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।। सरस्वती नः सुभगा मयस्करत् ।।

Master of Science

PGZY-106(N)

Chordata



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संदेश

प्रयागराज की पवित्र भूमि पर भारत रत्न राजर्षि पुरुषोत्तम दास टण्डन के नाम पर वर्ष 1999 में स्थापित उत्तर प्रदेश राजर्षि टण्डन मुक्त विश्वविद्यालय, प्रयागराज उ0प्र0 का एकमात्र मुक्त विश्वविद्यालय है। यह विश्वविद्यालय उ0प्र0 जैसे विशाल जनसंख्या वाले राज्य में उच्च शिक्षा के प्रत्येक आकांक्षी तक गुणात्मक तथा रोजगारपरक उच्च शिक्षा के अवसर उपलब्ध कराने में निरन्तर अग्रसर एवं प्रयत्नशील है। तत्कालीन देश की सामाजिक एवं आर्थिक परिस्थितियों में एक वैकल्पिक व नवाचारी शिक्षा व्यवस्था के रूप में भारत में मुक्त एवं दूरस्थ शिक्षा प्रणाली का पदार्पण हुआ था, परन्तु वर्तमान परिस्थितियों तथा तकनीकी का सार्थक प्रयोग करते हुये मुक्त एवं दूरस्थ शिक्षा आज की सर्वोत्तम पूरक शिक्षा व्यवस्था के रूप में स्थापित हो चुकी है।

वर्तमान शिक्षा प्रणाली के सामने व्याप्त पाँच मुख्य चुनौतियों - (i) पहुँच (Access), (ii) समानता (Equity), (iii) गुणवत्ता (Quality), (iv) वहनीयता (Affordability) तथा (v) जवाबदेही (Accountability) को केन्द्र में रखकर घोषित देश की राष्ट्रीय शिक्षा नीति (NEP-2020) के प्रस्तावों को क्रियान्वित करने में उत्तर प्रदेश राजर्षि टण्डन मुक्त विश्वविद्यालय कृत संकल्पित है। उ0प्र0 की माननीय राज्यपाल एवं कुलाधिपति की सद्इच्छाओं के अनुरूप उत्तर प्रदेश राजर्षि टण्डन मुक्त विश्वविद्यालय, शैक्षिक दायित्वों के साथ-साथ सामाजिक दायित्वों के निर्वहन में भी लगातार नवप्रयास कर रहा है। चाहे वह गाँवों को गोद लेकर उनके समग्र विकास का प्रयास हो या ग्रामीण महिलाओं, ट्रान्सजेन्डर व सजायाफ्ता कैदियों को शुल्क में छूट प्रदान कर उनमें आत्मविश्वास जागृति व उच्च शिक्षा के प्रति अलख जगाने का प्रयास हो।

राष्ट्रीय विकास को बढ़ावा देने के लिए शिक्षा एक मूलभूत जरूरत है। ज्ञान-विज्ञान एवं तकनीकी के क्षेत्रों में हो रहे तीव्र परिवर्तनों व वैश्विक स्तर पर रोजगार की परिस्थितियों में आ रहे परिवर्तनों के कारण भारतीय युवाओं को विभिन्न क्षेत्रों में गुणवत्तापूर्ण शैक्षिक अवसर उपलब्ध कराने पर ही भारत का भविष्य निर्भर करेगा। इसीलिए विभिन्न क्षेत्रों में सफलता हेतु शिक्षा को सर्वसुलभ, समावेशी तथा गुणवत्तापरक बनाना समसामयिक अपरिहार्य आवश्यकता है। वर्तमान परिस्थितियों ने परम्परागत शिक्षा को और भी सीमित कर दिया है जिसके कारण मुक्त एवं दूरस्थ शिक्षा व्यवस्था ही एकमात्र पूरक एवं प्रभावी शिक्षा व्यवस्था के रूप में सार्थक सिद्ध हो चुकी है। ऐसी स्थिति में विश्वविद्यालय का दायित्व और भी बढ़ जाता है। इस दायित्व को एक चुनौती स्वीकार करते हुए विश्वविद्यालय ने प्राचीन तथा सनातन भारतीय ज्ञान, परम्परा तथा सांस्कृतिक दर्शन व मूल्यों की समृद्ध विरासत के आलोक में सभी के लिए समावेशी व समान गुणवत्तायुक्त शिक्षा सुनिश्चित करने तथा जीवन पर्यन्त शिक्षा के अवसरों को बढ़ावा देने के लिए अपने शैक्षिक कार्यक्रमों में जागरूकता में प्रमाणपत्र, डिप्लोमा, परास्नातक डिप्लोमा, स्नातक, परास्नातक तथा शोध उपाधि के समसामयिक शैक्षिक कार्यक्रमों की संख्या तथा गुणात्मकता में वृद्धि की है।

शैक्षिक कार्यक्रमों में संख्यात्मक वृद्धि, गुणात्मक वृद्धि तथा रोजगारपरक बनाने के साथ-साथ प्रत्येक उच्च शिक्षा आकांक्षी तक पहुँच सुनिश्चित करने के लिए अध्ययन केन्द्रों व क्षेत्रीय केन्द्रों के विस्तार के साथ-साथ प्रवेश परीक्षा, प्रशासन तथा परामर्श (शिक्षण) में आनलाइन व्यवस्थाओं को सुनिश्चित किया गया है। विश्वविद्यालय कार्यप्रणाली में पारदर्शिता तथा जवाबदेही सुनिश्चियन की दृष्टि से तकनीकी के प्रयोग को बढ़ाया गया है। 'चुनौती मूल्यांकन' की व्यवस्था सुनिश्चित करने का कार्य किया गया है, तो शिक्षार्थी सहायता सेवाओं में भी वृद्धि की जा रही है। शिक्षार्थियों की समस्याओं के त्वरित निस्तारण हेतु शिकायत निवारण प्रकोष्ठ को सुदृढ़ करने के साथ-साथ पुरातन छात्र परिषद को गतिशील किया गया है।

"गुरुकुल से छात्रकुल" के सूक्त वाक्य को आत्मसात करते हुए विश्वविद्यालय ने शिक्षार्थियों को विश्वविद्यालय द्वारा तैयार किये गये गुणवत्तापूर्ण स्वअध्ययन सामग्री उपलब्ध कराने के साथ-साथ विश्वविद्यालय की वेबसाइट पर भी उपलब्ध कराया गया है। छात्रहित को ध्यान में रखते हुए शिक्षकों द्वारा तैयार व्याख्यान को भी ऑनलाईन उपलब्ध कराया गया है।

शोध और नवाचार के क्षेत्र में अग्रसर होते हुए विश्वविद्यालय अनुदान आयोग (UGC) नई दिल्ली तथा माननीय राज्यपाल एवं कुलाधिपति, उ0प्र0 की अनुमति से विश्वविद्यालय में शोध कार्यक्रम पुनः प्रारम्भ किया गया है तथा वर्ष पर्यन्त समसामयिक विषयों पर व्याख्यान, सेमिनार, वेबिनार तथा आनलाइन संगोष्ठियों आदि की श्रृंखला भी प्रारम्भ की गयी है। विभिन्न क्षेत्रों में रिसर्च प्रोजेक्ट सम्पादन पर भी ध्यान केन्द्रित किया गया है। पुस्तकालय को अत्याधुनिक तथा सुदृढ़ बनाने हेतु कदम उठाये गये हैं। शिक्षकों व कर्मचारियों के स्वास्थ्य तथा कल्याण की योजनायें क्रियान्वित की गयी हैं।

प्रो0 सत्यकाम
कुलपति

Uttar Pradesh Rajarshi Tandon
Open UniversityUttar Pradesh
Rajarshi Tandon

Master of Science
PGZY-106(N)
Chordata

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Course Introduction

Hemichordates and Chordates are both members of the phylum chordates. Chordates are characterized by the presence of a notochord, a dorsal hollow nerve cord, pharyngeal slits and post anal tail. Hemichordates also known as acorn worms, are the subphylum of chordates, that exhibit certain chordate characteristics. They play an important role in the evolutionary understanding of chordate development and diversity.

This course is divided into three blocks as Block -I, Block-II & Block-III.

Block-I Origin and Classification of Chordates. (This block of the study material incorporates four units).

Block-II Amphibians, Reptiles and Birds. (Incorporates three units 05 to 07)

Block-III Origin and Evolution of Mammals. (Units 08 to unit 12)

Block-I Introduction

You will be introduced by origin and classification of chordates. This block of the study materials incorporates 04 units (unit 1 to 4) as under.

Unit-I Begins with (primitive chordates) General characters and classification of Hemichordates,

Unit 2 Deals with the Urochordata and Cephalochordata.

Unit 3 You will study about origin, evolution and adaptive radiations of vertebrates

Unit 4 deals with the general account of Elasmobranchi, Holocephali, Dipnoi and Teleostomi.

Objectives:

After studying this block you will be able to-

- know about Hemichordata, Urochordata and Cephalochordate.
- Origin, evolution and adative radvation of vertebrates.
- General account of Elasmobranchii, Holocephali, Dipnoi and Teleostomi

UNIT-1 : PRIMITIVE CHORDATES

1.1 Introduction

Objectives

1.2 Origin of Chordates

1.3 General Characters &Classification of Chordates

1.4 Classification of Hemichordata

1.5 Study of *Balanoglossus*

1.6 *Balanoglossus* and its Affinities

1.7 Summary

1.8 Terminal Questions

1.9 Answers

1.1 INTRODUCTION

The name of phylum Chordata is derived from the two words the "chorde" meaning string or cord and "ata"meaning bearing. The common characteristic feature of phylum Chordata is the presence of a stiff, supporting rod-like structure along the back, the notochord (Gr., noton = back; L. chorda = cord) which is found in all the members of the phylum at some stage of their lives. Thus, chordates are those animals which have a cord, i.e., notochord.

The phylum Chordata was created by Balfour in 1880. The phylum Chordata includes primarily the Protochordata (Acraniata) and Vertebrata (Craniata). Phylum Chordata is the largest of the deuterostome phyla.

Phylum Chordata is fundamentally characterised by the presence of a notochord, a dorsal hollow nerve cord and paired pharyngeal [relating to the pharynx] gill slits.They are bilaterally symmetrical, triploblastic, coelomate with organ-system level of organisation.Phylum Chordata is divided into 4 subphyla: Hemichordata,Urochordata CephalochordataandVertebrata.Hemichordata is a phylum which consists of triploblastic, enterocoelomate, and bilaterally symmetrical marine deuterostome animals, generally considered the sister group of the Echinoderms and since long has been considered to be lowest chordate group. It has recently been Seporrated from the phylum chordata and given a status of a independent Invertebrate phylum. They appear in the Lower or Middle Cambrian and include two main classes: Enteropneusta (acornworms), and Pterobranchia. In Urochordata, notochord is present only in larval tail, while in Cephalochordata, it extends from head to tail region and is persistent throughout their life.Examples: Urochordata – Ascidia, Salpa, Doliolum; Cephalochordata – Amphioxus or Lancelet.

Objectives :

After studying this unit you will be able to know about :

- Origin of chordates.
- General characters and classification of chordates and hemichordate.
- The structure and various systems ofBalanoglossus.
- The affinities ofBalanoglossuswith Chordata, Annelida and Echinodermata.

1.2 ORIGIN OF CHORDATES

The chordates include organisms having a notochord, a dorsal tubular (hollow) nerve cord, pharyngeal gill-slits and a few features such as axiate organisation, bilateral symmetry, triploblastic condition, coelom, metamerism (segmentation), organ-systems, etc., that are common with the nonchordates.

The geological records established beyond doubt that the chordates originated prior to Cambrian period as the oldest fossils of known vertebrates have been discovered in Cambrian strata.

Most zoologists, such as Romer, Berril and Barrington, etc., now favour the deuterostome line of chordate evolution, according to which the phyla Echinodermata, Hemichordata and Chordata show common ancestry on embryological and biochemical evidences. The protochordates are the connecting link between early chordate ancestors and vertebrates. The differentiation probably occurred much earlier than Cambrian period.

The earliest traces of vertebrates have been found in the rocks of the late Cambrian period and Ordovician period. A number of fishes followed in Silurian period and became abundant in the Devonian period. The subsequent periods show the evolution of amphibians, reptiles, birds and mammals.

Several theories have been proposed to explain the origin of chordates from nonchordate groups.

According to one theory chordates are originated from echinoderms the Echinoderms are radially symmetrical animals and show no typical chordate characters, yet they seem to be most closely related to chordates. The Auricularia larva of Echinoderms is a free-swimming bilaterally symmetrical larva, and closely resembles the Tornaria larva of hemichordates. Both have similar ciliated bands in loops, a dorsal pore, sensory cilia at the anterior end and a complete digestive system of verbal health and posterior anus.

According to another theory there is a strong suggestive evidence that the early evolunary stage of Deuterostomia was sessile or sedentary. The pharynx perforated by gill-slits is likely an adaptation to sedentary habit. No doubt, hemichordates are secondary and have pharynged gill slits and a hollow dorsal nerve cord.

W. Garstang (1928) and N.J. Berrill (1955) gave importance to the tadpole like larva of urochordates which carries typical chordate characters, namely, a notochord in tail along with segmented mytomes, dorsal hollow nerve cord, sense organ and pharyngel gill-silts. Garstang (1928) suggested that chordates evolved from some sessile, filter feeding urochordate by the larval stage evolving into adult by neoteny and by losing the sedentary adult stage.

1.3 GENERAL CHARACTERS & CLASSIFICATION OF CHORDATES

1. Chordates are aquatic, aerial or terrestrial. All are free-living with no finally parasitic forms.
2. Body small to large, bilaterally symmetrical and metamerically segmented.
3. A postanal tail usually projects beyond the anus at some stage of life and may or may not persist in the adult.
4. Exoskeleton often present; well-developed in most vertebrates.
5. Body wall triploblastic, i.e., presence of three germ layers- ectoderm, mesoderm and endoderm.
6. Coelomate animals, i.e., a well-developed true coelom is always present which is enterocoelic or schizocoelic in origin.

7. Notochord is always essentially present at some stage of life cycle. It is completely or partly replaced by vertebral column in majority of animals. (Vertebrates)
8. A cartilaginous or bony, living and jointed endoskeleton present in the majority of members (Vertebrates).
9. Paired pharyngeal gill-slits are present on either side of the pharynx at some stage of life, may or may not be functional.
10. Digestive system is complete with digestive glands.
11. Blood vascular system is closed. Heart ventral with dorsal and ventral blood vessels. Hepatic portal system is present which is well developed.
12. Excretory system comprising proto-or meso-or metanephric kidneys.
13. Nerve cord is dorsal and tubular. Anterior end usually enlarged to form brain.
14. Sexes separate with rare exceptions.

- Three common fundamental morphological features are as follows:
    1. Notochord (a longitudinal supporting rod-like structure);
    2. Dorsal tubular (hollow) nerve cord; and
    3. Pharyngeal gill-slits.

1. Notochord or Chorda Dorsalis:

The notochord (Gr., noton = back; chorda = cord) is a rod-like, elongated, elastic structure situated just above the alimentary canal and immediately beneath the dorsal tubular nerve cord. It is composed of large vacuolated notochordal cells enclosed in an outer fibrous and an inner elastic sheath of connective tissue.

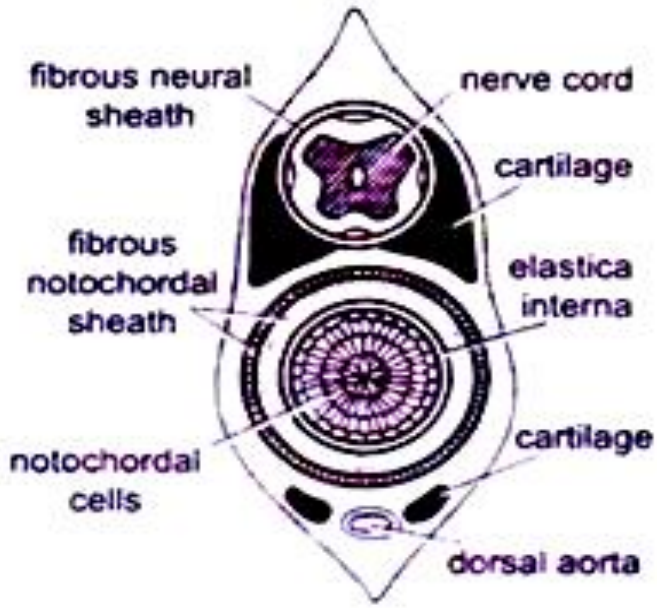


Fig 1.1 Notochord of young dogfish

2. Dorsal Tubular Nerve Cord:

In chordates, there is a dorsal, hollow or tubular, fluid-filled nerve cord lying just above the antero-posterior axis of the body. The nerve cord is formed by an infolding of mid-

dorsal strip of neural ectoderm and encloses a cavity or canal, the neurocoel. The nerve cord lies above the notochord and outside the coelom, extending lengthwise in the body. This tubular nerve cord persists throughout the life in chordates.

3. **Pharyngeal Gill-Slits:**

The gill-slits have many alternative names, such as gill-clefts, pharyngeal or branchial-clefts, visceral-clefts, visceral or branchial-pouches. In all the chordates, at some stage of their life history, a series of paired internal gill-slits or gill-clefts perforate through the pharyngeal wall of the gut behind the mouth.

Phylum Chordata is first divided into 3 or 4 primary subdivisions called subphyla based on the character of notochord.

These are:

Subphylum Hemichordata

Subphylum Urochordata

Subphylum Cephalochordata

Subphylum Vertebrata

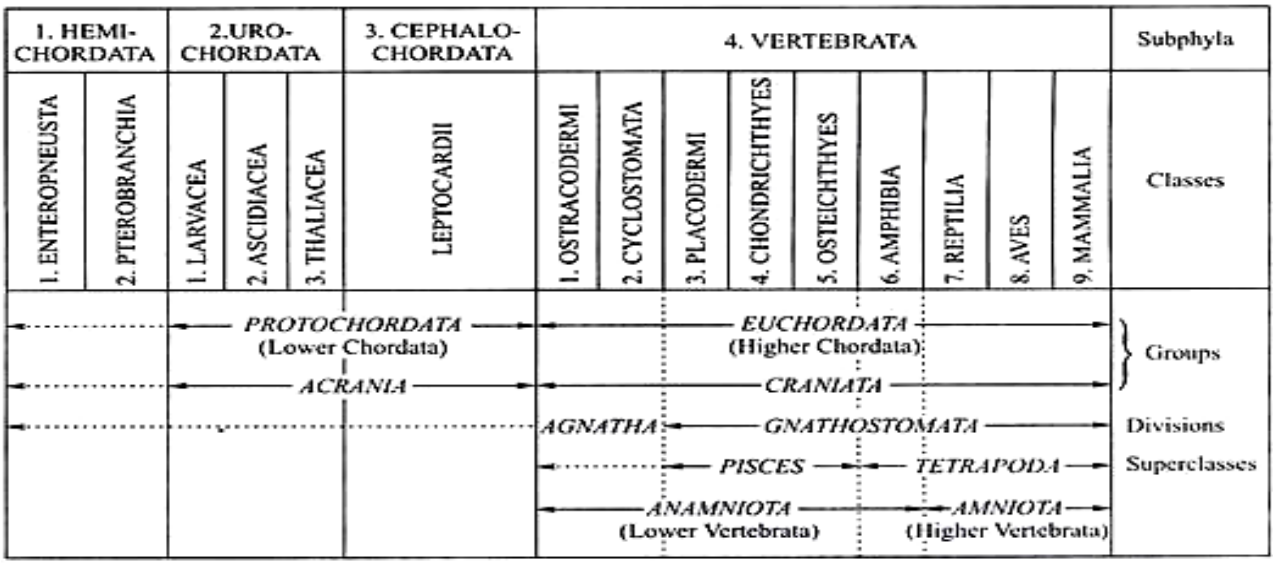


Fig : subdivisions of the phylum Chordata.

Source: https://www.notesonzoology.com/wp-content/uploads/2017/07/clip_image002_thumb2-1.jpg

- Subphylum Hemichordata (Gr., hemi = half; chorde = cord) have long been considered to be the lowest chordates. But recent workers consider the so called notochord of hemichordates not a true notochord but stomochord. In recent years the hemichordates have been separated from the phylum Chordata and given the status of a separate independent invertebrate phylum.

  Subphylum Urochordata (Gr.,oura = a tail; L., chorda = cord) includes 3 classes (Larvacea, Ascidiacea and Thaliacea), subphylum Cephalochordata (Gr., kephale = head; L., chorde = cord) includes a single class (Leptocardii), while the subphylum Vertebrata (L., vertebratus = backbone) is divided into 9 classes (Ostracodermi, Cyclostomata, Placodermi, Chondrichthyes, Osteichthyes, Amphibia, Reptilia, Aves and Mammalia).

- **Protochordata and Euchordata:**

  The first two subphyla under phylum Chordata are Urochordata and Cephalochordata. They are all marine, relatively small and without a vertebral column or backbone. They are often collectively referred to as the invertebrate chordates or nonvertebrates or protochordates (Gr., protos = first; chorde = cord). They are regarded to be early, primitive or first chordates closely allied with the ancestral chordate stock.

  Earlier, the Protochordata was treated as a distinct phylum with the Hemichordata included in it as a third subphylum. At present, the Hemichordata is considered as an independent invertebrate phylum, while the Urochordata and Cephalochordata are considered to be true chordate subphyla. Therefore, the term "Protochordata" no longer includes any zoological taxonomic position, but is merely descriptive.

  The third subphylum Vertebrata, possessing a vertebral column, is considered to be more advanced and belongs to the subdivision Euchordata of the phylum Chordata. Sometimes, the protochordates are known as the lower chordates or the euchordates as the higher chordates.

- **Acrania and Craniata:**

  The Protochordate subphyla lack a head and cranium, therefore, they are known as Acrania (Gr., a = absent, kranion = head). On the other hand, the subphylum Vertebrata (subdivision Euchordata) possesses a distinct head and a cranium, therefore, they are known as Craniata. Typically the body of Craniata comprises a head, neck, trunk and tail.

- **Agnatha and Gnathostomata:**

  The Vertebrata (or Craniata) are further subdivided into two unequal sections- Agnatha and Gnathostomata. Agnatha (Gr., a = not; gnathos = jaw) lack true jaws and paired appendages. and include a small number of primitive but highly specialised fish-like forms, the extinct Ostracoderms and modem Cyclostomes. All other vertebrates have true jaws and paired appendages and are called Gnathostomata (Gr., gnathos = jaw; stoma = mouth). In earlier Agnatha and Gnathostomata were considered as the subphyla of phylum Chordata. In the recent years, they are considered as branches or groups or super classes of subphylum Vertebrata.

- **Pisces and Tetrapoda:**

  Gnathostomata is divided into two superclasses- Pisces and Tetrapoda. The superclass Pisces (L., piscis = fish) includes all the fishes which are strictly aquatic forms with paired fins. The superclass Tetrapoda (Gr., tetra = four; podos = foot) includes four-legged land vertebrates including amphibians, reptiles, birds and mammals.

- **AmniotaandAnamnia:**

  This method of grouping the vertebrates is based on the presence of or absence of an embryonic membrane, the amnion. The amnion holds the developing embryo in a reservoir of fluid and allows the laying of eggs on land. The animals that possess the amnion belong to Amniota which includes the classes Reptilia, Aves and Mammalia. The animals without amnion are Anamniota which includes cyclostomes, fishes and amphibians. Sometimes the anamniotes are referred to as the lower vertebrates and amniotes as higher vertebrates.

1.4 CLASSIFICATION OF HEMICHORDATA

Hemichordata (Gr., hemi, half; chorde, cord) means they are 'half' of 'part' chordates, They are usually marine vermiform, solitary, or colonial enterocoelous coelomate animals with an intra-

epidermal nervous system and a pre-oral with or without gill-slits.

Phylum Hemichordata Characteristics:

- They are exclusively marine, solitary or colonial, mostly tubicolous.Their body is soft, fragile, vermiform, unsegmented, bilaterally symmetrical, and triploblastic.
- The body is divisible into proboscis, collar, and trunk.Body wall with a single-layered epidermis with mucous glands. No dermis.
- Coelom enterocoelous, divisible into protocoel, mesocoel and metacoel.Buccal diverticulum, earlier considered as the notochord, present in the proboscis.
- The alimentary canal is a straight, complete, or U-shaped tube.Dorso-lateral pharyngeal gill-slits, when present, one to several pairs. Ciliary filter feeders.
- Simple, open, and well-developed circulatory system, including a dorsal heart and 2 longitudinal vessels, one dorsal and one ventral.Excretion by a single glomerulus situated in the proboscis.
- Primitive type nervous system consisting mainly of subepidermal nerve plexus.Dorsal collar nerve cord hollow.
- Reproduction is mainly sexual. Sexes usually separate. Gonads one to several pairs.
- External fertilization in seawater.Development direct or indirect with a free-swimming Tornaria larva.

Example: *Balanoglossus*.

Classification of Hemichordata

Class 1- Enteropneusta

- Solitary and burrowing worm like marine forms commonly called “acorn” or “tongue worm”.
- Body consists of usual division, viz., proboscis separated by the narrow stalk from the ring shaped collar which is succesteted by an elongated trunk. Proboscis cylindrical and tapering.
- Straight alimentary canal; with a terminal anus.Numerous pairs of U-shaped gill-slits.
- Two pairs of hepatic caeca present in the middle of the trunk.
- Sexes separate. Gonads numerous, scan-like.
- Development with or without tornaria larva.

Examples: *Balanoglossus*, *Saccoglossus*.

Class 2. Pterobranchia

- Sedentary, solitary or colonial, sessile, and tubicolous. Living inside secreted chitinous tubes.
- Body short, compact, with stalk for attachment. Proboscis with ciliated tentacles to produce ciliary feeding currents of water.
- Collar bearing ciliated arms(lophophore). One pair of gill-slits or none, never U-shaped.
- U-shaped alimentary canal. Anus dorsal lying near the mouth. Separate or united sexes. Gonads single or one pair.

- Development direct, may or may not include a free-swimming larval stage. Asexual reproduction by budding in some form.

Class 3 Planctosphaeroidea

- Class is represented by a few small, rounded, transparent, and pelagic larvae, supposed to be specialized tornaria of some unknown hemichordate termed *Planctosphaera pelagica*.
- Larval body covered by extensively branched ciliary bands.
- The alimentary canal is L-shaped.

Example: Tornaria

Class 4 Graptolite

- Extinct colonial hemichordates, mainly known from fossil structures of their tubes.
- These are abundant in the Ordovician and Silurian periods.
- Each animal is housed in a zooid.
- Their tubular chitinous skeleton and colonial habits show an affinity with *Rhabdopleura*.

Example: *Dendrograptus*.

SAQ-1

1. Phylum Chordata by fundamentally characterised are, presence of a notochord, a dorsal hollow nerve cord and paired **……**
2. The Protochordates arethe connecting link between early **……..** and **……..**
3. The Protochordate subphyla lack a head and cranium, therefore, they are known as **…….**
4. The subphylum Vertebrata (subdivision Euchordata) possesses a distinct head and a cranium, therefore, they are known as **…….**

1.5 STRUCTURE OF *BALANOGLOSSUS*

Hemichordata (Gr., hemi, half; chorde, cord) means they are ‘half’ of ‘part’ chordates, a fact that is disputed. They are usually vermiform, solitary, or colonial enterocoelous coelomate animals with an intra-epidermal nervous system and a pre-oral with or without gill-slits and without typical nephridia.

These animals are also known as "Acorn worms". They were initially grouped under Phylum Chordata. But, research has proven that none of these organisms have a post-anal tail or even the notochord, which is a distinguishing feature of chordates. Hence, these animals have been given a separate phylum, called the Hemichordata.

*In Balanoglossus*sp., there is no definite endoskeleton but there are four structures of a supporting nature, they are a buccal diverticulum, proboscis skeleton, branchial skeleton, and a pygochord.

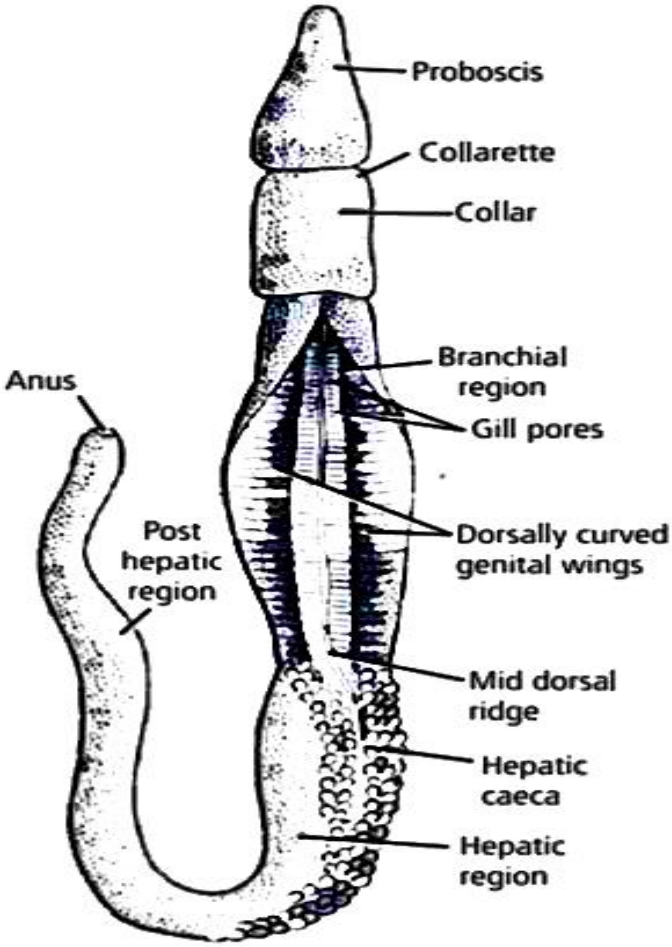


Fig.: ***Balanoglossus*** **- External features**

Proboscis Skeleton:

Proboscis skeleton or nuchal skeleton is formed by the basement membrane becoming thick to form a laminated plate from which arise two thin horns or cornua, the plate usually has a midventral keel. The proboscis skeleton lies in the proboscis stalk, while its horns extend into the roof of the buccal cavity.

Branchial Skeleton:

The walls of the U-shaped gill-clefts are supported by skeletal rods called primary and secondary gill-rods formed by thickening of the basement membrane.

Proboscis:

- The proboscis is a short club-shaped structure forming the anterior most division of the body.
- The proboscis narrows posteriorly to a proboscis stalk.
- It is hollow and communicates with the exterior by a single proboscis pore situated on the left side of the proboscis.

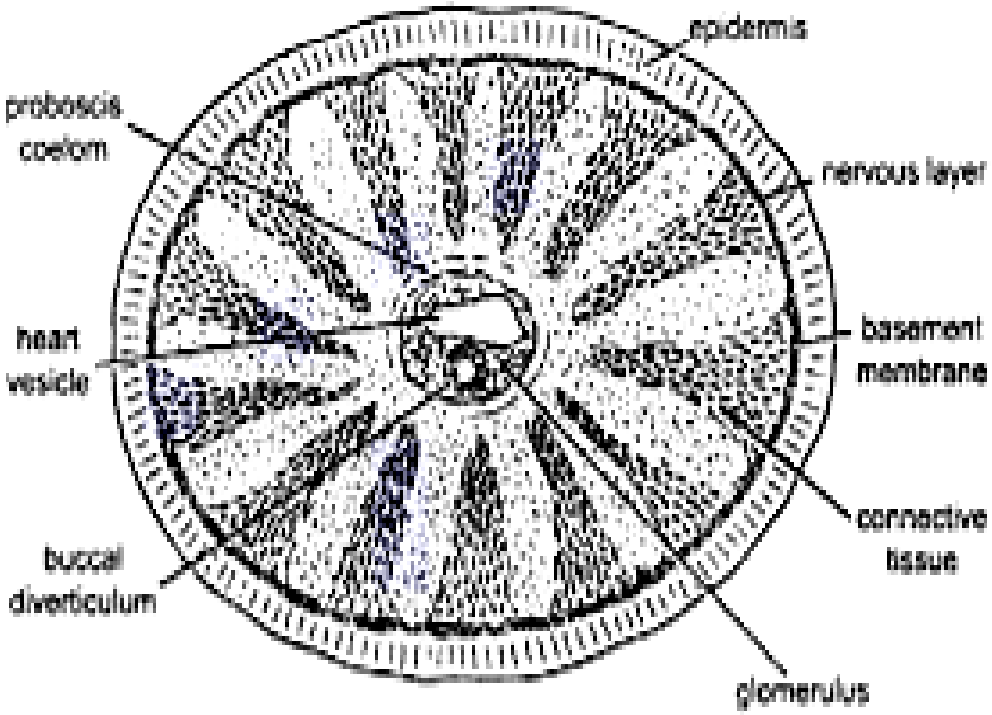


Fig: Balanoglossus T.S. of proboscis

Collar:

- The median part of the body consists of short and cylindrical part, its a flap of muscular tissue forming the collar.
- The proboscis is anterior to the collar.
- The proboscis stalk and a portion of the posterior part of the proboscis are concealed by the collar.
- The wall of the collar is thick and highly muscular and enclosed the cavity, the collar coelom. It opens outside through a pair of collar pores into the first pair of the gill pouches.
- The collar cavity is paired and opens to the exterior by two apertures.

Trunk:

- The trunk is rather long. The branchiogenital region is marked by a pair of lateral thin flap-like longitudinal genital wings which contain the gonads.
- Double rows of gill-slits or pharyngeal slits are present on the dorsal surface of this region.
- The gill-slits increase in number with the age of animal.
- The gill-slits are placed on a prominent elongated ridge.
- Trunk is divisible to anterior branchio-genital region, a middle hepatic region, and posterior abdominal region.
- In the hepatic region are present double row of hepatic caeca.

Hepatic region:

- The hepatic region is externally marked by the sacculations of the intestine.
- The caudal region is more or less uniform in diameter and is marked externally by annulations.
- The trunk bears a mid-ventral and a mid-dorsal ridge which contain the longitudinal blood vessels and the longitudinal nerves.
- The hepatic region tapers posteriorly and terminates into the anus.

Body Wall of Balanoglossus:

- The body wall is composed of a ciliated epidermis.
- The ciliated cells are mostly tall and slender.
- Gland cells are also present in the epidermis.

There are three types of gland cells:

(a) Reticulate gland cells, where the cytoplasm contains mesh-like reticulum;

(b) Mulberry gland cells, having coarse granules and

(c) Coblet cells, which are filled up with fine granules.

- The cytoplasm is homogeneous.
- The cell body is divided into two parts— a distal flask-shaped expanded portion and a proximal slender stalk. The stalk extends up to the base of the epidermis. The base of the epidermis is occupied by a thick nervous layer.
- A very thin connective tissue layer is present between the nervous layer and the epidermis.
- The nervous layer is separated internally by a well-developed basement membrane.

Coelom of Balanoglossus:-

- Balanoglossus possesses a spacious coelom. The coelom is enterocoelous in origin and is lined by coelomic peritoneum.
- The original cavity of the coelom is greatly reduced by the presence of fibrous network and muscle fibres.
- Coelomic sacs are present in the body of Balanoglossus.

Proboscis Coelom:

- Proboscis has thick muscular walls and its cavity the proboscis coelom.
- The proboscis coelom is an unpaired cavity.
- The proboscis coelom is a single space in the proboscis which is largely occupied by muscles and connective tissue and a few structures like buccal diverticulum, glomerulus and central sinus or heart.
- Dorsally, towards the posterior side, the proboscis coelom is divided by a dorsal mesentery into right and left ventro-lateral compartments which extend into the proboscis stalk; the left compartment is larger than the right and communicates with the exterior through the

proboscis pore situated mid-dorsally at the base of the posterior stalk.

- Ventrally the proboscis coelom is divided by a ventral mesentery into right and left ventro-lateral compartments which are continuous behind the mesentery.

Collar Coelom:

- The collar is also muscular it may contain one or two coelomic cavities.The collar coelom or mesocoel has two cavities lying side by side in the collar, one on each side between the collar wall and buccal cavity. The two cavities are partitioned by incomplete mid-dorsal and mid-ventral mesenteries.
- The collar coelom does not communicate with the proboscis coelom, but posteriorly, its each cavity opens into the first gill sac of its side by a canal called collar canal. Each collar coelom opens to the exterior by a collar pore.
- The collar coelom is greatly obliterated by the collar musculature and connective tissue.

Trunk Coelom:

- The trunk coelom or metacoel has two closed cavities lying between the body wall and alimentary canal.
- The two cavities are separated by an incomplete dorsal and a complete ventral mesentery.
- In the branchio-genital region each cavity is further divided by a lateral septum into a dorso-lateral and ventro-lateral compartment.
- The trunk coelom is separated from the collar coelom by a collar-trunk septum. The trunk coelom is obliterated by the trunk musculature.

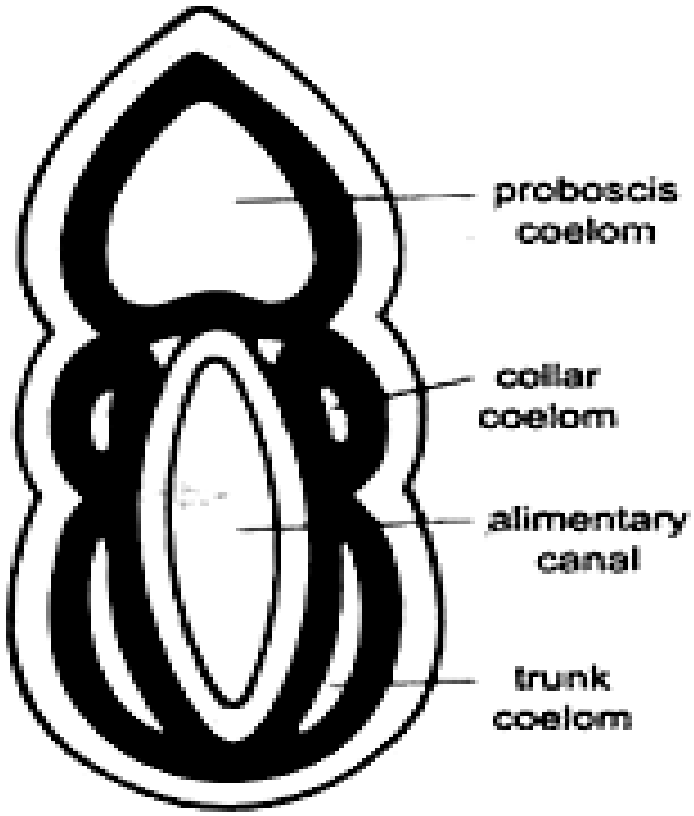


Fig: Balanoglossus coelomic cavities

Endoskeleton

Balanoglossus has no definite endoskeleton of bone or cartilage. the following four type structures are present:

(i) Buccal diverticulum,

(ii) proboscis skeleton,

(iii) branchial skeleton, and

(iv) pygochord.

(i) **Buccal diverticulum:**

- The roof of buccal cavity (lying inside collar region), a short stiff, thick-walled, hollow projection extends forwards through the proboscis stalk into the proboscis coelom.
- Its wall is composed of a single layer of tall, slender, vacuolated endodermal cells. For a long time it was considered a notochord (Bateson, 1885), or stomochord (Willey, 1899 and Dawydoff, 1948).

(ii) **Proboscis skeleton:**

- The proboscis or nuchal skeleton is a Y-shaped chitinous structure formed by the thickening of the basement membrane. It consists of a broad, flat, roughly rectangular median plate produced ventrally into a keel and posteriorly into two diverging hors.
- The median plate lies below the buccal diverticulum in the proboscis stalk while the two horns extend backwards into the roof of the buccal cavity. The median plate remains embedded in a reticulum of stiff chondroid tissue which resembles vertebrate cartilage.

(iii) **Branchial skeleton:**

- It is also formed by the thickening of the basement membrane. It consists of numerous M-shaped chitinous skeletal rods that lie in the wall of the pharynx and support the U-shaped gill slits that perforate it.
- The middle arm of the skeletal rod is thicker than the others and bifurcated at the free end which indicates that it is formed by the fusion of two arms of two adjacent ‘inverted U-shaped’ rods that join to form the M-shaped rod.

(iv) **Pygochord:**

- In the post-hepatic region of the trunk, mid-ventrally between the intestine and body wall, develops a rod-like thickening called pygochord. Its cells are vacuolated.
- Pygochord is longitudinal rod-like structure extending from the ventral side of the intestine to the body wall, its function is not known but it may support the soft abdominal region.

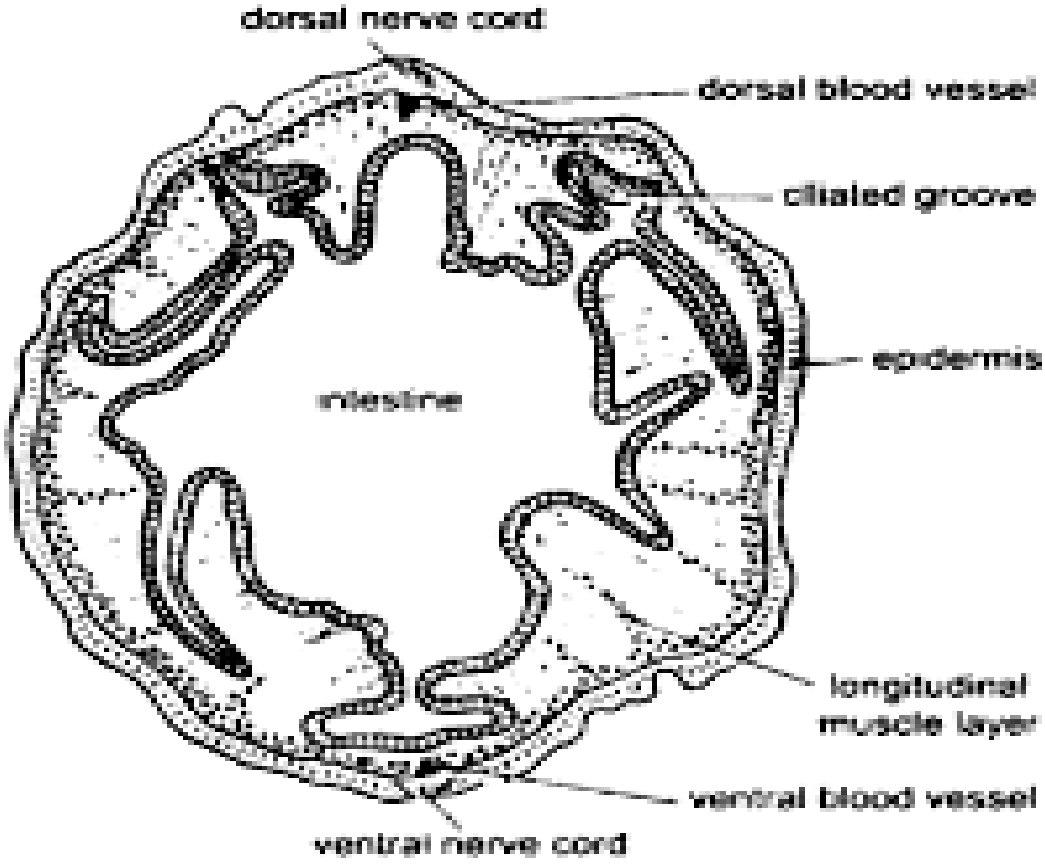


Fig Balanoglossus T.S. through post-hepatic intestine

Digestive and Respiratory Systems of Balanoglossus:

- The alimentary canal is a straight tube running between the mouth and anus. It is peculiar because musculature is absent.
- The mouth is situated ventrally at the base of proboscis, within the collar into the dorsal half of the anterior portion of the alimentary canal open the internal gills-silts. Each of these is in the form of a long narrow U shaped, The two limbs separated by a narrow process as the tongue-bar-containing a prolongation of the body cavity.
- The tongue bars are immovable and remain fixed. The tongue bar does not touch the ventral side of the pharyngeal slit — as a result each pharyngeal slit assumes a U-shaped appearance.
- The portions of the pharyngeal wall separating the successive pharyngeal slits are called primary pharyngeal bars or septa and the tongue dorsal nerve dorsal blood pharyngeal bar cord vessel pore coelomic cavity bar (tongue bar) tongue bars that come to divide the primary pharyngeal slits are called secondary pharyngeal bars.
- The secondary pharyngeal bars have a coelomic canal derived from the trunk coelom. The lateral sides of the primary and secondary pharyngeal bars are beset with lateral cilia, and help to move water currents through the pharynx.
- The buccal tube opens into the pharynx.The pharynx is an elongated structure and plays the double role of food concentration and respiration.
- A para pharyngeal ridge on each side divides the cavity of the pharynx into two incomplete

halves—a dorsal respiratory half pierced by gill-slits and a ventral half that helps in food concentration. The pharynx leads into a short oesophagus which is followed posteriorly by the intestine.

- The intestine is a straight tube and is distinguishable into an anterior hepatic region, marked by the sacculations on the dorsal wall of the intestine and a narrow post-hepatic region that opens to the exterior through the anus.
- The branchial region is perforated by a longitudinal series of pharyngeal slits or gill-slits
- Balanoglossus have separate gill-pore for each branchial sac, but, in *Balanoglossus misakiensis*, the first four branchial sacs fuse with each other and open to the exterior through a common pharyngeal or gill-pore. The gill-pores are situated along a longitudinal groove, called branchiogenital groove which also contains the gonopores.

Feeding and Digestion:

- Balanoglossus is a 'ciliary feeder'. Its food comprises of microscopic organisms and organic particles present in water and the bottom sand in which it makes its burrows.
- The lateral cilia lining the gill-slits set up a current of water which enters through the mouth, takes its course through the buccal cavity, pharynx, gill-slits and branchial sacs, and leaves through the gill pores. This is the respiratory-cum-food current.
- Balanoglossus takes sand as it burrows through the sand. The mucus, secreted by the proboscis, entangles the sand or other food particles from the surrounding region and the mucus coated particles are pushed directly into the mouth by the action of cilia.
- The epidermal secretion in Balanoglossus, in addition to its normal participation in loco-motion and burrowing, plays an essential role in feeding process.
- During feeding, the proboscis is protruded from the mouth of burrow. In this condition, the particles adhere to the mucus secreted by the epidermal glands and are carried towards the mouth.
- The lateroventral beating of dorsal cilia at the base of the proboscis is significant in this ciliary feeding mechanism.
- A U-shaped epidermal groove bordered with strong cilia (preoral ciliary organ) situated at the base of proboscis plays significant role in the process. The preoral ciliary organ has receptor functions and provides a means for testing water and its contents approaching the mouth.

SAQ-2

1. The superclass Tetrapoda (Gr., tetra = four; podos = foot) includes four-legged land vertebrates including amphibians, **……..,…….**

2. Balanoglossus is a **…….**

3. In Balanoglossus sp., are present thebuccal diverticulum, proboscis skeleton, branchial skeleton, and a **……..**

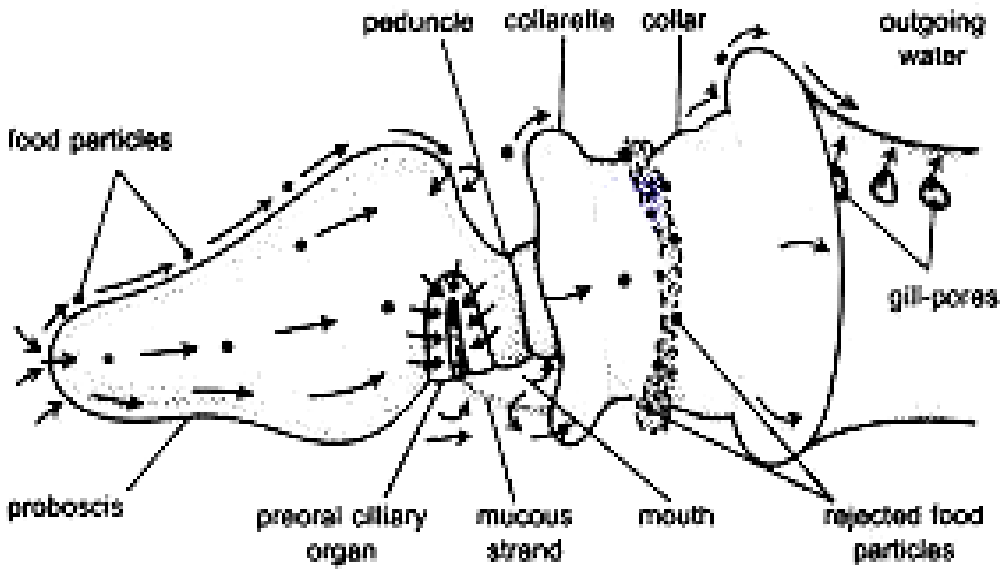


Fig: Balanoglossus feeding current

Respiratory Mechanism:

- In Balanoglossus, the cilia present in the gill apparatus and in the pharyngeal cavity help to maintain a powerful current of water.
- The water current enters into the mouth and goes out through the gill-pores. The incoming water current brings food as well as fresh oxygen dissolved in water. During the expulsion of the water through the gill-pores, the carbon dioxide goes out along with the exhalant water current.

Circulatory System of Balanoglossus:

- The circulatory system is well-developed is Balanoglossus . It comprises of blood, propulsatory heart vesicle, definite blood vessels and lacunar spaces.
- The blood is colourless and contains a few detached endothelial cells. There are two main longitudinal blood vessels running along the length of the body. The dorsal vessel is situated just below the dorsal nerve cord and is contained in the dorsal mesentery.
- The blood flows anteriorly through the dorsal vessel. The ventral vessel is located in the ventral mesentery and in it the blood flows posteriorly. These two blood vessels are composed of an inner endothelium surrounded by muscle layer.
- The dorsal vessel extends from the anus to the collar where it takes a median position between two perihaemal cavities. The dorsal vessel at this region expands to form venosus sinus which passes anteriorly into a central sinus or heart. The central sinus is situated above the buccal diverticulum.
- Immediately on the dorsal side of the central sinus there is a triangular sac called heart vesicle. The blood passes directly into the glomerular cavities from the central sinus. From the glomerulus, the blood is collected by four vessels. These vessels are regarded as the arteries.The arteries are:a mid-dorsal proboscis artery, a mid-ventral proboscis artery andtwo efferent glomerular arteries.
- The mid-dorsal and mid-ventral proboscis arteries supply blood to the proboscis wall. The

efferent glomerular arteries run backward on the two sides of the buccal diverticulum. These vessels then run ventrally to encircle the buccal tube as the peribuccal arteries. The peribuccal arteries unite together ventrally to form the ventral longitudinal vessel.

- The ventral longitudinal vessel gives origin to a ventral collar vessel to supply the collar. The collar tissue contains two distinct lacunar networks which communicate posteriorly with a ring vessel. The ring vessel is located in the collar-trunk septum. It arises from the ventral longitudinal vessel and is connected with the dorsal longitudinal vessel.
- The ventral longitudinal vessel continues up to the anus and gives off lacunar networks all along the alimentary canal. The ventral longitudinal vessels give out a vessel in each gill septum which bifurcates to supply the two adjacent tongue-bars. Thus, each tongue-bar receives two afferent branchial arteries which break up into a plexus.
- From this plexus an efferent branchial vein is formed. It runs dorsally up to the middle of the tongue-bar and joins with the efferent branchial vein of the adjacent tongue-bar. The common branchial vein opens into the dorsal longitudinal vessel.

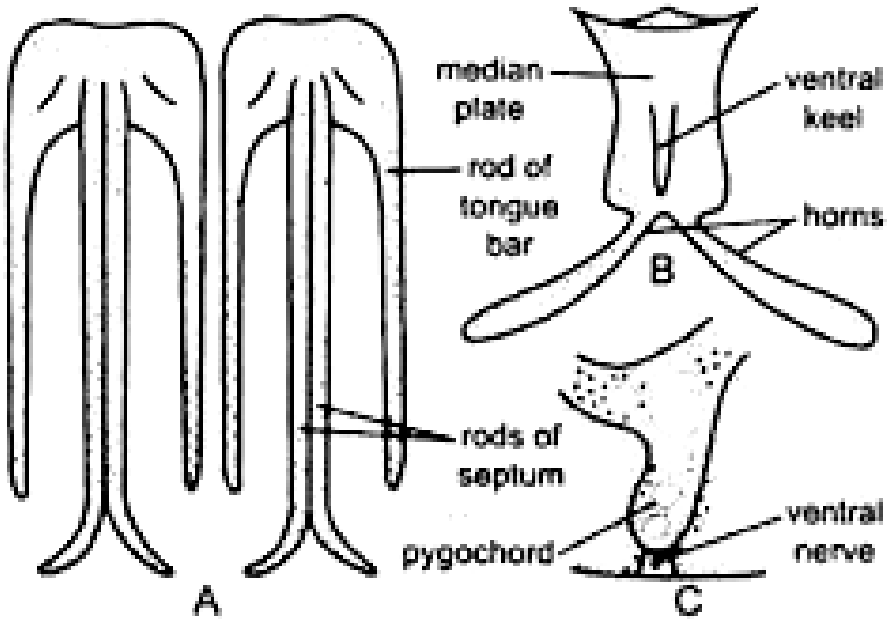


Fig: Balanoglossus skeletal A- Branchial , B-Proboscis skeleton, C- Pygochord

Excretory and Nervous System of Balanoglossus:

- A mass of coelomic evaginations in the proboscis complex is regarded as the excretory organ. Because of its similarities with the glomeruli of vertebrate kidney, the organ is regarded as the glomerulus.
- The glomerulus is situated on either side of the heart vesicle and assumes the shape of the heart vesicle and the central sinus .
- The cavities of the glomerulus are filled with blood which is confluent with the blood of the central sinus.
- **The nervous system** of enteropneusts shows some resemblance to the ectoneural system of echinoderms. The nervous system of Balanoglossus represents a very primitive condition. It consists of an intra-epidermal nervous layer at the base of the epidermis.

- The nervous layer is composed of longitudinal nerve fibres with bipolar and multipolar nerve cells at the margin. The nervous layer becomes thickened to form two nerve cords, one is situated in the mid-dorsal and the other in the mid-ventral lines of the trunk.
- The ventral and the dorsal trunk cords are connected by a circumenteric or peribranchial nerve ring along the collar- trunk septum. The dorsal trunk cord in the collar leaves the epidermis and projects into the collar coelom as the collar cord or neurocord.
- The collar cord is situated above the buccal tube and contains a continuous lumen in other hemichordates.

Sexual Reproduction:

- The sexes are separate (gonochoristic), but the males and females cannot be distinguished externally. The gonads are sacculated bodies arranged in longitudinal rows outside the coelom of the branchiogenital region of the trunk.
- Many secondary gonads are produced from the primary gonads. Each gonad proliferates and bulges into the coelomic cavity.
- Each gonad is covered by somatopleure and forms a slender tubular neck which opens externally by a gonopore. The gonopores are situated in the branchiogenital groove. The gametes are discharged to the exterior and fertilization is external.
- The eggs are small.The yolk content is very poor.
- Balanoglossus exhibits great regenerative potency. Isolated pieces from the trunk have the inherent property to regenerate the lost parts.

Development of Balanoglossus:

The development is indirect, i.e., the development is followed by the metamorphosis of a well-developed larval form.

Pre-larval Development:

- The pre-larval developmental stages resemble closely that of Branchiostoma. The cleavage is holoblastic and occurs along radial planes. The resultant blastomeres are approximately equal. A coeloblastula is produced which is transformed into a gastrula by invagination within 24 hours.
- The developing embryo elongates along the anteroposterior axis and develops cilia. The mouth and the anus are formed anew. The coelom develops by enterocoelic method. After about 24 to 36 hours, the embryo escapes as a larva. known as Ttornania Larva

Tornaria Larva:

The Tornaria larva has an oval and bilaterally symmetrical body. The size of the tornaria larva varies from 1-3 mm, The mouth is present on the ventral side near the equatorial plane of the body. The portion of the body anterior to the mouth is prolonged into a preoral lobe.Anterior end of the pre-oral lobe bears a distinct apical plate bearing nerve fibres, ganglionic nerve cells, a tuft of immobile cilia and a pair of pigmented eye-spots. There are three distinct ciliated bands on the body. The names of the bands have been given according to their position. The preoral and postoral ciliated bands unite for a short distance at the apical plate.The other ciliated ring is present around the anus. This band is called the circumanal ciliated band or telotroch. The cilia in this band are long, powerful and act as the chief locomotors organ of Tornaria. The anus is located medially on the posterior end of the body. The digestive tract is distinguishable into oesophagus, stomach and

intestine.The Tornaria larva possesses only one pair of gill-slits. Five coelomic cavities are present which exhibit the trisegmental condition of the body. Finally, the Tornaria larva sinks to the bottom and metamorphoses into an adult. The body becomes divided into three parts by two constrictions. It then undergoes morphological changes to become an adult.

1.6 AFFINITIES OF BALANOGLOSSUS

Many authors have claimed Hemichordata as a separate phylum under the non-chordates.

Affinities with Non-chordate:

Balanoglossus shows many structural similarities with non-chordates.

Affinities with Annelida:

- Both of them have a vermiform and coelomate body.
- The arrangement of the blood vessels is similar.
- The collar of Balanoglossus is comparable to the clitellum of oligochaetes.
- The Trochophore larva of annelids bears close structural resemblances with the Tornaria larva, specially in the apical sense organ and the ciliated rings.

Differences :

(i) The Trochophore larva bears a pair of nephridia which are absent in Tornaria larva,Bio-chemistry is dissimilar and Notochord is absent in Annelida.

Affinities with Echinodermata

Adult resemblances

- Enterocoelic origin of coelom and its division into three successive parts.
- Heart vesicle and glomerulus of enteropneusts are considered homologous to the dorsal sac and axial gland of echinoderms.
- Nervous system is poorly developed and forms epidermal nerve plexus.
- Common habits and ecological niches and remarkable power of regeneration.

Larval resemblances

- Small, pelagic, transparent and oval.
- Identical ciliated bands taking up a similar twisted course.
- Enterocoelic origin and similar development of coelom.
- Proboscis coelom opening to outside by proboscis pore of tornaria comparable to hydrocoel of echinoderm dipleurula.
- Blastopore becomes the anus (Deuterostomia) and digestive tract is complete with mouth, anus and same parts.

Affinities with Chordata

Presence of the three fundamental chordate characteristic; that is, (i) a notochord, (ii) a dorsal hollow nerve cord and (iii) pharyngeal gill-slits (pharyngotremy).

Differences:

- A true notochord is not present in hemichordates. Unlike that of the chordates, the so-called "notochord" is very short, confined to proboscis and without any supporting function. Instead of being called notochord, it is now preferred to be called as buccal diverticulum or stomochord.
- Nervous system is distinctly of the invertebrate type being intra-epidermal in position and having a ventral nerve cord and a circumenteric nerve ring which are absent in chordates.
- Gill slits of Balanoglossus are numerous and dorsal in position, whereas they are 5 to 7 and lateral in higher chordates.
- Hemichordates lack metameric segmentation, cephalisation, paired appendages, postanal tail, exoskeleton, living endoskeleton, dermis, liver, haemoglobin, red blood corpuscles, etc.
- Hemichordates have peculiar division of body and coelom (into proboscis, collar and trunk), single-layered ciliated epidermis, hepatic caeca, dorsal heart, open neurocoel, colourless blood, numerous gonads, etc.

1.7 SUMMARY

- Phylum Chordata are fundamentally characterised by the presence of a notochord, a dorsal hollow nerve cord and paired pharyngeal [relating to the pharynx] gill slits.
- Hemichordata is a phylum which consists of triploblastic, enterocoelomate, and bilaterally symmetrical marine deuterostome animals.
- Urochordata, notochord is present only in larval tail, while in Cephalochordata, it extends from head to tail region and is persistent throughout their life.
- The protochordates are the connecting link between early chordate ancestors and vertebrates.
- A cartilaginous or bony, living and jointed endoskeleton present in the majority of members (vertebrates).
- Paired pharyngeal gill-slits are present on either side of the pharynx at some stage of life, may or may not be functional.
- Hemichordata (Gr., hemi = half; chorde = cord) have long been considered to be the lowest chordates.
- At present, the Hemichordata is considered as an independent invertebrate phylum, while the Urochordata and Cephalochordata are considered to be true chordate subphyla.
- The protochordate subphyla lack a head and cranium, therefore, they are known as Acrania (Gr., a = absent, kranion = head).
- Balanoglossus animals are also called as Acorn Worms.
- *In Balanoglossus* sp., buccal diverticulum, proboscis skeleton, branchial skeleton, and a pygochord present.
- Balanoglossus is a 'ciliary feeder'.
- The subphylum Vertebrata (subdivision Euchordata) possesses a distinct head and a cranium, therefore, they are known as Craniata.
- The body of Craniata comprises a head, neck, trunk and tail.

- Gnathostomata is divided into two superclasses- Pisces and Tetrapoda.
- The superclass Pisces (L., piscis = fish) includes all the fishes which are strictly aquatic forms with paired fins.
- The superclass Tetrapoda (Gr., tetra = four; podos = foot) includes four-legged land vertebrates including amphibians, reptiles, birds and mammals.

1.8 TERMINAL QUESTIONS

1. Describe in details classification of phylum chordata upto classes.

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2. Explain the main characteristics features of phylum chordata.

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3. Describe in details Protochordata and the Buccal diverticulum

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4. Describe in detail the alimentary canal and circulatory system in Balanoglossus.

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5. Describe in detail the affinities of Balanoglossus.

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Write short notes on:

(a) Chorda dorsalis

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(b) Metamerism

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(c) Pygochord

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(d) Proboscis skeleton

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1.9 ANSWERS

SAQ-1

1. pharyngeal gill slits.
2. chordate ancestors and vertebrates.
3. Acrania
4. Craniata.

SAQ-2

1. reptiles,birds and mammals.
2. ‘ciliary feeder’.
3. pygochord present.

UNIT-2 : UROCHORDATA AND CEPHALOCHORDATA

Structure A : Urochordata

2.1 Introduction

Objectives :

2.2 General Characters

2.3 Classification

2.4 Study of Herdmania and its affinities

Structure B : Cephalochordata

2.5 Introduction

2.6 General characters

2.7 Classification

2.8 Study of *Branchiostoma* (Amphioxus) and its affinities

2.9.1 Summary

2.9.2 Terminal Question

2.9.3 Answers

Structure : Urochordata

2.1 INTRODUCTION

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

Objectives :

After studying this unit you will be able to know about :

- General characters and classification of Herdmania, Cephalochordates.
- General characters and classification up to order level. Branchiostoma and its affiniti e s.

2.2 GENERAL CHARACTERS

1. Exclusively marine commonly known as sea squirts.
2. Cosmopolitan found in all sea and at all depth.
3. Solitary or colonial
4. Fixed or free swimming and pelagic.
5. Body is covered by a cuticular tunic or test in adult stage. (hence the name "tunicata".
6. The adult body degenerated, sac like unsegmented.

7. Notochord present in the larval stage and is absent in the adults. This notochord is present only in tail region hence called Urochordata.
8. Dorsal tubular nerve cord is present in the larval forms, while degenerates and remains in the form of small ganglion in adults.
9. Numerous gill slits are present.
10. Blood vascular system open type. Heart ventral, simple and tubular.
11. Coelom is completely absent, even the pericardical cavity is not coelomic.
12. Excretion by neural gland, pyloric gland and nephrocytes.
13. Alimentary canal complete. Pharynx large, Ciliary feeders.
14. Sexes are united i.e. hermaphrodite. Fertilization cross and external.
15. Development indirect through a free swimming tailed larva with basic chordate characters. Retrogressive metamorphosis.

2.3 CLASSIFICATION

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

2.4 STUDY OF HERDMANIA AND ITS AFFINITIES

Habits & Habitat

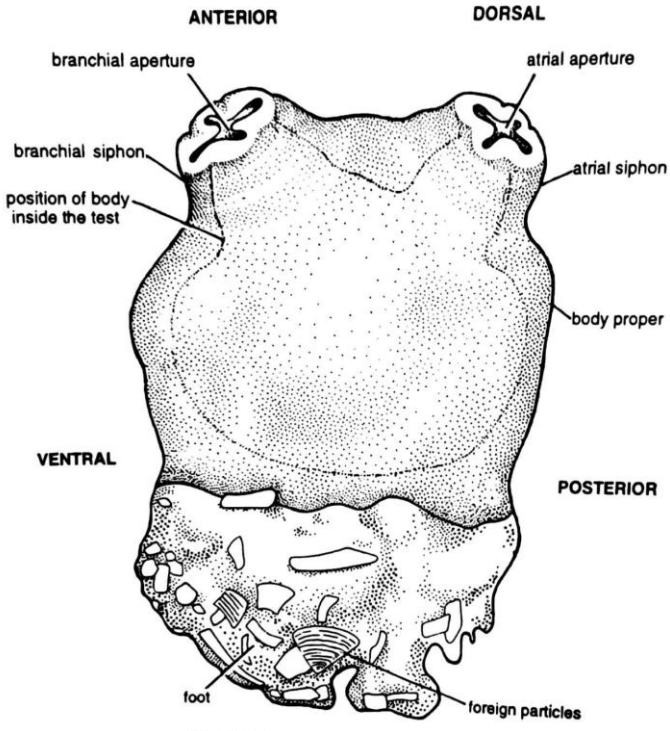


Fig: *Herdmania* : External feature

Herdamina is a solitary marine animal and generally found at places where abundant polychaete

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

Morphology

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

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

Body wall

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

Coelom & Atrium

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

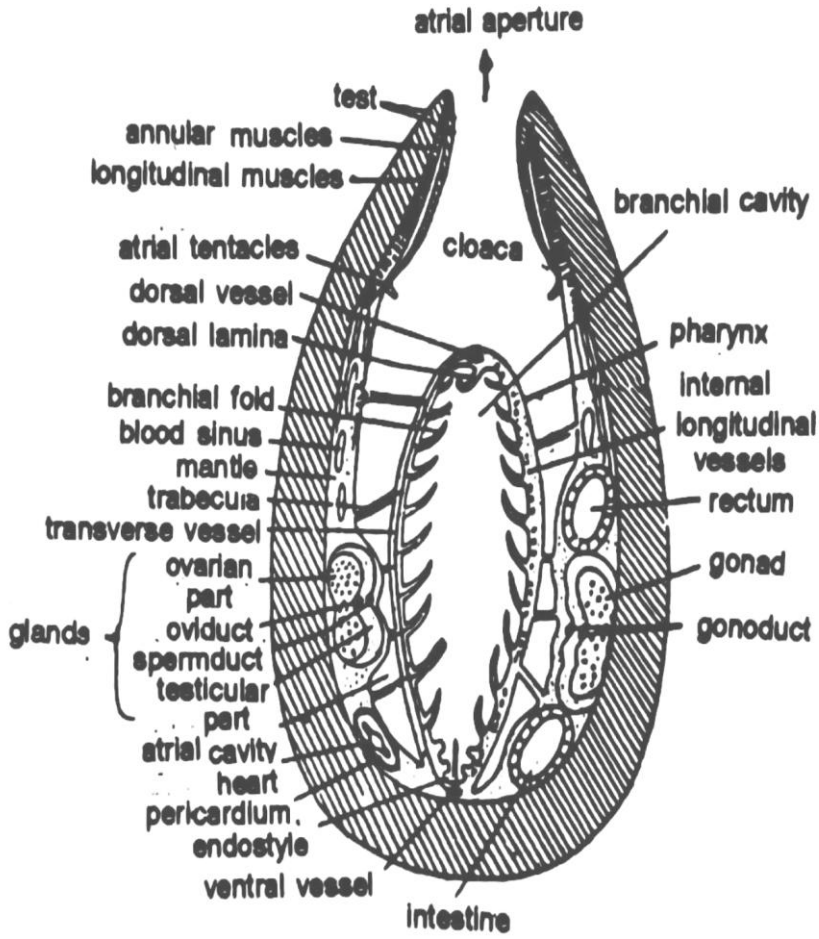


Fig: *Herdamina:* Section of body

Digestive system

The digestive system includes the alimentary canal and digestive glands.

Alimentary Canal

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

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

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

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

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

(b) Branchial Sac : It is a large spacious structure. The lateral wall of the pharynx is perforated by several rows of gill slits or stigmata arranged in transverse rows, through these the cavity of the pharynx communicates with the atrial cavity. The edges of stigmata are beset with cilia which drive currents of water from the pharynx into the atrial cavity. The stigmata are not gill clefts but they are formed by subdivision of a few original gill clefts. Between the stigmata the wall of the pharynx has transverse and longitudinal bars containing blood vessels, thus the pharynx appears like a basket. The inner surface of each lateral wall of branchial sac is raised into 9 to 10 longitudinal folds. These folds starting from behind the posterior peripharyngeal band and extending dorsally upto area which surround the opening of the oesophagus.

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

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

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

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

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

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

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

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

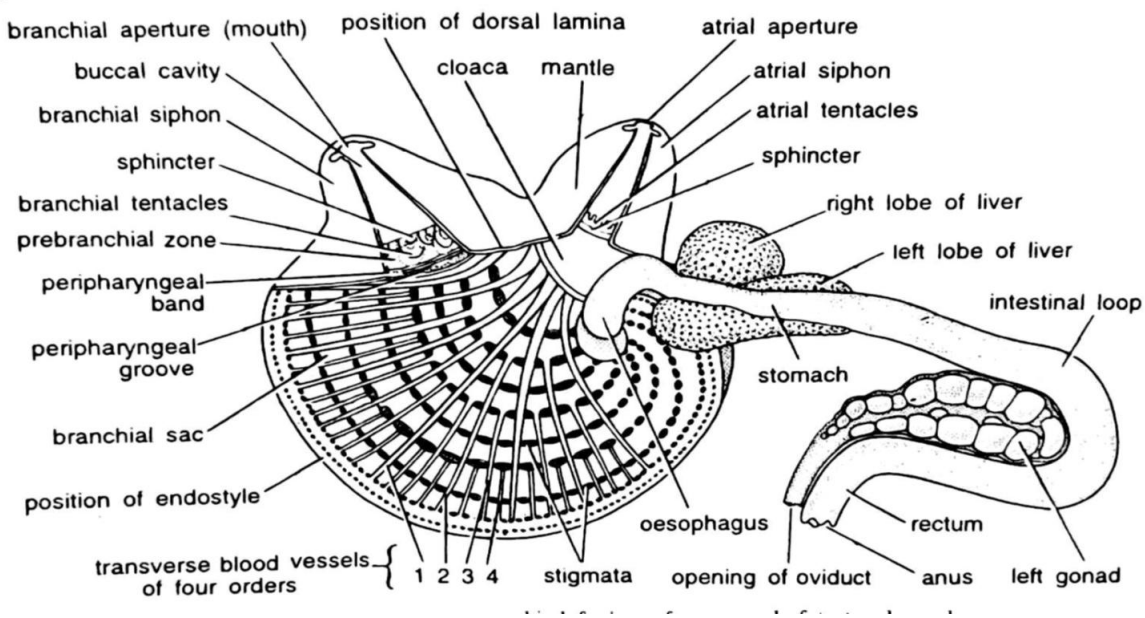


Fig: *Herdmania*: Alimentary Canal

Digestive gland :

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

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

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

Food and feeding

The food of *Herdmania* are microscopic planktonic organisms such as protozoans, algae, diatoms, fragments of decaying animals. The animal is ciliary or filter feeder. A continuous water current is set by the rapid beating of cilia of stigmata causes water to enter into the mouth and passing into the pharynx from where it goes out through the stigmata into the atrial cavity and then to the exterior through the atrial aperture. The current of water carries in minute organic food particles which pass into the pharynx, where they settle down on the pharyngeal walls. Gland cell of the endostyle secrete mucus. The mucus is lashed out transversely from the endostyle by its cilia, at right angles to the endostyle. The food particle lying on the lining of the pharynx are caught in the mucus and generally transported upwards along the pharyngeal wall to dorsal lamina, in passing the food particle and mucus are rolled into a cylindrical mass. The dorsal lamina cilia convert the cylindrical mass into a string in the tube formed by curving upwards of languets, the food laden mucus string is carried into the oesophagius.

Digestion

In *Herdmania* liver secrete yellowish brown colour digestive enzyme like amylase split

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

Respiratory System

The water current entering into the pharynx brings dissolved oxygen in sea water. The pharyngeal wall is highly vascular transversed by rich network of blood vessel and is also very thin enabling gaseous exchange. The CO_2 of blood diffuses into water and O_2 from water into blood. The respiratory surface is increased by longitudinal folds and papillae. The respiratory pigment of blood seems to be incapable of absorbing any oxygen. Then gaseous exchange also occurs in the vascular trabeculae of atrium. The test also provides a respiratory surface as it contains vascular ampullae and blood vessels.

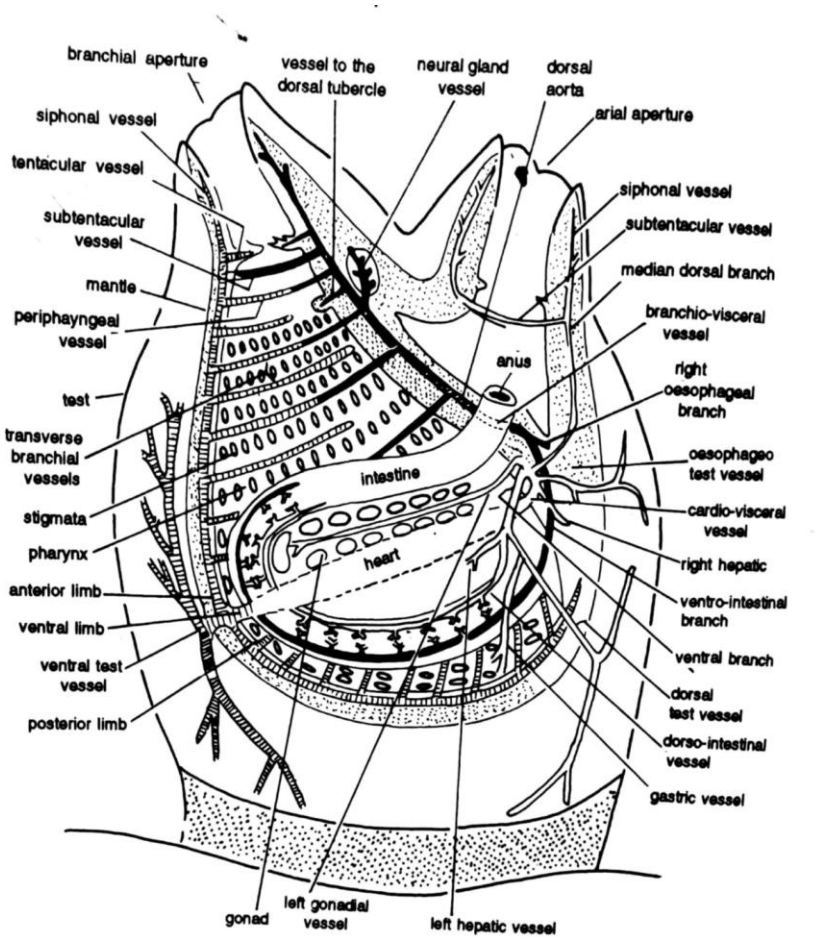


Fig: *Herdmania* blood vascular system

Circulatory System

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

Heart

The heart is thin walled, tubular and contractile structure is situated in the pericardium, below the right gonad. The heart is internally composed of epithelium and externally by a striated muscular layer. There is no valve is present in heart to regulate the direction of blood flow. The pericardium is

closed at both the ends and its cavity is filled with blood like fluid.

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

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

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

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

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

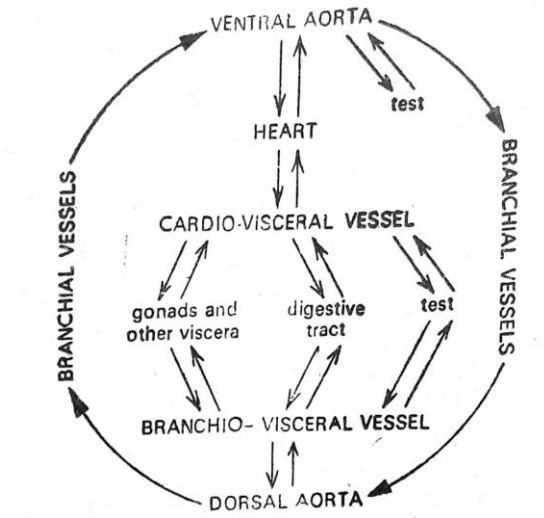


Fig: *Herdmania* Course of circulation

Circulation

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

Blood

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

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

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

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

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

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

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

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

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

Nervous System

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

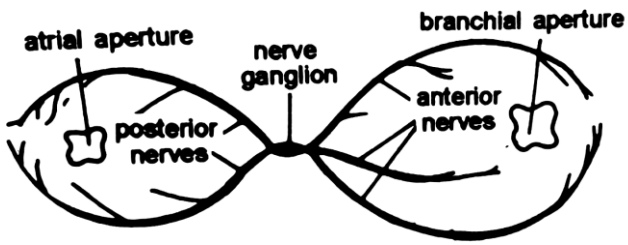


Fig: *Herdmania* Nervous system

Sense Organ

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

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

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

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

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

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

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

Excretory Organ

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

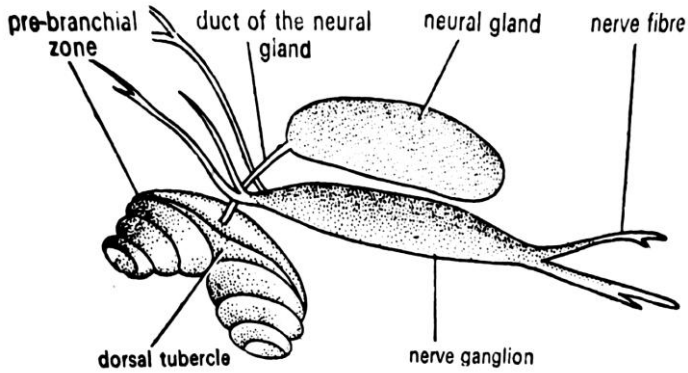


Fig: *Herdmania* : Neural gland

Reproductive System

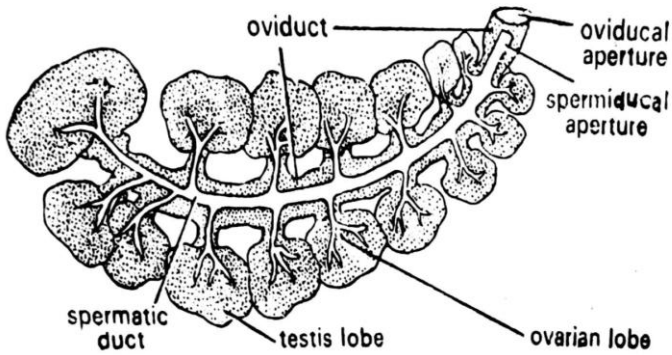
*Herdmania*is hermaphrodite, but cross fertilization occurs. The animal is protogynous i.e. the ovaries mature much before the testes. The two large gonads are embedded in the mantle, the left one lies in the loop of the intestine and the right one dorsal to the heart. Each gonad consists of twenty lobes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

ductules. The oviduct and vas deferens run parallel and open by their own apertures into the atrial cavity where ova and sperms are discharged. The sex cells pass out of the atrial siphon into the sea.

Fig: *Herdmania* Gonad

Fertilization :

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



Development:

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

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

Tadpole Larva:

The tadpole larva of *Herdmania* has a short oval body and along tail. The entire body of tadpole is divided into two parts i.e. trunk and tail. The trunk is covered by a thin and transparent test, secreted by the ectoderm, which becomes flattened in the tail region and forms a tail fin. The tail is four times long as the trunk and is laterally compressed. At the anterior end of the trunk are three adhesive papillae made of ectodermal secretary cell, whose secretion helps in the attachment of the larva with the substratum during metamorphosis. The nervous system consists of an enlarged anterior part called sense vesicle or brain which is hollow. The sense vesicle is continued posteriorly into a solid, thick mass of nerve cells, called visceral ganglion, it is continued into the tail and lies mid dorsally. The sense vesicle contains a pigmented otocyst and two pigmented unequal ocelli as sense organs. The ventral side of the nerve cord lie notochord which runs from the endoderm cells of the trunk to the end of the tail. The notochord persists only in the tail region. In tadpole alimentary canal is fully developed and distinguished into pharynx, oesophagus, stomach and intestine. Mouth remains covered by test, so no feeding is possible. The pharynx has an endostlye and also some stigmata. An atrial cavity is formed around the pharynx and it opens to the exterior by an atrial aperture lying dorsally. The heart and pericardium have been formed in tadpole larva.

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

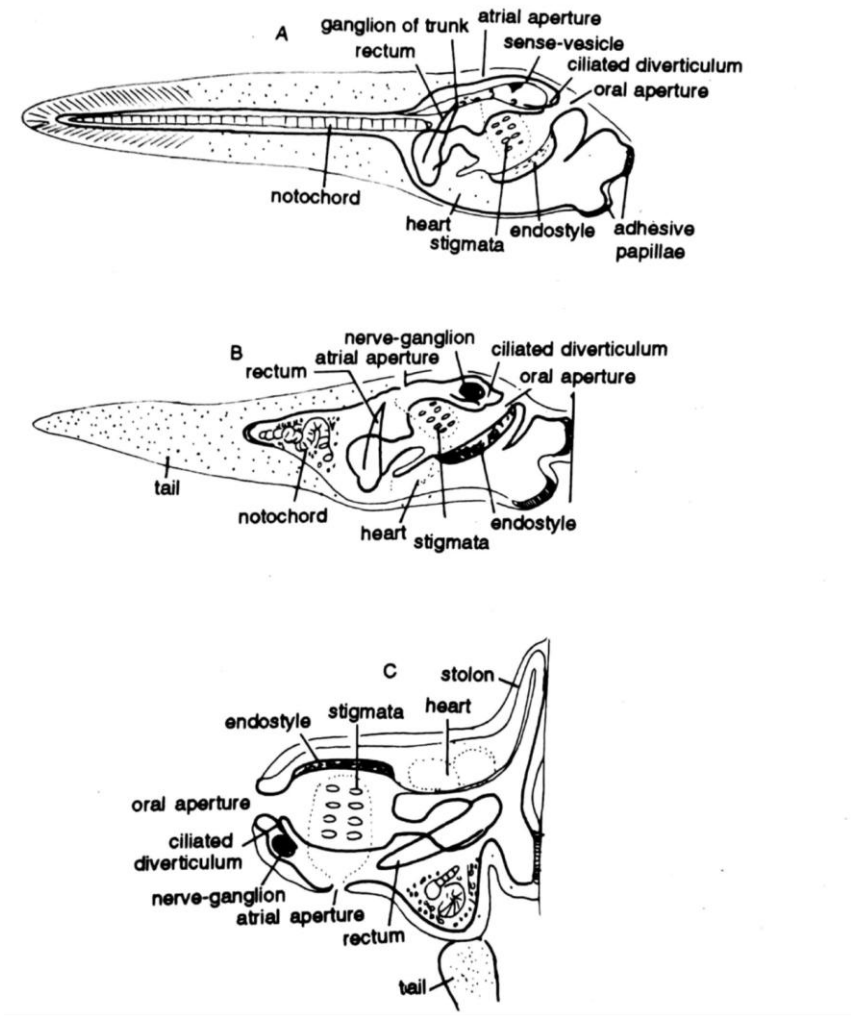


Fig: *Herdmania :* Retrogressive metamorphosis

Retrogressive Metamorphosis

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

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

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

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

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

number by division.

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

(6) Heart and circulatory system develops.

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

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

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

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

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

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

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

Affinities of Urochordata

The ascidian tadpole larva possesses all the three basic chordate characters i.e. (i) Rod like notochord forming axial skeleton of tail. (ii) Dorsal tubular nerve cord (iii) Presence of gill slits in the pharyngeal wall. These characters have lost in adult ascidian. But it has many characters that resembles or show its affinities with chordate. These are as follows.

1. Similiar ciliary filter feeding or food concentration mechanism and respiratory mechanism like Amphioxus.
2. Large pharynx with similar accessories.
3. Branchial tentacles resemble the velar tentacle of Amphioxus.
4. The pharynx of tunicates is like that of cephalochordata with numerous stigmata, gland ciliated endostyle, peripharyngeal bands and a dorsal lamina.
5. Typhlosole is comparable to spiral valve of elasmobranch.
6. Endostyle is homologous with thyroid gland of vertebrate.
7. Neural gland is homologous with pituitary gland of vertebrate.

Beside these the ascidians tadpole larva also resemble higher chordates characters in

(a) Post anal tail covered by vertical caudal fin

(b) Type of cleavage & gastrulation

From above characters, it came to conclusion that urochordata have been derived from a free swimming chordate ancestor and it has close affinities with cephalochodata, so that they show common ancestry.

SAQs 1.

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

(i) The Annular muscles are found near ----------.

(ii) Matrix in test of Herdmania is made up of ----------.

(iii) Accessory respiratory organ in Urochordaters is ----------.

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

Structure B : Cephalochordata

2.5 INTRODUCTION

Cephalochordata are small fish like animals and shows main chordate characters. The notochord of cephalochordata extend the entire length of the body projecting beyond the nervous system to the tip of the snout, hence it is called cephalochordata. They have a dorsal tubular neural tube without a defined brain. The pharynx is large and contains numerous gill clefts opening into an ectoderm lined atrium, not to the exterior. The pharynx has an endostyle and ciliated tracts which are mainly for ciliary feeding. Metamerism is well marked. The gonads are segmental. It has definite coelom. Excretory organs are segmental nephridia. The cephalochordata is closely related to the urochordata, hence they are placed in the same group, i.e. Acrainata.

2.6 GENERAL CHARACTERS

1. Exclusively marine, widely distributed in shallow waters.
2. Sedentary and buried with only anterior end of body is projecting above bottom sand.
3. Body is small, slender fish like, metameric and transparent.
4. Head is absent. Body is divided into trunk and tail.
5. Paired appendages are absent. Median fin is present.
6. Exoskeleton is lacking.
7. Coelom is enterocoelous and reduced in the pharyngeal region by development of atrial cavity.
8. Digestive system is complete. Pharynx large perforated by numerous persistent gill slits opening into atrium.
9. Respiration by general body surface.
10. Circulatory system well developed, closed and without heart and respiratory pigment.
11. Hepatic portal system is well developed.
12. Excretion by protonephridia with solenocytes.
13. Dorsal tubular nerve cord without ganglia and brain. Dorsal and ventral nerve root separate.
14. Sexes separate. Gonad numerous. Gonoduct lacking.
15. External fertilization in sea water.
16. Development indirect through free swimming larva.

2.7 CLASSIFICATION

Phylum : Chordata

Group : Acrania

Subphylum : Cephalochordata

Class : Leptocardii

Family : Branchiostomidae

Genus : *Branchiostoma*

2.8 STUDY OF BRANCHIOSTOMA (AMPHIOXUS) AND ITS AFFINITIES

Habits and Habitat

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

Morphology

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

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

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

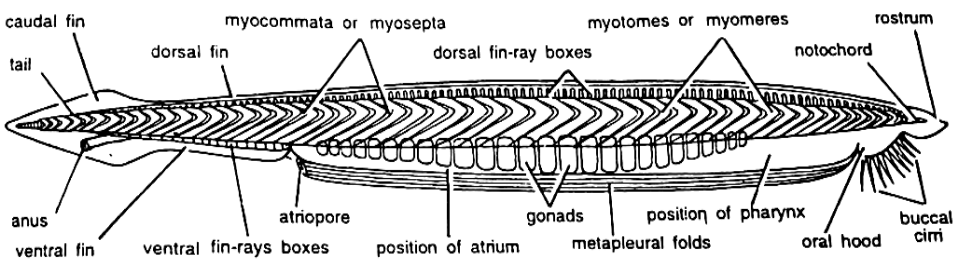


Fig : *Branchiostoma* External feature

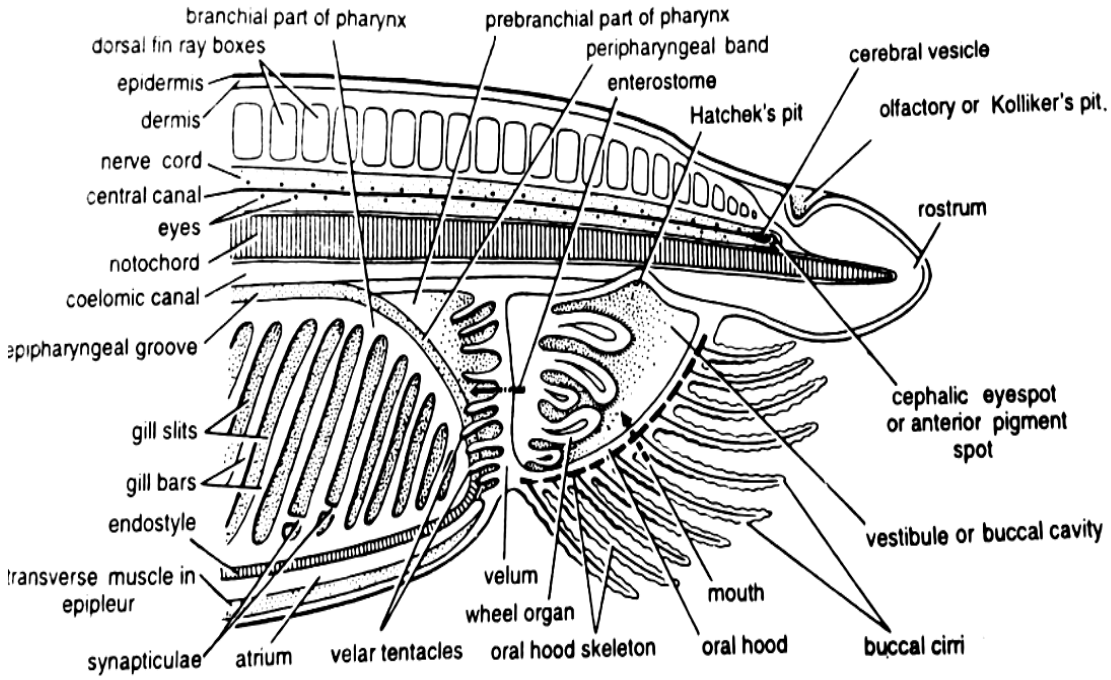


Fig: *Branchiostoma* Enlarged L.S. of anterior end

Body wall

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

Skeleton

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

Coelom

The body cavity is a well developed coelom lined with somatic and splanchnic mesodermal epithelium, it contains a lymph like coelomic fluid. Behind the pharynx the coelom is a spacious

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

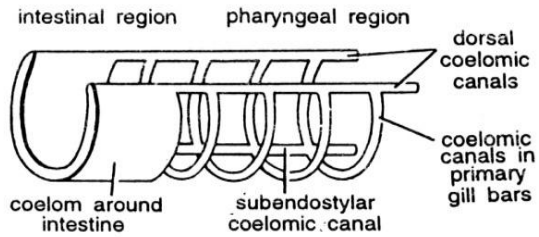


Fig : *Branchiostoma* Diagrammatic representation of coelom

Atrium

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

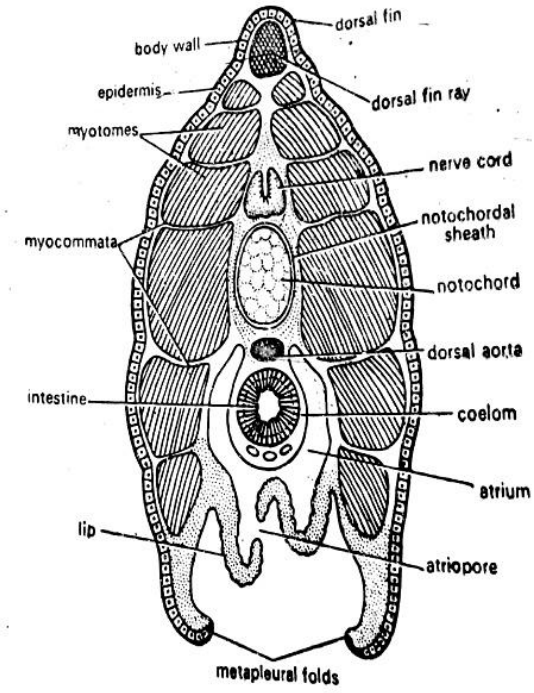


Fig : *Branchiostoma* T.S through atripore

Circulatory System

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

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

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

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

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

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

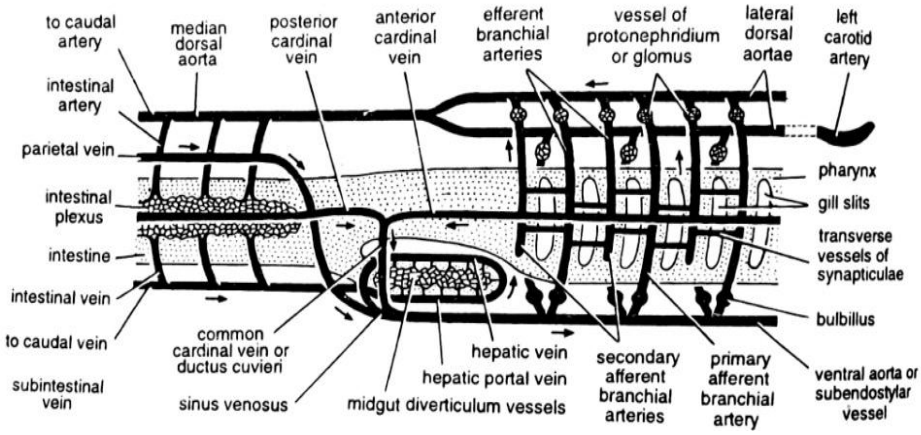


Fig: *Branchiostoma* : Circulatory system

Digestive System

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

Alimentary canal

The alimentary canal is a straight complete tube from mouth to anus. A mouth leads into an oral hood, the space enclosed by the oral hood is an ectoderm lined vestibule or buccal cavity, which is funnel shaped. At the back of the vestibule is a vertical velum having a hole in the middle known as enterostome. The edges of the velum bear 12 or more slender, ciliated velar tentacle, which normally project backwards forming a strainer. The enterostome lead into a pharynx. The pharynx is a large, laterally compressed sac with its walls perforated by more than 150 pairs of gill clefts, through which the pharyngeal cavity communicates with the atrial cavity. The gill slits bear no gills and their number increases with age of the animal on the posterior side of pharynx. Between the gill clefts the wall of the pharynx is known as gill bars or gill lamellae. The gill bars are of two types, primary gill bars and secondary gill bars or tongue bars, they alternate regularly and differ in their structure and

mode of development. Both primary and secondary gill bars are covered on their external surface by sparsely ciliated ectodermal or atrial epithelium, but on inner anterior and posterior surface by endodermal pharyngeal epithelium, which is heavily ciliated. These cilia on the anterior and posterior endodermal surfaces of gill bars are long lateral cilia which propel water and the cilia on the inner endodermal surface of each gill bar form a long but narrow tract of frontal cilia which propel mucus.

The gill bars are supported internally by gelatinous skeletal gill rods, all gill rods are united dorsally, but ventrally their free ends are forked in the primary gill bars, and unforked or simple in the secondary gill bars. The primary gill bars are connected to each other by transverse junctions called synapticula which also contain gelatinous rods and blood vessel. In the pharynx, mid dorsally is a ciliated epipharyngeal groove which lead into the opening of oesophagus at the posterior end of the pharynx. In the mid ventral wall of the pharynx is a shallow groove called endostyle. The endostyle is lined with four longitudinal tracts of gland cells which secrete mucus. The epipharyngeal groove and endostyle are joined to each other anteriorly by two ciliated peripharyngeal bands, each running on one side in the wall of pharynx just behind the velum.

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

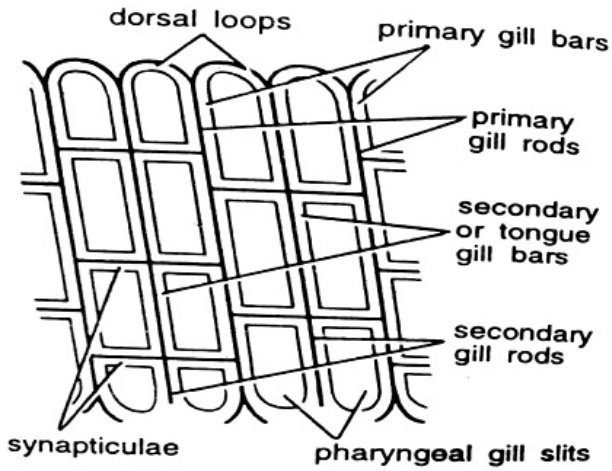


Fig: Branchiostoma A part of pharyngeal wall

Digestive gland

The mid gut diverticulum or liver is a main digestive gland. It arises as a blind pouch from the ventral junction of oesophagus and mid gut and extends forward into atrial cavity on the right side of

pharynx up to one third of its length. Its zymogen cells secrete a number of digestive enzymes. The epithelial lining of intestine also contains numerous gland cells that secrete digestive enzyme.

Feeding

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

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

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

Digestion

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

Respiration

In Branchiostoma special respiratory organ are lacking. In Branchiostoma some exchange of $O_2$and CO_2occurs between the water current and blood through the gill cleft but this appears doubtful since the blood contain no respiratory pigment. It appears more probable that an exchange of gases occurs over the whole surface of the body and particular in the wall of atrium.

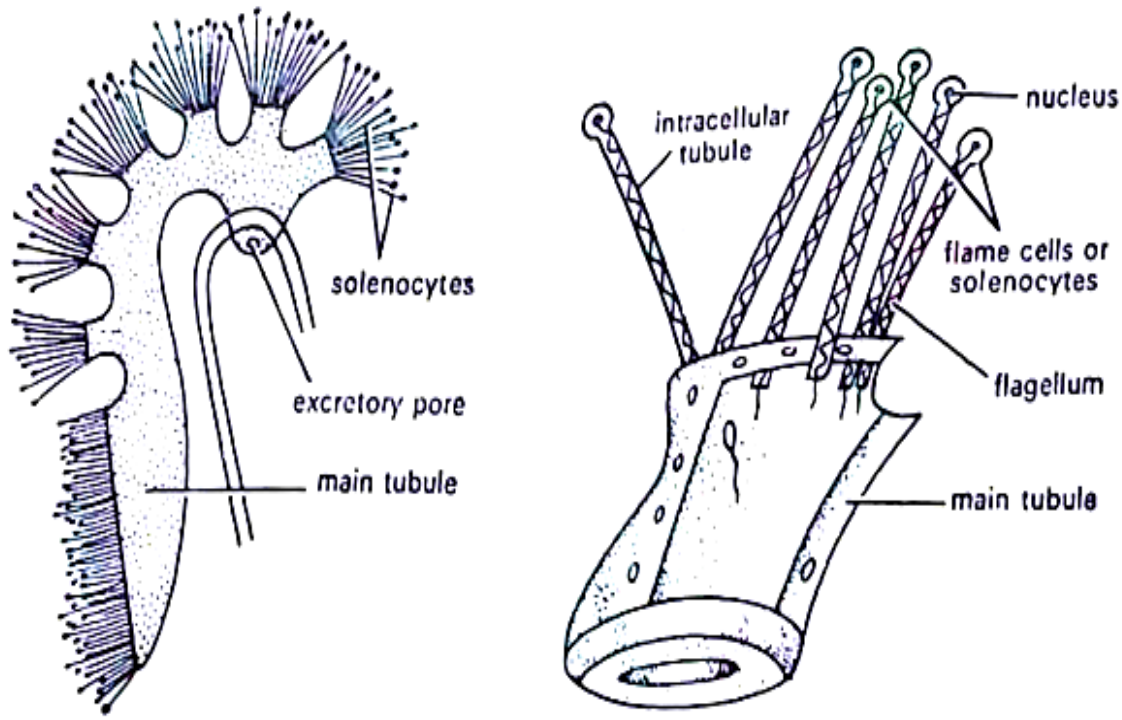
Excretory System

In Branchiostoma excretory organs are about 90 pairs of segmentally arranged nephridia are of closed type called protonephridia. Which there lie above the gill clefts on each side corresponding to

primary gill bars. Each protonephridium is a bent nephridial tube having groups of thin tubules ending in solenocytes. Each solenocyte has a round nucleated head leading into a thin tubule which contains a vibratile flagellum. The tufts of solenocytes project into the dorsal longitudinal coelomic canals and are bathed in coelomic fluid. The nephridia are also supplied with small blood vessels. The nephridial tube opens by nephridiopore into the atrium at the upper end of a gill cleft lying against a secondary gill bar. So one end of the protonephridium lies in the coelom and the other end opens into the atrium. Protonephridia absorb nitrogenous waste from the blood sinuses and coelomic fluid by diffusion, and discharge it into the atrium.

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

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



A **B**

Fig: *Branchiostoma* A : Entire nephridumB : A portion of nephridium

Nervous system

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

On the anterior end the central canal dilates into a cerebral vesicle or ventricle and from its roof,

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

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

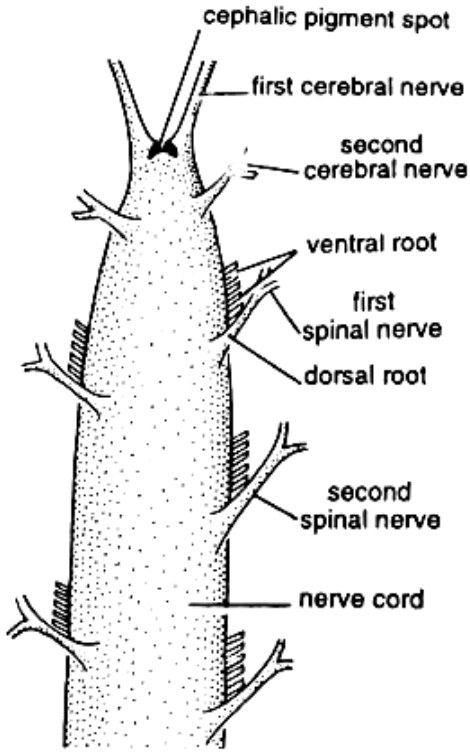


Fig: *Branchiostoma*, Anterior part of central nervous system

Sense organs

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

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

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

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

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

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

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

Reproductive system

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

Affinities of Cephalochordata

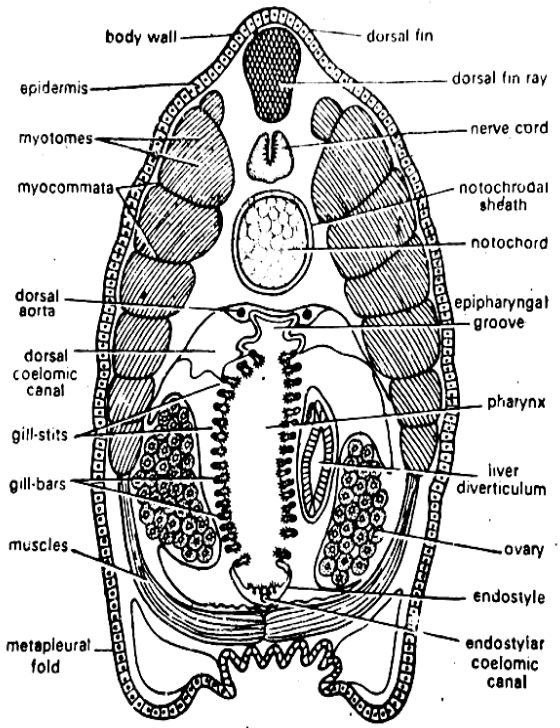


Fig: *Branchiostoma* T.S passing through posterior region of pharynx showing gonads

Cephalochordata possesses all the three basic chordate characters i.e. presence of notochord, dorsal tubular nerve cord & pharyngeal gill-slits in both larva & adult stages. It has been observe that Cephalochordata and Urochordata have many similar characters like primitive ciliary feeding mechanism with a large pharynx having many gill-clefts, an endostyle which produce mucus, peripharyngeal bands and an epipharyngeal groove (dorsal lamina). The ectodermal lined atrial cavity opens to the exterior by an atriopore or its homologue, the atrial siphon. There is also a similarity of eggs of some tunicates to these of Amphioxus.

It has been observed that adult urochordates have some feature which are not present in cephalochordate like unsegmented body, body is covered by a test made of cellulose, it has enterocoelic coelom, without notochord, well developed muscular heart covered by peritoneum, without nephridia, sexes united with hermaphrodite gonads, larva undergoing retrogressive metamorphosis to become adult. These differences in characters, show that cephalochordate are better evolved than urochordates.

The Amphioxus having secondary or specialized characters like

1. A very large and elaborate pharynx with an accompanying multiplication of gill-clefts. The extra number of gill-clefts is unrelated to body segmentation.
2. There is an oral hood with highly developed equipment and the velum is elaborate.
3. Formation of a large atrium with an atriopore.
4. An extreme anterior extension of notochord seen in no other chordate, this may be the reason for a small brain.
5. Peculiar reduction and distortion of coelom by the atrium.

From above these characters it is concluded that Amphioxus possesses a peculiar admixture of primitive, degenerate as well as specialized or secondary characters. As it is compared to vertebrates, it lacks many crainata structures. But it has basic chordate characters. More over it has post anal tail, hepatic diverticulum, hepatic portal system and the beginning of a ventral heart. These characters shows the original chordate ancestor to which Amphioxus belong. However its secondary or specialized characters shows that it is not on the direct line of chordate descent in evolution. Hence it is placed in an independent subphylum Cephalochordata

SAQs 2.

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

(i) The primary gill rod encloses ----------

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

(iii) In *Branchiostoma* gonads are arranged metamerically one pair in each segment from ---------

(iv) The atrium in *Branchiostoma* is formed by----------

2.9.1 Summary

In the first unit Urochordata is taken. In Urochordata *Herdmania* is referred. They are widely distributed in marine water. They are attached to the rocky sea bottom by a broad base. In *Herdmania*there is a peculiar characters in metamorphosis in which their larva having pharyngeal gill slits, a dorsal tubular central nervous system and notochord continued to the tail are lost in adult except gill cleft, so the larva having advanced characters than adult, such metamorphosis is called retrogressive metamorphosis. The larva of *Herdmania* is geo-negative and photopositive after metamorphosis it is photonegative and geo-positive.

In second unit, Cephalochordata is taken which is primitive chordate. They are more closely related to vertebrate than other group of living organism. It is suggested that the evolution of ancestral chordates has taken place in the auricularia larva of echinodermata by which it changes into an ancestral chordate. In this unit there is detailed study of *Branchiostoma*and its affinities have covered.

2.9.2 Terminal Question

Q1 Describe the external morphology of *Herdmania.*

Q2 Describe theBranchial Sac in *Herdmania.*

Q3 Describe the changes in retrogressive metamorphosis.

Q4. Explain Eye spot of *Branchiostoma*?

Q5. Explain digestion in *Branchiostoma* ?

Q6. DescribeInfundibular organof *Branchiostoma* ?

2.9.3 Answers

SAQ 1

(i) Heart

(ii) Tunicine

(iii) Test

(iv) External and cross fertilization

SAQ 2 (i) Blood vessel and coelomic canal

(ii)s Oral hood

(iii) 25 to 51

(iv) A pair of metapleural folds

Terminal question

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

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

2. It is a large spacious structure. The lateral wall of the pharynx is perforated by several rows of gill slits or stigmata arranged in transverse rows, through these the cavity of the pharynx communicates with the atrial cavity. The edges of stigmata are beset with cilia which drive currents of water from the pharynx into the atrial cavity. The stigmata are not gill clefts but they are formed by subdivision of a few original gill clefts. Between the stigmata the wall of the pharynx has transverse and longitudinal bars containing blood vessels, thus the pharynx appears like a basket. The inner surface of each lateral wall of branchial sac is raised into 9 to 10 longitudinal folds. These folds starting from behind the posterior peripharyngeal band and extending dorsally upto area which surround the opening of the oesophagus.

On the ventral side of pharynx there is a mid ventral longitudinal groove called endostyle or hypobranchial groove. It starts from the ventral margin of the posterior peripharyngeal band

running centrally and terminating into a pit, a short distance from the oesopheageal opening on the dorsal side, but its wall extend upto the oesopheageal opening as the retropharyngeal bands.

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

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

3. These changes are as follows

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

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

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

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

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

(6) Heart and circulatory system develops.

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

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

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

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

UNIT-3 : ORIGIN,EVOLUTIONANDADAPTIVERsADIATIONS OF VERTEBRATES

Structure A : Agnatha

3.1 Introduction Origin evolution &General characters of Agnatha (Petromyzon)

Objectives :

Structure B : Fishes

3.2 Introduction

3.3 General characters &Classification of Pisces

3.4 Types of scales & Fins of fishes

3.5 *Scoliodon* as type study

3.6 Migration & Parental care in fishes

3.7 Summary

3.8 Terminal Question

3.9 Answers

Structure A : Agnatha

3.1 INTRODUCTION ORIGIN EVOLUTION AND GENERAL HARACTERS OF AGNATHA (PETROMYZON)

The Agnatha are the earliest known vertebrates and are characterized by the absence of Jaws. These are similar to fish with some distinguishable features. Approximately 84 species of agnathans are present in the world today. Agnathans are jawless fishes belonging to the phylum- Chordata, subphylum-Vertebrata, consisting of both present (Cyclostomes) and extinct (Conodonts & Ostracoderms,) species and lived during Silurian and Devonian periods. There are two living group of agnatha i.e. lampreys and hagfish is Members of both the groups lack jaws, internal ossification, scales and paired fins and both the groups share pore like gill openings and an eel like body form. In other respect both the groups are morphologically different. Hagfishes are the least derived of the two while lamprey derived many morphological characters. Hence it gets most similar to the gnathostomes than hag fish. Because of this difference both are kept in separate vertebrate classes. The group is of great evolutionary interest, however because it includes the oldest known craniate fossils and because the living Agnathans have many primitive characteristic.

From the paleantology record, it is inferred that Ostracoderm were the earliest known vertebrates. They were primitive and mostly armoured, bottom living fishes. These were the first vertebrates that dominanted their contemporary habitat. The ostracoderms are of great importance as they are earliest vertebrate and to known the way of life and they are different from pre-vertebrate & larva in the course of evolution.

It has been reported that ostracoderms were first to appear in the middle of Ordovician and they were wide spread. They led successful life during the Silurian period but in the Devonian period there number started on decreasing and in Carboniferous none of them survived. So they flourished between 350 & 275 million year ago. The ostracoderm had to compete with invertebrates like arachnids, eurypterids and other invertbrates in their habitat. The Invertebrates during this period ranged from few inches to about two feet long.

The ostracoderms were clearly vertebrate in structure, but they differ from later vertebrates except the cyclostomes, which are descended from them, in having no movable jaws. There mouth was rounded & suctorial. Due to this and some other characters Ostracoderms & Cyclostomes are placed as the separate subdivision of Agnatha.

Ostraderm were shown by their flattened ventral surfaces to the adapted to a sluggish bottom living habit, but some were free swimming though probably still living and feeding near the bottom. From these evidences it shows that they are only the early evidence of any vertebrate from the rock of Ordovician. But the earlier than those in which the first fossils of complete ostracoderm were occur, we have fragmentary remains of early vertebrate scales but not much more. We have one poorly preserved fossil from Famoytius kerwoodii (upper or middle Silurian), which is no earlier in time than the ostracoderms but has been believed to be a persistent member of a more primitive group antecedent to them.

Today we have the cyclostomes, lamprey and hag fish. These are agnatha, undoubtly descended from the ostracoderms, but greatly modified in adaptation to their habit of feeding on living fish. Their biology helps us to understand that of ostracoderm.

Objectives :

After studying this unit you will be able to know about :

- Origin evolution &General characters of Agnatha
- Characters & Classification of PiscesTypes of scales & Fins of fishes
- Migration & Parental care in fishes

General characters of Agnatha (petromyzon)

- Agnatha are earliest known vertebrates and are characterized by absence of jaws.
- Teeth, paired appendages and exoskeleton are also absent.
- Skull has a membranous roof.
- Single median nasal opening present.
- Vertebral column consists of a persistent notochord with a fibrous neural tube.
- Presence of large number of gill-slits, (from 7 – 14 pairs.)
- Absence of conus in the heart.
- A persistent hypophysial sac.
- One or two semicircular ducts in the ear
- Long kidneys and long archinephric ducts
- Genital ducts absent.
- Pineal apparatus fairly well developed
- Larval stage is microphagus and has an endostyle similar with that of the protochordes.

Subphylum Agnatha is divided into two classes Ostracodermi and Cyclostomata

Class – I Ostracodermi (Extinct)

- Fossil jawless agnatha of fresh water
- They had fish like bodies with heavy armour.

- They had heavy bony dermal plates in the skin.
- Some of the forms had one pair of fins behind the head
- They had single nostril on the top of the head
- There was a slit like mouth at the extreme front end of the head. It was used for scooping decaying matter from the floor.
- The paired eyes were situated on the top of the head. Median pineal eye was also present.
- The gill-slits were round and all have similar gill pouches.
- The endoskeleton was moderately ossified.
- Two semi-circular canals were mostly present in the ear.

Example : *Cephalaspis*

Class – II Cyclostomata (Living)

- Body is long, rounded and eel like.
- Skin is soft, smooth and without exoskeleton.
- Mouth is suctorial devoid of functional jaws.
- Nostril is single and median.
- Paired fins or lateral appendages are absent.
- Skeleton is cartilaginous.
- Notochord is persistent.
- Heart is two chambered and aortic arches are many.
- Digestive system lack a stomach, Intestine with a fold typhlosole.
- Two mesonephric kidneys with ducts to urino-gential papilla.
- Dorsal nerve cord with differentiated brain. 8 to 10 pairs of cranial nerve.
- Sexes separate or united. Gonad single, large without gonoduct
- Fertilization external.
- Development is direct or indirect.

Order -1 Petromyzontia

- Mouth ventral, within a suctorial buccal funnel beset with many horny teeth.
- Nostril dorsal. Naso-hypophyseal sac closed behind, not connected to pharynx.
- Gill pouches and gill slits 7 pairs each, opening in a separate respiratory pharynx.
- Seven pairs of gill-slits.
- Dorsal fin well developed.
- The gills open into a respiratory tube below the oesophagus.
- Dorsal and ventral roots of spinal nerves remain separate.
- Ear with 2 semicircular canals.

- Eggs numerous, small, development indirect with a long larval stage and metamorphosis.
- Both marine and fresh water forms.

Example – *Petromyzon* or *lamprey*

Order – 2 Myxinoidea

- Mouth terminal with 4 pairs of tentacles and few teeth. No buccal funnel.
- Nostril terminal. Naso-hypophyseal duct opens behind into pharynx.
- Gill pouches 6 to 15 pairs.
- Dorsal fin absent.
- Dorsal and ventral roots of spinal nerve united.
- Ear with only 1 semicircular duct.
- Egg few, large.
- Development direct.

Example – *Myxine* or hag fish, *Bdellostoma*

SAQs 1.

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

(i) ---------- is a superclass of jawless fish

(ii) In Agnatha ---------- pairs of gill slits are present.

(iii) Member of class Myxini are ---------

(iv) *Petromyzon* belongs to order ----------

Structure B : Fishes

3.2 INTRODUCTION

Superclass Pisces are truly jawed aquatic vertebrates. It includes all types of fishes. Pisces are poikilotherms (cold blooded) vertebrates. There are about 30,000 to 40,000 species of fishes differing widely from each other in shape size and habits and habitat. They have organs of locomotion and respiration related to a permanent aquatic life. The chief and generally the lonely respiratory organs are the gill. The organs of the locomotion are the paired pectoral and pelvic fins and the unpaired, dorsal, anal and caudal fins. Fishes are thought to have originated from sea squirt, which are similar to primitive fish. The study of fishes is called Ichthyology. Fishes usually have a stream lined body but some are elongated snake-like and few are dorso-ventrally flattened.

3.3 GENERAL CHARACTERS & CLASSIFICATION OF PISCES

General Characters

- Aquatic, either fresh water or marine
- Cold blooded vertebrates
- The skin is covered with scales, dermal denticles or bony plates.
- Body usually streamlined but some are elongated snake like and few are dorso-ventrally compressed.

- Presence of paired and unpaired fins supported by soft or spiny rays.
- Dorsal, caudal and anal fins are unpaired, while the pectorals and pelvic (ventrals) are paired.
- Tail is muscular and used for propulsion.
- Nostrils are paired but do not open into pharynx except lung fishes.
- Presences of barbles (excellent tactile organs) in some Teleostomi.
- The endoskeleton is cartilaginous or bony.
- Organ of respiration are gills but accessory respiratory organs may also be present.
- Gills are borne by true gill-arches. They open outside by gill-slits which are covered by operculum in Teleostomi
- The gill- slits are never more than seven pairs. Usually five pairs are present.
- A swim bladder or air bladder is usually present but secondarily lost in some species.
- Lateral line system is well developed.
- Heart is venous and two chambered i.e. one auricle and one ventricle.
- Ten pairs of cranial nerves are present.
- Only internal ear is present.
- The kidney is mesonephros.
- The gonads process true gonoducts.
- Sexes are separate and development is indirect.
- Amnion and allantosis are absent in the embryonic stages

Classification of Pisces

According to Berg (1940) super class Pisces has been divided into seven classes i.e. Pterichthys, Coccostei, Acanthodii, Elasmobranchi, Holocephali, Dipnoi and Telostomi. The first three are extinct and belong to Placoderms. Remaining 4 living classes are discussed here.

Class – I Elasmobranchii

- Skin is covered with placoid scales or naked.
- Endoskeleton cartilaginous, often calcified.
- Gill slits 5 – 7 on each side.
- Operculum or gill cover absent
- Air bladder and lungs are absent.
- Mouth is ventral
- Cloaca is present
- Male usually possesses claspers
- Mostly marine

Subclass –I Selachii

- Paired fin without a median axis
- Base of pectoral fin constricted
- Pectoral radial jointed

- Vertebral centra usually differentiated
- Males with claspers

Super order –I Pleurotremeta

- Gill slits on lateral side
- Anterior margin of pectoral fin free
- Hyomandular bearing branchial ray
- Right & left halves of pectoral girdle dorsally separated

Order – 1 Lamniformes

- Two dorsal fin without spines
- Anal fin present
- 5 gill arches

Example –*Scoliodon, Stegostoma, Sphyrna*

Super order –II Hypotremata

- Gill slits on ventral side
- Anterior margin of pectoral fin fused with sides of the body or head
- No branchial ray on Hyomandibular
- Two halves of pectoral girdle united either to each other or to the vertebral column

Order – 1Rajiformes

- No electric organs between head & pectoral fins
- Pre-orbital cartilages not enlarged.

Example -*Rhinobatils, Trygon, Pristis, Raja*

Order – 2 Torpediniformes

- Electric organs present between head & pectoral fins
- Pre-orbital cartilages greatly enlarged.

Example -Astrape (*Torpedo* , Electric ray)

Class – IIHolocephalii

- Palato-quadrate fused to the neuro-cranium.
- 4 gill-slits on each side covered by operculum.
- An inter-orbital septum is present dorsal to the brain case
- Cloaca is absent
- Male with claspers
- Two halves of the pelvic girdle not fused

Subclass –I Chimarae

- Notochord persistent, usually surrounded with numerous partly calcified rings
- No true centra
- Pectoral fin normal types

Order – 1Chimaeriformes

- No electric organs between head & pectoral fins
- Pre-orbital cartilages not enlarged.

Example -*Chimaera (Rat fish, Ghost fish)*

Class – IIIDipnoi

- Palato-quadrate firmly fused to the neuro-cranium
- Dermal bones are present on the skull, jaws and pectoral arch
- Single gill-slits on either side are present.
- Cycloid scales covering the skin
- Internal nares are present
- Operculum, air bladder and cloaca are present
- Paired fins are lobate
- Pelvic girdle unpaired

Super order –I Ceratodi

- No gular plates
- Cranial roof bones few but large
- Caudal fin diphycercal, confluent with dorsal and anal fins.
- Pelvic girdle unpaired and unossified

Order – 1Ceratodiformes

- Endocranium cartilaginous
- Air bladder single

Example – *Neoceratodus, Ceratodus*

Order – 2Lepidosireniformes

- Endocranium membraneous
- Air bladder paired

Example – *Protopterus, Lepidosiren*

Class – IV Teleostomi

- Endoskeleton more or less bony
- Palato-quadrate not fused with endocrainium.
- Single external gill-slit on each side of the head
- Mouth is terminal
- Operculum is present
- Air bladder is usually present.
- Cloaca and claspers are absents

Subclass –I Sarcopterygii

- Paired fin leg like or lobed with a fleshy, bony central axis covered by scales
- Dorsal fins 2. Caudal fin heterocercal with an epichordal lobe
- Olfactory sacs usually connected to mouth cavity by internal nostrils
- Popularly fleshy or lobe finned or breathing fish.

Order –1 Crossopterygii (lobe fin fishes)

- Paired fins with a scale covered lobe
- Internal nares are present

- Squamosal bone present
- Caudal fin 3 lobed
- Spiracles present
- Air bladder vestigial

Example –*Latimeria, Coelacanthus*

Subclass –II Actinopterygii (Ray fin fishes)

- The fishes which live in fresh or marine water
- Paired fins thin, broad, without fleshy basal lobes and supported by dermal fin rays
- One dorsal fin, may be divided
- Caudal fin without epichordal lobe
- Internal nares are absent
- Squamosal bone absent
- Popularly called ray finned fishes

Order –1Polypteriformes

- Rhomboid ganoid scales and lobed pectoral fins
- Dorsal fin of 8 or more finlets
- Pectoral fins with a small prominent base
- Air bladder bilobed opening into the intestine ventrally

Example – *Polypterus* (bichir)

Order –2Acipenseriformes

- Body covered with five rows of bony scutes
- Skeleton largely cartilaginous
- Snout elongated
- Caudal fin is heterocercal

Example – *Acipenser* (Sturgeon)

Order –3 Amiiformes

- Caudal fin abbreviate heterocercal
- Premaxillary not protractile, firmly articulated with the cranium.
- Vertebrae centra non-opisthocoelus
- Pectoral radials are attached to the scapula-coracoid cartilage

Example – *Amia* calva

Order –4Lepidosteiformes

- Skin covered with rhombic ganiod scales
- Nasal openings at the end of much elongated snout
- Caudal fin abbreviate heterocercal
- Vertebrae completely ossified, opisthocoelus
- Air bladder cellular

Example – *Lepidosteus* (Gar-pike)

Order –5Clupeiformes

- Scales are well developed and cycloid
- Caudal din homocercal
- Dorsal and anal fins are without spines
- Vertebral centra completely ossified
- Weberian apparatus absent

Example – *Clupea, Salmo, Notopterus, Hilsa*

Order –6 Scopeliformes

- Dorsal and anal fins without spines
- An adipose fin is present
- Mouth large and provided with numerous small teeth
- Luminous organs are usually present

Example –*Harpodon* (Bombay Duck)

Order –7Cypriniformes

- A peculiar weberian apparatus, connecting the ear with the air bladder is present
- Air bladder is connected with the alimentary canal by a duct
- Fins either without spines or dorsal, anal or pectoral have a spine each
- Ventral fins are abdominal

Example –*Labeo, Catla, Cirrhinus, , Wallago etc.*

Order –8 Anguilliformes

- Body elongated eel like
- Skin naked or with minute scales embedded in it.
- Dorsal and anal fins are long and narrow and usually confluent behind.
- Pelvic fins, if present, abdominal
- Air bladder connected with the intestine

Example –*Anguilla*

Order –9 Beloniformes

- Body elongated covered with cycloid scales
- Ventral fins abdominal
- Some of them are capable of jumping into the air and glide with the help of enlarged pectoral fins

Example –*Belone, Exocoetus* (Flying fish)

Order – 10 Syngnathiformes

- Body covered with protective layer of scales or bony rings
- Mouth is terminal, snout tubiform
- Fin rays of dorsal, anal and pectoral fins not branched

Example –*Hippocampus* (Sea horse), *Syngnathus* (Pipe fish)

Order – 11 Ophiocephaliformes

- Body covered with cycloid scales
- Head depressed, covered with large scales
- Fins without spines
- Accessory respiratory organs are present
- Air bladder very long, prolonged into caudal region

Example –*Ophiocephalus* (Channa)

Order –12 Symbranchiformes

- Body eel like or snake like, devoid of scales
- Air bladder absent
- Fins without spines
- Dorsal, caudal and anal fins are continuous
- Gill-slits single, transverse and ventral

Example –*Amphipnous, Symbranchus*

Order –13 Perciformes

- Fins usually with spines
- Two dorsal fins
- Ventral fins thoracic with not more than 6 rays
- Weberian apparatus absent

Example –*Anabas* (Climbing perch)

Order – 14 Pleuronectiformes

- Body flat adapted for bottom living
- Both the eyes are on the upper side
- Skull asymmetrical
- Fins usually without spines
- Air bladder is absent in adults

Example –*Synaptura, Pleuronectus, Solea*

Order –15 Mastacembeliformes

- Fresh water eel-shaped fishes
- Dorsal, caudal and anal fins are confluent. Sometimes a small caudal fin is separate
- Some free spines present before dorsal fin
- Anal fin with three spines
- Ventral fin absent
- Pectoral fins are present
- Buccal cavity enlarged for air breathing

Example –*Mastacembelus*

Order –16 Echeniformes

- First dorsal fin is modified into an adhesive disc for attachment
- Scales cycloid

- No spines in second dorsal and anal fins
- Air bladder is absent

Example –*Echeneis, Remora*

Order –17 Tetrodontiformes

- Scales are modified into spines
- Scutes or bony plates cover the body
- Gill-slits are restricted
- Air bladder present or absent
- Ventral fins thoracic or sub-thoracic

Example –*Ostracion, Tetradon, Diodon*

Order –18 Lophiiformes

- First ray of the spinous dorsal fin is placed on the head and transformed into illicium
- Orbitosphenoid, basiophenoid and opisthotic bones are absent
- Air bladder is absent

Example - *Lophius*

3.4 TYPES OF SCALES & FINS OF FISHES

Scales of the fishes

Fishes are aquatic and are found in all type of water such as fresh, marine, brackish water. The skin of many fishes is covered with an exoskeleton in the form of scales, which protects the body internal parts. Some of the fishes are without scales e.g. cat fishes, while *Polyodon* and *Acipenser* posses an intermediate condition, having scales or plates only at some specific regions of body.

The scales undergo several modifications, for example paired jaw teeth in the sharks are regarded as modified scales. The teeth forming the saw of *Pristis* and sting of the sting-ray are modifications of scale. These scales are useful for protection against predators.

Types of scales: According to structurally scales are classified into 4 types

(i) Rhomboid or Ganoid scales : The ganoid scales are thick, usually rhomboid or diamond shaped plates closely fitted side by side like tiles, providing bony armour to the body of fish. These are characteristic of the primitive actinopterygians called ganoid fishes and are of various forms& structure.

These scales are heavy and have an outer layer of hard inorganic enamel like material called ganoine. The middle layer is cosmine containing numerous branching tubules. The inner most layers are thickest and are made up of lamellar bone isopedine. These scales grow by the addition of new layers of lower as well as upper surface. These scales are usually rhomboid in shape and articulate by peg and socket joints. The ganoid scales are best developed in the chondrostean and holostean fishes.

In *Acipenser*, they are in the form of large isolated bony scutes and are present in fine longitudinal row at places where there is great wear and tear. On Lepidosteans the scales are hard, polished rhombic plates fitting edge, thus forming complete armour. Scales of this fish have lost the middle cosmine layer thus reducing their thickness and rigidity.

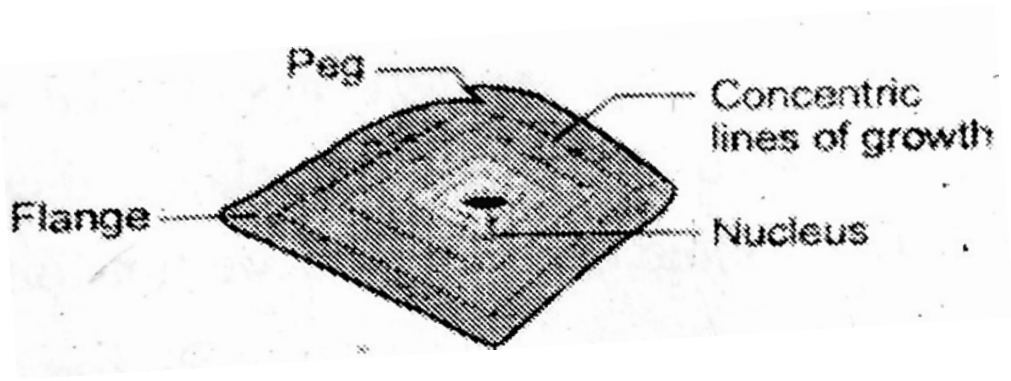


Fig : Ganoid scale

(ii) Placoid scales : Placoid scales are tough and found in elasmobranch fishes only for e.g. Rays and Shark. It consists of two parts, the basal plate and spine. The basal plate is diamond shaped and lies embedded in the dermis of the skin and spine projecting out through the epidermis. The spine has an external covering of enamel like hard, transparent material called vetrodentine. This is followed by a layer of dentine enclosing a pulp cavity from which several branching dentinal tubules radiate in different direction. The centre of the basal plate is performed by an aperture to provide entrance to the blood vessels and nerves from the dermis. The scales are closely set, but do not overlap each other.

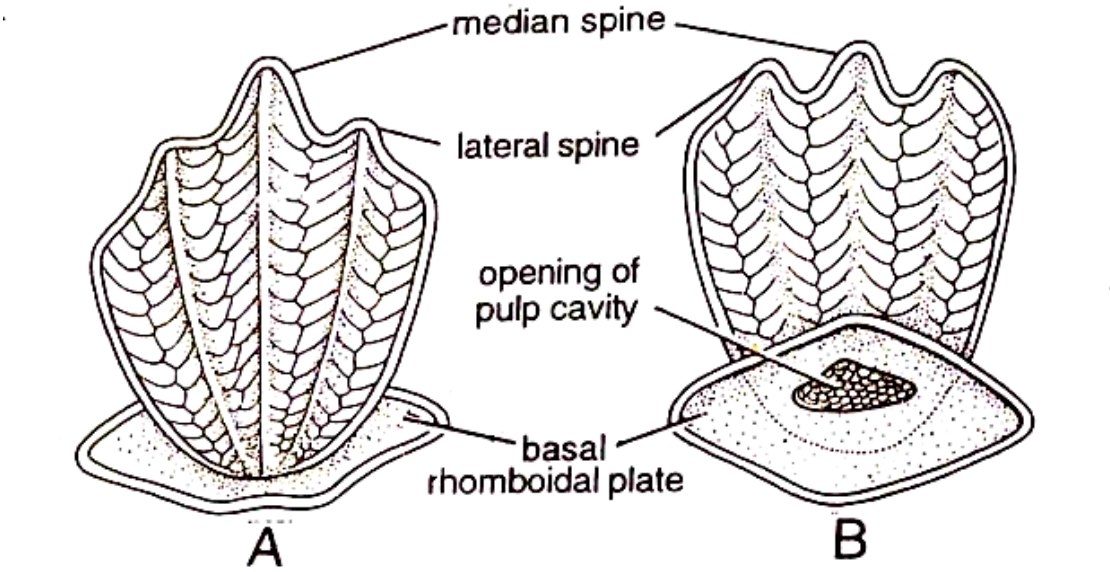


Fig: *Scoliodon* Placoid scale (A)Dorsal view (B)Ventral view

(iii) Cycloid Scales : The cycloid scales are thin flexible, translucent, rounded in shape thicker in the centre and thinning out towards the margin. They are marked with several concentric lines of growth which can be used for determining the age of the fish. Theses scales are composed of a thin upper layer of bone and lower of fibrous connective tissue. They overlap each other, each scale embedded in a small pocket of dermis. Cycloid sales are found in lung fishes some holostean (*Amia*) and the lower teleostean fishes like *labeo, Catla, Barbus, Cirrhinus* etc.

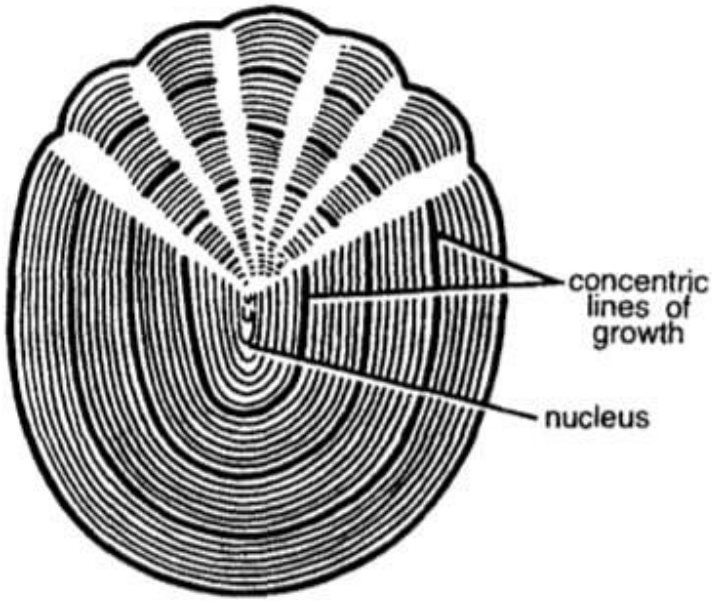


Fig : Cycloid scales

(iv) Ctenoid Scales : The ctenoid scales are also circular and can be distinguished from the cycloid by having a more less serrated free edge, moreover several spines are present on the surface of the posterior area of the scale. These are characteristic of modern higher teleostean such as perch, sun fish etc.

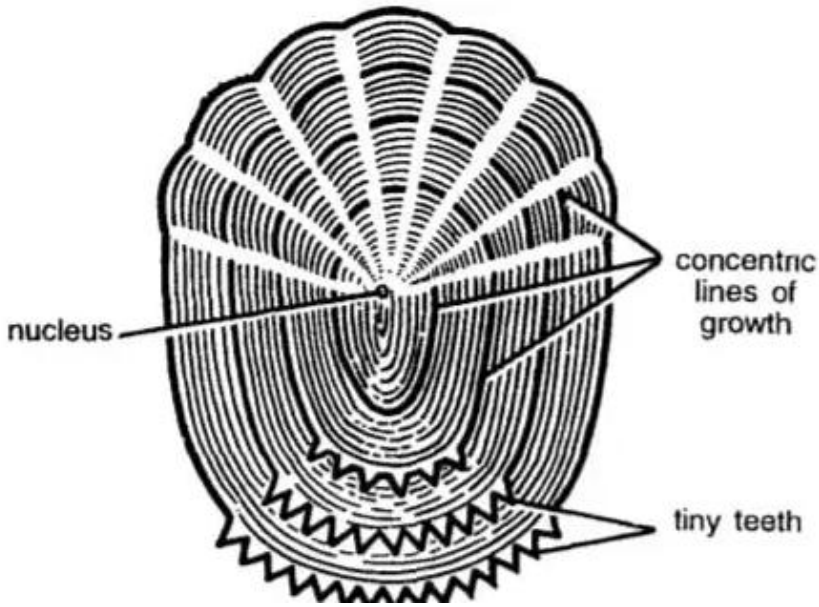


Fig : Ctenoid Scale

Fin of fishes

The chief locomotory and balancing organ in fishes are fins. These are of two types, median or paired and unpaired fins. Fishes swim with their fins which are thin broad folds of integument internally supported by fin rays, which may be bony, cartilaginous, fibrous or horny. Median fin lies on the dorsal side of body of fish, it may be single, double or triple, and an anal on the ventral side

behind the vent and a caudal at the end of the tail. The paired fins are the pectoral and pelvic. Both the paired and unpaired fins are supported by skeletal rod called the radial fin dermal.

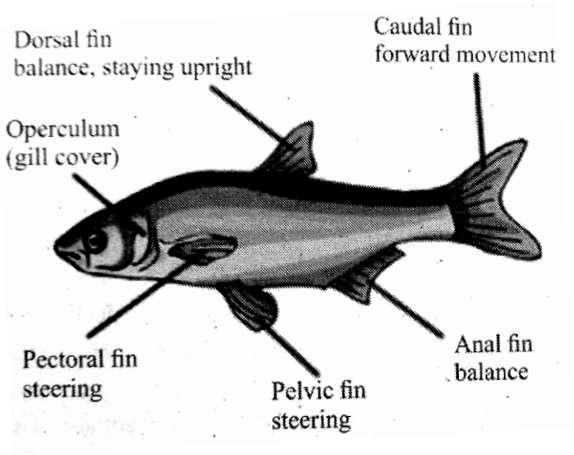


Fig: Fish external feature showing paired and unpaired

Paired or Median fin : It is develop as a result of differentiation in a continuous embryonic fin fold. The median fin are of 4 types

(i) Anterior or first dorsal fin: The anterior dorsal is large and is situated little in front of middle of the body. It is triangular in shape.

(ii) Posterior orSecond dorsalfin : It occupies a median position between the first dorsal and tip of tail.

(iii) Ventral fin : It is present on the ventral side little infront of the caudal fin. It also appears triangular.

(iv) Caudal fin : The caudal fin differs from the dorsal and anal fins in the nature of its supporting skeleton. It is of 3 types

(a) Protocercal or diphycercal tail fin : It is most primitive types of tail fin, which is found in *Amphioxus* and Cyclostomes. The vertebral column extends straight back to the tip of tail dividing the fin symmetrically and equally into the dorsal or epichordal and ventral or hypochordal lobes. The modern cyclostomes, primitive sharks, *Chimaera,* lung fishes (Dipnoi) living crossopterygii (*Latimeria*) larval, Teleosts and deep sea fishes exhibits diphycercal tail fin. *Latimeria* and extinct coelacanths have unique symmetrical three lobes tail with a marked median lobe. In *Chimaera* and some deep sea fishes the fin is isocercal in nature, which is elongated.

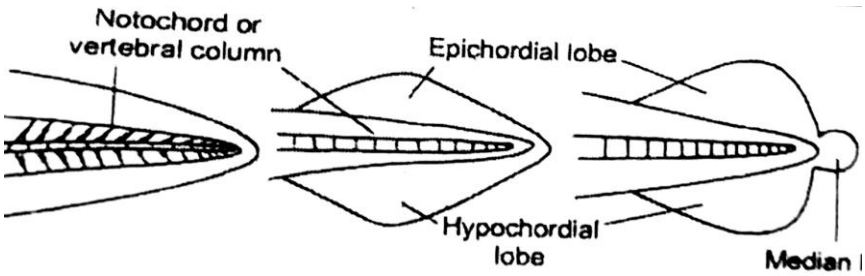


Fig : (a)Protocercal or diphycercal tail fin (b)Modified diphycercal tail fin

(b) Homocercal Tail fin : Higher bony fishes having such types of caudal fin. It epichordal and hypochordal lobes are of equal size. Internally the tail is asymmetrical and the hinder end of the vertebral column is turned upward and greatly shortened. In

this type the original dorsal lobe or epichordal is suppressed. Only the originally ventral lobe or hypochordal is greatly developed into a single or two equal and symmetrical lobes.

Such types of caudal fin are found in fishes which have terminal mouth and its strokes force the fish straight forward. For example *Labeo rohita, Catla catla, Cirrhinus mrigala* etc.

There are certain variations are observed in homocercal tail fin. For example in tuna and cod the upturned urostyle of vertebral column is reduced or absent. In chondrosteans like *Polypterus*, *Amia*, Lepidosteans the urostyle is a bit elongated and upturned also with or without upturned fleshy lobe.

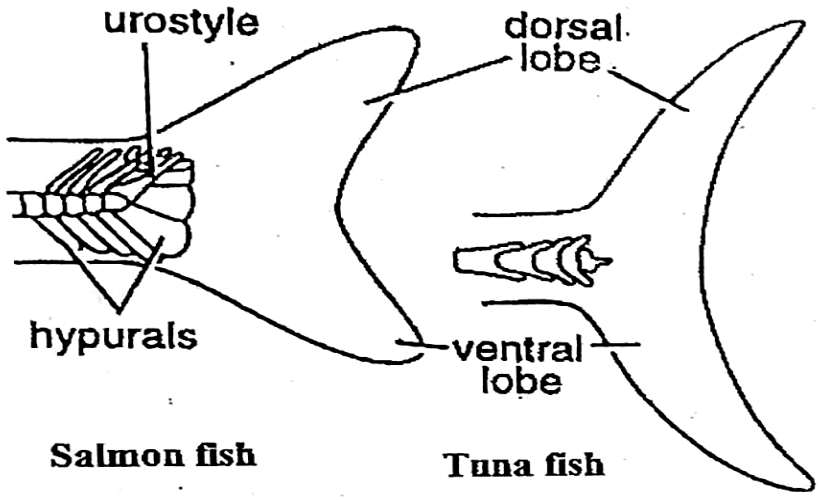
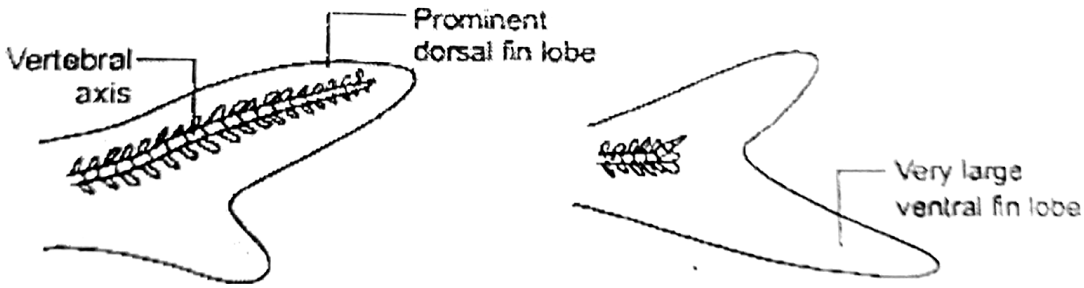


Fig : Homocercal tail fin

(c) Heterocercal Tail fin : In such type the vertebral column is bend upward and reaches up to the tip of the more prominent dorsal lobe, which make the caudal fin a symmetrical. It is found in *Scoliodon*, extinct dipnoans, *Acipensor*, *Polyodon* etc. Such type of heterocercal caudal fins observed in bottom feeder with ventral mouth and without swim bladder. The strokes of larger dorsal lobe in swimming serve to direct fish toward bottom. These are characteristic of chondrichthyes and some primitive bony fishes. There is also an opposite condition of heterocercal, in which the vertebral lobe. This types of caudal fin are found in flying fish (*Exocoetus*), to attain maximum speed for gliding as is leaves the water. It is also found in some primitive fishes % Ostracoderm.



(a)Heterocercal tail fin (b)Hypocercal tail fin

Fig : Tail fin fins of fishes

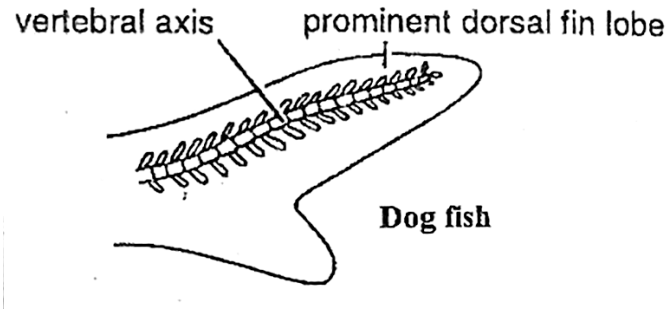


Fig: Heterocercal fin

Paired fin : These are not present in ancestral vertebrate, They were developed during the course of evolution. It is of 2 types

(i) Pectoral fin : The pectoral fins are large and triangular expansions which arise from the ventral-lateral margins of the trunk just behind the gill clefts and extend backwards. Pectoral fin has pterygiophores of cartilage to which muscles are attached for moving the fins. The proximal pterygiophores are called basals and distal are called radial. The basal consist of 3 parts and an inner metapterygium. Extending from the basals are three rows of numerous radials forming proximal, mesial and distal cartilage called somactidia. Arising from the distal somactidia are horny, unjointed exoskeletal ceretotricha or fin rays, the support the fin blade.

(ii) Pelvic fin : The pelvic fins are smaller the pectoral fins. They are sub-triangular in shape. They arise close together from the ventral surface at the junction of the trunk and the tail and enclose the close the aperture. In females, these are simple but in males each of them is connected with a copulatory organ called clasper. Pelvic fin has the same endoskeletal structures as the pectoral fin. There is a single basal called basipterygium to which several somactidia are attached. The fin blade is supported by exoskeletal fin rays.

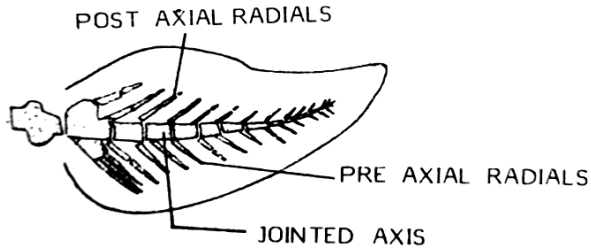


Fig: Pelvic fin *Ceratodus*

3.5 *SCOLIODON* AS TYPE STUDY

Phylum : Chordata

Group : Vertebrata

Division : Gnathostomata

Super class : Pisces

Class : Chondrichthyes

Subclass : Selachii

Order : Squaliformes (Pleurotremata)

Family : Carcharinidae

Genus : *Scoliodon*

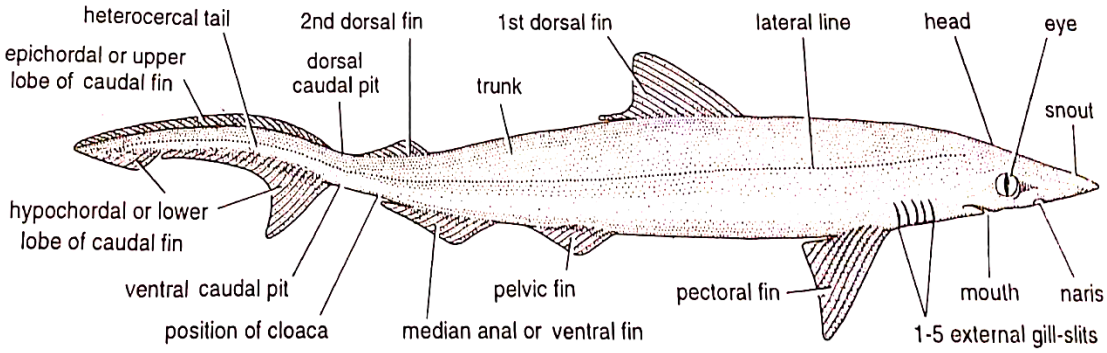


Fig: *Scoliodon :* External feature

Habit and habitat

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

Morphology

Shape, size and color

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

Division of body

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

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

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

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

Skin

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

(i) **Epidermis :** The epidermis is composed of many layer of stratified epithelial cells. The

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

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

Placoid Scale

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

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

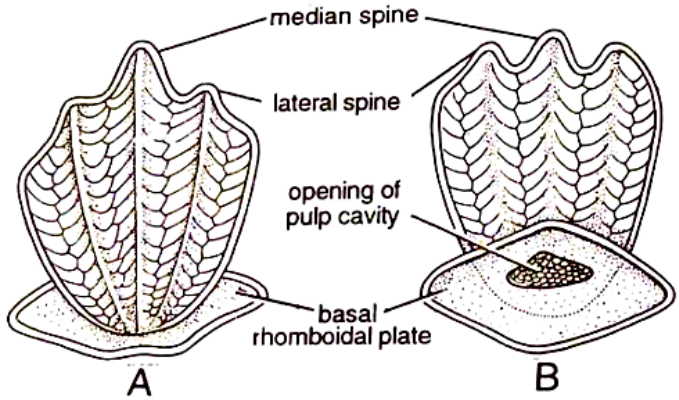


Fig: *Scoliodon* Placoid scale (A)Dorsal view (B)Ventral view

Locomotion

The locomotion of *Scoliodon* has been explained by Breder (1926) and Gray (1933). They have shown their experiment by taking series of photographs at definite interval of time of a swimming fish against a back ground marked with a graduated scale. They have shown by a series of timed photographs the entire body of fish takes part in progression or swimming. The force which drives a fish through water is produced by longitudinal muscle fibres of myotomes, their contraction causes the body to bend. Waves of curvature or bending pass alternately on each side of the body from the head to the tail, because the myotomes contract one after the other from before behind. This bending

is more noticeable behind the head region and especially in the tail, because of progressively greater transverse amplitude of the waves as they pass backwards. As one wave of contraction passes backwards on one side, it is followed by a similar second wave on the other side of the body. This contraction of successive myotomes causing waves of bending is called metachronal contraction. In metachronal contraction each segment or part of the body moves in a transverse direction to its path of swimming in such a way that it is bent at an angle or obliquely backward movement to push the water backwards. Thus the whole body operated as a single self propelling system and the fish is thrust forward.

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

The median dorsal fin keeps the fish steady in a horizontal plane. Equilibrium in a vertical plane is controlled by the movable pectoral fins, the smallest movement of these fins prevents yawing and restores the original direction of locomotion. The paired fins and caudal fin prevent pitching. The powerful movements of the heterocercal tail not only give a forward thrust to the fish, but they also make the fish dive head downwards this is counter balanced by the paired fins, chiefly the pectoral fins. The pectoral fins lie in front of the centre of gravity and act as elevators, forcing the head upwards. Hence the heterocercal tail and pectoral fins neutralize each others effects and maintain the fish in a constant plane. Turning is produced either by a wave of myotomal contraction only one side of the body or by asymmetrical braking with the pectoral fins.

Coelom

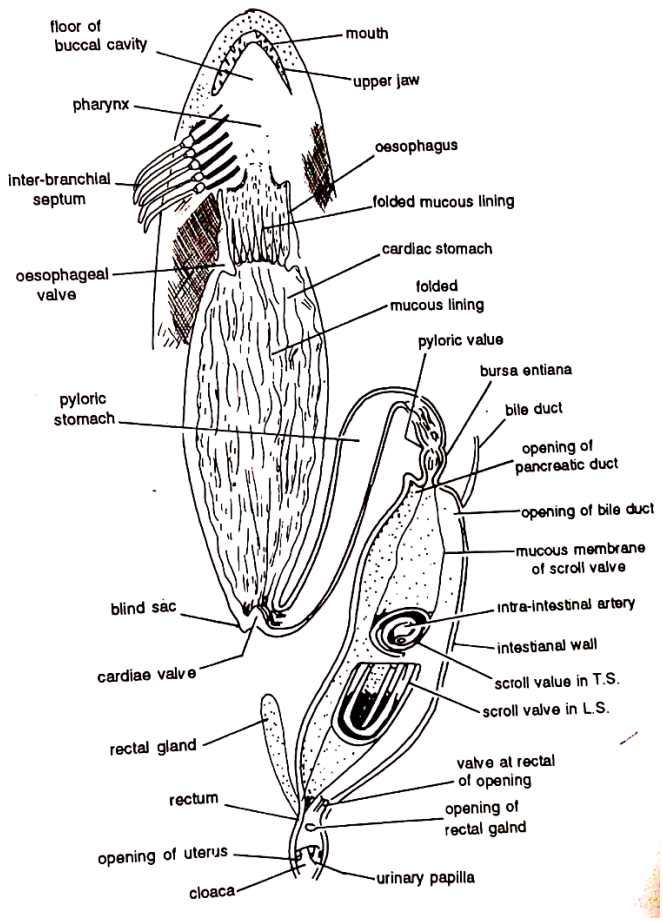


Fig: *Scoliodon* Digestive system

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

Digestive system

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

Alimentary Canal

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

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

(ii) **Buccal cavity :** The mouth opens into a spacious dorso-ventrally flattened buccal cavity. The buccal cavity is lined with a thick mucous membrane. The mucous membrane is raised

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

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

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

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

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

Digestive Gland

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

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

(ii) Pancreas : It is a compact whitish or pale bilobed gland situated in the angle between cardiac and pyloric stomach. It consist of a longer dorsal lobe running parallel to the posterior part of cardiac stomach and aventral lobe lying closely applied to the pyloric stomach. The

pancreatic ductopens into the intestine just opposite to the opening of the bile duct.

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

Physiology of digestion

Food, feeding and physiology of digestion

The *Scoliodon* is predaceous carnivorous and feed mainly on other fishes, but the diet may also includes rock crabs, lobsters, and spider. The teeth are only meant to prevent the escape of prey from the mouth and it do not perform the function of mastication. The teeth are only used for tearing the food. There are no salivary gland present in mouth hence there is no digestion in the buccal cavity. The wall of the pharynx possesses numerous mucous glands which only help in the passage of food. The oesophagus has also no digestive function. The digestion only starts in the cardiac stomach. The mucous membrane of cardiac stomach secretes the gastric juice which contains pepsin and hydrochloric acid that convert proteins into syntonin, proteoses and peptones. The gastric juice is not able to digest chitin. The pyloric stomach and scroll valve have no digestive activity of their own but they activate the pancreas. The pancreas secretes trypsin, amylopsin and lipase. As the semi-digested food enters the intestine it is acted upon by the bile and the pancreatic juice. The bile makes the food alkaline and thus helps the action of pancreatic juice. The trypsin acts on the remaining proteins, amylopsin converts starch into sugar and lipase turns fats into fatty acids. The digested food is absorbed into the blood over the extensive surface of the intestine and scroll valve. The undigested food is eliminated out through the cloacal aperture.

Respiratory system

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

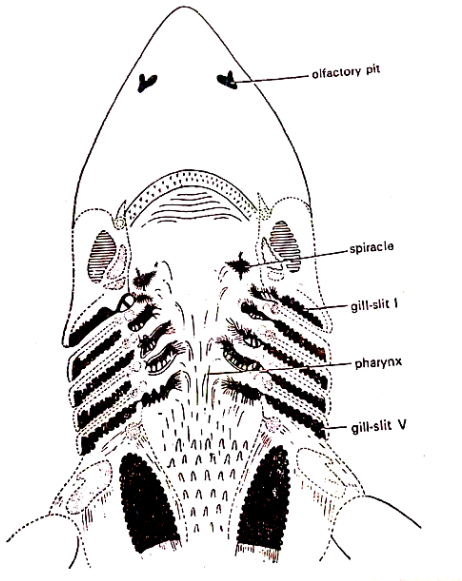


Fig: *Scoliodon* Pharynx exposed to show gill pouches

Respiratory Organ

There are five pairs of lateral gill pouches situated in the lateral walls of the pharynx and are

arranged in a series on either side. Each gill pouch is compressed anterior–posteriorly and communicates with the cavity of the pharynx through a large internal brachial aperture and with the exterior through a narrow external branchial aperture or gill slit. The endodermal mucus membrane of gill pouch is raised into a series of horizontal folds to form lamelliform branchial lamellae. The branchial lamellae have a rich blood supply and they have a very thin covering membrane through which blood is exposed to sea water for exchange of gases. Each gill pouch has two sets of gill lamellae, one on its anterior wall and the other on the posterior. Each set of lamellae is a half gill or hemibranch, so that gill pouch has two hemibranches. The gill pouches are separate from each other by muscular inter branchial septa of connective tissue. The inter branchial septa extend well beyond the branchial lamellae, then each bends posteriorly to protect the lamellae. Each gill receives blood from the afferent branchial vessels and passes it to the efferent branchial loop at the branchial vessels and passes it to the efferent branchial loop at the sides of arch. The blood is oxygenated when it passes through the network of capillaries and CO_2 is removed. Infront of hyoid arch or first internal gill slit there is an oval spiracle on either lateral side of pharynx. It has no gill lamellae or external branchial apertures hence it is regarded as vestigial gill pouch. The hyoid arch bears a hemibranch posteriorly. The first four branchial arches bear a holobranch each, the fifth branchial arch has no branchial lamellae, thus *Scoliodon* has nine hemibranch on each side.

Mechanism of Respiration

The floor of the bucco-pharyngeal cavity is depressed by hypo-branchial muscles and the mouth is opened, at the same time the visceral arches expand the wall of the pharynx, so that sea water containing dissolved oxygen rushes in through the mouth. Entry of water into external branchial apertures is prevented by an anterior fold of skin on each gill pouch. The bucco-pharyngeal floor is then raised and the mouth is closed, and contractions of the wall of the pharynx force the water into internal branchial apertures, the oesophagus being closed, and then into gill clefts, where it washes the branchial lamellae and goes out of the external branchial aperture. The flow of blood in branchial lamellae is from top towards the base, that is in a direction opposite to that of the water current. The blood comes in contact with highest concentration of water and lowest concentration of carbon dioxide. Thus an efficient exchange of O_2 band CO_2 takes place between the blood and sea water.

Physiology of Respiration

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

Blood vascular System

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

Heart

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

(i) Sinus Venosus : The sinus venosus is a triangular thin walled chamber elongated transversely and lying along the base of the pericardial cavity. On both the lateral side of

sinus venous receive venous blood through ductus cuvieri and on the posterior side it receive through a pair of hepatic sinus. The sinus venous open anteriorly into the auricle through the sinu-auriclar aperture, which is guarded by a pair of membranous valves, sinu-auricular valve, which prevent the back flow of the blood.

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

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

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

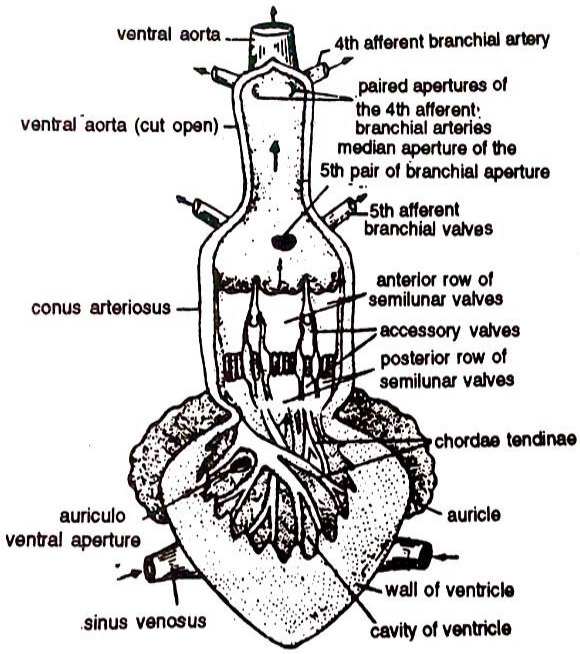


Fig: *Scoliodon*: Heart dissected from ventral side to show internal structure

Working of heart

The heart of *Scoliodon* is of venous type because it only pump venous or deoxygenated blood. It has single circuit type of circulation i.e. only once time blood can pass through heart. In heart sinus venous and auricle are the receiving chamber while ventricle and conus arteriosus constitute the forwarding chamber of the heart. The rhythmic contraction and relaxation of cardiac muscle is called heart beat. The contraction is called systole and relaxation is called diastole. The initiation and wave

of excitation or contraction starts from sinus venous, then reaches to the auricle, ventricle and ended at conus arteriosus. As the blood is filled in sinus venous, it contract and forcing the blood into auricle through sinu-auricular aperture. The valve prevent the back flow of blood. Now the auricle contracts and the blood reaches the ventricle through auriculo-ventricular aperture. Then ventricle contracts and passes the blood into conus arteriosus, from where it enters the ventral aorta. The venous or deoxygenated blood passes to the gills for aeration by afferent branchial vessels. The oxygenated blood is forced to different body parts by efferent branchial vessels and dorsal aorta. The venous blood is returned to the heart from different parts of the body, thus only the venous blood passes through the heart. During course of its circulation the blood passes through heart only once in its complete circuit. Thus the heart of Scoliodon is venous heart and the blood circulation is of single type of circulation.

Blood

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

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

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

Nervous system

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

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

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

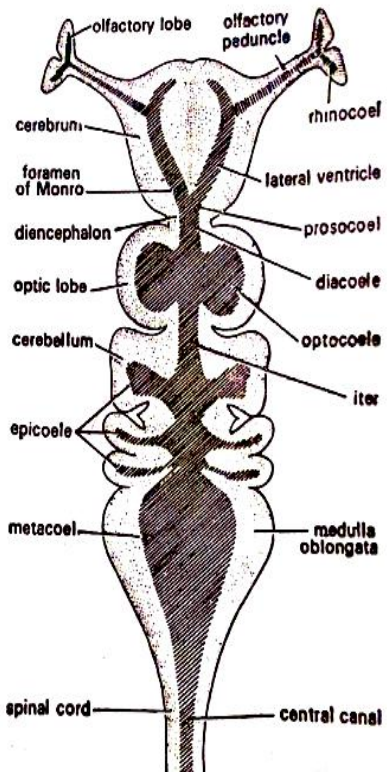


Fig: *Scoliodon* Horizontal longitudinal section of the brain

Brain

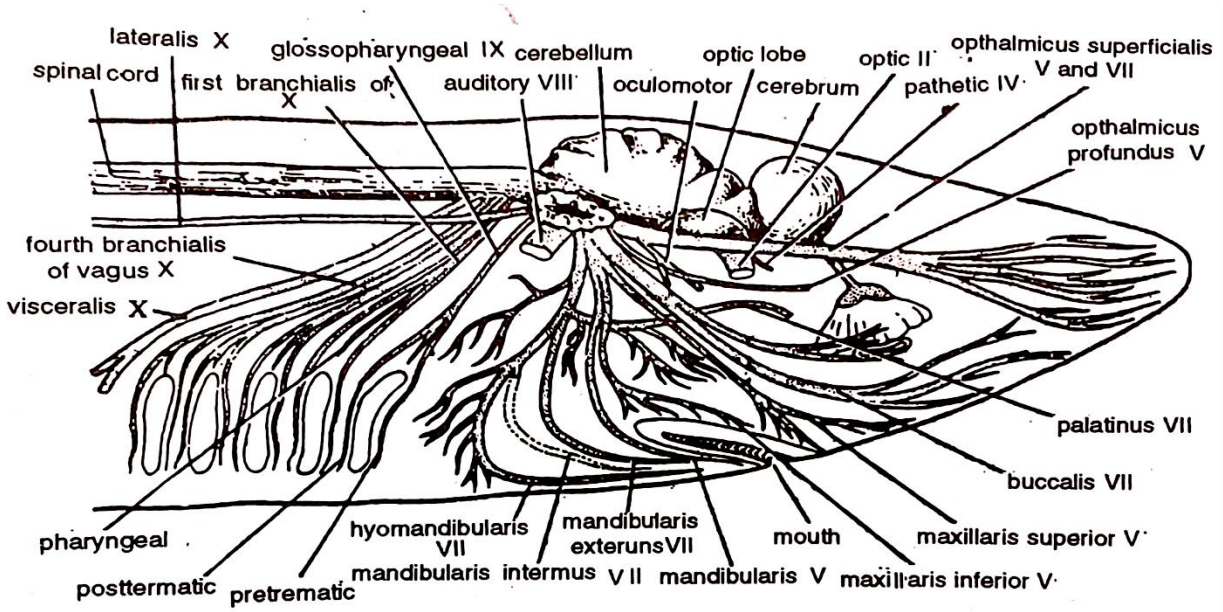
The brain of *Scoliodon* is enclosed within the chondrocranium and it is divided into 3 parts i.e. fore brain, mid brain and hind brain.

Fore brain

It consists of two parts cerebrum and diencephalon. The cerebrum form the anterior part of the brain and is undivided mass of nervous tissue. There is no median groove to separate the cerebrum into right and left cerebral hemispheres. From either antero–lateral side of cerebrum arise a narrow but a stout olfactory stalk terminating into a large bilobed olfactory lobe. It lies immediately behind the large olfactory sac that opens to outside through the nostril or nares. The dorsal surface of cerebrum is quite smooth, but on its mid-ventral surface there is a small aperture called the neuropore, through which comes out a pair of delicate nerves called spre-olfactory nerves. The cerebrum is continued posteriorly into the narrow diencephalon which is extremely short and is completely covered by the forward prolongation of the cerebrum. The roof of diencephalon is extremely thin and membranous which is highly vascular and is known as anterior choroid plexus. The posterior dorsal end of the diencephalon gives rise to a pineal stalk which end in a rounded knob like structure called pineal body. The floor of diencephalon gives off a hollow outgrowth, called infundibulum which projects downward and backward. The infundibulum possesses at its distal end a rounded structure called hypophysis. On either side of infundibulum lie the two lobi inferior, the distal end of each is continued into a glandular sac called sacccus vasculosus. Near the anterior end of diencephalon lies the optic chiasma which is formed by the crossing of the two optic nerves.

Mid brain

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



Hind brain

The hind brain consists of two parts cerebellum and medulla oblongata. The cerebellum is large, elongated and well developed. It extends forwards up to the cerebrum and posteriorly covered the parts of medulla oblongata. The dorsal surface of cerebellum having irregular fold and it divide the

cerebellum into three lobes by two transverse furrows. The median longitudinal furrow divide the cerebellum into right and left halves. The medulla oblongata is triangular in shape and forms the posterior part of the brain. From its anterior end arise a pair of hollow outgrowths, the corpora restiformia which lie on the dorso-lateral side of the medulla and are slightly overlapped by the cerebellum. The corpora restiformia of two sides are connected with the help of a band of nervous tissue. The floor and sides of the medulla oblongata are thick, while the roof is extremely thin and non-nervous and bears the posterior choroid plexus. The 5^{th}, 6^{th}, 7^{th}, 8^{th}, 9^{th}& 10^{th} cranial nerves arise from the medulla oblongata.

Cavities of brain

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

Spinal cord

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

Fig: *Scoliodon* Crainal nerves in right lateral view

Cranial nerve

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

(b) Saccular : It supply to cochlea.

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

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

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

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

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

pharynx and also supply the branchial bundles.

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

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

Spinal nerves

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

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

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

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

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

Autonomic nervous system

The autonomic nervous system consist of a paired series of irregularly arranged ganglia situated anteriorly in the dorsal wall of the posterior cardinal sinuses and posteriorly in the dorsal part of the kidney on each side of the mid-dorsal line. The first ganglia are small. The second or gastric ganglion is fairly large, being formed by the fusion of a number of ganglions. It lies immediately behind the post-branchial plexus. It is connected with numerous fibres from spinal nerves and gives off branches to the viscera. The succeeding ganglia are small. There is always at least one ganglion in each segment, but often there are two or three in a segment. Some time the ganglia of successive segments are joined by longitudinal connectives, but there is no definite continuous chain. The posterior ganglia innervate the genital ducts, kidney, urinary sinus, intestine and rectum.

Sense organ (Receptor organs)

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

(i) Olfactory organs

(ii) Optic or photoreceptor organs

(iii) Stato acoustic organ

(iv) Lateral line organs or neuromast

(v) Ampullae of Lorenzini

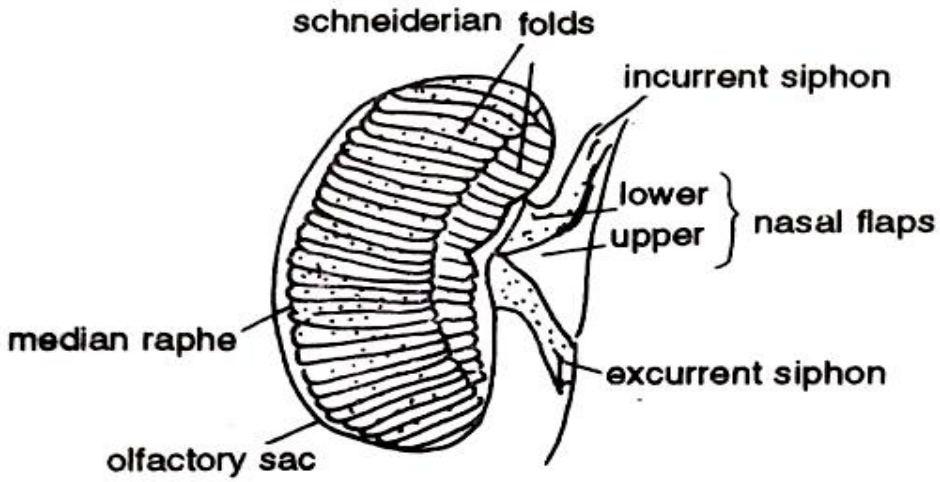


Fig: *Scoliodon* Olfactory organ

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

Each external nostril is more or less completely divided into two, a lateral incurrent siphon and a median excurrent siphon by three nasal flaps. The median raphe of the schneiderian folds lies parallel to the long axis of the nasal aperture and therefore the current of water that enters through the incurrent siphon is at first directed against the oval wall of the olfactory sac, then turns internally to the nasal valve in the direction of the median raphe and finally passes out through the median excurrent siphon. The current of water enters at the lateral end of the nasal aperture and thus takes a zig-zag course through the olfactory sac finally leaving by a mesial end of the nasal aperture. The great size of olfactory sacs in Scoliodon is highly developed sense of smell. The highly developed sense of smell enables them to detect foods.

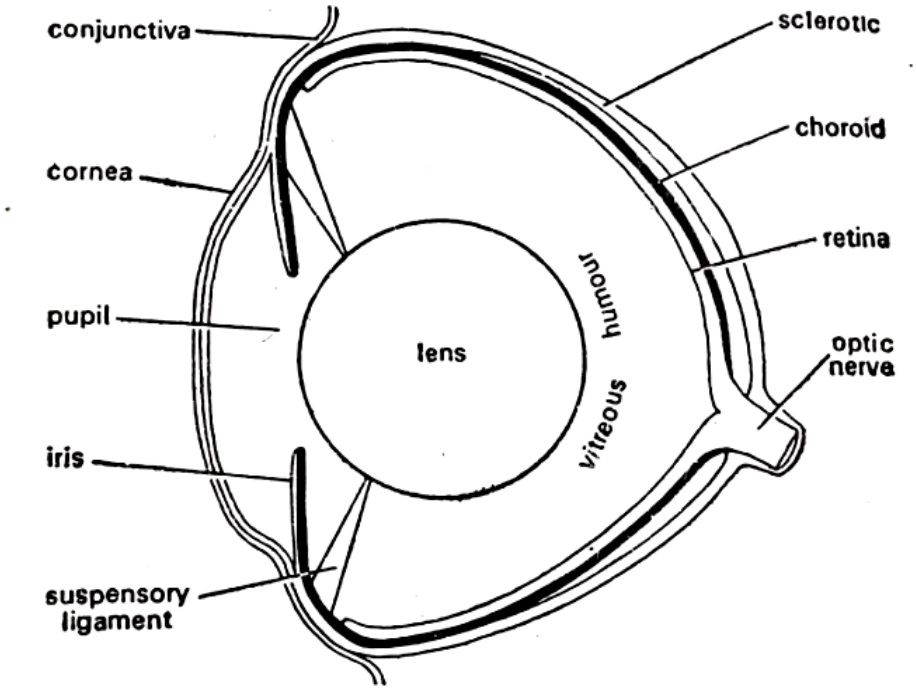


Fig: *Scoliodon* V.S. of eyeball

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

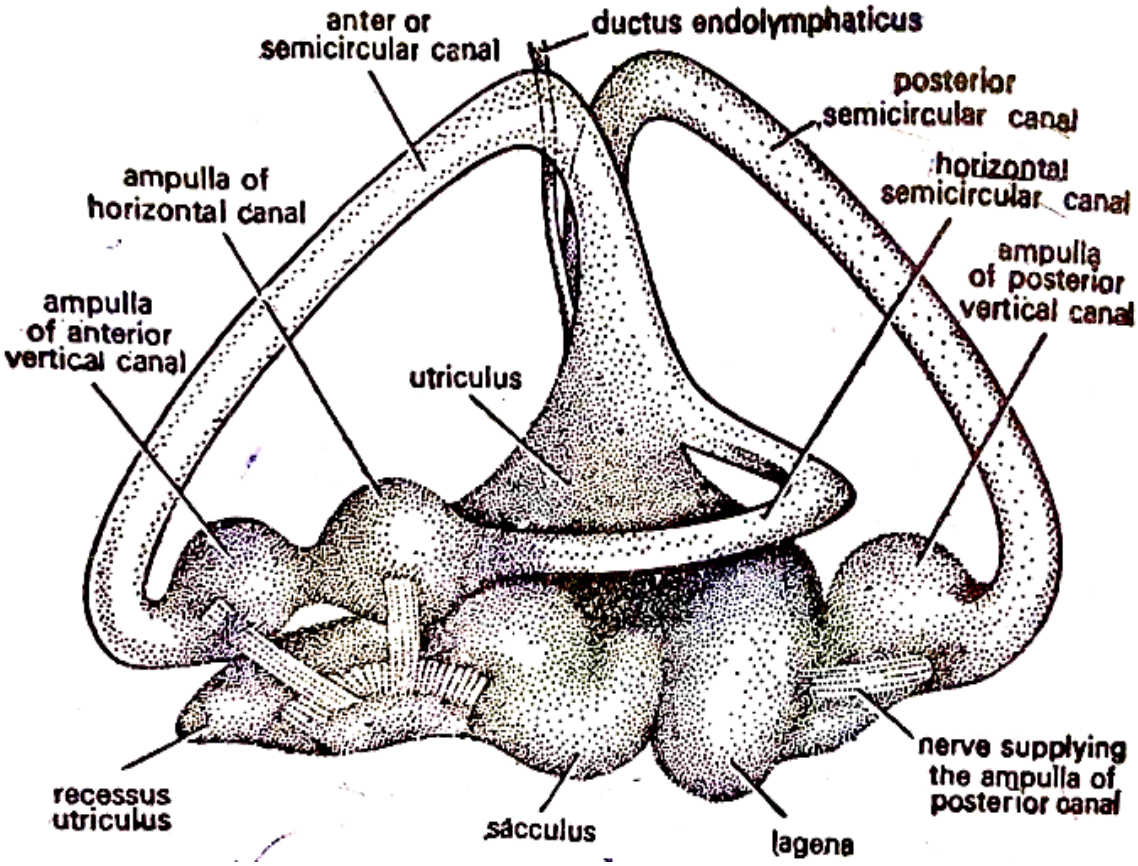


Fig: *Scoliodon* Membranous labyrinth

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

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

canals are called cristae.

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

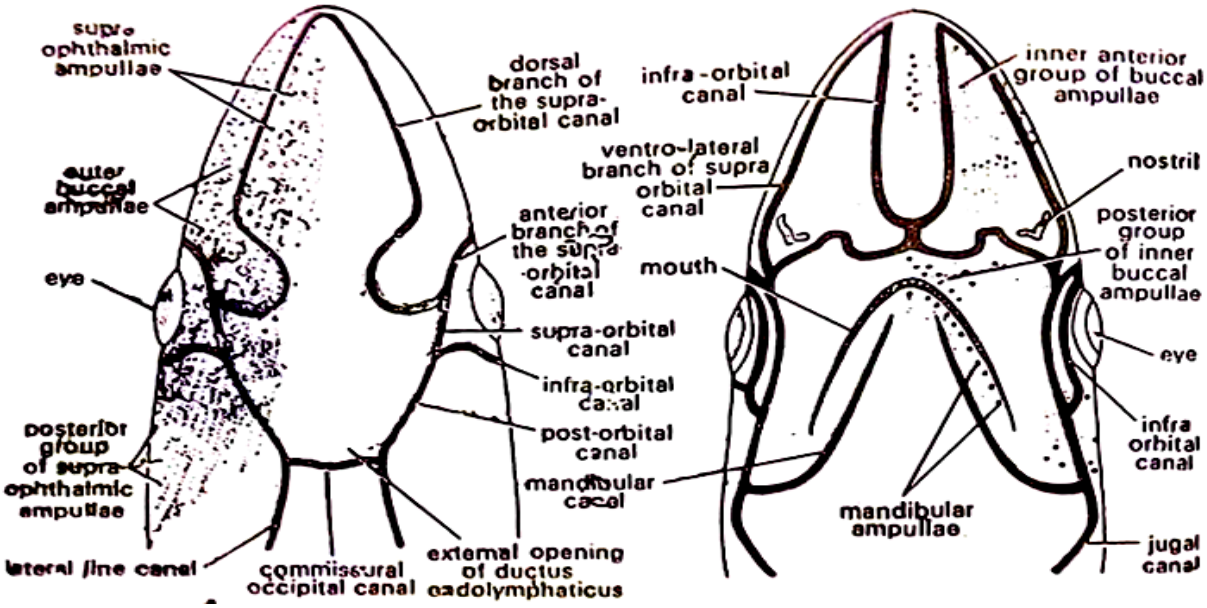


Fig: ***Scoliodon*** **Neuromast organs (A) Dorsal surface (B)Ventral surface**

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

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

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

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

vibrations in the water.

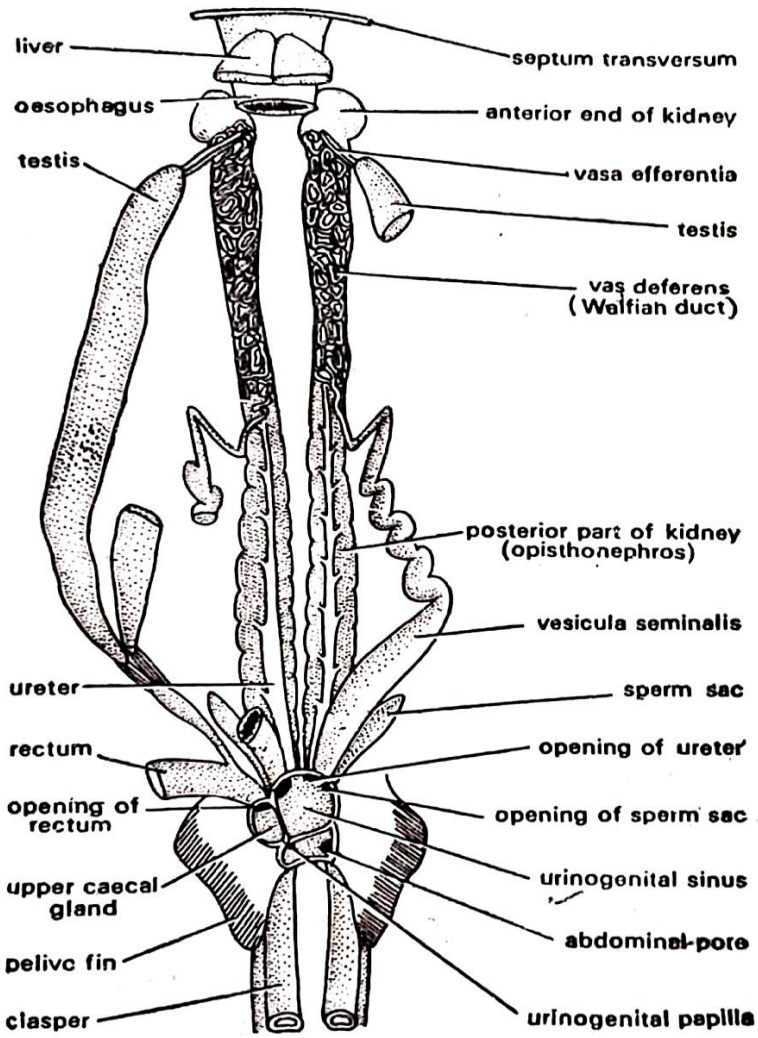
(v) Ampullae of Lorenzini : These are found in clusters on the dorsal and ventral surfaces of the head or snout embedded below the skin but opening externally on the surface of the skin. Each ampullla has a pore opening on the surface, the pore leads into an elongated tubules, which ends in a radially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

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

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

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

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



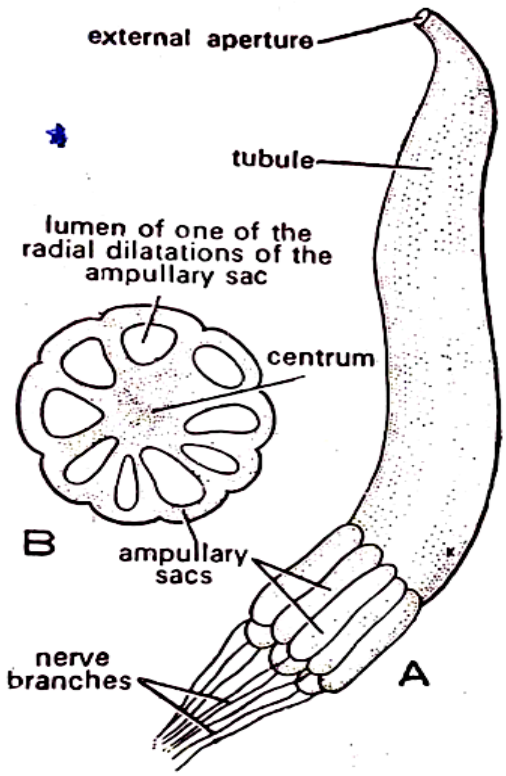


Fig: *Scoliodon* Male urinogenital organs

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

Urinogenital System

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

Male Urinogenital system :

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

Reproductive organs

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

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

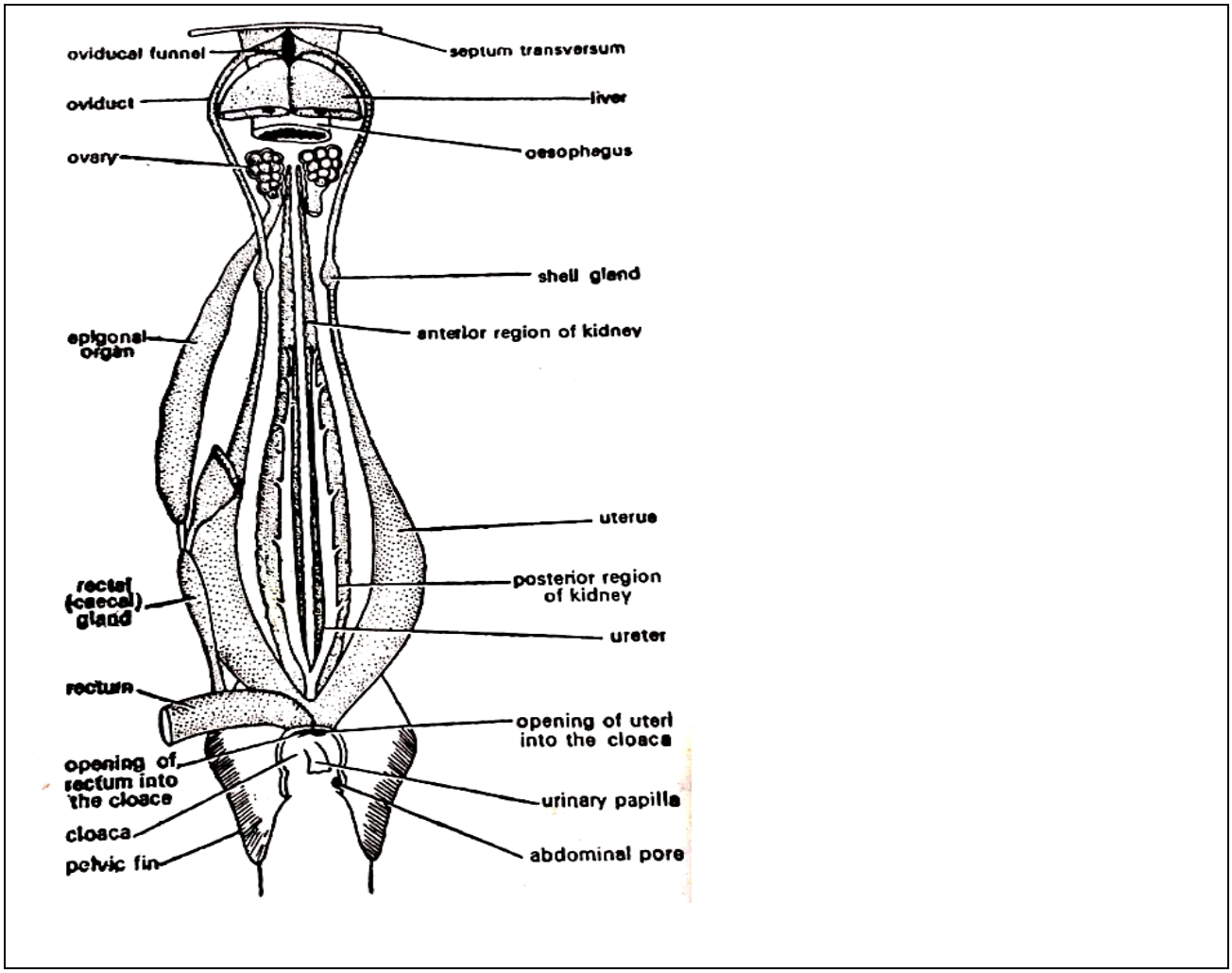


Fig: *Scoliodon* Female urinogenital organs

Female urinogenital organ

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

The female excretory organ differ from the male organ in following

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

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

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

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

Reproductive organs

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

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

Reproduction

Copulation

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

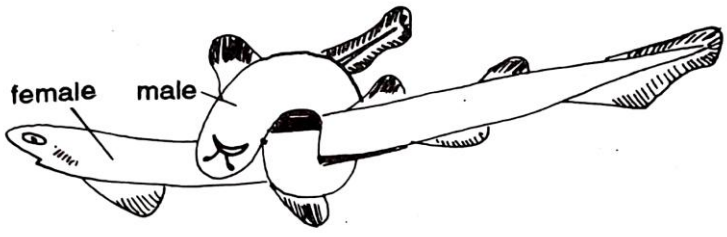


Fig: *Scoliodon* : Copulation

Fertilization

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

Development

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

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

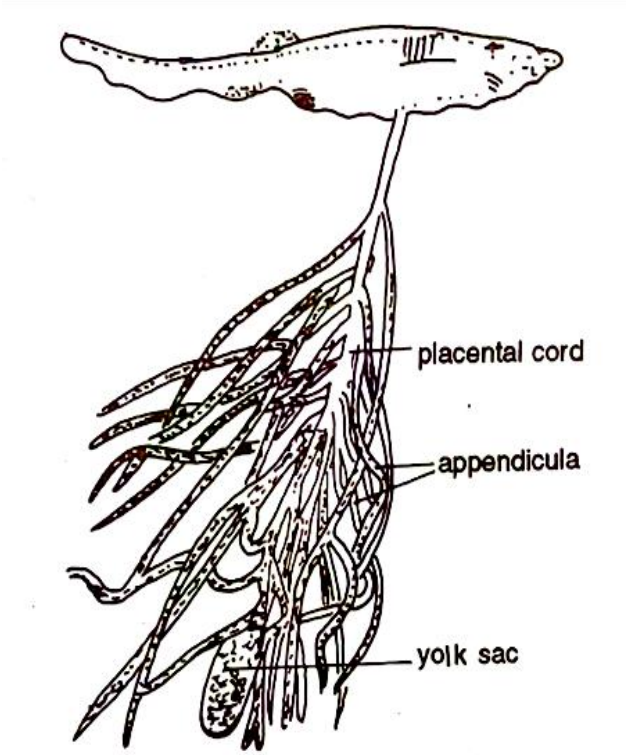


Fig: *Scoliodon* Embryo with placenta

3.6 MIGRATION & PARENTAL CARE IN FISHES

Fishes species normally restrict to a definite geographical range within which they are constantly in movement. A few species travel long distances moving from fresh water to sea water or vice versa. This movement of fish in large numbers for the purpose of feeding and spawning is known as "migration". It take place in vertical direction as from the deeper to the surface or it may be in a horizontal direction, either upstream or downstream. According to Haepe (1931) def the migration is defined as "A class of movement which impels migrants to return to the region from which they have migrated". Migration may be due to

(i) Alimental migration : In search of food and water

(ii) Gametic migration : For reproduction

(iii) Climatic migration : To secure more suitable climatic conditions

(iv) Osmo-regulatory migration : For water balance

Some migratory fishes are

(1) Cod (*Gadus morhua*)

(2) Herring (*Clupea harengus*)

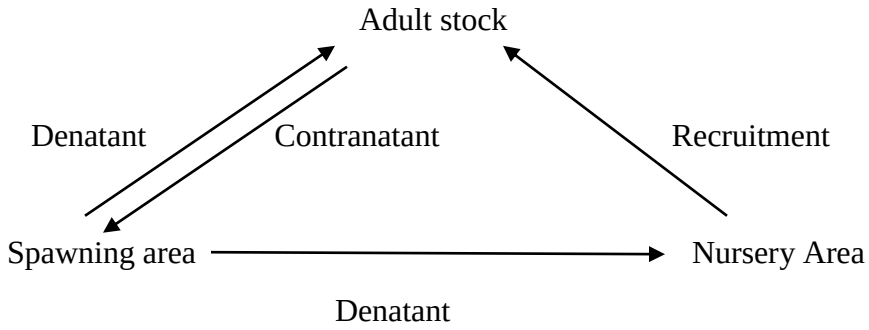
(3) Salmon (Salmo sps)

(4) Eel (*Anguilla anguilla*)

(5) Plaice (*Pleuronectus platessa*)

(6) Hilsa (*Hilsa ilisha*)

According to Harden and Jones (1968) defined migration as a movement from spawning to nursery ground from nursery ground to feeding ground feeding ground to spawning.



A fish can make migratory movements by several methods

(i) By drifting : The fishes are carried passively by water current. This is called drift. This is directional movement i.e. fish are moving direction of water movement.

(ii) Random locomotory movements : It leads to an uniform distribution or to an aggregation. If there are no differences in environmental field i.e. in an uniform environment. The fish is released from a point spread equally in all directions. It is diffusion. In case if there is difference in environmental condition like temperature, light then there will be an aggregation to a point take place such type of movements is called kinases. This term was given by Farenkel and Gunn (1940).

(iii) Oriented swimming movements : The fishes swim in a particular direction

(a) Either towards or away from the source of stimulation.

(b) At some angle to an imaginary line running between them and the source of stimulation.

Types of migratory Fish :

Myers (1949) classified migratory fishes into 3 types

(i) Diadromous : These fishes migrate between the fresh water and the sea and may be 3 types

(a) Anadromous : Those fishes migrate from sea to inland water of river during their breeding season to lay eggs. After laying eggs they return back to their feeding place in the sea. For example – *Salmon, Hilsa, Sea lamprey, Shad.*

(b) Catadromous : These fishes migrate from fresh water to the sea for the purpose spawinging for e.g. Fresh water eels *Angullia angullia*.

(c) Amphidromous : These fishes migrate from the fresh water to the sea or vica-vewrsa which is not the purpose of breeding but for certain other reason. e.g. some gobies fall in the category.

(ii) Potamodromous : Those fishes in which migration remain confined to fresh water for e.g. carps and the trout travel long distances in large rivers in search of spawning grounds. After egg laying at suitable place, they return to the feeding ground.

(iii) Oceanodromous : Those fishes live and migrate in the sea, for e.g. Many marine fishes like herrings, meckerels and tunas. Theses fishes migrate seasonally from the hot to cold water for the purpose of spawning after which they return to their feeding ground.

Advantage of migration : According to Nikolsky, migration is an adaptation toward abundance. The spawning or nursery grounds may not have enough food to maintain both the mature and immature members of a large population. Hence it would be an advantage to have separate spawning, nursery and feeding grounds. The fact that many commercial species are migratory, supports the view that migration is an adaptation toward abundance.

Factor influencing Migration : Migrations are influenced by several factors which may be physical, chemical and biological. Physical factors include the bottom materials, depth of water, pressure, temperature, light intensity and photoperiod, current, turbidity etc. The chemical factors are the salinity, pH, smell and taste of water. The biological factors influencing migration are the sexual maturity, blood pressure, food, memory physiological clock and the endocrine glands. Presence or absence of the predators and competitors may also be considered as the biological factor governing migration of fishes.

Migration of Eels

There are about 14 to 16 species of fresh water eel which are catadromous migrant. In these fishes their feeding and growing phase takes place in inland water or river where as they migrate to the sea-water for spawning. The two species of Atlantic eel, the European eel (*Anguilla anguilla*) and American eel (*Anguilla rostrata*) are found in the countries bordering on both the sides of North Atlantic. The European eel is found along the eastern part of the sea and while American eel is found on the western part of the sea. The two species differ from each other int the number of their

vertebrate ranging from 110 to 119 in European and from 103 to 1121 in the American eel. Their life cycle are as follows.

Life cycle of European eel (*Anguilla anguilla*)

Distribution : The European eels are found in the river (inland) waters of the countries along the eastern part of the atlantic ocean. These are found from Murman coast to North Africa, Iceland, the Azores, Madeira, and the Canary Island, Baltic and the Mediterranean countries, the black sea a, sea of azov, and the red sea. A few species are also present in East Africa. There are 2 stages are found in the life history of eel.

(i) ***Yellow eels :*** This represent the feeding and growing phase.

(ii) ***Silver eels*** : This represent the breeding phase.

Spawning : Fresh water eels are found in the river, lakes estuaries and ponds altaining a length of over five feet. The growth of the female fish in fresh water is far superior than the growth of the male fish. Due to this female fish attain sexual maturity at an early age. So during migration male fish are about 8 - 10 year old, while the female are 10 – 18 year old.

Transformation into silvery eels : During the begin in early autumn, certain changes occur in the body of eel. So that they easily migrated to the spawning ground. These are as follows

(a) The colour of skin changes from yellowish green top silvery white on the sides and blackish along the back.

(b) The skin increases in the thickness.

(c) The eyes becomes enlarged, probably to adapt to a life at a considerable depth, like as in deep sea fishes.

(d) Retinal pigments (chryopsin), similar to those of deep sea fishes appear.

(e) Lips become thinner and the snout sharper.

(f) Pectoral fins becomes more pointed and grow darker in colour.

(g) Fishes stop feeding during the time with the result that these alimentary canal shrinks.

(h) The rete mirabilia of swim bladder become remarkably enlarged.

(i) The osmo-regulatory mechanism gets altered and chloride secreting cells gills increase in number.

(j) The reproductive organs become well developed.

The eels migrate down the rivers reaching the sea in late summer. It is believed that there theses eels cross the Atlantic ocean covering three to four thousand miles reaching their spawning grounds in the western Atlantic ocean south of Bermuda and takes about 6 – 7 months.

Fertilization :

Now fish select suitable place for spawning and are segregated in pair. Shallow saucer like nests are prepared where spawning take place. It is believed that the eels spawn at a depth of about 400 meters below the surface at 16 – 17^0C. The parent dies after spawning. Their eggs are pelagic. Now the egg move upward or toward surface during this the processes of development completes and hatching occur at depth of 200 meters at 20^0 – 25^0C.

Leptocephali larva and the larva drift : The larva hatching out of the egg is called a protocephaline larva. It bears a yolk sac and remain confined to a depth of 200 meter.

As the yolk sac is gradually absorbed the protocephalin larva changes into a leptocephalus larva

The leptocephalus larvae are devoid of yolk sac continue to depth range of 50 - 100 meters. Their bodies have a glassy transparency but their eyes have a silvery appearance. They are flattened leaf like in structure and vary in length from 5 mm to 180 mm length. The leptocephalu larva has following characteristic.

(i) Presence of large sized eyes, nose and the brain.

(ii) Skeleton unossified

(iii) Only the mandibular, hemibranch bear the gill filaments.

(iv) Teeth are long and needle like.

(v) Gut assumes from of a more or less straight tube.

(vi) Red blood corpuscles, spleen and the air bladder are not found.

(vii) Kidney are a glomerular.

The larva swims with eel like undulating movement of the body and exhibits diurnal vertical migration approaching the surface only at night. The leptocephali migrate by north Atlantic drift from their spawning grounds in Sargasso Sea to nursery grounds in the coastal waters of Europe. It takes two and half years are spent in such a homeward migration, during which the larva grow in size and attain a length of about 70 – 80 mm.

Elevers : When the leptocephali reach the coastal waters of Europe metamorphosis changes these into the elever also called glass eel. The period of metamorphosis extend to about a year in which certain changes occur.

(i) The larva stop feeding at the onset of metamorphosis.

(ii) The needle like teeth are lost and replaced by the newer ones.

(iii) The body which was deep from dorsal to ventral edge in letocephalus, now become cylindrical in shape and reduced to the thickness of the head.

(iv) The length of larva a also decreases.

(v) The elevers are translucid at first and become pigment later.

Return to parental home

The elevers continue to developin coastal waters for about three years. As they grow sufficiently stronger they swim up the river and reaches to their parental home.

After reaching the home of their parents the elevers become cylindrical in shape and acquire a total pigmentation. They transform into yellow eel like forms, which feed and grow for several years and become sexually mature (silver eel) before starting their breeding migration to the sea.

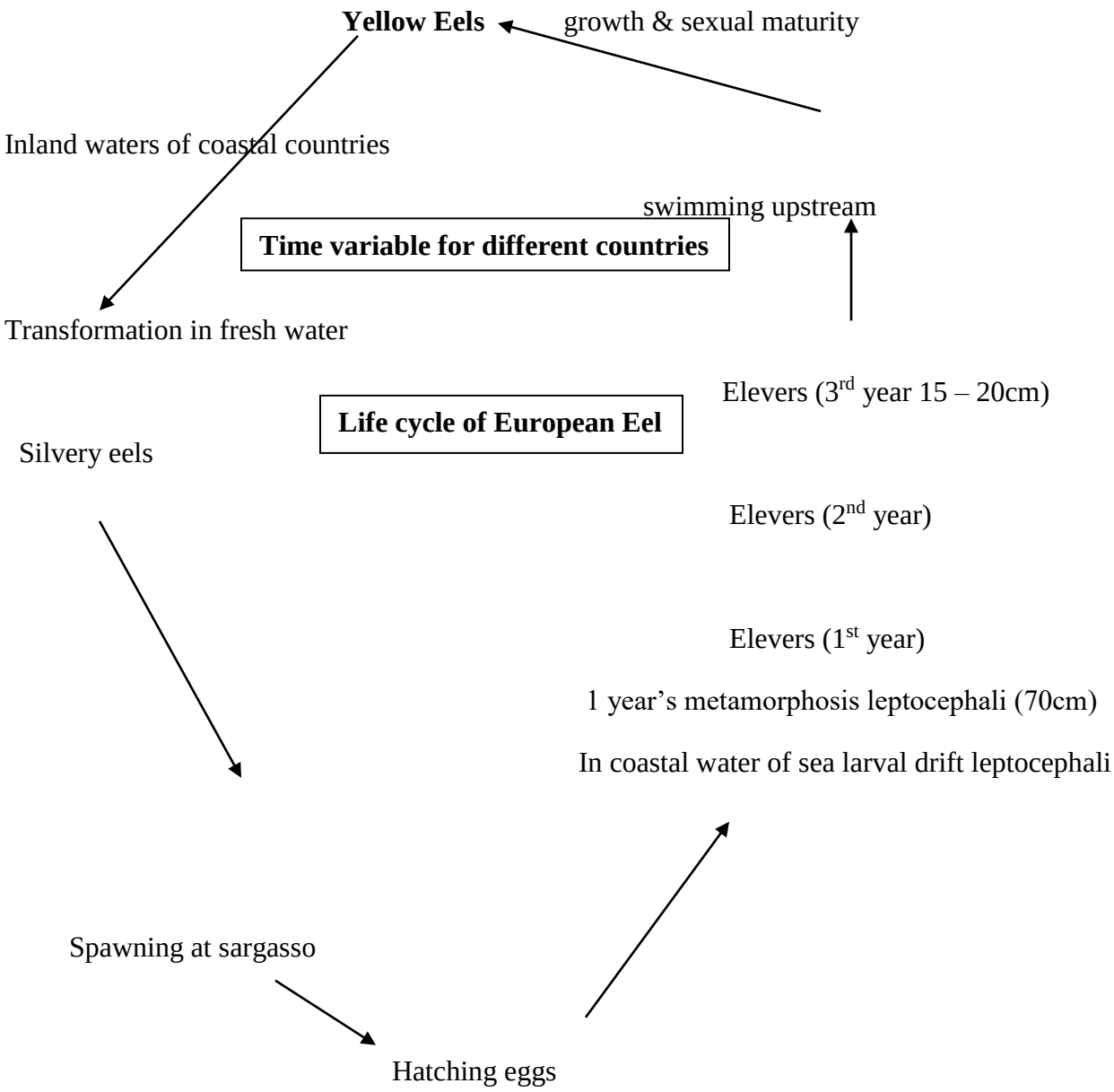


Fig : Outline of life cycle of the European Eel

Parental care in Fishes

In fishes it is generally observed that parents do not care their eggs or young once but there are some fishes where parental care has been observed. It has also been observed that one or both the parents are involved in caring their eggs or young once. This is referred as paternal care. It is an inborn instinct behavior. The protection of caring of eggs & young once help individual for their survival against struggle for existence. The fishes develop various structures for proper development of eggs & young once. It takes place by various methods.

(i) Formation of nest : The male of several fishes prepare nest for laying eggs by the females and then the male keeps close watching over the eggs till their hatching. *Amia* construct crude circular nest made up of aquatic plants. The male keeps guard the eggs and after hatching, it also takes care of the young one for sometime afterwards.

The most interesting example is stickle back (*Gasterosteus aculeatus*), in this male collects aquatic weeds which are joined together by a sticky secretion produced from the kidneys of

the male. When the nest assumes a considerable size the male makes a small tunnel. The male drags a mature female into the tunnel for the laying eggs. Then male keeps watch over the fertilized eggs till development is over. Some fishes prepare foamy nests or floating nests by blowing bubbles of air and sticky mucus as found in *Betta, Macropodus* etc.

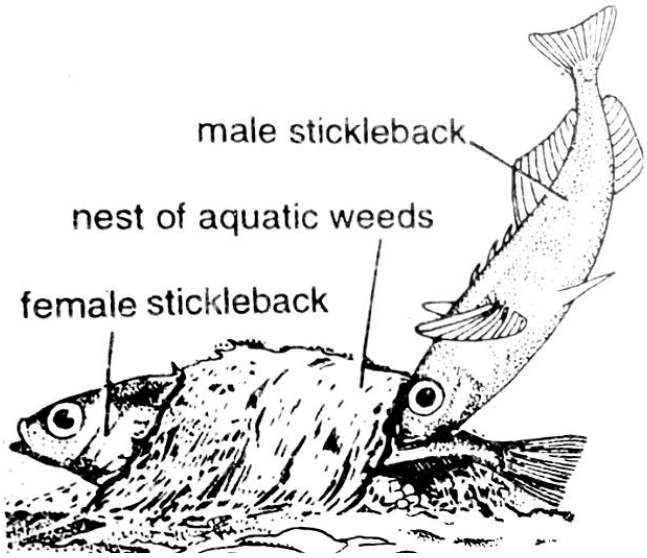


Fig : Stickle back : female at the nest & male stimulate for egg laying

(ii) Mouth Cavity : In some fishes, the fertilized eggs develop within mouth cavity. In cat fish *Arius* male carry the egg as well as young one in their mouth cavity. In Cichlids, the female carry the eggs in their mouth cavity, the young once uses the mouth cavity as shelter at the time of danger.

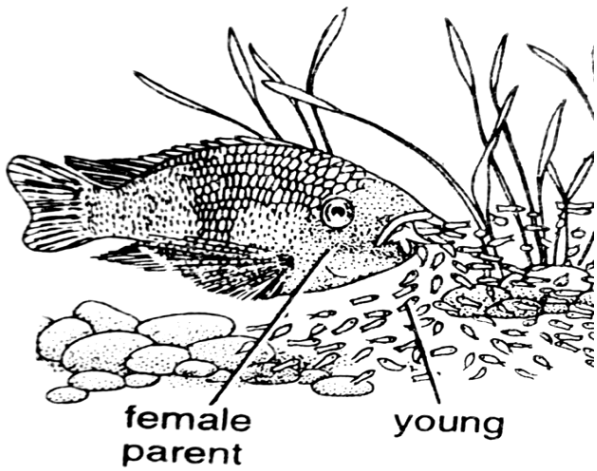


Fig: Young once take shelter in buccal cavity of female

(iii) Coiling around eggs : In *Pholis*, the eggs are rolled into a rounded ball and the male guards the eggs ball by coiling around it.

(iv) Integumentary Cups : In cat fishes *Platystacus* the fertilized eggs are pressed into the soft and spongy skin of belly of the female. Each egg become attached in a cup like integumentary depression and carried until hatching.

(v) Brood pouch : In *Hippocampus* and *Syngnathus* the female transfer eggs into the brood pouch on the belly of male to be kept until hatching takes place.

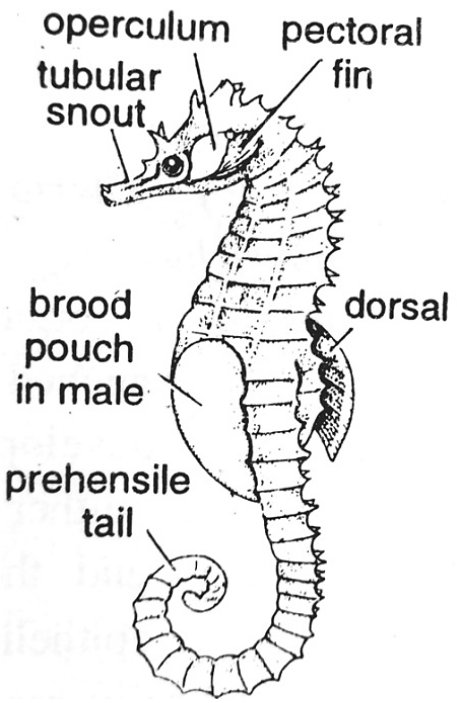


Fig: *Hippocampus* showing male brood pouch

(vi) Mermaids purses : Oviparous sharks (e.g. *Scyllium*) lay fertilized eggs inside protective horny egg capsules as Lennon "mermaids purse", which remains anchored to sea weeds by its long tendrils . The young hatch out after rupturing the eggs case.

(vii) Attachment to body : It has been observed that male of *Kurtus* entangle the mass of eggs at the hook like structure present on the head until the eggs hatches.



Fig: *Kurtus* have hook like structure on head to which egg entangle

(viii) Viviparity : The highest degree of parental care is found in viviparous fishes such as *Scoliodon*. Both fertilization and development are internal and nutrition is drawn by yolk sac placenta.

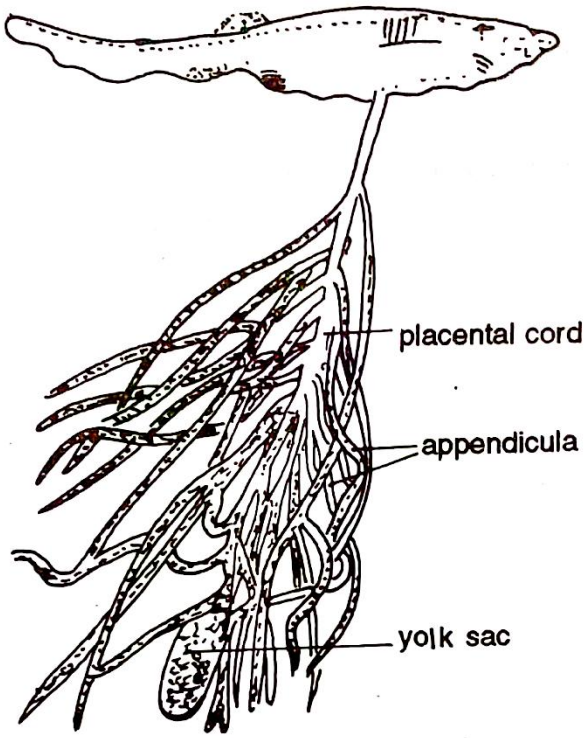


Fig: *Scoliodon* Embryo with placenta

SAQs 2.

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

(i) Paired fins in fishes are ----------

(ii) A homocercal tail is found in ----------

(iii) Bony fishes are ----------

(iv) Shark belongs to ----------

3.7 SUMMARY

In the first unit there is description of Agnatha in which it origin & evolution and general characters are disscused. The classification of agnatha is also done in very detailed manner.

In second unit is described general characters of fishes and classification of Pisces. There is also detailed information of types of scales and fin of fishes. In this unit there is also description of *Scoliodon* in which its habit and habitat, structure, fin, skin, respiratory organ, digestive organ, heart, excretory, developmental processes in very detailed manner. This unit also contains migration of fishes and parental care in fishes in very detailed manner.

3.8 TERMINAL QUESTION

Q1 Describe the General characters of Agnatha.

Q2. Describe theGeneral Characters of Pisces.

Q3. Explain heart of *Scoliodon.*

Q4 Describe the migration in fishes.

3.9 ANSWERS

SAQ 1

(i) Agnatha

(ii) 7 - 14

(iii) Hag fish

(iv) Petromyzontia

SAQ 2

(i) Pectoral & pelvic

(ii) Teleosts

(iii) Osteichthyes

(iv) Chondrichthyes

Terminal question

1. General characters of Agnatha

- Agnatha are earliest known vertebrates and are characterized by the absence of jaws.
- Teeth, paired appendages and exoskeleton are absent.
- Skull has a membranous roof.
- Single median nasal opening.
- Vertebral column consists of a persistent notochord with a fibrous neural tube.

- Presence of large number gill-slit, from 7 – 14 pairs.
- Absence of conus in the heart.
- A persistent hypophysial sac.
- One or two semicircular ducts in the ear
- Long kidneys and long archinephric ducts
- Genital ducts absent.
- Pineal apparatus fairly well developed

2. General Characters of Pisces

- Aquatic, either fresh water or marine
- Cold blooded vertebrates
- The skin is covered with scales, dermal denticles or bony plates.
- Body usually streamlined but some are elongated snake like and few are dorso-ventrally compressed.
- Presence of paired and unpaired fins supported by soft or spiny rays.
- Dorsal, caudal and anal fins are unpaired, while the pectorals and pelvic (ventrals) are paired.
- Tail is muscular and used for propulsion.
- Nostrils are paired but do not open into pharynx except lung fishes.
- Presences of barbles (excellent tactile organs) in some Teleostomi.
- The endoskeleton is cartilaginous or bony.
- Organ of respiration are gills but accessory respiratory organs may also be present.
- Gills are borne by true gill-arches. They open outside by gill-slits which are covered by operculum in Teleostomi
- The gill- slits are never more than seven pairs. Usually five pairs are present.
- A swim bladder or air bladder is usually present but secondarily lost in some species.
- Lateral line system is well developed.

3. The heart of *Scoliodon* is dorso ventrally bent, triangular, muscular, reddish brown in color.

It is enclosed by a double layered membrane of which outer membrane is called pericardial

membrane and inner is known as parietal membrane. In between these two layers a pericardial fluid is present which make the heart moist and also it prevent the shock. The heart of *Scoliodon* receive deoxygenated or venous blood only, which is pump into gills for oxygenation or aeration. Hence such type of heart is called venous or branchial heart. The heart consist of 4 chambers i.e. sinus venosus, atrium, ventricle and conus arteriosus.

4. Fishes species normally restrict to a definite geographical range within which they are constantly in movement. A few species travel long distances moving from fresh water to sea water or vice versa. This movement of fish of a very large number for the purpose of feeding and spawning is known as “migration”. It take place in vertical direction as from the deeper to the surface or it may be in a horizontal direction, either upstream or downstream.

According to Haepe (1931) defined the migration as “A class of movement which impets migrants to return to the region from which they have migrated”. Migration may be due to

(i) Alimental migration : In search of food and water

(ii) Gametic migration : For reproduction

(iii) Climatic migration : To secure more suitable climatic conditions

(iv) Osmo-regulatory migration : For water balance

UNIT-4 : GENERAL ACCOUNTS OF ELASMOBRANCHII, HOLOCEPHALI, DIPNOI AND TELEOSTOMI

Structure of Unit

4.1 Introduction

Objectives

4.2 General characters of Elasmobranchii

4.3 General characters of Holocephali

4.4 General characters of Dipnoi

4.5 Teleostomi

4.6 Adaptative Radiation in bony fishes.

4.7 Summary

4.8 Terminal Questions

4.9 Answers

4.1 INTRODUCTION

Fishes are a group of aquatic chordates that have gills and lack limbs. The term fish is an informal label that does not refer to a single taxonomic group but instead is used as a general term to refer to various aquatic craniates. In this unit you will learn briefly about the **Elasmobranchii, Holocephali, Dipnoi and Teleostomi.** Elasmobranch is a subclass chondrichthyes Elasmobranchii includes cartilaginous fishes. It includes sharks, rays and skates. Holocephali (Gr. Holos = entire + kephale = head), is a very small ancient group of highly specialized marine fishes. It comprises of rat-tailed fish the chimaera. The Dipnoi, commonly known as lung fish, include the Australian lungfish (*Neoceratodus*), the African lungfishes (*Protopterus*), the South American one (*Lepidostren*). Teleost, include any members of a large and extremely diverse groups of ray-finned fishes.

Objectives:-

After study this unit you will be able to know:

- General account of Elasmobranchii
- Information about Holocephali
- Characteristic features of Dipnoi and Teleostomi
- Adaptative radiation in bony fishes

4.2 GENERAL CHARACTERS OF ELASMOBRANCHII

Elasmobranch is a subclass chondrichthyes Elasmobranchii (Gr. Elasmo = a flat plate + branchia = gills) includes cartilaginous fishes. It includes sharks, rays and skates, which have placoid scales, ventral mouth, heterocercal tail, clasper and lack air-bladder and operculum. Members of this class are called Plate- like gilled fishes. Group is characterized by the presence of gills for respiration and paired fins for swimming. They belong to one of the two distinct lines of evolution of the super class Pisces cartilaginous Fishes of Chondrichthyes (Gr. chondros, cartilage + ichthys, fish) [second line of evolution being bony fishes or Osteichthyes (Gr. osteon. bore). They originated in Devonian (around 400 million years ago), flourished in jurassic and persist till date.]

General Characters-

- These are mostly marine and predaceous fishes, having cartilaginous endoskeleton, which are often calcified.
- The integument develops any hard parts as is the case in the majority of the Chondrichthyes; they take the form, not of regular scales, as in most other fishes, but of numerous rough, hard placoid scales. The skin is naked or covered with tough and minute placoid scale which are dermal in origin.
- Gills slits 5-7 on each side which are not covered by an operculum.
- The elasmobranchii head is in many cases produced forwards into a long rostrum. This is of great length and bordered with triangular teeth in the sawsharks (Pristiophorus) and sawfishes (Pristis). In the Hammerhead Shark (Sphyrna) the anterior part of the head is extended transversely and the eyes are carried at the lateral extremities.
- Jaws are well developed. Mouth is ventrally placed. A spiral valve or scroll valve is usually present in the intestine.
- Paired fins (pectoral and pelvic fins) are broad. The caudal fin is heterocercal.
- The mouth is situated on the ventral surface of the head, usually a considerable distance from the anterior extremity. In front of each angle of the mouth is the opening of one of the olfactory sacs.
- Two chambered heart, which has a well developed sinus venosus and conus arteriosus. RBCs are oval and nucleated. There is well developed renal portal system.
- Kidneys are mesonepric. They are ureotelic (Urea).
- The brain bears large olfactory lobes and a large cerebellum. The skull is an undivided mass of cartilage, hardened, in many cases, by deposition of calcareous matter, but not containing any true bony tissue. It consists of a cartilaginous case which protects the brain and the organs of special sense.
- They have 10 pairs of cranial nerves. Their streamlined body shapes help to decrease the friction of the water flowing along the body. Lateral line system is well developed.
- Air bladder and lungs are absent. They have only internal ears (membranous labyrinth) which helps them in balancing.
- Some of them have electric organ (eg .Torpedo) and some possess poison sting (eg. Trygon). Electric organs occur in several elasmobranch. They are best developed in the electric-rays, numb-fishes, or torpedos, in which they form a pair of large masses running through the entire thickness of the body, between the head and the margin of the pectoral fin. They have cloaca.
- Urinogenital Organs and Reproduction -The kidneys differ somewhat in the two sexes. In the male the anterior portion persists in the epididymis, and its duct becomes the sperm duct, while the posterior portion, which is the functional kidney, has a duct or ducts of its own. In the female selachian there is no direct connection between the reproductive and renal organs.
- The anterior portion of the kidney may be functional, and its duct persists, opening along with those of the posterior portion. In the male the urinary ducts open into a median chamber-the urinogenital sinus, which extends into the cloaca, which also receives the spermiducts. It communicates with the general cavity of the cloaca by a median opening

situated on a papilla-the urinogenital papilla. In the female there is a median urinary sinus, into which the urinary ducts open, or the later may open separately into the cloaca.

- Claspers are present in male. The oviducts are called Mullerian ducts. The fertilization is internal. They are viviparous or ovoviviparous (eggs hatch in mother's genital tract). Development is direct.

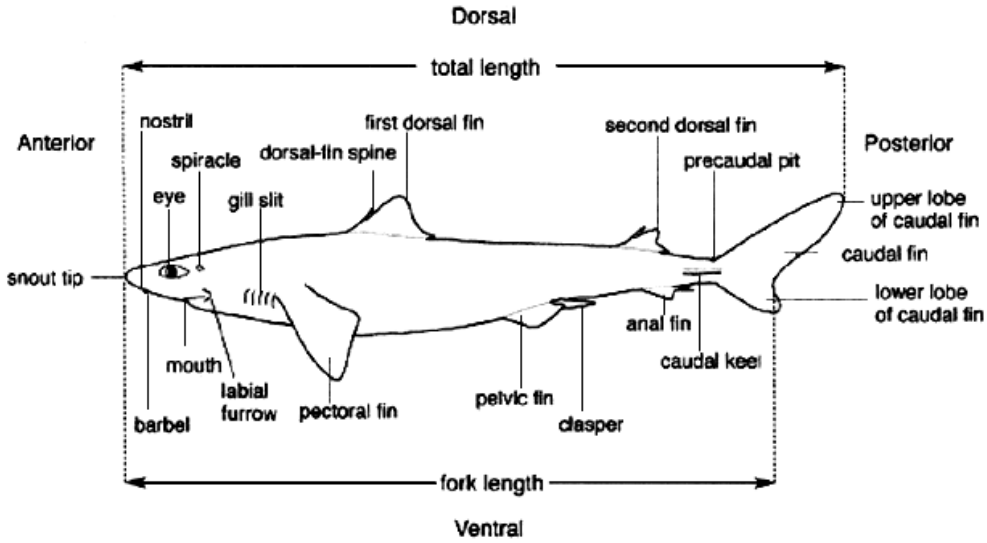


Fig : Elasmobranchii

Origin and evolution of Elasmobranchii

Class Elasmobranchii includes sharks (Sub class Selachii) rays skates and sawfish. Members of this class are characterized by having 5-7 pairs of gill clefts, rigid dorsal fins and placoid scales and the teeth. The upper jaw is not fused to the cranium and the lower jaw is articulated with the upper jaw. The inner portion of pelvic fins are modified into claspers in male to transfer sperms.

Elasmobranchs originated from some placoderm during Ordovician period and evolved into sharks, rays, skates and sawfish. Fossilised shark teeth are known from the early Devonian period (around 400 million ago). It indicates that elasmobranchs appeared in early Devonian period of Palaeozoic era and soon became well established, continuing upto the present time. During Carboniferous period, the sharks underwent a period of diversification with many new forms. Many of these became extinct during the Permian, but the remaining sharks underwent a second burst of adaptive radiation during the Jurassic period, around which time the skates and rays first appeared. Many surviving orders of elasmobranchs date back to the Cretaceous or even earlier.

Elasmobranchs are primarily marine fishes that possess a cartilaginous skeleton which is probably a secondary feature and does not represent primitive condition. Sharks are generally considered to be primitive than the bony fishes, but they appeared at later stage, than the first bony fishes. However they possess a low grade of structure and organization.

Cladoselache is one of the earliest sharks that lived during the upper Devonian. It had a typical shark like body, heterocercal tail, two dorsal fins and pectoral and pelvic fins. The pectoral fins were very large and were simple extensions of the body wall. The skull was amphistylic, From such an ancestral type, the cartilaginous fishes evolved along several line. The most primitive of these were the pleurocanth sharks that appeared during the Carboniferous and are exemplified by the genus Pleurocanthus. Like the Cladoselachians, they also had amphistylic jaw suspension but were specialized in some respects. The body was shark-like with a diphycercal tail and a long dorsal fin.

Paired fins were of the archipterygeal type and a long spine projected backward from the skull.

During the Mesozoic era, the advanced sharks appeared in which the skull became hyostylic providing more freedom to the jaws which is a characteristic feature of the advanced sharks. From the Mesozoic times, the sharks evolved along two lines, giving rise to the modern sharks and the rays. The sharks are active fast swimmers and are predaceous fishes. They possess a torpedo- like body, strongly heterocercal tail and paired fins with narrow bases. The skates and the rays, consisting the other evolutionary line, become specialized for bottom living habit. In these fishes the pectoral fins are greatly enlarged and fused with the body, the tail is narrow whip-like and the gill slits are ventrally placed. Some genera, Heterodontus, like Hexanchus and Chlamydoselache, occupy an intermediate position between the primitive clasoselachians and the advanced sharks and may be called "living fossils".

SAQ-1

1. Elasmobranchs are Ordovician originated from some **……..** in period and evolved into **…….**
2. …… is one of the earliest sharks and lived during the upper Devonian.
3. Cartilaginous fishes are……..
4. Playcoid scales are present in …….

4.3 GENERAL CHARACTERS OF HOLOCEPHALI

Structure of Holocephali

Holocephali (Gr. Holos = entire + kephale = head), is a very small ancient group of highly specialized marine fishes. They appeared first in the lower Jurassic and at present, are represented by a few marine genera only. It includes the only cartilaginous fishes having fleshy opercular covering of the gills. Like the Acanthodians, they seem to represent divergent and specialized descendants of some primitive elasmobranch ancestor.

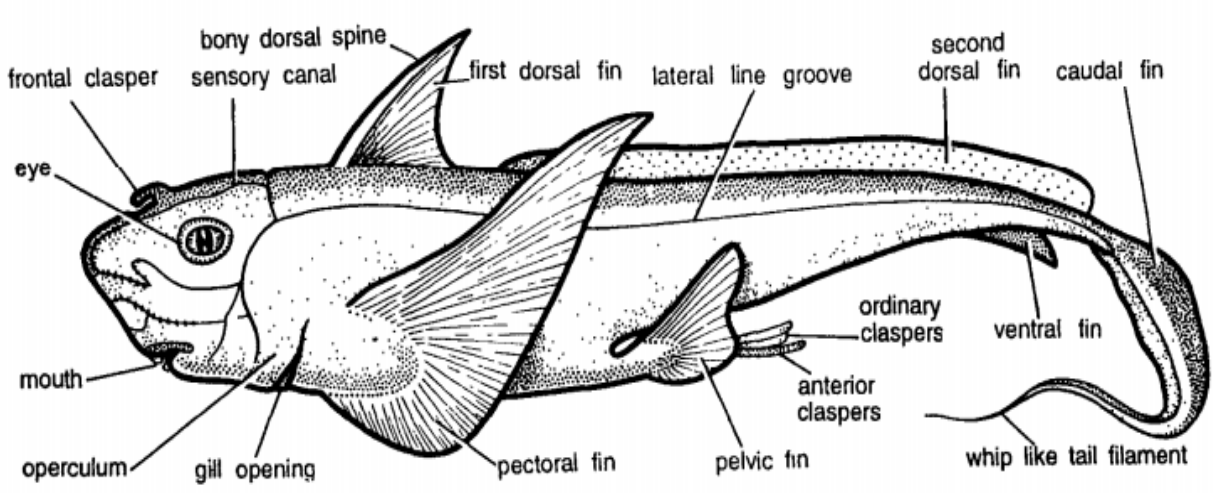


Fig: Rat-tail fishes

Source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.notesonzoology.com

General Characters:-

- The body of Holocephalians is shark like in appearance but the head is large and compressed,

with a small mouth.

- They have four gills – slits, covered by fleshy operculum so that only a single branchial aperture is present on both side of head. Operculum is supported by branchial rays which is attached to the hyoid arch.
- Spiracle and cloaca are absent.
- The urigenital aperture is distinct from the anus.
- Two dorsal and a ventral fin are present. Tail is heterocercal, but in chimaera, it is whip-like. The pectoral and pelvic fins are large in size. The anal fin is small.
- Sexes are separate and sexual dimorphism well marked. Females are larger than males. Male has a shallow glandular pouch in front of the pelvic fin which contains a peculiar anterior clasper covered with denticles. The function of this clasper is not known. In addition, the male fish has a pair of ordinary clasper behins the pelvic fins, and a frontal clasper on the dorsal surface of the head.
- Skin is smooth and silvery.
- Laterla line system has open grooves in chimera and a closed tube in callorhynchus, with many branches on head.

Endoskeleton:

- The vertebral column consist of the persistent notochord with cartilaginous arches. In Chimera, calacified rings are embedded in the notochordal sheath.
- The neural arches of first few vertebrae are fused to form a plate giving attachment to the first dorsal fin.
- Holostylic skull and palate-quardrate is fused with the cranium. Lateral cartilages are fully developed. Jaw suspension is autostylic. In collorhynchus, the three cartilaginous is autostylic.
- In Callorhynchus, the three cartilaginous rods grow forward from the cranium to give support to the snout. These rods are very much reduced in Chimara. Each pelvic half consists of a narrow illiac region and a broad pubo-ischial region. The nasal capsules are devoid of cartilaginous wall and are therefore, continuous with the craniate cavity.
- The hyomandibular does not participate in the suspension of the jaw. Such suspension is called holostylic.
- There are 5 gills arches with four gill-slits covered by operculum.
- The mouth is small and ventral in position. The tooth plates have reduced pulp cavities and the layer of enamel, called vasodentine. They have and irregular surface and sharp cutting age.
- Two pairs of teeth are present in the upper jaw and one pair in the lower jaw. Besides these, a pair of small vomarine teeth , and a pair of a large palatine teeth are also present in the upper jaw. A short oesophagus opens to the exterior by anus. The true stomach is absent and the intestine has a spiral valve.

Respiratory System:

The respiratory organs consists of three pairs of holobranchs on the first three branchial arches, and two pairs of hemibranches on the hyoid arch and the fourth branchial arch. The fifth arch is gill-less and the inter-branchial septum is reduced. A fleshy cutaneous opercular fold grow over the gill

clefts. The gill clefts open to the exterior by a single branchial aperture lying between the free margin of the fold and the body wall.

Circulatory system: Closed circulatory system. Heart is similar to other fishes. The consists a sinus venosus, altrium, ventricle and conus with three rows of valves. The holocephlian retain urea in the blood for osmoregulation as in sharks.

Nervous System:

- The cerebral hemispheres are small and spindle shaped which is connected with olfactory bulb by means of a narrow peduncle separately. Diencephalon is long and trough shaped.
- Cerebellum is small and the medulla oblongata is produced laterally into restiform bodies. The pineal body is a small rounded structure at the end of a pineal stalk. The hypophysis is composed of intra and extra cranial portions.

Sensory Organs:

- Holocephalian's eyes are large in relation to the body size, which is an adaptation to their total habitat in the deep sea.
- Eye lids are absent. Membranous labyrinth consists of three semi-circular canals.
- The lateral line system is well developed, consisting of groove-like open canals. These are specially developed in the region of the head and on the ventral side of the snout which is differ from elasmobrachs possibly because of a change in the snout's structure or the style of their food detection.

Urinogenital Organs:

- The kidney (two in number) of holocephalians is opisthonephric having a large number of uriniferous tubules and built upon the basic pattern of the other fishes.
- The reproductive organs of the female resemble those of the elasmobranchs and consist of a pair of ovaries, shell glands and uteri. In the male, testes are large oval bodies but contain only immature sperms. The vas deferens is coiled up to form epididymis attached to the anterior part of the kidney. The sperms become mature in the epididymis and form spermatophores. The terminal part of the vas deferens is swollen to form vesicula seminalis which is divided into several chambers by means of transverse septa. The spermatophores are stored in these compartments and or finally passed into the urinogonital sinus.

Fertilization:

- The fertilization is internal and the cleavage holoblastic type.
- the egg becomes surrounded by a horney egg shell seereted by the shell glands.
- The incubation period is fairly long, for example, in Callorhynchus, it extends from 9-12 months.

Eggs and Development:

- The holocephalians are oviparous. Their eggs are characteristically spindle shaped covered with horny egg capsules, secreted by the shell glands.
- The capsules of Hydrolagus measure about 15 cm and those of Callorhynchus, about 25 cm, in length. The eggs are laid in pairs, and contain three compartments.

Affinities of Holocephali

Holocephali occupies a position in between the cartilaginous and bony fishes and have conserved several primitive characteristics, from so called Placoderm ancestors.

Resemblances with the Elasmobranchs:

Holocephalians show both, the characters of palaeozoic elasmobranchs as well as those of modern living sharks.

Primitive Features of Holocephali, resembling with Primitive Sharks:

- The tail is heterocercal.
- A stiff spine along the anterior edge of the first dorsal spine is retained from the ancient sharks,
- Mouth placed ventrally as also in the modern sharks.

Features of Holocephali:resembling with Modern Shark's

Skin smooth and silvery. Cartilaginous endoskeleton, devoid of any replacing or dermal bone. The vertebral column is ancestrous and ribless consisting of a persistent notochord with cartilaginous arches. Lack of bony jaws.

Simplified brain (Diencephalon only elongated due to large sized eyes). The general development of chondrocranium. A pair of claspers present posterior to the pelvic fins in the male, as in elasmobranchs. Besides these, anterior claspers and the frontal claspers are also present in Holocephali. The paired fins and girdles are built upon the elasmobranch pattern. The tail is heterocercal.

Air bladder is absent. A spiral valve is present in the intestine. A separate posterior superficial ophthalmic foramen is present. The reproductive organs on the elasmobranch pattern. The conus arteriosus is present in the heart and contains three rows of valves.

Urea is retained in the blood for osmoregulation. Presence of egg capsule. The lateral line canals are distinct and suggestive of the sharks. Excretory system on the Elasmobranch pattern.

Resemblances with Dipnoi:

Nature of skull, Unconstricted notochord, Presence of crushing tooth plates. ¬

Resemblances with Teleosts:

An operculum is present Single external branchial chamber is present. Reduced interbranchial septum, allowing gill filament to project beyond it. Spiracle and Cloaca absent. Four complete aortic arches serving the four gill openings.

Primitive Characteristics:

Cartilaginous endoskeleton, Persistent notochord with cartilaginous arches., Separate external openings for each gill slit, Large opercular covering of the gill slits.

Specialized Features:

Jaw suspension holostylic, Presence of unusual frontal claspers, Absence of scales.

4.4 GENERAL CHARACTERS OF DIPNOI

- Although the gas-bladder, the lungs of the lungfishes (Dipneusti or Dipnoi) are respiratory like the lungs of higher vertebrates, however the homologies of the organs are not clear. Most

comparative anatomists believe that the lungs of the lungfishes and the gas bladder of higher fishes are related in evolution. In addition to respiration the gas bladder had developed many other functions during the diversification of fishes, such as gravity adjustment, hydrostatic equilibrium, sound production and assistance in sound reception.

- The Dipnoi, commonly known as lung fish, are considered to be specialized or degenerate descendants of the more primitive lobe fins fishes which they closely resemble. They were once supposed to be the ancestors of the amphibians, a view no longer held. They are large, bizarre fishes represented only by three living genera and furnishing an example of discontinuous distribution. In all three, the air bladder serves functionally as a lung by which they can breathe air, when required. The endangered monotypic Australian lungfish, *Neoceratodus* (-Epiceratodus) *forsteri*, restricted to fresh waters, attains a length of 1.5 meters or more. It has a single lung (Monopneumona) and cannot survive out of water. The monotypic South American lungfish is *Lepidosiren paradoxa*, while the African lungfish, Protopterus, has four or so related species. These two genera have weekly developed gills so that they will drown if prevented from using their paired lungs (Dipneumona). They live on mud swamps or marshes.
- During drought, when the marshes dry up, they aestivate by secreting mucous cocoons in mud, in which they become dormant and breathe atmospheric air through burrow openings. These 1 to 2 meters long, elongated, eel-like or snake-like forms have unique filamentous but highly mobile paired appendages Lung fishes are mostly cartilaginous. They have specialized crushing tooth plates to feed effectively upon shell fish. Their embryogeny is more primitive than that of other living bony fishes. Cleavage of eggs is holoblastic and gastrulation occurs by invagination. Their tadpole like larva has external gills as accessory respiratory structures.
- Like the lungs of all other vertebrates, the lungs of the lungfishes originate as a median ventral evagination of the embryonic foregut.
- In the Australian lungfish (*Neoceratodus*) the lung in the adult is a bilobed structure that lies dorsal to the gut but maintains a pneumatic duct that opens into the ventral wall of the gut. In the African lungfishes (*Protopterus*) and in the South American one (*Lepidostren*) the lung is also paired and bilobed but is ventral to the gut.

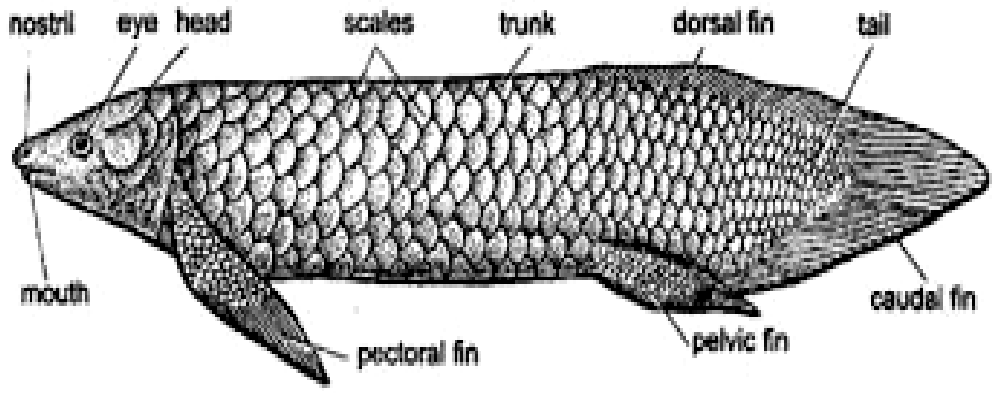


Fig: Neoceratodus

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In all kinds of lungfishes the internal surfaces of the lungs have subdivisions. These subdivisions reach the height of their development in the African species where the lungs closely resemble those

of land-living amphibians. The blood supply to the lungs comes from the last efferent branchial artery (the fused third branchial artery in *Protopterus* and the fourth in the other lungfishes), and blood aerated in the lungs returns to the heart directly through a pulmonary vein into the left side of the atrium. A "spiral" value also divides the conus arteriosus and partially separates oxygenated and deoxygenated blood in its distribution to the gill vessels.

- The African lungfish (*Protopterus annectens*) aestivates in a cocoon of hardended slime that is brown and parchment like.
- The three genera of living Dipnoi are allied in all the essential features of their structure. Therefore it is only necessary to mention here the principal points in which *Neoceratodus* and *Lepidosiren* differ from *Protopterus*. *Protopterus* and *Lepidosiren* resemble one another more closely than either resemble with *Neoceratodus* and are placed in the same family, the *Lepidosirenidae*.

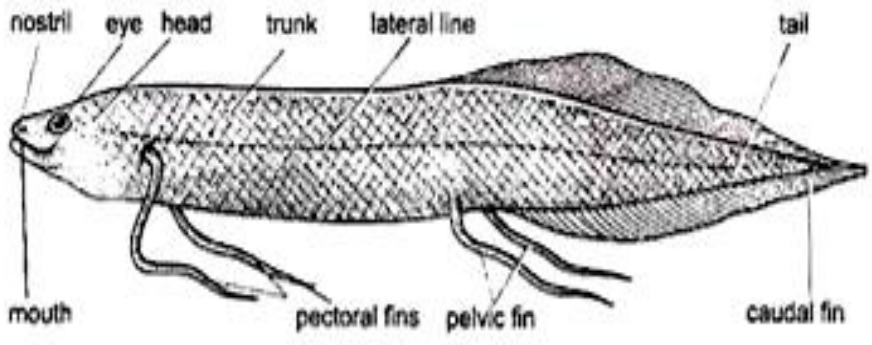


Fig: Protopterus

Source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.notesonzoology.com

- The limbs of *Lepidosiren* are similar to those of *Protopterus,* but in Neo ceralodus they are broad and leaf-like, with a correspondingly modified skeleton. The tapering central axis is composed of a stout basal cartilage and a number of short, cartilaginous segments, with serially arranged rows of jointed, *cartilageinous radialia,* projecting on either side. The skull of *Neoceratodus* differs somewhat from the *lepidosiren* type, being an undivided mass, devoid of fontanelles. In many respects it resembles the skull of the fossil dipnoan Ceratodus, and is more primitive than that of *lepidosirenids.* Furthermore, true *splenials* and vestigial dentaries are present.
- There are two lungs in *Protopterus* and *Lepidosiren,* but only one in *Neoceratodus.* The monopneumonous condition in *Neoceratodus* is possibly due to the suppression of the original left lobe (Goodrich). The internal structure of the lung, too, is simpler in this species. In *Neoceratodus* only four pairs of gills are developed, but each gill arch carries a double row of filaments. The hyoidean gill is a true pseudobranch. A peculiarity in this genus is that the branchial lamellae of each gill arch extend on to the dorsal and ventral walls of the gill cleft, so that the hemibranchs of each cleft are continuous, both dorsally and ventrally. The fifth arch lacks gills.
- The vascular system of *Lepidosiren* closely resembles that of *Protopterus.* In *Neoceratodus,* however, there are several points of difference. The heart in this genus is less specialised, in that the longitudinal septa of the conus are incomplete and represented by longitudinally arranged valves. Consequently there is more mixing of oxygenated and deoxygenated blood supplied to the anterior afferent vessels. Since there is a hyoidean pseudobranch (as opposed to

a hemibranch in *Protopterus* and *Lepidosiren*), the anterior afferent vascular system is different. The pseudobranch is supplied by a vessel from the efferent branchial artery of the first gill-arch. Anterior and posterior cerebral arteries originate from the pseudobranch.

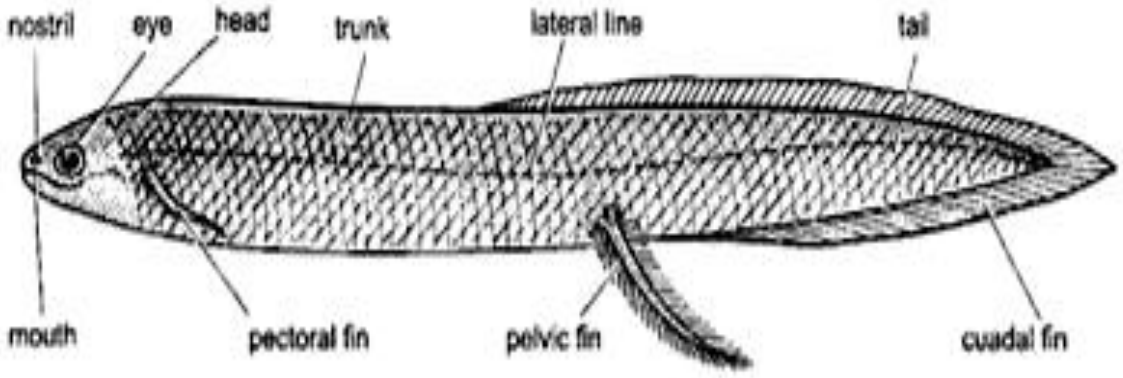


Fig: Lepidosiren

Source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.notesonzoology.com

- The venous system in *Protopterus* and *Lepidosiren* is very similar, and represents in general a more advanced evolutionary stage than that of Neo ceratodus. An abdominal vein, derived from the union of the pelvic veins, is present in *Neoceratodus*, but not in the other genera.
- The brain of *Neoceratodus* differs from that of *Protopterus* (and *Lepidosiren*) in having paired optic lobes and a clearly demarcated bulbus and lobus in the olfactory tract. In cach genus the alimentary canal is similar in most respects except for differences in dentition. In the urinogenital system the kidneys are relatively more elongate in *Protopterus* and *Lepidosiren* than in *Neoceratodus*. In *Lepidosiren* the posterior aspects are unfused.
- The testes of *Protopterues* and *Lepidosiren* are elongate, and divisible into an anterior, longer spermatogenic part and a posterior vesicula seminalis. In *Neoceralodas* and *Lepidosiren* about six vasa ellerentia rise from the posterior region and enter the mesonephric tubule, the spermatozoa then passing through the mesonephric ducts. This arrangement shows considerable affinity with the Amphibia

Origin and evolution of Dipnoi

The origin and evolution of Dipnoi remains problematic due to diverse opinions. They combine characteristics in which they resemble almost all the other groups of fishes as well as Amphibia. Fossil primitive Dipnoi (e.g. *Diptems*), shows greater similarity with fossil crossopterygians (e.g. *Osteolepis*), than do their living members. During the course of their evolution, the modern Dipnoans have undergone several changes or specializations such as :

- Anterior dorsal fin was reduced and eventually lost.
- Remaining median fins elongated and fused so that originally heterocercal tail became symmetrically diphycercal.
- Reduction in number of dermal bones of skull and operculum.
- Thick bony cosmoid scales modified into thin cycloid scales.
- Extensive sheet of cosmine covering head and body was lost.
- Fusion of conical teeth into crushing tooth plates to feed effectively upon shell fish.

- Air bladders became functional lungs not unlike those of higher vertebrate

Evidence indicates that Dipnoi are degenerate descendants of Crossopterygii to which early dipnoans closely resembled. Romer (1945) held the view that Dipnoi and Rhipidistian Crossopterygii had a common ancestor.

SAQ-2

1. …….. comprises of rat-tailed fishes
2. The ……. gas-bladder lungs of the lungfishes
3. Australian lungfish……..
4. South American lungfish is ……..
5. African lungfish……..

4.5 TELEOSTOMI

Class-Teleostomi (Bony fishes)

This class includes a large number of true bony fish species in which primary upper and lower jaws are supplemented by the addition of membrane bones which form the secondary jaws. Hence they called Teleostomi (Gr Teleos= complete or perfect + stoma = mouth) or perfect-mouthed fishes. Teleostomi shows the following characteristics-

- These inhabit all shorts of water fresh, brakish or salt: worm or cold.
- Body is spindle-shaped and streamlined.
- The body is covered with thin dermal Cycloid, Ctenoid or Ganoid scales and many lack scales entirely (eg., the members of the family Siluriidae and some bottom dwellers).
- The paired and unpaired fins are mostly present. The fins are supported by mostly bony fin rays. The tail is usually homocercal.
- Endoskeleton is made up of bone, except sturgeons and some other examples.
- Notochord is replaced by distinct bony vertebrae, Pelvic girdle usually small and simple or absent, generally vertebrae are amphicoelous. Claspers are absent.
- The mouth is terminal and is provided with teeth.
- Anus is present and cloaca is absent.
- Respiration is carried out by 4 pairs of gills on bony gill arches, covered by bony operculum on either side.
- An air bladder is present with pneumotic duct which may or may not be connected to the pharyx.
- Heart has two chambers (1 auride + 1 ventricle) and ventrally placed. Sinus venosus and conus arteriosus are present.
- Adult kidney is mesonephric. These are ureotelic.
- Brain has very small olfactory labes, small cerebrum and well developed optic labes and cerebellum. Cranial nerves are 10 pairs.
- Lateral line system is well developed. Internal ear has 3 semicircular canal.

- They are unisexual and have paired gonads.
- Fertilization is usually external. These are mostly oviparous, rarely ovoviviparous or viviparous.
- Eggs are minute to 12mm. cleavage is meroblastic and has direct development, rarely with metamorphosis.
- Some of the freshwater forms are the carp, perch, bass, trout, catfish, sucker, etc. some of the marine fishes are the perch, tarpon, meckerel, tuna, sailfish, barracula, flying fish etc.

Crossopterygii –

- **Vertebral column and skull: (Rest part).** The spines on the back are hollow hence called coelacanth. Notochord is unconstrited. The skull resembles with that of Oteolepides in possessing a movable hinge between the parietals and post-perietals. There are five gill arches of which the first four or attached to the copula. Below the lower jaw are two bony plates called the 'gular plates'. There is no internal nostril in *Latimeria.*
- **Sacles:-** The scales are cosmoid which are round and massive. The main buccal plate is almost horny. The tubercles on the scales are separate units and hollow. The scale overlap so much so that the whole body has three scales thick covering thus forming a powerful protective covering.
- **Swim Bladder:**- The swim bladder of coelacanth is extremely variable and even vestigial. It is in the form of a small tube, extending from the ventral side of the bladder and is also surrounded by a layer of fat. The bladder has no pulmonary function. The flesh of the fish is extremely oily.
- **Heart:**- It is primitive and is relatively in an unfolded condition with the atrium lying posterior to the ventricle, presenting the condition of the original vertebrate heart.
- **Digestive organs:**- The oesophagus is a thick, muscular tube followed by a spacious double limbed stomatch. The boundary between the stomach and the oesophagus can be seen only histologically. The stomach has well developed gastric glands. A short chamber, bursa entiana, is present as in many fishes and is guarded by a sphincter. The intestine is long and has a spiral value. This is followed by rectum opening into the cloaca. A rectal gland is also present. Liver is bilobed, left lobc. Being much larger than the right. A large gall bladder is present and pancreas is well developed.
- **Urinogenital organs:**- The kidneys are fused and attached to the ventral wall of the abdominal cavity. The ureters are present and each expends into a bladder, so that there are two bladder. Testes are paired partly segmented and lie posterior to the anus. The urinogenital aperture is situated between the pelvic fins.
- **Sense organs:** Two sense organs are present in the rostral region. One of the these consists of a large single median chamber opening to the exterior by means of three pairs of tubes. It is permanently full of jelly like material like that of the ampullae of Lowrenzini. The second is the paired olfactory organ, opening to the exterior by anterior and posterior nasal apertures.
- **Feeding habit:**- The live on the bottom between 70 and 600m and feed on fish and squid. Possible they rest on the bottom on their lobed fins, and use them to walk while catching the prey.

Affinities of Coelacanth or Latimeri Lateimeria/crossptergii shows the following affintities with different animal groups-

(a) Affinities with Elasmobranch (cartilaginous fish): There are some similarities in the anatomy and physiology of *Latimeria* and cartilaginous fish, specially in the mechanism of osmoregulation. Like the Elasmobranchs, *Latimeria* also maintain a high concentration of urea in the blood and thus isotoic with the sea water. The structure of the pituitary gland also resemble with that of the Elasmobranch.

(b) Affinities with Osteolepides:- The skull resembles with that of the osteolepids in possessing a movable hinge between the parietals and post parietals bone of skull.

(c) Affinites with Actinopterygii:- The paired fins resemble superficially with those of actinopterygians.

(d) Affinities with Teleostomi (bony fishes):- They are similar with Telestomi as in the bony skeleton presence of bony (dermal) scales and swim bladder.

(e) Affinities with Rhipidistians:- Coelacanths resembles the Rhipidistians in the following features which suggest close relationship between the two groups-

(i) Presence of intracranial hinge although the mechanism of hinge differs in two groups.

(ii) Poorly ossified vertebral column.

(iii) Cosmoid type of scales.

(iv) Structure of pectoral and pelvic giridles

(f) Affinities with Amphibians:-

(i) The skeletal elements of parired fins lobes resemble the proximal skeletal elements of tetrapods limbs.

(ii) The bones of the paired fins articulate with the pelvic and pectoral girdles, much like those of tetrapods.

(iii) Skull was similar to that of earliest amphibians.

(iv) Fresh water forms migrated from one body of water to another because they could use their air bladders like lungs.

(v) Many had internal nares piercing the roof of mouth cavity, although not meant for breathing.

Classification of Teleostomi

Teleostomi is classified into two sub- classes-

(A) Subclass -1 crossopterygii

(B) Subclass – 2 Actinoptergii

(A) Subclass -1- Crossopterygii

- They have paired lobate fins having a scale covered lobe. Candal fin has three lobe or heterocercal.
- The pactoral fins are supported by an endoskeleton consisting of a jointed median axis bearing radials on each side (biserial). Premaxillae and maxillae are present.
- Scales are covered by a thick layer of cosmine. Internal nostrils are present or absent.
- Branchiostegal rays are absent replaced by jugular plates. The crossoptergii are divided into two orders. (1) Osteolepiformes (2) Coelacanthiformes.

(B) Subclass – 2 Actinopterygii

This groups includes all the ray finned fishes. They have following characters.

(i) Paired fins are thin, broad, without fleshy basal lobes and supported by dermal fin rays.

(ii) One dorsal fin may be divided.

(iii) Caudal fin without epichordal lobe.

(iv) Olfactory sac not connected to mouth cavity.

(v) Popularly called ray finned fishes. Divided into 3 superorders, namely Chondrostei, Holostei and Teleostei.

SAQ-3

1. Bony armor fishes are ……..
2. The lung fish found in tropical Africa is ……..
3. In Holocephali respiratory organ……..

4.6 ADAPTIVE RADIATION IN BONY FISHES

The teleosts or Teleostei (Gr., teleios- complete. + osteon = bone) are the largest super order in the sub class Actinopterygii, the ray-finned fishes. They make up 96% of all extant, species of fish. Teleosts are arranged into the 40 orders and 448 families. Teleosts inhabit all the types of water, fresh, marine, estuarine and swamps.

The first teleosts are represented by the genus Leptolepis which appeared in the Jurassic and which is intermediate between holostean and teleostean fishes. In teleosts the scales lost the layer of ganoine and became thin and transparent. The caudal fin is completely homocercal. The vascular lung is modified into swim blander. The internal skeleton is ossified with specializations in the skull. By cretaceous the teleosts were very well established and had radiated into a number of adaptive lines. A number of teleosts live in the fresh water to which they have returned back from the sea. The teleosts represent the most successful group of the fishes.

Fossil record indicates that early bony fishes (placoderms, crosspterygians) evolved lungs as an adaptation to the unreliable freshwater conditions of the Devonian period. Their lungs were similar to those of the living African lung fish *Protopterus* and originated as a pair of ventral sac-like pouches connected to pharynx (or oesophagus) by single duct. From this generalized condition three lines of evolution emerged

- One line led to the air bladder shift of origin from and connection with gut from ventral to dorsal side. The lateral attachment to gut of air bladder in the teleost.
- second line of evolution without change in position but with extension internal foldings, led to lungs for respiration found in land vertebrates
- They were lost in elasmobranchs and few teleost.

The adaptive radiation in bony fishes enables the fish to evolve different methods of locomotion and feeding. In bony fish, adaptive radiation takes place because of the development of strong jaws, paired fins and a vertebral column. Romer (1965) included Elasmobranchii and Holocephali as subclasses into a single class Chondrichthyes including all the cartilaginous fishes, Similarly all bony fishes (Teleostomi) under a single class Osteichthyes which was divided into two subclasses, Sarcopterygii and Actinopterygii.

The fish's solution, in response to this problem, is to achieve some degree of streamlining. As a result, fishes from the same habitat look very much alike. It is not that these fishes are closely related because of their similar look, but the solution to the locomotion through the water is a common one.

Fishes of the teleostan type first appeared in the fossil record in the middle Triasic, but the change from the holostean to the teleostean type must have begun much earlier in some forms. According to green wood et., the teleostean fishes are separted into three divisions under which teleosts are regrouped into eight super orders. Each of these three divisions represents a distinct phyletic lineage derived from holosten level of organization.

Recently Lauder and Liem (1983) and Nelson (1984) have divided teleosts into four distinct lineage, groups but These four groups,each represent a separate evolutionary line are-

- Osteoglossomorpha, consisting of a few peculiar species of the order osteoglossiformes and about 190 species of specialized African electric fishes.
- Elopmorpha, including elopiformes, true eels and sping eels
- Clupeomorpha; which are highly specialized planked feeders.
- Euteleotei or the "true teleosts" forming the main line of teleostean evolution and corn be further divided into a number of separate evolutionary lines of these ostriophysi form the largest and most distinctive group and includes fresh water minnous, carps, cat fishes and characins. This maybe considered as a fifth line of teleostean evolution.
- Among the varios living primitive groups of teleosts only elopids and salmonids are sufficiently generalised to be suitable morphologically as based type for the major teleostean radiations. Other primitive groups like the clupeiformers and the Osteoglossiformes are too specialized for this role.

LOCOMOTION IN THE BONY FISHES:

- One key to success in the bony fishes is the presence of a swim bladder. This is a gas-filled sac, located dorsally within the body cavity. This sac, originally evolved as an air bladder or accessory lung, was connected directly to the esophagus.
- Although some fishes still have the swim bladder connected to the digestive tract, in most modern fishes the swim bladder is a separate organ. The fishes can adjust the amount of gas within the bladder to lighten their body weight. The lighter weight makes it easier for the fishes to maintain a specific depth without an excess expenditure of energy.
- The bony fishes can browse at one spot without sinking, while the shark must continue swimming. Fishes that hold position in the water for some length of time have a swim bladder, whereas those bony fishes that are fast moving, streamlined and pelagic often lack air bladders.

4.7 SUMMARY

- Fishes are a group of aquatic chordates that have gills and lack limbs.
- Fish do not include tetra pods (four-limbed vertebrates such as amphibians, reptiles, birds and mammals) and for this reason the group is considered to be paraphyletic. Most fish breathe using gills. They take water in through their mouth and push it out through their gills. As the water enters the fishes' mouth, it is rich in oxygen.
- When it passes through the gills, the oxygen is absorbed from the water as it flows through the capillary-rich gill filaments. At the same time, the waste product of respiration--carbon dioxide--is released into the water before it is then released from the gills through openings on

either side of the pharynx.

- Most fish are cold-blooded animals that have a streamlined body that is adapted for efficient movement in water.
- Elasmobranch is a subclass chondrichthyes Elasmobranchii (Gr. Elasmo = a flat plate + branchia = gills) includes cartilaginous fishes. It includes sharks, rays and skates.
- Holocephali (Gr. Holos = entire + kephale = head), is a very small ancient group of highly specialized marine fishes. It comprises of rat-tailed fishes.
- The Dipnoi, commonly known as lung fish, are considered to be specialized or degenerate descendants of the more primitive lobe fins which they closely resemble.
- In the Australian lungfish (Neoceratodus) the lung in the adult is a bilobed structure that lies dorsal to the gut but maintains a pneumatic duct that opens into the ventral wall of the gut. In the African lungfishes (Protopterus).
- The South American one (*Lepidostren*) the lung is also paired and bilobed but is ventral to the gut.

4.8 TERMINAL QUESTIONS

Q.1 What are the important structures in the bony fishes? Describe their adaptive radiation in detail.

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Q.2 Describe in detail the general characters of Elasmobranchii?

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Q.3 Describe in detail the general characters of Holocephali?

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Q.4 Describe in detail the general characters of Teleostomi?

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Q.5 Describe in detail general characters of Dipnoi?

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……s

Write shorts notes on:

(a) Bony fishes

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……

(b) Cartilagenous fish

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……

(c) Protopterous fish

……
……

(d) Lepidosiren

……
……

4.9 ANSWERS

SAQ-1

(1) Placoderm , Sharks, Rays, (2) Cladoselache (3) Chondrichythyes (4) Protopterus

SAQ-2

(1) Holocephali (2) Dipnoi (3) Neoceratodus (4) Lepidosiren (5) Protopterus

SAQ-3

(1) Ostracoderms (2) Protopterus (3) Sharks

BLOCK-II

In the previous block you have studied about the origin and classification of chordates. In this block you will be introduced by Amphibians, Reptiles and Birds. This block is divided into three units (unit 5, unit 6 and unit 7).

Unit 5 deals with the Amphibians, unit 6 you will study about Reptiles and unit 7 deals with the origin and evolution of birds.

Objectives:

After studying this block you will be able to-

- know about general characters and classification of Amphibians and Reptiles.
- understand origin and evolution of birds.

UNIT-5 : AMPHIBIA

5.1 Introduction

Objectives

5.2 General characters and classification up to order level

5.3 *Rana tigrina* as type study

5.4 Parental care & Neoteny

5.5 Summary

5.6 Terminal Question

5.7 Answers

5.1 INTRODUCTION

Amphibia was the first animal class that attemped a transition from aquatic to terrestrial mode of life. But they were not fully terrestrially adapted. However these inhabit both the aquatic and land environment.. That is why these animals are called as Amphibia (amphi=dual or double & bios=life). Structurally Amphibians are intermediate between the fish and reptiles.

Objectives

After studying this unit you will be able to know about :

- General characters and classification up to order level*Rana tigrina*.
- Parental care & Neoteny

5.2 GENERAL CHARACTERS AND CLASSIFICATION UP TO ORDER LEVEL

General Characters

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Classification

Kingsley Noble(1924) classifiedAmphibians into 2 subclassesnamely Stegocephalia and Lissamphibia, each having 3 orders out of these six orders, first three are extinct and rest of three are living orders or class Amphibia.

Subclass –I Stegocephalia (Extinct)

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

Order –I Labyrinthodontia

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

Example : *Eryops, Capitosaurus*

Order – II Phyllospondyli

- They were distributed from Carboniferous to the Permian period.
- They were small, salamander like amphibians.
- The vertebrae were tubular with the notochord and spinal cord lying in one cavity.
- The Centrum was represented by the thick floor of each vertebral ring.

- The transverse processes were well marked with short ribs
- Cartilaginous pubis and coracoids.
- Three pairs of gills in long larval life resembled the Urodela.

Example : *Ichthyostega*

Order –III Leposondyli

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

  Example: *Diplocaulus, Sauropleura*

Subclass –II Lissamphibia(Living)

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

Order –I Apoda or Gymnophiona

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

Example :*Ichthyophis, Uraeotyphlus.*

Order –II Caudata or Urodela

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

Example : *Ambystoma, Salamandra, Necturus, Siren*

Order –III Salientia or Anura

- Specialized amphibian without tail in adults.
- Head and trunk are fused.
- Neck and tail are absent.
- Hind limbs usually adapted for leaping & swimming.
- Adult without gills or gill openings.

- Eyelids well formed. Tympanum present.
- Skin loosely fitting, scalesless, Mandibles toothless.
- Fertilization is usually external.

Example : *Rana, Hyla, Rhacophorus*.

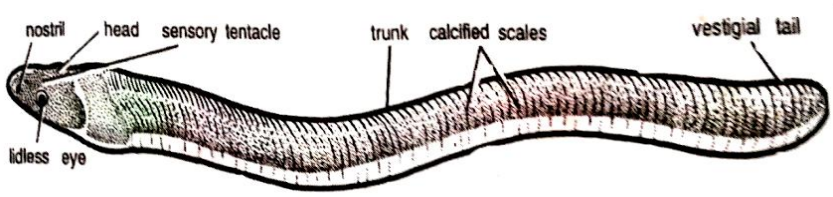


Fig: *Ichthyophis*

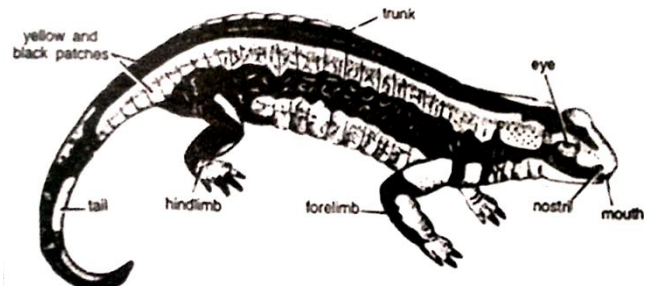


Fig: *Salamandra*

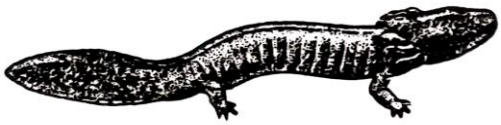


Fig: *Necturus*

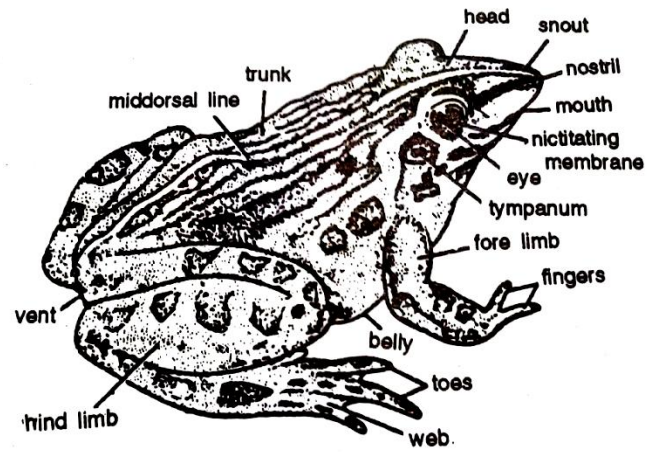


Fig: *Rana sp.*

5.3 *RANA TIGRINA* AS TYPE STUDY

Systemic Position

Phylum- Chordata

Sub Phylum- Vertebrata

Division- Gnathostomata

Super class- Tetrapoda

Class- Amphibia

Order- Anura

Type - *Rana trigrina*

The *Rana trigrinaor Hoplobatrachus tigerinus* or Indian Bull frog are generally found in or near water and in very damp place on land. It lives near water probably to carry out the cutaneous respiration by keeping the skin moist as soon as it gets dry and to escape from the enemies by slipping or jumping into the water. Frogs are cold blooded or poikilotherms animals. The body temperature of frog fluctuates with that of the environment. During adverse environmental conditions in cold winter or dry hot summer days, frogs burry in the soft damp bottom mud for protection. They become metabolically inactive and stop feeding, living only on the glycogen and fat stored in their bodies. Lung respiration is suspended and cutaneous respiration through damp skin alone is sufficient. This state of dormancy or suspended animation is called hibernation or winter sleep during winter and aestivation or summer sleep during summer. As the cold winter or hot summer ended, the frog comes out to lead a normal life once again. Frogs are carnivorous and feed on living insects, worms, molluscs and tadpole, which are caught by a sudden flip of its large protursible sticky tongue attached at the front end and free behind.

External Feature

Shape & Size: The body of frog is spindle- shaped, pointed anteriorly and rounded posteriorly. It is slightly flattened dorso-laterally and streamlined to swim through water. The body of frog is divisible into head, trunk and tail and there is no neck to connect head and trunk together. The size of frog varies from species to species or even in same species depending upon the age of the individual. The range varies from 12 to 18 cm in length and 5 to 8 cm in width.

Skin & Color: The skin of frog is thin, moist, slimy, smooth and fitting loosely on the body. The color of the body at the dorsal slide is green with black or brown spot while its ventral surface is light pale yellow color. The color of the skin is basically due to the three layers of pigment cells. The melanophores lie in the deepest layer, guanophores lies in the intermediate layers and lipophores overlying these. The guanophores are full of granules which by diffraction produce green color, while the lipophores filter out blue. The change in color of skin is produced by expansion of pigment in the melanophores under the influence of secretion of pituitary gland

Division of body: - The body of frog is divided into two part head and trunk. The head and trunk are broadly joined.

Head: - The head is almost triangular and somewhat flattened. It's anteriorly directed blunt apex is known as snout. On the top but on either side, the head bears two large prominent bulging eyes. This position enables the frog to see in all the directions and thus compensate the disadvantage on land due to the absence of the neck. The eyes are rounded and protected by two eyelids, the upper eyelids is thick, fleshy, opaque and almost immovable but the lower one is thin, transparent and capable to cover the eye. Beneath there is a transparent or third eyelid or nictitating membrane which is merely

an outgrowth of the lower lid that can move upward over the eye ball to keep it moist in the air but as a protection when under water. The frog can see through it. In the middle of the head just infront of the eyes, there is a light colored patch the brow spot which represents the third eye of its ancestor frogs. There are no external ears but behind below each eye there is a nearly circular obliquely placed area covered with a tough transparent covering or membrane, the tympanic membrane under which is the Eustachian tube lies the internal ear. At the tip of the snout are placed laterally two nostrils or external nares communicating with the buccal cavity through internal nares, through which the frog takes in air for the purpose of respiration. The head also bears a wide horizontal opening the mouth which is extended nearly from one ear to the other. In the male frog under the head on either side are placed two bluish to produced crocking sound to attract the females for copulation.

Trunk: - The head is broadly joined with short somewhat flattened trunk of which at the dorsal side, in the resting stage there is a characteristic hump which is due to the linking of the hip girdle to the vertebral column. Attached to the trunk are two pairs of limbs. The fore limbs are shorter while the hind limbs are larger. The fore limbs are meant to hold and support the front part of the body at the time of jumping but the hind limbs assist in swimming as the webs are present in between the toes. Each fore limb consists of an upper arm, fore arm, wrist and hand bearing 4 digits without web. Thumb or pollex is vestigial. In male frog the base of first inner finger is thickened, especially in breeding season, forming the nuptial pad for clasping the female during amplexus. The much elongated and powerful hind limbs or legs arise close together posteriorly from trunk. Each hind limb consists of the thigh, shank, much lengthened ankle and large foot having 5 slender clawless toes connected by broad thin webs of skin which assist in swimming. In addition there is rudimentary sixth digit called prehallux which is enclosed within the skin and is not seen as sixth digit. At the posterior end of the body in between the hind limbs there is a cloacal opening through which faeces, urine and reproductive bodies are discharged.

Sexual dimorphism

There are some differences in external characters by which male and female frogs can distinguished

1) Males are generally smaller and darker in color than females.
2) Males are slimmer while females stouter especially when they contain eggs.
3) Males croak loudly as they have vocal sacs which are absent in females. The ear drum is larger in male.
4) Males have swollen copulatory or nuptial pads on inner fingers, especially developed in breeding season for grasping the female during mating. Nuptial pads are lacking in females.
5) In copulating frogs in amplexus, the upper one is male and the lower one is female.

Digestive system

The digestive system of frog consists of alimentary canal and its associated digestive glands.

Alimentary canal: The alimentary canal of frog is a long, coiled tube of varying diameter starting from mouth and ends at cloaca. It consists of buccal cavity, pharynx, oesophagus, stomach, small intestine, large intestine and cloaca.

1- Mouth: The alimentary canal starts with mouth opening. It is a very wide gap extending from one side of the snout to the other. It is bounded by two bony jaws covered by immovable lips. Upper jaw is fixed while the lower jaw can more up and down to close or open the mouth.

2- Buccal cavity: The mouth opens into a wide and broad cavity called buccal cavity. It has ciliated columnar epithelial lining contains mucous glands which secrete mucus for lubricating food. There is no salivary gland in buccal cavity.

(a) Teeth: The upper jaws bears a row of closely set small, uniform and hook like pointed maxillary teeth. The lower lacks teeth. There are two more patches of teeth found one on either side of the median line of the roof of the buccal cavity are known as vomerine teeth as they are found on vomer bone. The vomerine teeth are small in size and uniform in structure. They are not used for chewing but prevent the escape of the captured prey. They are curved backwards and attached to the bone (acrodont).

The teeth's of frog are similar i.e. homodont and are present without socket i.e. acrodont. But each teeth is attached to the jaw bone by a broad base made of the bone like substance. The free part or crown of teeth is made of a hard ivory like substance, dentine, which is traversed by numerous fine canals. Tip of the crown is covered by a very hard, resistant and glistening substance called enamel. The tooth contains a central pulp cavity open at the side and filled with a soft nourishing pulp containing connective tissue, blood vessels, nerve and odontoblast cells that produce new material for the growth of tooth. As the teeth are replaced by several times during the life cycle of the frog, so they are called polyphyodont.

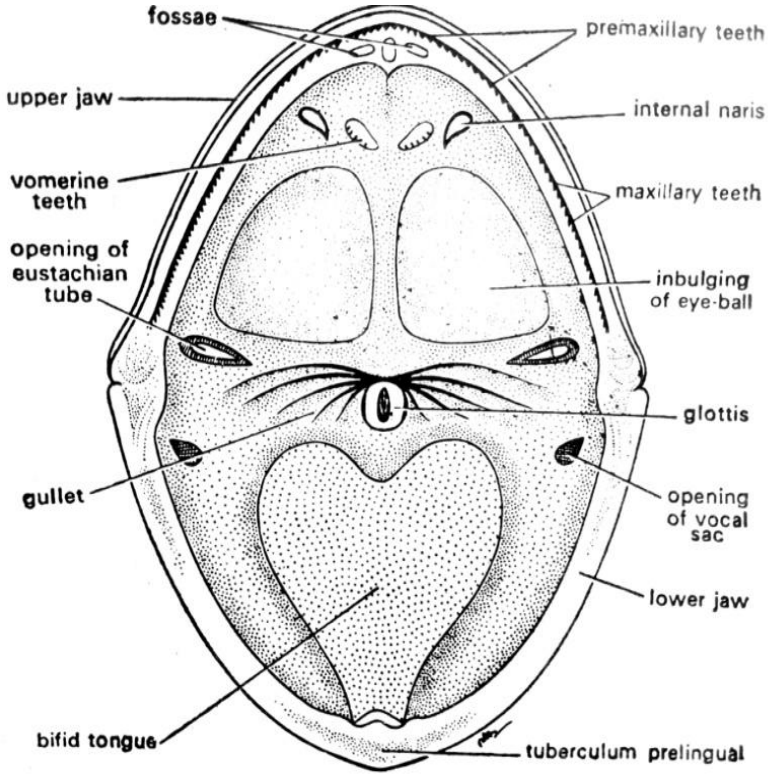


Fig: Frog Bucco-pharyngeal cavity of male frog

(b) Tongue: On the floor of buccal cavity lies a large, muscular sticky protractible tongue. Its anterior end is attached to the inner border of lower jaw. Its posterior end is free and bifid which can be flicked out and retracted suddenly after capturing the prey with its slimy surface. The protrusion of the tongue is brought about by the change of pressure in large sublingual lymph sac.

(c) Internal nostrils: The roof of buccal cavity contains anteriorly, just infront of vomerine teeth, a pair of small openings of internal nares by which the nasal cavities open into buccal cavity. to help in respiration.

3- Pharynx: The buccal cavity opens into short pharynx. There is no demarcation line between buccal cavity and pharynx. A median elevation on the floor carries a longitudinal slit like aperture called glottis, leading into the laryngo-tracheal chamber. In the roof on either lateral side are a wide Eustachian aperture which opens into the middle ear. In male frog, on the floor of pharynx, on either side near the angle of two jaws, is present the small opening of a vocal sac. The vocal sac act as resonators. The pharynx abruptly tapers behind to lead into oesophagus through a wide opening called gullet.

4- Oesophagus: The oesophagus is a short, wide muscular and highly distensible tube. Its mucous epithelial lining is folded longitudinally and contains some mucous glands. Longitudinal folding of the oesphagus allows its expansion during the passage of food into stomach. The glandular lining of oesophagus secretes an alkaline digestive fluid.

5- Stomach: The stomach lies on the left side of the body cavity and is attached to the dorsal body wall by a mesentery. It is a large, broad and slightly curved bag with thick muscular walls. Its large broader anterior part called cardiac stomach, while the short narrower posterior part called pyloric stomach. The inner surface of stomach has several prominent longitudinal folds which allow its distension when food is received. The wall of stomach contains gastric glands which secrete pepsinogen and unicellular oxyntic glands secrete hydrochloric acid. The posterior or pyloric ends of stomach are slightly constricted and it open into small intestine, which is guarded by pyloric valve. The stomach act as storage and digestion of food.

6- Small intestine: The small intestine is a long, coiled and narrow tube, about 30 cm long and attached mid-dorsally to body wall by mesenteries. It is made up of two parts, a small anterior duodenum and a much longer posterior ileum.

(a) Duodenum: The stomach open into duodenum, which is U shaped. It receives a common hepato-pancreatic duct from liver and pancreas bringing bile and pancreatic juice. Tshe internal mucous lining forms low transverse folds.

(b) Ileum: It is the longest part of alimentary canal and makes several loops before enlarging posteriorly to join rectum. The internal mucous lining forms many longitudinal folds, but there are no true villi, definite glands and crypts as in higher vertebrates. The digestion of food and absorption of digested food occur in the small intestine.

7- Large intestine or rectum: It is a short, wide tube, about 4 cm long running straight behind to open into cloaca by anus. It is guarded by an anal sphincter. Its inner lining forms numerous low longitudinal folds. Its function is the re-absorption of water and the preparation and storage of faeces.

8- Cloaca: It is the small terminal sac like structure into which opens the anus and the urinogential apertures. Cloaca opens to outside by the vent or cloacal aperture, lying at the hind end of body.

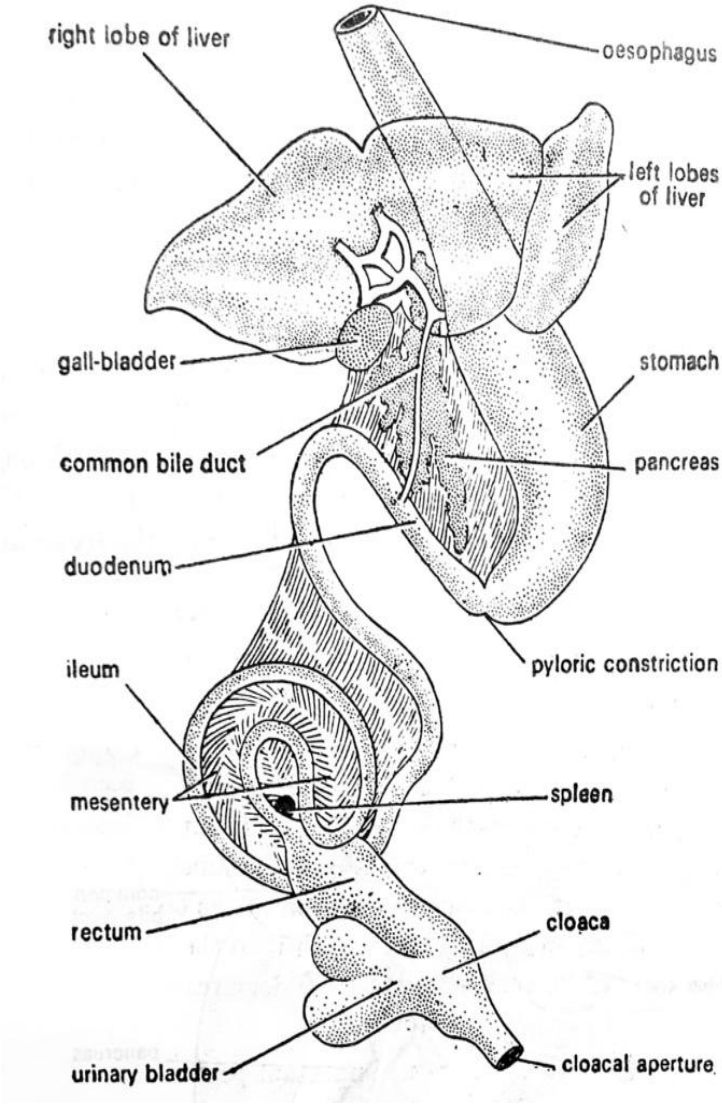


Fig : Alimentary canal of Frog

Digestive gland - The alimentary canal of frog is associated with digestive glands. These include liver, pancreas, gastric gland (stomach) and intestinal gland etc.

Liver: It is the largest gland present in the body. It is reddish brown colored, multilobed gland located close to the heart and lung. In frog liver consist of 3 lobes i.e. right, left and median. It contains numerous polygonal cells, which secrete a greenish alkaline fluid, called Bile. This bile is stored in a large, spherical, greenish and thin walled sac. The gall bladder is present between the lobes of liver. The cystic duct from gall bladder and hepatic duct from liver combine to form a common bile duct. The common bile duct runs through pancreas and joins the pancreatic duct to form a hepatopancreatic duct which ultimately opens into duodenum. The bile has no digestive enzyme, it only emulsifies fats.

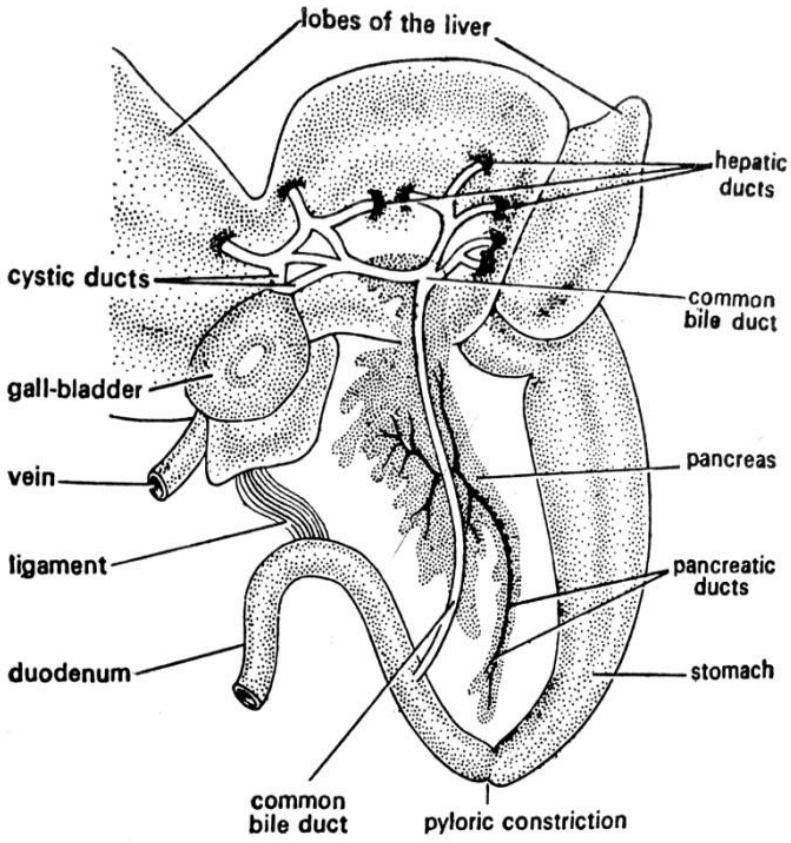


Fig: Frog : Digestive organs & glands

Pancreas: The pancreas of frog is much branched, irregular, flattened and yellow colored gland lying in the mesentery between stomach and duodenum. It has both exocrine and endocrine function. The exocrine function is performed by scattered cells of islets of Langerhans, which produce insulin hormone. The endocrine cells secrete pancreatic juice, which help in digestion.

Food – The frog is strictly carnivorous. It feeds chiefly on earthworm, spiders, insects, crustacean, molluscs, small fish and even small frogs and tadpoles. This food contains protein, carbohydrate and fats.

Feedings – When any prey comes near the frog, it opens its mouth and suddenly flicks out its sticky tongue and strikes the prey. As soon as the prey comes in contact with the tongue it immediately adheres to it. The tongue is withdrawn into the buccal cavity. Once the prey is caught into the buccal cavity it would not be allowed to escape due to the presence of the hook like inwardly directed maxillary and vomerine teeth. From the buccal cavity it is pushed into the oesophagus by the contraction of pharyngeal wall and then by peristalsis into the stomach.

Digestion – The captured prey does not undergo any change in the buccal cavity as there is no salivary gland in the mouth, only mucus is secreted . Which lubricates the food for easier passage. The food reaches the stomach through the oesophagus by peristalsie movement.

Stomach: When the stomach is filled with food, the gastrin hormone is secreted, which activate the gastric gland for the secretion of gastric juice. The gastric juice contains digestive enzyme pepsin. The oxyntic cell secretes HCl which make the medium highly acid ie.pH 1 to 1.5 so that pepsin can act. The pepsin is found in inactive form-pepsinogen, which is converted into pepsin by HCl. This pepsin breaks the protein into peptones and proteoses.

HCl

Pepsinogen ——Pepsin——→

(Inactive form) (Active form)

Pepsin

Protein ——————→ Peptones + Proteoses

Function of HCl

1) Conversion of inactive enzyme into active form
2) Medium should be changed i.e. highly acidic
3) It prevents bacterial decomposition
4) Dissolve harmful substance

After 3 – 4 hours of digestion in stomach. The food is thoroughly churned and changes into thick creamy acidic fluid called chyme. The chyme food descends down into duodenum by opening through pyloric sphincter of stomach.

Intestine: As the acid chyme food enters into the duodenum, the acid nature of food stimulates certain hormones.

a) ***Enterogasterone*** – It stop the secretion of gastric juice.

b) ***Secretin*** – It stimulate the pancreas for secreting pancreatic juice.

c) ***Cholecystokinin*** – It causes gall bladder to contract and release of bileinto duodenum through heptopancreatic duct.

d) ***Pancreozymin*** – It also stimulate pancreas.

e) ***Enterocrinin***- It stimulates secretion of intestinal juice or succus entericus.

All these act on food to digest thoroughly.

(1) **Bile–** It is a greenish alkaline fluid secreted by liver. It does not contain any digestive enzyme. It contain bile salts such as sodium bicarbonate, sodium glycolate, sodium torocholate etc. which not only neutralize the acidity of the semi-digested foods, chyme but also prepare it for the activity of enzymes of pancreatic juice which can act only in the alkaline medium. The bile break down fats into small globules which can be emulsified. It also helps in activating pancreatic lipase.

(2) **Pancreatic juice-** It is secreted by pancreas by the effect of secretin hormone. It is alkaline (p^H 8 to 9.5) in nature. It produces 3 types of digestive enzyme.

a) *Trypsin* – It is found in inactive form trypsinogen, which is converted into active trypsin by Enterokinase. The trypsin act on protein, peptone and proteoses to form simple protein or polypeptide.

Enterokinase

Trypsinogen ——Trypsin——→

Trypsin

Protein+ Peptone + Proteoses peptones——→

b) *Amylopsin*- It acts on starch, to reduce them into maltose.

Amylopsin

Starch → maltose

c) *Steapsin* - It acts on fat to form fatty acids and glycerol.

Steapsin

Emulsified fat → fatty acid + glycerol

(3) Succus Entericus – The intestinal juice contain various enzyme, which digest all protein, carbohydrate, and fat and changes into simple protein i.e. amino acid, glucose and fatty acid & glycerol, so that they can easily absorb. The important intestinal juice or succus entericus contain enzymes which are erepsin, maltase, lactase, sucrose, lipase etc.

Erepsin

Protein + peptone + polypeptide → amino acid

Maltase

Maltose → glucose

Sucrase

Sucrose → glucose +fructose

Lactase

Lactose → glucose + galactose

Lipase

Fat → fatty acid + glycerol

After the digestion all the digestive materials are released into blood which are taken to all body cell for maintaining life. And undigested food is removed through cloaca.

Respiratory system

Respiration is an exchange of gases through the respiratory surface i.e. to obtain oxygen and give out carbon dioxide for the oxidation of organic substance, so the systems which involve in this process are called respiratory system. In adult frog respiration is carried out by 3 types i.e. skin or cutaneous respiration, bucco- pharyngeal cavity or buccal respiration and lungs or pulmonary respiration.

1) Cutaneous respiration or skin respiration – The skin of frog is an important organ of respiration, the frog due to its amphibious mode of life, it passes its maximum time in water. During this period the skin only serves as an organ of respiration for gaseous exchange. The frog during summer sleeping (aestivation) and winter sleeping (Hibernation) also respire through skin.

The skin of frog is very thin and is richly supplied with blood capillaries and it remains moist due to mucus secreted by mucous glands. During gaseous exchange the oxygen fist dissolves in the moisture present over the body and diffuses into the blood circulating in the blood capillaries while carbon dioxide passes out from the blood into the surrounding medium by diffusion.

2) Buccal respiration – Such type of respiration take place when frog in on land. In this type, when the floor of the buccal cavity is lowered or raised, it causes the air sucked into the buccal cavity or expelled out through the external and internal nares. When the floor of buccal cavity is lowered, the air enters the buccal cavity. The mucus lining of the buccal cavity is richly

supplied with blood capillaries and remain moist by the mucus, the oxygen of air dissolves in the layer of mucus and then goes into the blood with the help of hemoglobin. At the same time Co_2 is given out into the buccal cavity from the blood which is expelled along with residual air through the nostrils, when the floor of the buccal cavity is raised, during this respiration glottis in remain closed-

3) **Pulmonary respiration** – Pulmonary respiration is brought about by lungs. In frog two lungs are present which are ovoid, thin walled, elastic sac, with shallow internal folds that increases the inner surface to form many chamber called alveoli. These are separated from each other through septa. These are lined with blood capillaries of pulmonary circulation and remain moist with mucus secreted by mucous glands situated in the wall. The inner surface of the alveoli is covered with a single layer of epithelial cells which are very thin and flattened except on the edge of the septa where they are ciliated and cylindrical. On the inner side of the epithelium there is areolar type of connective tissue comprising blood vessels and unstriped muscle fibres which gives remarkable power of contraction and expansion to lungs. The outer surface of the lung is coated with coelomic epithelium called peritoneum. Each lung is connected by a short bronchus to the larynx, the so-called voice box behind the glottis. The larynx is supported by a ring like cricoid cartilage and two cresentic arytenoids cartilage which prevents the larynx from collapsing.

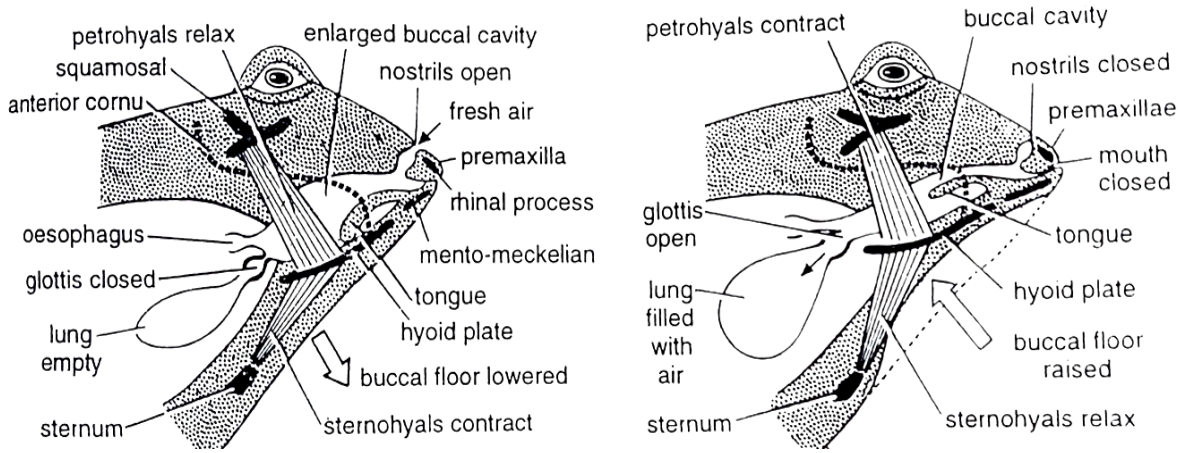


Fig : Frog Diagrammatic representation of respiratory mechanism by showing two types of muscle

Mechanism of pulmonary respiration- The incoming and outgoing of the air from the lung is brought about by the action of the floor of the buccal cavity which actually acts as a buccal force pump. The rhythmic up and down movements of the floor of the buccal cavity are brought about by the action of two special sets of muscles sternohyal and petrohyal muscles. The sternohyal muscles are attached at the lower end to sternum and at the upper end to the under surface of cartilaginous hyoid apparatus embedded in the floor of buccal cavity when these muscles contract the hyoid apparatus along with floor of the buccal cavity is pull down ward that results in the enlargement of the buccal cavity due to which the pressure of the enclosed air in the buccal is reduced and consequently more of air from the surrounding environment enter through the nares. The other muscle is petrohyal muscles are attached to the upper surface of hyoid apparatus and to the squamosal bone of skull, when this muscle contract it raised the upper surface, this results in the reduction of the buccal cavity forcing a part of the air to go out through the nares. The whole mechanism of respiration involves two steps i.e. inspiration and expiration.

1) **Inspiration** - The entering of air into the lungs is called inspiration. This is brought about by contraction of sternohyal muscles, causes the hyoid apparatus and floor of buccal cavity is lowered. This enlargement of buccal cavity draws air through the nostrils into buccal cavity, the glottis now opens and the mentomeckelian bones of lower jaw push upwards the premaxillae bones of upper jaw, so that the nostrils are closed. At the same time the petrohyal muscles contract, this results in lifting the hyoid apparatus along with the floor of the buccal cavity forcing the air to enter into the lung through the glottis. During these activities the mouth, external nares and the gullet remains closed.

2) **Expiration** – Empting of lung is called expiration, this is brought about by the contraction of the lungs and abdominal muscles. It is just reversed process with external nares closed, the floor of the buccal cavity is lowered and the air from the lungs is drawn into the buccal cavity through the glottis and finally the glottis is closed and premaxillae come back into their original position due to which the external nares are opened. Now the floor of the buccal cavity is raised forcing the air to go out through the external nares.

Blood vascular system

The prime function of blood is to distribute the digested food and oxygen to different parts of the body to carry out life activities. The blood vascular system consists of Heart, Arterial system, Venous system, Blood, Lymphatic system.

1) **Heart** – The heart of frog is dark red colored, somewhat conical or triangular in shape with broad base directed anteriorly and narrow apex posteriorly and is present at mid ventral line between the forelimb. The heart is enclosed by two membranes, an outer pericardium and inner epicardium. Between these two membranes a pericardial fluid is present which keep the heart moist and also protect the heart from outer shock.

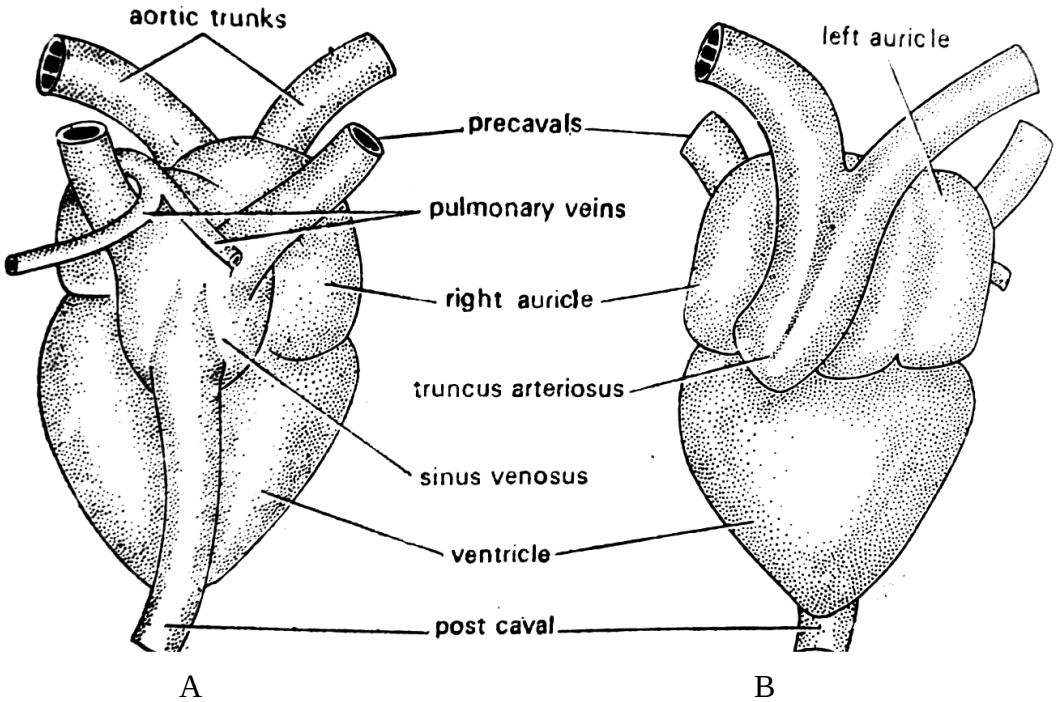
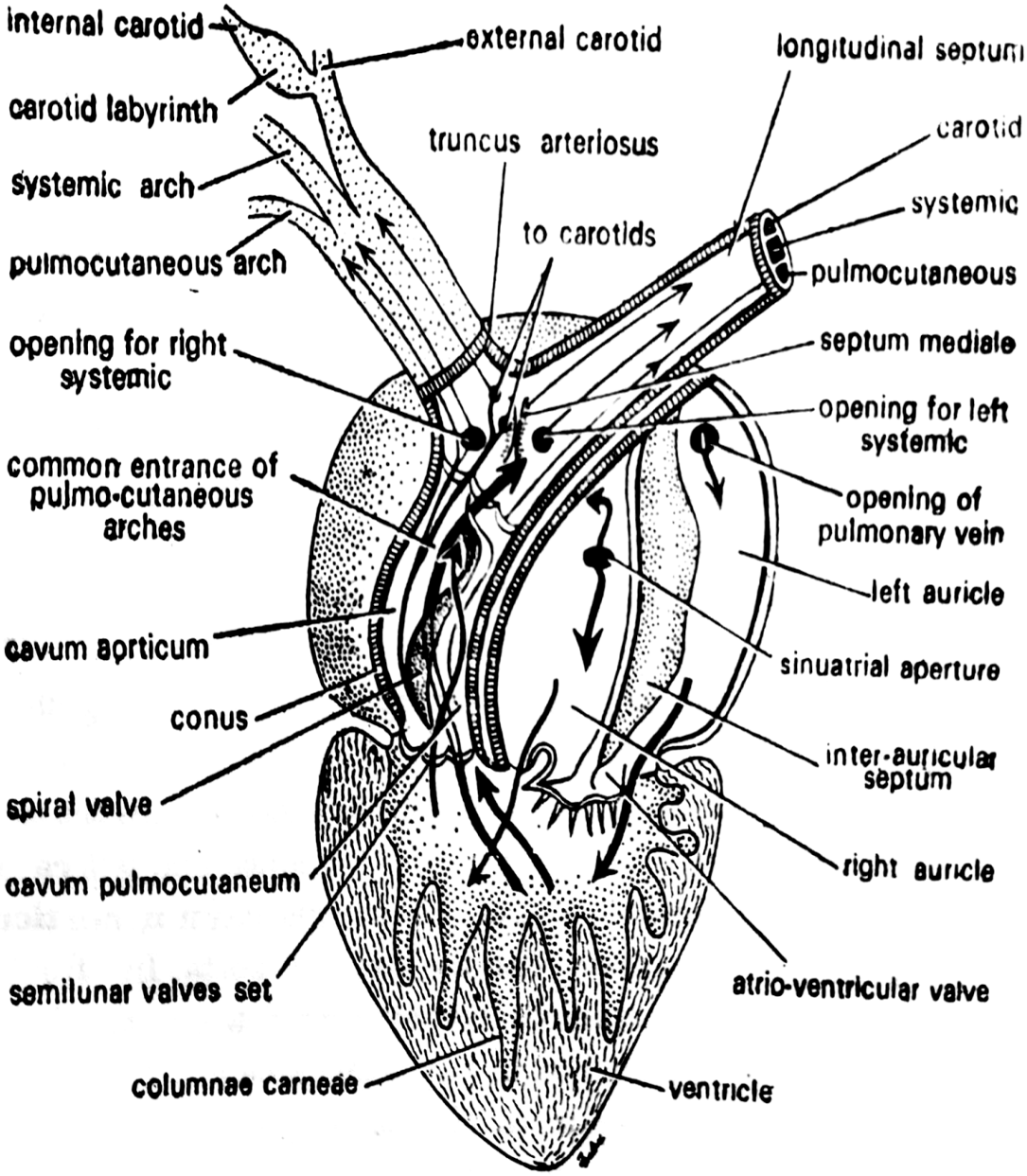


Fig : Frog heart (A) Dorsal view (B) Ventral view

External structureof heart – Externally heart look like triangular with anterior broader portion and posterior narrower part. The anterior broader part is known as auricle, while posterior narrower part is called ventricle. The two auricles are separated longitudinally by interauricular groove. The

auricles are separated from ventricle by a coronary sulcus. The auricle consists of two chambers, while ventricle is single chamber. So the frog heart is 3-chambered. On the dorsal side of heart is a triangular chamber, sinus venous is present, into which open two pre-caval vein and one post caval vein. From the ventral upper right side of ventricle arises a cylindrical structure called truncus arteriosus, which immediately bifurcates anteriorly into two branches or trunks. Each branch further breaks up into three arches carotid, systemic and pulmo-cutaneous.



Frog : Internal Structure of frog

Internal structure of heart– Internally the heart is 3 chambered with two auricles and one ventricle. The two auricles are separated by a thin vertically inter-auricular septum into right and left auricle. The right auricle is largest than the left. The sinus venous opens into dorsal wall of right auricle through a large oval aperture called sinu-auricular aperture, which is guarded by a pair of flap like valves. In the left auricle a pulmonary vein open without valve, near inter auricular septum. Both the auricles open into the ventricle by a single auriculo-ventricular aperture, which is guarded by two pairs of flap like auriculo- ventricular valve.

The ventricle is much muscular and its wall is spongy. The inner surface of ventricle is provided with ridges called columnae carneae and deep pockets or depressions called fissures. These greatly reduce the cavity of ventricle. The flaps of auriculo-ventricular valves are connected to the wall of ventricle by thread like chordae tendineae. The ventricle open into truncus arteriosus which is guarded by 3 semi lunar valve, which prevent back flow of blood from truncus arteriosus into ventricle. The spirally twisted cavity of truncus arteriosus divided into long basal thick walled conus arteriosus or pylangium and a short distal thin walled bulbous aorta or synangium. The large twisted longitudinal spiral valve divides incompletely the cavity of conus arteriosus or pylangium into a left dorsal cavum pulmo-cutaneum and a right ventral cavum aorticum. The spiral valve is attached dorsally, while its ventral edge is free. The truncus arteriosus at their distal end i.e. synangium divided into two aortic arches and each aortic arches subdivided into carotid, systemic and pulmonary arches.

Working of heart – The contraction and relaxation of cardiac muscles is called heart beat. So in each heart beat two step tale place.

1) Contraction or systole
2) Relaxation or diastole

The sinus venosus receives de-oxygenated blood from pre-caval and post-caval vein. As the sinus venosus is filled with blood it contract due to presence of pacemaker or sinu-auricular node in its wall, which initiates the heart to contract. The muscle of the auricles are continuous with those of the ventricle, so therefore the wave of excitation or contraction starts from the sinus venosus and ends at the truncus arteriosus, thus all these chambers contract in sequence manner. As soon as sinus venous contract its de-oxygenated blood is pumped into the right auricle through sinu-auricular aperture. At the same time the left auricle receives blood from the lungs *via* pulmonary vein. When both the auricles are filled with blood it contract simultaneously so that the blood is driving into the ventricle through the auriculo-ventricular aperture. The flow of blood in the heart can be explained by two theories. **According to old theory**, the two sides of the ventricle receive blood from auricles of their respective sides e.g. the left side of ventricle receives blood from the left auricle and the right side from right auricle. The blood comes from the lung into the left auricle and then into the left side of the ventricle is regarded as oxygenated blood and the blood which comes from the sinus venosus into right auricle and then to the right side of the ventricle is de-oxygenated blood. The mixing of blood is avoided in the ventricle because of the viscous nature of blood and the spongy texture of the ventricle. Thus an impure or de-oxygenated blood is present in the right side, pure or oxygenated blood on left side and in middle the mixing of the two bloods take place. When the ventricle is contracted the blood goes into the truncus arteriosus by opening through semilunar valve. The spiral valve in the conus arteriosus is so placed that it allows the de-oxygenated blood from the right side of the ventricle to go into the pulmocutaneous arch and the mixed blood from the middle of the ventricle into the systemic arch and oxygenated blood from the left side of the ventricle into the carotid arch, which has a swollen carotid labyrinth due to which blood pressure is raised and only the last oxygenated portion of blood from the ventricle is permitted to enter into the carotid arch. This explanation of the flow of blood from the ventricle into the arches is now discarded.

According to modern theory proposed by Vandervael (1963) and Foxon, blood coming into auricles whether from lungs or sinus venosus is oxygenated because oxygenation of blood takes place not only in the lung but also in the skin and the buccal cavity. It means that the blood which comes into sinus venosus from skin and buccal cavity is equally oxygenated. On contraction of the two auricle the blood of the same comes into ventricle where the two get completely mixed up and this mixed blood is distributed to all parts of the body through the common carotid, systemic and pulmocutaneous arches. The ventricle contracts forcing its blood into truncus arteriosus which goes

into both parts of the conus arteriosus. The blood passes first into the pulmonary arches because their opening lies in the cavum pulmoncutaneum, the remaining blood goes to the systemic and carotid arches. The spiral valve takes no part in turning the blood, it only supports the conus arteriosus and prevent it from collapsing. The carotid labyrinth does not raise the pressure of blood but it is sensory and detects pressure changes of oxygen in the blood.

The Vandervael and Foxon have also pointed out that the blood which comes into sinus venosus from different parts of the body through veins, is more oxygenated than the blood which comes from the lungs because oxygenation of blood in frog takes place mostly in the skin and buccal cavity even more than in the lungs, when the frog is on land but when it is in water oxygenation of bloods is brought about by only skin and buccal cavity.

Arterial system

The blood vessels which carry the blood away from the heart to different parts of the body constitute the arterial system. The arterial system starts from truncus arteriosus. From anterior region of truncus arteriosus divide into two aortic arches i.e. left and right arches. Each arch is further divided into three arteries, an anterior carotid arch, middle systemic arch and posterior pulmo-cutaneous arch.

1) **Carotid arch** – It is a short blood vessel running forward and outward and divide into two branches external and internal carotids.

   (a) External carotids: It is also called lingual arch and going to lower jaw and tongue.

   (b) sInternal carotids: It is larger outer branch carrying to orbit and brain. Each internal carotid at its commencement bear a swollen carotid body or labyrinth formed from the second pair of gill-slit. Carotid bodies or labyrinths have a network of capillaries and chromaffin cells. They detect the pressure of oxygen and Co_2 in the blood. The internal carotid divides into 3 branches – a palatine to the roof of mouth, a cerebral to the brain and an ophthalmic to the eye.

2) **Systemic arch**: It is the largest of the three arches and with greatest distribution of blood. The two systemic arches curve dorsally around the oesophagus and join with each other behind the heart to form the dorsal aorta which goes backward beneath the vertebral column. In its course each systemic arch gives off 3 arteries.

   a) Oesophageal artery: It supply to the oesophagus. It may arise from occipito-vertebral.

   b) Occipito-vertebral: It supply to the oesophagus, vertebral column and spinal cord.

   c) Subclavian: It is a large artery supplying the shoulder region and extending into the forelimb as branchial artery.

Dorsal aorta – It is formed by the union of two systemic arches. It runs posteriorly lying mid-dorsally, just beneath the vertebral column. It gives number of arteries.

a) Coeliac-mesenteric artery: It is a single large artery, arising from the junction of the two systemic arches. It has two main branches:

   (i) Coeliac artery: It sends branches to the stomach (gastric) & liver (hepatic)

   (ii) Anterior mesenteric: It sends branches to the duodenum, spleen and ileum (Intestinal)

b) Gonadial artery: A pair of short arteries to gonad called spermatic in male frog and ovarian in female frog.

c) Renal artery: While passing between the two kidneys, dorsal aorta sends off 5-6 pairs of

small renal arteries in a series into both the kidneys.

d) **Posterior mesenteric: I**t arises from the posterior end of dorsal aorta, or sometimes from anterior mesenteric. It goes to large intestine or rectum.

e) **Common iliacs**: Posteriorly the dorsal aorta divides into two large iliac arteries supplying the hind limb. Each iliac as it enters the leg gives off following arteries:

(i) **Epigastric artery**: It gives to the ventral body wall.

(ii) **Recto-vesicular artery**: It gives to the rectum and urinary bladder.

(iii) **Femoral artery**: It gives to the hip and upper thigh.

(iv) **Sciatic artery**: It gives to the lower leg.

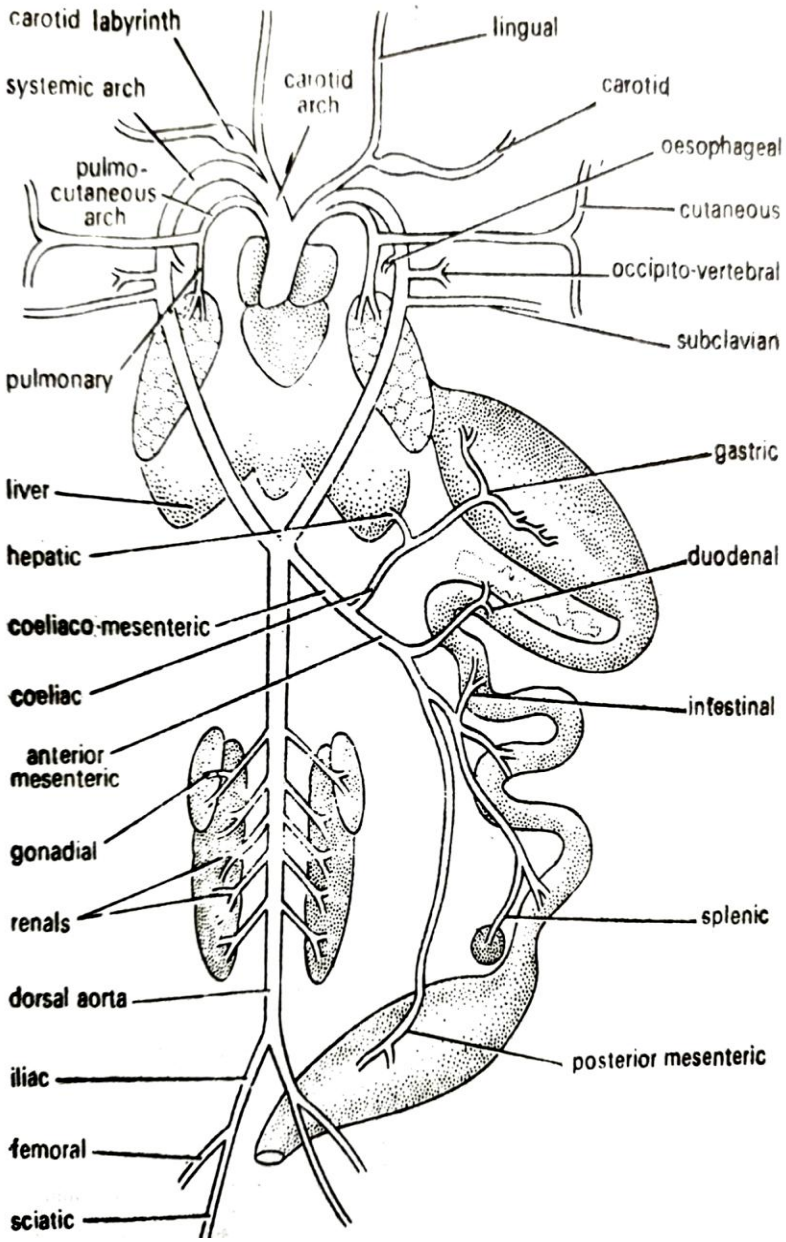


Fig : Frog Arterial System

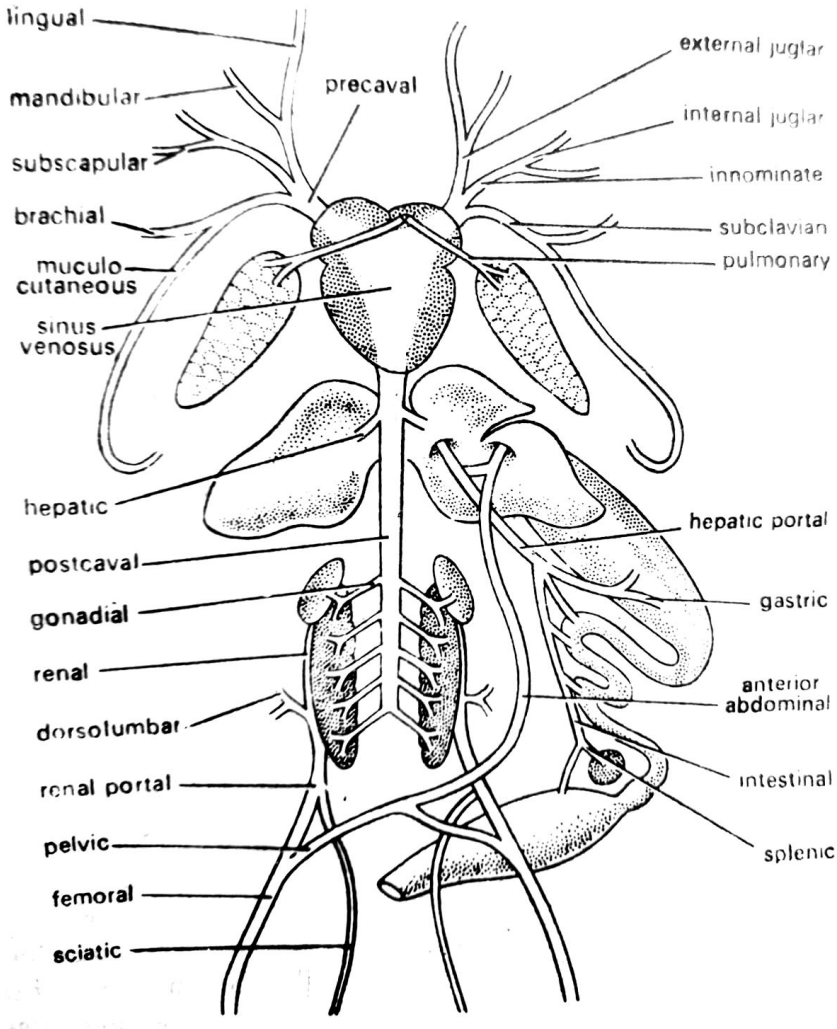


Fig : Venous system of frog

VENOUS SYSTEM

The blood vessels which carry the blood towards the heart constitute the venous system. It means the blood from different parts of the body is returned into heart by veins. These are as follows -

1) **Pulmonary veins**: The blood from two lungs is collected by right and left pulmonary veins which unite to form a common pulmonary vein, opening directly into the left auricle on the dorsal side.

2) **Vena cava**: The blood from the rest of the body comes to the sinus venosus through two pre-caval veins and one post caval vein.

   a) **Pre-caval or anterior vena cava**: The right and left pre-caval or anterior venae cavae collect the venous blood from the anterior part of body. Each pre-caval vein is formed by the union of three veins -

      (i) External jugular: It receives branches from the tongue by lingual vein and from outer margin of lower jaw by mandibular vein.

      (ii) Innominate: It is formed by internal jugular from cranial cavity and orbit and sub scapular from shoulder and back of arm.

      (iii) Subclavin: It receives branches from arm (brachial) and from skin and muscles of the

abdomen and also mucous membrane of mouth and head muscle.

(b) Post vena cava: It receives blood from the legs, kidneys, gonads and vein. It arises between the kidneys and runs forward ventrally to the dorsal aorta in the mid ventral line. Before it is communicated with the sinus venosus, it receives hepatic veins from the liver. Five or six renal veins collect the blood from each kidney and pour it into the posterior vena cave. The veins from the gonads (sperm in male and ova in female) opens either directly to the vena cava or to the anterior most renal vein.

In frog two well developed portal systems are renal portal system and hepatic portal system.

1) **Renal portal system**: The veins which collect the blood from the posterior region of the body constitute renal portal system. The blood of each hind leg is collected by two veins, an outer femoral and an inner sciatic. On entering the abdominal cavity the femoral divides into a dorsal renal portal and a ventral pelvic vein. The renal portal unites with the sciatic and while running along the outer border of kidney of its side it receives blood from lumber region by a dorso-lumber vein. Renal portal vein enters the kidney by several branches which break up into capillaries. The pelvic veins of both sides unite to form a median ventral or anterior abdominal vein. It receives blood from urinary bladder and ventral abdominal wall and runs towards to enter liver into which it breaks up into capillaries. Before entering into liver the anterior abdominal and hepatic portal veins are connected by a small loop.

2) **Hepatic portal system**: It collects the blood from the alimentary canal through many branches and carries it to the liver where the veins breaks up into capillaries and the blood is collected by hepatic veins to pour into the post vena cava .

Blood

Blood is a liquid connective tissue and consists of plasma and suspended cells. Plasma constitutes 60% of total blood and suspended cells are 40%. The suspended cells or corpuscles are of 3 types:

(i) Erythrocytes

(ii) Leucocytes

(iii) Thrombocytes

(i) Erythrocytes: The erythrocytes or red blood corpuscles (RBC) are oval, flattened, nucleated, and biconvex. There size varies from 14 to 23 µ. There number is 2,50,000 to 4,50,000 per cubic millimeter of blood. The RBC contains iron containing red respiratory pigment haemoglobin, which serves to carry oxygen in chemical combination to the tissue.

(ii) Leucocytes: Leucocytes or white blood corpuscle (WBC) are colorless, nucleated and mostly amoeboid cells of at least five types. There number is 5000 to 7000 per cubic millimeter. The function of WBC are phagocytic, ingesting bacteria and other foreign particles that appear in blood, and remove dead or old tissue cells. The WBC of frog are of three types lymphocytes, monocytes and granulocytes. The granulocytes may be neutrophils, eosinophilic and basophilic.

(iii) Thrombocytes: Thrombocytes or blood platelets are small, nucleated, spindle cells. They play an important part in blood coagulation.

EXCRETORY SYSTEM

Excretory system of frog is similar in both male and female. The excretory system consists of a pair of kidney, ureters, urinary bladder and cloaca.

1-Kidney: In frog two kidney are present, which are found in the lymph spaces above the coelom.

They are attached on either side of the vertebral column. They are covered by the peritoneum on the ventral surface only. The kidney are elongated, flat and reddish brown structures with outer edges smooth and convex but inner edges are notched and straight. On the ventral surface of each kidney lies adrenal or supra-renal gland.

Histologically each kidney consists of a mass of nearly 2000 microscopic uriniferous tubules or nephrons and blood vessel, which are embedded in connective tissue. The nephrons are the functional unit of excretion. Each uriniferous tubule has two ends. The proximal end form a double walled cup with a narrow opening called Bowman's capsule, it encloses a bunch or network of fine capillaries called glomerulus. The bowman's capsule and glomerulus together constitute Malpighian body. From renal artery large no of afferent blood vessel arises which enter into bowman capsule and make network of capillaries called glomerulus. From these capillaries arise efferent blood vessels which join with renal vein. The uriniferous tubule remains much convoluted and surrounded by a capillary network from renal portal vein. At the distal end of uriniferous tubule opens into a collecting tubule running transversely across the kidney near its dorsal surface. All the collecting tubule opens toward inner margin of kidney into a longitudinal bidder canal and toward outer margin into a longitudinal ureter. The ventral surface of each kidney have many ciliated funnel called nephrostomes, they drain wastes from body cavity (coelom) and connect to renal veins in.

2-<u>Ureter</u>: It is a fine, white tube starting from the posterior outer margin of each kidney and run back ward to open into dorsal wall of cloaca. The opening of both the ureters is located on two papillae placed side by side dorsally in cloaca. In male frog the ureters are called urino-genital ducts because they pass out sperm as well as urine.

3- <u>Urinary bladder</u>: A large transparent, bilobed, thin walled elastic urinary bladder opens into the ventral wall of cloaca by sphincter aperture opposite and below the openings of ureter.

4- <u>Cloaca</u>: It is a small median chamber into which open the anus, urino-genital apertures and urinary bladder. Cloaca opens to outside by a sphinctered cloacal aperture lying at the hind end of trunk between bases of hind legs.

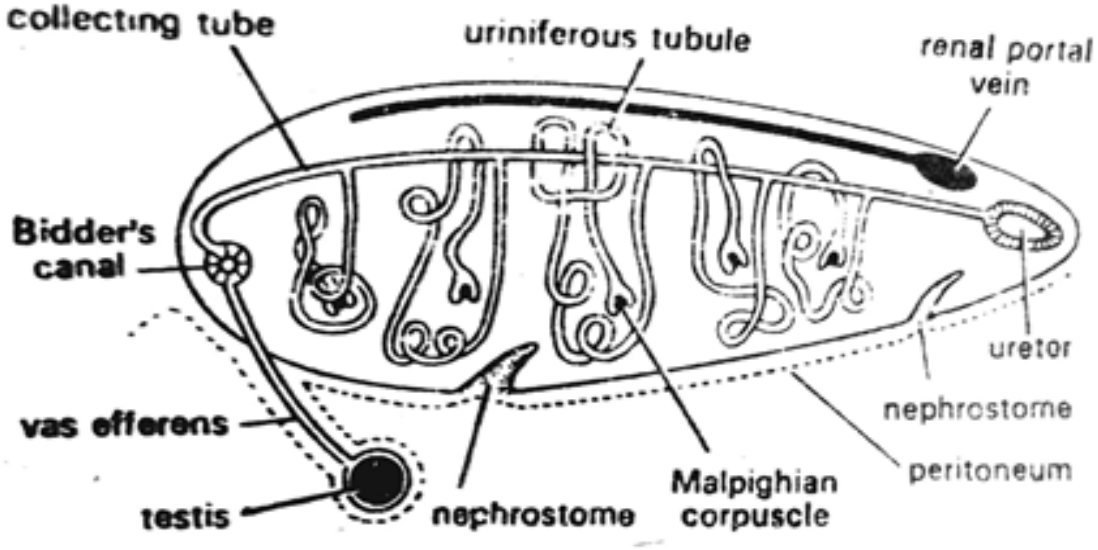


Fig : Frog Diagramsmatic representation of kidney

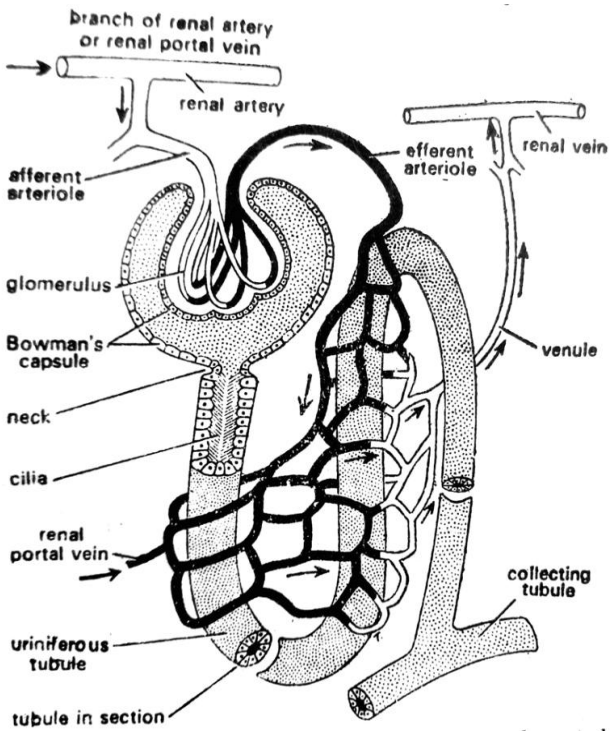


Fig : Frog structure of nephron

Physiology of excretion –

Due to continuous catabolic activity taking place in body, it produces certain harmful substances, which are harmful to body, so they are eliminated by kidney. The blood brings these substances into the kidneys through renal arteries and renal portal veins. The blood enters into glomeruli from afferent arteriole which has wider lumen then the capillaries, so that the blood in glomeruli is under higher pressure which causes filtration of blood. The glomerular filtrate contains urea, inorganic salt, glucose and large quantities of water. The glomerular filtrate passes through the thin wall of the bowmen capsules into the renal vein through the efferent arteriole. There are certain useful substances like glucose, amino acids, in-organic chlorides, and some water, which are filtered, so these substance should be re-absorbed in convoluted tubules and put back into the blood of capillaries of renal veins, while harmful substances such as urea and other salts along with water from urine which passes through the collecting tubes into ureters and goes to the cloaca. It is stored in the urinary bladder for a time when bladder is full, its involuntary muscle contract the urine is forced into the cloaca which is voided at intervals through the cloacal aperture.

Frog is ureotelic animal i.e. it excrete large amount of urea. The formation of urea takes place by two steps:

1-Formation of urea

2-Formation of urine & its excretion

1-Formation of urea: It is a biochemical process which takes place in liver in two steps:

(i) ***Deamination***: Burning of amino acid and formation NH_3.

(ii) ***Urea cycle***: The NH_3 enter into the urea cycle and form urea.

2-Formation of urine & its excretion: It is a mechanical process which takes place in kidney. It includes 3 steps:

(i) Ultra filtration

(ii) Selective re-absorption

(iii) Secretion

After the entire process is completed urine is formed which is collected into ureter and pass down into cloaca.

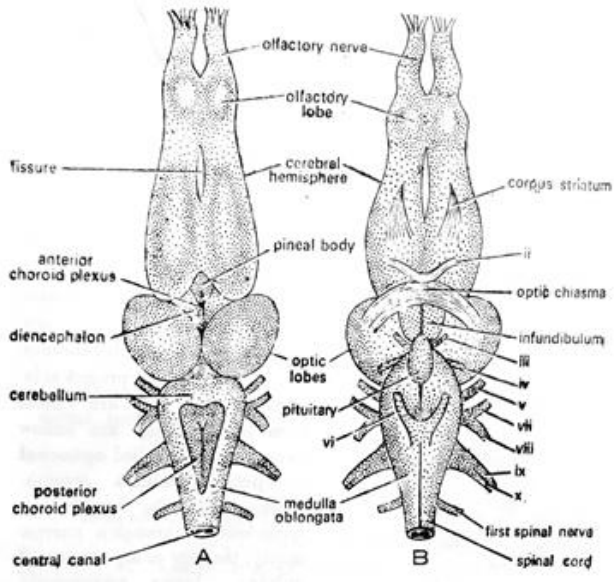


Fig: Frog brain (A) Dorsal view (B)Ventral view

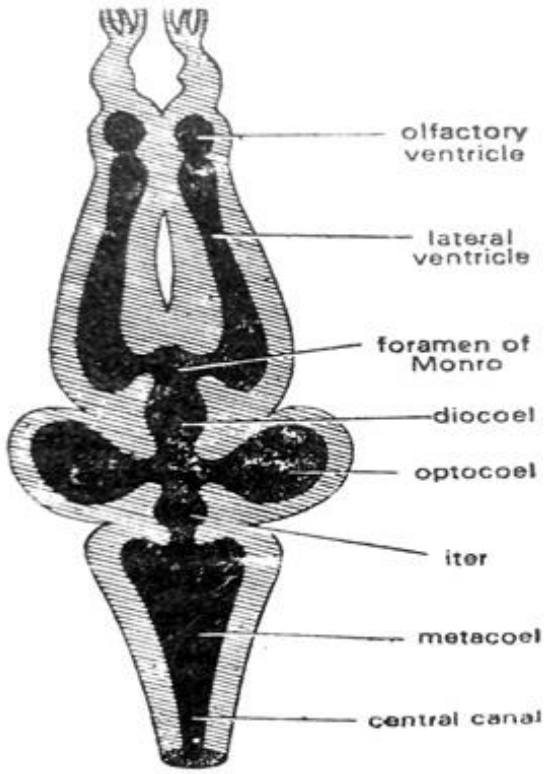


Fig Frog Brain L.S showing ventricles

Nervous System

The nervous system of frog consist of three things

(1) Central nervous system: Brain and spinal cord

(2) Peripheral nervous system: Cranial and spinal nerve

(3) Autonomous nervous system

Brain

The brain of frog is a cylindrical, bilaterally symmetrical, white coloured structure, situated in the cranial cavity of the skull. It is surrounded by two connective tissue membrane, the inner membrane is delicate, pigmented, vascular and called piameter while the outer membrane is tough, fibrous and called durameter. The space between the two membranes are filled with a clear, watery and lymphatic cerebro-spinal fluid which protected and nourishes brain. This fluid is also fills the hollow inner cavity of central nervous system. The brain of frog is divided into 3 main parts

(1) Fore brain or Prosencephalon

(2) Mid brain or Mesencephalon

(3) Hind brain or Rhombencephalon

(1) Fore brain or Prosencephalon: It is the largest part of brain which consists of two olfactory lobe, two cerebral hemisphere and a diencephalon. The two olfactory lobes are present anteriorly, small and spherical lobes each sending a small olfactory nerve to the nasal chamber of its side. The two lobes are united but each contains a separate small cavity called olfactory ventricle or rhinocoel.

Behind the olfactory lobes from two large cerebral hemisphere, which are long, oval and smooth structures, narrow in front but broad behind and separated from one another by a deep mid- longitudinal groove or fissure. Each cerebral hemisphere have a large cavity called I, II or lateral ventricles which are continuous anteriorly with the olfactory ventricle. On the posteriorly the lateral ventricles communicate with each other and with the ventricle of diencephalon by an opening called interventricular foramen or foramen of Monro. On the ventro- lateral side of each cerebral hemisphere is thick fibrous tract called corpus striatum, which contain a network of white medullated nerve fibres and nerve cells. The corpora striata of two hemispheres are joined by a transversely running tract of fibres called anterior commissure and form a thick floor of the brain. They have a thick roof which is called pallium in which more nerve cells have moved to the periphery.

Diencephalon is a short, rhomboid depressed region just behind the cerebrum. It has small internal cavity called III ventricle. It has thick lateral walls called optic thalamic and a thick floor called hypothalamus. Its dorsal roof contains a network of blood capillaries called anterior choroid plexus, behind which arises a small hollow projection, pineal stalk. The ventral surface of the diencephalon bear X- shaped optic chiasma formed by the two optic nerves crossing each other. Just posterior to optic chiasma is a large median bilobed projection, the infundibulum which bears a flattened oval pituitary body.

(2) Mid brain or Mesencephalon: It is the broadest part of brain having two dorso-laterally large rounded optic lobes. It has a hollow cavity called optocoel or optic ventricles. The optocoel is connected anteriorly with the cavity of third ventricle of diencephalon and posteriorly with the IV ventricle of medulla oblongata through a narrow canal called iter or aqueduct of sylvius. The two thick longitudinal bands of nerve fibres called crura cerebri, run longitudinally beneath optic lobes connecting diencephalon and medulla oblongata.

(3) Hind brain or Rhombencephalon: It consists of two part cerebellum and medulla oblongata. The cerebellum is a narrow solid ridge or band lying dorsally immediately behind the optic

lobe.

Medulla oblongata is short and somewhat triangular structure which is simply a widening of spinal cord. It also has triangular cavity called IV ventricle. It is continuous anteriorly with iter and posterorly with the central cavity of spinal cord. On the dorsal surface of the medulla oblongata there is a triangular area of reddish brown color which is called posterior choroid plexus.

Function of different parts of brain

Brain is the centre of control of all vital activities as it receives impulses from different parts of the body through sensory nerves and issues orders through motor nerve fibres to different parts of the body for appropriate action.

Olfactory lobes: These are concerned with sense of smell

Cerebral hemisphere: These are the seat of memory, intelligence, consciousness and will and regulate voluntary action.

Diencephalon: It controls the metabolism of the fats and carbohydrates and also regulates the genital function.

Optic lobes: These are concerned with the sensation of sight and also control the movement of eye muscles.

Cerebellum: It controls the mechanism of the automatic movement and also brings about co-ordination on movement in locomotion.

Medulla Oblongata: It is an important nerve centre. It controls important involuntary function such as heart beat, respiration, metabolism, swallowing, taste, hearing, sound production and secretion of various digestive juices.

Spinal cord

The spinal cord runs posteriorly from medulla oblongata through foramen magnum and lies protracted within the neural canal of vertebral column. It is short, thick, cylindrical, flattened and white in color. The spinal cord is also surrounded by the two menings, piameter& durameter. The cavity of spinal cord also contains cerebro-spinal fluid. The posterior portion of spinal cord terminates into a fine, non nervous filament filum terminale in the urostyle. The spinal cord shows swelling into two places brachial enlargement between forelimbs and sciatic or lumber swelling anterior to filum terminale. The entire length of spinal cord contains two longitudinal groove one on dorsal side and another on the ventral side. The dorsal groove is called dorsal fissure and ventral groove is called as ventral fissure. These two fissures almost completely divide the spinal cord into two symmetrical halves. The spinal cord is also formed of grey matter with ganglion cells and non medullated nerve cells surrounding the central canal and white matter with ganglion cells and medullated nerve fibres surrounding the grey matter. The grey matter is produced at the corners into dorsal and ventral column or horns while the white matter is divided by grey matter into four zone i.e. dorsal, ventral and two lateral zones.

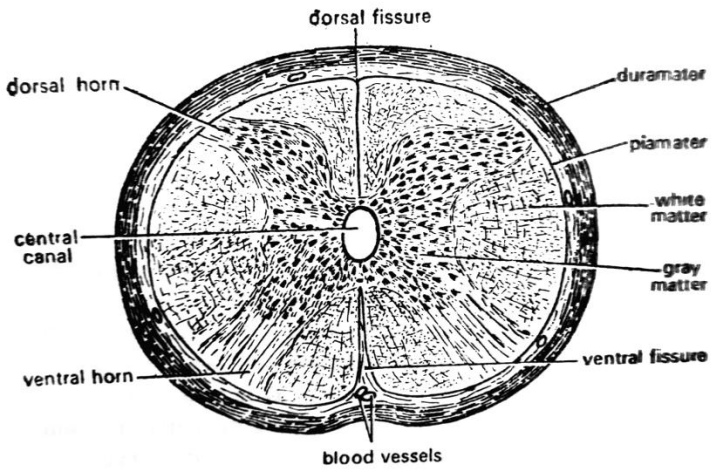


Fig T.S of spinal cord

Cranial nerves

In frog 10 pairs of cranial nerves are found which emerge from the cranium various foramina to supply the different organs of the body. These are as follows

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

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

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

(4) Nerve IV or Trochlear nerve: It arises from the dorso-lateral surface of the mid brain, between the optic lobe and the cerebellum. It supply the superior oblique muscles of the eye ball. It is motor in nature.

(5) Nerve V or Trigeminal nerve: It is the largest of the cranial nerves arising from the medulla oblongata. It divide into three branches (a) Ophthalmic superficalis- enters along the dorsal border of the orbit and goes to the skin of the snout. It is sensory in nature. (b) mandibular and (c)maxillary arise from a common stem and then separate. The mandibular goes to the muscles of lower jaws and the maxillary form the two branches going to the skin of the upper jaws and upper lip. Maxillary is sensory in nature and mandibular is motor.

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

(7) Nerve VII or Facial nerve: It arises from the medulla oblongata. It is mixed in nature. It divides into two branches

- **(a) Palatine –** It goes to the roof of the buccal cavity.
- **(b) Hyomandibular –** It goes to the tongue and muscles of the lower jaws.

(8) Nerve VIII or Auditory nerve: It arises from medulla oblongata and goes to the internal ear. It is sensory in nature.

(9) Nerve IX or Glossopharyngeal nerve: It arises from medulla oblongata and goes to tongue and pharynx. It is mixed in nature.

(10) Nerve X or Vagus nerve: It arises from medulla oblongata and goes to the visceral branch to the larynx, oesophagus, stomach, heart, and lungs. It is mixed in nature.

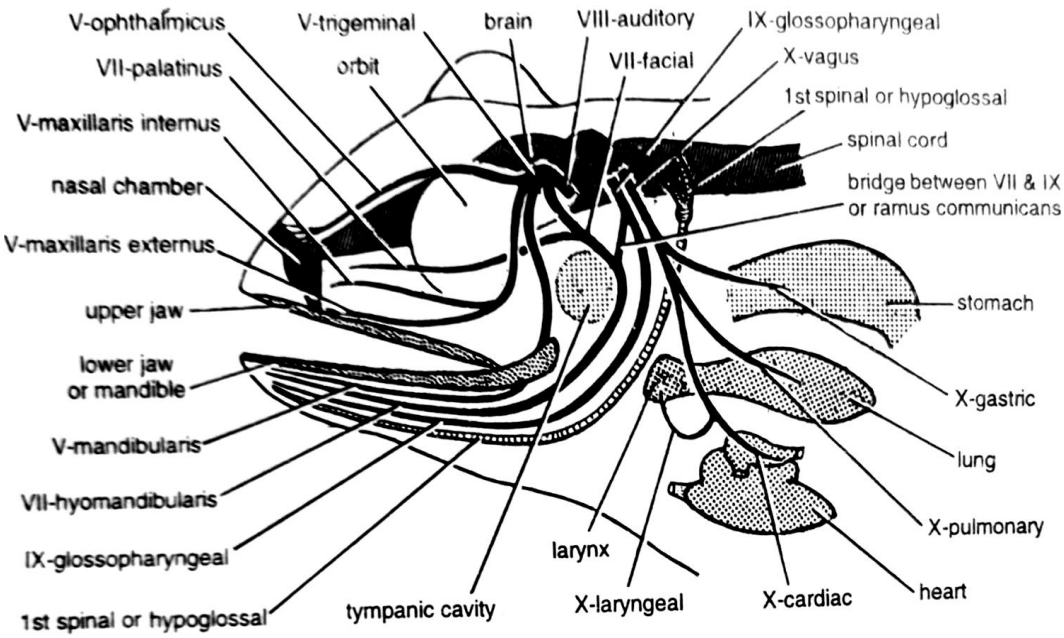


Fig : Frog different cranial nerve

Sense organ

In frog various types of sense organ or receptors are found, which receive sensations or stimuli due to changes in the external or internal environment. The sensory nerves carry nervous impulses from sense organs to the central nervous system, where they are interpreted as characteristic sensations. The important sense organs are

(1) Eye

(2) Ear

Eye: In frog two eyes are situated in the orbital fossae on either side of the head. It's one third is visible externally and remaining two third part lies hidden in the orbit. The eyes are covered with two eyelids. The upper eyelid is immovable as it has no power of independent movement, while the lower one is movable. Each eye has a transparent nictitating membrane which covers the eyes when the frog goes inside the water or underground. The nictitating membrane is not a border of the lower eye lid which lies folded beneath the opaque part of the lower eye lids. The frog can protrude its eye with the help of levator bulbi and can with draw with the help of retractor bulbi.

The eye ball is moved by a set of six extrinsic muscles of which four are rectus muscle (anterior rectus, posterior rectus, superior rectus, inferior rectus). These muscles rotate the eye ball forward, backward, upward, downward respectively. They arises from the inner wall of the eye and pass diverging as they go to the places of their insertion around the equator of the eye ball at various points. The other two muscles are superior and inferior oblique muscle. The superior oblique muscles bring about the rotation of the eye ball along the axis between the optic nerve and cornea, while inferior oblique muscles bring just the opposite movement. The muscle arises from the front part of the orbit.

The surface of the eyes remained moist, it is due to the presence of Harderian glands situated at the

lower inner angle of the eye. These glands secrete a liquid which lubricates the eye. The eye ball is made up of three concentric layer, outer sclerotic, middle choroid and inner retina layer.

Sclerotic layer: It is the outer most dark blue layer which is made of connective tissue and cartilage. It occupies two thirds of the entire circumference of the eye ball and is mostly out of the sight being within the orbits. The remaining one third of it is continued infront as an arched transparent cornea. It simply maintain the shape of the eye ball and also protects the eye ball and also provides surface for the attachment of extrinsic eye muscles. Cornea is covered externally by a thin transparent membrane called conjunctiva. Conjunctiva is formed by epidermis which become transparent and is continued with the inner lining of the eyelids.

Choroid layer: It is the middle layer which is made up of loose connective tissue fibres having many blood capillaries and pigments cell. At the anterior side, the choroid layer get separated from the sclerotic layer forming a circular curtain like iris. At the site where choroid is separated from sclerotic, there is a thick ring like ciliary body is present. There are dorsal and ventral protector lens muscles which are attached inside to the ciliary body and outside to the cornea. In the middle of the iris is an aperture which is called as pupil, which appears like a black spot in the middle of the yellow iris in the entire eye. Behind the pupil is present a large, spherical and transparent crystalline lens enclosed in a delicate lens capsule. It is held in place by suspensory ligament from ciliary body. The iris divide the hollow of the eye ball into a small anterior aqueous chamber lie between cornea and lens and large posterior vitreous chamber lie between lens and retina layer. The anterior aqueous chamber is filled with a watery aqueous humour and posterior vitreous chamber is filled with jelly like substance called vitreous humour. Both the humours serve to maintain the form of eye ball.

Retina layer: It is the inner most and most sensitive layer restricted to the posterior part of the eye ball behind ciliary body. It is made up of several layers. The outer most is the pigmented layer which is attached to the choroid. Below it lies specialized sensory cells. The inner most layer is formed by nerve fibres which converge to form the optic nerve. The light falling on retina stimulates rods and cones and the impulses are conducted by optic nerve to brain. The spot where optic nerve comes out of the eye ball is form on image. The posterior part of the retina which is just opposite to the lens is called area centralis or yellow spot, which contains only cones and has yellow pigment, the images are normally focused on this area.

Working of Eyes: The eyes of frog work like a "box camera". The pupil can be dilated or contracted to admit more light in darkness and less light in brightness. The light rays coming from an object into eye are refracted by cornea and lens and form an object into eye refracted by cornea and lens and form an inverted image on the retina, which is rightly corrected by the brain. The impulse set up by the stimulation of rod and cones are transmitted to brain over optic nerve. The frog's lens does not change in shape or position resulting in poor accommodation. Therefore frog is myopic and it can efficiently see only near objects. Due to widely separated eyes, frog has monocular vision, and it can perceive movements better than other forms.

The rods and cones are modified sensory cells which have been so named due to their shape. These cells are placed at right angle to the surface of the retina and thin ends are embedded in a layer of pigmented cells. The rods are cylindrical cells containing a purple pigment (Rhodopsin). The cones are conical and contain visual violet (Iodopsin) pigment. These two light sensitive pigment are synthesized by vitamin A. The rods are meant simply to perceive the amount of light while the cones are distinguishing color.

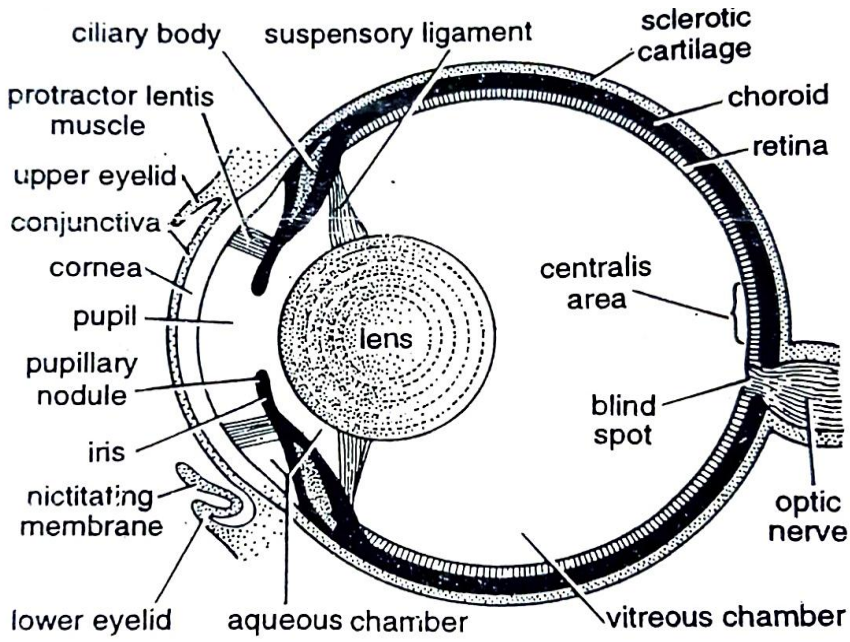


Fig: Frog V.S. of eye

Ear or Stato acoustic organ

In frog ear consists of two parts middle ear and internal ear. There is no external ear in frog. The ear of frog can be seen just behind the eye. It is the middle ear. The middle ear contains a cavity called tympanic cavity. It is closed externally by the conspicuous ear drum or tympanic membrane, which is dark, flat circular patch of skin behind eye. The tympanic membrane is tightly stretched over a ring like cartilage called annulus tympanicus. The cavity of middle ear contains air and it communicates with the pharynx ventrally through a canal called Eustachian tube. The bony partition between tympanic cavity and auditory capsule is perforated by a small oval aperture called fenestra ovalis which remains closed by a membrane and a cartilaginous nodule, stapedial plate. A slender club like rod called columella auris, which is partly made up of bone and partly cartilage, extends across the tympanic cavity. Its outer end is attached to the ear drum while inner end to the stapedial plate.

The internal ear consists of a bony auditory capsule which is cartilaginous in the beginning but later in the adult is bony. It is formed by the pro-otic bone. The auditory capsule is filled with watery fluid called perilymph, in which the membranous labyrinth floats which is partially supported by connective tissue.

The membranous labyrinth is a complicated in structure consisting of an oblong utriculus on the dorsal side to which the three semicircular canals are connected and the sacculus on the ventral. The three semi-circular canals are placed at right angles to one another, these being one anterior vertical semi-circular canal and a posterior vertical semi- circular canal, while the third is a horizontal semi-circular canal. The anterior and posterior canals have their adjacent limbs dorsally united and open into the utriculus through a common opening where as the horizontal semi-circular canal opens into the utriculus at either end. Each semicircular canal at its one end is dilated to form a small round ampulla. The ampullae of the anterior and horizontal semi-circular canals are found at their anterior ends and that of the posterior canal is at its posterior end.

The sacculus is irregular in shape projecting downward and forward from the utriculus. From the posterior side of the sacculus arise two small dilations, the lagena or cochlea and the pars basilaris which is now regarded as a part of legena. From the inner side of the sacculus arises a narrow tube,

the ductus endolymphaticus, which contains a milky fluid of calcium carbonate.

The entire membranous labyrinth is a hollow in its structure and is filled with a fluid called endolymph which contains pieces of calcium carbonate forming otoliths or ear stones. The various parts of the membranous labyrinths are innervated by the fibres of the auditory nerve. The wall of entire membranous labyrinth is made of connective tissue and is lined with cubical epithelial cells. The epithelial lining is modified at certain places to form receptors of the labyrinth which are called sensory patches or acoustic spots. There is one acoustic spot in each ampulla, one spot in the utriculus, one in the sacculus and one in the legena. The acoustic spots of the ampullae are called cristae, while those of the utriculus, lagena and sacculus is called maculae. The macula of utriculus is a large pars neglecta and that of lagena is called basilar papilla. The cristae and maculae have the same structure as they are made of sensory cells being supported cells. The sensory cells have stiff and tapering hair like processes called sensory hairs at their inner but free ends, their lower ends are connected with nerve fibres of the auditory nerve.

Function of Ear: There are two functions of ear i.e. balancing and hearing

(1) **Balancing**: The semicircular canals along with their ampullae and the utriculus are concerned with the balancing of the body. On any change in the position of the animal the endolymph and the otolith start movements and also exert pressure due to which the three cristae and one macula are stimulated. From which the impulses of change of position are transmitted by nerve fibres of the auditory nerve to the brain which sends the impulses to muscles concerned to bring the correct position.

(2) **Hearing:** The sacculus and lagena are the main structure of the membranous labyrinth which are concerned with the hearing. During hearing the sound waves strike the surface of the tympanic membrane and set it to vibrate. This vibration is transmitted through columella and stapedial plate of the middle ear to perilymph of auditory capsule. From perilymph, vibration are transmitted to the endolymph of membrane labyrinth and stimulate the sensory hair cells of sacculus and lagena. The nerve impulses reaching brain through auditory nerve are perceived as sound.

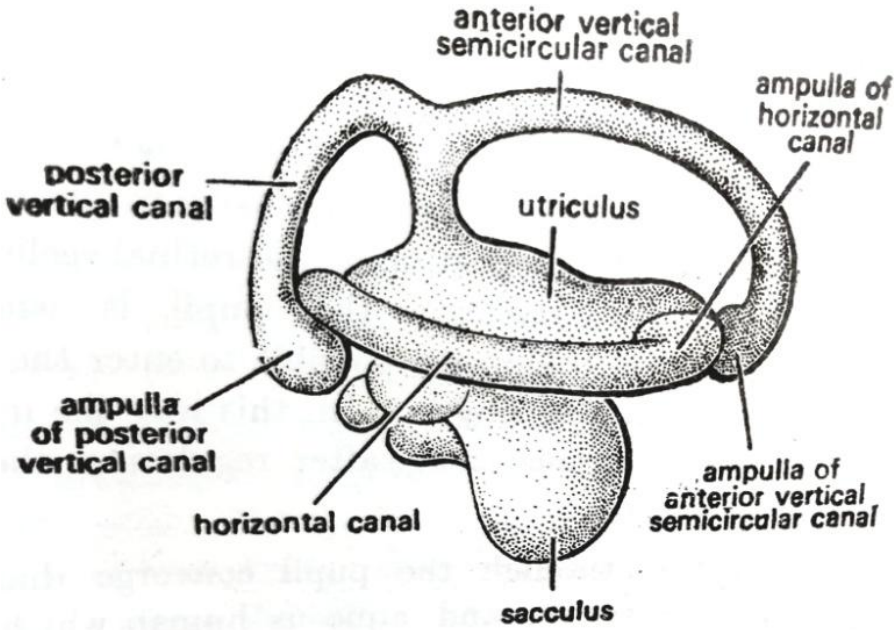


Fig : Internal ear

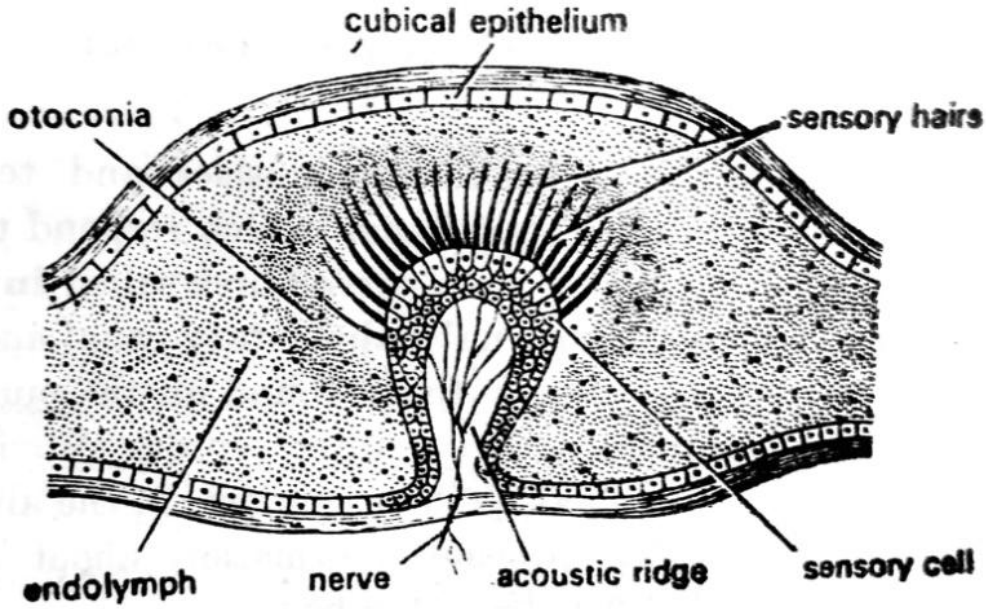


Fig: Frog Section of ampulla

Male reproductive system

The male reproductive system consists of two testis, vasaefferentia and urino-genital duct. The copulatory organs are lacking in frog.

(1) Testis: It is an elongated or ovoid, light yellow color body attached to the anterio-ventral surface of each kidney by a double fold of peritoneum called mesorchium. Each testis contains a compact mass of much coiled seminiferous tubules. The epithelial lining of seminiferous tubules produces spermatozoa by spermatogenesis. The sperms are microscopic elongated about 0.03 mm long structure. It consists of a small rounded anterior acrosome, along cylindrical head containing nucleus, a short middle piece containing centrioles and mitochondria and a much elongated posterior motile tail terminating in a flagellum. Near the anterior end of each testis, several branched finger like fat bodies are found which provide reserve food to nourishing of developing spermatozoa during hibernation.

(2) Vasa- efferentia: All the seminiferous tubules in a testis are connected to form 10 to 12 narrow tubes called vasa efferentia. These leaves from the inner margin of testis run through mesorchium and enter the inner margin of kidney to open into the bidder's canal. Later it is connected to the ureter through collecting tubules of kidney. Thus vasa efferentia conduct mature spermatozoa from testis to the ureter of kidney.

(3) Urino-genital duct: In male frog ureter act both as urinary duct and as a vas deferens. Hence it is called as urinogenital duct. The ducts of both the sides open into roof of cloaca separately on urinogenital papillae.

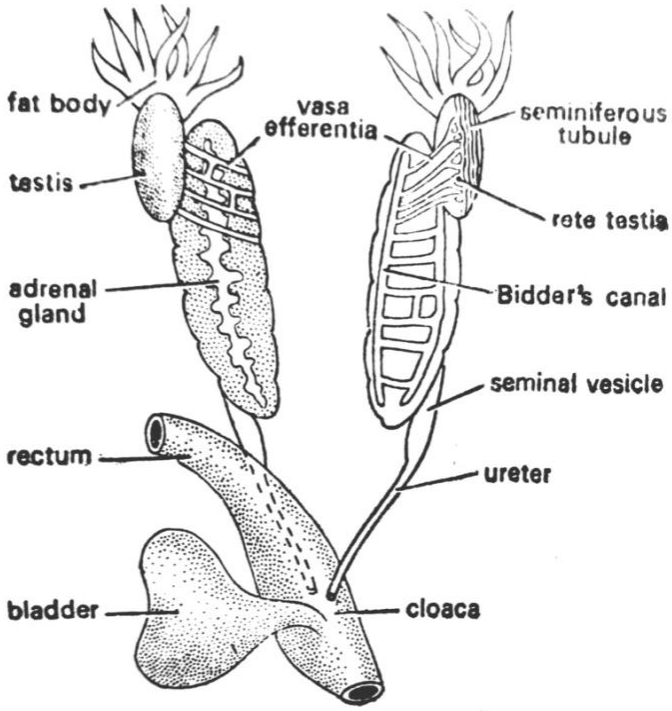


Fig : Frog : Male urinogenital organs

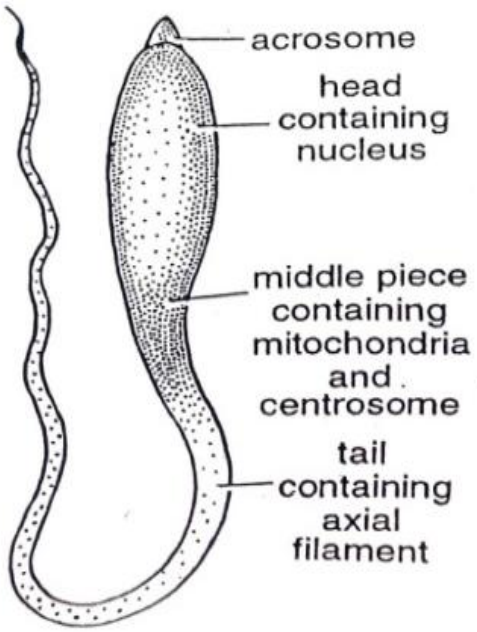


Fig : Sperm of frog

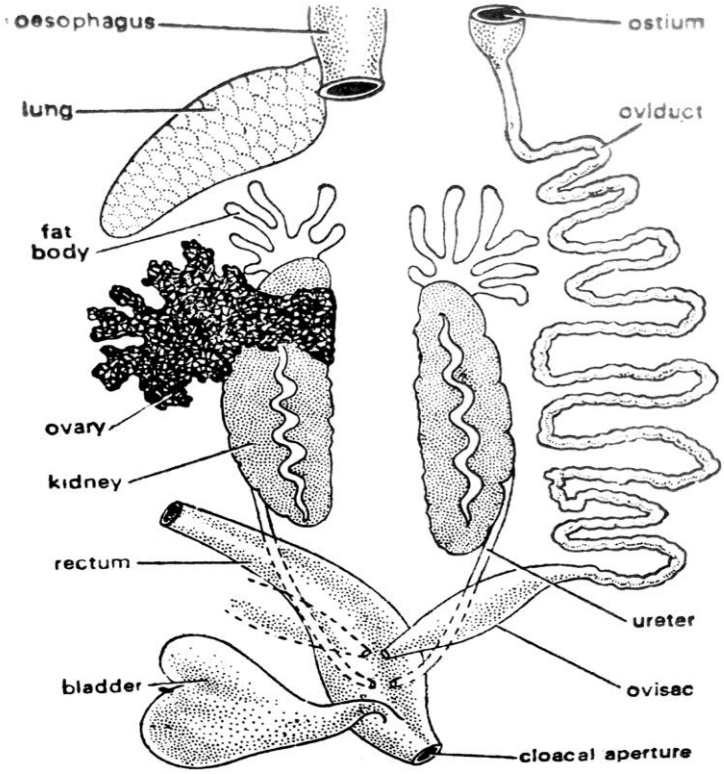


Fig : Female urinogenital organs

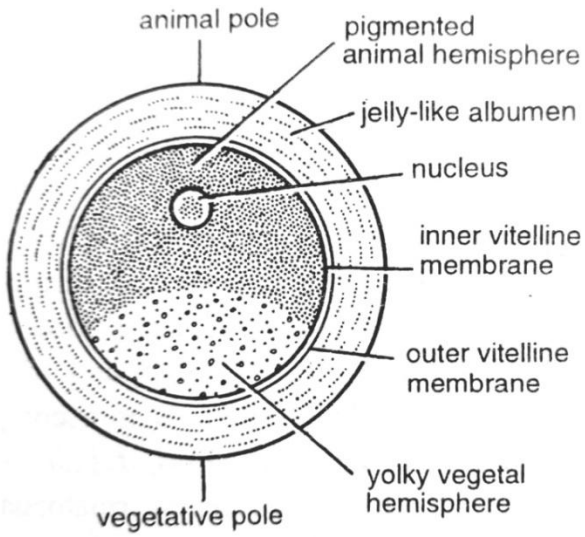


Fig : Frog : unfertilized ova

Female reproductive system

The female reproductive system consists of two ovaries and two oviducts.

(**1**) **Ovaries**: It is a large irregular folded, multilobed, hollow sac grayish or blackish in color. During breeding season the two ovaries become greatly enlarged. Each ovary is attached to the dorsal abdominal wall near kidney by a peritoneal fold called mesovarium. In each ovary contains innumerable dark round ova in different stages of development, which arise from germinal epithelium by oogensis process. When ripe ova are shed by rupture of ovarian wall

into the body cavity from where they are moved by cilia of peritoneum into the ostia of oviducts. In female ovary are also attached with fat bodies as in male.

(2) Oviducts: The two oviducts are long and much coiled white glandular tubes not connected directly to the ovaries. Their anterior ends from ciliated funnel like opening, called ostia. These are placed anteriorly in the body cavity at the bases of lungs one on either side of oesophagus. The cilia present on the inner walls of oviducts move the eggs posteriorly, while glands secrete an albuminous coat around each egg during its passage. The posterior ends of oviducts open dorsally into cloaca separately on papillae just infront of the aperture of ureters. Just before entering into cloaca, each oviduct forms a thin walled enlargement called uterus. The eggs are collected inside uterus before being laid.

Ova: The unfertilized ripe eggs of frog are spherical and are nearly 1.75 mm in diameter. Its upper black pigmented half containing nucleus called animal hemisphere. The lower whiter half containing yolk is called vegetal hemisphere. The egg of frog is telolecithal and radially symmetrically. The eggs are surrounded by two layered vitelline membrane. The outer albuminous coat in contact with water swells up into a thick jelly like layer which probably prevents overcrowding and protected from infections and predators.

Fertilization

It is a process of fusion of male gamete with the female gamete. In frog fertilization is external i.e. it take place in water. The entire process of fertilization takes place in a sequence of steps

(1) Penetration of sperm and formation of fertilization membrane: At the end of copulation female lays eggs, which are in secondary oocyte stage, where second maturation division is incomplete. At the same time male releases spermatic fluid over eggs. A large number of sperms swim in spermatic fluid, piercing the outer jelly, but only one of them will reach at the surface of eggs. The movement it started to enter, cortical granules burst open into the peri-vitelline space sand their contents become adhere to the vitelline membrane which now become thick to form the fertilization membrane. This membrane checks the entry of other sperms into the eggs.

The sperm enter in eggs through their animal hemisphere side and usually about 40^0 from the pole. The sperm breaks the eggs-membranes with the help of an enzyme hyaluronidase. The ovum form a small crator like projection called cone of fertilization, through which sperms are engulfed by a complex process.

(2) Peri-vitelline space and rotation of eggs: The penetration of ovum by the sperm has caused some cortical reactions which give up certain amount of its fluid. This fluid collect between the vitelline membrane and the egg plasma membrane, termed as peri-vitelline space. Its formation releases the eggs from the grip of its coverings, permits the egg to rotate freely within them. So that the heavier vegetal hemisphere come to lie downward and the darker and lighter animal hemisphere comes to the upward. Such rotation is called rotation orientation.

(3) Penetration and copulation path: In frog whole spermatozoa enters the ovum in the animal hemisphere. The tail is then disintegrates, only the head and middle piece travel steadily carrying a trail of black pigment behind it which results from decreased pigment content. The straight path followed by the head and middle piece inside the egg is called the "penetration path." But if female pronucleus is excentrically placed, then the path followed by the male pronucleas is first straight then inclined to an angle. This inclined path is called 'copulation path' and it is also marked by a trail of pigment. But if the female pronucleus is centrally placed and the sperm nucleus does not change its path, then the penetration and the copulation path remain the same. As the head and mid piece of the sperm move along penetration path, the

usual rotation of these parts occurs, thus placing the mid piece in the lead.

(4) Completion of second maturation division: As the sperm enters into the ovum the second maturation division which was arrested earlier, start is very fast and it under go to complete their second maturation division by giving out their second polar body to change into female pronuclei and ready to fuse with male pronuclei.

(5) Amphimixis: The sperm nucleus also become vesicular and is called sperm pronucleus. The sperm pronucleus along with its centriole moves towards the eggs pronucleus and ultimately both pronucleus together to form zygotic nucleus.

Metamorphosis

The term metamorphosis is derived from a Greek word metamorphosis which means "to transform". In embryology it is defined as transformation of the larva into adult during which many structural as well as physiological changes takes place when tadpole larval is about 8 week old, it under goes a series of rapid changes, which transform it into a young frog. This is called metamorphosis.

The metamorphosic changes in frog tadpole can be grouped into three categories:

(A) Change in Habit and habitat

(B) Change in Morphology

(C) Change in Physiology

(A) Change in Habit and habitat:

(i) In frog metamorphosis is associated with a transition from an aquatic to a terrestrial mode of life. The metamorphosing larva comes frequently to the surface of water to breath air. Later it begins to take short trips to land and it becomes amphibious.

(ii) The change of environment during metamorphosis is associated with a change in feeding. The tadpoles are herbivores feeding upon algae and other vegetable matter, which they scrap off with the help of the horny teeth, surrounding their mouths. Adult frogs are carnivorous and they live on insects, worm etc. Sometime they also devour larger prey such as small frogs and even little birds and rodents, which they overpower and shallow.

(B) Change in morphology:

(a) Destructive change or Regressive change: These include the reduction or complete disappearance of those organ or structures which are necessary during larval life, but not required in the adult. The important changes of this nature are as follow:

(i) The long tail of the tadpole along with the fin folds is absorbed again during metamorphosis and disappears altogether at the end of the metamorphosis.

The reduction of the tail is affected by autolysis of the component tissues with active participation of amobeboid macrophages. These are rich in lysosomes that contain a proteolytic enzyme Cathepsin. The macrophages phagocytes the debris of the disintegrating cells. During metamorphosis, the tadpole is nourished by the substance on its tail.

(ii) The gills are resorbed, the gill clefts are closed and the branchial cavities disappear. The resorption of gills also takes place by autolysis.

(iii) The horny teeth of the pre-oral disc as well as the horny lining of the jaws shed.

(iv) The lateral line sense organs present in the skin of tadpoles, disappear during metamorphosis.

(v) The cloacal tube becomes shortened and reduced.

(vi) Some blood vessels, including parts of the aortic arches are reduced.

(b) Constructive changes or Progressive changes: These include the development of some organs which become functional only during and other metamorphosis.

(i) There is a progressive development of the limbs which increase in size and differentiation. The fore limbs, which in the tadpole develop under cover of opercular membrane, break through to the exterior. At the same time, there is a great increase in the length and strength of the hind limbs. Joints develop in them and the after appear.

(ii) The middle ear develops in connection with the first pharyngeal pouch. The tympanic membrane develops. It is supported by the circular tympanic cartilage and enables the frog receive air borne vibrations.

(iii) The eyes bulges up on the dorsal surface of the head and develop nicating membrane.

(iv) There is a development of the tongue and the vomerine teeth.

(c) Remodeling of some structure: Some organs which function both in the larva and adult change their differentiation during metamorphosis so as to meet the requirements of the adult mode of life.

(i) The skin of the tadpole is covered with a double layered epidermis. The number of layers of cells in the epidermis increases during metamorphosis. Surface layers become cornified multicellular mucus and serous glands develops in the skin. The pigmentation of the skin is changed and newpatterns and colors appear.

(ii) There is a widening of the mouth gap due to rotation of the quadrate cartilages backwards and the true jaws become functional.

(iii) The tongue grows much larger and more muscular.

(iv) The stomach and liver enlarges.

(v) The eyes become more prominent

(vi) In tadpole the intestine is very long and spirally coiled, which metamorphose in adult into greatly shortened and straight. This is due to change in feeding habit from herbivores to carnivorous.

(vii) The two chambered heart of tadpole if transformed into a three chambered heart of frog.

(viii) Lungs do not undergo major changes. They develop very gradually and fully functional.

(ix) The cartilaginous skeleton of tadpole undergoes ossifications.

(x) The larval pronephric kidney is transformed into a mesonephric kidney.

(xi) The blood vascular system is modified with the disappearance of some aortic arches and increases of blood supply to the lungs and the skin.

(C) Change in Physiology:

(i) The endocrine function of the pancreas starts at metamorphosis as it begins to secrete insulin and glucagon hormones. This is related to the increased role of the liver in the turnover of glycogen.

(ii) A marked change takes place in the excretory function. In the tadpole, the end product of nitrogen metabolism is ammonia which is easily disposed off by diffusion in water. After metamorphosis, the frogs excrete most of their nitrogen in the form of urea and only small amounts as ammonia. The ammonia is highly toxic and if accumulated in a terrestrial animal, it could become dangerous. This change over occurring in the late stages of metamorphosis is due to a changed function of the liver, which begins to synthesize urea.

Physiological control of metamorphosis in frog

Metamorphosis in frogs is initiated by the anterior lobe of the pituitary, when it reaches a certain degree of differentiation and becomes capable of producing the thyrotrophic hormone (TTH). The thyrotrophic hormone activates the thyroid gland which builds up and releases the thyroid hormones. The most important hormones are tri-iodothryonine (I_3Thn) and tetra-iodothyronine (I_4Thn) or thyroxine. Of these two compounds, thyroxine is produced in much greater quantities and is thus the main action substance released by the thyroid gland, although the activity of tri-iodothryonine is three to five times as high as that of thyroxine. The thyroid hormone is carried to the various body organs through the blood stream and affects the tissues directly. While it causes the degeneration and necrosis of some cells it stimulates the growth and differentiation of others, thus causing the metamorphosis.

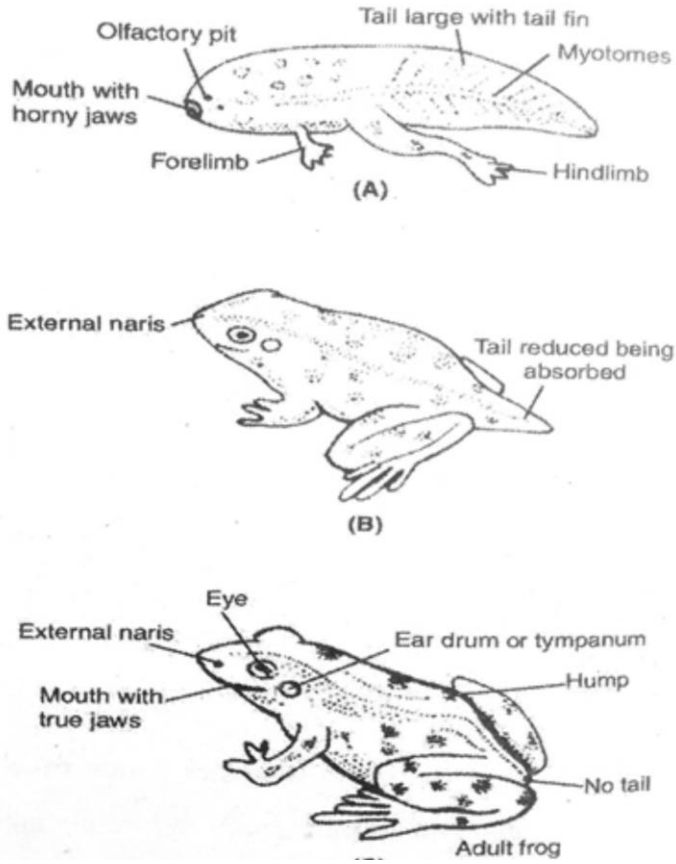


Fig Frog : Stages of metamorphosis

5.4 PARENTAL CARE & NEOTENY

Parental Care

The protection and care taken by their parents to their eggs and developing offspring at nursery stages is known as parental care. It is an inborn instinctive behavior, shown by different groups of animal, which are directly related to their existence. Parental care has solved the survival problem because it helps in preservation of species.

The well developed parental is found in amphibian. For parental care many extreme modifications in structure and behaviors of amphibian has been observed. There are various method of parental care found among amphibians. These are

(i) Deposition of eggs in suitable place and preparations of nest

(ii) Carrying the eggs by parents

(iii) Development of brood pouch

(iv) Viviparity

(i) Deposition of eggs in suitable place and preparations of nest : This is a primitive methods of parental care. It is of following types

- **Mud nest :** Female *Hyla faber* (Tree frog) construct 7 – 10 cm deep hole in the mud in shallow water. The female lays eggs in it. After about two days of nest building, the male discharges sperms, fertilizing the eggs. Egg and early stages of larva are saved from predator.
- **Tunnel nest :** Female Japanese tree frog (*Rhacophorous ocellatus*) makes a spherical hole of 6 9 cm wide in mud banks. Both male & female sinks in the hole embraced with each other. They make the surface of tunnel, smooth while sinking. Finally they close the mouth of tunnel Female emits a spongy ball from her cloaca, laying eggs on it. Eggs become entangled with frothy bubbles. Now male discharges its sperm on the frothy bubble fertilizing the eggs.
- **In nest on trees or rocks overhanging the water :** Tree frog of South America (*Phyllomedusa*), India (*Rhacophorous malabariens*) and Africa (*Chiromantis*) etc. keep their eggs in the nest made on the leaves of trees. The nest is covered by many other leaves. Eggs develop into larva. After hatching larvae jump into the water. Metamorphosis of larvae takes place in water.
- **In gelatinous transparent bag :** Female *Phrynixallus biroll* secrete bag and keep their fertilized eggs in it. The transparent membranous bag is left in water current of hill stream. Entire metamorphosis occurs in it. Small frogs come out of this bag.
- **On trees or moss away from water :** *Hylodes* of American frogs keep their eggs below the rocks, moss and leaves of trees. The eggs are bigger in size. Development of eggs occurs fastly as yolk is in sufficient in quantity. Young frog comes out and performs pulmonary respiration.

(ii) Carrying the eggs by parents : It is following types

- **Eggs are protected by covering them with their body :** Male *Mantophryne robusta* species covers the eggs by elastic gelatinous covering in row. Their number in one row is about 17 and they form a bunch. Male sit on the bunch off eggs and holds them with help of fore limbs. Limbless amphibian (*Icthyophis*) surrounds eggs with the help of

their body.

- **Around the legs and neck :** The males of midwife toad *Alytes abstetricans*show peculiar type of parental care. This type of toad is abundant in Italy. Several males are reported to collect around a female on the land. Out of the male becomes successful to grasp round the waist of female. The male in this position massages and lubricate the cloacal region of the female were upon the female discharges the eggs. The eggs are fertilized during the explosion of the eggs by sperms of the grasping male. After fertilization the eggs are wrapped around the back of the thigh and it withdraws himself into a hole near the pond. When the eggs are ready, the male carries them to nearest water where the larva comes out. Development and metamorphosis take place in water.

  Desmognathus fucus carry their eggs around neck.

- **On the back :** Female Brazilian tree frog (*Hyla goeldii*) carries eggs on her back. Male helps to place the eggs on her back.

- **Tadpoles carried by parents :** South American *Phyllobates* and *Dendrobates* carry their tadpoles on their back. Tadpoles remain attached with the back of parents, with the help of sucker like lips and flat abdomen. Tadpoles are being carried by their parents if the pond becomes dry.

(iii) Development of brood pouch : Parents care and carry their eggs and tadpoles in their special self made brood pouches. These are of various types

- **In small cell like pouches on back :** Small cutaneous pouches are formed on back of female of *Pipa cryptobranches*, *Desmognathus gastrotheca* species of frog. Eggs are surrounded by these cutaneous pouches. Each pouch is covered by a lid. These pouches are formed by the secretion of cutaneous glands. Each pouch consists of more than 100 eggs. Development of eggs and metamorphosis of larva occurs in these pouches. Full developed young frogs come out from these pouches.

- **Common pouch :** In N*ototrima* all eggs are placed in a common pouch. This common dorsal pouch is formed only in breeding season. The pouch bears a small hole. The transfer of eggs in these pouches is still not known.

- **On the exposed belly of females :** Female *Rhacophorous reticulate* of Ceylon carry their eggs on their belly. Eggs remain attached with the skin of belly. On removal of eggs the belly bears small grooves.

- **In the mouth or gull pouch :***Rhinoderma darwinni* of chili are very small frog. Male of this species keep 10 to 15 young frogs in the gullar pouch where they metamorphose. The gull pouch is modified vocal sac. West African female of *Hylambates breviceps* keep eggs in her mouth where the eggs develop. The numbers of eggs are less but size bigger.

(iv) Viviparity : The two species of small toads of western Africa *Pseudophyrne vivipara* and *Nectophryne tortnieri* are viviparous. They give birth to their young. Their embryo are found in their uterus. Embryos of *Pipa dorsigera* get nutrition by pseudo placenta.

An extreme modification is observed in *Salamendra atra* and *Salamendra maculosa*. The eggs are placed inside the uterine cavity where entire development of tadpole is completed. The larvae remain attached with the uterine wall membrane which functions as physiologically in the manner of a primitive placenta. The broad and vascular tail also helps in metabolic exchanges. Several month later the female goes to the water and give birth to 10 - 150 young of small sized, with the forelimbs

developed.

Conclusion Study of parental care among amphibians reveals that parental care in amphibian is done by all possible methods i.e. laying eggs in proper places, preparation of nests, carrying of eggs and tadpoles by parents, development of brood pouch in parent body, viviparity and nutrition of embryo by pseudo-placenta. Thus the mode of parental care in amphibian is well advanced over fishes. This help in preservation of amphibian.

Neoteny

The term neoteny and paedogenesis are synonyms but it is not correct. The word neoteny refers as the retention of larval characters in the adult body for example in adult Salamanders the larval gills are found.The other example is retention of embryonic cartilaginous skeleton in adult Salamanders. The word paedogenesis refers to a condition in which the larva does not convert in adult,but develops gonads and production of young once. The example has been observed in gall fly, liver fluke and salamanders. So neoteny emphasizes the retention of embryonic or larval features in the adult body.

In certain species of Mexican salamanders (Ambystoma) the larval known as tadpole, is often incapable of achieving metamorphosis. The larva continues to grow and reaches the stages of sexual maturity, when it is still in larval stage. These giant larvae are known as Axolotle larva. For the first time axolotls were described by Hernandez (1600), and named Atolacalt. Johnston in 1767 affirmed that the axolotls only a water were illusions. In Cuvier(1865), observe that shortly after laying eggs, the female axolotl underwent metamorphosis.

Environmental factor affecting neoteny

The exact causes of neoteny are not properly understood. Environmental factor affect metamorphosis in several ways. Abundance of food, cold temperature or insufficient iodine (thyroxin) may cause failure of metamorphosis and retention of larval features. This is indicated by the fact that drying up of swamps, lack of food and rise in temperature in surrounding water induce axoltols to metamorphosis. In USA, the axoltols metamorphosis in the ordinary manner from larvae to the adult but the axolotls of Mexican lakes remain permanently in water, possessing gills throughout the life and lay eggs when transferred to the eastern states or experimentally treated with thyroxine or TSH.These axolotls lose their gills develop lungs and become adult air breathing natives in tiger salamander. Responses of larval tissues to thyroid hormones are reduced as temperature drops and disappears entirely below 5^0 C. Various extrinsic and intrinsic factors are supposed to be responsible for such as unusual phenomenon.

Extrinsic factors

(i) Abundance of food and other favorable requisites in the aquatic life is the cause of retention of larval features (Gadow 1903).

(ii) Deep water and coldness inhibits the secretion of thyroxine (Shufeldt)

(iii) Saline nature of water is responsible for neoteny (Weismann)

(iv) Low temperature is responsible for the arrest of metamorphosis (Huxley, 1929)

Intrinsic Factors

Gressner (1928) was of opinion that insulin hormone inhibits metamorphosis. But recent research has revealed that metamorphosis is primarily influenced by

(i) Varying threshold levels of thyroxin and its analogues

(ii) Degree of responsiveness of the larval tissue to the hormones.

Etkin and his co-worker have established the role of prolactin on metamorphosis. They have shown that level of prolactin act as an inhibitor in the over all control of metamorphosis.

Axolotle larva possesses three pairs of external gills and a tail having a caudal fin. It exhibits the phenomenon of neoteny or paedogenesis. If the food and water are scarce and iodine is lacking in water then the axolotle larva leaves water for land and becomes an adult without metamorphosis. During metamorphosis the gills and tail fin are lost. In the abundant supply of food and water containing iodine compounds, the axolotle larva does not change into an adult but remains in the larval form and becomes sexually mature to start reproduction. Metamorphosis in axolotl is induced by injecting thyroid extract.

Type of neoteny

(i) Artificial neoteny: Neoteny is artificial when it is induced in amphibians by artificial means. Metamorphosis is brought about by the hormone of thyroid gland.Permanent and more or less giant larva is obtained by removing the thyroid gland or by submitting the animal to chemicals with anti-thyroid or anti-pituitary thio-uracil, basolan etc. effect the gonads hence total neoteny is not obtained.

(ii) Permanent neoteny: Permanent neoteny is shown by several Perennibranchiate salamanders such as Necturus, Sirens and Proteus. They remain larval throughout, even thyroxine treatment fail to induce metamorphosis. Their neoteny must be due to lack of capacity of the tissue to undergo metamorphosis.

Significance of neoteny

Weismann (1875) thought neoteny to be a case of retarded evolution or atavism, i.e. reversion of ancestral condition. According to Bolk, de Beer, Cuenot and other neoteny has played its part in the genesis of our own species. Man resembles the giant foetus of the great ape for more than adult ape. It is thus tempting to imagine that the passage from ape to man involved some process of foetalization, connected with variations of hormonal equilibrium and a slowing down in rate of growth.

It is generally assumed that it is a device to keep up their progeny by means of protecting them in all stages. Thus offering the life to the young and avoid dangers during their complicated life cycle. It is obvious that it seems as advice for the future of its race, thus a scarce played by the nature.

SAQs 1.

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

(i) Urostyle is present in ----------

(ii) --------- is the process of transformation from an immature form to an adult form in two or more distinct stages.

(iii) ---------- is a complex behavior shown by parents to take care of the offspring

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

5.5 SUMMARY

In this unit you willstudy the general characters and classification up to order level of class amphibian. In this unit there is discussion of *Rana tigrina* as type study in which you will study different parts and their physiology like digestive system and its physiology of digestion, respiratory organ and mechanism of respiration, heart, and its working, blood, nervous system brain, spinal cord, cranial nerve, spinal nerve, sense organ- optic organ, stato-acoustic organ, excretory organ,

male and female urino-genital system, male and female reproductive organ, reproduction, copulation, fertilization, and development. In this unit there is also discussion about parental care & neoteny in very detailed manners.

5.6 TERMINAL QUESTION

Q1. Explain the general character of Class Amphibian.

Q2. Describe the Environmental factors affecting neoteny.

Q3. Describe theparental care in amphibian .

5.7 ANSWERS

SAQ 1

(i) Anura

(ii) Metamorphosis

(iii) Parental care

(iv) Caudata

Terminal question

1. The general character of class amphibian are

- Aquatic or semi-aquatic (fresh water), air and water breathing, carnivorous, cold blooded oviparous, tetrapoda vertebrates.
- Head distinct, trunk elongated. Neck and tail may be present or absent.
- Limbs usually 2 pairs (tetrapods), some limbless. Toes 4-5 (pentadactyle) or less. Paired fins absent. Median fins, if present without fin rays.
- Skin soft, moist and glandular. Pigment cells (chromatophores) present.
- Exoskeleton absent. Digits clawless. Some with concealed dermal scales.
- Endoskeleton mostly bony. Notochord does not persist.
- Skull articulates with the atlas by two occipital condyles.
- Mouth large. Upper or both jaws with small homodont teeth. Tongue often protrusible. Alimentary canal terminates into cloaca.

- Respiration by lungs, skin and mouth lining. Larva with external gills which may persist in some aquatic adult.
- Heart 3 chambered (2 auricles & 1 ventricle). Sinus venous present. Aortic arches 1-3 pairs. Renal and hepatic portal systems well developed.

2. The exact cause of neoteny are not properly understood. Environmental factor affect metamorphosis is several ways. Abundance of food, cold temperature or insufficient iodine (thyroxin) may, causes failure of metamorphosis and retention of larval features. This indicated by the fact that drying up of swamps, lack of food and rise in temperature in surrounding water induce axoltols to metamorphosis. In the USA, the axoltols metamorphosis in the ordinary manner from larvae to the adult but the axolotls of Mexican lakes remain permanently in water, possessing gills throughout the life and lays eggs when transferred to the eastern states or experimentally treated with thyroxine or TSH, these axolotls lose their gills develop lungs and become adult air breathing native tiger salamander. Responses of larval tissues to thyroid hormones are reduced as temperature drops and disappears entirely below 5^0 C. Various extrinsic and intrinsic factors are supposed to be responsible for such as unusual phenomenon.

3. The protection and care taken by their parents to their eggs and developing offspring at nursery stages is known as parental care. It is an inborn instinctive behavior, shown by different groups of animal, which are directly related to their existence. Parental care has solved the survival problem because it helps in preservation of species.

The well developed parental is found in amphibian. For parental care many extreme modifications in structure and behaviors of amphibian has been observed. There are various method of parental care are found among amphibians. These are

(i) Deposition of eggs in suitable place and preparations of nest

(ii) Carrying the eggs by parents

(iii) Development of brood pouch

(iv) Viviparity

UNIT-6 : REPTILIA

6.1 Introduction

Objectives

6.2 General characters and classification up to order level

6.3 *Uromastrix*as type study

6.4 Identification of poisonous and non-poisonous snakes and biting mechanism of snake

6.5 Extinct reptiles

6.6 Dinosaurs – Types and evolutionary significance

6.7 Summary

6.8 Terminal Question

6.9 Answers

6.1 INTRODUCTION

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

Objectives

After studying this unit you will be able to know about :

- General characters and classification up to order level*Uromastrix.*
- Identification of poisonous and non-poisonous snakes and biting mechanism of snake
- Extinct reptiles
- Dinosaurs – Types and evolutionary significance

6.2 GENERAL CHARACTERS AND CLASSIFICATION UP TO ORDER LEVEL

General Characters

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

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

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

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

(5) Skin dry and without any gland.

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

(7) Characteristic T-shaped interclavicles present.

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

(9) Alimentary canal terminates in a cloacal aperture.

(10) Carnivorous.

(11) Respiration by lungs.

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

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

(14) Kidneys metanephric. Excretion uricotelic.

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

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

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

(18) No parental care.

Classification

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

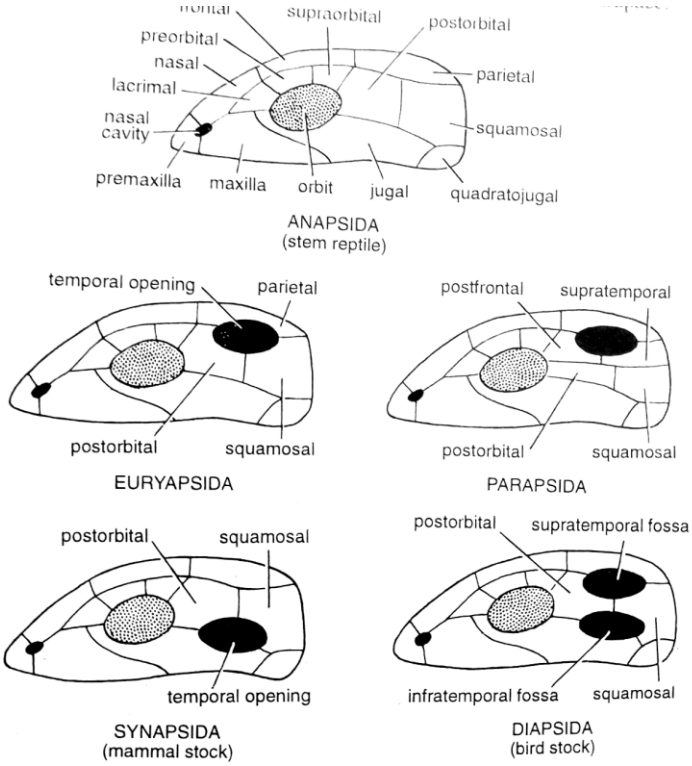


Fig : Types of Skulls

Subclass –I Anapsida

Primitive reptiles with a solid skull roof. No temporal opening present.

Order – I Cotylosauria (Stem Repteiles, Extinct)

- Extinct Reptiles, having complete skull root.
- Jaws and teeth poorly developed.
- Limbs weak and project laterally
- Pelnic gradles flat and plate like
- Extinct vesculelanecs with labyrinthodant Amphibians. only example- Seymouria

Order – II Chelonia

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

Example : *Chelone, Testudo*

Subclass –IIEuryapsida(Extinct)

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

Subclass –III Parapsida (Extinct)

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

Order –I Protosauria

- From Permian to Triassic

  Example: *Araeoscelis*

Order –II Plesiosaur (Flying reptile)

- From Triassic to Cretaceous

  Example : *Pilosaurus, Plesiosaurus.*

Order –III Ichtyosauria (Aquatic reptile)

- From Triassic to Cretaceous

  Example : *Mixosaurus, Ichthyosaurus*

Subclass –IV Synapsida (Extinct) (Mammal like repitle)

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

Order –I Pelycosauria

Example : *Varanosaurus, Dimetrodon.*

Order –II Mesosauria

Example : *Mesosaurus.*

Subclass –IV Diapsida

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

Order –I Rhynchocephalia

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

Example : *Sphenodon* (only living species).

Order –II Squamata (Living)

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

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

Order –II Crocodilia (Living)

- Large sized carnivorous and aquatic reptiles.
- Tail long, strong and laterally compressed.
- Limbs short but powerful, clawed and webbed.

- Skin thick with scales bony plates and scutes.
- Quadrate immovable.
- Teeth numerous, thecodont lodged in sockets.
- Heart completely 4 chambered.
- Cloacal aperture is a longitudinal slit.
- Male with a median, erectile grooved penis.

Example : *Crocodylus, Alligator*

SAQs 1.

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

(i) The reptiles are the first vertebrates adapted for life on ----------

(ii) Reptiles flourished and attained maximum development during the -------era.

(iii) Reptilia are ---------

(iv) In ---------- skull with two temporal openings on either side behind the eye.

6.3 *UROMASTRIX* AS TYPE STUDY

Systemic Position

Phylum- Chordata

Sub Phylum- Vertebrata

Division- Gnathostomata

Super class- Tetrapoda

Class- Reptilia

Order- Squamata

Genus – *Uromastrix*

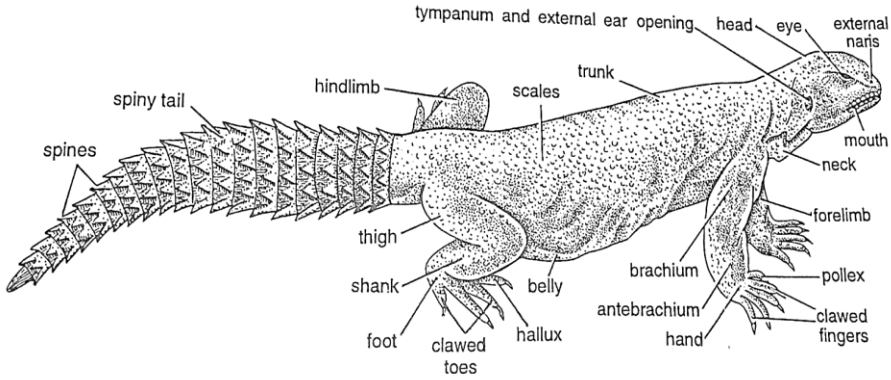


Fig : *Uromastix* External feature

Introduction

There are 11 species of the genus *Uromastix* inhabiting the desert regions of North Africa and North-Western Asia. The only one species*Uromastix hardwickii* is represented in India. It is found almost throughout North-Western India (Punjab, Haryana, Rajasthan, Uttar Pradesh) and Gujarat. It has not

been reported from South India. It is also found in Sindh and Baluchistan in Pakistan. The lizard is commonly known as “Sanda” in Hindi and “Sanha” in Punjabi.

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Uromastix is gentle and quiet in habit and it can be easily tamed in captivity. It is a burrowing lizard. It digs its own burrow in the ground with its powerful claws. It is diurnal. It retreats into burrow at night or in the day during very hot or cold weather. The burrow is also used for shelter and protection against enemies and for laying eggs. At night, the lizard closes the entrance of the burrow for safety.It is chiefly herbivorous and feeds on grasses, flowers, fruits and succulent leaves of wild shrubs and trees. It sometimes preys on insects. In captivity it can be fed on pieces of bread and moistened or roasted gram. During winter usually from December to March, *Uromastix* undergoes hibernation in order to avoid the cold season. It suspends feeding, slows down all activities and passes through a period of dormancy inside its burrow. During hibernation the lizard lives on the accumulated fat of the body.

The breeding season of *Uromastix* begins in March and April in Northern India. During breeding season males become agile and aggressive and resort to fighting for the females. Courtship precedes copulation which takes place generally between 10 a.m. and 3 p.m. on a clear warm and sunny day. During mating, the male everts both its hemipenes, one of which is inserted into the cloaca of the female to discharge the spermatic fluid.

Fertilization is internal. *Uromastix* is oviparous. The female lizard lays about 10 to 15 large eggs which possess thin membranous shell. The eggs are laid in the burrow of the female in late April or early May. The eggs measure 20 to 30 mm in size are dusty white in colour, rich in yolk and develop with the heat of the sun. Cleavage is meroblastic. The newly hatched young resemble the parents.

Habitat:

Uromastix inhabits dry sandy tracts such as deserts with scanty vegetation. It lives in individual burrows and prefers dry places. It is usually found in soft yellowish soil. It is also called “Sand lizard” because of its sandy habitat.

Economic Importance:

The flesh of *Uromastix* particularly the tail muscles, is eaten by some tribal people and considered a delicacy. The oil extracted from its fat bodies is sold by roadside quacks is claimed as cure for impotence and used for massage.The powder of its faeces mixed with “kajal” is supposed to cure corneal opacity. The skin of this lizard is used for making fancy leather articles and even exported.

Shape, Size and Colour:

Uromastix is long, massive and depressed body. The length of the body may vary from 20 to 30 cm. The general colour of the body on the dorsal surface is yellow-brown with dark spots, while the ventral surface is light pale.The whole body surface is covered with granular epidermal scales.

Division of Body:

The body of *Uromastix* is divided into four regions

1. Head,
2. Neck,

3. Trunk
4. Tail.

1. Head:

The head is small, depressed and roughly triangular and produced in front into a short and blunt snout. The mouth is anterior and like a wide slit bounded by immovable lips covered with scales. Lower lip is rounded but the margin of upper lip is sharp covering the lower lip.

A pair of oval openings, the external nares, is located at the anterior end of snout above the mouth. During digging, the nostrils become closed by a prominent swelling of their posterior mucous linings which serve as valves. A pair of small bead-like eyes is situated dorso-laterally almost in the middle of the head. The pupil is round and the iris is light orange in colour.Each eye has two thick movable eye-lids and a nictitating membrane. Eye-lids are well developed. The lower eye-lid is much more mobile than the upper one. The two eye-lids completely close the eye. In addition to the two eye-lids, the nictitating membrane is a transparent thin membrane and is placed in the anterior corner of the eye. It also acts like a third eye-lid.

The nictitating membrane cleans the cornea at the time of need. Behind the eyes are two shallow pits called the external ear openings or auditory meatus. At the base of each auditory meatus lies an oval tympanic membrane. The meatus has a denticulated anterior border but the posterior border is not denticulated.

2. Neck:

Head is followed by the neck. The neck is short and devoid of gular pouches. There are prominent folds of skin on the ventral and lateral sides of the neck when the animal is at rest but these folds disappear when the animal stretches out its neck.

3. Trunk:

The neck is followed by the long, broad and depressed trunk to which are attached two pairs of limbs. The trunk is smooth and flattened ventrally but rough and convex dorsally. Its lateral sides skin is loosely folded. On the ventral surface a thick-lipped transverse cloacal aperture is placed at the junction of the trunk and the tail.

4. Tail:

The tail is long, thick and strongly depressed, wide at the base and tapers toowards posteriorly. There are about twenty transverse rows of hard and strongly keeled scales covering the dorsal surface of the tail. These scales form a sort of armour for self-defence and it also check the loss of water. Due to the presence of spiny scales on the tail*Uromastix* is also called the spiny-tailed lizard. Behind the cloacal aperture on the ventral side at the broad base of the tail is present a pair of nodule-like swellings which are due to the presence of hemi-penis in male.

According to Keith (1955) the whole body of *Uromastix* is covered with scales. The scales present on the dorsal surface of the head are unequal, smooth or keeled. These are larger on the snout but become smaller towards the eye. The scales on the cheeks are oval and 12-14 in number. These are called upper labials.The scales present on the dorsal surface are small, numerous with or without larger scales lying between them. The ventral scales are sub-quadrangular in shape and they are bigger even than the bigger dorsal scales. The gular scales are rounded and smaller than ventral. On the tail are present spinose scales. Due to the presence of spinose scales *Uromastix* is called spiny-tailed lizard.

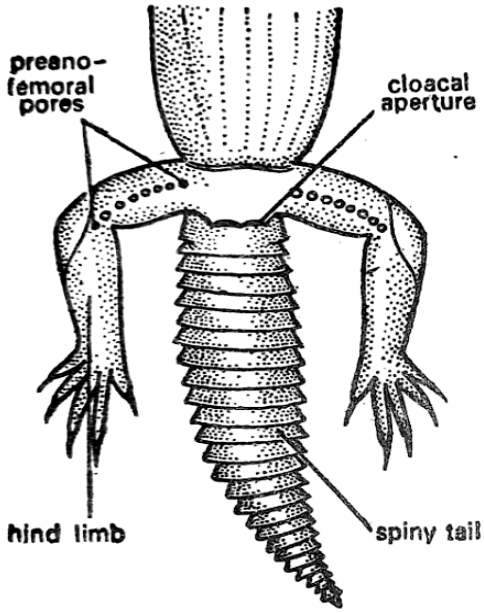


Fig : *Uromastix* Posterior tail part

Sexual Dimorphism:

In the male, the cloaca possesses a pair of protrusible copulatory organs, called hemi-penis. These open separately into the proctodaeum. These are absent in females. In the male, in breeding season, a pair of nodule-like swellings appears ventrally at the base of the tail just behind cloacal aperture. These are also absent in females. Besides these, preanofemoral pores on the ventral surface of thighs are conspicuous in male than in the female.

Appendages:

There are two pairs of limbs emerging laterally from the trunk-one pair of forelimbs and one pair of hindlimbs. They are pentadactyle type and adapted for burrowing.

1. **Forelimbs:**

   The forelimbs arise laterally from the trunk just behind the neck. These are shorter than the hindlimbs. Each forelimb consists of the usual three parts, viz., upper arm or brachium, the forearm or antebrachium and the hand possessing the five digits or fingers. The first finger or pollex is the smallest and the fourth is the largest. All the digits end in pointed curved claws. The lower surface of hand bears transverse rows of leaf-like adhesive pads.

2. **Hindlimbs:**

   The hindlimbs arise from the posterior end of the trunk. Each hindlimb consists of a proximal thigh, middle shank or crus and distal foot or pes provided with five clawed toes. The digits of the hindlimbs gradually increase in length- the first or the hallux is the smallest and the fourth is much longer, while the fifth is again small. All the digits are provided with strongly curved claws.

3. **Preanofemoral pores:**

   There are about 9 to 18 prominent pores arranged in a curved row on the ventral surface of both thighs from cloaca to the knee-joint. These are called preanofemoral pores and more prominent in male. Each pore is surrounded by a ring of scales, amongst which one is larger than the others. Each pore leads into a tubular gland producing a horny secretion which

foams temporary spines which help in copulation.

Skin or Integument:

The skin of *Uromastix* is rough, dry and scaly and has almost no glands. It prevents the loss of water. This is an adaptation to prevent evaporation of water. Histologically skin shows two layers- an outer epidermis and an inner dermis.

1. **Epidermis:**

   The epidermis is stratified layer and derived from ectoderm. It consist of several layers. The epidermis having a well developed stratum corneum or horny layer which serves admirably to protect the lizard from desiccation.The stratum corneum is composed of thin, flattened and dead cells due to the deposition of horny scleroprotein or keratin. The epidermis produces horny scales covering the body. This layer is sloughed off periodically in flakes (ecdysis). Below this is a layer of chromatophores, which are not found in the skin of those areas which are covered with scales.At the base of epidermis lies a single-layered germinal epithelium with prominent nuclei. The germinal epithelium proliferates cells which move outward and form the stratum corneum. The horny layers covering the terminal ends of digits form the claws.

2. **Dermis:**

   The dermis lies beneath the epidermis. It is a well developed thick layer of dense fibrous connective tissue. It contains muscle-fibres, blood vessels, nerves and chromatophores. The scales covering the entire surface of the animal are formed from special folds of dermis.There are no glands in the skin except a few femoral glands which are found on the ventral surface of the thigh. These glands secrete a substance in males that hardens into temporary spines which help in clasping the female at the time of copulation.

3. **Muscles:**

   Below the body wall or skin is present a layer of muscles which help in locomotion. Beneath the muscle layer is the peritoneum which is formed of closely fitting mesodermal cells. It encloses the body cavity.

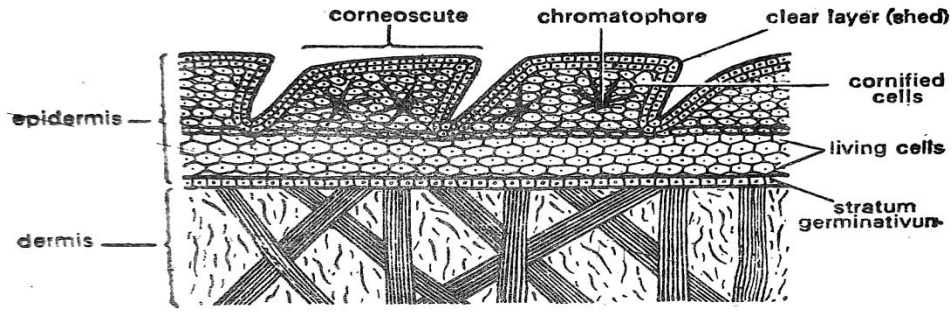


Fig : V.S. of skin

<u>Digestive system</u>

The mouth open in a fairly a wide gaps bounded by the upper and lower immovable and muscular lips. The mouth opens into the buccal cavity. The buccal cavity is narrow infront but broad posteriorly. It is lined with mucous membrane and contains teeth, tongue and internal nares. The teeth are present on the premaxilla and maxillae of upper jaw and dentaries of lower jaw. They are acrodont. The tongue is anteriorly narrow end is free and notched (bifid) at the tip and protrusible. The posterior broad end is fixed and widely bifurcated. The buccal cavity opens into the pharynx.

The pharynx opens into oesophagus. The oesophagus open into a long, cylindrical sac like structure called stomach. The stomach appears U-shaped differentiated into 2 parts anterior part is cardiac stomach and posterior is pyloric stomach. The pyloric stomach open into a small intestine, which is long, narrow and coiled tube. The small intestine is divided into duodenum and ileum. The ileum opens into the large intestine. The large intestine is differentiated into anteriorly thin walled colon and posteriorly thick walled rectum. The anterior part of colon is dilated into a blind pouch the caecum. An ileo-colic valve is present internally at the junction of ileum and caecum. The function of colon is the formation of faeces and absorption of water. The colon open into the rectum, which is short, tubular and thick walled and serve to store the faeces. The rectum opens into the cloaca which opens to the exterior by the cloacal aperture. The cloaca is divisible into 3 chambers, the protodeum, urodaeum and coprodaeum. The division of cloaca into chambers serves for re-absorption of water both from the faeces and urine.

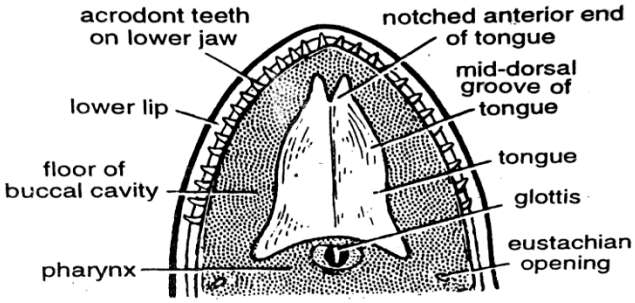


Fig : *Uromastix* : Floor of buccal cavity

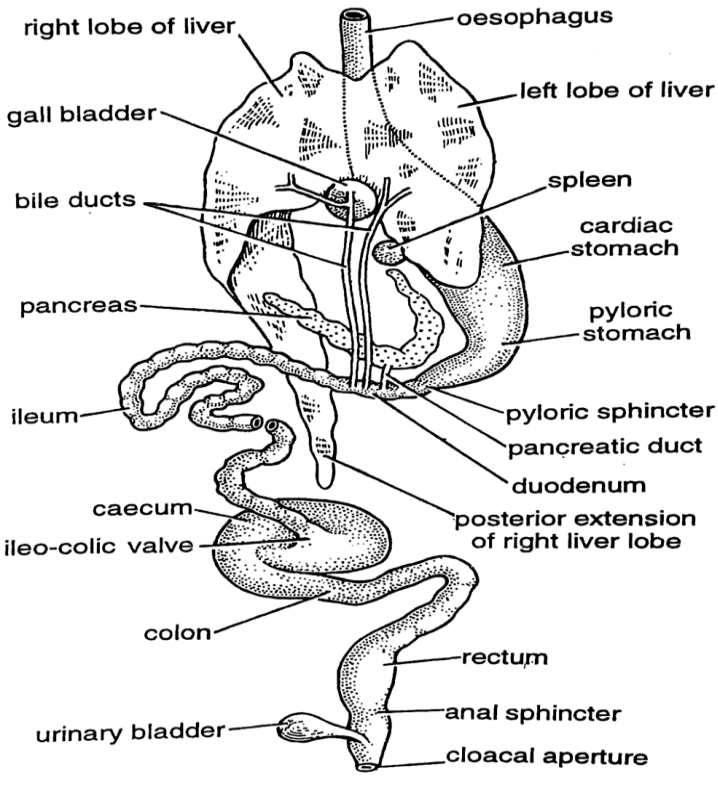


Fig : *Uromastix* Alimentary canal

Digestive gland

***Salivary gland* :** There are a few salivary glands which open into the buccal activity and secrete

mucus.

Liver : It is a large, bilobed gland dark red in colour. The right lobe of liver is larger, narrower and longer and its posterior end reaching up to the right gonad. The left lobe is shorter & broader.

Pancreas : It lies between the stomach & duodenum.

Respiratory System

The respiratory system of *Uromastix* consists of two parts i.e. respiratory tract and respiratory organs.

Respiratory Tract:

It starts from the external nares. These are a pair of small oval apertures on the snout slightly above the mouth. On its inner side each nare possesses a prominent swelling of mucous membrane which serves as a valve to close the aperture during burrowing. The external nares lead into small sacs called nasal chambers or olfactory sacs which lying in the skull.The nasal chambers open posteriorly by a pair of small apertures called internal nares into the anterior part of a spacious bucco-pharyngeal cavity. On the floor of bucco-pharyngeal cavity between the basal bifurcations of the tongue lies a small median longitudinal slit called the glottis which leads into a short median chamber called larynx.The wall of larynx is supported by a pair of arytenoid and a median cricoid cartilages. The arytenoid cartilages are situated in the antero-lateral wall of the larynx and give support to the lips of glottis. Posteriorly these two cartilages articulate with the antero-lateral sides of the cricoid cartilage. In *Uromastix* vocal cords are lacking.The larynx is provided with two pairs of muscles- the inner musculus compressor laryngis which serves as a sphincter of the glottis and the outer musculus dilator laryngis which serves as a dilator of glottis. The larynx leads posteriorly into the trachea; which is an elongated cylindrical tube running backwards through the neck ventral to oesophagus.

The wall of the trachea is supported by a series of complete cartilaginous rings throughout its length which prevent the trachea to collapse. Some of the tracheal rings are bifurcated. After entering the thorax the trachea bifurcates into two very short narrow tubes called bronchi, which are also supported by complete cartilaginous rings. Each bronchus enters the lung of its side and does not branch into intrapulmonary extensions or bronchioles.

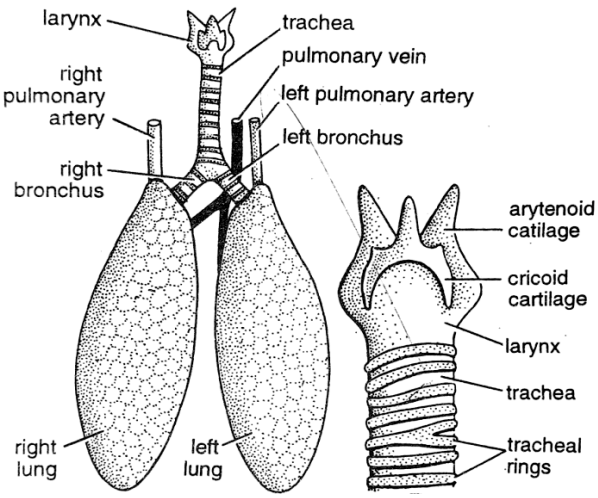


Fig: *Uromastix* (A) Respiratory system in ventral view

(B) Larynx and trachea in dorsal view

Respiratory Organs:

Uromastix have a pair of lungs. They are situated one on either side of the heart in the thoracic cavity. Both the lungs are symmetrical in shape and size. They are elongated, fusiform, thin-walled elastic hollow sacs of orange colour. The posterior ends of lungs appear pointed when they are empty but rounded when they are inflated.The inner lining of the lungs is raised into a network of low ridges which enclose shallow depressions or alveoli. The cavity of the lung is continuous. These ridges are more numerous and closer in the anterior part of the lung than in the posterior part. The ridges increase the respiratory surface area of lungs. The walls of the lungs and alveoli have a rich supply of blood-capillaries.The blood supply is more abundant in the anterior part of the lungs than in the posterior part. So the anterior parts of the lungs are more respiratory than the posterior parts. The bronchi do not branch into bronchioles in the lungs. The blood entering the lungs through pulmonary artery is deoxygenated and the oxygenated blood is carried to the heart by pulmonary vein.

Mechanism of Respiration:

In the*Uromastix* process of respiration is brought about by their ribs and their inter-costal muscles. The inter-costal muscles bring about the increase or decrease in the size of pleuro-peritoneal cavity. When the cavity is increased the lungs expand and fresh air enters into the lungs from outside through the nostrils, buccal cavity, glottis, trachea and bonchii. When the cavity is decreased the lungs are pressed and the air is forced out through the same above passage. Exchange of gases takes place in the alveoli through their thin moist walls. In *Uromastix* the respiration is only pulmonary.

Circulatory System

The circulatory systemof *Uromastix* is closed type and consists of three parts:

1. The Heart
2. The Blood Vessels (Arteries and Veins)
3. The Blood.

1. Heart:

The heart of *Uromatix*is 3 chambered but the ventricle is incompletely divide by inter-ventricular septum, which arises from the apex of ventricle. The sinous venous is bilobed and reduced and open into the right auricle. The opening is guarded by valve. The pulmonary vein brings oxygenated blood and open into left auricle. The right auricle is always bigger than left auricle. The inner wall of right auricle having interlacing muscle which is known as musculi pectinate. The right and left auricle open into ventricle by atrio-ventriculo aperture guarded by valve. The ventricle is muscular which is incompletely divided by an inter-ventricular septum arising from the apex. This inter ventricular septum divide the ventricle into a large cavity on the right side which is known as cavum dorsal and smaller on the left side is known as cavum pulmonale. The trunous arterious disappear and spilt and which arises directly from the ventricle. The opening of each is guarded by 3 semi-lunar valves. The right systemic which is also known as cartico-systemic arises from the left ventricle carrying oxygenated blood. From the right ventricle arises 2 aortic arches, the inner aortic arches is known as left systemic aortic arch because it travel (goes) supplies the left side. The right and left aortic arches communicate with each other by a common opening known as foramen of Panizzae. From the outer side of the right ventricle arises 3rd aortic arch known as pulmonary aortic carrying de-oxygenated blood to the lung.

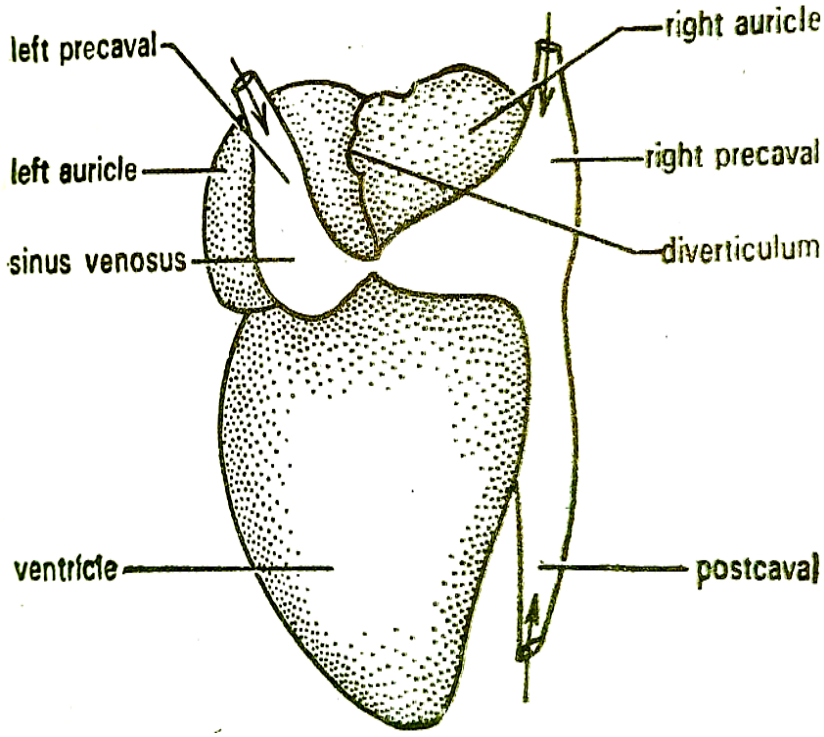


Fig: External feature of heart dorsal view

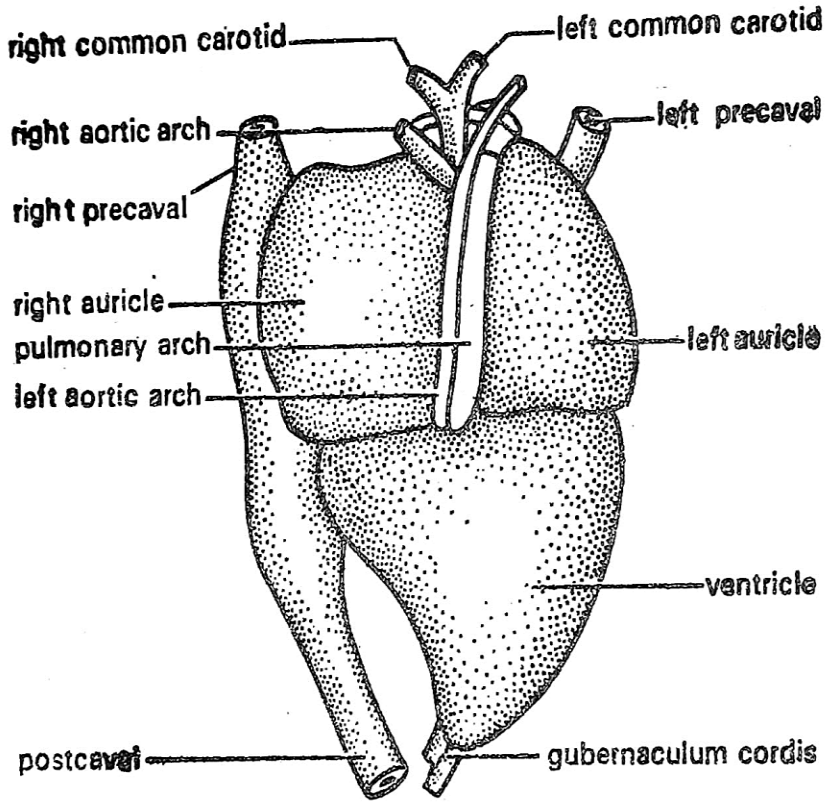


Fig : External feature of heart ventral view

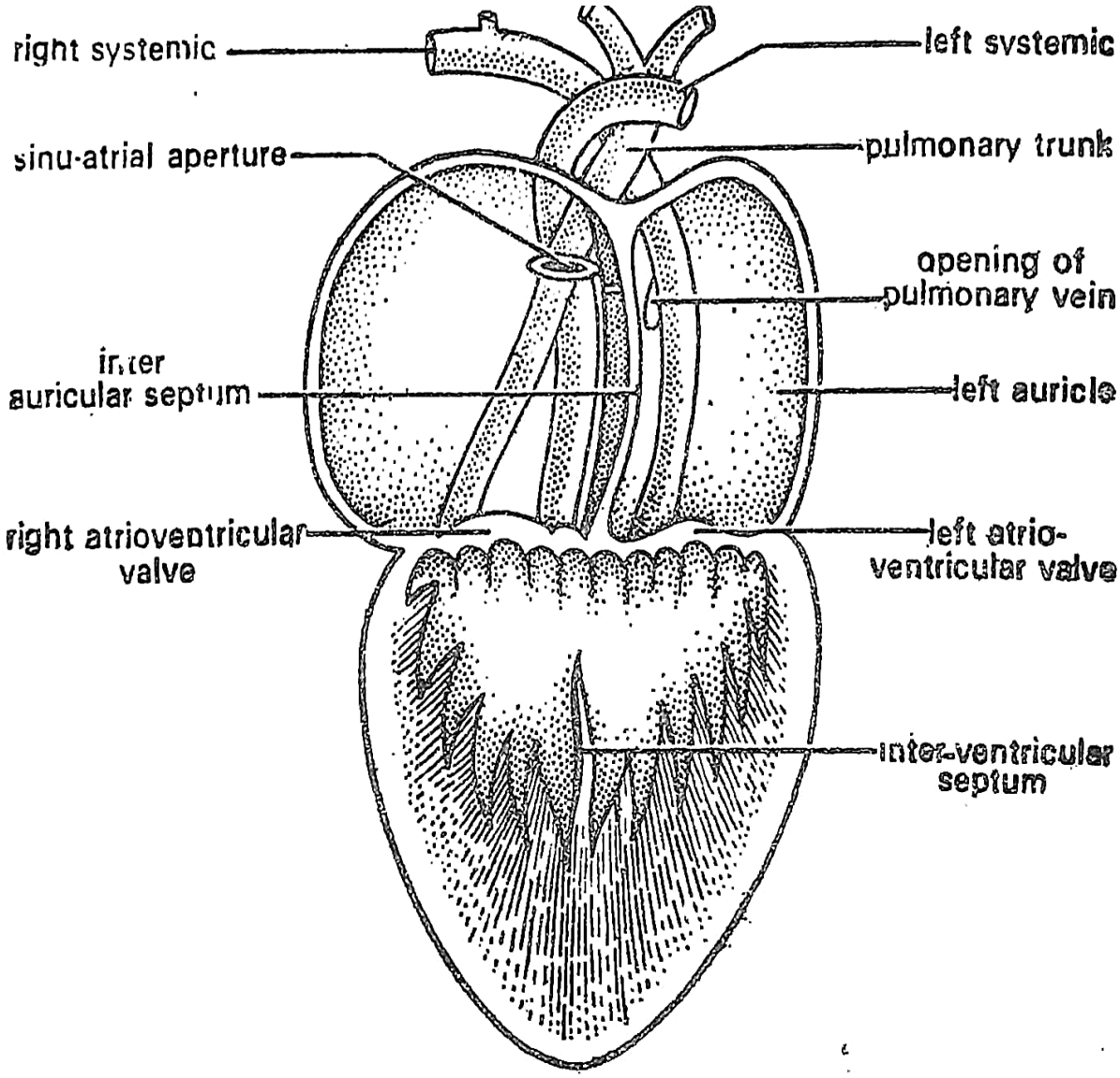
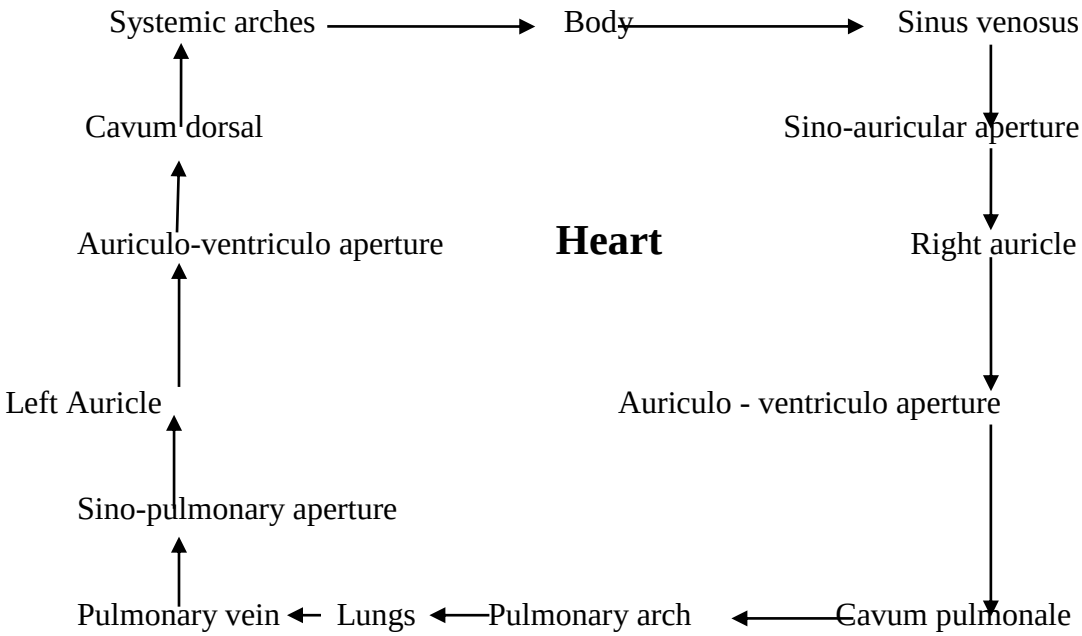


Fig :*Uromatix* Internal structure of heart

Working of Heart:

The sinus venosus receives deoxygenated blood from the whole body by way of three venae cavae. When the sinus venosus contracts, it's drives the blood into the right auricle through the sinu-auricular aperture. In the mean time the left auricle receives oxygenated blood from the lungs through the pulmonary vein.Now the auricles contract almost simultaneously forcing the deoxygenated blood from the right auricle into the cavum pulmonale (right side of the ventricle). During this process, return of blood to the sinus venosus is prevented by the sinu-auricular valves. From the left auricle the oxygenated blood enters into the cavum dorsale (left side of the ventricle).In the middle portion of the ventricle some mixing of pure and deoxygenated blood takes place. Now the ventricle contracts in such a way that the muscular ridge keeps the deoxygenated and oxygenated blood separate. The contraction of ventricle sends the deoxygenated blood from the cavum pulmonale into the pulmonary arch and the oxygenated and partly mixed blood from the cavum-dorsale into the systemic arches which is distributed to the entire body.The head receives the purest blood. The return of blood from the ventricle into the auricles, during the contraction of ventricle, is prevented by the auriculo-ventricular valves. The return of blood from the aortic arches in the ventricle is checked by the semi-lunar valves at the base of arches.

The flow of blood circulation is as follow in *Uromastrix*



2. Blood Vessels:

There are two types of blood vessels i.e. arteries and veins. The arteries carry blood from the heart to the various organs of the body and collectively form the arterial system. The veins collect blood from various organs of the body and return it to the heart and collectively form the venous system. The arteries and veins are connected by way of capillaries.

Arterial System :

There are three aortic arches which arise independently from the ventricle these arethe pulmonary arch and aright and left systemic arches.

(A) Pulmonary Arch: The pulmonary arch lies ventrally and arises from the right ventral side of the ventricle (cavum pulmonale). It travels forwards and curves and becomes dorsal to the left systemic arch, where it soon divides into right pulmonary and left pulmonary arteries going to the right and left lungs respectively.

(B) Systemic Arches: Both the systemic arches arise directly from the cavum dorsale of the ventricle carrying oxygenated blood. The left systemic arch is fully visible in the ventral view of the heart. It arises from the right side of the ventricle but curves later to the left and carries mixed blood. The right systemic arch arises from the left side of the ventricle and lies dorsal to both the pulmonary and the left systemic arches. Later it curves to the right side. The two systemic arches communicate with one another by a foramen of Panizzae situated where the arches cross each other anterior to the heart. Both the systemic arches then turn upwards, backwards and inwards and join posterior to the heart in the mid-dorsal line to form dorsal aorta.The right systemic arch gives off a very short artery before it starts curving to the right in the notch between the two auricles which is called the innominate artery. The right systemic arch also gives off a common subclavian artery before joining the left systemic arch.

(a) Common Carotid Arteries:

The innominate arises from the right systemic arch and it bifurcates to form the right and left common carotid arteries. Each common carotid runs forward for some distance

parallel to the systemic arch of its side and then divides into the external and the internal carotid arteries.The external and the internal carotid arteries extend forwards through the neck both of which branch into numerous arteries supplying oxygenated blood to the head anterior mesenteric region. Each internal carotid artery is connected with the systemic arch of its side by a vessel called the ductus caroticus.

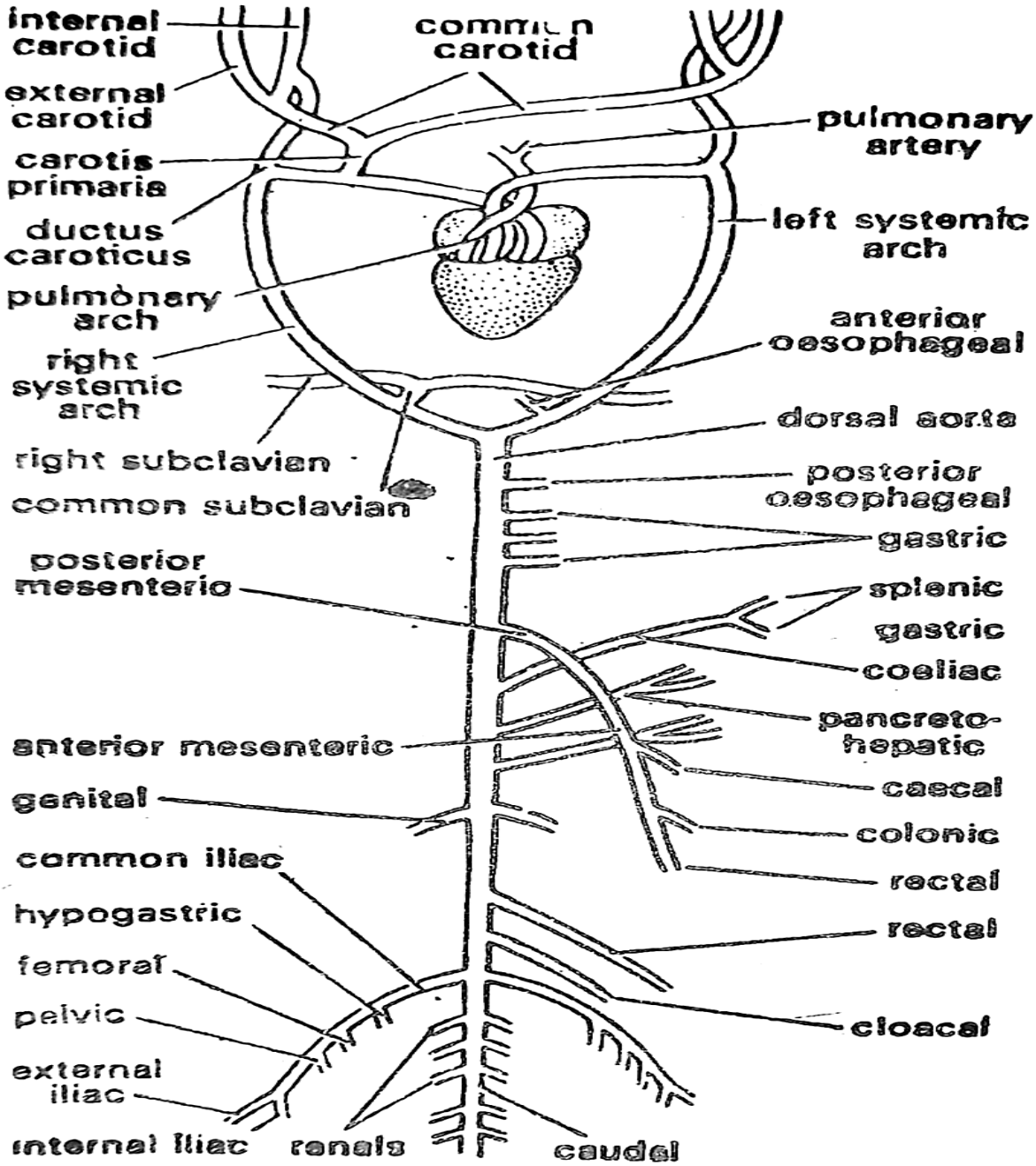


Fig: *Uromatix* Arterial system

(b) Common Subclavian Artery:

It arises from the right systemic arch before it joins the left systemic arch. It soon divides into the right and the left subclavian arteries which run outwards to supply the respective forelimb. Each subclavian artery gives off three vessels i.e. scapular to the scapular region, coracoid to the coracoid muscles and brachial to the arm.

(c) Anterior Oesophageal Artery:

The left systematic arch also gives off a small anterior oesophageal artery which supplies the anterior part of the oesophagus.

Dorsal aorta:

The dorsal aorta is formed by the union of the right and left systemic arches.**It extends straight backwards in the mid-dorsal line beneath the vertebral column and giving off the following arteries:**

(i) Posterior Oesophageal Artery: Just after the formation of the dorsal aorta, a small unpaired artery arises from it which is called the posterior oesophageal artery. It supplies blood to the posterior part of the oesophagus.

(ii) Gastric Arteries: Three small unpaired gastric arteries arise behind the posterior oesophageal artery. These arteries supply blood to the anterior, middle and posterior part of stomach and are called anterior, middle and posterior gastric arteries.

(iii) Posterior Mesenteric Artery: The posterior mesenteric artery is large and unpaired, arises far forward at the level of the fifth parietal just in front of the origin of coeliac. It runs backwards and distributes blood to the large intestine by three branches are caecal, colic (colon) and rectal.

(iv) Coeliac Artery: It arises behind the posterior mesenteric and runs forwards crosses the posterior mesenteric and supplies blood to the spleen and to stomach by two branches are spleenic and gastric.

(v) Pancreao-Hepatic Artery: It is a fairly large unpaired vessel supplying blood to the duodenum, liver and pancreas.

(vi) Anterior Mesenteric or Intestinal Artery: It arises behind the pancreao-hepatic artery and supplies blood to the entire small intestine by a number of branches.

(vii) Genital or Gonadial Arteries: These are paired arise near the tenth parietal and supply blood to the gonads and supra-renal glands. They are called spermatic arteries in the male and ovarian arteries in the female.

(viii) Rectal Artery: It is an unpaired artery, arises in between the 13^{th} and 14^{th} parietals. It passes down along the dorsal wall of the rectum and supplies blood to it.

(ix) Cloacal Artery: It is an unpaired median artery which arises close to the common iliac arteries. It supplies blood to the lateral wall of the cloaca and the terminal portion of the rectum.

(x) Common Iliac Arteries:A pair of large common iliac arteries arises near the middle region of the kidneys and enters the hind-limbs. Before entering the limbs each common iliac artery gives off a hypo-gastric artery to the urinary bladder, a femoral artery to the thigh muscles and a pelvic artery to the pelvic girdle and the fat bodies. It supplies the hind-limbs by two branches are external and internal iliac arteries.

(xi) Renal Arteries: Three pairs of small renal arteries supply blood to the kidneys.

(xii) Caudal Artery: The posterior end of the dorsal aorta continues behind as the caudal artery. The caudal artery runs through the haemal canal of the caudal

vertebrae.

(xiii) SParietal Arteries: During its course, the dorsal aorta also gives off about 15 pairs of small parietal arteries supplying blood to the trunk muscles and caudal muscles.

Venous System

The left auricle receive the blood by two pulmonary veins from lungs. The blood from the other parts of the body is returned by three large veins are two pre-cavals (right and left) return the blood from the anterior side, while the post-caval veins return the blood from the posterior side and enter into the bilobed sinus venosus which joins the right auricle.The venous system of *Uromastix* consists of following veins:

a. Pre-caval veins;

b. Post-caval vein;

c. Hepatic portal vein;

d. Renal portal vein.

(a) Pre-caval Veins: There are two pre-caval veins the right and left which drain the blood from the anterior body region like head, neck, shoulders, forearms and thoracic wall.Each pre-caval is formed by the union of four veins:

(i) Common jugular,

(ii) Subclavian,

(iii) Inter-costal and

(iv) laryngo-tracheal.

(i) Common Jugular Vein:

The common jugular vein is formed by the union of external and internal jugular veins at the level of the tympanum. The external jugular vein receives blood from the upper jaw by a maxillary vein and from the lower jaw by a mandibular vein. The internal jugular receives blood from the brain by a cerebral vein and from the orbital region by an orbital vein.The common jugular runs back into the neck where it receives blood from the auditory region of the head by a temporal vein. A little behind the junction of common jugular vein and temporal vein there is a large sinus (expansion) called jugular sinus.

(ii) Subclavian Vein: The large subclavian vein runs inwards from the forelimb and joins the posterior end of jugular sinus.**The subclavian vein receives blood from the arm through three small veins:**

(a) Scapular from the shoulder region

(b) Brachial from the arm

(c) Axillary from the arm-pit and thorax

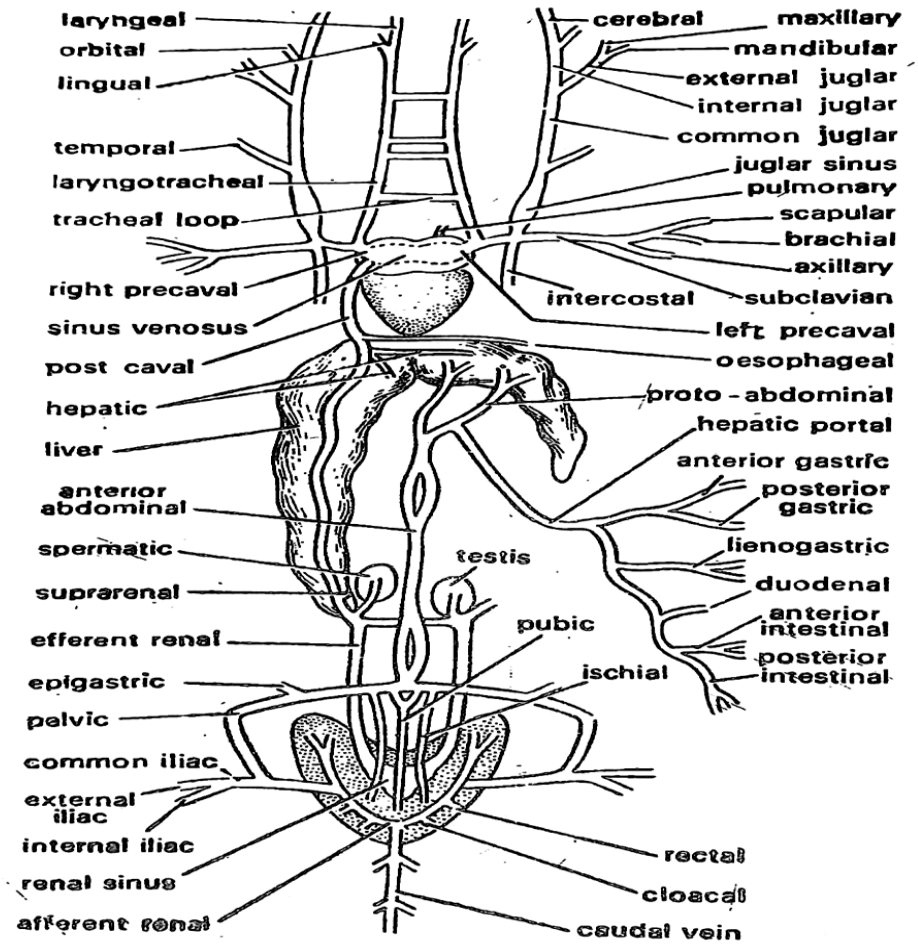


Fig: *Uromatix* Venous system

(iii) Inter-costal Vein:

The inter-costal vein collects blood from the skin and muscles of the chest and runs forwards to meet the pre-caval vein internal to subclavian. By the union of common jugular, temporal, subclavian and intercostal, a large pre-caval vein is formed that opens into the sinus venosus.

(iv) Laryngo-tracheal Vein: The laryngo-tracheal vein is a very slender vessel. It receives a very fine lingual vein from the tongue and a laryngeal vein from the larynx and trachea. It then passes backwards alongside of the trachea and joins the pre-caval close to its entry into the sinus venosus.The two laryngo-tracheal veins are symmetrical running parallel to the trachea and are interconnected by four or five transverse tracheal loops.

(b) Post-caval Vein: The post-caval vein opens into the right posterior angle of the sinus venosus. It collects blood from the posterior region of the body i.e. kidneys, gonads and liver. It arises from the region of kidneys. Blood from the kidneys is collected through capillaries in a thin-walled renal sinus lying in the middle region of the kidneys.A pair of efferent renal veins commences from the renal sinus and pass forwards along the sides of the vertebral column up to the gonads being separated from one another by a pad of connective tissue. The right efferent renal vein is thicker than the left. Both the efferent renal veins receive blood from dorsal bodywall through a few small veins in the way. Just behind the gonad the left efferent renal vein sharply bends medially and joins the right efferent renal vein to form the commissural vein. A small genital vein from the gonads and a fine supra-renal vein from the supra-renal gland on each side pours into the commissural vein or the efferent renal vein of

that side.Only the right efferent renal vein proceeds as the post-caval vein, which passes through the right lobe of the liver and opens into the sinus venosus. The post-caval vein during its course also receives two or more hepatic veins from the liver and a small vertebral vein from the backbone. A small oesophageal vein from the oesophagus joins the post-caval after its emergence from the liver.

(c) Pulmonary Vein:

There is a single pulmonary vein formed by the union of several veins from both the lungs. It runs along the ventro-lateral border of the trachea and passes dorsally to the sinus venosus before opening into the left auricle close to the inter-auricular septum. It is the only vein which carries oxygenated blood.

(d) Hepatic Portal Vein:

The blood rich food from various regions of digestive tract is carried to the liver by hepatic portal vein. It is formed by the union of several veins from the different regions of the alimentary tract such as the anterior and posterior gastric veins from the stomach, lieno-gastric vein from the spleen and a part of the stomach, duodenal vein from the duodenum, anterior intestinal from the ileum and posterior intestinal from the caecum, colon, and rectum.The hepatic portal vein and all its tributaries run in the mesentery. Anteriorly, the hepatic portal vein receives a branch of the anterior abdominal vein called the porto-abdominal vein and enters the middle of the left lobe of the liver where it capillarises. Blood from the liver as is collected by the hepatic veins and poured into the post-caval. The hepatic portal system is formed by the hepatic portal vein and porto-abdominal vein.

(e) Renal Portal and Anterior Abdominal Veins:

The deoxygenated blood from tail is collected by a median caudal vein. The caudal vein starts from the tip of the tail and runs in the haemal canal of the caudal vertebrae receiving on its way several paired branches from the tail muscles. The caudal vein after reaching the kidneys divides into a pair of diverging renal portal or afferent renal veins.The afferent renal veins pass over the ventral surface of the kidneys partly buried in their substance. They receive cloacal and rectal veins from the cloaca and rectum respectively. The renal portal vein of each side continues forward into the kidney its side and ramifies into capillaries.

The venous blood from each hindlimb is collected by the internal (sciatic) and external iliac (femoral) veins. These two unite after entering the abdominal cavity to form a common iliac vein which is connected to the renal portal vein by a transverse connection (iliac-afferent union) near the middle of the kidney. Each common iliac vein extends forwards as the pelvic or lateral vein along the dorsal surface of the large yellow fat body.The pelvic vein receives in the way fine adipose veins from the fat body, ischial vein and epigastric vein from the dorsal bodywall, vesicular vein from the urinary bladder and parietal veins from the posterior muscles. A fine median pubic vein joins both the pelvic veins. The two pelvic veins converge in front of the kidneys and unite in the mid-ventral line to form the anterior abdominal vein. The anterior abdominal vein is formed by the imperfect union of two pelvic veins.

3. Blood:

*Uromastix*are cold-blooded or poikilothermous. Red cells are nucleated. The total haemoglobin concentrations and oxygen carrying power of the blood are less. The white blood cells are eosinophils, basophils neutrophils, lymphocytes and monocytes.

Nervous system

The nervous system in *Uromastix* is consists of central nervous system, peripheral nervous system and autonomic nervous system. The central nervous system consists of brain and spinal cord.

1. Brain:

The brain of*Uromastix* is very simple. The brain is surrounded by two layer outer tough fibrous membrane durameter and inner vascular piameter. In between the two layers arachnoid fluid is present which protects the brain.**The brain of *Uromastix* is divided into the three parts:**

(i) The forebrain,

(ii) Midbrain and

(iii) Hindbrain.

(i) Forebrain:

The forebrain forms the anterior part of the brain. It consists of large swollen and elongated cerebral hemispheres, olfactory bulbs and diencephalon. It consists of three partscerebral hemispheres, olfactory bulbs &diencephalon.

(a) Olfactory Bulbs:A pair of smaller olfactory bulbs and their posterior narrow stalks, olfactory peduncles by which they are attached with their corresponding cerebral hemispheres, are the anterior parts of the forebrain. From olfactory bulbs originate the olfactory nerves. The cavity of each olfactory bulb is called rhinocoel.

(b) Cerebral Hemispheres: The cerebral hemispheres are two oval structures. It is narrow in front but broad behind closely applied together in the median line but a dorsal median longitudinal fissure forms the demarcation between the two.The roof of each cerebral hemisphere is thin and called the pallium and the thick ventral and lateral walls together constitute the corpus striatum. The pallium in *Uromastix* is thick. In *Uromastix* the cerebral hemispheres are large due to large fibrous tracts called corpora striata.The two corpora striata are connected by a transverse anterior commissure which receives many efferent fibres from the side walls of the diencephalon. Above the anterior commissure lies the hippocampal commissure which connects the hippocampal regions of the cerebral hemispheres. Each cerebral hemisphere encloses a cavity, the lateral ventricle or paracoel which is continuous in front with the rhinocoel of the olfactory lobe of its side.

(c) Diencephalon:

The diencephalon is a small rounded area situated between the cerebral hemispheres and the midbrain. The lateral walls of the diencephalon are thick forming the optic thalami. The thick floor forms the hypothalamus. The roof of the diencephalon is thin-walled and highly vascular forming the anterior choroid plexus.Behind the anterior choroid plexus lie the habenular commissure and posterior commissure which is a transverse band of nerve fibres. From the thin dorsal surface of the diencephalon arises a median outgrowth, the pineal apparatus, which consists of two parts, the anterior parietal organ or parietal eye lying in the parietal foramen and the posterior pineal body or epiphysis.The parietal organ or parietal eye is considered to be functional eye. From the thick ventral surface of the diencephalon arises an infundibulum behind which is attached the pituitary body or hypophysis. Optic chiasma is situated anterior to the infundibulum.Optic chiasma is formed by the crossing of two optic nerves. Diencephalon encloses a laterally compressed cavity, the diacoel or third ventricle, which communicates with the lateral ventricles of the cerebral hemispheres by a small

common aperture the foramen of Monro.

(ii) Midbrain:

The midbrain consists of two dorso-laterally placed rounded optic-lobes. On the ventral surface of the midbrain lie two bands of longitudinal, nerve fibres, stretching between the forebrain in front and the medulla oblongata behind, these are the crura cerebri.Each optic lobe contains a ventricle called the optocoel. The two optocoels open into a narrow median canal, the iter, which connects the diacoel (cavity of diencephalon) in front and the metacoel (cavity of cerebellum) behind.

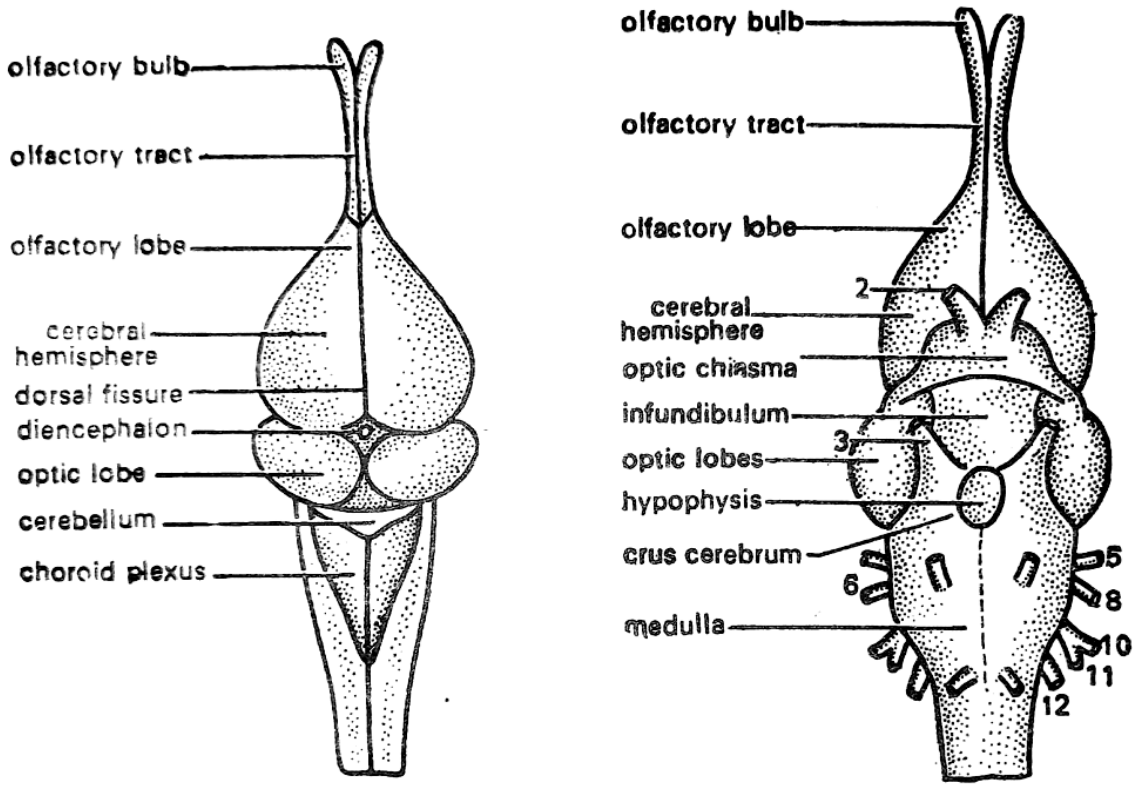
(iii) Hindbrain:

The hindbrain consist of the cerebellum and the medulla oblongata.

(a) Cerebellum: The cerebellum is poorly developed in *Uromastix*. It is merely a flattened semicircular ridge at the anterior dorsal surface of the medulla oblongata.

(b) Medulla Oblongata: The medulla oblongata is the posterior part of the brain. It is broad in front and narrow behind. It has a prominent ventral flexure where it passes into the spinal cord. The roof of the medulla is thin, vascular and folded forming the posterior choroid plexus. It encloses a cavity called fourth ventricle or metacoel or myelocoel. Its cavity is connected with the diocoel through a narrow median passage, the iter.

All the ventricles of the brain are continuous and posteriorly connected with the cavity of the spinal cord and full of a watery fluid called cerebro-spinal fluid secreted by the choroid plexuses.



(A) Dorsal view **(B) Ventral view**

Fig : *Uromastix* Brain (A) Dorsal view (B) Ventral view

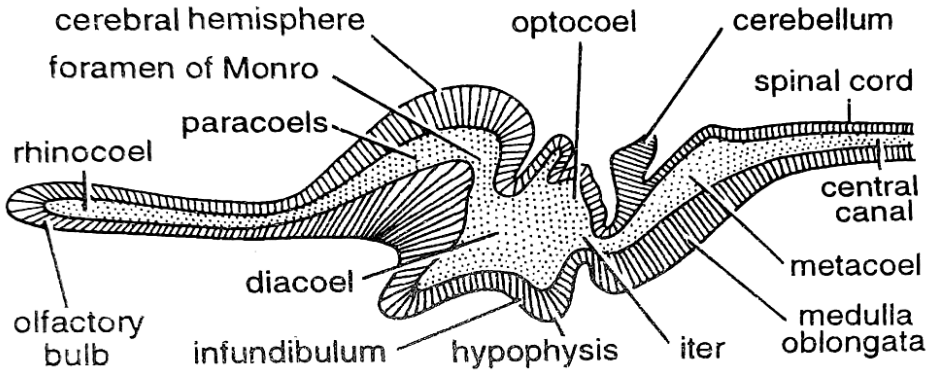


Fig : Brain in sagittal section showing ventricles

Histology of Brain

The brain is composed of two types of nervous tissue, the grey matter and white matter. The grey matter is composed of nervecells and the white matter consists of nerve fibres. In the forebrain the grey matter is external and white matter is internal, while in the midbrain and medulla oblongata the arrangement is reverse of this.

Functions of Brain:

- The olfactory lobes control the sense of smell.
- The cerebral hemispheres get the impulses from the sense organs and initiate motor impulses for voluntary movements. The cerebral hemispheres are the seat of intelligence, memory, emotions and will.
- The diencephalon acts as a relay station in conveying the impulses to the cerebral hemispheres and as integrating centre for the autonomic nervous system,
- The optic lobes are concerned with the sense of sight. The crura cerebri carry the sensory impulses from the medulla oblongata and the spinal cord to the optic thalami and then to the cerebral hemispheres.
- The cerebellum coordinates the voluntary movements and also maintains the equilibrium.
- The medulla oblongata controls the involuntary movements. Therefore, it is regarded as the most important part of the brain.

2. Spinal Cord:

The spinal cord is a long, whitish and dorso-ventrally flattened tube. It is situated in the neural canal of the vertebral column. It is also covered by the same covering of the brain. A very shallow groove, the dorsal fissure, occurs along the mid-dorsal line of the cord. A prominent mid-ventral groove called the ventral fissure extends along the entire length of the spinal cord.A thin longitudinal vertical septum of connective tissue lies in the thickness of the spinal cord beneath the dorsal fissure. The spinal cord encloses a narrow central cavity known as central canal. The central canal opens anteriorly into the fourth ventricle of the medulla oblongata but is closed posteriorly. It is filled with the cerebro-spinal fluid.The spinal cord is composed of two types of nervous tissue inner grey matter and the outer white matter. In cross section the grey matter is appeared as H-shaped with prominent dorsal and ventral columns or cornua from which arise the dorsal and ventral roots of the spinal nerves.

The grey matter is mainly composed of nerve cells and non-medullated nerve-fibres. The white matter is divisible into the dorsal, ventral and lateral funiculi. It comprises medullated nerve fibres.The spinal cord conducts sensory and motor impulses to and from the brain. It is also a centre of reflex action.

B. Peripheral Nervous System:

The peripheral nervous system consists of twelve pairs of cranial nerves from the brain and sixteen pairs of spinal nerves from the spinal cord. The eleventh or accessory and the twelfth or hypoglossal originate from the medulla behind the tenth pair and innervate the muscles of larynx, neck and tongue. The sixteen pairs of spinal nerves originate by two roots, dorsal and ventral, as in other vertebrates.

C. Autonomic Nervous System:

The autonomic nervous system consists of two conspicuous white ganglionated sympathetic trunks which are continued along each side of the vertebral column. Each of these autonomic trunk ganglion is connected with the corresponding spinal nerve by ramus communicans. The autonomic nervous system performs both sensory and motor functions and helps to regulate involuntary reaction.

Sense Organ

Olfactory Organs:

The olfactory organs are more complex in*Uromastix*. The nasal cavities open at the end of the snout by the external nares and by a pair of slit-like internal nares situated near the middle line of the palate open into the cavity of the mouth. The external nares open into the vestibule through which air passes to the sensory epithelium of the nasal or olfactory cavity. The nasal cavity contains a convoluted turbinal bone over which the mucous membrane extends.Its cell are sensitive to chemicals in solution. In *Uromastix* there are a pair of vomero-nasal organs or organs of Jacobson. The organs of Jacobson are well developed sac-like chambers lying below the nasal cavity but above the buccal cavity. Each organ consists of a blind sac lined with olfactory epithelium. It develops as a ventral hollow outgrowth of the nasal cavity. They are lined with olfactory epitheliumin front of the internal nares.

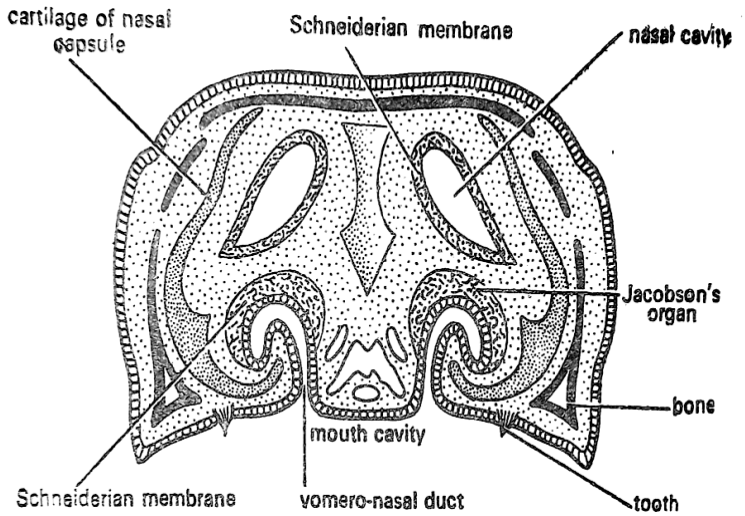


Fig : T.S. of head showing Jacobson's organ

Jacobson's Organs:

The organ of Jacobson is innervated by branches of the olfactory and the trigeminal nerves. These organs serve to smell the food when it has been taken into the buccal cavity.

Eyes :

The eyes of *Uromastix* exhibit eyelids. Both the eyelids are movable but the lower eyelid is more movable in comparison to the upper eyelid. The eyelids close the eyes to protect them from the dust, heat and rain. There is a third eyelid called nictitating membrane in the anterior corner of the eye which develops and lies folded beneath the lower eyelid.The nictitating membrane can be drawn rapidly over the moist cornea and thus it protects and cleans the eye. The Harderian gland lying on the anterior side of the eyeball lubricates the nictitating membrane and the lacrymal gland lying on the posterior side of the eyelid keeps the eye moist and clean. The tears (water fluid) are passed from the eye into the nose through a lacrymal duct.The eye ball of *Uromastix* consists of the three layers

(i) Outer fibrous tunic or sclerotic,

(ii) Middle uvea or choroid

(iii) SInner retina.

(i) Fibrous Tunic:

The thick and tough fibrous tunic protects the eyeball and maintains its form. The fibrous tunic layer is divided into an anterior small transparent and exposed portion called the cornea and a posterior large opaque cartilaginous portion called the sclerotic lying hidden in the eye orbit.The cornea is supported by a ring of eleven small sclerotic bones or ossicles, present around the iris. The cornea is curved and provides the main refracting surface. A thin transparent epithelial layer is fused to the outer surface of the cornea known as conjunctiva. The conjunctiva is continued over the inner surface of the eyelids.

(ii) Uvea: Uvea is differentiated into three regions

(a) A greater part of it is thin, vascular and pigmented and lies in close contact with the sclerotic. It is called the choroid. It serves to darken the eye.

(b) At the junction of the sclerotic and cornea, the uvea forms a thick ring which constitutes a part of the ciliary body,

(c) Just in front of the cavity of the eye, forming a part of the circular partition is the iris. The iris is perforated at the centre by an aperture called pupil. The iris possesses circular and radial muscles to reduce and enlarge the pupil respectively. The iris contains pigment cells which impart it its characteristic light-orange colour.

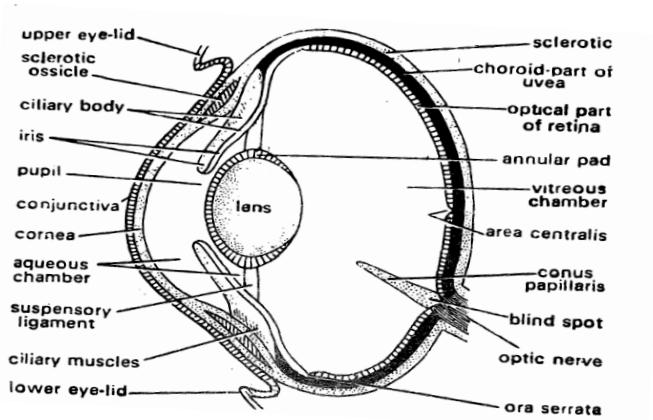


Fig: *Uromastix* V.S. of eye

(iii) Retina: Retina lies inside the entire uvea and is differentiated into 2 regions

(i) Its portion lying in contact with the choroid is thick and sensitive and is called the optical part of retina. It contains more cones than rods so they are good daylight vision and probably good colour perception.

(ii) SThe remaining portion of retina is thin and non-sensory. It lines the iris and ciliary body. The part forming the ciliary body is known as the ciliary part and that to the iris as the iridial part. The junction of the optical and ciliary parts of the retina is irregular and is called ora serrata.

The lens is a biconvex transparent body lying immediately behind the iris. It is more convex behind than in front. A ring of soft tissue the annular pad, surrounds the circumference of the lens. The lens is suspended and held in position by radially arranged fibres which arise from the ciliary body and are attached to the annular pad and form the suspensory ligament. The suspensory ligament is formed of ciliary muscles and ciliary processes.The lens and its suspensory ligament divide the cavity of the eye into two unequal compartments, the anterior small aqueous chamber and the posterior large vitreous chamber. The aqueous chamber is further divided by iris into anterior and posterior parts containing a clear watery fluid, the aqueous humour, and are continuous through the pupil. The aqueous humour keeps the eyeball taut or stretched for distinct vision.

The optic nerve arises from the inner surface of the retina and joins the brain after piercing through all the three eye-coats at the back of the eyeball. The point of origin of optic nerve is called the blind spot. No image is formed at this point. A small part of the retina opposite the centre of the lens is the place of the most distinct vision. It is called the area centralis or yellow spot. A peculiar pigmented, blackish brown, highly vascular, cushion-like rod, the conns papillaris, projects into the vitreous humour from the blind spot. Probably it provides nutrition.Accommodation for near vision is usually produced by the striated ciliary muscles, so arranged that they cause the ciliary process to squeeze the lens, making its anterior surface more rounded.

Ear

The ear of *Uromastix* consists of two parts i.e. middle ear and internal ear. External ear is absent in*Uromastix*.

Middle Ear:

The middle ear comprises an air-filled cavity called the tympanic cavity. It is bounded externally by the tympanum and internally by the auditory capsule. The tympanus lies behind the jaws, sunk a little below the surface. From the lower part of the tympanic cavity a narrow passage the Eustachian tube, extends downwards and inwards to open into the posterior part of the pharynx.A slender rod-like ear ossicle, the columella auris, stretches across the tympanic cavity. The columella auris is divided into two parts: the inner bony stapes fitting into a small membrane covered aperture fenestra ovalis, and the outer cartilaginous extra stapes is attached to the inner surface of the tympanum.

Internal Ear:

The internal ear is situated in the auditory capsule. It is a soft, delicate and complicated structure known as membranous labyrinth. The membranous labyrinth consists of two parts, upper cylindrical part is known as the utriculus and the lower large and rounded part is sacculus. Three semi-circular ducts (2 vertical and 1 horizontal) open into the utriculus at both of their ends. The two vertical ducts join together by their adjacent ends before opening into the utriculus. One end of each semicircular duct is enlarged to form an ampulla.The sacculus gives rise to a small lobe called pars lagena. It is an

uncoiled tube and hearing is performed by it. The Organ of Corti are carried on a basilar membrane and are in contact with a tectorial membrane attached to the limbus.

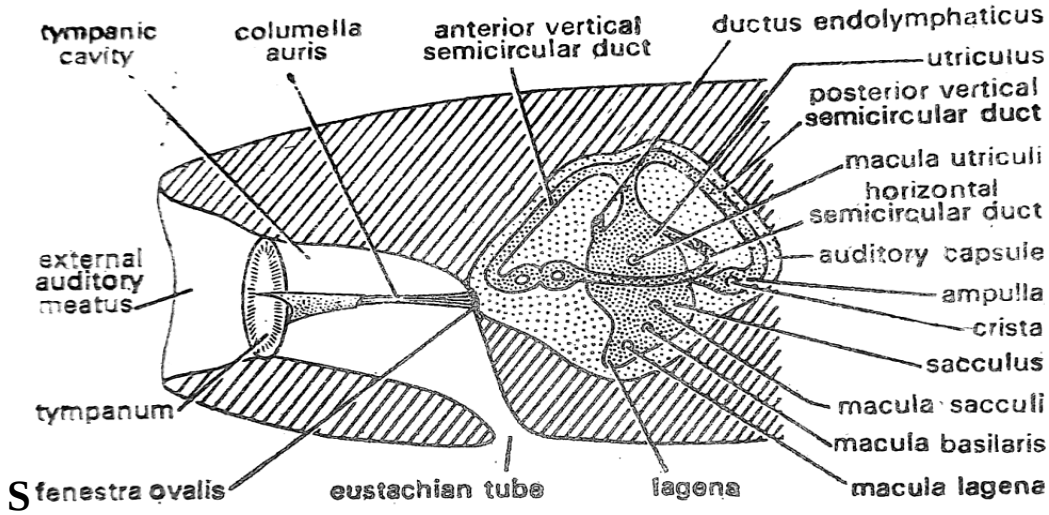


Fig : *Uromastix* Ear

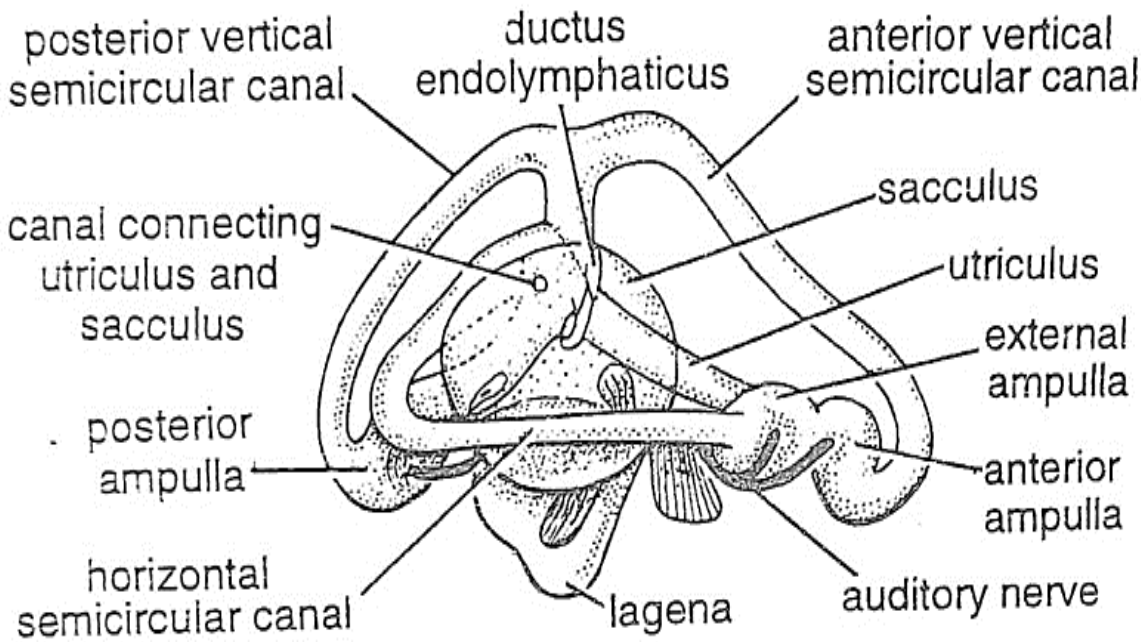


Fig : *Uromastix* membranous labyrinth

Urino-genital system

In *Uromastix* the excretory and reproductive systems are closely associated with each other hence the two systems are described under urino-genital system. The sexes are separate but the sexual dimorphism is not well developed in *Uromastix*.

Excretory System:

The excretory system is similar in both the sexes and it consists of a pair of kidneys, a pair of ureters

and an unpaired urinary bladder.

Kidneys: The kidneys are elongated, compact, dark-red colour and is situated in the posterior region of the body, one on either side of and close to the median line. The kidneys are attached with the dorsal body wall outside the body cavity and are covered with peritoneum on their ventral surface only.

In *Uromastix*kidneys are metanephric type. Each kidney is roughly divided into two lobes, the anterior broad and posterior narrow. The broad anterior lobes of both the kidneys are free and slightly apart, while the narrow posterior lobes are united so that they appear in V-shaped.

Histology: The kidneys are composed of coiled uriniferous tubules which are embedded in connective tissue having blood vessels, nerves and muscle fibres. These tubules communicate with their corresponding ureters.

Ureters: From the ventral side of each kidney arises a narrow, short, delicate metanephric duct or ureter. Both the ureters open behind on the dorsal side into the middle chamber urodaeum of the cloaca. Their openings into the urodaeum lie on small papillae.

Urinary Bladder: The urinary bladder is a median thin-walled sac opening into the urodaeum of cloaca ventrally.

Physiology of Excretion:

Uromastrix is uricotelic, its nitrogen waste is largely excreted as uric acid. The water is reabsorbed in the urodaeum, with the precipitation of the organic matter as a chalky white mass of urates. This help the animal to absorb large amount of water for conservation of water for terrestrial life

Reproductive System

Male Genital Organs

The male reproductive organ consists of a pair of testes, a pair of vas deferens and a pair of copulatory sacs or hemipenis.

Testes: The testes are two white oval colour situated in the body cavity at the anterior of kidneys. Both the testes are not on the same level. The right testis is slightly anterior of the left one. Both the testes are suspended from the dorsal body wall by the peritoneal fold, mesorchium. The adrenal gland is attached to the posterior side of each testis.

Vasa deferentia: The vasa deferentia or Wolffian ducts are narrow convoluted tubes running backwards from the epididymis of testes along the dorsal bodywall. Posteriorly the vasa deferentia pass over the ventral surface of the kidneys and open into the urodaeum of the cloaca on the dorsal side in front of the opening of the ureters.From each testis several delicate vasa efferentia formed by the union of seminiferous tubules of testis and it passes through the mesorchium and form epididymis present on the outer posterior surface of the testis.

Hemipenes:

The hemipenes are the copulatory organs of *Uromastrix*. These are two eversible hollow sacs lying under the skin behind the cloacal aperture at the base of tail. They appear as pocket-like swellings when withdrawn and almost cylindrical when everted. Each hemipenis consists of a proximal hard stalk or pedicel and a distal soft head or glans.

A longitudinal groove extends along the outer side of the stalk and ends in a depression on the head of the hemipenis. During copulation seminal fluid flows through the groove. Proximally the hemipenes communicate with the opening of vas deferens in the urodaeum of the cloaca. During copulation only one hemipenes is inserted into the cloaca of the female for the discharge of

spermatozoa. Erection of the hemipenes is due to muscular action and filling with blood then they are everted and become cylindrical and project beyond the cloaca.

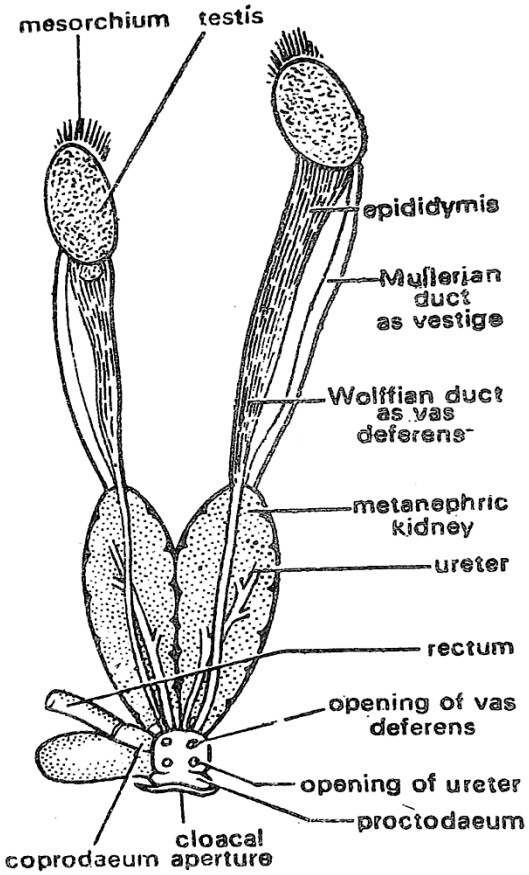


Fig : *Uromastix* male urino-genital system

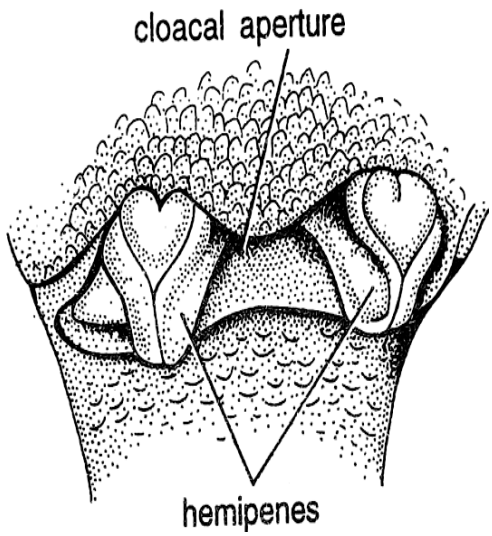


Fig : *Uromastix* Hemipenes projecting through cloacal aperture

Female Genital Organs

The female reproductive organs of *Uromastrix* consist of a pair of ovaries and a pair of oviducts.

Ovaries: The ovaries are yellowish-white in colour and are irregular in shape. The ovaries are situated in the posterior part of the body cavity anterior to the kidneys. The right ovary is slightly anterior to the left. Each ovary is held to the dorsal bodywall by a double fold of peritoneum called the mesovarium. The outer surface of each ovary is produced into several rounded raised up areas or follicles.The follicles contain oocytes which are in different stages of development. The ovary is formed of several lobules lined by germinal epithelium. Its cells undergo oogenesis to form the ova. The mature ova are released into the body cavity by rupture of ovary and release of follicles. They float in the coelomic fluid of the body cavity.

Oviducts: The oviducts or Mullerian ducts are long, thin-walled coiled tubes lying outside the ovaries. Each oviduct is attached to the dorsal bodywall by a broad ligament or mesotubarium. Each oviduct opens into the anterior part of the body cavity by a wide externally directed ciliated aperture, ostium situated at the end of a large oviducal funnel.Posteriorly the oviducts open independently in the cloaca (urodaeum) in its dorsal wall, their openings lying in front of those of the ureters. While passing along the ventral surface of the kidney, the oviduct is enlarged so as to form a shell-gland or ovisac, whose function is to secrete egg-shell around the fertilized eggs and to store them. The terminal part of the oviduct is called vagina. It opens dorsally into the urodaeum of cloaca.

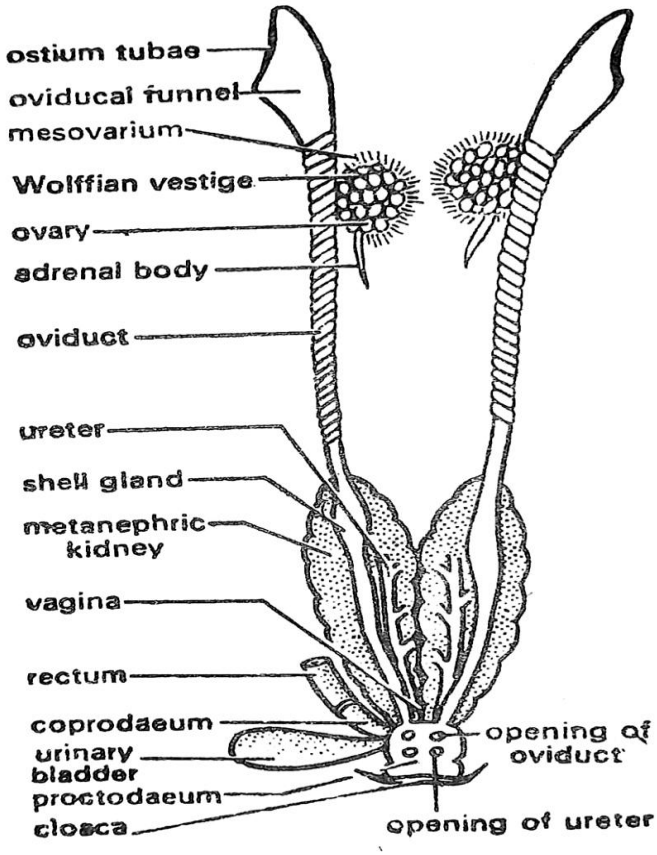


Fig : *Uromastix* female urino-genital system

SAQs 2.

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

(i) *Uromastix*is commonly known as ----------

(ii) Lips guarding mouth in *Uromastix* are ----------.

(iii) In*Uromastix* liver is attached to the body wall by a peritoneal fold called --------

(iv) SSWalls of larynx are supported by ---------- & ----------

6.4 IDENTIFICATION OF POISONOUS AND NON-POISONOUS SNAKES AND BITING MECHANISM OFSNAKE

Identification of poisonous and non-poisonous snakes

Majority of snakes are non-poisonous. There are about 2500 species of snake, out of which only 300 species of snakes are found in India. The important poisonous snakes in India are Cobra, Krait, Pit viper, Indian viper, Rattle snake, Russell viper and sea Snake. The majority of people die due to sheer shrink of snakes and some due to ignorance and unscientific methods of treatment. Therefore it is necessary to have more knowledge about snake, which can reduce high mortality from snake bite. The following key is used for identification of poisonous and non-poisonous snakes.

1. If the tail is laterally compressed and rudder shaped, it is and marine snake.

2. If tail is rounded or cylindrical and not laterally compressed, it is terrestrial snakes. It has to be examined for its ventral side scales

(i) If all the ventral scales are small or the ventral scales are somewhat broad, it is a non-poisonous snake.

(ii) If ventral scales are large transverse plates extending fully across the ventral side or belly, the snake may be poisonous or non-poisonous. Then dorsal scales of head are to be examined

(A) If all the dorsal scales of the head are small, then it may be a viper.

(a) If there is a loreal-pit between the nostril and the eye, and it is Krait viper.

(b) If sub-caudals are double and there is a loreal-pit, then it is Aussel viper.

(B)If dorsal side of the head has both small scales and large shields, the snake may nor may not be poisonous, to ascertain it has to be looked at the side of the head.

3. If the third supra-labial shield touches the nostril and eye, then it is a poisonous snake, may be Cobra, king Cobra or coral snake.

4. If upper side of the head has both small scales and large shields but there is no loreal-pit, and the third supra-labial shield does not touch the eye, then the back of the snake and ventral side of the lower jaw is to be examined.

(i) The middle row of scales on the back called vertebrals may be larger than others.

(ii) Ventral side of the lower jaw has fourth infra-labial shield larger than the others.

If both (i) and (ii) characters are present, then it is Krait.

5. If the snake has small scales and large shields on the head but does not have the characters of cobra, krait or coral snake, then it is non-poisonous

Structures	**Characters**	**Nature**	**Snake**
1.Tail	(a)Tail laterally compressed, oar-like	Poisonous	Sea snakes, *Hydrophis*, *Enhydrina*

	(b)Tail ylindrical, tapering	Poisonous or non-Poisonous	
2.Belly scales or ventrals	(a)Bellyscales small, continuous with dorsal		
	(b)Ventrals not fully broad to cover belly	Non- Poisonous	Pythons
	(c)Ventrals broad to covering belly		
3.Head scales, Loreal pit, sub-caudals	(a)Head scales small. Head triangular. No loreal pit. (i)Sub-caudals double (ii)Sub-caudals single	Poisonous Poisonous Poisonous	Pitless viper *Vipera russelli* *Echis carinata*
	(b)Head scales small a loreal pit present between nostril and eye	Poisonous	Pit vipers *Lachesis* *Ancistrondon*
	(c)Head with large shields. No loreal pit.	Further investigation	
4.Vertebrals, 4^{th} infra labial, 3^{rd} supra labial	(a)Vertebrals enlarged, hexagonal 4^{th} infra labial largest	Poisonous	*Krait, (Bungaraus)*
	(b)Vertebrals not enlarged 3^{rd} supra-labial touches eye and nostril (i)Neck with a hoodand spectacle mark (ii)Hood absent. Coral spots on belly	Poisonous Poisonous Poisonous	 Cobra, (Naja) Coral snakes, Callophis

Biting mechanism in snake

Poison Apparatus : The poisonous snake's have poison apparatus in their head. The poison apparatus consist of poison glands, their ducts and a pair of fangs.

Poison gland : The two sac like poison glands are situated one on either side of upper jaw. The poison glands are modified superior labial glands or parotid glands. Each gland is surrounded by thick fibrous connective tissue and fan shaped constrictor muscle or temporal or masseter muscle. During biting these muscle contact so that poison comes out from poison gland.

Poison duct : A narrow poison duct arise from anterior end of poison gland and move forward and open at the base of a poison fang to enter its groove or canal.

Fangs : The fangs are long, curved, sharp and pointed maxillary teeth. If it is lost or damaged, it is replaced by new ones. On the basis of structure and position 3 types of fangs occurs in poisonous snake.

The poison apparatus is associated with specialized bands of three types of muscle. These are (i)diagastric muscle, (ii)sphenopterygoid or protractor-pterygoid, (iii)anterior and posterior temporalis. The diagastric muscle is attached to the squamosal of the skull at one end and articulates of the lower jaw. The sphenopterygoid is attached anteriorly to the sphenoid region of skull and posteriorly to the dorsal surface of the pterygoid. It helps in pulling the pterygoid forward. The anterior and posterior temporalis muscles are attached to the side walls of the cranium and lower jaw. They help in closing the lower jaw.

Biting mechanism in viper : It is a series of movement first by the contraction of diagastric muscle, the mandible or lower jaws move downward causing opening of mouth which causes the lower end of quadrate to move forward which pushes the pterygoid forward. It is also brought about by contraction of sphenopterygoid muscle. As the pterygoid move forward it pushes the ectopterygoid upwards. This causes the maxilla bearing fangs to rotate through 90^0 at the hinge joint with lachrymal. So that the fangs become vertically erect and directed forward. The fang is nearly horizontal in position when the mouth remains closed. But during opening of the mouth to bite, the fang become in vertical position. A simultaneous stretching of constrictor muscles around the poison gland forces its poison through poison duct into the canal or groove of fang to be injected into the victim. After biting the mouth is closed by the contraction of temporal muscle and all the above movement are reversed. The fangs embedded in the prey which is drawn into the mouth and the vertical fangs rotate to be become horizontal. It takes longer time to open the mouth than to close it.

Snake venom

Venom is a sticky liquid of faint yellow or greenish colour. It is tasteless and odourless and acidic in reaction. It is a complex mixture of enzymes and specific toxins and is a good digestive juice. It is fatal only when mixed in blood. It is precipitated in reagents such as silver nitrate and potassium permanganate. It can be dried and kept indefinitely retaining its poisonous properties. It can be dissolved in water, salt solution or glycerine when it is equally poisonous. The snake venoms are divided into two categories – neurotoxic and haemotoxic. Neurotoxins are found in Cobra, Krait and sea snakes. They cause death by paralysis of respiratory muscles and asphyxiation. Haemotoxins are found in viper they cause tissue destruction and widespread hemorrhage.

Antivenom Serum or Antivenin

To cure from snake bite is an anti-venom serum, or antivenin which is injected into the body of the victim to counteract snake venom. Different antivenins are required against different snake due to difference in the qualities of their venoms. Antivenin is prepared by injecting a horse with gradually increasing doses of a snake venom until the horse become fully immunized to any amount of venom injected. Now blood serum of horse is collected and preserved. This is anti-venom serum or antivenin which has developed sufficient antibodies to neutralize the effect of that particular snake venom.

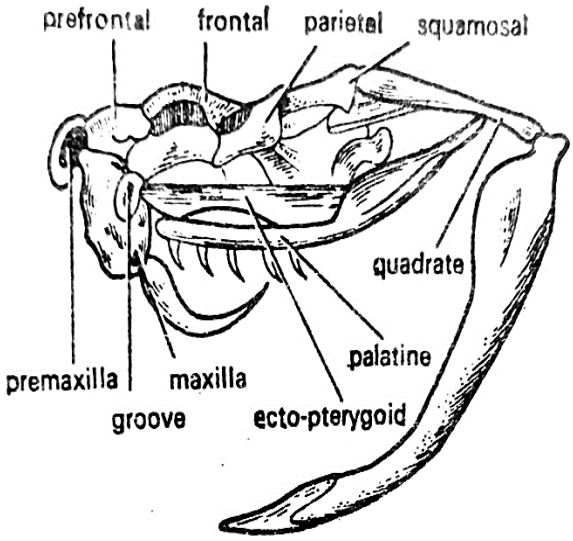


Fig : Close mouth of snake

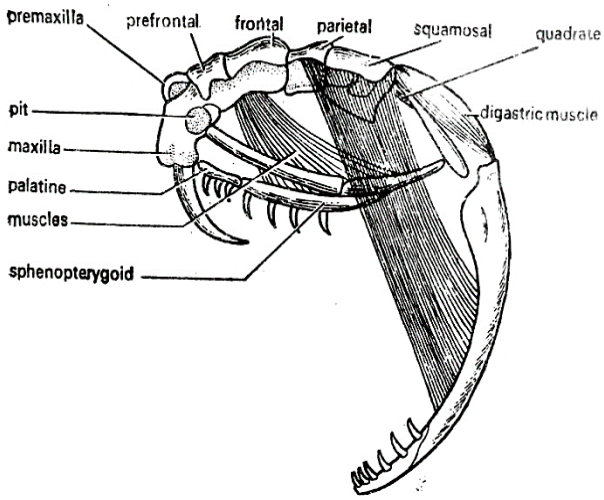


Fig : Open mouth of snake

6.5 EXTINCT REPTILES

Dinosaurs were a successful group of animals that emerged between 240 million and 230 million years ago and came to rule the world until about 66 million years ago, when a giant asteroid slammed into Earth. During that time, dinosaurs evolved from a group of mostly dog and horse size creatures into the most enormous beasts that ever existed on land. Some meat-eating dinosaurs shrank over time and evolved into birds.

During the roughly 174 million years that dinosaurs existed the world changed greatly. When dinosaurs first appeared in the Triassic period (251.9 million to 201.3 million years ago), they roamed the supercontinent of Pangaea. But by the time the asteroid hit at the end of the cretaceous period (145 million to 66 million years ago), the continents were in approximately the same place they are today.

The dinosaurs which roamed the earth and found in land, water and air and suddenly disappeared by the end of Mesozoic area. No fossils recorded after cretaceous period. Why they failed to survive

after cretaceous period. No satisfactory explanation prevails among the paleontologist or zoologist. The extinction of dinosaurs from the surface of the world is not clear.

According to the IUCN red list of threatened species (version 2016.3) there are 26 reptile species that became extinct in recent years. The subjoined list contains 32 extinct reptile species and 6 reptiles subspecies. The extinct flying reptiles called Pterosaurs or Pterodactyls are now thought to have been warm blooded and covered with hair. Ever since the dinosaurs died off 65 million years ago, reptiles have had it relatively easy in the extinction, not nearly assusceptible to environmental changes as birds, mammals and amphibians. Regardless here is a few list of snakes, turtles, lizard and crocodiles that have gone extinct in historical times.

- **The Round Island Burrowing Boa :** The Round Island burrowing boa (*Bolyeria multocarinata*) is an extinct species of snake in the family Bolyeriidae in the monotypic genus *Bolyeria*, which was endemic to Mauritius. It was native to Round Island, a tiny island of the coast of Mauritius in East Africa. It preferred to live on the top layers of volcanic slopes, and was once found on several other islands around Mauritius.Its population went down by the 1940's, and could only be found on Round Island after 1949.It was last seen in 1975. The cause of extinction was non-native species of rabbits and goats. They destroyed the vegetation and upset the boa's habitat.



Fig : The Round Island Burrowing Boa

- **The cape Verde Giant Skink :***Macroscincus coctei* also called the cape Verde giant skink *lagarto* or Cocteau's skink, is a species of lizard, a reptile that was at one time known to inhabit the islets of Branco and Raso in the cape Verde islands of the Atlantic Ocean, were once home to the Cape Verde giant skink species, which has since disappeared due to habitat damage caused by human. Skinks are just as susceptible to extinction as any other animal, thus the Cape Verde giant skink vanished in the early 20th century, and the species was formally declared extinct in 2013.The most diverse lizards in the world, skinks not to be confused with skunks can be found in deserts, mountains, and arctic regions. The local residents of the Cape Verde Islands, who valued this reptile for its priceless "skink oil," did not help this species to adapt.

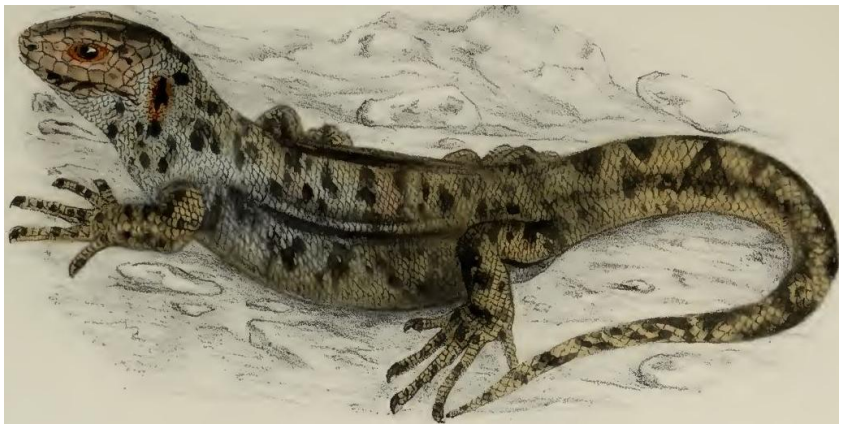


Fig : The cape Verde Giant Skink

- **The Jamaican Giant Galliwasp :** The Jamaica giant galliwasp (*Celestus occiduus*) is a species of lizard in the Anguidae family. The Jamaican Giant Galliwasp is an extinct galliwasp endemic to the island of Jamaica that was last reported in the 1840s. It is the largest galliwasp in the World with mature adults having a snout to vent length often exceeding 30cm. Jamaican Giant Galliwaspshas a smooth, shiny skink-like appearance. They are large in size with a long robust body and head and powerful jaws. It was likely exterminated by introduced predators like mongoose.



Fig : The Jamaican Giant Galliwasp

- **The Kawekaweau :** Kawekaweau was a giant forest gecko in Newland. Only one person had seen a living specimen and he'd killed it. Then a stuffed gecko turned up in a museum in France. No one knows where it came from. Scientists only known about kawekaweau, a large brown gecko that lived in the forests of New Zealand. **The** arboreal and nocturnal New Caledonian gecko is the largest known gecko species, growing to lengths of about 14 inches and weighing 8 to 12 ounces. It is a vocal lizard that produces an array of sounds, including grumbles and growls.They were long-extinct. The closest any encounter any biologist had ever had with one happened in 1873, when he heard a Mori chief describe killing a kawekaweau in 1870.



Fig : Kawekaweau

- **The Martinique Giant Ameiva :** The Martinique giant ameiva (*Ameiva major*) was a species of lizard in the family Teiidae. It is believed to have been endemic to Martinique, though at least one scholar disputes this, instead placing it on Les Iles de la Petite Terre are two small uninhabited islands located about 10 km to the south east of the island of Grande –Terre in the lesser Antilles within the Guadeloupean archipelago. It is known only from museum specimens collected by early European explorers. Its extinction may have been caused by a hurricane or though the introduction of predatory species to the island.



Fig : Martinique Giant Ameiva

- **The Rodrigues Giant Tortoise :** The saddle backed Rodrigues giant tortoise (*Cylindraspis vosmaeri*)was a species of giant tortoise in the family Testudinidae. The Rodrigues Giant tortoise came in two varieties, both of which disappeared around the turn of the 19th century, the domed tortoise *Cylindraspis peltastes* which only weighed about 25 pounds and the saddle-backed tortoise, *Cylindraspis vosmaeri*, which was substantially bigger. Both of these testudines lived on the island of Rodrigues, located about 350 miles east of Mauritius in the Indian Ocean. The species was endemic to Rodrogues. Human exploitation caused the extinction this species around 1800.

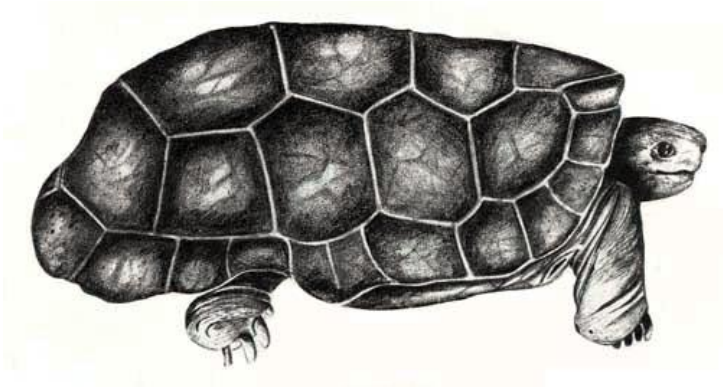


Fig : Rodrigues Giant Tortoise

- **The Giant Monitor Lizard :***Megalania prisca* is an extinct giant goanna or monitor lizard. It is largest terrestrial lizard known was a giant goanna (monitor lizard). First described from the Darling Downs in Queensland by Sir Richard Owen in 1859. *Megalania* lived in a variety of eastern Australian Pleistocene.*Megalania prisca* was an enormous monitor lizard and up to 5 metres long and with an unusual crest on its snout. The teeth of *Megalania* were sharp and recurved with wrinkled, **infolded** enamel. *Megalania* had small bones (osteoderms) embedded in the skin of the snout and nape of the neck.Its habitats were open forests, woodlands and perhaps grasslands. *Megalania* would have been a formidable reptilian predator like its relative the Komodo Dragon of Indonesia, and may have eaten large mammals, snakes, other reptiles and birds.The youngest fossil remains date to around 50,000 years ago. The first aboriginal settlers of Australia might have encountered them and been a factor in their extinction. They may be extinct due to climate change or the disappearance of this reptile's usual prey.



Fig : Giant Monitor Lizard

- **The horned Turtle :***Meiolania* is an extinct turtle species that lived primarily on Lord Howe Island and mainland Australia. This species was originally thought to be a lizard species similar to the 'Megalania.' They were giant roaming lizards that are now extinct. Both of these were named by paleontologist Richard Owen back in 1859. However, scientists later discovered through fossil analysis that these are in fact turtles. Their name *Meiolania* is still retained as a legacy. The horned turtle *Meiolania* with their spiked heads and tails, they are among the largest and most bizarre turtles ever to have lived. The last of these turtles is thought to have become extinct about 2000 years ago. The bones of these extinct turtle have been found on Lord Howe Island 600 km from main land and the island of New Caledonia.



Fig : *Meiolania*

- **The Quinkana :** *Quinkana* is an extinct genus of mekosuchine crocodylians that lived in Australia. Quinkana went extinct about 40,000 years ago, by the Pleistocene. *Quinkana* had become one of the top terrestrial predators of Australia. They possessing long legs and ziphodont teeth. *Quinkana* was far from the biggest crocodile that ever lived, but it made up for its relative lack of heft with its unusually long legs and sharp, curved, tyrannosaur-like teeth. *Quinkana* comes from the Quinkana a legendary folk Aboriginal myths. They may be extinct either because of hunting by aboriginal settlers or by the disappearance of its accustomed prey.

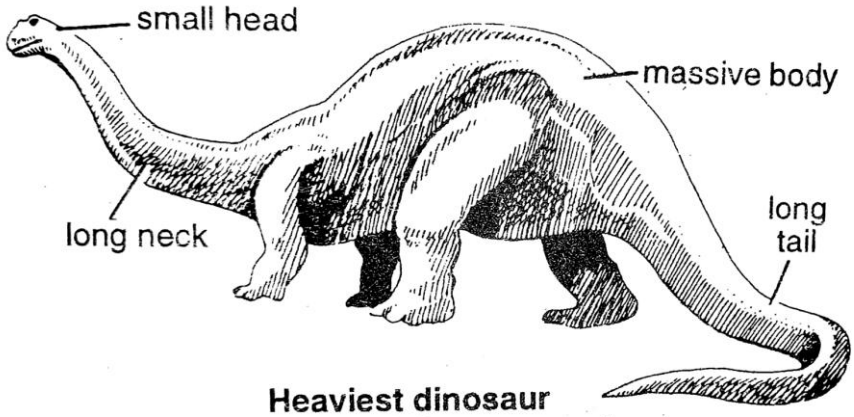


Fig : *Quinkana*

- **Dinosaurs :**Dinosaurs are a diverse group of animals of the clade dinosaurs. They first appeared during the Triassic period 230.4 million years ago and were the dominant terrestrial vertebrates for 135 million years from the start of the Jurassic until the end of the Cretaceous of Mesozoic era.Dinosaurs are a varied group of animals from taxonomic, morphological and ecological stand point.

(A) Brontosaurs :

- They were also called as thunder lizard
- **Brontosaurus are** of large herbivorous sauropod dinosaurs living during the Late Jurassic and Early cretaceous epochs (163.5 million to 100.5 million years ago). Its fossil was first discovered in western North America in 1874 and first described in 1879 by American paleontologist Othniel Charles Marsh.
- They attained a length of 25 meters, a height of 4 – 5 meters and weight of 45 metric tons
- It was a swamp dweller, herbivorous dinosaurs with a 4 legged gait.
- The neck was very long and balanced by an equality long and heavy tail.
- It was the largest reptile.



Heaviest dinosaur
Apatosaurus (=Brontosaurus)

(B) Tyrannosaurs :

- It lived throughout Western North America, particularly an island continent known as Laramidia. Tyrannosaurus had a much wider range than other tyrannasaurids. Fossil are found in a variety of rock formation dating to the Maastrichtian age of the upper cretaceous period, i.e. 68 to 66 million years ago. It was the last known member of the tyrannosaurids and among the last non-avian dinosaurs to exist before the cretaceous Paleogene extinction event.
- Tyrannosaurs were the killing machines of the Cretaceous period
- They are among the largest known terrestrial carnivores.
- Tyrannosaurs measured up to 12 meters long and weighed up to 6 tonnes.
- Tyrannosaurs had a large skull over, 1.35 meters in length.
- Its jaw was lined with serrated teeth up to 16 cm long and 2.5 cm wide.

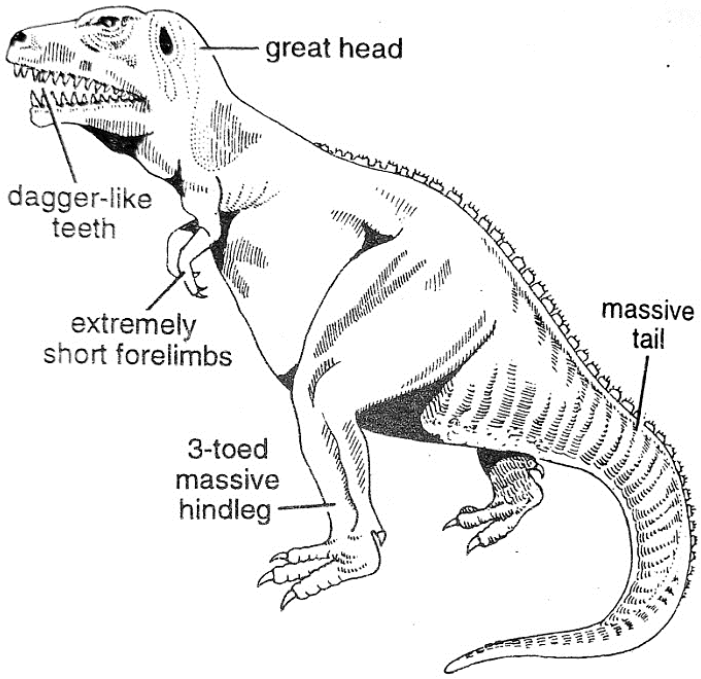


Fig : Flesh eating dinosaurs : *Tyrannosaurus rex*

(C) Stegosaurus :

- *Stegosaurus* is a genus of herbivorous four-legged, armoured dinosaurs from the late Jurassic, i.e. Characterized by the distinctive kite-shaped upright plates along their backs and spike on their tails. Fossils of the genus have been found in the western United States and in Portugal, where they are found in kimmeridgian to tithonian aged strata, dating to between 155 and 145 million years ago. The three species that have been classified in the upper Morrison formation of the western US are *S. stenops*, *S. ungulatus* and *S. sulcatus*. The remains of over 80 individual animals of this genus have been found. *Stegosaurus* would have lived alongside dinosaurs such as *Apatosaurus*, *Diplodocus*, *Camarasurs* and *Allosaurs*, the latter of which may have preyed on it.
- They were large, heavily built, herbivorous quadrupeds with rounded backs, short forelimbs, long hind limbs, and tails held high in the air.Its height is 14 feet, length is 25 feet and weight is 6000 pounds.
- The large triangular plates that ran along its back were probably arranged in a double row and its tail was armed with four long spikes.
- The plates may have served the purpose of regulating stegosaurs internal temperature, dissipating heat when turned from the sun, absorbing heat when faced into the sun.

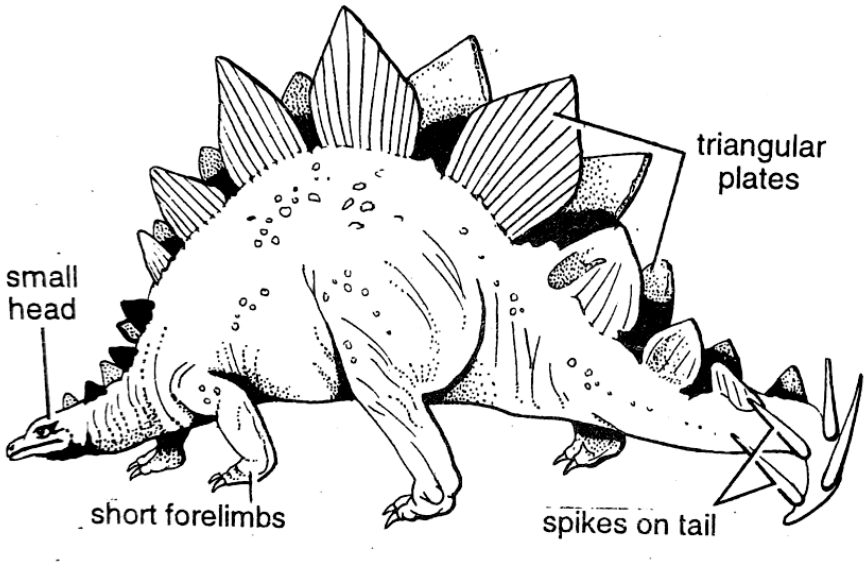


Fig : Horned dinosaurs Stegosaurs

(D) Triceratops :

- *Triceratops* is one of the most recognizable of all dinosaurs and the most well-known ceratopsid. It was also one of the largest up to 8–9 metres (26–30 ft) long and 5–9 metric tons (5.5–9.9 short tons) in body mass.
- The term Triceratops means three horned face. It is derived from the Greek word.
- Triceratops is a genus of herbivorous ceratopsid dinosaurs that first appeared during the late Mastrichtian stage of the late Cretaceous period, about 68 million years ago in North America.
- It is one of the last known non-avain dinosaurs genera and become extinct in the Cretaceous Paleogene extinction event 66 million years ago.

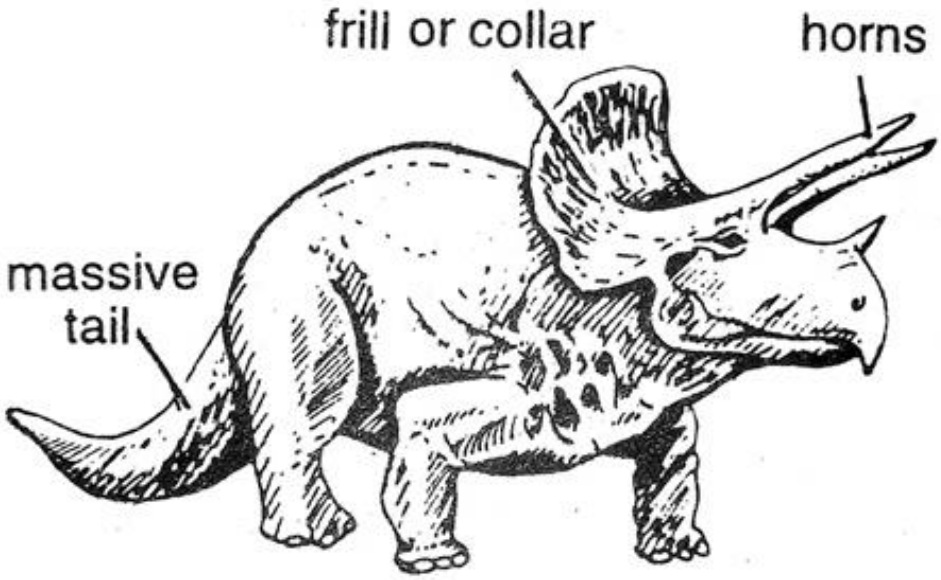


Fig : Plated dinosaurs Triceratops

(E) Pteranodon :

- *Pteranodon* from ancient Greek word *pteron means* wing and *anodon* means toothless is a genus of pterosaurs that included some of the largest known flying reptiles, with *P. longiceps* having a wingspan of over 6 m (20 ft).
- They lived during the late cretaceous geological period of North America in present-day Kansas, Nebraska Wyoming, South Dakota and Alabama. More fossil specimens of *Pteranodon* have been found than any other pterosaur, with about 1,200 specimens known to science, many of them well preserved with nearly complete skulls and articulated skeletons.
- It was not a dinosaur, but was a close relative of the dinosaurs.
- *Pteranodon* wing-span is longer than that of any known bird, with wingspans over 6 meters (20 ft)
- It had a crest on its head, no teeth at all and a very short tail.

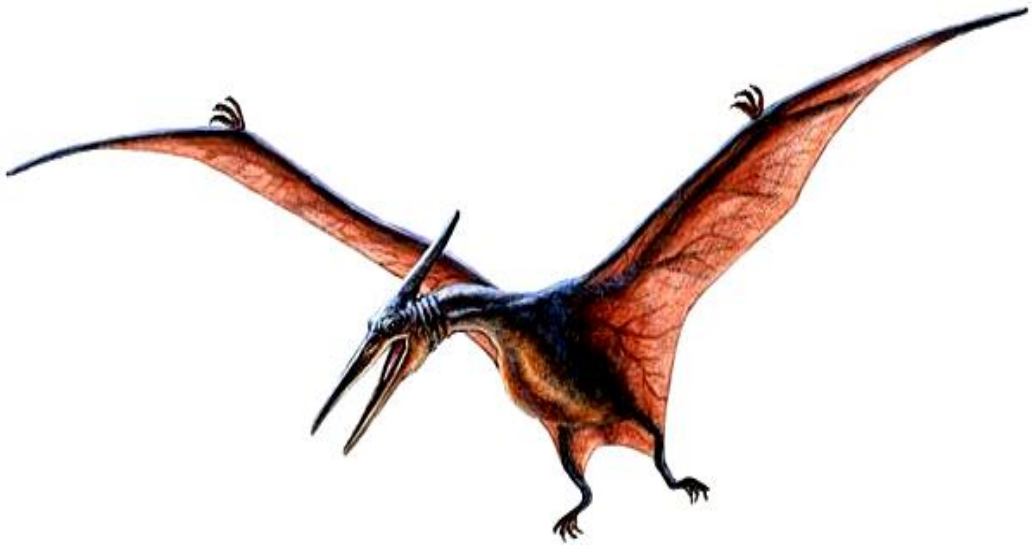


Fig :*Pteranodon*

Ichthyosaurs :

- Its mean fish Lizard.
- It first appeared in the Triassic period.
- In the Jurassic period Ichthyosaurs reached their highest diversity.
- The last Ichthyosaurs disappeared in the cretaceous period.
- The earliest Ichthyosaurs had long flexible bodies and probably swim by undulating like living eels.
- The shapes of these Ichthyosaurs is like that of living tunas and mackerels
- Most known specimens about 2 meters long, but largest individual up to 3.3 meters long.
- Rare fossils have been found that show Ichthyosaurs actually giving birth to live well developed young.

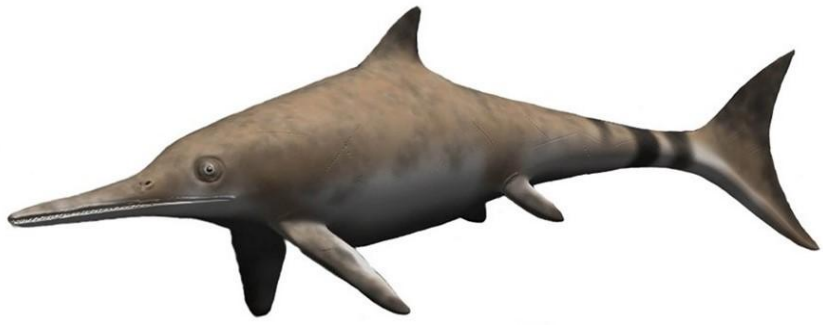


Fig : Ichthyosaurs

Causes of Extinction of reptiles

The extinction is the processof evolution that leads to the disappearance of a population or species. The dinosaurs which roamed the earth about 150 million years ago and ruled the entire environment such as land, water and air but suddenly they were extinct or disappeared by the end of Mesozoic era. There are no fossil records are available after cretaceous period.

The K-T extinction stands for cretaceous (K) tertiary (T) extinction. This is a global extinction even that witnessed the elimination of about 70% of the species living on the earth within a very short time 65 million years ago. This mass extinction is known as KT extinction. KT boundary is the point between the cretaceous (K) and the tertiary (T) period is known as the KT boundary.

Biological view of dinosaurs extinction

- **Competition :** The extinction of dinosaurs is due to the competition with small, predaceous agile mammals. The predaceous mammals stole the eggs from the nests of dinosaurs causing their extinction of their races.
- **Size :** Some of the dinosaurs were too gigantic in size. With this enormous size they were too clumsy to survive. There gigantic forms possessed very small brains. They were not brainy enough to make rational decisions in adverse conditions.
- **Changes in climatic conditions :** By the end of cretaceous period, the different continents occupied the changes of the positions of the land masses, seasonal changes rather extreme cold, highly affected the many regions. The sudden drops of the temperatures of the living area of the dinosaurs affected the metabolic rate, by which the temperature of the body decreased and they were unable to feed. Even warm blooded animals suffered in the climatic extremes in various regions. According to one thought that there is wide spread draught in the upper cretaceous period was the result of extinction of dinosaurs.
- **External terrestrial impact theory :** It was estimated that the asteroid that hit the earth would have 10 km in diameter releasing immense energy. It not only destroyed a region up to thousands of kilometers but also formed cloud of dust that interrupted the sun light reaching the surface of earth for year. The plants which is the main basis of food chain could not survive and eventually the dinosaurs died.
- **Racial Senescence :** It is believed that the groups of individuals became old and fallowed extinction due to senescence degeneration.
- **Diseases :** It is suggested that most of the dinosaurs become extinct due to numerous illness and diseases like slipped discs. Some zoologist suggested that new kind of insects evolved which spread deadly diseases.
- **Vegetation :** During the cretaceous period there is great changes of vegetation had began and

new flowering plants appeared, that was the direct causes of extinction of numerous dinosaurs, which had adopted in feeding on them. The appearance of new floras containing a high percentage of alkaloids made many plants unconsumable to them and therefore, due to starvation dinosaurs fell in death. The new floras could have affected the production of hormones of the dinosaurs, resulting the production of infertile eggs.

6.6 DINOSAURS – TYPES AND EVOLUTIONARY SIGNIFICANCE

The word dinosaur consists of two Greek word “deinos” mean terrible and “sauros” mean lizard. The first dinosaur fossils were discovered in the early nineteenth century. Sir Richard Owen coined the term "dinosaur" (meaning "terrible lizard") to describe these "huge fossil lizards" in 1841.

Dinosaurs are reptiles from the clade Dinosauria. During the Triassic epoch dinosaurs first appeared between 243 and 233.23 million years ago, while the exact origin and chronology of dinosaur evolution are still being researched. After the Triassic Jurassic extinction crisis 201.3 million years ago, they became the dominating terrestrial vertebrates and their supremacy lasted through the Jurassic and Cretaceous ages. Birds are contemporary feathered dinosaurs that evolved from older theropods during the late Jurassic period and they are the only dinosaur lineage known to have survived the Cretaceous–Paleogene extinction catastrophe around 66 million years ago, according to the fossil record. Dinosaurs are split into two groups, one with reptilian pelvis (Saurischia), and other with a bird like pelvis (Ornithischia)

(i) Saurischia : They started their career as small bipedal forms but progressively they become large massive and become quadrupedal secondarily. It has following characters

- In almost all sauropods the hind legs were disproportionately large.
- Fore and hind limbs had 3 fingers of which one was opposable like thumb and used for grasping.
- Saurischians were both herbivorous and carnivorous quadrupeds.
- 3 toed hind limbs adapted for running.
- They are mostly of large size and included largest land living animals. e.g. *Diplodocus*, *Apatosaurus* (Brontosaurus), *Camarosaurus* and *Brachiosaurus*.

(ii) Ornithischia : It is bird like hipped dinosaurs. It has following characters

- Ornithischian were bird like dinosaurs the most primitive and probably they descended from some thecodont stalk.
- Most of them were bipedal
- Thumb was like that of sharp dagger
- As they were herbivorous it is believed that the dagger like thumb was used for defense.
- They possessed a peculiar armature in the form of heavy plates and spines.
- In size they were like present day elephant.
- Their head was reduced and the brain was very small.
- The spinal cord at the base of the tail was enormously enlarged and according to some it formed the real brain at the unusual site.
- At their back they had two rows of large plates the powerful tail had two or more pairs of foot-long spines.
- They are also known as horned dinosaurs.

- They stand as end products of dinosaurian evolution
- They were moderate in size like that of present day Rhinoceros.
- They had enormously large head armed with long horns.
- The striking feature was its large and bony collar frill. This frill extended sideways and backwards forming a shield over the shoulder.

Dinosaurs are a diverse collection of species in terms of taxonomy, morphology and evolutionary history and ecology. Based on fossil evidence, paleontologists have identified over 900 different genera and over 1000 different species of non-avian dinosaurs. Extinct species (birds) and fossil remains of dinosaurs may be found on every continent.

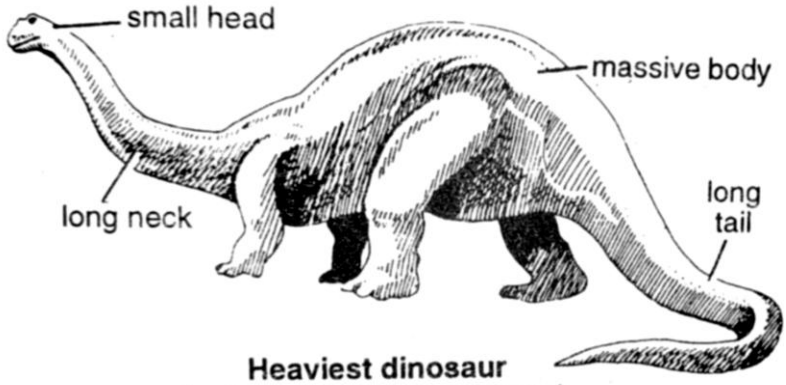
Before birds were recognized as dinosaurs in the early part of the twentieth century, most scientists assumed dinosaurs were lethargic and cold-blooded. The majority of research done since the 1970s, has shown that dinosaurs were busy animals with high metabolisms and multiple social characteristics. Some were carnivorous, while others were herbivorous. Evidence implies that all dinosaurs laid eggs and that many dinosaurs both avian and non-avian had the ability to create nests.

Despite the fact that dinosaurs were bipedal at the time many prehistoric groups contained quadrupedal animals, with some being able to switch between the two. All dinosaur groups include elaborate display structures like horns or crests, and some extinct groups acquired skeletal adaptations like bony armour and spines. Many prehistoric dinosaurs (non-avian and avian) were large-bodied, the largest sauropod dinosaurs were estimated to have reached lengths of 39.7 meters (130 feet) and heights of 18 meters (59 feet). They were the world's largest terrestrial creatures.

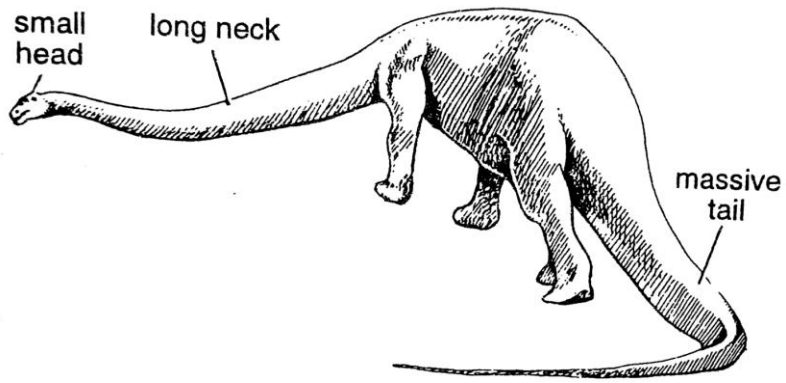
Dinosaurs are commonly defined as the group that includes the Most Recent Common Ancestor (MRCA) of Triceratops and modern birds (Neornithes) and all of their descendants. This definition includes major groups such as Ankylosaurians (armoured herbivorous quadrupeds), Stegosaurians (plated herbivorous quadrupeds), Ceratopsians (bipedal or quadrupedal herbivores with neck frills), Pachycephalosaurians (bipedal herbivores with thick skulls), Ornithopods (bipedal or quadrupedal herb (mostly large herbivorous quadrupeds with long necks and tails).

Evolutionary Significance

- Dinosaurs continue to fascinate young and old alike and that makes them a great educational tool as well as unique research opportunities
- Dinosaurs also include the largest terrestrial animals of all time in their ranks and so provide interest for biomechanics, the evolution of large size, the structures of ecosystems.
- Their fossil record, the only form of direct evidence about their early evolution and history is very scant.

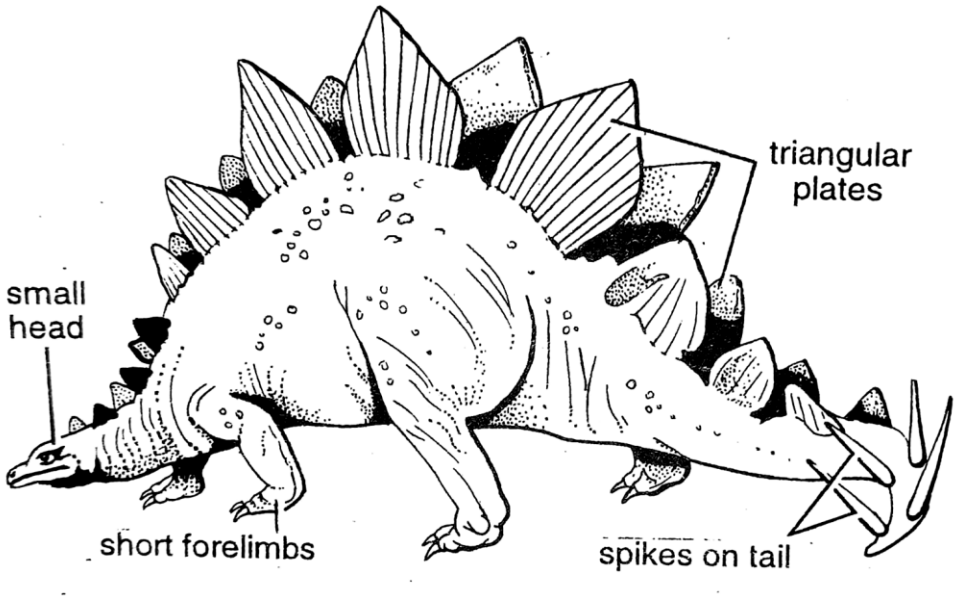


Heaviest dinosaur
Apatosaurus (=Brontosaurus)



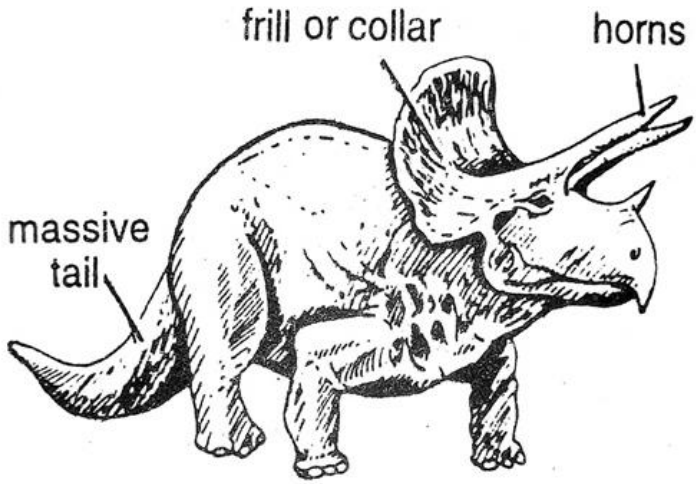
Longest dinosaurs : Supersaurus (137 feet)

Diplodocus



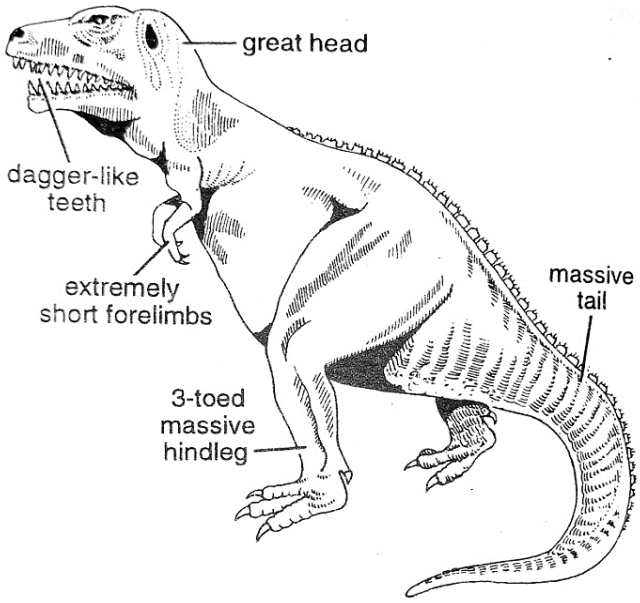
Horned dinosaurs

Stegosaurs



Plated dinosaurs

Triceratops



Flesh eating dinosaurs

Tyrannosaurus rex

6.7 SUMMARY

In this unit you willstudy the general characters and classification of class reptilia. It also include complete study of *Uromastix* in which its systemic position, body form, habit and habitat, different system including digestive system, respiratory system, heart, arterial and venous system, brain, sense organ, urino-gential system.

This unit also contains identification of poisonous and non-poisonous snake and biting mechanism of snake. It also contains extinct reptiles in very detained manner. In this unit it also contain dinosaurs it types and evolutionary significance also in very detailed manner.

6.8 TERMINAL QUESTION

Q1. Explain the general character of class reptilia.

Q2. Describe the female genital organ of*Uromastix*.

Q3 Describe the general characters of Ornithischia.

6.9 ANSWERS

SAQ 1

(i) Dry land

(ii) Mesozoic

(iii) Carnivorous

(iv) Diapsida

SAQ 2

(i) Spiny tailed lizard

(ii) Fleshy and movable

(iii) Hepatic omentum

(iv) Arytenoid and cricoids cartilage

Terminal question

1. The general character of class reptilia are

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

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

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

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

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

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

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

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

(9) Alimentary canal terminates in a cloacal aperture.

(10) Reptiles are carnivorous.

(11) Respiration by lungs.

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

2. The female reproductive organs of *Uromastrix* consist of a pair of ovaries and a pair of oviducts.

Ovaries: The ovaries are yellowish-white in colour and are irregular in shape. The ovaries are situated in the posterior part of the body cavity anterior to the kidneys. The right ovary is slightly anterior to the left. Each ovary is held to the dorsal bodywall by a double fold of peritoneum called the mesovarium. The outer surface of each ovary is produced into several rounded raised up areas or follicles.The follicles contain oocytes which are in different stages of development. The ovary is formed of several lobules lined by germinal epithelium. Its

cells undergo oogenesis to form the ova. The mature ova are released into the body cavity by rupture of ovary and release of follicles. They float in the coelomic fluid of the body cavity.

Oviducts: The oviducts or Mullerian ducts are long, thin-walled coiled tubes lying outside the ovaries. Each oviduct is attached to the dorsal bodywall by a broad ligament or mesotubarium. Each oviduct opens into the anterior part of the body cavity by a wide externally directed ciliated aperture, ostium situated at the end of a large oviducal funnel.Posteriorly the oviducts open independently in the cloaca (urodaeum) in its dorsal wall, their openings lying in front of those of the ureters. While passing along the ventral surface of the kidney, the oviduct is enlarged so as to form a shell-gland or ovisac, whose function is to secrete egg-shell around the fertilized eggs and to store them. The terminal part of the oviduct is called vagina. It opens dorsally into the urodaeum of cloaca.

3. Ornithischia : It is bird like hipped dinosaurs. It has following characters

1. Ornithischian were bird like dinosaurs the most primitive and probably they descended from some thecodont stalk.
2. Most of them were bipedal
3. Thumb was like that of sharp dagger
4. As they were herbivorous it is believed that the dagger like thumb was used for defense.
5. They possessed a peculiar armature in the form of heavy plates and spines.
6. In size they were like present day elephant.
7. Their head was reduced and the brain was very small.
8. The spinal cord at the base of the tail was enormously enlarged and according to some it formed the real brain at the unusual site.
9. At their back they had two rows of large plates the powerful tail had two or more pairs of foot-long spines.

UNIT-7 : ORIGIN AND EVOLUTION OF BIRDS

7.1 Introduction

Objectives

7.2 General characters classification up to order level.

7.3 Study of Columbia (Pigeon)

7.4 Characteristic of Archaeopteryx

7.5 Flight adaptation & bird Migration

7.6 Summary

7.7 Terminal Question

7.8. Answers

7.1 INTRODUCTION

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

Objectives

After studying this unit you will be able to know about :

- General characters classification up to order level of Columbia (Pigeon)
- Characteristic of Archaeopteryx
- Flight adaptation & bird Migration

7.2 GENERAL CHARACTERS CLASSIFICATION UP TO ORDER

- The birds are feather covered, air breathing, warm blooded, oviparous, bipedal flying vertebrates.
- Body is more or less spindle shaped and divisible into four distinct regions head, neck trunk and tail.
- The jaws are elongated into a toothless beak or bill.
- Neck is long and flexible, tail is short and stumpy.
- Limbs are two pairs. Forelimbs are modified as wings for flying. The hinds limbs are adapted for walking, running, perching, swimming etc. They bear four clawed digits of which the first one or hallux is directed backwards and the remaining three infront.
- The birds have an epidermal exoskeleton represented by
  - Feathers forming a non conducting body covering for warmth.
  - Claws on the toes.
  - Sheaths on the beaks

- The skin is dry and devoid of glands except the oil or preen gland at the root of tail.
- Pectoral muscles of flight are well developed.
- The endoskeleton is bony. The bones are pneumatic or hollow and without bone marrow. This makes the body light. The bones are usually fused.
- The skull is smooth and monocondylic, bearing a single occipital condyle. Cranium large and dome like.
- Lower jaw consist of 5 to 6 bones and articulates with quadrate.
- Vertebral column short. Centra of vertebrate heterocoelous. Cervical vertebrae numerous, bear small cervical ribs. Some thoracic vertebrae are fused together. A synsacrum results by fusion of posterior thoracic, lumber, sacral and anterior caudal vertebrae. Few tail vertebrae compressed laterally and the last 3 or 4 fused into a ploughshare bone, pygostyle.
- The sternum is large and bears a keel for the attachment of flight muscle.
- Ribs double headed or bicephalous and bear posteriorly directed uncinate process.
- Both clavicle and single interclavicles fused to form a "V" shaped bone called furcula or wish bone.
- The pelvic girdle is large, strong and fused with the synsacrum. The acetabulum is perforated.
- The heart is four chambered. Sinous venous and truncus arteriosus are absent. The right systemic arch only persists, the left one disappears. The RBC are nucleated.
- The lungs are compact, spongy and non-distensible and provided with thin walled air sacs.
- Larynx is without vocal cords. A sound box or syrinx is present.
- Kidney metanephric and 3 lobed. Ureter open into cloaca. Urinary bladder absent. Birds are urecotelic. Excretory substance of urates eliminated with faeces.
- Brain with greatly developed cerebellum, cerebrum and optic lobes. Cranial nerves twelve pairs.
- The eyes are surrounded by sclerotic plates and contain vascular pectin.
- The olfactory organs are poorly developed.
- The birds have 3 – chambered cloaca.
- Sexes separate. Sexual dimorphism well marked. Male has a pair of abdominal testes and a pair of sperm ducts. Male without copulatory organ except in ratitae, duck etc. The female has a single functional left ovary and oviduct.
- Fertilization internal, preceded by copulation and courtship. Female oviparous. Eggs large with much yolk and hard calcareous shell.
- Eggs develop by external incubation. Cleavage discoidal meroblastic. Development direct. Extra embryonic membrane (amnion, chorion, allantosis and yolksac) present.
- Newly hatched young fully formed (precocial) or immature (altrical).
- Parental care is well marked.

Classification Of Aves

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

Subclasses I: Archaeornithes

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

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

This subclass includes a single order

Order 1 : Archaeopterygiformes

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

Subclasses II: Neornithes

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

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

This subclass is divided into 4 super orders:

Super-order1: Odontognathae

(Gr., *odontos*, teeth)

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

This super order has 2 orders

Order 1. Hesperornithiformes

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

Example : *Hesperornis, Baptornis* .

Order 2. Ichthyornithiformes

1. Whether teeth were present is not a definite.
2. Neck vertebrae amphicoelous.
3. Shoulder girdle well developed.
4. Sternum with a well developed keel.

Example : *Ichthyornis, Apatornis.*

Super-order 2 : Palaeognathae or Ratitae

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

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

This has super order has 7 orders

Order 1: Struthioniformes

(Gr. *struthio,* ostrich + form)

1. Head, neck and legs sparsely feathered.

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

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

Order 2:Rheiformes

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

Example : *Rhea americana* (rhea) of America

Order 3 :Casuariformes

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

Example : Cassowaries of Australia and Emu of New Zealand

Order 4 : Apterygiformes

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

Example : Kiwi (*Apteryx*) of New Zealand

Order 5 : Dinornithiformes

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

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

Order 6 : Aepyornithiformes

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

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

Order 7 : Tinamiformes

1. Small terrestrial birds, not flightless but essentially great runners (cursorial).
2. Sternum is keeled.
3. Pygostyle reduced.
4. Egg shells with high gloss.

   Example : *Tinamus. Eudromia*

Super-order 3 : Impennae

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

   This has only 1 order

Order 1 : Sphenisciformes

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

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

Super-order 4 : Neognathae or Carinatae

1. Most modern, usually small sized, flying birds.
2. Wings well developed, feathers with interlocking mechanism.
3. Rectrices present and arranged regularly.
4. Pterylae are regular.
5. Oil gland is present.

6. Skull is neognathous, that is vomer is short allowing palatines to meet.
7. Skull suture disappear very early.
8. Quadrate is double headed.
9. Sternum with a well developed keel.
10. Uncinate processes are present.
11. Pygostyle is present.
12. Scapula and coracoids meet at a right angle or acute angle.
13. Pectoral muscle large.
14. Male has no copulatory organ.
15. Young are altricious.

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

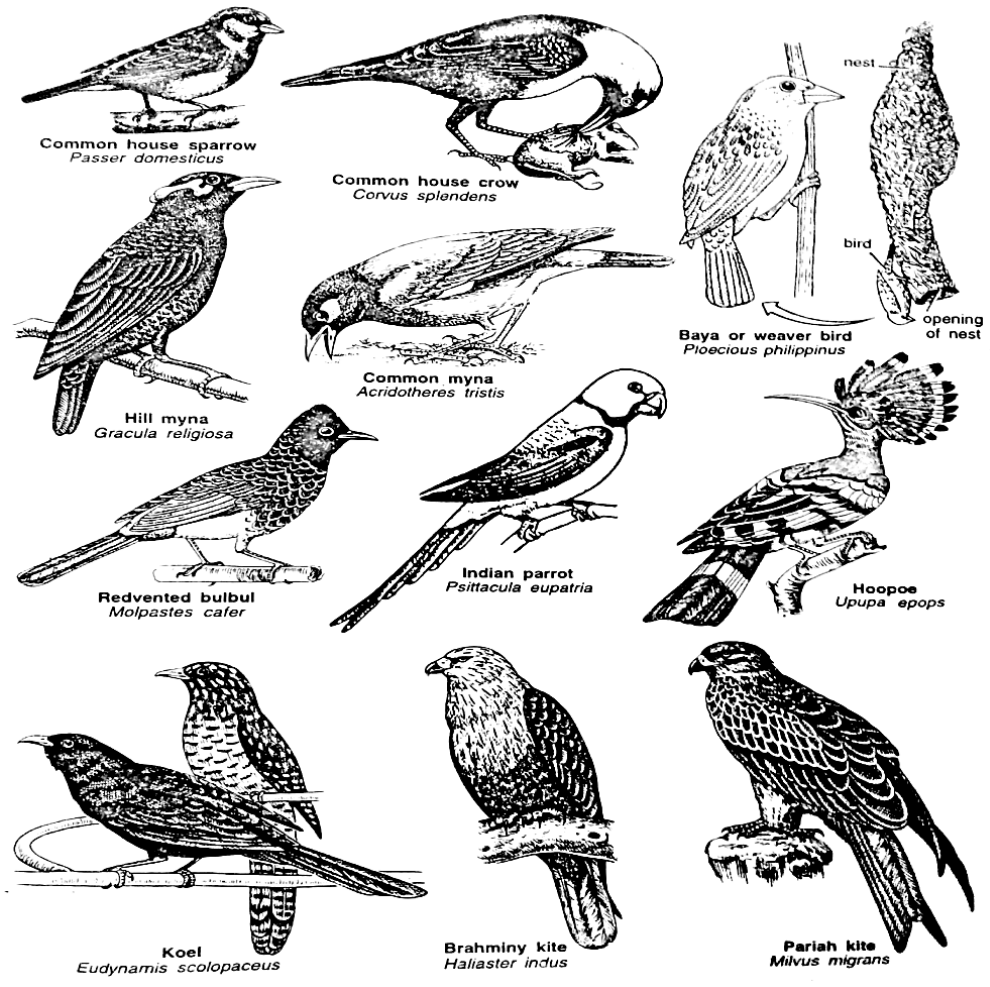


Fig : Some common Indian Birds

Group A : Arboreal Birds

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

this group.

Order 1 : Passeriformes

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

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

Order 2 : Piciformes

1. Includes highly specialized wood - boring birds like woodpeckers, toucans, sap-suckers.
2. Bill is hard and powerful.
3. Tongue is long and protrusible.
4. Insectivorous.

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

Order 3 : Columbiformes

1. Includes doves and pigeons.
2. Beak usually soft and slender.
3. Crop large producing pigeon milk to feed youngs.
4. Fruit and grain rating birds.
5. Mostly good filers.

Examples : *Columba livia* (Blue rock pigeon)

Order 4 : Psittaciformes

1. Includes parrots, parakeets, cocatoos, macaws etc.
2. Beak stout, narrow, sharp edged and hooked at the tip.
3. Upper jaw movably articulated with the skull.
4. Feet zygodactylus that is two toes infront and two toes behind. Outer toe not reversible.
5. Have considerable memory.
6. Vegetarian.
7. Feathers green, blue, yellow or red.

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

Group B : Terrestrial birds

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

Order 5 : Galliformes

1. Include game birds with short powerful flight.
2. Feet usually massive adapted for scratching and running.

3. Beak short.
4. Feathers with aftershaft.
5. Graminivorous (grain eating).
6. Palatable.

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

Order 6 : Cuculiformes

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

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

Group C : Swimming and diving birds

Order 7 : Anseriformes

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

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

Order 8 : Coraciiformes

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

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

Order 9 : Gaviiformes

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

Example : *Gavia* represented by four species.

Order 10 : Podicipediformes or Colymbiformes

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

Example : Rebes(*Podicipes*)

Order 11 : Procellariformes

1. It include sea birds.

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

Examples : Albatross (*Diomedea*)

Order 12 : Pelecanioformes

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

Example : Pelican (*Pelecanus*)

Group D : Shore birds and wading birds

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

Order 13 : Charadriformes

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

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

Order 14 : Ciconiiformes

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

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

Order 15 : Gruiformes

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

   Examples : *Fulica atra* (Common coot)

Group E : Birds of Prey

Order 16 : Falconiformes

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

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

Order 17 : Strigiformes

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

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

Group F : Aerial Birds

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

Order 18 : Micropodiformes or Apodiformes

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

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

Order 19 : Caprimulgiformes

1. It includes shy, nocturnal and insectivorous.
2. Beak small and delicate.
3. Mouth wide, margined with long bristle like sensory feathers.
4. Feathers soft.

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

SAQs 1.

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

(i) Birds are ----------

(ii) Egg of birds are with shell so they are ---------- .

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

(iv) Flightless birds are included in ----------

7.3 STUDY OF COLUMBIA (PIGEON)

Systemic Position

Phylum - Chordata

Group	-	Vertebrata
Subphylum	-	Gnathostomata
Class	-	Aves
Subclass	-	Neornithes
Super order	-	Neognathae
Order	-	Columbiformes
Genus	-	*Columba*

Habit & Habitat

The columba or pigeons are widely distributed in Asia, Europe & North Africa. In India its two subspecies *Columba livia neglecta*&*Columba livia intermedia* are found. The Columba livia neglecta has large size & pale colour and is found up to 13000 feet on the Himalayas while Columba livia intermedia is asmaller and darker in colour and occurs throughout India.

The pigeon or Columba livia in perfect freedom in ledges, fissure, and holes of rocks, forts, old building. They also live in city & town where have plenty of grains. There favourable places are like big building, godowns, grain markets, temples, mosques, churches, tombs, railway station rtc. They never nest on trees. The pigeons are in offensive, harmless, timid & feeding & gregarious birds. The pigeons are vegetarians, feeding on grains, pulses, seeds of fruits & grasses.

The pigeon is provided with long powerful wings which are well adapted for swift and strong flight on earth, they walk on their two legs i.e. bipedal locomotion. They produce a characteristic sound gootur –goon, gootur goon.

During breeding season pigeon make a simple, flat and artless nest of small sticks and thin roots etc. all sort of places where there is some shelter from rain & sun. The eggs are laid in these nest and further development occurs in these nest. Pigeon lead a monogamous life i.e. one male with one female. The pigeon lay eggs in the nest and are incubated by the warmth of the parent's body are immature, helpless & featherless and are nourished by pigeon milk produce by their crop. The parental caring & homing instinct are well developed.

External features

Shape & size

The body of pigeon is spindle shaped measuring about 33 cm in length and well adapted for rapid flight. It is a salty- grey bird with glistening metallic green and purple sheen on the upper breast and around the neck. Eyes and feet are pink. The wing has two black bars.

Division of body

The body of pigeon isbilaterally symmetrical, compact, boat shaped streamlined well adapted for their aerial mode of life. The body of pigeon is divisible into head, neck, trunk and tail.

(1) Head : Head is comparatively small, spherical and situated at the anterior most part of the body. Beaks present anteriorly are formed by the elongation of upper and lower jaw and they are devoid of teeth. At the base of the beak are the external nostrils overhung by a swollen, sensitive soft skin called cere. Eyes are prominent, round and laterally present. Eyes are protected by an upper eyelid, lower eyelid, and a transparent nictitating membrane. Posterior to the eyes are the ear openings which lead to the tympanic membrane by short tube, external auditory meatus.

(2) Neck: The neck is long, flexible and well demarcated from head and trunk. It helps in handling of food and compensates the forelimbs which have modified into wings.

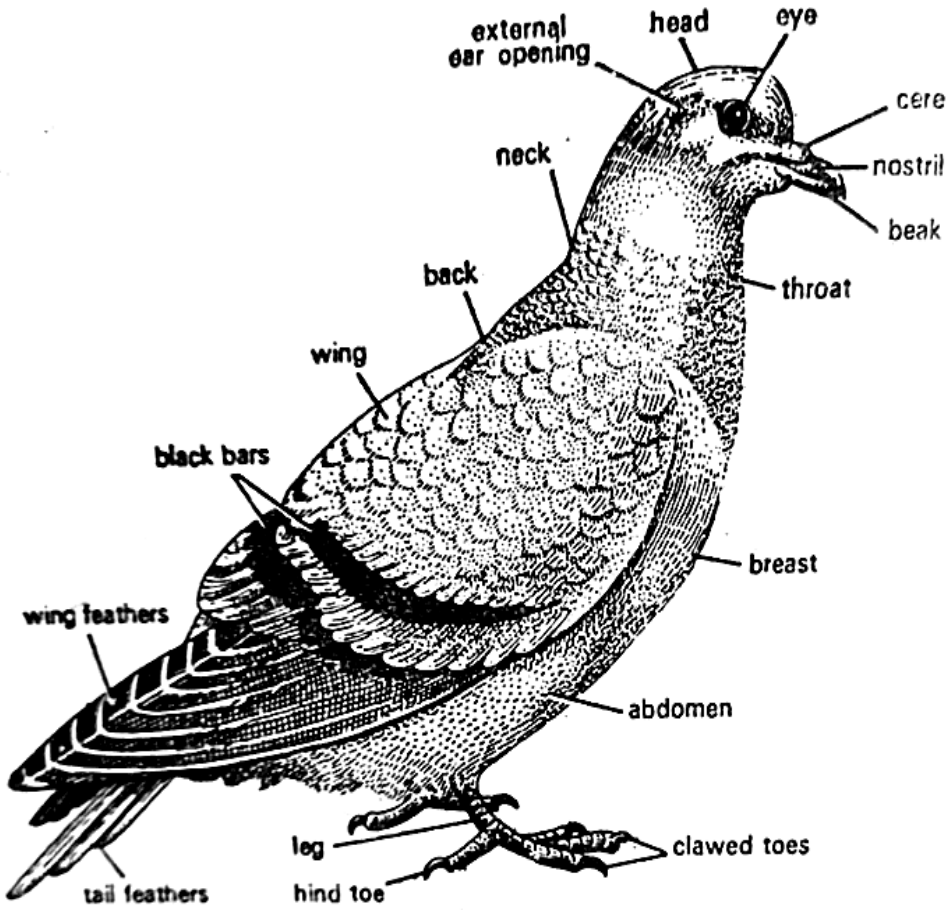


Fig: Pigeon External Feature

3. Trunk: The trunk is compact and spindle-shaped, bearing a prominent bony ridge, the keel or carina, at its mid-ventral line. The spindle shaped trunk bears a pair of wings and a pair of legs. The cloacal aperture opens ventrally at the hind end of the trunk. Dorsally the base of the tail has a knob like papilla, which bears the opening of the preen gland or uropygial gland. It is the only cutaneous gland present and its oily secretion is used for lubricating or preening the feathers. The tail is used as a rudder in flight. Fore limbs are modified into wings. The wings have three typical regions, the upper arm (brachium), lower arm (ante - brachium) and the hand (manus). Three clawless and imperfectly marked digits are present on each hand. While at rest, each forelimb is folded in the form of 'Z'; during flight they are extended. With the modification of the forelimbs for flight, the whole weight of the body is supported by the hind limbs, while the bird is at rest or walking; the hind limbs are therefore attached anteriorly from the trunk to balance the body and support the weight of the body at rest. They are warm blooded or homeothermic.

(i) Legs:

The hindlimbs or legs arise somewhat anteriorly from the trunk to balance and support the entire weight of the body at rest. Each hindleg comprises three parts: the thigh, shank and foot. The thigh is short, closely bound to the trunk, and directed downwards and forwards. The shank is long and extends from the knee downwards and backwards.

The foot is clearly divisible into a proximal portion, the tarso-metatarsus, and four digits. The digits are long and clawed. The first digit is called hallux and is directed backwards. The remaining three digits, the 2nd, 3rd and 4th extend forward. The legs are efficient organs of perching and locomotion with long toes and curved claws.

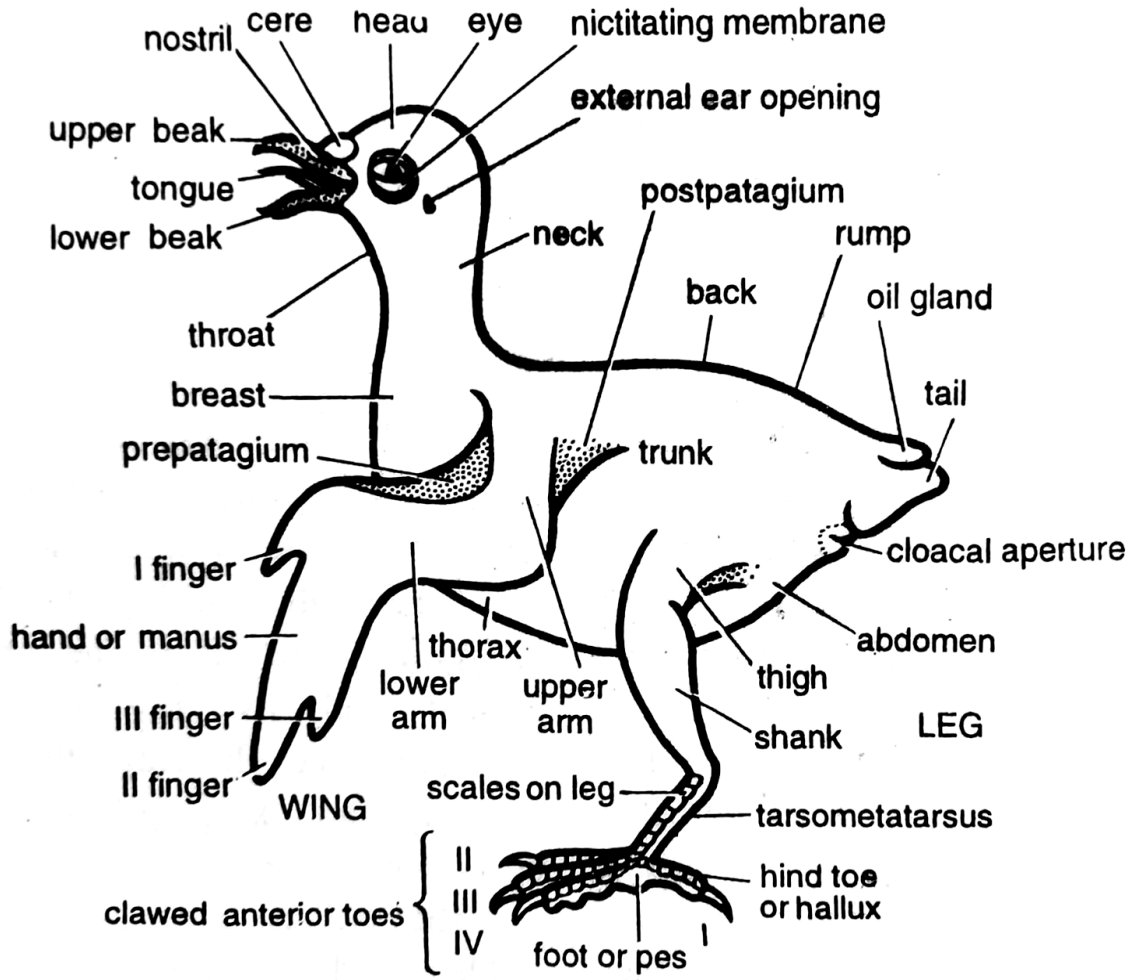


Fig: Pigeon, defeathered bird in left lateral view.

4. Tail:

After removal of the feathers it can be seen that the true tail is short, conical projection of the trunk, known as uropygium. It bears a group of elongated tail-feathers or rectrices. On the dorsal surface of uropygium is a papilla bearing on its summit the opening of a preen, coccygeal, or oil-gland.It is the only integumentary or cutaneous gland found in birds. Its oily secretion is used for lubricating or dressing the feathers and beak (makes them water-proof and shining). It produces a specific recognition scent and it elaborates ergosterol, which, when exposed on the feathers, is transformed by sunlight to vitamin D.The tail with its feathers is used as a rudder during flight and a balancer in perching.

Skin:

The skin of pigeon is dry, loose, hard and thin. Histologically, it consists of an outer epidermis of ectodermal origin and an inner dermis of mesodermal origin.

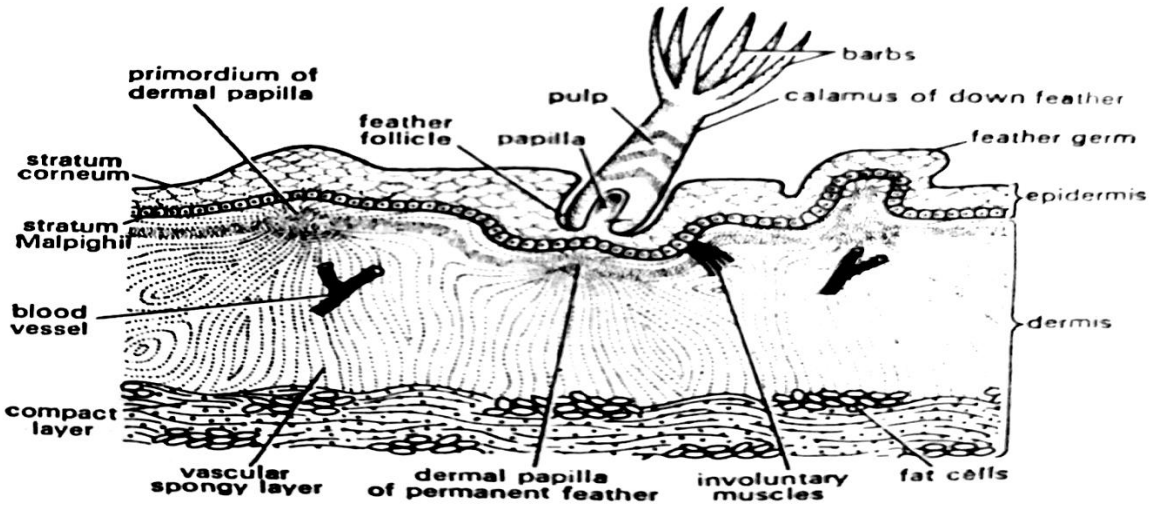


Fig : Pigeon V.S. of skin

(i) Epidermis:

The epidermis is several layers thick and composed of an outer epitrichium, a middle stratum corneum and an inner stratum germinativum or stratum Malpighii. The epitrichium is composed of a single row of flattened delicate cells. The stratum corneum is horny and protective and made of flat cornified cells.It is modified to form several exoskeletal structures, such as the corneoscutes or scales on the feet, rhamphotheca or horny covering on the beaks, claws and toes and feathers which covers the most of the body. The stratum germinativum is made up of large, cylindrical and continuously dividing cells. It gives origin to the cells of epitrichium and stratum corneum.

(ii) Dermis:

The stratum germinativum of epidermis is followed by dermis. The dermis consists of muscle fibres, nerve fibres, blood capillaries, and connective tissue.

The epidermis and dermis have no pigmented cells, however, pigments occur in scales and feathers only. The skin lacks in sweat and any other type of cutaneous gland, except the uropygial or preen gland present dorsally at the base of tail.

Exoskeleton:

The pigeon has well developed exoskeletal system which serves many functions such as protection of body from temperature fluctuations of environment, radiations and mechanical injuries of various sorts. Further it makes the body of pigeon well adapted for aerial mode of life.

The exoskeleton of birds is derived from epidermis and occurs in the form of horny claws, beaks, spurs, webs, scales, feathers. Spurs are lacking in pigeons. Spur is a bony outgrowth of tarso-metatarsus in the male fowl and some other birds. It is covered by a horny, scale-like epidermal sheath and pointed in shape.

(i) Scales:

In pigeon, the scales are confined to the shanks and feet and some at the base of the beak. The scales are cornified derivatives of the stratum germinativum of epidermis which form a protective covering of body parts and are shed and replaced by moulting.

(ii) Feathers:

The entire body of pigeon is covered with a close and continuous covering of feathers, which constitutes the plumage. They are light, strong, elastic, water proof and show many colours due to melanin pigment of various shades as well as due to iridescence. Melanin range from black through brown to yellow and laid down in the feathers by special cells in the papilla. Carotenoid pigments are also found, such as the yellow zooxanthin, the red astaxanthin.

Structure of a typical feather in Pigeon:

The structure of a feather, a contour feather which occurs on general body, wing and tail, can be considered as typical. A typical contour feather consists of a central axis, main stem or scapus and an expanded distal portion, the vexillum or vane.

1. Scapus (Axis):

The scapus is divided into a basal portion, the calamus and an upper shaft or rachis.

(a) Calamus:

The calamus is hollow, tubular and semitransparent. The base of calamus remains inserted into a pit or follicle of the skin, from which non-striated muscle fibres pass to the feather and provide movement to each contour feather. The calamus opens below by a small opening called inferior umbilicus, which receives a small, conical, nutritive dermal papilla from the dermis.The nutrients and pigments are passed through the dermal papilla into the feather from the dermis, during the development of feather. Another pore, called superior umbilicus, occurs on the ventral side of junction of calamus and rachis.In some pigeons and many other birds, a small tuft of soft down feather, called after shaft or hyporachis, occurs near the superior umbilicus and covers it.

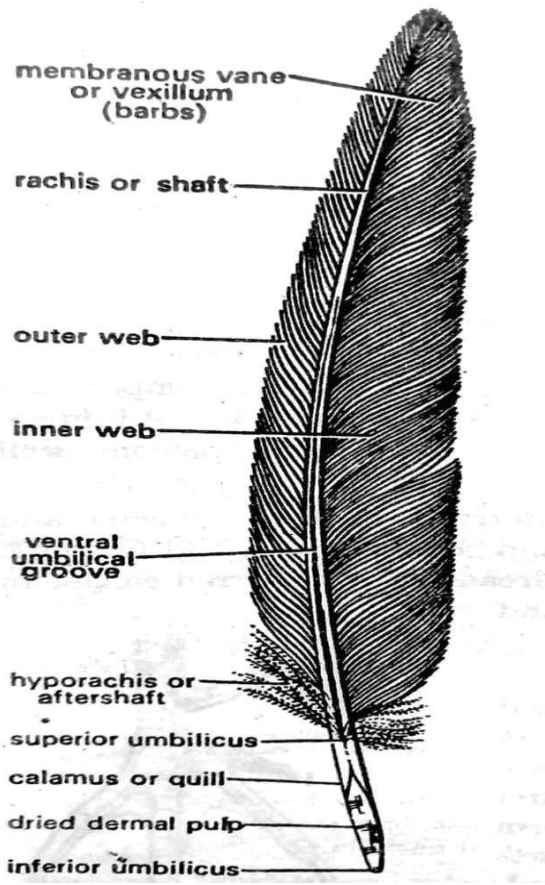


Fig: Pigeon : A typical feather in ventral view

(b) Rachis:

The part of the scapus above the calamus is a rachis. It forms the longitudinal axis of the vane. It is solid, opaque, roughly quadrangular in transverse section and filled with a closely packed mass of pith cells. A longitudinal furrow, the umbilical groove, runs along the ventral or inner surface of the rachis throughout its length.

2. Vane:

The rachis bears a fan-like, webbed or expanded membranous part of the feather, the vexillum or vane. The vane is divided by rachis into two unequal lateral halves. Its proximal end is broader than the distal end. Each half of vane is composed of a series of numerous (about 600), parallel, closely spaced, delicate, lateral, thread-like structures called the barbs or rami. The barbs arise obliquely outwards from the two lateral sides of the rachis.The size of barbs gradually decreases towards both the ends of the rachis. Each barb on either side bears a fringe of small, extremely delicate, oblique filamentous processes, the radii or barbules. The barbules are of two types- proximal barbules directed towards the base of feather and distal barbules directed towards the tip of feather.The lower edge of distal barbules bears minute, hamuli, barbicels or booklets and the upper edge proximal barbules are deeply curled or rolled to form a groove and flange. Hooklets of distal barbules hook over the grooved edges of proximal barbules binding the barbs together.With this limited sliding interlocking arrangement, all the barbs and barbules are loosely held together, so that the vane forms a flexible, firm, wide, flat and continuous surface for striking the air during flight. This interlocking mechanism can be broken down so that the barbs become separate, but can be joined again by “preening” the whole feather.

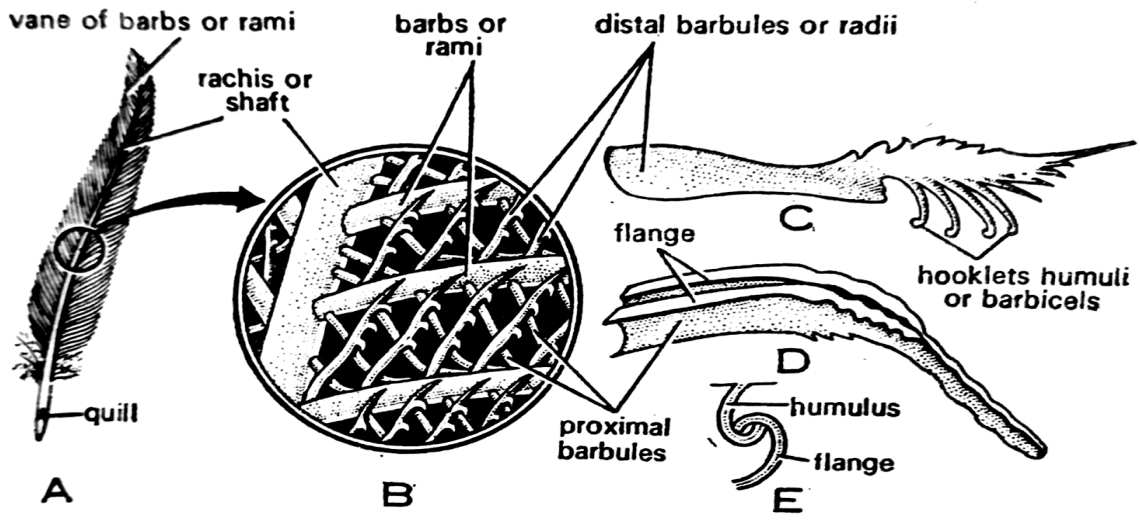


Fig: Detailed structure of a feature

(A) Complete feather

(B) A small part showing interlocking mechanism

(C) A distal barbules

(D) Two proximal barbules

(E) Humulus of a distal barbules interlocking with the flangeof a proximal barbules.

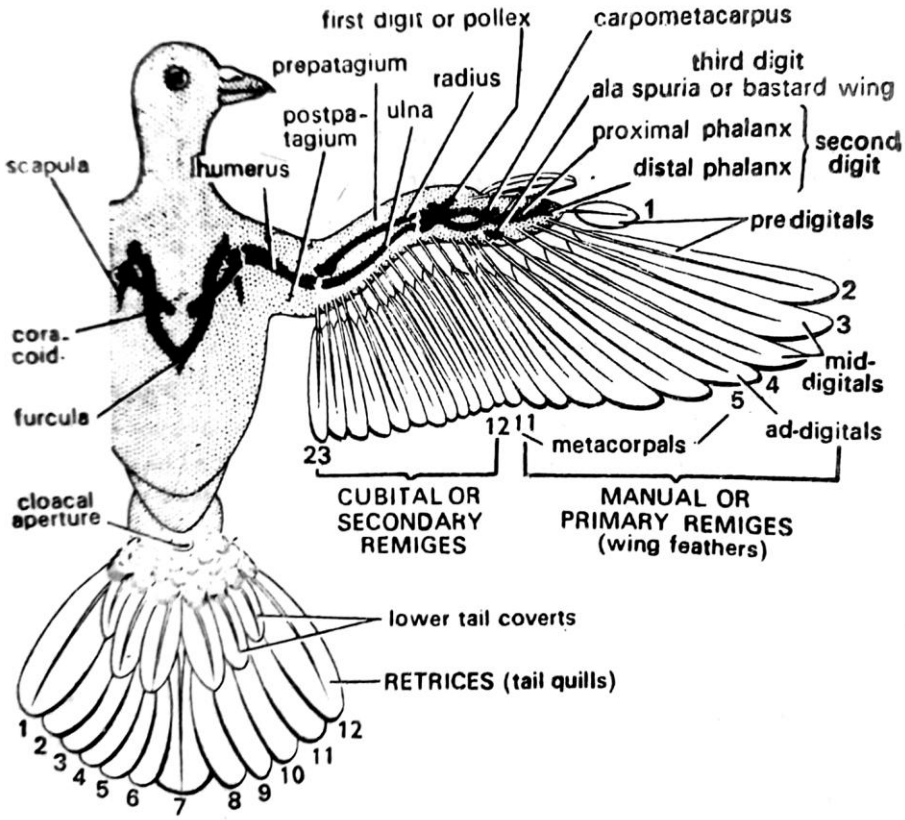


Fig: Pigeon : Arrangement of remiges and retrices

Kinds of Feathers:

There are four types of feathers present in pigeons and they are quills or flight feathers, contour feathers, filoplumes, and down feathers.

1. **Quills or Flight Feathers**
    - These are the strong and large feathers of pigeons.
    - The pigeon uses these feathers for flight.
    - These feathers have comparatively strong rachis.
    - Quills or flight feathers are further classified into three types and they are remiges, rectrices, and coverts.

    Remiges

    - Flight feathers of wings are called remiges.
    - It is also termed as pinions or wing quills.
    - Their inner or posterior half of the vane is slightly broader than the outer or anterior half.
    - Each wing of a pigeon contains 23 remiges.
    - Eleven remiges are attached to the hand. They are called primaries or manuals.
    - Of these 11 manuals, the first four feathers are attached to the second digit and they are termed as digitals.
    - Of these four digitals, two of them are attached to the distal phalanx and termed as pre-digitals. Rest two are attached to the proximal phalanx and termed as mid-digitals.
    - The remaining seven manuals are attached to the metacarpal and termed as metacarpals.
    - The remaining twelve remiges are attached to the forearm and called secondaries or cubitals.

    Rectrices

    - Flight feathers of tail are called rectrices.
    - They are also termed as tail quills.
    - There are 12 rectrices present in pigeon.
    - These rectrices form semi circle, fan like manner on the tail.
    - These feathers help the bird as a brake and in steering the flight.

    Coverts

    - Bases of remiges are covered by upper and under wing-coverts.
    - Bases of rectrices are covered by upper and under tail-coverts.
    - Coverts are smaller in size than the remiges and rectrices but structurally same.
    - They close the interstices between quills of flight feathers, thus presenting a continuous area to oppose the buoyancy of air.

2. **Contour Feathers**

- These feathers form the general body covering.
- They are smaller and woolly feathers.
- They have poorly developed barbules.
- Contour feathers provide a smooth surface to the body.
- They make a good heat-conserving layer.

3. Filoplumes (Hair feathers or pin feathers)

- These are the small, delicate, and hair-like feathers.
- These feathers are present all over the body.
- They are seen in the plucked pigeon.
- They consist of a short calamus and a long thread-like rachis with a few weak barbs and barbules at the free tip.

4. Down Feathers (plumules)

- These are small, soft, and woolly feathers present only in a newborn baby.
- They have no rachis.
- They form the natal covering of the newly hatched birds.
- Adult pigeons do not have down feathers. The down feathers are being replaced by the contour feathers as the bird grows into the adult.

Uses of Feathers in Pigeon

Feathers have several important and decorative functions for pigeons. The uses of the feathers in pigeons are given below:-

1. Protection

Feathers are a durable covering of the pigeons and protect them from any mechanical and physiological injury.

2. Heat Retention

Heat retention is one of the most important functions of the feathers for pigeons. The birds can maintain 104° to 112°F with the help of feathers in any kind of weather. During cold weather, feathers help to prevent heat loss from the body.

3. Organ of Flight

This is the most important function of feathers. Birds or pigeons can fly with the help of feathers. Feathers are light, elastic and horny structures. Pigeons fly in the air with the help of flight feathers and flight muscles.

4. Protective Coloration or Camouflage

As pigeons or other birds have different pigments, they have different colored feathers which help them camouflage and protect the birds from their enemies.

5. Sex Determination

Usually, the male birds have more attractive feathers than the females which help them in attracting the females during the breeding season.

6. Natal Covering

Down feathers are of special importance as natal covering in birds.

7. Formation of Nest

Pigeons as well as other birds use their feathers in the formation of nests to make them more comfortable.

Digestive system

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

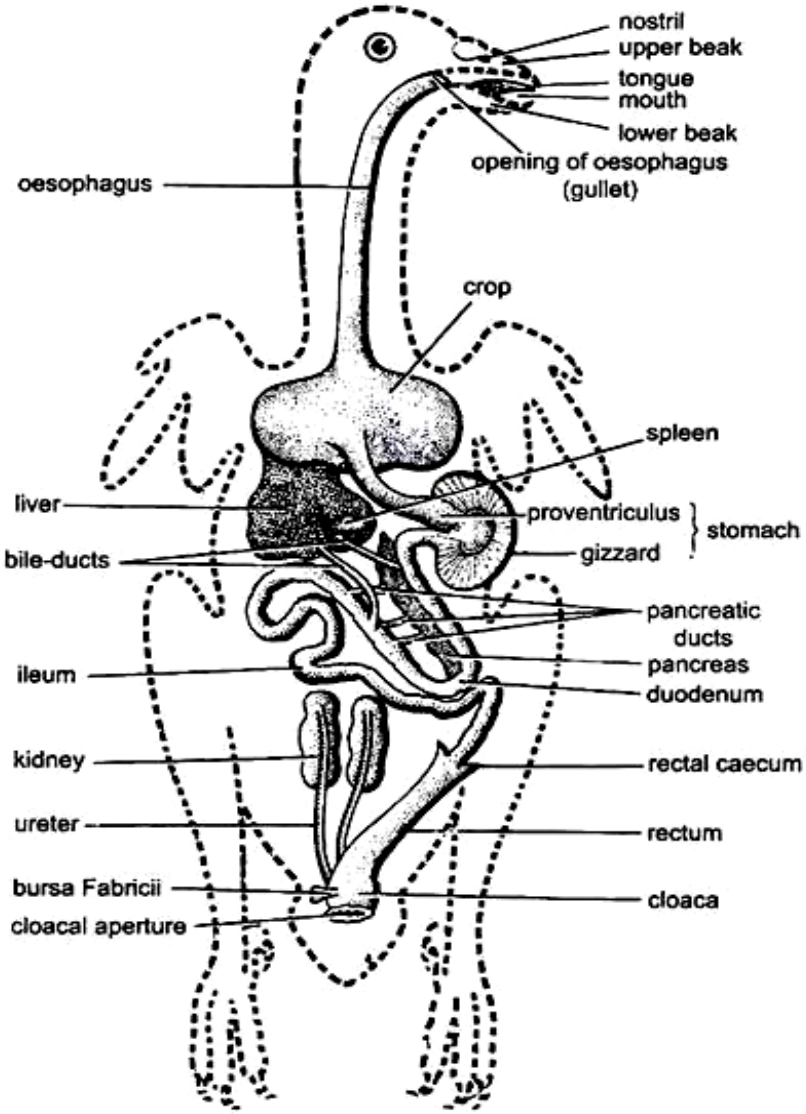


Fig : Pigeon, Alimentary canal

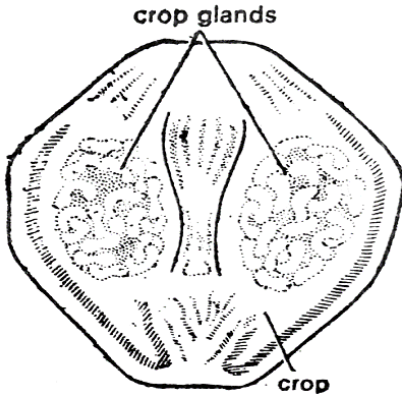


Fig : Pigeon Crop cut open

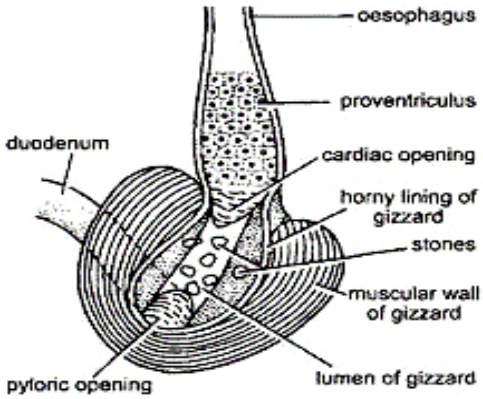


Fig: Stomach in sagittal section

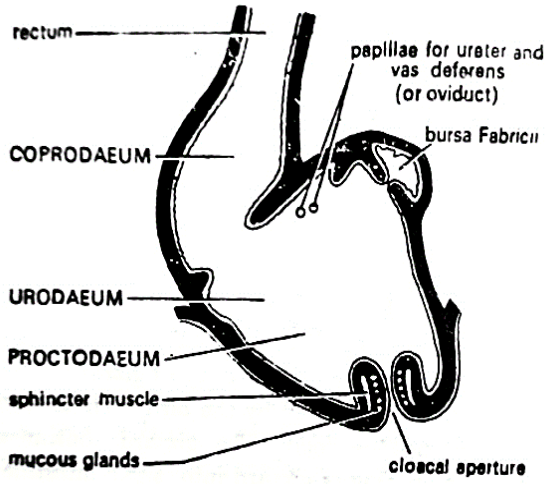


Fig : Pigeon Cloaca in longitudinal section

Digestive Gland

Salivary gland : Pigeon has no salivary gland but has small buccal gland which secrete mucus to moisten food and probably amylase

Liver : Liver is divided into right & left lobe. In pigeon there is no gall bladder.

Pancreas : Well develop

Respiratory System

The respiratory tract consists of following parts starting from external nares which open into nasal chamber. This open inside to the pharynx by internal nares, through the glottis it open into trachea. The anterior part of the trachea is larynx. It is not the sound box (compare to other it is sound box). The trachea leads to open into syrinx, a some swollen structure which is the sound box of the bird. It is provided with internal and external tympanic membrane. After that the trachea divide into 2 branches called bronchii. This enter into the lung..

Lung : The lung of pigeon has bright red colour, it is small, compact, slightly distensible, highly vascular and is not capable of expansion (other vertebrate the lung can store air). Lung cannot store air. They are solid, spongy and lie in the pleural cavity. From the dorsal and dorso-lateral side it is not covered by the peritoneal membrane. Only from the ventral side it is covered called pleura or pulmonary aponeurosis and muscle attached with it is called costo-pulmonary membrane.

After entering the bronchii into the lung it does not divide and only lose the cartilaginous ring and called primary bronchus and it move toward the posterior end and is called mesobronchus, it divide and give the secondary bronchii and from the secondary bronchii it gives the tertiary bronchii and parabronchi. The lung parenchyma has hexagonal area which are surrounded by parabronchii and they have interlacing blood vessel and a system of air capillary. The air capillary is joint by parabronchii. The air capillary has a vascular respiratory surface from which the gaseous exchange takes place (compare to the vertebrate that they have alveoli for the respiratory surface but in bird has no alveoli). From the lung many air sac arise.

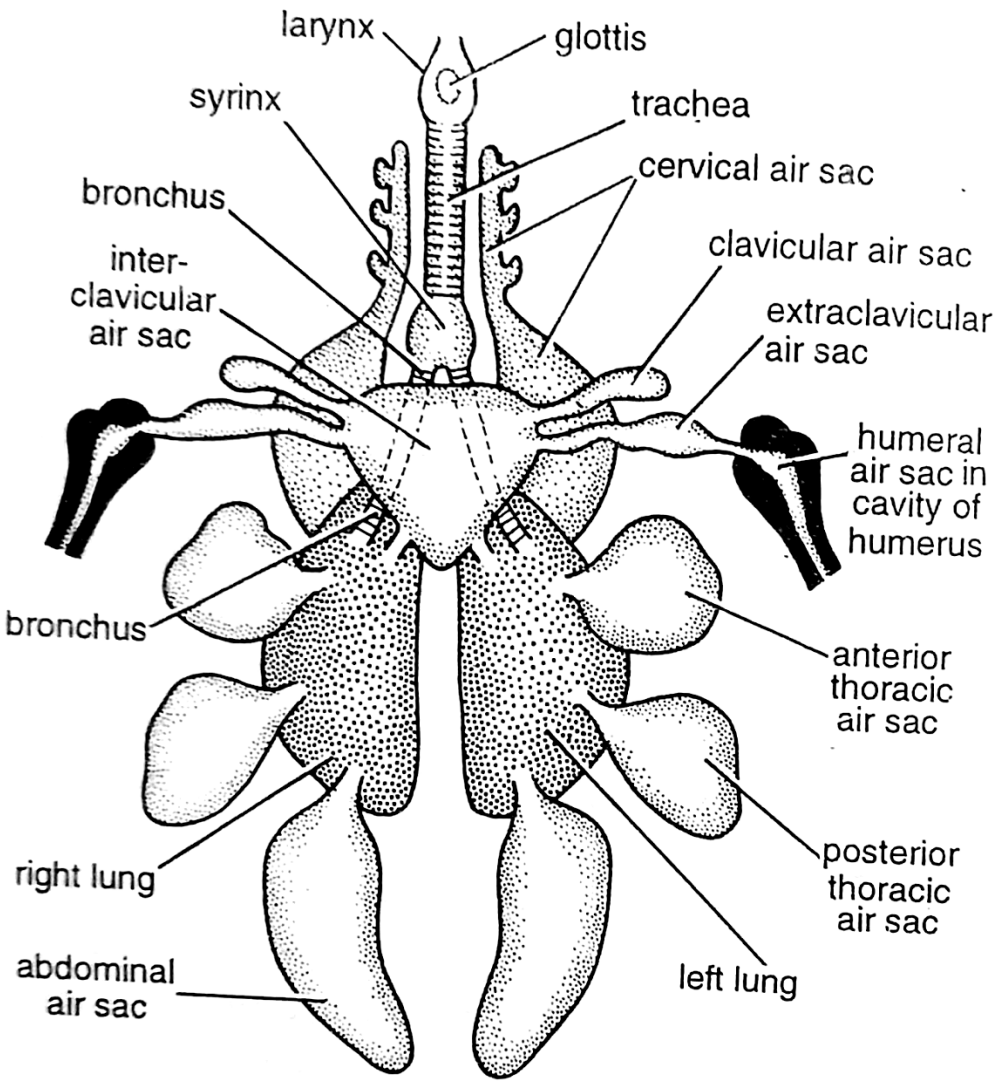


Fig : Pigeon Lung and Air sacs

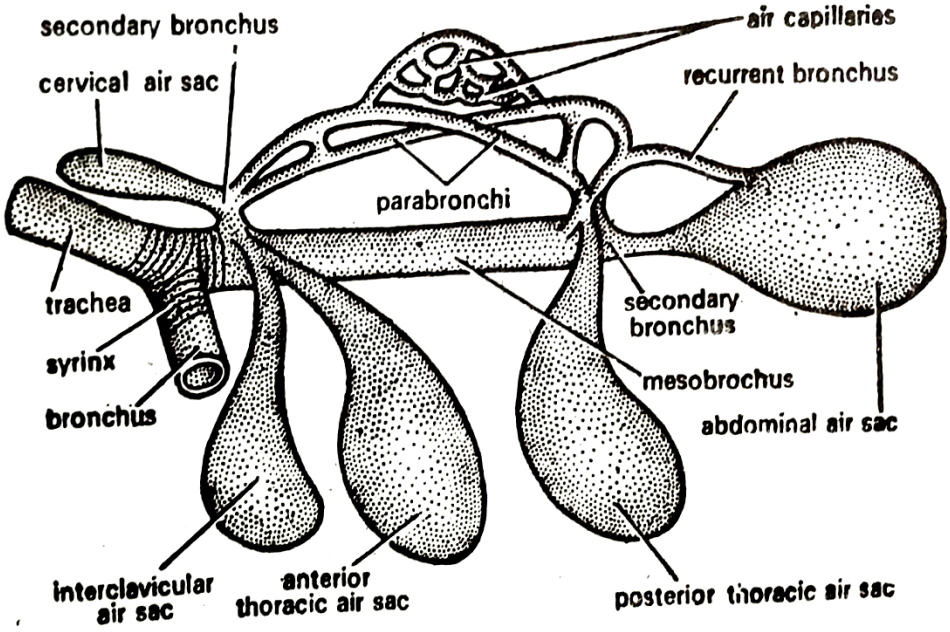


Fig : Pigeon Scheme of lung and air sacs

Air Sacs

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

(i) **Inter clavicular air sac :** It is in the median, somewhat triangular and connect the two lung by the secondary bronchii. It is present in between the angle of two limb of the furcula. From the interclavicular air sac 2 tubular like out growth. One of which enter into the cavity of humerous through the pneumatic foramen.

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

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

(iv) **Posterior thoracic air sac :** It arise from the posterior side of the lung.

(v) **Abdominal air sac :** It is large and arise from the distal end of the lung, it somewhat cover the intestine and abdominal portion.

Function :

Air sac is not respiratory organ. It acts as to supply the pure air to the air capillary of respiration. According to some scientist the anterior sac will act are expiratory and they are more active during flight. While posterior air sac are inspiratory and are, more active during when the bird is not flying. The air sac also acts as balloon giving the buoyancy in flight and reduce the specific gravity of bird due to the contained warm air.

Respiratory mechanism

The lungs are not dilatable since the skeleton around them forms a rigid framework. Inspiration is passive and expiration is an active process. During respiration the sternum is drawn towards the vertebral column, by contraction of the muscles of the body-wall. As is drawn up, the elastic ribs are bent so as to bring about a decrease in the size of the body cavity and the air from the lungs is forced out. When the muscles relax, the body-cavity recovers its size and air is drawn in.

Syrinx

The larynx does not take part in the production of voice. The **voice box** lies deep down where the trachea divides into two bronchi, and is known as **syrinx**, a structure characteristic of birds. It consists of a chamber with its walls supported by three or four rings of the trachea and the first ring of each bronchus; its inner lining is raised into folds, the vibrations of which is caused by the movement of air results in the production of sound.

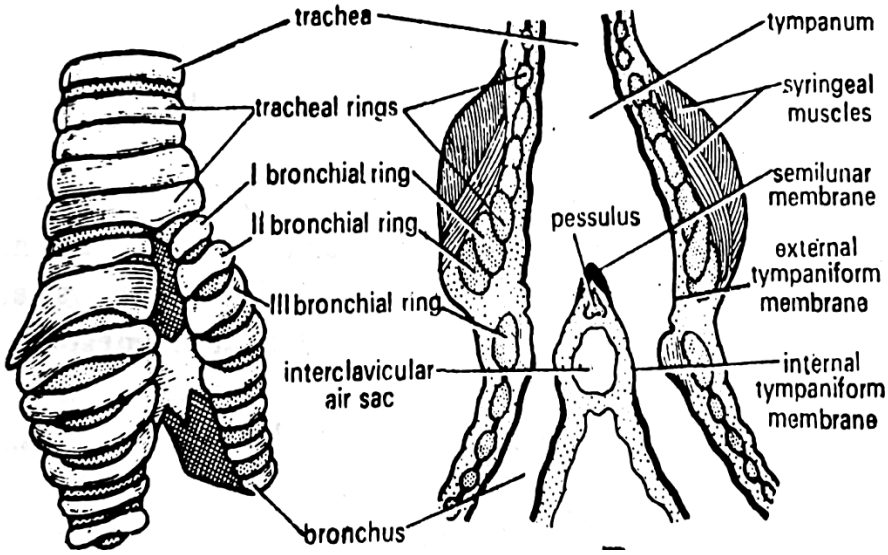


Fig : Pigeon Syrinx (A) External View (B) Longitudinal view

Circulatory system

The arculelory system is closed circulatory system. It is known as closed circulation, due to complete pulmonary respiration. The heart is more muscular, compact and large in size. It is situated in the mid ventral region of the thoracic. The heart is covered by pericardium. The right auricle is larger then left auricle. The auricle and ventricle are demarked by a groove known as coronary sulcus or coronary groove. The sinous venous disappear but fuses or incorporated with the right auricle. In the right auricle open 2 pre-cava and one post cava. The opening of the posterior vena cava is guarded by a valve known as Eustachian valve.

The right auricle opens into right ventricle which is guarded by a single valve mono-cuspid valve (in case of mammal the right auriculo-ventriculo opening is guarded by tricuspid which is the characteristic feature of mammalian heart). The right ventricle is less muscular and is smaller then left ventricle because the left ventricle has to pump pure blood throughout the body. The left auriculo-ventriculo opening is guarded by bicuspid valve, which are in mammal are known as Mitral valve. In transverse section of ventricle we see that left ventricle is more muscular & larger than right ventricle. The inner wall of the ventricle become thicker & muscular known as papillary muscle. These are very small develop in mammal. The truncus arterious disappear and split in 2

aortic arches. The one which arises from the right ventricle is known as pulmonary aorta carrying de-oxygenated blood to the lung. The opening of which is guarded by 3 semi-lunar valve. From the left ventricle arise the right systemic aorta carrying oxygenated blood to the body. It is also known as right carotico-systemic. In bird the left systemic is absent.

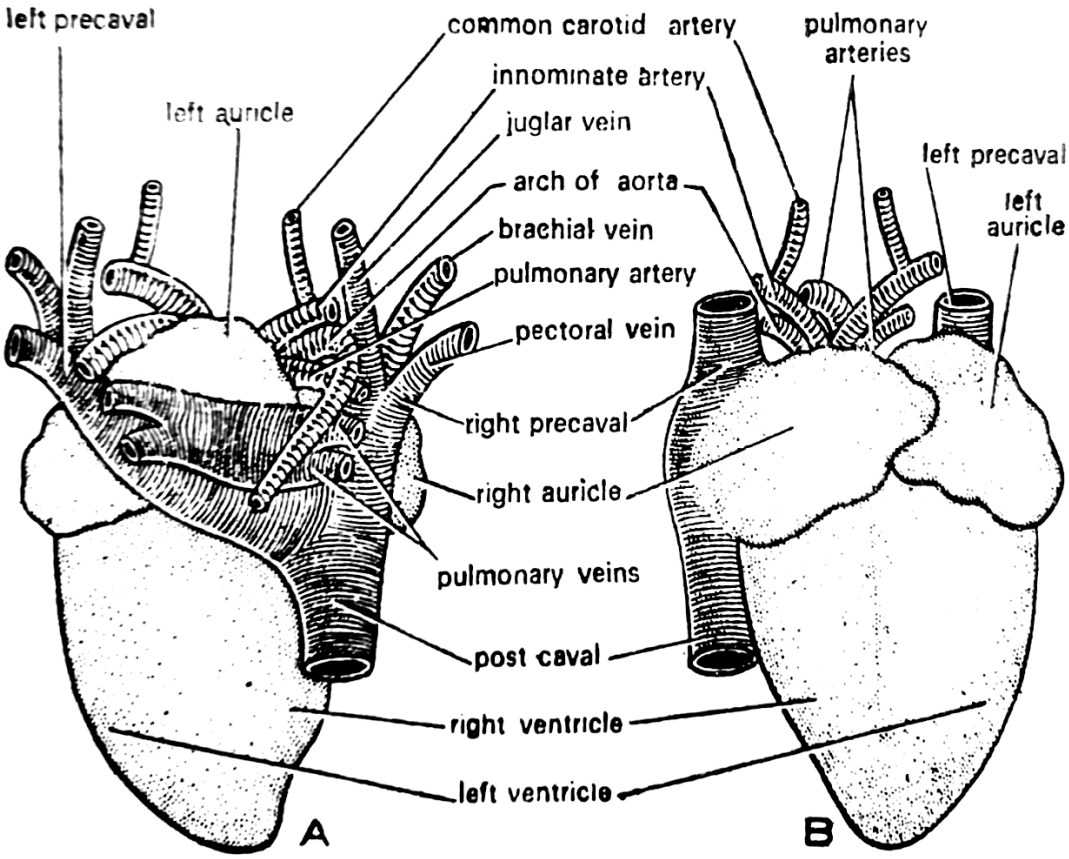


Fig: Pigeon heart (A) Dorsal view (B) Ventral view

The arterial system

The right aortic arch curves over to the right side giving off at the curve the right and the left innominate arteries; each of these gives rise to a carotid artery and a subclavian artery, the former carrying blood to the brain.

The subclavian artery divides into a brachial artery conveying blood to the arm, and a pectoral artery to the muscles of the wings. The aortic arch passes backwards as the dorsal aorta, from which are given off the unpaired coeliac artery supplying blood to the stomach, the liver and few parts of intestine; the unpaired anterior mesenteric artery to the great part of the intestine; the paired anterior renal arteries to the anterior lobes of the kidney; the paired femoral arteries supplying blood to the anterior region of the thigh and the paired sciatic arteries supply blood to the posterior parts of the thighs and the leg.

From the each sciatic artery arises a middle renal artery to the middle lobe of the kidney and a posterior renal artery to the posterior lobe; the unpaired posterior mesenteric artery supplies blood to the rectum and the cloaca, the paired internal iliac arteries to the pelvis and the caudal artery which is the terminal portion of the dorsal aorta extends to the tail.

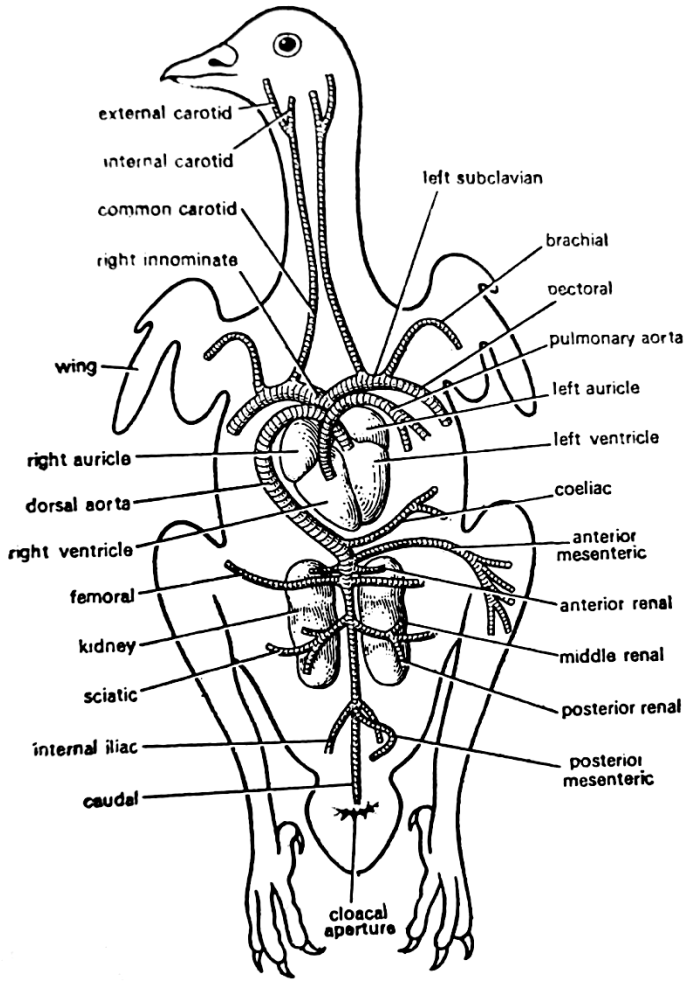


Fig : Pigeon : Arterial System

The venous system

The precaval vein of each side is formed by the union of the jugular vein from the head, the brachial vein from the arm, and the pectoral vein from the pectoral muscles. The jugular vein of the two sides are connected in front by a transverse vessel. The postcaval vein is formed by the union of the two iliac veins in front of the kidney. Each iliac vein is in turn formed by the union of the femoral vein from the leg, an efferent renal vein from the kidney, and the renal-portal vein from the posterior regions. The hepatic-portal circulation is present and the blood from the liver is emptied into the postcaval vein by three hepatic veins.

The caudal vein from the tail divides into the right and the left renal-portal vein each of which enters the kidney. Before entry, the renal-portal vein is joined by the internal iliac vein from the pelvis. As the renal-portal vein passes through the kidney, it receives the sciatic and the femoral vein from the leg, and finally emerges from the kidneys as the iliac vein. The renal- portal veins do not break into capillaries in the kidney but only send a few small branches; renal -portal circulation is therefore not well developed in the bird.

At the place of bifurcation of the caudal vein into the two renal-portal veins arises the median coccygeomesenteric vein which is characteristic of birds.

This vein runs forward, receives in its course veins from the rectum, and joins the hepatic portal vein. The epigastric vein returns the blood from the mesenteries and joins one of the hepatic veins.

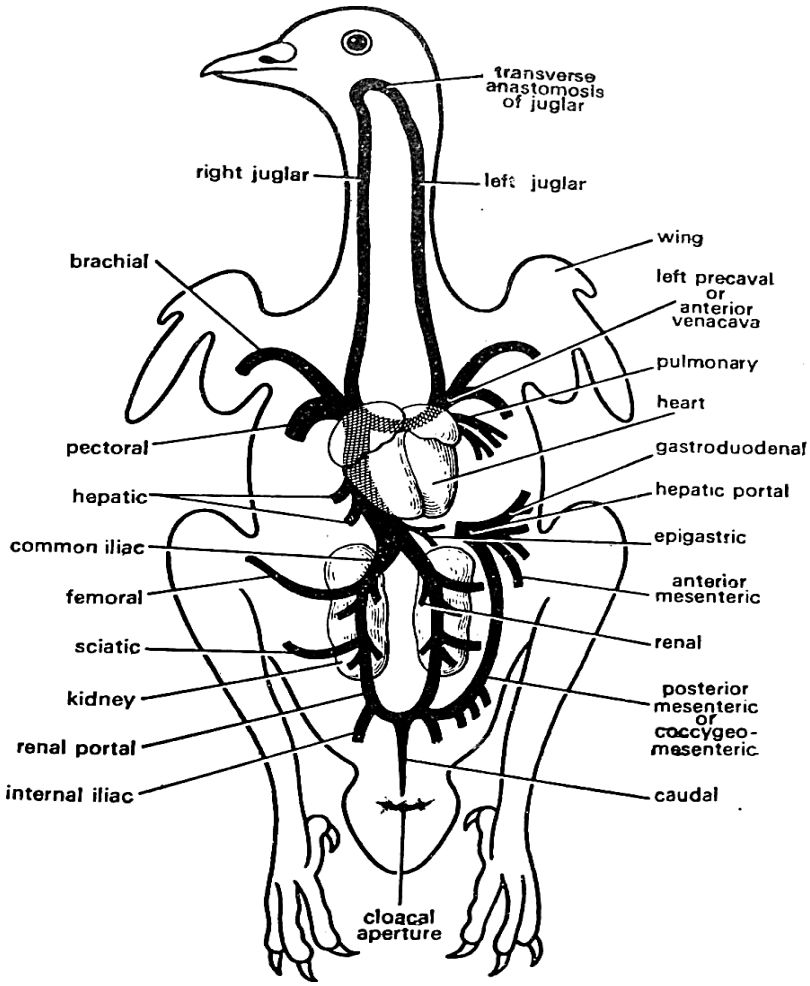


Fig : Pigeon : Venous system

Nervous system

The nervous system consists of central nervous system which includes the brain and spinal cord, the peripheral nervous system and the autonomous nervous system. The brain of pigeon is larger than in lower forms, it is short, broad and rounded within cranial cavity. It is covered by two meninges, the outer duramater and an inner pia- arachnoid membrane and the space between the two meninges is filled with cerebrospinal fluid. The cerebral hemispheres of the pigeon are large and extend behind to meet the cerebellum. The cerebrum controls voluntary movements and is the centre for memory and intelligence. The diencephalon is covered dorsally by the cerebral hemispheres and cerebellum. The diencephalon relays impulses to the cerebral hemispheres, integrates the autonomic system and the perception of extreme cold, pain, heat etc. On the ventral side of the diencephalon is the opticchiasma, behind the chiasma projects the infundibulum bearing a large hypophysis or pituitary. The optic lobes are large and occupy a lateral position owing to the large size of the cerebral hemispheres and cerebellum. Optic lobes are centres for sight. The pineal body and infundibulum are present. The cerebellum is highly developed and convoluted indicating the delicate sense of equilibrium and the great power of muscular co-ordination required for birds.

The cerebellum extends backwards covering a large part of the medulla oblongata which descends downwards to join the spinal cord. The medulla oblongata controls the involuntary movement. The olfactory lobes or bulbs are small and degenerate due to poorly developed organs of smell.

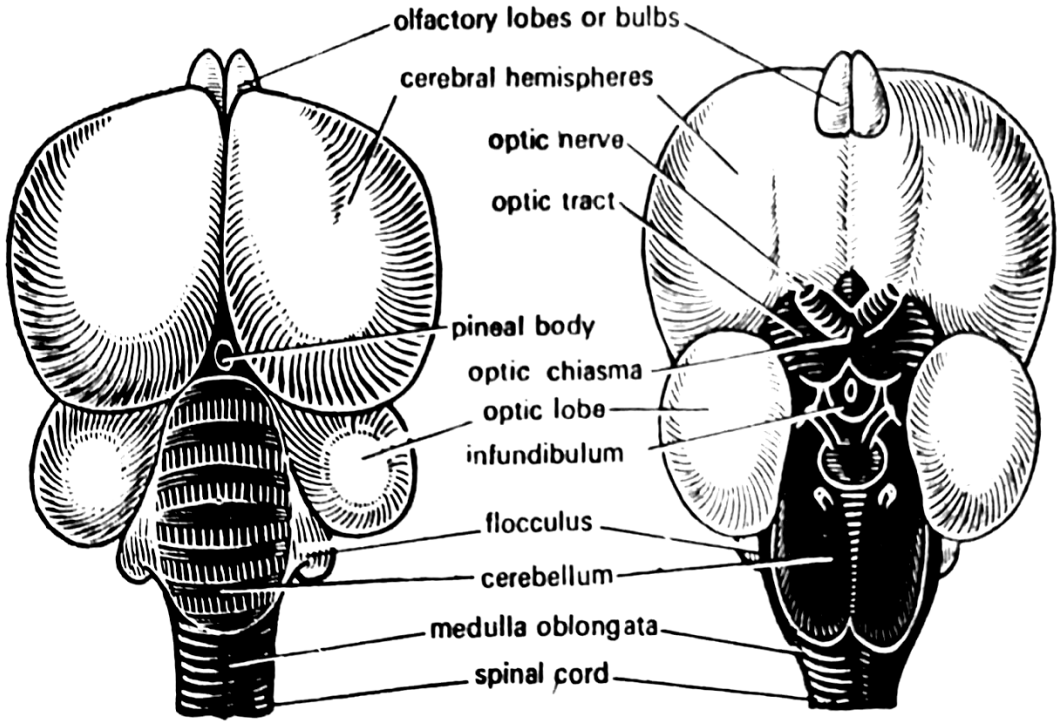


Fig : Pigeon Brain (A) Dorsal View (B) Ventral view

The peripheral nervous system consists of 12 pairs of cranial nerves and 38 pairs of spinal nerves. The autonomic nervous system of pigeon includes the sympathetic and parasympathetic nervous system. It contains the nerves and ganglia. The sympathetic nerves supply the alimentary, respiratory, circulatory and urino-genital systems.

Cranial nerve

Cranial nerve arises from the brain. Pigeon have 12 pairs of cranial nerves. These are as follows

(i) Olfactory nerve – Sensory

(ii) Optic nerve – Sensory

(iii) Oculomotornerve –Mixed

(iv) Trochlear nerve – Motor

(v) Trigeminalnerve – Mixed

(vi) Abducens nerve – Motor

(vii) Facial nerve – Mixed

(viii) Auditorynerve –Sensory

(ix) Glossopharyngeal nerve - Mixed

(x) Vagus nerve - Mixed

(xi) Spinal accessorynerve – Motor

(xii) Hypoglossal nerve – Motor

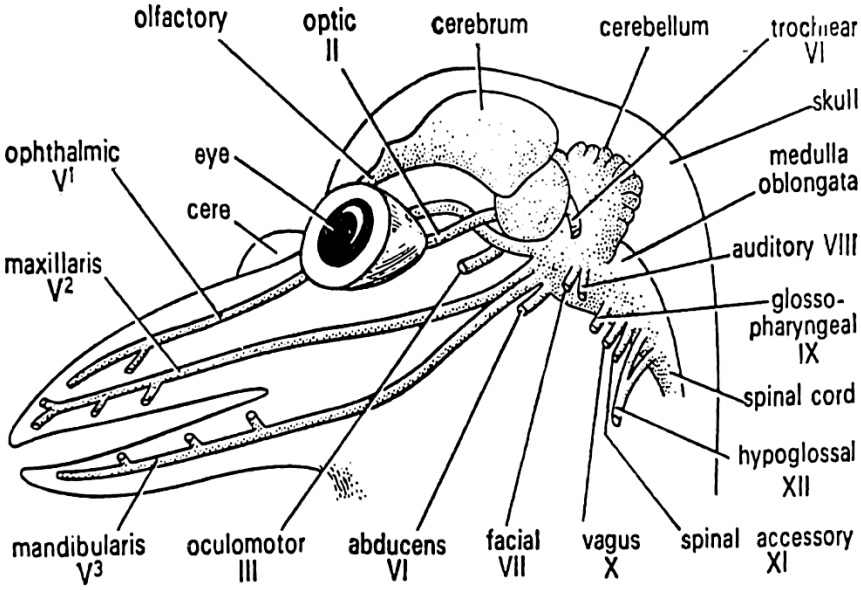


Fig : Pigeon Cranial nerve

Spinal nerve

The nerves which arise from the spinal cord are called spinal nerves. The number of spinal nerves of pigeon corresponds to the number of its vertebrae. Each spinal nerve arises as a dorsal and ventral root. The dorsal root has a ganglion and carries only somatic sensory and visceral sensory fibres. The ventral root has somatic motor and visceral motor fibres.The dorsal and ventral roots unite inside the vertebral column (inside the central canal) and come outside the column as spinal nerves. Each spinal nerve divides into dorsal ramus, long ventral ramus and ramus communicans.

In pigeon, the cervical spinal nerves pass out to the neck region. The last three cervical nerves and first thoracic nerve form a brachial plexus going to the wing. Next five thoracic spinal nerves pass between the ribs. Following these is a lumbo-sacral plexus which may be separated into lumbar, sacral and pudendal plexuses.The lumbar plexus of three nerves supplies the thighs. Five nerves of the sacral plexus unite to form a sciatic nerve which passes through the thigh and goes to the lower leg. The pudendal plexus sends branches to the cloaca and the tail.

Sense Organs

The pigeonhas receptors or sense organs for touch, smell, taste, sight and hearing which are stimulated by the environment. These sense organs are termed external receptors or exteroceptors.The pigeon possesses following exteroceptors:

(1) Tactile Organs:

These are poorly developed in birds due to feathery covering of the body. Tactile organs of pigeon remain confined to the bill and tongue of pigeon. The cere is a sensitive soft fold of skin at the base of the upper beak in pigeons, is said to have a stimulating effect during love making. The tactile organs are composed of cells with a flattened nerve ending between cells. These are comparable to Meissner's corpuscles in mammals. Merkel's corpuscles are also found in many birds. The corpuscles of Herbst, resembling Pacinian corpuscles of mammals, are found in the dermis, are vibration receptors, sensitive to mechanical deformation by rapid pressure changes.They are found in great numbers in the beaks and also in the feather follicles. Tactile nerves are also present at the base of the feathers, especially those of the wings and tail.

(2) Gustatory Organs (Chemoreceptors):

The sense of taste and smell are little developed. The sense organs of taste, the taste buds, occur in limited number on the dorsal surface of tongue. The sense of taste is poorly developed in pigeons.

(3) Olfactory Organs:

Birds are usually unable to distinguish delicate odours, and on the whole their sense of smell is very poor, as flying animals cannot depend on smell. The nasal cavity is large but the olfactory epithelium is restricted. Birds use the nose to test air coming from the internal nostrils.

Structure of Olfactory Organs:

The nostrils, overhung by cere, lead into the small, paired olfactory sacs or nasal chambers in the base of upper beak. The two chambers are separated medially by mesethmoid and bounded externally by ectoethmoid. The ectoethmoid produces inwards three scroll-like turbinal processes to increase the olfactory surface.The nasal chamber has an anterior non-sensory respiratory part and a posterior sensory part. The non-sensory part or vestibulae contains the anterior turbinal covered by laminated epithelium.The sensory or olfactory part contains the middle and posterior turbinals invested by the one-layered olfactory mucous epithelium or Schneiderian membrane, which is made of basal cells, supporting cells and elongated neuro-sensory cells. The neuro-sensory cells remain connected with olfactory nerve. Both the olfactory chambers remain communicated to the pharynx by the internal nares.

(4) Auditory Organs or Ears:

The sense of hearing is acute in pigeon. Its auditory sense organs, ears, serve their dual function of equilibrium and hearing. Auditory organs consist of a fundamental ear, the internal ear or membranous labyrinth and middle ear or tympanic cavity. They lack external ear.

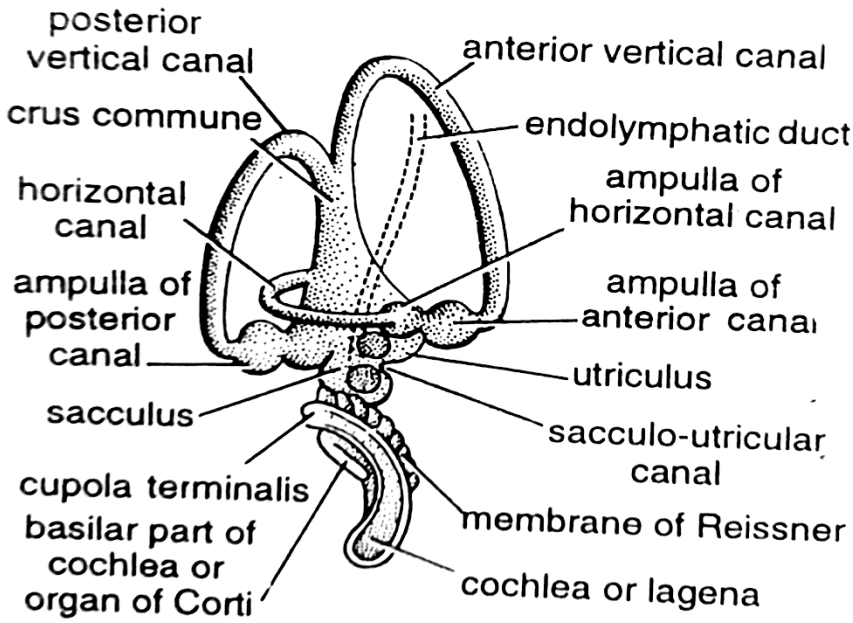


Fig : Internal ear (membranous labyrinth)

Internal Ear:

The internal ear or membranous labyrinth lies embedded in a dense ivory like bone in the side wall of the skull and is surrounded with a perilymph fluid. Membranous labyrinth is filled with a dense fluid, called endolymph. It contains a high concentration of potassium, maintained by the activity of a tegmentum vasculosum, which also absorbs sodium.It consists of three semicircular canals (one horizontal, one anterio-vertical and one posterio-vertical) relatively small sacculus and utriculus and a short blind tube, the cochlear duct or lagena. The proximal limbs of anterior and posterior semicircular canals unite to form a crus commune. The sacculo-utricular connection is narrow. From the sacculus arises an endolymphatic duct which ends in the duramater.

The cochlear duct, with its surrounding bony labyrinth or cochlear canal, is called cochlea. The cochlear duct is a slightly curved tube, surrounded by a perilymphatic space within a bony tube. In a transverse section, the cochlea shows three chambers, an upper scala vestibuli, a middle scala media and a lower scala tympani. The scala media is the actual cochlear duct and contains endolymph, while other two scalae are filled with perilymph.

At the apex of the cochlea (scala media), the scala vestibuli and scala tympani are continuous, this junction is known as the helicotrema, near it the scala media ends blindly. At the inner end of cochlea, scala vestibuli is continuous with fenestra ovalis, while the scala tympani with the fenestra rotunda. The floor of scala media is formed by the basilar membrane and the roof by the Reissner's membrane. The basilar membrane consists of tall auditory hair cells, together constituting an organ of corti.

The organ of Corti is sensitive to sounds of higher frequencies. The free ends of the auditory cells bear hairs, which are embedded in a tectorial membrane, lying above the organ of corti. From the basal ends of the cells arise nerve fibres which unite to form the cochlear branch of the auditory nerve. The cochlear duct at its apical end has another set of auditory hair cells, their hairs embedded in a gelatinous cupola terminalis having minute calcareous otoliths.

At the tip of the cochlear duct is the lagena. Groups of auditory cells are called cristae and maculae. Those present in the ampullae of three semicircular canals are called cristae ampullares which possess the sense of direction and equilibrium. One macula is present in utriculus and one in sacculus. One macula is present in the lagena (tip of cochlear duct). Macula lagena is separated from the other maculae by a long cochlear duct. It perceives low frequency sounds.

Middle Ear:

A circular external ear opening lies on each side of the head, behind the eyes concealed beneath auricular feathers. It leads into a short canal, the external auditory meatus, at the base of which lies a thin, transparent, vibrating septum, called tympanum or ear-drum.The ear-drum is followed by the cavity of middle ear or tympanic cavity. From the tympanic cavity arises a eustachian tube which unites with its fellow to open by a common aperture in the pharynx. The eustachian tube serves to equalize the air pressure on both sides of the tympanum.Across the tympanic cavity lies a single rod-like bone, the columella auris, which transmits sound waves from tympanum across the tympanic cavity to the fenestra ovalis of the inner ear. The outer end of columella auris has three rayed cartilaginous processes called extra columella connected to the inner surface of tympanic membrane, and its inner disc-like bony part, the stapes, is wholly occluded the fenestra ovalis.Columella auris (stapes) is derived from the hyoid arch. Sound is transmitted from the tympanum by the columella auris (stapes). Extra columella reduces the amplitude and increase the force of vibrations. There is single middle ear muscle attached to columella and tympanum and innervated by facial nerve. Acoustic vibrations are transmitted to an oval window and so around cochlea to a round window. The equilibratory and auditory parts of ear of pigeon are well developed. Ability to localise sound in

birds is high.For the purpose of direction-finding they have developed very long cochlea and an asymmetrical arrangement of ear cavities (Strix) or asymmetrical external ears (Asio).

(5) Visual Organs or Eyes:

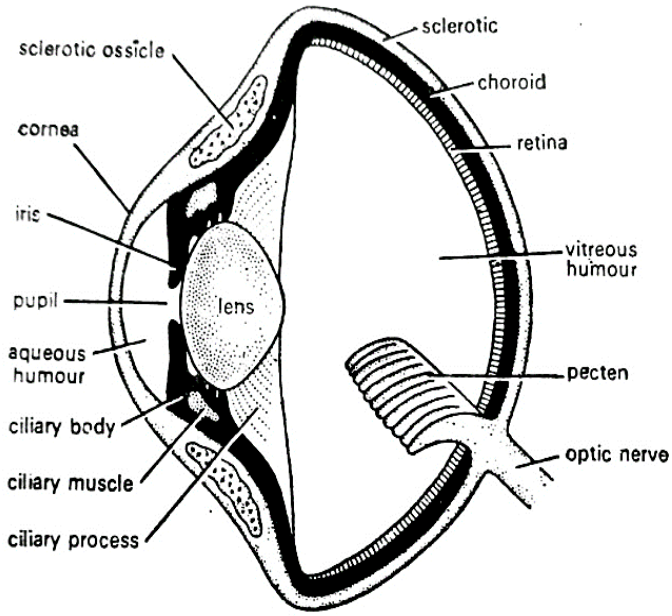


Fig : Fig : Pigeon Eye in sagittal section

The eyes of pigeon are well developed and are very large in correlation with an aerial life for a precise vision over considerable distances.

Shape:

The eyeball is not spherical, the lens and cornea bulge forwards in front of the posterior chamber. This form is maintained by a ring of bony sclerotic plates.

Eyelids:

The eyebrows or eyelashes are absent. There occur two inconspicuous eyelids, a slightly movable upper eyelid and a more movable and well developed lower eyelid which rises upwards to close the eye during the sleep. A semi-transparent third eyelid or nictitating membrane occurs as a fold at the anterior angle of the eye.It can be drawn posteriorly over eye with great rapidity. It cleans the eyeball and also protects the eyes from wind and during flight and from water during swimming in aquatic birds. It also protects the eyes from glare of the sunlight during day in nocturnal birds.

Glands:

The nictitating membrane is lubricated by the oily secretion of a harderian gland occurring in the inner angle of the eye. The tear gland or lacrymal glands are also well developed and lie below the outer angle of lower eyelid. Their watery secretion nourishes the non-vascular cornea, and also keeps it clean.The wall of hollow eyeball consists of three usual layers, an outer sclerotic, a middle choroid and an inner retina.

Sclerotic:

The external coat of the eyeball is sclerotic. In the posterior hidden part of the eye, it is opaque, white, dense and cartilaginous. In front in the exposed part of the eye, it bulges out to form a convex, transparent and horny cornea of connective tissue.The cornea is externally covered by a thin, transparent, sensitive and vascular epithelial membrane, the conjunctiva, which is formed by

modified epidermis and is continuous with the mucous lining of the eyelids. Anteriorly, at the junction of cornea and sclerotic coat, the latter is strengthened by a ring of 10-12 small overlapping bony, sclerotic plates or ossicles.

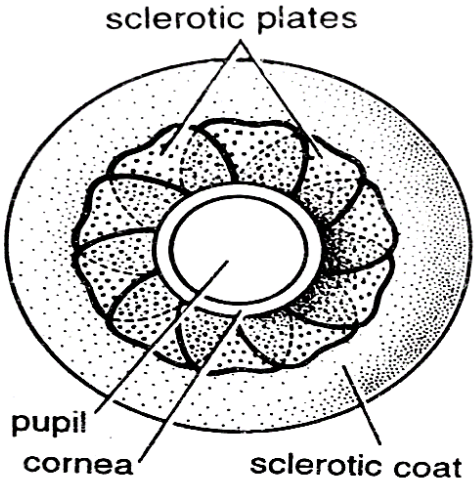


Fig : Pigeon Eye in outer view showing sclerotic plates

Choroid:

The sclerotic coat is followed by the middle layer, the choroid, which is thin, dark pigmented and highly vascular. The choroid closely lines the sclerotic, but it separates in front to form a circular, pigmented diaphragm, the iris, perforated by a rounded aperture, the pupil. The iris regulates the amount of the entering light. It contains intrinsic circular and radial smooth muscles, the circular muscles contract the pupil, while radial muscles dilate it.Along the peripheral margin of the iris, the choroid forms a ring-like ciliary body which is a thickened fold containing smooth ciliary muscles. From ciliary body arises a striated ciliary process or suspensory ligaments and attached to the lens. The ciliary muscles are divided into anterior crampton muscles and posterior brucke muscles.The Brucke muscles draws the lens forward into the anterior chamber so that since the shape of the eye is fixed by the sclerotic plates, the lens becomes more curved and hence, accommodated for near vision. Contraction of the iris sphincter assists in this process. At the same time the crampton muscles pull the cornea reducing its radius and further assist in accommodation. The circular and radial muscles of the iris and ciliary muscles are under the control of the autonomic nervous system receiving sympathetic and parasympathetic fibres.

Retina:

The innermost coat of the eyeball is a thin, light sensitive nervous layer called retina. It is transparent, devoid of blood vessels, thick and consists of nerve fibres, nerve cells and minute rods and cones. Pigeon, being a diurnal bird, has largely more cones than rods. The high resolving power and high powers of discrimination and of movement detection depend on the great density of the cones.

Sensitive Spots:

The retina has two sensitive spots or fovea. The central fovea, which lies near the centre of retina as a slight depression, is more sensitive and used for lateral or monocular vision. The second fovea, the temporal fovea, lies more towards the outer side of the eye and is used for forward or binocular vision. The foveae have comparatively more cones and give more distinct vision. The cones of birds often contain carotenoid oil droplets, which are also found in frogs, turtles and marsupials.

In diurnal birds, they are red, yellow, orange or colourless, but in nocturnal ones pale yellow or colourless. Colour droplets may produce narrow-band sensitivity channels for the mediation of colour discrimination. The lower part of retina contains yellow droplets and upper part (dorso-posterior) contains red droplets. These droplets serve as fibers and increase the colour vision of birds up to great degree. The red may provide finer colour discrimination of objects in feeding.

Lens:

The lens is biconvex, soft, pliable, crystalline, colourless, transparent and is surrounded by a fibrous capsule. It remains suspended just behind the iris by suspensory ligaments. It divides the eye cavity into a small anterior aqueous chamber and a large posterior vitreous chamber.

The aqueous chamber is filled with a colourless watery fluid, the aqueous humour, while vitreous chamber contains a thick colourless, gelatinous vitreous humour. The two humours keep the eyeball tight or tense and also serve to focus the light rays on the retina.

Pecten:

Pecten is a pleated, strongly pigmented vascular fold projecting into the cavity of the eye from the entrance of the optic nerve. It detects minute movements at great distances and is small. It is also well developed in pigeon.

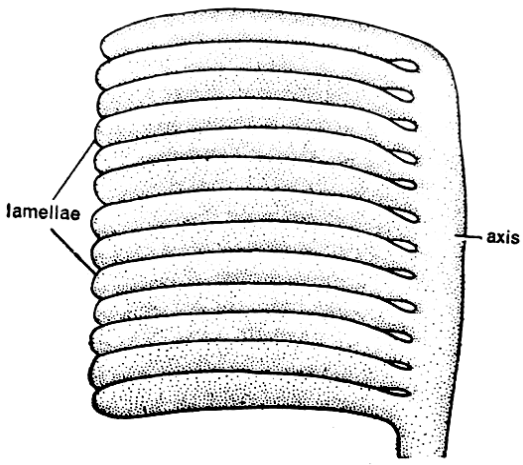


Fig : Pigeon Pecten

Functions of Pectin:

There are many speculations about the function of pecten but none is known definitely. Probably its main function is to bring oxygen and nourishment to the retina, which in birds has no capillary circulation. It helps in accommodation, it is not likely that it actually assists in focussing, for instance, by pressing forward the lens, and no changes have been seen in it during accommodation. However, it might possibly assist by adjusting the intraocular pressure, which must be increased by the extensive changes in the lens during accommodation.

Vision:

In pigeon, because the cornea projects outwards and the posterior part is expanded, so the eye is broader than deep. Due to expansion of retina over the broad posterior portion, the distant objects are sharply focussed on it. Further, though the eyes are lateral in position, there is an overlapping of the two visual fields to some extent. This is called binocular vision. It is worth noting that there occurs little movement in pigeons' eyes due to ill-development of extrinsic eyeball muscles and that is compensated by flexibility of neck which turns the neck very quickly.

Urino-genital system

The urino-genital system of pigeon consists of excretory as well as reproductive organs. These are as follows

Excretory Organs

The excretory organs of pigeon consist of two kidneys and two ureters. The urinary bladder is absent in adults to reduce the body weight (flight adaptation).

(i) Kidneys:

The main excretory organs of pigeon are two dark brown, flattened three-lobed metanephric kidneys lying posterio-dorsally in the body cavity and embedded in the hollow of the pelvic girdles. Their ventral surface is covered by peritoneum. They are provided with venous blood by the renal portal veins and arterial blood from the renal arteries.The renal arteries supplying the glomeruli, while the tubules are supplied both by efferent glomerular arterioles and branches of the portal veins. A small yellowish, elongated and streak-like adrenal body lies attached ventrally to the anterior lobe of each kidney which is an endocrine gland.

Each kidney consists of masses of numerous tightly packed, convoluted uriniferous tubules. Pigeon have comparatively more tubules. Each uriniferous tubule has small glomerulus and a specialised portion called the loop of Henle. Loops of Henle are long. The glomerulus filters the blood and filtrate passes through the long loop, where much of its water is reabsorbed. Thus, much concentrated urine passes down to the ureter.

(ii) Ureter:

The uriniferous tubules of each kidney unite to form a ureter or metanephric duct. The ureter is a narrow, straight tube, arising ventrally from the anterior lobe of the kidney and running backwards to open into the middle compartment of the cloaca, urodaeum, through its dorsal wall.

Physiology of Excretion:

The excretory system is highly specialised for water-saving. The pigeon are urecotelic because in them the end product of urinary excretion is relatively insoluble uric acid which is synthesised in liver.Semisolid viscous urine comes from the kidneys into the urodaeum from where it passes up into the coprodaeum and large intestine, where further water is reabsorbed and the mixed faeces and urinary products are then excreted as the characteristic semisolid white guano. Urine is hyperosmotic to the blood.

Male Reproductive Organs

Sexes are separated and sexual dimorphism is absent in pigeon. The male reproductive organs of pigeon are testes and vasa deferentia and there occurs no penis.

(i) Testes:

The two oval and white testes, each attached to the anterior end of a kidney by mesorchium (fold of peritoneum). The right testis is slightly smaller than the left. The testes increase many times in size during the breeding season, usually under regulation by changes in illumination. The weight of testis is about 1000 times greater in the breeding season than in the non-breeding period, when it contains only spermatogonia.Both testes have masses of coiled seminiferous tubules with groups of interstitial cells between them. The cells of lining epithelium of seminiferous tubules produce spermatozoa by undergoing spermatogenesis. The interstitial cells are also called Leydig cells and produce male sex hormone, testosterone.

The seminiferous tubules join to form a long epididymis.The testes are permanently retained within the body cavity.

(ii) Vasa deferentia:

From the inner border of each testis arises a convoluted wolffian or mesonephric duct, its anterior end is an epididymis and the rest is a vas deferens. The epididymis is connected with the seminiferous tubules of the testis by extremely fine tubules, the vasa efferentia. Vas deferens runs backwards along the outer side and parallel to the ureter of that side to open into the urodaeum on a very small erectile papilla posterior to the ureter.For temporary storage of spermatozoa, the hind end of each vasa deferens becomes swollen called the seminal vesicle. There is no copulatory organ in pigeon.

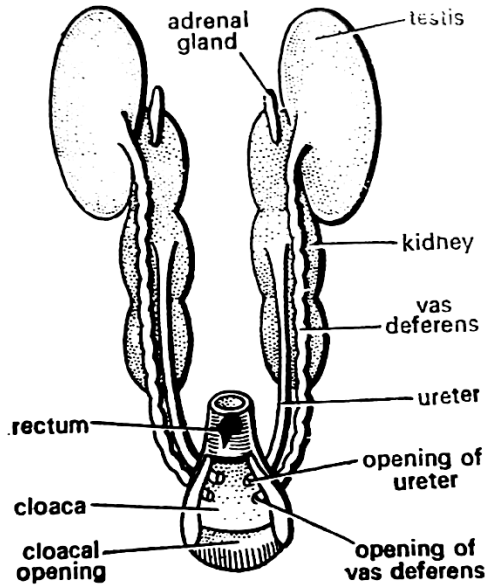


Fig : Pigeon Male urino-genital system

Female Reproductive Organs

The adult female has only the left ovary and left oviduct as their main reproductive organs. In the embryo there are two ovaries and two oviducts, but during development, the ovary and oviduct of right side become more or less completely atrophied.

(i) Ovary:

A large-sized irregular-shaped left ovary occurs at the ventral side of anterior lobe of left kidney. It remains attached to the kidney by mesovarium, a double-fold peritoneum. During breeding season the size of the ovary increases considerably due to the influence of FSH and LH of anterior pituitary. The ovary secretes oestrogen which modifies the accessory sexual organs and behaviour.The surface of ovary remains studded with numerous follicles or ovisacs of different sizes and each contains a single ovum or oocyte. The ova are at various stages of development. These follicles project from the surface of the ovary in birds.Of the large number of oocytes only few ripen to make the large follicles. Each follicle produces a large yolky, polylecithal ovum which when mature escapes by the rupture of the follicle into the coelom. After each follicle has bursted it quickly regresses. There is no corpus luteum. The released ova in the coelom are caught by the enlarged ciliated and muscular funnel of the oviduct. Ovulation depends on the cyclic release of luteinizing hormone (LH).

(ii) Oviduct:

The left oviduct (Mullerian duct) is a long broad, thick-walled, convoluted tube passing backwards to the cloaca. It remains attached to the dorsal body wall by mesotubarium, a double fold of peritoneum. The oviduct anteriorly has an expanded muscular and ciliated coelomic funnel or ostium or infundibulum with fimbriated margin. It opens by a wide, slit-like aperture into the coelom near the ovary.The oviduct has various parts. As an ovum enters the ostium and passes down, the walls of ostium secrete the thin chalaziferous layer of dense albumen around the egg. The succeeding part of the oviduct called glandular part or magnum has tubular glands which secrete the albumen or egg white. The magnum is followed by isthmus which secretes a parchmentlike double shell membrane around the albumen. Uterus is thin walled and is lined by nidamental glands which form an outer hard calcareous shell around the shell membranes. The last portion of oviduct is vagina which is muscular, thick-walled and contains mucus secreting unicellular glands which secrete pigment, external cuticular layer of the cell and mucus for expelling the egg. The oviduct opens into urodaeum.

Copulation:

During copulation the proctodaea of male and female are everted and are pressed together so that the sperm is ejaculated directly into the urodaeum of the female and travel up the oviduct. The fertilization takes place in the upper part of the oviduct before the coverings (calcareous shell) are formed around the egg. The female pigeon are oviparous lays two eggs in a nest. The eggs are incubated by both parents for 14 days at a temperature of 38° to 40°C. At the end of incubation the young's called squabs hatch by breaking the shell with a caruncle. The squabs are altricial being naked and unable to feed for themselves. They are fed for a time by both parents on pigeon milk formed by the epithelium of the crop.

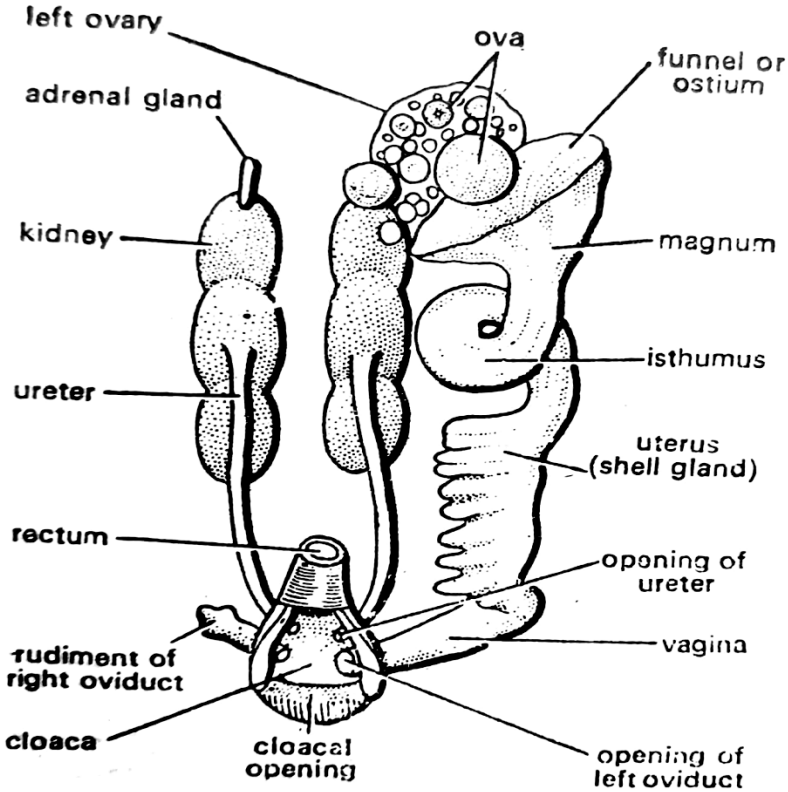


Fig : Pigeon Female urino-genital system

7.4 CHARACTERISTIC OF ARCHAEOPTERYX

Phylum-Chordata

Group -Vertebrata

Sub-Phylum-Gnathostomata

Class-Aves

Sub Class-Archaeornithes

Genus- *Archaeopteryx*

The two perfectly persevered specimens of Archaeopteryx was obtained from the Jurassic deposit of Bavaria in Germany. The first fossil record was discovered by Andreas Wagner in 1861 and the second skeleton was discovered in 1877.From these fossil record it was concluded that Archaeopteryx is terrestrial bird and its size is of crow with long tapering tail like that of a typical dinosaur. The Archaeopteryx is considered to be a connecting link or transitional stage between reptiles and birds, so it possesses both reptilian as well as avian characters.

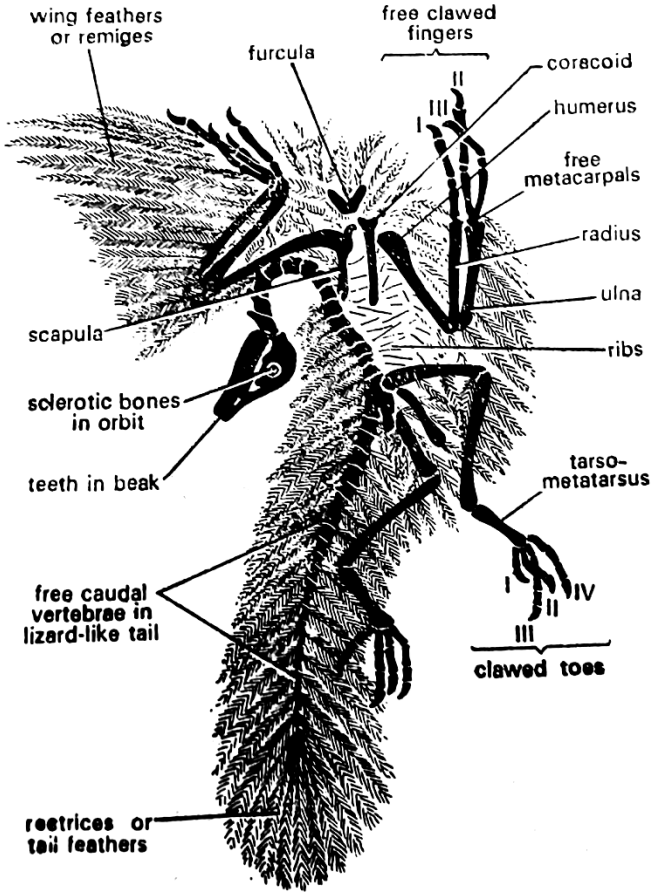


Fig: Fossil *Archaeopteryx* (Berlin specimen)

Reptilian characters:-

1) Scales are present on body and limbs.
2) Bones are non-pneumatic.
3) The strong jaws have small equal conical enamel crowned and thecodont teeth and present

only the infront part. There are 26 teeth in the upper jaws and 6 in the lower.

4) A long tapering lizard like tail composed of about 20 free caudal vertebrae no pygostyle.
5) Cervical vertebrae are fewer (9 or 10) then in any other birds. There is no fusion of trunk and sacral vertebrae.
6) The centra of vertebrae are amphicoelus as in reptiles.
7) The ribs are single headed without uncinate process. Abdominal ribs are present similar to that of sphenodon and crocodile. Sternum may be weak or absent.
8) The comparative length of the fore limbs and the hind limbs is of reptilian type. Skeleton of hand present reptilian pattern. The phalanges being 2, 3 and 4 respectively in first, second, and third digits which terminating into a claws.
9) Carpals and metacarpals are free. No fused carpometacarpus.
10) Pelvic girdle shows an elongated ileum and backwardly directed pubis, which are separated.

Avian characters:

1) The body of Archaeopteryx is covered by well developed contour and flight feathers.
2) The fore limbs are modified as wings for flight, It bears remiges and three digits each.
3) The tail bears elongated rectrices, arranged in two lateral rows.
4) The skull is proportionally large, monocondylic with a large rounded brain case, large orbits and intimate fusion of bones.
5) The two jaws are elongated into a beak.
6) The bones of girdles and limbs are eminently bird like. Scapulae are elongated and curve.
7) The two clavicles are fused into 'V' shaped "furcula".
8) Tibia and fibula are separated.
9) Foot consist of a tarso-metatarsus bearing 4 clawed toes having 2,3,4, and 5 phalanges respectively. The halux is directed posteriorly and is apposable.
10) The sclerotic ossicles are present in eyes.

Significance of Archaeopteryx:

As Archaeopteryx exhibit both Reptilian as well as Avian characters. So there is a controversy that it is not true reptile as well as it is not true bird also. The Archaeopteryx as was endotherm or warm blooded as other birds. The cerebral hemispheres were smooth, long and narrow and cerebellum was small, thus the brain is reptilian type. Archaeopteryx could not only fly efficiently but it could only fly volplane from tree to tree in forests, because the sternum is small, flat and without a keel, the wing spread is small and it has an elongated feathered, lizard like tail. Thus from this it is classified in a separate subclass Archaeopteryx, because of its peculiarities distinct from all other birds, fossil as well as living, which are placed in the subclass Neornithes.

7.5 FLIGHT ADAPTATION & BIRD MIGRATION

Flying Adaptations In Birds

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

physiology and embryology of birds are highly modified for flight. These are as follows :-

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

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

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

(i) The feathers covering the body reduce friction.

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

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

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

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

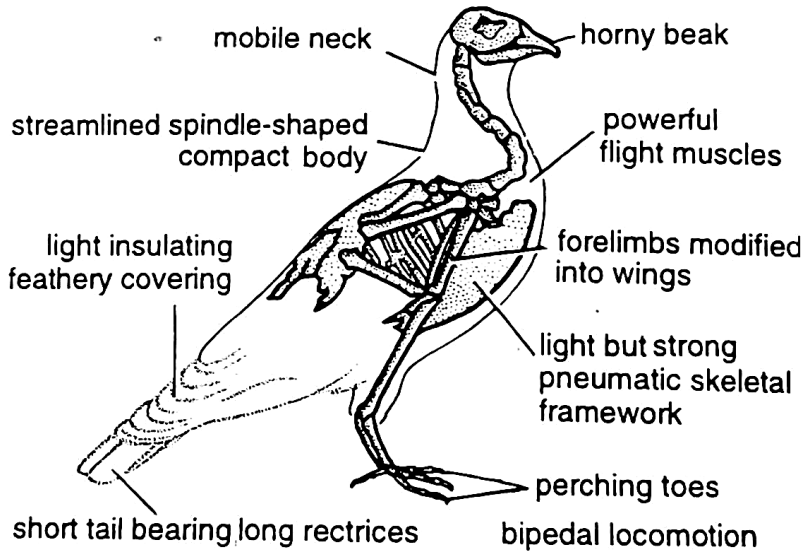


Fig : Diagrammatic representation of flight adaptations

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

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

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

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

(7) Bipedal locomotion : The forelimbs being no longer available, the hind limbs or legs anteriorly from the trunk to balance and to support the entire weight of the body and for locomotion on the ground or in water. Bipedal is as characteristic of birds as flight, since flightless birds have all retained the habit of walking on two legs. The legs are also relatively stronger.

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

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

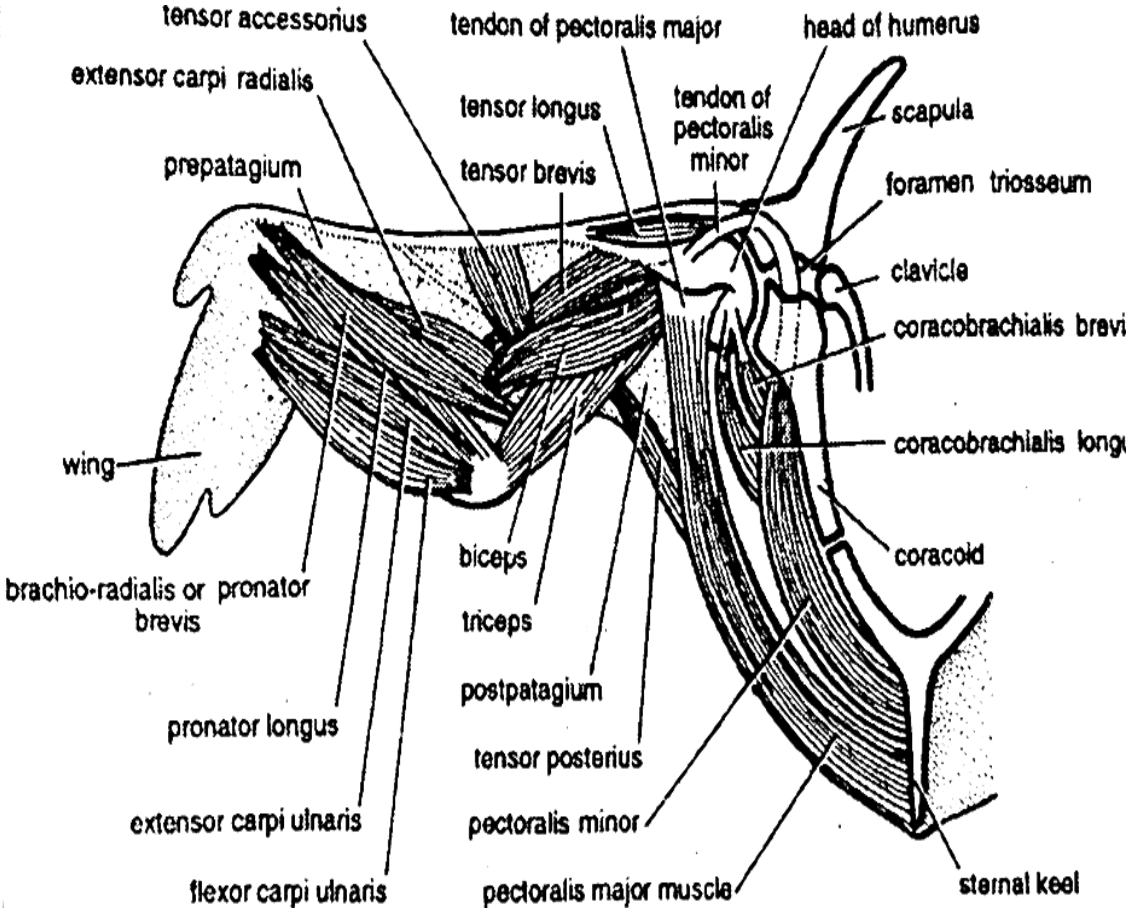


Fig : Flight muscle of breast and right wing in ventral dissection

(10) Air sacs and respiration : The air sacs are thin walled, not muscular sac connected to the lungs. There are four paired and one unpaired air sacs. The paired air sac are cervical, anterior thoracic, posterior thoracic and abdominal and unpaired interclavicular air sac. They occupy the space between the internal organs and extend into the cavities of bones. They serve as reservoirs of air. In other vertebrates air is supplied to the lungs only once and that is

during inspiration. But in birds during expiration also air is supplied to the lungs from the air sacs. Thus, in birds blood is oxygenated twice during a single breathing. This is called double oxygenation or double ventilation. Thus the respiratory system of birds is highly adapted to supply more oxygen to flight muscles. The air sacs also help in internal perspiration which helps in regulation of body temperature.

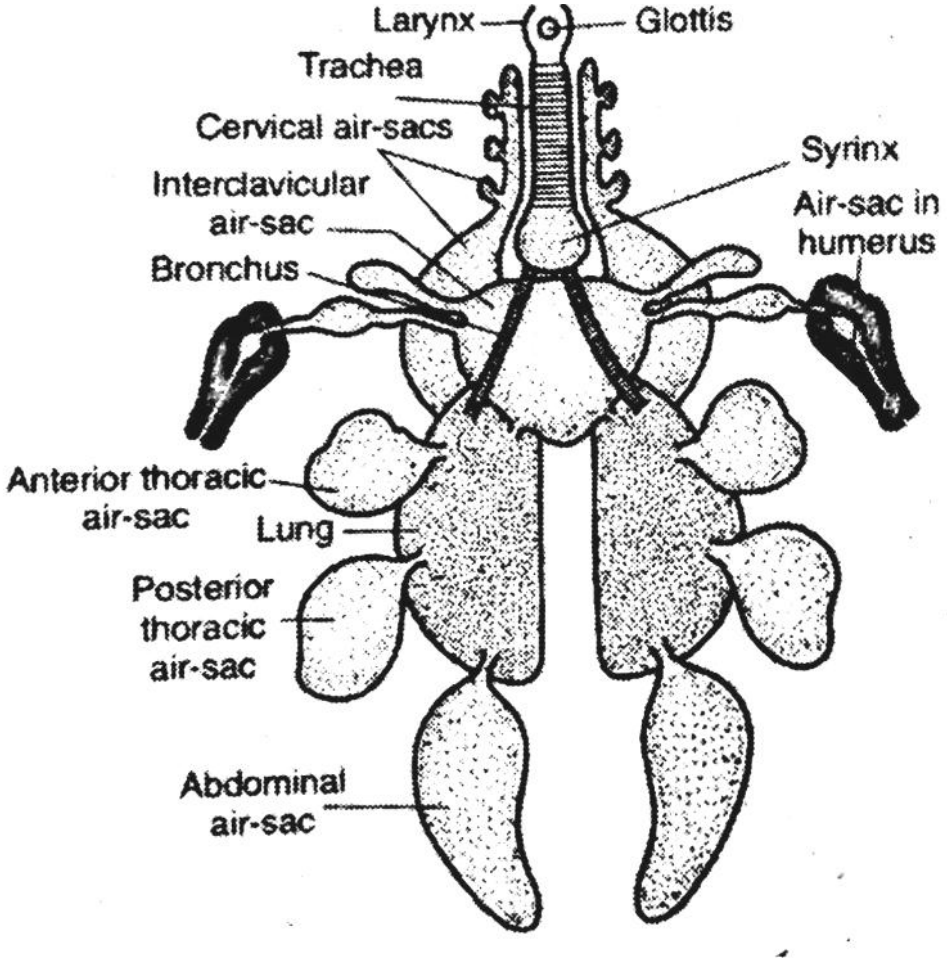


Fig : Air Sacs Respiratory system of Pigeon

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

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

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

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

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

(iv) Absence of teeth.

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

(vi) Absence of urinary bladder.

(vii) Production of solid excretory waste.

(viii) Presence of feathers.

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

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

(ii)Efficient double circulation of blood.

(iii)The blood contains high proportion of haemoglobin.

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

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

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

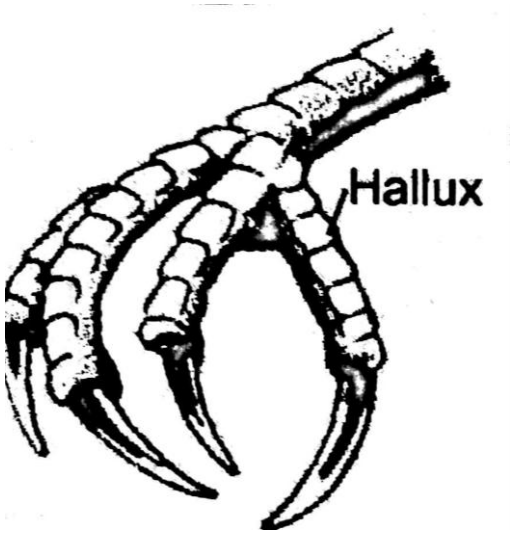


Fig : Perching type of foot

(17) Endoskeleton :

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

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

(iii) The shortening of caudal vertebrae and formation of pygostyle (fusion of last four

caudals) provided stability in the air.

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

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

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

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

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

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

Migration of Bird

Migration is defined as the movement of animal from one place to another. The movement results in the temporary or permanent absence from one home range and the establishment of a residence in another. The movement of bird is due to obtain favourable condition for survival, breeding, feeding etc. In birds the migration means two way journeys **- *onward journey*** from the "**home"** to the **"new"** places and ***backward journey*** from the "new" places to the "**home"**. This movement occurs during the particular period of the year and the bird usually follows the same route. Majority of birds have the inherent quality to move from one place to another, such birds are called **migratory birds**. While some birds such as Bobwhite and other birds do not migrate at all and they remain throughout the year in a country, such birds are called **resident birds**. The migration may be due to

(1) Climatic migration: - Then there are certain changes in climatic condition of environment.

(2) Alimental migration: - Then there are scarcity of food which induce animal to move from these place.

(3) Gametic migration: - When the animal move for suitable breeding ground.

Kinds of bird migration

The migration of bird takes place in a variety of manners. Some are as follows:-

(i) Latitudinal migration: - The latitudinal migration means the movement from north to south and vice versa. Most birds live in the land masses of the northern temperate and subarctic zones, where they get facilities for nesting and feeding during summer. During winter, when the northern hemisphere becomes covered with ice and snow, these birds move towards south for shelter. Several ***North American*** and ***Eurasian birds*** cross the equator to spend winter in deeper and warmer parts of South America and Africa. The **American golden plover** passes the nine months of winter 8000 miles South in the plains of Argentina, thus enjoying two summer each year and knows not a hint of winter. ***Ruff breeds*** of Siberia travels to Great Britain, Africa India and Sri Lanka, thus travelling a distance of 6000 miles.

(ii) **Altitudinal Migration: -** The Altitudinal or vertical migration means from high mountains in the summer to low valleys in the winter occur in many Indian and foreign mountaineer birds. In India a number of species during summer migrate from planes to the slopes of Himalayas ascending thousands of feet above sea level and return to planes on the commencement of winter e.g. **Common wood-cook, Bush chat** and **Scolopax rusticola**. Altitudinal migration is also observe in the **Grebes** and C**oots** of Andes in Argentina, **violet green swallows** of great Britain and the **willow ptarmigan** of Siberia.

(iii) **Longitudinal migration: -** Some birds make longitudinal migration i.e**. east to west or vice-versa**. The **Patagonian plover** visits the Falkland Island and **SouthPatagonian** in September and October for breeding.

(iv) **Partial migrations:-** The **blue birds** and many **blue jays** of Canada and Northern United states are partial migrants. In such type all the birds of a group of migratory birds do not leave the native land and hence are always represented by certain individuals. But these individual, are not always the same.

(v) **Irregular migration: -** In some birds such as **Herons, Cuckoos, thrushes** after breeding, the adults and the young may stray from their home to disperse in all directions over many or a few hundred miles in search of food and safety from enemies.

(vi) **Seasonal migration: -** The birds also migrate due to change in season. In Britain **Swift swallows, nightingales** and **cuckoos** are summer visitors, because they arrive in spring from the South, remain to breed and leave for the South in autumn. Some birds such as **Fieldfare**, **Snowbunting** and **Redwing** are winter visitors as they arrive in autumn, chiefly from north, stay throughout the winter and fly northwards again in spring.

<u>Mode of Migration</u>

(i) **Time of migratory flight: -** According to the time of migration, the migration may be classified as diurnal or nocturnal migration.

(a) **Diurnal migration: -** When migration take place only in **day time** are called **Diurnal migration** such as in **Crows, Swallows, Robins, Blackbirds, Hawks, Blue-birds, Jays, Cranes, Geese, Duck, Swans** etc. They may stop to forage in suitable places but swallows and swifts capture their insect food in the air as they travel. These diurnal migratory birds often travel in flocks, which may be well organized.

(b) **Nocturnal migration: -** When migration takes place only in night time are called **Nocturnal migration**. These are **Sparrows**, **Warblers** and **Thrushes** which prefer to fly at night under the protective covering of darkness, to escape their enemies. By flying at night, they arrive at the day take break, rest, procure food during day time and then start again at the approach of night.

(ii) **Range of migration: -** The range of migration varies from one or few miles to thousands of miles in different groups of migratory birds for e.g. **Himalayan SnowPartridges** cover a distance of about one to two miles, **Chicades** travel about 8000 feet, while **Golden Plovers, Sand Pipers, Boblinks** and **Swallow** cover 6000 to 9000 miles from the Arctic to the grassy plains of Argentina or the Patagonian beach in South America. **Arctic tern** migrates about 11000 miles from the coast of Labrador to Antarctic.

(iii) **Altitude of flight: -** Some birds fly very close to the earth, while most routine migration probably takes place within 3000 feet of the earth. Some small birds have been reported to fly at 5000 to 14000 feet altitudes. Some species of bird can cross the Andes and the Himalayas at altitudes of 20000 feet or more.

(iv) Velocity during migration: - The speed or velocity of flight of migratory birds varies from individual to individual and species to species. It is affected by the speed of air and its direction and it has also been reported that birds travel faster during migration than other time. The speed of **Cranes, Carrions, Crow** and **Finches** during migration is 30 miles per hour. The **Golden Plover** holds the world record with the longest nonstop bird flight, from Hudson Bay and Alaska to South America a distance of 2400 miles.

(v) Routes of migration: - The migratory birds usually follow definite line of flight. The route followed by them, may be the same while going and returning back or may be different. The different migratory birds may follow the different route are as follows.

(a) Sea routes: - Many marine birds follow sea routes. The land birds can cross as much as 400 miles of ocean in a stroke but if there are intermediate islands the distance covered may be more. Certain birds can cross the Atlantic Ocean between Azores and Portugal (900miles) and the ocean between the continents of North America and Bermuda.

(b) Coast routes: - Certain birds migrate through coast route. Some important coast route are East Atlantic coast line, West Atlantic coast line, East Pacific coast line, West Pacific coast line, East Indies coast line and west Indies coast line.

(c) River- valley routes: - Some birds while migrating from planes to hills and from hills to planes, the migratory birds cross rivers and river- valley falling in the way.

(d) Mountain ranges: - Very rarely the bird cross mountain ranges.

The river valleys, mountain ranges and coastal routes provide good land marks for the migratory birds, which enable the birds to recognize and remember the routes and entrance to the countries. Deviation in path sometime occurs due to configuration of land, coastline, and course of Great River or intervening mountain chain.

(vi) Segregation during migration: - Some birds such as **Kingfishers, Swifts** and **Night hawks** travel in separate companies, but certain other birds such as **Swallows, Vultures, Blue birds, Turkey** etc. usually travel in mixed companies of several species due to similarity in their size, method of search of food etc. In some species the male and female members travel separately the male arrive first to build the nest. The young bird generally accompany the female.

(vii) Order of migration: - During migration the birds follow a definite order and this order is strictly followed. Normally the adult migrate first and they are followed by young's. It has found that urge of migration occurs due to the maturity of gonads which instigate them to migrate towards their breeding grounds. Hence, the adults with ripe gonads start the migration. During the back flight the order becomes reversed, the young birds start first and follows the same path which their parents had followed while coming from that places. In adult precedence there is always a definite sequence. The adult male take the lead, adult females next in order and the birds of the year follow them and in the end come the weak and wounded birds.

(viii) Regularity of migration: - Several species of migratory birds show a striking regularity, year after year, in their timing of arrival and departure. In spite of long distances travelled or vagaries of weather, they are often punctual within a day or two in their time of arrival. Further most migratory birds come back to the same breeding place year after year.

Significance of Bird Migration

The advantage of bird migration are obvious and logical. The migration helps bird to avoid harsh

climatic extremes. Migration from higher altitudes and latitudes (i.e. breeding areas in the north) during winter affords protection from cold and stormy weather, shorter days available for searching food and scarcity of food.

The migrants get more food and better conditions in their winter quarters in temperate or tropical regions than they would if they stayed at home.

Whereas a return in summer to the breeding areas in north once again provides suitable and unconquered nesting grounds, abundance of food, with minimum efforts, and long hours of day light for searching food at a time when their population in increasing greatly.

Thus birds migrate in order to utilize the food supply of both the hemispheres and to exploit new areas for nesting purpose, till the condition become inclement for them.

SAQs 2.

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

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

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

(iii) Hollow bone is the characteristic feature of ----------.

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

7.6 SUMMARY

In this chapter it contains origin & evolution of birds in which it include general characters and classification of class aves. It also include complete study of pigeon or *Columba* in which its systemic position, body form, habit and habitat, different system including digestive system, respiratory system, heart, arterial and venous system, brain sense organ, urino-gential system.

This unit also contains characters of Archaeopteryx, Flight adaptations in bird and migration of birds in very detailed manner.

7.7 TERMINAL QUESTION

Q1 Describe the general characters of subclasses neornithes.

Q2 Describe thetrunk of Pigeon.

Q3. Explain significance of Archaeopteryx .

Q4 Describe the significance of bird migration.

7.8 ANSWERS

SAQ1 (i)Uricotelic

(ii)Cleidoic

(iii)Oviparous

(iv)Ratitae

SAQ 2 (i)Air sacs

(ii)Reptiles

(iii)Birds

(iv)Forelimbs

Terminal question

(1) The general characters of subclasses Neornithes are follows

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

(2) The trunk is compact and spindle-shaped, bearing a prominent bony ridge, the keel or carina, at its mid-ventral line. The spindle shaped trunk bears a pair of wings and a pair of legs. The cloacal aperture opens ventrally at the hind end of the trunk. Dorsally the base of the tail has a knob like papilla, which bears the opening of the preen gland or uropygial gland. It is the only cutaneous gland present and its oily secretion is used for lubricating or preening the feathers. The tail is used as a rudder in flight. Fore limbs are modified into wings. The wings have three typical regions, the upper arm (brachium), lower arm (ante - brachium) and the hand (manus). Three clawless and imperfectly marked digits are present on each hand. While at rest, each forelimb is folded in the form of 'Z'; during flight they are extended. With the modification of the forelimbs for flight, the whole weight of the body is supported by the hind limbs, while the bird is at rest or walking; the hind limbs are therefore attached anteriorly from the trunk to balance the body and support the weight of the body at rest. They

are warm blooded or homeothermic.

(3) The Archaeopteryx exhibit both Reptilian as well as Avian characters. So there is a controversy that it is not true reptile as well as it is not true bird also. The Archaeopteryx as was endotherm or warm blooded as other birds. The cerebral hemispheres were smooth, long and narrow and cerebellum was small, thus the brain is reptilian type. Archaeopteryx could not only fly efficiently but it could only fly volplane from tree to tree in forests, because the sternum is small, flat and without a keel, the wing spread is small and it has an elongated feathered, lizard like tail. Thus from this it is classified in a separate subclass Archaeopteryx, because of its peculiarities distinct from all other birds, fossil as well as living, which are placed in the subclass Neornithes.

(4) The advantage of bird migration are obvious and logical. The migration helps bird to avoid harsh climatic extremes. Migration from higher altitudes and latitudes (i.e. breeding areas in the north) during winter affords protection from cold and stormy weather, shorter days available for searching food and scarcity of food.

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BLOCK-III

In the previous block you have studied about the Amphibians, Reptiles and Birds. In this block you will be introduced by Origin and Evolution of Mammals. This block is divided into five units (unit 8 to 12) as under.

Unit 8 In this unit you will study about origin and economic importance of mammals. General characters and classification of prototheria, metatheria and eutheria.

Unit 9 This unit deals with the evolution of man, relationships of man with other primates. This unit also deals with fossil record of ancestry of man.

Unit- 10 This unit deals with comparative anatomy of digestive and respiratory system.

Unit –In unit 11 you will study comparative anatomy of skeletal and circulatory system.

Unit- 12 This unit deals with the comparative anatomy of excretory and reproductive system.

Objectives:

After studying this block you will be able to-

- know about origin and evolution of mammals.
- understand comparative anatomy of vertebrates.

UNIT-8 : ORIGIN OF MAMMALS, GENERAL CHARACTERS AND CLASSIFICATION UP TO ORDER LEVEL, AFFINITIES OF PROTOTHERIA, METATHERIA AND EUTHERIA, ECONOMIC IMPORTANCE OF MAMMALS

8.1 Introduction to Mammals

Objectives

8.2 General Characters

8.3 Classification up to order

8.4 Origin and evolutionary history of Mammals

8.5 Affinities of Prototheria

8.6 Affinities of Metatheria

8.7 Affinities of Eutheria

8.8 Importance of Mammals

8.9 Summary

8.10 Terminal Questions

8.1 INTRODUCTION TO MAMMALS

Mammals are group of warm blooded advanced vertebrates including humans characterised by the presence of mammary glands. They have well developed brain in comparison to other vertebrate groups representing some of the advanced form of creatures on the earth.

There are about more than 4,600 reported species of mammals showing variation in the diversity of form and habitat. Mammals feed their young ones with the milk secreted from the specialized sebaceous glands (mammary glands). Another important feature exhibited by mammals is presence of hair which is composed of keratin and is modified epidermis. Mammalian hair is highly variable in form, shape, density, color and distribution. Most of this variability relates form and function. These hairs can be categorized as vibrissae, fur, guard etc. and all of them have a nerve plexus at their base.

Objectives:

After studying this unit you would be able to:

- Know and understand the origin of mammals
- Understand the course of evolutionary history of mammals
- Explain the morphological advancement in mammalian skeleton
- Discuss the similarities and dissimilarities between different orders (animals) of class mammalia

8.2 GENERAL CHARACTERS

Mammals show following characteristics:

- Presence of mammary glands
- Presence of hair
- Presence of external pinna
- Internal separation of thoracic and abdominal portion by dome shaped diaphragm
- Presence of region of the brain known as Neocortex (newly formed cortex)
- Presence of sebaceous and sweat glands
- They possess different types of teeth (heterodont)
- Presence of cervical vertebrae and dicondylic skull
- Respiration through lungs
- Presence of 4 chambered heart
- Presence of single-boned lower jaws
- They possess 12 pairs of cranial nerves.
- Excluding Monotremata all mammals are viviparous
- Mammals have acoelous vertebrae i.e with flat centrum and also consists of neural arch and a thin plate-like disc of bone: epiphyses at each end
- Tympanic membrane (ear drum) is supported by 3 auditory bones- malleus, incus and stapes
- Most of the mammals develop a connecting tissue Placenta between maternal and foetal tissue for protection and nourishment of developing foetus
- Left aortic arch is retained

8.3 CLASSIFICATION UP TO ORDER

- Phylum Chordata
- Subphylum Vertebrata

Class Mammalia

- **Subclass Prototheria**:

*Order 1: Docodonta (Triassic-Jurassic) eg: *Morganucodon, Docodon*

*Order 2: Triconodonta (Triassic-Jurassic) eg: *Triconodon*

*Order 3: Multituberculata (Jurassic-Eocene) eg: *Plagiaulax*

Order4: Monotremata (Pleistocene-Recent) Egg laying mammal eg: *Tachyglossus (Echidna),* Platypus

- **Subclass Theria:**

*Infraclass 1: Pantotheria

*Order 1: Eupantotheria (Jurassic) eg: *Amphitherium*

*Order 2: Symmetrodonta (Jurassic) eg: *Spalacotherium*

Infraclass 2: Metatheria (Cretaceous-Recent)

Order: Marsupialia (Presence of marsupium pouch) eg: Macropus (Kangaroo)

Infraclass 3: Eutheria (Cretaceous-Recent) Presence of Placenta

Includes 16 living orders

Order 1: **Edentata** (Toothless mammals) eg: Armadillos, sloths, anteaters

Order 2: **Pholidota (Scaly ant eaters) eg: Manis (pangolin)**

Order 3: **Carnivora (Specialized flesh eating i.e. prominent canines) eg: bears, wolfs, cats, dogs, Leopard, Fox, Panda etc.**

Order 4: **Rodentia (A pair of gnawing incisors) eg: Rat, Porcupine squirrels etc.**

Order 5: **Lagomorpha (Gnawing incisors with a small second pair) eg: rabbits, Hares**

Order 6: **Cetacea (Aquatic mammals) eg: dolphins and whales, Seals, Walrmn**

Order 7: **Artiodactyla (even-toed ungulates) eg: goats, hippos, giraffes**

Order 8: **Tubulidentata (Teeth have tubulidentate lacking enamel) eg: Single genus Orycteropus (Aardvarks or cape and ant-eater)**

Order 9: **Dermoptera (Gliding mammals; Flying lemurs) eg: Colugos, Lynocaphales**

Order 10: **Insectivora (Plantigrade foot with 5 toes in each foot) eg: moles and shrews like Erinaceus, Talpa**

Order 11: **Chiroptera (Forelimbs adapted as wings) eg: bats and flying foxes.**

Order 12: **Primates (Monkeys, apes and men) eg: primates**

Order 13: **Perissodactyla (Odd-toed ungulates) eg: horses, rhinos, tapirs**

Order 14: **Hyracoidea (herbivores with short leg and rudimentary tail) eg: hyraxes**

Order 15: **Proboscidea (Presence of proboscis or trunk) eg: elephants and similar extinct Mammals**

Order 16: **Sirenia (Sea cows: fully** aquatic herbivorous mammals) eg: manatees

*Represents extinct groups

8.4 ORIGIN AND EVOLUTIONARY HISTORY OF MAMMALS

The Mammalian group has developed along many lines and many of which have already become extinct, while others such as rodents, primates etc. are dominating the land today. Depending upon the jaw articulation fossil records it was suggested that full mammal-like condition established by the middle of Jurassic period (nearly 150 million years ago). Further studies suggested that by the Jurassic times the Synapsid reptiles had developed some mammalian characters like large brain, warm blood, hair, diaphragm, single left aortic arch etc. The story of origin and evolution of mammal begins with the fossil records collected from Mesozoic era and can be summarized as below:

- **Mesozoic mammals:** The history of mammals based on fossil record can be traced back to their origin from stem reptiles (cotylosaurians) during Permian (more than 225 million years ago). Some of the anapsid reptiles (with no hole in skull roof) like *Solenodonsaurus* from

Carboniferous and Permian times besides giving rise to modern reptiles to dinosaurs to birds also produced mammals. This view is supported by the series of fossil records alongwith some living fossils: the monotremes from Australia. First distinct mammalian stock is reported from late Carboniferous period with special type of cotylosaurian reptile with tympanum behind the jaws and later a lateral temporal aperture. This group became abundant and grew as pelycosaurs and therapsids of Permian and Triassic time but gradually died during Jurassic and therefore only a few fragmentary remains of small mammals were reported. Later during Cretaceous some of these small animals grew and led to the arousal of different forms of animals before Eocene (Lillegraven, Kielan-Jaworoska and Clements 1979). The evidences of preliminary mammalian evolutionary history were recorded from the fossils obtained from Permian Red Beds of Texas nearly 200 million years ago followed by fossil records from Upper Permian and Triassic Karroo Beds of South Africa.

During these early phases the mammalian lines were flourishing with maximum being carnivorous. Early mammal-like forms became larger in size but were few in numbers which further dominated during Permian time. Permian mammal like forms possessed hair and were warm blooded with reptilian brain. Rodent-like mammalian forms (multituberculates) slowly became numerous but went to extinction in Eocene. 70 million years ago from Cretaceous time the first fossil remain of mammals similar to those alive today were recorded. These were similar to modern hedgehogs. The descendants of these shrew like animals multiplied and by early Palaeocene (65 million years ago) led to production of ancestors of most modern orders of mammals.

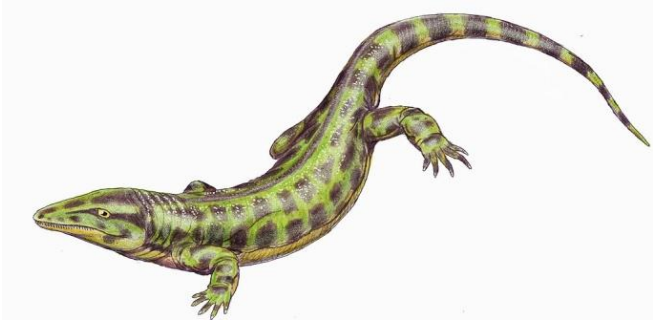


Fig 8.1: *Solenodonsaurus* (Anapsid reptile) (By Dmitry Bogdanov - dmitrchel@mail.ru, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=3996417).

- **Synapsida (Mammal like reptiles with joined arches):** The skull being the hardest parts of the body were among the prominent fossil records based on which the origin of mammals can be traced back. The main feature of the skull of the population through which the mammals group evolved was the development of hole in the roof of skull on the side of temporal region. This temporal fossa was bounded by post-orbital and squamosal bone on upper side and jugal and squamosal below. As per earlier hypothesis, a single fossa was formed by the union of two present in diapsid reptiles and hence were referred as Synapsida. The Anapsida group (with no hole in skull roof) and the Synapsida group appeared in the rocks at the same time where the later were presumed to be derived from former. The details of Anapsida are mainly derived from the lower Permian time. In *Captorhinus* and similar Anapsid fossils from lower Permian the otic notch was not observed which is present in the amphibian skull. Instead the tympanum lay behind the quadrate providing the complete side of skull as a stiff support for jaw. A series of evolutionary changes occurred ending into one of the important characteristic feature of skeleton of mammals that is conversion of hinder jaw bones namely quadrate and articular into ossicles for production and transfer of vibrations to ear. *Captorhinus* and some similar animals alsoexhibited modification in limb

leading towards the mammalian condition such as becoming moderately elongated and slender to hold vertically under the body. The teeth also specialized with rows of crushing teeth (probably in order to eat molluscs) on the edge of jaw and long overhanging in premaxillae.

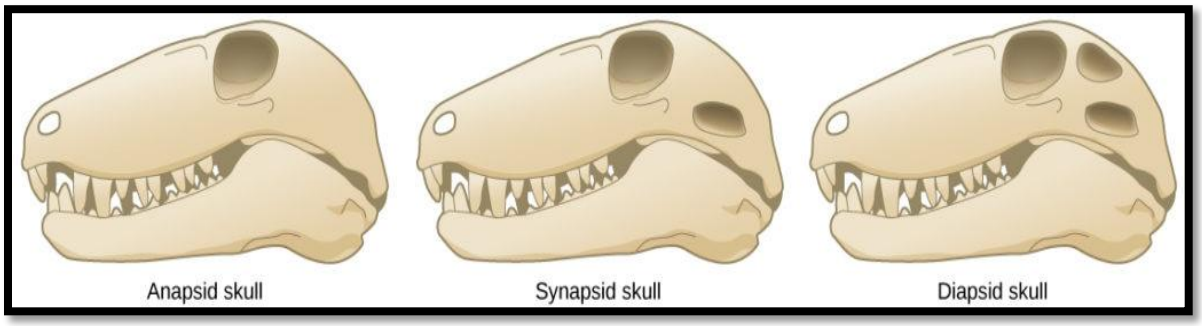


Fig 8.2: Diagram showing temporal fossa in Anapsid (absent), Synapsid (One fossa) and Diapsid (two fossa) skull.(https://bio.libretexts.org/Courses/Lumen_Learning/Book%3A_Fundamentals_of_Biology_I_%28Lumen%29/15%3A_Module_12-_Vertebrates/15.06%3A_Evolution_of_Amniotes)

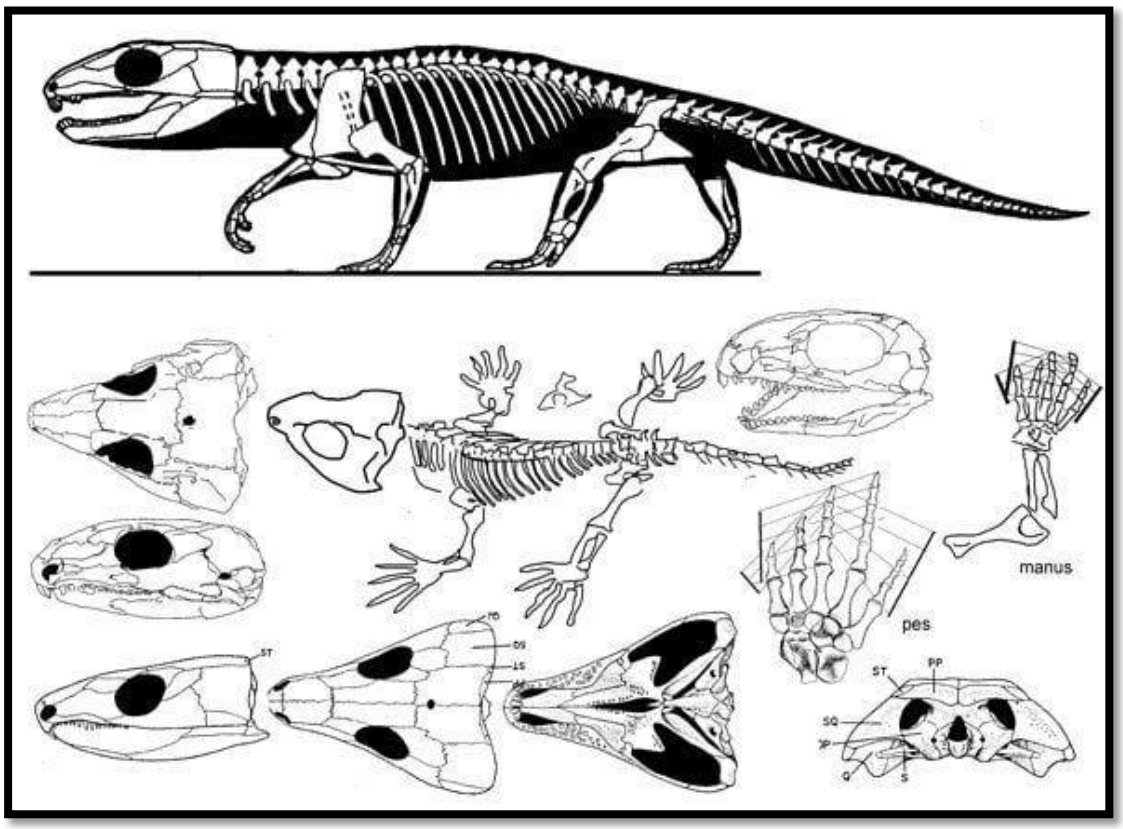


Fig 8.3: *Captorhinus*(https://alchetron.com/Captorhinus)

- **Pelycosauria (Mammal-like):** From anapsids such as *Captorhinus* there was an early offshoot line of development forming a Synapsid group presumably around the middle of Carboniferous period (300 million years ago). The early synapsids from middle Carboniferous, Pennsylvanian and Lower Permian especially in North America were together referred as Pelycosaurs (Theromorphs). Eg: *Varanosaurus*, a 90 cm long carnivore reported from Texas Red Beds exhibiting lizard like features variating from anapsids or earlier

diapsids. The teeth of this animal showed onset of mammalian differentiation with one or more elongated canines. In addition to this the skull also showed advancement with long anterior region and relatively high posterior part enabling a large brain case and deep jaw. Other pelycosaurs developed long neural spine presumably supporting a web and used in temperature regulation to absorb or radiate heat eg: *Edaphosaurus* (herbivorous) and *Dimetrodon* (carnivorous). It is believed that from allies or animals similar to *Dimetrodon*, a line evolved which are known as Therapsida that leaded to mammals.



Fig 8.4: *Varanosaurus* (90 cm long Synapsid carnivore)
(https://www.sciencephoto.com/media/888355/view/varanosaurus-illustration)



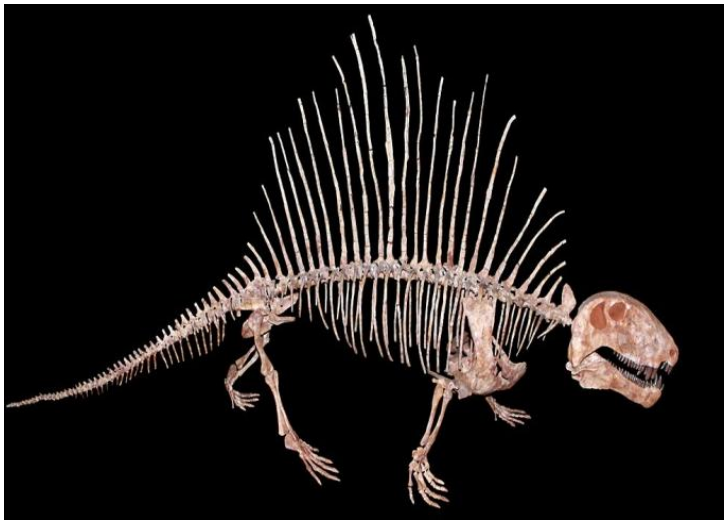


Fig 8.5: *Dimetrodon* *(https://www.mydinosaurs.com/blog/dimetrodon-closely-related-humans-dinosaurs/)* **and Skeleton of *Dimetrodon incisivum*** (Sphenacodontidae; Permian, Texas, USA; Staatliches Museum für Naturkunde Karlsruhe, Germany).

- **Therapsida (Mammal-arched):** The animals belonging to order Therapsida the forelimbs and hindlimbs were of almost equal size and tended to be turned under the body in order to lift the body off the ground. The skull deepened and brain case enlarged, there was development of secondary bony palate. Teeth became differentiated according to their function and bones of lower jaw (except dentary) gradually reduced. The therapsids can be divided into two groups namely Anomodontia (herbivorous) and Theriodontia (carnivorous) where the latter preyed upon the former. The early anomodonts included *Moschops,* the Dinocephalia i.e. with terrible heads. Their legs turned under the body, phalanges became reduced to mammalian formula of 2.3.3.3.3. These anomodonts became specialized and were the first among the great tetrapod herbivore reptiles in later Permian. By early Triassic, the suborder Theriodontia developed mammal like type of organization in several independent lines. The temporal opening became wider, the occipital condyle became double as in mammals, large columella articulated with quadrate and acted as efficient vibrator (Hotton 1959). A secondary palate developed that enabled breathing and holding the prey at same time. The teeth became differentiated into incisors, canines and cheek teeth with several cusps.

  Cynognathus and other Triassic cynodonts (dog toothed) were typical theriodonts showed mammalian features. Theses carnivores had dog-like appearance with heavy reptilian build. By the end of Triassic the animals of dominant theriodontia almost disappeared.

  Study of Synapsids mainly from Karroo showed a series of fossils with first reptiles and latest being like true mammals.

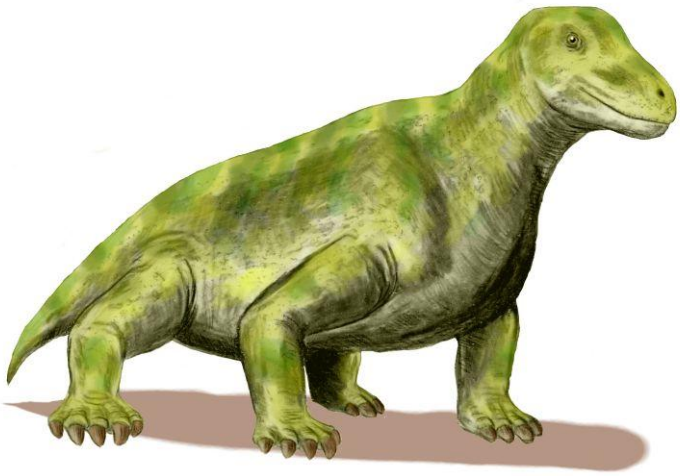


Fig8.6: *Moshops*, Anomodont herbivore of later Permian Period.(https://commons.wikimedia.org/wiki/File:Moschops_BW.jpg)

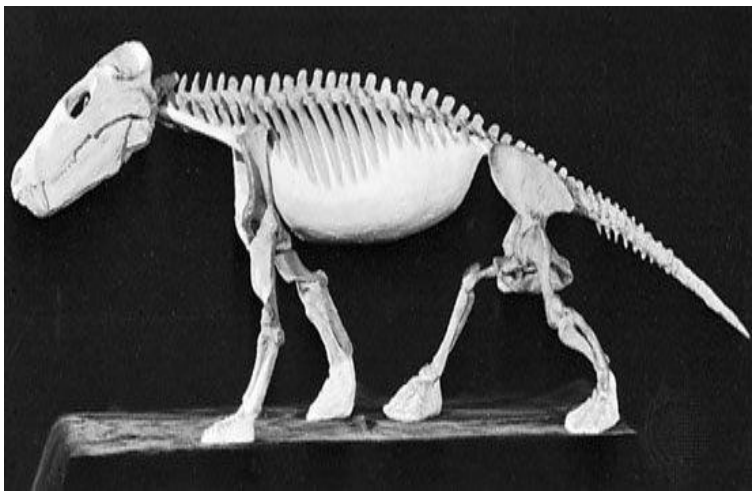




Fig 8.7: *Cynognathus* , a Triassic cynodonts (dog toothed) typical theriodonts (carnivorous)showingmammalian featuresand skeleton of *Cynognathus*

(https://fossil.fandom.com/wiki/Cynognathus?file=Cynognathus_BW.jpg;

https://www.britannica.com/animal/Cynognathus).

- **Appearance of Mammals (From Triassic to Cretaceous):** The mammals resembling the modern mammal appeared in late Cretaceous. For more than 90 million years ago, the mammals reported were of small size probably being arboreal and nocturnal (Kielan-Jaworowska 1971; Jenkins and Parrington 1976). The fossil record of early mammals is very scarce. With the availability of skull and other fossil records the mammals can be considered as monophyletic class with two subclasses: Prototheria and Theria (Kermack 1967; Hopson 1970) were differentiated mainly on the basis of teeth and wall of skull. Subclass Prototheria included the extinct order Mutituberculata which dominated earlier and the surviving egg laying mammals Monotremata and two controversial orders Triconodonta and Docodonta. Subclass Theria included all the modern mammals. The two subclasses diverged from Upper Triassic.

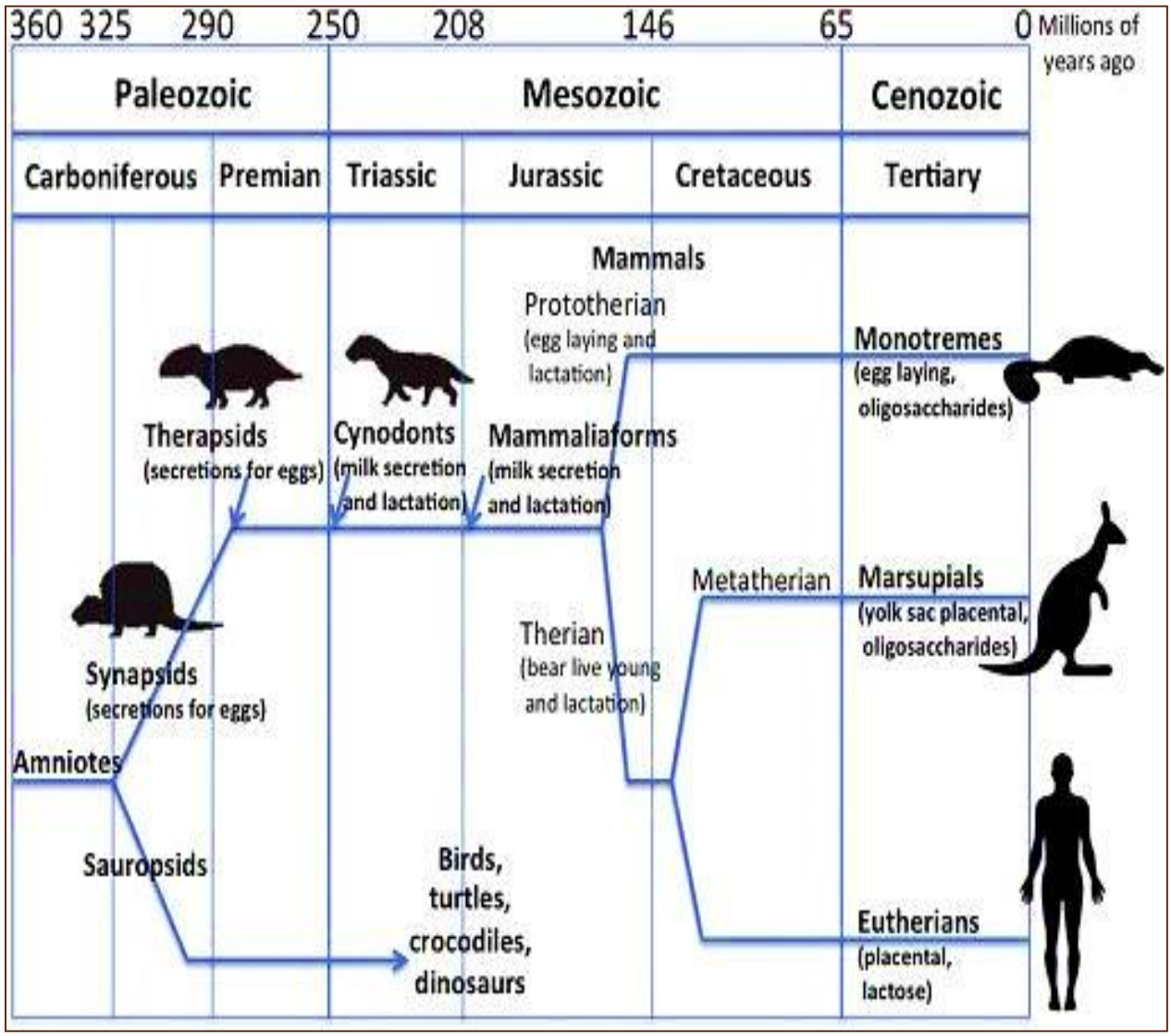


Fig 8.8: Evolution of Mammals (Walker and Thomas, 2019)

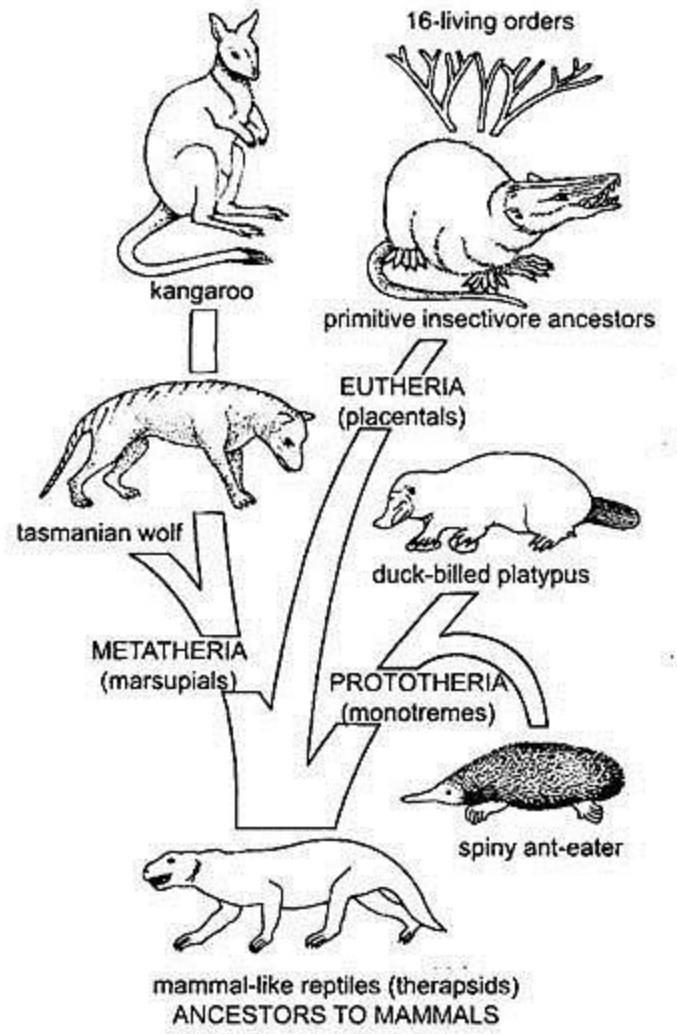


Fig 8.9: Hypothetical phylogenetic tress showing evolution of mammalian stock(https://www.notesonzoology.com/wp-content/uploads/2017/07/clip_image002-136.jpg)

8.5 AFFINITIES OF PROTOTHERIA

The subclass prototheira includes the **egg-laying mammals** such as : *Tachyglossus* (*Echidna*)and *Ornithothyncus* (Duck-billed platypus). The only living members of this subclass include order Monotremata which are mostly restricted to Australia and New Guinea. These endothermic animals show following characteristics:

- Body covered with hairs
- Pelvic girdle shows epipublic bones
- Mammary glands without teats
- External pinnae are absent
- Corpus callossum absent in brain
- Cochlea is simple and is not coiled
- In males testis is abdominal
- Females lay eggs

- In young ones teeth are present which is replaced by horny plates in adults
- Tuberculum is absent in ribs
- Digestive and urinogenital tract opens out through cloaca and cloacal aperture

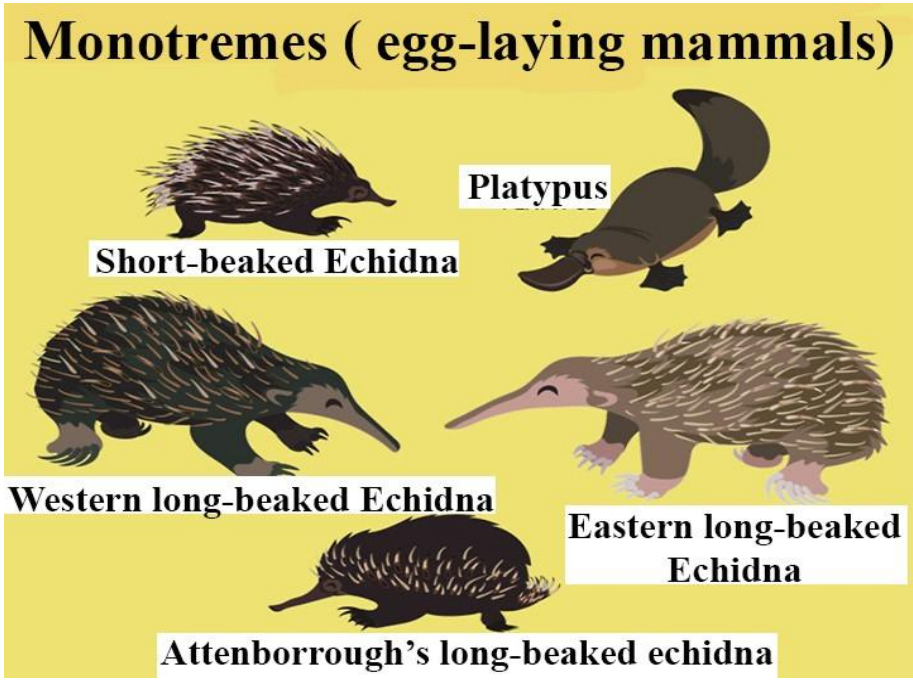


Fig 8.10: Prototherian mammals (Animals of order Monotremata)(https://www.toppr.com/ask/content/story/amp/evidence-from-biogeographical-distribution-70360/)

Protherians show affinities with reptiles and birds and a little advancement leading to mammalian features. The affinities with different groups have been discussed below:

- ***Affinities with Reptiles:*** Monotremes show some reptilian features such as:
  - Presence of shallow cloaca
  - Presence of ectopterygoid in skull
  - Presence of Vomer
  - Vertebrae without epiphysis and presence of cervical ribs
  - Thoracic ribs are single headed
  - Presence of T-shaped interclavicles
  - Plate like coracoid and presence of epicoracoid
  - Absence of Corpus callossum
  - Presence of ventral abdominal vein
  - Females lay large yolky eggs (Oviparous)
  - Abdominal testes
  - Presence of caruncle (egg-tooth) in newly hatched young ones
  - Absence of uterus and vagina

- Egg shows meroblastic cleavage

- ***Affinities with Aves:*** The resemblance between monotremes and birds is probably due to common ancestry. Some of the resembling features are:
  - Beak of birds and beak of platypus shows resemblance
  - Absence of teeth in adults
  - Spur in tarsal region
  - Webbed feet
  - Presence of oil gland
  - Presence of obliterated sutures in skull
- ***Affinities with Mammals:***Despite of the similarity with reptiles and birds the prototherians exhibit some prominent mammalian features which is why they have been kept under class mammalian. The mammalian features present in prototheria are:
  - Presence of hair on body
  - Presence of mammary gland
  - Presence of pinna
  - Warm blooded
  - Glandular skin with sweat and sebaceous gland
  - Presence of diaphragm separating thoracic and abdominal region
  - Dicondylic skull with craniostylic jaw suspension
  - Lower jaw of single bone dentary
  - Presence of 3 ear ossicles
  - Presence of 7 cervical vertebrae
  - Segmented sternum
  - 4 chambered heart
  - Only left aortic arch is present
  - Presence of corpora quadrigemina

Prototherians are a blend of reptilian and mammalian characters suggesting an intermediate stage between the two groups. The similarities of prototheria with reptiles and aves led to its placement in a separate subclass than the other members of class mammalian. Monotremes can therefore be considered as an offshoot of main mammalian evolution which retained some primitive characters alongwith some advanced features.

8.6 AFFINITIES OF METATHERIA

Metatheria includes **marsupials that give birth to immature young ones which are retained and nourished in abdominal pouch** till they grow enough to live outside. Eg: *Macropus* (Kangaroo). They are mostly herbivorous and have following features:

- Presence of marsupium in females

- Ear with pinna
- Presence of mammary glands
- Marsupial bone is present
- Coracoid and interclavicles are absent
- Corpus callossum absent
- Viviparous
- Immature young ones are born and brought into the marsupium
- Digestive and urinogenital tracts open out by separate structures that are controlled by common sphincter muscle
- Epiphyses on vertebrae

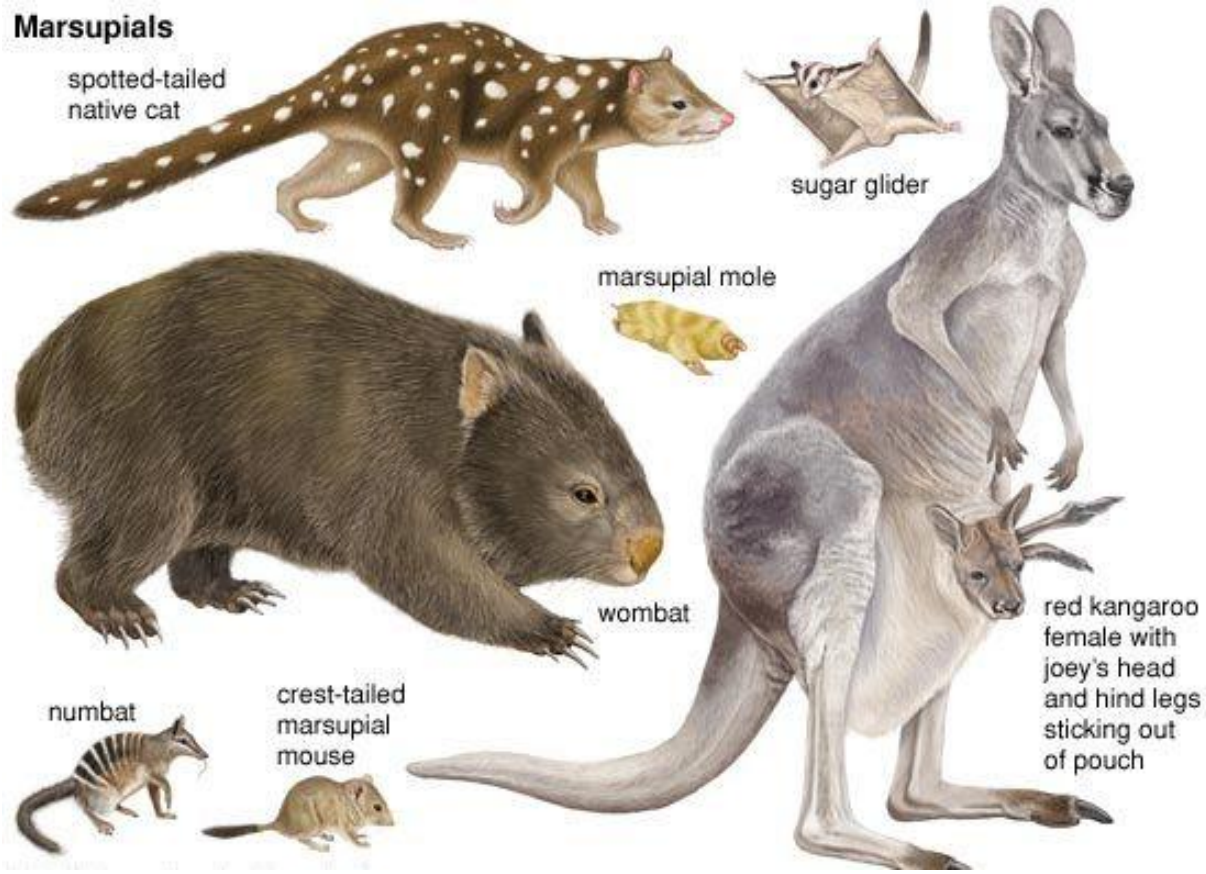


Fig 8.11: Metatherian mammals (Animals belonging to order Marsupialia)
(https://www.britannica.com/animal/marsupial/Paleontology-and-recent-history)

- ***Affinity with Prototheria:***
  - Presence of cloaca
  - Clavicles and epipubic bones (in pelvic girdle) present
  - Presence of ring like tympanum
  - Tympanic bulla is absent

- Corpus callosum absent
- True allantoic placenta is absent
- Relatively simple brain with large olfactory bulbs and anterior commissure

➢ ***Affinity with Eutheria:***

- Presence of hairs and external ears
- Presence of sebaceous and mammary glands with teats
- Presence of 4 optic lobes in brain
- Heterodont teeth
- Viviparous females
- Presence of uterus and vagina
- Cochlea spirally coiled
- Reduced coracoids
- Testes in scrotal sacs
- Presence of placenta

Metatherians are more evolved than prototherians but primitive to eutherians, hence can be regarded as transitional stage in evolution of mammals.

8.7 AFFINITIES OF EUTHERIA

It is the largest subclass of mammals and includes the animals **that give birth to young ones and posses' placenta for nourishing the foetus.** They have longer gestation and after birth the mother feeds her young ones with milk. Eg: Primates, dog, cats etc. The characteristic features of eutherians are:

- Well developed mammary glands with teats
- Marsupium is absent
- Claoca and epipubic bone absent
- Corpus callossum well developed
- Testes in scrotal sacs
- Viviparous
- Vagina is single
- Well developed allantoic placenta



Fig 8.12: Eutherian mammals (Animals belonging to different orders of class mammalian)slideplayer.com/slide/3718267/

- ***Affinities with Prototheria:***
  - Presence of hair on body
  - Presence of two occipital condyle
  - 7 cervical vertebrae
  - Presence of mammary gland
  - Non-nucleated RBC
  - Presence of diaphragm
  - Intestinal caecum is present
- ***Affinities with Metatheria:***
  - Small sized brain
  - Large olfactory region
  - Presence of hair on skin
  - Presence of external pinna
  - 4 optic lobes
  - Viviparous
  - Yolkless small egg
  - Presence of Placenta

Eutherians are among the most advanced forms of mammalian with true placenta. They include the highest evolved mammals.

8.8 IMPORTANCE OF MAMMALS

Mammals occupy an important position in ecosystem as they can feed at various levels of food chains, as herbivores, insectivores, carnivores and omnivores. They are economically important in relation to human beings as they serve or harm man (the evolved mammals) in various ways:

Beneficial Mammals:

Since the beginning of civilization, man has been domesticating various mammals for their own benefit. Man would probably not be able to survive without other mammals, particularly the domesticated species. Some of the mammals are domesticated for meat, milk, wool and hair while the others for transportation purpose and many other economic purpose. Some of them have been discussed below:

- **As Food:**

  Mammals have been serving as food for man in form of meat and milk. The domesticated mammals provide enormous quantities of various kinds of meat and meat products. Large even-toed ungulates such as cattle, buffaloes, pigs, goats, sheep etc. provide the bulk of meat supply of the world. Cows, buffaloes, goats, sheep, llamas, camels etc. provide milk which forms an important product for human food. Additional food products such as Ghee, butter, cheese and curd are also prepared from the obtained milk.

- **For Commercial Products:**

  Mammals have been used for providing leather and fur for the manufacture of clothing and for a variety of other purposes. Leather and fur are also used for the manufacture of bags, shoes, belts, purses, garments, etc., and support big industries. Most of the fur-bearing mammals are fast becoming scarce so that man-made acrylic fibres, designed to look-like fur, now compete with and replacing the natural furs.

  The wool of sheep is the most important animal fibre. It is extensively used for weaving into cloth for winter. Goats, sheeps, camels, etc., also produce wool. Hairs of camels, pigs and others are used to make brushes.

  Ambergris, obtained from sperm whales is used as a base in fine perfume. Similarly Musk, another substance used in perfumes is obtained from the glands of musk deer. Blubber of baleen whale and seal are the source of edible fat or oil.

  Ivory obtained mainly from the tusks of elephants and walrus is used for making toys and in decorations.

- **In agriculture:**

  Bullocks, buffaloes, horses and camels are employed for ploughing fields. They also provide manure in the form of dung and urine. The manure nitrifies soil and yield fuel biogas.

- **For Transportation:**

  Various mammals have been domesticated by man in transportation and draft of heavy loads such as horses, mules, bullocks etc.

- **As Pollinators:**

  Arboreal mammals such as bats, squirrels, monkeys are good pollinators as they help in the

pollination of flowers during their visit from one tree to another in search of fruits. In East Indies, bats are said to pollinate bananas.

- **As Scavengers:**

  Hyaenas and jackals are of great utility as scavengers in nature. The common pig also clears away the refuge in the Indian villages and towns.

- **In Recreation:**

  Many mammals are preferred as pets such as dogs, cats, monkeys, bears, rabbits, etc. Lions, tigers, horses, elephants and monkeys are generally employed in sports and circuses. Bull fights are one of the prime sport in Spain. Larger and rare varieties of mammals are exhibited in zoological gardens and national parks.

- **As study model:**

  Common mammals such as rats, guinea pigs, rabbits, cats, pigs, monkeys, apes, dogs, etc., are extensively used in laboratories for research and scientific studies.

Harmful Mammals:

Apart from being beneficial the mammals also pose some harmful impact on man such as:

- **Disease Carriers:**

  Rats, mice, pigs, cats, dogs, etc., transmit many diseases to humans such as plague, typhoid, hydrophobia, etc. Rodents are the worst carriers and distributors of the germs of certain diseases. Recently bats have been reported to carry virus which led to the advent of corona pandemic. Diseases caused and carried by the mammals lead to high mortality rate.

- **Pests:**

  Many mammals act as pests. Most dangerous mammals to crops are the rodents. They consume all kinds of food stuffs and destroy property similarly squirrels damage grain and other crops. Besides these deer, bear, boar, hippopotamus, elephant, kangaroo, etc., also damage and eat up crops.

- **Predators:**

  Lions, tigers, wolves and bears prey at times on domestic cattle, sheep, hogs, poultry, etc. Wolves and hyaenas sometimes attack sleeping persons. Sanguivorous bats feed on blood of various mammals, including man.

8.9 SUMMARY

Mammals are warm blooded animals which posses mammary glands and hair on the body. Mammals have evolved from Synapsid reptiles with series of evolution changes in skull and vertebrae ending into the important characteristic feature of skeleton of mammals. There was evolution in the structure of brain, jaw suspension and development of ear ossicles for better vibrations in ear drum. From anapsids such as *Captorhinus* there was an early offshoot line of development forming a Synapsid group. The early synapsids from middle Carboniferous, Pennsylvanian and Lower Permian especially in North America were together referred as Pelycosaurs. It is believed that from allies of pelycosaurs, a line evolved which are known as Therapsida that leaded to mammals. The mammals on the basis of their characteristics have been divided into 2subclass namely: Prototheria and Theria. Former includes order Monotremata (egg laying mammals) showing some primitive features as that of reptiles whereas latter was divided into infraclass Metatheria (Order Marsupialia) and Eutheria (with 16 living orders including Primates).

Eutherians include the mammals with most advanced features.

8.10 TERMINAL QUESTIONS

Q1. Comment upon the characteristics of class Mammalia.

Q2. Give the classification of class Mammalia upto orders.

Q3. 'Mammals have evolved as an offshoot from reptiles'. Comment upon the statement emphasizing on the evolution of mammals.

Q4. Give a detail account of affinities of Infraclasses of class Mammalia.

Q5. Differentiate between Prototheria and Eutheria.

Q6. Multiple Choice Questions

i) Which of the following is an example of egg laying mammal:

a) Eqqus

b) *Macropus*

c) *Echidna*

d) *Pangolin*

ii) Mammals are proposed to be evolved from:

a) Anapsida

b) Synapsida

c) Eurapsida

d) Diapsida

iii) Placenta is present in:

a) Metatheria

b) Prototheria

c) Eutheria

d) Both a and c

iv) Which of the following is not a characteristic of mammal:

a) Presence of 7 cervical vertebrae

b) Presence of mammary glands

c) Presence of scales

d) Presence of diaphragm

v) During the course of mammalian evolution the hinder jaw bones mainly quadrate and articular got converted into:

a) Ossicles

b) Ostia

c) Hard bones

d) Dentary

UNIT-9 : EVOLUTION OF MAN, RELATIONSHIPS OF MAN WITH OTHER PRIMATES, FOSSIL RECORD OF ANCESTRY OF MAN

9.1 Introduction

Objectives

9.2 Primates

9.3 Relationship between man and other primates

9.4 Fossil record of ancestry of man

9.5 Summary

9.6 Terminal Questions

9.7 Answers

9.1 INTRODUCTION

Man belongs to the family Hominidae of the order Primates.Human evolution is an elaborate process involving series of changes and modifications starting from apelike ancestors and reaching the present day humans. As per the scientific reports and evidences the physical and behavioral traits shared by all people originated from apelike ancestors and have evolved over a span of approximately 6 million years. Physical as well as genetic similarities show that the modern human species has a very close relationship to another group of primate species (apes). Humans and the chimpanzees (large apes) from Africa and gorillas share a common ancestor that lived between 8 and 6 million years ago. As per the studies conducted so far it is believed that humans first evolved in Africa and most of the human evolutionary processes occurred on that continent as the early humans fossils have been recorded from Africa. Between 2-1.8 million years ago the early humans first migrated out of Africa into Asia and entered Europe later between 1.5 million and 1 million years ago.

Approximately 4 million years ago, one of the earliest defining human features, bipedalism (ability to walk on two legs) evolved. Other important humanoid characteristics viz. large and complex brain, capacity for language and the ability to make and use tools developed later in the course of evolution. The agricultural practice and the rise of the first civilizations occurred within the past 12,000 years. The evolutionary process involves a series of changes that causes arousal of a species, its adaptation to the environment and later even their extinction. All the species on earth have originated through the process of biological evolution. This evolution occurs when there is any inheritable change in the genetic material. The expression of gene may influence the body or behavior of an organism; hence the genetically inherited characteristics can influence the likelihood of an organism’s survival and reproduction. The parents pass adaptive genetic changes to their offspring, and ultimately these changes become common throughout a population. The offspring inherits those genetic characteristics which enhances the chances of their survival and ability to reproduce. Over time, genetic change can alter a species' overall way of life and leads to evolutionary changes. Similar was the case with human evolution, all new genetic variations that were beneficial and helped in their survival and better adaptation to environment were inherited leading to the course of evolution and reaching to the most evolved species of date *Homo sapiens. Homo sapiens*, the most prominent species on earth is the result of over 7 million years of evolution. The records of human evolution have been maintained through fossil records, morphological, physiological and embryological studies.

The scientific study of human evolution is known as *Paleoanthropology* which is a subfield of anthropology (study of human culture, society, and biology). Paleoanthropology involves an understanding of the similarities and differences between humans and other species in respect to their genes, structure, physiology and behavior. Early human fossils and archeological remains offer the most important clues about this ancient past. These record of remains include bones, tools and any other evidence like footprints, butchery marks on animal bones etc.

Objectives:

This unit will help you to:

- Understand the characteristics of order Primate
- Discuss the similarities and dissimilarities between man and apes
- Understand and explain the evolution of man with course of time

9.2 PRIMATES

Order Primates belonging to class Mammalia includes animals such as lemurs, monkeys, apes and humans. The order Primates includes more than 500 species and is the third most diverse order of mammals after rodentia and Chiroptera. Despite of some notable variations between some primate groups, they share several anatomic and functional characteristics that indicate their common ancestry. The first primates appeared nearly more than 60 million years ago. The primate group evolved over the vast period of time and many of which are now extinct while others are still alive accounting for 350 different species of living primates.

Primates have the following features:

- Relatively large and complex brain
- Eyes are forward-facing with overlapping fields of view that allow depth perception
- Grasping hands with long fingers to fold around objects
- Opposable thumbs
- Eye sockets with a ring or cup of bone surrounding and supporting the eyes
- Presence of flat nails
- Well-developed clavicle
- Two or more nipples in females for supply of milk
- Presence of sensitive pads under the tips of the fingers and toes containing special touch receptors called Meissner's Corpuscles
- Presence of penis and testes in males

Primates are generally classified on the basis of their evolutionary history based on a branch of science called phylogeny. Phylogeny shows how species are related by common ancestors. The phylogenic tree below shows the phylogeny of primates.

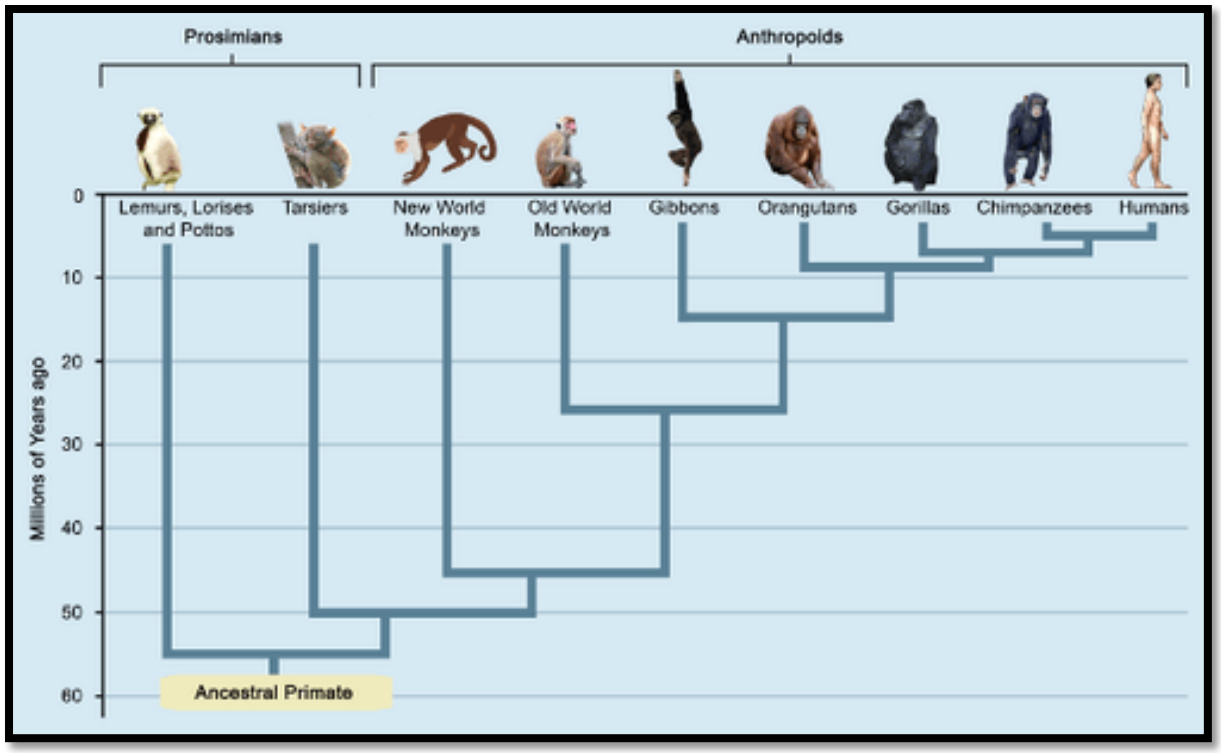


Fig 9.1: Phylogenic tress showing the categorization of primates into prosimians and anthropoids (https://flexbooks.ck12.org/cbook/ck-12-college-human-biology-flexbook-2.0/section/7.2/primary/lesson/primate-classification-and-evolution-chumbio/).

Traditionally the classification of primates does not necessarily reflect their evolutionary history. It is based primarily on morphological similarities rather than common ancestors. Primates have traditionally been divided into two major groups: *Prosimians* and *Anthropoids*. Prosimians are generally small in size and have characteristics similar to the earliest primates and include lemurs, lorises, and tarsiers. Anthropoids on the other hand tend to be larger and less similar to early primates and include monkeys, apes, and humans.

9.3 RELATIONSHIP BETWEEN MAN AND OTHER PRIMATES

Advancement in science has led to genetic analysis that indicates that humans are most closely related to chimpanzees and bonobos. The studies indicates that there is only 1.2% difference in the DNA between chimpanzees and humans followed by gorillas of the African great ape family with a difference of about 1.6% in DNA sequence with humans.

It is quite interesting to note that chimpanzees, bonobos and humans all share the same percent difference in DNA compared to African great apes indicating that they have diverged from a common ancestor at a similar time. The difference between African great apes, humans, bonobos and chimps from Asian great apes (orangutan) is about 3.1% which indicates that at some point there was a common ancestor that diverged into two lineages, one of which the Asian great apes, and other the African great ape and its descendants (including humans).

Evolutionary history reveals our relationship with old world monkeyslike rhesus monkey sharing a difference off about 7% difference with humans, chimps, bonobos and apes.

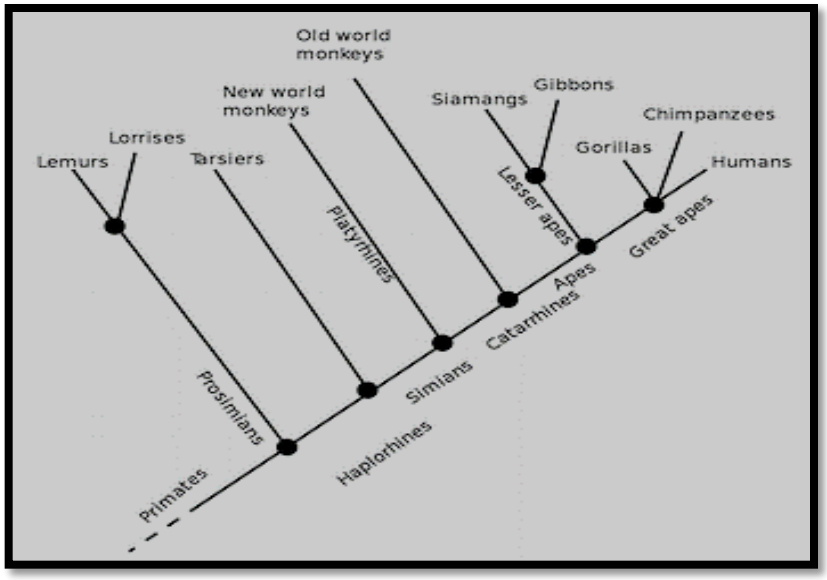


Fig 9.2: Genetic data used to reconstruct phylogenetic tree that shows relationship of humans to other extant primates(https://study.com/academy/lesson/genetic-relationship-between-humans-other-primates.html)

Order primates include three living suborders namely Lemuroidea, Tarsioidea and Anthropoidea with following characters:

Suborder 1. Lemuroidea (eg: Lemur)

- Arboreal, omnivorous and mostly nocturnal.
- They have poor vision.
- Macrosomatic brain with relatively small cerebral hemispheres.
- The allantois is large.
- Placenta is diffuse and non-deciduate.

Suborder 2. Tarsioidea(eg: Tarsier)

- Posses very long tarsal region
- Arboreal, mainly insectivorous and nocturnal.
- The eyes are large and directed forward with good vision.
- The cerebral hemispheres are large and cover the cerebellum and mid brain.
- Reduced allantois .
- Discoidal and deciduate placenta.
- Tuft of hair at the end of the tail.

Suborder 3. Anthropoidea (eg: Apes ad Man)

- Arboreal or terrestrial, gregarious and diurnal.
- Mainly omnivorous

- Very intelligent and lead a social life.
- Eyes are large and forward facing with clear vision.
- Microsomatic brain (completely covering the cerebellum) with large cerebral hemispheres.
- Reduced allantois.
- The placenta is discoidal and deciduae.

The lemurs, lorises and tarsiers are collectively called prosimians while the monkeys, apes and man are collectively called simians.

9.4 FOSSIL RECORD OF ANCESTRY OF MAN (EVOLUTION OF MAN)

Hominidae family (order Primates) includes hominoids (the great apes). Fossil record and comparison of human and chimpanzee DNA suggests that humans and chimpanzees diverged from a common hominoid ancestor approximately 6 million years ago.The evolutionary branch led to development of many species including humans. The term *hominin* is used to refer to those species that evolved after the split of the primate line. Animals that are more closely related to humans than to chimpanzees are designated as hominins. They were predominantly bipedal and include those groups that likely gave rise to our species. Relatively few hominin fossils have been recovered and on the basis of all the collected evidences the course of evolution from early hominins to modern humans has been drawn.

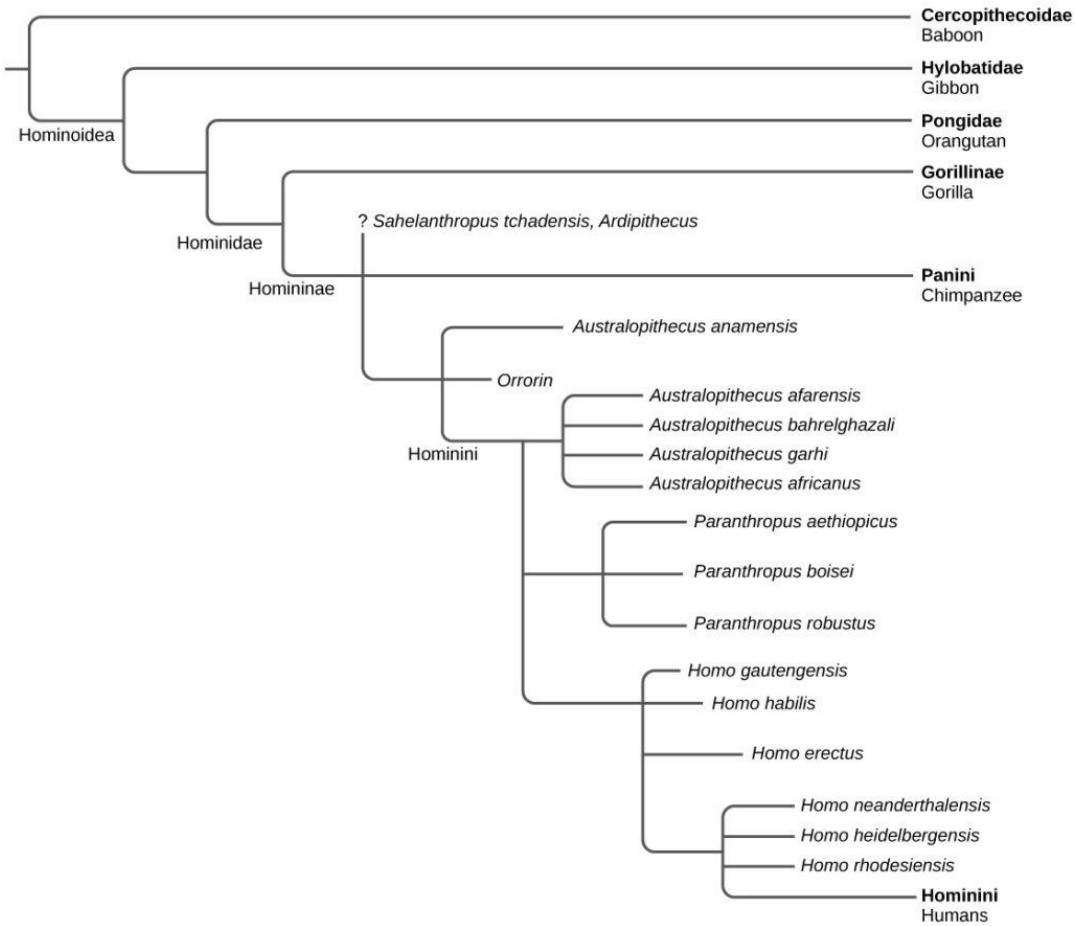


Fig 9.3: Chart showing the evolution of modern human(https://bio.libretexts.org/Bookshelves/Introductory_and_General_Biology/Book%3A_General_Biology_%28Boundless%29/29%3A_Vertebrates/29.07%3A_The_Evolution_of_Primates/29.7B%3A_Early_Human_Evolution).

The oldest hominin *Sahelanthropus tchadensis* is reported from early 7 million years ago. A single skull specimen of this genus was found in Chad. The fossil recovered is informally called "Toumai" which is a mosaic of primitive and evolved characteristics. However it is a bit unclear that how this fossil fits in the frame given by molecular data, namely that the line leading to modern humans and modern chimpanzees apparently bifurcated about 6 million years ago. At present this species is not considered as an ancestor of modern humans.

*Another hominin*fossil *Orrorin tugenensis* was recently recovered in 2000. *Orrorin* shows some similarity with modern humans as compared to australopiths, although *Orrorin* is much older. Although the possibility of *Orrorin* to be human ancestor has not been ruled out but the fact is still unkown .

A third genus, *Ardipithecus* was discovered in the 1990s, however some scientists did not believe the organism to be a biped therefore suggested that it would not be considered a hominid. The status of this genus as a human ancestor is uncertain.

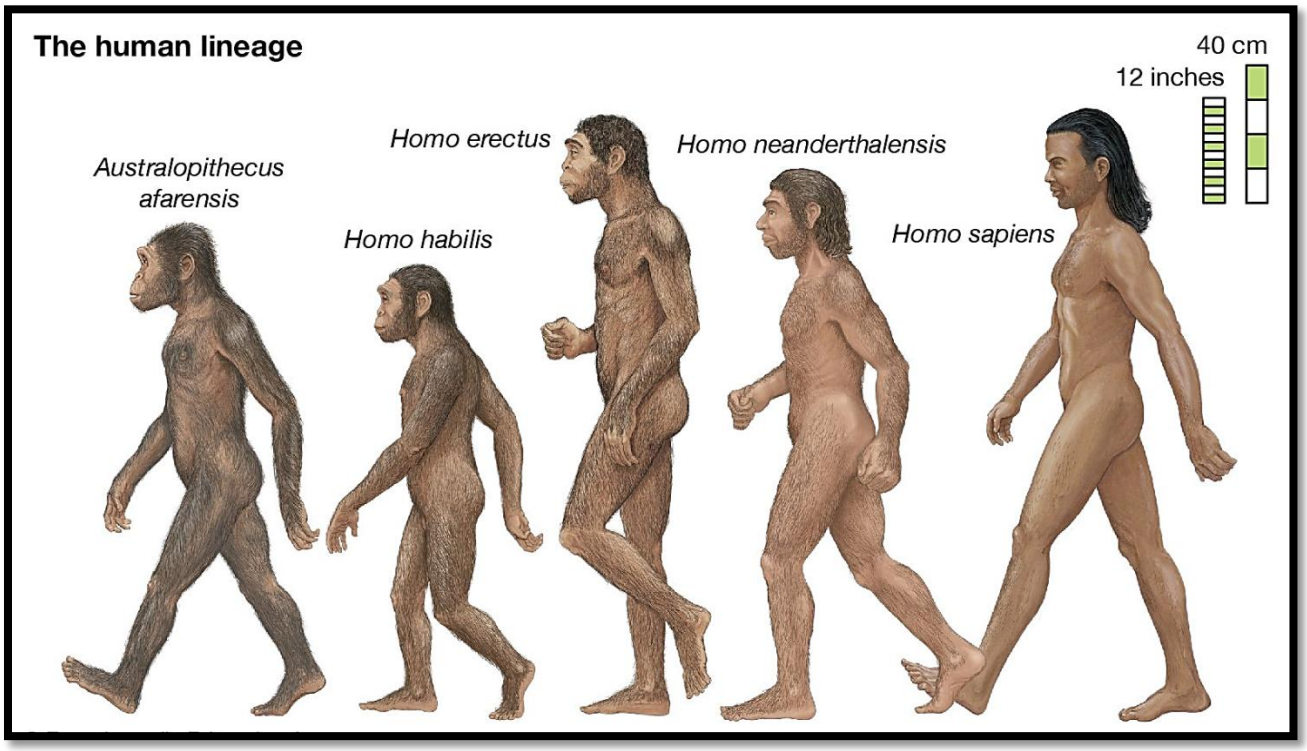


Fig. 9.4: Diagram showing human lineage

(https://www.britannica.com/science/human-evolution).

- *The Earliest hominids:*

  The earliest known hominid fossil is Ramapithecus from Africa and Asia from later Miocene and Pliocene nearly 14-8 million years ago. The records of jaws, teeth and skull fragments show more similarities with man than apes.

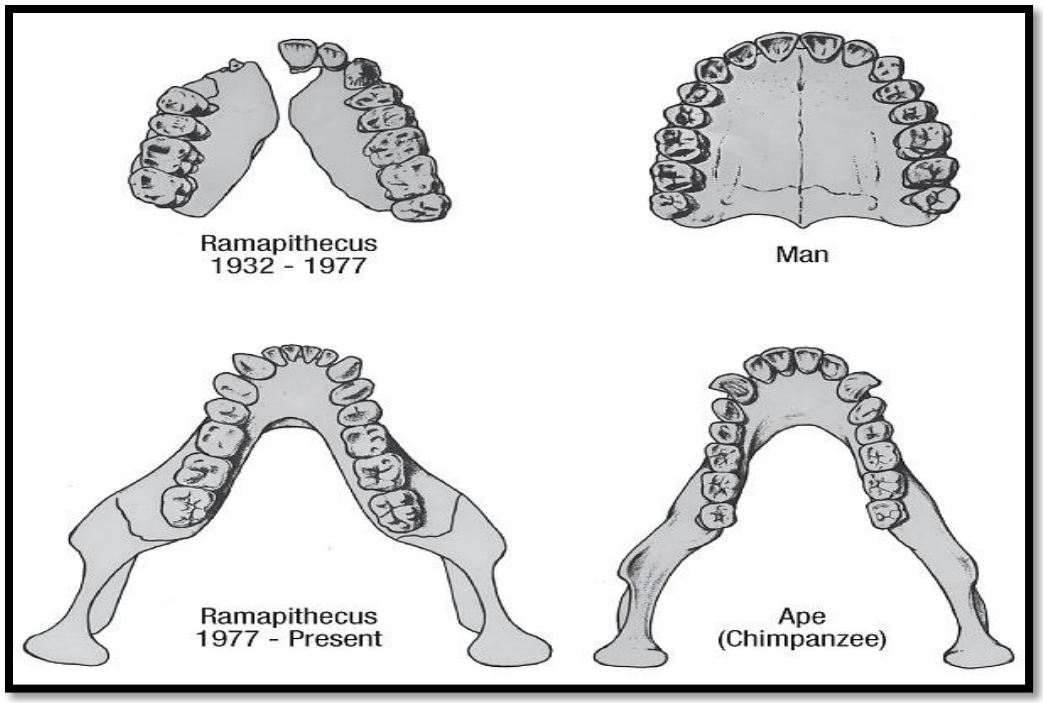


Fig 9.5: Teeth and jaw in Ramapithecus , Ape and Man

*(*https://selfstudyanthro.com/2019/01/09/ii-1-2-1-1-ramapithecus/*).*

The jaws were relatively short and delicate and canines as well as premolars were smaller in comparison to pongids (great apes). Some workers consider these fossils to be placed in genus Dryopithecus or to be evolved from it. The molars showed interstitial wear and the massive jaws indicate their use in powerful transverse masticatory movements. Dental structures indicate their herbivorous diet.

- *Australopithecus:*

Australopithecus ("southern ape") is a genus of hominin that evolved in eastern Africa approximately 4 million years ago and went extinct about 2 million years ago. The bones of *Australopithecus* probably represent three species none of which contained our ancestors but evolved parallel to them. The first fossil was a juvenile skull discovered from limestone cave at Tuang in South Africa and described by Dart (1925) as *A. africanus.* The fossil, which is informally called "Lucy," is significant because it was the most complete australopith fossil found. The cranial capacity of the skull of *Australopithecus* was around 450-500ml which was little larger than that of ape. They showed bipedalism. The foramen magnum was at centre of skull with head balanced on neck rather than hanging forward as in apes. The mandibles were larger than modern man but the teeth formed a rounded arcade with vertical incisors. The pelvic bones which were found had a broad ilium helping to raise the body into an upright position on two legs.

Australopithecus had a number of characteristics that were more similar to the great apes than to modern humans such as sexual dimorphism was more exaggerated than in modern humans. Some of the australopithecine skulls were heavily built with large brow ridges and large teeth. Many workers considered it as a separate species and referred it as *A. robustus* . Another species namely *A. boisei* was found in East Africa and was originally called as *Zizanthropus* by L.S.B. Leakey. *Australopithecus* is of particular interest to us as it is thought that genus *Homo* evolved from *Australopithecus* about 2 million years ago.



Fig 9.6: The skull of (a) *Australopithecus afarensis* and (b) modern humans(https://bluebox.creighton.edu/demo/modules/en-boundless-old/www.boundless.com/biology/textbooks/boundless-biology-textbook/vertebrates-29/the-evolution-of-primates-177/early-hominins-682-11905/images/skull-comparison-em-australopithecus-afarensis-em-vs-modern-humans/index.html).

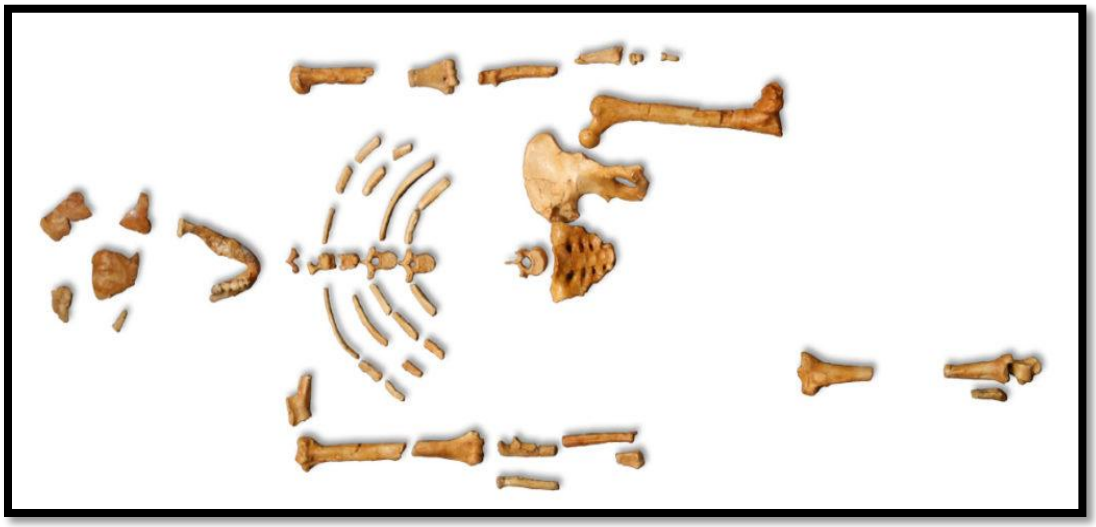


Fig. 9.7: Skeleton of adult female *Australopithecus afarensis* (Lucy) discovered in the mid

1970s(credit: "120"/Wikimedia Commons).

- ***Homo habilis:***

The human genus, *Homo*, first appeared between 2.5 and 3 million years ago. Fossils of a species called *H. habilis* were the oldest examples in the genus *Homo*. Compared to *A. africanus*, *H. habilis* had a number of features more similar to modern humans. *It* had a jaw that was less prognathic than the *Australopithecus* and a larger brain(600–750 cc). However, *H. habilis* retained some features of older hominin species, such as long arms. The name *H. habilis* means "handy man," which is a reference to the stone tools that have been found with its remains. Their brain size, features of their hands and feet, and evidence that they may have used stone tools all suggested that a new type of human ancestor had been found.The discovery of *Homo habilis* started in 1959 with two teeth unearthed from Olduvai Gorge in Tanzania by a team of Louis and Mary Leakey. Additional partial skeleton fossils discovered in 1986 have revealed that this species was more ape-like.



Fig. 9.8: Skull and Jaw of *H. habilis*(https://australian.museum/learn/science/human-evolution/homo-habilis/).

- ***Homo erectus****:*

Java and Pekin man with large brains were generally called as *Homo erectus* (earlier referred as *Pithecanthropus* and *Sinanthropus)*. Java man were found in 1981 from gravel beds nearly 1.9±0.4 million years ago. Similar fossils were found Choukoutien near Pekin. The cranial bones from Java were very thick with low forehead, large brow ridges and large nuchal area at back for attachment of muscle. The cranial capacity varied from 800-1000ml. The post-cranial skeleton of *H. erectus* was quite similar to that of modern man. Pelvis allowed alternating tilt and foots were arched (Day 1973).

The cranial capacity of Pekin were around 850-1300ml with an average of 1075ml. The forehead was steeper, rounded palate, smaller teeth in comparison to Java fossils. The brain of *H. erectus* (1400ml) showed an increase in size from that of *Australopithecus* to modern man.



Fig.9.9: Skull of *Homo erectus* with prominent brow and a nose that pointed downward rather than forward(https://commons.wikimedia.org/wiki/File:Homo_erectus_skull_-_Naturmuseum_Freiburg_-_DSC06767.jpg)

- ***Homo neanderthalensis:***

H. neanderthalensis may be referred as presapiens which were thicker and more heavily built than modern skull. They were found from the sites nearly 100000 and 50000 years ago. The skull were generally long and low with sides bulging, large brow ridges and low forehead (Wood 1978). The cranial capacity was larger than modern human. The nearnderthals lived in Europe and parts of Asia and North Africa. The incisors were large with cheek teeth of about modern size.

Neanderthals made and used sophisticated tools, fire, lived in shelters, made and wore clothing. They were skilled hunters of large animals and also ate plant foods and occasionally made symbolic or ornamental objects. Evidences provide ample proof that Neanderthals deliberately buried their dead and occasionally even marked their graves with flowers.



Fig. 9.10: Skull(https://www.livescience.com/28036-neanderthals-facts-about-our-extinct-human-relatives.html)and diagram of *Homo neanderthalensis*(https://www.britannica.com/topic/Neanderthal).

- ***Homo sapiens:***

The skull of modern man i.e. *Homo sapiens* is nearly 50,000 years old. The remains of Homo sapiens were first discovered in Europe and were named Cro-Magnon. They have greater breadth in parietal region than at base, posses' steeply rising forehead and prominent chin. The earliest known skull of this species is from Omo, Kenya (130000 years ago). The evidences support that *H. sapiens* originated in the African late middle Pleistocene. As per the genetic data *H. sapiens H. neanderthalensis* shared a last common ancestor in the middle Pleistocene .

H. sapiens has relatively lightly built skeleton distinguished in many anatomic details such as high cranium, rounded in lateral profile, rounded and quite thin-boned braincase overhanging a greatly reduced face a small face retracted under the frontal bone, a true chin even in infants and a narrow trunk and pelvis with short superior pubic rami. In the lower jaw, the chin is not simply a swelling in the midline of the mandible but a complex and distinctive structure that does not exist in other. Cranial capacity of *Homo sapiens* is about 1300 to 1400 cc which is smaller than its ancestor Neanderthal man.

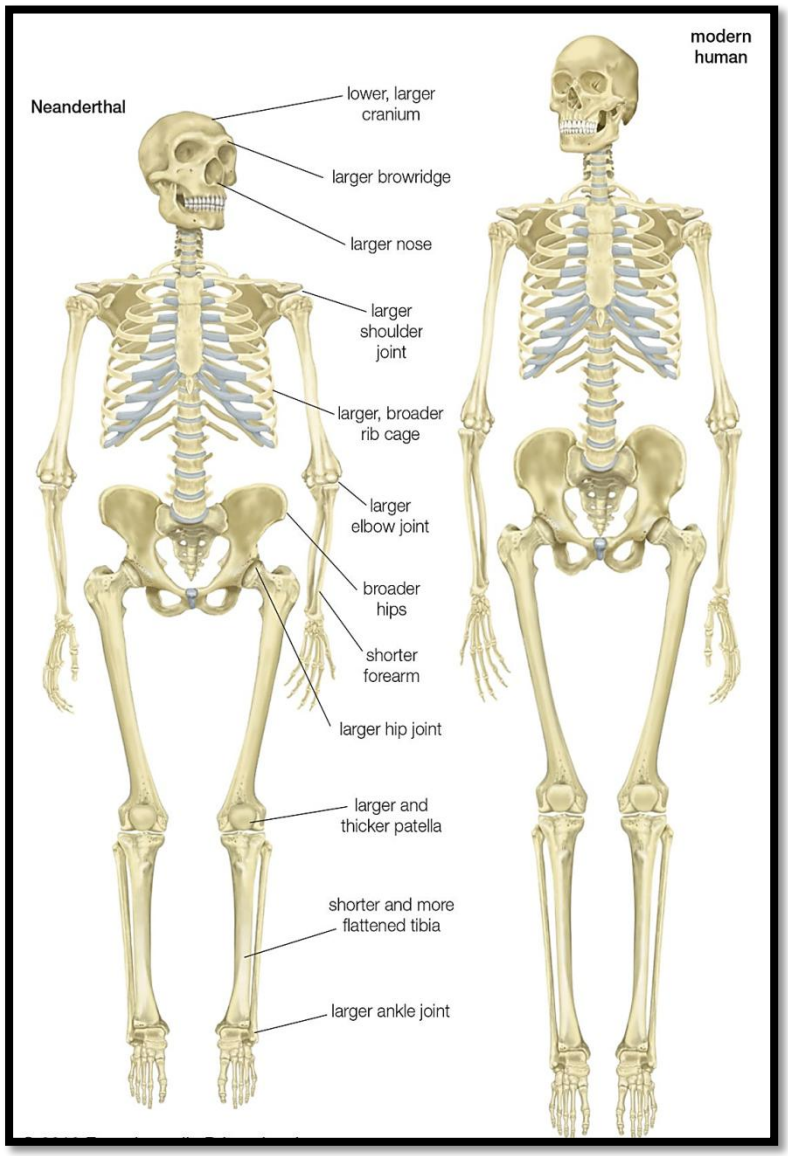


Fig 9.11: Skeleton of *H. neanderthalensis* and *H. sapiens* (https://www.britannica.com/topic/Homo-sapiens/Behavioral-influences).

9.5 SUMMARY

Evolution is a gradual process that involves changes over time from simple to more complex forms. Humans are believed to have developed from simpler forms. Human evolution is the evolutionary process by which human beings developed on earth.During the course of evolution different species of humans evolved and adapted to the changing environment with best of their abilities. Evolution of human can be summarized as:

Dryopithecus:

- Deemed to be the ancestors of both man and apes.
- Lived in China, Africa, Europe and India.
- The genus Dryopithecus refers to the oak wood apes.
- Could have predominantly been herbivores.

Ramapithecus:

- First remains were discovered from the Shivalik range (Punjab) and later in Africa and Saudi Arabia. They lived in open grasslands.
- Thickened tooth enamel, robust jaws and shorter canines.
- Use of hands for food and defence and extrapolations of upright posture.
- Some workers suggested them to be kept under Dryopithecus

***Australopithecus*:**

- Inhabited in the mainland of Asia.
- Have large jaws and human-like teeth.

Homo habilis:

- Used stone tools with hands therefore referred to as handyman
- Able to communicate with each other.
- Homo erectus-
- More-evolved human beings with large brain sizes.
- Invented fire and were carnivorous

Homo neanderthalensis:

- Cranial capacity of Neanderthal grew from 1200 to 1600 cc.
- This species of hominids could hunt big animals such as mammoths.
- Used sophisticated tools, fire, lived in shelters, made and wore clothing.

Homo sapiens:

- First discovered in Europe and were named Cro-Magnon.
- Jaws are quite reduced, the modern man’s chin appeared, and the skull was rounded

- These are modern men with average 1350cc brain capacity.
- They gathered food through hunting

9.6 TERMINAL QUESTIONS

Q1. What are Primates? Give the charateristic features of primates.

Q2. Write an essay on 'Evolution of man'.

Q3. How are man and other primates related?

Q4. Multiple choice questions:

i) Anthropoids include:

a) Man and Monkey

b) Apes

c) Man, monkey and apes

d) Monkey and apes

ii) Which of the following is the correct sequence of human evolution:

a) *Australopithecus, Homo habilis, Homo sapiens, Homo erectus, Homo neanderthalensis*

b) *Homo neanderthalensis, Australopithecus, Homo habilis, Homo sapiens, Homo erectus*

c) *Australopithecus, Homo neanderthalensis, Homo habilis, Homo sapiens, Homo habilis*

d) *Australopithecus, Homo habilis, Homo erectus, Homo neanderthalensis, Homo sapiens*

iii) Which of the following is known as 'Handy man':

a) *Homo habilis*

b) *Australopithecus*

c) *Homo neanderthalensis*

d) Cromagnon man

iv) 'Lucy' belongs to genus:

a) Homo habilis

b) Australopithecus

c) Homo neanderthalensis

d) Homo sapiens

9.7 ANSWERS

Q 4 (i) c ; (ii) d ; (iii) a ; (iv) b

UNIT-10: COMPARATIVE ANATOMY OF VERTEBRATES, COMPARATIVE ANATOMY OF DIGESTIVE SYSTEM, RESPIRATORY SYSTEM

10.1 Introduction to Vertebrates

Objectives

10.2 Comparative anatomy of vertebrates

10.3 Comparative anatomy of digestive system

10.4 Comparative anatomy of respiratory system

10.5 Summary

10.6 Terminal Questions

10.7 Answers

10.1 INTRODUCTION TO VERTEBRATES

Chordata includes group of animals that bear stiff, supporting rod like structure known as notochord along the dorsal surface at some stage of their life. All other animals that do not show the presence of notochord at any stage of their life fall under phylum nonchordata. It is the largest of deuterostome phyla and the chordate animals show following three fundamental characteristics:

- Presence of notochord
- Dorsal tubular (hollow) nerve cord
- Pharyngeal gill-slits

Balfour in 1880 identified and created this phylum which includes Protochordates (Acraniata) and Vertebrates (Craniata). Subphylum Vertebrata (L., *vertebrates= jointed*) derived its name because of the presence of serially arranged vertebrae which forms a major part of axial exoskeleton, vertebral column or backbone. Another important feature of this subphylum is the presence of anterior skeleton cranium (skull). Some of the important characters of vertebrate animals are:

- Presence of vertebrae
- Presence of skull or cranium hence also named as **Craniata**
- Presence of pharyngeal gill slits
- Dorsal hollow nerve cord
- Notochord invested by cartilage or may be replaced by vertebral column
- Lower vertebrates are aquatic while higher are mostly terrestrial
- Bilateral symmetry
- Metamerically segmented
- Presence of shiczocoelus coelom
- Body divisible into head, trunk and postanal tail. Additional neck region is also found in some forms
- Trunk bears two lateral jointed appendages which may be reduced or absent in some forms

- Integumentary system comprises of outer epidermis and inner dermis
- Endoskeleton jointed formed of bones or cartilage or both consisting of skull, vertebral column, girdles and limb bones
- Respiration by gills in lower aquatic form and by lungs in terrestrial forms
- Closed blood vascular system
- Excretion by paired mesonephric or metanephric kidneys
- Presence of special sensory organ including eyes, auditory organs and brain
- Presence of endocrine glands
- Development may be direct or indirect

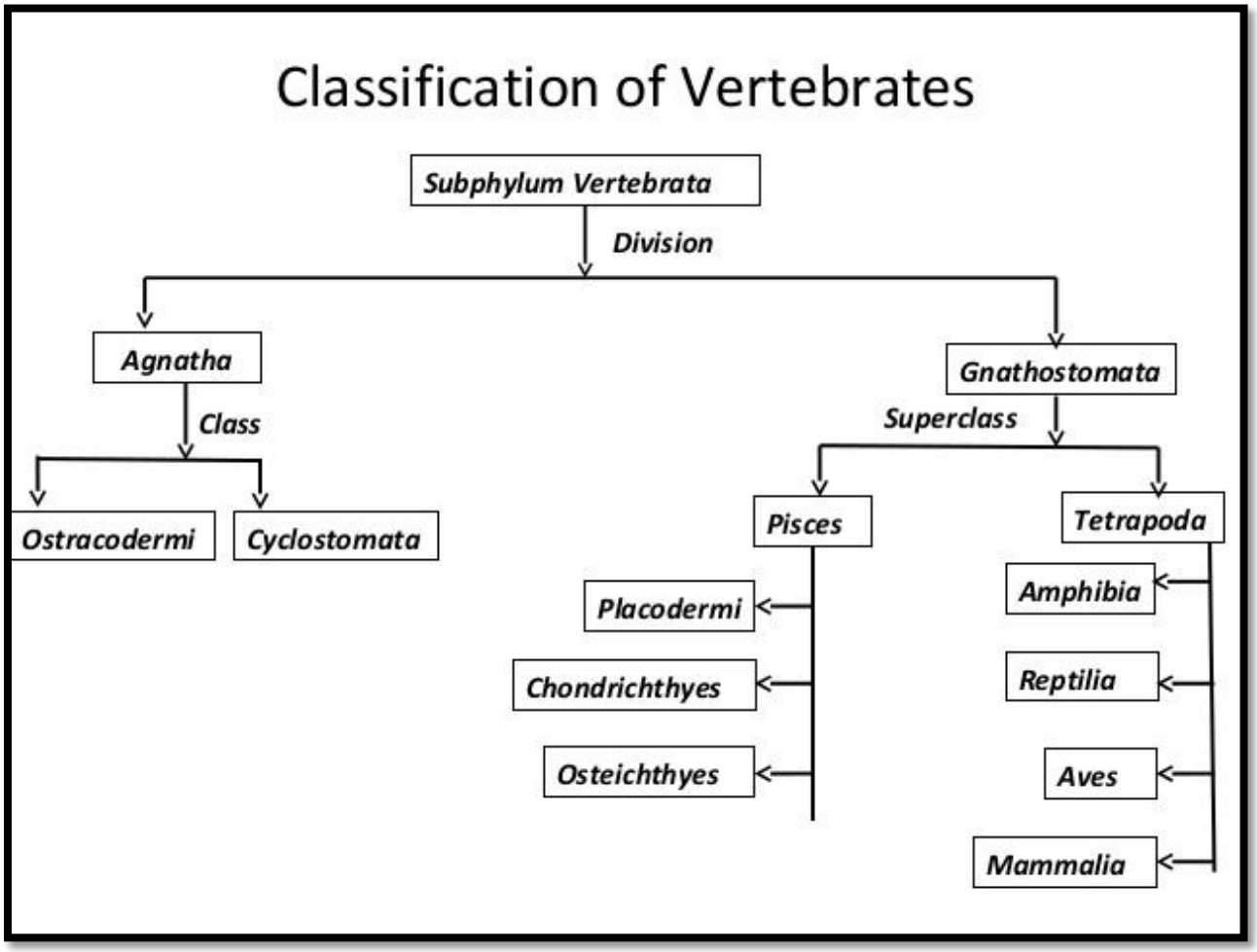


Fig 10.1: Classification of Vertebrates (https://www.w3schools.blog/division-gnathostomata).

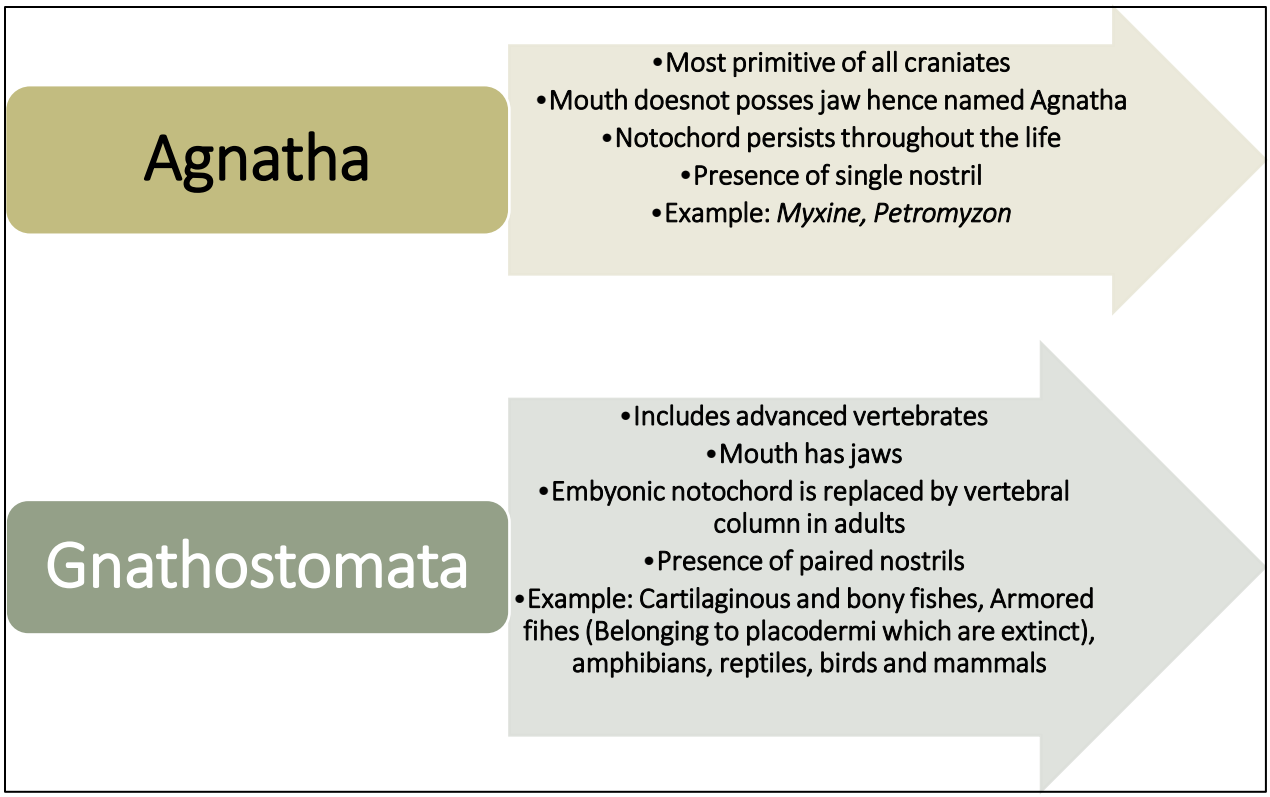


Fig 10.2: Characters and examples of two divisions of phylum Vertebrata.

Objectives:

The study of this chapter will provide:

- Better understanding of Vertebrates
- Knowledge of vertebrate classification and comparative anatomy of digestive system among different vertebrates
- Details of respiratory system among different vertebrates

10.2 COMPARATIVE ANATOMY OF VERTEBRATES

Study of comparative morphology deals with anatomy and its significance. The use of comparison in comparative morphology is not only a tool which shows the extent of similarities among the organisms it also emphasizes the functional and evolutionary themes vertebrates carry within their structures. Comparative studies also help formulate the questions and get the answers based on observations such as different types of fish tails in different group of fishes is according to their habit and habitat. For example the teleost fishes which have swim bladder either sink to bottom or float on the surface. Therefore their vertical position is easily maintained by homocercal tail (equal tail) whereas in sharks which lack swim bladders and tend to sink have heterocercal tail with extended lobe on one side that provides lift during swimming to help counteract this sinking tendency.

Making comparison itself is not just a quick and easy device but whenever used it acts as a tool of insight that guides our analysis and helps us set up hypotheses about the basis of animal design. Comparative anatomy of vertebrates allows us to draw a clear picture of advancement of characters among different vertebrate groups and eve also answers to some of the evolutionary

classification of animals.

10.3 COMPARATIVE ANATOMY OF DIGESTIVE SYSTEM

The adult digestive system includes digestive tract and accessory digestive glands. Former is a tubular passageway that extends through the body from the lips of the mouth to the anus or cloacal opening. Glands embedded in the walls lining the tract release secretions directly into the lumen. Digestive system enables turning a food into usable fuel for the body. The digestive system breaks up the large molecules contained in a succulent meal so they can be absorbed into the bloodstream and made available for use throughout the body. Bolus is a lump of food in the mouth which is digested by both mechanical and chemical processes. The mechanical chewing with teeth and churning of food in digestive tract break up the bolus, reducing it to many smaller pieces and thereby increasing the surface area available for chemical digestion by enzymes. Muscles along the walls of the digestive tract produce waves of contraction termed as peristalsis that constrict food in the lumen, mixing and forcing it from one section of the tract to the next. All the above actions converts the bolus, into pulpy mass of fluid more commonly called chyme or digesta.

The primitive intestine or archenteron is produced by invagination or other processes in the gastrula. It starts with a simple tube of endoderm with one opening to the exterior known as blastopore which is situated at the future posterior end of the embryo. This endodermal tube persists as the lining of the adult digestive tract and of all of its derivatives. The adult digestive tract consists of a thick-walled tube, composed of both endodermal and mesodermal elements where the latter predominates. The anterior and posterior ends of the digestive tube are lined by ectoderm as a result of invagination processes. The anterior invagination is called the stomodaeum while the posterior one is called proctodaeum. The anatomy of digestive tract in various vertebrates has been discussed below:

- **Mouth:** In *Amphioxus* the mouth originates on the left side in series with the gill slits. This mode of origin supports the view that the vertebrate mouth arose by the fusion of the first pair of gill slits. However, it seems more probable that various asymmetries in the development of *Amphioxus* are peculiar to that animal and not of phylogenetic significance. During the years of acceptance of an annelid-arthropod ancestry for vertebrates it was proposed that the original annelid mouth and stomodaeum are represented by the pituitary and its opening and that the present vertebrate mouth is a new formation. However, the annelid-arthropod theory of vertebrate ancestry is now discredited in favuor of an origin from the echinoderm-hemichordate line. The vertebrate mouth is therefore the same as that of its immediate invertebrate ancestors and is not a new formation.

  Digestive tube or tract begins with oral or buccal cavity at the anterior followed by pharynx, esophagus, stomach, small intestine, large intestine or colon and cloaca. The oral or buccal cavity is bounded by the jaws in front and on the sides, palate lying above with buccal floor bearing the tongue below. Higher vertebrate forms also bear lips and. The space between lips and teeth is known as vestibule. In *Amphioxus* and *Ammocoetes* the oral cavity consists of the space enclosed by the oral hood and is definitely bounded from the pharynx by the velum. The position of the velum corresponds to the boundary between stomodaeum and pharynx of gnathostomes.

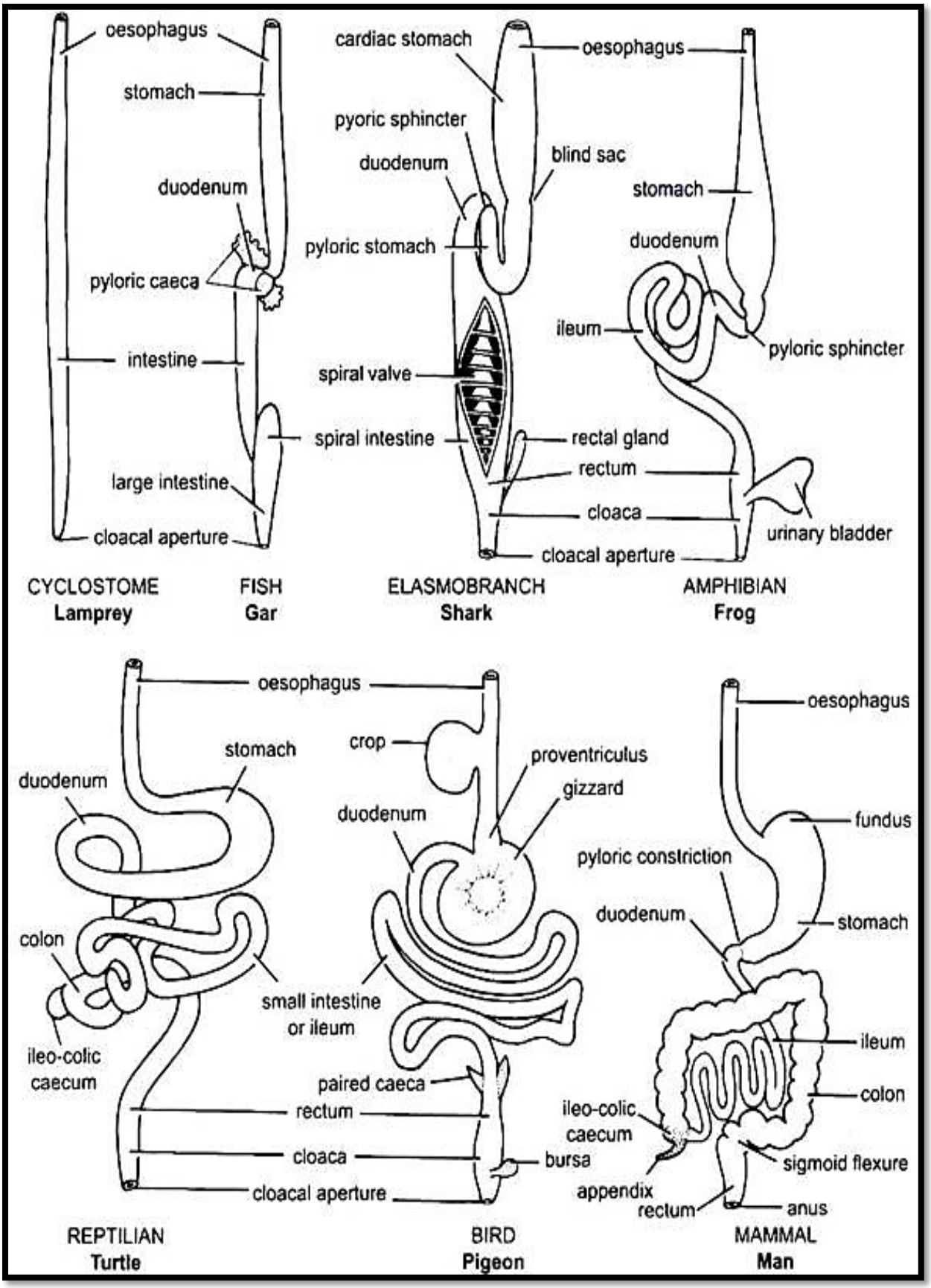


Fig 10.3: Digestive tract in some vertebrates

(https://www.notesonzoology.com/vertebrates/digestive-system-of-vertebrates-with-diagram-chordata-zoology/8977).

In Dipnoi, Crossopterygii and tetrapods the nasal cavities open into the roof of the oral cavity by the internal nares. These are primitively placed anteriorly but tend to move backward and in Crocodile, birds and mammals aquire a far posterior position through the formation of the secondary palate. A part of what was originally the oral cavity thus becomes enclosed between the secondary palate and the original palate or buccal roof and this enclosure constitutes the nasopharyngeal passages by which the nasal cavities are prolonged posteriorly to open by the internal nares (choanae) now situated near the beginning of the pharynx. In birds the secondary palate is imperfectly formed whereas well developed in mammals where it is continued backward by a fleshy fold known as soft palate which helps to separate the food and respiratory passages.

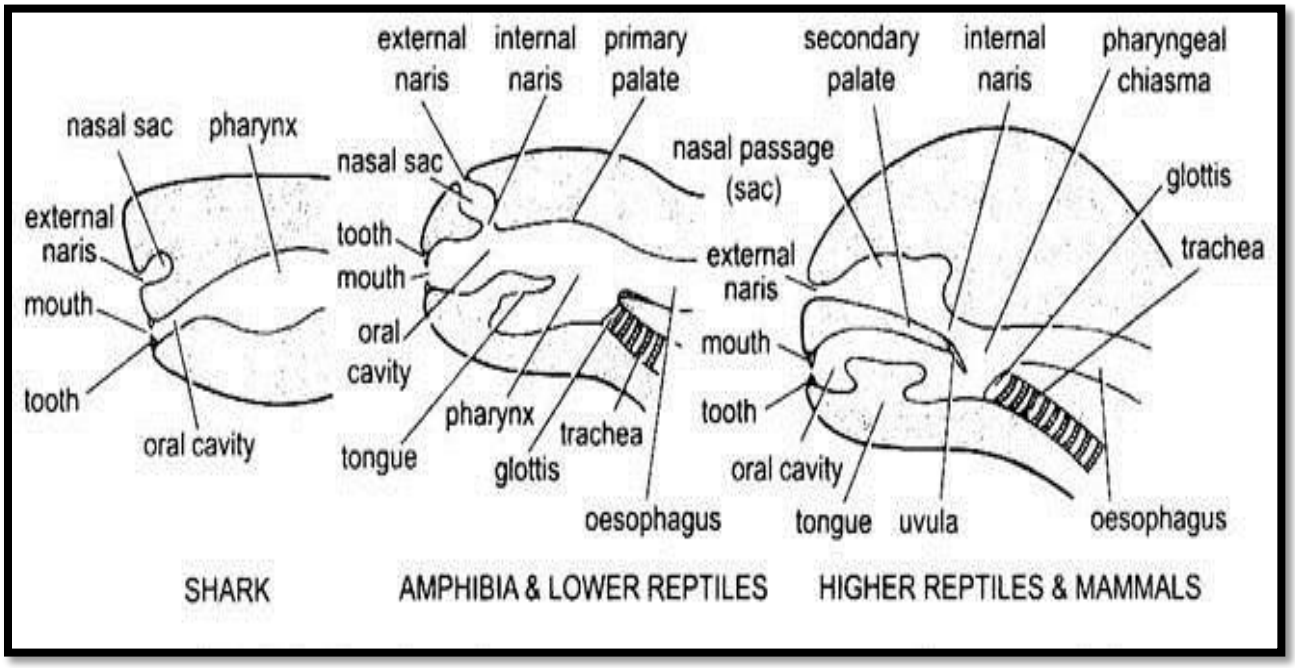


Fig 10.4: Nasal passage and buccal cavity in various vertebrates(https://www.notesonzoology.com/vertebrates/digestive-system-of-vertebrates-with-diagram-chordata-zoology/8977).

The primary tongue observed in fishes is simply a part of the buccal floor demarcated anteriorly by a fold. This primary tongue does not contain any muscle or glands. Within amphibians, a crescent shaped gland field develops in front of the primary tongue and fuses with it to form the definitive tongue. In amniotes tuberculum impar (similar to gland field) develops in front of primary tongue and fuses with it and in addition to it a pair of lateral lingual swellings join the tuberculum impar. Therefore definitive amniote tongue comprises of four swellings. The amniote tongue is invaded by voluntary musculature, derived from the hypobranchial musculature and is also innervated by the twelfth cranial nerve (hypoglossal). Here the tongue is richly supplied with glands and taste organs.

In Tetrapods numerous multicellular oral glands are also imbedded in the walls of the oral cavity and open into it. They are of two general kinds namely: mucous-secreting glands and sebacious glands secreting enzymes, poisons etc. or are of mixed nature. These glands are usually named according to their location such as labial glands (on lips) and dental glands (on teeth) etc. Such oral glands are

few in amphibians but many in reptiles in form of lingual (tongue), sublingual, palatine, and labial (lip) glands. The poison glands of snakes are enlarged, modified upper labial glands are associated with teeth. Most birds are well equipped with oral glands quite similar to that in reptiles, although fish eating birds may lack them. In mammals there are enlarged oral glands, the salivary glands opening into the oral cavity by one or more long ducts. The principal salivary glands are the parotid, sublingual, submaxillary, and infraorbital. The salivary secretion is employed chiefly for moistening the food and contains digestive enzymes in only a few mammals. Besides large salivary glands,

1. Mucous glands	Absent in aquatic forms	Present in internal epithelial lining of bucco-pharyngeal cavity and oesophagus. Secrete *mucus* to lubricate passage of food.	Mucous glands are scanty.	Mucous glands few. Present mainly in buccal cavity and on tongue.	Mucous glands present throughout the lining of digestive tract.
2. Salivary glands	Absent	Absent	According to Keith, a few mucus-secreting salivary glands are present in buccal cavity.	*Buccal glands* of mouth cavity probably secrete *mucus*, but they are not salivary glands.	4 kinds of salivary glands with separate ducts lead into buccal cavity. They secrete *saliva* and an enzyme *ptylin*.
3. Gastric glands	Present in stomach. Gastric juice contains pepsin and HCl.	Present in stomach lining secreting pepsinogen and HCl.	Present in mucous lining of stomach	Present in lining of proventriculus secreting peptic enzymes and HCl.	Present and secrete pepsinogen, renin and HCl.
4. Pancreas	A compact, whitish and bilobed gland found between cardiac and pyloric stomach.	Much branched, irregular, cream-coloured gland lying between stomach and duodenum.	Narrow, elongated, whitish gland present between pyloric stomach and duodenum.	A pinkish, band-like narrow gland lying between two limbs of duodenum.	Irregular, diffused pinkish gland surrounded by duodenal loop.
5. Pancreatic ducts	A single duct opens independently into the proximal end of intestine.	Small pancreatic ducts open ino bile duct.	A single pancreatic duct opens independently into duodenum.	3 pancreatic ducts open independently into the distal limb of duodenum.	A single pancreatic duct leads into the distal limb of duodenum.

mammals have have labial, cheek or buccal, lingual, palatine glands, etc.

Fig 10.5: Chart showing different digestive glands

(https://www.faunafondness.com/comparative-study-of-digestive-system-of-vertebrate/).

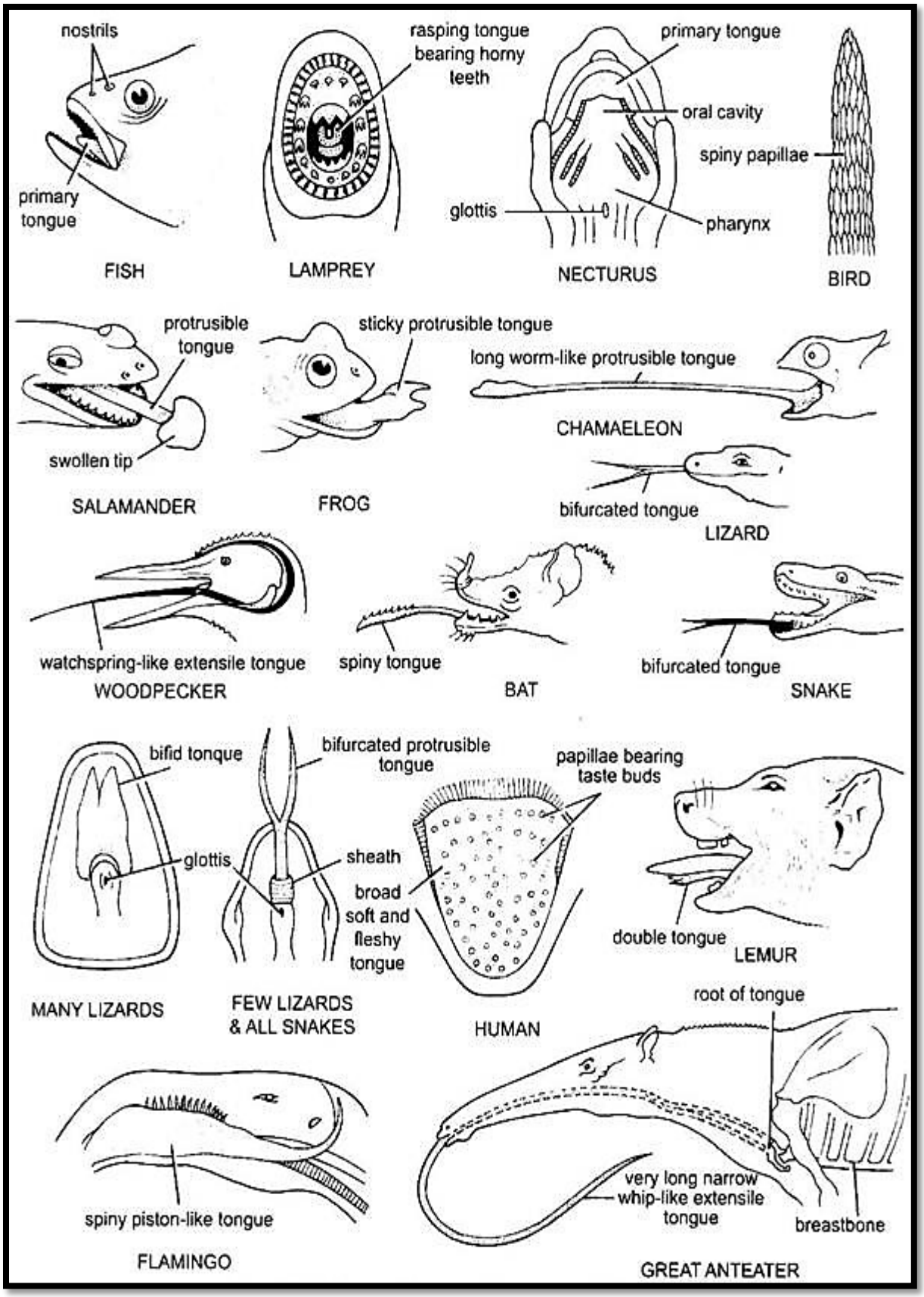


Fig 10.6: Different types of tongue in some vertebrates

((https://www.notesonzoology.com/vertebrates/digestive-system-of-vertebrates-with-diagram-chordata-zoology/8977).

From the roof of the buccal cavity an epithelial evagination occurs in the embryo, producing a blind pouch which is known as Rathhe's pouch finally fuses with the brain wall. The compound structure so formed is called the hypophysis or pituitary body. The part derived from the oral epithelium is termed the adenohypophysis. Hatschek's pit and groove found in *Amphioxus* are often considered as forerunners of the adenohypophysis.

- **Pharynx:** In *Amphioxus* and *Ammocoetes* the pharynx is delimited anteriorly by the velum whereas in gnathostomes its anterior boundary is indefinite but may be set just anterior to the first gill slit or its representative (opening of the auditory tube). The gill slits are passages from the pharynx to the exterior; the pharyngeal openings are the internal gill slits. The number of gill slits was probably large in ancestral chordates, but in present vertebrates the greatest number is seen in hagfishes (up to fourteen). Six is believed to be the typical gnathostome number; but the first gill slit between the mandibular and hyoid arches is generally modified or reduced (forming the spiracle). As we move beyond fishes the number of gill slits appearing in the embryo gradually reduces and often the openings fail to break through. There are no gill slits in adult vertebrates above urodele as they close over during development. In amniotes the gills fail to appear even in the embryo.

  The duct connecting the lungs with the pharynx is termed the trachea or windpipe, and the opening into the pharynx is the glottis. The trachea is very short in amphibians but of considerable length in amniotes. The walls of trachea wall are stiffened by complete or incomplete cartilaginous rings.

- **Oesophagus:** Posterior to the glottis the digestive tract narrows to the esophagus which is generally short in fishes and amphibians, elongated in amniotes because of the posterior descent of the viscera. Oesophagus is lined by a stratified epithelium similar to that of the buccal cavity and is provided by striated musculature. Enlargement of oesophagus is termed a crop or ingluvies which occurs in many birds, especially grain-eating ones where it may form a large sac-shaped appendage. Crop serves for storage or preliminary digestion. In cud-chewing mammals the lower end of the oesophagus contributes croplike sacs to the complicated stomach.

- **Stomach or ventriculus:** Oesophagus is followed by a spindle sacciform shaped **enlarged** stomach which is provided with enzyme and acid secreting glands inbuilt with thick muscular wall of smooth muscles. In lower vertebrates there is often little or no external demarcation between esophagus and stomach and the proximal limit of the stomach can then be differentiated only by the presence of the gastric glands. Stomach is divided into two regions: Cardiac stomach which is next to oesophagus and Pyloric stomach that leads into the intestine and terminates by a strong sphincter muscle known as pylorus.

  A definite stomach is lacking in *Amphioxus* and cyclostomes. In lower fishes the stomach is a straight or J- or V-shaped tube, whereas teleosts frequently lack a stomach. In amphibians and reptiles there is a tubular stomach. The stomach in birds is divided into the proventriculus, which bears the gastric glands and the gizzard provided with a thick muscular wall and hard cornified lining. The gizzard is best developed in grain and seed-eating birds which also contains gravel that helps in grinding up the hard food.

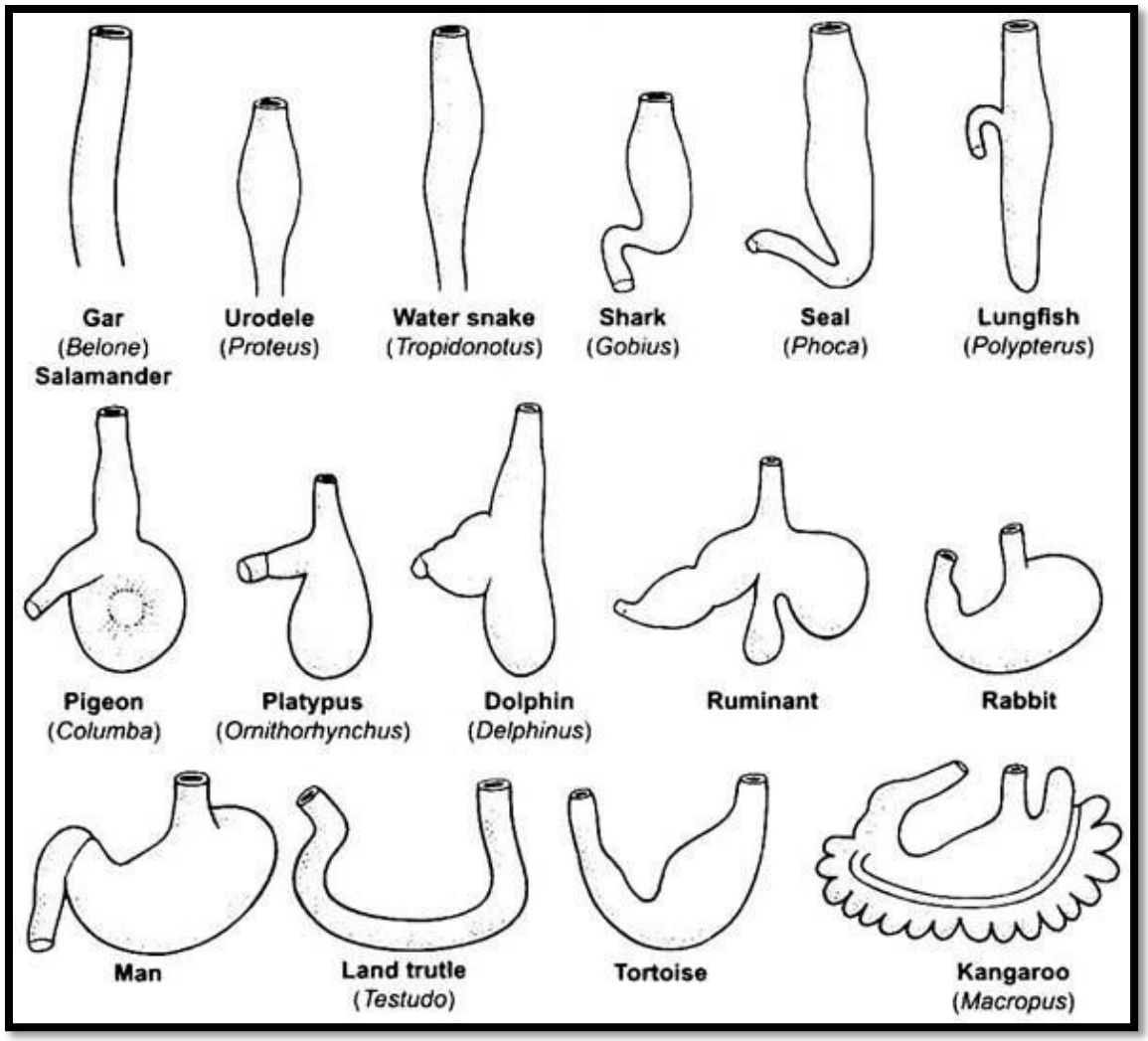


Fig 10.7: Different structure and shape of vertebrate stomach(https://www.notesonzoology.com/wp-content/uploads/2017/07/clip_image014-26.jpg).

- **Small intestine:** The Pyloric end of stomach is followed by tube like structures known as small intestine. The anterior portion of small intestine is termed as duodenum which receives the ducts from liver and pancreas. In cyclostomes there is a low fold in the intestinal wall and this is apparently the forerunner of the spiral valve, a wide, spirally coiled fold filling the greater part of the small intestine in elasmobranchs, dipnoi and many ganoids. The part of the intestine having the spiral valve is often called valvular intestine. Spiral valve increases the absorptive surface of the intestine. Teleosts lack a spiral valve and instead have one to many (maximum upto 900) diverticula know as the pyloric caeca that projects from the proximal part of the small intestine. These caeca increases the absorptive surface area. The small intestine usually is observed to be longer in herbivorous than in carnivorous animals. Liver is an important organ that is known to secrete the bile which is poured into minute ducts that unites to form the larger hepatic ducts. These join the cystic duct or duct from the gall bladder; and the common bile duct or choledochal duct so formed, empties into the small intestine not far beyond the pylorus, either with or without joining the pancreatic duct. The bile helps in digestion of fat. Apart from secretion of bile the liver helps in storage of excess of sugar as glycogen; production of urea and other nitrogenous wastes; control of food and other substances in the blood. The Ammocoetes larva has both gall bladder and bile duct, but these degenerate during metamorphosis. Fishes, amphibians and reptiles generally have a gall

bladder but this organ is lacking in many birds, including pigeons, and in a number of mammals (Cetacea, Perissodactyla, many Artiodactyla, and others).

Pancreas proliferates from the intestinal epithelium shortly beyond the liver proliferations, usually as one dorsal and two ventral outgrowths which unite to form a single gland. This grows out into adjacent mesenteries and may form a compact or more or less diffuse organ. All three stalks of the outgrowths may persist as pancreatic ducts, but usually the number is reduced to one or two. These ducts open into the duodenum separately from, or after joining, the common bile duct. *Amphioxus* has no pancreas, but one is present throughout vertebrates, although in many teleosts it is so diffuse that it cannot be recognized macroscopically. The pancreas consists of two kinds of cells: the regular gland cells which secrete pancreatic juice into the duodenum (most important digestive fluid of vertebrates) and small cells know as islets of Langerhans which produces insulin hormone that is necessary for the metabolism of carbohydrates. In some fishes the islets are gathered together into a small body near the main pancreas.

- **Caecum:** At the junction of small and large intestine there is generally a diverticulum, the colic caecum. It is first seen in a few amphibians and is usually present throughout amniotes. In reptiles it is of small size. Birds generally have two colic caeca while mammals usually have a conspicuous caecum which may be very long and large in herbivores. A few mammals have two caeca. In primates and some other mammals the end of the caecum degenerates into a slender appendage known as vermiform appendix. The function of the colic caecum is uncertain except in those animals with a very large caecum where assists in digestion and absorption.
- **Large intestine or colon:** The large intestine follows the small intestine ad can be demarcated by increased diameter and also by the presence of one or two caeca. In fishes, the large intestine is usually quite short and not distinctly marked off from the small intestine. In elasmobranchs it bears a slender projection: rectal gland which secretes mucus. In amphibians and birds the large intestine is also short while reaches a considerable length in mammals. In many vertebrates terminal part of the large intestine is called cloaca where it receives the urinary and genital ducts. There is no cloaca in Holocephali, ganoids, teleosts and mammals (except in monotremes). In the absence of a cloaca the end section of the large intestine is called rectum.
- **Urinary bladder:** In most tetrapods there is a sac like structure known as urinary bladder that serves as a reservoir for the urine. It is present as a ventral outgrowth of the cloaca or, urogenital canal (in case of absence of cloaca). In amniote embryos the enlarged urinary bladder, termed as allantois projects far beyond the embryo and serves as a respiratory organ. The adult bladder is a portion of the allantois. Birds have no urinary bladder in the adult state, although their embryos are provided with a large allantois.
- **Anus:** The digestive tract ends up and finally opens to the exterior by anus. In vertebrates, anus is not at the posterior end of the body but is shifted to the ventral surface at the base of the tail region. In most vertebrate embryos there is a solid or hollow extension of the gut into the tail, forming the postanal gut. This later vanishes. Its occurrence would seem to indicate an originally more posterior position of the anus.

Characters	FISH Dogfish *(Scoliodon)*	AMPHIBIA Frog *(Rana)*	REPTILIA Lizard *(Uromastix)*	AVES Pigeon *(Columba)*	MAMMALIA Rabbit *(Oryctolagus)*
[I] ALIMENTARY CANAL					
1. Major parts of alimentary canal	1. Buccal cavity 2. Pharynx 3. Oesophagus 4. Stomach 5. Intestine 6. Cloaca	1. Buccal cavity 2. Pharynx 3. Oesophagus 4. Stomach 5. Intestine 6. Cloaca	1. Buccal cavity 2. Pharynx 3. Oesophagus 4. Stomach 5. Intestine 6. Cloaca	1. Buccal cavity 2. Pharynx 3. Oesophagus 4. Stomach 5. Intestine 6. Cloaca	1. Buccal cavity 2. Pharynx 3. Oesophagus 4. Stomach 5. Intestine 6. Cloaca
2. Mouth opening	On Ventral side of head. Small, crescentic or semioval, bound by jaws.	Terminal along anterior end of head. Large, semicircular, slit-like bounded by jaws.	Terminal along anterior end of head, Large, semicircular, slit-like, bounded by jaws.	Terminal, V-shaped slit with a wide gape, bounded by jaws and horny beaks.	Sub - terminal, small, transverse slit, bounded by jaws.
3. Jaws and lips	Lower jaw movable. Lips absent. Jaws covered by spiny skin.	Lower jaw movable. Lips hard, immovable, scalesless.	Lower jaw movable. Lips hard, immovable, covered by scales.	Lower jaw movable Lips absent but horny sheaths or beaks present covering jaws.	Lower jaw movable. Lips movable. hairy. Upper lip cleft, bears vibrissae.
4. Teeth	Sharp, similar (*homodont*) and backwardly directed teeth present in several rows on skin of both jaws. Teeth are modified placoid scales and replaced by new ones (*polyphyodont*) during life.	Teeth small, conical, attached to bones or *acrodont*, *homodont*, *polyphyodont* and present on upper jaw only in a single row	Teeth small, conical, *acrodont* and *pleurodont*, found on both jaws in a single row.	Teeth completely absent in both jaws.	Teeth of several types (*heterodont*) with roots in sockets of jaw bones (*thecodont*) and occur in 2 sets in life (*diphyodont*). Present on both jaws.
5. Diastema	Absent	Absent	Absent	Absent	A toothless space called *diastema* present between incisor and premolar teeth.
6. Dental formula	Not represented	Not represented	Not represented	Not represented	Teeth represented by a dental formula written as : $i\frac{2}{1}$, $c\frac{0}{0}$, $pm\frac{3}{3}$, $pm\frac{3}{3} = 28$.
7. Function of teeth	Grasping prey	Holding prey	Grasping and holding prey.	—	Cutting, holding and mastication of food.
8. Buccal cavity	Spacious. Dorsoventrally flattened.	Large, wide and shallow.	Narrow in front, but broad posteriorly.	Narrow, roughly triangular	Large, spacious.
9. Vestibule	Absent	Absent	Absent	Absent	Mouth opens into a narrow space bounded by jaws, lips and cheeks, called *vestibule*.
10. Palate	Absent. Skull forms roof of bucccal cavity	Absent. Skull forms roof of buccal cavity.	Absent in lizards & snakes. A false or pseudopalate present in crocodilians.	Palate incomplete, formed by lateral folds which do not meet mesially.	A secondary palate present forming roof of buccal cavity.
11. Tongue	Small, non muscular, nonglandular, non-protrusible, attached at base. Not used in food capture. Taste buds lacking.	Large, muscular, sticky. Anterior end attached. Posterior end free bifid, highly protrusible and used for capturing insect prey. Covered with few taste buds.	Large, roughly triangular, muscular, glandular, attached mid-ventrally. Anterior tip free, bifid and protrusible. Covered with fine papillae having taste buds.	Tongue large, narrow, somewhat triangular, attached and non-protrusible. Covered with fine horny processes with scanty taste buds.	Large, muscular, attached mid-ventrally. Groved mid-dorsally. Anterior tip free, rounded and protrusible. Covered with 4 kinds of papillae containing taste buds.

12. Internal nares	Absent	Small, two. Open on buccal roof anteriorly, just in front of vomerine teeth.	Small, two rounded, open near anterior end on roof of buccal cavity.	Small, slit-like, open rather posteriorly into buccal cavity or pharynx.	Do not open into buccal cavity but much posteriorly in the roof of pharynx.
13. Pharynx	Buccal cavity merges insensibly into a large posterior pharynx.	Buccal cavity passes without demarcation into a short pharynx.	Buccal cavity merges posteriorly into a broad pharynx.	Buccal cavity merges behind into pharyngeal cavity.	Pharynx is short, narrow and differentiated into *nasopharynx*, *oropharynx* and *laryngopharynx*.
14. Gill slits	Pharyngeal wall on either lateral side has a pit-like *spiracle* and 5 vertical *gill slits*.	Spiracles and gill slits absent.	Spiracles and gill slits are lacking.	Spiracles and gill slits are absent.	Spiracles and gill slits are lacking.

15. Eustachian openings	Absent	A wide eustachian opening lies on roof, laterally near jaw angle, on either side.	A pair of openings of eustachian tubes lie on side of roof.	Middle of roof behind internal nares contains a single eustachian opening.	Sides of nasopharyngeal wall are pierced by a pair of oval eustachian openings.
16. Glottis	Absent since there is no trachea and no lungs.	Floor carries a median slit-like opening or glottis leading into laryngotracheal chamber.	A median slit-like glottis on floor leads into trachea.	Floor of pharynx carries an oval glottis with tumid lips.	Floor of laryngopharynx has a median vertical slit-like glottis leading into larynx.
17. Epiglottis	Absent	Absent	Absent	Absent	An anterior bilobed cartilaginous flap or epiglottis guards against food entering glottis.
18. Buccopharyngeal structures	Mucous lining of pharynx contains dermal *denticles*.	In male frog only, floor of pharynx carries an *opening* of *vocal sac* on either lateral side near jaw angle. *Eye balls* bulge internally on roof into buccal cavity.	Mucous lining of pharynx is thrown into distensible *longitudinal folds*.	Nasal chambers open through internal nares into roof of pharynx.	Nasal chambers open through *internal naris* into roof of laryngo-pharynx.
19. Oesophagus	Short and wide tube with thick muscular wall, longitudinal mucous folds and opening into cardiac stomach with a *sphincter* or *oesophageal valve*.	Short, wide, muscular with longitudinal mucous folds highly distensible and not clearly demarcated from pharynx and stomach.	Long, narrow, muscular tube with longitudinal mucous folds. Highly distensible. Without a crop.	Long, wide, muscular, thick-walled and distensible. In front of sternum, its middle part forms a large, bilobed, thin-walled elastic sac, crop or food reservoir.	Long, narrow, muscular, elastic tube, without crop, of uniform diameter, opening into stomach.

20. Stomach	Large, muscular, U-shaped or S-shaped. Clearly divided into a long, broad, proximal *cardiac stomach* and short, narrow, distal *pyloric stomach*. Junction of the two marked by a *blind sac* and a *sphincter valve*. Longitudinal mucous folds well developed in cardiac part.	Stomach large, broad, simple, curved, muscular sac, on left side of body cavity. Anterior cardiac and posterior pyloric parts not marked off externally. Blind sac and cardiac valve absent.	Stomach long, tubular or spindle like, curved muscular tube lying on left side. Cardiac and pyloric parts indistinct externally. Longitudinal mucous folds well developed in cardiac part.	Stomach small and divided into 2 distinct parts : an anterior narrow, tube- like glandular *proventriculus*, and a posterior broad, muscular, biconvex *gizzard* internally lined by thick, horny epithelium.	Stomach large, bean-shaped, lying transversely on left side. Distinguished into 3 regions : *cardiac*, *fundic* and *pyloric*.
21. Bursa entiana and gizzard	Pylorica stomach opens through a *pyloric valve* into a small, globular, thick-walled muscular sac, the *bursa entiana*. Gizzard absent.	No bursa entiana and gizzard.	Bursa entiana and gizzard absent. there are no pebbles or stones in the cavity.	Bursa entiana absent. Cavity of gizzard has pebbles or stones to help in grinding food.	Bursa entiana and gizzard absent. Stones are also lacking inside.
22. Intestine	Short but straight and wide tube not differentiated into small and large intestines.	Long, coiled and narrow tube differentiated into small and large intestines.	Long, coiled, narrow and clearly differentiated into small and large intestines.	Long, coiled, narrow and clearly marked into small and large intestines.	Long, coiled, narrow and well differentiated into small and large intestines.
23. Small intestine	No external differentiation between duodenum and ileum.	Duodenum and ileum well marked.	Duodenum and ileum well marked.	Duodenum and ileum well marked.	Duodenum and ileum well marked.
24. Duodenum	Absent.	Straight tube forming 'U' with stomach. Receives bile and pancreatic juice through a common hepatopancreatic duct.	Straight tube receiving separate bile and pancreatic ducts.	U-shaped tube receiving 2 bile ducts and 3 pancreatic ducts, separately.	Distinct U-shaped loop receiving 1 bile duct and 1 pancreatic duct.
25. Ileum	Not differentiated.	Small and coiled.	Short and coiled.	Long and coiled.	Extremely long and coiled.
26. Valves & villi	Mucous lining of intestine folded into a longitudinal *scroll* or *spiral valve*. Villi absent.	Mucous lining forms several longitudinal folds, but spiral valve and villi are absent.	Inner longitudinal folds present but valves and villi are absent.	Inner surface bears numerous small finger like processes or villi. Spiral valve absent.	Villi are well developed and numerous. Spiral valve absent.
27. Sacculus rotundus	Absent	Absent	Absent	Absent	Distal end of ileum expanded to form sacculus rotundius.

28. Caecum	Absent	Absent	A large caecum and an *ileo-colic valve* present between small and large intestines.	Junction of two intestines marked by the presence of a pair of short conical *rectal* or *colic caeca*.	A large thin-walled tubular and spirally constricted caecum present into which sacculus opens through an *ileo-caecal valve*.
29. Vermiform appendix	Absent	Absent	Absent	Absent	Distally caecum ends blindly as vermiform appendix.
30. Large intestine	Last part of intestine forms a short *rectum* of narrow diameter, opening into cloaca	It forms a short but broad *rectum* opening into cloaca.	Short and forms an anterior thin-walled narrow *colon* and a posterior thick-walled broad *rectum* opening into cloaca.	Forms a short but broad *rectum* only which leads into cloaca.	Very long and forms an anterior sacculated *colon* and a posterior beaded *rectum*.
31. Rectal glands	A tubular rectal gland of unknown function opens dorsally into rectum.	No rectal gland.	No rectal gland.	No rectal gland.	No rectal gland.
32. Cloaca, abdominal pores & bursa Fabrici	Rectum opens behind into a simple cloaca through anus guarded by *anal sphincter*. It also contains *urinogenital apertures* and a pair of *abdominal pores* from peritoneal coelom. *Bursa Fabrici* absent.	Rectum opens through anus into a single sac like cloaca, also containing urinogenital apertures. *Anal sphincter* present but *abdominal pores* and *bursa Fabrici* absent.	Rectum opens into a tripartite cloaca divided into 3 linear chambers : *corodaeum*, *urodaeum* and *proctodaeum*. *Anal sphincter* present but *abdominal pores* and *bursa Fabrici* absent.	Rectum opens behind through anus guarded by *anal sphincter* into a tripartite cloaca made of 3 linear chambers, as in a lizard. *Abdominal pores* are absent. In young birds only a small thick-walled blind pouch, *bursa Fabrici*, present dorsally on proctodaeum.	Cloaca absent. Rectum leads directly to outside by anus provided with an anal sphincter. No *abdominal pores* and no *bursa Fabrici*.
33. Cloacal aperture	Cloaca opens by a mid-ventral longitudinal slit between pelvic fins.	Cloaca opens at the hind end of trunk between hind limbs through a circular cloacal aperture.	Cloacal aperture is a mid-ventral transverse slit at the base of tail.	Proctodaeum opens at the base of tail ventrally by a transverse slit with turnid lips.	No cloacal aperture.

Fig 10.8: Chart showing comparative anatomy of digestive system in different vertebrates
(https://www.faunafondness.com/comparative-study-of-digestive-system-of-vertebrate/).

10.4 COMPARATIVE ANATOMY OF RESPIRATORY SYSTEM

In vertebrates, oxygen is taken up from respiratory organ such as skin, gills and lungs and mixed into blood then transported to each and every cell of tissues. Haemoglobin (red coloured respiratory pigment) combines with oxygen in form of oxyhaemoglobin and is carried to different tissues where it readily gives up oxygen to the tissues and picks up carbon dioxide released by tissues after oxidation of food stuffs. The respiratory systems in different vertebrates have been discussed below:

- **In Agnathans**

  In agnathans the pharynx is subdivided with ventral part forming a respiratory tube that is

isolated from the mouth by a valve called the velum. This separation enables feeding in adults by preventing the prey's body fluids from escaping through the gills or interfering with gas exchange. The water is pumped in and out of the gill pouches instead of taking it in through the mouth.

- **In fishes:**

Sharks like other species of fish uses gills to breathe. There are usually five to seven gill arches, each bearing one gill slit. In most of the fish species these gills are covered by the operculum which acts as a lid over the gill. However, sharks lack this covering instead a modified slit- 'spiracle' lies immediately behind the eye. Sharks uses gill slits to oxygenate their blood whereas the spiracle assists in the process of taking water in. With forward movement of shark the water is taken into the mouth and over the gills. This is known as "ram ventilation". While at rest the shark actively pumps water over its gills.

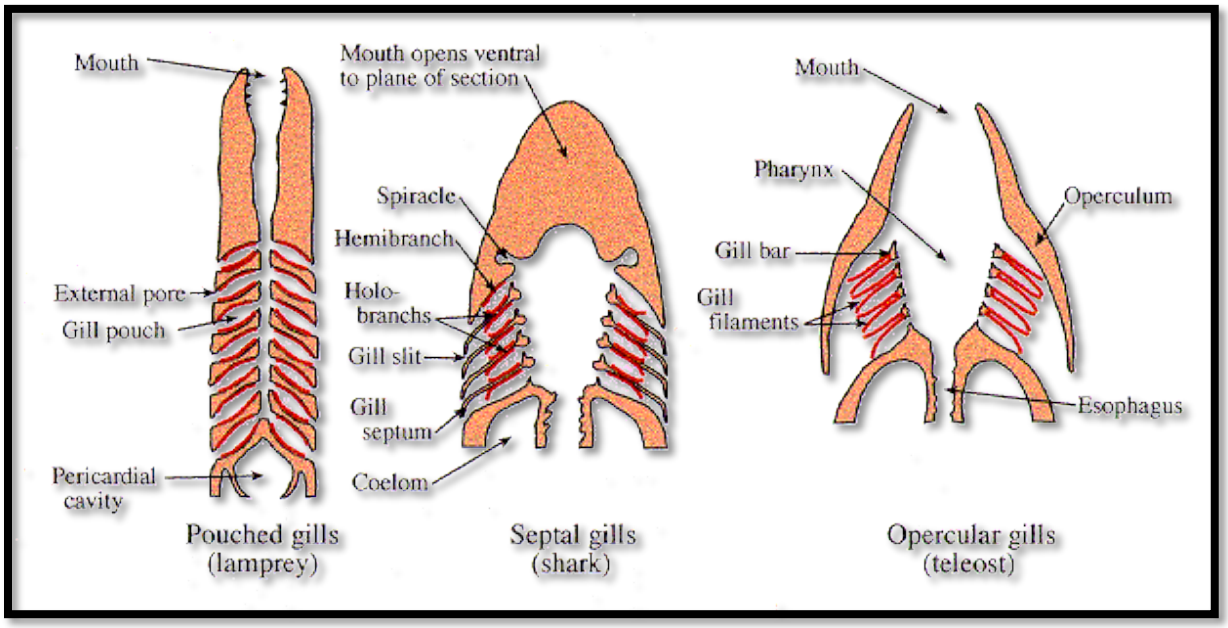


Fig 10.9: Respiratory system in Agnathans and fishes

(http://people.eku.edu/ritchisong/342notes8.html).

In bony fishes the operculum is bony or cartilaginous which provides a protective cover over the branchial arches and gills. In addition, the operculum is part of the dual pump used to ventilate the gills. Each gill is V-shaped and composed of primary lamellae that are subdivided into secondary lamellae and supported on a branchial arch. Tiny adductor muscles cross between filaments to control the arrangement of adjacent gills that govern the flow of water across the secondary lamellae. As in most other fish a gill, a countercurrent exchange system is established with flow of blood one direction and water in opposite direction within secondary lamellae.

Air-filled sacs arise early in bony-fish evolution and serve respiratory and hydrostatic functions. In lungfishes and tetrapods, the respiratory function predominates involving lungs into action. The lungs are subdivided into alveoli. Air forced into these lungs exchanges with capillary blood circulating in the walls of the alveoli. It is not surprising that almost all bony fishes possess some form of gas bladder (or lung). Air-filled gas bladders provides buoyancy to the fish body and help resist its tendency to sink.

Fishes that ventilate through gas bladder do so by gulping and forcing fresh air through the pneumatic duct.

- **In Amphibians:**

  The basic mechanism of amphibian gill ventilation includes a buccal cavity and a pharyngeal cavity separated from each other by a valve known as velum. Salamander larvae typically have both internal and external gills. Pumping action of the throat provides unidirectional stream of water to internal gills. Feathery external gills are held out in the passing current, allowing water to flow across them. In absence of water current or is stagnant water the larvae waves its gills back and forth thereby irrigating the capillary beds. Larvae of anurans employ buccal and pharyngeal force pumps to produce a unidirectional flow of water across the gills and generate a food-bearing current.

  The buccal cavity in amphibian is separated from the mouth by the oral valve and from the nares by an internal narial valve**.** Inhalation leads to depression of floor of the buccal cavity which lowers the pressure within it. The velum closes temporarily to prevent entry of water into the pharyngeal cavity but water fills the buccal cavity through the mouth and nares. Near the end of the inhalation stage, pharyngeal constriction causes rise in pressure within the pharyngeal cavity relative to the buccal cavity which keeps the velum in closed position and pushes water across the gill curtain. The exhalation stage starts with elevation of the floor of the buccal cavity, raising the pressure within it and forcing the oral and narial valves to close.

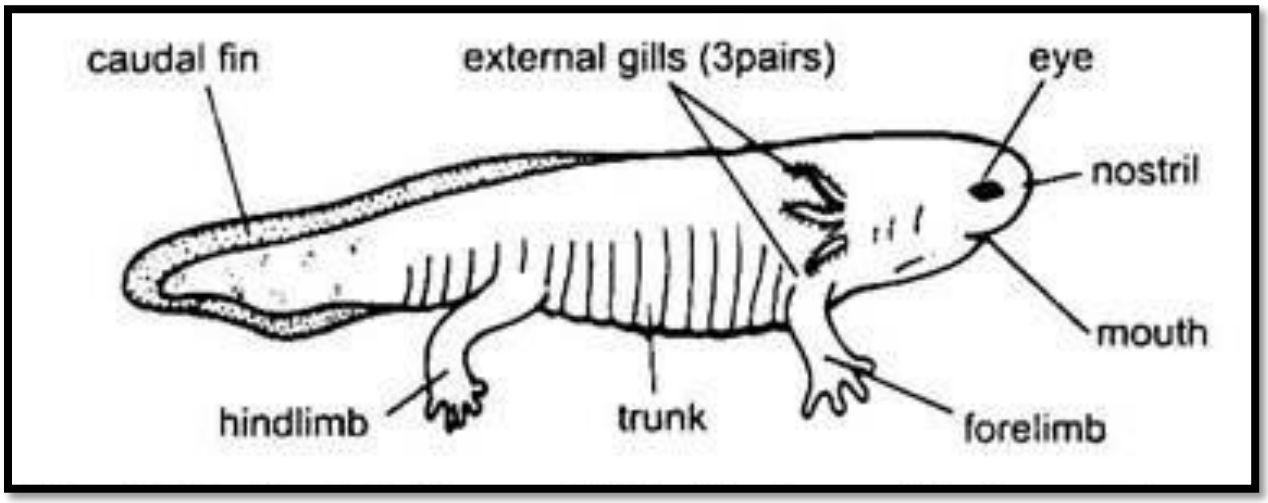


Fig 10.10: Salamander larva showing external gills

(https://www.notesonzoology.com/wp-content/uploads/2017/07/clip_image002-106.jpg).

With metamorphosis of amphibian larva the gills are lost in adult. Respiration through skin (cutaneous respiration) continues to play an important role in meeting respiratory demands after metamorphosis and lungs, if present are ventilated by a buccal pump. The four stages of lung ventilation in frogs are

i) In the first stage, the buccal cavity expands to draw fresh air in through the open nares.

ii) Secondly the glottis opens rapidly releasing spent air from the elastic lungs. This air streams across the buccal cavity with little mixing and is vented through the open nares.

iii) In third stage, the nares close and floor of the buccal cavity rises forcing fresh air held in the cavity into the lung through the open glottis.

iv) Lastly the glottis closes retaining the air that has just filled the lungs, and the nares open again.

To some extent frogs have retained the basic pattern of lung filling deployed by lungfishes. However, all of this changes in reptiles, birds, and mammals. The mechanism of ventilation in these groups is the aspiration pump, a departure from that of amphibians and earlier air breathing fishes.

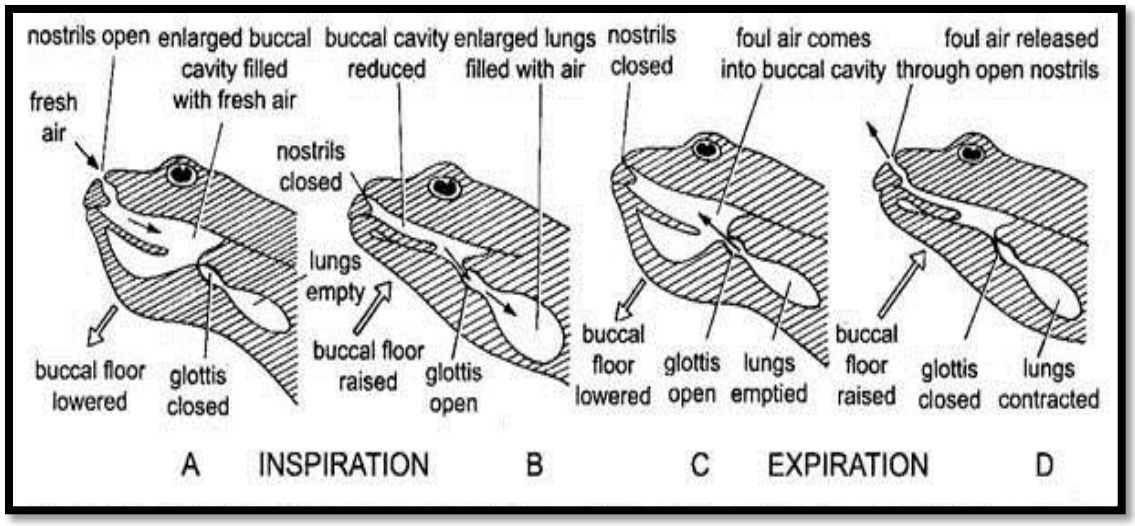


Fig 10.11: Breathing movements during ventilation of lungs in frog (https://www.notesonzoology.com/wp-content/uploads/2017/07/clip_image011-1.jpg).

- **In Reptiles:**

  In reptiles pharyngeal furrows and occasionally pharyngeal slits appear during the early embryonic development, however, they never become functional after birth. In some reptiles cutaneous respiration is significant while most of the reptiles have paired lungs for respiration. The lungs of snakes and most lizards typically include a single central air chamber into which alveoli open. The thin walls of each carry capillary beds and may be subdivided by even smaller internal septa. In monitor lizards, turtles and crocodiles the single central air chamber is subdivided into numerous internal chambers that receive air from the trachea.

  These internal chambers are ventilated by respiratory movements, whereas the exchange of gas between the alveoli and these chambers appears to occur by diffusion. Filling of the lungs in all reptiles is based on an aspiration pump mechanism, although the anatomical parts that actually participate may differ. The aspiration pump acts on the walls of the lung to change its shape and induce airflow in or out. Ribs alter the shape of the body walls around the lungs and intercostal muscles running between these ribs move them. The enlarged rib cavity around the lungs decrease pressure within them which results in rushing of air into the lungs. During active exhalation different sets of intercostal muscles contract to fold the ribs back and inward, thus compressing the lungs within their cavity and expelling air. Occasionally the exhalation process is passive. Between breaths, the glottis is closed to prevent premature escape of air.

  In Ophidia (snakes) the long, narrow lungs extend through most of the length of the body. In primitive snakes, as in other reptiles the lungs are paired, but in many advanced snakes the left lung is reduced and often lost entirely. In most snakes alveoli are prominent anteriorly but they reduce gradually and become absent posteriorly producing two regions of the lung, an anterior respiratory portion (alveoli) and a posterior saccular portion. Ribs and associated

muscles run the entire length of the thorax so that regional compression and expansion of the body wall expand or deflate the lung. Opening and closing of the glottis are synchronized with these movements. Gas exchange occurs in the respiratory portion of the lung. The saccular portion of the lung acts as a bellows when the anterior body is occupied with different functions and unavailable to compress or expand the lung such as at the time when a snake swallows prey the body becomes distended as food passes slowly through the oesophagus, yet ventilation of the lungs continues.

In turtles the shell around the lungs prevents changes in shape and precludes aspiration pumping using the ribs. In soft-shelled turtles movements of the hyoid apparatus draw water in and out of the pharynx. Oxygen is absorbed in the pharynx to sustain the turtle while it is submerged. In snapping turtles, the plastron is reduced, permitting deformations of the body wall that contribute to lung ventilation.

More commonly, in-and-out movements of the limbs alter pressure on the lungs, and special sheets of muscles within the shell change pulmonary pressure. Lungs and other viscera in turtle reside in a single fixed cavity, so any change in volume alters pressure on the lungs.

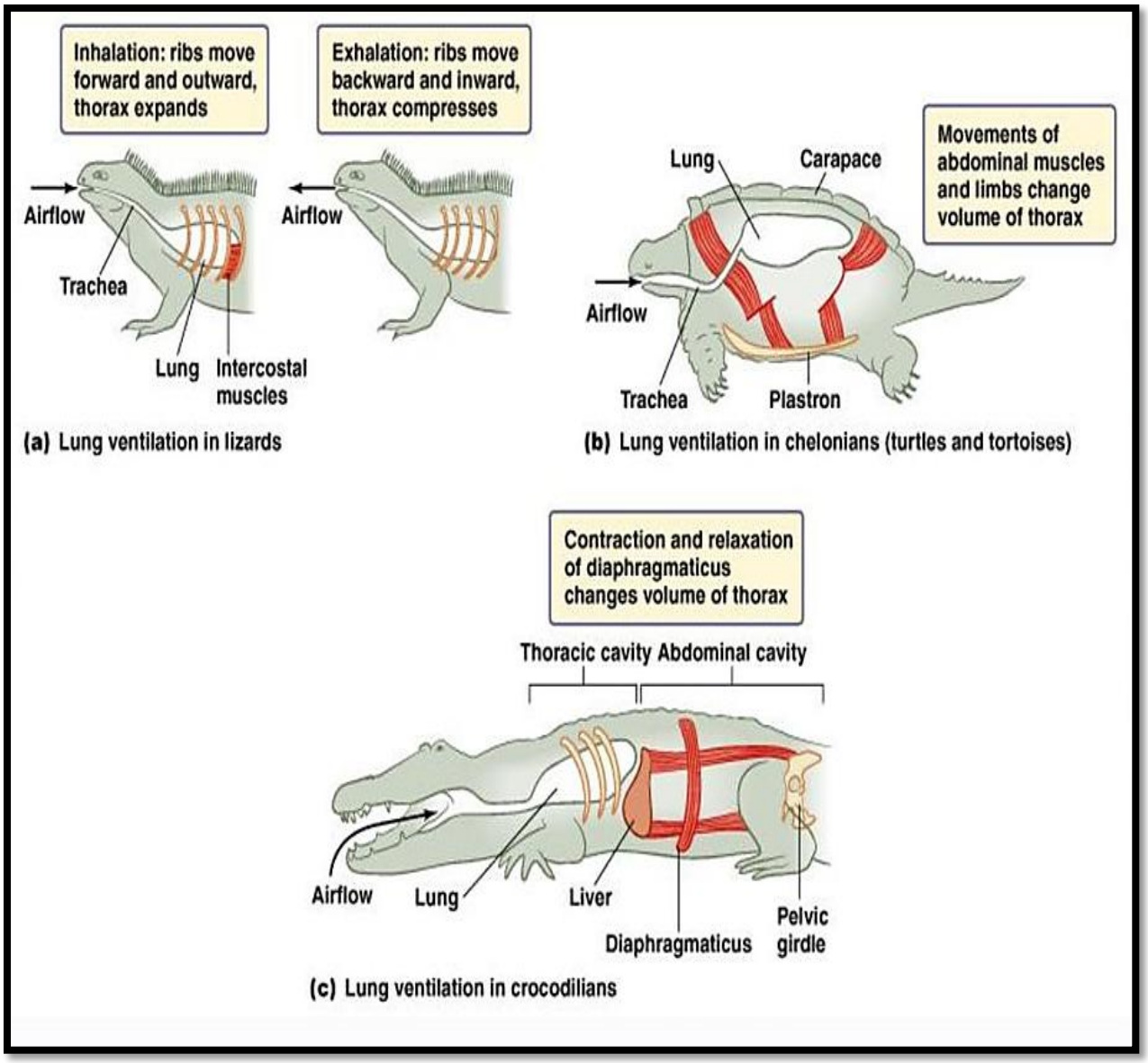


Fig 10.12: Lung ventilation in differentreptiles (https://quizlet.com/249206895/respiratory-system-diagram/).

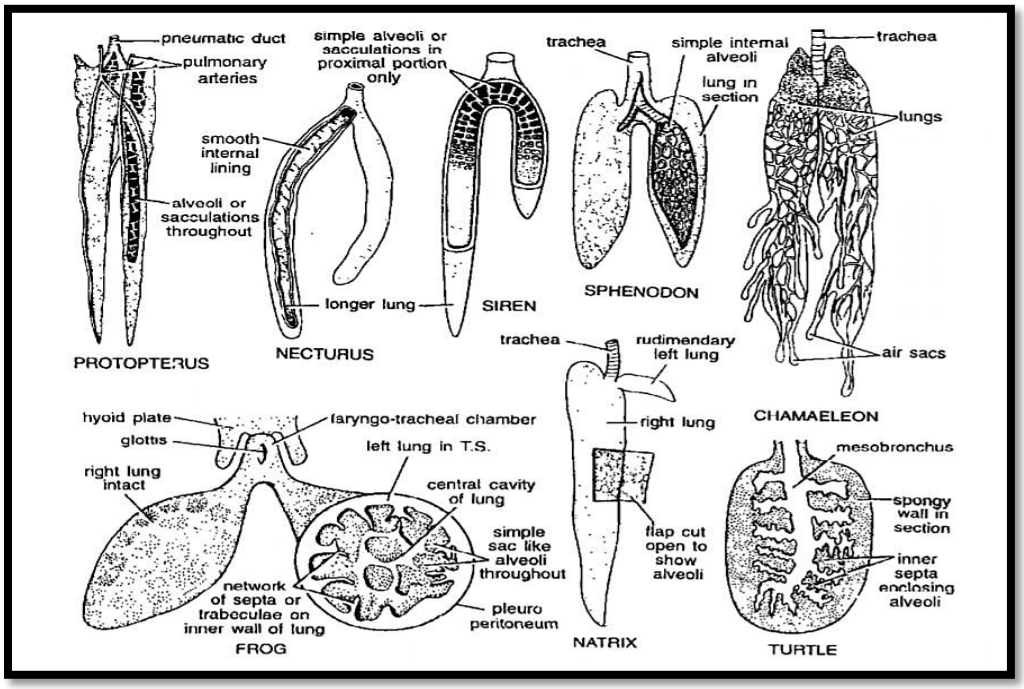


Fig 10.13: Different type of vertebrate lungs(https://www.faunafondness.com/comparative-study-of-respiratory-system-of-vertebrate/).

- **In Birds:**

  In birds respiratory organ is the lungs. Like mammals, birds have two lungs connected to a trachea and ventilated by anaspiration pump. Beyond this, however, the structural similarities are few. For example, there are no blind-ended alveoli in and out of which air moves. On the contrary, the conducting passages branch repeatedly and eventually form numerous tiny, one way passageways, the **parabronchi** that permit air to flow through the lungs. Small **air capillaries** open off the walls ofeach parabronchus and gas exchange with the blood actually occurs in the air capillaries.

  Nine avascular **air sacs** are connected to the lung, although they are tucked in among the viscera and extend into the cores of most large bones. Thus, the bones of birds contain air instead of marrow. Number of air sacs varies among different birds such as 6 in house sparrow, 12 in shorebirds. The trachea is divided into two **primary bronchi** (mesobronchi) that do not enter the lung but extend posteriorly to reach the posterior air sacs. Along the way primary bronchi give rise to numerous branches, the most prominent of which include **latero-, ventro-,** and **dorsobronchi** as well as **secondary bronchi.** These lead to the parabronchi. During passage through the parabronchus gases diffuse between the lumen of the parabronchus and the connecting, blind-ended air capillaries.Oxygen diffuses in from the air capillaries into the adjacent blood capillaries that give up carbon dioxide to the air capillaries. Thus, the walls of air and blood capillaries constitute the sites of gas exchange.

  In single breath the passage of air through the sacs and lungs includes two complete cycles of inhalation and exhalation. During the first inhalation, air enters the trachea, passes along the primary bronchi and then is divided: Some air passes directly to the lungs and the rest fills the posterior air sacs (posterior thoracic and abdominal air sacs). Upon the first exhalation air from these posterior air sacs now flows through the lungs, displacing the spent air that exits via the trachea.

As the second inhalation begins, the entering air again divides, some refilling the posterior air sacs and the rest flowing through the lungs, pushing the remainder of the spent air of the previous cycle out and temporarily into the anterior air sacs. With the second exhalation air in these anterior sacs now exits along with air from the lungs, replaced by air from the posterior air sacs which now flows through the lungs. Thus, this pattern of ventilation produces a nearly continuous, unidirectional flow of fresh air across the lungs.

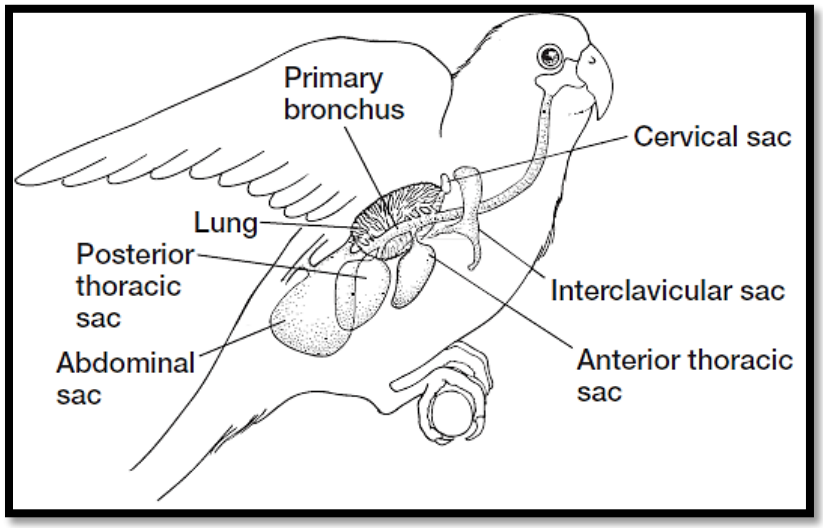


Fig 10.14: Respiratory tract in bird.

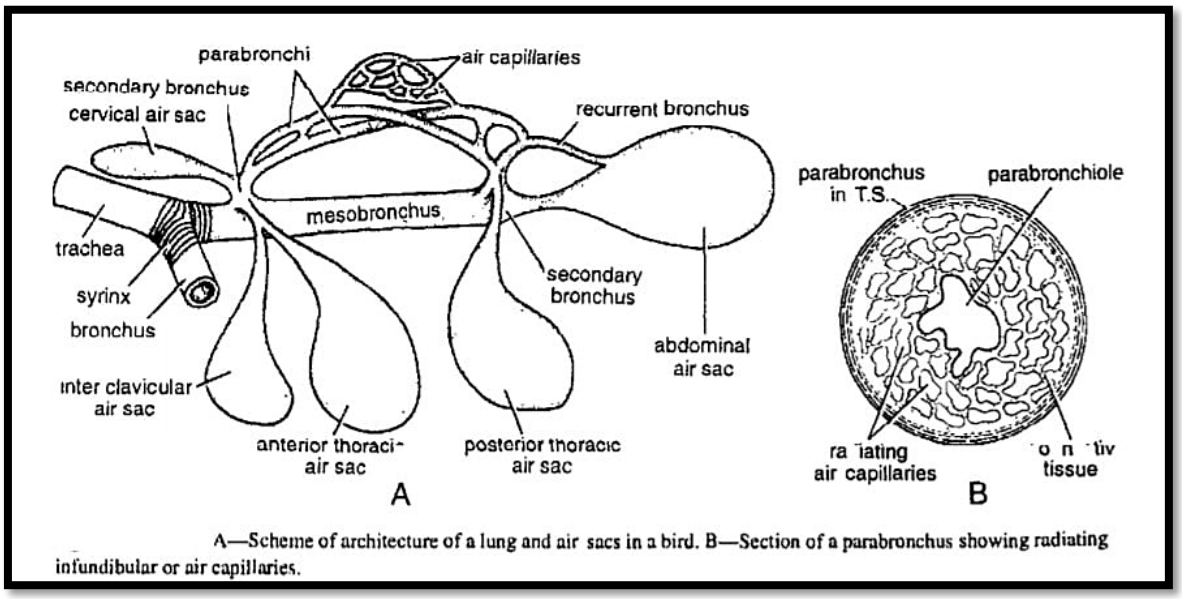


Fig 10.15: A) Schematic architecture of lung and air sacs in bird. B) Section of a parabronchus showing radiating infundibular or air capillaries(https://www.faunafondness.com/comparative-study-of-respiratory-system-of-vertebrate/).

- **In Mammals:**

Lungs take over the charge of respiration in mammals. Changes in the shape of the rib cage and **diaphragm** contribute to the pumping mechanism of air and helps in respiration. The diaphragm consists of **crural, costal,** and **sterna** parts, all of which converge on a **central tendon.** The diaphragm in mammals lies anterior to the liver, and acts directly on the **pleural cavities** in which the lungs reside. The ribs are interconnected with intercostal muscles. The

transversus abdominis, serratus and rectus abdomen is that are inserted on the ribs and originate outside the rib cage all aid in mammalian lung ventilation.

Mammalian respiration involves: Inhalation, Exhalation and Pause. During inhalation, the external intercostal muscles contract to rotate the adjacent ribs and medial sternum forward. Cotraction of muscles leads to forward, downward and sagittal movement of rib thereby expanding the rib cage. Dome-shaped diaphragm also flattens further enlarging the thoracic cavity. Increase in area reduces the pressure and hence the air is drawn in. During exhalation, internal intercostal muscles relax and pulls the ribs back similarly relaxation of diaphragm causes it to recoil and resume its dome shape. Regaining original state causes the chest volume to decrease thereby forcing air from the lungs towards outside. One cycle of inhalation and exhalation is followed by a short pause.

The mammalian diaphragm lies immediately posterior to the lungs and separates the thoracic cavity containing the lungs from the abdominal cavity containing other major viscera. At the time of rest the muscularized diaphragm is the principal component in mammalian lung ventilation. However, during locomotion in quadrupedal mammals the rib cage may receive ground reaction forces through the forelimbs that slightly change its shape. The abdominal viscera act as a kind of "piston," first pressing anteriorly on the thoracic cavity and then sliding posteriorly, releasing pressure on the lungs. A running mammal takes advantage of this rhythmic movement of the viscera, expelling air when the viscera press against the thorax and inhaling when they move away. Thus, in cursorial mammals breathing patterns and locomotor gait are often coupled.

The respiratory passageway includes trachea, bronchi, bronchioles that further divides and produces smaller and smaller branches until they finally terminate in blind-ended compartments known as **alveoli** which characterize the respiratory bronchioles and air sacs. The trachea, bronchi, and terminal bronchioles that transport gas to and from the alveoli are called the **respiratory tree** because of their branching pattern. A large exchange area is essential in mammals to sustain the high rate of oxygen uptake required by an active endotherm. The nasal passages not only form part of this conducting system but serve to warm and moisten the entering air.

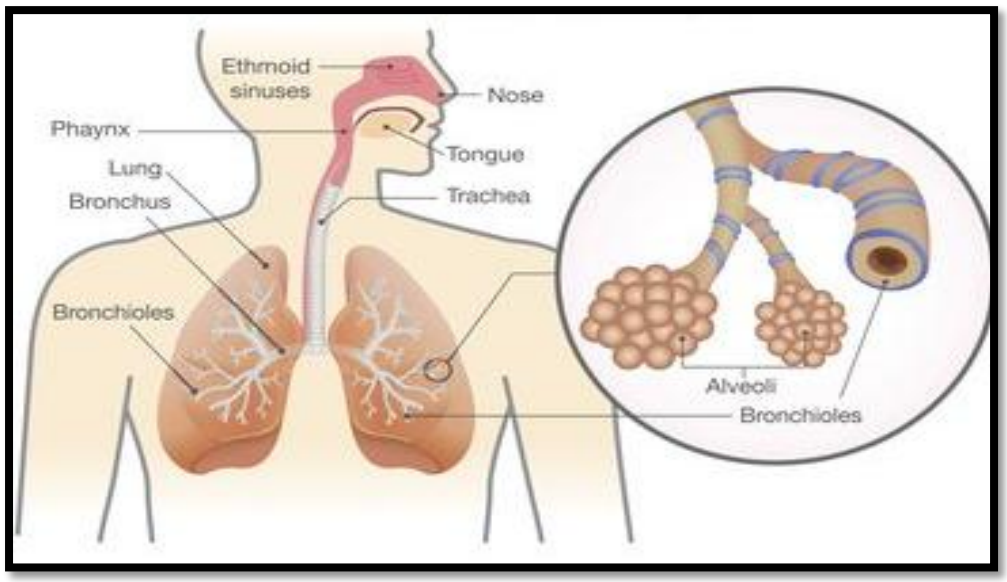
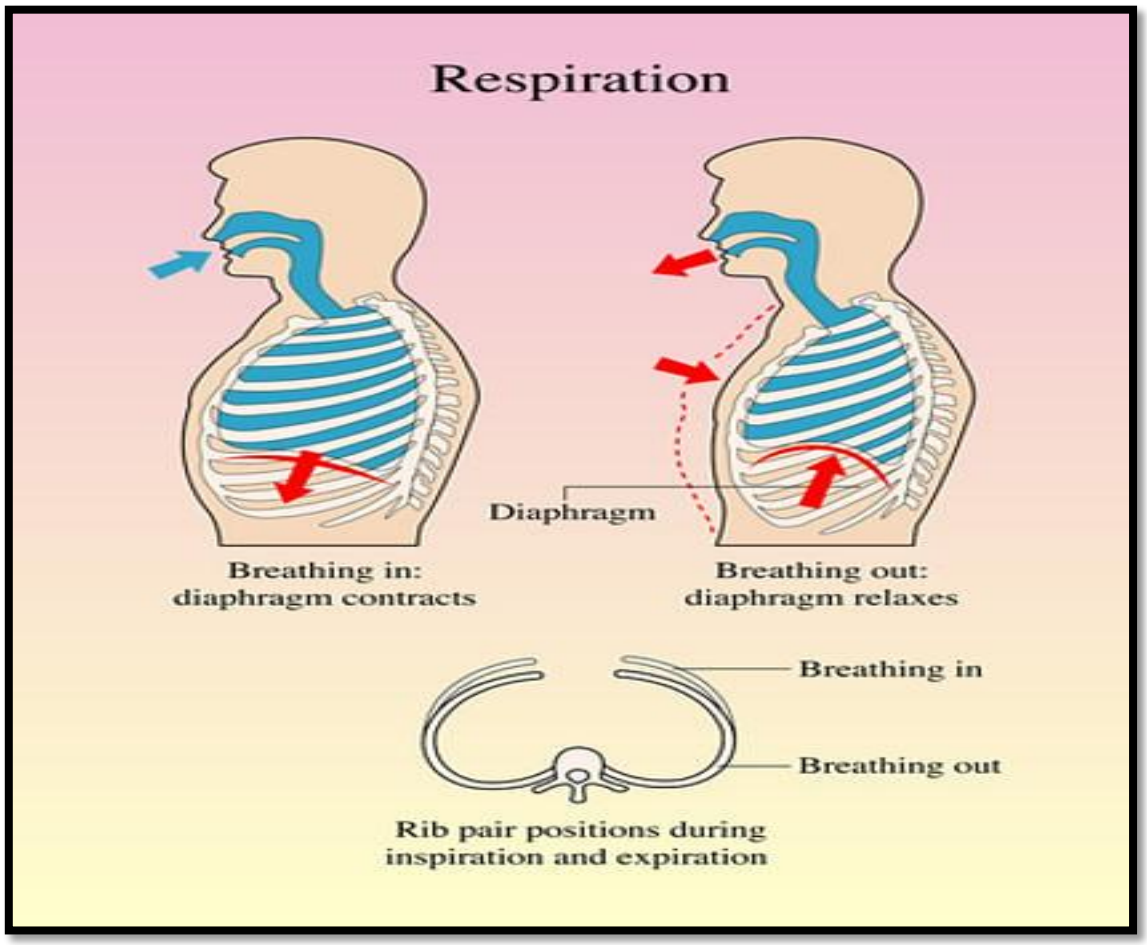


Fig 10.16: Respiratory system in humans(https://sciencing.com/human-respiratory-system-works-5387071.html).



Characters	FISH Dogfish *(Scoliodon)*	AMPHIBIA Frog *(Rana)*	REPTILIA Lizard *(Uromastix)*	AVES Pigeon *(Columba)*	MAMMALIA Rabbit *(Oryctolagus)*
1. **Type of respiration**	*Aquatic* as it lives permanently water.	*Amphibious*, i.e., *aquatic* as well as *aerial*, as it lives both on land and in water.	*Aerial*, as it lives permanently on land and breathes in air.	*Aerial* or pulmonary, breathes air.	*Aerial* or *pulmonary* as it is terrestrial and breathes in air.
		[I] RESPIRATORY TRACT			
2. **Parts of respiratory tract**	Includes mouth, buccal cavity, pharynx, internal gill-slits, gill pouches and external gill-slits. Internal nares, glottis and laryngo-tracheal chamber absent.	Includes external nares, nasal chambers, internal nares, bucco-pharyngeal cavity, glottis and laryngo-tracheal chamber. Gill slits and gill pouches absent.	Includes external nares, nasal sacs, internal nares, buccal cavity, pharynx, glottis, trachea and bronchi. Gill slits and gill pouches absent.	Includes same parts as in lizard.	Includes same parts as in lizard or pigeon.

Fig 10.17: Mechanism of respiration in human (http://www.biologyreference.com/Re-Se/Respiration.html).

Characters	Dogfish *(Scoliodon)*	Frog *(Rana)*	Lizard *(Uromastix)*	Pigeon *(Columba)*	Rabbit *(Oryctolagus)*
3. Passage of water or air	Water enters through mouth and leaves through external gill slits.	Air enters through external nares and leaves also through them. Mouth not used for entry of air.	Air enters and leaves through external nares. Mouth not used for respiration.	Air enters and leaves through external nares. Mouth not used for respiration.	Air enters as well as leaves through external nares. Mouth not used for respiration.
4. External nares	Ventral, crescentic apertures, each divided by a skin flap. Exclusively olfactory. Not used in respiration.	Dorsal on tip of snout. Small, circular apertures without valves. Used in respiration.	Dorsal on tip of snout. Small oval apertures with a valve. Olfactory as well as respiratory.	Dorsal at base of upper beak. Narrow slit-like, without valve and covered by a sensitive skin fold or cere. Used in respiration.	Dorsal above mouth. Large oval openings without valves. Olfactory as well as respiratory.
5. Nasal chambers	Separate, large, with folds but without turbinals. Internal nares opening into mouth absent.	Separate, small, without turbinals. Open into anterior part of buccal roof by two internal nares.	Separate, small, without turbinals and open anteriorly into buccal cavity by two internal nares.	Separate, small, without turbinals and open into pharynx by two internal nares.	Separate, elongated, with turbinals and open into laryngopharynx by a single internal nares.
6. Glottis & epiglottis	Glottis and epiglottis absent.	Floor of pharynx carries a median slit-like aperture or glottis leading into laryngo - tracheal chamber. Epiglottis absent.	A median slit like glottis on floor of pharynx leads into trachea. Epiglottis absent.	Floor of pharynx carries an oval glottis with tumid lips. Epiglottis absent.	Floor of laryngopharynx has a median vertical glottis leading into larynx and protected by a bilobed cartilaginous flap or epiglottis.
7. Larynx and trachea	Absent	Fused forming a laryngo-tracheal chamber containing vocal cords. Thyroid cartilage absent.	Larynx and trachea separate. Vocal cords and thyroid cartilage absent in pharynx.	Larynx and trachea separate. Larynx without vocal cords and thyroid cartilage.	Larynx and trachea separate. Larynx contains vocal cords and thyroid cartilage.
8. Syrinx	Absent	Absent	Absent	Present at lower end of trachea and serves for sound production.	Absent
[II] RESPIRATORY ORGANS					
9. Respiratory organs	Only gills present for aquatic respiration.	Gills present in tadpole larva for aquatic respiration and lungs in adult for aerial respiration.	Gills absent. Only lungs present in the adult.	Gills absent. Only lungs present in adult.	Gills absent. Only lungs present in adult.
10. Gills and gill clefts	Include 5 pairs of pharyngeal *gill pouches* containing 5 pairs of lamelliform *gills*	Tadpole larva develops 5 pairs of *gill pouches* and 4 pairs of *gill clefts*. 3 pairs of filamentous *external gills* appear for aquatic respiration. Gills later become *internal* as in fishes but disappear during metamorphosis.	Embryo develops temporary pharyngeal gill pouches and gill slits which later disappear.	Embryo develops temporarily 4 pairs of pharyngeal gill pouches and 3 pairs of gill slits.	Embryo develops temporarily 4 pairs of gill pouches but gill slits do not form.

11. Lungs	Absent altogether	2 lungs, ovoid, thin walled, elastic hollow sacs of pinkish colour, suspended freely inside peritoneal cavity. Without lobes.	2 lungs, elongated, fusiform, thin-walled elastic hollow sacs of orange colour, lying in thoracic cavity. Without lobes.	2 lungs, small, ovoid, compact, inelastic bright red, attached dorsally to thoracic vertebrae and ribs. Without lobes.	2 lungs, large, soft, elastic, spongy, pink in colour, each enclosed in a lateral *pleural cavity* of thorax. Right lung made of 4 lobes, left lung of 2 lobes.
12. Peritoneum		Lungs completely enclosed by peritoneum.	Completely surrounded by peritoneum	Dorsal attached side of lung not covered by peritoneum.	Surrounded by peritoneum on all sides.
13. Alveoli		Alveoli providing surface for gaseous exchange few in number. Therefore central cavity of lungs large.	Inner septa low and *alveoli* shallow. Central cavity smaller.	Lungs without alveoli but with an intricate system of ramifying and anastomosing *air capillaries*.	Inside lungs, terminal branches of bronchioles end into grape-like clusters of small, blind *alveoli*, highly vascular.
14. Air sacs		Air sacs absent.	Air sacs absent.	A system of large, thin-walled, elastic, non-vascular *air sacs* around and connected with the lungs.	Air sacs absent.
15. Bucco-pharyngeal respiration	Absent	Epithelial lining highly vascular so that bucco-pharyngeal respiration very effective.	Absent	Absent	Absent
16. Cutaneous respiration	Absent	Moist and richly vascular skin serves efficiently for exchange of gases.	Absent	Absent	Absent

	[III] RESPIRATORY MECHANISM				
17. Breathing movements	During *inspiration* buccal floor is lowered by a series of *hypobranchial muscles*. During *expiration* buccal floor is raised by *constrictor* and *interbranchial muscles*.	*Inspiration* due to lowering of bucco-pharyngeal floor is brought about by *sternohyal muscles* white *expiration* by raising the floor by *petrohyal muscles*.	Both *inspiration* as well as *expiration* are brought about by *ribs* and *intercostal muscles*.	*Inspiration* and *expiration* occur due to activity of *sternum, intercostal muscles* and *abdominal muscles*.	*Inspiration* and *expiration* are caused by the action of *diaphragm* and *intercostal muscles*.
18. Efficiency	Highly vascularized gills serve as efficient organs for gaseous exchange in water.	Mixed air entering lungs and less number of alveoli account for inefficiency of pulmonary respiration, wihich is supplemented by bucco-pharyngeal and cutaneous respiration.	Less number of alveoli and stay of residual foul air account for poor aeration of blood by lungs.	Presence of open air capillaries, air sacs and absence of residual foul air make avian lungs most efficient among all vertebrates.	Presence of large number but blind alveoli and residual foul air make mammalian lungs less efficient than those of birds.

Fig 10.18: Chart showing comparative anatomy of Respiratory system among different vertebrates (https://www.faunafondness.com/comparative-study-of-respiratory-system-of-vertebrate/).

10.5 SUMMARY

Digestive system is a tubular passageway that extends through the body from the lips of the mouth to the anus or cloacal opening. The adult digestive system includes digestive tract and accessory digestive glands Glands embedded in the walls lining the tract release secretions directly into the lumen. Digestive system enables turning a meal into usable fuel for the body. The digestive system varies across vertebrate group in terms of presence or absence of some structures or division of the existing regions.

Respiratory system includes the structures involved in respiration in different vertebrates. Respiration occurs through different structures such as skin, gills and lungs. The mechanism of respiration also varies in different vertebrates. The complexity of structure increases as we move along different tetrapods. Fishes predominantly respire through gills, amphibians respire through skin, gills and lungs, reptile through gills and lungs, birds through lungs and mammals respire primary through lungs.

10.6 TERMINAL QUESTIONS

Q1. Give a detailed account of comparative anatomy of respiratory system in vertebrates.

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Q2: Write about the different respiratory structures found among different vertebrates.

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Q3: With the help of diagram explain the mechanism of respiration in humans.

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Q4: Multiple Choice Questions:

i) Cutaneous respiration occurs through:

a) Lungs

b) Gills

c) Skin

d) All of the above

ii) **Parabronchus is found in:**

a) Fishes

b) Amphibians

c) Reptiles

d) Aves

e) Mammals

iii) **Which of the following structures are involved in mammalian respiration**:

a) Ribs and intercoastal muscles

b) Intercoastal muscles

c) Diaphragm

d) Both a and c

iv) Pulmonary respiration means:

a) Respiration through lungs

b) Respiration through lungs and gills

c) Respiration through pulmonary veins

d) Respiration through gills

v) In Agnathans the respiratory tube is separated from mouth by a valve……

a) Epiglottis

b) Glottis

c) Velum

d) Valve

10.7 ANSWERS

Q4: i) c, ii) d, iii) d, iv) c , v) d

UNIT-11 : COMPARATIVE ANATOMY OF SKELETON SYSTEM, CIRCULATORY SYSTEM

11.1 Introduction

Objectives

11.2 Comparative anatomy of Skeletal system

11.3 Comparative anatomy of Circulatory system

11.4 Summary

11.5 Terminal Question

11.6 Answers

11.1 INTRODUCTION

Skeleton is the hard tissue of the body that supports it to acquire a shape. In invertebrates the skeleton is mostly secreted on the surface and thereby forms a nonliving exoskeleton. On the contrary, skeleton of vertebrates develops mostly under the surface forming a living or growing endoskeleton.

Vertebrate skeletons are broadly classified into 3 types

1) **Epidermal horny exoskeleton:** It includes hard, keratinized or horny derivatives of epidermis. Eg: nails, claws, hairs etc. It is interesting to note that all living amphibians lack an exoskeleton.
2) **Dermal bony skeleton:** It is derived from the dermis of skin and includes scales and plates or scutes (iosteoderms) found in fishes, reptiles and mammals.
3) **Endoskeleton**: As the name indicates, it forms the major part of vertebrate skeleton that lies inside the body and develops from mesenchyme. During starting phase of embryonic development the endoskeleton comprises of cartilage which is eventually replaced by bone in most adult vertebrates.

Importance of Endoskeleton:

Endoskeleton in vertebrates performs following functions:

- Physically supports the body
- Provides definite body shape and form
- Protects by there the delicate internal organs like brain, heart etc.
- Provides surface for attachment of muscles
- Permits growth of huge body size
- Serves as levers on which muscles can act
- Production of blood cells from bone marrow
- Ear ossicles help in auditory function
- Helps in breathing (tracheal rings, ribs)

On the basis of location of endoskeleton within body the endoskeleton of vertebrates is differentiated

into 3 major categories namely: Axial, Appendicular and Heterotopic. The other categorization of endoskeleton includes two different forms: Somatic and Visceral skeletons.

i) **Somatic skeleton:** It includesskeleton of body wall comprising of axial and appendicular skeleton.

   a) ***Axial skeleton:*** All that lies on the central axis of body such as vertebral column, ribs, sternum and most of the skull (neurocranium and dermatocranium).

   (b) ***Appendicular skeleton***: It includes girdles and limb bones.

ii) **Visceral skeleton**: It includes skeleton of pharyngeal wall (splanchnocranium).

All animals from the simplest protozoans to the most complex vertebrates need that food absorbed through digestive tract and oxygen collected in respiratory organs must be transported to all parts of the body for metabolism; the waste products of metabolism must be transported from the sites of their productions to excretory organs for their quick elimination from body, and the hormones from endocrine tissues must be conveyed to suitable sites for utilization. All these processes require an adequate internal system for circulating nutrients and other materials throughout the body becomes necessary, called circulatory system. The body of an organism needs this circulatory system for distributing digested food, water, oxygen, numerous secretions and waste products throughout the body. The chordates have a completely closed circulatory system which includes the blood vascular system and the lymphatic system. The blood vascular system consists of closed tubes or blood vessels such as arteries, veins and capillaries inside which a transporting fluid, the blood is kept in circulation by a definite pumping organ, the heart.

Objectives:

After studying you will be able to:

- Understand the skeletal organization and circulation of substances in different vertebrates
- Enhance your knowledge on osteology and circulatory system
- Discuss the difference of skeletal arrangements in different vertebrates
- Compare the circulatory system in different vertebrates

11.2 COMPARATIVE ANATOMY OF SKELETAL SYSTEM

The skeletal system starts with the skull at the top of every vertebrate and forms the head region. Skull is derived from three major embryonic components namely neurocrancium or chondrocranium, dermatocranium and splanchnocranium. Neurocranium includes the cranium or brain box that houses the brain, three pairs of sense capsules containing olfactory, optic and otic sense organs. The dermatocranium includes membrane or dermal bones attached to neurocranium and splanchnocranium while the latter includes the visceral or pharyngeal skeleton that forms a series of paired arches providing jaws, support for tongue (hyoid), and support for gill region. The skull of different vertebrates differ significantly which have been summarized below:

SKULL OF DIFFERENT VERTEBRATES

Although the basic architechtural organization of neurocranium, dermatocranium and splanchnocranium is same in all the vertebrates, however, there are many differences in general form and detailed structure.

- *In Cyclostomes*:

  Skull in cyclostomes is of primitive type as it retains cartilaginous embryonic neurocranium

with an imperfect fibrous roof without dermal plates or bones. Even the Visceral skeleton is not comparable with that of higher vertebrate and appears as a branchial basket.

- *In Chondrichthyes*:

  The neurocranium is cartilaginous and brain is completely roofed. Olfactory and otic capsules are fused with the chondrocranium but optic capsules remain free. In elasmobranchs the dermal bones are absent.

- *In Osteichthyes*:

  In primitive bony fishes (Sturgeon, spoonbill, Amia, etc.) and earlier crossopterygians the neurocranium is flat, completely roofed, cartilaginous and partially ossified forming many sculptured dermal bones by fusion of dermal scales. In *Polypterus* the neurocranium is extensively ossified. In some primitive teleosts such as salmon and trouts the chondrocranium is mostly cartilaginous. While in higher teleosts the skull is very specialized, laterally compressed and well ossified. Dermal bones are present in bony fishes which are smooth, without ganoin, and not scale-like. Cartilaginous visceral arches chages to bones or is replaced by dermal bones. Upper jaw is formed by dermal bones: premaxilla and maxilla. Lower jaw (Meckel's cartilage) has three bones namely dentary, angular and articular-the last hinging on quadrate which attaches to cranium.

- *In Amphibia:*

  The change in living style from water to land led to many modifications in amphibian skull. Modern amphibians posses fewer bones and increased embryonic cartilage in skull which is markedly platybasic and flattened. Bones such as basioccipital, supraoccipital, basisphenoid and presphenoid are absent. Hyomandibular becomes columella of the middle ear. Ventral wall of otic capsule bears a membrane covered aperture known as fenestra ovalis into which columella articulates for transmitting sound waves. The skull of amphibian is dicondylic i.e. presence of two occipital condyles, one on each exoccipital.

  The visceral skeleton of amphibia is similar to bony fishes except that the number of gill-bearing arches is reduced.

- *In Reptilia:*

  In modern reptiles the neurocranium shows extensive ossification except in naso-ethmoidal region. The skull of reptile is monocondylic (one occipital condyle) and more dermal bones than in Amphibia. Skull is tropibasic. One or two temporal openings (temporal fossa) occur behind the orbits, except in Chelonia. Pineal foramen is lost (except in *Sphenodon* and many lizards). Prootic, epiotic and opisthotic of otic region remain separate. A quadratojugal is absent. Quadrate is movable at both ends showing streptostylism. There is tendency to form a Turbinal element in nasal passage and secondary palate is formed. A transverse ectopterygoid and a vertical epiterygoid are present. Hyomandibular is modified into columella of middle ear. Lower jaw has a large toothed dentary, angular, supraangular, splenial, coronoid and articular bones.

- *In Aves:*

  Bird skull shows resemblance with reptilian skull. It is moocodylic and eurocranium is well ossified. Modifications observed in skull of birds are associated with flight and altered feeding habits. Skull is large, penumatic and light with very thin dermal bones and practically without sutures. Premaxillary and dentary are elongated to form a toothless beak necessary for feeding. Cranium is large and its roof is domed to accommodate the larger brain. Orbits

are large, separated by a thin interorbital septum and each with a ring of dermal sclerotic bones. Foramen magnum faces downwards. There is a columella in the middle ear as found in reptiles. Quadrate is streptostylic. Lower jaw has one cartilage bone (articular) and four dermal bones.

- *In Mammalia*:

  Mammalian skull is dicodylic (two occipital condyles) a condition inherited from ancestral synapsid reptiles. Prefrontals, postfrontals, transpalatines, supraorbitals, postorbitals, parasphenoid, quadratojugals, quadrates and all lower jaw bones except dentary are absent. Occipital bones fuse into a single piece enclosing foramen magnum. Otic bones become fused into a petrosal or periodic. 3 ear ossicles are pfreset amely:- malleus (articular), incus (quadrate) and stapes (columella or hyomandibula). A complete secondary palate is present. Teeth are heterodont and present on premaxillae, maxillae and dentaries. Pterygoids are insignificant. Lower jaw on either side is made of a single dentary there being no trace of Meckel's cartilage. Hyoid arch mainly contributes to hyoid apparatus. Remaining visceral arches contribute to thyroid, epiglottis, arytenoids, cricoid, tracheal rings, etc.

JAW SUSPENSIONS:

The method of attachment or suspension of jaws from the chondrocranium is termed as jaw suspension or suspensorium. 5 different types of jaw suspensions have been recorded:

1. **Autodiastylic:** The jaws are attached to the cranium by anterior and posterior ligaments. Hyoid arch remains completely free or independent and does not support the jaws. The gill cleft in front of hyoid arch bears a complete gill and does not form any spiracle. Example: In some earliest gnathostomes such as acanthodians.
2. **Amphistylic:** The quadrate or the basal and otic processes of upper jaw are attached by ligaments to chondrocranium. Similarly, the upper end of hyomandibula is also attached to chondrocranium, while the two jaws are suspended from its other end. This arrangement makes a double suspension (amphi = both+style = bracing) since both the first and second arches participate in bracing the jaws against the chondrocranium. Example: This is a rather primitive arrangement found in Crossopterygii and some primitive sharks such as *Heptanchus*.
3. **Hyostylic:** Upper jaw (palatoquadrate) is loosely attached by anterior ethmopalatine to cranium. Both the jaws are braced against hyomandibular, the upper end of which fits into auditory region of skull. Since only hyoid arch braces or binds the two jaws against cranium, this jaw-suspension is termed hyostylic. It provides the jaws a wider movement and helps in swallowing larger preys. Example: Found in most elasmobranchs and all bony fishes.
4. **Autostylic:** Hyomandibular does not participate but becomes modified into columella or stapes of middle ear for transmitting sound waves. Upper jaw (palatoquadrate) is directly and intimately bound to cranium by investing dermal bones (auto = self). The articular of lower jaw articulates with the quadrate of the upper jaw. Example: Found in extinct placoderms, chimaeras, lung fishes and most amphibians, reptiles and birds.
5. **Craniostylic:** This is considered as a modification of autostylic suspension. Upper jaw fuses throughout its length with cranium and hyomandibular forms the ear ossicle stapes. But articular and quadrate also become modified into ear ossicles malleus and incus, respectively. Consequently two dermal bones, dentary of lower jaw and squamosal of skull provide the articulation between jaw. Example: Found in mammals.

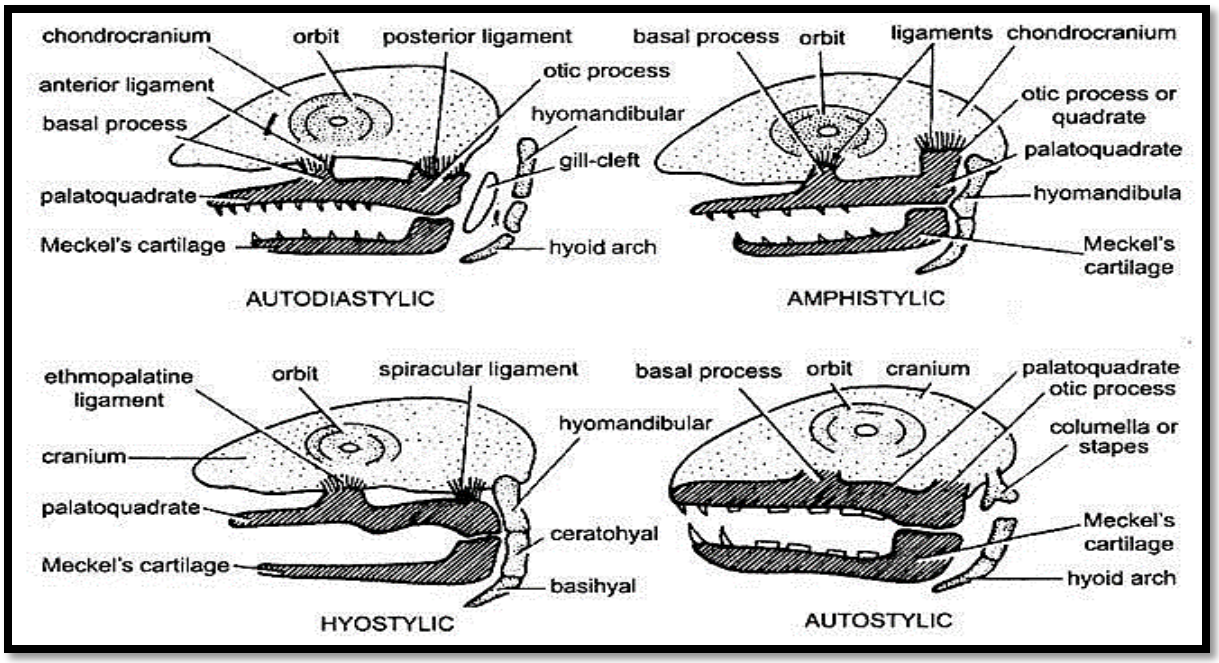


Fig 11.1: Types of jaw suspension in vertebrates (https://www.notesonzoology.com/wp-content/uploads/2017/07/clip_image010-41.jpg).

VERTEBRAL COLUMN

- **Notochord:**

  Notochord is a slender, stiff, unsegmeted, gelatinous rod foud in all chordate embryos. It is present below the nerve cord and above the digestive tract. It is believed that notochord originated from endoderm. In protochordates (*Amphioxus*) and cyclostomes (lamprey) the notochord persists throughout life and continues to grow with the animal.

  In fishes and higher vertebrates the notochord is later on surrounded by cartilaginous or bony rings, called vertebrae. In most fishes and aquatic amphibians the adult notochord is constricted within each vertebra. It is not constricted in lungfishes and sturgeon. In tetrapods the vertebrae is practically obliterated.

- **Vertebrae:**

  Backbone or vertebral column of all vertebrates is formed of a metameric series of many small and essentially similar pieces called vertebrae. Thus, a vertebra is the unit of vertebral column. Vertebrae are named after the region of body in which they occur.

Vertebral column of fishes comprises only trunk (abdomen) and caudal (tail) vertebrae . In tetrapods, vertebral column includes five regions viz: cervical,thoracic, lumbar, sacral and caudal, each having usually several vertebrae. Amphibians have a single cervical (atlas) and only one sacral (9th) vertebra.

Vertebrae differ in different vertebrates or even in different regions of the same vertebrate, but all vertebrae are built according to a similar basic pattern and structure having a cylindrical, spool-like body or centrum(encloses or replaces the embryonic notochord), a neural arch (above the centrum) and produced dorsally into a neural spine. Successive neural arches enclose a vertebral or neural canal in which the spinal cord lies. The caudal vertebra in fishes also has a ventral haemal arch enclosing a haemal canal through which the caudal artery and vein pass. Haemal arch also carries a ventral haemal spine.

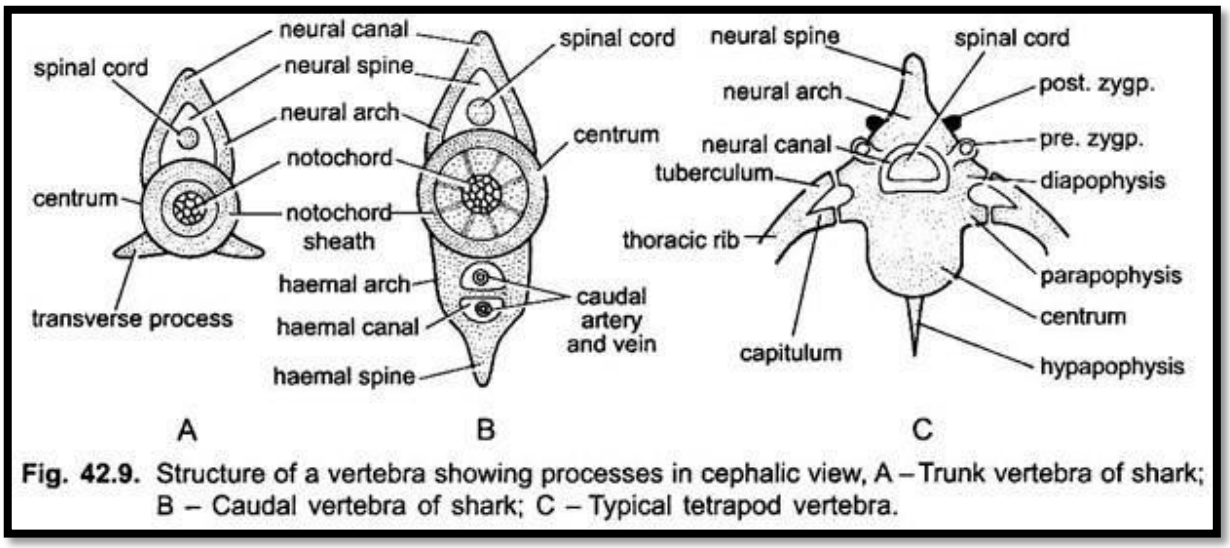


Fig. 42.9. Structure of a vertebra showing processes in cephalic view, A – Trunk vertebra of shark; B – Caudal vertebra of shark; C – Typical tetrapod vertebra.

Fig 11.2: Structure of vertebra showing processes A) Trunk vertebrae of shark, B) Caudal vertebrae of shark, C) Typical tetrapod vertebrae (https://www.notesonzoology.com/wp-content/uploads/2017/07/clip_image010-41.jpg).

Types of processes:Various kinds of processes (apophyses) arise from the arches or centra of vertebrae.

i) **Zygapophyses**: Paired articular facets, the pre- and post- zygapophyses project from anterior and posterior faces of neural arch. These serve for articulation between adjacent vertebrae. Zygapophyses is absent in fish vertebrae.

ii) **Transverse processes**: Lateral transverse processes arise from centrum and serve for attachment of ligaments and muscles.

iii) **Diapophyses:** Daipophyses projects laterally from centrum or neural arch and articulates with tuberculum (dorsal head) of thoracic rib.

iv) **Parapophyses:** Parapophyses projects laterally from centrum and articulates with capitulum of rib.

v) **Basapophyses:** Basopophyses project ventrolaterally from centrum or haemal arch, or meet ventrally to form haemal arch.

vi) **Pleurapophyses:** These are lateral transverse processes fused with short ribs at their tips.

vii) **Hypapophysis:** It is a single prominent mid-ventral projection of centrum in certain vertebrae.

The shape and structure of centrum vary among different vertebrae and therefore the vertebrae of vertebrates can be identified on the basis of centrum. On the basis of the particular shape of centra the following main 6 types of vertebrae are classified:

1) **Acoelous or amphiplatyan**: Centrum is flat at both ends without a concavity or a convexity, e.g. vertebrae of mammals.

2) **Procoelous:** The anterior face of centrum is concave and posterior face convex. e.g. typical vertebrae of frog and most reptiles.

3) **Opisthocoelous:** Centrum is convex anteriorly and concave posteriorly e.g. cervical vertebrae of some large ungulates.

4) **Amphicoelous:** Centrum is concave at both ends. e.g. vertebrae of most fishes and tailed amphibians, 8th vertebra of frog

5) **Biconvex:** Centrum is convex at both ends. e.g., sacral or 9th vertebra of frog.

6) **Heterocoelousor Saddle shaped:** Ends of centra are shaped like a saddle. e.g. vertebrae of modern birds.

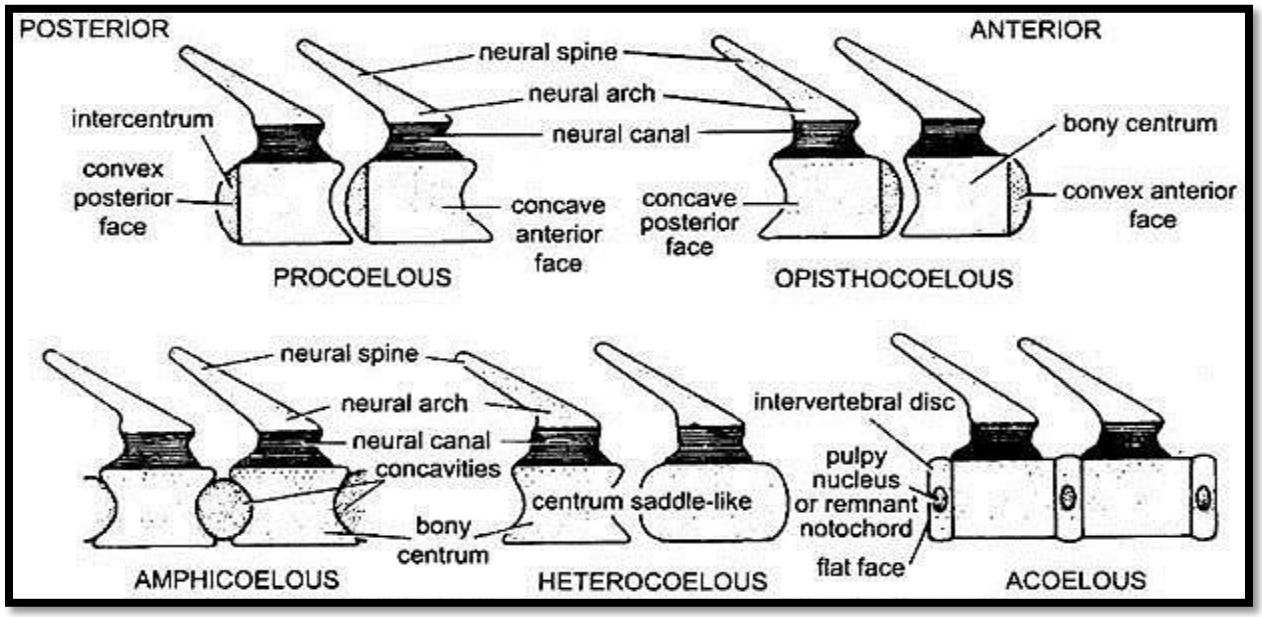


Fig11.3: Types of vertebrae based on shape of centrum (https://www.notesonzoology.com/wp-content/uploads/2017/07/clip_image010-41.jpg).

Vertebral columns in:

- *Agnathans*: Only skeletal elements associated with the notochord are paired, lateral neural cartilages
- *Cartilaginous fishes:* Theydo not have typical fish vertebral columns. Thevertebrae include neural arches (cartilaginous dorsal plates) & dorsal intercalary plates are located between successive arches
- *Teleosts:* Havewell-ossified amphicelous vertebrae, notochord persists within each centrum (but constricted)and theneural arch associated with each centrum & hemal arches in tail (caudal) vertebrae.
- *Chondrosteans (sturgeons & paddlefish) & modern lungfishes: Have* incomplete centra, notochord is not constricted *and* cartilage deposited in notochord sheath provides structural support. 2 centra and 2 sets of arches (Diplospondyly) per body segment occurs in some fish (including sharks).

- *Tetrapods:* Vertebral column in tetrapods can be differentiated into cervical, dorsal and caudal region.

i) Cervical region

- Amphibians- Single cervical vertebra is present that allows little head movement
- Reptiles- Increased numbers of cervical vertebrae (usually 7) with increased flexibility of head
- Birds - Variable number of cervical vertebrae (as many as 25 in swans)
- Mammals: Usually 7 cervical vertebrae is present

In reptiles, birds, & mammals first two cervical vertebrae are modified & called the atlas and axis. Atlas is the 1st cervical vertebra which is ring-like (most of centrum gone) and provides 'cradle' in which skull can 'rock' while Axis is the 2nd cervical vertebra.

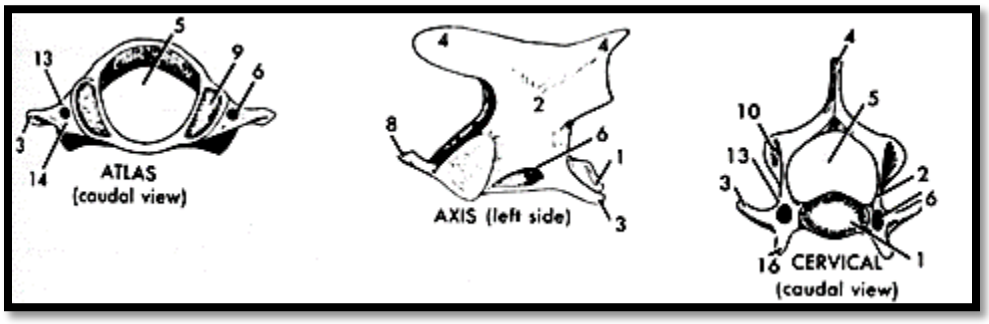


Fig 11.4: View of atas, axis and cervical vertebrae.

Transverse foramen (6 in above caudal view of a cervical vertebra) is found in cervical vertebrae of birds and mammals that provides canal for vertebral artery & vein.

ii) Dorsal region

- Dorsals - Name given to vertebrae between cervicals and sacrals when all articulate with similar ribs. e.g., fish, amphibians and snakes.
- In Crocodilians, lizards, birds and mammals the ribs are confined to anterior region of trunk
- Thoracic - vertebrae with ribs
- Lumbar - vertebrae without ribs
- Sacrum and Synsacrum
- Sacral vertebrae have short transverse processes that hold the pelvic girdle and hindlimbs against the vertebral column
- In Amphibians 1 sacral vertebra is present
- In living reptiles and most birds 2 sacral vertebrae are present
- In almost all mammals 3 to 5 sacral vertebrae are present
- Sacrum is single bony complex consisting of fused sacral vertebrae; found when there is more than 1 sacral vertebra

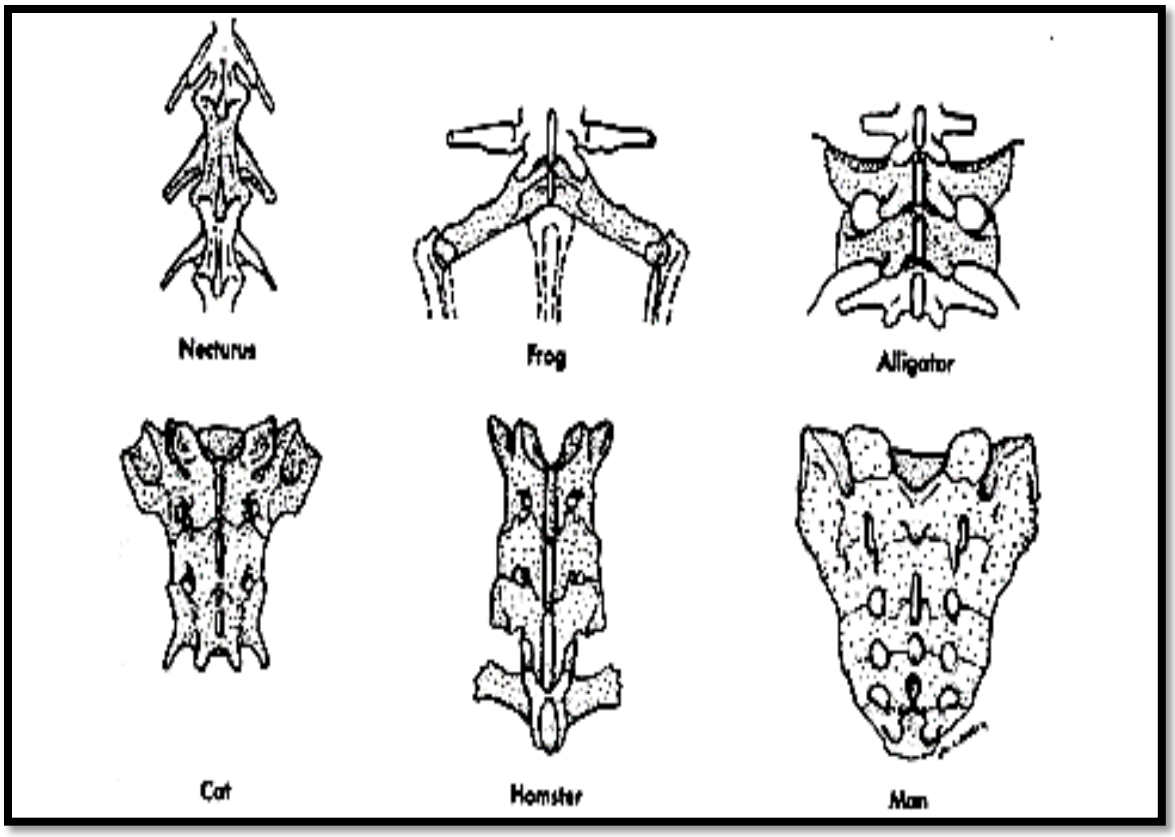


Fig 11.5: Sacrum in different vertebrates.

- Synsacrum is found in birds which are produced by fusion of last thoracic, all lumbars, all sacrals and first few caudals. It is fused with pelvic girdle and provides rigid support for bipedal locomotion

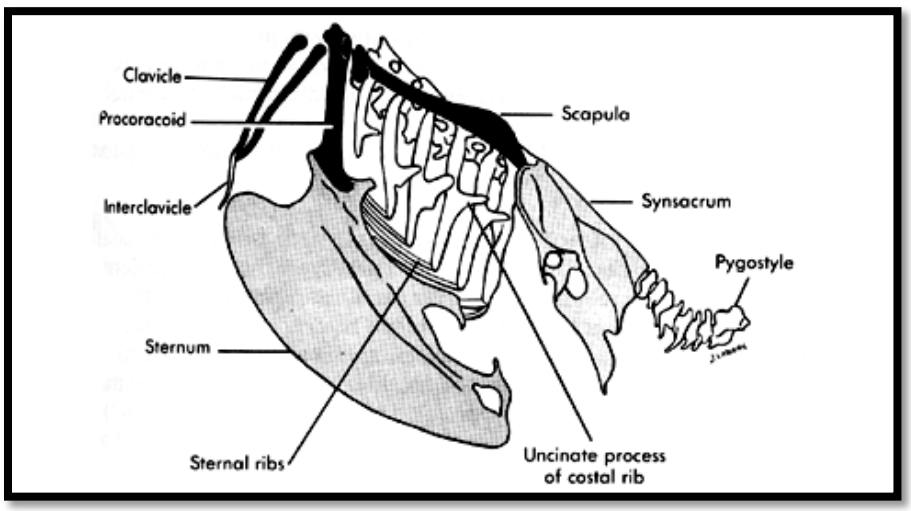


Fig 11.6: Synsacrum shown in vertebrae of a bird.

iii) Caudal region

- In primitive tetrapods 50 or more caudal vertebrae were present
- In present-day tetrapods the number of caudal vertebrae is reduced. The arches and processes get progressively shorter

- In anurans a unique terminal segment called the urostyle is present
- In birds the last 4 or 5 caudal vertebrae fused to form **pygostyle**
- In apes and humans the last 3 to 5 caudal vertebrae fused to form **coccygeal** or tail bone
- **Sternum**: This is strictly a tetrapod structure and primarily, an amniote structure.
- Sternum is absent in early and present day amphibians except anurans
- In Amniotes sternum is a plate of cartilage and replacement bone. It articulates with the pectoral girdle anteriorly and with a variable number of ribs

APPENDICULAR BONES IN VERTEBRATES:

Appendicular bones consist of pectoral and pelvic girdles along with skeleton of fins and limbs. Some vertebrates have no appendicular skeleton such as agnathans, apodans, snakes and some lizards and in others it is much reduced.

Pectoral girdle:

- **In fishes:** It is V-shaped structure made up of right and left halves united mid-ventrally. Each half is made up of coracoid portion, scapular portion and suprascapular portion. Pectoral girdle is embedded in lateral and ventral body wall posterior to gills in the region of heart. Pectoral girdles provide attachment to myotomes, pectoral fins and other muscles. Pectoral girdlealsosupportsandprotects heart.

  A pectoral fin is made up of basal and radial cartilages. Basal cartilages are propterygium, mesopterygium and metapterygium. Proximally these cartilages articulate with scapular and coracoid portions of pectoral girdle. From basal cartilages extend numerous radial cartilages or somactidia, each made up of 2 or 3 segments. The coracoid portion contains foramina for branchial artery and nerves.

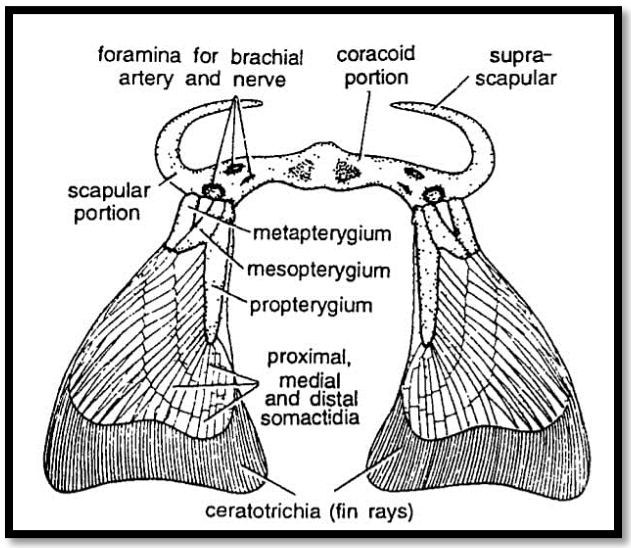


Fig 11.7: Pectoral girdle of *Scoliodon* (https://www.faunafondness.com/pectoral-girdle/).

- **In Amphibia (Frog):** The pectoral girdle is found embedded in the body wall in thoracic region. It is composed of two identical halves which are permanently attached with sternum. Each half is composed of scapular and coracoid regions. The scapular region consists of suprascapula and scapula. Former is a broad, flat and rectangular bone having free calcified

cartilaginous margin whereas latter is also flat and contains a cup-like glenoid cavity for humerus. The coracoid region is made up of two bones, namely clavicle and coracoid and two cartilages viz. epicoracoid and precoracoid. Pectoral girdle protects viscera and gives support to limbs. Other structures seen regarding sternum are episternum, omosternum xiphisternum and mesosternum.

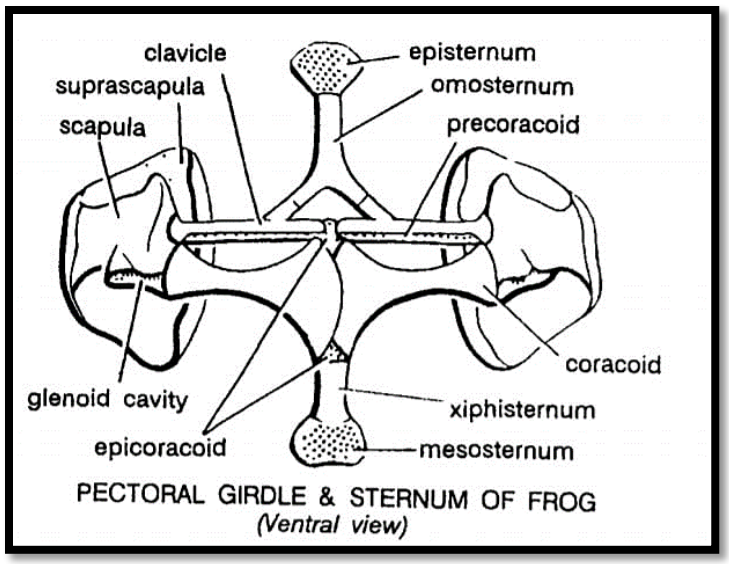
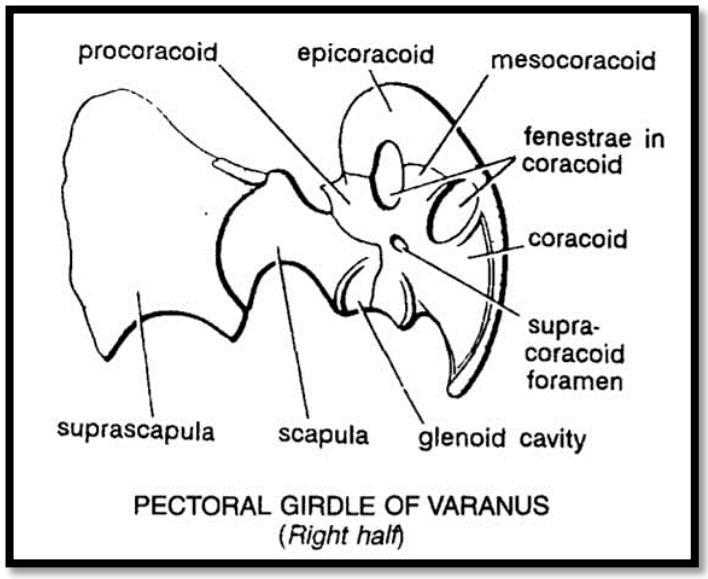


Fig 11.8: Pectoral girdle of Frog(https://www.faunafondness.com/pectoral-girdle/).

- **In Reptiles (*Varanus*):** Pectoral girdle of is made up of two identical halves, firmly attached with a T-shaped interclavicle or episternum. Each half is composed of suprascapula, scapula, coracoid, interclavicle and clavicle. Suprascapula is flattened, calcified and cartilaginous plate, articulating ventrally with scapula. Its dorsal margin is free and curved. Scapula is completely ossified, flattened and unfenestrated plate, articulating with suprascapula and coracoid. Coracoid is a flat bone partly ossified and partly cartilaginous. It contains two large fenestrae, which divide ossified region into three parts, namely anterior procoracoid, middle mesocoracoid and posterior broad coracoid proper. Inner end of coracoid lying over fenestrae is cartilaginous and termed epicoracoid. At the posterior junction of scapula and coracoid is a cup-shaped glenoid cavity for the head of humerus. Interclavicle (episternum) is T-shaped investing bone between two halves wheras clavicle is short, curved dermal bone, articulating with suprascapula and interclavicle.



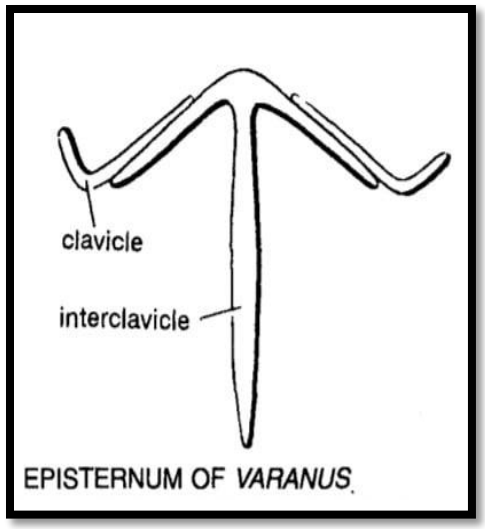


Fig 11.9: Pectoral girdle and episternum of *Varanus* (https://www.faunafondness.com/pectoral-girdle/).

- **In Birds:** Pectoral girdle in bird is peculiarly inverted L-shaped and composed of coracoid, scapula and clavicle. Coracoid is a large, stout and rod-shaped bone. Its distal end is produced into a hook-like acrocoracoid process, while proximal end is flattened to articulate with coracoid groove on the antero-Iateral border of sternum. Below acrocoracoid process, the inner surface of coracoid articulates with scapula, while outer surface contains a cup-shaped glenoid cavity for humerus head. Scapula is a sabre-like bone. Anteriorly it contains a cup-shaped depression, forming part of glenoid cavity and on inner side it has an acromian process. Clavicles fuse to form a V-shaped furcula or merry thought or wishbone. Each clavicle is a rod-shaped bone. Ventrally both clavicles unite to form interclavicle or hypocleidium.

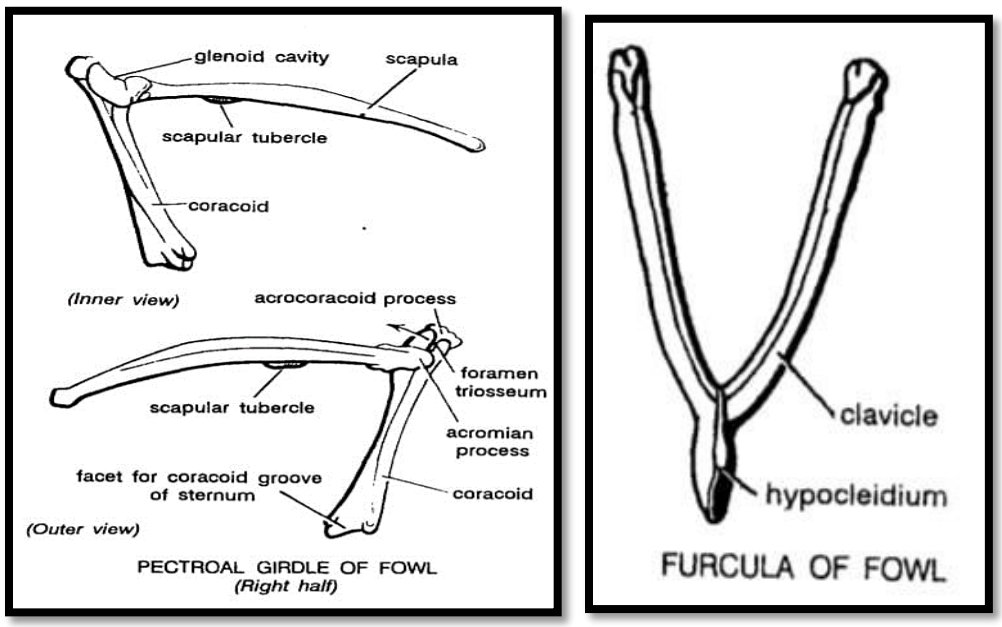


Fig 11.10: Pectoral girdle and furcula of Fowl(https://www.faunafondness.com/pectoral-girdle/).

- **In Mammals (Rabbit):** Each half of pectoral girdle is made up of clavicle and scapula-coracoid. Scapula-coracoid is a triangular replacing bone. The apex contains a concavity called glenoid cavity for humerus head. Over glenoid cavity hangs a coracoid process. A

distinct vertical spine divides outer surface of scapula and it terminates below into an acromian process, which further gives posteriorly a metacromian process.

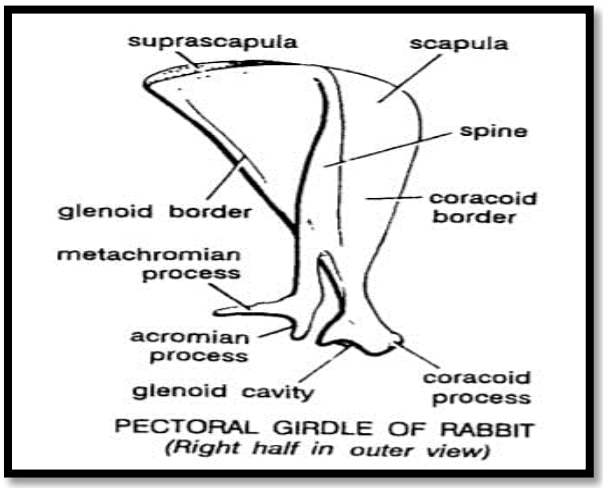


Fig 11.11: Pectoral girdle of Rabbit(https://www.faunafondness.com/pectoral-girdle/).

Pelvic Girdle:

The pelvic girdle is directly attached to the vertebral column in the sacral region. The pelvic girdle consists of two similar halves which are known as ossa innominata.

- **In fishes (*Scoliodon*):** It is made up of a simple flattened and transverse cartilaginous rod called ischiopubic bar, having a small blunt iliac process on either side projecting above the acetabular facet for articulation of the basal cartilage of pelvic fin.

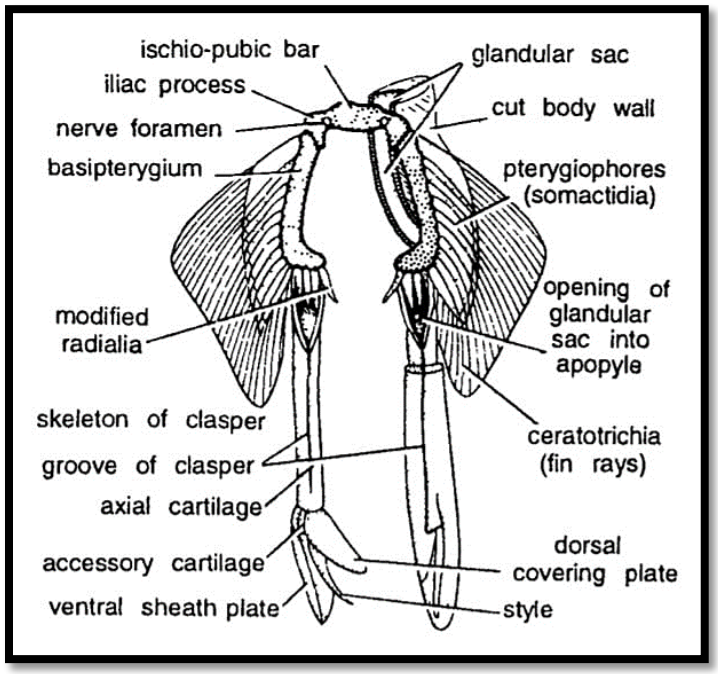


Fig 11.12: Pelvic girdle of *Scoliodon* (https://www.faunafondness.com/pelvic-girdle/).

- **In Amphibia (*Bufo*)**: The pelvic girdle is a V-shaped structure formed by the partial fusion of two hip bones. Each half of the girdle is exactly identical with the other. It comprises of illium, ischium and pubis. Illium is a long cylindrical bone, the anterior end of which articulates with the expanded transverse processes of the 9th vertebra and **the** posterior end

flattens and unites with other bones of the girdle. Ischium is a small piece of bone. The two ischia of both the halves unite to form the posterior part of the disc whereas pubis is a small piece of cartilage, placed at the ventral surface of the disc between the ilium and ischium. The two pubis of both the halves fuse together. The cavity at the junction of the ilium, ischium and pubis, into which fits the head of the femur is known as acetaulum

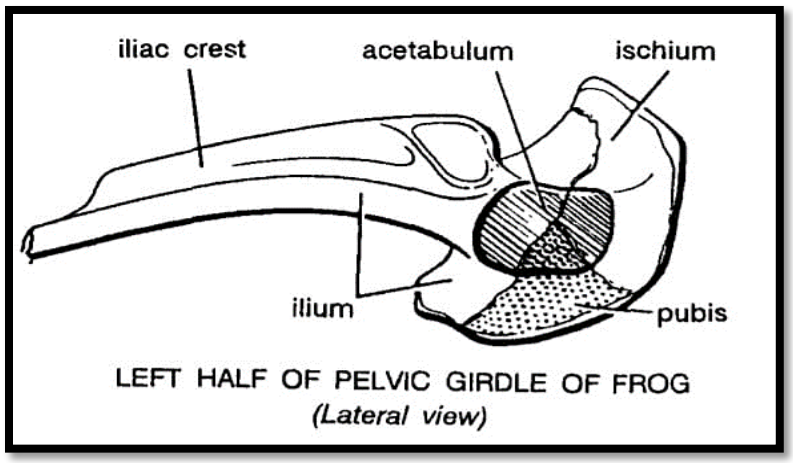


Fig 11.13: Pelvic girdle of *Bufo* (https://www.faunafondness.com/pelvic-girdle/).

- **In Reptiles:** Consists of two equal halves. Ilium is large compressed rod, passes upwards and backwards from the acetabulum to articulate with the sacral region of the vertebral colum. Ischium is a stout bone and runs downwards and backwards. It articulates with its fellow of the opposite side in the ischiatic symphysis. The symphysis form a plate of calcified cartilage and separates the two ischia at their ventral ends. Pubis is slender, runs downward and forward from the acetabulum and meets its fellow in the middle line by public symphysis. Epipubis is a small nodule of calcified cartilarge, placed between the anterior ends of the pubes.

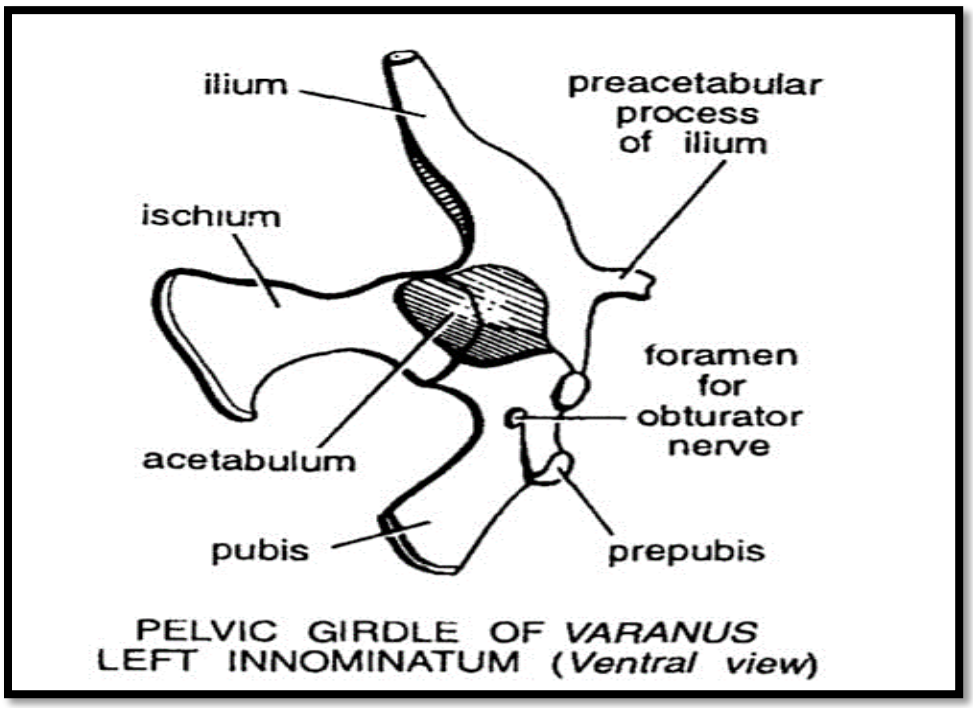


Fig 11.14: Pelvic girdle of *Varanus* (https://www.faunafondness.com/pelvic-girdle/).

- **In Birds (Columba):**Ilium is a large, flat bone attached to the whole of the synsacrum. It can be divided into two almost equal halves, the pre- and post-acetabular portions. On the posterior edge of the acetabulum, the ilium is produced into a process, the antirochanter. Ischium is short, stout bone, runs backward from the acetabulum. Posteriorly, the ischum is connected with the ilium but anteriorly they are separated by an ischiatic formen. Pubis is slender, curved rod, runs backward from the acetabulum. It lies parallel to the ventral edge of the ischium and separated from it by a large obturator foramen. The acetabulum is not a closed cavity but is perforated by an aperture covered by a membrane.

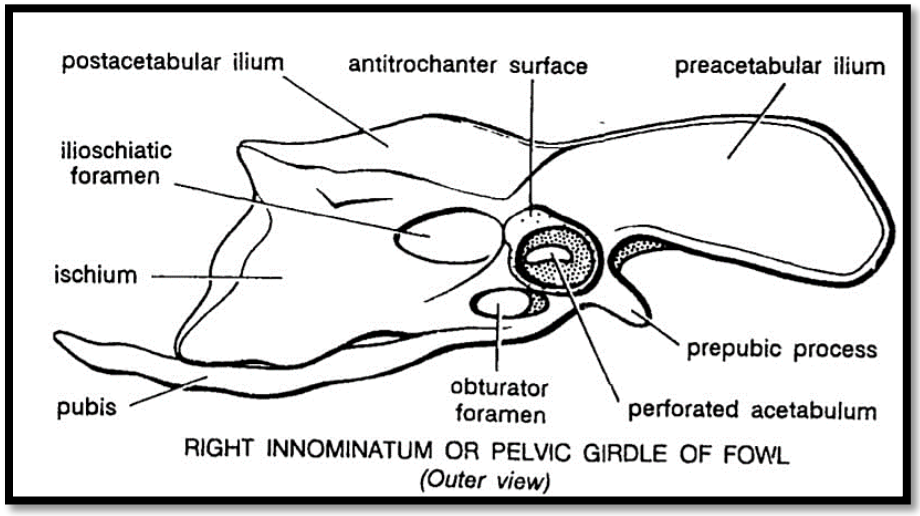


Fig 11.15: Pelvic girdle of *Fowl*(https://www.faunafondness.com/pelvic-girdle/).

- **In Mammals:** Ilium stout large bone which runs forward and slightly upwards from the acetabulum. The distal end is broad to articulate with the flank of the scarum. Ischium is short and flat which runs backward from the acetabulum. The posterior margin ofthe ischium is thickened. Pubis is slender which extends downward and backward from the acetabulum. Ventrally, it joins with its fellow of the opposite side to from the pubic symphysis. The ischium and the pubis enclose a large foramen, the obturator foramen.

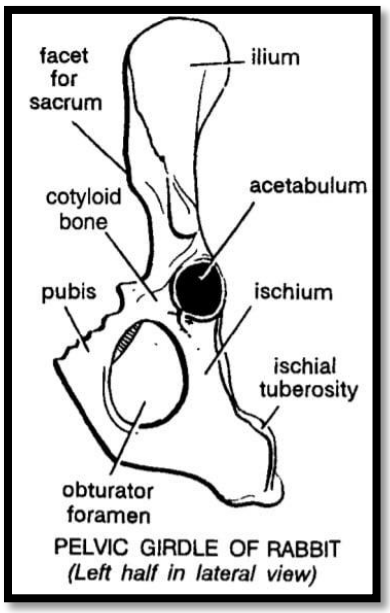


Fig 11.15: Pelvic girdle of Rabbit(https://www.faunafondness.com/pelvic-girdle/).

- **Limb bones:**

Appendages or limbs of vertebrates are varied across vertebrate group. Cyclostomes do not have lateral appendages. Cartilaginous (sharks) and bony fishes have median and paired fins for locomotion in water. In a median fin skeleton consists of a single row of rays called pterygiophores or radialia. Paired fins include pectoral and pelvic fins. In majority of Chondrichthyes (e.g. sharks) a pectoral fin has 3 basalia, termed the pro-, meso-and metapterygium, respectively, and a number of radialia or somactidia arranged around them. In bony fishes, basalia are absent while radials are reduced to small ossicles which lie within the bodywall.

In amphibians, reptiles, birds and mammals pentadactyl limbs are present. Their bones probably represent greatly modified pterygiophores serially homologus in fore and hind limbs. Their basic pattern remains the same throughout tetrapods. Proximal part of limb includes a single rod-like bone humerus in forelimb and femur in hind limb. Middle part includes 2 elongated bones: radius and ulna in forelimb and tibia and fibula in hind limb. Distal part of forelimb called hand or manus includes carpals, metacarpals and phalanges. Similar part in hind limb is called foot which includes tarsals, metatarsals and phalanges. However, these bones show various structural modifications due to adaptations for different modes of life. These modifications mainly involve reduction in number of bones of the hand or foot.

I. Axial skeleton (median)			*II. Appendicular skeleton (lateral, paired)*		*Heterotopic bones (miscellaneous)*
Skull	**Vertebral column**	**Thoracic basket**	**Girdles**	**Limb bones**	**Develop in association with certain organs**
A. Neurocranium 1. Cranium or brain box surrounding brain 2. Sense capsules (*i*) Olfactory-nose (*ii*) Optic-eyes (*iii*) Auditory ears	**Vertebrae** 1. Cervical-neck 2. Thoracic-chest 3. Lumbar-lower back 4. Sacral-hip 5. Caudal-tail	**A. Ribs** Paired; bony cartilaginous **B. Sternum-** Breast bone	**A. Pectoral** Anterior or shoulder girdle. Includes : 1. Scapula-dorsal 2. Clavicle-anterior 3. Coracoid-posterior	**A. Forelimb** 1. Humerus -upper arm 2. Radius and ulna-forearm 3. Carpals-wrist 4. Metacarpals-palm 5. Phalanges-fingers	**1. Os cordis-**Inter ventricular septum of heart in deer and bovines. **2.** Rostral-Pig's snout.
B. Dermatocranium Membrane or dermal bones of skull **C. Splanchnocranium** Includes visceral arches or pharyngeal skeleton 1. Upper jaw 2. Lower jaw 3. Hyoid 4. Larynx			**B. Pelvic** Posterior or hip girdle Includes : 1. Ilium-dorsal 2. Pubis-anterior 3. Ischium-posterior	**B. Hind limb** 1. Femur-thigh 2. Tibia & fibula-shank 3. Tarsals-ankle 4. Metatarsals-sole 5. Phalanges-toes	**3. Os penis-** Penis of bats, rodents, marsupials, carnivores, insectivores, whales, lower primates. **4. Os clitoridis-** Clitoris of otters, rabbits several rodents. **5. Pessulus-** Syrinx of bird. **6. Epipubic-** Ventral abdominal wall of monotremes and marsupials. **7. Sesamoid-** Pisciform in hand, patella (kneecap), etc.

Fig 11.16: Endoskeleton of land vertebrates

Region of skull	Cartilage or replacement bones	Membrane or dermal bones	Bones of mixed origin
A. Chondrocranium 1. Occipital	* Supraoccipital Exoccipital * Basioccipital	Parietal * Interparietal Postparietal	
2. Parietal	* Basisphenoid Pleurosphenoid		
3. Frontal	Orbitosphenoid * Presphenoid	Frontal Postfrontal Lacrimal	Prefrontal
4. Olfactory capsule	* Mesethmoid Turbinals, Cribriform, Ectethmoid } (Ethmoid)	Nasal Vomer Septomaxillary	
5. Otic capsule	Epiotic Prootic Opisthotic	Squamosal Supratemporal	Sphenotic Pterotic
6. Optic capsule	Sclerotic		
7. Palate		* Parasphenoid Vomer (in mammals) Endopterygoid or Pterygoid, Ectopterygoid	Palatine
B. Splanchnocranium 1. Upper jaw	Quadrate (incus) Epipterygoid Alisphenoid Metapterygoid	Premaxilla Maxilla Jugal Quadratojugal	
2. Lower jaw	Articular (malleus) Mentomeckelian	Dentary (mandible) Coronoid Splenial Angular Supraangular	
3. Hyoid arch	Hyomandibular Columella (stapes) Symplectic Inter-epi-, hypo-, cerato- * basihyal		
4. Gill-cover		Preopercular Opercular Subopercular Interopercular Gular	

N.B. – All bones are paired. Single bones are marked with an asterisk (*).

Fig 11.17: Types of bones in Skull of vertebrates

11.3 COMPARATIVE ANATOMY OF CIRCULATORY SYSTEM

A well-developed circulatory system is a prerequisite for rapid internal transport of gases, nutrients, wastes, etc. within the body of organism. Chordates have a completely closed circulatory system which can be differentiated into two systems: blood vascular and lymphatic system.

A). Blood vascular system: It consists of heart, arteries, veins, capillaries and blood. Heart is a modified blood vessel with muscular walls which contracts periodically to pump blood throughout body. Arteries are blood vessels that carry blood away from the heart (oxygenated blood) while capillaries are minute tubes with thin walls in tissues, that connect the smallest arteries (arterioles) with the smallest veins (venules). Veins carry blood towards heart

(deoxygenated blood) from capillary networks. When blood flows through capillaries connected by arteries and veins, the blood vascular system is said to be closed as in annelids and vertebrates. On the other hand, the animals that lack capillaries have ope or lacunar system eg: Mollusca and arthropoda.

B). Lymphatic system: It occurs exclusively in chordates, except cyclostomes and cartilaginous fishes. It consists of lymph and lymph channels. Lymph is the tissue fluid lying between and bathing body cells. It is similar to blood plasma but lacks the red blood corpuscles and some proteins while lymph capillaries form a network of minute, blind-ending channels that collect lymph. Lymph vessels are larger thin-walled vessels formed by the union of lymph capillaries, and finally emptying into veins whereas lymph nodes, found only in mammals on lymph vessels, produce lymphocytes of blood and form an important link in body's defense mechanism.

In cyclostomes and chondrichthyes lymphatic system is absent but little sinusoids are found, representing the first stage of development. Bony fishes and all tetrapods are provided with lymphatic system. But as far as circulation is concerned, it is active in amphibian due to development of lymph heart. Lymphatic glands first appeared in reptiles and are found in birds and mammals as well.

Heart in different vertebrates:

- **In Cyclostomes:** They have 2 chambered with single circuit venous heart. Cyclostomes such as ammocoete larva, lamprey, hagfish have the simplest heart condition among the vertebrates with a linear series of 4 chambers namely sinus venosus, atrium, ventricle, and a small conus arteriosus. Only atrium and ventricle represent true chambers. Heart is present in the common body cavity along with other visceral organs.
- **In Elasmobranch:** They have 2 chambered with single circuit venous heart. Heart of a cartilaginous dogfish is typical and generalized for most fishes. It is a muscular and dorso-ventrally bent, S-shaped tube consisting of 4 chambers arranged in a linear sequence. Of these, sinus venosus and conus arteriosus are accessory chambers. Auricle and ventricle are true chambers therefore heart is considered two-chambered in fishes. Thin-walled sinus venosus receives venous blood of body through larger veins and opens anteriorly into atrium through the sino-atrial aperture guarded by a pair of valves. Atrium is large, thin-walled, elastic and muscular chamber lying dorsal to ventricle. It opens ventrally into ventricle through an atrio-ventricular aperture guarded by a pair of valves. Ventricle has very thick and muscular walls. It opens into a muscular tube of narrow diameter, the conus arteriosus, having a series of semilunar valves. All the valves of heart prevent backflow or regurgitation of blood. Heart of fishes is enclosed in a small pericardial cavity separated from general coelom by a transverse septum. In front of pericardial cavity, conus become continuous with the ventral aorta. In cartilaginous fishes transverse septum is perforated by a pair of openings through which pericardial cavity communicates with coelom.
- **In Teleosts:** 2 chambered with single circuit of blood circulation. Heart of bony fishes resembles in all respects that of elasmobranchs. In some Chondrostei (*Polypterus*) and Holostei (*Lepidosteus*), conus is long with numerous valves. In *Amia*, conus and number of its valves are reduced. While in Teleostei, conus is much reduced or even absent as it fuses with ventricle, and retains a single pair of semilunar valves. Instead, the part of ventral aorta in contact with conus becomes greatly enlarged with thick muscular walls and called bulbus arteriosus. It is elastic and inflates like a balloon when the ventricle contracts. All blood passing only once through heart is non-oxygenated. It is pumped into gills for aeration before

distribution to body. Such a heart is termed a branchial or venous heart.

- **In *Dipnoi*:** It has 3-Chambered transitional heart. Since the fishes show shift of respiration from gills to lungs, the heart and aortic arches also become modified. Along with the systemic circulation, a new shorter pulmonary circulation develops so that aerated blood from lungs (or swim bladder) returns directly to the heart without making a roundabout route of the whole body. Atrium of lung fishes (and most urodele amphibians) is divided by an incomplete inter-auricular septum perforated by the foramen ovale into right and left auricles. This results in a mixing of oxygenated blood received from lungs into left auricle, and deoxygenated blood from rest of body into right auricle. A partial partition also divides the ventricle while a horizontal septum divides the conus of lungfishes into a dorsal and a ventral part.
- **In Amphibia**: 3-Chambered heart where amphibians heart (anurans) shows an advance over the fish heart. A twisting occurs in dorsal atrium shifting anteriorly to ventricle. Similarly, sinus venosus opens into the right atrium dorsally instead of posteriorly. The inter-auricular septum is complete without foramen ovale therefore oxygenated and deoxygenated bloods are separate. Ventricle is undivided or single, but its thick muscular wall rises into trabeculae permitting only little mixing of bloods. In urodeles, conus is reduced and replaced by a bulbus arteriosus. In anurans, from left ventricle on its anterolateral margins conus (or truncus) arteriosus arises which is prominent and divided by a spiral valve which directs deoxygenated blood into pulmonary vessels and oxygenated blood into systemic vessels. The lumen of conus arteriosus is called pylangium which is occupied by spiral valve.
- **In Reptiles:** 3-chambered heart of reptiles shows further improvement over that of amphibians. It becomes more strongly muscular. It has two auricles and two ventricles but in most reptiles, ventricle is partially divided by an incomplete inter-ventricular septum, which reduces the mixing of oxygenated and deoxygenated blood. In crocodilians, this septum is complete thus making an effective 4-chambered heart, having two auricles and two ventricles. However, complete separation of oxygenated and deoxygenated blood is not achieved. The right and left systemic aortae carrying arterial and venous bloods respectively, join to form the dorsal aorta in which the both bloods get mixed before distribution. Besides, a small opening, called foramen of panizza connecting the two aortae at their base, brings about some mixing of blood. In crocodiles foramen panizza becomes obliterated.

  A sinus venosus is present in all reptiles which is large in turtles, small in snakes and lizards and distinct internally in crocodiles. Partially 4 chambered heart in reptiles with 2 auricles and 2 incomplete ventricles allow partial mixing of arterial and venous bloods before distribution. Thus, they represent transitional hearts showing a midway condition between 2-chambered heart of fishes with a single circulation and 4-chambered hearts of bird and mammals with double circulation and complete separation of arterial and venous blood.
- **In Birds and Mammals:** They have 4-Chambered, double circuit pulmonary hearts. Ventricles in birds and mammals are completely divided therefore their heart is completely 4-chambered with 2 auricles and 2 ventricles. Right auricle receives deoxygenated blood returning from body and passes it to right ventricle which pumps it to lungs for reoxygenation wheras left auricle receives aerated blood from lungs and pours into left ventricle which pumps it to entire body through systemic circulation. Thus there is double circulation in which there is no mixing of oxygenated and non-oxygenated blood at all. Such a heart is known as a pulmonary heart.

  Left auricle receives blood directly through pulmonary veins. Primitive conus arteriosus is

completely replaced by a pulmonary aorta leaving the right ventricle for lungs, and a single systemic aorta leaving the left ventricle for body. All major vessels have valves basally at the point of exit from or entry into heart. Blood from the walls of the heart is brought to the auricle by means of coronary sinus in right atrium. Intermixing and backflow of blood during circulation between auricles and ventricles are ensured by the presence of Tricuspid valve between right atrium and right ventricle whereas Mitral valve between left atrium and left ventricle.The opening of the sinus is guarded by valves called coronary valve also known as Thebsian valve. Although, interauricular septum is complete in adults but a fine depression, fossa ovalis is present which marks the site of foramen ovale. The fossa ovalis is surrounded by a prominent ridge annulus ovalis.

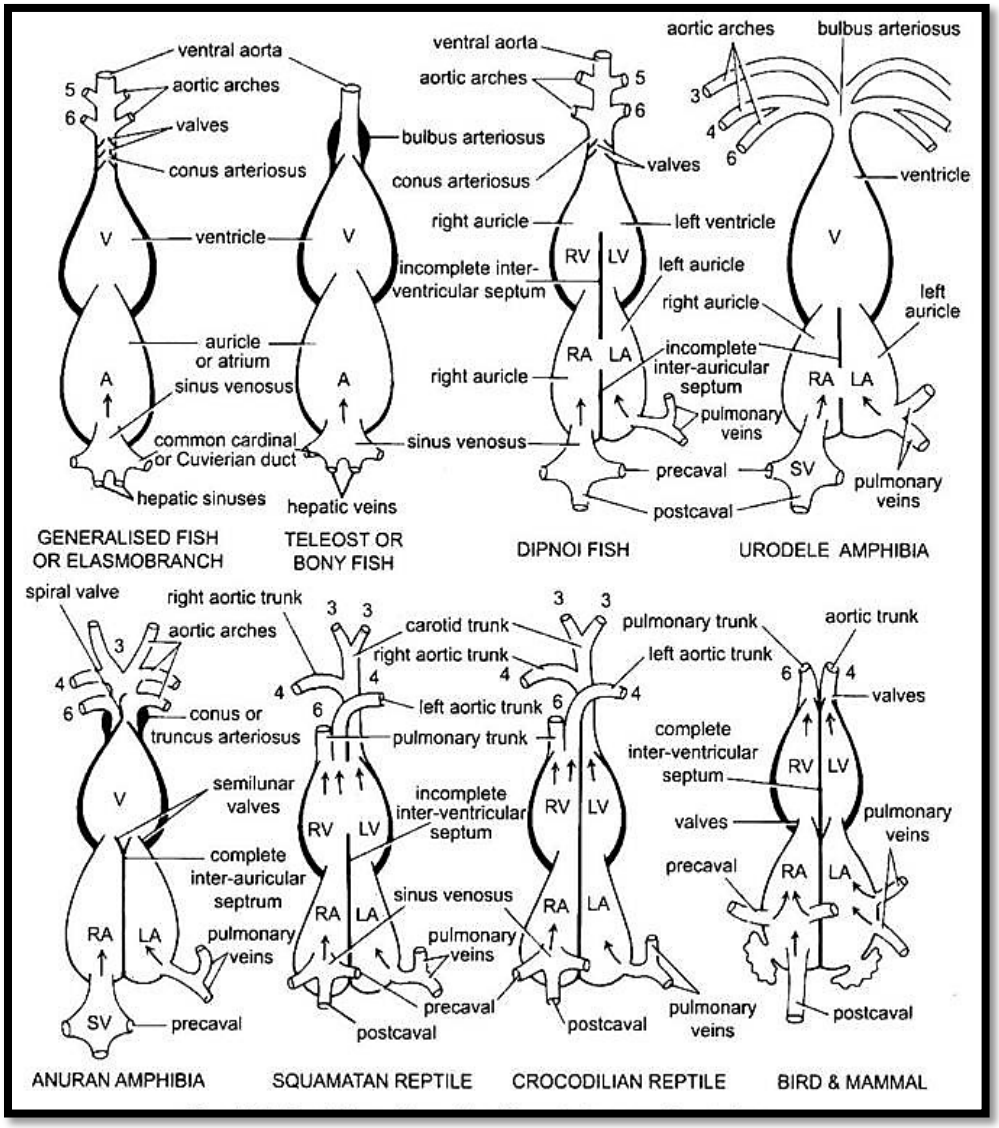


Fig 11.18: Evolution of heart in different vertebrates(https://www.faunafondness.com/comparative-anatomy-of-hearts-of-vertebrate/).

Modifications of Aortic Arches in Vertebrates:

Basic arterial channel in a typical vertebrate embryo includes a ventral aorta, a dorsal aorta and usually 6 pairs of aortic arches connecting ventral aorta with the dorsal aorta. Blood leaves the heart through ventral aorta which runs forward, midventrally beneath the pharynx and branches anteriorly into a pair of external carotid arteries into head whereas ventral aorta gives off 6 pairs of

aortic arches running through the visceral arches. Each aortic arch consists of a ventral afferent branchial artery carrying venous blood to capillaries in a gill and a dorsal efferent branchial artery taking arterial blood from the gill. All the efferent branchial arteries of the same side dorsally join a lateral dorsal aorta or radix which is extended into head as the internal carotid artery. The two lateral dorsal aortae unite just behind the pharynx to form a single median dorsal aorta which continues behind into tail region as caudal artery.

The variation and complexity in the heart and the aortic arches are due to shift from gill respiration to lung respiration. The modifications mainly concern the aortic arches which undergo a progressive reduction in number from lower to higher vertebrates.

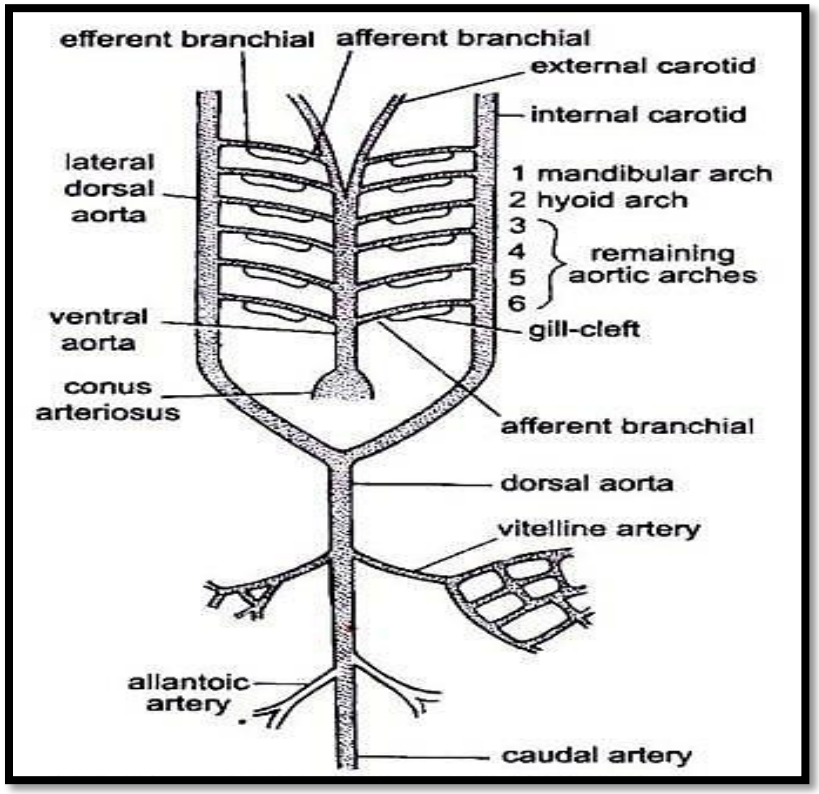


Fig 11.19: Embyonic aortic arches and arteries

(https://www.notesonzoology.com/vertebrates/circulatory-system-in-vertebrates-with-diagram-chordata-zoology/9063).

- **In Branchiostoma** (*Amphioxus*): Approximately 60 pairs of aortic arches are present that connect the ventral and dorsal aortae.
- **In *Petromyzon*:** 7 pairs of aortic arches are found whereas in other cyclostomes the number varies from 6 in *Myxine*) to 15 pairs in *Eptatretus*.
- **In Fishes:** The primitive elasmobranch such as *Heptanchus* has 7 pairs of aortic arches. Most of the fish embryos present the primitive plan with 6 or more pairs of aortic arches each passing through a gill. As the fishes move to adult stage the number is reduced to 4 or 5. In most sharks only 5 pairs: II, III, IV, V, and VI are functional. The first gill slit forms the spiracle which is non-functional as a gill. Accordingly the first arch (mandibular) is absent or represented by an efferent pseudobranchial artery. In most teleosts or bony fishes, only 4 pairs (III, IV, V and VI) remain functional whereas the first two: I and II arches tend to disappear.

  In Dipnoi, gills are poorly developed so that a pulmonary artery arises from the efferent part

of the VI arch on each side and supplies blood to the developing air bladder or lung. In *Protopterus* III and IV embryonic arches are uninterrupted by gill capillaries. In teleosts or bony fishes, each gill has one afferent and one efferent artery.

- **In Amphibians:** I and II arches totally disappear in all tetrapods. In tetrapods true internal gills are absent so that aortic arches do not break up into afferent and efferent arteries. With the introduction of lungs as main respiratory organs and the diminishing importance of gills, the aortic arches of amphibians show a modification from those of fishes. Urodeles or the tailed amphibians live in water and retain external gills permanently in addition to lungs. Accordingly, their aortic system shows only partial shift from condition in fishes. III, IV,V and VI aortic arches (4 pairs) are usually present, although in some forms such as *Necturus*, *Siren* etc. theVth arch is incomplete, reduced or absent. Therefore tailed amphibians show variation from 4 to 3 pairs of aortic arches. Ill arch forms the carotid arches, IV the systemic arches. The radix or lateral aorta between III & IV arches may persist as a vascular connection termed ductus caroticus. VI arch on either side becomes the pulmocutaneous artery or arch, supplying blood to skin and lungs.

  In the larval stage of an anuran or tailless amphibian due to gill respiration the arrangement of aortic arches is similar to an adult urodele. As the larva metamorphoses the gills are lost therefore aortic arches I, II and V disappear altogether. Ductus caroticus also disappears so that the III or carotid arch takes oxygenated blood only to head region. IV or systemic arch on each side continues to dorsal aorta to distribute blood elsewhere except head and lungs. Ductus arteriosus also disappears so that VI or pulmocutaneous arch supplies venous blood exclusively to lungs and skin for purification. Thus, adult anurans exhibit only 3 functional arches (III, IV and VI) which are also retained by the amniotes or higher vertebrates.

- **In Reptiles**: Reptiles are fully terrestrial vertebrates and therefore the gills disappear altogether and are replaced by lungs. Only 3 functional arches (III, IV and VI) are present. But elongation of neck, posterior shifting of heart and partial division of ventricle brings about certain modifications in the aortic system such as: the entire ventral aorta and conus split forming only 3 trunks-two aortic or systemic and one pulmonary; Right systemic arch (IV) arises from left ventricle carrying oxygenated blood to the carotid arch to be sent into head; Left systemic arch (IV) leads from right ventricle carrying deoxygenated or mixed blood to the body through dorsal aorta; Pulmonary trunk (VI) also emerges from right ventricle carrying deoxygenated blood to the lungs for purification; Ductus caroticus and ductus arteriosus are absent. This ductus caroticus is present in certain snakes and lizards (*Uromasitx*), ductus arteriosus in some turtles, and both in *Sphenodon*.

- **In birds and mammals:** In birds and mammals the chambers are completely separated and therefore there is no mixing of oxygenated and deoxygenated blood. As usual, 6 arches develop in the embryo which is reduced to only 3 arches (III, IV, VI) in the adult. Other features include:

  - Replacement of ventral aorta by two independent aortae or trunks-systemic and pulmonary.
  - Arch III with remnants of lateral and ventral aortae represents carotid arteries, which arise from systemic aorta.
  - Aortic arch IV is represented by a single systemic aorta, right in birds and left in mammals emerging from left ventricle and carrying oxygenated blood.
  - The only remaining part of the other lost systemic arch is represented by a subclavian

artery, on left side in birds and on right side in mammals.

- Aortic arch VI forms a single pulmonary trunk taking deoxygenated blood from right ventricle to the lungs.
- Embryonic ductus caroticus and ductus arteriosus also disappear.

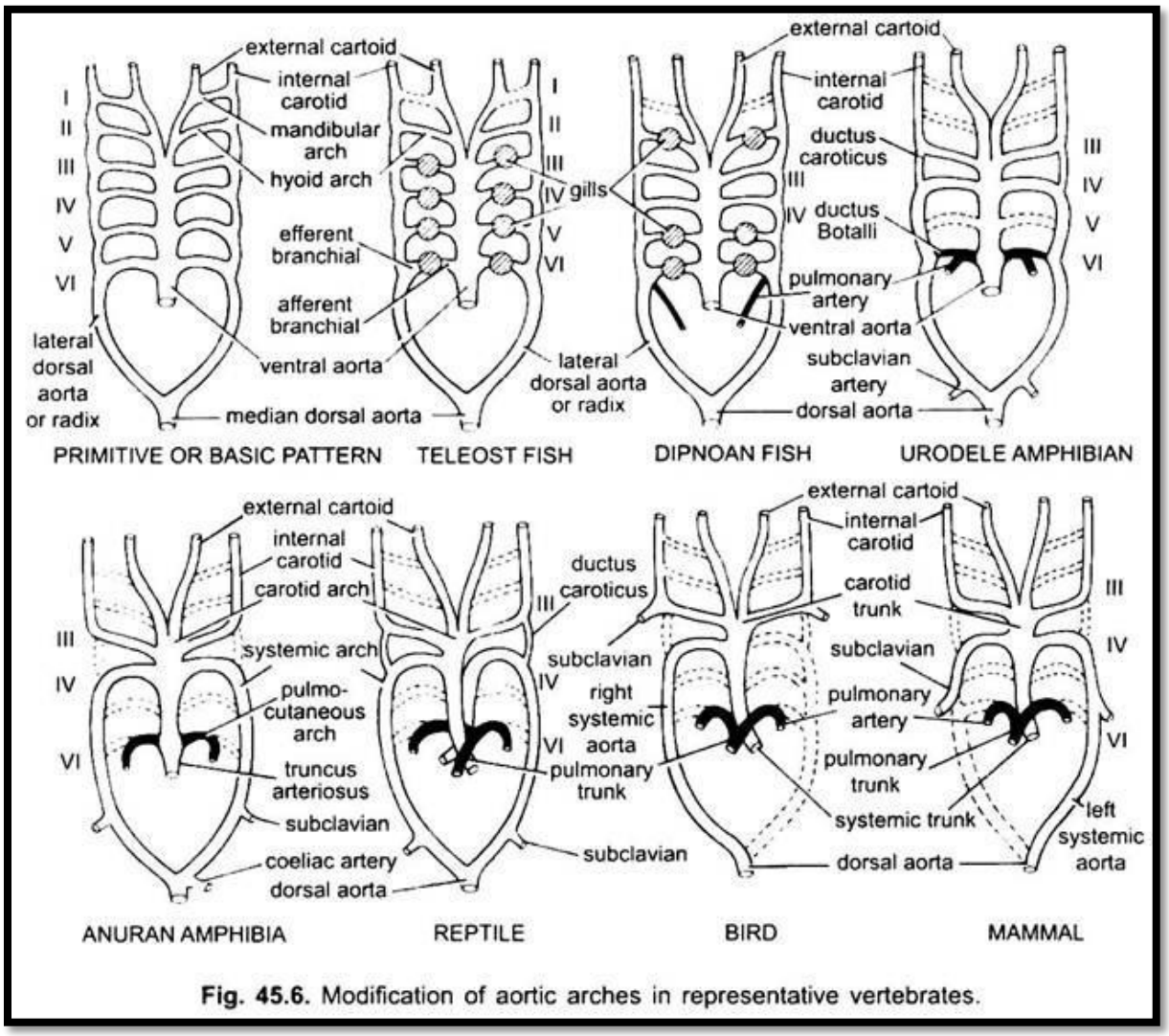


Fig. 45.6. Modification of aortic arches in representative vertebrates.

Fig 11.20: Modification of aortic arches in vertebrates

(https://www.faunafondness.com/comparative-anatomy-of-hearts-of-vertebrate/).

Characters	FISH Dogfish *(Scoliodon)*	AMPHIBIA Frog *(Rana)*	REPTILIA Lizard *(Uromastix)*	AVES Pigeon *(Columba)*	MAMMALIA Rabbit *(Oryctolagus)*
1. Position of heart in body	Heart lies mid-ventrally beneath pharynx in pericardial cavity separated from peritoneal cavity by a partition, called *septum transversum*, perforated by a *pericardio-peritoneal canal.*	Heart lies mid-ventrally beneath oesophagus in thoracic cavity. Septum transversum is absent.	Heart lies mid-ventrally above sternum in thoracic cavity. There is no septum transversum.	Heart lies mid-ventrally in thoracic cavity surrounded by lobes of liver.	Heart lies enclosed in a median pericardial cavity of thorax, between the pleural cavities containing lungs.
2. Pericardium	Heart lies protected within a 2-layered membranous *pericardium.*	Heart lies enclosed by a thin, transparent, 2-layered sac, the *pericardium.*	Heart lies protected within a 2-layered, thin, transparent sac, the *pericardium.*	Heart enclosed by a thin, 2-layered, transparent, membranous sac, the *pericardium.*	Heart completely surrounded by a 2-layered membranous sac, the *pericardium.*
3. Size, shape and colour	Small, S-shaped, dorso-ventrally bent and raddish brown.	Small, somewhat conical or triangular and reddish in colour.	Small, roughly triangular and reddish in colour.	Comparatively larger, conical in shape and reddish in colour.	Larger pear-shaped and reddish in colour.
4. Chambers	Consists of a linear series of 4 chambers : sinus venosus, auricle, ventricle and conus, all distinguished externally. But only auricle and ventricle are true chambers, hence *2-chambered.*	*3-chambered*, made of 2 auricles and 1 ventricle. Auricles not demarcated externally. Besides, sinus venosus and truncus arteriosus also present.	*3-chambered*, made of 2 auricles and one incompletely divided ventricle, all faintly demarcated externally. Sinus venosus also present.	*4-chambered*, made of 2 auricles and 2 ventricles. Ventricles not distinguishable externally.	*4-chambered*, made of 2 auricles and 2 ventricles, all distinguishable externally.
5. Sinus venosus	Triangular, extending transversely over posterior region of ventricle and fused with pericardial wall. Receives venous blood from body by two *ducti Cuvieri* laterally and two *hepatic sinuses* posteriorly.	Triangular, dark coloured, attached dorsally over auricles and ventricles. Receives venus blood by 3 venae cavae : two anterior *precavals* and one posterior *postcaval*, joining at its angles.	Sinus venosus is large, bilobed, attached transversely to dorsal surface of auricles. Formed by the union of 2 *precavals* and 1 *postcaval.*	Sinus venosus absent, said to be incorporated into right auricle. Thus 3 caval veins open directly into right auricle.	Sinus venosus absent and merged into right auricle. Their union marked externally by a groove, *sulcus terminalis*, and internally by a muscular ridge, crista terminalis. 3 venae cavae open directly into right auricle.
6. Sinus-atrial aperture	Sinus opens into posterior end of auricle by a sinuatrial aperture guarded by a pair of membranous *valves.*	Sinus opens into dorsal wall of auricle by a large, oval, sinu-atrial aperture guarded by a pair of flaplike *valves.*	Sinus opens into right auricle through an oval aperture with muscular *lips* and *without valves* according to Bhatia. (1929).	Sinus venosus absent. However, opening of postcaval into right auricle guarded by a muscular *Eustachian valve.*	Sinus venosus absent. However, opening of postcaval into right auricle guarded by a rudimentary *Eustachian valve.*
7. Atria or auricles	Atrium or auricle somewhat triangular. Undivided internally due to lack of an *interauricular* septum.	Auricles somewhat rectangular. Do not form auricular appendages. Internally divided completely into right and left auricles by an *inter-auricular septum.*	Two auricles divided completely by an *inter-auricular septum.* Right auricle gives off a small *diverticulum* from its dorsal antero-medial surface.	Two auricles divided by an *inter-auricular septum.* Dorsal anteromedial diverticulum absent.	Two auricles completely separated by an *inter auricular septum.* Right auricle without diverticulum.

8. Atrial wall	Thin-walled, spongy, moderately muscular.	Thin walled, without muscular processes.	Thin-walled, inner lining forming a network of low muscular ridges.	Comparatively thick-walled with inner surface raised into muscular ridges.	Comparatively thick walled. Inner surface raised into a network of muscular ridges called *musculi pectinati*.
9. Auricular appendix	Each auricle laterally projects beyond ventricle as ear like *auricular appendages*.	Absent	Absent	Absent	Each auricle produced behind into a swollen flap, the *auricular appendix*, slightly covering the ventricle of its side.
10. Pulmonary veins	Absent and therefore do not open into auricle.	A common pulmonary vein opens into left auricle.	A common pulmonary vein opens into left auricle	Four pulmonary veins open by a common aperture into left auricle.	Two pulmonary veins open by a common opening into left auricle.
11. Auriculo-ventricular aperture & valves	Atrium opens into ventricle through its dorsal wall by a single auriculo-ventricular aperture guarded by a pair of membranous valves.	Both auricles open into ventricle posteriorly through a common large auriculo-ventricular aperture guarded by 2 pairs of flaplike valves.	Both auricles communicate behind with ventricle through separate right and left auriculo-ventricular apertures due to backward extension of interauricular septum into ventricle, each guarded by a valve of one semilunar flap.	There are two separate circular auriculo-ventricular apertures. Right valve is made of a large muscular fold, while left valve is *bicuspid*, made of two membranous flaps.	There are two separate auriculo-ventricular apertures. Right aperture is guarded by a *tricuspid valve* made of 3 triangular flaps or cusps, while left *bicuspid* or *mitral valve* consists of 2 flaps only.
12. Ventricles	Small, pearshaped thickwalled undivided chamber lying ventral to sinus and auricle. *Interventricular septum* not found.	Small, conical, thick-walled undivided chamber lying posterior to auricles. No *interventricular septum*.	Small, conical thickwalled chamber lying behind auricles. Incompletely divided by a prominent oblique *muscular ridge* or septum into a larger dorsal part, *cavum dorsale*, and a smaller ventral part, *cavum pulmonale*.	Two right and left, large, thick-walled ventricles, completely separated by a vertical *interventricular* septum.	Two large and thick-walled right and left ventricles completely separated by a vertical *interventricular septum*.
13. Chordae tendineae	Cavity of ventricle traversed by numerous muscular strands, *chordae tendineae*, giving it a spongy texture.	Flaps of auriculo - ventricular valve attached to wall of ventricle by thread like *chordae tendineae*.	Free edges of auriculo – ventricular valves attached to inner wall of ventricle by firm cords, the *chordae tendineae*.	Flaps of auriculo - ventricular valves attached to papillary muscles by *chordae tendineae*	Free edges of valvular flaps connected to papillary muscles by long, tough connective tissue strands, *chordae tendineae*.
14. Columnae carneae	Absent	Irregular strands or ridges given from inner wall of ventricle.	Prominent ridges raised from inner surface of wall of verticle.	Bars of muscles traversing cavities of ventricles.	Small irregular muscular ridges projecting from wall of ventricles.
15. Papillary muscles	Absent	Absent	Absent	These are prominent muscular projections from inner wall of ventricles.	These are large, conical, nipple-shaped muscular elevations from inner wall of ventricles.

16. Conus or truncus arteriosus	Conus arteriosus is a stout, undivided, muscular tube given anteriorly by ventricle. Its cavity contains 2 rows of 5 a semilunar valves each, 3 larger and 2 smaller. *Spiral valve* absent.	Truncus arteriosus is a pear-shaped tube arising anteriorly from right ventral side of ventricle. It's cavity is divided by 3 semilunar valves into a distal chamber, *synangium* and a proximal chamber, *pylangium*. Latter is further divided by a *spiral valve* into *cavum pulmocutaneum* and *cavum aorticum*.	Conus or truncus arteriosus absent.	Conus or truncus arteriosus absent.	Conus or truncus arteriosus absent.
17. Aortic arches	Conus leads anteriorly into a *ventral aorta* which gives off 5 pairs of lateral arotic arches.	Truncus bifurcates anteriorly into right and left trunks each dividing into 3 aortic arches : *common carotid*, *systemic* and *pulmocutaneous*. Ventral aorta absent.	Ventral aorta absent. 3 aortic arches arise directly from ventricle : *pulmonary* from cavum pulmonale and *right* and *left systemic* from cavum dorsale.	Ventral aorta absent. Only 2 aortic arches arise : *pulmonary* from right ventricle and *right systemic* leaving left ventricle.	Ventral aorta absent. Only 2 aortic arches present : *pulmonary* arising from right ventricle and *left systemic* from left ventricle.
18. Foramen Panizzae	Absent	Absent	Present at the point of contact where two systemic arches cross each other.	Absent.	Absent

Fig 11.21: Comparative anatomy of heart in different vertebrates(https://www.faunafondness.com/comparative-anatomy-of-hearts-of-vertebrate/).

11.4 SUMMARY

- Skeleton is the hard tissue of the body that provides physical support, imparts shape. Skeletal system in vertebrates can be divided into axial and appendicular bones.
- Vertebral column of fishes comprises only trunk and caudal vertebrae.
- In tetrapods, vertebral column includes five regions viz: cervical,thoracic, lumbar, sacral and caudal, each having usually several vertebrae. Amphibians have a single cervical (atlas) and only one sacral (9th) vertebra.
- Vertebrae differ in different vertebrates or even in different regions of the same vertebrate, but all vertebrae are built according to a similar basic pattern and structure having a cylindrical, spool-like body or centrum, however, the centrum varies among the vertebrates such as amphicoelous is found in most fishes and tailed amphibians, heterocoelus in birds, acoelus in mammals etc.
- Circulatory system comprises of heart, veins and arteries and is responsible for circulation of oxygen and digested food material across body and removal of waste (carbon dioxide).
- The heart varies across vertebrates from being 2 chambered in cyclostomes and teleost fishes, 3 chambered heart in dipnoi, amphibia and most reptiles to 4 chambered heart in birds and reptiles. Mixing of deoxygenated and oxygenated blood is avoided in birds and mammals due to complete partition of right and left atrium and ventricle.
- There is also modification in aortic arches across vertebrate group. The number of aortic arches is more in primitive and lower vertebrates and they decrease as we move from fishes to mammals.

11.5 TERMINAL QUESTION

Q1. Give a comparative account of axial sketetal system in vertebrates.

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Q2: Write a note on appendicular skeletal system in different vertebrates.

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Q3. What is circulatory system? Elaborate on the modification of aortic arches in different vertebrates.

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Q4: Comment upon heart in different vertebrates.

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Q5. Multiple Choice questions:

i) Birds have:

a) Acoelus centrum

b) Heterocoelus centrum

c) Amphicoelus centrum

d) Procoelus centrum

ii) Craniostylic jaw suspension is found in:

a)Fishes

b) Reptiles

c) Birds

d)Mammals

iii)Amphibia have:

a) Monocondylic skull

b) Dicondylic skull

c) Acondylic skull

d) Tricondylic skull

iv) Crocodyle has:

a) 2 chambered heart

b) 3 chambered heart

c) 4 chambered heart with partial mixing of blood

d) 4 chambered heart with complete separation

v) Number of aortic arches in adult mammals is:

a) 3

b) 4

c) 5

d) 6

11.6 ANSWERS

Q5: i) b, ii) d, iii) b, iv) c, v) a

UNIT-12 : COMPARATIVE ANATOMY OF EXCRETORY SYSTEM, REPRODUCTIVE SYSTEM

(Urinogenital System)

12.1 Introduction

Objectives

12.2 Comparative anatomy of Excretory system

12.3 Comparative anatomy of Reproductive system

12.4 Summary

12.5 Terminal Question

12.6 Answers

12.1 INTRODUCTION

The metabolic wastes produced within the body include carbon dioxide, ammonia, urea, uric acid, inorganic salts etc. These excretory wastes are removed from body through a system called as excretory system (urinary system) wherein carbon dioxide is removed from skin, gills and lungs while other excretory substances are removed by kidneys. In vertebrates, there is pair of kidneys lying on the dorsal to coelom in the abdomen region on either side of vertebral column. Structural and functional unit of kidney is known as nephrons (uriniferous tubules) whose structure, number ad arrangement varies in different vertebrates. The nephrons in embryo arises from a special part of mesoderm known as mesomere or nephrotome. Nephron is differentiated into three parts namely peritoneal funnel, Malpighian body and tubule. Peritoneal funnel is a funnel like ciliated structure present near the free end of a nephron.Near the free end of a uriniferous tubule is a funnel-like ciliated structure called peritoneal funnel. Malpighian body consists of a cup-like, hollow, double-walled structure also known as Bowman's capsule. It encloses a tuft of blood capillaries called glomerulus and is supplied blood by a branch of renal artery called afferent arteriole while an efferent arteriole emerges out of glomerulus to join the capillary network surrounding the tubule. Bowman's capsule and enclosed glomerulus together form a renal corpuscle or Malpighian body. Malpighian bodies filter water, salts and other substances from blood. Further they are directed to tubules where more substances are secreted into filtrate, while some are reabsorbed. All the tubules of embryonic kidney are convoluted ductules that conduct the final filtrate to a longitudinal duct which opens behind into embryonic cloaca.

Reproductive system comprises of gonads that are responsible for release of gametes that fuse to form zygote. Gonads comprise of a paired testis in males and ovaries in females. All vertebrates are dioecious (male and females sexes are separate) except the hermaphrodite cyclostomes and a few bony fishes. Reproductive glands or gonads of males (testes) produce the male gametes called sperm while female gonads (ovaries) produce ova. In the embryo, gonads originate as a pair of thick elevated folds or genital ridges of coelomic epithelium from the roof of coelom, one on either side of the dorsal mesentery. Genital ridges are much longer than the functional adult gonads indicating that in the ancestral vertebrates the gonads extended the whole length of the pleuroperitoneal cavity. Gonads remain suspended in coelom from dorsal bodywall by a fold of dorsal mesentery, called mesorchium in males and mesovarium in females.

Urinary system of vertebrates includes kidneys and their ducts, while reproductive system includes male and female gonads and their ducts. Kidneys help in removal of metabolic wastes and regulate the composition of body fluids, while reproductive organs helps in propagating the species.

The two systems however remain functionally unrelated but are intimately related morphologically in vertebrates because the male urinary ducts are also used for discharging gametes. For this reason, it is more convenient to consider and study the two systems together as the urogenital or urinogenital system.

Objectives:

After studying this unit you will be able to:

- Explain the excretory/urinary system in vertebrates
- Explain the reproductive system in different vertebrates
- Understand the concept of urinogenital system as a whole
- Discuss the comparative anatomy of urinogenital system in vertebrates

12.2 COMPARATIVE ANATOMY OF EXCRETORY SYSTEM

Kidneys and ducts form the basis of excretory system in vertebrates. In vertebrate, kidneys are a pair of compact organ, lying dorsal to coelom in trunk region, one on either side of dorsal aorta. Each kidney is composed of a large number of units called uriniferous tubules or nephrons.

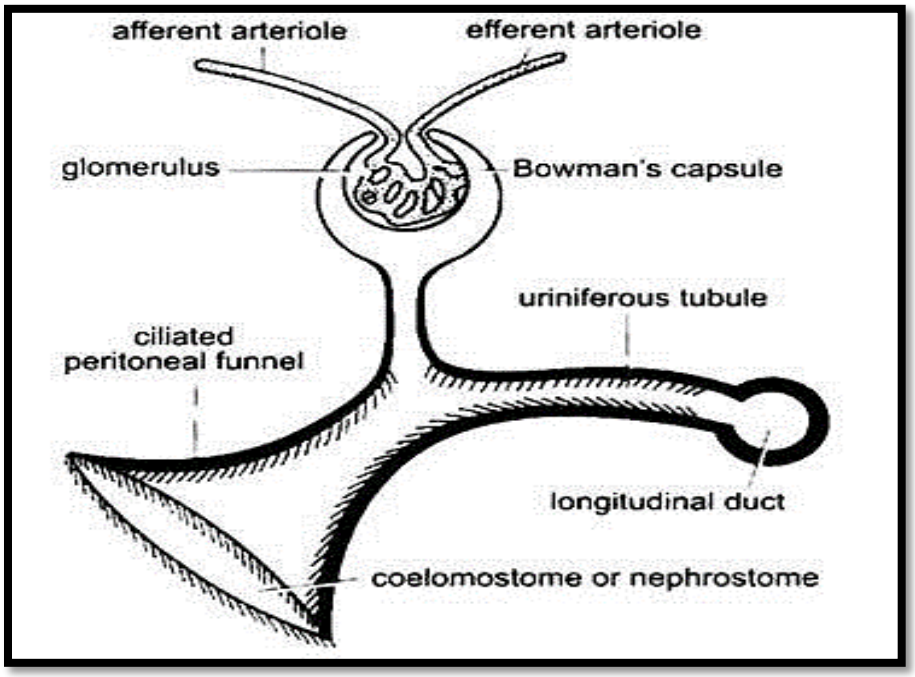


Fig 12.1: Structure of embryonic kidney tubule (https://www.notesonzoology.com/vertebrates/vertebrate-kidneys-and-ducts-with-diagram-chordata-zoology/8717).

Archinephros: This is regarded as hypothetical primitive kidney of ancestral vertebrates. It extends along the entire length of coelom therefore are referred to as complete kidney or holonephros. Its tubules are segmentally arranged, one nephron for each body segment. Each tubule opens by a peritoneal funnel or nephrostome into coelom. External glomerulus without capsule is suspended in coelom near each nephrostome. All the tubules are drained by a common longitudinal Wolffian or archinephric duct opening behind into cloaca. At present it is found in the larvae of certain cyclostomes (*Myxine*), but absent in any adult vertebrate. It is propounded that this type of kidney gave rise to all the other types kidneys in vertebrates during the course of evolution.

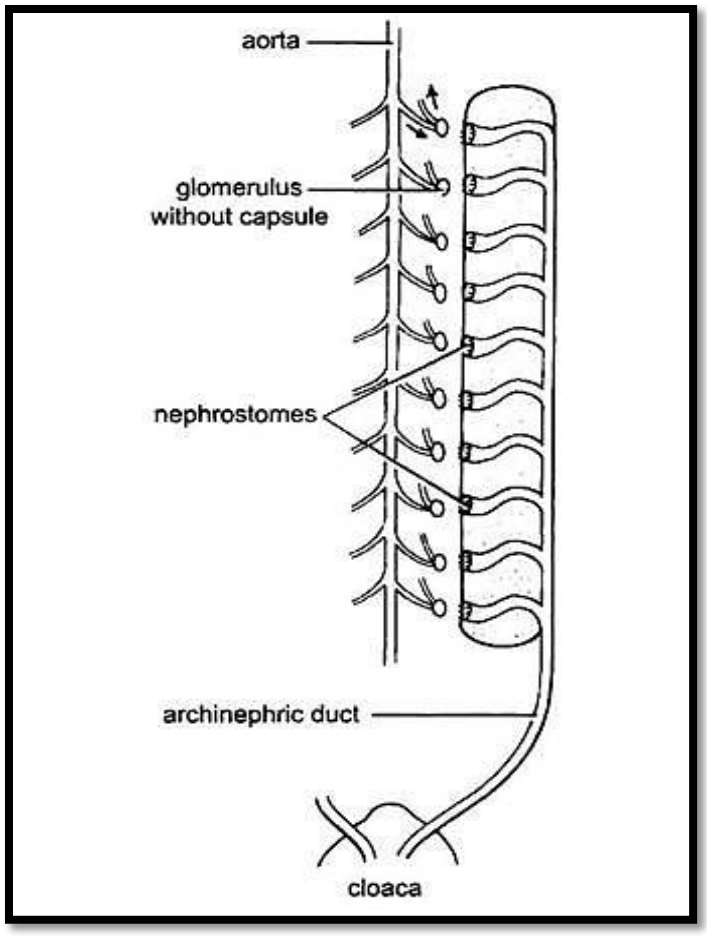


Fig 12.2: Archinephros kidney(https://www.notesonzoology.com/vertebrates/vertebrate-kidneys-and-ducts-with-diagram-chordata-zoology/8717).

Modern vertebrates exhibit three different types of adult kidneys namely pronephros, mesonephros and metanephros

- **Pronephros**: In the embryos of all vertebrates, the first kidney tubules appear dorsal to the anterior end of coelom, on either side are called pronephros as they are first to appear. It is also known as head kidney because of its anterior position immediately behind the head. A pronephros kidney consists of 3 to 15 tubules segmentally arranged, one opposite each of the anterior mesodermal somites. There are only 3 pronephric tubules in frog embryo, 7 in human embryo and about a dozen in chick embryo. Each tubule opens into coelom by a funnel or nephrostome. In some cases, glomeruli unite to form a single compound glomerulus, called glomus. Glomus and tubules become surrounded by a large pronephric chamber derived from pericardial or paraperitoneal cavity. Originally each tubule has its individual external aperture, but secondarily all tubules of a pronephros open into a common pronephric duct, leading posteriorly into the embryonic cloaca. ***Pronephros is functional, if at all, only in embryonic or larval stage, however it is retained throughout life in adult cyclostomes and a few teleost fishes, but it is nonurinary and mostly lymphoidal in function***. It is soon replaced by the next stage or mesonephros.
- **Mesonephros**: In the embryo, a mesonephros develops from the middle part of intermediate mesoderm, posterior to each pronephros soon after its degeneration. At first, the new mesonephric tubules join the existing pronephric duct and are segmentally disposed. Later on the tubules multiply by budding so that their segmental arrangement is disturbed due to

increased number of tubules per segment. Tubules of pronephros and mesonephros develop similarly and are homologous. However, mesonephros is functionally better than pronephros because mesonephric tubules are more numerous, longer and develop internal glomeruli enclosed in capsules forming Malpighian bodies. Thus, they remove liquid wastes directly from glomerular blood rather than indirectly from coelomic fluid as in case of a pronephros. The mesonephros is also termed Wolffian body. With disappearance of pronephros, the old pronephric duct becomes the Wolffian or mesonephric duct. ***In reptiles, birds and mammals mesonephric kidney is functional only in the embryos and is replaced by metanephric kidney in the adults. In fishes and amphibians, mesonephros is functional both in embryos as well as adults.*** Nephrostomes are generally lacking in mesonephros of embryonic amniotes. In sharks and caecilians, tubules extend posteriorly throughout the length of coelom and are sometimes called a posterior kidney or opisthonephros. In adult anurans, urodeles and embryonic amniotes the mesonephros does not extend posteriorly. Mesonephric kidney is not metameric, but in myxinoids it is segmental and sometimes called a holonephros.

- **Metanephros:** The functional kidney of higher vertebrates or amniotes is a metanephric kidney. It is formed from the posterior end of the nephrogenic mesoderm which is displaced somewhat anteriorly and laterally. When metanephric tubules develop, all the mesonephric tubules disappear except those associated with the testis in male and forming vasa efferentia.

  The adult metanephric kidney of amniotes differs from that of mesonephric or opisthonephric in anamniotes chiefly on the following basis:

  - In its origin from only caudal end of nephrogenic mesoderm
  - In greater multiplication and posterior concentration of nephrons or tubules. They are particularly very large in number and highly convoluted in birds and mammals contributing to large size of kidney. Each kidney of man is estimated to be composed of about 1 million nephrons. The high rate of metabolism yields a large amount of wastes to be excreted.
  - In developing a new urinary duct, called metanephric duct or ureter. It is budded off from the base of the Wolffian duct and grows anteriorly and dorsally, and eventually the metanephric tubules open into it. Its dilated distal tip forms pelvis which forks several times to become the collecting tubules. Its proximal portion becomes the metanephric duct or ureter that empties into cloaca or urinary bladder in mammals.
  - The mammalian metanephros shows greatest organization of all, with several additional features. A thin, **U-shaped loop of Henle** forms between proximal and distal convolutions of a metanephric tubule which are absent in reptiles and rudimentary in birds. Kidney shows an outer cortex with concentration of renal corpuscles and an inner medulla having collecting tubules and loops of Henle, which are aggregated into Urinogenital System in vertebrates one or several pyramids tapering into pelvis. Mammalian kidneys do not receive afferent venous blood supply as there is no renal portal system.

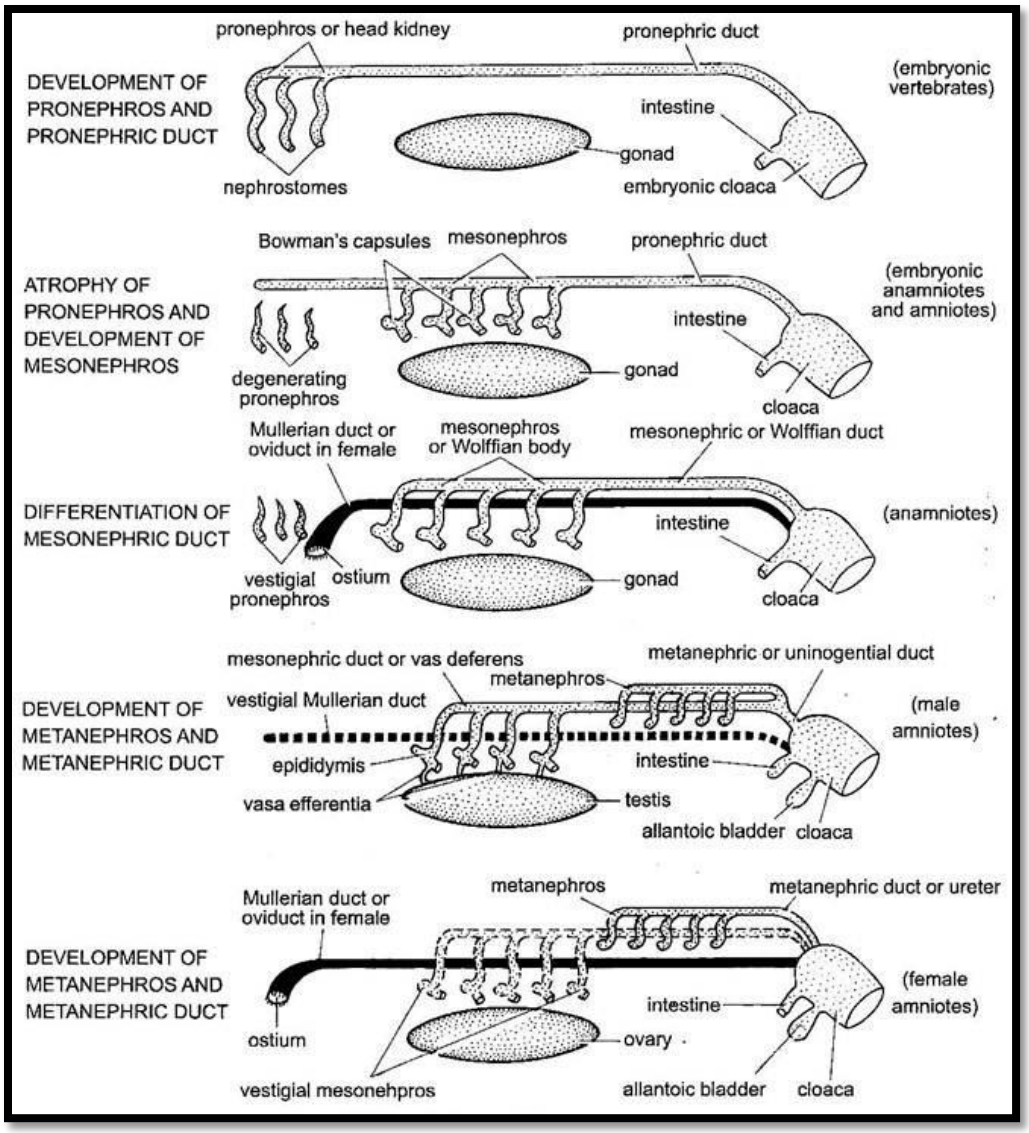


Fig 12.3: Evolution of kidney in vertebrates(https://www.notesonzoology.com/vertebrates/vertebrate-kidneys-and-ducts-with-diagram-chordata-zoology/8717).

Urinary Bladders in Vertebrates: Urinary bladder can be considered as bag like structure that is found in many vertebrates for storing urine before it is discharged.

- **In cyclostomes, elasmobranchs, some lizards, snakes, crocodilians and most birds:** Urinary badder is absent.
- **In most fishes and Dipnoi:** In most fishes it is simply a terminal enlargement of mesonephric ducts and called a tubal bladder whereas in Dipnoi it evaginates from dorsal wall of cloaca and is probably homologous to the rectal gland of elasmobranchs.
- **In Amphibians:** Urinary bladderin tetrapods evaginates from the ventral wall of cloaca and is termed a cloacai bladder in amphibians.
- **In Mammals:** In amniotes, the adult bladder is derived from the proximal part of embryonic allantois, hence called an allantoic bladder. Kidney ducts or ureters generally open dorsally into cloaca. But in mammals, except monotremes, the ureters lead directly into the urinary bladder which opens to outside through a short tube, the urethra. Mammals lack a cloaca as the dorsal part of embryonic cloaca forms the rectum and the ventral part becomes the

urethra.

12.3 COMPARATIVE ANATOMY OF REPRODUCTIVE SYSTEM

In vertebrates sexual reproduction is observed which involves the role of gonads and their associated ducts. In vertebrates the sexes are separate (dioecious) with the exception of hagfishes and a few bony fishes having a hermaphrodite gonad. Generally there is presence of one pair of gonads but some vertebrates have a single gonad only because of either fusion of both embryonic genital ridges (most cyclostomes, perch and some other fishes) or degeneration of one juvenile gonad (hagfishes, some elasmobranchs and lizards, alligators and most birds). Gonads are usually associated with special gonoducts or genital ducts such as vasa deferentia in males and oviducts in females These genital ducts transport gametes to cloaca or to outside body. Genital ducts are absent in cyclostomes and a few elasmobranchs. Their eggs and sperm escape body cavity via abdominal pores. The gonad and genital ducts in male and female have been discussed below:

Testes and male genital ducts: Testes of vertebrates are paired organs of moderate size usually found attached to kidneys. Each testis is a compact gland covered by coelomic epithelium and composed of numerous highly coiled seminiferous tubules embedded in connective tissue. Tubules are lined by germinal epithelium which gives rise to billions of sperm. Once the sperm matures, they are set free in the lumen of tubules which moves towards the genital ducts.

- **In Cyclostomes:** They have single median testis without a genital duct. Sperms are released in the coelom from where they pass through abdominal pore located at posterior part of coelom. In dogfish, the two testes are elongated bodies.
- **In fishes:** In most anamniotes the opisthonephros (or mesonephros) is differentiated into anterior genital and posterior renal portions. In the anterior genital portion in males, some uriniferous tubules lose excretory function, form slender vasa efferentia and become continuous with seminiferous tubules of the adjacent testis. They serve to convey sperm of testis to the mesonephric duct of kidney. Thus, in male anamniotes, mesonephric or wolffian duct forms a urinogenital duct, serving both as a vas deferens for sperm as well as a ureter for urine.

  In many elasmobranchs such as dogfish accessory urinary ducts pour urine from kidney to cloaca so that the mesonephric duct serves entirely or mainly as a vas deferens. The anterior genital part of kidney along with the part of mesonephric duct forms an epididymis.
- **In Amphibia, Reptiles and Birds:** In the embryos of Anura, each testis is made of two portions. In male frog, the anterior portion disappears and the posterior portion becomes the adult functional testis. In adult male toad, the anterior portion also persists as the Bidder's organ, containing large cells similar to immature ova.

  In male amniotes, a metanephros develops as the adult functional kidney with its own urinary duct or ureter to transport urine. Thus mesonephric or Wolffian duct becomes solely a genital duct or vas deferens. The remnants of embryonic mesonephros and a coiled portion of mesonephric duct become the epididymis of the adult kidney. From each testis sperms pass first through epididymis, then through vas deferens to reach urethra.
- **In Mammals:** In most mammals testes descend permanently into extra-abdominal skin bags called scrotal sacs. In rabbits, bats and rodents, they are lowered into sacs and retracted at will. Passage between abdominal cavity and scrotal sac, through which testis descends, is called inguinal canal. However some mammals such as monotremes, insectivores, elephants, whales, etc., lack scrotal sacs so that their testes remain permanently intra-abdominal like ovaries.

Anamniotes exhibit external fertilization therefore copulatory organs are absentin them whereas in amniotes fertilization is internal therefore preceded by copulation or mating. Male amniotes usually develop copulatory organs for transferring sperm into the genital tract of females during copulation. They are particularly characteristic of reptiles and mammals. In elasmobranchs bases of pelvic fins are modified as copulatory organs called claspers. These are grooved, cylindrical structures that are inserted into the female cloaca to inject sperm. In dog fishes and some allied forms there is blind muscular sac called siphon, located at the base of claspers. This sac gets filled with sea water which is used to force the spermatic fluid into the cloacae of female. In several teleosts, the anal fin is modified as a gonopodium for sperm transport which is modification of anal fin. Snakes and lizards have a pair of retractile, grooved and sac-like hemipenes which can be everted through cloaca. Their retraction is controlled by modified body wall musculature. Turtles, crocodilians, some birds and prototherian mammals have an unpaired, grooved and erectile penis formed as a thickening of cloacal floor. Only higher mammals have a true external, erectile penis with a tubular groove continuous with a spongy urethra. A series of accessory sex glands associated with penis secrete a fluid in which sperm are carried and provide motility to them.

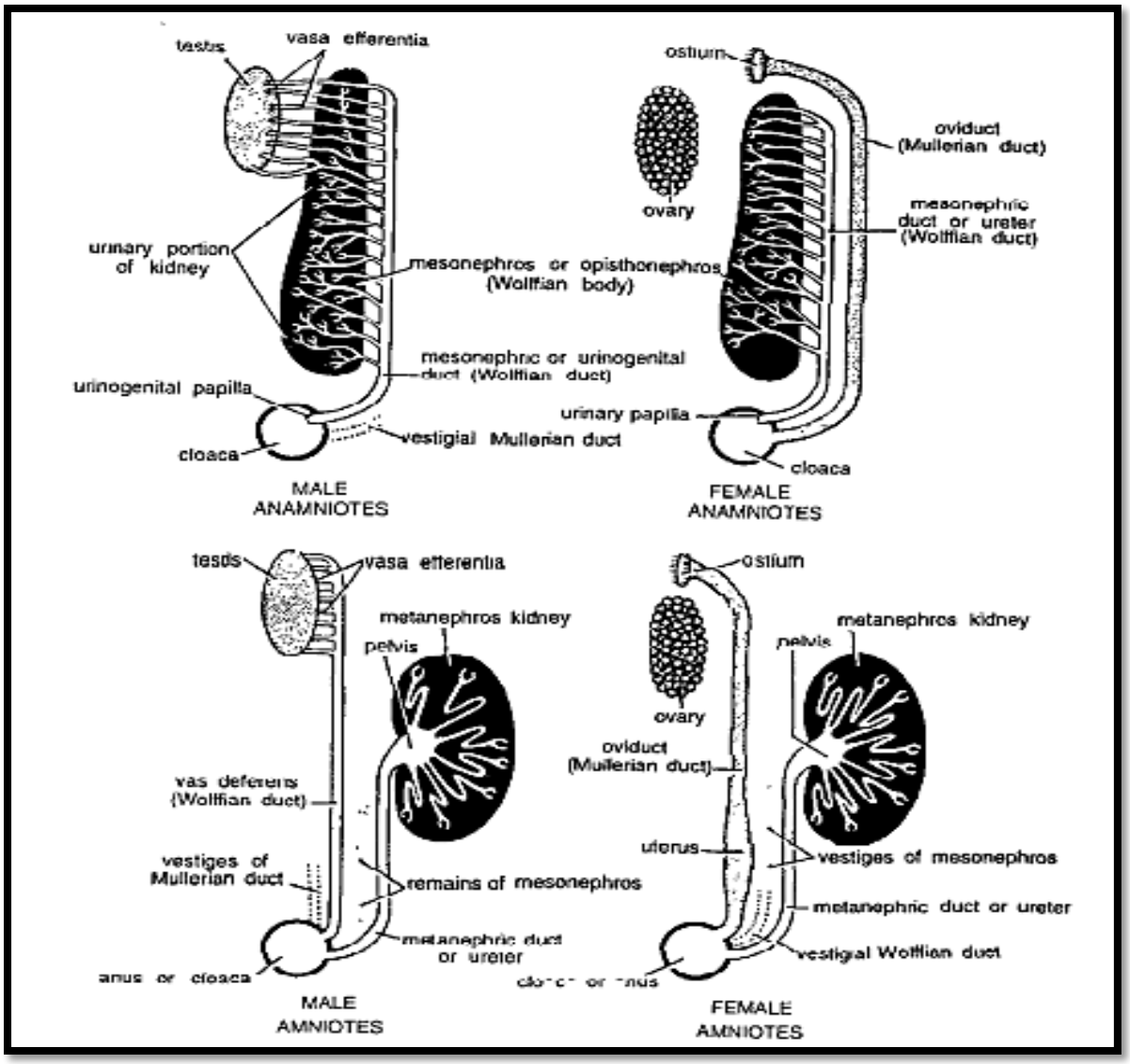


Fig 12.4: Evolution of Urogenital system and ducts in vertebrates(https://www.bioscience.com.pk/topics/zoology/item/776-comparative-anatomy-excretory-system-of-reptile-bird-and-mammal)

Ovaries and female genital ducts:

- **In anamniotes:** The female anamniotes posses large ovaries occupying much of the body cavity and produce thousands of eggs as fertilization is external. Only a single median ovary occurs in cyclostomes, as in some teleosts (e.g. perch). They are not attached to kidneys like testes in the males. Only the right ovary is functional in many elasmobranchs. Ovaries are hollow and saccular in fishes and amphibian. In teleost, mature eggs are released either internally into the central ovarian cavity. In adult female anamniotes, both the Mullerian duct (oviduct) and the Wolffian duct (mesonephric or urinary duct) are present. In female elasmobranchs, the Mullerian duct is formed differently by the longitudinal splitting of the pronephric duct.
- **In amniotes:** Ovaries in amniotes produce fewer eggs because fertilization is internal. Ovaries of reptiles and birds are still large and the eggs produced contain much yolk. However, mammalian eggs contain very little yolk so that their ovaries also remain quite small. Ovaries are generally paired structures whereas only the left ovary becomes mature in birds and some primitive mammals (e.g. *Ornithorhynchus*). Histologically, an ovary is a mass of connective tissue with an outer layer of germinal epithelium showing ova in various stages of development. It is compact in amniotes, especially in mammals in which each ovum is surrounded by a follicle. In tetrapoda, mature eggs are extruded externally into the surrounding coelom or body cavity. This process is termed ovulation. In all vertebrate embryos, except cyclostomes, the coelomic epithelium on the outside of mesonephric duct develops a groove which becomes closed to form a tube called Mullerian duct. In adult males, Mullerian duct becomes vestigial and functionless whereas in adult females, it grows larger and becomes the female genital duct or oviduct. It opens anteriorly into coelom, in the region of degenerating pronephros, by a coelomic funnel or ostium and terminates posteriorly into cloaca.

In adult female amniotes, with the development of adult metanephros and its metanephric duct or ureter, mesonephros and its duct (Wolffian duct) degenerate leaving only vestiges known as provarium. In viviparous mammals, posterior ends of both the Mullerian ducts become fused and are modified into a uterus in which the embryos develop and a vagina which receives the male copulatory organ during copulation. The remaining anterior parts or oviducts are relatively short, narrow and convoluted and called the fallopian tubes.

The condition of uteri varies in different mammals like when uteri remain double without fusion, it is called duplex uterus (marsupials). When uteri partially fuse so as to form two horns and two separate lumens inside it is called bipartite uterus (hamster, rabbit). In ungulates there are two horns with a single internal cavity,it is termed bicornuate uterus. In Primates, some bats and armadillos uterine horns are absent and both uteri fuse completely with a single internal cavity, it is termed simplex uterus.

Characters	FISH Dogfish *(Scoliodon)*	AMPHIBIA Frog *(Rana)*	REPTILIA Lizard *(Uromastix)*	AVES Pigeon *(Columba)*	MAMMALIA Rabbit *(Oryctolagus)*
[I] URINARY AND EXCRETORY SYSTEM					
1. Excretory organs	Include a pair of *kidneys*, a pair of *urinary ducts*, and a *urinogenital sinus*. No bladder.	Include a pair of *kidneys*, a pair of *ureters* a *urinary bladder* and *cloaca*.	Include a pair of *kidneys*, paired *ureters*, a *urinary bladder* and *cloaca*. No bladder.	Include a pair of *kidneys*, a pair of *ureters* and *cloaca*.	Include a pair of *kidneys*, paired *ureters*, a *bladder* and *urethra*
2. Kidneys	Adult kidneys greatly elongated antero - posteriorly, ribbon-like flat, and attached to dorsal abdominal wall. Each kidney has 2 distinct parts Anterior narrow part is *non-excre Tory*, genital in male but non-genital in female. Posterior broader part is functional kidney and called *opistho-nephros*.	Adult kidneys are elongated, oval, flat and attached dorsally one on either side of vertebral column in posterior abdominal cavity. They are not differentiated into parts and are *mesonephric*.	Adult kidneys are small, irregular, attached dorsally and lie in pelvic region at the base of tail. Each kidney is *bilobed*. Anterior broad lobes remains free while posterior narrow lobes become united forming a V-shaped structure. Kidneys are *metanephric*.	Adult kidneys are small, flat, dorsally attached in pelvic region, embedded in hollows of pelvis. Each kidney is *trilobed*, made of anterior, middle and posterior lobes Kidneys are *metanephric*.	Adult kidneys are small, beanshaped and attached much anteriorly and asymmetrically in anterior abdominal cavity. Kidneys are *metanephric* and not divided into lobes.
3. Histology of kidneys	Covered ventrally by *peritoneum*, not differentiated into *cortex* and *medulla* and made of a compact mass of coiled *uriniferous tubules*.	Same as in fishes	Same as in fishes and amphibians.	Kidney covered ventrally by *peritoneum*, differentiated into *cortex* and *medulla* and contains a very large number of *uriniferous tubules*.	Each kidney covered ventrally by *peritoneum*, differentiated into an outer *cortex* and inner *medulla*, and made of much convoluted *uriniferous tubules*.
4. Uriniferous tubules	Have a special urea absorbing segment. Loop of Henle absent.	Lack a urea-absorbing segment and loop of Henle.	Lack urea-absorbing segment and loop of Henle.	Lack urea absorbing segment, but water absorbing loop of Henle present.	Absorb urea through glomerular filteration and tubular reabosrption and also have water absorbing loop of Henle.
5. Peritoneal funnels	Nephrostomes present.	Nephrostomes present.	Nephrostomes absent.	Nephrostomes absent.	Nephrostomes absent.
6. Ureters	Kidney ducts or mesonephric ureters of both sides run over ventral surface of kidney and open into a urinogenital sinus, which leads into cloaca. Ureters open separately in male but by a common aperture on a urinary papilla in female.	Mesonephric ureters arise and run along outer side of kidneys and open behind by separate apertures directly into cloaca. A urinogenital sinus is absent.	Metanephric kidney ducts or ureters run ventrally over kidneys and open dorsally and separately into middle chamber of cloaca, called *urodaeum*. Urinogenital sinus absent.	As in reptiles, ureters are metanephric. They run ventrally over kidneys and open behind separately into urodaeum through its roof. Without pelvis.	Metanephric ducts (ureters) arise from inner middle concavity or hilus of kidney and open dorso-laterally into urinary bladder. Cloaca absent. Ureters begin from a wide funnel-like cavity in kidney, called *pelvis*.

7. Urinary bladder	Absent	A large thin-walled membranous elastic bilobed urinary bladder opens ventrally into cloaca by a sphinctered aperture.	Small, thin-walled, inelastic, undivided sac opening ventrally into coprodaeum of cloaca.	Absent	Large, median, pear-shaped, muscular sac. Its neck, called *urethra*, opens at the tip of penis in male and into vestibule of female which opens to outside through vulva.
8. Nature of excretion	Predominantly ammonotelic because excrete more ammonia than anything else.	*Ureotelic*, excreting predominantly urea along with water.	*Urecotelic*, excreting semisolid uric acid and urates which are not much soluble in water.	Like reptiles, birds are also *urecotelic* excreting mainly uric acid and urates in a semi-solid state.	*Urecotelic* since chief excretory product in urine is urea dissolved in water.
		[II] MALE REPRODUCTIVE SYSTEM			
1. Sexual dimorphism	Found, as in male fish inner portions of pelvic fins form *claspers* for transferring spermatozoa during copulation.	Not distinct. However, in male frog, base of first inner finger forms a thick *nuptial pad* during breeding season to clasp female in amplexus	Poorly developed, shown by the swellings of hemipenes mid-ventrally behind cloaca in male, and by more conspicuous *pre-anofemoral pores* in male.	Sexual dimorphism is absent in pigeon	Sexual dimorphism is well marked due to presence of *penis* and *scrotal sacs* containing testes only in male.
2. Male reproductive organs	Include a pair of testes, vasa efferentia, paired vasa deferentia, epididymes, seminal vesicles, urogenital sinus, sperm sacs and pelvic claspers.	Include two testes, several vasa efferentia, two urinogenital ducts and cloaca.	Include one pair each of testes, vasa deferentia and copulatory sacs, and cloaca.	Include 2 testes, 2 vasa deferentia, 2 seminal vesicles and cloaca.	Include 2 testes, 2 epididymes, 2 vasa deferentia, urethra, penis and some accessory glands.
3. Testes	Very long, cylindrical, attached mid-dorsally to abdominal wall by a double peritoneal fold or *mesorchium*.	Ovoid or rod-like, light yellow, attached to antero-ventral surface of kidneys by *mesorchium*.	Oval, white, bodies, attached much ahead of kidneys to dorsal abdominal wall by *mesorchium*. Right testis somewhat anterior to left one.	Oval, white bodies attached by *mesorchium* antero-ventrally to kidneys. Right testes slightly smaller.	Small, oval, white bodies. Remain inside abdominal cavity in young. But descend outside abdomen in *scrotal sacs* during breeding season in adult.
4. Rectal gland	Posterior ends of testes attached by a nonglandular tissue to a rectal gland.	*Rectal gland* absent.	*Rectal gland* absent.	*Rectal gland* absent.	*Rectal gland* absent.
5. Scrotal sacs	Absent	Absent	Absent	Absent	Present
6. Spermatic cord and gubernaculum	Absent	Absent	Absent	Absent	Each testes attached by anterior end to dorsal abdominal wall by a *spermatic cord* and by posterior end to wall of scrotal sac by *gubernaculum*.
7. Vasa efferentia	Leave anterior end of testis to join *Wolffian* or *mesonephric duct* called vas *deferens*.	Leave from inner end of testis and enter kidney to join *Bidder's canal* which in turn opens into *ureter* or *urinogenital duct*.	Leave from outer-posterior surface of testis and form a much convoluted mass, the *epididymis*.	Leave from inner border of testis to form an *epididymis*.	Leave inner border of testis to form an *epididymis*.

8. Epididymis	It is the anterior extremely coiled and narrow part of vas deferens all along the ventral surface of anterior genital part of kidney.	Vas deferens does not form an *epididymis*.	Formed by anterior part of vas deferens as a thick undifferentiated, convoluted mass along the outer surface of testis.	Poorly developed. Formed by anterior part of vas deferens as a coiled mass lying along the inner surface of testis.	Epididymis well developed and has 3 distinct parts: *caput*, *cauda* and *corpus epididymes* attached to the anterior, posterior and inner sides, respectively, of testis.
9. Vasa deferentia	Each vas deferens or Wolffian duct serves only as genital duct and opens independently into urinogenital sinus.	Each vas deferens unites with ureter of its side forming a *urinogenital duct*, opening separately into roof of cloaca.	Both vasa deferentia open independent of ureters dorsally into roof of urodaeum or middle chamber of cloaca.	As in lizard, two vasa deferentia open independent of ureters into urodaeum.	Two vasa deferentia, arising from cauda epididymis of their side, open into neck of urinary bladder or urethra.
10. Seminal vesicle	Terminal part of each vas deferens expands into a wide straight tube or *seminal vesicle* for storage of sperms.	In some species of frog, terminal part of urinogenital duct enlarges forming a temporary *seminal vesicle*.	Seminal vesicles not formed.	Small seminal vesicle formed for temporary storage of spermatozoa.	Small, slightly bifurcated blind sac, called *uterus masculinus* or *seminal vesicle* opens dorsally and independently into urethra.
11. Sperm sacs	A pair of club-shaped blind sperm sacs of doubtful function open into urinogenital sinus.	Sperm sacs absent.	Sperm sacs absent.	Sperm sacs absent.	Sperm sacs absent.
12. Copulatory organs	Copulatory apparatus includes a pair of *siphons* for flushing spermatozoa with sea water, and a pair of grooved *pelvic claspers* for transferring spermatozoa into cloaca of female during copulation.	Copulatory apparatus absent. Fertilization external, in water, where ova and spermatozoa are shed during amplexus.	A pair of eversible vascular *copulatory sacs* present mid-ventrally at the base of tail. During copulation they become everted through cloaca as cylindrical *hemipenes* to convey spermatozoa into cloaca of female.	Copulatory apparatus absent. During copulation male bird rides on back of female, their cloacae are closely apposed and transfer of sperms effected quickly.	It includes small erectile cylindrical *penis* in front of anus of male. It serves to transmit sperms into vagina of female during copulation
13. Accessory sex glands	Do not occur.	Do not occur.	Tubular preano-femoral glands produce a horny secretion which forms temporary spines for grasping female during mating.	Do not occur.	Male has one pair each of prostate, Cowper's, perenial and rectal glands. Their secretions either attract the female or contribute to semen.

[III] FEMALE REPRODUCTIVE SYSTEM

1. Female reproductive organs	Include a pair each of ovaries, oviducts, shell glands, uteri and epigonal organs and a single rectal gland, a vagina and a cloaca.	Include a pair of ovaries, a pair of oviducts and a cloaca.	Include paired ovaries oviducts, vaginae, shell glands and a cloaca.	Include only left ovary, left oviduct including uterus, shell gland and vagina, and a cloaca.	Include paired ovaries, oviducts, uteri and single vestibule, vagina, clitoris and some accessory glands.
2. Ovaries	Ovaries are paired, irregular, small, lobulated bodies attached just behind liver to dorsal abdominal wall by a double peritoneal fold called *mesovarium*.	Ovaries are a pair of large irregular, multilobed, hollow, blackish bodies attached near kidneys to dorsal abdominal wall by *mesovarium*.	Ovaries are small, paired, white, void bodies suspended by *mesovaria* well ahead of kidneys. Right ovary is attached somewhat anterior to the left one.	Left ovary is a large irregular white body attached ventral to anterior lobe of left kidney by *mesovarium*. Its surface has numerous *egg follicles* or *sacs* each with a developing ovum.	Two ovaries are small, oval, white bodies attached symmetrically and dorsally behind kidneys by *mesovaria*.
3. Epigonal organs and rectal glands	Ovaries are connected by elongated epigonal organs posteriorly to a rectal gland of unknown function.	Epigonal organs and rectal gland absent.	No epigonal organs and no rectal gland.	Both epigonal organs and rectal gland lacking.	There are no epigonal organs and rectal gland.
4. Oviducts	Oviducts or *Mullerian ducts* are a pair of large but straight ducts, opening posteriorly into cloaca, Their narrow anterior ends form *oviducal funnels* which meet mid-dorsally just behind septum transversum and open into abdominal cavity by a single *slit-like opening*.	Oviducts are very long and much coiled glandular tubes opening behind into cloaca. Their anterior ends form separate *oviducal funnels* with separate openings or *ostia*, at the bases of lungs.	Oviducts are 2 long, wide, thin walled, much plaited tubes opening behind separately into urodaeum. Anterior broad end of each forms a large *oviducal funnel* with a large externally directed ciliated opening or *ostium*, much ahead of ovaries.	Left oviduct is a long and wide tube with thick walls opening behind into urodaeum of cloaca. It opens anteriorly near let ovary by a large *oviducal funnel* with a wide fimbriated *ostium* facing inwards.	Two oviducts are large, coiled tubes meeting behind into vagina, and called *Fallopian tubes*. Anterior end of each opens near ovary by a small *oviducal funnel* with fimbriated *ostium*.
5. Shell glands	A little distance behind funnel, oviduct forms a small enlargement or *shell gland*. It secretes a thin membrane over descending fertilized eggs.	Shell glands are absent.	While passing over kidney, each oviduct forms a slight dilation or *shell gland* into which fertilized eggs are covered by shells.	Behind ostium, left oviduct is divided into several parts: magnum, is thymus, uterus and vagina. Uterus secretes the hard calcareous egg shell.	No shell glands present in oviducts.

6. Uterus	In the region of kidney, each oviduct forms a wide *uterus* inside which the embryos develop.	Before entering cloaca, each oviduct expands into a thin-walled *ovisac*, erroneously called *uterus* which is absent.	Uteri are absent.	Uterus demarcated as stated above but *true uterus* for development of embryos absent.	Fallopian tubes are followed by much wider, longer convoluted, vascular and muscular *uteri* where embryos develop.
7. Vagina & vestibule	Two uteri unite posteriorly into a common median vagina opening into cloaca. Vestibule absent.	Vagina absent. So-called uteri or ovisacs open directly into cloaca. Vestibule absent.	Short terminal part of each oviduct, called *vagina*, opens dorsally into urodaeum. Vestibule lacking.	The last part of single left oviduct, called *vagina*, also opens in the roof of urodaeum. There is no vestibule.	Both uteri meet into a common long, wide and median *vagina*. It opens with urethra into common *urino-genital sinus* or *vestibule*.
8. Vulva	Vulva absent. Instead cloaca opens directly to outside through a large median shallow groove.	No vulva present. Cloaca opens directly to exterior through a small circular cloacal aperture.	No vulva. Cloaca opens through a transverse slitlike aperture.	No vulva. Cloaca opens midventrally by a transverse cloacal aperture.	Vestibule opens to outside ventral to anus, through a longitudinal slit-like aperture called *vulva*.
9. Special glands	No special glands associated with female genital tract.	No glands as in fish	No glands as in fish and amphibians	No special glands as in fish, amphibians and reptiles.	Special female sex glands include Cowper's, perineal and rectal glands.
10. Milk glands	Absent	Absent	Absent	So-called pigeon's milk, fed to young ones, is secreted by crop glands.	Mammary glands secrete milk and open on 4 or 5 pairs of ventral teats or nipples in female rabbit.

Fig **12.5: Comparative account of urogenital system in different vertebrates**(https://www.faunafondness.com/comparative-account-of-urinogenital-systems-of-vertebrate/).

12.4 SUMMARY

The urogenital system of vertebrates comprises of excretory or urinary system and the reproductive system. The former consists of a pair of kidneys and their ducts and functions for the elimination of nongaseous waste metabolic products, especially those resulting from the breakdown of proteins. The reproductive system consists of a pair of sex glands or gonads and their ducts. Because of the close association anatomically of these two systems often they are considered together as the urogenital system. The association consists of the utilization of the excretory ducts by the sex glands for the discharge of the sex cells to the exterior. The evidence indicates that this relation is primary among the vertebrates and that there is a tendency toward the complete separation of the two systems in the evolution of the vertebrate classes. Such separation is, however, achieved only in the females of the primate mammals (and teleosts). Some of the important points of consideration are:

1. The urogenital system is derived from the mesomere of the embryo.
2. The urinary or excretory system consists of the paired kidneys and their ducts. Primitively, each kidney extended the length of the pleuroperitoneal cavity and was composed of segmentally arranged tubules and a collecting duct. Such a kidney is termed holonephros or archinephros, and its duct the archinephric duct.

3. The combination of glomerulus and nephrocoel wall is termed a renal corpuscle.
4. A holonephros exists only in the embryos of myxinoid cyclostomes.
5. The most anterior vertebrate kidney is termed the pronephros; it is similar to the holonephros, composed of segmental tubules provided with peritoneal funnels. It appears in the embryos of all vertebrates but persists and remains functional throughout life only in the cyclostomes and a few teleost fishes. Its ducts, the pronephric ducts, grow backward and open into the cloaca.
6. As the pronephros degenerate, there develop behind them the second kidneys, or mesonephric (also called Wolffian bodies), which differ chiefly in having more than one tubule per segment.
7. In amniotes the mesonephric kedney degenerate during development, and there appear behind them the third kidneys, or metanephros. These develop in part from the remaining tissue of the mesomere and in part by outgrowth from the Wolffian ducts near their termination in the cloaca.
8. In anamniotes, in general, the second kidney utilizes the tissue which in amniotes furnishes both mesonephros and metanephros. Hence, the ichthyopsidan kidney does not exactly correspond to the mesonephros of amniote embryos, although usually called so. It is here termed opisthonephros.
9. Pronephros, mesonephros, and metanephros appear to be successive alterations of the original holonephros.
10. The genital system of vertebrates consists of the paired male sex glands or testes and the paired female sex glands or ovaries and their respective ducts. These ducts, however, are kidney ducts; hence the close association of urinary and genital systems. Testes and ovaries arise as mesomere thickenings which project into the coelom near the kidneys.
11. The ducts of the ovaries are termed Mullerian ducts or, better, oviducts; they have no direct connection with the ovaries but open close to them into the coelom by a funnel-like ostium believed to represent one or more pronephric peritoneal funnels.
12. Except in placental mammals the oviducts enter the cloaca separately. In placental mammals the oviducts are more or less fused and differentiated into uterine tube, uterus, and vagina.
13. The testes are located inside the abdominal cavity except in mammals, where in many cases they descend temporarily or permanently into an inguinal pouch of the body wall, called the scrotum.
14. A definite organ of copulation, the penis, is first seen in reptiles, occurs in seine birds, and is general throughout mammals.

12.5 TERMINAL QUESTION

Q1. Give general account of evolution of kidney in vertebrate series.

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Q2. Compare the reproductive system in different vertebrates.

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Q3. Write short notes on:

a) Pronephros

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b) Metanephros

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c) Mullerian duct

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d) Bowmans capsule

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Q4. Multiple choice questions:

i) Functional unit of kidney is:

a) Nephron
b) Neuron
c) Renal capsule
d) Tubule

ii) In mammals testes are found in:

a) Peyer's patches
b) Bidder's organ
c) Inguinal canal
d) Scrotal sacs

iii) Hypothetical primitive kidney is:

a) Archinephros
b) Pronephros
c) Nephron

d) Mesonephron

iv) Oviduct in vertebrates is modified:

a) Wolffian duct

b) Mullerian duct

c) Inguinal canal

d) Urinary duct

v) Bicornuate uterus is found in:

a) Primates

b) Marsupial

c) Birds

d) Ungulates

12.6 ANSWERS

Q4 i) a, ii) d, iii) a, iv) b, v) d

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