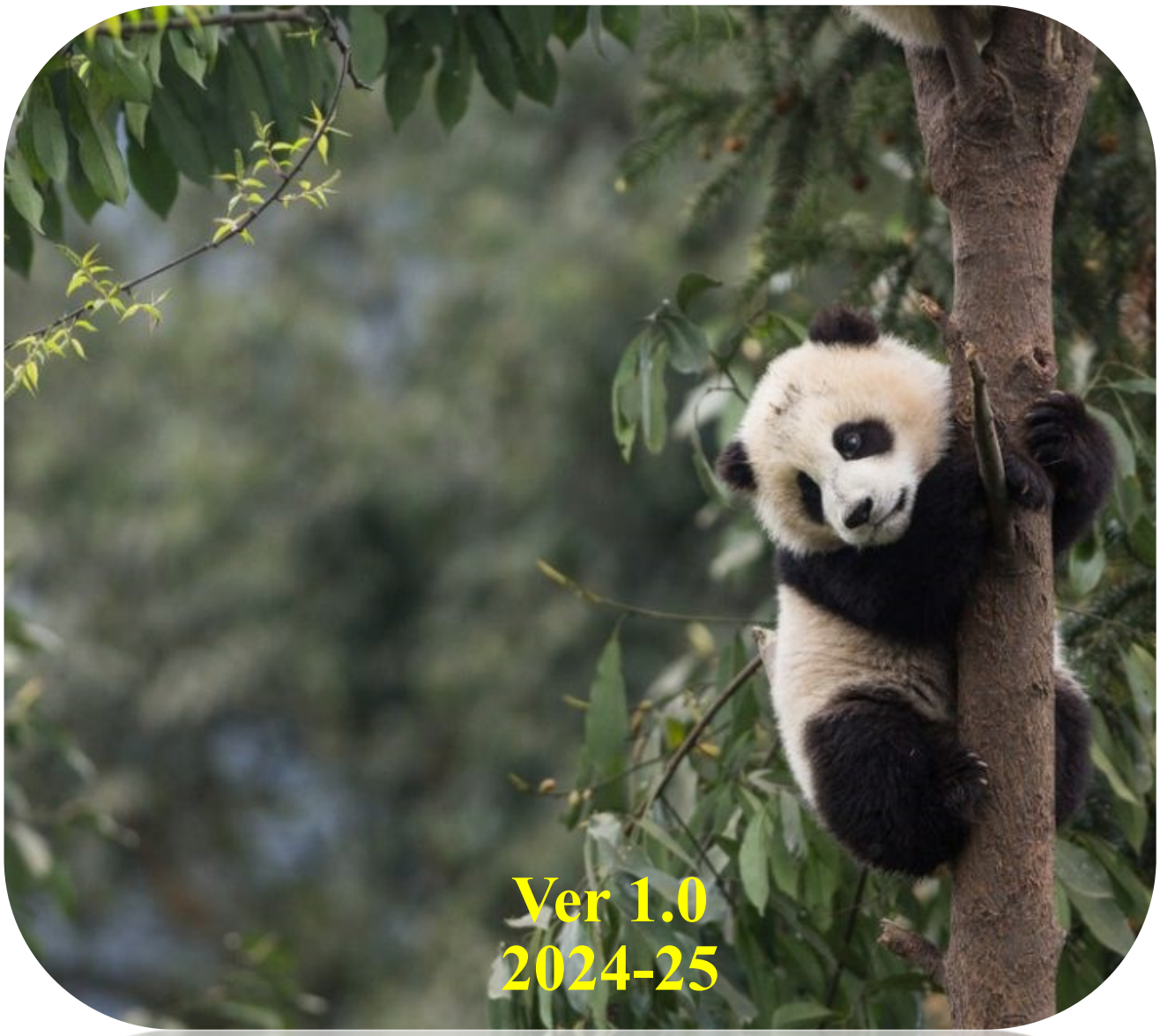
BIOLOGY OF CHORDATES

ZOOLOGY (H) :: SEMESTER III



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dr k HarisH BabU

PS GOVT DEGREE COLLEGE :: PENUKONDA
SRI SATYASAI Dt

SEMESTER-III
COURSE 5: ANIMAL DIVERISTY-II BIOLOGY OF CHORDATES

LEARNING OBJECTIVES

- To understand the animal kingdom.
- To understand the taxonomic position of Protochordata to Mammalia.
- To understand the general characteristics of animals belonging to Fishes to Reptilians.
- To understand the body organization of Chordata.
- To understand the taxonomic position of Protherian mammals.

LEARNING OUTCOMES: By the completion of the course the graduate should able to –

- Describe general taxonomic rules on animal classification of chordates
- Classify Protochordata to Mammalia with taxonomic keys
- Understand Mammals with specific structural adaptations
- Understand the significance of dentition and evolutionary significance
- Understand the origin and evolutionary relationship of different phyla from Prochordata to Mammalia.

SYLLABUS

UNIT – I

1.1 General characters and classification of Chordata up to classes

1.2 Salient features of Cephalochordata, Salient features of Urochordata

1.3 Structure and life history of *Herdmania* Retrogressive metamorphosis –Process and Significance

1.4 Cyclostomata, General characters

1.5 Comparison of Petromyzon and Myxine

***Activity**: Model preparation/ Assignment / Students Seminar/ Quiz/ Project/ Peer teaching/ Report writing after watching any video on the above*

***Evaluation**: Instructor supposed to prepare a detailed Rubrics for the evaluation of the above activity*

UNIT – II

2.1 General characters of Fishes, Salient features Dipnoi

2.2 *Scoliodon*: External features, Digestive system, Respiratory system

2.3 *Scoliodon* Structure and function of Heart, Structure and functions of the Brain

2.4 Migration in Fishes,

2.5 Types of Scales

***Activity**: Model preparation/ Assignment / Students Seminar/ Quiz/ Project/ Peer teaching/ Report writing after watching any video on the above*

***Evaluation**: Instructor supposed to prepare a detailed Rubrics for the evaluation of the above activity*

UNIT – III

3.1 General characters of Amphibia, General characters of Reptilia

3.2 Rana hexadactyla: External features, Respiratory system, Structure and function of Heart

3.3 Rana hexadactyla structure and functions of the Brain

3.4 Calotes: External features, Digestive system, structure and function of Brain

3.5 Identification of Poisonous snakes

***Activity**: Model preparation/ Assignment / Students Seminar/ Quiz/ Project/ Peer teaching/ Report writing after watching any video on the above*

***Evaluation**: Instructor supposed to prepare a detailed Rubrics for the evaluation of the above activity*

UNIT – IV

4.1 General characters of Aves

4.2 Columba livia: External features, Digestive system, Respiratory system

4.3 Columba livia: Structure and function of Heart, structure and function of Brain

4.4 Migration in Birds,

4.5 Flight adaptation in birds

***Activity**: Model preparation/ Assignment / Students Seminar/ Quiz/ Project/ Peer teaching/ Report writing after watching any video on the above*

***Evaluation**: Instructor supposed to prepare a detailed Rubrics for the evaluation of the above activity*

UNIT – V

5.1 General characters of Mammalia

5.2 Classification of Mammalia up to sub - classes with examples

5.3 Comparison of Prototherians, Metatherians and Eutherians

5.4 Dentition in mammals,

5.5 Aquatic mammals Adaptations

***Activity**: Model preparation/ Assignment / Students Seminar/ Quiz/ Project/ Peer teaching/ Report writing after watching any video on the above*

***Evaluation**: Instructor supposed to prepare a detailed Rubrics for the evaluation of the above activity*

Co-curricular activities (suggested)

- Preparation of charts on Chordate classification (with representative animal photos) and retrogressive metamorphosis
- Clay models of Herdmania and Amphioxus
- Visit to local fish market and identification of local cartilaginous and bony fishes
- Maintaining of aquarium by students
- Model of fish heart and brain
- Preparation of slides of scales of fishes
- Visit to local/nearby river to identify migratory fishes and prepare study notes
- Preparation of Charts on above topics by students (Eg: comparative account of vertebrate heart/brain/lungs, identification of snakes etc.)

- Collecting and preparation of Museum specimens with dead frogs/snakes/lizards etc., and/or their skeletons
- Additional input on types of snake poisons and their antidotes (student activity).
- Collection of bird feathers and submission of report on Plumology
- Taxidermic preparation of dead birds for Zoology Museum
- Map pointing of prototherian and metatherian mammals
- Chart preparation for dentition in mammals

REFERENCE BOOKS

- J.Z. Young, 2006. The life of vertebrates. (The Oxford University Press, New Delhi). 646 pages. Reprinted
- Arumugam, N. Chordate Zoology, Vol. 2. Saras Publication. 278 pages. 200 figs.
- A.J. Marshall, 1995. Textbook of zoology, Vertebrates. (The McMillan Press Ltd., UK). 852 pages. (Revised edition of Parker &Haswell, 1961).
- M. Ekambaranatha Ayyar, 1973. A manual of zoology. Part II. (S. Viswanathan Pvt. Ltd., Madras).
- P.S. Dhami & J.K. Dhami, 1981. Chordate zoology. (R. Chand & Co.). 550 pages.
- Gurdarshan Singh & H. Bhaskar, 2002. Advanced Chordate Zoology. Campus Books, 6 Vols., 1573 pp., tables, figs.
- A.K. Sinha, S. Adhikari& B.B. Ganguly, 1978. Biology of animals. Vol. II. Chordates. (New Central Book Agency, Calcutta). 560 pages.
- R.L. Kotpal, 2022. Modern textbook of zoology, Vertebrates. (Rastogi Publ., Meerut). 632 pages.
- E.L. Jordan & P.S. Verma, 1998. Chordate zoology. (S. Chand & Co.). 1092 pages.
- G.S. Sandhu, 2005. Objective Chordate Zoology. Campus Books, vii, 169 pp.
- Sandhu, G.S. & H. Bhaskar, H. 2004. Textbook of Chordate Zoology. Campus Books, 2 vols., xx, 964 p., figs.
- Veena, 2008. Lower Chordata. (Sonali Publ.), 374 p., tables, 117 fig

SEMESTER-III : COURSE 5: ANIMAL DIVERISTY-II BIOLOGY OF CHORDATES PRACTICALS

LEARNING OBJECTIVES

- To understand the importance of preservation of museum specimens
- To identify animals based on special identifying characters
- To understand different organ systems through demo or virtual dissections
- To maintain a neat, labeled record of identified museum specimens

SYLLABUS:

1. **Protochordata**:
   Herdmania, Amphioxus, Amphioxus T.S through pharynx.
2. **Cyclostomes**:
   Petromyzon and Myxine.
3. **Pisces**:
   Pristis, Torpedo, Hippocampus, Exocoetus, Echeneis, Labeo, Catla, Clarius, Channa, Anguilla.
4. **Amphibia**:
   Ichthyophis, Amblystoma, Axolotl larva, Hyla,
5. **Reptilia**:
   Draco, Chamaeleon, Uromastix, Testudo, Trionyx, Russels viper, Naja, Krait, Hydrophis, Crocodile.
6. **Aves**:
   Psittacula, Eudynamis, Bubo, Alcedo.
7. **Mammalia**:
   Ornithorhynchus, Pteropus, Funambulus.
8. **Dissections-As per UGC guidelines**
   Scoliodon *IX* and X, Cranial nerves, Brain
   Mounting of fish scales

   ***Note**: 1. Dissections are to be demonstrated only by the faculty or virtual.*

9. Laboratory **Record work** shall be submitted at the time of practical examination.

RFERENCE WEB LINKS:

https://nt7-mhe-complex-assets.mheducation.com/nt7-mhe-complex-assets/Upload20190715/InspireScience6-8CA/LS15/index.html

https://themammallab.com/

http://abacus.bates.edu/acad/depts/biobook/LabConCh.htm

https://virtualzoology.wordpress.com/scoliodon/

http://www.zoologyresources.com/uploadfiles/books/dc64b77d8769325515d17c945e461b45.pdf

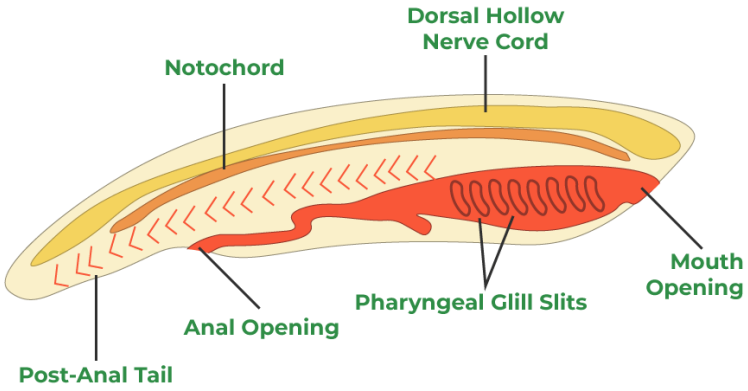
1.1.General characters and classification of Chordata up to classes

1. Notochord / Chorda dorsalis -

- Notochord is a solid rod-like structure which is present just below the nerve cord and above the alimentary canal.
- It is situated at the dorsal surface and extended from the anterior to posterior end of the body.
- It is mesodermal in origin and forms a primary endoskeleton which provides the support to the body.
- In Protochordates, the notochord is not replaced by a vertebral column.
- In vertebrates, notochord is replaced by backbone or vertebral column in adults.

2. Dorsal Hollow Nerve Cord -

- In the organisms belonging to phylum Chordata, the central nervous system (CNS) is located at the dorsal surface of the body.
- A single, hollow, tubular nerve cord is found beneath the body wall and just above the notochord.
- Nerve cord is ectodermal in origin.



3. Pharyngeal Gill Slits -

- In phylum chordata, paired lateral gill clefts are present in the walls of pharynx for respiration in the both embryonic and the adult stage.
- In aquatic chordates (pisces) and lower chordates, pharyngeal gill clefts are found in the both embryonic and the adult stage.
- In terrestrial chordates, gill clefts are found only in the embryonic stage and are absent in adults.
- The main respiratory organs are lungs in adults.

4. Anal tail

- Tail is reduced or absent in chordates but if it is present then it's found in the post anal part of the body.

Other characters of phylum Chordata –

Level of organization: Organ-system level of organisation.

Symmetry: Bilaterally symmetrical.

Germ layers: Triploblastic animals

Segmentation: Metameric segmentation present

Body plan: Tube-within-tube body plan.

Cephalization: Cephalization is present which is defined as the differentiation of a definite head at the anterior end. The sense organ, nervous tissue (brain) and food catching organs are present at the anterior end.

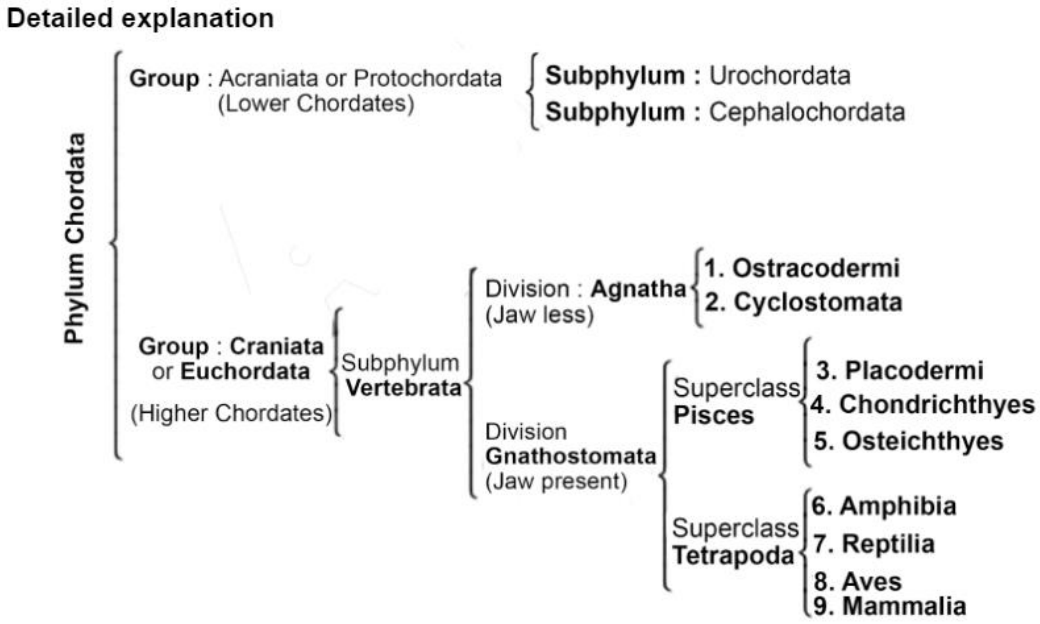
Coelom (body cavity): Eucoelomates, Enterocoelom is present.

Digestion: Digestive system is complete.

Respiration and excretion: Specialised organs are present for respiration and excretion.

Circulatory system: Closed circulatory system is present. Ventral heart.

Reproductive System: Reproduction is sexual, They are mostly unisexual i.e sexes are separate in them. Gonads are present in them with gonoducts



Phylum chordata is divided into 2 groups, on the basis of cranium, -

a. Acraniata/Protochordata (lower chordates)

- It is divided into two sub phyla –

  1. Urochordata (ex. Herdmania)

  2. Cephalochordata (ex. Amphioxus)

b. Craniata/Eurochordata (higher chordata)

- Craniata includes the sub - phylum Vertebrata which is further categorized into 2 divisions, on the basis of jaws –

a. Agnatha (jawless vertebrates)

- It is further divided into two classes –

  1. Ostracodermi (extinct)

2. Cyclostomata (ex: Petromyzon, Myxine)

b. Gnatha (jawed vertebrates)

- It is further divided into two super classes -

1. Pisces (true fishes)

- It is further divided into three classes –

i. Placodermi (fossils) - ex: Climatius

ii. Chondrichthyes (cartilaginous fishes) - ex: Scoliodon

iii. Osteichthyes (bony fishes) - ex: Labeo

2. Tetrapoda (usually having four limbs)

- It is further divided into four classes –

i. Amphibia

ii. Reptilia

iii. Aves/ Birds

iv. Mammalia

1.2.1. Salient features of Urochordata

***** Notochord is present at the tail region. Tail is only present in larvae and not in adult. That means, tail is absent in adult.

* Large pharynx with endostyle and two to many gill-slits are present.

* A dorsal atrial aperture and a terminal branchial apertures are usually present.

* They are the filter feeders.

* Respiration takes place through test or gills.

* A complete alimentary canal is found.

* Excretion occurs by neural glands, pyloric glands and nephrocytes.

* Blood vascular system is open type. A ventral tubular heart is found. Vanadocytes are present which extract vanadium from sea water.

* In larvae a dorsal, hollow nerve cord is found, but in adult get reduced into a single nerve ganglion.

* Reproduction is mostly sexual, but some reproduces asexually (budding) too.

* Development is indirect, Retrogressive metamorphosis occurs.

* Fertilization is external but cross fertilization is the rule.

* Most of the Tunicates are monoecious.

* They are exclusively marine and cosmopolitan.

* They may be solitary or colonial. Some are pelagic.

* Triploblastic animals i.e., body is derived from 3 embryonic germ layer (ectoderm, mesoderm, and endoderm).

* Body is bilaterally symmetrical,

* Body is covered by a tunic or test which is mainly composed of Tunicine (similar to cellulose).Hence the name Tunicata is given to it.

* Body segmentation is absent.

* Organ-system grade of body oraganisation is seen.

* Coelom is usually absent. Instead of it an ectoderm lined atrial cavity is present which opens to outside by an atrial aperture.

* Adults are sessile, but larvae are free-swimming.

1.2.2. General Characteristics of Cephalochordata

- The subphylum cephalochordata is found inhabiting shallow temperate and tropical oceans, buried in coarse sand.
- Cephalochordates possess five characteristics that are found in all chordates at some point in their life. They are:
- A notochord
- Dorsal hollow nerve cord
- Pharyngeal slits
- Endostyle
- Post-anal tail
- The subphylum cephalochordata possesses around thirty species in two families, making it the smallest phyla in the animal kingdom.
- *Branchiostoma* of the family Branchiostomatidae is the most common genus of the subphylum.
- They are also known as acraniates because they do not possess a true brain, braincase or cranium as found in vertebrates.
- The pharynx has many gill slits that are surrounded by an atrium for protection.
- The body of lancelets, like other vertebrates, is made up of segments that are known as metameres.
- The segmentation helps in the more effective locomotion of the organisms.
- A secondary body cavity, similar to coelom in vertebrates, is also found in cephalochordates.
- Externally, they have a dorsal fin that extends from the upper surface of the body and continues into a caudal fin around the tail and finishes as a ventral fin to the lower surface of the atrium.
- There are no paired fins found.
- The notochord extends through the entire body and provides the required support to the organisms.

- The nervous system is composed of the hollow nerve cord that possesses a small swelling which is barely qualified as the brain.
- Small eyelike organs are found in the nerve cord that detect light, its direction and change in intensity.
- For digestion, their mouth is covered with an oral hood that is the entrance for incoming food particles.
- The edges of the oral hood have buccal cirri that are filament-like projections. They filter out any large food particles from entering the buccal cavity.
- Respiration takes place with the help of gills that possess gill slits.
- The circulatory system of cephalochordates is closed and is very similar to vertebrates. The only striking difference is that they lack a heart.

1.2.1 Structure and life history of *Herdmania*

Herdmania is a genus of sea squirts, which are marine invertebrates belonging to the class Ascidiacea within the phylum Chordata. These organisms are also known as ascidians or tunicates.

External Structure

1. **Body Shape and Size**:
   - Herdmania typically has a cylindrical or barrel-shaped body.
   - The body is covered by a tough outer tunic, composed of a cellulose-like substance called tunicin.
2. **Siphons**:
   - **Incurrent Siphon**: Located at the top (anterior end) of the body, through which water enters.
   - **Excurrent Siphon**: Positioned laterally or on the opposite side, through which water exits after passing through the body.
3. **Tunicate Body Wall**:
   - The tunic is often rough and can have various colors depending on the species.
   - It serves as a protective layer against predators and environmental factors.

Internal Structure

1. **Pharyngeal Basket**:
   - The most prominent internal feature is the pharyngeal basket, which is a large, perforated structure used for filter feeding.
   - It is lined with cilia that create a water current, trapping food particles.
2. **Digestive System**:
   - Water carrying food particles enters through the incurrent siphon and passes through the pharyngeal slits into the atrium.

- The food is then transported to the esophagus, stomach, and intestine for digestion.

3. **Circulatory System**:
   - Herdmania has an open circulatory system with a simple heart located at the base of the pharyngeal basket.
   - Blood flows through vessels to various parts of the body, including the tunic.
4. **Nervous System**:
   - A rudimentary nervous system with a cerebral ganglion situated between the two siphons.
   - This ganglion controls the opening and closing of siphons and other basic functions.
5. **Reproductive System**:
   - Hermaphroditic, possessing both male and female reproductive organs.
   - Gonads are located close to the intestinal loop, releasing gametes into the atrium to be expelled through the excurrent siphon.

Life History of Herdmania

Larval Stage:

The life cycle begins with a free-swimming larva known as a tadpole larva.

The larva possesses a notochord, a dorsal nerve cord, and a post-anal tail, exhibiting typical chordate features.

Metamorphosis:

The larva undergoes a dramatic metamorphosis upon finding a suitable substrate to attach to.

It loses its chordate characteristics, such as the tail and notochord, as it transforms into the sessile adult form.

Adult Stage:

As adults, Herdmania are sessile, attached to substrates like rocks, shells, or submerged objects in the marine environment.

They are filter feeders, drawing water through their bodies to extract plankton and detritus.

Reproduction:

Reproduction typically involves the release of eggs and sperm into the water column, where external fertilization occurs.

The resulting zygote develops into a larva, continuing the life cycle.

Regeneration:

Herdmania exhibits some capacity for regeneration, particularly of the tunic and parts of the internal structures if damaged.

1.2.1 Retrogressive metamorphosis – Process and Significance

Retrogressive Metamorphosis in Herdmania

Retrogressive metamorphosis is a process where the larval form of an organism possesses more complex structures, and as it transitions to the adult form, it loses these complex structures, becoming simpler. In Herdmania, this process is particularly fascinating and significant due to its implications in evolutionary biology.

Process of Retrogressive Metamorphosis in Herdmania

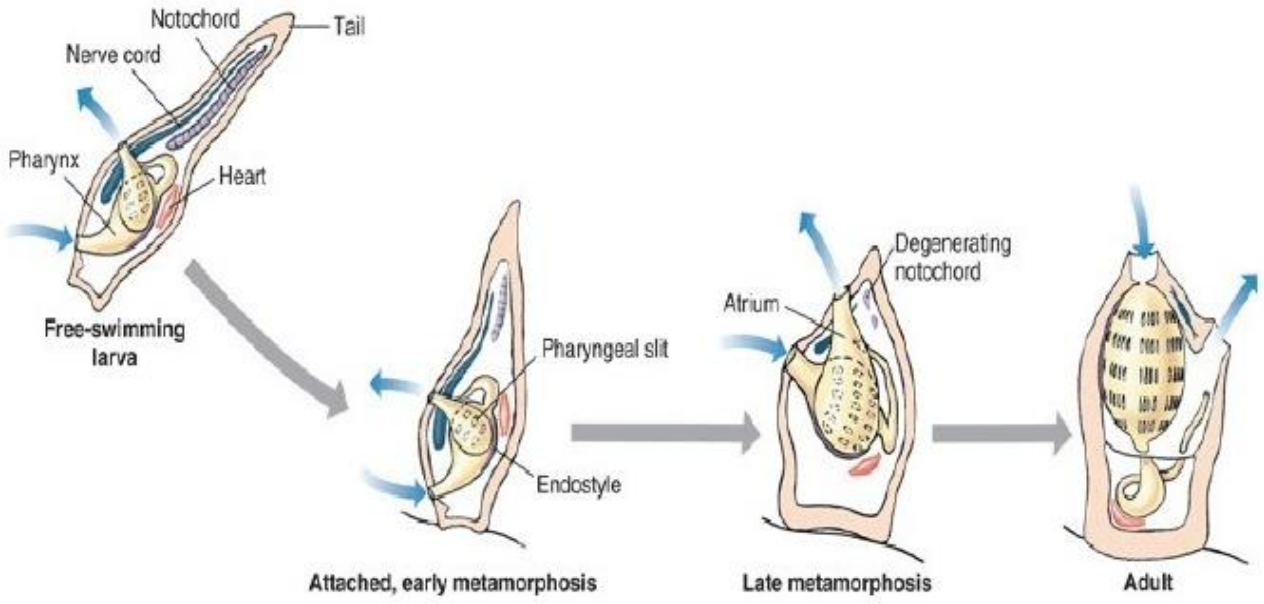
1. **Larval Stage**:
    - The Herdmania larva, known as a tadpole larva, is free-swimming and exhibits typical chordate features.
    - **Notochord**: A flexible, rod-like structure that provides support.
    - **Dorsal Nerve Cord**: A hollow tube of nervous tissue.
    - **Pharyngeal Slits**: Used for filter feeding.
    - **Post-anal Tail**: Provides motility for swimming.
    - **Sensory Organs**: An ocellus (simple eye) and a statocyst (balance organ).
2. **Settlement**:
    - The larva swims for a short period before finding a suitable substrate to attach to, usually within a day or two.
    - Upon finding a suitable surface, the larva attaches using adhesive papillae located at the anterior end.
3. **Metamorphosis**:
    - Once attached, the larva undergoes dramatic changes, losing its complex structures and adopting a simpler form.
    - **Degeneration of Chordate Features**: The notochord, dorsal nerve cord, tail, and sensory organs degenerate.
    - **Development of Adult Structures**: The body reorganizes into the sessile adult form, developing features such as:
        - **Incurrent and Excurrent Siphons**: For water intake and expulsion.
        - **Pharyngeal Basket**: Enlarges and becomes the primary filter-feeding apparatus.
        - **Tunic Formation**: The outer protective tunic develops fully.

Significance of Retrogressive Metamorphosis

1. **Evolutionary Implications**:
    - Retrogressive metamorphosis in Herdmania provides insight into the evolutionary transition from motile, free-swimming larvae to sessile adult forms.

- It exemplifies the adaptive strategies that have evolved in sessile marine organisms for survival and reproduction in their specific ecological niches.

2. **Chordate Evolution**:
   - The presence of chordate features in the larval stage highlights the evolutionary link between simple invertebrates and more complex vertebrates.
   - It provides a living example of how more complex structures can evolve and be subsequently reduced or lost when they are no longer advantageous in the adult form.
3. **Ecological Role**:
   - The process allows Herdmania to occupy a niche as efficient filter feeders in the benthic marine environment.
   - By transitioning from a motile larval stage to a sessile adult stage, Herdmania can exploit different ecological resources, reducing intraspecific competition for food and space.
4. **Adaptation to Environment**:
   - The ability to undergo retrogressive metamorphosis allows Herdmania to maximize its chances of survival and reproductive success in a stable, resource-rich environment.
   - The sessile adult form is well-adapted to filter feeding, a mode of feeding that is efficient and effective in marine ecosystems.
5. **Model for Study**:
   - Herdmania serves as a model organism for studying developmental biology and metamorphosis.
   - It provides a unique opportunity to study the genetic and biochemical processes involved in the loss and reorganization of complex structures.



1.4.1. Cyclostomata, General characters

1. The body is round and elongated like an eel.
2. The paired fins are absent.
3. Median fins with cartilaginous fin rays.
4. No paired appendages.
5. The skin is soft and smooth, devoid of any scales.
6. Spleen is absent.
7. The exoskeleton is absent. The endoskeleton is cartilaginous with no bones.
8. The notochord is present throughout their lives.
9. The digestive system is devoid of any stomach.
10. The nostril is single and median.
11. The gills are five to sixteen in pairs.
12. The heart is two-chambered.
13. The brain is visible.
14. The lateral line acts as a sense organ.
15. About ten pairs of cranial nerves are present.
16. The sexes are separate. Some hagfish species are believed to be hermaphrodite.
17. A pair of mesonephric kidneys make up the excretory system.
18. Development may be direct or indirect.
19. Ex., Petromyzon and Maxine.

The cyclostomes are sub-divided into two major orders.

Petromyzontiformes

Lampreys or lamper eels belong to this order.

- They are found in both marine and freshwater.
- They have a ventral mouth with many horny teeth.
- The nostril is present dorsally.
- They possess a well-developed dorsal fin.
- The dorsal and ventral roots of spinal nerves are separate.
- The development is indirect.

Ex., Petromyzon, Lampetra

Myxiniformes

Hagfishes represent this order.

- They are found exclusively in the marine environment.
- They have a terminal mouth with few teeth.
- They have no buccal cavity.
- The nostril is terminal.
- They possess 6-14 pairs of gill slits.
- The dorsal and ventral roots of the spinal nerves are not separate.
- Eggs are large and few in number.
- The dorsal fin is usually absent, or weak.

Ex., Myxine, Paramyxine.

1.4.2. Comparison of Petromyzon and Myxine

Myxine	Petromyzon
1. Myxine is exclusively marine.	**1**. Petromyzon live in rivers and seas.
2. The fin of Myxine is confined to tail.	2. Petromyzon have two unpaired dorsal fins and a tail fin.
3. Numerous large glands are present in the complex slimy skin of Myxine.	3. Sensory structures in the complex, slimy, pigmented skin.
4. Buccal funnel is absent in Myxine. The mouth is edged with tentacles supported by cartilage.	4. Buccal funnel is present in Petromyzon, surrounded with papillae.
5. A single median tooth and two rows of smaller teeth present on the tongue.	**5**. Teeth many, yellow and horny. The tongue also bears horny teeth.
6. Eyes of Myxine are hidden and rudimentary.	6. Eyes are hidden and retarded in the larva, exposed and complete in the adult Petromyzon.
7. Six pairs of gill pouches opening directly into the gullet and less directly to the exterior.	7. Seven pairs of gill pouches, opening directly to the exterior and less directly into the adult gullet.
8. Ear with a utriculus and two semicircular canals.	8. Ear of Petromyzon is more complex and has a sacculus in addition.
9. The nostril large, unpaired, dorsal and opens into the pharynx through a passage, the pituitary sac.	9. The nostril unpaired, dorsal and ends blindly in the pituitary sac.
10. A velum separates the buccal cavity from the pharynx.	**10**. A velum guards the respiratory tube from the buccal cavity.
11. The intestine of Myxine is very wide and bears longitudinal ridges.	11. The intestine is without convolution. Typlosole and slight spiral valves present.
12. No urinogenital sinus, only one genital pore.	12. A urinogenital sinus and two genital pores.
13. Skull of Myxine is without any roof.	13. Skull of Petromyzon is very imperfectly roofed.
14. Skeletal system of Myxine is less developed, only a hint of a branchial basket.	**14**. Hints of vertebral arches, cartilaginous branchial basket round gill pouches.
15. Cerebrum and cerebellum rudimentary.	15. All the components of the brain are distinct and well-marked.
16. Protandrous hermaphrodite.	16. Sexes are separate in Petromyzon.
17. Ova of Myxine is large and oval with attaching threads.	17. Ova of Petromyzon is small and spherical, threads.
18. Cleavage meroblastic in Bdellostoma.	18. Cleavage holobastic.
19. Development direct in Bdellostoma.	**19**. Development with a metamorphosis.

2.1.1 General characters of Fishes

1. Fishes are aquatic, and cold blooded vertebrates.

2. Their body is divisible into head, trunk and tail. Neck is absent.

3. It has a spindle shaped body. It is helpful in swimming.

4. The body is covered by scales. They are placoid scales, cycloid scales, ctenoid scales, ganoid scales etc.

5. Respiration is by gills. Gills are the extensions of the pharynx. In the elasmobranches fishes, the gills will open separate. In bony fishes the gill slits are covered by operculum.

6. On the head a pair of nostrils are present internal nostril are absent. In Dipnoi internal nostrils are present

7. On the head a pair of eyes is present.

8. On the lateral sides of the body Lateral line sense organs are present .They detect the pressure changes of water.

9. The body shows paired and unpaired fins. Pelvic and pectoral fins are paired. Dorsal and ventral fins are unpaired. They maintain balance in water. They are useful for locomotion.

10. The digestive system is well developed. In the intestine of shark scroll valve is present. The nervous system contains brain and spinal cord. Brain is small & it will not occupy the entire cranial cavity.

11. 10 pairs of cranial nerves are present.

12. Kidneys are mesonephric.

13. Urinary bladder is absent

14. The skeleton of some fishes is made by cartilage. They are called cartilage fishes. In some fishes the skeleton is made by bone. They are called bony fishes.

15. In some fresh water fishes accessory respiratory organs are present. They will take up aerial respiration.

16. Sexes are separate. In male sharks claspers are present.

17 Many fishes are oviparous. Some fishes are viviparous.

18. In the development of fishes amnion is not developed. Hence these animals are called **anamniotes.**

2.1.2. Salient features Dipnoi

* The Dipnoi are a group of sarcopterygian fish, commonly known as the lungfish.

* Lung fishes are large, bizarre fishes, live in **shallow continental waters** and swamps in Africa, South America and Australia. During the dry season, they are buried in mud entering a kind of hibernation or lethargy.

* Lung fishes are slender fish-like or eel-like creatures, 1 to 2 meters in length.

* Body is covered by overlapping cycloid scales.

* Paired pectoral and pelvic fins are narrow lobe-like or filamentous, with a central axis of flesh and bone.

* Dorsal, Anal and Caudal fins are fused to form a continuous, symmetrical, diphycercal tail, supported by partly calcified fin rays.

* Snout is depressed bearing external nostrils enclosed within upper lip and two internal nostrils open into the mouth cavity.

* Mouth is subterminal or ventral.

* Eyes are small.

* Endoskeleton is mostly cartilaginous.

* Both gill and pulmonary respiration take place in the lung-fishes. The nostrils help in aerial respiration. Air-bladder (swim-bladder) is modified into the “lung”.

At present, the Dipnoi are represented by three genera occurring in widely separated tropical and subtropical freshwater habitats. (Discontinuous distribution)

* They are considered as **living fossils.**

* There are only three genera of lungfish alive today and each is found on a single continent. The Australian lungfish is *Neoceratodus*; in South America lives *Leipdosiren*; and *Protopterus* lives in Africa.

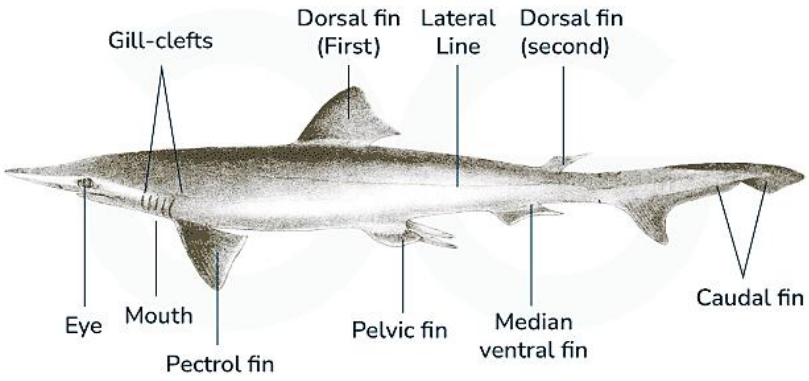
Lungfish are believed to be the closest living relatives of the tetrapods, and share a number of important characteristics with them.

2.2.1. Scoliodon: External features

Scoliodon, commonly known as the spiny dogfish, is a species of shark belonging to the family Squalidae. It is characterized by several distinctive external features that contribute to its survival and adaptation in its marine habitat. Let's explore these features:

1. Body Shape: Scoliodon has a fusiform (spindle-shaped) body, which is streamlined and hydrodynamic, allowing for efficient movement through the water.

2. Dermal Denticles: The skin of Scoliodon is covered in dermal denticles, small tooth-like scales that provide protection against abrasions and reduce friction with the surrounding water.



3. Coloration: The dorsal surface of Scoliodon is typically gray or grayish-brown, providing camouflage against the darker depths when viewed from above. The ventral surface is lighter in color, which helps to camouflage the shark from predators looking up from below.

4. Head and Snout: Scoliodon's streamlined appearance and pointed head facilitate its quick swimming motion. Take note of the prominent snout that gives this shark its common name, spadenose shark.

5. Mouth and Teeth: Scoliodon has a large, terminal mouth located on the underside of the head. The mouth is equipped with rows of sharp, triangular teeth, well-suited for grasping and tearing prey.

6. Spiracles: Positioned behind the eyes, Scoliodon possesses a pair of small openings called spiracles. These structures enable the shark to pass water over its gills while resting on the seafloor, allowing for respiration even when the shark is stationary.

7. Fin Structure: Scoliodon possesses several distinct fins, each serving specific functions:

- **Dorsal Fins**: The two dorsal fins that are present are the first and second. These fins allow for more stable swimming.
- **Caudal Fin**: The caudal fin, or tail fin, is forked, allowing for powerful and efficient swimming.
- **Pectoral Fins**: The shark uses its pectoral fins on either side of the body to help it navigate and maintain balance.

- **Pelvic Fins**: The shark's stability and control are enhanced by its pelvic fins which are situated on its ventral side.
- **Anal Fin:** Situated near the tail on the ventral side, the anal fin helps in mobility and navigation.

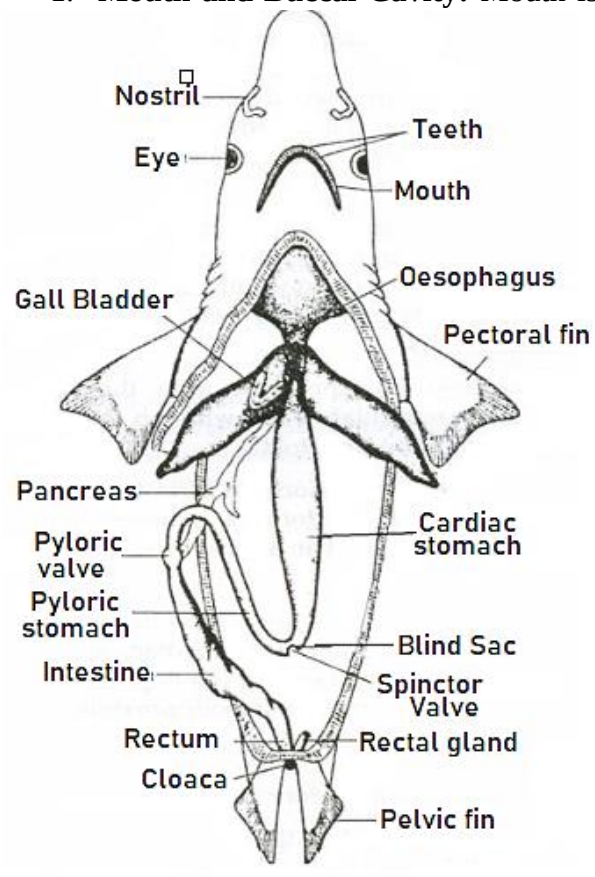
7. Lateral Line: The shark uses its lateral line which runs the length of its body to help detect vibrations and movement in the water.

In summary, the external features of Scoliodon are well-adapted to its marine environment, providing it with the tools necessary for efficient swimming, hunting, and survival. From its streamlined body shape to its specialized sensory organs, each feature contributes to the shark's success as a predator in the ocean ecosystem.

2.2.2. Scoliodon: Digestive system

Scoliodons digestive system is a fascinating aspect of its biology, showcasing adaptations for carnivorous feeding and efficient nutrient absorption. It follows a typical vertebrate pattern but exhibits some modifications suited to its carnivorous diet. It consists of several organs and structures, each playing a specific role in the digestion and absorption of nutrients.

1. **Mouth and Buccal Cavity:** Mouth is located ventrally and is equipped with numerous sharp teeth for capturing and tearing prey. The buccal cavity, the space behind the mouth, is lined with mucous membranes and contains taste buds that aid in locating food.



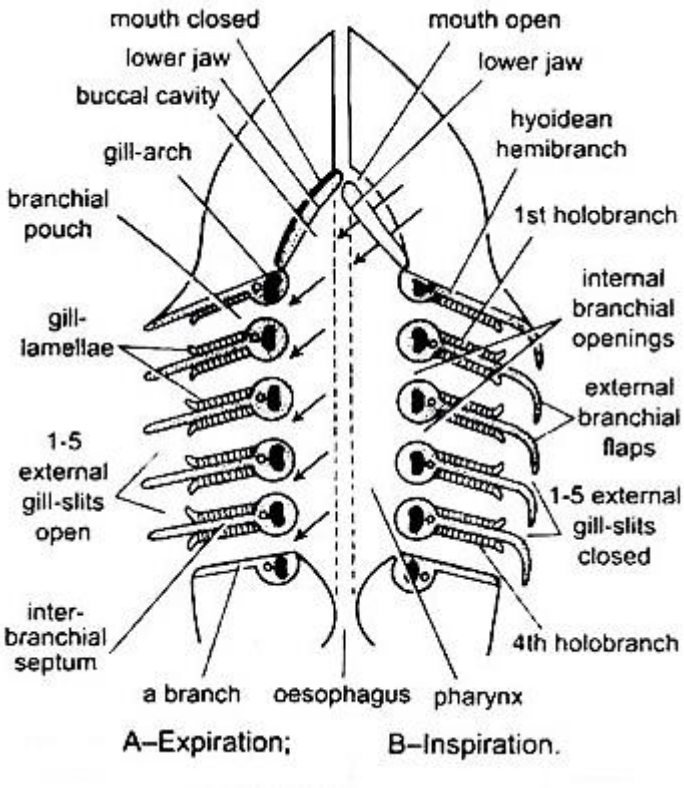
2. **Pharynx and Esophagus:** The pharynx serves as a common passage for both food and air. From the pharynx, the food enters the esophagus, a muscular tube that transports it to the stomach through peristaltic contractions.

3. **Stomach:** stomach is J-shaped, secretes gastric juices containing hydrochloric acid and digestive enzymes, facilitating the breakdown of proteins and other macromolecules present in the prey.

4. **Liver:** The liver is large and complex, performing multiple functions essential for digestion and metabolism. It produces bile, which is stored in the gallbladder and released into the intestine to aid in the emulsification and digestion of fats.

5. **Pancreas:** The pancreas secretes digestive enzymes into the intestine, further breaking down carbohydrates, proteins, and fats into smaller molecules that can be absorbed by the body.
6. **Intestine:** The intestine is divided into two regions: the anterior small intestine and the posterior large intestine. The small intestine is the primary site of nutrient absorption, where villi and microvilli increase the surface area for absorption. The large intestine is responsible for reabsorbing water and electrolytes from undigested food material.
7. **Rectum and Anus:** The rectum stores fecal matter temporarily before it is expelled from the body through the anus.
8. **Digestive Glands:** In addition to the liver and pancreas, other digestive glands scattered throughout its digestive tract, secreting enzymes and other substances to aid in digestion.
9. **Cloaca:** It is a common chamber that receives waste products from the digestive, urinary, and reproductive systems before they are expelled from the body.
10. **Adaptations:** The digestive system is adapted for processing a diet consisting mainly of fish, crustaceans, and other small marine organisms. Its sharp teeth and powerful jaws facilitate efficient prey capture and mastication. The presence of strong digestive enzymes enables rapid breakdown of prey tissues, ensuring effective nutrient extraction.

2.2.3 Scoliodon: Respiratory system



The respiratory system of Scoliodon is an intricate network of organs and tissues responsible for the exchange of gases, primarily oxygen and carbon dioxide, between the organism and its environment. This system ensures the efficient uptake of oxygen required for cellular respiration while expelling metabolic waste in the form of carbon dioxide. Let's explore its structure in detail:

1. Nasal Region: Scoliodon possesses paired external nares, or nostrils, which serve as the primary entry point for respiratory gases. Inside the nasal region, the nasal cavity is lined with mucous membranes containing olfactory receptors, aiding in the detection of odors and potentially assisting in locating food sources.

2. Pharynx: The nasal cavity leads posteriorly into the pharynx, a common passageway for both the respiratory and digestive systems. The pharynx serves as a junction where the respiratory pathway diverges towards the respiratory organs while the digestive pathway leads to the esophagus.

3. Gills: The hallmark of aquatic respiration in Scoliodon is its gills, which are highly specialized structures for gas exchange. Scoliodon possesses five pairs of gills located on each side of the pharynx. Each gill consists of a series of gill arches, which support the gill filaments.

4. Gill Filaments: Extending from each gill arch are numerous gill filaments, arranged in a comb-like fashion. These filaments greatly increase the surface area available for gas exchange. The gill filaments are richly supplied with blood vessels, facilitating the exchange of oxygen and carbon dioxide across the respiratory membrane.

5. Operculum: Each gill slit is covered by a protective flap of tissue known as the operculum. The operculum helps regulate the flow of water over the gills and protects them from damage. It opens during inhalation, allowing water to pass over the gills, and closes during exhalation to prevent the entry of debris.

6. Countercurrent Exchange: Blood flow through the gills of Scoliodon is arranged in a countercurrent fashion, optimizing the efficiency of gas exchange. This means that blood flows in the opposite direction to the water passing over the gills, maximizing the diffusion gradient for oxygen uptake and minimizing the loss of oxygen to the environment.

7. Respiratory Pigments: Scoliodon possesses respiratory pigments, such as hemoglobin, within its blood. These pigments bind with oxygen molecules, enhancing the capacity of the blood to transport oxygen from the gills to the body tissues. This ensures efficient oxygen delivery to cells, supporting metabolic processes.

8. Exhalation: After oxygen has been extracted from the water and carbon dioxide has been released, the water exits through the gill slits. Exhalation in Scoliodon is a passive process driven by the elastic recoil of the gill filaments and the closure of the operculum.

In summary, the respiratory system of Scoliodon is intricately adapted for efficient gas exchange in its aquatic environment. From the entry of water through the nasal region to the countercurrent exchange mechanism in the gills, each component plays a vital role in ensuring the oxygen supply necessary for the organism's survival.

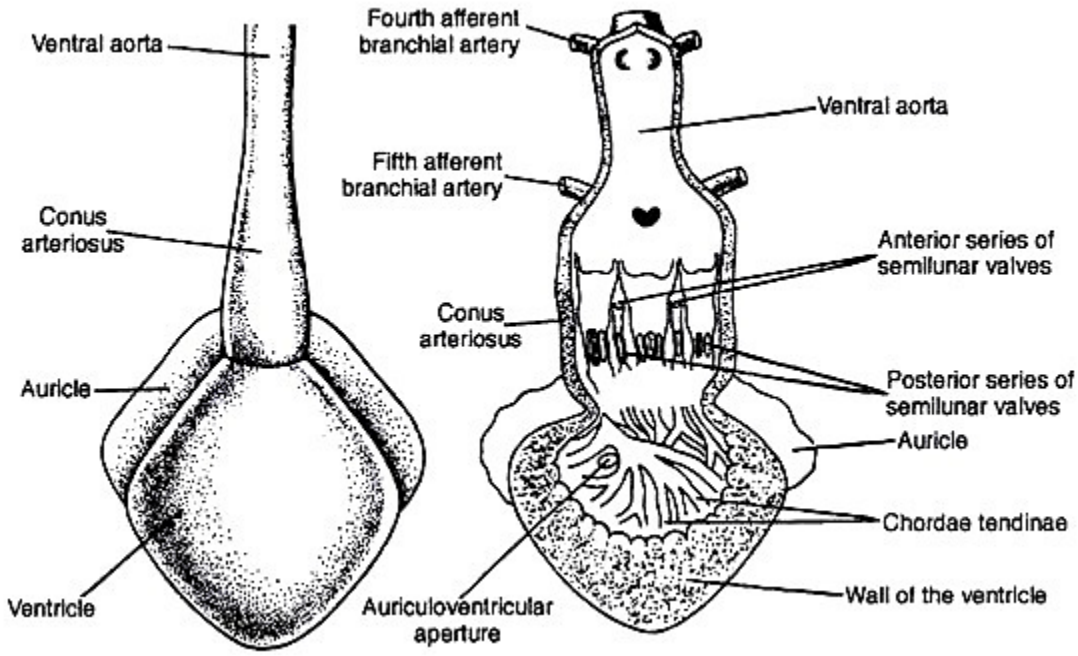
2.3.1 Scoliodon Structure and function of Heart

Heart:

The heart of Scoliodon lies mid-ventrally beneath the pharynx in the head region. It is a simple dorso-ventrally bent S-shaped muscular tube. It lies in the pericardial cavity, bounded by a two-layered membranous pericardium. It is a median triangular cavity lying between the gills with the apex directed forwards, and is almost completely occupied by the heart. The heart of Scoliodon contains only the impure blood, hence, it is called venous or branchial heart.

The heart consists of four chambers:

a. The sinus venosus, b. The atrium, c. The ventricle and d. The conus arteriosus.



a. Sinus venosus: It is a highly contractile thin-walled tubular chamber. The beating of the heart originates from this part. Two great veins, the **ductus Cuveiri**, open into the sinus venosus, one on each lateral side. Two **hepatic sinuses** enter the sinus venosus posteriorly. The sinus venosus opens into the auricle by **sinuauricular aperture** which is guarded by a pair of valves.

b. Auricle: The auricle is a large, triangular and thin walled chamber situated dorsal to the ventricle but in front of the sinus venosus. The auricle communicates with the ventricle through a slit-like **auriculo-ventricular aperture** guarded by two lipped valves. The receiving chambers (sinus venosus and auricle) receive the venous blood from all parts of the body.

c. Ventricle: The ventricle has a very thick muscular wall. Its inner surface gives many muscular strands, which gives it a spongy texture. It is an oval chamber and constitutes the most prominent part of the heart. The conus arteriosus is a stout median muscular tube arising from the ventricle.

d. Conus arteriosus: The lumen of the conus arteriosus is provided with two transverse rows of semilunar valves. To keep the valves in position the free ends of the valves are attached to the ventricular wall by fine tendinous threads called **chordae tendinae**. The conus arteriosus is continued forward as the **ventral aorta**.

Working of Heart: The function of the heart is to receive the deoxygenated blood from all parts of the body and to pump it for aeration to the gills. Such a type of heart is designated as the venous or branchial heart, because only the deoxygenated blood circulates through it.

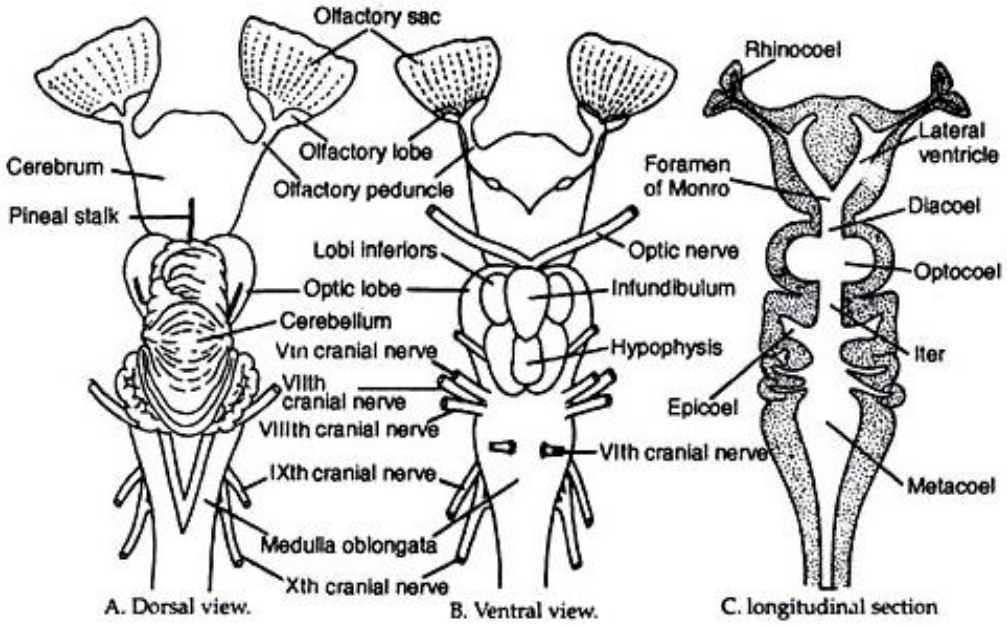
2.3.2. Scoliodon Structure and functions of the Brain.

In Scoliodon the brain lies enclosed within the chondrocranium and is made of the same three basic parts of the vertebrate brain-forebrain, midbrain and hindbrain.

1. Forebrain: The forebrain consists of a massive undivided **cerebral hemisphere**.

Cerebral hemisphere: The cerebral hemisphere is relatively larger than that of other fishes.

Olfactory lobe: From the anterior end of cerebral hemisphere arise two stout olfactory peduncles; each terminates into a large bilobed **olfactory lobe.**The olfactory lobes lie close to the olfactory capsules. Each olfactory nerve is composed of many bundles of nerve fibres. The surface of the cerebrum is smooth and the walls are thick. A small opening called the neuropore is present on the mid-ventral surface of the cerebrum.



Diencephalon: The posterior part of forebrain (diencephalon) is very short. The roof of the **diencephalon** is thin, non-nervous and contains the **anterior choroid plexus**. The lateral walls of the diencephalon form two thickened bodies called **thalami**. A long and slender tube, the pineal organ or epiphysis cerebri projects from the roof of the diencephalon. The floor of the diencephalon (or hypothalamus) is well-formed. A hollow infundibulum is given off from the floor of the diencephalon.

The infundibulum is dilated to form two oval thick-walled bodies called lobi inferiores whose distal ends are produced into two thin-walled glandular sacs called sacci vasculosi. The lobi inferiores are the centres for gustation and smell.

The hypophysis is attached to the infundibulum. The optic chiasma lies in front of the infundibulum. The optic chiasma is formed by the decussation of the nerve fibres of two optic nerves.

2. Midbrain: The midbrain is large and consists of two round **optic lobes**. The optic lobes are situated behind the diencephalon. The floor and the side walls are relatively thicker. The midbrain is considered as the centre of coordination.

3. Hind indbrain: The hindbrain consists of a highly developed **cerebellum** and a **medulla oblongata**.

Cerebellum: The dorsal surface of the cerebellum produces many irregular convolutions. The cerebellum contains a small cavity. The cerebellum is also a centre of co-ordination. The cerebellum is divided into three lobes by two well-marked transverse furrows.

Medulla oblongata: The medulla oblongata is triangular and the anterior end gives a pair of hollow **corpora restiformia** with trace of convolutions in adults. The medulla controls respiration. Two corpora restiformia are connected by the transverse nerve band. The roof of the medulla oblongata is non-nervous and bears the posterior choroid plexus. The hind- brain controls swimming movements.

Ventricles: The ventricles of the brain are moderately developed. The cerebral hemispheres contain narrow lateral ventricle. The third ventricle is extended forward about half the length of the cerebral hemispheres. The floor of the fourth ventricle is very much thickened. The fourth ventricle is large and extends dorsally into the cerebellum and is continuous behind with the cavity of the spinal cord. The **iter** (i.e., the communicating duct between the third and the fourth ventricles) is wider. Although the cerebrum is undivided, there are two lateral ventricles which are continued to the rhinocoels (cavity of the olfactory lobes).

2.4.1 Migration in Fishes

Migration is the orderly movement of animals from one place to another place in search of food, breeding habitat and better climate. Distances can range from a few meters to thousands of kilometers. Fish typically live in a constant habitat and restrict their movements within a specific territory. However, several fish species migrate between freshwater and saltwater.

Causes of fish migration

- In search of food (Alimental migration)
- For reproduction or spawning (Gametic migration)
- For protection (Protective migration)
- For better climate (Climate migration)
- For Osmoregulation (Osmoregulatory migration)

Factors affecting fish migration

Physical factor: Light, Temperature, turbidity, depth of water etc.
Chemical factor: Salinity, pH value etc
Biological factor: Predators, Competitors, shortage of food, hormonal secretion etc.

Types of fish migrations

Based on direction Myers recognized three patterns of fish migration. They are as followed

1. Potamodromous fishes: Migration from one place to another only with in fresh water. Ex. Carps, Catfish

2. Oceanodromous fishes: Long journey from one place to another with in sea. Ex. Herrings, Cod, Tuna.

3. Diadromous fishes: Fish migration between fresh water and seawater. It is further classified into the following three types.

i. Anadromous

Journey of marine fishes from sea to fresh water for spawning is called anadromous migration. Ex. Salmon, Trout, shad and Lamprey etc.

Salmon travels thousands of kilometers in the sea and then several hundred kilometers into the fresh water rivers to reach the spawning grounds. They migrate in pairs. In the course of the journey, female salmon develop black spots and male salmon develop red spots. The reproductive organs ripen and the alimentary canal shrinks. Females lay the eggs in saucer shaped nests. Then the male releases the sperms and the eggs are fertilized. After egg laying the spent fishes returns to their home. It takes about a year to complete this upstream and downstream journey. Salmon attain sexual maturity in about seven years. After attaining full sexual maturity, they return to fresh water rivers for breeding purpose.

ii. Catadromous

Fish migration from fresh water to ocean for spawning is called catadromous migration. Ex. Fresh water eel (Anguilla sps).

European eels are yellow when they are feeding and growing. A change in color to silver indicates the breeding phase. A male eel aged 8-10 years and a female eel aged 10-18 years prepare for migration. Their feeding stops, digestive tract shrinks and become function less. Gonads enlarged, the eyes become large, lips thinner and the pectoral fins becomes more pointed. They travel 3-4 thousands kilometers. It is believed that the eel spawn at the depth of about 400-500 meters below surface at 16-17^{0}C. The parents die after spawning. Eggs hatched into a larva known as Leptocephalus. It takes three years in reaching home.

iii. Amphidromous

Migration of fishes from sea to rivers and vice versa, but not for breeding purpose is called amphidromous migration. This is mainly for food and change of environment. Ex. Gobies fishes.

Fish migrations based on food, spawning, climate and water current

Spawning migration: Migration from feeding to breeding place. Ex. Hilsa

Feeding migration: Migration from breeding to feeding place. Ex. Eel

Climatic migration: Migration occurs in response to harsh climatic conditions. Ex. arctic and subarctic fishes migrate in ordered to avoid ground ice, surface ice and cold water.

Contranatant migration: Movement of migratory fishes against the water current.

Detanatant migration: Movement of migrating fishes in the direction of water. Ex. Adult salmon from sea to river.

Some other movements also fund in fishes like

Latitudinal Migration: Migration from north to south and vice versa. Ex. Sword fish

Vertical migration: Up and down migration in the water body to search food and protection. Ex. Mackerel.

Overwintering migration: Overwintering is the inactive stage of lifecycle of fishes in which they stop feeding less consumption of oxygen, low activities etc. to search the proper place for that period they migrate, Ex. flatfishes

Shoreward migration: Temporary movement of fishes on land. Ex. Common eel can travel in moist land found in between two ponds.

Advantages of fish migration

Migration has multiple advantages such as

- Fish get more food, better climatic condition and breeding place
- Fish gets better adapting in new places.
- There will be wide distribution
- Less competition.

Disadvantages of fish migration

It includes

1. Long journey is wasteful and many migrating fishes get lost while migrating.

2. Numerous migrating fishes are eaten by predators.

3. Dams construction check migration and the concerned fish species become extinct.

3.2.1. *Rana hexadactyla*: External features

Frogs are amphibians, they can live both on land and in water. A frog is a poikilotherm, which means that it is a cold-blooded animal. The frog is a chordate and the body is divisible into head and trunk. Neck and tail are absent in a frog. The skin of the frog has mucus, which makes the skin moist, smooth and slippery. The skin of the frog has the ability to absorb water.

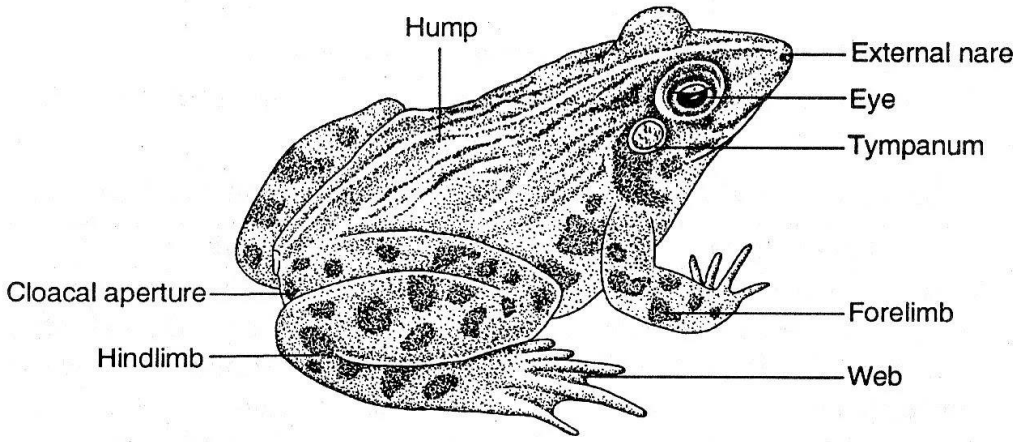
Head: Head is triangular and somewhat flattened. Mouth lacks lips and cheeks. It helps in ingestion of the pray. A pair of **nostrils** one on each side of the snout opens into buccopharyngeal cavity. A pair of prominent **bulging eyes** found on dorsolateral sides of the head. Eyes are guarded by **immovable upper eye lid** and **lower rudimentary movable eye lid**. Third eye a **nictitating membrane** is present. It is semitransparent and freely movable. **Brow spot** is located just in front of two eyes represents third eye of their ancestors. External ears are absent.

Vocal cards: Ventral surface of the head in males contain two bluish patches of vocal sacs which acts as a resonators during the production of croacking sound.

Trunk: It is short, broad and somewhat flattened with dorsolateral dermal plicae and characteristic dorsal hump. At the posterior end of the trunk, a cloacal aperture is present.

Limbs: Attached to the lateral sides of the trunk, there are a pair of forelimbs and hind limbs are present. Both are useful for walking, leaping, and digging. Fore limbs consists of Upper arm, forearm and wrist. Hind limbs are longer, larger, stronger and muscular than forelimbs. Each hind limb consists of thigh, shank and ankle.

Sexual dimorphism: Frogs exhibit sexual dimorphism because they are unisexual. Vocal sacs and the copulatory pad on the forelimbs are characteristics of male frogs that set them apart from female frogs. These physical traits are absent in female frogs.



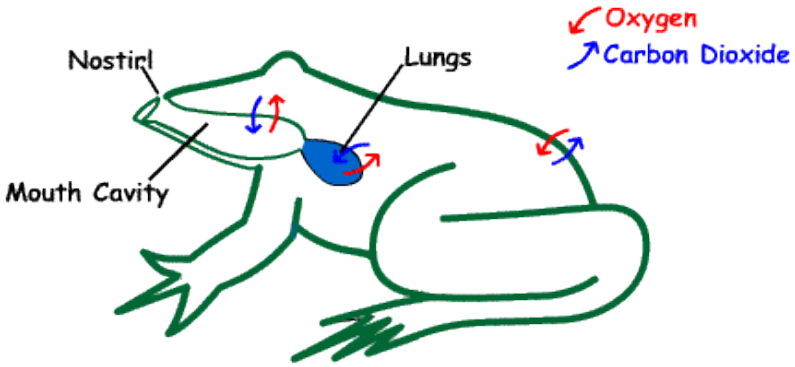
3.2.2. *Rana hexadactyla*: Respiratory system

Respiratory system is comprised of the organs that help in the intake and supply of oxygen to the tissues as well as to get rid of excess carbon dioxide. **Branchial respiration** occurs in case of tadpoles or larval stage. It takes place by means of external gills.

Respiration in adult frog occurs through 3 different ways: **Cutaneous respiration, Buccal respiration and Pulmonary respiration.**

i. Cutaneous respiration:

Frog skin is well adapted to respiratory function because it is thin, densely supplied with blood capillaries, and constantly wet with water and mucus released by mucous glands. Cutaneous respiration takes place all the time, whether frog is in or out of water or in hibernation.



ii. Buccal respiration:

In buccal respiration on land, the mouth stays permanently closed while the nostrils remain open. The floor of the buccal cavity is alternately raised and lowered. It allows the air to be drawn into and expelled out of the buccal cavity repeatedly through the open nostrils. The glottis remains closed during buccal respiration. It is done so that no air enters or leaves the lungs into buccal cavity. The mucus epithelial lining of buccal cavity is rich in blood capillaries which absorbs O_2 in the air and gives out CO_2.

iii. Pulmonary respiration:

Pair of lungs serve as the organs of aerial respiration. The lungs are not just respiratory organs, but they are also hydrostatic organs, allowing the frog to float in water when expanded. The respiratory fact allows air to enter and exit the lungs.

Respiratory tract: The external nostrils, nasal chambers, internal nostrils, bucco-pharyngeal cavity, glottis, laryngo-tracheal chamber, and a pair of bronchi are all part of this shape. On the floor of the pharynx, the median slit-like glottis opens into the larynx (laryngo-tracheal chamber). The larynx is a tiny sac with two arytenoid and one cricoid cartilage supporting its walls. The larynx is surrounded by a thin ring of cartilage called cricoid cartilage.

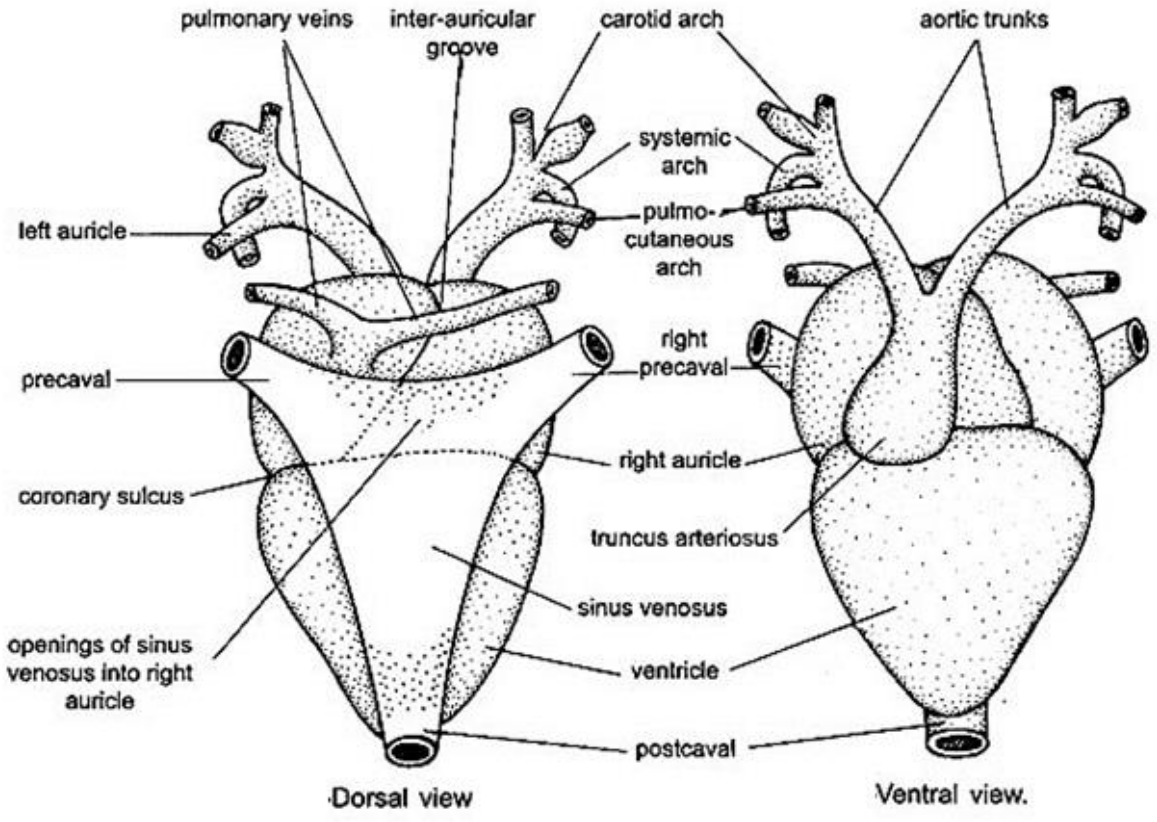
The arytenoid cartilages are semilunar valves that sit on top of the cricoid cartilage. The glottis' lateral boundaries are formed by their top edges. They let the glottis be opened or closed by attaching to muscles. The vocal cords, a pair of elastic bands stretching longitudinally across the larynx, are the primary sound-producing organs.

Lungs: In the anterior section of the body cavity, there are two lungs, one on each side of the heart. They're ovoid, thin-walled, elastic sacs with shallow internal folds or septa that expand the interior surface to generate multiple alveoli chambers. These are separated by septa from one another.

Pulmonary Respiration Mechanism: In case of frogs, the lungs are poorly developed. Thus, the insufficient supply of O_2 obtained through lungs is supplemented by the moist skin and buccal cavity. The movement of the floor of the buccal cavity, which functions as a force pump, is responsible for the entering and exiting of air from the lungs. Two sets of muscles, the sternohyal and petrohyal muscles are responsible for the actions of the buccal cavity floor.

3.2.3 *Rana hexadactyla*: Structure and function of Heart

The heart in the frog is situated ventrally to the liver and is a dark red coloured muscular organ which helps in the pumping of blood. The two layers of blood are pericardium and epicardium the outer layer is known as pericardium while the inner layer is known as epicardium between these two layers pericardial fluid is present which helps in reducing the friction during the functioning of the heart.



A. External Structure of Heart

Externally heart looks like a triangular structure. It is reddish color. It is 3 chambered besides sinus venosus and truncus arteriosus. Its anterior end is broad and posterior end is somewhat pointed. The anterior broader part is called auricles whereas the posterior part is called ventricles.

i. Auricles are two chambered: left and right auricles. These auricles are demarcated externally by very faint longitudinal inter-auricular groove. So it externally appears one.

ii. Ventricle is single chambered. It is most important part of the heart. It is conical in shape with thick muscular walls. It is clearly separated from auricles by coronary sulcus.

iii. Sinus venosus: On the dorsal surface of heart, **two precaval** and a **postcaval** fused to form wide chamber called sinus venosus. It is thin walled dark colored triangular structure which opens into the right auricle. It receives impure blood from all parts of the body and pours it into right auricle.

iv. Truncus arteriosus: It is a tubular structure arise from the right side of the ventricle is called truncus arteriosus. It extends forward over the right auricle and finally divides into two branches to form aortic trunks. Aortic trunk consists of- carotid arch, systemic arch and pulmonary arch.

B. Internal Structure of Heart

The wall of heart consists of three layers- outer epicardium, middle mesocardium and inner endocardium. Internally heart is 3-chambered with two auricles and one ventricles.

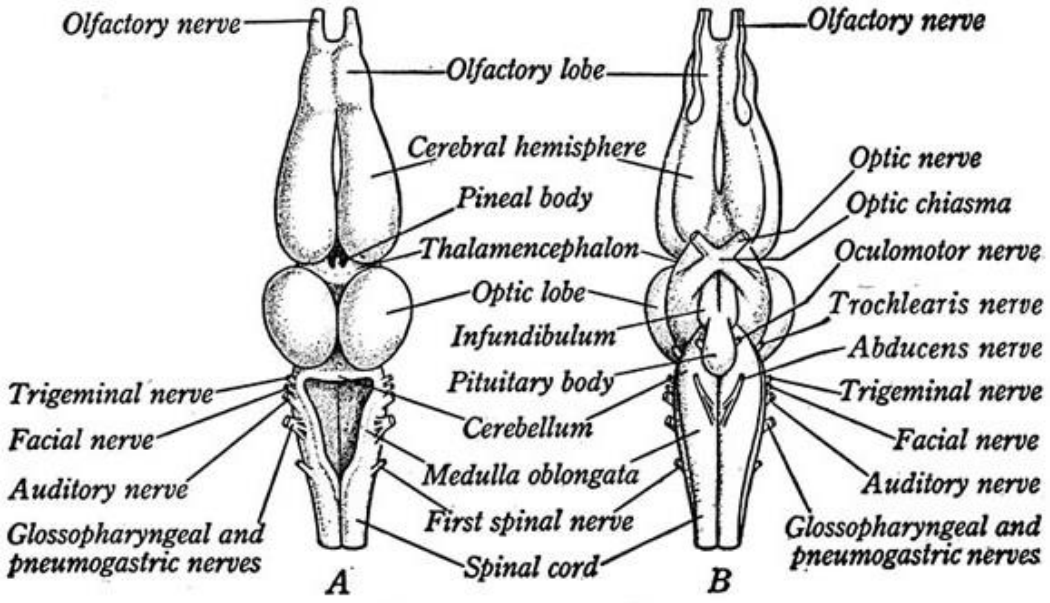
i. Auricles: The two auricles are separated from each other by **interauricular septum**. Right auricle is larger than left. In the right auricle, close to the septum there is a transverse oval opening called **sinuauricular aperture**. The blood enters into right auricles through this aperture. This aperture is guarded by two lip like flaps called **sinu-auricular valves**. These valves allow the flow of blood towards right auricles but prevent backward flow of blood. In left auricle close to the septum there is a small opening of **pulmonary vein** which has no valves. The left auricles receives blood from lungs through pulmonary veins.

ii. Ventricles: The ventricle has a thick muscular and spongy wall having numerous longitudinal clefts, separated from each other by muscular projections called **columnae carnae**. The two auricles open into a single ventricle chamber by **auriculo-ventricular aperture** which is guarded by two pairs of **auriculoventricular valves**. The valves are provided with **chordae tendinae**. The chordae tendinae pull the flaps backward to close the opening and thus prevent the valves from the backward flow of blood into the auricles.

From the right anterior side of the ventricle, **truncus arteriosus** arises. The ventricle opens into truncus arteriosus and the opening between these two is guarded by **semilunar valves**. When ventricles contract semilunar valves are pushed apart and make a free passage for the blood from the ventricles to truncus arteriosus but prevent back flow of blood from truncus arteriosus into the ventricles.

3.3.1 *Rana hexadactyla* structure and functions of the Brain

Brain is covered by two meninges: outer tough, fibrous duramater and inner vascular, pigmented piamater closely attached to the brain. Sub-dural space between duramater and piamatar is filled with cerebrospinal fluid which acts as shock absorber.



A. Dorsal View B. Ventral View

i. Forebrain (prosencephalon): It consist of olfactory lobes, cerebrum (cerebral hemispheres) and diencephalon. Midbrain or mesencephalon consist of optic lobes and optic chiasma. Hindbrain or rhombencephalon is composed of cerebellum and medulla oblongata.

Olfactory lobes are a pair of large, fused, bulbous lobes in front of **cerebral hemispheres**. Cerebrum consists of two cerebral hemispheres separated by a median longitudinal fissure. Each cerebral hemisphere encloses a cavity called as lateral ventricle. Both the lateral ventricles open in 3rd ventricle or diacoel through foramen of Monro.

Diencephalon lies just next to cerebral hemispheres and encloses the 3rd ventricle or diacoel. From its ventral side arises infundibulum with **pituitary body**. Pineal body and stalk is present on dorsal side. **Pineal body** lies outside the skull on the skin as brown spot in adult.

ii. Mid brain (mesencephalon): It consist of optic lobes and optic chiasma.

Optic lobes are paired, large, hollow enclosing optocoel which open into fourth ventricle through **iter** or **aqueduct of Sylvius**. X-shaped **optic chiasma** lies on the ventral surface.

iii. Hind brain (rhombencephalon): It is composed of cerebellum and medulla oblongata.

Cerebellum behind the optic lobes is not well developed in frog. Medulla oblongata is the posterior most part of the brain and encloses 4th ventricle or metacoel. Its roof has vascular posterior choroid plexus.

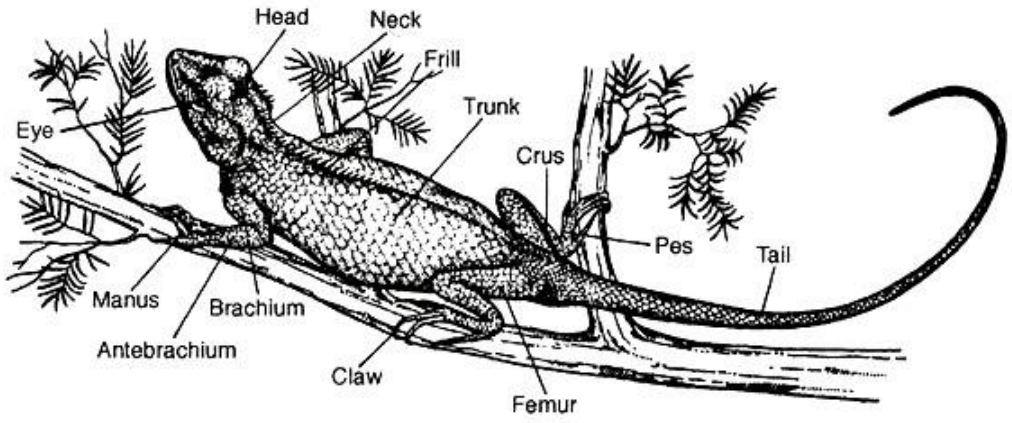
Brain Functions: Olfactory lobes are centres of smell, intelligence, memory. Voluntary actions are controlled by cerebrum. Diencephalon regulates genital function and sleep. Optic lobes are with the sense of sight. Equilibrium is maintained by cerebellum. Medulla controls involuntary action like heartbeat, respiration, digestion, excretion etc.

3.4.1 *Calotes*: External features

The body of Calotes is divisible into three regions: head, trunk and tail. A small narrow neck joins the head with the trunk.

Colour: Male is brightly coloured, golden yellow with a greenish tinge. Throat is scarlet red, often with a black transverse bar. Female is not so brightly coloured.

Skin: The body is entirely covered by epidermal horny, imbricate and backwardly directed scales of unequal size which are periodically shed in flakes. On the head, a prominent shield covers the parietal foramen and two spines are present above each ear opening. Over the head and trunk, along the mid-dorsal line, is a characteristic crest of large spine-like movable scales directed backward and gradually diminishing in size posteriorly. Male is larger and stronger than female, measuring about 35 cm in length including tail



Head: The head is more or less triangular in appearance. The snout is short, pointed and bears a pair of apertures called external nares. The eyes are provided with movable nictitating membrane. Mouth is a transverse aperture and is terminal in position. Lips are absent. The tympanum is situated behind the eyes.

Trunk: Trunk is elongated, sub- cylindrical and bears two pairs of appendages, the forelimbs and hind-limbs.

Limbs: Each forelimb is divisible into brachium, anti- brachium and manus. Likewise, the hind- limb is divisible into femur, crus and pes. The limbs end in digits and the digits are provided with sharply pointed claws.

Cloaca: The cloacal aperture or vent is a transverse opening and is situated in the postero ventral part of the trunk and at the base of the tail. A large cloacal plate is situated in front of the cloacal aperture.

Tail: The tail is long, slender and tapering. It measures twice as long as the head and body. Males measure 120-140 mm from snout to vent with a tail of 300-500 mm. The body length of females is less by 15-20 mm.

3.4.2 *Calotes*: Digestive system

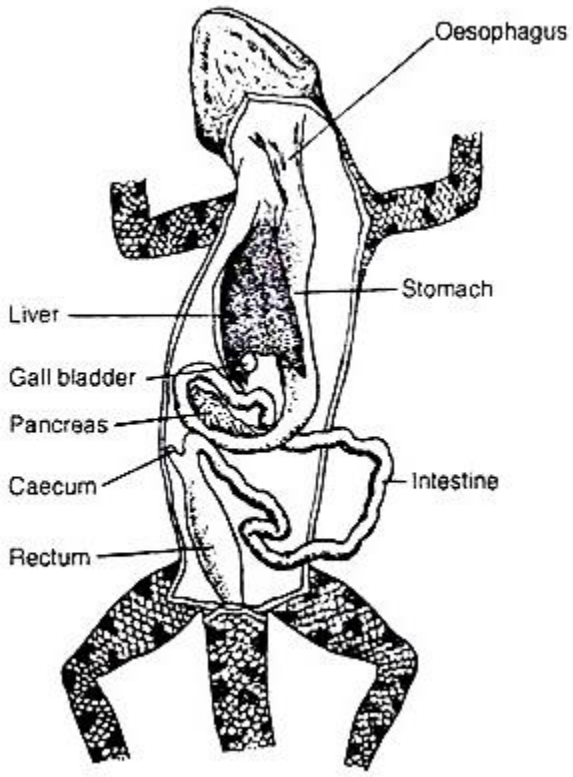
The **alimentary canal** starts from the mouth.

Mouth: Mouth is a transverse terminal aperture provided with **jaws**. The jaws are provided with **teeth**. The teeth are sharp, small, pointed and recurved backwards. They are actually simple cones (haplodont) having an enamel cap and an interior ortho-dentine. The teeth are pleurodont and homodont type.

Buccal Cavity: The mouth leads into the buccal cavity which is large and compressed dorsoventrally. At the posterior part of the roof of buccal cavity, there are two openings for the **internal nares**. The floor of the cavity houses a median and muscular **tongue**. The tongue is protrusible and the apex of the tongue is slightly bifurcated.

The buccal cavity passes to the stomach through **pharynx** and **oesophagus**.

Stomach: The stomach is elongated, sac-like and placed more or less vertically. The stomach is divisible into a cardiac and a pyloric portion. The pyloric part of the stomach is followed by small intestine which is narrow tubular and coiled.



Small Intestine: The small intestine may again be divided into a U-shaped duodenum and a long much-coiled ileum.

Large Intestine / Cloaca: The small intestine is followed by a large intestine (or rectum) which is small, sac-like and opens into the cloaca. At the junction of ileum and rectum a small projection called coelic caecum is present.

Anus: Cloaca opens to the exterior by the anus (or vent).

ii. Digestive glands: Small unicellular salivary and mucous glands are present in the buccal cavity. The most important of the digestive glands is the liver, which is massive and situated dorsal to the stomach. The liver is divided into left and right lobes. Both the lobes are united anteriorly. The liver secretes bile. The bile remains stored in the gall-bladder.

The inner wall of the stomach is beset with a large number of unicellular parietal glands and gastric glands which secrete hydrochloric acid and digestive enzymes, respectively.

Pancreas is a flat, whitish and elongated structure. It opens into the beginning of the duodenum. The secretion of pancreas is called pancreatic juice.

Mechanism of food-getting and digestion: The food of Calotes consists mainly of small living insects. Ingestion is done with the help of the tip of the tongue and the insect is taken inside alive. The sticky mucous secretion helps to catch the prey.

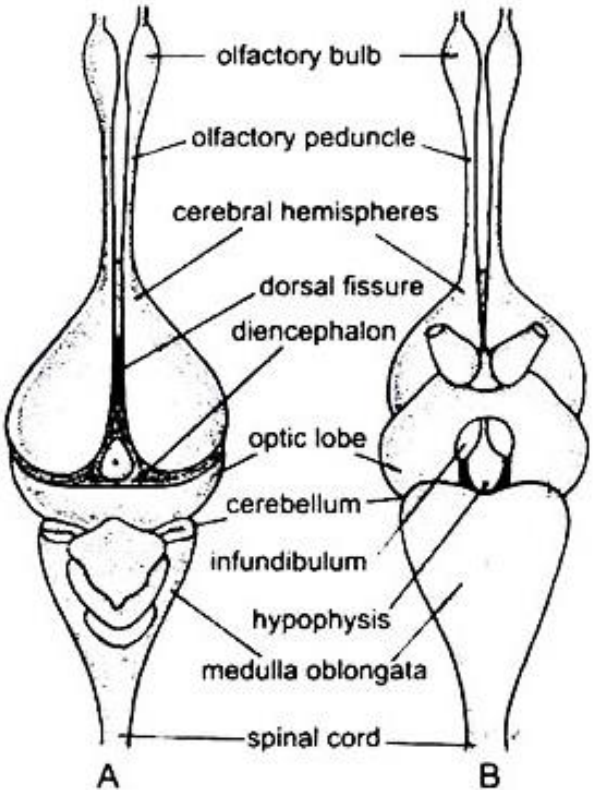
In the stomach HCl and pepsin react on the food matter. HCl makes the medium acidic. Pepsin reacts with the protein part of the food and breaks it into peptone and proteoses.

In the duodenum, bile neutralizes the acidic half-digested chyme and emulsifies the fat part of the food. Pancreatic enzymes, trypsin (present in pancreatic juice) react with protein and proteoses and convert them into soluble amino acids. Amylase reacts with carbohydrate and transforms into glucose. Lipase reacts on fat converting it to fatty acid and glycerol.

The mixture of food containing simpler and soluble products and undigested food materials passes into the intestine. The lining of the intestine absorbs the soluble products while the undigested food particles are stored in the rectum from where these are voided to the exterior periodically.

3.4.3 *Calotes*: Structure and function of Brain

The brain is lodged in the cranium. The brain as well as the spinal cord is enveloped by two meninges, the piamater and duramater. The piamater is vascular and closely applied with the brain, while duramater is fibrous and lies outside the piamater. In between these two membranes is a space, subdural space.



Brain of an adult Calotes is differentiated into: a. Forebrain, b. Midbrain, and c. Hind-brain

i. Forebrain: It consists of telencephalon anteriorly and diencephalon posteriorly.

Telencephalon: From the side wall of telencephalon emerges a pair of sac-like projections called **olfactory lobes**. The posterior part of the telencephalon is elongated and is called **cerebral hemisphere** or cerebrum. The roof of the cerebral hemispheres is thin but the ventrolateral walls are thick. The thick region is called **corpus striatum**. The roof of the cerebral hemispheres is called **neopallium**, because the grey matters are situated on the outer margin.

Diencephalon: The diencephalon bears on the dorsal surface two projections called **parietal organ** and **pineal body**. The parietal organ is situated anterior to the

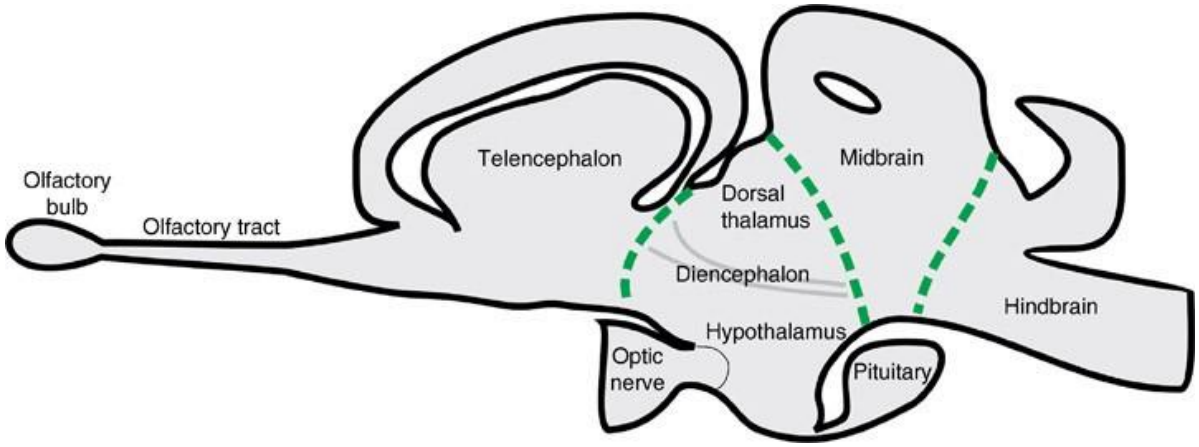
pineal body. Another projection called **paraphysis** is present in a reduced condition. From the ventral side of the diencephalon hangs a funnel-like structure called **infundibulum** on the apex of which is situated the **pituitary body** or **hypophysis**. The roof of diencephalon is thin, highly vascular and is called **roof-plates**. The lateral walls are called **thalami** and the floor is called **hypothalamus**. Parietal and pineal bodies arise from the roof-plate. The thalamus is thick. From the hypothalamus the infundibulum arises.

ii. Mid Brain: It consists of a pair of oval optic lobes or **corpora bigemina** which arise as projections of the dorsolateral walls. Ventral to the optic lobes, there are a pair of longitudinal bands or peduncles called **crura cerebri**, which connect the hindbrain to the midbrain. The roof of the **mesencephalon** becomes thick to give rise to the **optic lobes**. Its floor is also thick and gives rise to the **crura cerebri**.

iii. Hind Brain: The hindbrain consists of narrow and non-convoluted **metencephalon** or **cerebellum** and a long **myelencephalon** or **medulla oblongata**, which continues posteriorly with the spinal cord. The roof of the metencephalon is thin and non-nervous but the floor is thick. The myelencephalon is similar to metencephalon in regard to its floor and roof.

iv. Ventricles: Internally, the brain bears cavities which are continuous to one another and to the spinal cord. The cavity is filled with **cerebrospinal fluid**. The cavities in the cerebral hemispheres are called **lateral ventricles** or **first and second ventricles**. The diencephalon contains the **third ventricle** while the **fourth ventricle** is situated in the medulla oblongata.

The two lateral ventricles are communicated to the third ventricle or diacoel by a small opening called **foramen of Monro**. The third and fourth ventricles or mesocoels are communicated with each other by a narrow passage called **iter** or **aqueduct of Sylvius**.



3.5. Identification of Poisonous snakes

In snakes' scales, plates and shields, their arrangement and size shows high degree of variation and they help in the identification of poisonous snakes. The common characteristic features of poisonous snakes are:

1. Poisonous snakes are generally brightly coloured.

2. **Shape of head**: Head long, triangular and the posterior portion is wide.

3. **Neck**: Neck of poisonous snake is always constricted.

4. **Hood**: Present in majority cases; highly developed in Cobra group (Naja sps). Absent in Coral snakes, Krait, Russell's viper etc.

5. **Tail**: Tail tapers abruptly. In sea snakes (Hydrophidae) the tail is flattened to form an oar-shaped structure and in land snakes the tail is cylindrical.

6. **Head scales**: Scales on top of the head are usually small. Ex: Viper

7. **Dorsal scales**: Dorsal surface scales are smaller but the spinal (vertebral) scales are larger and hexagonal in kraits.

8. **Ventral scales**: Broad Ventral scales are usually completely across the belly, but in sea snakes ventral scales are present not across the body.

9. **Loreal shield**: Present and shapes may be variable in poisonous snakes.

10. **Supra / Infra labials**: Third supra labial shield is large. Ex. Naja or coral Snake. Fourth infra labial is large. Ex: Krait

11. **Caudal scales**: Mostly undivided except in coral and cobra snakes.

12. **Teeth**: Most of the teeth are solid and uniform except maxillary teeth which are large, and provided with groove or canal. These large teeth are called 'Fangs'.

13. **Poison gland**: Present. Paired poison glands are **on upper jaw.**

14. **Poisonous snakes have less**-developed muscular system.

15. **Lungs**: One of the lungs has either been reduced or absent

16. **Hypophysis**: Hypophysis developed throughout the vertebral column

17. **Streptostylism**: Well-marked

Ex: Saw Scaled Viper (Echis carinatus), Common Krait (Bungarus caeruleus), Banded Krait (B. fasciatus), Russell's Viper (Vipera russelli), King Cobra (Ophiopagus hannah), Indian Monocled Cobra (Naja naja kaouthia).

4.1. Aves Characteristics

Some general characteristics of Aves are the following-

- They are bipedal feathered animals. The fore-limbs of birds have developed into wings that help them to fly.
- Their back-limbs have become legs that help them for swimming, walking, etc. Mostly, birds have four toes on their legs. However, two or three toes are also rarely visible.
- Aves are homeothermic or warm-blooded creatures. Because of this, birds can keep a stable body temperature even when flying at high altitudes.
- Only the uropygial gland or oil gland is situated near the tail.
- Their jaws are transformed into beaks and they don't have any teeth. With the help of a beak, birds can feed in different ways like tearing flesh, crushing seeds, sipping nectar, etc.
- Additional chambers called gizzard and crop are found in their alimentary canal. The crop chamber helps to soften the stored food, whereas the gizzard crushes the food. Few seed-eating birds like pigeons lack gall bladder in their system.
- Lungs act as the primary respiratory organ in birds. Their lungs are inelastic and spongy. Lungs have air sacs to supplement respiration.
- In birds, an organ called syrinx helps to produce voice.
- Birds have a four-chambered heart and a reduced renal portal system. Also, their cardio-vascular system lacks sinus venosus.
- The kidneys in birds are metanephric that help to filter the nitrogenous fluid waste via the ureters, into the cloaca. Their renal system lacks a urinary bladder.
- Brain consists of the cerebrum, cerebellum, and large optic lobes. Furthermore, 12 pairs of cranial nerves are present.
- Birds have highly developed sight, but their smelling sense is poor. They have eyes and visible ear openings. Their ears are divided into three parts – internal, middle, and external.
- Their endoskeleton is bony, and the bones are hollow. For this reason, the bones in birds are lighter than most animals. The bones lack bone marrow. The skull consists of a single occipital condyle.
- Some other class Aves facts – they are spindle-shaped, and their shape helps to reduce the wind resistance while flying. Also, their feather passes the air to minimize air friction.
- The fight muscles of Aves are highly developed.
- The female birds have one ovary on the left side of the body and one oviduct. However, non-functional right ovaries and oviducts can be found in some cases.
- Sexual dimorphism can be found in Aves, and they are oviparous. Bird eggs consist of four embryonic membranes – yolk, allantois, amnion, chorion.

4.2.1. External features of Pigeon (Columba livia)

The compact, boat shaped streamlined body of pigeon is well adapted for their aerial mode of life. The body of pigeon is divisible into head, neck, trunk and tail.

Head is comparatively small, spherical and situated at the anterior most part of the body. **Beaks** present anteriorly are formed by the elongation of upper and lower jaw and they are devoid of teeth. At the base of the beak are the **external nostrils** overhung by a swollen, sensitive soft skin called **cere**. **Eyes** are prominent, round and laterally present. Eyes are protected by an upper eyelid, lower eyelid, and a transparent **nictitating membrane**. Posterior to the eyes are the **ear** openings which lead to the **tympanic membrane** by short tube, **external auditory meatus**.

Neck is flexible, cylindrical and long which connects the head with the **trunk.**

Trunk: The spindle shaped trunk bears a pair of **wings** and a pair of **legs**. The **cloacal aperture** opens ventrally at the hind end of the trunk. Dorsally the base of the tail has a knob like papilla, which bears the opening of the **preen gland** or **uropygial gland**. It is the only cutaneous gland present and its oily secretion is used for lubricating or preening the feathers. The tail is used as a rudder in flight.

Fore limbs are modified into wings. The wings have three typical regions, the upper arm (brachium), lower arm (antebrachium) and the hand (manus). Three clawless and imperfectly marked digits are present on each hand. While at rest, each forelimb is folded in the form of **'Z'**; during flight they are extended.

Hind limbs: With the modification of the forelimbs for flight, the whole weight of the body is supported by the **hind limbs**, while the bird is at rest or walking; the hind limbs are therefore attached anteriorly from the trunk to balance the body and support the weight of the body at rest. They are warm blooded or **homeothermic**.

Exoskeleton

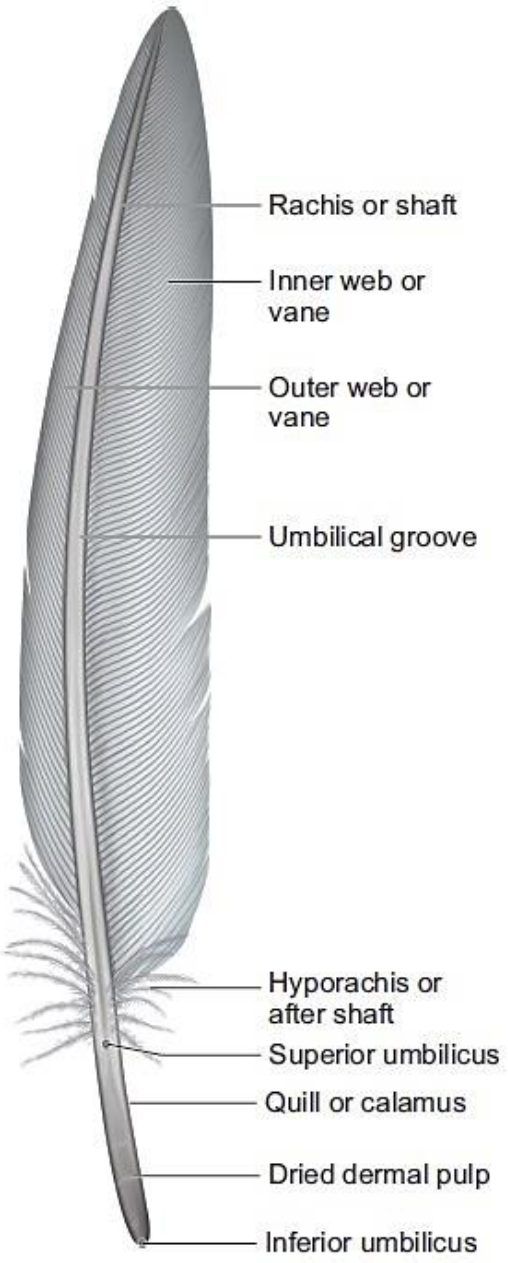
The exoskeleton of pigeon is derived from the **epidermis** and occurs in the form of **horny claws, scales** and **feathers**. Beaks are used for ingestion, fighting and preening of feathers. Claws are used for walking and perching. Epidermal scales are present on the foot and the entire body is covered by feathers. Arrangement of feathers on the body of bird is called **pterylosis**. Feathers are of three kinds: large **quill feathers** on wings and tail which are used for flight; **contour feathers**, form a covering for the body and **filoplumes,** lie between the contour feathers. The **nestlings** are covered with **down feathers** which resemble the filoplumes.

Structure of a Quill feather

The quill feather has a stem or **scapus** and is divided into a lower hollow part called **calamus or quill** and an upper solid portion called **rachis**.

Lower end of the stem has an opening called **inferior umbilicus** which receives a dermal papilla, supplying nutrients and pigments for the growing feathers.

A second opening the **superior umbilicus** occurs at the junction of the quill and the rachis, on the inner face of the feather; close to this opening is a small tuft of soft feathers called **after shaft**. Attached to the rachis are small filament or **barbs** ; the rachis with the barbs constitute the **vane or the vexillum**. Each barb is fringed with an oblique set of processes called **barbules**, which have minute **hooklets** or **barbicels** by which adjacent barbs are hooked together to form a continuous blade for striking the air during flight.



4.2.2. Digestive System of Columba livia

The long coiled alimentary canal consist of buccal cavity, pharynx, oesophagus, crop, stomach, small intestine and Large intestine.

Mouth: Mouth is covered by a toothless, horny, upper and lower **beaks**. Behind the mouth, there is a wide buccal cavity.

Buccal Cavity: In the floor of the **buccal cavity**, a large, narrow, horny **tongue** is present with scanty **sensory papillae** and numerous **mucus glands**.

Pharynx/ Oesophagus: Buccal cavity leads into the pharynx followed by the oesophagus, which enlarges to form a thin walled, bilobed elastic sac, the **crop**. The crop serves as a food reservoir.

Stomach: Beyond the crop the **oesophagus** enters the **stomach** which is differentiated into anterior glandular **proventriculus** and a posterior muscular **ventriculus** or **gizzard**. The proventriculus has a mucus lining which secretes the gastric juice.

Gizzard: The walls of the gizzard is thick, muscular and has many tubular glands. The cavity of the gizzard contains grit or small pebbles called **gastroliths** that are swallowed by the bird. These stones helps the bird in grinding the food.

Small Intestine: The gizzard leads to a **small intestine** which consists of a 'U' shaped **duodenum** and **ileum**. The **pancreas** lies between the two limbs of the duodenum and receives three ducts from the pancreas and two bile ducts from the **liver**. The inner lining of the ileum contains numerous **villi** which helps in absorption.

Large Intestine: The ileum continues into the large intestine, which is short and is differentiated into rectum and cloaca. A pair of small blind pouches called **rectal caeca** is present at the junction of the ileum and rectum.

Cloaca: The rectum leads into the **cloaca** which is divided into the anterior **coprodaeum** into which the rectum opens, the middle **urodaeum** into which the **urinigenital** ducts open, and the posterior **vestibule** or **proctodaeum**, which opens to the outside by the cloacal aperture.

Digestive glands: Buccal glands, salivary glands, gastric glands, liver, pancreas and intestinal glands are the **digestive glands** which enhance the process of digestion in pigeon. There is **no gall bladder** in the pigeon though present in many other birds. Pigeons produce 'milk', a cheesy and nourishing secretion, from both the sexes. It is formed by the degeneration of the epithelial cells lining the crop. It is regurgitated and fed to the young birds.

Mechanism of Digestion: The pigeon feeds on grains. As birds have no teeth, the food swallowed by it passes through the **gullet** or **oesophagus** into the **crop** where it is stored. There are mucous glands in the crop; food is softened by being mixed with the **mucus** and the secretion of the **buccal glands,** aided by the warmth of the body. The food then enters the **stomach,** where it is digested by **gastric juices** secreted in the **proventriculus**; the food is also **crushed** in the **gizzard** with aid

of gastroliths. The food is thus reduced to smaller particles and the partly digested food passes into the **intestine** where it is mixed with the **bile** and **pancreatic juice**, and further digestion is affected.

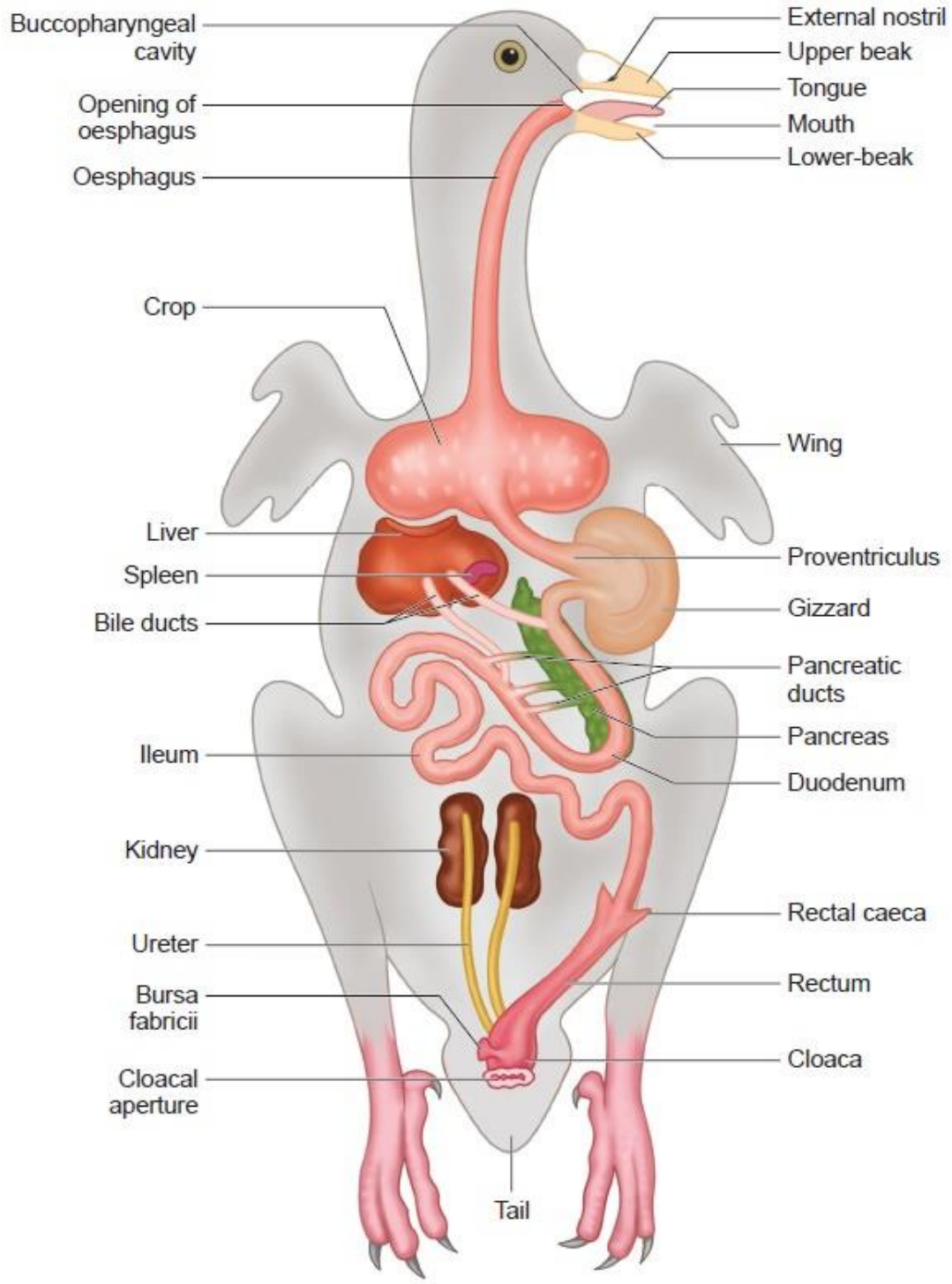


Figure 4.29 Pigeon – Digestive System

4.2.3. Respiratory system of Columba livia

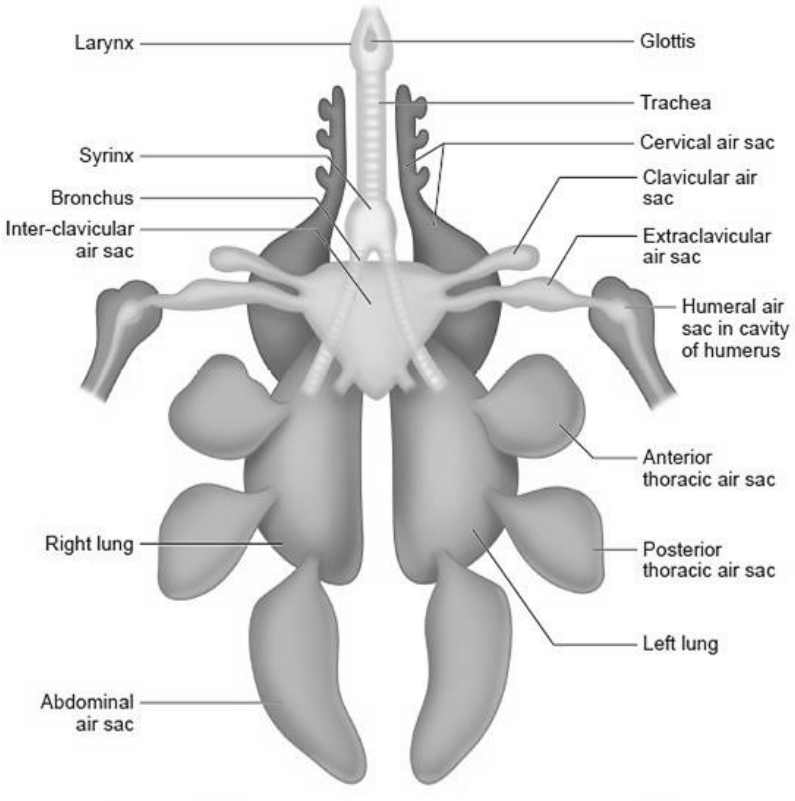
In birds the type of respiration is **pulmonary.** The respiratory system includes the respiratory tract, the respiratory organs and air sacs. A true muscular diaphragm is absent in birds.

The **respiratory tract** includes the nares, nasal sacs, glottis, larynx, trachea and syrinx. The **respiratory organs** are the lungs and air sacs.

The larynx opens into the trachea and is supported by a series of closely set rings.

The **voice box** lies deep down where the trachea divides into two bronchi, and is known as **syrinx**, a structure characteristic of birds.

The trachea divides into two **bronchi**, each of which divides and sub-divides into smaller branches, ultimately ending in fine air-capillaries which lies intermingled with the capillaries of the pulmonary vessels.



Lungs are solid spongy organs; attached dorsally to the ribs.

There are nine air-sacs: a pair of cervical sacs at the base of the neck one on each side; a single median interclavicular air sac connected with both lungs and situated in between the two limbs of the furcula and on either sides it gives off an extraclavicular air sac communicating with an air - cavity of the humerus and a clavicular air sac; two pairs of thoracic air sacs and a pair of abdominal air sacs. This complicated arrangement adds to the efficient respiratory function and maintenance of a high temperature.

Respiratory mechanism

The lungs are not dilatable since the skeleton around them forms a rigid framework. Inspiration is passive and expiration is an active process. During respiration the sternum is drawn towards the vertebral column, by contraction of the muscles of the body-wall. As is drawn up, the elastic ribs are bent so as to bring about a decrease in the size of the body cavity and the air from the lungs is forced out. When the muscles relax, the body-cavity recovers its size and air is drawn in.

4.3.1. Structure and function of Heart of Columba livia

Pigeon has an efficient circulatory system to meet the metabolic demands of flight, but also plays a significant role in maintaining the body temperature.

The circulatory system of pigeon includes the heart and blood vessels. The **heart** of the pigeon is **four chambered** with two auricles and two ventricles. There is no sinus venosus.

The two **precaval veins** or **superior venae cavae**, a **post caval vein** or **inferior vena cava** opens into the right auricle; the pulmonary aorta and systemic trunks arise from the right and left ventricles respectively.

The right side of the heart is completely separated from the left side of the heart by a septum.

The right auricle opens into the right ventricle by the **right auriculo ventricular** aperture and the left auricle into the left ventricle by the **left auriculo ventricular** aperture. There are **valves** at these apertures, which allows the blood to flow only in one direction, i.e., from the auricle into the ventricle but not backwards. The right auriculo-ventricular valve consists of a single flap without connecting **chordae tendinae**; the valve on the left side has two flaps connected to the **papillary muscles** by chordae tendinae.

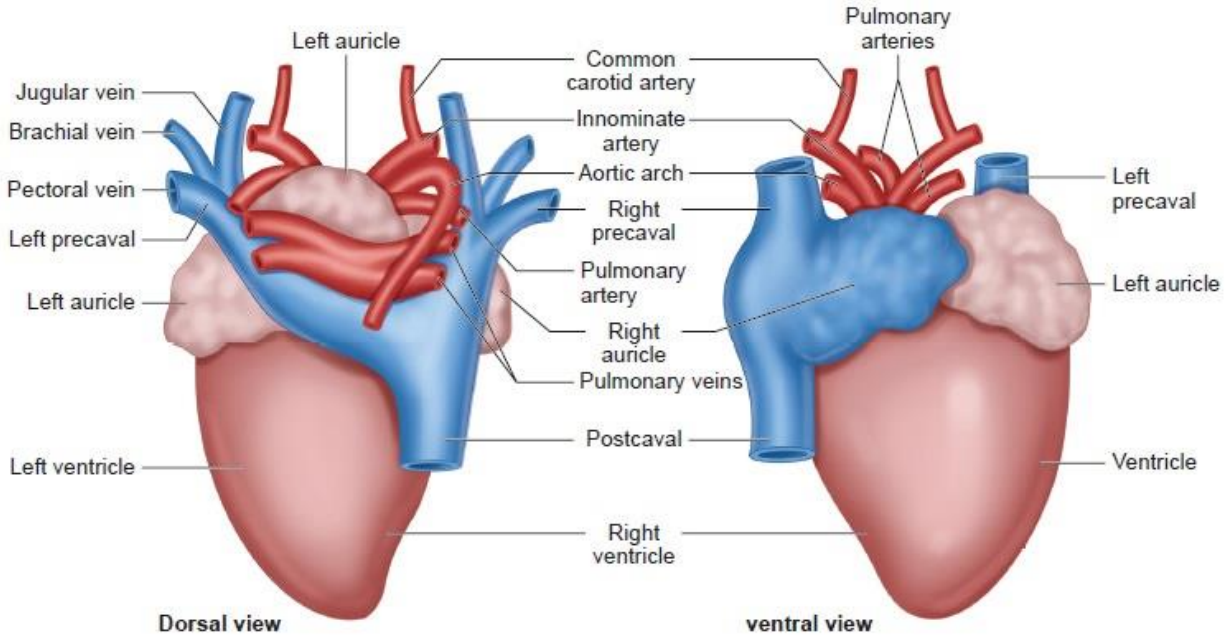
The pulmonary aorta arises from the right ventricle and the aortic arch from the left ventricle. The pulmonary veins open into the left auricle. There are three **semilunar valves** at the junction of the pulmonary aorta and the right ventricle.

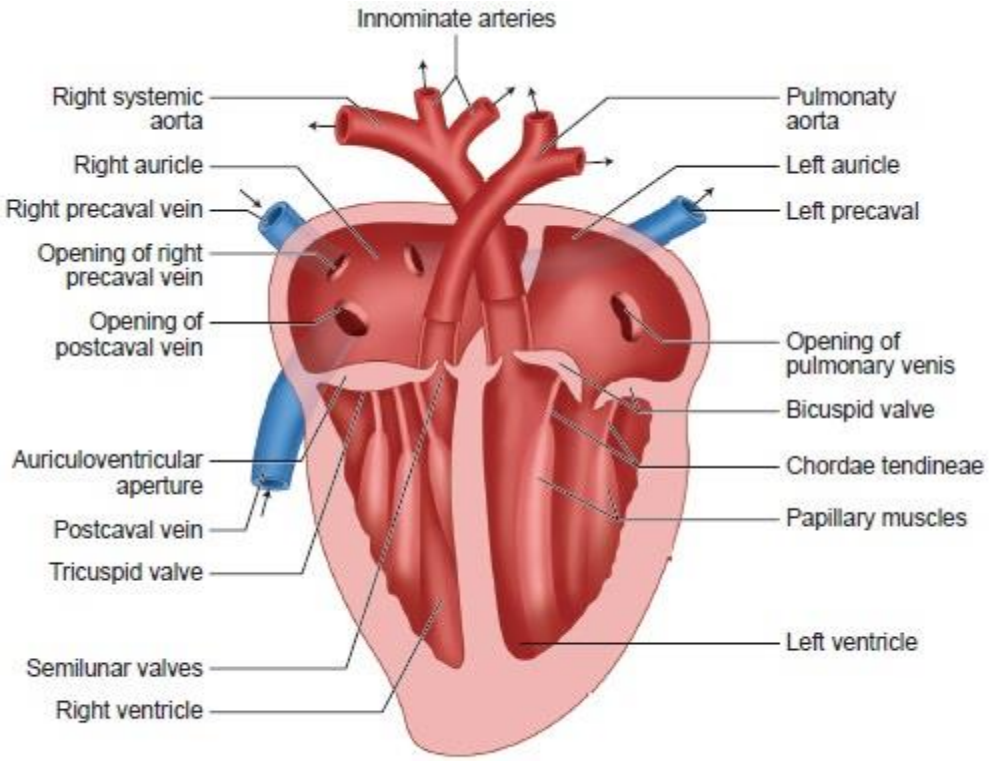
The pulmonary aorta divides into two branches, each entering a lung. Only the right aortic arch is present in birds.

The right auricles of the heart receives venous blood from all parts of the body except the lungs, through the **precaval** and **post caval** veins.

The right ventricles pumps venous blood into the lungs through the **pulmonary aorta.** The oxygenated blood from the lungs is returned to the left auricle through the **pulmonary veins**. From the left ventricle a single right aortic arch carries oxygenated blood to the different parts of the body.

The right half of the heart receives and discharges only **venous blood** and the left half only **arterial blood**. Thus birds possess a **complete double circulation** which includes the **pulmonary circulation** and **systemic circulation**.


Left auricle
Common carotid artery
Pulmonary arteries
Jugular vein
Brachial vein
Innominate artery
Pectoral vein
Aortic arch
Left precaval
Right precaval
Left precaval
Pulmonary artery
Left auricle
Left auricle
Right auricle
Pulmonary veins
Postcaval
Left ventricle
Ventricle
Right ventricle
Dorsal view
ventral view


Innominate arteries
Right systemic aorta
Pulmonaty aorta
Right auricle
Left auricle
Right precaval vein
Left precaval
Opening of right precaval vein
Opening of postcaval vein
Opening of pulmonary venis
Bicuspid valve
Auriculoventricular aperture
Chordae tendineae
Postcaval vein
Papillary muscles
Tricuspid valve
Left ventricle
Semilunar valves
Right ventricle

4.3.2. Structure and function of Brain of Columba livia

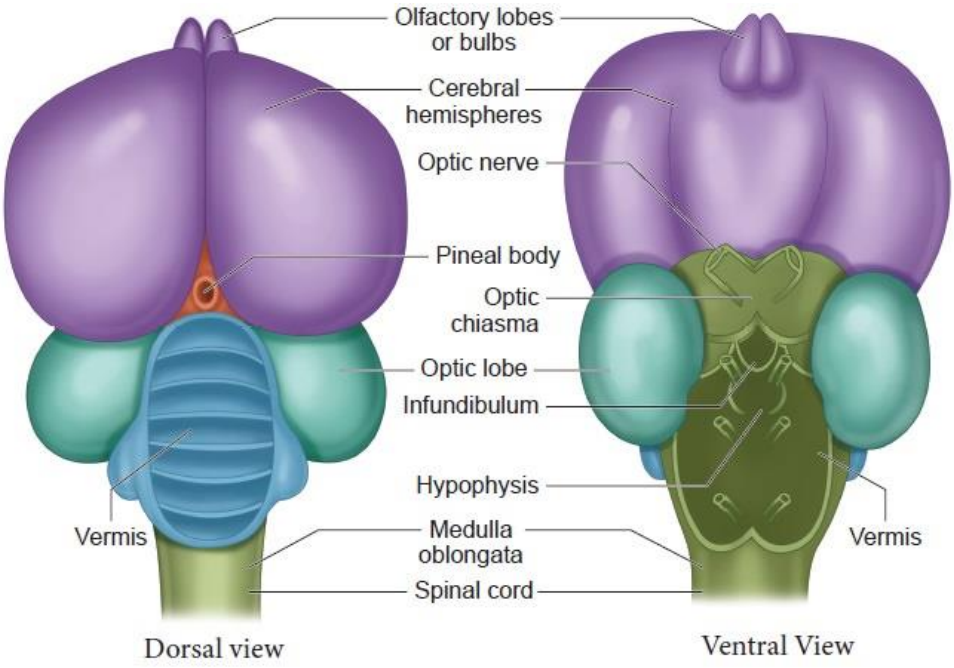
The **brain** of pigeon is larger than in lower forms, it is short, broad and rounded within cranial cavity. Brain is covered by **two meninges**, the **outer duramater** and an **inner pia-arachnoid membrane** and the space between the two meninges is filled with **cerebrospinal fluid**.

The **cerebral hemispheres** of the pigeon are large and extend behind to meet the cerebellum. The cerebrum controls voluntary movements and is the center for memory and intelligence.

The **diencephalon** is covered dorsally by the **cerebral hemispheres and cerebellum**. The diencephalon relays impulses to the cerebral hemispheres, integrates the autonomic system and the perception of extreme cold, pain, heat etc.

On the ventral side of the diencephalon is the **optic chiasma**, behind the chiasma projects the infundibulum bearing a **large hypophysis** or pituitary.

The **optic lobes** are large and occupy a lateral position owing to the large size of the cerebral hemispheres and cerebellum. Optic lobes are centres for sight. The **pineal body** and **infundibulum** are present.



The **cerebellum** is highly developed and convoluted indicating the delicate sense of equilibrium and the great power of muscular co-ordination required for birds.

The cerebellum extends backwards covering a large part of the **medulla oblongata** which descends downwards to join the spinal cord. The medulla oblongata controls the involuntary movement. The olfactory lobes or bulbs are small and degenerate due to poorly developed organs of smell.

4.3 Migration in Birds

Migration in birds is a phenomenon in which birds travel from one place to another in search of favourable conditions and more resources for their survival. Bird migration is a two-way journey from breeding or resting place to feeding or nesting place and vice versa. It is a periodic, regular, to and fro movement.

Some species of birds do not migrate and remain in a place throughout the year are called **residents.** Ex. Bobwhite, Rufflet, Sand goose etc. The birds from northern hemisphere are more migratory than the southern hemisphere. Ex. Siberian crane, Golden plover, Cuckoos etc.

Bird migration may be **diurnal, nocturnal** or both. Ex. Hawk, Robin of diurnal, Sparrow, Webler of nocturnal and duck, gull of both. Distance travelled by migratory birds depends on the local condition and species of birds. Ex. Golden lover is the non-stop fighter; Arctic terns are king of migrants.

i. Causes of bird migration

- Due to seasonal changes, scarcity of food, the shortening of daylight, increase in cold etc.
- According to Bissonnette, decrease in pituitary activity in winter cause bird to migrate southward. In summer, the pituitary activity becomes active and gonads develop, so, the birds return northward for breeding.
- Migration is a part of the sexual cycle. Birds begin to migrate northward as their gonads begin to swell
- The birds also migrate to save their offspring and themselves from predators and diseases.

ii. Factors affecting the migration

Physical factor: Light, temperature, a velocity of wind etc. affect bird migration

Metabolic factor: When birds consume more amount of food, the fats deposited under subcutaneous layer affects the nervous system, then, the birds migrate towards the breeding place.

Hormonal or Biological factor: Due to the intensity of light, the pituitary gland stimulated which secretes the gonadotrophic hormone (FSH and LH). These hormones activate gonads, which affect nervous system, and then the birds migrate towards breeding place.

Shortage of food: In the northern hemisphere, due to ice sheet during winter, shortage of food occurs. So, the birds migrate towards southern hemisphere

iii. Types of bird migrations

Latitudinal migration: North to south and vice-versa. Ex. Siberian crane

Longitudinal migration: East to west and vice-versa Ex. Starling bird

Vertical migration: Up and down in the mountain region Ex. Daphe

Partial Migration: Within a single species, some do migrate and some do not. Ex. Birds of the temperate regions

Irregular migration: Migrate in all direction covering few or many miles Ex. Herons

Regular migration: Birds can out from their nest in the morning to search food and return back in evening hour Daily. Ex. Pigeon, Sparrow

Seasonal migration: Some birds are winter visitors like know bunting whereas some birds are summer visitors like swift

iv. Advantages of bird migration

- Birds get more food, better climatic condition, and breeding place
- Birds get better adaptability in new place
- There will be the wide geographical distribution of birds

v. Disadvantages of bird migration

- Predator will die due to the shortage of food when birds of that place migrate
- During migration, birds need to face several risks (pollution, storms, wildfires, and habitat destruction along migration routes) in enormous number of birds die
- They can carry the germs like bird flu
- Hunting along migration routes threatens some bird species

4.4.2 Flight Adaptation in Birds

Flying is a unique ability of birds, and for this, they have acquired various adaptations. It's obvious that birds have evolved wings to fly, but their flight is so energy-intensive that they have evolved many adaptations to improve it.

There are two main types of flight or aerial adaptation in birds.

i. Morphological Adaptation

The following morphological adaptations to flight are found in birds:

Body contour: Bird's bodies are streamlined, and spindle-shaped to help overcome air resistance.

Compact Body: The body of birds is compact and is light and strong dorsally and heavy ventrally. This shape helps in maintaining equilibrium in the air.

Body covering of Feather: The body of all birds is covered by feathers, helps in maintain its buoyancy and constant body temperature.

Wings: The wings of birds are unique, powerful, and propelling organs that are modified form of forelimbs. The wings are the sole organs of flight.

Mobility in the neck and head: In birds, the neck is long and flexible which helps in the movement head.

Perching: When a bird sits on a branch of the tree, the toes close around the twig automatically (for arboreal life). It happens due to a mechanism known as perching. Birds can sleep in this position without any fear of falling off.

Short tail: Rectrices serves as a rudder during flight. The short tails also assist in steering, lifting, and counterbalancing during flight and perching.

ii. Anatomical adaptation:

The following anatomical adaptations are found in flying birds:

Flight muscles: A bird's wings are controlled by the flight muscles, which weigh about one-sixth of its body weight, while its back muscles are reduced. Large muscles, the pectoralis major depress the wings, while the pectoralis minor elevates them.

Lightness and Rigidity of Endoskeleton: Flying birds have very stout and light skeletal structures. Flying birds have pneumatic bones, which are filled with air sacs. Bone marrow is absent. Due to the fusion of bones, the skeletal framework becomes compact, centralized, and rigid.

Digestive system: Birds' rectum become much smaller and do not store undigested food. Birds lack gall bladders, which minimizes their body weight.

Respiratory system: There is a remarkable system of air sacs in the lungs of birds, which reduce the specific gravity of birds and facilitate complete aeration.

Circulatory system: Birds have large, four-chambered, powerful, and efficient hearts. Hemoglobin is abundant in the red blood cells of birds.

Warm bloodedness: In birds, the body temperature is constant and high, which allows them to fly at high altitudes and stay active all year round.

Excretory system: The urinary bladder is absent in birds. Semi-solid uric acid is excreted out immediately, since it does not remain in the body for long.

Reproductive organs: The left side of female birds has a single functional ovary. Furthermore, it reduces body weight, which is essential for flying.

5.1 Class – Mammalia Characters

Mammals are one of the most evolved species and have advanced characteristics. Important features of class mammalian are:

* Most dominant and found in almost all types of habitats.

* They are worm blooded and give birth to young ones.

* They have mammary glands i.e. milk-producing glands, to feed the young ones

* Body covered by hair or fur. Skin contains sebaceous and sweat glands

* External fleshy pinna is present.

* Skull is dicondylic. Cervical vertebrae and single boned lower jaw is present.

* Heterodont, thecodont and diphyodont type dentition is found.

* The heart is four-chambered. Only left aortic arch is present. RBC are non-nucleated

* Respiratory organs are lungs. Diaphragm helps in respiration.

* Middle ear has three tiny bones

* Well developed brain with cerebrum, cerebellum and medulla. Neocortex and Carpus callosum present

* Separate sexes and internal fertilization. Testes remain in scrotal sacs.

* Mostly viviparous, few are oviparous. The development is direct.

5.2 Classification: Mammalia divided into two subclasses

Subclass 1: Prototheria

1. External ear without pinna.

2. Teeth are absent in the adults.

3. Cloaca is present.

4. Mammary gland without nipples.

5. Testes are abdominal, no scrotum

6. Corpus callosum absent.

7. Egg laying animals.

8. No placenta

Ex: Duck billed platypus, Anteater

Subclass 2: Theria

1. External ear pinnae are present.

2. Teeth are well developed.

3. Cloaca is absent.

4. Mammary gland is present with nipple.

5. Tests are descending in to scrotal sac.

6. Urethra is common for vasa differentia and urinary bladders.

7. Viviparous animals.

Infraclass 1: Metatheria

1. Marsupium is present females.

2. Mammary glands developed.

3. Marsupial bone is present.

4. Coracoid and interclavicle are absent.

5. Epiphyses on vertebrae.

6. Corpus callosum poorly developed.

7. Vagina and uterus are double

8. Primitive placenta is present.

9. Viviparous.

Ex: Kangaroo, Opossum

Infraclass 2: Eutheria

1. Marsupium is absent.

2. Mammary glands well developed.

3. Epipubic bone absent.

4. Cloaca is absent.

5. Carpus callosum well developed.

6. Tastes in Scrotal sac.

7. Vagina is single.

8. Viviparous.

9. Placenta well developed.

Ex: Horse, Rat, Man

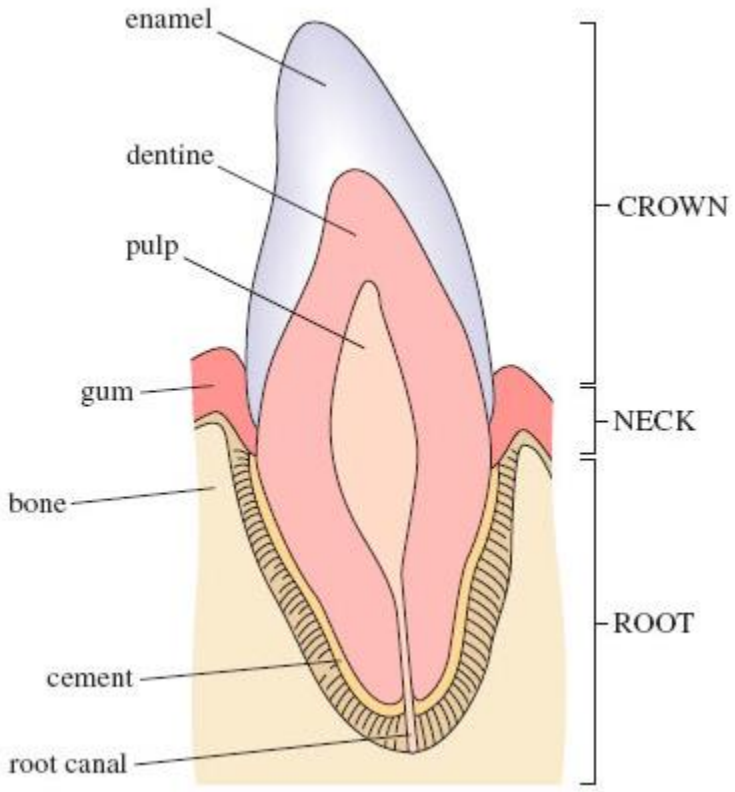
5.3 Comparison of Prototherians, Metatherians and Eutherians

SN	Prototherian	Metatherian	Eutherian
1.	It includes egg laying mammals, in which egg are large yolky and shelled	It includes all mammals more closely related to marsupials than to placentals.	They are true mammals and females have mammary glands.
2.	Mammary glands are without nipples	Mammary glands lack nipples, but the skin over their mammary glands exude milk for their babies	Mammary glands with nipples.
3.	Gynecomastia Both male and female suckle the young ones is found in these animals.	Only females have mammary glands and show parental care.	Only female have mammary gland and show parental care
4.	In Prototherian all the three tract ie Anus, Urinary tract, reproductive tract commonly open into Cloaca	In Marsupials, the genital tract including urinary tract and reproductive duct is separate from the anus.	In Male anus is separate and the urinogenital duct is separate. But in females the urinary tract, reproductive tract and anus is separate.
5.	In Males testis are abdominal and scrotum is absent.	In Male, the scrotum is present in front of the penis.	In Male, the scrotum is present behind the penis
6.	Young ones are hatch from egg after incubation	The young are born immature and for further development takes place in mothers pouch.	The young develop inside the mother's womb.
7	Ear without pinna	Ear with pinna	Ear usually with pinna
8	No Corpus callosum	No Corpus callosum	Corpus callosum present.
9	No Marsupial pouch	Marsupial pouch often present	No Marsupial pouch
10	No placenta	Placenta small, intrauterine development brief, young extremely small and helpless, brought up in marsupial pouch, if present.	Placenta large, intrauterine development prolonged, young advanced and fully formed.
11.	Eg: Ornithorhynchus or Duck billed Platypus. Tachyglossus or Echidna or Spiny anteater	Eg: Marsupial Kangaroo, opossum, wombats	Eg: Tiger, Man, Elephants and Rhinoce

5.4.1. Dentition in Mammals

Dentition is the number, kind, arrangement, and structure of the teeth. Teeth are the dermal derivatives of integument. They are developed as a result of calcification in the mucous membrane of the buccal cavity. The teeth are present in almost all the mammals except in a few mammals in whale, the teeth are fused into plates and lost in the adult stage of Ant eaters. But in Echidna (spiny ant eater) the teeth are absent even in the embryo.

Structure of tooth: Each typical mammalian tooth is placed in the socket over the jaw bone. It is distinguished into three main parts.



i. Root - It is the basal part embedded in the bony socket of jaw.

ii. Neck - it is the part above the root enclosed by the gum.

iii. Crown - It is the upper part beyond the surface of the gum.

The toot is separated from the socket by a vascular peridontal membrane. The vertical section tooth consists of the following parts.

a. Pulp cavity: The entire tooth encloses a central pulp cavity surrounded by a layer of odontoblast cells filled with soft pulp. It is made up of connective tissue, blood vessels and nerve fibers.

b. Dentin: A substance chemically similar to bone- dentine forms the major part of the tooth. But the dentine is permeated by numerous thin canaliculi.

c. Enamel: It is present over the dentin in the crown and neck regions of the tooth. It is hardest and contains only traces of living matter.

d. Cement: It surrounds the denting of the root portion of the tooth. It is bony in nature.

Types of Dentition

* **Dentition on the basis of origin** the teeth are classified into 3 types, namely Acrodont, Pleurodont, and Thecodont.

i. **Acrodont:** teeth are attached on the top surface of the jaw bone as in fish and amphibians.

ii. Pleurodont: teeth are attached to the rim of jaw. This type of dentition is found in lizards and not in mammals.

iii. Thecodont: the teeth have roots and the roots are embedded in sockets of jaw bone and is seen in all mammals.

* **Dentition on the basis of function**

i. **Homodont:** all teeth are functionally and anatomically of the same type. Eg. Dolphins.

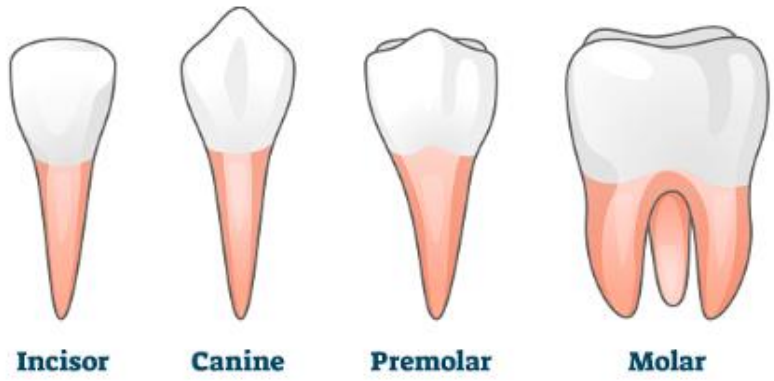
ii. Heterodont: the teeth are different in shape and function and are present in the same animal. In heterodont type, teeth are differentiated into four types, namely incisors, canines, premolars and molars.

* **Dentition on the basis of appearance**

Based on the number of sets of teeth that develops during the life time, the teeth are classified into 3 types. Monophyodont, Diphyodont, and Polyphyodont

i. Monophyodont: teeth appear only once in lifetime. Eg. Moles and squirrels.

ii. Diphyodont: dentition is a characteristic of mammals in which milk teeth appear in the young ones but as they grow and jaw becomes larger, milk teeth are replaced by larger permanent ones to fit in the larger jaw bone. In bats and guinea pigs, the milk dentition is lost even before birth. In Homo sapiens (man), the milk teeth are replaced by the permanent teeth around the age of 7 years.



*** Dentition on the basis of function**

i. Polyphyodont: dentition involves replacement of teeth from time to time several times in lifetime found in lower vertebrates.

Types of Teeth In heterodont dentition, there are four different types of teeth:

a. Incisors: They are flat chisel-shaped teeth having a single root. They are used for cutting.

b. Canines: Canines are sharp pointed teeth having a single pointed crown and a single root. They are used for piercing and tearing the flesh of the prey.

c. Premolars and Molars (cheek teeth): They are collectively called grinders. They have two or more roots and the crowns bear complex cusps or tubercles. The cheek teeth are used for grinding the food.

*** Dentition on the basis of shape**

The molars show many cusps on their surface. Based on the number and shape of the cusps different types of teeth have been distinguished. They are:

1. Monocuspid: This is characterized by the presence of only one cusp.

2. Bicuspid: When two cusps are present, the tooth is called bicuspid.

3. Tricuspid: These are molars having three cusps. Tricuspid teeth are also called triconodont and trituberculate.

4. Bunodont: In bunodont type, the crown has a number of blunt or pointed cusps. Eg. Man.

5. Lophodont: When the cusps are arranged in the form of ridges, it is called lophodont. Eg. Indian elephant.

6. Selenodont: These are molars with cusps in the form of crescent. Eg. Cow and sheep.

7. Secodont: In secodont type of molars, the crown has cusps having sharp cutting edges. Eg. Carnivorous mammals.

8. Hypsodont: These are molars with high crowns and short roots. The cusps are crescent-shaped.

9. Brachydont: Molar teeth with short crown and with neck at the surface of the gum are called brachydont. They have also crescent shaped cusps.

Mostly the number of teeth is fixed in each mammalian species. Mammalian heterodont dentition is expressed by a '***dental formula'***. The number and arrangement of teeth in each half of the upper and lower jaws is constant and identical. Hence the teeth can be expressed by using the initials - I, C, P and M. The number of teeth differs in the various orders of mammals and is closely related to their feeding habits. Typical number of teeth in the mammals is 44. This can be observed in Horse and pig and their dental formula is I 3/3 –C 1/1 –P 4/4 –M 3/3 x 2 = 44

The numerator indicates the number of teeth on one side of upper jaw. The denominator indicates the number of teeth on one side of the lower jaw. As the two halves of each jaw have same number and kind of teeth, the number of teeth on one side alone is usually ex pressed in the formula.

5.4.2. Adaptations of Aquatic Mammals

Mammals, predominantly terrestrial, exhibit adaptations for life on land. Some mammals have successfully transitioned to aquatic habitats, evolving from their terrestrial ancestors.

Terrestrial Lung-Breathing Forms

1. Original Terrestrial Mode: Aquatic mammals, despite their aquatic lifestyle, breathe air through lungs. This suggests their evolutionary origin as terrestrial lung-breathing forms.

2. Reversion to Aquatic Life: Aquatic mammals, notably whales, have transitioned to water, possibly due to intense competition for food and shelter on land. This reversion to aquatic life has been remarkably successful.

Categories of Aquatic Mammals

1. Amphibious Mammals: Mammals not permanently residing in water but using it for food and shelter. Adaptations: Small external ears. Webbed feet. Flattened nails. Subcutaneous fat. Ex: Beaver, musk rat, nutria, otter, mink, etc. Orders: Carnivora, Rodentia, Artiodactyla, Marsupialia, Monotrernata, etc.

2. Aquatic Mammals: Spend most of their time in water but come to land for reproduction. Ex: Seals, hippopotamus.

3. Marine Mammals: Never come to land; fully adapted to life in water. Ex: Whales.

Adaptations of Aquatic Mammals

1. Modifications of Original Structures

i. Body Shape: Fish-like form, elongated head, and streamlined body reduce resistance and enhance swimming.

ii. Large Size and Weight: Large size reduces skin friction, aids heat retention, and provides buoyancy in water.

iii. Flippers: Forelimbs transformed into skin-covered, un-jointed paddles for swimming stability.

iv. Hyperdactyly and Hyperphalangy: Extra digits and phalanges increase flipper surface area for efficient swimming.

v. Nostril Placement: Nostrils far back on the head allow breathing without raising it much out of water.

vi. Mammary Ducts: Mammary ducts dilate to form milk reservoirs, facilitating underwater suckling.

vii. Oblique Diaphragm: Oblique diaphragm enlarges thoracic cavity for better lung expansion.

viii. Large Lungs: Large, unlobulated lungs aid in maximum air intake during submersion.

ix. Intra-Narial Epiglottis: Tubular intra-narial epiglottis allows simultaneous breathing and feeding underwater.

x. Endoskeleton Modifications: Cranium becomes small and wider; cervical vertebrae fuse; ribs arch dorsally.

xi. Teeth in Toothed Whales: Monophyodont, homodont teeth assist in capturing and swallowing prey without mastication.

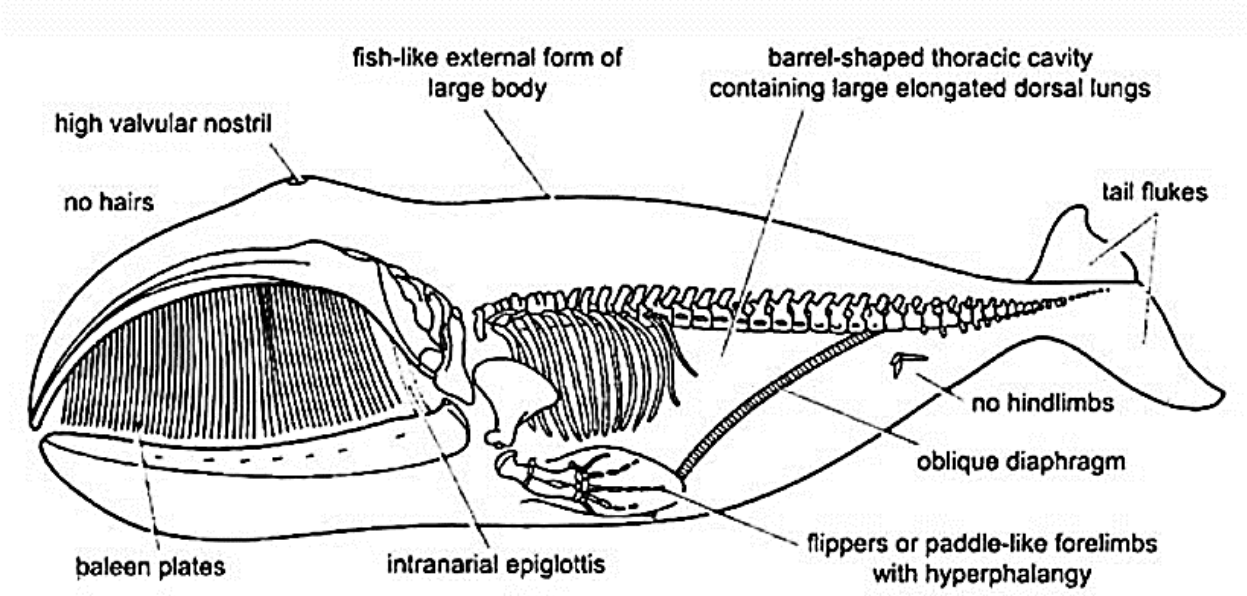


Fig. Body outline structure of the Whale.

2. Loss of Structures

i. Loss of Hairs: Smooth, glistening skin due to the absence of hairs, except for sensory bristles.

ii. Absence of Pinnae: Pinnae absent to maintain streamlined body shape during swimming.

iii. Loss of Various Glands: Nictitating membranes, eye cleansing glands, lacrimal glands, and skin glands are absent.

iv. Reduced Hind limbs and Pelvis: Hind limbs represented by knobs in the fetus; pelvis rudimentary or absent in adults.

3. Development of New Structures

i. **Tail Flukes**: Lateral expansions on the tail called tail flukes for propelling through water.

ii. **Dorsal Fin**: Unpaired adipose dorsal fin serves as a rudder or keel during swimming.

iii. **Blubber**: Thick subcutaneous layer of fat (blubber) for insulation, buoyancy, and emergency food reservoir.

iv. **Baleen in Whalebone Whales**: Absence of teeth replaced by baleen plates for filtering plankton.

v. **Foam**: Emulsion of fat, mucus, and gas in middle ear cavities for sound insulation and improved hearing.

vi. **Melon**: Fatty mass in front of nostrils to detect pressure changes in water.

vii. **Harderian Glands**: Secretion protects eyes underwater.

Conclusion

* Aquatic mammals showcase a variety of adaptations, including modifications of original structures, loss of certain features, and the development of new structures.

* These adaptations demonstrate the remarkable evolutionary transitions that have enabled mammals to thrive in aguatic environment