PREFACE

In a bid to standardise higher education in the country, the University Grants Commission (UGC) has introduced Choice Based Credit System (CBCS) based on five types of courses: core, generic discipline specific elective, and ability/ skill enhancement for graduate students of all programmes at Elective/ Honours level. This brings in the semester pattern, which finds efficacy in tandem with credit system, credit transfer, comprehensive and continuous assessments and a graded pattern of evaluation. The objective is to offer learners ample flexibility to choose from a wide gamut of courses, as also to provide them lateral mobility between various educational institutions in the country where they can carry acquired credits. I am happy to note that the University has been recently accredited by National Assessment and Accreditation Council of India (NAAC) with grade “A”.

UGC (Open and Distance Learning programmes and Online Programmes) Regulations, 2020 have mandated compliance with CBCS for all the HEIs in this mode. Welcoming this paradigm shift in higher education, Netaji Subhas Open University (NSOU) has resolved to adopt CBCS from the academic session 2021-22 at the Under Graduate Degree Programme level. The present syllabus, framed in the spirit of syllabi recommended by UGC, lays due stress on all aspects envisaged in the curricular framework of the apex body on higher education. It will be imparted to learners over the six semesters of the Programme.

Self Learning Materials (SLMs) are the mainstay of Student Support Services (SSS) of an Open University. From a logistic point of view, NSOU has embarked upon CBCS presently with SLMs in English. Eventually, these will be translated into Bengali too, for the benefit of learners. As always, we have requisitioned the services of the best academics in each domain for the preparation of new SLMs, and I am sure they will be of commendable academic support. We look forward to proactive feedback from all stake-holders who will participate in the teaching-learning of these study materials. It has been a very challenging task well executed, and 1 congratulate all concerned in the preparation of these SLMs.

I wish the venture a grand success.

Professor (Dr.) Subha Sankar Sarkar

Vice-Chancellor

Netaji Subhas Open University

Under Graduate Degree Programme
Choice Based Credit System (CBCS)
Subject: Honours in Zoology (HZO)
Course: Diversity of Chordates
Course Code: CC-ZO-04

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: Course Writer :
Dr. Bibhas Guha
Assistant Professor of Zoology
Netaji Subhas Open University

: Course Editor :
Professor B. B. Jana
Retd. Professor of Zoology
Kalyani University

: Format Editor :
Dr. Bibhas Guha, NSOU and **Dr. Sanjoy Mandal, NSOU**

Netaji Subhas Open University

UG : Zoology
(HZO)

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Unit 1 ❑ Protochordata

Structure

1.1 Objectives

After studying this unit, learners would be able to understand the following—

- the characteristics of chordates.
- the general characteristics of hemichordata, urochordata and cephalochordate.
- the larval forms in protochordates.
- an idea about tornaria and tadpole larva.
- the retrogressive metamorphosis in ascidia.

1.2 Introduction

The phylum chordata comprised of a varied group of diverse animals ranging from

ascidian to man. The most important features of phylum chordate are presence of: (i) notochord; (ii) dorsal tubular nerve cord; (iii) pharyngeal gill slits and post and tail. The hemichordate, urochordata and cephalochordate were considered as the invertebrate members of the phylum chordata, thus, separated as "invertebrate chordates" (Hyman, 1959). The protochordates are a connecting link between the vertebrates and other deuterostomes (animals where the anus develops from the blastopore and the mouth is formed a new).

However, the phylogenetic status of hemichordate is a subject of great controversy. According to recent classification urochordata, cephalochordata and vertebrata belong to a cephalochordates and vertebrates are more closely related with other. But the chordate nature of urochordates and cephalochordates is well established though their relationships with the vertebrates and with each other are difficult to ascertain.

1.3 General characteristics of hemichordata, urochordata and cephalochordata

1.3.1 Hemichordata

The phylum hemichordata represents a group of lowest invertebrate chordate having profound phylogenetic significance. This group forms a sort of structural bridge between the nonchordates and chordates. Hemichordata was previously known as enteropneusta due to the presence of gill slits in *Balanoglossus clavigerus* (Gegenbaur, 1870). Bateson (1885) suggested the name hemichordata in place of enteropneusta.

Example: *Balanoglossus*

General Characteristics:

(i) They are solitary or colonial, soft and fragile animals.

(ii) Body divisible into three regions: proboscis (protosome); collar (mesosome); trunk (metasome).

(iii) The representatives are vermiform, unsegmented, bilaterally symmetrical and triploblastic.

(iv) Appendages are absent; in few forms the collar may bear arms with tentacles.

(v) Buccal diverticula is present.

(vi) Alimentary canal is complete. This is either a "straight" or 'U'- shaped tube.

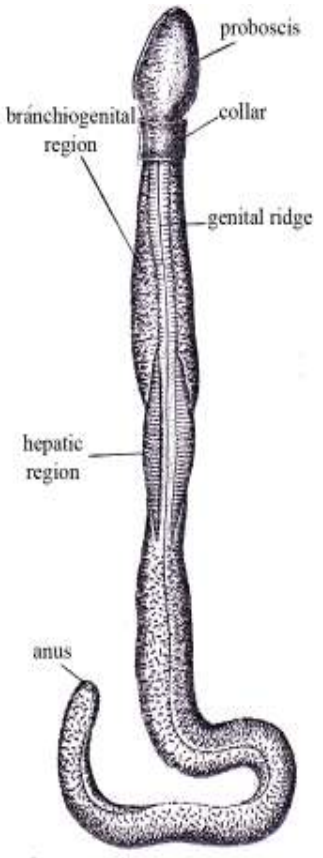


Fig-1 : External Structures of *Balanoglossus*

(vii) Mostly marine in habitat and feed on micro-organisms and debris by ciliary mode of mechanisms.

(viii) One to several pairs of gill-slits present.

(ix) Circulatory system is open type with a central sinus heart vesicle, dorsal and ventral vessels, sinuses and lateral vessels.

(x) Excretion is performed by glomerulus, present in proboscis and connected with blood vessels.

(xi) Nervous system is primitive, comprising mainly of an intra epidermal nerve plexus.

(xii) Mode of reproduction is sexual but a few forms exhibit asexual reproduction.

(xiii) Development is direct (without larval stage) or indirect (with a tornaria larva).

1.3.2 Urochordata

The members of the phylum urochordata exhibit a high degree of diversity in form, habit and habitat. The urochordates are also known as tunicates (L. tunica; an undergarment) or Ascidian (Gr. Askos; a leather bag).

Example: *Ascidia*

General characteristics:

(i) Exclusively marine, solitary or colonial, fixed or pelagic.

(ii) Body varies considerably in size, form and colour.

(iii) Unsegmented body is covered by a test or tunic.

(iv) They have two pores related to the atrial and branchial siphons.

(v) Coelom is absent; the atrial cavity receives gonoducts, anus and gill-slits.

(vi) In larva, notochord is present but absent in adult.

(vii) Alimentary canal is complete, presence of spacious pharynx.

(viii) Respiration by gill slits and test.

(ix) Circulatory system closed type. Heart is tube like and central in position.

(x) Excretion is performed by nephrocytes, neural gland and pyloric glands.

(xi) In adult the nervous system is represented by single dorsal ganglion.

(xii) Usually bisexual. Fertilization is external. Asexual reproduction by budding.

(xiii) Development indirect, through tadpole larva. Metamorphosis is retrogressive.

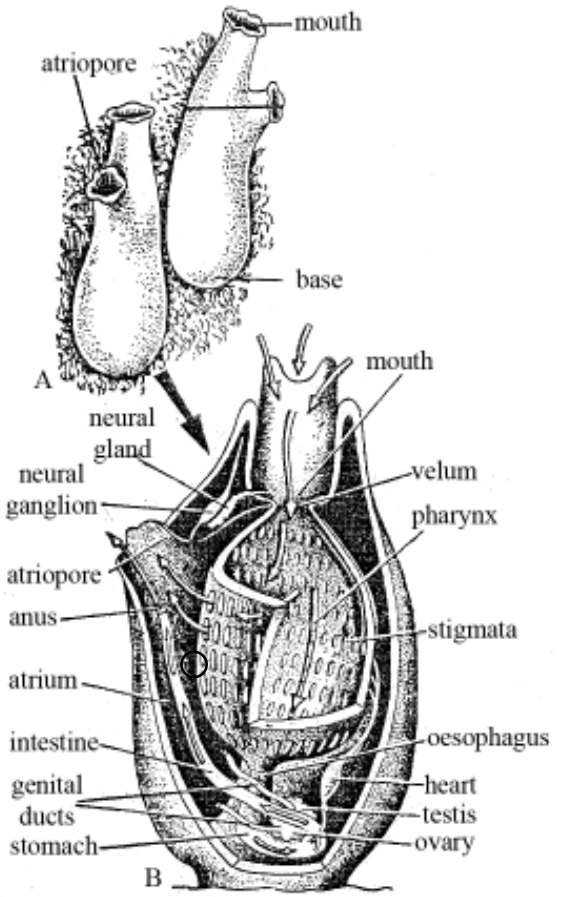


Fig-2 : Anatomical organisation of adult *Ascidia*

1.3.3 Cephalochordata

The cephalochordate is an important group of animals for phylogenetic analysis and

comparative anatomy of the chordates in general. Despite their great variety all these types show certain common features, often referred to as the typical chordate characters. It is better to regard these not as a list of isolated "characters" but as the signs of a certain pattern of organization that is characteristics of the group.

Example: *Branchiostoma* (*Amphioxus*)

General characteristics:

(i) Marine animal, commonly found in the sandy shores of the sea.

(ii) Sedentary animal, although it can swim actively in water.

(iii) Small lancet-shaped body is divisible into the body proper and definite post-anal tail.

(iv) The oral hood bears more than twenty stiff buccal or oral cirri or tentacles.

(v) The mouth is kept hidden within the oral hoods.

(vi) Presence of wheel organ.

(vii) The anus is situated of the left side of the ventral fin.

(viii) The atrium opens to the exterior through a round atriopore located closed to the anterior end of the ventral fin.

(ix) On the lateral sides of the body there are numerous gill-slits which remain partly covered by the lateral folds of the body.

(x) The body is provided with a dorsal fin, which joined to a somewhat caudal fin present round the tail.

(xi) A ventral fin runs along the mid ventral line lying between caudal fin and atriopore.

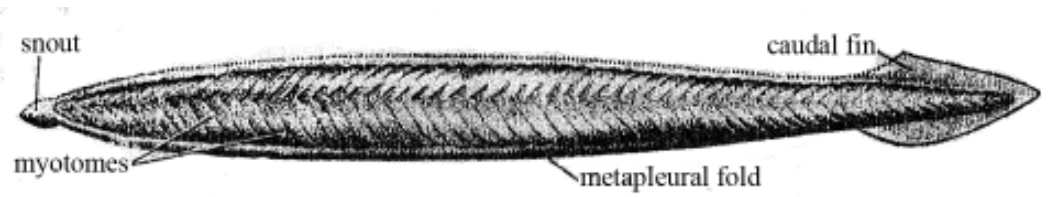


Fig.3 : A diagrammatic view of *Branchiostoma (Amphioxus)*

1.4 Study of larval forms in protochordates

1.4.1 Introduction

Protochordates are an informal category of animals (*i.e.*, not a proper taxonomic group), named mainly for convenience to describe invertebrate animals that are closely related to vertebrates. This group is composed of the Phylum Hemichordata and the Subphyla Urochordata and Cephalochordata. Tornaria larva is the larva of Hemichordata (*Balanoglossus*) and tadpole larva is the larval form of Urochordata (*Ascidia*).

1.4.2 Tornaria larva

Balanoglossus reproduces normally by sexual process. A sexual reproduction occurs very rarely. The development is indirect, i.e., the development is followed by the metamorphosis of a well developed larval form, the tornaria larva. This larva was first discovered by Johannes Muller (1850), who gave the name tornaria due to its habit of rotating in circle. General characteristics of tornaria larva are:

(i) Oval in shape and bilaterally symmetrical body.

(ii) Size varies from 1 to 3 mm.

(iii) The mouth is present on the ventral side near the equatorial plane of the body.

(iv) Anterior to the mouth there is a prolonged preoral lobe.

(v) There are three distinct ciliated bands on the body.

(vi) The preoral and postoral ciliated bands unite for a short distance at the apical plate.

(vii) One ciliate ring is present around the anus, which is called circumanal ciliated band or telotroch.

(viii) The cilia in the band are long, powerful and act as the chief locomotor organ.

(ix) The anus is located medially on the posterior end of the body.

(x) The digestive tract is distinguishable into oesophagus, stomach and intestine.

(xi) Possess one pair of gill slits.

(xii) It undergoes morphological changes to become an adult.

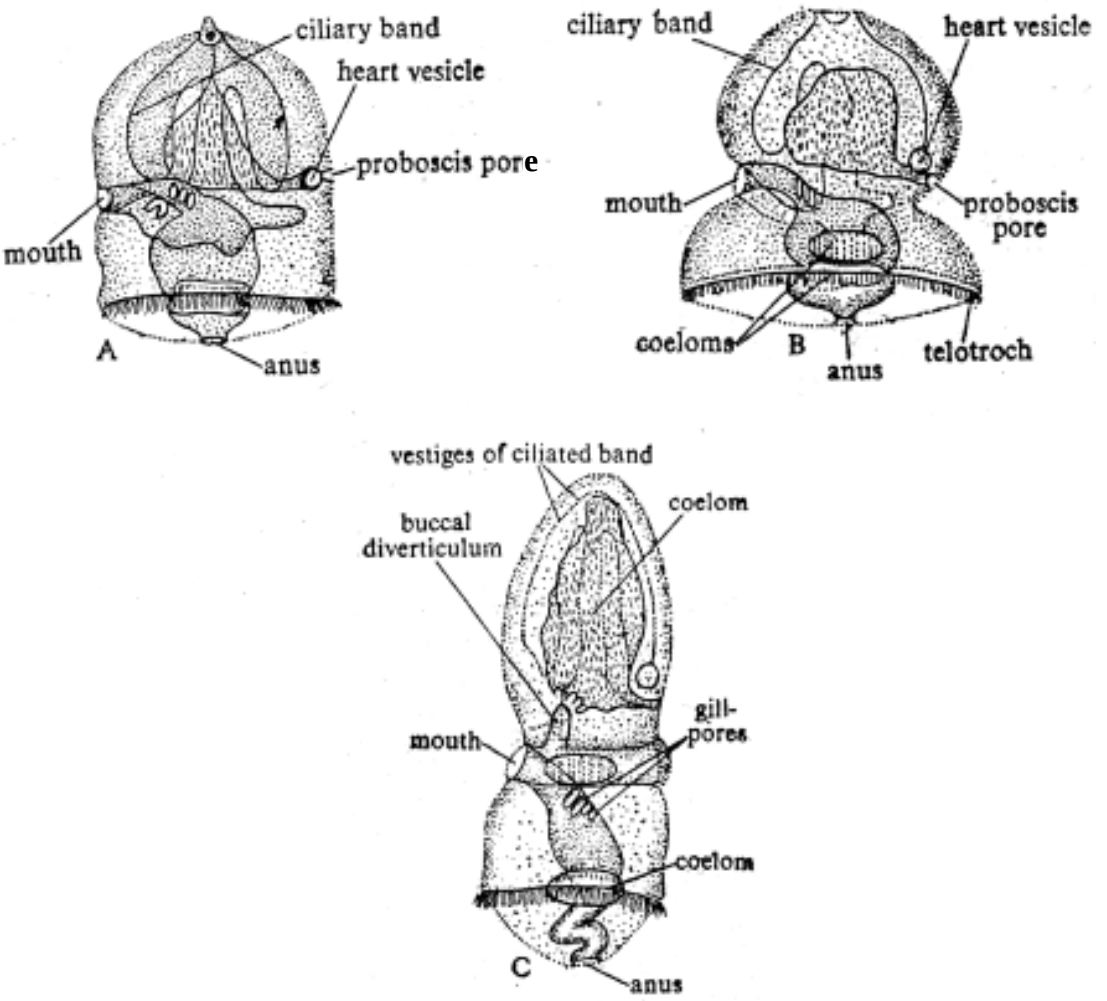


Fig.-4 : (A) A full drown Tornaria larva; (B-C) Stages of subsequent metamorphosis of tornaria larva

1.4.3 Tadpole larva

The larval form present in the life history of *Ascidia* is called tadpole larva. The general characteristics of tadpole larva is as follows—

(i) Highly motile and does not take food from the outside.

(ii) The body is more or less oval in outline.

(iii) Body divisible into head and tail region.

(iv) The whole body is covered by tunic.

(v) The head is elliptical and has three adhesive papillae or chain warts.

(vi) The tail is laterally compressed and pointed terminally.

(vii) The tail is provided with caudal fin.

(viii) The dorsal and ventral fins are continuous along the tail and are marked with striae.

(ix) The central nervous system is situated dorsal to the notochord.

(x) A single median eye is present.

(xi) An otocyst, the organ of balance is situated in the ventral side.

(xii) The notochord is restricted only in the tail region.

(xiii) Segmental muscle bands are present in the tail region.

(xiv) The mouth is present and the alimentary canal is rudimentary.

(xv) Well developed pharynx is sac like.

(xvi) A fully developed endostyle and two pairs of gill slits are present.

(xvii) Non functional heart with epicardia lies beneath the endostyle.

(xviii) The paired atrial sacs are present.

(xix) Just after hatching the tadpole larva becomes positively phototactic and negatively geotactic.

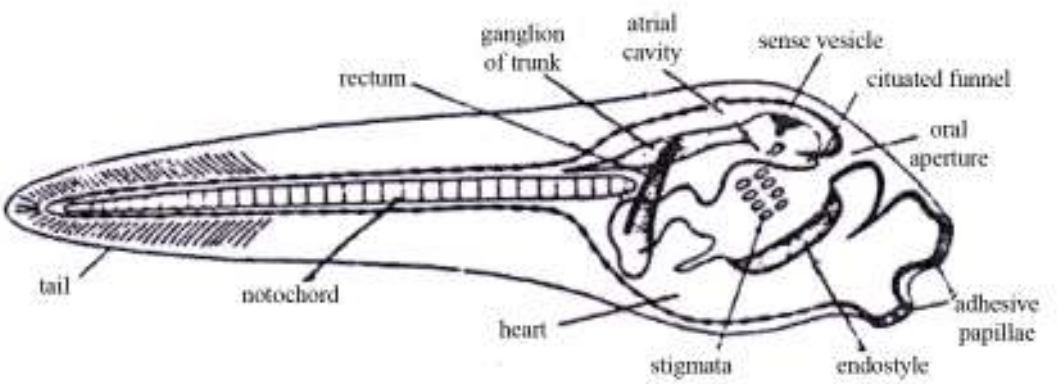


Fig.5 : *Ascidia sp.*—A free swimming tadpole larva

1.5 Retrogressive metamorphosis in urochordata

The subphylum urochordata constitutes an unique group of animals under the phylum Chordata. In urochorates, the notochord is confined to the tail region in the adult stage, thus named as urochordata. This subphylum is sub-divided into three classes: (i) Ascidiacea; (ii) Thaliacea; and (iii) Larvacea or Appendicularia. The unique example of this group is *Ascidia*. *Ascidia* is a hermaphroditic animal, known for its indirect development; *i.e.*, the development is accompanied by metamorphosis. Metamorphosis in most animals, is a progressive process. But, in *Ascidia* the developmental events are largely retrogressive. In *Ascidia*, a highly developed tadpole larva, in course of ontogenic development transforms into a sessile and degenerated adult. The metamorphosis in *Ascidia* shows a peculiar scheme of retrogression of a complex and well organized larval form to a simpler degenerated adult amply speak for the retrogressive metamorphosis in *Ascidia*. In Ascidian metamorphosis, two sets of changes occur: (i) the disappearance of notochord, nerve chord and muscle bands; (ii) formation of stigmata, specialization of pharynx, over development of atrium etc. The essence of retrogressive metamorphosis in *Ascidia* is therefore; (i) the differential growth and disappearance of histologically differentiated larval tissues; and (ii) the formation of the adult structures from the residual larval tissue.

A. Pre-larval stages:

(i) The egg are small and almost yolkless.

(ii) The segmentation is holoblastic and nearly equal at the initiation.

(iii) Gastrulation occurred by invagination.

(iv) The gastrula after about three days transformed into free swimming tadpole larva.

(v) The tadpole larva has all the characteristics of chordate organization.

B. Larval stages:

(i) The tadpole larva is very active and do not take food from outside.

(ii) The body is more or less oval in outline.

(iii) Body divisible into two regions; i.e., head and tail.

(iv) The whole body is covered by tunic.

(v) The tail is laterally compressed and pointed terminally and provided with caudal fin.

(vi) The dorsal and ventral fins are continuous along the tail and marked with striae.

(vii) The central nervous system is situated dorsal to the notochord.

(viii) The notochord is restricted in the tail region.

(ix) A single median eye is present.

(x) An otocyst, the organ of balance is situated in the ventral side.

(xi) The mouth and the alimentary canal is rudimentary.

(xii) The pharynx is sac like and is well developed.

(xiii) A fully developed endostyle and two pairs of gill slits present.

(xiv) Non functional heart with epicardia lies beneath the endostyle.

C. Metamorphosis and emergence of the adult:

The free swimming tadpole larva after a short period of free existence fixes itself to sea weeds or stones by adhesive papillae and immediately falls a victim of first degeneration and undergoes progressive and retrogressive changes during its development.

I. Progressive changes:

(i) The branchial chamber becomes enlarged and the number of stigmata are enhanced;

(ii) The post pharyngeal portion of the gut gets divided into different parts;

(iii) The atrium becomes more extensive;

(iv) The development of velum is observed;

(v) The gonads and gonoducts appear from the mesoderm.

II. Retrogressive changes:

(i) The length of the tail becomes greatly diminished.

(ii) The nerve chord becomes restricted to the trunk region and is ultimately reduced to a solid nerve ganglion;

(iii) The notochord becomes coiled, disorganized and finally disappeared;

(iv) The trunk becomes broadened;

(v) The number of the striae are diminished and become restricted to certain regions;

(vi) The muscle band also become degenerated;

(vii) The tail is further shortened;

(viii) Shifting of the mouth is caused by the rapid growth of the region between the adhesive papillae;

(ix) The tail becomes more shortened and partially withdrawn into the test.

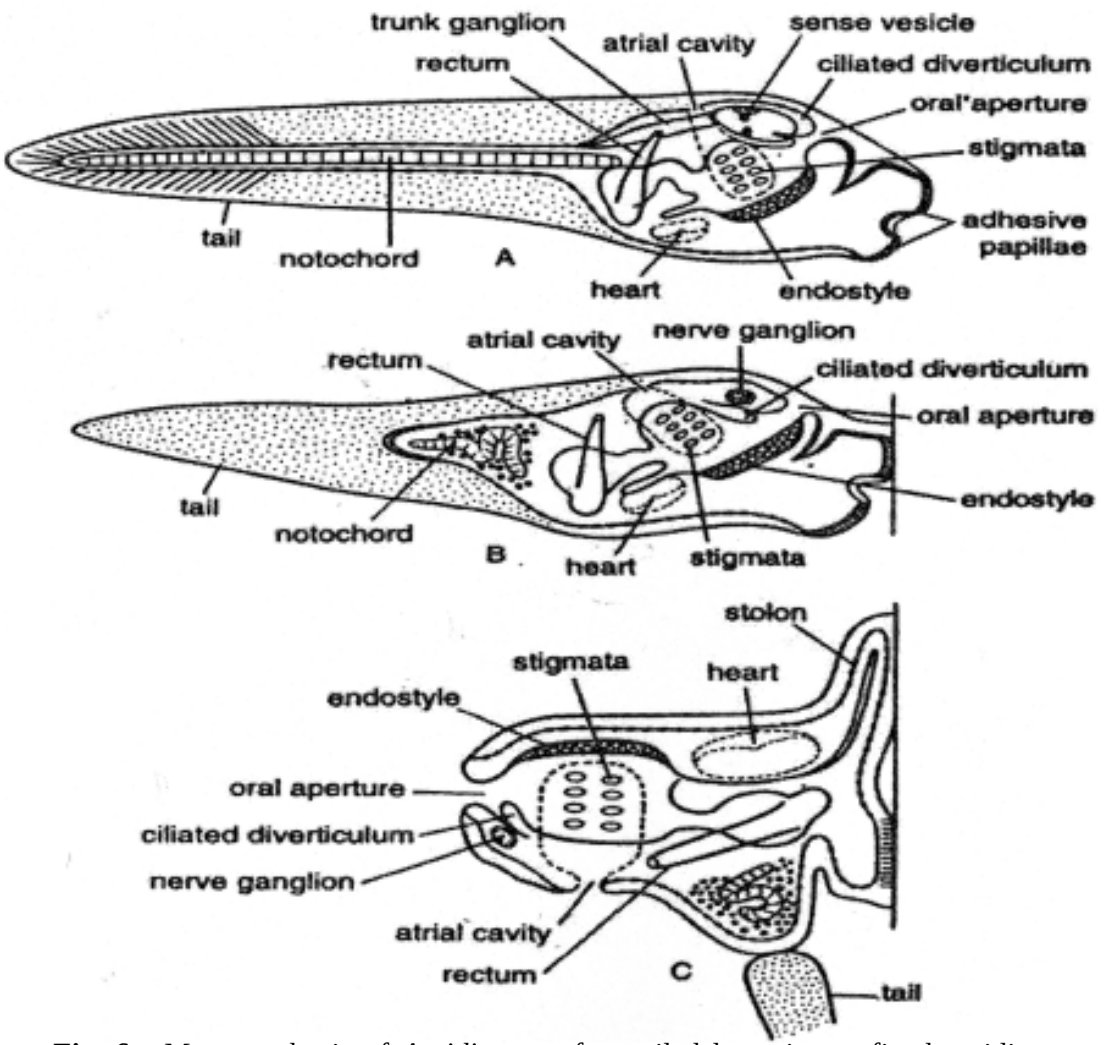


Fig. 6 : Metamorphosis of *Ascidia* sp. - free tailed larva into a fixed ascidian

A : Progressive changes; B : Retrogrossive changes C : Adult *Ascidia*

1.6 Summary

- Urchordata, Cephalochordata and Vertebrata belong to a cephalochordates and vertebrates are more closely related with other.
- Tornaria larva is the larva of Hemichordata and tadpole larva is the larval form of Urochordata.
- Retrogressive metamorphosis is an unique feature of *Ascidia*.
- Metamorphosis of tadpole larva occur through both the progressive and retrogressive changes.

1.7 Questions

(i) Write the unique characteristics of chordotes.

(ii) Write the general characteristics of hemiehordata, urochordata and cephalochordate.

(iii) Draw the structure of tornaria larva and discuss its importance.

(iv) What is meant by retrogressive metamorphosis?

(v) Write a brief note on retrogressive metamorphosis in ascidia with suitable diagram.

1.8 Suggested readings

1) The life of vertebrates by J. Z. Young; Year: 1981. Published in India by Oxford University Press, New Delhi.

2) Study material Post Graduate Zoology (Paper: 1). Structure and function of chordates and non-chordates, Year: 2010. Pub: Registrar, Netaji Subhas Open University.

3) Learning protochordata through latest portfolio of theory and practice. Edited by P.K. Verma and Nandita Pande (Editor-in-Chief: Brian Jenkins); Year: 2002; Pub: Dominant Publisher and Distributors, New Delhi-110002

4) Biology of Animals (Volume-II) by Arup Kumar Sinha, Simananda Adhikari and Banku Behari Ganguly; Year 1991; Pub: New Central Book Agency

5) Elyman, L (1959). The invertebrates: smaller coelomate groups. McGraw Hill, New York.

Unit 2 ❑ Origin of chordata

Structure

2.1 Objectives

After studying this unit, learners would be able to understand the following—

- the salient features of chordates.
- different theories relating with the origin of chordates.
- different views about the origin of chordates.
- the Gastang's theory of origin of chordates.

2.2 Introduction

The phylum chordata is known to have the unique features such as for the presence of notochord, dorso-tubular nerve cord and pharyngeal gill slits. It was and is still a genuine paradox to the systematic position as to what evolutionary changes in the general organization of animal body led to the emergence of chordates. Since later part of the nineteenth century various conflicting views have been proposed to explain the origin of chordates. The views tracing the origin of chordates from a number of invertebrate phyla have been discarded, yet among the major invertebrate phyla the annelid and arachnid theories claiming possible source of its ancestry. The echinoderm theory having an utmost relevance with and holding key to chordate ancestry.

2.3 Echinoderm theory of origin of chordates

Among the major phyla of non-chordates, the echinoderms are the most striking evidence of chordate ancestry. Larval forms usually represent past ancestral forms. Larval evidence strongly suggests that the protochordates evolved as small, bilaterally symmetrieal animals possessing many of the features of larval echinoderms, or the hemichordates but lacking specializations of either the fully formed chordates (or vertebrates) or the echinoderms. With the assumption of redial symmetry and sessile mode, these form give rise to echinoderms, but some of them retained the original bilateral symmetry and by developing gill slits, better musculature and notochord give rise to the chordates.

Evidence based biochemical analysis provides strong relationship between the echinoderms and the chordates. The similarity of blood serum, muscle chemistry and the presence of phosphocreatinine and phosphoarginin as suppliers of energy to muscles in both echinoderms and chordates claimed much more closer relationship between the two groups. These two components are not present together in other invertebrate phyla.

2.4 Views of different scientists on the origin of chordates

Based on the research supports, the view of the Echinoderm theory of origin of chordates is more pertinant. The following are the views of the scientists.

1) The theory given by **Johannes Muller (1860)** is based on the comparative studies of larval stages of echinoderms and hemichordates. Tornaria larva of hemichordates resembles echinoderm larvae of bipinnaria, auricularia, dipleurula and doliolaria, which all possess ciliary bands and apical tuft of cilia may insight a clue about the origin of chordate.

2) **Garstang's neotenous larva theory (1894)** proposed that the ancestry of chordates and of the vertebrates is to be traced during the larval stages of the invertebrates rather than in their adults. He advocated that "if the ciliated bands of the auricularia larva of the sea-cucumber were to become accentuated and rise up as ridges leaving a groove between them, and if these ridges were to fuse, converting a groove into a tube, a structure would be produced which has all the relations of a nervous system". Garstang's

theory further asserts that if the larval forms of such animals persisted and become sexually mature, they would provide exactly the necessary material for the evolution of the chordates.

3) Some authors advocated that the similarity between the larval forms was the result due to similar ecological factors. **H. B. Fell (1965)** concludes that the similarity of the free swimming larvae of some echinoderms and *Balanoglossus* provides no concrete evidence of common ancestry. **Gregory (1951)** states that *Balanoglossus* may not be a chordate at all and that its bag like ciliated swimming larva is merely a parallel adaptation for securing suitable location for their sessile adults.

4) **N. J. Berrill (1955)** suggests the following larval sequence for the ancestry of chordates: Echinoderm → auricularia → hemichordate-tornaria→ protochordate-ascidian tadpole → permanently free swimming chordate.

   This view agrees with Gastang's theory but not in the manner in which Gastang assumes the changes to have taken place. However, Berrill's view places the ascidians is the main line of the origin of chordates, at least as larva.

5) **Hyman (1959)** and others also believe that the pterobranchs (Hemichordate) may be similar to the common ancestor of both the echinoderms and the hemichordates.

6) **Jefferies (1975)** opined that the origin of chordates is to be found among the carpoid fossils (subphylum-Homalozoa; phylum- Echinodermata) which have an echinoderm like skeleton of calcite known as "calcichordate theory". In his theory, Jefferies argued that two of the carpoid orders, the "Cornutai" and "Mitrata" should be placed in a separate subphylum "calcichordata" which had echinoderm affinities are actually more closely related to the early chordates. Jefferies states that a cephalodiscus like hemichordate gave rise to two lines of evolution, one by losing the gill slits and elaborating the tentacles towards the echinoderms and the other by losing the tentacles and elaborating the left gill slits toward the early chordates whose earliest representatives was the carpoid comuta.

7) **Barrington (1979)** states the "The view that larval biology contains the key to chordate ancestry is highly speculative, although it dose not lack biological plausibility. It is not the only way of looking at the problem".

8) **Young (1981)** states that the Bateson (1886)-Gastang (1894) theory of the origin of chordates is correct. The chordates are related to the sessile lophophore feeders which in course of time acquired the pharyngeal gill slits and their larva to have muscles, a notochord and a nerve tube. Then by paedomorphosis the sessile stage disappeared and the chordates began the course of evolution.

9) **Pouch, Heiser and McFarland (1990)** commented about the phylogenetic affinities of chordates and invertebrates remain uncertain. Although the weight of evidence favours deuterostomes as the group from which chordates arose, no living adult or larval deuterostomes can yet be identified as their closest living relatives.

Although genomic approaches to chordate phylogenies suggested to the traditional euchordata view : vertebrates and cephalochordates as sister groups to the exchision of basal tunicates and placed vertebrates and tunicates as sister groups. This theory has received support from alfactores hypothesis (Dunn et al, 2008)

In the foregoing views of different scientists it may say that Bateson (1886)-Gastang (1894) theory of the origin of chordates is correct (Young, 1981). Romer (1965, 1970) pointed out that the chordates have arisen from some sort of echinoderm like ancestors. His ancestral prototype is a sessile filter-feeder which acquired pharangeal gill-slits and their larval forms possessed muscles, notochord and nerve tube. Then by paedomorphosis the sessile stage disappeared and the free chordates started their evolution. However, in-spite of this generally agreed proposition, an element of uncertainty still remains due to lack of adequate concrete evidences. Further more, Garstang's dipleurula theory were more accepted.

2.5 Summary

- Phylum chordata is known to have the unique features like notochord, dorso-tubular nerve cord and pharyngeal gill slits.
- Evidence based biochemical analysis provides strong relationship between the echinoderm and the chordate.
- Romer (1965, 1970) pointed out that the chordates have arisen from some sort of echinoderm like ancestors.

2.6 Questions

i) What do you mean by chordate?

ii) Write about the echinoderm theory of origin of chordates.

iii) Discuss in brief about the views of different scientists for the origin of chordates.

2.7 Suggested readings

1) The life of vertebrates by J. Z. Young; Year: 1981. Published in India by Oxford University Press, New Delhi

2) Study material Post Graduate Zoology (Paper: 1). Structure and function of chordates and non-chordates, Year: 2010. Pub: Registrar, Netaji Subhas Open University

3) Learning protochordata through latest portfolio of theory and practice. Edited by P.K. Verma and Nandita Pande (Editor-in-Chief: Brian Jenkins); Year: 2002; Pub: Dominant Publisher and Distributors, New Delhi-110002

4) Biology of Animals (Volume-II) by Arup Kumar Sinha, Simananda Adhikari and Banku Behari Ganguly; Year 1991; Pub: New Central Book Agency

5) Text Book of Zoology Vertebrates (volume-2) 7th Edition by T. Jeffery Parkar and Williama Haswell (Edited by Marshall & Williams) Year: 1995. Pub: AITBS Publishers & Distributors, New Delhi-110051

Unit 3 ❑ Agnatha

Structure

3.1 Objectives

After studying this unit, learners would be able to understand the following—

- the salient features of agnathans.
- the general characteristics of cyclostomata.
- the classification of cyclostomata.
- the salient features of ammocoetes larva.

3.2 Introduction

The class cyclostomata (cyclos = round and stoma = mouth) are the modified and degenerate off shoot of the primitive vertebrate stalk. Cyclostomata is a group of agnathans that comprises the living jawless fishes-the lampreys and hagfishes. They are parasitic, usually feeding on fish in their adult stage. Morphologically, they resemble with the eels. They are known to be the only living vertebrates without true jaws, hence called Agnatha.

3.3 General characteristics of cyclostomata

1) The mouth is round and suctorial.
2) The paired fins are absent.
3) Median fins with cartilaginous fin rays.
4) No paired appendages.
5) The skin is soft and smooth and devoid of scales.
6) The exoskeleton is absent. The endoskeleton is cartilaginous without bones.
7) The notochord is persistant throughout life.
8) The digestive system is devoid of any stomach.
9) The nostril is single and median.
10) Pharayngeal gill slits with about 5-15 pairs of gills are present.
1l) The heart is two-chambered.
12) The cerebellum is small.
13) Spleen is absent.
14) The lateral line acts as a sense organ.
15) The ninth and tenth cranial nerves are not present.
16) The sexes are separate. Some hagfish species are believed to be hermaphrodite.
17) Excretory system consists of a pair of mesonephric kidney.
18) Development may be direct or indirect through ammocoetes lerva.

3.4 Classification of cyclostomata

The subphylum Agnatha is divided into two classes—Cyclostomata and Ostracodermis. The class Cyclostomata is further sub-divided into two orders: 1) Petromyzontia is exlempified by Lampreys; and 2) Myxinoida is represented by Hagfish.

Order-l: Petromyzontia (Lamprey)

Characteristics:

1) Both the larval form and adult are marine and freshwater in habitat.
2) They have a ventral mouth with many horny teeth.
3) The mouth is present in the buccal funnel.
4) The buccal funnel is suctorial and shows horny teeth.
5) The nostril is present dorsally and no connection with the pharynx.
6) Eyes are functional.
7) Seven pairs of gill slits are present.
8) Well developed dorsal fin is present.
9) Branchial basket is complete.
10) Brain is well developed.
11) Pineal eye is well developed.
12) Ear has two semicircular canals.
13) The development is indirect.

Example: *Petromyzon* (Sea-lamprey); *Lampetra fluviatilis*

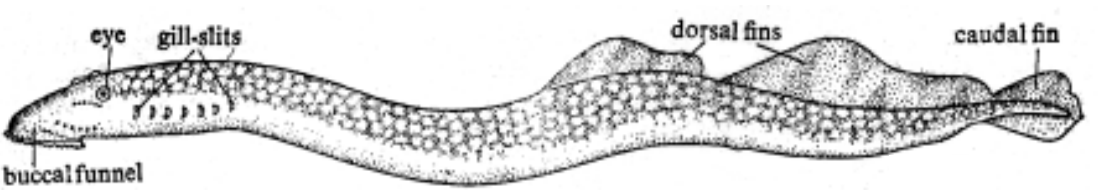


Fig 3.1: External structures of *Petromyzon*

Order - 2: Myxinoidea

Characteristics:

1) They are found exclusively in the marine environment.
2) They have a terminal mouth with few teeth.
3) Buccal funnel is absent.

4) They possess 6-14 pairs of gill slits.
5) The nasal sac opens into pharynx through a canal.
6) Eyes are vestigial and few in number.
7) Dorsal fin is either absent or very small and weak.
8) Branchial basket is poorly developed.

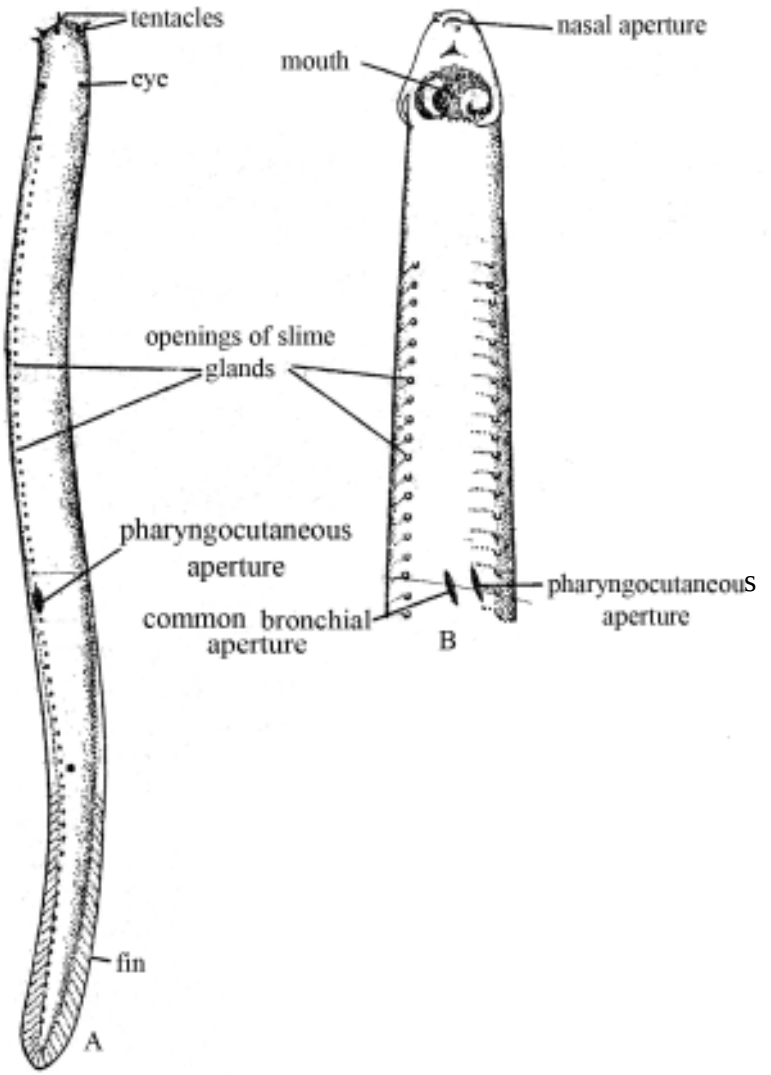


Fig 3.2: Structure of the hagfish. (A) Dorsal view of an entire *Myxine*; (B) Ventral view of anterior end of *Myxine*.

9) Brain is of primitive type.
10) Pineal eye is reduced.
11) Ear has only one semicircular canal.
12) The hag-fishes are all marine in habitat.
13) Eggs are large and few in number.

Example: *Myxine glutinosa* (Hag-fish or slime eel); *Eptatretus* (Bellostoma)

3.5 Development of lamprey

The eggs of lamprey are telolecithal, having a large amount of yolk. Cleavage is holoblastie but unequal resulting in the formation of blastula. Blastula consists of micro and macromeres. Invagination in blastula gives rise to gastrula. Gastrulation occurs by invagination and the blastopore takes up a postero-dorsal position and becomes converted into arms. The development of the central nervous system is peculiar in lampreys. It develops as a solid cord or keel which hollows to form the lumen of the nerve cord. This process is called as thickened keel method. After about twenty-one days a young larval form hatches out as the ammocoetes larva.

3.5.1 Salient features of ammocoetes larva

1) Ammocoetes is a freshwater larva of *Petromyzon*.
2) Transparent and eel like body.
3) It lives inside U-shaped burrow. At times it comes out of burrow.
4) Colour is muddy brown.
5) Body is divisible into head, trunk and a tail.
6) Suctorial buccal funnel absent.
7) Oral hood surrounds the mouth in the place of the buccal funnel.
8) Trunk has a single dorsal fin.
9) Tail has a caudal fin which is in continuation of the dorsal fin.
10) Teeth are absent but several branched buccal tentacles surrounded the mouth.
11) The alimentary canal includes a mouth, buccal cavity, pharynx, intestine and anus.
12) A velum is present between the buccal cavity and the pharynx.

13) The pharynx has an endostyle, a pair of peripharyngeal bands and a hypopharyngeal groove.
14) Eyes are vestigial and concealed below the skin.
15) Pineal eye is well developed.
16) Trunk has seven pairs of gill-slits just behind the head.
17) Liver, bile duct and gall bladder are present.
18) Protonephric kidney present.
19) It exhibits filter feeding.

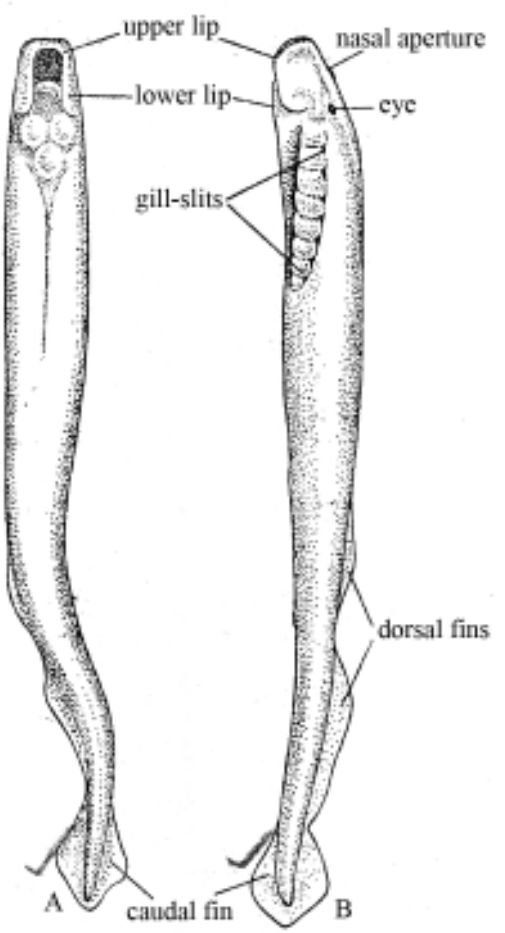


Fig 3 : Anatomical organisation of Ammocoetes larva of *Petromyzon*; A.Ventral view B. Lateral view

20) Respiratory current goes into the pharynx through mouth and comes out through gill-slits.

21) Heart with pericardium is present.

3.6 Summary

- Cyclostomata is a group of agnathans that comprises the living jawless fishes—the lampreys and hagfish.
- The class cyclostomata is sub-divided into two order—1) Petromyzontia and 2) Myxinoidea
- Ammocoetes is a freshwater larva of *Petromyzon*.

3.7 Questions

i) Who are called as agnatha?

ii) Write the general characteristics of cyclostomata.

iii) Write the classification of cyclostomata up to order with its distinctive characteristics and example.

iv) Write the salient features of ammocoetes larva

3.8 Suggested readings

1) The life of vertebrates by J. Z. Young; Year: 1981. Published in India by Oxford University Press, New Delhi

2) Learning protochordata through latest portfolio of theory and practice. Edited by P.K. Verma and Nandita Pande (Editor-in-Chief: Brian Jenkins); Year: 2002; Pub: Dominant Publisher and Distributors, New Delhi-110002

3) Biology of Animals (Volume-II) by Arup Kumar Sinha, Simananda Adhikari and Banku Behari Ganguly; Yearl991; Pub: New Central Book Agency

4) Text Book of Zoology Vertebrates (volume-2) 7th Edition by T. Jeffery Parkar and Williama Haswell (Edited by Marshall & Williams) Year: 1995. Pub: AITBS Publishers & Distributors, New Delhi-110051

Unit 4 ❑ Pisces

Structure

4.1 Objectives

After studying this unit, learners would be able to understand the following—

- the characteristics of pisces.
- the general characteristics of Chondrichthyes.
- the general characteristics of Osteichthyes.
- the classification of pisces up to order.
- fish migration.
- fish osmoregulation.
- the parental care of fishes.

4.2 Introduction

Fishes are aquatic cold blooded vertebrates which exploit the aquatic habitat and become a "sentinel organism" of the water bodies. Fishes constitute the first group of animals that have developed the biting jaws in the phylogenetic history of vertebrates. Fishes are known for its unique characteristics, like- (i) fins with dermal fin rays; (ii) presence of dermal scale; and (iii) presence of lateral line sense organ. The biology of fishes is so diverse that it is extremely difficult to give a concise account of the group. Living fishes with jaws mostly fall into two well marked classes- (i) the cartilaginous fish (Condrichthyes); and ii) bony fishes (Osteichthyes). These groups arose in the late devonion period.

4.3 General characteristics of chondrichthyes

1) Exclusively marine fishes.
2) Streamlined body provided with cartilaginous endoskeleton.
3) Mouth is located on ventral side.
4) Gill slits are separate and without gill cover (operculum).
5) Pelvic fins bear claspers in males.
6) Skin is tough and provided with minute placoid scales.
7) Predatory animals with powerful jaws and teeth.

Example: Shark, Rays, Skates etc.

4.4 General characteristics of osteichthyes

1. The endoskeleton is cartilaginous in the embryonic stage, but adult are with bony endoskeleton.
2. Caudal fin usually homocercal type.
3. The exoskeleton, if present comprised of cycloid, ctenoid or ganoid scales.
4. The mouth is terminal. Digestive tract leads into an anus. Cloaca is absent in bony fishes.
5. External nares are present lie on the dorsal surface of the snout.
6. Bony fishes have a swim bladder (also called air bladder), arising from the dorsal wall of the oesophagus, used to maintain balance.
7. Four pairs of gills covered by an operculum on each side.
8. Single circuit heart is two chambered (one auricle and one ventricle) and also has sinus venosus and conus arteriosus. Lung fishes have three chambered heart (two auricles and one ventricle).
9. Kidneys are mesonephric. Ammonia is chief nitrogenous waste.
10. Presence of ten pairs of cranial nerves.
11. The brain bears relatively small olfactory lobes and cerebellum.
12. Lateral line system is well developed.
13. They have internal ears which helps the fish keep its balance.
14. Fertilization is generally external. Most forms are oviparous, some are ovoviviparous.
15. Some bony fishes show parental care.

Examples:

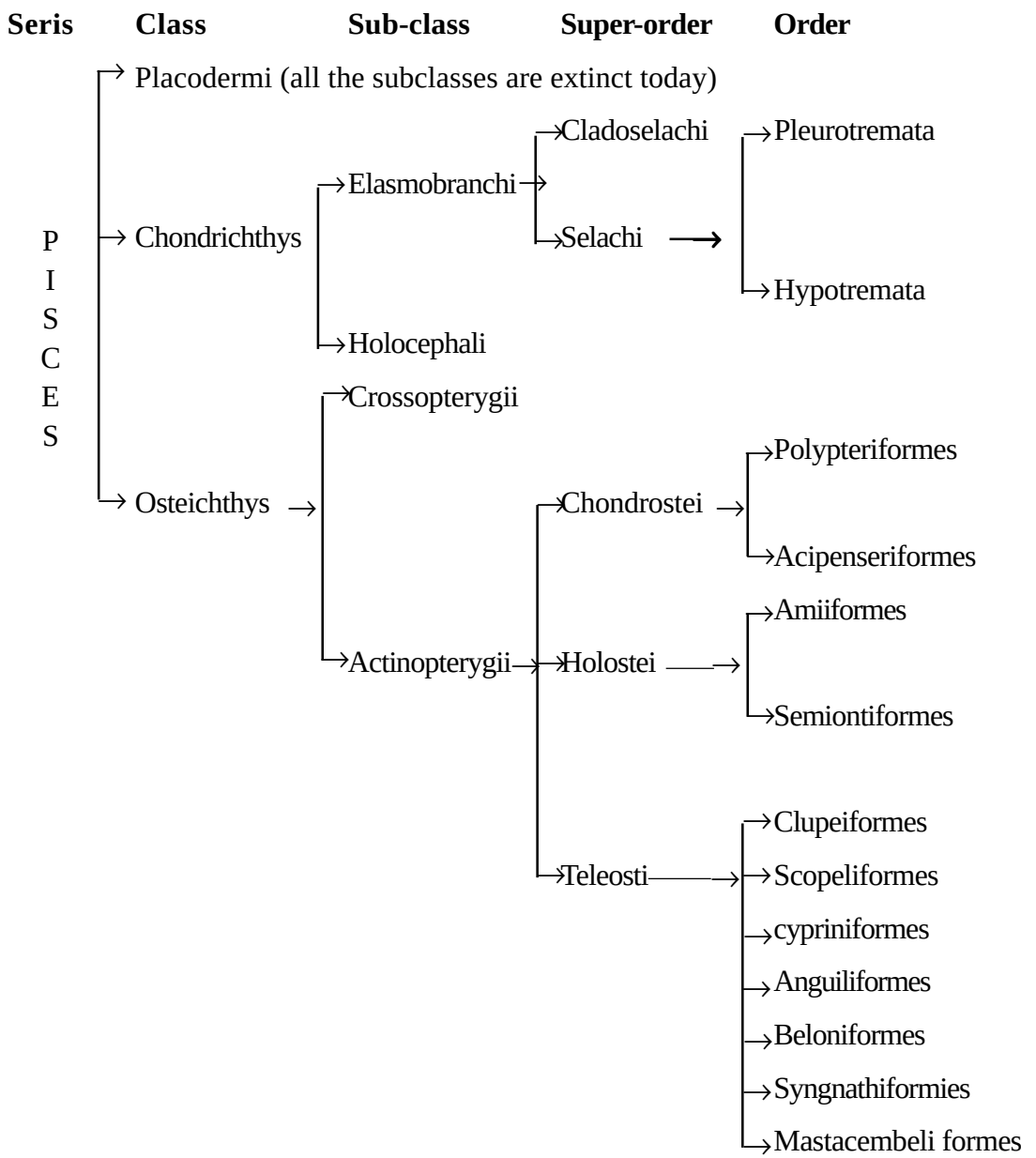
Marine Fishes: *Exocoetus, Hippocampus, Echeneis* (Sucker fish), *Lophius* (Angler fish) etc. **Fresh Water Fishes:** *Labeo, Catla, Clarias* (Magur), *Anguilla, Anabas, Mystus* etc.

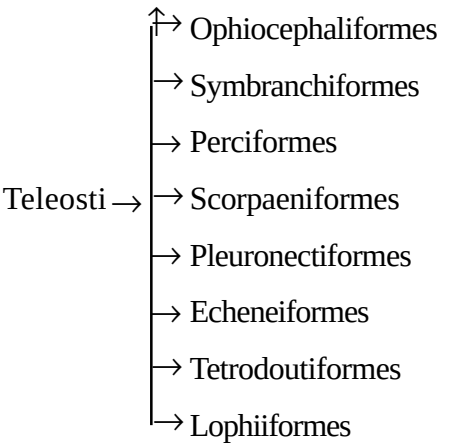
4.5 Classification of pisces up to order

There are difference in the classification scheme of pisces according to different authors. Considering all the views, the following classification is a combined classification based on Romer (1959) and Parker & Haswell (1967). According to

them pieces has been placed in a different "series". The series "pisces" have been classified into three different classes, *i.e.*, placodermi, chondrichthys and osteichthys.

The following is a schematic diagram of classification of pisees





Series: Pisces

1. **Class:** Placodermi (6 subclasses): All the subclasses are extinct today.
2. **Class:** Chondrichthys

2.1 Subclass: Elasmobranchi

Characteristics:

(i) Exclusively marine

(ii) Body provided with placoid scales

(iii) Pelvic fins modified as claspers in males

(iv) Heterocercal type of tail

(v) Mouth ventral in position

(vi) Cloaca present

(vii) Spiracle present

2.1.1 Superorder : Cladoselachi (extinct Sharks)

(i) Paired fins with a median axis

(ii) Vertebra not differentiated

(iii) Tail fin variable

2.1.2 Superorder: Selachi (Modern cartilaginous fishes)

Characteristics:

(i) Paired fins are folded

(ii) Tail fin heterocercal

(iii) Males with claspers

(iv) Five pairs of gill slits

(v) Operculum absent

(vi) Placoid scales present

2.1.2.1 Order: Pleurotremata (Shaks and Dogfishes)

Characteristics:

(i) Body cylindrical

(ii) Gill slits laterally placed

(iii) Pectoral fins small in size

(iv) Eyes laterally placed

2.1.2.2 Order: Hypotremata (Skates and Rays)

Characteristics:

(i) Body dorsoventrally flattened

(ii) Gill slits ventrally placed

(iii) Pectoral fins large and fused on the lateral margins

(iv) Bottom dwellers

2.2 Subclass: Holocephali *(Chimaera)*

Characteristics:

(i) Four pairs of gills

(ii) Notochord persists

(iii) Teeth modified as crushing plates

(iv) Mouth with lips

(v) Holostylic jaw suspension

(vi) Tail whip-like

(vii) Spiracles absent but a single nostril present

(viii) Skin naked with scattered placoid scales

3. Class: Osteichthys

3.1 Subclass: Crossopterygii *(Latimeria)*

Characteristics:

(i) Internal nares present

(ii) Fins lobed except the first dorsal fin

(iii) Scales with cosmine layer

(iv) Air bladder lung-like

(v) Jaw suspension autostylic

(vi) Notochord persists and vertebrae unossified

3.2 Subclass: Actinopterygii *(Rayfin bony fishes)*

Characteristics:

(i) Fins with fin rays

(ii) Tail fin homocercal types

(iii) Scales cycloid and ctenoid

(iv) Internal nares absent

(v) Air bladder present but no lungs

(vi) Jaw suspension methystylic

3.2.1 Super order: Chondrostei

Characteristics:

(i) Skeleton partly cartilaginous

(ii) Ganoid scales present

(iii) Two internal nostrils present

(iv) Air bladder two-lobed and ventral

3.2.1.1 Order: Polypteriformes *(Polypterus)*

3.2.1.2 Order: Acipenseriformes *(Acipenser; Polyodon)*

3.2.2 Superorder: Holostei

Characteristics:

(i) Skeleton partly cartilaginous

(ii) Teeth sharp

(iii) Ganoid scales on body

(iv) Air bladder lung-like

(v) Tail fin homocercal

(vi) Opisthocoelous vertebrae

3.2.2.1 Order: Amiiformes *(Amia calva)*

3.2.2.2 Order: Semiontiformes *(Lepidosteus)*

3.2.3 Super order: Teleostei

Characteristics:

(i) Bony skeleton

(ii) Tail homocercal

(iii) Scales cycloid and ctenoid

3.2.3.1 Order: Clupeiformes *(Herrings; Salmons, Sardines)*

3.2.3.2 Order: Scopeliformes *(Bombay duck)*

3.2.3.3 Order: Cypriniformes *(=Ostariophysi) (Labeo, Catla, Mystus, Clarias, Wallago, Heteropneustes)*

3.2.3.4 Order: Anguilliformes *(Eels)*

3.2.3.5 Order: Beloniformes *(Flying fishes)*

3.2.3.6 Order: Syngnathiformes *(Sea horse and Pipe fish)*

3.2.3.7 Order: Mastacembeliformes *(Eel-like Mastacembelus)*

3.2.3.8 Order: Ophiocephaliformes *(Ophiocephalus)*

3.2.3.9 Order: Symbranchiformes *(Eel-like Amphipnous)*

3.2.3.10 Order: Perciformes *(Lates; Perea)*

3.2.3.11 Order: Scorpaeniformes *(Scorpion fish)*

3.2.3.12 Order: Pleuronectiformes *(Flat fishes)*

3.2.3.13 Order: Echeneiformes *(Sucker fish)*

3.2.3.14 Order: Tetraodontiformes *(Tetrodon; Diodon; Ostracion)*

3.2.3.15 Order: Lophiiformes *(Angler fishes)*

4.6 Fish migration

4.6.1 Definition

The term migration may be applied to the cycle or periodic travels of an animal if it returns eventually to the original place of departure. Such movements can be constructed with emigrations and involves a change in location not necessarily followed by return journey. Fish exhibit migration due to searching of food, shelter and for breading purpose.

4.6.2 Types of migratory movements

According to Thompson (1942) migratory movement was grouped into the following categories:

A. Local and seasonal movements: There are merely changes of ground at a particular time of year. The migratory movements are sometime very small often larger but still confined within one geographical area.

B. Dispersals: The movements are more extensive only the breeding area is well defined and the movement is ideally an even and outward spread from the centre.

C. True migration: True migration is the movement between highly separated and well defined areas. The movement impels migrant to return to the region from which they have migrated.

4.6.3 Pattern of fish migration

Several authors have coined specialized terms considering the return of water current and character to designate the pattern of fish migration.

A. Movements in relation to water current: Merk (1915) introduced two terms, denatant and contranatant movements of fishes. Denatant means swimming or drifting or migrating with the current and contranatant means swimming or migrating against the current. The young stages of fish generally drift with the current to the nursery ground, the spawning migration is against the current. Again the adult fishes swim against the current to reach the spawning area.

B. Movements in relation to water character: Mayers' (1949) has proposed some terms to designate the fish migration considering the water characteristics.

1. Diadromous: Truly migratory fishes which migrate between the sea and fresh water. This type of migration has following sub-divisions.

(a) Anadromous: Diadromous fishes which spend most of their lives in sea and migrate to freshwater for breeding, *e.g: Salmon, Sea lamprey, Tenulosa ilisha* (Hilsa).

(b) Catadromous: Diadromous fishes which spend most of their lives in freashwater and migrate to the sea for breeding, e.g: Eeuropean eel (*Anguilla anguilla*) eel.

(c) Amphedromous: Diadromous fishes where migration from freshwater to the sea or vice-versa, is not for the purpose of breeding but occurs regulatory at some other definite stage of the life cycle, e.g. Fresh water mullet (*cestraeus plicatitis*).

(d) Limnodromous : Many freshwater fishes leave the lakes to spawn in the river. This is called as limnodromous migration. e.g. : white fish (*coregonus lavaretus*).

2. Potamodromous: True migration of fishes whose migration occur wholely in the fresh water, *e.g:* Some species of salmon and trout.

3. Ceranodromous: Truly migratory fishes which live and migrate wholely in the sea. *e.g: Harring, Cod.*

4.6.4 Factors affecting fish migration

The following are the factors affecting fish migration.

Physical factor : light, temperature, turbidity, depth of water etc.

Chemical factor : Salinity, pH value of water etc.

Biological factor : Predators, competitors, Shortage of food, hormonal secretion etc.

4.6.5 Different stimuli and fish migration

Fish migration is considered to be directed by various stimuli. These stimuli have been discussed below.

A. Chemical stimuli: The alfaction play a vital role in finding food and locating areas which could be characterized by chemical clues. Different experiments prove that the threshold of smell of fishes is very much slower than that of test. Parker (1922) has rightly classed the alfactory organ of fishes as a distance receptor.

B. Temperature stimuli: Temperature may act as sensory receptor ordinate on the metabolism. In teleost the thermal receptors are scattered by spinal nerves.

C. Water current stimuli: So far as migration is concerned, the reaction of fish to water currents is one of the most interesting aspects of their behavior directing the course of their movements. To select the rheotactic response the visual and tactile sense organs are necessary.

D. Light stimuli: Fish react phototactically to light. The eye is the main receptor for light. In some fishes, in the pineal area, the dermal photoreception also occurs. Under natural conditions, most fishes often show a vertical migration from deep water by day of shallow water by night and probably the phototactic reactions are efficiently used by fish on migration.

E. Electrical stimuli: Regnarl (1932) was the first to suggest that the electro-magnetic force generated by moving water could have some biological significance. Thornton (1932) argued that deep sea fish could defeat the another animals by means of the electric current produced by their own motion.

F. Celestrial stimuli: Various evidences like compass reaction suggests that the fishes make are of celestrial clues for orientation during migration. Haster et al (1958) observed it in the White Ban (*Roccus chysops*). Migration of Sole (*Solea vulguris*) in Southern North Sea is oriented at right as lightened by Haswell (1960).

4.7 Fish osmoregulation

4.7.1 Introduction

The water is essential component of all living cell and it is the universal biological solvent. As the life began in the water medium most of the organism live in water

medium and face the more problem of osmoregulation. Fish, migrate from freshwater to marine water and vice-versa, thus requires osmoregulation. Freshwater fish and seawater fish osmoregulate in different ways. Due to the different nature of the salinity of water in which they live, their process of osmoregulation is different. Osmoregulation is the process by which an organism regulates the water balance in its body and maintains the homeostasis of the body. It includes controlling excess water loss or gain and maintaining the fluid balance and the osmotic concentration, i.e., the concentration of electrolytes. It ensures that the fluids in the body do not get too diluted or concentrated.

4.7.2 Types of osmoregulation

There are two major types of osmoregulation—

1. Osmoconformers: Osmoconformersare organisms that keep their internal fluids isotonic to their environment, that is, they maintain an internal salinity similar to their ambient conditions. These organisms try to maintain the osmotic pressure of their body equal to their surrounding environment. Most of the marine invertebrates, hagfish, skates and sharks are osmoconformers.

2. Osmoregulators: These organisms maintain their internal osmolality, which can be extremely different from that of the surrounding environment, through physiological processes.

Some fish have evolved osmoregulatory mechanisms to survive in all kinds of aquatic environments. When they live in fresh water, their bodies tend to take up water because the environment is relatively hypotonic. In such hypotonic environments, these fish do not drink much water. Instead, they pairs a lot of very dilute urine, and they achieve electrolyte balance by active transport of salts through the gills. When they move to a hypertonic marine environment, these fish start drinking sea water; they exerete the excess salts through their gills and their urine.

4.7.3 Osmoregulation in freshwater fishes

The body fluid of freshwater fishes is generally hyperosmotic to their aqueous medium. Thus, they are posed with two types of osmoregulatory problems- i) because of hyperosmotic body fluid they are subjected to swelling by movement of water into their body owing to osmotic gradient; ii) since the surrounding medium has low salt concentration, they are facing with continual loss of their body salts to the environment. Thus, freshwater fishes must prevent net gain of water and net loss of salts. Net intake of water is prevented

by kidney as it produces a dilute, more copious urine (**Fig.** 1).

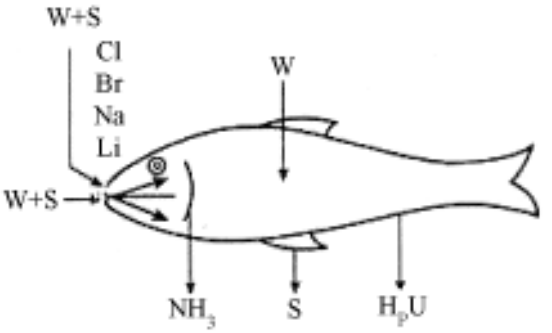


Fig. 1 Osmoregulatory inflow and outflow of salts and water in a fresh water fish. HpU : hypotonic urine; S : salt W : water, W + S : water and salt.

On the other way, the useful salts are largely retained by re-absorption into the blood in the tubules of kidney, and a dilute urine is excreted. Although some salts are also removed along with urine which creates torrential (loss of some biologically; important salts such as KC1, NaCl which are replaced in various parts. As for example, NaCl actively transported in the gills against a concentration gradient in excess of 100 times. In these fishes the salt loss and water uptake are reduced by the integument considerable with low permeability or impermeability to both water and salt also by not drinking the water (Fig. 2).

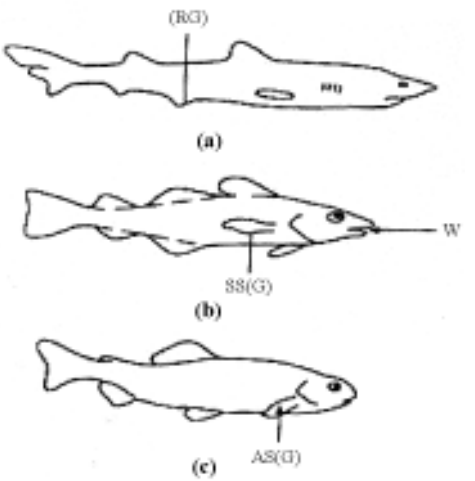


Fig:2 Exchange of water and salt in some fishes. (a) marine elasmohranch does not drink water and has isotonic urine; (b) marine teleost drinks water and has isotonic urine; (c) freshwater teleost drinks no water and has strongly hypotonic urine; AS(G) : absorbed salt with gill; HrNaCl (RG) : hypertonic NaCl

from rectal gland; SS(G) : secretes salts from gill; W : water.

4.7.4 Osmoregulation in marine water fishes

In marine fishes, the concentration of body fluid and marine water is almost similar. Therefore, they do not require much energy for maintenance of osmolarity of their body fluid. As for example is hagfish, *Myxine* whose plasma is iso-osmotic to the environment. Hagfish maintains the concentration of Ca^{++}, Mg^{++} and SO_4^{++} significantly lower and Na^+ and Cl^+ higher in comparison to sea water.

Modern bony fishes (marine teleost) have the body fluid hypotonic to sea water, so they have tendency to lose water to the surroundings particularly through gills via epithelium. The lost volume of water is replaced by drinking salt water (Fig.3).

About 70- 80% sea water containing NaCl and KC1 enters the blood stream by absorption across the intestinal epithelium. However, most of the divalent cations like Ca^{++}, Mg^{++} and SO_4^{++} left in the gut are finally excreted out. Excess salts absorbed along with sea water is ultimately received from the blood with the help of gills by the active transport of Na^+Cl^- sometimes K^+ and eliminated into the sea water. However, divalent ions are secreted into the kidney (Fig. 3).

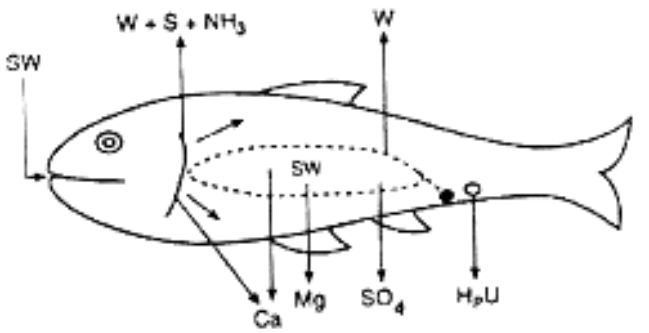


Fig. 3: Osmotic regulation in marine bony fishes. HpU : hypotonic urine; SW : sea water; W + S + NH_3 : water, salt and ammonia; W : water.

Thus, urine is iso-osmotic to the blood but rich in those salts, particularly $Mg2^{++}$, Ca^{++} and SO_4^{--} which are not secreted by the gills. Combined osmotic action of gills and kidney in marine teleost resulted in the net retention of water that is hypotonic both to the ingested water and urine. By using similar mechanism some teleost species such as the salmon maintain more or less constant plasma osmolarity in-spite of being migratory between marine and freshwater environment.

4.8 Parental care in fishes

4.8.1 Introduction

Parental care is an adaptation to protect the offspring for continuity of race. However, all fishes do not exhibit parental care. Those fishes are highly fecund, fertilized eggs or youngs and leave to the mercy of nature after egg laying. But there are many fishes where definitive parental care has been evolved. These fishes, in general, are less fecund and lay small number of eggs. Therefore, various devices have been adopted to ensure proper development of the eggs into adults. One or both the sexes may participate in the process.

4.8.2 Prelude of parental care

Aims of reproduction is the perpetuation of the race in the living organisms and is assumed by-

A. Producing large number of offspring, without paying any attention, few will survive in many teleosts.

B. Some fishes produce fewer offspring, therefore the parental care is very strong.

4.8.3 Biological modification with regard to parental care

Parental care normally include some changes in the parental activity and also involve some structural modification.

A. Eggs laid down in protected place: Protection of developing youngs is found in some fishes. The protection is normally accomplished in the following ways-

1. Embryos in shelled cases: The provision of the hard and impermeable egg shell and good supply of yolk is common in several elasmobranchii eggs. Example: *Scyllium sp.*

2. Cocoon: Protection affords by cover or cocoon within which several eggs remain enclosed. Example: Lung fishes.

B. Eggs laid down in unprotected place: Here care is given by parents.

1. Selection of site: The fish select the site for laying their eggs according to their habitat, which they feels to protect their affsprings from different hazardous environment.

(a) *Tenulosa, Salmon* (anadromous fish) select fresh water for spawning.

(b) Freshwater eels (*Anguilla*) have catadromous habit, descending into the ocean to bring the eggs to salt water habit for development.

2. Deposition of eggs: Remarkable protection is given by many fishes in depositing the eggs in suitable places to ensure safety of the offspring. For example, *Rhodens* deposit its eggs into the mantle cavity of the pond muzzle by means of a seasonally developed ovipositor. Eggs may be entangled in hollow ropes, so that they are not scattered. Example: *Pearch.*

3. Nest building: Construction of nest for reception of the fertilized eggs varies from small hole to a beautiful and elongated structure.

(a) Flighting fish (*Betta splendens*) builds any nests prepared by blowing bubbles of air and sticky mucus are also encountered in many fishes. The bubbles of air and mucus adhere to form a floating mass of foam. The eggs are collected by the male and he throws them in such a way that the eggs can adhere to the lower surface of the foamy nest.

(b) Some fishes digged up muddy floor and filled up with small stones for deposition of their eggs. Example: *Salmon*.

(c) The male of many cichlids fishes prepare shallow basin like nest with a layer of fine sand for laying eggs by the females. Example : *Oreochromis* sp.

(d) North American cyprinids construct elaborate nests composed of large lips of stone pebbles.

(e) African asteoglossid (*Heterostis*) make nest by cleaning a space among the aquatic vegetation. Nest measuring about space 1 feet in length and 2 feet in depth and wall made up of grass, thickening much where they deposit their eggs.

(f) In labyrinth fishes they makes a nest by bubbles of air and sticky mucous. The male keep the eggs inside the nest.

C. Care regarded by carrying the eggs/youngs: Some fishes rendered highest degree of protection by carrying eggs/youngs with them. They do not build nests.

1) Mouth cavity as shelters:

(a) In cichlids, the female carry their eggs in their mouth cavity. Even after hatching, they try to uses the mouth cavity as shelter at the time of danger

(found in tilapia). In a catfish *Arius*, the male carry the eggs as well as young fry in the mouth cavity.

(b) In South American cichlids, the females in addition to care for the eggs, the parent allow newly hatched larvae to feed on the mucous covering of their body.

2) Formation of pouch:

(a) In Brazilian catfish, male develops an enlarged lower lip in the form of a pouch. The eggs are incubated in the pouch.

(b) Indopacific catfishes, *Kurtus* exihibited by male. Males provided by a bony hook like projection from their forehead during breeding season. This is for the attachment of garland formed by eggs attached with each other.

3) Coiling round eggs: In *Pholis*, the eggs are rolled into a rounded ball and one of the parents possibly male, guards the egg ball by coiling round it.

4.8.4 Structural modification with regard to parental care

(a) In many male Perciformes, the forehead provided with a bony cephalic hook being supported by a special processes of skull on extension, the egg has become attached to these hook.

(b) In *Platystacus*, the carrying of eggs is of advanced type. The skin at the lower surface of the body of the female become soft and spongy during spawning season. Immediately after the fertilization of the egg, the female presses her body against the egg in such a way that each egg becomes lodged in a small integumentary depression. Each egg is attached inside the cup by an inconspicuous stalk. The eggs remain in this position till hatching.

(c) The male of the pipe fish and sea horse (*Hippocampus*) developed a simple groove lined with soft skin and a special pouch closed by flaps of skin respectively. The eggs are transferred into the brood pouch by the female and development takes place within the brood pouch.

4.8.5 Internal incubation

(a) In some bony fishes, development takes place within the vascular and follicles of the ovary.

(b) In some cases fertilization takes place with the follicle buds, further development occurs in the cavity of the ovary after the egg leaves the tissue. Example: Embiotoced fishes.

(c) Super foetation, i.e., developing more than one group simultaneously into the same ovary in some cyprinoderm fishes.

4.8.6 Viviparity

The sprinids in Central Europe, take remarkable precaution for safety of their offspring oviduct is drawn out from the body and from ovipositor and females lay eggs inside the ovipositor.The retention of the embryos within the body of the parent until the end of the embryonic life. Most of the fishes, who have well defined structure meant for nutrition all and respiratory exchanges between the parent and the developing youngs. The nutrition is drawn by forming yolk sac placenta in most of the cases. The highest degree of parental care found in viviparous fishes.

4.9 Summary

- Fish are aquatic cold blooded vertebrates which exploit the aquatic habitat.
- Migration may be applied to the cycle or periodic travels of an animal if it returns eventually to the original place of departure.
- Fish migration is considered to be directed by various stimuli.
- Osmoregulation is the process by which an organism regulates the water balance in its body and maintains the homeostasis of the body.
- Parental care is an adaptation to protect the offspring for continuity of race. Fish exhibits parental care.

4.10 Questions

i) Write the general characteristics of chondrichthyes.

ii) Write the general characteristics of osteichthyes.

iii) Classify pisces up to order with distinctive characters and examples.

iv) Write a short note on fish migration.

v) What is fish osmoregulation?

vi) Write on the parental care in fishes.

4.11 Suggested readings

1) The life of vertebrates by J. Z. Young; Year: 1981. Published in India by Oxford University Press, New Delhi

2) Study material Post Graduate Zoology (Paper: 1). Structure and function of chordates and non-chordates, Year: 2010. Pub: Registrar, Netaji Subhas Open University

3) Learning protochordata through latest portfolio of theory and practice. Edited by P.K. Verma and Nandita Pande (Editor-in-Chief: Brian Jenkins); Year: 2002; Pub: Dominant Publisher and Distributors, New Delhi-110002

4) Biology of Animals (Volume-II) by Arup Kumar Sinha, Simananda Adhikari and Banku Behari Ganguly; Year l991; Pub: New Central Book Agency

5) Text Book of Zoology Vertebrates (volume-2) 7th Edition by T. Jeffery Parkar and Williama Haswell (Edited by Marshall & Williams) Year: 1995. Pub: AITBS Publishers & Distributors, New Delhi-110051

Unit 5 ❑ Amphibia

Structure

5.1 Objectives

After studying this unit, learners would be able to understand following—

- the characteristics of amphibian.
- the classification of amphibian.
- the parental care in amphibians.

- ❖ the metamorphosis in amphibians.
- ❖ the hormonal control for metamorphosis.

5.2 Introduction

Amphibia, the first land vertebrates to become adapted to life on land. They are known for pentadactyle limb, presence of middle ear. This group arose in the Devonion period and was completed by the reptiles in course of time. This class falls into three main divisions— (i) anura which includes the frog and toad; (ii) urodela includes; newts and salamanders and (iii) apoda that includes superficially worm Gymnophiona. In the present chapter the general characteristics, classification, parental care and metarporphosis in amphibians will be discussed. The study of amphibians is called Ichthyophis, while the study of both reptiles and amphibians is called herpedology.

5.3 General characteristics and classification up to order

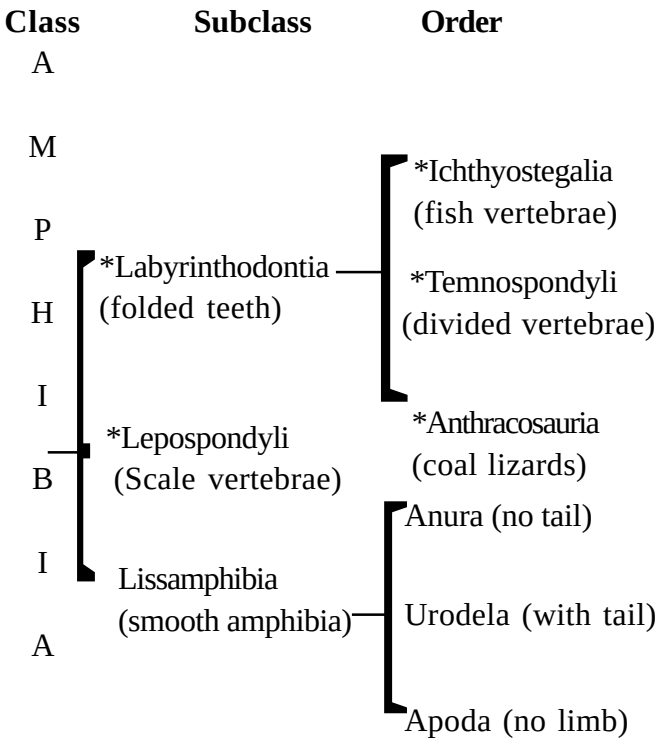
5.3.1 General characteristics of class amphibia

1. Cold blooded vertebrates.
2. Amphibious in nature, *viz*., live both land as well as in water.
3. Body is divisible into head and trunk. Tail may be present in some amphibians.
4. The skin is smooth or rough having glands which keep the animals moist.
5. Usually without scales, if present, they are hidden beneath the skin (e.g., *Caecilians*).
6. Paired fins are absent. Unpaired fins may be present. Two pairs of limbs are used for locomotion except *Caecilions*.
7. The gills are present at least in the larval stage; some adult forms also carry external gills in addition to lungs (e.g., *Necturus*, *Proteus*).
8. Skull is dicondylic, *i.e*., with two occipital condyles for articulation with vertebral column.
9. The respiratory organs are lungs, bucco-pharyngeal cavity, skin and gills.
10. The heart is three chambered, having two auricles and one ventricle. Presence of sinus venosus and truncus arteriosus.
11. Kidneys are mesonephric. Larvae and tailed amphibians (e.g., salamander) are ammonotelic. Frogs and toads are ureotelic.

12. Alimentary canal, urinary and reproductive tracts open into a common chamber called cloaca which opens outside through cloacal aperture.
13. Ear consists of internal and middle ear. Tympanum (outer membrane) covers the middle ear.
14. The eyes have eyelids. Nictitating membrane is well developed.
15. Ten pairs of cranial nerves are present.
16. Lateral line system is found during their development.
17. Fertilization is external. However, in *Salamander* and *lehthyophis* (blind worm) fertilization is internal.
18. Development is mostly indirect.

5.3.2 Schematic diagram of classification of living amphibians

The following classification is based on Young (1981). * marked subclass and orders are extinct now, thus not been included.



Sub-class: Lissamphibia (smooth amphibia)

General characteristics:

1. Found throughout the tropical and temperate areas of the world.
2. Possess a broad skull, the orbits enlarged into cheek and temporal regions.
3. Teeth are fang-like, *i.e.,* pedicellate.
4. Vertebrae are monospondylics (*i.e.,* wanting separate intercentra).
5. In the ear, auricular operculum and columella are present.
6. Scale-less smooth skin possess numerous glands.
7. Respiration through skin.

Order-1: Anura (Sometimes referred to as Salientia)

General characteristics:

1. These animals are short, four-legged, stout bodied and tailless.
2. They possess well developed eyelids and distinct tympanum.
3. Large eyes are situated well ahead of the head.
4. Wide mouth, may or may not possesses tongue.
5. The posterior limbs are longer than the anterior limbs.
6. Frontal and parietal bones of the skull are joined to form a single bone called frontoparietal.
7. Mandible is devoid of teeth.
8. There are five to nine pre-sacral vertebrae in the vertebral column.
9. The post-sacral vertebrae are fused to form a rod-like structure, called urostyle.
10. Vertebrae always possess zygapophyses and transverse processes except the atlas.
11. The tibia and fibula are fused at least proximaily and distally.
12. Generally fertilization is external. Tadpole larva metamorphoses to adult.

Examples: *Duttafrinus melanostictus* (common Indian toad), *Hyla annectans Rana tigrina* (Indian Bull frog), *Rhacophorus malabaricus, Bufo melanostictus.*

Order-2: Urodela (also known as Caudata) (Gk. Oura = tail; delos = visible)

General characteristics:

1. These animals are lizard-like in appearance, with distinct head and a well- developed tail.
2. There are two pairs of weak limbs in the body.
3. In aquatic forms a lateral line system is present.
4. Small eyes are without lids. In cave- dwellers, eyes are lost.
5. Usually four pairs of aortic arches are present.
6. The columella in the middle ear is absent.
7. Kidney is opisthonephric type.
8. In the skull, cartilagenous elements are only found in occipital region.
9. The vomer and palatine are fused to form vomero-palatine.
10. Vertebrae may be amphicoelous or opisthocoelous, with ribs.
11. Simple pectoral girdle is composed of cartilage.
12. There is an Y-shaped bone epipubis attached to the pubis.
13. Fertilization is generally internal.

Examples: *Tylototriton* (Only Indian genus), *Ambystoma, Triton, Necturus, Salamandra, Triturus.*

Order-3: Apoda (Also known as Gymnophiona or Caecilia)

General characteristics:

1. These are worm-like, limbless burrowing creatures.
2. Body smooth, slimy and externally segmented by a series of annular grooves within which small, granular dermal scales are embedded.
3. Lidless eyes are reduced and covered by the skin or by the maxillary bones.
4. A peculiar conical flap-like, protrusible sensory tentacl is present in between nostril and eye.
5. Both the tympanum and tympanic cavity are absent.

6. Tongue is fused with the floor of the mouth cavity.
7. Tail, if present, is short and conical.
8. Skull is solid and compact. Maxilla and palatine fused to form maxillopalatine.
9. Teeth are present on the premaxilla, maxillopalatine, vomer and dentaries.
10. Vertebrae are amphicoelous and with persistent notochord.
11. Pectoral and pelvic girdles are absent. There is no sternum.
12. Intestine is straight.
13. Only right lung is well developed.
14. Only pulmonary and systemic arches are present.
15. Fertilization may be external or internal.
16. The eggs are large and yolky.

Examples: *Ichthyophis* (India), *Uraeotyphlus malabaricus* (South India), *Gegenophis* (South India).

5.4 Parental care in amphibians

5.4.1 Introduction

Parental care is mostly a modification in the parents to take care of the off-springs so that with a meager number of eggs continuation of race can be maintained. In amphibia, the reproductive mechanism had undergone extensive modifications perpetuation of race can be maintained either the process of overproduction of eggs or by caring of a small number of eggs. Rearing or care of the offsprings is an acheivement in the trend of evolution. However, the phenomenon of parental care is quite well developed in amphibians where extreme modifications in structure and behaviour are observed.

5.4.2 Types of parental care

There are various ways by which the parental care is manifested in amphibians.

1. Selection of site: In certain frogs and toads care of the eggs has been taken by selection of suitable site.

Example: In *Rhacophorus schlegli*, the eggs are laid in a hole on muddy bank of

river or pond and covered by foamy mucus to prevent desiccation. The eggs are washed out into the water of the river or pond or by rain and development starts.

In *Triton* and *Leptodactylus* the eggs are laid under the surface of the leafs near the vicinity of water.

2. Frothing of water: *Rhacophorus maculates* (both male and female) just after laying eggs the surrounding water is made frothy by the wriggling movement of hindlimbs, so that the eggs are prevented from desiccation and also can escape the sight of enemies.

3. Formation of nests: The parents take care of the laying eggs in the nests formed by them.

For example: *Hyla faber,* dig a hole in the mud for the developing eggs and the surplus mud nest. *Phyllomedusa,* the leaf nest is formed by folding the margin of the leaves.

Triton constructed shoot nest by fixing the shoots of the trees in which the eggs are deposited and the youngs are developed. The whole nest remains covered by a gelatinous secretion.

4. Carrying eggs over the body: *Hyla goeldii* female carry the eggs in the broad pouch that are placed on their back. The young come out as full- fledged frog with tail. Likewise, the female *Cryptobatrachus* carry the eggs on the back. *Desmognathus* female carry eggs and live in underground hole.

5. Carrying larvae from one place to another: In *Arthroleptis*, the tadpole larvae are attached to the males and are carried from one pond to other. However, at the time of danger they are kept inside the buccal cavity.

6. Placement of eggs in safest part: In *Ichthyophis*, the body remains coiled round the egg mass to guard them until hatching.

In *Rhinoderma darwini*, the eggs are swallowed by the males and are placed inside the inflated vocal sac. The eggs may remain there until hatching or even up to the completion of metamorphosis.

7. Viviparity: In *Salamandra atra* the eggs are placed inside the uterine cavity where entire tadpolehood is completed. The larva remain attached with the uterine wall by membrane which functions physiologically in the manner of a primitive placenta.

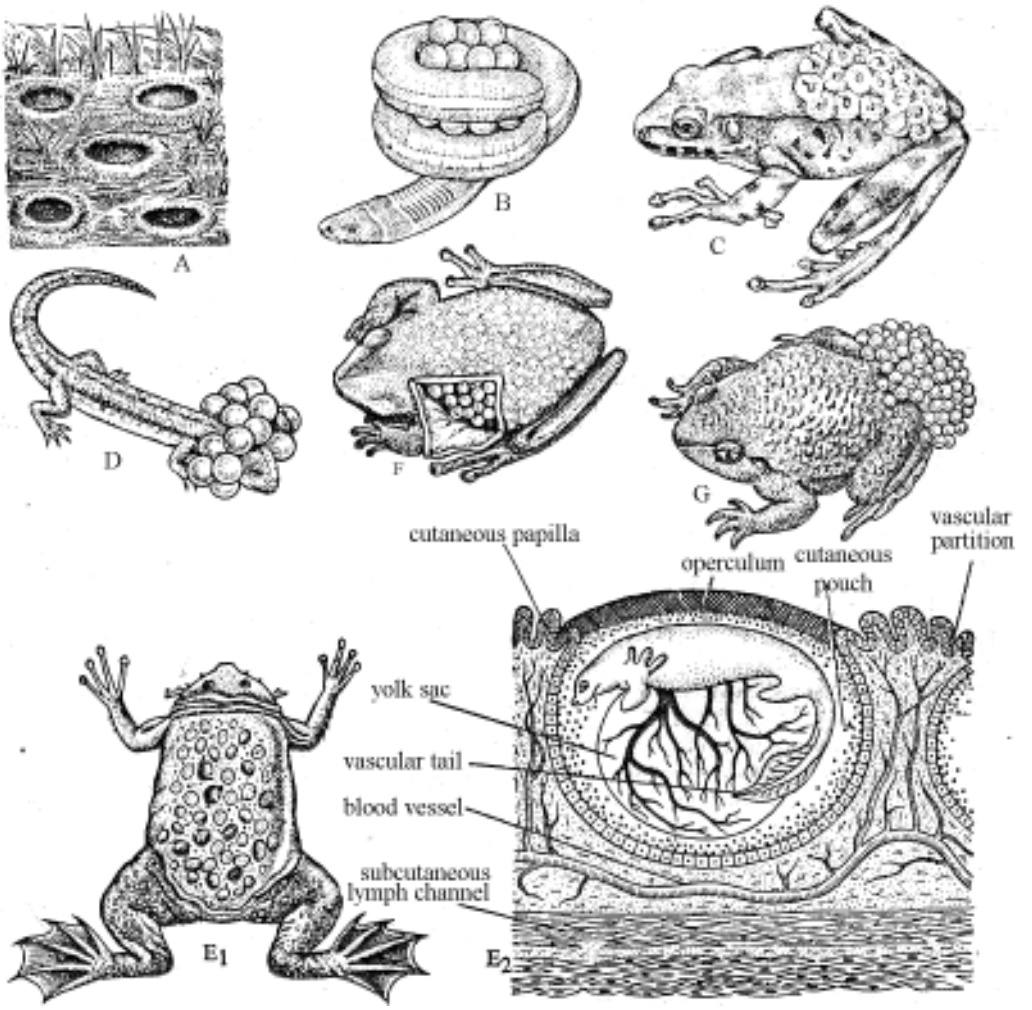


Fig-1. Parental care in amphibians : A. Mud nests of *Hyla*; B. *Ichthyopis* coiling round the eggs; C. *Cryptobatrachus evansi*, where the brood pouches are opened to show developing eggs. D. *Desmoguathus fuscus* with eggs; E_1 : *Pipa pipa*; E_2 : Pseudoplacenatation in *Pipa dersigera*; F : *Gastrotheca*; G. *Alytes*

5.5 Metamorphosis in amphibians

5.5.1 Definition

Metamorphosis may be defined as "a rapid differentiation of adult characters after a relatively prolonged period of slow or arrested differentiation in a larva". According

to Duellman and Trueb (1986), metamorphosis can be defined as "a radical transformation from larval life to the adult stage involving structural, physiological, biochemical and behavioural changes."

5.5.2 Types of amphibian metamorphosis

There are two types of metamorphosis—Progressive and Retrogrossive.

Progressive metamorphosis: During metamorphosis if the animal progresses in the evolutionary grades, the metamorphosis is considered as a progressive metamorphosis; *e.g.,* in most anurans of amphibia.

Retrogressive metamorphosis: When metamorphosis takes place in lower direction, *i.e.,* by metamorphosis the animal retrogresses or shows indication of degeneration in the scale of evolution, called retrogressive metamorphosis. It is found in neotenic forms like salamanders.

5.5.3 Metamorphic changes of amphibians

Metamorphic changes in amphibians takes place in the following three stages :

Premetamorphic stage: The stage is characterized by the considerable growth and development of larval structures but metamorphosis does not occur.

Prometamorphosis: The stage is characterized by the continuous growth specially the development of limbs and initiation of metamorphic changes.

Metamorphic climax: The stage is characterized by the radical changes in the features of the larva, and climax is considered by the loss of most larval features.

5.5.4 Structure of metamorphic tadpole larva

Structure of a freshly hatched tadpole larva

1) A freshly hatched tadpole larva has a limbless body.
2) The body is divided into an ovoid head, a short trunk and a slender tail.
3) Anus is situated ventrally at the root of the tail.
4) An adhesive sucker is present on the ventral side of the head by which the tadpole larva attaches itself to the aquatic weeds.
5) The mouth is absent.

6) The yolk material provides the nutrition.
7) The respiratory organs are in the forms of three pairs of highly vascular and branched feathery external gills.
8) After a few days the mouth is formed near the sucker.
9) A pair of horny jaws surrounds the mouth.
10) The tail becomes more elongated and develops a dorsal and a ventral fin.
11) V-shaped myotomes develop on both the sides of the tail.
12) At this time free-swimming tadpole larva ingests aquatic weeds, as a result of which the alimentary canal becomes extremely elongated.
13) To accommodate such a long alimentary canal inside the cavity of the short trunk, it becomes spirally coiled like the spring of a watch.

Structure of an advanced tadpole larva

1) In the advanced stage, the pharynx of the tadpole larva becomes perforated by gill- slits.
2) External gills disappear and the internal gills are formed between the gill slits.
3) The gills and the gill-slits are covered by the operculum (or gill-cover).
4) The tadpole larva has three pairs of external gills at the start which are subsequently replaced by three pairs of internal gills.
5) In the larval stages, the arterial arches also show modifications in terms of both external and internal gills.
6) The operculum fuses with the trunk on all sides except a small opening, called spiracle on the left side.
7) Water enters into the pharynx through the mouth and goes out through the spiracle.
8) During this transit of water the internal gills are bathed with water containing oxygen dissolved in it.
9) While the internal gills are functioning, a pair of lungs develops as outgrowths from the pharynx on the ventral surface.

10) The hind limbs appear prior to the forelimbs.

11) The forelimbs remain first hidden under the operculum and subsequently emerge through it.

12) At this stage both the internal gills as well as the newly formed lungs are functional.

13) When the lungs become fully developed, the internal gills become degenerated.

14) At this stage it looks like a miniature toad except having a tail.

15) As the limbs are developing, the animal enters into a period of starvation.

16) The material of the tail becomes eventually absorbed into the body.

Structure of a freshly formed toad

1) After the absorption of tail, the young toad leaves the primal aquatic home and comes to the land and then starts hopping.

2) The mouth becomes wider and a pair of true bony jaws replaces the horny jaws.

3) It now changes its food habit to become carnivorous type, as a result the alimentary canal becomes short and less coiled.

Types of changes in tadpole lerva

The changes that take place in the tadpole can be divided into following four groups.

A. Changes of tadpole in habit and habitat

(i) With the metamorphosis, the metamorphosed larva leaves aquatic medium and frequently visits the land.

(ii) The herbivorous tadpole larva changes into carnivorous specially consume the insects (insectivorous).

(iii) The preying habits develop in the adults which become more active and swift moving.

(iv) In the ftrst stage of adult toad, they jump into nearby pond and in other aquatic habitats and then jump on the land by their elongated hind limbs.

B. Morphological metamorphic changes

I. Regressive changes:

(i) The tissues of tail and tail fin are completely absorbed into the body.

(ii) The horny jaws With teeth are shed and mouth becomes a large transverse slit.

(iii) The external gills disappear and the gill slits communicate to the pharyngeal cavity.

(iv) The length of the alimentary canal is reduced substantially.

(v) The changes of the blood vascular system take place and ultimately some blood vessels are reduced.

(vi) The lateral line sense organ disappears.

(vii) Operculum and spiracle disappear.

II. Progressive changes:

(i) The fore and hind limbs increase in size.

(ii) The tongue becomes long and more elastic which is free and bifid posteriorly.

(iii) The eyes become large and prominent and develop eye-Iids and nictitating membrane.

(iv) External nostrils communicate with buccal cavity through internal nostrils.

(v) Tympanum and middle ear develop.

(vi) Liver becomes more enlarged.

(vii) Three chambered heart develops from two-chambered heart.

(viii) Pronephros is replaced by mesonephros in kidney.

C. Biochemical changes during metamorphosis

(i) The concentration of serum protein becomes about double during metamorphosis.

(ii) Biosynthesis and concentration of haemoglobin are greater in adult than in larvae.

(iii) In the liver, DNA synthesis, lipid synthesis, enzymes for ornithine urea cycle increase during adult stage.

(iv) Alkaline phosphatase and hydrolase decrease in adult stage of the anurans.

D. Physiological changes

(i) At the beginning of metamorphosis, the pancreas starts to secret insulin and glucagon hormones. This is related to the enhanced role of the liver.

(ii) During the larval stage, the end product of nitrogen metabolism is ammonia. But after metamorphosis, the toads and frogs excrete most of their nitrogen in the form of urea. This shift from ammonotelism to ureotelism with the change of habitat from aquatic to land.

5.5.5 Hormonal control for metamorphosis

Two hormones such as Triiodothyronine (T_3) and Tetraiodothyronine (T_4) or thyroxine are necessary for biochemical and morphological changes during metamorphosis. These thyroid hormones are produced by the induction of anterior pituitary lobe or pars distalis when it reaches certain degree of differentiation. Then it is capable to synthesize a hormone, thyrotropin (Thyroid Stimulating Hormone, TSH) which acts on the thyroid, stimulating the production and secretion of triiodothyronine (T_3) and thyroxine hormones.

In pre-metamorphic stage the prolactin level is high but levels of thyroid stimulating hormone (TSH) and thyroid hormone (T_3, T_4) are low. The hypothalamus - pituitary link is poorly developed. In pro-metamorphosis, the hypothalamus and pituitary link develops.

The prolactin level is low but the levels of thyroid stimulating hormone (TSH) and thyroid hormones (T_3, T_4) are high. In metamorphic climax, the prolactin level increases suddenly, then maintains steady low level. The TSH is high until the end of climax and the level of thyroid hormone (T_4) becomes low.

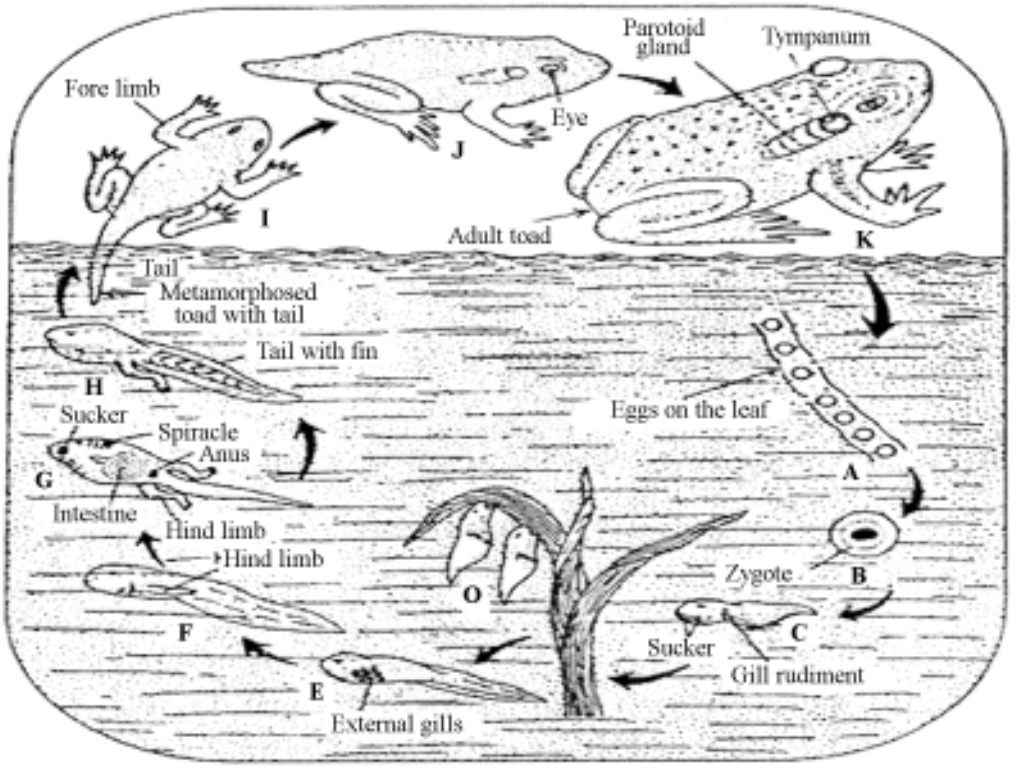


Fig-2. Schematic representation of the larval development and metamorphosis of *Bufo* sp.

5.5.6 Metamorphosis of toad

The young tadpole larva resembles a fish. It leads an independent and self-supporting life. This fish like tadpole larva completely metamorphoses into toad, and it is exclusively a progressive process. Daniel (1963) reports the hatching in about 4 days after laying. According to Mohanty-Hejmadi and Dutta (1978), the development is rapid being completed in 34-52 days.

5.6 Summary

- Amphibia, the first land vertebrates to become adapted to life on land.
- The phylum amphibia possess three living order, i.e., anura, urodela and apoda.
- Amphibians exhibit parental care.

- Tadpole is the larva of amphibians.
- Triiodothyronine (T_3) and Tetraiodothyronine (T_4) or thyroxine are necessary for biochemical and morphological changes during metamorphosis in amphibians.

5.7 Questions

i) Write the general characteristics of amphibian.

ii) Discuss in details about the classification of living amphibians with distinctive characters and examples.

iii) Write a short note on the parental care in amphibians.

iv) What is metamorphosis?

v) How many types of metamorphosis are found in amphibian? Give details.

vi) Discuss about the hormonal control for metamorphosis in amphibian.

5.8 Selected readings

1) The life of vertebrates by J. Z. Young; Year: 1981. Published in India by Oxford University Press, New Delhi.

2) Biology of Animals (Volume-II) by Arup Kumar Sinha, Simananda Adhikari and Banku Behari Ganguly; Yearl991; Pub: New Central Book Agency.

3) Text Book of Zoology Vertebrates (volume-2) 7th Edition by T. Jeffery Parkar and Williama Haswell (Edited by Marshall & Williams) Year: 1995. Pub: AITBS Publishers & Distributors, New Delhi-110051.

4) Vertebrates Comparative Anatomy, Function, Evolution (Fourth Editon) by Kenneth V. Kardong. Year: 2010. Pub: Tata McGraw-Hill

Unit 6 ❑ Reptilia

Structure

6.1 Objectives

After studying this unit, learners would be able to understand the following—

- the general characteristics of reptiles.
- the classification of reptiles.
- General affinities of sphenodon.
- the systematic position of reptiles.
- Parental care in reptiles.
- Poison apparatus in snake.
- Structure of fang in snakes.
- Biting mechanism of poisonous snakes.

6.2 Introduction

Reptiles are the true land vertebrates that left the habit of going to water for laying eggs. In fact, the emergence of reptiles as the true land-dwelling vertebrates offers the greatest dramatic event in the course of evolution. Reptiles are tetrapod vertebrates, that either have four limbs or limbless snake that are descended from four-limbed ancestors. Reptiles arose from a carboniferous amphibian stock which had probably developed the shelled amniotic egg. Most reptiles are oviparous, although several species of squamates are viviparous. The fetus develops within the mother, contained in a placenta rather than an egg shell. In the present chapter the general characteristics, classification, affinities of sphenodon, poison apparatus and biting mechanism in snakes will be discussed in more details.

6.3 General characteristics and classification up to order

6.3.1 General characters of reptiles

1) They are both terrestrial and aquatic (both marine and freshwaters) in habitat.

2) Their skin is dry, cornified and usually covered by epidermal scales or scutes.

3) There are a few integumentary scent glands secreting pheromones during breeding seasons.

4) Single external nasal opening is present on the snout.

5) Vomero-nasal organ (organ of jacobson) is well-developed.

6) Single occipital condyle in the skull is present for the attachment with atlas.

7) Mandible consists usually six pieces of bones.

8) Vertebrae are procoelous. Sternum is greatly developed with ribs.

9) Two pairs of pentadactyle limbs are present. The limbs end in clawed digits.

10) The cloacal opening is either transverse or longitudinal.

11) A post-anal tail is present.

12) The heart is composed of two auricles and a partially divided ventricle (in crocodile the ventricle is completely divided).

13) The kidney is metanephric type.

14) Males possess copulatory organs.

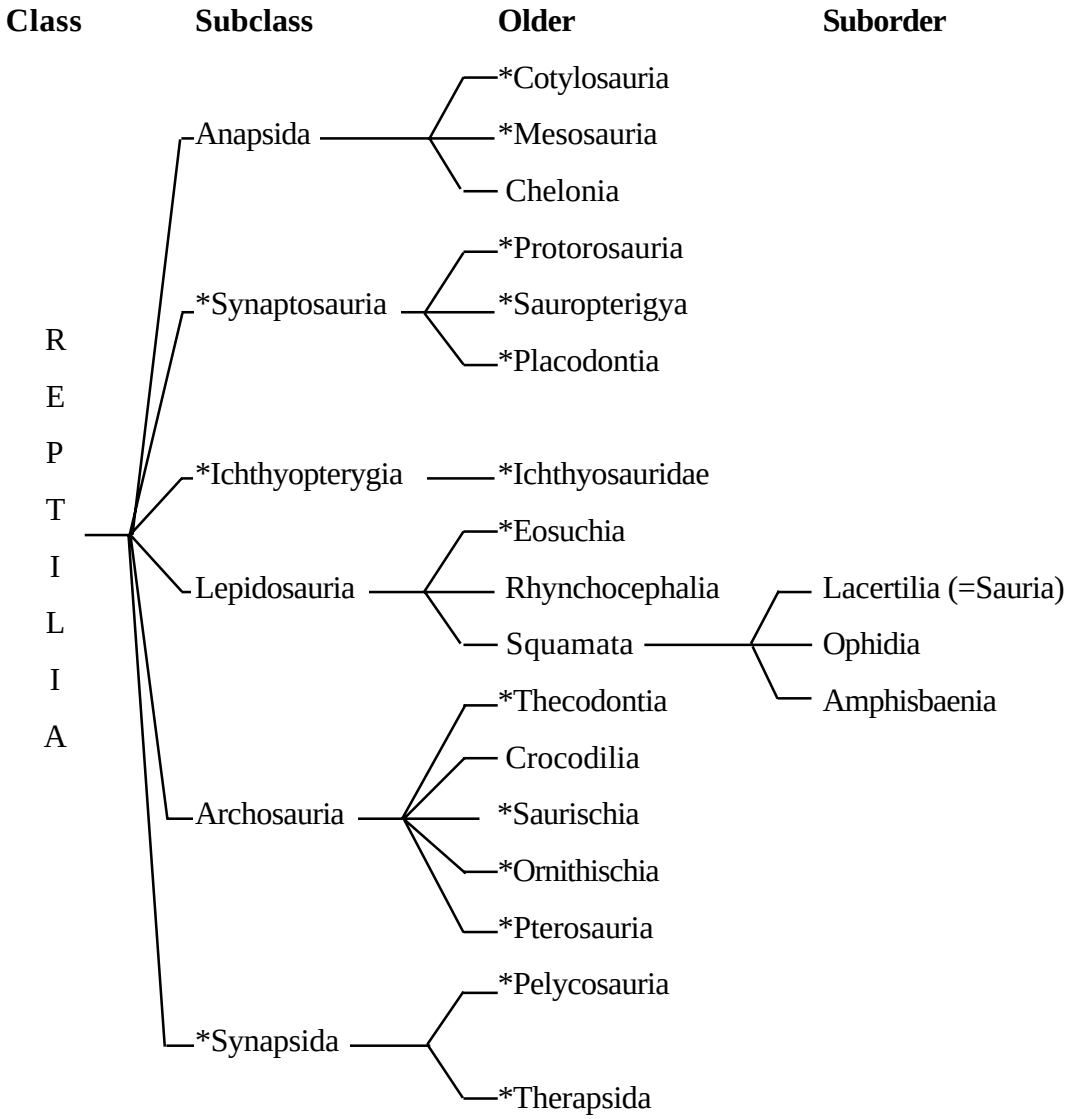
15) Presence of twelve pairs of cranial nerves.

16) Fertilization is internal.

6.3.2 Classification scheme of reptiles

Although different scientists classified reptilia based on the characters of different reptilians, but here we follow the classification given by Young (1981). The following is the schematic diagram of the classification of Reptilia. The (*)marked sub-class and orders are considered as extinct.

Classification scheme of Reptilia



I. Subclass-1 : Anapsida

General characters:

1) The roof of the skull is solid.
2) The skull is devoid of fossae behind the eyes.

Order: Chelonia (Gk. Chelone = a tortoise)

General characters:

1) Body is dorsoventrally flattened and more or less elliptical.
2) Body is dorsally covered by a shield like carapace and ventrally by a plate, plastron.
3) Neck, limbs and tails are retractile. Tail is very short.
4) Weak limbs are pentadactyle and in some marine forms modified into paddles.
5) In adults, teeth are absent and the jaws are covered by sharp horny plates.
6) The cloacal opening is longitudinal.
7) These are oviparous animals.
8) In the skull, quadrate bone is immovably articulated, i.e., monimostylic.
9) Thoracic vertebrae and ribs are usually fused with carapace.
10) Pectoral girdle consists of a scapula, a long pro-coracoid, and a coracoid.
11) The pelvic girdle is composed of ilium, ischium, and pubis.

Examples: *Trionyx* (Indian soft shell turtle), *Chelone* (Green turtle), *Dermochelys* (Leather back turtle) etc.

II. Subclass-2: Lepidosauria (Gk., Lepis = scale; Squaros = Lizard)

General Characters:

1) The skull of this group is diapsid with two temporal vacuities.
2) Lizard-like reptiles with scaled skin.

This subclass includes two living orders- (i) Rhynchocephalia ; and (ii) Squamata.

Order-1: Rhynchocephalia (Gk., Rhynchos = a beak/snout; Kephale = a head)

General characters:

1) Dorsal side is covered by small granular scales and on the ventral side the scales are trans-formed into transverse square plates of larger size.
2) Tail is bilaterally compressed and crested with power of regeneration.
3) At the dorsal side a median row of erective spines (frill) extends from the top

of the head to the tip of the tail.

4) The eyes are large with vertical pupil.
5) The cloacal aperture is a transverse slit.
6) Males do not have copulatory organ.
7) Skull is composed of paired premaxillae, nasals, frontals, and parietals. The quadrate is immovable.
8) Vertebrae have amphicoelous centra with persistent notochord.
9) Vertebrae possess chevron bone.
10) Abdominal ribs are present. The ribs are single headed and bony.
11) The teeth are of acrodont type.
12) Vomerine teeth are present in youngs but in adults these are replaced by pads.
13) Brain is simple with a very well-developed parietal organ (third eye).

Examples: *Sphenodon punctatus* and *Sphenodon guntheri*.

Order-2: Squamata (Latin, sqamatus = scaly)

General characters:

1) The skull of these animals bears superior temporal fossa.
2) The maxilla, palatine and pterygoid are immovably articulated with the skull.
3) The quadrate is movable.
4) Lower jaw is composed of several pieces of bones.
5) Teeth are either acrodont or pleurodont type and are borne usually on the maxillae, premaxillae and palatines.
6) Vertebrae are of procoelous type and possess chevron bone.
7) The ribs are single-headed.
8) Cloacal aperture is a transverse slit.
9) Organ of Jacobson is well-developed.

This order includes three sub-orders.

Sub-order-1 : Lacertilia

General characters :

1) Elongated body, usually two pairs of limbs and long tail.
2) Distinct neck; upper and lower eyelids are usually movable.
3) Excepting the limbless lizards, the limbs are pentadactylus, each digit ending in a claw.
4) Teeth homodont type.
5) Urinery bladder present.
6) Cerebral hemisphere are short.
7) Quadrate is slightly movable.
8) 12 pairs cranial nerve.
9) Tympanum is distinct.

Examples : *Phrynosoma, Chamaeleou, Uromastyx*

Sub-order-2 : Ophidia

General characters:

1) Cylindrical body with limbs.
2) Neck usually indistinct.
3) Limbs secondarily lost.
4) Eyelids absent and fused with the eyes.
5) Mictitating membrane immovable.
6) Conical recurved teeth.
7) Urinary bladder absent.
8) Brain extremely elongated andproject in between the eye.
9) 10 pairs cranial nerves.
10) Quadrate in highly flexable.

Example—*Python molurus, Boa constrictor, Vipera russelli*

Sub-order-3 : Amphisbaenia

General characters :

1. These are worm-like lizards having no limbs.

2. The eye and ears are completely concealed under the skin.

3. The tail is very short.

4. The worm-like body is covered with soft skin possessing numerous rings, which are divided into little square.

5. Fossorial creatures having compact and highly ossified skull.

6. Teeth either acrodont or pleurodont type.

Example—*Amphisbaena fuliginosa, Blanus*

Subclass-2: Archosauria

General characters:

1) The skull is of diapsid type.

2) Some forms are toothlen and in others only. Palatal teeth are lost.

3) The lower jaw is with vacuities between dentary and angular.

Order: Crocodilia

General characters:

1) Predatory, Semi-aquatic reptiles.

2) Large, solidly built, lizard-like body.

3) Long flattened snouts.

4) Laterally compressed tails.

5) Eyes, ears, and nostrils at the top of the head.

6) The skin is thick and covered in non-overlapping scales.

7) They have conical, peg-like teeth and a powerful bite.

8) They have a four chambered heart.

9) They are largely carnivorous, the various species feeding on animals such as fish,

crustaceans, molluscs, birds, and mammals.

10) Females lay eggs in holes or in mounds and. unlike most other reptiles, care for their hatched young.

Example: *Crocodile*

6.4. Affinities of *Sphenodon*

6.4.1 Introduction

The order rhynchocephalia under the phylum reptilia includes five families of which four are extinct today. The only family sphenodontidae includes the sole living representative *Sphenodon punctatum*. It is regarded as a living fossil and is popularly call as "Hatteria" or "Tuatera". *Sphenodon* had many primitive features of its triassic ancestors, almost in an unchanged form while its contemporaries have all vanished. Thus, in search of the affinities of the *Sphenodon* is matter of great concern.

6.4.2 Distribution

Members of the order rhynchocephalia was wide spread in North America, Europe, South Africa. But today *Sphenodon punctatum* is found only along the North coast of Newzeland. It is thus an example of relic distribution. The probable cause behind such restricted distribution is that it could not compete with large size reptiles and mammals and elsewhere, while such animal could not reach Newzeland thereby favorably flourishing growth occurred there.

6.4.3 Habit

i) Sluggish and slow moving animal.

ii) Primarily nocturnal.

iii) Timid, but can attack any intruder in its burrow.

iv) Carnivorous and mainly insectivorous.

6.4.4 Habitat

Sphenodon lives in the burrow of soft soil. It is found in primarily in forest and secondarily in grassland.

6.4.5 Food

Sphenodon is carnivores, eating mainly insects. The diet mainly consists of beetle, crickets and other small insects, earthworms, snails, birds and their eggs and even small mammals.

6.4.6 General characters

i) Lizard like body. The tail is bilaterally compressed and twisted.

ii) The body is dull olive green in colour with yellow spots above and whitish below.

iii) Pentadactylus and clawed digit adapted for walking.

iv) The body covered with small granular scales except the lower side where the scales from transverse rows of large square plates.

v) The skull is composed of paired pre-maxilla, nasals, frontal and parietal. A parital foramen and three temporal fossa are present.

vi) Small, sharp and pointed acrodont teeth.

vii) Transverse cloacal aperture present.

viii) Lungs primitive type with simple sac like alveoli.

ix) Sinus venosus distinct and absorbed in right auricle.

x) It smells on the air borne odour while the food is being taken into the mouth.

xi) Rod and cones are present in the retina of the eyes.

xii) Urinary bladder present. Excreta mainly uric acid.

xiii) Fertlization is external.

6.4.7 Evolutionary position of *Sphenodon*

Sphenodon is undoubtedly a primitive and generalized type of reptiles but its systematic position varies according to views of different scientists. The anatomical peculiarities / general characters of *Sphenodon* have already been discussed.

Affinities: with different groups

I. With chelonia:

Similarities:

(i) The quadrate is immovable;

(ii) Caudal ribs are fused with vertebrae;

(iii) Urinarry bladder is present;

(iv) Pecten is absent.

Dissimilarities:

(i) In *Sphenodon* the vomer is paired but in chelonian;

(ii) Sternum is present in *Sphenodon* but it is absent in chelonian;

(iii) Anal opening is transverse in *Sphenodon* but longitudinal in chelonis;

(iv) The penis is absent in *Sphenodon* but present in chelonian;

(v) The oviduct in *Sphenodon* opens dorsally by in chelonian it opens ventrally.

Comments : Though some degree of similarities is apparent between *Sphenodon* and crocodilian, the dissimilarities are more pronounced. Thus, it is not justified to place the *Sphenodon* in the same taxonomic rank as that of the orders of crocodilian and chelonis.

II. With lacertilia:

Similarities:

(i) General body structure is identical;

(ii) Proatlus is present in both;

(iii) Caudal vertebrae are separated by septum;

(iv) Remnent of notochord is present between the vertebrae;

(v) Ribs are single headed;

(vi) Chevron bones are present;

(vii) Cloacal glands are present;

(viii) Oviducts opens dorsally.

Dissimilarities:

(i) In *Sphenodon* the quadrate is immovable but in lacertalia it is movable;

(ii) The vertebrae are amphicoelus in *Sphenodon* but in lacertilian they are procoelus (except Gecko);

(iii) Clavical and interclavical are present in *Sphenodon* but absent in limbless lacertilian;

(iv) Conus arteriosus is present in *Sphenodon* but absent in lacertilian;

(v) Uncinate process is present in *Sphenodon* but absent in lacertilian.

Comments: Huxley (1869) strongly advocated that that the *Sphenodon* should be included under lacertilian as the differences between the two are very insignificant. Although this view was opposed by a few workers and therefore not accepted.

III. With crocodilia:

Similarities:

(i) The quadrate is iommovable;

(ii) Proatlus is present;

(iii) The skull is of diapsid type;

(iv) Ribs bear uncinate process;

(v) Caudal ribs are fused with vertebrae;

(vi) Abdominal ribs are present;

(vii) Chevron bones are present.

Dissimilarities:

(i) The teeth are acrodont in *Sphenodon* but thecodont in crocodilian;

(ii) The nasal opening is double in *Sphenodon* but single in crocodilian;

(iii) The vertebrae are amphicoelus in *Sphenodon* but procoelus in crocodile;

(iv) Clavical is present in *Sphenodon* but absent in crocodile;

(v) Pectin is absent in *Sphenodon* but present in crocodile;

(vi) Penis is absent in *Sphenodon* but present in crocodile.

Comments: The dissimilarities are pronounced between them, hence, they may be placed separately.

6.4.8 Phylogenetic views

1. **Gadow (1901):** He refers *Sphenodon* as “the last living witness of Bygone ages. This primitive animal almost ideally generalized type of reptiles is living fossile”.

2. **Newmann (1939):** Rhynchocephalia is an aberrant group which first appear in the triassic and had a modest carrier. Through the mosaic and is now represented by one very conservative living species.
3. **Sedgwick (1966):** *Sphenodon* is neither an ancestral group nor is closely allied to ancestor of reptiles and or birds. The rhyncocephalia is essentially reptilian, i.e., it present all the typical features of reptilian organization in full development.
4. **Romer (1966):** Both the lizards and rhyncocephalias have been derived from the same general stock of primitive Eouscuchian which death back to upper permian.

6.4.9 Discussion

Sphenodon has changed little since time of its origin and has laregely remained in eusochian evolution. Thus, it represents a very slow rate of evolution, i.e., an example of bradytilic evolution. On the other hand, taehytelic and horowtetic evolution means fast and average rate of evolution. Among its affinities with the living form *Sphenodon* shows the close affinities with the lacertilian (lizard). Both the group appear in the triassic period again of its affinities with the fossile reptiles, it shows a strong relationship with eousuchia particularly youngians and also to prolacerta. That eousuchian particularly the prolacerta is also most close to lacertiiian. The eousuchia, *Sphenodon* and lacertiiian shows a triangular relationship with each other. On the other hand, the *Sphenodon* has certain features like, double temporal fossa, akinate skull, absence of penis etc. which sharply differentiate it from lacertilia. It thus appear that the eousuchia one hand give rise to rhyncocephalians and on the other hand to the lacertilian through a prolacerta type of reptiles. So, it is wise to treate *Sphenodon* or rather rhyncocephalian as a separate order or a group from the lacertilian having a close relationship that was inhabitant from common ancestry on euosuchia.

Considering foregoing discussion, *Sphenodon* is occupied the following systematic position—

Class: Reptilia

Sub-class: Lepidosauria

Order: Rhyncocephalia

Family: Sphenodontidae

6.5 Poison apparatus in snake

6.5.1 Poison gland

The poison apparatus of snakes consists of a pair of poison glands, their ducts and a pair of fangs. In poisonous snakes the poison glands are situated one on either side of the upper jaw. The poison glands are possibly the superior labial glands or parotid glands. Each poison gland is sac like and provided with a narrow duct at its anterior end. The duct passes forward along the side of the upper jaw and loops over itself just in front of the fang and opens either at the base of the fang or at the base of the tunnel on the fang. The poison gland is held in position by ligaments. An anterior ligament attaches the anterior end of the gland to the maxilla. A posterior ligament extends between the gland and the quadrate. Fan-shaped ligaments are situated between the side walls and squamoso- quadrate junction.

6.5.2 Fangs

The fangs are sharply pointed and enlarged maxillary teeth. Snakes eject venoms by their two hollow maxillary teeth called fangs. Fangs (Fig-1.) are long, sharply pointed and hook like being extremely hard and calcified with a superficial enamel layer.

Poisonous apparatus of a snake

1) Poison gland
2) Nostril
3) Fang
4) Tongue

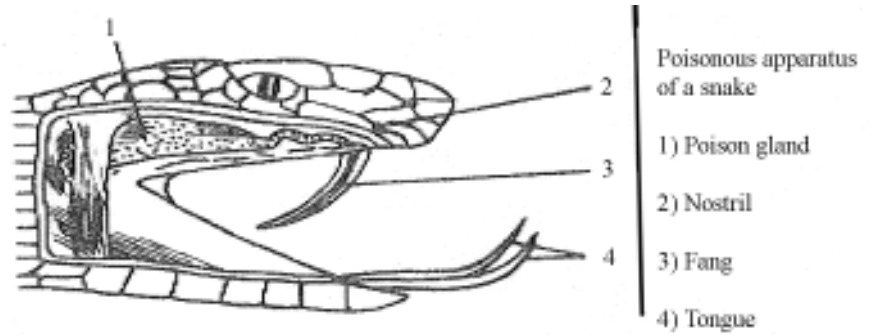


Fig 1: Diagram of a fang

6.6 Biting mechanism of poisonous snakes

Boltt and Ewer (l964) studied the biting mechanism on Puff adder *(Bitis arietans)* give a general idea about the biting mechanism of snake which is applicable to all poisonous snakes. The mechanism also entails the same story in case of Indian poisonous snakes, specially the cobra and viper groups. The mechamsm of biting is a complicated process and the sequences of biting are in three steps as follows—

(a) Opening of the mouth: Just before striking, the digastric muscle contracts, as a result of which the mouth opens (see fig. 2B).

(b) Rotation of maxilla: As the mouth opens, the lower jaw moves forward and a rotation of the squamosal, quadrate and mandible in relation to each other occurs and the sphenopterygoid muscles contract. This contraction results in the forward movement of pterygoid and up-pushing of the ectopterygoid. The upward movement of the ectopterygoid brings about a rotation of the maxilla on its own axis round the lacrimal and as the end result the fang is raised and comes to its striking position (Fig-2C, D). The fang is nearly horizontal in position when the mouth remains closed. But during opening of the mouth to bite, the fang assumes almost vertical position.

It has been suggested that the quadrate is loosely attached to the posterior part of the pterygoid and the weak force, which is generated by the rotation of the lower end of quadrate, could not help in the forward movement of ptecygoid and ectopterygoid. The movement of the pterygoid and ectopterygoid is effected by the contraction of their own muscles, the protractor and levator pterygoidei (Fig. 3), which jointly act to push the pterygoid and ectopterygoid directly forward. As a result the maxilla rotates in its own axes. The erection of fangs is not related to the opening and closing of the mouth. The fangs can be erected independently.

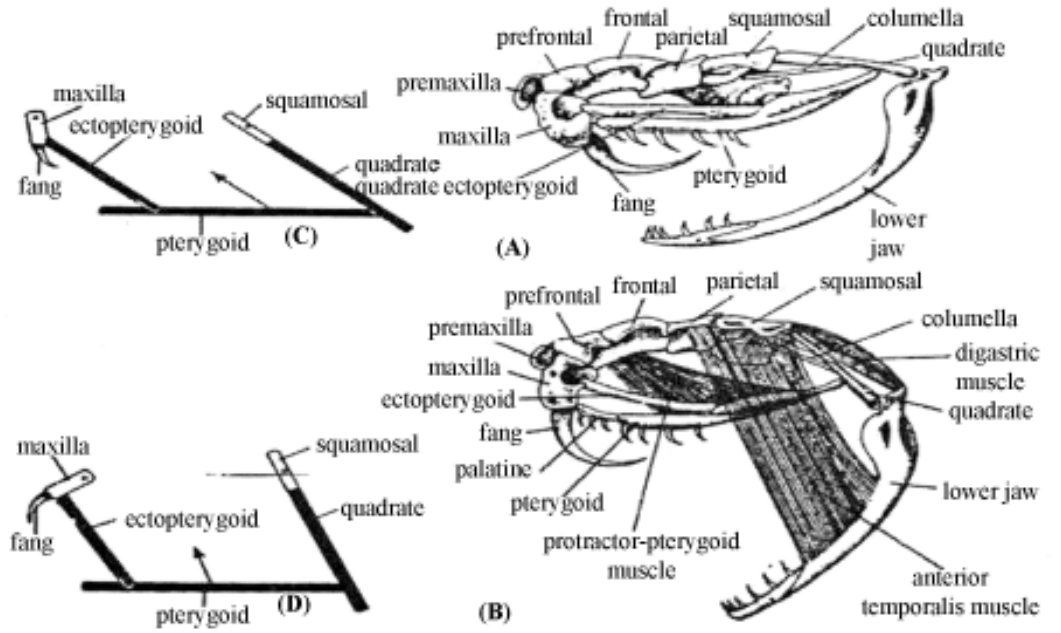


Fig-2 : Showing partly opened (A) and fusly opened (B) mouth of a poisonous snake. Note the relative position ol the fang, maxilla, lower jaw, quadrate and squamosal, (C and D) Schemes showing the relative position of principal bones involved in the erection of fang.

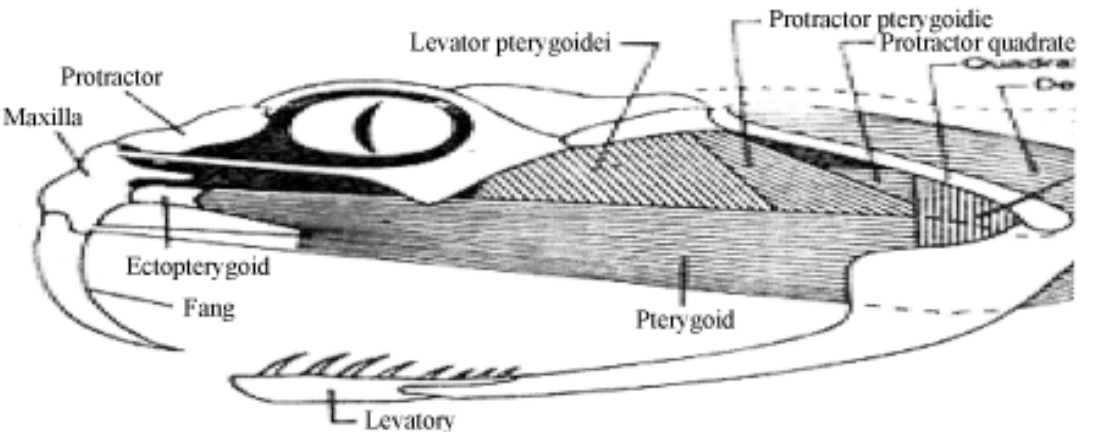


Fig-3: Different types of muscles in the mouth

(c) Closing of mouth: This is brought about by the contraction of the temporalis muscles and sphenopterygoid muscles. The point of the fang is directed backward while the mouth is closed. It takes a longer time to open the mouth than to close it.

6.7 Summary

- Reptiles are the true land vertebrates that left the habit of going to water for laying eggs.
- *Sphenodon* is regarded as a living fossil and is popularly know as "Hatteria" or "Tuatora".
- The poison apparatus of snakes consists of a pair of poison glands, their ducts and a pair of fangs.
- The mechanism of biting of snake is a complicated process and composed of—(i) opening of mouth; (ii) rotation of maxilla and (iii) closing of mouth.

6.8 Questions

i) Write the characteristics of reptilians.

ii) Classify reptilian up to order with distinctive characters and suitable examples.

iii) Discuss about the affinities of *sphenodon*.

iv) Write about the evolutionary position of *sphenodon*.

v) What is parental care?

vi) Write in brief about the parental care in amphibians.

vii) Draw the poison apparatus in snake.

viii) What is fang?

ix) Discuss about the biting mechanism of poisonous snakes.

6.9 Selected readings

1) The life of vertebrates by J. Z. Young; Year: 1981. Published in India by Oxford University Press, New Delhi.

2) Biology of Animals (Volume-11) by Arup Kumar Sinha, Simananda Adhikari and Banku Behari Ganguly; Year 1991; Pub: New Central Book Agency.

3) Text Book of Zoology Vertebrates (volume-2) 7th Edition by T. Jeffery Parkar and Williama Haswell (Edited by Marshall & Williams) Year: 1995. Pub: AITBS Publishers & Distributors, New Delhi-110051.

4) Vertebrates Comparative Anatomy, Function, Evolution (Fourth Editon) by Kenneth V. Kardong. Year: 2010. Pub: Tata McGraw-Hill.

Unit 7 ❑ Aves

Structure

7.1 Objectives

After studying this unit, learners would be able to understand the following—

- The characteristics of aves.
- The classification of aves.
- *Archaeopteryx* and its importance.
- Migration in birds.
- The evolutionary significance of migration of birds.
- The flight adaptation in birds

7.2 Introduction

Birds, also known as aves or avian dinosaurs, are a group of endothermic vertebrates, characterized by feathers, toothless beaked jaws, hard shelled eggs, a four-chambered heart, and a strong light weight skeleton. They constitute a highly specialized group of vertebrates which have attained the peak of evolutionary perfection. Many species of birds are economically important as food for human consumption and raw material in manufacturing process. Domesticated and undomesticated birds (poultry and game) being important sources of eggs, meat, and feathers. Peacock is the national bird of our country. They are essentially "glorified reptiles" and the discovery of fossil of Archaeopteryx, amply speaks about the reptilian origin of birds. The present chapter deals with the general characteristics, classification, *archaeopteryx*-connecting link, flight adaptations and migration in birds.

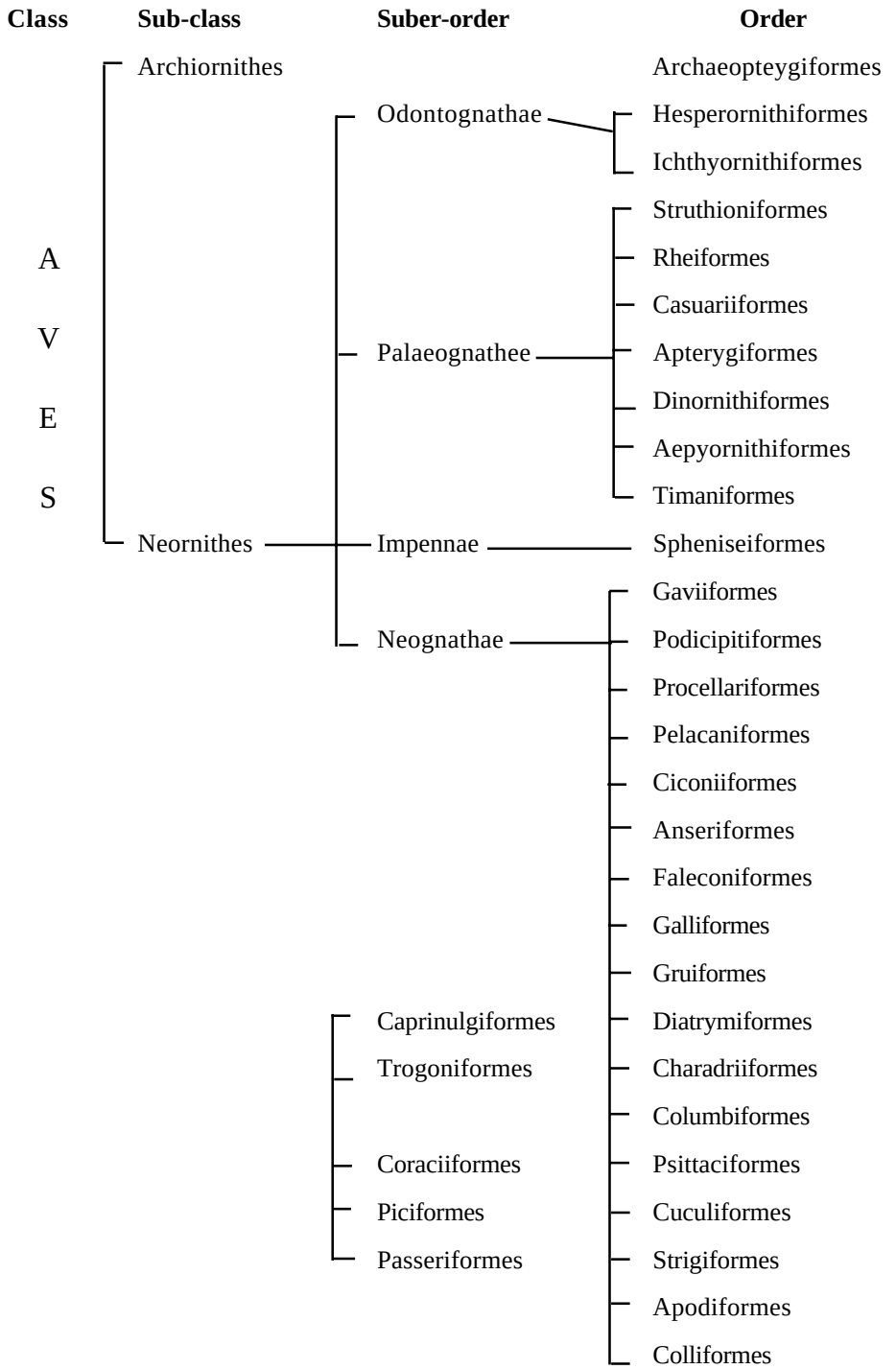
7.3 General characteristics and classification up to order

7.3.1 General characters of class aves

1) Body is covered with feathers and has three distinct divisions with a flexible neck.
2) Two pairs of limbs, the anterior pair modified as wings for flight, and the posterior pair adapted for perching, walking or swimming.
3) Each foot is usually with four toes.
4) Mouth opens through a projecting beak or bill provided with horny sheath.
5) The skeleton is strong, bones fully ossified, and pneumatic.
6) Skull with a single occipital condyle; sutures obliterated.
7) Pelvis fused with a number of vertebrae but open ventrally forming synsacrum.
8) Tail vertebrae few and compressed posteriorly forming pygostyle in modern birds.
9) Sternum enlarged, usually with a median keel.
10) Syrinx, the voice box, is situated at the base of the trachea.
11) The lungs are compact, attached to the ribs and connected to thin-walled air sacs extending between internal organs.
12) Heart is four-chambered with two atria and two ventricles. Unlike mammals, red blood corpuscles are nucleated.
13) Urinary bladder absent, excreta semisolid.
14) Females usually with only left ovary and oviduct.
15) Fertilization is internal.
16) Birds are oviparous animal.
17) Eggs with large amount of yolk, telolecithal; cleavage is meroblastic.

7.3.2 Scheme of classification of aves

Different scientists classified aves based on the characters of different birds, but here we follow the classification given by Young (1981). The following is the schematic diagram of the classification of aves.


Class
Sub-class
Suber-order
Order
A
V
E
S
Archiornithes
Archaeopteygiformes
Neornithes
Odontognathae
Hesperornithiformes
Ichthyornithiformes
Palaeognathee
Struthioniformes
Rheiformes
Casuariiformes
Apterygiformes
Dinornithiformes
Aepyornithiformes
Timaniformes
Impennae
Spheniseiformes
Neognathae
Gaviiformes
Podicipitiformes
Procellariformes
Pelacaniformes
Ciconiiformes
Anseriformes
Faleconiformes
Galliformes
Gruiformes
Caprinulgiformes
Diatrymiformes
Trogoniformes
Charadriiformes
Columbiformes
Coraciiformes
Psittaciformes
Piciformes
Cuculiformes
Passeriformes
Strigiformes
Apodiformes
Colliformes

Subclass-1: Archiornithes

Mesozoic ancestral or lizard birds with long tail and teeth in both the jaws.

Order: Archaeopterygiformes

General characters:

1) Forelimbs bear remiges.
2) Long tail with many vertebrae, which gradually taper to the distal end. The rectrices are arranged in two lateral rows on each side of the caudal vertebrae.
3) The carpals and metacarpals free and hand with three clawed digits.
4) The eyes were large.
5) Enamelled crowned teeth on both the jaws.
6) The sacrum made up of only about six vertebrae.
7) Thin abdominal ribs or gastralia or so-called ventral ribs were on ventral wall of abdomen.
8) The cerebral hemispheres smooth, long and narrow and cerebellum small.

Examples: *Archaeopteryx lithographica, Archaeornis siemensi.*

Subclass-2: Neornithes

General characters:

1) Tail greatly shortened usually ending in a pygostyle, around which the rectrices are arranged in a semicircle.
2) Except a few extinct forms all are without teeth.
3) The sternum is well-developed and usually keeled or carinate.

The sub class neornithes have been divided into four superorders: Odontognathae, Palaeognathae, Impennae and Neognathae.

Superorder-1 : Odontognathae

General characters:

1) Clavicle not fused. Sternum is without keel.
2) Both the jaws are with teeth.

3) Flightless, specialized for swimming, about 150 cm in length.

Order-1: Hesperornithiformes

General characters:

1) Flightless; adapted for swimming.
2) Forelimbs with vestigeal humerus only.
3) The hind limbs laterally directed with webbed feet.
4) The pygostyle absent.
5) Teeth pointed, arranged in grooves in both the jaws, Premaxilla without teeth.
6) The quadrate single, basipterygoid process absent.
7) Sternum without keel.
8) Long neck provided with heterocoelous vertebrae.
9) Pectoral girdle much reduced, and clavicles not fused.

Examples: *Hesperornis, Hargeria, Neogaeornis, Baptornis, Enaliornis etc.*

Order- 2: Ichthyornithiformes

General characters:

1) The neck vertebrae is amphicoelous.
2) The sternum had a well-developed keel, and the wings are unlike modern birds.
3) Clavicles fused.

Examples: *Ichthyomis, Apatormiis etc.*

Superorder-2 : Palaeognathae

General characters:

1) The feathers are primitive, without hooked barbules. Barbs remain free.
2) The rectrices are absent or irregularly arranged.
3) The wings reduced in size or vestigeal or absent.
4) Pygostyle small or undeveloped.
5) The sternum is flat, raft-like.

6) The coracoid and scapula are comparatively small and completely closed.
7) The vomer is large and broad and separates the palatines; which do not come in contact with the cranium.
8) The quadrate articulates with the skull by a single or partially divided facets.
9) The males are with erectile penis and the females have clitoris. The young are precocious.

The superorder has seven orders.

Order-1: Struthioniforms

General characters:

1) Flightless, terrestrial omnivores with small wings, usually kept folded during running but may be expanded to act as a steering.
2) Head, neck and leg sparsely feathered.
3) Feathers are without after shaft.
4) Tail feathers are replaced by tail coverts.
5) Hind limbs are strongly built and only 2 toes (3rd and 4th) in each foot are present.
6) The sternum lacks keel.
7) Pubic symphysis present.
8) Pygostyle absent.

Example: *Struthio camelo*

Order-2: Rheiformes

General characters:

1) Each foot with three front toes, webbed at the base.
2) Sternum un-keeled.
3) At nesting a male defends 3-7 females, digs nest and all females lay about 50 lemon-yellow eggs in the same nest; male incubate them for about 40 days.

Example: *Pteronemia pennata*.

Order-3: Casuariiformes

General characters:

1) Flightless, terrestrial, running herbivore birds with comparatively small wings supported by a single digit.
2) The neck and body densely feathered.
3) Feathers with after shaft nearly equal to shaft.
4) With incomplete lining of feathers on neck; inner one of the three toes is a defensive structure, provided with claw.

Example: *Dromaeus* (Emu), *Casuarius* etc.

Order-4: Apterygiformes

General characters:

1) Relatively small, almost wingless, hen like, nocturnal, omnivorous running birds.
2) Bills long and slender with nostril at the tip.
3) Wings degenerated with vestigeal humerus, only one digit and no flight feathers.
4) Each leg bears four-clawed toes.
5) Body plumage fluffy, hair-like, without after shafts.
6) Sternum un-keeled. The eyes are small.
7) Lays only one white egg at a time. Eggs are largest of all the living birds.

Example: *Apteryx* (Kiwi).

Order- 5: Dinornithiformes

General characters:

1) Feathers with large after shafts and without barbicels.
2) Beak short.
3) Hind limbs massive with four toes.
4) Sternum reduced and un-keeled. Coracoid, scapula and wing bones reduced or absent.

Example: *Dinornis.*

Order-6: Aepyornithiformes

General characters:

1) Giant flightless Madagascar elephant birds.
2) Wings were relatively tiny but legs stout and powerful and with four toes.
3) Egg are largest of all known animal eggs; capacity about 10 litres.

Example: *Aqjyornis*

Order-7: Tinamiformes

General characters:

1) Partridge are quail-like, almost tailless, herbivores, essentially cursorial birds.
2) Sternum is keeled, and the palate palaeognathus.
3) Pygostyle reduced.
4) The eggs with glossy white shell and incubated by males.

Examples: *Crypturellus, Eudromea* etc.

Superorder-3: Impennae

Evolved from ancestors having wings used for both swimming and flight and gradually changed to form an effective paddle for swimming. The superorder has only one order.

Order-1: Spheniseiformes

General characters:

1) Body streamlined, and offers least possible resistance to diving and submarine activities.
2) Closely packed plumage; feathers small, scale-like, dense, over entire body without apteria.
3) Hind limbs modified for swimming; The feet are strongly webbed.
4) The integument is provided with, thick, fatty, insulating layer.
5) The bones, excluding certain skull bones, are solid.
6) Air sacs absent.

7) The bones of featherless wings flattened and united to form a powerful, resistant paddle or flipper moving only at the shoulder joint.

8) Monogamous and one egg is laid at a time. Feed on fishes, crustaceans, squids, etc.

Examples: *Aptenodytes, Pygoscelis, Eudyptes, Eudyptula, Spheniscus* etc.

Superorder-4: Neognathae

General characters:

1) Modern birds with well-developed wings, keeled sternum, and fully adapted for flight.

2) Beaks without teeth.

3) Slender vomer separates the palatines imperfectly.

4) The palatines are protruded posteriorly and in contact with the base of cranium and remain movably articulated with small pterygoids.

5) Tail vertebrae 5 or 6.

6) Pygostyle absent.

7) Forelimbs with metacarpals joined, and fingers included in wings.

Order-1: Gaviiformes

General characters:

1) Piscivorous birds adapted for diving and swimming. They are capable of flight.

2) The neck is long. Legs are posteriorly placed and completely encased with skin.

3) The digits webbed; wings short.

4) Eggs are laid in nests among piles of vegetation.

Example: *Gavia*

Order-2: Podicipitiformes

General characters:

1) Fresh water, compact-bodied animals.

2) Toes lobate.

3) The reduced tail bears degenerated tail feathers.

4) Lungs are placed far back.

Examples: *Podiceps, Aechmophorus, Podilymbus, Centropelara* etc.

Order-3: Procellariformes

General characters:

1) Long-winged sea birds; come to land only in breeding season and build-up nest in holes.

2) Nostril tubular, arid horny sheath of hooked bill composed of several plates.

3) Hind toe vestigeal or none (as in diving petrels).

4) Plumage compact and oily.

5) Wings long, narrow, span may be over three metres.

Examples: *Diomedea, Puffinus, Pelecanoides* etc.

Order-4: Pelecaniformes

General characters:

1) Voracious fish-eaters.

2) Nostril vestigeal or absent.

3) A gular pouch or throat is present, except in tropical birds.

4) In pelicans, body is heavy, long pouch used to scoop fishes from water.

Examples: *Pelecanus, Phalacrocorax, Sula, Anhinga, Fregata, Phaethon* etc..

Order-5: Ciconiiformes

General characters:

1) Long-necked body.

2) They are either with decorative plumages, bare areas on head (storks); bill abruptly de-curved at middle (flamingos).

3) The pattern of beak varies and with sharp cutting edges.

4) Except flamingos web between the toes are absent.

5) Speedy fliers; legs adapted for quick walking on mudflats.

Examples: *Ardea, Egretta, Nycticorax, Phoenicopterus* etc.

Order-6: Anseriformes

General characters:

1) All are efficient fliers and almost cosmopolitan in distribution.
2) Body covered with soft cornified epidermis containing numerous sense pits with harder cap at tip.
3) Tongue fleshy, legs short.
4) Feet webbed.
5) The tail is usually short and many feathered.

Examples: *Ansera, Coscoroba, Mergus, Oxyura* etc.

Order-7: Falconiformes

General characters:

1) Powerful, predaceous birds are distributed almost everywhere except Antarctica.
2) Mandible sharp-edged.
3) Feathers are stiff.
4) Eyes laterally placed and with extremely sharp power of vision.
5) Mostly monogamous. Females incubate eggs. The males feed the females during incubation.

Examples: *Gypes, Gymnogypes, Aegypices, Falco, Accipiter* etc.

Order-8: Galliformes

General characters:

1) Gregarious, non-migratory, ground dwelling game-birds, cosmopolitan in distribution.
2) The head is small and body compact.
3) The legs are massive, clawed and used for scratching soil for searching food.
4) Three toes are anteriorly directed.

5) Wings, in the majority, short and round.

6) The beaks are strong built, arched, suitable for picking up grains or seeds.

7) Males are aggressive polygamous.

Examples: *Crax, Lagopus, Alectoris, Opisthocomus,* etc.

Order-9: Gruiformes

General characters:

1) Small size, weak flight, or flightless.

2) Toes are not webbed.

3) Nest may be built on the ground.

Examples: *Grus* (Cranes), *Rallus, Fulica, Gallinula, Turnix, Monias,* etc.

Order-10: Diatrymiformes

General characters:

1) Large flightless terrestrial birds.

2) Massive head, beak and neck.

Example: *Diatryma.*

Order-11: Charadriiformes

General characters:

1) Plumage dense and firm.

2) Toes usually webbed, at least at the base.

3) More or less long-legged (shore birds), strong-winged (gulls), or with only three toes and legs far back in position.

4) Eggs heavily spotted.

Examples: *Charadrius, Jacana, Rostratula, Haemantopus* etc.

Order-12: Columbiformes

General characters:

1) The wings are long, pointed and enable the birds to make sustained flight at a

great speed.

2) Bills short and slender; the base of beak covered by a soft skin bearing longitudinal slit-like nostril called cere.
3) The head and neck small and compact.
4) Legs are small. All the toes lie in same plane and are provided with straight tarsus usually shorter than toes.
5) The crop is large producing 'pigeon milk.'
6) Monogamous but lives in groups.
7) Usually lay 2-3 eggs; both male and female incubate the eggs.

Examples: *Columbia, Pterocles, Syrrhypta, Streptopelia, Didunculus* etc.

Order-13: Psittaciformes

General characters:

1) Adapted for arboreal life and can also climb.
2) Loud-voiced birds, chiefly frugivorous with brilliant plumage of green, blue, yellow or red.
3) Beak stout, narrow, sharp-edged, and hooked at the tip used for climbing.
4) The upper mandible is movably articulated with the frontal bone of the skull.
5) Bill with soft cere, often feathered.
6) The toes two in front and two behind, the outer hind toe is not reversible and used for grasping.
7) Live in flocks, but strictly monogamous.
8) The nest is built in the holes of trees.
9) The young are nourished till they attain maturity.

Examples: *Ara* (Macaw), *Kakatoe, Psittacula, Nestor, Rhynchopsitta* etc.

Order-14: Cuculiformes

General characters:

1) Toes are two in front, and two behind. Outer toe reversible; the feet are not adapted for grasping.

2) Bill moderate, tail long.

3) Many old-world cuckoos are parasitic, thfe females lay eggs in the nest of other birds like crow.

Examples: *Cuculus, Chalecites* etc.

Order-15: Strigiformes

General characters:

1) Plumage sofit-textured.

2) Head large and round.

3) The beak is short.

4) Feet adapted for grasping, claws sharp.

5) Ear openings large, often with flap-like cover, sometimes asymmetrical.

6) Eyes large, round, directed forward and each in a disc of radial feathers.

7) Retina contains principally rods to perceive low intensity light.

8) The prey is swallowed whole.

9) Eggs are white. Nests are built in holes of trees or buildings.

Examples: *Bubo, Tyto, Asio, Otus, Nyctea* etc.

Order-16: Apodiformes

General characters:

1) Legs very short, feet very small, wings pointed and bills small and weak (swifts) or slender with long tubular tongue (humming birds).

2) In swifts the mouth is broad and eyes are large.

3) In humming birds, plumage is brilliant, iridescent, specially on head and neck of males.

4) Feed on nectar, small insects and spiders from the blossom by tubular protrusible tongue and needle-like bill.

5) Eggs are white.

Examples : *Apus, Cypsiurns, Chaetura* etc.

Order-17: Coliiformes

General characters:

1) Small body, passerine-like, colies or mouse birds with short legs, sharp curved claws.
2) The first and fourth toes reversible, which help in creeping on trees.
3) The feathers hair-like and soft; tail very long.
4) Usually a crest is present on the head.

Example: *Colius.*

Order-18: Trogoniformes

General characters:

1) The bills are short, and stout with bristles at the base.
2) The tip of the beak hooked and, in some, indented.
3) Feet small and weak. The first and second toes are directed backwards and third and fouth toes anteriorly placed.
4) Feathers soft and lax, help in noiseless flight.
5) Tail long and stiff, supports against vertical surface at the time of digging.

Examples: *Herpaetes, Hypodermes, Calures* etc.

Order-19: Coraciiformes

General characters:

1) In most, wings and legs are short and beak long.
2) In some, anteriorly directed toes are fused at the base (syndactylous) and in others one of the toes is reversed (zygodac-tylous).
3) Nests are built in holes of trees, etc.

Examples: *Alcedo, Ispidina, Dacelo, Chlorocerle* etc.

Order-20: Piciformes

General characters:

1) The feet is zygodactylous. Second and third toes are directed forward and first and fourth pointed backward.

2) Tail feather stiff with pointed tips.

3) Bill stout, tongue protrusible, roughed, or with barbs near tip.

Examples: *Picus, Sphyrapicus, Pynx, Ramphastos* etc.

Order-21: Passeriformes

General characters:

1) Small perching birds or passerines, adapted to various habitats and distributed widely.

2) All are adapted for land life and the four digits remain in the same level.

Examples: *Muscivora, Passer, Fringilla, Aethopyga* etc.

Order-22: Caprinulgiformes

General characters:

1) Colouration protective, helps the bird in concealing.

2) Plumage soft-and arranged in the fashion of that of owl.

3) Legs and feet small and weak, not adapted for grasping.

4) Bills are small, delicate, but the mouth opening wide and margined with long bristle-like feathers with specialised sensory receptors.

Examples: *Podargus, Nyctibius, Nyctidramus* etc.

7.4 *Archaeopteryx*- a connecting link

Archaeopteryx, meaning "old wing", is a genus of bird-like dinosaurs that is transitional between non-avian feathered dinosaurs and modern birds. The name derives from the ancient Greek "archalos" meaning "ancient", and "pteryx" meaning "feather" or "wing". *Archaeopteryx*- a connecting link (missing link) between reptiles and birds and it possess both the reptilian and avian characters. The reptilian and avian characters of *Archaeopteryx* are as follows:

I. Reptilian characters:

(i) Jaws are provided with homodont teeth;

(ii) Long lizard like tail with twenty free caudal vertebrate;

(iii) Bones are not pneumatic;

(iv) Cervical vertebrae are 9-19 in number;

(v) Amphicoelous vertebrae as in *Sphenodon*;

(vi) Cervical and abdominal ribs are present. Ribs are single headed and without uncinate process;

(vii) Sternum is weak or absent;

(viii) Eyes are provided with sclerotic ossicles;

(ix) Scales are present;

(x) Carpels and metacarpals are free; there is no carpo-metacarpus;

(xi) Pelvic girdle has an elongated ilium and a backwardly directed pubis.

II. Avian characters:

(i) Presence of feathers;

(ii) Fore limb are modified as wings;

(iii) Tail bears two rows of feathers;

(iv) Brain case is rounded;

(v) Bones in the skull is intimately fused;

(vi) Beaks are present;

(vii) Bones in the limbs and girdles are bird like

(viii) A keel is present in the sternum;

(ix) Tibia and fibula are separate;

(x) V-shaped furcula is present.

7.5 Migration in birds

7.5.1 Introduction

Migration is the seasonal or periodical mass movement of the animals away from and back to their natural habitat. The word migration means going from one place to another. Almost all the group of animals showing migratory habit, but birds are the classical example of animal migration. In bird, "migration" means two ways journeys,

onward journey from "home" to " new places" and back journey from "new places" to "home". This movement occurs in the particular period of the year and birds usually follow the same route.

5.2 Definition

Migration is one of the marvelous achievement of birds flight. Although this phenomenon is defined in many ways but Thompson has described bird migration as follows - "changes of habitat periodically, retuning at internal recurrent and alternative in direction which tend to serve optimum ertvironmental condition at all time".

5.3 Types of migration

Birds migrate in a variety of ways. Following kinds of avian migration have been recognized by different ornithologists.

I. Seasonal migration

A. Latitudinal migration: In this type of migration, the direction is usually from northern, to southern hemisphere or from southern to northern pole. The distance is from few kilometers to thousands of kilometers. In terms of the occurrence of birds in an area bird species are :

(i) **Permanent resident:** Species representing in an area throughout the year even though some individuals migrate.

(ii) **Summer resident:** Species present only during the wormer part of the year, which includes breeding season, that may extend from early spring to late autumn.

(iii) **Winter visitor:** Species, present only during winter or non-breeding period of the year, *e.g*, spot tail duck, brown headed plovers.

(iv) **Transient visitor:** Species present only during the certain period which is neither the summer or breeding season nor the winter. E.g., Golden plover, Sand piper.

(v) **Accidental visitor:** Species of birds that are rarer, irregular in occurrence.

B. Altitudinal migration: Here the birds of high altitude migrate to low altitude and again return back to the high altitude, is known as altitudinal migration. The range of migration is about few kms up and down slops of the mountain. This is particularly marked among species of Himalayan range.

C. Longitudinal migration: Longitudinal migration is also called East-West migration. This migration is found in the birds of southern hemisphere. Sea birds undergo this sort of migration.

D. Erratic migration: Erratic, vagrant, irregular or wandering migration occurs in birds like great Blue Heron, Cuckoos, Plover etc. Here the birds do not follow the different laws of migration and hereby migration occurs in a haphazard manner. In such birds the adults and young ones may start from their home to disperse in any direction over a few hundred miles in search of food.

E. Local migration: Local migration does not necessarily involved a change of latitudinal or altitudinal and is often quite limited in the distance covered. It may be due to seasonal changes, i.e., draught, heavy rains etc., or due to scarcity of food and water. E.g., *Hawks, Pegions, Swifts, Swallows.*

II. Special type of migration

Apart from the above mentioned types of migration there are some special types of migration like-

A. Alimental migration: This occurs as a result of storage of food and water and may occure at any time of the year. *E.g.*, Insectivorous birds.

B. Climatic migration: Migration due to climate change of the environment daily or seasonally.

C. Gonadal migration: This results from a need to occupy some special region or environment for some parts of the reproductive process.

D. Lumar migration: Some marine birds migrate under the influence of tides rather than calendar year.

7.5.4 Causes of bird migration

Generally the environmental factor is the main causative factor for bird migration. The following are believed to play an important role in bird migration.

1. Scarcity of food: Lack of food leads to migration of birds. Insectivorous birds migrate to other areas before the insects go into hiding to avoid the cold. Scarcity of food in winter in the northern hemisphere is a cause of bird migration in many cases, but the aquatic species leaves the northern hemisphere much before their food supply is cut off by the freezing of lakes, ponds and rivers.

2. Climatic change: Sudden or abrupt climatic changes or seasonal changes might compete the birds to migrate. Increase of cold might also be a cause of migration.

3. Breeding purpose: It is possible that birds migrate to favourable place to complete their breeding cycle as their original home has become unfavourable for breeding either to seasonal changes, decrease in day length or due to other factors.

4. Increased population: Increased population of a particular area is also another cause of bird migration.

7.5.5 Modes of migration

A. Nocturnal migration: Some birds migrate only during night. During day time they take rest, procure food and then start to migrate again at night. Most song birds are nocturnal travelers that probably fly singly or widely spaced, loose groups. They initiate a fly of 30 minutes to 1 hour after sun set and fly continuously throughout most of the night covering approximately 300-600 km on each night of travelling. An individual usually does not fly each night.

Example: Wood cocks, Wood piecers.

B. Diurnal migration: There are birds which migrate only during day time starting their journey with sunrise. These diurnal migrants are known to fly in flocks and to follow along to propagate leading lines and become tired along their migratory route in a series of discrete one day flight.

7.5.6 Range of migration

The range of migration varies among different birds. It may vary from one or few miles to thousands of miles. It depends upon the local climate condition and also the natural wind current.

Example:

(i) The Himalayan snow partidages cover a distance of only 1-2 miles during migration.

(ii) The golden plover covers a distance of 11,250 km and the Arctic tern covers a distance of 22,500 km during migration.

(iii) Penguins migrate by swimming about few hundred kilomiters.

(iv) Swallows from North Europe to South Africa covers 8,650 km.

(v) Cuckoo breeds in India and spend summer in Africa covering a distance of 7,250 km.

7.5.7 Altitude of migration

Diurnal migrants cover an altitude of 3000-14000 ft. However, nocturnal migrants cover an altitude of 5000-14000 ft.

7.5.8 Velocity of migration

The flight speed of birds during migration varies in different groups of birds. It depends on the size of the birds and is affected by wind speed and wind direction. For example, Cranes and Finches fly with an average speed of 30 miles per hour. Maximum speed is attained by Indian swifts whose speed is about 170 miles per hour.

7.5.9 Regulation of migration

Several species of migratory birds show a striking regularity year after year in their timings of arrival and departure. These birds normally migrate during particular time of year with very slight deviations.

7.5.10 Routes of migration

Most species of birds usually follow definite routes of flight during migration. The routes are as follows—

(i) Sea route: This rout is used by different birds.

(ii) Coast birds: Afford migration highways from a large number of migrants.

(iii) River and river valley routes: Migrating from planes to the hills and from the hills to the planes. During migration the birds cross rivers and river valleys following them as part of their routes.

(iv) Mountain range: Few birds cross mountain ranges during migration.

7.5.11 Guiding mechanism in bird migration

Birds have wonderful power of navigation and orientation. Even under odd conditions they do reach specific breeding and wintering destinations with grept regularity. Different theories have been proposed that birds are guided by a number of factors.

A. Topographic landmarks: Diurnal migrants are influenced by general topographic features such as, rivers, river-vallys, coast lines, mountain range etc. Birds have quite good visual activity and have been shown to be capable of recognizing salient feature of the terrain and of remembering this information for long periods of time. This system

is useful only for traversing areas, that have already become familiar as a result of previous flights.

B. Sun orientation: The sun is an extremely important directional cue for diurnally migrating and homing birds. In principle, the sun could provide the necessary map information as well as serving as a compass. The general use of the sun appears to be as a dominant cue for maintaining a bearing that is determined by some other means.

C. Stellar navigation: The birds are exclusively guided by the stars during night. Sauer (1958) suggested that the birds like warbler possess hereditary mechanism to orient themselves by the stars during nocturnal migration. It is possible that birds find their compass direction by reference the orientation by star patterns.

D. Geomagnitism: Some ornithologists have suggested that the Earths magnetic field plays an important role in bird orientation. Griffith (1948) suggested that birds are sensitive to the Earths magnetic field and are guided by it.

7.5.12 Stimulants for migration

Different factors have been advocated as the stimulants for migration.

1. Gonodal stimuli: It is widely accepted that migration towards the breeding ground is associated with gonadal changes and that the sex hormones play a primary stimulatory role in bird migration. Rowan (1931) first proposed that spring migration is stimulated by hormones secreted by developing gonads as that autumn migration is caused by gonad regression. However, available evidence suggests that gonads and sex hormones do not play a primary regulatory role in bird migration in general.

2. Endocrinal stimuli: Migration may be possibly stimulated by the endocrine system. The pituitary may play a primary regulatory role in migration. Gonadotrophin as well as the neurosecretary material of the hypothalamus before migration may act as a trigger for migration.

3. Photoperiodism: Photoperiodism is the response of living organism to the relative duration of cycles of light and darkness. The varying day length causes gradual change and fat deposition in birds, which may trigger the urge to migrate.

7.5.13 Problems of migration

Factors, both man made and natural, may cause great problems to migratory birds. These are stromes and hurricans, strong currents of winds, fog, man made towers and light houses, etc.

7.5.14 Evolutionary significance of migration

1. It will reduce the population density and allows the weaker individuals to survive specially who can not take part in migration.
2. Migration may sometimes lead to the isolation and make opportunity for the formation of new species.

7.6 Flight adaptation in birds

7.6.1 Introduction

In many respecs birds are the most highly specialized animals of the craniates class. According to Young (1958) birds are regarded as the " masters of the air". Amongst every part of their organization is modified in accordance with the aerial mode of life. They have become flying machines largely through the evolutionary gifts of feathers, wings, hollow bones, warm blooded, a remarkable system of respiration, a strong large heart and powerful breast muscles. These modifications have fulfilled two primary requirements for any flying machine, high power and low weight.

7.6.2 Principles for aviation

A. Downward pull of gravity: The flying animal must overcome the downward thrust of gravity which is the problem of first importance.

B. Sustaining surface: Flying animas must have a flight surface either in the form of a membrane or specialized structures like the feathers.

C. Lightness: The animals must be comparatively light particularly in relation to the strength of the muscles, that move the wing. They should have a well developed mechanism for wing movement and flight control.

D. Body contour: The shape of the flying animal should be such as to provide minimum resistance against air.

E. Maintenance of balance and steering: Flying animals must maintain balance and steer while propelling forward.

F. Perfection of sense organs: Specialization of entire system is required to guide balance, vision, etc.

G. Body metabolism: High rate of body metabolism is required to convert chemical energy into mechanical energy.

7.6.3 Types of flight adaptations in birds

The bird provides both morphological and anatomical adaptations for flight. The following are the modifications in birds.

I. Morphological adaptations:

1. Body contour: The birds have a spindle-shaped body to offer less air resistance during flight. This helps the birds to conserve energy and become more efficient at flying.

2. Compact body: The body of a bird is compact, dorsally strong and ventrally heavy to maintain equilibrium in the air. Their wings are attached on the thorax, the light organs like lungs and sacs are positioned high, heavy muscles placed centrally are other features that help in flight.

3. Body covered with feathers: The feathers are smooth, directed backwards, and closely fitting which make the body streamlined and reduce friction during flight. It lightens the body weight and protects it from the effect of environmental temperature. They also have a wide surface area for striking the air. Feather insulates the body and prevents any loss of heat from the body. This helps the birds to bear low temperatures at higher altitudes.

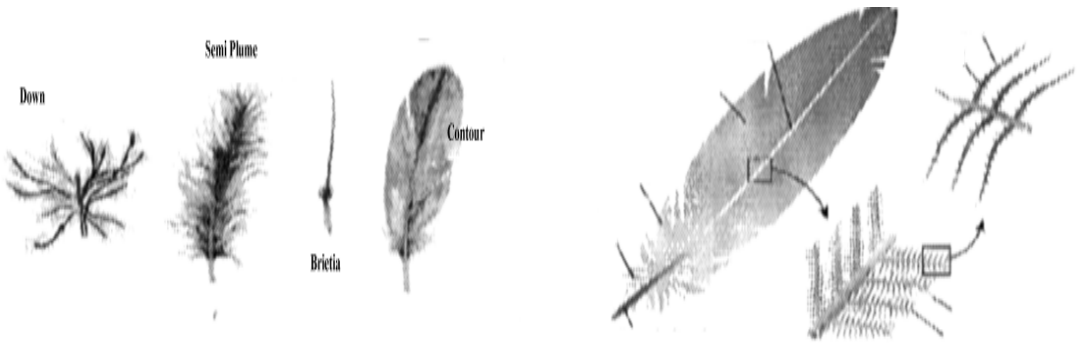


Fig.1 : Different types of feathers

4. Forelimbs modified into wings: The forelimbs are modified into wings which is the only organ of flight. These consist of a framework of bones, muscles, nerves, feathers, and blood vessels. The wings have a large surface area, which support the bird

in the air. The wings have a thick strong leading edge with a concave lower surface and a convex upper surface. This helps in increasing the air pressure below and reducing the air pressure above. Thus the bird can fly upward and forward during flight.

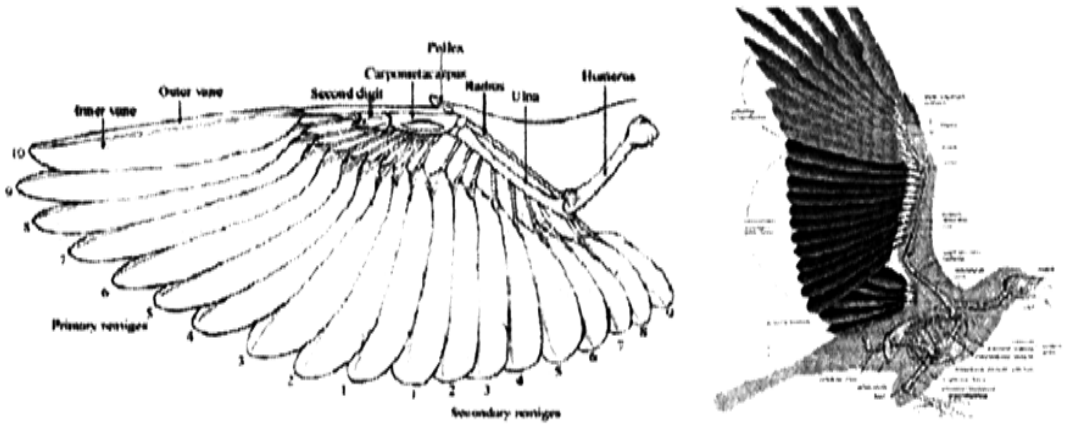


Fig. 2: Organisation of feathers

5. Mobile neck and head: The birds have a long and flexible neck which helps in the movement of head important for various functions. They possess a horny beak which helps them to pick the grains and insects while feeding.

6. Bipedal locomotion: The anterior part of the body of a bird helps in taking off during flight. The anterior part of the body also helps birds to land. The hind limbs help in the locomotion on land and support the entire body weight of a bird.

7. Perching: While sitting on the branch of a tree, the toes of birds wrap around the twig. This is known as perching. The muscles are so well-developed that a bird can sleep in that position without falling.

8. Short Tail: The tail bears long feathers that spread like a fan and function as a rudder during flight. They also help in balancing, lifting, and steering while flying and perching.

II. Anatomical adaptations

1. Flight muscles: The well-developed muscles control the action of the flight muscles. It is so well developed that it weighs about 1/6th of the whole body of bird. The flight muscles are striated. Additionally, the muscles on the wings are large. Other muscles help the above muscles in functioning.

2. Light and rigid endoskeleton: The birds have a very stout and light skeleton. The bones are hollow, filled with air sacs. They are provided with a secondary plastering to increase their rigidity. The bones are fused and lack bone marrow. The birds lack teeth. The thoracic vertebrae are fused except for the last one. This plays an essential role in the action of wings striking the air.

3. Digestive system: The birds have a very high rate of metabolism. Therefore, food digests rapidly. The length of the rectum is reduced because of the minimum undigested waste. Birds have no gall bladder which reduces the weight of the bird.

4. Respiratory system: The respiratory system of birds is designed in such a manner that the food is oxidized rapidly and a large amount of energy is liberated. Since the metabolism rate is high, a large number of oxygen molecules are required by the body. For this, the lungs are provided with air sacs. Presence of air-sacs is one of the important characteristics of birds.

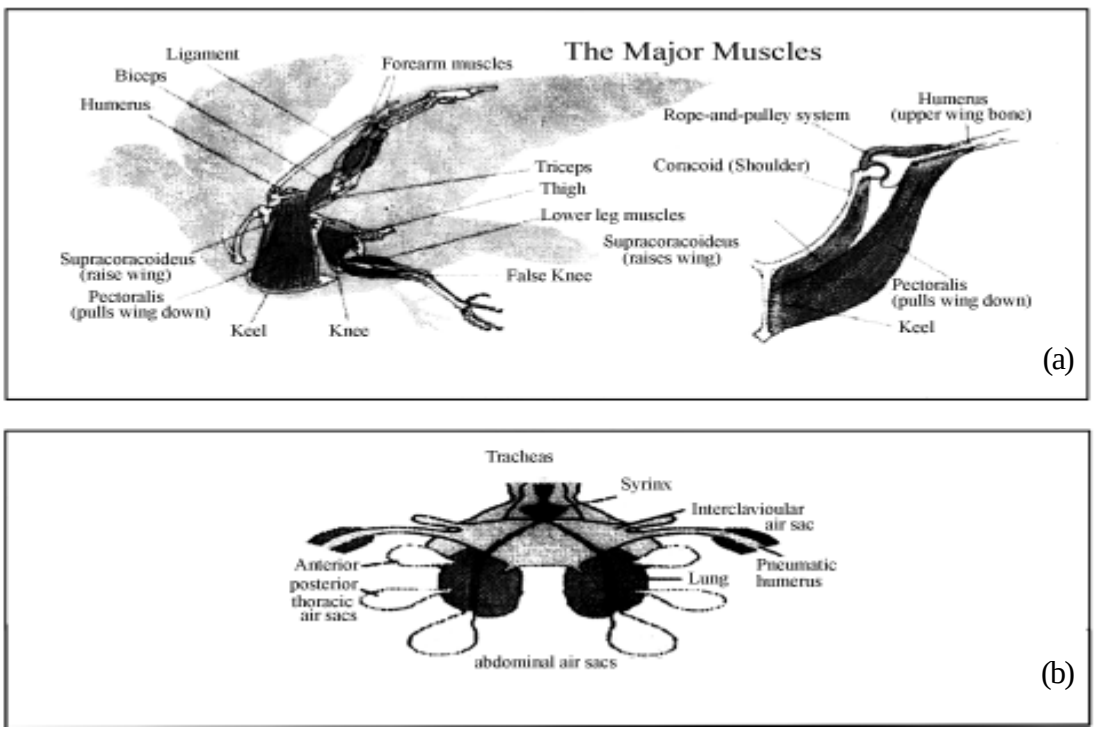


Fig-3 : (a) The major muscles for flight (b) Air sacs in birds

5. Circulatory system: Rapid supply of oxygen is required by the blood due to rapid metabolism rate in birds. Therefore, birds require an efficient circulatory system.

Birds have a four-chambered heart that performs double circulation. This prevents the mixing of oxygenated and deoxygenated blood. Also, the birds contain a large amount of haemoglobin in their nucleated red blood cells which helps in the quick aeration of body tissues.

6. Homoithermous: The temperature of the body of a bird remains high and does not change with the change in the environment. This facilitates the birds to fly at very high altitudes.

7. Excretory system: The nitrogenous waste is converted to less toxic organic compounds such as uric acid. They have no urinary bladder. The uriniferous tubules efficiently absorb water.

7.7 Summary

Birds constituting a specialized group of vertebrates evolved from reptiles during Mesozoic era. The invasion of bird into the air was a remarkable incidence in geologic past. True adaptation into the aerial life only possible by modifications of almost every part of the body together. All such modified parts have their own contribution during flight and if any one of these is disturbed, the whole set up may be disturbed leading to loss of flight. Thus not only air sacs or feathers or pneumaticity, but the coordinated function of all the modified parts render true flight.

7.8 Questions

i) Write the general characteristics of class aves.

ii) Classify aves up to order with distinctive characters and suitable example.

iii) Discuss that "*Archaeopteryx*-a connecting link".

iv) Write in brief about the migration in birds.

v) What is flight adaptation?

vi) Write a brief note about flight adaptation in birds.

7.9 Selected readings

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4) Text Book of Zoology Vertebrates (volume-2) 7th Edition by T. Jeffery Parkar and Williama ; Ecited by Marshall & Williams) Year: 1995. Pub: AITBS Publishers & Distributors, Nev. Delhi-110051

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Unit 8 ❑ Mammals

Structure

8.1 Objectives

After studying this unit, learners would be able to understand the following—

- The characteristics of mammals.
- The classification of mammals.

- The affinities of prototheria.
- Idea about the adaptive radiation in mammals.
- The adaptive radiation in mammals with reference limb structure.

8.2 Introduction

Mammals (Latin mamma means "breast") are vertebrate animals constituting the class-Mammalia, and is characterized by the presence of mammary glands which in females produce milk for feeding (nursing) their young, a neocortex (a region of the brain), fur or hair, and three middle ear bones. These characteristics distinguish them from reptiles and birds, from which they diverged in the late Triassic period. The modern mammalian orders arose in the Paleogene and Neogene periods of the Cenozoic era, and have been among the dominant terrestrial animal groups from 66 million years ago to the present. Most mammals are intelligent, with some possessing large brains, self awareness and use tools. The present chapter will discuss about the general characters of mammals, classification of mammals, affinities of prototheria, adaptive radiation with reference to locomotory appendages mammals.

8.3 General characters and classification up to order

8.3.1 Definition of classification

Classification means the ordering of animals into the definite groups on the basis of their similarity and interrelationship.

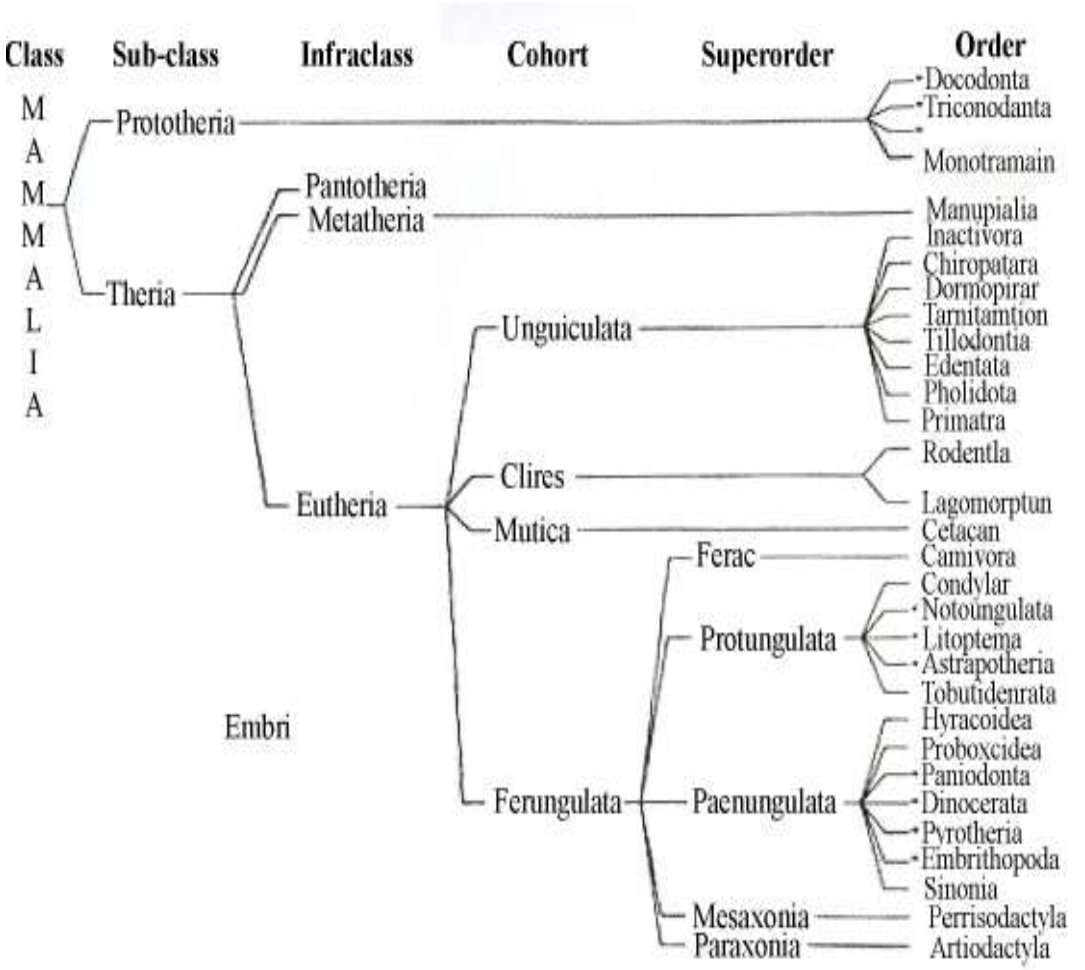
8.3.2 General characters of mammals

1. Body covered by epidermal hair.
2. Integumentary glands are mainly, sweat (sudoriferous), sebaceous (oil), scent (odoriferous) glands.
3. Mammary glands are present.
4. External pinna is present.
5. Eyes with upper and lower eyelids and often with eyelashes.
6. Nictitating membrane is translucent and hairless; it is vestigial in higher mammals.

7. A muscular diaphragm is present in between the thoracic and abdominal cavities.
8. Endo-thermal homoeothermic animals.
9. Red blood corpuscles are non-nucleated, biconcave and usually circular in form.
10. Four-chambered heart is highly powerful.
11. Only left aortic arch is present in the arterial system.
12. Cerebral hemispheres are very large and highly convoluted.
13. Cerebellum is large, complex and solid.
14. Presence of a single urinary bladder.
15. Testes remain in scrotal sacs except in prototheria.
16. Small eggs are devoid of yolk.
17. Fertilization is internal.
18. Viviparous animals.
19. The skull has double occipital condyles. Quadrate absent.
20. A bony palate is formed by the union of premaxillae, maxillae and palatines that separates the nasal passage from the buccal cavity.
21. The lower jaw is composed of a pair of bones; the dentaries.
22. Vertebrae are acoelous type.
23. Ribs are double-headed-capitulum and tuberculum.
24. The teeth are heterodont, thecodont and diphyodont type.
25. Paired forelimbs and hind limbs are present.
26. The digits of the limbs are provided with either claw or nail or hoof.
27. Twelve pairs of cranial nerves.
28. Kidneys are metanephric type.

8.3.3 Scheme of classification of mammals

In the present text, classificatory scheme of mammals as proposed by J. Z. Young (1981) is followed. For description, only living groups are considered. The extinct groups are marked with asterisks (*).



Subclass-1: Prototheria (Greek: protos = first, therion = beast)

General characters:

(i) The females lay eggs.

(ii) The testes are abdominal.

(iii) The cloaca receives the openings of urinary bladder, vas deferens and ureters.

(iv) Ribs are single headed.

(v) The mammary glands lack teats.

(vi) External pinna absent.

(vii) In childhood, teeth are present but in adults teeth are lacking.

This subclass includes four orders of which only monotremata is the only living group.

Order: Monotremata

General characters:

(i) Body is covered over with soft hair. Hair on the dorsal side may be coarse or spine-like.

(ii) Webbed digits are ended in sharp claws.

(iii) Pinna is distinct but small.

(iv) Brain lacks corpus callosum.

(v) Tail may be present or absent.

(vi) Dental formula: i = 0/5, c = 1/1, p = 2/2, m = 3/3.

(vii) Eggs are large and undergo meroblastic cleavage.

(viii) Tongue is long and sticky.

(ix) Sutures are obliterated in the skull.

Examples: *Ornithorhynchus, Tachyglossus, Zaglossus, Echidna* etc.

Subclass-2: Theria (Greek: therion = beast)

General characters:

(i) Females do not lay eggs but give birth to young ones.

(ii) Mammary glands are provided with nipples or teats.

(iii) Pinna or external ear is present.

(iv) The ureters open directly into the urinary bladder.

(v) Teeth are present throughout the life period.

(vi) Testes are situated in the scrotum.

(vii) Ribs possess two heads for articulation with vertebrae.

This subclass includes three infraclasses, of which pantotheria is extinct.

Infraclass-1: Metatheria (Greek: Meta = next to)

General characters:

(i) The youngs are born in an immature condition and undergo further development in the marsupium of females.

(ii) Mammary gland with teats and opens into the marsupium.

(iii) Epipubic bone of the pelvic girdle protects the marsupial sac.

(iv) Placenta is choriovitelline type.

This infraclass includes single order.

Order: Marsupialia (Latin: Marsupium = a sac)

General characters:

(i) Body in covered with soft fur.

(ii) Pinna is well developed.

(iii) Most of the female members possess marsupium.

(iv) Tail is well-developed and helps in balancing.

(v) The fourth toe is largest. All digits are clawed.

(vi) Forelimbs are shorter than the hind limbs.

(vii) Dental formula is: i = 5/4, c = 1/1, p = 3/3, m= 4/4.

(viii) Caudal vertebrae are with chevron bone.

(ix) Atlas is incomplete and is provided with cartilage in the ventral incomplete side.

Examples: *Macropus* (Kangaroo), *Didelphis* (Opossum), *Petaurus* (Flying opossum) etc.

Infraclass-2: Eutheria (Greek: eu = true)

General characters:

(i) The youngs pass through a considerable period of prenatal growth.

(ii) Brain is highly-developed; the two hemispheres are connected by corpus callosum.

(iii) The anal and urinogenital apertures are separate.

(iv) The tympanic bone is ring-like and forms a tympanic bulla.

(v) Dental formula is: i = 3/3, c = 4/1, pm = 4/4, m = 3/3. In some cases teeth are absent.

(vii) Epipubic bone in the pelvis is absent.

Cohort: Unguiculata

General Characters:

(i) These eutherians possess nails or claws in their digits.

This cohort contains six living orders.

Order-1: Insectivora (Latin: insecta = in sects; voro = to eat)

General characters:

(i) Body covered with hair, some possess dorsal spines which are modified hair.

(ii) Nocturnal and insectivorous animals.

(iii) Skull is constricted in the middle.

(iv) The zygomatic arch and bony palate are incomplete.

(v) Teeth have sharp molar cusps.

(vi) Each limb possesses five digits with claws.

(vii) Locomotion is plantigrade type.

(viii) Caecum in the intestine is small or absent.

(ix) Scrotum is absent and the testes are internally situated.

(x) Uterus is bicornuate type.

(xi) Mammary glands are many and are distributed all along the two milk-lines on the ventral surface.

Example: *Talpa* (Mole), *Tupaia* (Tree-shrew), *Erinaceus* (Hedgehog) etc.

Order-2: Chiroptera (Lptin: cheir = Hand; pteron = wing)

General characters:

(i) The forelimbs are modified to form wings.

(ii) The bones of the digits of the forelimbs are elongated except pollex.

(iii) These bones support a membrane that runs between forelimbs and hind limbs. This membrane is called as patagium.

(iv) An inter-femoral membrane is present between the femurs. It is supported by a cartilaginous calcar of the ankle.

(v) A short tail is often included in the inter-femoral membrane.

(vi) Pollex is small, free from the wing and bears claw.

(vii) The hind limbs are weak, having five clawed-digits.

(viii) Pinna is well-developed.

(ix) Nocturnal animals and are able to fly and catch prey in the dark with the help of their special radar system. This capacity is called echolocation.

(x) The sutures of the skull is obliterated.

(xi) The ribs are flat and fused with the vertebrae to become rigid during flight.

(xii) The hind limbs are rotated, so the knee is directed backward.

(xiii) The testes are abdominal in position.

(xiv) Only one young is born at a time.

(xv) The sternum is provided with a flat keel for the attachment of pectoral muscle.

Examples: *Pteropus* (Fruit bat), *Rhinolophus* (Horseshoe bats), *Desmodus* (Vampire bats)

Order-3: Dermoptera (Latin: Derma = skin; pteron = wing)

General characters:

(i) These are herbivorous, tree-living and their size is like that of a large squirrel.

(ii) The lower incisors are combed.

(iii) The tympanic ring forms the bulla and the lower margin of the external auditory meatus.

(iv) Brain is primitive and the optic lobes are not covered by cerebrum.

(v) Fingers are not elongated to support the wings as in bats.

Example: *Cynocephalus* (= Galeopithecus) (Flying lemur or colugo).

Order-4: Edentata (Latin: E/ex = without; dens = tooth)

General characters:

(i) Incisors and canines are absent but molars are long and similar in appearance.

(ii) Enamel and root of the teeth are absent but pulp cavity is persistent.

(iii) Tongue is sticky in nature.

(iv) Skull is small in comparison to body size.

(v) The zygomatic arch is reduced or absent.

(vi) Olfactory lobe of the brain is well-developed.

(vii) In the pectoral girdle, clavicle is present but the coracoid and acromion are fused.

(viii) In the pelvic girdle, ischium is united with anterior caudal vertebrae.

(ix) Posterior thoracic and lumbar vertebrae are with additional pair of zygapophyses.

Example: *Dasypus* (Nine banded armadilo), *Myrmecophaga* (Giant ant-eater), *Bradypus* (Three toed sloth) etc.

Order-5: Pholidota (Greek: pholis = scale)

General characters:

(i) Horny scales are present in an imbricated fashion.

(ii) The ventral side of the body is covered with hair.

(iii) Eyes are small and pinna is ill-developed.

(iv) Tail is long and tapering.

(v) The short and powerful limbs possess five clawed-digits in each.

(vi) The claws of the forelimbs are curved and sharp.

(vii) Locomotion by hind limb is plantigrade in nature.

(viii) Tongue is long, sticky and protrusible and is retained in a sac.

(ix) Teeth are absent.

(x) Skull is long and cylindrical.

Example: *Manis crassicaudata* (Indian Pangolin), *M. pentadactyla* (Chinese Pangolin).

Order-6: Primates (Latin: primus = first; Primate = One first in rank)

General characters:

(i) Body is covered with thick hair except the palm, sole and some parts of the face.

(ii) Neck is short and mobile.

(iii) Forelimbs are shorter than hind limbs.

(iv) Pentadactyl limbs possess digits with flat nail.

(v) The pollex or thumb, hallux or first toe are smaller than other digits and are opposable.

(vi) Locomotion is plantigrade type.

(vii) A tail is present.

(viii) Mammae are two and thoracic in position.

(ix) Testes lie in scrotal sac.

(x) The eyes are directed forward and the vision is binocular and stereoscopic.

(xi) Teeth show reduction in number.

(xii) Zygomatic arch is complete.

(xiii) Foramen magnum faces downward.

Example: *Homo sapiens* (Man), *Gorilla, Presbytis* (Langur), *Hylobates* (Gibbon), *Loris* (Slender loris), etc.

Cohort: Glires

General characters:

(i) Teeth are specialized for gnawing.

(ii) Skull is long and low.

(iii) Temporal fossa widely opens to the orbit.

(iv) Brain is small with small cerebral hemispheres.

(v) Limbs are pentadactyle.

(vi) Radius and ulna are separate.

This cohort is divided into two orders - (i) Rodentia and (ii) Lagomorpha.

Order-1: Rodentia (Latin: rodere = to gnaw)

General characters:

(i) Body is covered with soft hair.

(ii) Eyes are small but pinna is well-developed.

(iii) Limbs are provided with blunt claws.

(iv) Forelimbs are smaller than the hind limbs.

(v) Locomotion is plantigrade type.

(vi) Intestine and caecum are large.

(vii) Testes are inguinal.

(viii) Females possess abdominal teats.

(ix) Single pair of large, chisel-shaped incisors are present both in upper and lower jaws.

(x) There are two premolars in the upper jaw and one in lower jaw.

(xi) The scapula is provided with acromion process.

Example: *Sciurus* (Squirrel), *Petaurista* (Flying squirrel), *Rattus* (Rat), *Cavia* (Guineapig) etc.

Order-2: Logomorpha (= Duplicidentata) (Latin: logos = hare; morph = form)

General characters:

(i) Body is covered with soft hair.

(ii) Eyes are large and pinna is long.

(iii) Pentadactyle limbs possess clawed digits.

(iv) Hind limbs are larger than forelimbs.

(v) The upper lip is provided with a cleft in the middle.

(vi) Tail is almost vestigial.

(vii) Testes lie inside the scrotum.

(viii) Mammary glands are abdominal in position.

(ix) Maxillae are laterally fenestrated.

(x) There are two pairs of incisors in the upper jaw, while it is one pair in lower jaw.

(xi) Canine absent and diastema is present.

(xii) There are three premolars in upper jaw and two in lower jaw.

(xiii) Scapula is with acromion and metacromion process.

(xiv) Tibia and fibula are fused.

Example: *Lepus* (Hare), *Oryctolagus* (Rabbit), *Ochotona roylei* (Himalayan mouse) etc.

Cohort: Mutica

General characters:

(i) These animals lack vocal cords, but can emit sound for various purposes, which is called 'whale song'.

(ii) Completely aquatic throughout their life cycle.

Order: Cetacea (Latin: cetas = whale)

General characters:

(i) The large, torpedo shaped body devoid of hair.

(ii) The skin is smooth and skin glands are absent.

(iii) The nictitating membrane of eye, pinna of ear and nail of the digits are absent.

(iv) Forelimbs are modified to form flippers

(v) Hind limbs are absent.

(vi) The tail terminates in a horizontal fin, called fluke.

(vii) Dorsal fin is fleshy; it is also a neomorphic structure.

(viii) A thick subcutaneous fat layer, called blubber, is present.

(ix) The lungs are highly elastic and extensible.

(x) Brain is highly developed but olfactory lobe is reduced.

(xi) Two mammary glands are located in the inguinal area.

(xii) Single, large, well-formed young is born at a time.

(xiii) The cranium is dorsoventrally flattened and the facial part is elongated.

(xiv) Cervical vertebrae are fused to form a bony mass.

(xv) Sacral vertebrae are absent.

(xvi) Caudal vertebrae are with chevron bones.

(xvii) Ribs lack heads.

(xvii) Humerus is short, stout and its head moves freely in the glenoid cavity.

Example: *Platanista* (Ganges dolphin), *Balaenoptera* (Blue whale) etc.

Cohort: Ferungulata

(i) Modern carnivores and hoofed animals.

(ii) From the fossil records it is evident that all of them arose from a common ancestral population in palaeocene period.

The cohort ferungulata is divided into five super orders.

Superorder-1: Ferae

(i) All the living members of this group are carnivorous.

Order: Carnivora (Latin: carno = flesh; voro = to eat)

General characters:

(i) Pentadactyle limbs, with digits ending in sharp claws; claws may be retractile.

(ii) Locomotion is either digitigrade or plantigrade type.

(iii) Intelligence in the form of mental alertness and coordinated actions is evident.

(iv) Brain is highly developed.

(v) Intestine is short and caecum is small or absent.

(vi) Testes are present in scrotal sac.

(vii) Mammae are abdominal in position.

(viii) Placenta is deciduate and zonary.

(ix) Uterus is bicornuate in shape.

(x) Skull is short. Sagittal and lambdoidal crests are well-developed.

(xi) Zygomatic arch is strongly built.

(xii) Each jaw possesses three pairs of incisors. Canines are large, sharp and pointed.

(xiii) The atlas is large and is provided with wing like lateral processes.

(xiv) Thoracolumbar vertebrae are 20 to 21 in number.

(xv) Sternum is long narrow and made up of 8 to 9 sternibrae. Sternal ribs are not calcified. Examples: *Canis* (Wolves, Dogs, Jackals etc.), *Vulpes* (Fox), *Ursus* (Bear), *Procyon* (Raccon), *Ailurus* (Panda), *Ailuropoda* (Giant Panda) etc.

Superorder-2: Protungulata

This super order includes one living order.

Order: Tubulidentata (Latin: tubulus = small tube; densf= teeth)

General characters:

(i) Body is covered by a dull-grey skin with unevenly distributed hair.

(ii) Head is elongated to form a tubular snout.

(iii) Pinna is long in size.

(iv) Forelimbs possess clawed digits.

(v) Hind limbs possess five toes with clawed digits.

(vi) Small mouth possesses long, protrusible tongue.

(vi) The cheek teeth are 4 or 5 in number. Incisors and canines are absent.

(vii) Ant-eater in habit.

Example: There is only one representative species present till now. *Orycteropus after* (ardvark) living in Africa and known as cape ant-eater.

Superorder-3: Paenungulata (= near ungulates).

General characters:

(i) All are herbivorous animals.

(ii) The legs are with long upper segments; ulna and fibula is complete.

(iii) They possess several digits, with nail but no well-marked hoofs.

(iv) The incisors and canine become reduced to single pair of large tusks in each jaw and the molars are specialised for grinding.

Order: Hyracoidea (Greek: hyrax = shrew; eides = form)

General characters:

(i) These are rabbit-like animals, with short tail and short pinna.

(ii) Locomotion is plantigrade type.

(iii) Forelimbs possess four functional digits and fifth one remains as vestige.

(iv) There are three digits in each hind limb. First and third digits possess hoof while second digit is clawed.

(v) The caecum has a pair of caecal pouches.

(vi) Abdominal testes are present.

(vii) Mammae are pectoral in position and two in number.

(viii) Uterus is paired; the placenta has an annular avascular allantois and haemochorial in nature.

(ix) Single pair of large and curved upper incisors with persistent root is present.

(x) Canines are absent; the lower incisors are comb-like and four in number.

Example: *Procavia* (= Hyrax), *Dendrohyrax* (Tree hyrax).

Order: Proboscidea

General characters:

(i) These are largest living land vertebrates.

(ii) Thick skin with scanty hair.

(iii) An enormously elongated nose and upper lip present.

(iv) Nostrils are situated at the tip of the trunk.

(v) Eyes are small but pinna is large.

(vi) Pentadactyle limbs are pillar-like. Digits are hoofed.

(vii) The immensely large hypsodont molars with numerous sharp transverse ridges are parts of the powerful grinding apparatus.

(viii) Cerebral hemispheres are relatively small and leave the cerebellum uncovered.

(ix) Stomach and intestine are simple; the caecum is long and sacculated.

(x) Testes lie close to kidneys, scrotal sac is absent.

(xi) Only one young is born at a time; gestation period 22 months.

Example: *Flephas* (Asian elephant), *Loxodonta* (African elephant).

Order: Sirenia (Greek: siren = sea nymph)

General characters:

(i) Herbivorous animals highly adapted for aquatic life.

(ii) They have a streamlined body form, with few hair and thick blabber.

(iii) The muzzle is round and the upper lip is protruding.

(iv) Nostrils are located on the upper surface of head and are provided with valves.

(v) Neck is short and pinna is absent.

(vi) Eyes are small with muscular eyelids.

(vii) There are no hind limbs and the pelvic girdle remains only as small rods.

(viii) The forelimbs are large; the digits are joined to form paddles, with a full pentadactyle structure.

(ix) Caudal vertebrae are well-developed.

(x) A strong terminal horizontal fin is present.

(xi) Ribs are round and the diaphragm is oblique.

(xii) Lungs contain large air sacs.

(xiii) Brain is small and the ventricles are exceptionally large.

(xiv) Testes are abdominal. Uterus is bicornuate.

(xv) The young are born in water and nursed at pectoral teats.

Example: Dugong (= Halicore) (Sea cow), Manatus (= Trichechus) (Manatee).

Superorder-4: Mesaxonia

(i) Axis of the limbs passes through the third digit (middle axis), which is called the mesaxonic condition. Ihe remaining digits are reduced.

Order: Perissodactyla (Greek: perissos = odd; daktylos = finger)

General characters:

(i) Herbivorous mammals having streamlined body.

(ii) The neck and facial parts are elongated.

(iii) Tail is with long tuft of hair.

(iv) The powerful limbs are suitable for fast running.

(v) The lower part of the limbs became elongated and the upper segments shortened.

(vi) Among the five digits, the first and fifth digits are lost. The second and fourth digits remain as splints. The middle or third digit is stout and is provided with hoof.

(vii) Olfactory lobe is highly developed.

(viii) The incisors are three in each quadrant of the jaws.

(ix) The canine may be reduced or absent and there is often a diastema.

(x) Ulna and fibula are reduced.

(xi) The femur is provided with a prominent process on the other surface of the shaft. The process is called third trochanter.

(xii) Placenta is of diffuse epitheliochorial type, with a large allantoic sac.

Example: *Tapirus* (Tapir), *Rhinoceros* (Rhinos - Indian and Javan), *Dicerorhinus* (Horses, Asses, Zebras).

Superorder-5: Paraxonia

(i) Axis of the limbs passes through the third and fourth digits.

Order: Artiodactyla (Greek: Artios = even; daktylos = finger)

General characters:

(i) These are toed ungulates and latest mammalign herbivores.

(ii) Neck is elongated but tail is small.

(iii) Usually possess a pair of epidermal horns.

(iv) Gait is digitigrade type. Hoofs have developed on the toes.

(v) The long metapodials have become united to make the cannon bone.

(vi) The eyes are large with horizontal pupil. Pinna is large with an acute sense of hearing.

(vii) Tongue is long, mobile, prehensile and pointed.

(viii) The canine may form tusks.

(ix) Molars are of hypsodont and solenodont (moon-tooth) condition.

(x) Stomach is complicated and divided into several chambers.

(xi) Mammae are abdominal or inguinal in position and may be more than one pair.

(xii) The olfactory organ and related parts of the brain are well-developed.

(xiii) The uterus is bicornuate type.

Examples: *Hippopotamus* (Hippo), *Camelus* (Camel, dromedary - Asia), *Ceruus* (Red deer), *Dama* (Fallow deer), *Giraffa* (Giraffe), *Gazella* (Gazelles), *Bison* (Buffalo), *Capra* (Goat), *Ovis* (Sheep).

8.4 Affinities of prototheria

8.4.1 Introduction

Prototheria is the subclass of mammals which consists of five orders, namely, monotremata, morganucodonta, docodonta, tricodonta and multituberculata. Most of the animals in this group are extinct. The egg-laying monotremes are known from fossils of the cretacious and cenozoic periods. They are represented today by the *plytipus*. Although prototheria resemble the reptiles and birds with some advanced characters, but establishing mammalian ancestry considering its affinity with these groups. Following are the affinities of this group with that of reptiles, birds and mammals.

8.4.2 Reptilian affinity

1. Presence of cloaca.
2. Presence of ectopterygoid in skull.
3. Vertebrae without epiphysis and with cervical ribs.
4. Ribs are single headed.
5. Cervical ribs are present.

6. Thoracic ribs are single headed.
7. A median T-shaped interclavicle is present.
8. Acetabulum in echidna is perforated.
9. Body temperature is not constant.
10. Cochlea of internal ear with lagina.
11. Ureters lead into a urinogenital sinus.
12. Corpus callosum is absent and anterior commissure is well developed.
13. Testis abdominal.
14. Oviparous and meroblastic segmentation.

Remark: Presence of strong reptilian features in monotremata speaks of its primitiveness, but possess some advanced characteristics like higher mammals.

8.4.3 Avian affinity

1. Beak of the *platypus* resembles that of birds.
2. Teeth in adults are absent.
3. Presence of webbed feet.
4. Oil gland is present.

Remark: The relationship between monotremes and birds does not stand on a solid ground. The characters seen in both of them are due to common reptilian ancestry.

8.4.4 Mammalian affinity

1. Presence of hair, mammary glands, oil gland and sweat glands.
2. Double occipital condyles.
3. Presence of palate.
4. A typical mammalian diaphragm is present in the body cavity.
5. Skull is dicondylic.
6. Sternum is segmented.
7. Lobes of liver typically mammalian.

8. Heart 4-chambered.
9. Only left aortic arch present.
10. Circulatory system is typically mammalian.
11. Presence of large ear ossicles.
12. Cochlea is slightly coiled.
13. Fertilization is internal.
14. A slender caecum demarcates two intestines.
15. Lobes of liver typically mammalian.
16. R.B.C. small, circular and non-nucleated.
17. Presence of 4 optic lobes (corpora quadrigemina).
18. Presence of milk glands secreting milk.

Remark: Though monotremes show affinity with non-mammalian groups, the above mentioned characters strongly speak for close and firm affinity with mammals.

8.4.5 Concluding remarks

There are two theories which explain the phylogeny of monotremes. One theory explains that monotremes evolved independently from early mammal-like reptiles and continued to survive in isolation as basically primitive mammals with certain specializations. Another theory advocates that monotremes have been derived from marsupials. Among the mammals monotremes are very much controversial due to their salient features. Thus, it seems to conclude that monotremes originated as a side line from the main line of mammalian evolution and have retained the characters through which ancestors of higher mammals have passed.

8.5 Adaptive radiation with reference to locomotory appendages

8.5.1 Definition of adaptive radiation

The concept of adaptive radiation in evolution was developed by H.F. Osborn in 1898. The diversification of different species of a genus or different group of organisms of related species in different ecological or geographical areas for survival is known as

adaptive radiation. This adaptive diversification leads to the origin of new species. Examples often given as evidence include Darwin's finches of the Galapagos Islands, varied limb structure of mammals, Australian marsupials, etc.

8.5.2 Adaptive radiation in limb structure of mammals

Mammalian limbs are the modifications of the pentadactylus limb. As the animals were terrestrial, thus these terrestrial ancestors were the ancestors of modern mammals. Of late, adaptive radiation occurred in five different lines or habitats with modifications in their limb structure (Fig-1).

1. One evolutionary line radiates to form arboreal forms which have adapted limbs for life in trees (e.g., squirrels, sloths, monkeys, etc.).
2. Another line leads to aerial representing mammals adapted for flight (e.g., bats). They are the only true flying mammals. Along this line we can place the gliding mammals such as “flying squirrel” in the same arena.
3. Third line of radiation gave rise to cursorial forms (e.g., horses and antelopes). They have developed limbs suitable to rapid movements over the surface of the ground. Along this line also developed other mammals with less strongly modified limbs, such as wolves, foxes, hyaenas, lions etc.
4. Fourth line of radiation formed the burrowing mammals, the fossorial mammals. Some of the fossorial mammals, like the moles, have modified their forelimbs for digging but they are poorly adapted for locomotion on the ground. While others like pocket gophers and badgers are expert diggers but they have retained structures enabling them to move readily on the surface of ground.
5. Fifth line of radiation leads to the aquatic mammals:
   (i) Whales and porpoises having limbs strongly adapted for aquatic life, but they cannot move about on land.
   (ii) Seals, sea lions and walruses have also strongly modified limbs for aquatic life but they are also able to move about on land.
   (iii) The third group includes accomplished swimmers such as others and polar bears which are equally at home in water or on land.

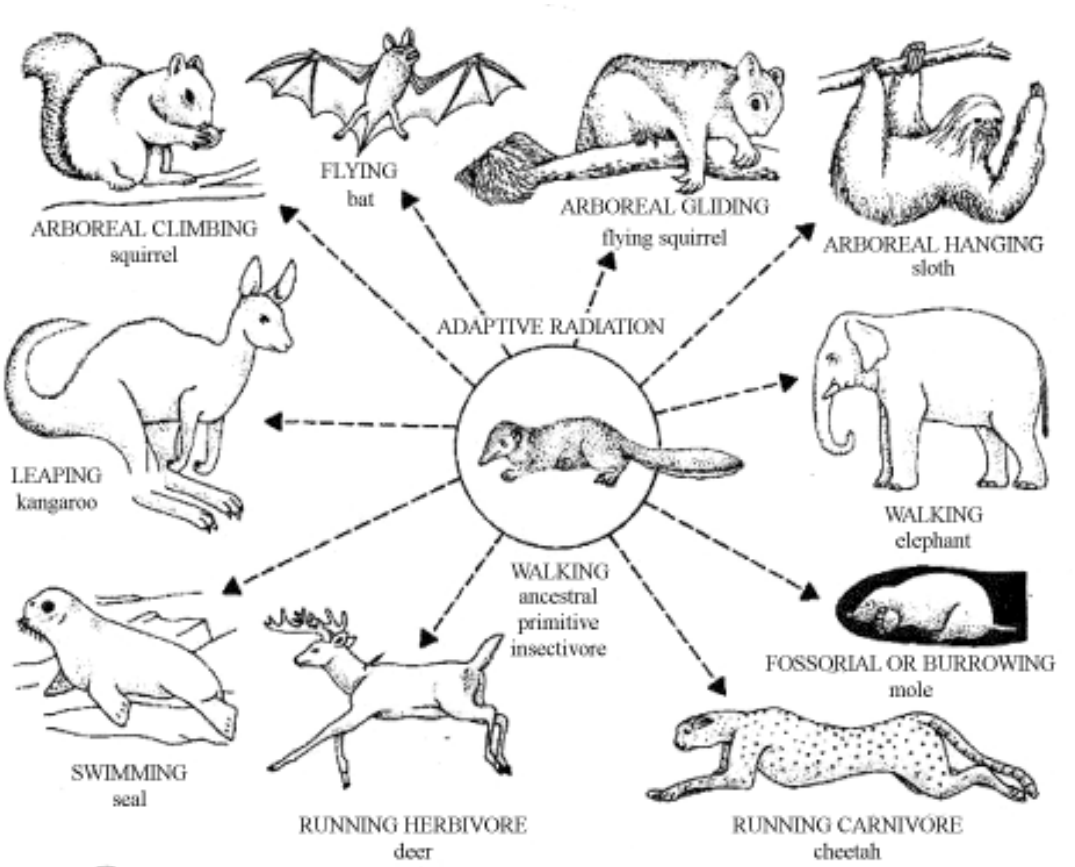


Fig-1 : Adaptive radiation of divergent evolution in mammals, based on locomotion

8.5.3 Remark

All the mammals of different radiating lines have limbs more or less adapted for some particular mode of locomotion. All the lines start from a common centre representing the short, pentadactylus limb of terrestrial mammals. From the centre, evolutionary lines radiate out in various directions. Hence, adaptive radiation is evolution in several directions starting from a common ancestral type. On the other hand, possession of this common limb pattern indicates close relationship not only among mammals but also by birds, reptiles and amphibians except fishes.

8.6 Summary

- Mammals are vertebrate animals characterized by the presence of mammary glands, fur or hair and three middle ear bones.
- Classification means ordering of animals into the definite groups on the basis of their similarity and interrelationship.
- Prototheria is the subclass of mammals represented today by *Plytipus.*
- The adaptive diversification leads to the origin of new species.

8.7 Questions

i) Write the general characteristics of mammals.

ii) Classify mammalian up to order with characters and suitable examples.

iii) Discuss about the affinities of prototheria.

iv) What is adaptive radiation?

v) Discuss adaptive radiation in mammals with reference limb structure.

8.8 Selected readings

1) The life of vertebrates by J. Z. Young; Year: 1981. Published in India by Oxford University Press, New Delhi.

2) Biology of Animals (Volume-11) by Arup Kumar Sinha, Simananda Adhikari and Banku Behari Ganguly; Year 1991; Pub: New Central Book Agency.

3) Text Book of Zoology Vertebrates (volume-2) 7th Edition by T. Jeffery Parkar and Williama Haswell (Edited by Marshall & Williams) Year: 1995. Pub: AITBS Publishers & Distributors, New Delhi-110051.

4) Vertebrates Comparative Anatomy, Function, Evolution (Fourth Editon) by Kenneth V. Kardong. Year: 2010. Pub: Tata McGraw-Hill.

Unit 9 ❑ Comparative anatomy of heart, kidney and brain

Structure

9.1 General plan and comparative account of heart

9.1.1 Objectives

After studying this unit, learners would be able understand the following—

- The structure and characteristics of heart.
- The comparison of heart in different groups of vertebrates.

9.1.2 Introduction

Heart in the vertebrates is a structure of modified blood vessel with thin walled venous collecting chamber, thick walled arterial forwarding chamber and the valves to prevent the back flow of blood. The heart is also a hollow muscular organ that rythmically contracts and relaxes. During each contraction-relaxation cycle, blood is drawn from the veins into a thin walled collecting chamber, the atrium, and is then passed to a second thick walled chamber, the ventricle, which forcibly contracts to distribute the blood to the arteries. Backflow is prevented by one-way valves.

9.1.3 A brief account of comparative anatomy of heart

The structure of heart has become modified in different group of vertebrate according to the shape and physiology of the animals. Fish have a simple two chambered heart which is, in essence, just a thickening of a section of the circulatory system, and the blood flows in a **single circuit** from heart to gills to body and back to the heart. Starting with the amphibians, the first vertebrates with lungs, the circulatory system adds a second loop or circuit. This design has the blood flow through the heart twice, on each trip around the system, once on the way to the lungs and once on the way back from the lungs, giving it an extra boost. This is called **double circulation**.

In amphibians, there are two atria but only a single ventricle, this results in the mixing of deoxygenated and oxygenated blood, but amphibians also gather oxygen through their moist skin, so this inefficiency is not critical. Beginning with the reptiles, a septum or wall develops that partly divides the deoxygenated blood from the oxygenated one in the ventricle. This is important because reptiles, with a watertight skin, rely entirely on their lungs for oxygen. Reptiles also have the unique ability to redirect or shunt blood leaving the heart back through the heart without passing through the body circuit, and to shunt deoxygenated body blood back through the body without going to the lungs. Being a reptile, the crocodilians have fully extended the septum and have a four-chambered heart, but there is speculation that dinosaurs may have had this innovation as well. Birds and mammals have the same four-chambered design, which has increased efficiency because deoxygenated and oxygenated blood cannot mix within the circulatory system.

9.1.4 Heart in different vertebrate groups

9.1.4.1 Cyclostomata:

(i) The heart of *Myxine* is "S" shaped and three chambered structure consisting of sinus venosus, auricle and ventricle. The conus arteriosus is ill developed but truncus arteriosus is well developed. Conus arteriosus is the forwarding part of the heart. It is enclosed by the pericardium. Truncus arteriosus is the basal portion of the artery.

(ii) In Ammocoetes larva, the heart is elongated and modified constriction of the ventral aorta.

(iii) In *Petromyzon*, the heart is similar to *Myxin*e but is supported by a cartilaginous plate and truncus arteriosus is absent.

9.1.4.2 Fishes: All the fishes have single circuit heart, through which impure blood passes to the gills and therefore, it is called branchial heart. The heart is "S" shaped and the compartment are arranged in a linear series. They contain only venous blood thus it is called venous heart.

A. Etesmchmnches:

(i) Heart consist of sinus venosus, auricle, ventricle and conus arteriosus.

(ii) Sinus venosus and auricle are thin walled while ventricle and conus arteriosus is thick walled. Sinus venosus receives blood from ductus cuvieri and hepatic vein.

(iii) The atrio-ventricular opening is guarded by a row of semicircular valve. The number of valves in conus arteriosus is numerous and usually arranged in three longitudinal rows.

(iv) In some Elasmobraches, the auricle is divided completely into right and left halves by an inter-auricular septum.

B. Teleosts:

(i) Conus arteriosus is short and represented by one or two sets of valves. In some cases conus arteriosus is absent.

(ii) The base of ventral aorta becomes muscular called Bulbous arteriosus, which is not actually a part of the heart.

(iii) In the heart of *Catla* appendages of ventral aorta are observed.

C. Ganoids:

The heart possess the valves in the conus arteriosus and are arranged in three longitudinal rows. The heart is similar with the elasmobraches.

D. Dipnoi:

(i) They are partly terrestrial and the heart is like terrestrial vertebrates.

(ii) Auricle is divided incompletely into left and right halves by intra-auricular septum. The oxygenated blood from lungs comes into the auricle, so mixing of pure and impure blood occurs in the auricles.

(iii) The auriculo-ventricular cushion is peculiar and the A-V aperture may be opened or closed by raising or lowering the cushion.

(iv) Conus arteriosus becomes spirally twisted and the cavity becomes complicated by the presence of valves.

(v) A spiral valve is present which extends forward to the anterior end of conus arteriosus.

(vi) Three rows of proximal valves are present in the conus arteriosus of *Protopterus* and *Lepidosiren*. In *Neoceratodus*, conus arteriosus lacks spiral valves, although a series of semilunar valves are present. The valves in the conus arteriosus are so arranged that the blood from right side of the ventricle is directed to the heart to the branchial arches. By this way mechanism towards the separation or systemic and pulmonary circulation is achieved.

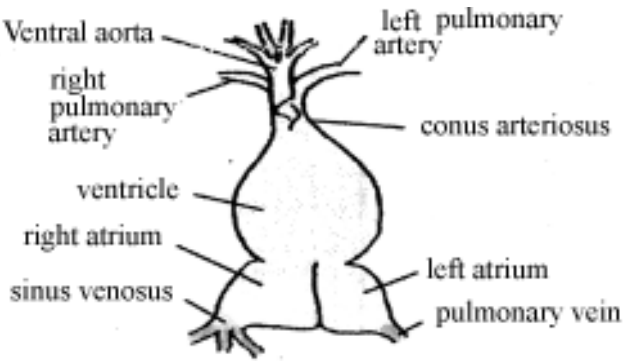


Fig-1. Diagramatic view of fish heart

9.1.4.3 Amphibia:

(i) Heart consists of one sinus venosus, two auricle and undivided ventricle and a conus arteriosus.

(ii) Conus arteriosus is made up of two regions, i.e., pylangium and synangium. The portion of the conus next to the ventricle is called pylangium while the distal part is synangium. Distal part becomes extended as bulbas arteriosus in some urodales. The left auricle is absent in piethodontid urodales where the lungs and pulmonary veins are missing.

(iii) The left auricle is absent in plethodonid urodales where the lungs and pulmonary veins are missing.

(iv) The auricles are separated by a complete inter-auricular septum. It is perforated in *salamander*.

(v) The venous blood returns to the right auricle while left auricle receives oxygenated blood. In all amphibians, where the conus arteriosus is present, there are two sets of valves which prevent the back flow of blood.

(vi) In amphibians, due to the presence of two auricles, oxygenated and deoxygenated blood comes to the heart separately but due to the presence of one ventricle mixing of pure and impure blood takes place. Therefore, amphibian heart is called transitional heart.

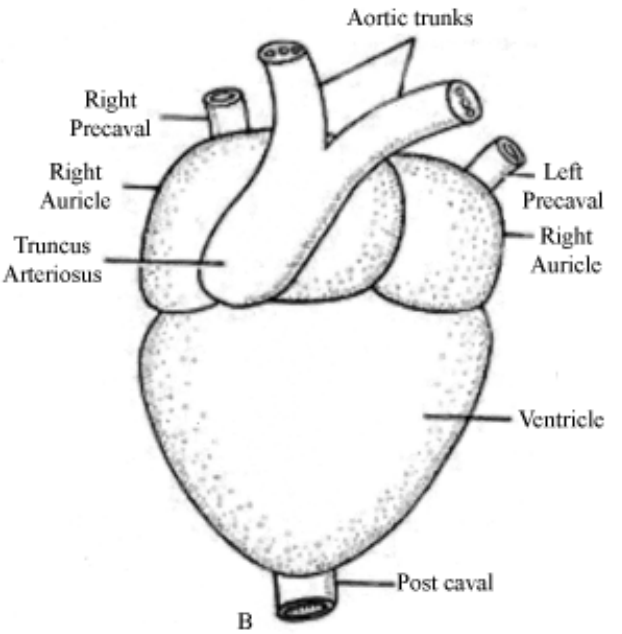


Fig-2. Diagramatic view of frog heart

9.1.4.4 Reptiles:

(i) Reptilian heart consists of two distinct auricles and a ventricle which is internally divided by an intra-ventricular septum into left and right portion.

(ii) In Chelonian, snake and lizards the septum is well developed but does not close off the left hand portion of the ventricle to the right hand portion. The left portion is larger and further divided into cavum venosum and cavum arteriosum. This secondary portion is formed by the fusion of trabeculae.

(iii) In Crocodiles, the cavity of the ventricle is completely divided into left and right

portion through at the point of contact. The crossing of left and right systemic arches there is an aperture called Foramen of Panizza, but the mixing of pure and impure blood does not occur.

(iv) Conus arteriosus is absent in the reptiles and the aortic arches arise directly from the ventricle.

(v) Sinus venosus shown a tendency to become fused with right auricle except *Sphenodon*, where sinus venosus is not properly distinguishable.

(vi) In reptiles, ventricle is incompletely divided into two chambers and therefore there is a tendency to become double circuit heart. Hence, the heart is called incomplete double cuicuit heart.

(vii) Conus arteriosus is fused with right ventricle and is present as a funnel shaped remnant.

(viii) The pulmonary artery arises from the right ventricle through an ostium, which is provided with valves.

(ix) Left ventricle is larger and also thick walled. Auriculo-ventricular opening is guarded by bicuspid valve.

(x) Left aortic arch arises from the left ventricle.

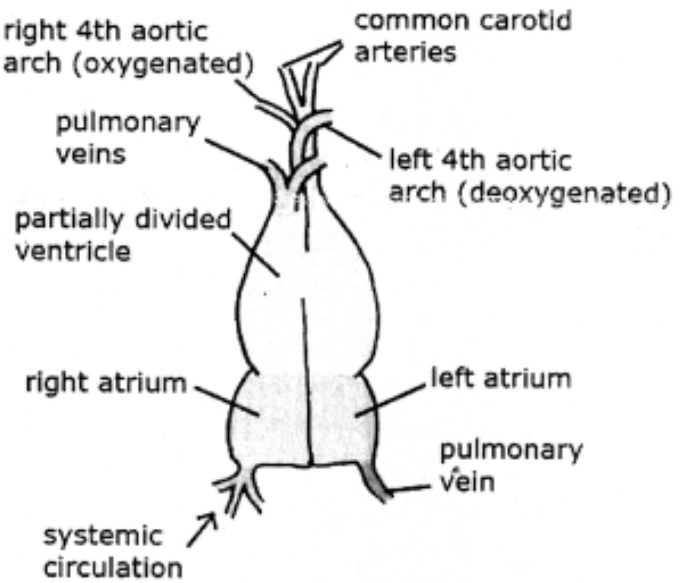


Fig-3. Diagramatic view of reptilian heart

9.1.4.5 Birds:

(i) In birds, heart is double circuit system having a completely divided ventricle and two auricles. So complete separation of pure and impure blood occurs.

(ii) The heart of bird is comparatively larger and the rate of heart beat is much higher than other animals. For example, 500/minute in sparrow.

9.1.4.6 Mammals:

(i) The heart is located in a space with the thorax. The space is called Mediastinum.

(ii) The heart is four chambered consisting of two auricles (left and right) and two ventricles (left and right). Sinus venosus is absent.

(iii) The right auricle receives the venous blood. An internally located ridge within the right auricle divides it into two regions- sinus venarum cavernum and right auricle.

(iv) Sinus venarum cavernum is smooth walled while the auricle is lined with fine muscular ridges.

(v) The left auricle is smaller in size.

(vi) Right ventricle is thick walled. Right auriculo-ventricular aperture has tricuspid valve.

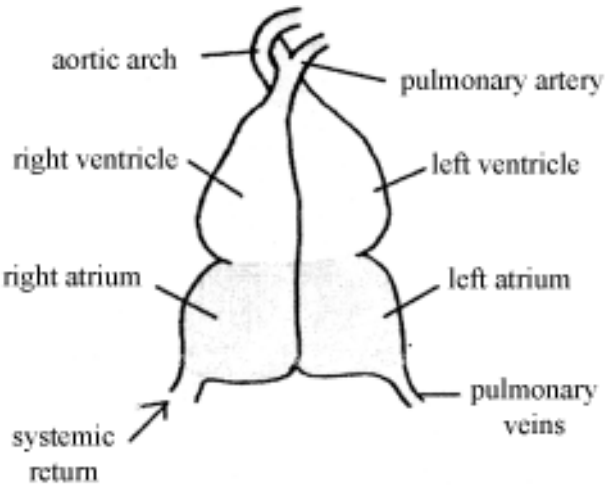


Fig-4. Diagramatic view of mammalian heart

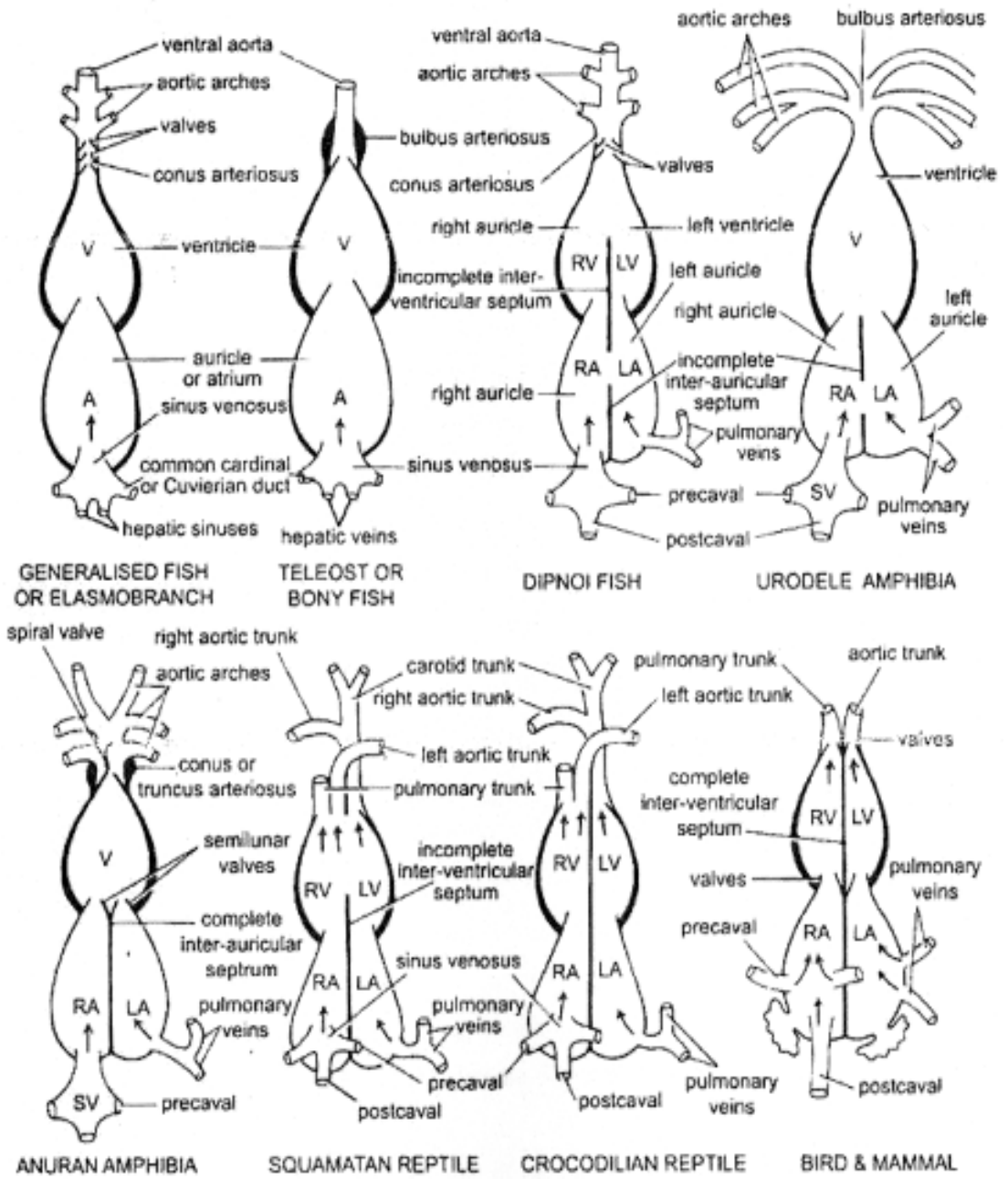


Fig-5. Evalution of heart in different classes of vertebrates
(A : Auricle; V: ventricle; RV : Right ventricle; LV : Left ventricle; LA : Left auricle; RA : Right auricle; SV : Sinus venosus)

The following figure will give an idea about evolution of heart in different vertebrate groups.

9.2 General plan and comparative account of kidney

9.2.1 Objectives

After studying this unit, tainers would be able to understand the following—

- ❖ The structure and characteristics of kidney.
- ❖ The comparison of kidney in different groups of vertebrates.

9.2.2 Introduction

Urinary system of vertebrates includes kidney and their ducts, while reproductive system includes male and female gonads and their ducts. The kidneys are a pair of bean-shaped organs present in all vertebrates. Kidneys excrete harmful metabolite nitrogenous wastes and regulate the composition of body fluid. Though the kidneys and gonads remain functionally unrelated, the two systems are intimately related morphologically in vertebrates because the male urinary ducts are also used for discharging gamates. For this reason it is more convenient to treat and describe the two systems as the urogenital or urinogenital system. All vertebrates have kidneys. Like the human kidney, they are made up of many nephrons. However, there are differences in the structure and functioning of various vertebrate kidneys that adapt them to the environment in which the animals live.

9.2.3 Basic structure and origin of kidney

Kidneys are a pair of compact organ lying to the dorsal to the coelom in trunk region one on either side of dorsal aorta. Kidneys are of different types in vertebrates.

1. Embryonic kidney: Each kidney is composed of a large number of units called uriniferous tubules or nephrons. Kidney tubules arise in the embryo from a special part of mesoderm called mesomere or nephrostome. The embryonic kidney is differentiated into three parts:

A. Peritoneal funnel: It is the free end of nephrone, opens into splanchnocoel to a wide aperture called coelomostome or nephrostome.

B. Malpigion body: It has two parts, cup shaped bowmans capsule and a glomerulus. In larval form and in embryo they may be aglomerular or without capsules.

C. Tubules: Tubules are convoluted ductulus that conduct the filtrate, while some are reabsorbed. Finally, the ductulus join into the longitudinal duct which opens behind into embryonic cloaca.

2. Archinephros:

(i) This is the hypothetical primitive kidney of ancestral vertebrates, which is also regarded as a complete kidney or holonephros, as it extends the entire length of the coelom. These are segmentally arranged, one per body segment.

(ii) Each tubule is opened by a peritoneal funnel or nephrostome into the coelom. Near each nephrostome an external glomerulus (without capsule) is suspended in the coelom.

(iii) All the tubules were drained by a common longitudinal Wolffian or archinephric duct opening into cloaca.

(iv) Such kidneys are found in the larvae of *Myxine* (cyclostomes), but not in adult. It is supposed that, all the kidneys of later vertebrates have been given rise during the course of evolution.

3. Pronephros:

(i) Pronephros develops from the anterior most part of the nephrons on either side immediately behind the head of the embryo, therefore it is called head kidney.

(ii) A pronephros consists of 3-15 tubules segmentally arranged, one opposite to each of the anterior mesodermal somites.

(iii) There are three pronephric tubules in frog larva, seven in human embryo and about a dozan in a chick embryo.

(iv) Each tubules opens into coelom by a funnel or nephrostome.

(v) When glomeruli project into the coelom with no bowmans capsule, called external glomeruli. But in some, the glomeruli are surrounded by bowmans capsule, these are called internal glomeruli.

(vi) The uriniferous tubules of each pronephros open into a common pronephric duct which grows back to enter the embryonic cloaca.

(vii) In some, there is a large cavity forming pronephric chamber. Glomeruli project into the pronephric chamber where they may unite to form a single compound glomerulus called glomus.

(viii) A pair of pronephric kidney appear in all vertebrate embryos but they become functional only in some cyclostomes and embryos of all anamniotes. In others, they degenerate during their course of development but their ducts persist.

4. Mesonephros:

(i) Mesonephros develops from the just posterior part of the pronephros of the nephrostome, soon after its degeneration,

(ii) At first, the new mesonephric tubules join with the existing pronephric duct and are segmentally disposed. Later on the tubules nephron multiply by budding so that their segmental arrangement is disturbed due to increased number of tubules per segment.

(iii) Mesonephros are functionally better because mesonephric tubules are numerous, longer and develop internal glomeruli, enclosed in capsules forming malpigion bodies. Thus, they remove liquid waste directly from coelomic fluid.

(iv) With disappearance of pronephros, the old pronephric duct becomes the mesonephric or wollfian duct.

(v) In anamniotes, the mesonephros extends throughout the length of the coelom behind the pronephros and is formed from the entire nephrostome left behind the pronephros, while in amniote embryos the mesonephros is form only from the middle part of the nephron and it does not extend throughout the length of the coelom. Hence, the term ophisthonephros is used for the kidney of adult anamniotes. The mesonephros'of anamniotes is not exactly equivalent to that of aipniote embryos.

5. Metanephros:

(i) Functional kidney of the higher vertebrates or amniotes is a metanephros. It is formed from the posterior end of the nephrogenic mesoderm.

(ii) When metanephric tubules develops the mesonephric tubules disappear except that it associated with the testis in male and for vasa efferentia.

(iii) A large number of highly convoluted tubules arose from metanephros and hence at the posterior part of the nephron the rate of element of waste is higher.

(iv) A new urinary duct is developed which is called metanephric duct or ureter. It is budded off from the base of the wolffian duct anteriorly and open into it. The

ureter empties water into cloaca or urinary bladder in mammals.

(v) The metanephros shows greatest organization of their tubules having glomerulus, capsule, renal tubules which is again differentiated into Henle's loop, proximal convoluted tubule (PCT) and distal convoluted tubule (DCT).

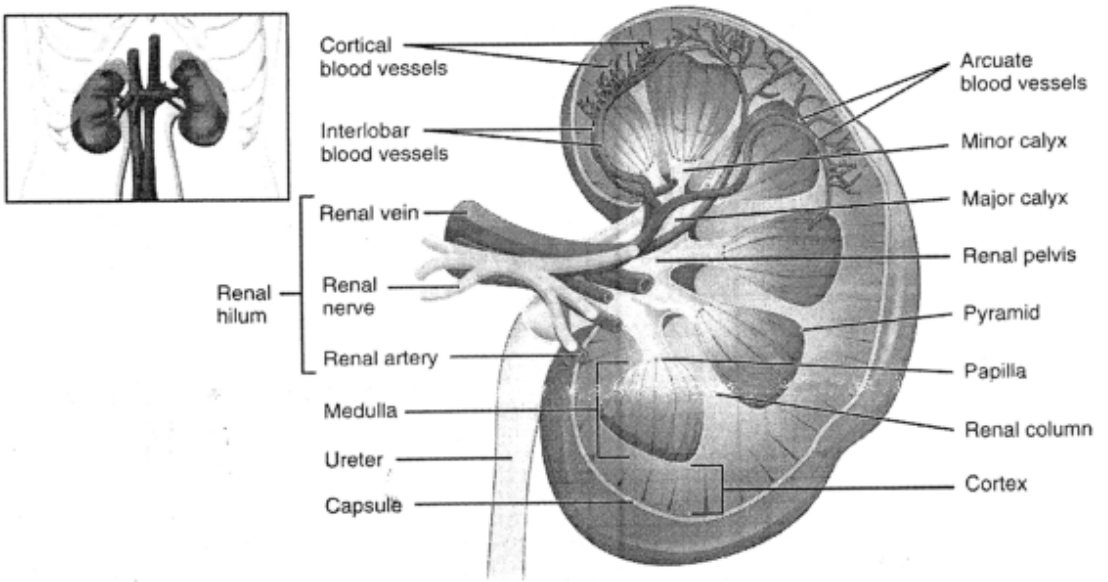


Fig-6: Basic structure of kidney in vertebrates

9.2.4 Kidneys in different group of vertebrate

9.2.4.1 Cyclostomes

(i) The pronephros is retained in adult hag fish (*Myxine*) which is hardly marked off from the mesonephros. The pronephros lies dorsal to the pericardial cavity.

(ii) In *Eptatretus*, the pronephric duct is present but in *Myxine* lacks such duct. The pronephric tubules have no communication with the exterior.

(iii) In *Petromyzon*, the pronephros does not persist in an adult. The mesonephros is the functional adult kidney. The mesonephros tubules are complicated and lack segmental disposition but in *Myxine* mesonephric tubules have segmental arrangement.

9.2.4.2 Fishes

(i) Adult fishes possess opisthonephros type of kidney. In most fishes, kidneys are

extremely elongated structures and extend the entire length of the body cavity. Usually the posterior side of the kidneys are fused and the anterior end remain free. The anterior part of the kidney is almost non-renal.

(ii) In Elasmobranchs, the kidneys in two sexes differ structurally. In males, the anterior non-renal part of the kidnay is well formed and sub serves reproductive reproductive function, but in females, the anterior part of the kidney is functionless and degenerated.

(iii) In telelosts, the anterior portion of the kidney is converted into lymphatic tissue and does not perform any renal function. There is no connection between testis and kidney. Marine teleost possess fewer number of glomerulus than the fresh water forms. In some cases, the kidneys are wholly glomerular. In toad fish, *Opsanus tau*, the kidneys are aglomerular.

9.2.4.3 Amphibia

(i) The kidneys in amphibian are of ophisthonephros type and the shape of the kidney corresponds to the shape of the body.

(ii) In urodales, and in the primitive frog (*Ascaphus*) the kidneys are elongated. Each kidney is divided into an anterior narrow non-renal part and a broad posterior renal part.

(iii) In *caecilians*, the kidneys are extremely elongated and occupy the whole length of the body cavity.

(iv) In case of anurans, the kidney become condensed and divided into lobes.

(v) The kidney tubules serving as the carriers of sperms may retain their glomeruli in *caelilians* and a salamander (*spelirpes*), but in most amphibians the glomerulus is lost. The testis discharges through the kidneys by the vasa efarentisa. So, the wolffian duct serves as the urinogenetal duct in males and as an ureter in females.

9.2.4.4 Reptiles

(i) The functional excretory organs in adult are the metanephric kidney. The shape of the kidneys in different reptiles is variable and the shape correspond the shape of the body cavity. The glomerulus inside the kidney is reduced in reptiles.

(ii) In lizards and crocodiles, the kidneys are much elongated and are housed in the

posterior part of body cavity. The posterior ends of the kidney shows a tendency of fusion in many lizards.

(iii) In snakes, the kidneys are slender and the position of the kidneys in the body cavity is asymmetrical, i.e, one kidney is located above the other side.

(iv) In turtles, the kidneys are more compact than the other groups.

9.2.4.5 Birds

(i) The structure and function of kidneys are similar throughout the class. The glomeruli show the general trends of reduction.

(ii) In pigeon, there is a pair of flat three lobed metanephric kidneys lying dorsally in the hollow of the pelvic girdle. They have masses of numerous coiled uriniferous tubules, each having a small glomerulus and short specialized portion called loop of Henle, which reabsorbs water from the glomerular filtrate. From each kidney arises a narrow metanephric duct or ureter, which opens into the urodaeum of the cloaca.

9.2.4.6 Mammals

(i) The kidney in mammals is metanephric. It is paired, bean shaped structure and is retroperitoneal in position. It is covered by a connective tissue or capsule. The median side of each kidney bears a depression called hillum. At this point ureter and renal veins leave the kidney and renal artery and nerves enter the kidney.

(ii) The cortical region possess renal corpuscles and convoluted portions of the tubules while the medulla is made up of a large area occupied by a number of renal pyramids.

(iii) In many mammals (*Proboscidea, Cetacea, Artiodactyla* etc.), the kidney retains embryonic lobulated condition. In others the kidney surface is smooth in adult stage.

9.3 General plan and comparative account of brain

9.3.1 Objectives

After studying this unit, learners would be able to understand the following—

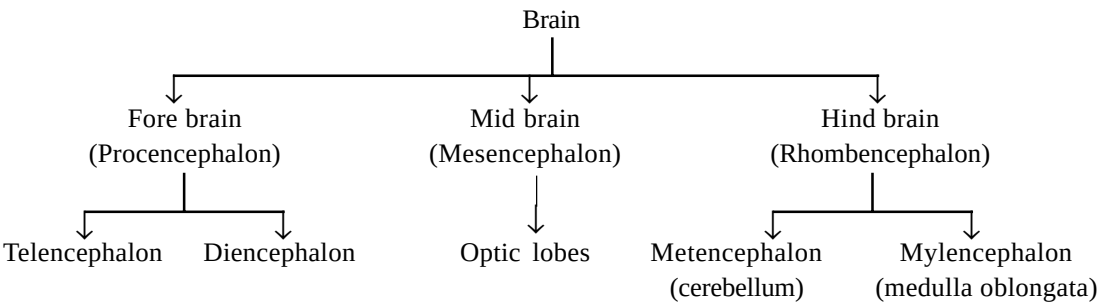
- The structure and characteristics of brain.
- The comparison of brain in different groups of vertebrates.

9.3.2 Introduction

With the evolution and development of lateral symmetry in the animal kingdom and for their necessity, one end of the animal is being used for locomotion and the other end, first coming in contact with the environment developed a concentration of nervous tissue as well as sense organs. These structures enabled the animals to cope with their environment in such a manner that they could survive better. The term cephalisation is used in referring to such localization of structures and functions in the head region. The central nervous system is the first organ that develops inside the embryo. It is ectodermal in origin.

9.3.3 General plan of brain in vertebrates

The main subdivision of brain in vertebrates is as follows:



Telencephalon: This is the most frontal part of the brain comprises of two cerebral hemispheres. It comprises of two parts, viz., cortex or pallium and medulla or corpus striatum. At the tip of the telencephalon there are two olfactory lobes or rhinincephalon. Two rhinocoels are present in these olfactory lobes. First and second ventricles are present in the two cerebral hemispheres.

Diencephalon: The third ventricle is bounded by diencephalon. The ventricle portion has a small elevated hypothalamus which holds pituitary gland. On the dorsal side there lies another structure, the pineal body. The third ventricle and the cerebral hemisphere are connected by foramen.

Cerebellum: This is the hind brain consist of a superficial layer of grey matter, the cortex overlying a mass of white matter. It has large parallel furrows on its surface. The fourth ventricle is present within the cerebellum which connects with the second by a canal.

Medulla oblongata: The most posterior part of the brain is medulla oblongata. The posterior part of the medulla oblongata is narrow and comes out from brain box through foramen magnum and forms a long structure, the spinal cord.

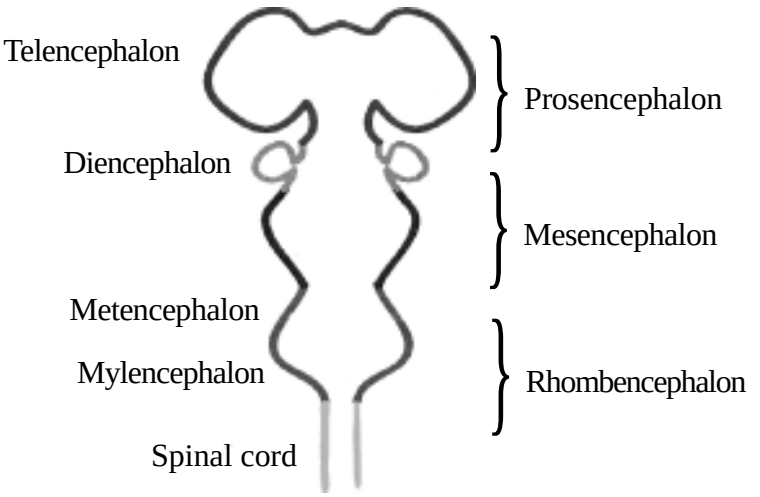


Fig-7: General plan of the structure of mammalian brain

9.3.4 Brains in different vertebrate groups

9.3.4.1 Cyclostomes

(i) Telencephalon is small, paired optic lobes weakly differentiated corpus striata.

(ii) Well developed pineal body. Anterior to it lies the parietal body.

(iii) Epiphysis and pineal body are photoreceptive organs.

(iv) One pair of optic lobe possess large optic vesicles.

(v) Infundibulum is small.

(vi) Havenular ganglia present and have two outgrowths.

(vii) Roof of the fourth ventricle has an extensive vascular network forming choroid plexus.

(viii) The metencephalon is a rudimentary lip like structure but no pons.

9.3.4.2 Elasmobranch

(i) Corpus striata is a bulging structure.

(ii) Olfactory lobes constitute the bulk of the telencephalon. From each olfactory lobe the conspicuous olfactory stalk arise terminating in an olfactory bulb.

(iii) Posterior limit of the telencephalon is marked by a transverse invaginated fold or velum.

(iv) Epiphysis is stalked.

(v) Parietal organ disappears after the temporary appearance during embryonic development.

(vi) The infundibulum develops a pair of elongated swellings.

(vii) Well developed optic lobe is partially covered by cerebellum. It is larger and active in dogfish than the sluggish rays and scates.

(viii) In *Torpedo*, two electric lobes that project into the fourth ventricle which supplies nerves to the electric organs.

9.3.4.3 Bony fishes

(i) Brain is small and the roof of procencephaion is thin and non nervous.

(ii) Convex corpus striata occupy the floor of thin region.

(iii) Shortened epiphysis.

(iv) Optic lobes are large.

(v) Cerebellum is small in dipnoans and ganoids, but large in most teleost, specially in most active ones.

(vi) Olfactory lobes are large and have no olfattory peduncles but are closely located in front of the cerebral hemispheres, each contains rhinocoels, while continues with lateral ventricle.

(vii) Dieancephalon is small and hidden dorsally by the mid brain.

(viii) The pineal body projects in front because it has a stalk. On the ventral side there lies an infundibulum to which the pituitary gland is attached.

(ix) Two large optic lobes with layers of neurones in its roof into which pass the fibres of the optic nerves.

(x) Cerebellum is large and bent upon itself, the anterior part does not project in front as in others but forms a valvula cerebella, which extends under the optic lobes. It is characteristics of bony fishes and controls active movement.

9.3.4.4 Amphibia

(i) Olfactory lobes are large, continuous with the distinctly separated cerebral lobes lie closely side by side and joined medially too.

(ii) Corpus striata projects upward from the telencephalon floor only slightly allowing for fairly large lateral ventricles and invaginate anterior to choroid plexus inside the cerebral lobes.

(iii) Diencephalon uncrowned, visible from above without inferior or saccus vasculosus. It has vestigial pineal body represented by a simple hollow stalk.

(iv) In adult anurans, the epiphysis is represented by a small median vesicle, the pineal gland close under the dorsal wall of the cranium.

(v) Skull is stegocephalus has a dorsal foramen which shows the presence in those primitive amphibians of either pineal or parietal eye. But parietal body is absent in modern amphibians.

(vi) The mid brain is well developed. It forms two large optic lobes, each having an optic ventricle or optocoel. Optic lobes are so spread apart as occupying a more lateral in position.

(vii) Cerebellum is very small in most forms, rudimentary in caecilians and in some urodales.

9.3.4.5 Reptiles

(i) Cerebrum is more or less developed. Corpus striata are so large that lateral ventricles are reduced.

(ii) Olfactory lobes are hardly distinguishable from the neopallial part of the telencephalon. In lizards and alligators with prominent projecting snouts, the olfactory lobes are extended into stalks and bulbs.

(iii) In diencephalon, thalamus is large. Hypophysis is attached to the infundibulum and definitely into anterior and posterior part.

(iv) On the dorsal wall of the third ventricle, the parietal, pineal and a third evagination, the paraphysis embryologically present, but in adult undergoes degeneration.

(v) Except *crocodiles* and *alligators*, the epiphysis is present as a glandular pineal structure.

(vi) In *Sphenodon*, the parietal organ reaches highest development, in which it extends as far as transparent window. On the roof of the skull, there is a third median eye with retina and a lens.

(vii) In snakes, there are four optic lobes.

(viii) Cerebellum is small but in swimming reptiles it is fairly developed.

(ix) Medulla oblongata with eight pairs of cranial nerves.

(x) Stegosaurus was indeed oldest *Dinosour*, the most peculiar is that it has two brain.

9.3.4.6 Birds

(i) The brain of the birds is more of an "eye brain" than a "nose brain" thus showing an advance over its forerunner.

(ii) Cerebral cortex is well developed than reptiles,with large corpus striata. The lateral ventricles are reduced due to increase thickness.

(iii) Olfactory lobes are fairly prominent in tooth bearing createceovus birds but in modem birds, it is absent or degenerating.

(iv) No trace of parietal organ; degenerating pineal body.

(v) The greatly developed optic lobes are crowned over laterally in position. But backward growth of cerebrum tends to burry the diencephalon and mesencephalon from the dorsal side.

(vi) The cerebellum consisting of a well defined median vermis as two lateral lobes. It is large in extremely active birds.

9.3.4.6 Mammals

(i) The primitiver tertiary mammals had a reptilian type of brain. In modern mammals, it is advanced than that of birds.

(ii) Cerebrum is highly developed by the development of corpus striatum and large

corpus callosum. But in marsupials and monotermes, corpus callosum is small.

(iii) In marsupials and monotermes, the archipallial olfactory parts of the brain is prominent but in higher forms, it is reduced. In man, seals and whales, it is entirely lacking.

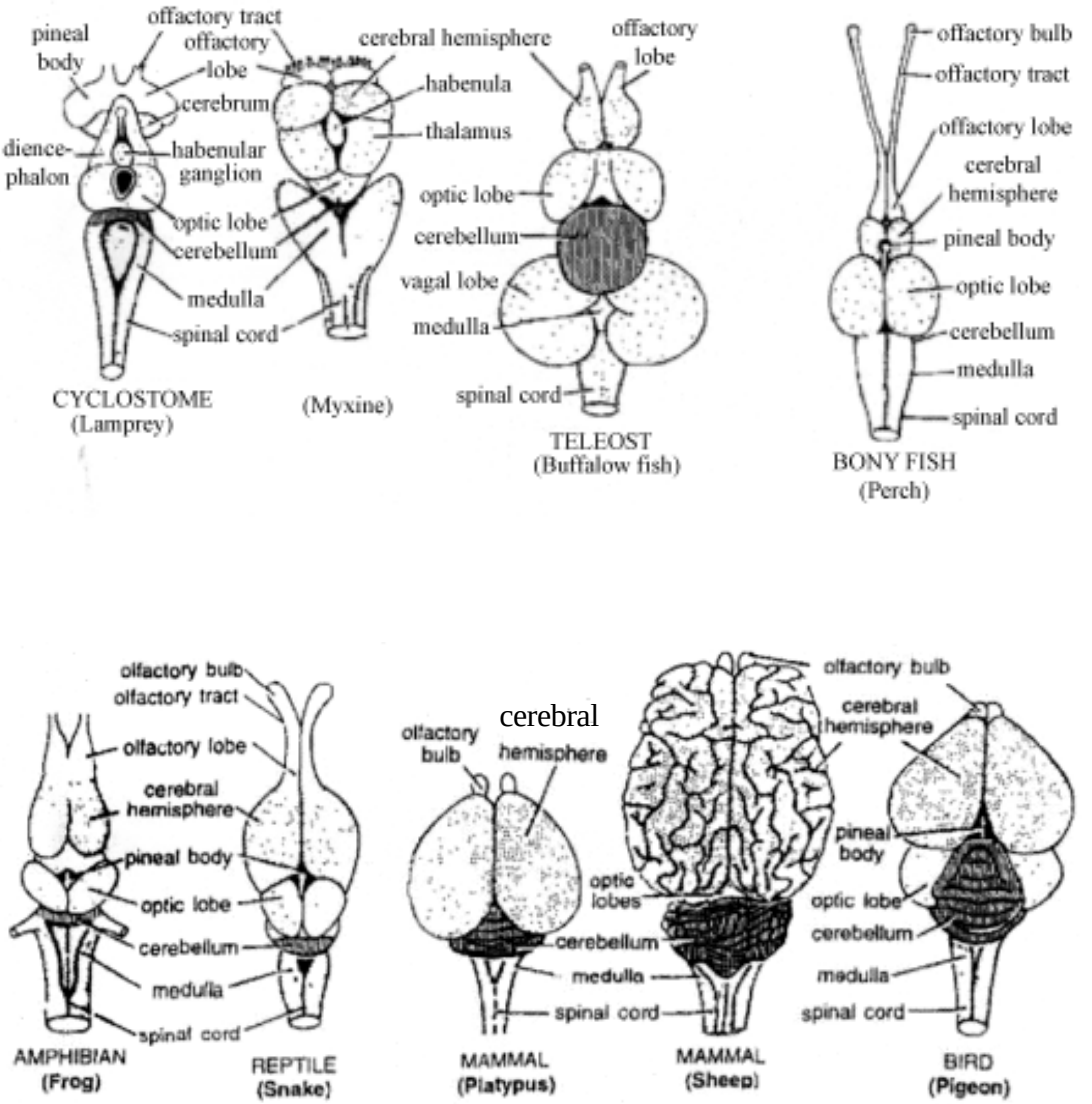


Fig-8 : Comparative account of brain of representative vertebrates (dorsal view)

(iv) Endocrine organs are connected with epiphysis. Diencephalon is covered by cerebral hemisphere.

(v) Optic lobes are two in lower forms but four in higher forms and relatively smaller. The corpora quadrigemina is covered by massive cerebrum.

(vi) Cerebellum is so much enlarged that they meet dorsally.

(vii) In addition to vermis, the lateral lobes floculi are of considerable size.

(viii) There is a definite bands of fibres encircling the brain stem, is known as pons.

(ix) Medulla oblongata is short and located under the prominent cerebellum.

9.4 Questions

1. Describe the structure of heart.
2. Give a comparative account of heart in tetrapoda with diagram.
3. What is the significance of reptilian heart.
4. What is nephron?
5. Write a comparative account of mammalian kidney.
6. Write the subdivisions of brain?
7. Write a comparative account of mammalian brain.

9.5 Selected readings

1) The life of vertebrates by J. Z. Young; Year: 1981. Published in India by Oxford University Press, New Delhi

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3) Text Book of Zoology Vertebrates (volume-2) 7th Edition by T. Jeffery Parkar and Williama Haswell (Edited by Marshall & Williams) Year: 1995. Pub: AITBS Publishers & Distributors, New Delhi-110051

4) Vertebrates Comparative Anatomy, Function, Evolution (Fourth Editon) by Kenneth V. Kardong. Year: 2010. Pub: Tata McGraw-Hill

Notes