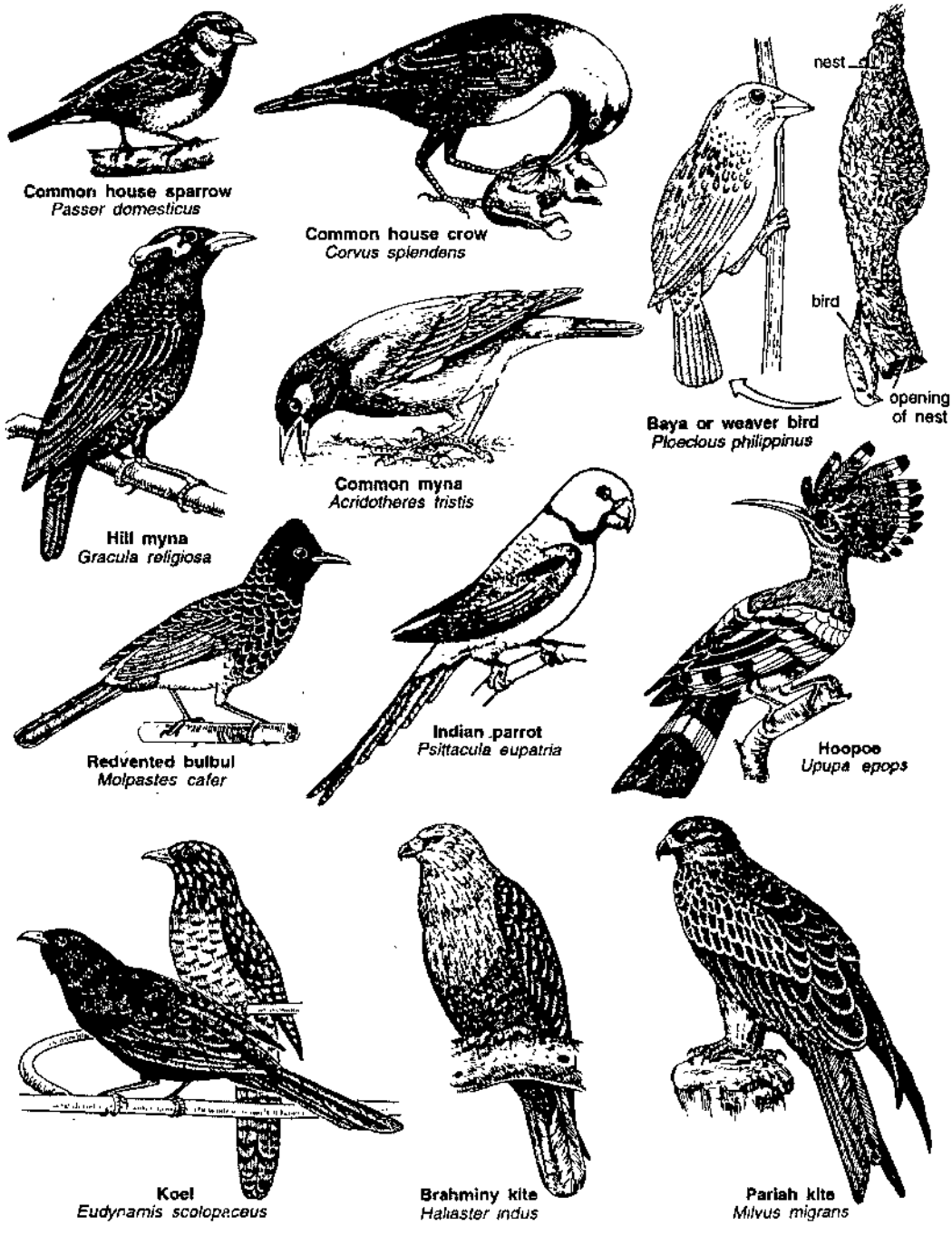



Fig. 4. Few common Indian birds

Examples. *Scolopax rusticula* (wood cock), *Aegialitis hiaticola* (ringed plover), *Hydrophasianus chirurgus* (Indian jacana), *Tringa glariola* (sand piper), *Capella* (snipe), *Larus* (gull), *Numenius* (curlew), etc.

### Order 14. Ciconiformes

It includes storks, herons, flamingos etc. Long-legged, marshy wading birds with long snake-like neck, pincer-like beak. Spoon bills have flattened beak dilated terminally in the form of spoon. Flamingos have very long slender neck and beaks abruptly bent down from the middle, example *Phonicopterus*. In storks the neck and beak long, stout, straight and cylindrical. Front toes are partially webbed having flattened claws. Examples. *Tentalus, Anastomus* and *Ciconia*, etc.

Herons frequenting lakes and rivers where they often been seen standing in ankle-deep water and watching for their prey. Examples, *Nycticorax* (night heron), *Butorides* (heron), etc.

In Ibises beak long and weak, nearly cylindrical and strongly curved. Examples. *Ibis, Inocotis*, etc.

### Order 15. Gruiformes

It includes cranes, bustards, sun-bitterns, etc. Legs long, front toes are partially webbed, but slightly webbed in *Heliornis*. Examples. *Antigone antigone* (sarus crane), *Collaris* (crane), *Rallus aquaticus* (water rail), *Otis* (bustard), *Choriotis* (bustard), etc.

## Birds of Prey

### Order 16. Falconiformes

It includes carnivorous vultures, carrion hawks, eagles and falcons, etc. Beak sharp, strong and curved terminating into hook-like structure. Feet are perching and toes with powerful claws. Examples. *Milvus migrans* (common pariah kite), *Haliaster indus* (brahminy kite), *Aster badius* (sparrow hawk), *Pseudogyps bengalensis* (white backed vulture), *Sarcogyps calvus* (king vulture), *Milvus ictinus* (red kite), *Baza* sps. (falcon), etc.

### Order 17. Strigiformes

It includes owls which are nocturnal birds having beaks stout, decurved with a sharp hook at the tip. Toes are padded below with long, sharp and curved claws. Eye large and directed forward. Examples. *Tyto alba* (barn owl), *Ketupa* (Brown fish owl), *Bubo tylopus* (great horned owl), etc.

## Aerial Birds

### Order 18. Micropodiformes (Apodiformes)

It includes swifts and humming birds.

Beak small and weak in swifts and slender and elongated in humming birds. Examples. *Micropodus* (Indian swift), *Cypselus* (swift), etc.

### Order 19. Caprimulgiformes

It includes owl-like nocturnal insectivorous birds.

Beak short, hooked, toothed and decurved. Eye large. Examples – *Caprimulgus* (goat sucker), *Chordeiles* (night hawks), *Batrachostomus* (frog mouth), etc.

## Flight Adatations in Brids

Birds are the masters of air (**Young**, 1958). Practically all the systems and organs are modified for the purpose of flying in the air. It is to escape from the land and sea bound predators and to make long migrations to take advantage of favourable seasons. Birds are best adapted morphologically, anatomically and physiologically.

### Morphological Adaptations

**1. Shape.** The body of the birds is spindle-shaped that faces minimum resistance from the wind and hence propelled smoothly through the air. Their body is compact and

light, but strong dorsally and heavier ventrally, which helps in balancing the body in the air. Wings are attached high up on thorax, and high position of lungs and air sacs, and low and centrally located heavy muscles, sternum and digestive organs are also important for the flight.

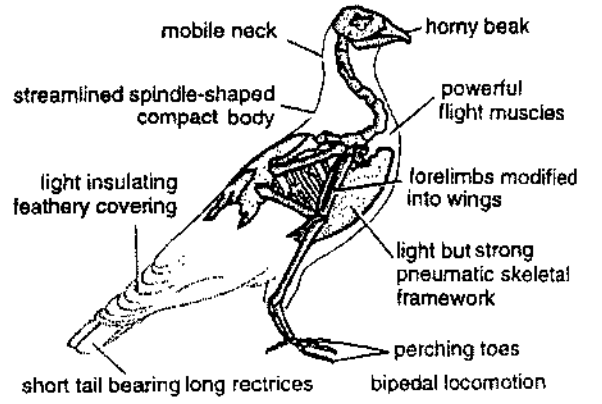



**Fig. 5. Spindle-shaped birds body and their light weight.**

**Exoskeleton** as feathers of birds is an important character of birds. They are closely fitted enclosing a layer of air in between the body and itself, which becomes warm due to body temperature. Thus, serving as non-conducting layer and make the body light in weight. The flight feathers and tail feathers have a broad flexible vane, through which air does not pass. Tail feathers serve as rudder during flight and balance the body during perching.

**2.** Both the jaws are projecting forward to form the beak used for taking food and for making nests and hence there is a loss of weight from the anterior end of the body.

**3.** Legs have shifted forwards for the sake of balancing and adjustment of the body.

Anterior limbs have modified as wings, situated high up on thorax, which help the bird to fly in the air.

### Anatomical Adaptations

**1. Large flight muscles.** Flight muscles on the breast are greately developed and weighs about one-sixth of the entire body. While back muscles are reduced. The wings are lowered by an enormous pectoralis major and elevated by pectoralis minor.

**2. Perching.** Hind limbs of birds are well suited for arboreal life. Their muscles help in perching over a tree etc., or to capture prey in case of carnivorous birds etc.

**3. Endoskeleton.** The reduction of the body weight to facilitate easy flight is braught by the pneumaticity of the bones. The bones are spongy and have extensions of the air sacs. The skeletal frame-work is compact and rigid. It is due to the fusion of certain bones.

**Skull.** The bones of the skull in adults are closely fused to with-stand the effect of varying pressures of the air. The teeth are lacking and jaws are covered by horny material.

**Vertebral column.** The first four thoracic vertebrae are fused to form a firm fulcrum for the working of wings. In flightless birds these are free.

**Synsacrum** is formed by the fusion of last thoracic vertebra, six lumbars, two sacrals and five anterior caudal vertebrae. It provides surface for the attachment of iliac bones of the pelvic girdle. The fustion of iliac bones with the synsacrum gives a long and strong grip of the backbone to the pelvic girdle. It facilitates the balance of the body.

**Pygostyle.** Last four or five caudal vertebrae are fused to form the pygostyle, which offers a strong attachment to the tail feathers.

**Sternum** has a vertical keel, which offers a surface for attachment for pectoral muscles and it also supports the viscera.

**Pectoral girdle** has a stout **scapula** runs on the outer side of the ribs to strengthen the thoracic basket formed by the fustion of fused thoracic vertebrae, lateral ribs with uncinate processes and ventral sternum.

**Clavicles** and **interclavicle** are fused to form a V-shaped bone, the **furcula** (mery thought), which acts as a spring to keep the wings well apart.

**4. Alimentary canal.** Mouth is very wide bounded by upper and lower beaks (jaws), which facilitate the easy ingestion of food. **Crop** (basal part of oesophagus) serves to store the food, which swallow the bird quickly. **Gizzard** is used to macerate the food. Rectum is short because faecal matter is relatively small and bird gets rid of it at once.

In cloaca, water is absorbed from the faeces and urine, thus, it helps in osmoregulation.

**5. Respiratory organs. Lungs** are solid, spongy and are closely fitted into the space between ribs. **Air sacs** are in communication with lungs for more rapid and efficient respiration. Air sacs do more perfect aeration of lungs and helps in the regulation of body temperature. Birds lungs are completely emptied with each breath and hence there remains no residual air, a more effective respiration.

While flying, movements of wings help in respiration by compressing and dialting the lungs and air sacs. Thus, birds breath more easily during flight.

**6. Warm bloodedness.** Birds are warm-blooded. Complete aeration of blood is responsible for high temperature of the body. It provides more energy to the bird during flight.

**7. Circulatory system.** Birds heart is completely four-chambered and they have double circulation of blood. Their red blood corpuscles have high proportion of haemoglobin, which is responsible for quick and perfect aeration of tissues.

**8. Urecotelic excretion.** Urinary bladder is not found in birds, hence urine is not stored in the body. Water of the excretory fluid is reabsorbed in the urinary tubules and coprodaeum of cloaca. Thus, the excreta becomes semisolid, that contains mainly insoluble uric acid and urates, which are expelled at once. This condition helps in reducing the body weight of the birds.

**9. Brain and sense organs.** Birds have acute sight and thus, their eyes are large, accordingly optic lobes are very large. Cerebellum is also well developed and convoluted, which is responsible for equilibrium and muscular coordination.

**10. Single ovary.** In the female birds, only single left ovary and oviduct is present that condition reduces the body weight essential for flying

## • 10.3. EXOSKELETON (FEATHERS) IN BIRDS PIGEON (*COLUMBA LIVIA*)

Birds possess an exoskeleton of feathers. The **feathers** are not uniformly distributed over the entire body, but are confined to areas **(pterylae)** in contrast to areas without feathers **(apteria).** They are shed at intervals. They are of utmost importance to the birds as they are light, elastic and water proof epidermal drivatives. They are derived from the reptilian scales as prooved by the presence of small feathers springing out from amongst the scales of feet in some birds. They form protective outer coverng over the body.

### Structure of a Typical Feather

A typical feather like **contour,** consists of :

1. A proximal quill or calamus.
2. Distal vane or vexillum.

**Quill or calamus.** It is hollow, semi-transparent and cylindrical stalk, which is partly embedded in the skin. It has a minute opening, the *inferior umbilicus* at the lower end through which a vascular papilla of the dermis projects into the growing feather. Another small opening, called **superior umbilicus** lies on the ventral side at the junction of quill and rachis. At this point, in some birds, there is a small tuft of feathers, called the **aftershaft** (hyporachis), which is very long in some cases **(emus).**

**Vane or vexillum.** Vane is the distal expanded part of the feather, which consists of a central

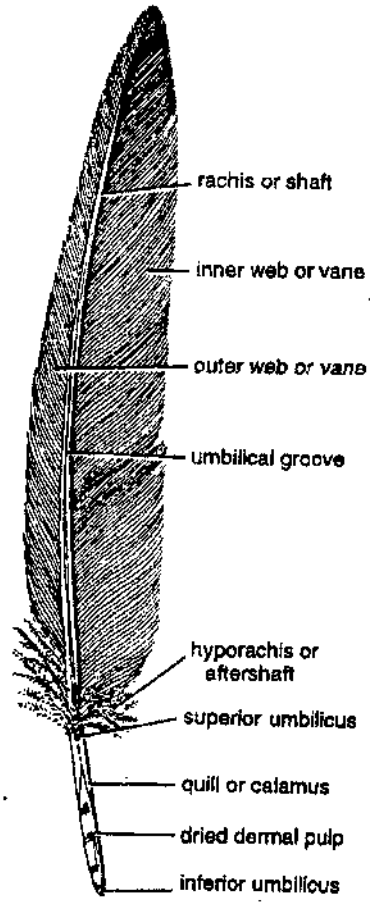



**Fig. 5. Pigeon. Structure of a typical feather.**

longitudinal solid **rachis.** It is a continuaton of the proximal quill and it bears a longitudinal ventral groove, the **umbilical groove.**

On either side of rachis are found a series of numerous **barbs** and their branches, the **barbules.** Barbs are delicate, thread—like horny plates, which extend obliquely outwards from the rachis. Each barb carries smaller processes, called the **barbules,** which are also set obliquely on each side of the barb in such a way that the barbules of the distal side overlap the barbule of the proximal side of the next higher barb. The lower edge of each distal **barbule** is fringed with small **hooklets** or **barbicels (hamuli)** at the distal end, which interlock with the corresponding **ridges** or **flanges** found over the **proximal barbules** of the next barb. Thus, by this **interlocking system of barbules** a continuous blade is formed for striking the air in flight.

Interlocking system of barbules provide an unbroken surfaces, flexibility and also resistance against air.

### Kinds of Feathers

On the basis of the arrangement of barbs and barbules and the length of the shaft or axis, the feathers are of four kinds :

1. Quill feather or pennae.
2. Down feather.
3. Filoplume.
4. Rictal bristles.

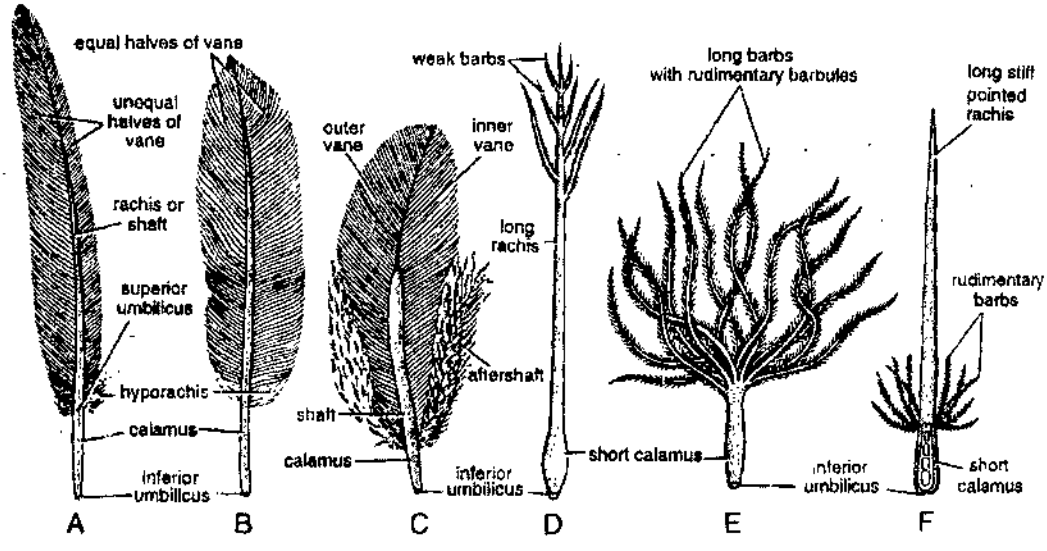



**Fig. 6. Kinds of feathers. A–Remix, B–Rectrix, C–Filoplume, E–Down, F–Rictal bristles.**

**1. Quill feather.** The quill feathers form the general covering of the adult body. In structure, they are similar to that of a typical as has been described above. According to the position they are differentiated into the following kinds :

**(a) Coverts.** Those small quill feathers, which found at the bases of the wings and tail feathers above and below are called the **coverts.**

**(b) Contours.** These are found over the general surface of the body and are relatively smaller and have poorly developed barbules.

**(c) Remiges.** Remiges are those feathers that are found over the fore-limbs of the birds and help in flight. They can be **primaries, secondaries** and **tertiaries,** if found scattered on the hand, on the forearm and on the upper arm, and elbow respectively.

**(d) Rectrices.** The contours when present on the tail are, called rectrices and these are arranged in a semi-circle over the uropygium and help in changing the direction of flight.

**2. Down feather.** They are small and soft having no rachis. Here the shaft is soft, the barbs and barbules do not form vane as hooklets are wanting. First formed down feather is, called the **nestling down feather,** which completely cover the youngs body.

They are very simple in structure having no distinct rachis. Barbs arise from the tip of the feather papilla, where as the barbules do not have hooklets. In the adult, some of the nestling down are replaced by the contour feathers, while the remaining ones are retained as **permanent down** or **powder down feathers** between the bases of contour feathers. The permanent downs have small hollow **quill** bearing numerous barbs distally, the rachis being absent. They keep the body warm acting as heat insulators.

**3. Filoplume.** They are still simpler in appearance and lie scattered in between the bases of contour feathers. They are hair-like, long with slender shaft or rachis, a short calamus and a few weak barbs at the tip.

**4. Rictal bristles.** These are believed to be modified filoplumes, which are hard hair-like found in some birds (fly catcher) near mouth. Each bristle has a short quill and a long stiff rachis, which bears few barbs at its base.

## • 10.4. FLIGHT MUSCLES OF PIGEON (BIRDS)

The flight muscles are the most highly developed muscles of birds that are associated with the forelimbs. In piegon, their flight muscles comprises **depressor, elevator, accessory depressors** and **tensor muscles.**

**1. Depressor muscles.** Depressor muscles are also, called as **pectoralis major**. They are of enormous size and weigh about one-fifth of the toal weight of the body. They are red in colour in flying birds, while in flightless fowl they are white. They are attached on the entire surface of the sternum of its side and on the other hand with the ventral surface of the humerus. When contract, these muscles depress the wings *producing a* ***down stroke***.

**2. Elevator muscles.** Elevator muscles are meant for raising the wings. These muscles are also, called **pectoralis minor** or **sub-clavius.** Each pectoralis minor arises from the anterior part of the sternum dorsal to the pectoralis major. Its strong tendon runs upward, passes through the **foramen of triosseum** and finally become inserted on the dorsal surface of the humerus bone. The foramen triosseum acts as a pully, therefore when pectroralis minor muscles contract, the wings are elevated.

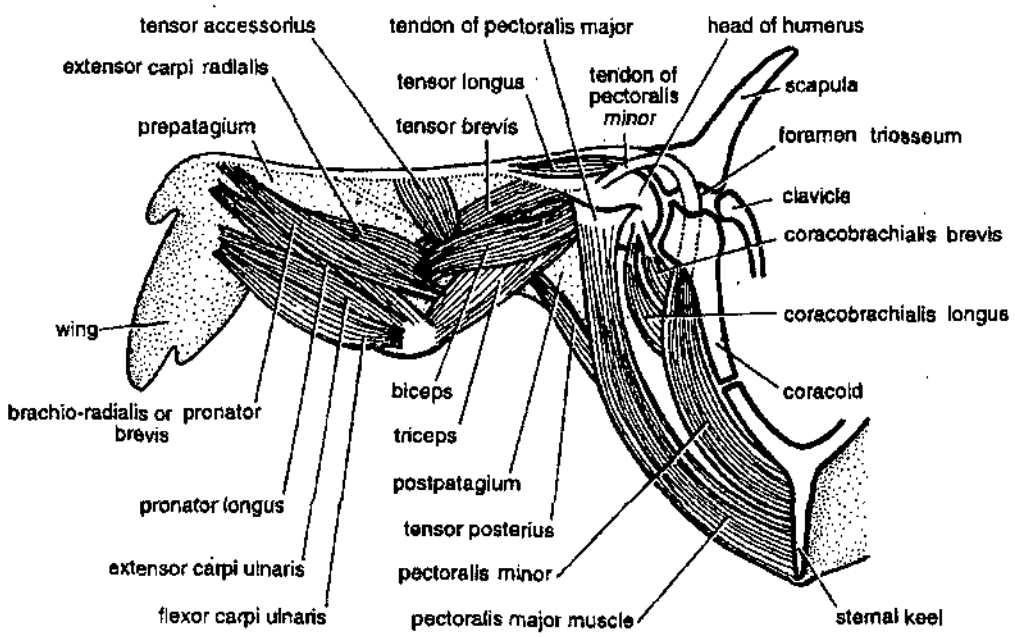



**Fig. 7. Pigeon. Flight muscles of Pigeon.**

**3. Accessory depressor muscles.** The accessory depressor muscles include the **coracohumeral** and **coracobrachialis. Coracobrachialis longus** is a small triangular muscle lying beneath the pectoral muscles and arises from the coracoid and

the sternum and its tendon is attached with the under surface of proximal part of humerus. **Coracobrachialis brevis** lies anterior to the longus. They help in pulling down the wings.

## • 10.5. PERCHING MUSCELES

While the bird is at rest or sleep on a support say twig or a bunch, it does not fall off. It is because of the curious arrangement of certain muscles and their tendons stretched on the legs and digits.

The perching muscles are the following :

**1. Flexor digitorum.** The flexor digitorum muscle is attached to the tibiotarsus bone of the shank. Its strong tendon passes over the metatarsal joint and at the base of digits divides into three branches, which become inserted on the underside of the three forwardly directed digits.

**2. Flexor perforans.** The flexor perforans muscle is stretched to the side of tibiotarsus. Its tendon is similarly stretched in the backwardly directed digit.

**3. Ambiens muscle.** It arises from the **pectineal process** of the ileum and found attached on the inner side of the femur. It gives of a tendon, which runs over the patella bone upon the knee joint and merges with the flexor digitorum muscle. It also helps in tightening the perch, but only flexing the second toe.

Besides these the big calf muscle **gastrocnemius** and the **peroneus longus** on the anterior side of tibotarsus (crust) assist in perching.

### Perching Mechanism

At the time of perching, the bending of metatarsal joints (between the tibiotarsus and tarsometatarsus) takes place over the shank. This brings about simultaneous pull upon the four tendons inserted on the underside of the toes, causing the toes to bend internally so as to grip the support firmly. When the bird is asleep then the weight of the body is enough to keep the tendons stretched and hence there is no danger of falling off.

When the bird want to leave the perch, the mesotarsal joint is extended with the result the toes are pulled apart releasing the grip. This is caused by the **tibialis anterior muscle** and its exterior tendon. The exterior tendon crosses the front of the ankle joint, trifurcattes and become inserted in all the three forwardly directed toes.

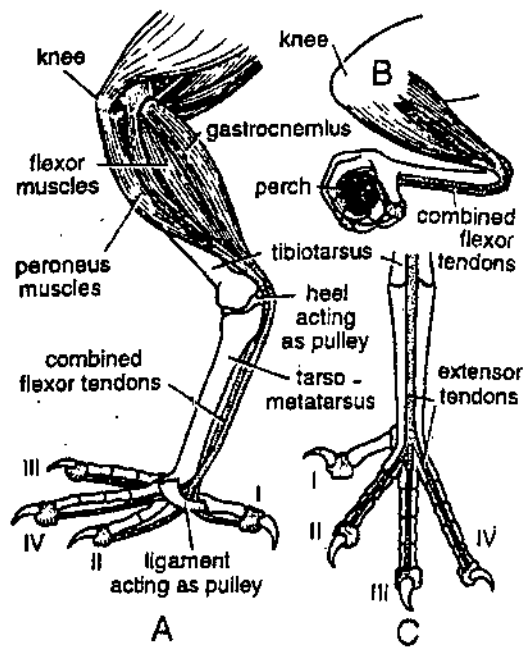



**Fig. 8. Perching muscles of pigeon.**

## • 10.6. DIGESTIVE ORGANS OF PIGEON

The alimentary canal of Pigeon consists of the following parts :

**1. Mouth and buccal cavity.** Mouth is bounded by an upper and lower horny beak, which bear no teeth. It leads into the **buccal cavity** at the floor of which lies the **tongue.** The tongue is usually long, narrow, triangular and pointed. It bears taste buds and mucous glands. Buccal cavity leads in to **pharynx.**

**2. Pharynx.** It is the posterior most part of the buccal cavity. In its roof opens a pair of internal nares and behind them lies a median aperture of the **eustachean tube.** At the base of the pharynx is an oval aperture, the **glottis** leading into trachea. Posteriorly the pharynx leads into oesophagus.

**3. Oesophagus.** It is a long, wide, thick-walled distensible tube running through the neck and at the base of neck, it enlarges to form **crop.**

**4. Crop (ingluvies).** It is a thin-walled, elastic non-glandular chamber into which hurriedly swallowed seeds are stored and softened. Inside the crop are two large patches of **crop glands,** which are present in both sexes. During breeding season, the crop glands become active to form **pigeon milk,** which is given to young ones. Crop leads into stomach.

**5. Stomach.** It is differentiated into two parts :

(i) Anterior part, **proventri- culus** containing the gastric glands. It represents the caradiac part and secretes gastric juices.

(ii) Posterior part, the **gizzard.** It is a very hard structure having thick and muscular walls. Its internal surface is lined by hard horny coat forming ridges and grooves. Its cavity contains small pieces of stones, which the bird habitually pick up during feeding. It is a powerful grinding organ. The gizzard is followed by the **intestine.**

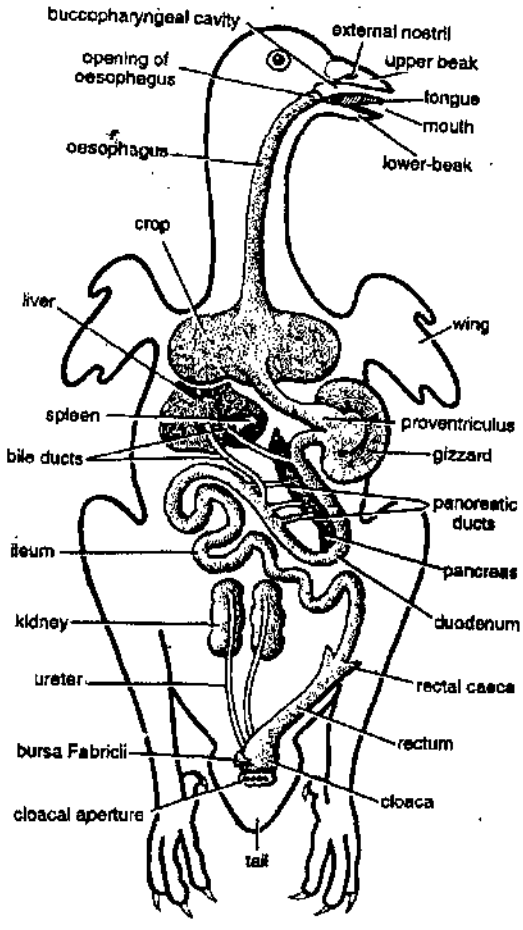



**Fig. 9. *Columba* (Pigeon). Digestive system.**

**6. Intestine.** It includes U-shaped **duodenum,** and long coiled **ileum.** In between the two limbs of duodenum lies the pancreas. The inner mucosa of the duodenum is prolonged to form a large number of **villi** and **crypts of lieberkuhn** in between the villi. Goblet cells are also found in the mucosa. In ileum, number of villi is much more numerus than the duodenum. It is continued behind as rectum.

**7. Rectum.** It is short and at the junction of the ileum and rectum found a pair of blind diverticulae, called the **caeca.** The rectum leads into **cloaca.**

**8. Cloaca.** It is divided into three parts, *i.e.,* anterior **coprodaeum** receiving the rectum, middle **urodaeum** receives ureters and genital ducts and posterior **proctodeum** leading to exterior by **vent.** A sac of unknown function, the **bursa Fabricii** opens into the *proctodaeum.*

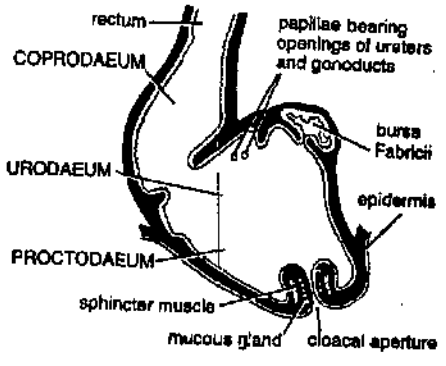



**Fig. 10. Cloaca of pigeon.**

### Associated Glands

No salivary glands are present, though some buccal glands are present in the mouth, which secretes mucous. There are two large glands found associated with the alimentary canal.

**1. Liver** is bilobed and lies on the dorsal and lateral sides of stomach. The left lobe is smaller. There are two bile ducts, one from each lobe, which lead to duodenum. **Gall bladder** is absent in pigeon. It secretes bile juice which is directly poured in the duodenum.

**2. Pancreas** is reddish, diffused gland, present in between the two limbs of duodenum. Three pancreatic ducts arise from it and open seprately in the distal limb of duodenum.

## • 10.7. RESPIRATION IN PIGEON

In general, respiration can be defined as a process by which oxygen is supplied to the protoplasmic system and from them carbon dioxide, heat and energy needed for metabolic activities is liberated. This process has two phases, *i.e.*, external respiration and internal respiration. The **external respiration** includes gaseous exchange in the respiratory organs, with the result oxygen comes in blood. The blood carries the oxygen to the tissues where again gaseous exchange takes place with the result oxygen is given to the protoplasm and carbon dioxide is taken from it. This is **internal respiration.** Usually under respiration, comes the first phase, which can be defined as — "*The process of supplying oxygen from the air or water to the blood stream and releasing the carbon dioxide.*" This gaseous exchange takes place through moist membranes in the lungs of birds.

### Respiratory Organs of Pigeon

Birds have extremely efficient and unique respiratory system. The respiratory organs includes the nostrils and nasal pasages, trachea, the bronchi, the lungs and the air sacs.

**1. Nostrils and nasal passages.** The paired nostrils lie at the base of the upper beak and are surrounded by soft, fleshy, naked, and sensory skin, the **operculum** or **cere.** These lead into short nasal passages, which open into the pharynx by internal nares. The **glottis** lies at the base of the tongue, it leads into trachea.

**2. Trachea.** At the anterior end of the trachea lies the **larynx** into which opens the glottis. It is supported by poorly developed cartilages, a **cricoid** divided into four pieces, called the **procricoids** and paired **arytenoids.** It does not function as vocal organ as in other vertebrates. Larynx continued behind in the trachea. The **trachea** is as long as the neck lying ventral to the gut and is supported by means of **complete bony rings.** The trachea divides into two **bronchi** within the body cavity.

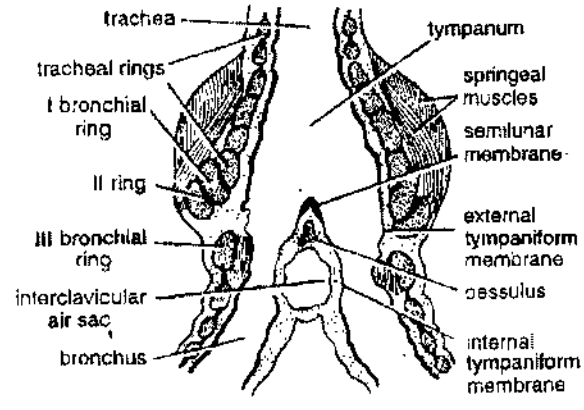



**Fig. 11. Pigeon. Syrinx. (L.S.).**

**3. Syrinx.** At the junction of trachea with the bronchi, lies the sound producing organ, the **syrinx.** It is supported by last 3 or 4 bony rings of trachea and first bony incomplete ring of each bronchus, which modify to form **syringeal arches.** These enclosed an enlarged chamber, the **tympanum.** It is lined by soft cushion-like mucous membrane. From the median lateral walls of each branchus arises a membranous fold, the **tympanic membranes,** projecting into the cavity of syrinx. From the dorsal side and where the trachea divides into bronchi, projects a bar of cartilage, called the **pessulus** into the tympanum. Its lower part supports a membrane, the **membrana semilunaris.**

Syrinx is operated by two sets of muscles :

1. A pair of **intrinsic syringeal muscles,** arising from the sides of trachea and are inserted into the syrinx.

2. A pair of **sterno-tracheal muscles,** arising from the sternum and are united with the trachea infront of syrinx.

Thus, sound is produced by the vibrations of **membrane semilunaris** and its pitch is controlled by these above muscles.

**4. Bronchi.** The **bronchi** run behind and each bronchus enters the lung of its own side. Each bronchus is supported by **cartilaginous rings,** which are incomplete mesially. As soon as bronchus enters the lung, it looses the cartilaginous rings and become **mesobronchus,** which enlarges to form **vestibule** inside the lung. The vestibule extends backwards and divides into 2 branches, one enters the abdominal and

the other **posterior thoracic air sacs.** Besides these the vestibule gives of series of tubes, *viz.*, **secondary bronchi,** *i.e.*, 4 to 6 ventral **endobronchi** and 7 to 10 dorsal **ectobronchi.** These secondary bronchi are further divided to give small tubes, the **parabronchi** (air pipes) of uniform diameter. These parabronchi of ecto- and endobronchi are connected with each other forming **inter-connecting loops.** The para-bronchi further divided into more thinner branches, the **air capillaries (bronchioles).** These are surrounded by blood capillaries.

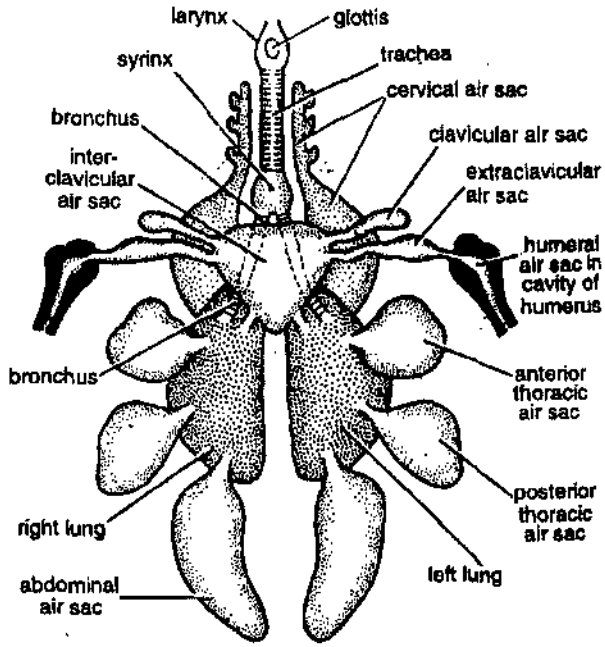



**Fig. 12. Columba. Respiratory organs.**

**5. Lungs.** The lungs are small, paired, compact structures, which are lodged one on either side in the thoracic cavity. They are solid, spongy and slightly elastic. Their dorsal surfaces are nacked and remain closely applied against the vertebral ribs and vertebral column. Ventrally they are covered by a strong sheath of fibrous tissue, which is called **pulmonary aponeurosis** or **pleura.** Small **costo-pulmonary muscles** arise from the junction of the vertebral and sternal ribs and spread fan wise over the pleura. The lungs of birds are characteristic in the possession of air sacs.

**6. Air sacs.** The air sacs are the expansions of the blind ends of some of the main bronchial tubes. They are extremely thin-walled and are lined with squamous epithelium and supporting connective tissue. They are externally covered by peritoneum. Some of them communicate with the air cavities in the bones. The air sacs make the body **pneumatic,** preserve heat and assist in respiration, making possible a complete gaseous exchange in the lungs at every breath. In pegion, there are five pairs of air sacs, which are listed below :

1. **A median interclavicular** at the angles of the two bronchi. It is originally paired, which unite in the centre to form **median inter-clavicular air sac.** It is connected with both the lungs and is produced on either side as short **axillary** or **clavi- cular air sacs** in the arm pits and an **extra-axillary air sacs,** which communicate the cavity of humerus.

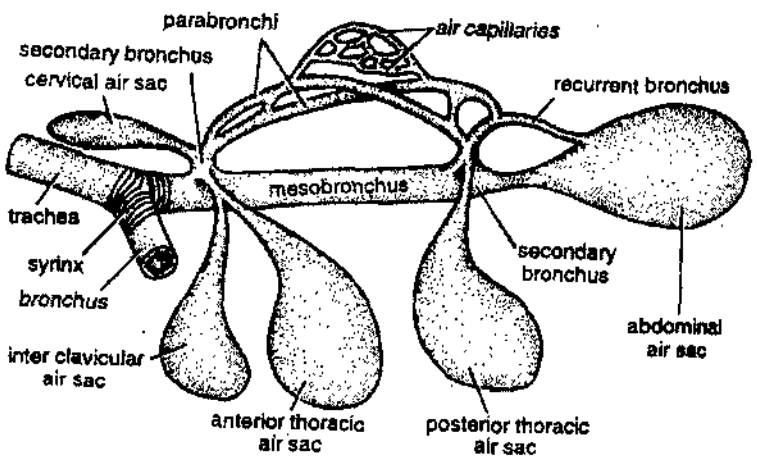



**Fig. 13. Pigen. Lungs and origin of air sacs.**

2. A pair of **cervical** or pre-branchial at the base of the neck. They give small prolongations in the neck.

3. A pair of **anterior thoracic** air sacs in the anterior part of the thoracic cavity.

4. A pair of **posterior thoracic** air sacs in the posterior part of the thoracic cavity applied to the side walls of the body.

5. A pair of **abdominal** air sacs which lie in the coils of intestine.

The abdominal and posterior thoracic air sacs are some times collectively, called as **inspiratory air sacs,** where as the remainng air sacs are, called **expiratory air sacs** as in them the air passes during expiration.

Each air sac receives one ventral endobronchus and several **recurrent bronchi** or **saccobronchi,** which connect the air sacs with the parabronchi. Recurrent bronchi are not found in cervical air sacs.

### Mechanism of Respiration

**At rest.** The inspiration and expiration is brought about by alternate lowering and raising of the sternum and ribs. By the contraction of **intercostal muscles.** which are stretched in between the ribs, the sternum is lowered. This causes an increase in the volume of the body cavity, with the result air enters the lungs and air sacs dilate. The air rushes them from out side through lungs. In pigeon, air first rushes only in the **inspiratory air sacs.** When sternum is raised, by the contraction of the **abdominal muscles,** the body cavity reduces in size, the air sacs are pressed and the air rushes out through lungs. But some of the air from inspiratory air sacs enters the expiratory air sacs. Thus, during inspiration the inspiratory air sacs are filled up and expiratory air sacs being emptied, while in expiration, the inspiratory air sacs become emptied and expiratory being filled up. The gaseous exchange takes place in the lungs, both during inspiration and expiration. Thus, no unused air is left in the lungs.

**During flight.** During flight, the sternum and ribs remain rigid and stationary. Therefore, their lowering and raising is not possible. The some effect is brought about by raising and lowering of the back and up and down movements of the wings.

## • 10.8. URINOGENITAL ORGANS OF PIGEON

Reproductive and excretory organs of birds, like other vertebrates are **mesodermal** in origin and develop quite independent of each other in the embryo. But in the adult, the two systems come close to each other intimately specially in the male, to perform the common cause. Therefore, the two systems are together spoken as urino-genital system.

### Excretory Organs

1. **Kidneys** are paired, flattened, irregular structures and are found in the posterior region of the body cavity. Each kidney is chocolate-coloured and is trilobed having anterior, middle and posterior lobes. Each lobe is made up of numerous **renal tubules,** which start as **Malpighian bodies** and possess **Henle's loop** in whch water is absorbed and thus helps in osmo-regulation. These renal tubules join and finally open into the ureter.

2. **Ureters** are paired and arises as narrow ducts from the first lobe of each kidney. They run behind and finally open separately into the urodaeum of cloaca. The **urinary bladder** is not present. Kidney excretes the nitrogenous waste in the form of **uric acid** granules, since the water is absorbed in the cloaca.

**Supra-renal** or **adrenal gland** are found attached on the anterior lobe of each kidney. It is yellow in colour and is endocrine in function.

### Male Reproductive Organs

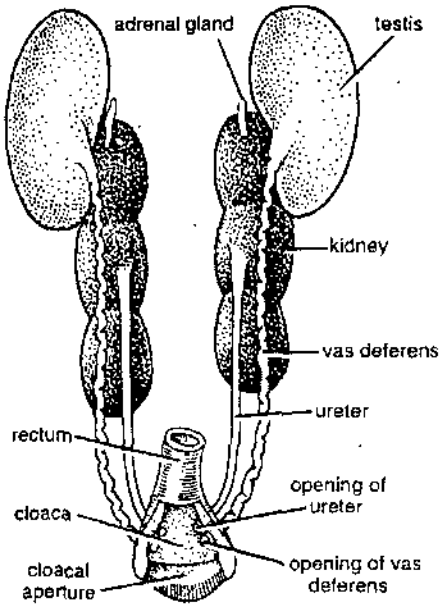
### MALE

The male organs comprise mainly the paired testes and paired vasa differentia. The copulatory organs are absent.

**1. Testes.** These are oval, whitish structures, which are attached to the anterior end of the kidney on the ventral surface with the help of **peritoneum.** The size of testes vary according to the season. In the breeding season, they increase in size. Each testis is formed of usual **seminiferous tubules** bound together by connective tissue. These tubules are lined by single layer of **germinal epithelium,** whose cells produce

spermatozoa. In between the tubules are found groups of **interstitial cells** or **cells of Leydig,** which are endocrine glands. There is no well marked epididymis.

**2. Vas deferens.** It arise from the inner border of each testis, runs behind parallel but outside the ureter and finally opens upon a small papilla into the urodaeum of cloaca. They open by separate apertures, which lie just behind the ureter openings. Before opening, each vas deferens dilates to form **seminal vesicle** to store the sperms.




**Fg. 14. *Columba*— Male urinogenital organs**

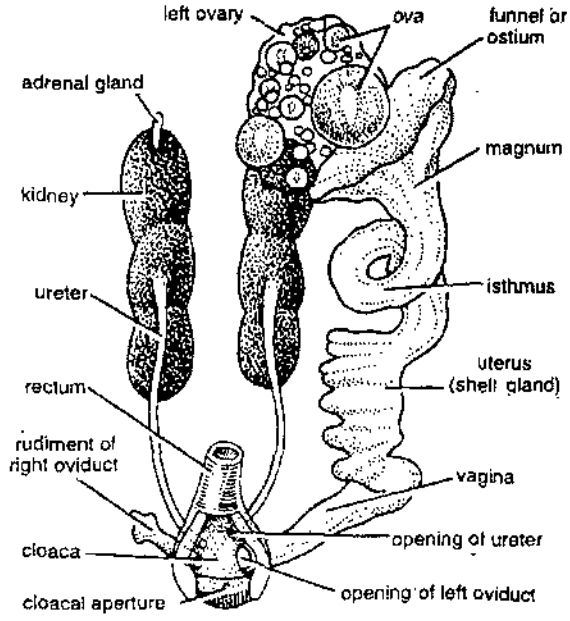



**Fig. 15. *Columba*—Female urinogenital organs**

## FEMALE

The female organs are characteristic in the possesion of only left **ovary** and left **oviduct.** The right ovary and oviduct are present in the embryo, but as the animal becomes adult, they degenerate, leaving only vestige of right oviduct attached to the right side of the cloaca.

**1. Left ovary** is large, lobulated and is attached to the first lobe of the left kidney by a fold of peritoneum. Its general surface is raised up into rounded elevations, each of which lodges an ovum in different stages of development.

**2. Left oviduct** is a long and convoluted tube, which can be differentiated into several regions :

(i) **Oviducl funnel.** It is the anterior most funnel-shaped part of the oviduct, which opens into the body cavity by a wide **ostium** facing ovary.

(ii) **Magnum.** Oviducal funnel leads into a glandular part, called the magnum, the secretion of which forms the albuminous coat over the egg.

(iii) **Isthmus.** It is the next part of the oviducts secreting **shell membranes.**

(iv) **Uterus.** Isthmus part of the oviduct leads into thin-walled uterus, which secretes the **shell.** Uterus passes behind into a short **vagina,** secreting mucous for making the egg slippery. It opens into the urodaeum of cloaca.

### Significance of one Ovary

During the embryonic development of most of the flying birds, both the ovaries and oviducts develop, but later on in the adult only of the left side persists and become functional. However, the rudiments of the right oviduct, of course non-functional, may be found attached to the cloaca on the right side. The disappearance of right ovary and oviduct seem to be associated with the aerial mode of life.

1. The birds lay eggs which are often of bigger size. The development of these bigger eggs simultaneously in the two oviducts was impossble without adversely affecting the size of the eggs or body.

2. In the flying birds, nature has taken all the possible measures to make the body lighter and more efficient. The absence of one ovary and oviduct seem to be associated with this need. The absence has no doubt reduced the weight of the body without effecting adversely the efficiency of the body.

## • STUDENT ACTIVITY

1. Write an essay on flight adaptation in birds.

2. Define the term adaptation. Describe how bird is adapted to its mode of life ?

3. Give the general characters of class Aves.

4. Classify birds giving important features and examples of each group.

## • VERY SHORT QUESTIONS

1. **What type of exoskeleton is found in birds.**
   **Ans.** Feathers over the body, scales and claws on legs.
2. **What type of centrum is found in birds vertebrae ?**
   **Ans.** Birds vertebrae have heterocoelous (saddle-shaped) centrum..
3. **Which vertebrae of birds form the pygostyle ?**
   **Ans.** Last three or four tail vertebrae are fused to form a plough-shaped pygostyle.
4. **Which organ in birds helps in producing the sound ?**
   **Ans.** Sound in birds is produced by syrinx. Larynx is non-functional.
5. **In which super order of birds are included the flightless birds ?**
   **Ans.** Super order Plaeognathae or Ratitae includes the flightless birds

6. **In which super order of birds are included the penguins ?**

   **Ans.** Penguins (*Aptenodytes*) belong to super order Impennae and are found in Southern hemisphere.

7. **In which super order are included the flying birds ?**

   **Ans.** Flying birds are kept in the super order Neognathae.

8. **Write the name of order in which birds of prey are included ?**

   **Ans.** Birds of prey, like vultures, eagles, falcons, etc. are kept in the order Falconiformes.

9. **Write the names of various types of feathers found in birds.**

   **Ans.** Contour feathers, filoplumes, down feathers and rictal bristles. Wing feathers are called remiges and tail feathers rectrices.

10. **Write the names of flight muscles which elevates and depresses the wings.**

    **Ans.** Pectoralis major (depressors), pectoralis minor (elevators), accessory muscles and tensor muscles.

11. **What is the function of crop in pigeon ?**

    **Ans.** Crop is the expansion of the oesophagus and is bilobed. Its function is to store hurriedly swallowed food grains by the pigeon.

12. **What are the divisions of cloaca ?**

    **Ans.** It is three-chambered, anterior coprodaeum, middle urodaeum, and posterior proctodaeum.

13. **Write the name of sound producing organ in birds.**

    **Ans.** Syrinx is the sound producing organ in birds. It is found at the junction of trachea and bronchi. **Larynx** is a voiceless chamber.

14. **What are the air sacs in birds ?**

    **Ans.** These are expansions of main bronchial branches. In pigeon, major air sacs are nine. Air sacs communicate with bronchi and also with cavities of bones. These are accessory breathing organs.

15. **How much chambers are found in the bird's heart ?**

    **Ans.** Four chambers : 2 auricles and 2 ventricles. Sinus venosus and conus arteriosus are absent. Conus arteriosus is also absent in reptiles.

16. **Which ovary is atrophied in female birds ?**

    **Ans.** Right ovary is atrophied to reduce the body weight of the bird.

## • TEST YOUR MEMORY

1. Remember the salient characters of Class Aves (Birds).
2. Which limbs are modified into wings.
3. Why bones in birds are spongy (pneumatic).
4. Remember the characters of flightless birds
5. Remember the name of extinct bird whose specimens are kept in Berlin museum and London museum
6. Remember the names of ostriches found in Africa and America.
7. Remember some of the names of birds roaming around you or near about your houses.
8. Remember the flight adaptations found in the bones of birds.
9. Why the uric acid is excreted in birds, remember its reasons.

UNIT

# 11

# SALIENT FEATURES AND AFFINITIES OF PROTOTHERIA, METATHERIA AND EUTHERIA

## STRUCTURE

- Salient features of Subclass Prototheria.
- Affinities of Prototheria with Metatheria and Eutheria.
- Salient features of Eutheria.
- Classification of Eutheria.
- Comparison of Prtotheria, Metatheria and Eutheria.
- Dentition in mammals.
  - Student Activity
  - Test Yourself

## LEARNING OBJECTIVES

After going through this unit you will learn :

- Sailent features, affinities of Prototheria; Salient features; Affinities of Metatheria; Salient features and affinities of Eutheria; Classification of Eutheria; Comparison between Prototheria, Metatheria and Eutheria, Dentition in mammals.

## 11.1. SALIENT FEATURES AND AFFINITIES OF PROTOTHERIA

Prototheria is the primitive Subclass of Mammalia which includes egg-laying mammals. It includes a single order, Monotremata or Ornithodelphia. Prototherians shows many characters in common with Sauropsida, *i.e.*, reptiles and birds. These are distributed only in Australia and the neighbouring islands of Tasmania and New Guinea. Order Monotremata includes the duck-billed platypus and spiny ant-eater.

**1. Habits and habitat.** Platypus is aquatic and spiny ant-eaters are terrestrial and both are burrowing in habit. Both are insectivorous, nocturnal, warm-blooded, four-footed and oviparous (egg laying).

**2. External features.** Body is covered with soft hairs among which sometimes spines may be present. Mammary glands present, but they lack teats. Young licks up the milk soaked into the hairs through pores in the mammary region of the mother. Pinna or external ears are absent. In *Ornithorhynchus* (duck-billed platypust) snout is flat and covered with leathery skin. Digits are webbed for swimming. Tail is broad, compressed and used for swimming.

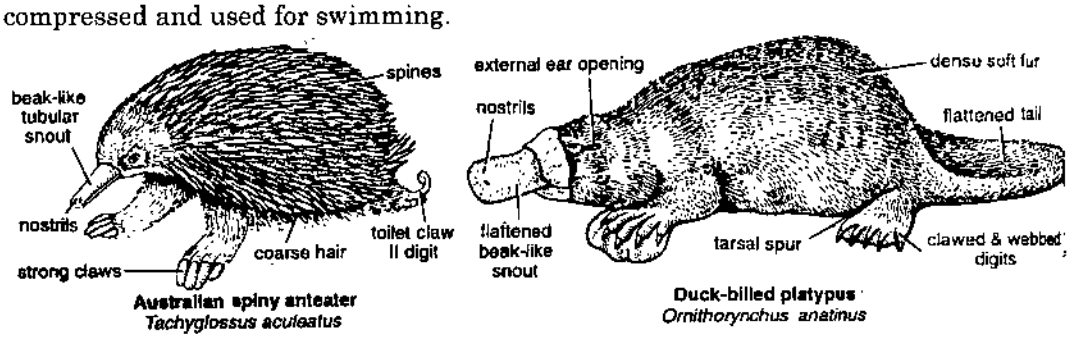



**Fig. 1. Monotremes (Egg laying mammals).**

In *Echidna* (= *Tachyglossus*) spiny ant-eater, the jaws are prolonged into a long snout. Body is covered with thick coarse hairs, spines on the dorsal side.

In both, jaws are covered with horny plates. Teeth are absent, and skin glandular. Body cavity divided into anterior thorax and posterior abdominal cavity by diaphragm.

**3. Endoskeleton.**, Skull is dicondylic (double occipital condyles), smooth and possesses no sutures. Alisphenoid bone is absent, but pterygoid and ectopterygoid bones are present. Lacrymal absent and jugal is reduced or absent. Tympanic bulla is also absent.

**Interclavicle** is T-shaped. Precoracoid and coracoid large, and scapula has no spine.

**Pelvic girdle** with epipubic or marsupial bones and acetabulum is perforated. Thoraco-lumbar vertebrae 19; sacral vertebrae 3 or 4 in *Tachyglossus* and 2 in *Ornithorhynchus*. Cervical (neck) vertebrae lack zygapohyses. Epiphyses are reduced in *Ornithorhynchus* and absent in *Tachyglossus*.

**4. Circulatory system.** Heart is four-chambered with muscular and incomplete right auriculo-ventricular valve. Chordae tendinae are absent. Warm-blooded. Body temperature vary from 25 to 28°C.

**5. Nervous system.** Brain is smooth in duck-billed platypus and convoluted in spiny ant-eater. Corpus callosum (A broad transverse band of nervous tissue connecting two cerebral hemispheres internally). Cochlea is less spirally coiled.

**6. Urinogenital system.** Kidneys are metanephric and ureters open into urinogenital sinus. **Left ovary** is large, while right ovary is reduced. Both oviducts open separately into cloaca. Uterus and vagina absent.

Testes are abdominal and penis is attached with the ventral wall of the cloaca. Vasa differentia open into urinogenital sinus separately. Only sperms pass through penis and not the urine.

**7. Development.** Fertilization is internal. Eggs have abundant yolk, and are incubated by mother. Embryonic development and formation of foetal membranes are of reptilian type.

## • 11.2. AFFINITIES OF PROTOTHERIA

Prototheria are usually referred as "living fossils" because they form a connecting link between reptiles and mammals. This suggest the reptilian ancestory of mammals.

### A. Reptilian Affinities

1 In both pinna is absent.

2. Most of the skull bones are fused like reptiles. Alisphenoid is absent in both. Jugal is reduced and tympanic bulla is absent in both. Epipterygoids can be compared with epipterygoids of reptiles.

3. **Vertebrae** lack epiphyses except the caudal vertebrae of duck-billed platypus.

Cervical ribs are present in both.

Sternum with T-shaped episternum or interclavicle.

Precoracoid and coracoid large without scapular spine in both. Epipubic (marsupial bones) in the pelvic girdle are present.

4. Brain lacks corpus callosum.

5. Cochlea not much coiled in both.

6. Auriculo-ventricular valve is incomplete in both.

7. Ureters open into urinogenital sinus in both.

8. Cloaca present in both.

9. Oviducts separate and open into cloaca in both.

10. Testes are abdominal in both.

11. In both, females are oviparous, eggs large and shelled. Segmentation is meroblastic in both.

### B. Mammalian Affinities

1. In both, body covering is hairy.

2. Females have mammary glands, but teats are absent in Prototheria and present in higher mammals (Eutheria).

3. Sweat and sebaceous glands are present in the skin.

4. In both, heart is four-chambered. Warm-blooded and red blood corpuscles enucleated. Only left aortic arch is present in both.

5. Diaphragm is present in between thoracic and abdominal cavity.

6. Three ear ossicle bones are present in the middle ear.

7. Liver in both typically similar, and intestinal caecum is present.

8. Corpora quadrigemina (four small rounded optic lobes collectively called corpora quadrigemina) is present in both.

9. Skull dicondylic and lower jaw is formed of only dentary.

Thus, prototherians are nearly half way between reptiles and higher mammals. They had evolved from an ancestral stock, therapsid (Synapsida-mammal-like reptiles) that had given rise to higher mammals.

## • 11.3. SALIENT FEATURES AND AFFINITIES OF METATHERIA

Subclass Theria includes two infra classes Metatheria and Eutheria. Infraclass Metatheria includes pouched mammals (female usually have a ventral abdominal pouch, the **marsupium** or marsupial folds enclosing mammary nipples supported with a pair of marsupial or epipublic bones). They have no true placenta. Youngs born immature and thus, are kept within marsupium and fed on milk until they are fully developed.

Due to the presence of marsupium in female, this group is called Marsupialia.

Their distribution is restricted only in the Australian region except American opossums.

**1. Habits and habitat.** Marsupials are terrestrial, burrowing or arboreal, herbivorous or carnivorous or omnivorous, nocturnal or diurnal, warm-blooded, viviparous (give birth to youngs) and pouched mammals.

**2. External features.** Body is covered with soft hairs. Forelimbs smaller than the hindlimbs. Pinnae or external ears well developed. Tail is long and prehensile acts as balancing organ during running. Mammary glands are modified sebaceous glands and have teats. Female usually with a marsupium on the ventral side of abdomen. It opens on the anterior side in kangaroos and posterior side in opossums. Marsupium encloses the teats of the mammary glands.

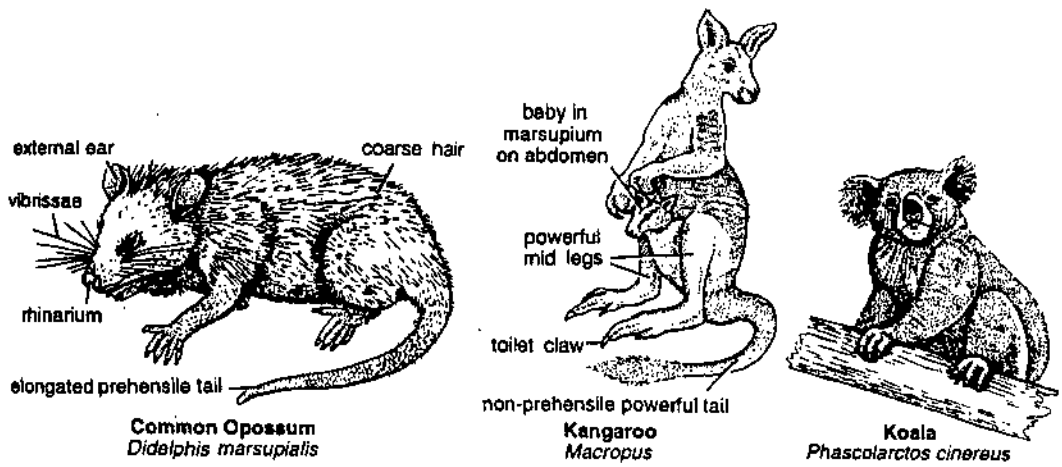



**Fig. 2. Metatherians.**

**3. Exoskeleton.** Epidermal horny hairs and claws, and skin is glandular.

**4. Endoskeleton.** Skull dicondylic. Cranial cavity small. Skull sutures present. Orbit and temporal fossa confluent due to absence of postorbital bar. Zygomatic arch possesses large jugal, which extends backward to take part in the formation of glenoid

fossa.. Pterygoid is small. Tympanic bulla absent. Ear ossicles three in the middle ear. Lower jaw is formed of only dentaries.

Vertebrae with epiphyses. Cervical vertebrae seven. Cervical ribs fused with their respective vertebrae. Thoracic vertebrae are 13, lumbar vertebrae are 7, caudal vertebrae with Y-shaped **chevron bone** except koala and wombat. Thoracic ribs double headed (bicephalous). Interclavicle absent.

In pectoral girdle, coracoids reduced, scapula with spine. In pelvic girdle, epipubic bones present infront of pubic symphysis for the support of marsupium.

**5. Digestive system.** Teeth more in number than that of eutherian number 44, and monophyodont (only single set of teeth). Teeth like eutherian are heterodont and thecodont. Premolars are 3/4 or 4/4. Anus and urinogenital aperture open into cloaca surrounded by a common sphincter.

6. Respiratory, circulatory and excretory systems are typically mammalian (eutherian type).

**7. Nervous system.** Brain is relatively small and less convoluted. Cerebrum and cerebellum small, while olfactory lobes are large. Anterior commissure (Roof of cerebral hemisphere's cavity is formed by corpus callosum, while lateral walls and floor by corpus striatum, and the two corpora striata are connected by a transverse anterior commissure.) is feebly developed or absent. Cochlea of internal ear is spirally coiled.

***8. Reproductive system.*** *In males, scrotal sacs are situated infront of penis* and penis is often bifurcated at the tip.

In females, both the oviducts open separately into urino-genital sinus and there are two uteri and two vaginae. Clitoris in females may be double.

**9. Development.** Eggs small, develop within uterus. Uterine development is of two weeks in opossums and five weeks in kangaroo. True allantoic placenta is absent except in Perameles. Youngs are born naked, blind and hardly an inch long. Their forelimbs are present and have claws by which young moves into the marsupium and clings to one of its teats.

## • 11.4. AFFINITIES OF METATHERIA

Metatherians in certain characters resemble with the prototherians and in some respects with the eutherians (placentals).

### A. *Affinities with Prototheria*

1. Cloaca is present in both.
2. Presence of clavicles, epipubic bones and ring-like tympanic
3. Tympanic bulla is absent in both.
4. Brain simple with large olfactory lobes, and anterior commissure in cerebral hemispheres. Corpus callosum is absent.
5. True allantoic placenta is absent.

Metatherians differ from prototherians mainly in being viviparous (prototherians are oviparous), having marsupial pouch, teats in mammary glands, presence of external ears, vertebrae with epiphyses, bicephalous ribs, absence of interclavicle and separate coracoids, adults have teeth, cochlea spirally coiled, bifid tip of penis, testes in scrotal sacs, development within uterus and viviparous.

### B. Affinities with Eutheria

1. Presence of hairs over the body and external ears.
2. Mammary glands with teats.
3. Testes within scrotal sacs and presence of penis.
4. Teeth heterodont and thecodont.
5. Coracoids reduced and interclavicle absent. Ribs bicephalous.
6. Presence of uterus and vagina.
7. Optic lobes four and cochlea spirally coiled.

8. Ova small (microlecithal)., gestation uterine and placenta present.

9. Viviparous.

But metatherians differ from eutherians in restricted distribution, having shallow cloaca, marsupial pouch, small cranium, absence of tympanic bulla, but alisphenoid bulla is present, epipublic bones present, absence of corpus callosum, and presence of two uteri, two vaginae, bifid penis, scrotal sac infront of penis, small gestation period and no true allantoic placenta

Thus, metatherians are more advanced than the oviparous prototherians and are more close to the eutherians. But still they are kept under a separate infraclass Metatheria. Higher and truely placental mammals are kept in the infraclass Eutheria and both are placed in subclass Theria.

## • 11.5. SALIENT FEATURES AND AFFINITIES OF EUTHERIA

1. **Body** hair clad, terrestrial and aquatic, air breathing, warm-blooded and viviparous, four-legged animals.

2. Body divisible into head, neck, trunk and tail.

3. **Limbs** two pairs and pentadactyle. Digits in each limb are five or less. Limbs are adapted for walking, running, climbing, burrowing, swimming or flying. Hind limbs are absent in sea cow, dugong and manatee (order Sirenia) and whales, dolphins and porpoise (order Cetacea).

4. **Exoskeleton** horny, epidermal hairs, spines, scales, claws, nails, hoofs, horns and bony dermal plates.

5. **Skin** glandular-sweat glands, sebaceous glands, mammary glands in females and scent glands.

6. Presence of diaphragm in between thorax and abdomen.

7. **Endoskeleton.** Skull dicondylic., large cranium, a single zygomatic arch and small pterygoids. Periotic and tympanic bones fused, periotic forms the tympanic bulla. Dentary bone forms half of the lower jaw. Lower jaw articulates with squamosal of skull. Vertebrae centrum is acoelous. Ribs bicephalous.

8. **Digestive system.** Cloaca absent (present in Prototheria and Metatheria). Buccal cavity is separated from nasal passages by a hard palate formed by premaxillae, maxillae and palatines. Teeth never exceeds 44 (3143/3143) heterodont, thecodont (placed in sockets) and diphyodont

9. **Respiration** by lungs and larynx with vocal cords.

10. **Heart** four-chambered and only left aortic arch is present. Renal portal system absent. Red blood corpuscles non-nucleated. Warm-blooded..

11. **Kidneys** metanephric. Urinary bladder present and excretion ureotelic (urea present in the urine).

12. **Brain.** Cerebrum and cerebellum large and convoluted, optic lobes four (corpora quadrigemina). Corpus callosum connecting both cerebral hemispheres internally is present. Cranial nerves twelve pairs.

13. **Eyes** with eye lids, upper eye lid is movable. Pinna (external ear) present. Three ear ossicles (malleus, incus and stapes) present in the middle ear. Cochlea spirally coiled.

14. **Sexes** separate and sexual dimorphism present. Testes placed in the scrotum outside the abdomen (Testes abdominal in Prototheria and Order Sirenia and Hyracoidea (*Hyrax*) of Eutheria. Eggs small without yolk.

15. Eutherians are viviparous (Prototherians are oviparous).

16. Development of egg takes place within uterus. Placenta and embryonic membranes present.

## • 11.6. CLASSIFICATION OF INFRACLASS EUTHERIA

Infraclass Eutheria includes about sixteen orders, which are as follows :

**Order 1. Insectivora.** Primitive small mammals having pointed snout. Limbs plantigrade with 5-clawed toes. Insect-feeding nocturnal mammals. Examples are *Talpa* (mole), *Sorex* (shrew), *Erinaceus* (hedgehogs), etc.

**Order 2 Chiroptera.** Flying mammals (bats). Forelimbs modified into wings (patagium) and hind legs short. Sternum keeled and clavicles fused with scapula and sternum. Pinna large and eyes small with poor vision. Nocturnal. Examples are *Pteropus* and *Cynopterus* (fruit bats), *Myotis* (little brown bat), *Vespertillo, Desmodus* (vampire bat), etc.

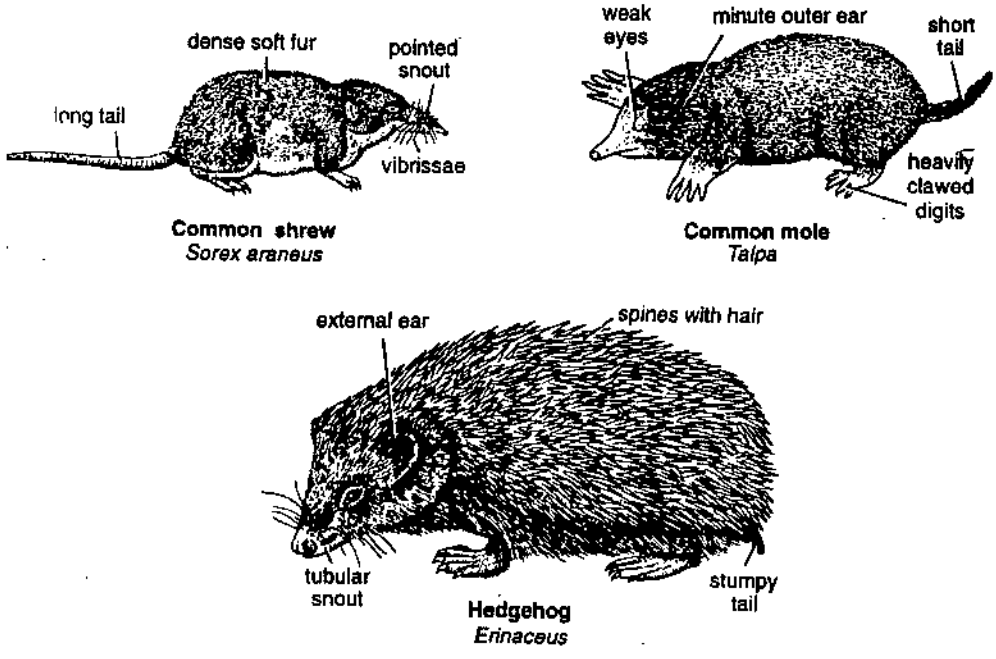



**Fig. 3. Insectivores.**

**Order 3. Dermoptera.** Small, clawed mammals with a fold of skin between neck, limbs and tail that acts as a parachute. Dentition 2143/3143 = 42. Nocturnal and feed on leaves and fruits. Example is *Cynocephalus* (= *Galaeopithecus*) found in southeast Asia.

**Order 3. Edentata.** Teeth absent or poorly developed molars without enamel. Head and snout elongated. Toes with strong curved claws. Testes abdominal. Examples are *Dasypus* (armadillo), *Bradypus* (sloth), *Myrmecophaga* (giant anteater).

**Order 4. Pholidota.** Body covered with long, overlapping horny plates with sparse hairs in between. Teeth absent, tongue slender and protrusible to catch insects. Limbs short with curved, clawed digits for digging. Testes abdominal. Nocturnal. Example scaly ant-eater (*Manis*).

**Order 5. Tubulidentata.** Body stout, pig-like having sparsely distributed hairs. Snout long with an elongated protrusible sticky tongue. Incisors and canine teeth are absent and have few enamelless teeth. Examples are *Orycteropus* (aardvark or cape anteater).

**Order 6. Primates.** Brain highly developed. Nails flat on fingers and toes. First finger usually opposable. Eyes large and forwardly directed. Mostly arboreal.

**Order Primates** is divided into three subclasses :

Lemuroidea, Tarsioidea and Anthropoidea

**(i) Lemuroidea.** Primitive, found in Madagascar, Africa and South eastern Asia. Arboreal, nocturnal, omnivorous. Snout elongated, tail elongated and non-prehensile, sometimes absent. Dental formula 2133/2133 = 36. Cerebellum not covered by cerebrum. Examples are *Tupaia* (tree shrew), *Cheiromys* (aye-aye), *Lemur* (lemurs), *Loris* (loris).

**(ii) Tarsioidea.** A little advanced and found in Philippines and nearby islands. Arboreal, nocturnal and mainly insectivorous. Eyes large protruding forward. Tail long,

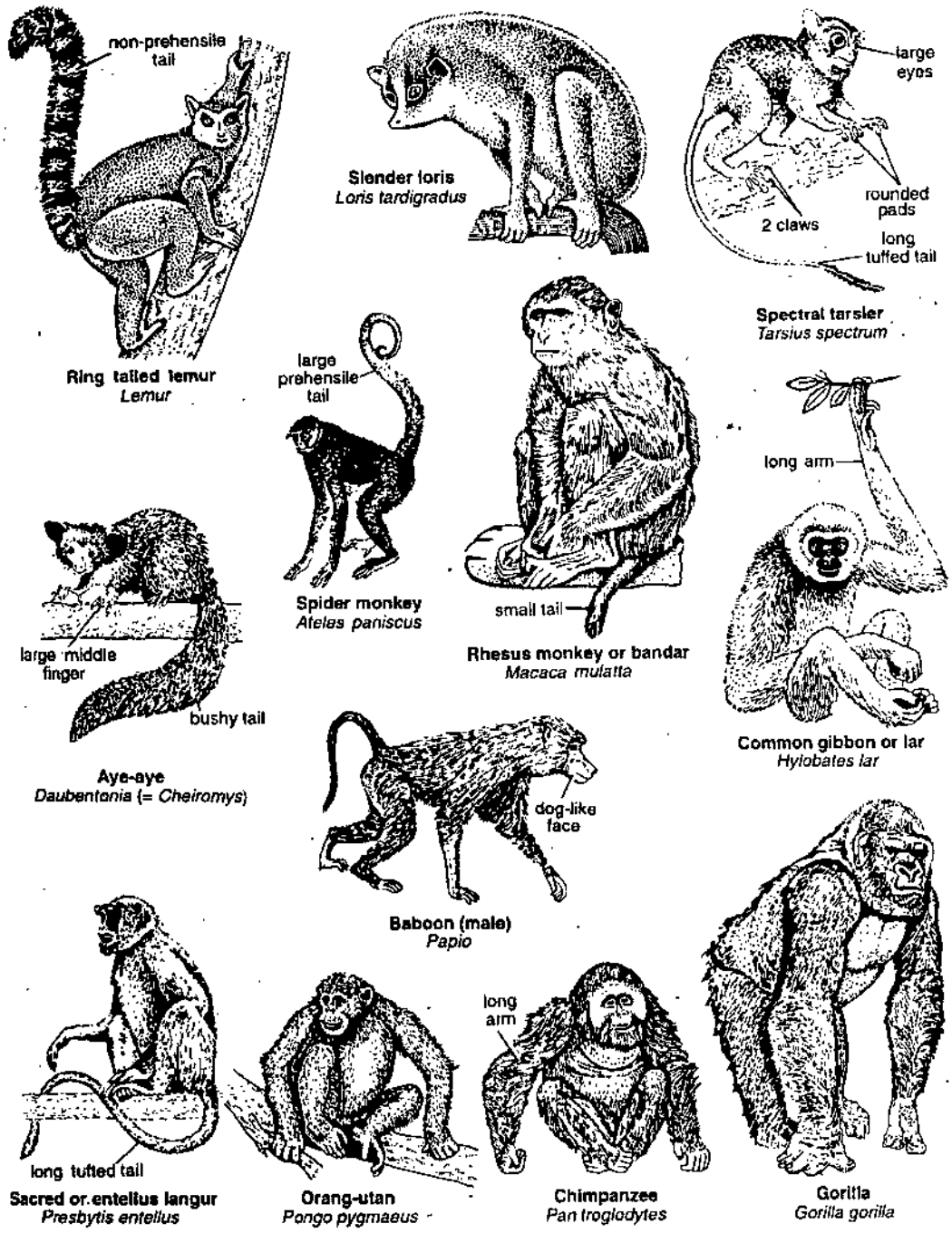



**Fig. 4. Modern Primate mammals.**



tufted and non-prehensile. Dental formula 2133/1133. Cerebellum not covered by cerebrum. Example is *Tarsius* (tarsier).

**(iii) Anthropoidea.** Most advanced and found worldwide. Arboreal or terrestrial, diurnal and mainly frugivorous. Face short. Forward looking eyes and vision stereoscopic. Tail when present prehensile. Dental formula 2/1343/2123 = 32. Cerebrum highly developed and covers the cerebellum. Examples are monkeys of old World and New World, apes and man.

**Order 7. Rodentia.** It includes small gnawing mammals, like rat, mouse, squirrel, guinea pig, beaver, porcupine, prairie dog. Jaw with two long rootless chisel like incisors growing throughout life. Canines absent. Clawed digits and space between molars and canines present (diastema). Testes abdominal. Examples are *Rattus, Mus, Funambulus, Cavia, Castor, Hystrix* and *Cynomys*.

**Order 8. Lagomorpha.** Presence of a pair of small upper incisors behind first pair of large chisel-like incisors.. Canines absent. One pair of incisors in the lower jaw. Upper jaw clefted in the middle. Testes extra-abdominal. Examples are *Oryctolagus* (rabbit), *Lepus* (hare), and *Ochotona* (pika).

**Order 9. Cetacea** Aquatic large fish-like mammals. Hairs on the body reduced and a few bristles are found over muzzle. Forelimbs modified into broad paddle-like flippers. Tail with two horizontal fleshy flukes with a notch and used in propulsion. Hindlimbs and external ears absent. Skull bones spongy and contain oils. Examples are toothed whales *Physeter* (sperm whale), *Phocaena* (porpoise), *Platanista* (Ganges dolphin), *Delphinus* (dolphin). Whalebone whales are *Balaenoptera* (blue whale), *Balaena* (right whale).

**Order 10. Sirenia.** Large, herbivorous aquatic mammals. Forelimbs modified into paddles and hindlimbs absent. Tail with horizontal lateral fleshy flukes with or without notch. External ears absent. Snout blunt and testes abdominal. Examples are *Trichechus* (manatee), *Dugong* (dugong).

**Order 11. Carnivora.** Predatory, flesh-eating mammals. Canines larger, incisors small six in each jaw, premolars have cutting edges and last two molars are crushing type (carnasial). Zygomatic arch strong for supporting powerful jaw. Digits with sharp, retractile claws. Examples are *Canis familiaris* (dog), *C. lupus* (wolf), *C.aureus* (jackal), *Vulpes* (red fox), *Lutra* (otter), *Acinonyx* (cheetah), *Panthera leo* (lion), *P. tigris* (tiger), *Herpestes* (mongoose), *Ursus* (bear), *Ailuropoda* (panda), etc. All these belong to Suborder **Fissipedia.**

*Odobenus* (walrus), *Callorhinus* (fur seal), *Phoca* (common sea), etc. belong to Suborder **Pinnipedia.**

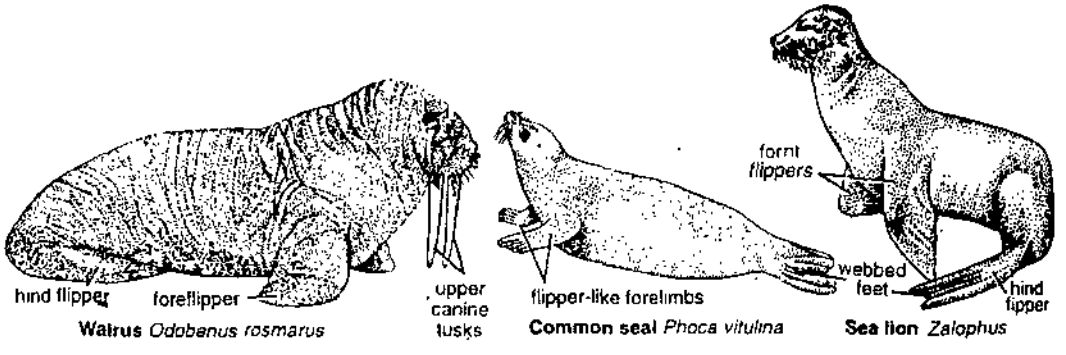



**Fig. 5. Carnivorous mammals.**

**Order 12. Hyracoidea.** Small mammals having 4 digits in forelimbs and 3 digits in hindlimbs. Digits possess flattened hoof-like nail, but the second digit in the hindlimb bears bifid claw. Presence of one pair of incisors in the upper jaw and three pairs in the lower jaw. Canines absent. Testes abdominal. Premolars and molars similar and lophodont. Examples are *Hyrax* (conies) found in South Africa, Syria and Arabia

**Order 13. Proboscidia.** Largest land mammals having large heads, massive ears, roughly hairless skin. Nose and upper lip produced to form long, flexible muscular proboscis having nasal passages opening at its tip. Two upper incisors elongated as tusks. Legs straight and bulky having 3 to 5 toes with small nail-like hoofs. Lower incisors and canines absent. Testes abdominal. Examples are *Elephas maximus* (Asiatic elephants). *Loxodonta africana* (African elephant), *Elephas cylotis* (pigmy African elephant).

**Order 14. Perissodactyla.** Herbivorous, odd toed hoofed mammals (one to three toes). Locomotion is unguligrade. Horns absent. Males with canines and premolars and molars alike. Examples are *Equas cabalus* (horse), *Equus asinus* (wild ass), *Equus zebra* (zebra), *Rhinoceros* (rhino), *Tapirus* (tapir), etc.

**Order 15. Artiodactyla.** Herbivorous, even toed, hoofed mammals. Presence of horns or antlers. Upper incisors and canines usually absent. Stomach four-chambered. Examples are *Camelus* (camel), *Hippopotamus ambhibius* (common hippopotamus),

*Carvus* (deer), *Moschus* (musk deer), *Ovis* (sheep), *Capra* (goat), *Giraffa* (giraffe), *Bos indicus* (ox), *Bos grunniens* (yak), *Bison* (bison), *Antilope* (blacbuck), *Bubalus bubalis* (water buffalo), etc.

## COMPARISON BETWEEN PROTOTHERIA, METATHERIA AND EUTHERIA

| | Prototheria | Metatheria | Eutheria |
|---|---|---|---|
| 1. | Primitive and oviparous. | Viviparous, youngs born immature, and nourished in marsupium. | Viviparous and youngs born fully developed. Marsupium absent. |
| 2. | Placenta absent. | Presence of yolk sac placenta. | Presence of true allantoic placenta. |
| 3. | Eggs megalecithal. | Eggs microlecithal. | Eggs microlecithal |
| 4. | Cleavage meroblastic. | Cleavage holoblastic. | Cleavage holoblastic. |
| 5. | Mammary glands without teats. | Mammary glands with teats present in marsupium. | Mammary glands with teats present on thorax or abdomen or both. |
| 6. | Pinna absent. | Pinna present. | Pinna present. |
| 7. | Teeth absent in adults but present in youngs | Teeth present in adults and are monophyodont and heterodont. | Teeth present in adults and diphyodont and heterodont. |
| 8. | Orbit is confluent with temporal fossa and zygomatic arch incomplete. | Orbit confluent with temporal fossa and zygomatic arch complete. | Orbit separated from temporal fossa and zygomatic arch complete. |
| 9. | Alisphenoid absent | Alisphenoid present. | Alisphenoid present. |
| 10. | Jugals absent. | Jugals share in the formation of glenoid cavity. | Jugals large and do not take part in the formation of glenoid cavity |
| 11. | Tympanic bulla absent. | Bulla is formed of alisphenoid. | Tympanic bulla is formed of periotic. |
| 12. | Epipterygoid present. | Epipterygoid absent. | Epipterygoid absent. |
| 13. | Satures in skull indistinct. | Satures distinct. | Sutures distinct. |
| 14. | Coracoids and precoracoids well developed. | Coracoids reduced and precoracoids absent. | Same as in Metatheria. |
| 15. | T-shaped interclavicle present. | Absent. | Absent. |
| 16. | Epipubic bone present. | Epipubic bone present. | Absent. |
| 17. | Ureters open into urino-genital sinus. | Ureters open into urinary bladder. | Same as in Metatheria. |
| 18. | Testes abdominal. | Testes extra-abdominal. Scrotum in front of penis. | Testes extra- or intra-abdominal. Scrotum behind penis in case of extra-abdominal testes. |
| 19. | Penis lies on the floor of cloaca, only sperms pass through it. | Penis often bifid lying behind scrotum. Urine and sperms both pass through it. | Penis well developed. Urine and sperms both pass through it. |
| 20. | Vasa deferentia open into urinogenital sinus. | Vas deferens open into urethra of penis. | Like Metatheria. |
| 21. | Oviducts are not differential into uteri and vaginae. | Two oviducts. Uteri and vaginae present. | Two oviducts fuse to form single uterus and vagina |
| 22. | Olfactory lobes large. | Olfactory lobes large. | Olfactory lobes comparatively small. |

| | | | |
|---|---|---|---|
| 23. | Cerebrum and cerebellum smooth and poorly developed. | Like Prototheria. | Cerebrum and cerebellum large with folds and grooves |
| 24. | Corpus callosum in cerebrum absent. | Absent. | Corpus callosum present. |
| 25. | Cochlea not spirally coiled. | Cochlea coiled. | Cochlea more coiled. |

## • 11.7. DENTITION IN MAMMALS

The mammalian teeth are highly specialised dermal derivatives and develop due to the classification of mucous membrane found over the two jaws. Teeth are present almost in all mammals except ant-eaters, Echidna etc. They form one of the important structure used for the classification of the class Mammalia. The teeth are borne on premaxilla, maxilla and dentary and their arrangement on these bones is called the **dentition.**

### Structure of Tooth

In mammals, each tooth is placed in the socket over the jaw bone and is divisible into three parts, **root, neck** and **crown.**

**(i) Root** remain burried in the socket of the jaw bone.

**(ii) Neck** is that part of the tooth, which is embedded in gum above the root. It is very small part of the tooth.

**(iii) Crown** remain projected above from the gum. In a vertical section, the tooth consists of the following parts.

**(a) Dentine.** The most part of the tooth is made up of **dentine,** which is traversed with **canaliculi.** The dentine is chemically similar to bone, but different histologically. The canaliculi contain protoplasmic processes of odontoblasts.

**(b) Enamel.** The crown is covered by a hard enamel having 93 percent inorganic salts, while in dentine these are 69 percent.

**(c) Cement.** The neck and root of the tooth formed by dentine are covered by **cement** containing 65 percent inorganic salts.

**(d) Pulp cavity.** The cavity of tooth being filled with a vascular jelly, called **pulp** and remain open below by an aperture through which blood vessels and nerve endings enter into it. In mammals where teeth have limited growth (man), the pulp cavity is very much reduced, but in those which grow throughout life (incisors of rabbit) there is a large and persistent pulp cavity. It is lined by a layer of odontoblast cells.

### Dentition in Mammals

In mammals, teeth are three types :

**1. Thecodont.** Such teeth have one or more roots, which are embedded in the sockets of jaw bones and only crown projects above the socket.

**2. Diphyodont.** In most mammals, there are two sets of teeth *i.e.,* a first set found in the youngs, called the **milk teeth** or **deciduous teeth,** which fall off later on and then replaced by second set of teeth, called the **permanent teeth.** But some mammmals are **monophyodont,** having only one set of teeth, *e.g.,* moles, squirrel, whales etc.

**3. Heterodont.** When the teeth are of different shape and function, the dentition is, called heterodont. Toothed whales are **homodont.** In mammals the teeth are of four kinds :

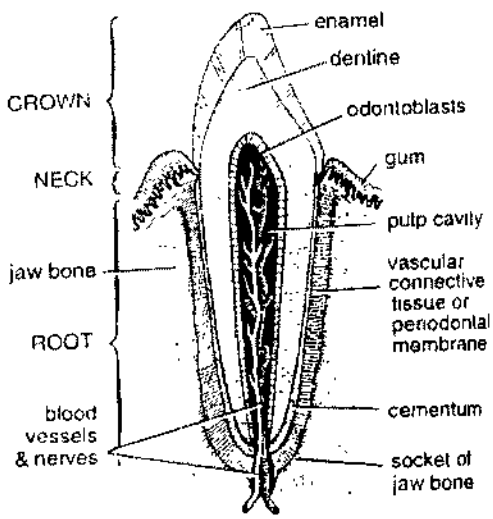



**Fig. 6. Vertical section of a mammal's jaw, showing the tooth in L.S.**

1. **Incisor** or **Cutting teeth** situated in the front part of the mouth, situated on premaxillae in the upper jaw and in the front part of the lower jaw. They have only one root.

2. ***Canine or teering teeth*** *situated behind the incisors and are longer than the* incisors, having only one root.

3. **Premolar** and **molar** are, called grinders, lie behind the canines. They are borne on the maxillae in the upper jaw and over the dentary in the lower jaw. They have two or more roots. Premolars are replaced once, while molars are never shed like others. They possess flat edges.

### Dental Formula

The arrangement of teeth differ in mammals and is closely related to their feeding *habits. The arrangement is expressed by a* ***dental formula.*** The number of teeth of dental formula when multiplied by two gives the total number of teeth present in the mammal. The typical number of teeth in mammal is 44, represented by the following dental formula :

$$I\frac{3}{3},\ C\frac{1}{1},\ Pm\frac{4}{4},\ M\frac{3}{3} = \frac{3, 1, 4, 3}{3, 1, 4, 3} \times = 44$$

**I** = incisors, **C** = canines, **Pm** = premolars and **M** = molars.

The **incisors** are small in carnivorous, but assume great importance in the herbivorous animals. The **canines** are of much importance in the carnivorous animals where they are used for killing and tearing the prey, but in herbivorous animals they may be absent. The dental formulae of some common mammals are as follows :

$$\text{Man} = I\frac{2}{2}, C\frac{1}{1} Pm\frac{2}{2} M\frac{3}{3} = \frac{2, 1, 2, 1}{2, 1, 2, 3} \times 2 = 32$$

$$\text{Rabbit} = I\frac{2}{1} C\frac{0}{0} Pm\frac{3}{2} M\frac{3}{3} = \frac{2033}{1023} \times 2 = 28$$

$$\text{Dog} = I\frac{3}{3}\ C\frac{1}{1} Pm\frac{3}{2} M\frac{2}{3} = \frac{3132}{3123} \times 2 = 36$$

$$\text{Mouse} = I\frac{1}{1},\ C\frac{0}{0}, Pm\frac{0}{0}, M\frac{3\ 1, 0, 0, 3}{3\ 1, 0, 0, 3} \times 2 = 16$$

$$\text{Cat} = I\frac{3}{3}, C\frac{1}{1}, Pm\frac{3}{3}, M\frac{1}{1} = \frac{3, 1, 3, 1}{3, 1, 3, 1} \times 2 = 30$$

$$\text{Sheep} = I\frac{0}{3}, C\frac{0}{1}, Pm\frac{3}{3},\ M\frac{3}{3} = \frac{0, 0, 3, 3}{3, 1, 3, 3} \times 2 = 32$$

$$\text{Kangaroo} = I\frac{6}{2}, C\frac{0}{0}, Pm\frac{1}{1}, M\frac{4}{4} = \frac{6, 0, 1, 4}{2, 0, 1, 4} \times 2 = 30$$

From the above formulae, it is clear that the teeth may vary in the two jaws. Thus, in the case of rabbit we find two incisors, three premolars and three molars on each side of the upper jaw and one incisor, two premolar and three molars in the lower jaw. The canines are absent in both the jaws with the result a space is left in between the incisors and premolars. This space is called the **diastema.**

## • 11.8. VARIATION OF TEETH IN MAMMALS

In **Monotremata** (duck-bill platypus) the true teeth are lacking, but epidermal teeth are present. In edentates the incisors and canines are absent and the molars are pillar like with no enamel and roots. In Philodota (*Manis*) teeth are entirely absent.

The form of teeth is dependent upon the nature of the diet. In **dolphins,** the teeth are monophyodont and similar, suited to take a firm grip of the prey. In **herbivorous** mammals, incisors are more in number for cutting and gnawing the herbage, canines are either absent or reduced and cheek teeth have transverse ridges. **In carnivorous** mammals, the canines are more elongated and pointed for tearing the flesh, premolars with cutting edges and molars for crushing the food. Thus, on the basis of shape, size and number of cusps the teeth are of following types :

1. **Monocuspid** with one cusp or tubercle.

2. **Bicuspid** having two cusps.

3. **Tricuspids** with three cusps. These have triconodont shape having 3 cone shaped buds. These 3 cones form separate cusps, arranged in a triangle forming tritubercular teeth.

4. **Bunodont** teeth possess small separate and rounded cusps for grinding *e.g.*, man, monkey.

5. **Lophodont** teeth having cusps forming ridges, called **lophs** that are folded intricately forming sharp ridges *e.g.*, elephant.

6. **Secodont** teeth possess pointed cusps, which forms sharp cutting ridges for cutting and tearing flesh *e.g.*, carnivores.

7. **Selenodont** teeth possess vertical crescent shaded cusps used for grinding the food *e.g.*, cattles and horses

Horse's selenodont teeth have high crown and short roots. Such teeth are, called **hypsodont.** While those selenodont teeth having low crowns are called **brachydont.**

## • STUDENT ACTIVITY

1. Give an account of distinguish characters and outline classification of mammals.

2. Give an account of general characters and affinities of Prototheria.

3. What are egg-laying mammals ? Describe their general characters.

4. Give the general characters and affinities of Metatheria.

5. What are marsupials ? What are their differences from Eutheria ?

6. Write down about the dentition in mammals.

## • VERY SHORT QUESTIONS

1. **In which mammals hindlimbs are absent ?**
   **Ans.** Cetaceans have no hindlimbs.
2. **Which types of teeth are present in eutherians ?**
   **Ans.** Thecodont, heterodont and diphyodont.
3. **Where monotremes are found ?**
   **Ans.** Monotremes are restricted in Australian region.
4. **In which group of mammals marsupium is found ?**
   **Ans.** Marsupium is found in metatherian animals
5. **Egg-laying mammals placed in which group of mammals ?**
   **Ans.** Egg-laying mammals are grouped in subclass Prototheria.
6. **Which marsupial is found in America ?**
   **Ans.** Opossum is found in America. Other marsupials are found in Australian region.
7. **Write the names of hoofed mammals (ungulates).**
   **Ans.** Hoofed mammals are *Equus* (horse, ass, zebra), *Rhinoceros, Sus* (pig), *Hippopotamus, Camelus, Llama,* and *Giraffa.*
8. **Write down a few names of cetaceans..**
   **Ans.** *Physeter* (sperm whale), *Orcinus* (killer whale), *Platanista* (Ganges dolphin), *Balaenoptera* (blue whale) etc., are cetaceans.
9. **Write down the names of toothless mammals.**
   **Ans.** *Bradypus* (sloths), *Myrmecophaga* (great anteater), *Dasypus* (armadillo) are toothless mammals.

## • TEST YOUR MEMORY

1. What are prototherians and their distribution.
2. Remember the external features of prototherians, metatherians and eutherians.
3. Remind the affinities of prototherians with metatherians and eutherians.
4. Remember the salient features of metatherians.
5. Write down the affinities of metatherians with prototherians and eutherians.
6. Remember the salient features of Eutheria.
7. Remember the various orders of Eutheria.