3rd SEM B.Sc. ZOOLOGY

CALICUT UNIVERSITY

ANIMAL DIVERSITY : CHORDATA PART - 1

2019 ADMISSION

Prepared by

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THIRD SEMESTER B. Sc. ZOOLOGY PROGRAMME
ZOOLOGY CORE COURSE – III (Theory)
ANIMAL DIVERSITY: CHORDATA PART - I
CODE: ZOL3B03T
[TAXONOMY, DIVERSITY, STRUCTURAL ANATOMY AND ADAPTATIONS OF CHORDATES]
[54 hours] [3 hours per week] [3 credits]

MODULE 1. Introduction [2 hrs]
Chordate characters (fundamental, general and advanced); chordates versus non chordates; diversity of chordates; outline classification down to classes; salient features of each subphylum.

MODULE 2.Subphylum UROCHORDATA [Tunicata] [5 hrs]
Classification of the subphylum down to classes. Affinities of urochordates with cephalochordates and vertebrates.
Class Ascidiacea e.g. Herdmania
Class Larvacea e.g. Oikopleura
Class Thaliacea e.g. Doliolum
Type: Ascidia [Morphology and retrogressive metamorphosis]; add a note on neoteny and paedogenesis.

MODULE 3.Subphylum CEPHALOCHORDATA [4 hrs]
Type: Branchiostoma [=Amphioxus]
Morphology and anatomical features; digestive system in detail; primitive, degenerate and specialized features [affinities and systematic position to be emphasized).

MODULE 4. Subphylum VERTEBRATA [3 hrs]
Salient features of subphylum vertebrata and its outline classification down to classes.
Division 1. AGNATHA
Characters, classificationdown to classes and examples: Myxine; Petromyzon [mention Ammocoetes larva]
Division 2. GNATHOSTOMATA

MODULE 5. Superclass PISCES [12 hrs]
Classification of Pisces down to orders; salient features of the following extant groups:
Class Chondrichthyes [Cartilaginous fishes]
Subclass Selachii e.g.Scoliodon, Trygon
Subclass Holocephali e.g.Chimaera
Class Osteichthyes [Bony fishes]
Subclass Sarcopterygii
1. Order Crossopterygii [Coelacanths] e.g. Latimeria
2. Order Dipnoi [Lung fishes] e.g. Neoceratodus, Protopterus, Lepidosiren (Add a note on the distribution of lung fishes).

Subclass Actinopterygii
1. Superorder Chondrostei e.g. Acipenser
2. Superorder Holostei e.g. Amia, Lepidosteus
3. Superorder Teleostei [Spiny-rayed fishes] e.g. Sardinella, Rastrelliger
Type: Mugil cephalus (Grey Mullet)
[Morphology, body wall, digestive system, respiratory system, circulatory system, excretory system, sense organs (neuromast organ in detail) and reproductive system].
Sub-terranean fishes from Kerala: Aenigmachanna Gollum (Gollum Snakehead), Kryptoglanis shajii, Horaglanis krishnai (Blind Catfish) & Monopterus digressus (Blind cave eel). Mention recent addition to ornamental fish trade - Sahyadria denisonii (Miss Kerala).

Super class TETRAPODA
MODULE 6. Class AMPHIBIA [13 hrs]
Classification of Amphibia down to orders with examples [of extant forms only].
Subclass Stegocephalia (extinct)
Subclass Lissamphibia
1. Order Apoda (=Gymnophiona) e.g.Ichthyophis, Uraeotyphlus
2. Order Caudata (=Urodela) e.g.Necturus, Ambystoma, mention Axolotl larva.
3. Order Anura (=Salientia) e.g.Duttaphrynus, Rhacophorus
Type: Hoplobatrachus tigerinus (Indian Bullfrog)
[Morphology, body wall, skeletal system,digestive system, respiratory system, circulatory system, excretory system, sense organs and reproductive system].
Mention about the diversity of bush frogs, dancing frogs and night frogs in Western Ghats and the discovery of Nasikabatrachus sahyadrensis (Purple frog).

MODULE 7. Class REPTILIA [15 hrs]
Classification of class Reptilia down to orders and salient features of the following orders (only extant forms):
Subclass I - Anapsida
1. Order Cotylosauria [stem reptiles] e.g.Hylonomus
2. Order Chelonia [common turtles, tortoises etc.] e.g. Melanochelys, Chelone
SubclassII - Diapsida
1. Order Rhynchocephalia e.g. Sphenodon
2. Order Squamata
 Suborder Lacertilia (Lizards) e.g. Chamaeleo, Hemidactylus
 Suborder Ophidia (Snakes)
Common venomous and non-venomous snakes of Kerala: a] Python molurus b]Ptyas mucosus c] Gongylophis (= Eryx) conicus d] Indotyphlops braminus e] Bungarus caeruleus f] Naja naja g] Daboia russellii h] Ophiophagus Hannah. Identification key for venomous and non-venomous snakes.
3. Order Crocodilia e.g. Crocodylus, Gavialis
[Mention the extinct subclasses Euryapsida, Parapsida and Synapsida (mammal like reptiles) and mention the origin of mammals from synapsids].

Type: Calotes versicolor (Garden Lizard)
[Morphology, body wall, skeletal system (exclude skull bones), digestive system, respiratory system, circulatory system, excretory system, sense organs and reproductive system].

MODULE 1
INTRODUCTION

Phylum chordata is a vast assemblage of apparently unrelated animals which possesses a combination of three fundamental features.

1. Notochord
2. Dorsal tubular nerve cord
3. Pharyngeal gill slits.

Notochord

 Also called corda dorsalis.

 Presence of axial supporting endoskeleton.

 Notochord is an elastic & cylindrical rod, placed in the longitudinal axis above the alimentary canal & below the nerve cord.

 It is formed of peculiar tissue called notochordal tissue, which consist of closely packed , vacuolated and fluid filled notochordal cells.

 The turgor pressure of the fluid content of these cells makes the notochord stiff & strong.

 Around the vacuolated cells is a layer of non vacuolated peripheral cells.

 Notochordal tissue is enveloped by an elastic connective tissue packing, called notochordal sheath.

 It consist of an outer elastic sheath, called primary sheath, & an inner fibrous sheath called secondary sheath.

 In primitive chordates it persist throughout life.

 In advanced chordates it is only embryonic & in the adult it gets partially or completely replaced by a cartilaginous or bony vertebral column.

Dorsal tubular nerve cord

- Nerve cord is dorsal, tubular, hollow, unpaired, non ganglionated and ectodermal.
- It encloses within a fluid filled central canal, called neurocoel.
- The anterior end of nerve cord dialates & undergoes specialization to form the brain.
- The remaining portion becomes the spinal cord.
- The fluid that fills the central cavity of brain & spinal cord is called cerebro-spinal fluid.

Pharyngeal gill slits

 Also called visceral clefts, branchial or visceral pouches.

 They are paired openings leading from the pharynx to the exterior.

 It appear during the development of every chordate, but in many aquatic forms they are lined with vascular lamellae which form gills for respiration.

 In terrestrial chordates, traces of gill slits are present during early development but disappear later in adults.

 In lower chordates, the visceral clefts are used as a feeding mechanism throughout life, but in higher chordates the gill clefts often form some endocrine glands.

General features

1. Chordates are aquatic, aerial or terrestrial. All are free living with no fully parasitic forms.
2. Size of the body ranges from small to large, bilaterally symmetrical & metamerically segmented.
3. Post anal tail usually projects beyond the anus at some stage of life and may or may not persist in the adult.
4. Well developed exoskeleton is present in most vertebrates.
5. Triploblastic body wall , consisting of three germinal layers , ectoderm, endoderm & mesoderm.
6. Coelomate animals – enterocoelic or schizocoelic in origin .
7. Notochord is present or replaced by vertebral column.
8. Presence of bony or cartilaginous endoskeleton.
9. Presence of pharyngeal gill slits.
10. Digestive system is complete with digestive glands.
11. Blood vascular system is closed type.
12. Excretory system comprising proto/meso/metanephric kidneys.
13. Nerve cord is dorsal & tubular.
14. Sexes are separate with rare exceptions.

Advanced features

1. Axiate organization

 Distinct polar axis

 Anterior – head , posterior – tail.

 Body running from head to tail – antero-posterior axis.

2. Bilateral symmetry

 Similarity of the left & right sides of the body.

3. Triploblastic condition

 Having three germinal layers - ectoderm , endoderm & mesoderm.

4. Coelom

 Coelomate animals , possess true coelom.

 Coelom is lined by mesoderm.

5. Metamerism

 Structure of animal resemble each other repeat regularly one after the other.

 Each sub division of body is called metamere.

 In higher chordates it is not present externally but is seen internally in nerves, blood vessels ,muscles , vertebrae , ribs ,… at least in their origin.

6. Organ system

 In chordates several organs work together to perform same function.

 Eg :- digestive system , circulatory system , respiratory system ,…

Chordates Vs non chordates

Chordates	Non chordates
1. Notochord is present either throughout life or during some stage of life.	Notochord is altogether absent at any stage of life.
2. Nerve cord is dorsal, tubular, unpaired & non ganglionated, & it is located above the alimentary canal & below the notochord.	Nerve cord, if present, is ventral , solid, paired & ganglionated, & is located below the alimentary canal.
3. Paired pharyngeal gill slits are present.	Pharyngeal gill slits are absent.
4. Heart is ventral to alimentary canal.	Heart is dorsal to alimentary canal.
5. Circulatory system is of closed type.	Circulatory system, if present , may be closed in some & open in others.
6. The direction of blood flow is forward ventrally & backward dorsally.	Blood flow is forward dorsally & backward ventrally.
7. Respiratory pigment haemoglobin is located in RBC.	Haemoglobin, if present, remains dissolved in blood plasma.
8. Post anal tail is present.	Post anal tail is absent.
9. Coelomic body cavity is present in all chordates.	Coelomic body cavity is present only in some ; in some others a false coelom is present & in some coelom is altogether absent.
10. Lateral appendages if present, will be two pairs in number.	Lateral appendages , if present, will be more than two pairs.

Diversity of chordates

- The chordates exhibit an astonishing diversity in form, physiology & habits.
- The number of chordate species is limited.

- About 49000 species are on record which are only half of the living species of molluscs & less than one tenth of arthropods.
- Chordates make remarkable contribution to the biomass of the earth.
- Nearly all of them are medium to large in size.
- Gigantic blue whale is 35 metres long & 120 tons in weight is the biggest known animal.
- Philippine goby is a fish, measuring only 10 mm in length.
- The chordates are able to occupy various kinds of habitats.
- They have adapted themselves to more modes of existence than any other group.
- They are found in the sea, freshwater, air & on all parts of land from the poles to the equator.

Classification of phylum chordata

Phylum	Subphylum	Division	Superclass	Class
Chordata	A.Cephalochordata	———	———	Cephalochordata
	B.Urochordata	———	———	(i)Ascidiacea (ii)Thaliacea (iii)Larvacea
	C.Vertebrata	(a)Agnatha	———	(i)Ostraodermi (ii)Cyclostmata
		(b)Gnathostmata	1.Pisces	(i)Placodermi (ii)Chondrichthyes (iii)Osteichthyes
			2.Tetrapoda	(i)Amphibia (ii)Reptilia (iii)Aves (iv)Mammalia

MODULE 2
SUBPHYLUM UROCHORDATA

Urochordata is a group of primitive, marine, solitary or colonial chordates, characterized by a secreted leathery covering around the body. They are mostly sedentary & rarely pelagic forms. They includes simple solitary forms & complex colonial forms.

Salient features

1. Body is encased within a tough & leathery covering, called *test or tunic*. It is composed of a polysaccharide called *tunicin*, which is closely related to cellulose.
2. Notochord is altogether absent in adult, but present in tail of the larva (hence the name urochordata) .
3. Nerve cord is present in larva, but it gets degenerated in the adult. In adult, the whole nervous system is represented by a neural ganglion.
4. Large pharynx surrounded by atrium is present.
5. In the adult, heart is simple & tubular, and it periodically reverses the direction of blood flow – a feature unique in animal kingdom.
6. Sexes are united (*hermaphrodites*).
7. Reproduction takes place asexually by budding & sexually by *gametogenesis & zygogenesis.*
8. Alternation of generation, sometimes accompanied by polymorphism.
9. Most forms are oviparous, but a few are ovoviviparous (*clavelina*).
10. In sexual reproduction development is indirect with a tailed free swimming larva called *ascidian tadpole.*
11. Metamorphosis is retrogressive.
12. Neoteny / paedogenesis – larva attains sexual maturity & starts sexual reproduction before completing metamorphosis.

Classification of urochordata

Sub- phylum urochordata is divided into three classes namely, *Ascidiacea , Thaliacea & Larvacea.*

Class *Ascidiacea*

Largest group of urochordates. It comprises mostly sedentary & a few free swimming tunicates, which may be solitary or colonial.

1. Absence of notochord & post anal tail in adult.
2. Prominent oral & atrial siphons.
3. Spacious atrium & dorsal atriopore.
4. Well developed pharynx with ciliated gill slits.
5. Looped intestine & absence of specialized digestive glands.
6. Non chambered & non valvular heart, enclosed within a thick pericardial tube.

7. Degenerate nervous system in the adult, represented by a solid nerve ganglion & a few nerves from it.
8. Absence of specialized sense organs in adult.
9. In colonial forms zooids may be either simple & separate with individual tests, or composite with a common test, common cloaca & common atrial siphon.
   Eg*:- Herdmania*

Class Thaliacea

Group of free swimming, pelagic, solitary or colonial tunicates.

1. Cylindriacal, barrel shaped of fusiform body, covered by thin or thick transparent & permanent test.
2. Muscle fibres are arranged in complete or incomplete circular bands or may be held diffusely.
3. Branchial & atrial apertures at opposite ends.
4. Absence of tail & notochord in adult.
5. Pharynx is large & it opens to the atrium either by a pair of large stigmata or by several pairs of small stigmata.
6. Alimentary canal is ventrally situated.
7. Asexual reproduction is by budding.
8. Gonads are hermaphroditic.
9. Development may be direct or indirect. Indirect development involves a tailed larva.
10. Life cycle is characterized by alternation of generation & polymorphism.
    Eg:- Doliolum, Salpa

Class larvacea

Larvcaea is a group of small, neotenic, transparent & free swimming tunicates, with a permanent tail, supported by persistent notochord. Larvacea indicates that the members are neotenic or paedogenetic & their larvae become sexually mature, without completing metamorphosis.

1. Test is a temporary, loose, non- cellular & jelly like envelope, commonly called the "*house*". It can be frequently removed & renewed.
2. Test has an inhalant & exhalent openings for the entry & exit of water.
3. There is permanent tail in the adult, supported by notochord.
4. Digestive tract is U shaped, with mouth & anus close to each other.
5. Phaynx is large, with only a single pair of gill slits which opens directly to the outside.
6. Endostylar groove may be reduced or absent.
7. Atrium is absent.
8. Asexual reproduction absent.
9. Sexes are united.
10. Larval metamorphosis is incomplete or absent.
    Eg:- *Oikopleura*

Affinities of urochordata with cephalochordate & vertebrata

Affinities with cephalochordates

1. Single layered epidermis.
2. Ciliary feeding.
3. A large pharynx with endostyle, peripharyngeal glands & epipharyngeal groove.
4. Gill slits.
5. Spacious ectoderm lined atrium.

Affinities with vertebrata

1. The endostyle of ascidians is homologous to the thyroid gland of vertebrates.
2. The typhlosole of adult ascidians is comparable to the projecting intestinal fold of some vertebrates.
3. Neural gland of ascidians is homologous to the adenohypophysis of vertebrates.
4. Post anal tail with well developed dorsal & ventral fin folds.
5. Supporting endodermal notochord in the tail region.
6. Dorsal neural tube of ectodermal origin.

Morphology of *Ascidia*

- Popularly known as "*sea squirt".*
- It is a sedentary marine chordate, remaining attached to the rocks & other substrata.
- Body is roughly oblong, cylindrical with a broad base for attachment.
- *Oral aperture/ branchial aperture/ mouth* : At the free terminus, is a wide aperture. This end is anterior end.
- *Atrial aperture* : A little behind the mouth, and located on one side. It marks the dorsal side of body.
- *Branchial siphon* : branchial aperture is situated on the summit of a small prominence.
- *Atrial aperture* : summit of atrial siphon.

Test or tunica

- The body is encased within a protective tough & leathery covering called test.
- Around the oral & atrial apertures, it gives out projecting lobes, which forms the lips of aperture.
- Test is made of complex polysaccharide *tunicin,* which is closely related to cellulose.
- Presence of tunicin is a unique feature of ascidians.
- Histologically, test is soft connective tissue, almost translucent matrix, different kinds of wandering cells, interlacing fibrils, minute calcareous spicules & branching blood vessels.

Body wall

- Body wall underlying test is called "*mantle*".
- It attached to the test only at the regions of oral & atrial apertures.
- Mantle encloses a large atrial cavity, which contains the internal organs.
- It forms oral siphon at oral aperture & atrial siphon at atrial aperture.
- The siphons & apertures can be closed or opened by muscular activity.
- Mantle is contractile, by its sudden contraction, jets of water can be forced out through the atrial aperture. The name "*sea squirt*" is derived from this feature.
- Mantle consist of three layers, namely *outer epidermis, inner epidermis & a middle layer of mesoderm*.
- Inner epidermis lines the atrium.
- Mesoderm forms a connective tissue. It consist of a gelatinous matrix in which muscle fibres, blood vessels, nerve fibres & wandering *mesoblast cells.*

Atrium

- It is a secondarily formed cavity inside the mantle.
- It completely surrounds the pharynx, except midventrally & also for a short distance antero-dorsally, here branchial wall fuses with mantle.
- It opens outside antero-dorsally by the atriopore.

Coelom

- Due to the extensive development of atrium, coelom gets highly reduced.
- In adult it is represented by renal, pericardial & gonadal cavities.

Metamorphosis

- Free swimming larva is non feeding, geonegative & photopositive.
- Later, becomes geopositive & photonegative.
- It swims downward in darkness, settles down to the bottom & attaches itself to a suitable substratum in an upside down posture with the help of a adhesive papillae.

Retrogressive metamorphosis

- The ascidian metamorphosis involves the degeneration & disappearance of most of its advanced features.
- It is a radical reversion from a highly organized to a poorly organized condition – it is called retrogressive metamorphosis.
- It involves
    a) Regression & disappearance of tail.
    b) Disintegration & dissolution of notochord, caudal portion of nerve cord, tail muscles,..
    c) Disappearance of sense vesicle, oscellus & otocyst.

d) Reduction of the visceral ganglion & its transformation to the nerve ganglion & the sub neural gland.

- Specialization of alimentary canal, with enlargement of branchial sac & multiplication of gill slits.
- Development of gonads & gonoducts.
- Formation of test or tunic.
- Invagination of test to branchial & atrial siphon.

- The portion of the body between the point of attachment & the oral aperture grows rapidly & disproportionately.
- This causes the rotation of the body in a postero-dorsal direction at about 180°.
- This loses the bilateral symmetry & its oral & atrial apertures are brought close to each other at the free distal end of the body.
- Larva transforms to sedentary adult by climb down from active free swimming larva with notochord, nervous system & sense organs to an inert adult.

Neoteny & paedogenesis

- Neoteny is the phenomena in which the organism is in juvenile stage and the physiological state (somatic growth) is slow down.
- Paedogenesis is the production of offspring by an organism in its larval or juvenile form; the elimination of the adult phase of the life cycle.
- Here the larvae of the organism attains sexual maturity, the sexual reproduction is accelerated.
- Therefore, neoteny is a feature of retarded growth and paedogenesis is of accelerated growth.

MODULE 3
SUBPHYLUM CEPHALOCHORDATA

Salient features

 Small ,marine, fish like primitive chordates.

 Popularly known as *lancelets*.

 Symmetrical (eg.,*Amphioxus*) or asymmetrical (eg.,*Asymmetron*) body without head, cranium & paired appendages.

 Soft & naked body surface, without exoskeletal structures.

 Body wall is composed of a series of metamerically arranged muscle segments, called *myotomes or myomeres.*

 Mouth & anus are ventral & sub terminal. Mouth is encircled by a fringe of tentacular cirri called *oral cirri or buccal cirri.*

 A persistent notochord extends throughout the length of the body.

 Presence of *atrium* opens outside by *atriopore.*

 Alimentary canal is straight & simple.

 Pharynx is enlarged with numerous gill slits.

 Blood is colourless.

 Excretory organs are paired ectodermal *nephridia,* with specialized cells called *solenocytes*.

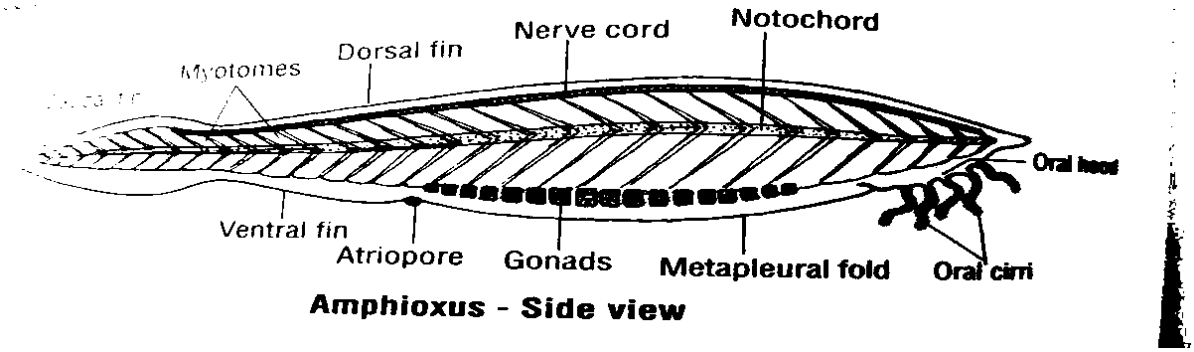
 CNS is dorsal & tubular, without well developed brain & specialized sense organs.

 Sexes are separate.

 Cephalochordate consist of a single class (Class Cephalochordata).

 Cephalochordates lead a burrowing life & enjoy worldwide distribution.

Type Branchiostoma (Amphioxus)



Amphioxus - Side view

Morphology & anatomical features

 Amphioxus is a small, almost transparent, superficially fish like animal.

 Body is long, slender,laterally compressed & sharply pointed at both ends.

 Paired fins are absent in *Amphioxus*.

 Dorsal,ventral & caudal fins are present.

 Anterior 2/3 rd portion of body is flat & rigid area called *epipleur*.

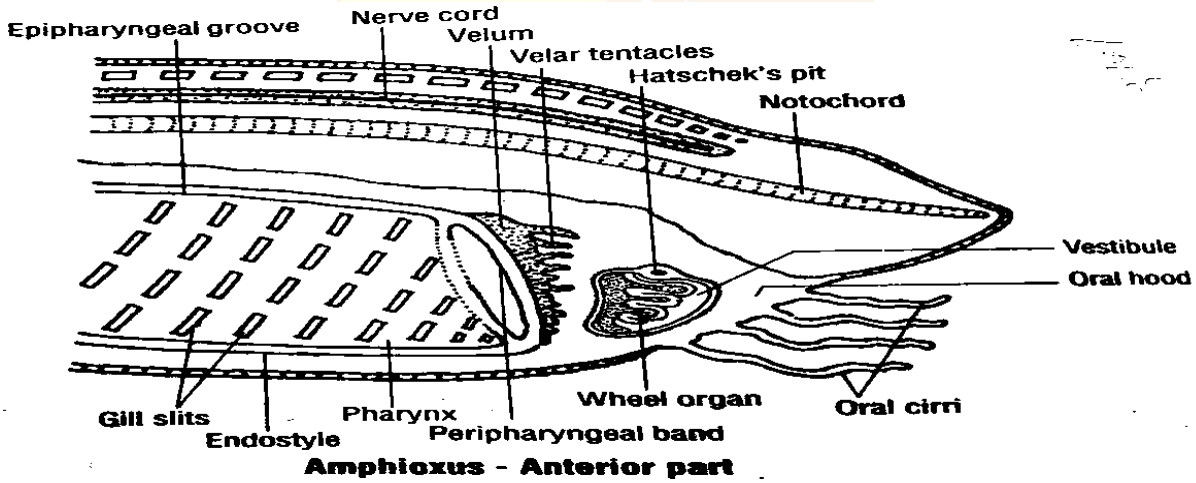
 Its lateral edges have hollow projecting ridges called *metapleural folds* or *atrial folds*.

 Posteriorly , the two metapleural folds meet together in the midventral line.

 Atrium is a spacious internal cavity that surrounds the pharynx ventrally & laterally.It opens to outside by atriopore. Shortly behind the atriopore, is the anus.

 Near the anterior tip of the body on the left dorsal side is a small pit called *olfactory pit* (pre oral pit or Kolliker's pit).

 Below the pointed anterior extremity is a funnel shaped depression, called *vestibule* or *stomodeum.*



Amphioxus - Anterior part

 It is surrounded by a frill like membrane called *oral hood.*The edges are frilled with a series of ciliated & tentacular process, called *oral cirri.*

 Oral hood bears the mouth.

 Wheel organ –ciliated ridges & grooves on the innerside of the epithelial lining of the oral hood.

 Velum- circular sphincter on the bottom of vestibule.

 Enterosome – small aperture on vestibule.

 Velar tentacles – ciliated tentacular process on vestibule.

 Hatschek's groove/pit – glandular mucus secreting groove running along the roof of vestibule.

Body wall

 The integument that covers the whole body of amphioxus is thin, soft & almost transparent.

 It has main three main parts, *epidermis, dermis & muscular part.*

 The body wall is lined internally by the *parietal peritoneum.*

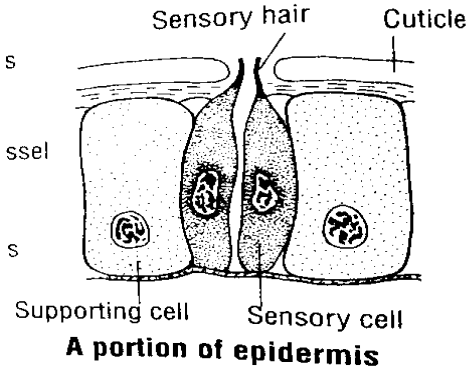
 Epidermis is single layered , consisting of three kinds of cells, supporting, sensory & muscular.

 Sensory cells are provided with sensory hairs.

 Dermis lies just below the epidermis, this together form the skin.

 Dermis is composed of soft, gelatinous connective tissue.

 It consist of a gelatinous matrix , connective tissue fibres & a few scattered cells, and is permeated by blood vessels & nerve fibres.



A portion of epidermis

 Dermis has two part, outer densely fibrous *cutis* & inner loosely fibrous *sub- cutis.*

 Muscular layer is the greater part of the body wall.

 It is metamerically segmented & each segments are called *myotomes* or *myomeres.*

 Myotome is a bundle of striated muscle fibres, enclosed within a connective tissue sheath.

 Adjacent myotomes are separated from each other by dense connective tissue partitions, called *myocommata*. They are formed by the fusion between successive sheaths.

 The contractions of myotomes result in locomotion.

Skeletal support

 The main endoskeletal structure of *amphioxus* is the notochord.

 It is long, cylindrical & terminally tapering rod, which extends longitudinally from one end of the body to the other.

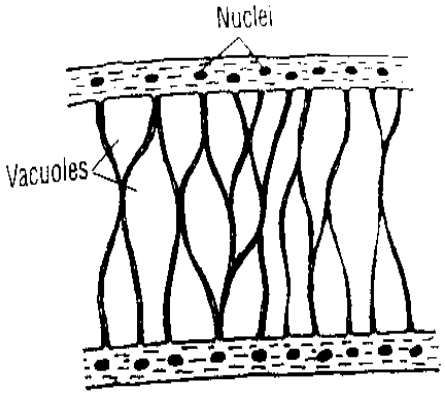
 It lies in the dorso – median line, below the nerve cord & above the alimentary canal.

 It extends beyond the myotomes at both ends.

 At the anterior end, it projects a little beyond the nerve cord also.

 This is for the burrowing habitat.

 Notochord is formed of specialized notochordal tissue, which is formed of large vacuolated fluid – filled cells.



Section of notochord

 Presence of large vacuole , the cytoplasm & nucleus of the cells are pushed towards the periphery.

 This pressure counterbalances the inward external pressure & thereby makes the notochord stiff & elastic.

 Notochord is enclosed within a *notochordal sheath* , it has 2 layers

1. Outer primary or elastic sheath (elastica externa) – formed by elastic connective tissue.

2. Inner secondary or fibrous sheath – formed by fibrous connective tissue.

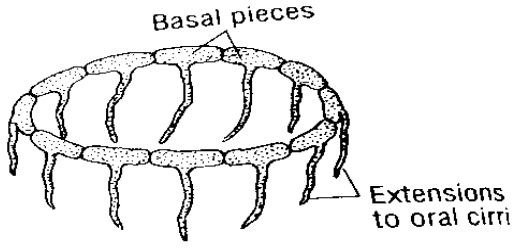
 Function of notochord to prevent the body from shortening when myotomes contract during locomotion.

 Skeletal elements are also seen in oral hood, dorsal & ventral fin folds and the gill bars of pharynx.

 These are only hardened connective tissue.

 Supporting the oral hood, is an annular ring of several cartilaginous pieces.

 The number of pieces is equal to the number of buccal cirri.



Skeleton of oral hood

 Each piece is seen at the base of a cirrus.

 Supporting the dorsal & ventral fin folds are connective tissue boxes, called fin rays.

 Dorsal fin has single series of fin rays, where as ventral fin has two series.

 Gill bars (pharyngeal wall between gill slits) are supported by stiff & slender gelatinous rods, known as gill rods.

Atrium

 Atrium is a spacious internal cavity that surrounds the pharynx ventrally & laterally.

 It is also called *peribranchial cavity.*

 Gill slits opens to atrium, which in turn open to outside by *atriopore*.

 Brown funnels/ atriocoelomic canals – a pair of forwardly directed pockets in the posterior end of pharynx.

 The function of brown funnels is not definitely known, they are suspected to have an excretory role.

 Sub atrial ridge – during the formation of atrium, each metapleural folds give out an inward ridge.

 Epipleur - The right & left ridges grow further, meet together & fuse to form a transverse shelf .

 Atrium is a part of a passage for a continuous water current.

Coelom

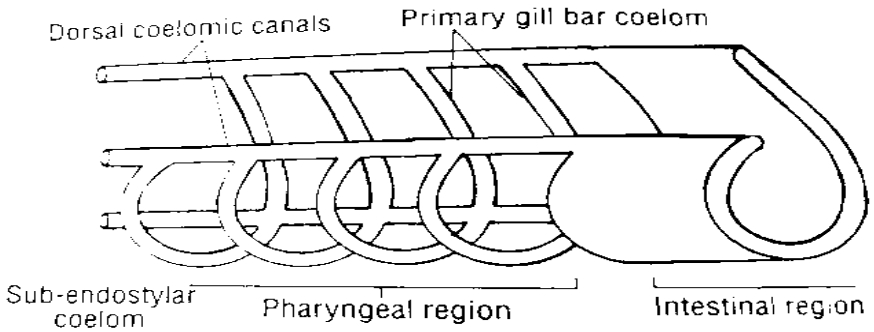
 Enterocoelic coelom, derived from archenteron.

 It is lined by mesodermal epithelium or peritoneum.

 In the intestinal region, behind the pharynx, coelom is spacious perivisceral cavity in which the alimentary canal is suspended by a dorsal mesentery.

 In the pharyngeal region of adult, coelom is represented by certain coelomic canals.

 Dorsal / dosopharyngeal coelomic canals – two dorso- lateral longitudinal canals, one on each side of the epipharyngeal groove.



Amphioxus - Coelomic spaces

 Sub-endostylar coelom – unpaired longitudinal canal, located midventrally below the endostyle (a glandular & ciliated tract on the pharyngeal floor) .

 Primary gill bar coelom – sub endostylar coelom connected to the dorso-lateral coelomic canals by paired vertical coelomic canals. They run along the primary gill bars.

Digestive system

 Alimentary canal is straight & unspecialized tube, extending between mouth & anus.

 Epithelial lining is richly ciliated.

 Alimentary canal is differentiated into mouth, vestibule, enterostome, pharynx, oesophagus, mid gut, ileo colonic ring, hind gut & anus.

 Mouth is a wide opening, seen in the lower part of oral hood.

 Mouth → vestibule → pharynx.

Pharynx

 Largest & widest part of alimentary canal.

 Perforated by numerous gill slits / visceral clefts.

 Gill slits are long, narrow & closely set, and arranged in vertical rows.

 Gill bars / branchial lamellae – narrow vertical strips of the pharyngeal wall, which separate successive gill slits. Two types – primary & secondary.

 Gill rods / branchial rods - Gill bars are supported by gelatinous skeletal rods.

 Primary gill bars – first formed bars, developed during the larval stage. It is composed partly of pharyngeal wall & body wall. It contains a persistent coelomic space, called *primary gill bar coelom.*

 Secondary gill bars – also called tongue bars, are the downgrowths from the dorsal wall of the primary gill slits. It divides the primary gill slits into secondary.

 Primary & secondary bars are richly ciliated.

Cilia on anterior & posterior faces – *lateral cilia*
Cilia on inner face – *frontal cilia*
Cilia on outer face – *atrial cilia*
Inner phase is covered by endodermal epithelium.
Outer phase by ectoderm.

 Primary rods are terminally forked, where as secondary ones are not forked.

 Primary rods contains extensions of dorso-lateral coelom, which are absent in secondary rods.

 Sinapticulae - primary & secondary bars are bridged by branchial junctions. They are stiffened by gelatinous skeletal rod & transversed by blood vessels. This appears like a complete basket-work & hence called *branchial basket.*

 Pharyngeal wall are provided with ciliated grooves. Dorso- median groove is called *epipharyngeal / hyperbranchial groove.*

 Ventro- median groove is termed as *hypobranchial grove / endostyle.*

 Peripharyngeal groove – these two grooves joins behind the velum.

Endostyle

 It is a shallow glandular gutter, lined with ciliated cells.

 Floor cilia – long cilia on the median strip.

 Mucus secreting glandular cells are alternating with ciliated cells.

Oesophagus

 It is a short narrow ciliated groove.

 Pharynx oesophagus mid gut.

 Mid gut diverticulum (liver diverticulum / hepatic caecum) – forwardly extending pouch on the right side of the junction of oesophagus & mid gut. Produces digestive secretions.

Ileo-colonic ring

 Short region followed by mid gut.

 Hind gut - Ileo-colonic ring opens to hind gut, which opens outside by anus.

Food & feeding

 Amphioxus is a microphagous ciliary filter feeder.

 Food collection depends entirely on an incoming water current,

 Mouth pharynx gill slits atrium atriopore.

 Food current is maintained by the action of pharyngeal cilia.

Mechanism of food concentration

 During feeding, oral cirri are kept inwardly turned & folded over one another, forming a fine sieve.

 This block sand & other large particles.

 Very fine food particles enter the pharynx.

 Endostyle secretes mucus, endostylar cilia will soon transfer the mucus to the ventro-lateral walls pharynx.

 Food particles get entangled in the mucus.

 Frontal cilia carry the food-laden mucus to the epipharyngeal groove.

 This mixture is swept to the oesophagus by the action of cilia in the epipharyngeal groove.

 The food & mucus passes down the gut by the action of cilia.

 It is moved from the oesophagus into the midgut where a lateral tract of cilia directs it into the midgut diverticulum from here the cord is returned again into the midgut.

 The ileo-colonic ring rotates the cord of food causing the food & enzymes to mix.

 Then the food is moved too hind gut.

Digestion & absorption

 Digestive enzymes are secreted by the epithelial cells of the gut & midgut diverticulum.

 They are mixed with food as it passes along.

 Digestion starts in the midgut & continued in the hindgut.

 Besides this extracellular digestion, intracellular digestion also occurs in which food particles are taken to the epithelial cell of the hindgut & digested there.

 Some papillae in the floor of atrium contain phagocytic cells which engulf food particles which may pass to the atrial cavity.

 Absorption takes place mainly in the hind gut & to lesser extent in the midgut. Some may takes place in caecum.

 The undigested residue & mucus are ultimately passed out by ciliary action.

Primitive characters

1. There is no specialized head.
2. Absence of paired limbs or fins.
3. Enterocoelus coelom.
4. Persistent notochord.
5. Complete myotonic segmentation.
6. Simple circulatory system without heart.
7. Straight alimentary canal without local specializations.
8. Simple & single layered epidermis.
9. Segmental gonads without gonoducts.
10. Lack of biting jaws.
11. Endostyle & ciliary mode of feeding.
12. Paired sense organs are absent.

Degenerate features

1. Poorly developed brain & simple sensory organs.
2. Lack of cartilaginous or bony endoskeleton.
3. Lack of gonoducts.

Specialized (secondary) features

1. Greately enlarged & elaborate pharynx.
2. Secondary multiplication of gill slits, raising their number much higher than the number of myotomes in which they occur.
3. Elaborate velum & oral hood equipment.
4. Anterior extension of notochord.
5. Formation of large atrium with atriopore.

Affinities & systematic position

Chordate affinities

 Presence of notochord, dorsal tubular nerve cord & pharyngeal gill slits.

Affinities with Hemichordata

 Pharyngeal apparatus with numerous gill slits & gill bars.

 Filter feeding mechanism.

 Respiratory mechanism.

 Entercoelous coelom.

 Numerous gonads without gonoducts.

Affinities with Urochordata

 Presence of numerous gill slits endostyle, epipharyngeal groove, peripharyngeal band, atrium & ciliary mode of feeding.

 Formation of notochord & nervous system.

Affinities with Cyclostomata

 Elongated, slender, fish like body.

 Continuous dorsal median fin.

 Mouth surroundeed by an oral hood.

 Presence of velum.

 Pharynx with an endostyle & gill slits.

 Presence of dorsal hollow nerve cord & notochord.

Affinities with Vertebrata

 Presence of post anal tail.

 Metameric myotomes.

 Coelom lined by mesodermal epithelium.

 Midgut diverticulum comparable with liver.

 Well formed hepatic portal system.

 Direction of blood flow is forward ventrally & backward dorsally.

Systematic position

1. The organization of amphioxus is very primitive & so it is an extremely primitive vertebrate.

2. The simplicity & organization of amphioxus is a secondary feature & so it is a degenerate descendant of early vertebrates.

3. It is a modified & degenerate ostracoderm (armoured & fish-like fossil agnathan), which has lost its armour.

4. It is a generalized form in the direct line of vertebrate ancestry. Its specialized features undoubtedly make it clear that amphioxus cannot be the direct ancestor of vertebrates, but it represents an early offshoot from the main line of vertebrate evolution, with obvious specializations for a sedentary mode of life.

MODULE 4
SUB PHYLUM VERTEBRATA

- Vertebrates are the chordates with vertebral column in the adult, partially or completely replacing the nervechord.
- Development of vertebral column is always accompanied by the development of cranium. So vertebrates are also called as craniates.
- Fully formed vertebrae with true centrum are found only in jawed vertebrates.
- Vertebrates are the chordates with vertebral column, cranium, complex brain, specialized sense organs, chambered & valvular heart & red blood corpuscles.

Salient features

1) ***Notochord in the embryo & vertebral column in adult.***
   - Notochord in embryo is partially or completely replaced by vertebral column.
2) ***High degree of cephalization***
   - Formation of distinct head region. Head region accommodates brain & sense organs.
3) ***Well developed nervous system & brain case***
   - There is a complex brain enclosed in cranium.
   - Sense organs are well developed & sensory perception is very high
   - Sensory & motor types of cranial & spinal nerves are present.
4) ***Gill slits & visceral arches***
   - Pharyngeal wall is perforated by gill slits, whose number is highly reduced.
   - Gill slits may be embryonic (amniota), larval (frogs) or present throughout life (fishes).
   - *Visceral or branchial arches* – series of skeletal elements in between the gill slits, which support the branchial wall.
   - Some of them get modified as jaws in jawed vertebrates.
5) ***Well developed endoskeleton***
   - There is a well developed cartilaginous or bony endoskeleton.
   - It gives form, shape, support & protection to the body.
   - It provides surfaces for the attachment of muscles.
   - It functions as levers in locomotion
6) ***Metamerism***
   - It is exhibited as arrangement of paired mesodermal somites in embryo & in adult in the arrangement of vertebrae, muscles, nerves,..
7) ***Closed type circulatory system***
   - Heart is chambered, valvular & myogenic, blood vesssels are tubular & blood is red coloured.
   - Haemoglobin is found in RBC's.
   - Blood flow is forward ventrally & backward dorsally.
8) ***Massive liver & pancrease***

- Liver & pancrease are large, and they develop as outgrowths from the gut.
- Liver is an important metabolic centre.
- Pancrease is a heterocrine gland, with enzyme secreting exocrine & hormone-secreting endocrine parts.

9) Mesodermal kidneys

- Vertebrate excretory organs are mesodermal kidneys.
- They are tubular glands, formed of mesodermal renal tubules & provided with a discharging duct.
- There are three types of kidney, namely pronephrous (hag fishes), mesonephrous (embryonic kidney of amniotes) & metanephrous (adult kidney of amniotes).

10) Schizocoelic coelom

- Coelom is schizocoelic, formed by the splitting of mesblast.

11) Development of neural crest

- Neural crest is the embryonic tissue, found in vertebrates.
- It give rise to head region especially the sense organs.
- Neural crest is an independent germ layer on par with ectoderm, mesoderm & endoderm.

12) Tripartite brain

- The brain of vertebrates is large & primarily three segmented, with fore brain (prosencephalon), mid brain (mesencephalon) & hind brain (rhombencephalon).

13) ***Duplication of Hox gene complex***

- Hox gene complex is characteristic of most animals.
- With increase in evolutionary complexity of organisms, there happened an increase in their genetic material also.

Classification

<table>
<tr><td colspan="3">Phylum vertebrata</td></tr>
<tr><td colspan="2">Infra phylum</td><td>classes</td></tr>
<tr><td colspan="2">Agnatha</td><td>1. Ostracodermi
2. Cyclostomata</td></tr>
<tr><td rowspan="2">Gnathostomata</td><td>Super class Pisces</td><td>1. Placodermi
2. Chondrichthyes
3. Osteichthyes</td></tr>
<tr><td>Super class Tetrapoda</td><td>1. Amphibia
2. Reptilia
3. Aves
4. Mammalia</td></tr>
</table>

Agnatha

- Agnatha is a group of primitive, jawless & fish like aquatic vertebrates.

- Nutrition is predatory & carnivory.
- They have pouches in the passages between pharynx & the exterior.
- The lining of the walls of these pouches bears gills.
- There is distinct cranium & an axial support by notochord.
- Nostril is single & median – monorhine condition.
- Paired fins are absent or without fin rays.
- Gonad is unpaired with gonoduct.
- Agnatha is classified into *ostracodermi & cyclostomata.*

Ostracoderms

- It includes extinct forms.
- They are small fish like, heavily armoured & jawless primitive vertebrates.
- They are filter feeding & bottom dwelling freshwater forms.
- Eg:- Pteraspis, Paraspis.

Cyclostomata

- Commonly called round mouthed or pouched gilled animals.
- They are the only representatives of primitive group of ancient vertebrates.
- They are *living fossils*.

Salient features

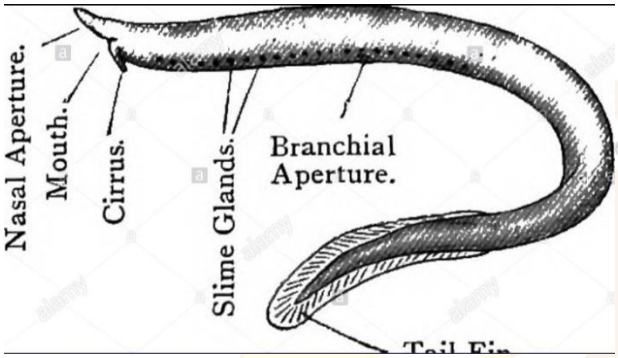
1. Long slender & cylindrical body, covered by soft, scaleless & glandular skin.
2. Paired lateral appendages are absent.
3. Antero – ventral, funnel like & sectorial mouth, without biting jaws.
4. Single median nostril (monorhine condition).
5. Persistent notochord & completely cartilaginous endoskeleton.
6. Vertebrae are represented by small imperfect neural arches, called *arcualia*, which are arranged over the notochord.
7. Straight alimentary canal without pancreas & spleen.
8. Two chambered heart with an auricle & a ventricle.
9. Multiple aortic arches in the gill region.
10. *Marsipobranchs (gill pouches)*– gills are arranged in paired lateral pouches.
11. Two kidneys with duct to urinogenital papillae.
12. Nervous system has a well differentiated brain & 8-10 pairs of cranial nerves.
13. Unpaired gonad, without gonoduct.
14. Fertilization is external. Development may be direct or indirect.
15. Indirect development involves *ammocoetes* larva.

Cyclostomes are grouped under two orders, namely Petromyzontia & Myxinoidea .

Petromyzontia includes lampreys & Myxinoidea includes hagfishes.

Myxine

- Commonly known as *hagfishes or slime eels.*
- They are exclusively marine & primarily deep- sea forms & cold water inhabitants.
- They enjoy world wide distribution, except in polar region.
- They never migrate to fresh water for breeding.
- Hag fishes are eel like scavengers, predators or ectoparasites subsisting mostly on carcasses & live fishes.
- They detect the carcasses by means of their sense of smell.
- The body of hagfish is long & cylindrical. It is covered by a soft, scaleless & glandular skin, provided with unicellular mucous glands.

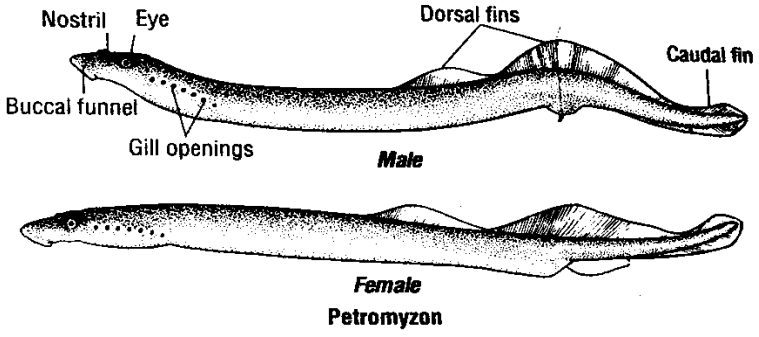


- Buccal funnel & teeth are lacking.
- Mouth is provided with two horny plates, armed with horny tooth like strutures.
- Around the margin of mouth tentacles (barbels) are present.
- Nostril is single median & terminal. It is connected to the pharynx by a broad nasopharyngeal tube.
- Paired lateral eyes are rudimentary & hence functionless.
- The only functional visual organ is the median & unpaired *pineal eye*, located on the top of the head.
- Vertebrae are altogether absent & the branchial basket is reduced.
- There are six pairs of gill pouches, they do not open directly & separately. Leading from each pouch is a long exit canal which join together posteriorly & form a common *branchial duct*. It opens out by a single *branchial pore*.
- The adult functional kidney is *pronephros*.
- In the internal ear of hagfishes, there is only a single semicircular canal.
- They have several hearts, large blood sinuses & low blood pressure.
- Accessory hearts are seen near the liver & caudal region. These hearts are aneural.
- They are hermaphrodites.
- They lay eggs which remain attached to the sea weeds.
- Development is direct without a larval stage.

Petromyzon

- It is an eel like marine animal, with distinct head, trunk & tail.
- They are similar to hag fishes in size & shape.
- Lampreys are carnivorous & true predators.
- At thhe anterior end of the head & directed downwards is a basin like depression called *buccal funnel or oral sucker.*
- It is surrounded by a marginal membrane, whose outer surface is provided with numerous *sensory cirri & overlapping oral fimbriae*.
- Projecting from the bottom of the buccal funnel is a protrusible prominence, called *rasping tongue*.
- Head bears a pair of well-developed , large & lidless lateral eyes, covered by transparent skin.
- On the mid dorsal surface of the head, is a median nostril.
- The skin is smooth & heavily pigmented, without exoskeletal structures.
- It has three parts, epidermis, dermis & muscular layer.
- Endoskeleton is formed of notochord, & the cartilaginous plates of tongue, buccal funnel,…
- They have cartilaginous vertebral structures called *arcualia*

- Skull is differentiated into cranium & sense capsules
- Sense capsules includes auditory & olfactory capsules.
- Digestive tract is straight & uncoiled tube, differentiated into mouth, buccal cavity, pharynx, oesophagus, intestine, rectum & anus.
- Hanging from the dorsal wall of intestine to the lumen is a longitudinal & spiral fold called *typhlosole.*
- The respiratory system consist of seven pairs of *gill pouches* in the pharyngeal region.



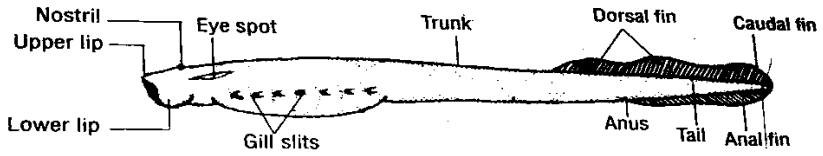
Petromyzon

- Blood vascular system is of closed type. It consist of heart, blood & blood vessels. Heart has three chambers namely atrium, ventricle & sinus vinosus. It is enclosed within a pericardium.
- The excretory organs are a pair of mesonephric kidneys.
- Nervous system consist of brain, spinal cord, nerves & sense organs. The major sense organs include pineal apparatus, paired lateral eyes & internal ears, olfactory organs & lateral line organs.
- Sexes are separate in adult, but young ones are hermaphrodites.

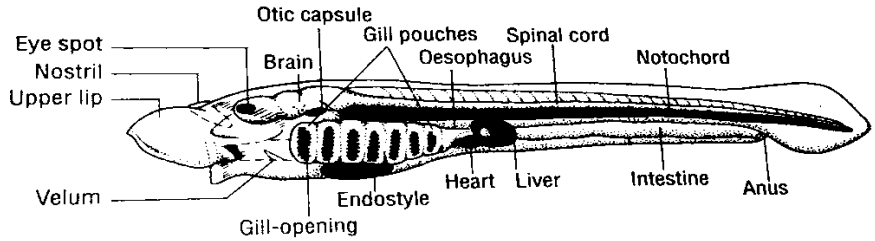
- Fertilization is external. Development is indirect with *ammocoetes larva*.

Ammocoetes larva

- It is the larva of petromyzon.
- It is a tiny, transparent creature similar to *Amphioxus*.
- The body of ammocoetes is thin & laterally compressed.
- Mouth is guarded below the lower lip, above the upper lip & oral hood.
- Pharynx is ciliated, & perforated by seven pairs of gill slits.
- The intestine of ammocoetes is straight & uncoiled.
- Liver, gall bladder & bile duct are present, though they are absent in the adult.
- It has a ventral heart.
- Nervous system consists of a distinct brain, auditory & olfactory sacs.
- Paired lateral eyes are functionless, hence the larva is blind.
- It has a larval life of three to seven years.
- The two major instinctive responses of the larva are *photokinesis & thigmokinesis*.



Ammocoete larva - external



Ammocoete larva - internal

Metamorphosis

- Its oral hood transforms to a round buccal funnel, armed with horny teeth.
- The continuous fin fold gets interrupted to form dorsal, caudal & anal fins.
- Paired lateral eyes grow out to the surface & become functional.
- The mucus-secreting endostyle which has been a feeding organ transforms to the endocrine thyroid gland.
- Pronephros gets replaced by mesonephros adult kidney.

Gnathostomata

- They are the vertebrates with toothed biting jaws & paired fins or limbs.
- Anteriorly enlarged & elongated cranium.
- Nasal capsules open out by a pair of nostrils.

- Complete vertebrae with distinct centrum & attached ribs.
- Presence of conus arteriosus.
- Atrium is postero-dorsal to ventricle.
- Presence of renal portal vein.
- Presence of true stomach & distinct spleen.
- Heterocrine pancreas, with exocrine & endocrine functions.
- Myelinated nerve fibres.
- Ovaries with distinct oviducts.
- Male gonoducts are linked to renal ducts.

MODULE 5

SUPERCLASS PISCES

- Pisces are cold blooded, aquatic, gill breathing, oviparous vertebrates.
- Streamlined body, covered by overlapping mesodermal scales, denticles, bony plates,…
- Paired fins & nostrils.
- Vertebrae partially or completely replaced by notochord.
- Digestive system has well developed stomach & pancreas.
- Opisthonephrous is the adult functional kidney.
- Neuromast organs for perceiving the movements & pressure changes in the surrounding water.
- Eggs are heavily yolked.

Classification of pisces

Super class	*Class*	*Sub class*	*Super order*	*Order*	*Sub order*
Pisces	Placodermi				
	Acanthodii				
	Chondrichthyes	Selachii (Elasmobranchii)	_____	Cladoselachii	
				Pleurocathodi	
				Protoselachii	
				Euselachii	Pleurotremata Hypotremata
		Bradyodonti	_____	Eubradyodonti	
				Holocephali	
	Osteichthyes	Sarcopterygii	_____	Osteolepidoti Coelacanthini Dipnoi	
		Actinoptrygii	Chondrostei	Acipenseroidea Polypterini	
			Holostei	Seminotoidea Amioidea	
			Teleostei	Isospondyli Ostariophysi Apodes Heteromi Mesichthyes Acanthopterygii	

Class Chondrichthyes

- It is a group of almost exclusively marine cartilaginous fishes.
- The group includes sharks, skates, chimaeras,…
- The largest fish ever lived on earth, come under this group.
- The largest living fish is the tropical whale shark.
- They are cartilagenous fishes.
- Exoskeleton consist of dermal denticles or placoid scales.
- Jaw suspension is hyostylic or amphistylic.
- Gills are lamelliform, operculum is absent.
- Mouth & external nostrils are ventral, internal nostrils are absent.
- Lungs & gas bladder absent.
- Cloaca present.
- Claspers are present in males as a copulatory organ.
- Tail is heterocercal.

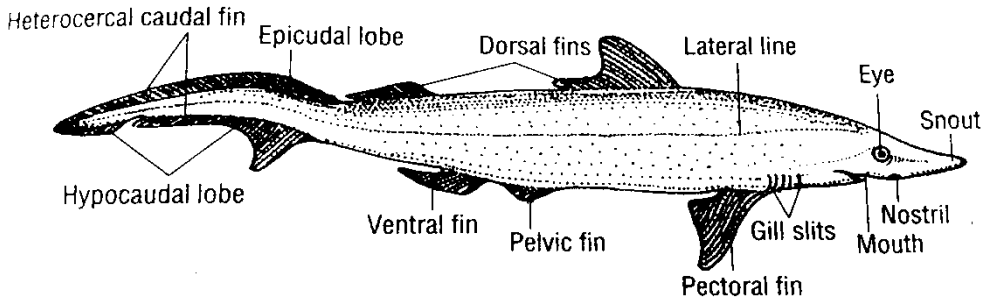
Sub class Selachii

- It includes four orders, of these three are extinct & the euselachii includes both extinct & living forms.

Order Euselachii

- It includes sharks, skates, rays,…
- Scales are placoid.
- Ventral mouth with teeth.
- Prominent pre-oral rostrum.
- Hyostylic or amphistylic jaw suspension.
- Presence of claspers.
- Absence of operculum.
- Eg:- Scoliodon & Trygon

Scoliodon



Super class : Pisces

Class : Chondrichthyes

Sub class : Selachii

Order : Euselachii

- Commonly called *Indian sharks*.
- They are marine cartilaginous fish inhabiting oceans & seas.
- It has an elongated, spindle shaped body tapered at the ends, making it a fast swimmer.
- The tail & trunk are laterally compressed, head region is dorsoventrally compressed.
- Presence of placoid scales.
- Head bears mouth, eyes, nostrils & gill slits
- Mouth is located ventrally.
- Two rows of teeth – homodont or polyphyodont.
- Eyes are lateral, each eye is provided with movable upper & lower eyelids & a transparent nictitating membrane.
- Trunk bears paired lateral fins & unpaired median fins.
- They conceive 8-19 embryos at a time

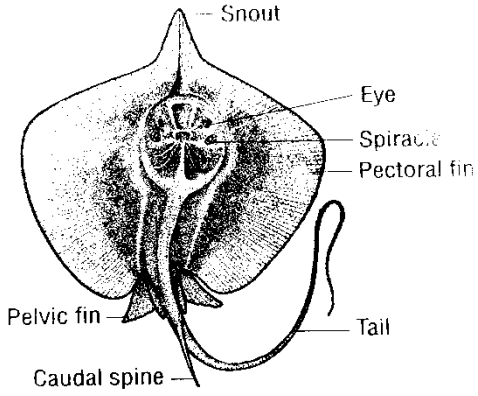
Trygon

Super class : Pisces

Class : Chondrichthyes

Sub class : Selachii

Order : Euselachii



Trygon

- Commonly called *sting ray or whip tailed ray*.

- They are bottom dwelling forms.
- Body is flat, oval or rhomboidal disc.
- Snout slightly pointed.
- Eyes & spiracles are dorsal & mouth, gill slits, nostrils are ventral.
- Pectoral fins are large. They continue anteriorly up to the snout.
- Caudal & dorsal fins are absent.
- Tail is long slender & whip like & armed with one or two erectile spines or stings.
- Carnivorous fish feeding on small fishes, crustaceans & molluscs.
- It is ovoviviparous.
- During the embryonic development numerous long, glandular filaments called , are formed in the uterine wall of the female. They secrete milk nutritive fluid to nourish the embryo.

Sub class Bradyodonti

- It includes both fossil & modern chimaeras.
- It includes two orders, of these Eubradyodonti includes extinct forms & Holocephali comprises living forms.

Order Holocephali

- Very ancient group of cartilaginous fishes.
- Naked skin with very few placoid scales, extra claspers.
- Four pairs of gill slits.
- Hyostylic jaw suspension.
- Intestinal spiral valves & unconstricted notochord is present.
- They are marine & deep sea forms.
- Eg:- Chimaera

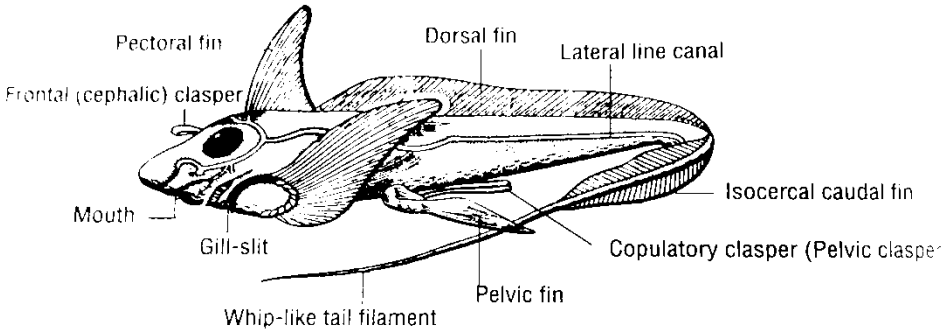
Chimaera (Hydolagus)

Super class : Pisces

Class : Chondrichthyes

Sub class : Bradyodonti

Order : Holocephalii



Chimaera monstrosa - Male

- Popularly known as *silver shark, king of herrings, rabbit fish,…*
- It is noted for its grotesque appearance.
- Endoskeleton is entirely cartilaginous.
- Smooth & scaleless body surface.
- Mouth armed with fleshy lips & tooth plates.
- Gills are covered by non skeletal operculum.
- Single branchial opening.
- Absence of spiracle & presence of long dermal spine in the first dorsal fin.
- Caudal fin is isocercal.
- Male has a pair of transverse slits, just infront of the pelvic fins, leading to shallow glandular pouches which lodge a pair of anterior claspers.

Class Osteichthyes

- They are the group of bony fishes.
- Embryonic endoskeleton is cartilaginous & adult endoskeleton is composed of membraneous bones & cartilages.
- Scales are of three types : *cycloid, cosmoid & ganoid.*
  Cycloid – circular or elliptical with concentric rings.
  Cosmoid – outer coat of *cosmine,* middle layer of *spongy bone* & an inner layer of *bony lamellae.*
  Ganoid – upper shining layer of *ganoine* & lower layer of *isopedin*.
- Caudal fin is *homocercal, diphycercal or gephyrocercal.*
  Homocercal – dorsal & ventral lobes are symmetrical externally & asymmetrical internally.
  Diphycercal – two lobes are symmetrical externally & internally.
  Gephyrocercal – pointed homocercal or heterocercal fin.
- Mouth is terminal or sub terminal.
- Nostrils are dorsal.
- Gills & gill openings are covered by operculum.
- Autostylic jaw suspension.

Sub class Sarcopterygii

- Popularly known as *lobe-finned fishes*.
- It comprises extinct osteolepids & the living coelacanths & lung fishes.
- Lobe like paired fins.
- Cosmoid scales.
- Presence of spiracles.
- Single or double air bladder.
- Presence of internal nostrils.
- Circulatory system modified for air breathing.
- It includes three orders Osteolepidoti, Coelacanthini & Dipnoi.
- Osteolepidoti is the extinct form.

Order Coelacanthini (Crossopterygii / Actinistia)

- Scales are cosmoid.
- Two dorsal fins & pedunculate, lobe like & scale covered paired fins.
- Diphycercal caudal fin.
- Calcified air bladder.
- Absence of internal nostrils & presence of external nostrils.
- Eg:- *Latimeria chalumnae smith*

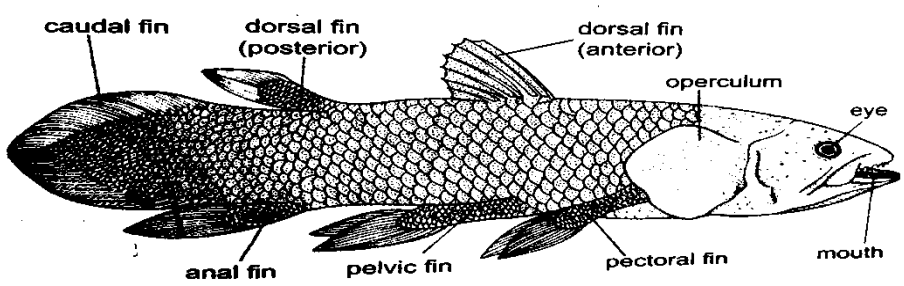
Latimeria chalumnae smith

Super class : Pisces

Class : Osteichthyes

Sub class : Sarcopterygii

Order : Coelacanthini



- Marine deep water forms.
- Diphycercal tail.
- Pedunculate, lobular & scale covered paired fins.
- Presence of external nostrils & absence of internal nostrils.

Order Dipnoi

- Popularly known as *lung fishes*.
- Diphycercal or gephyrocercal tail.
- Cycloid scales.
- Internal nostrils.
- Autostylic jaw suspension.
- Spiral valve in intestine.
- Presence of one or two lungs.
- They enjoy discontinuous distribution.
- Eg:- *Protopterus, Lepidosiren, Neoceratodus*.

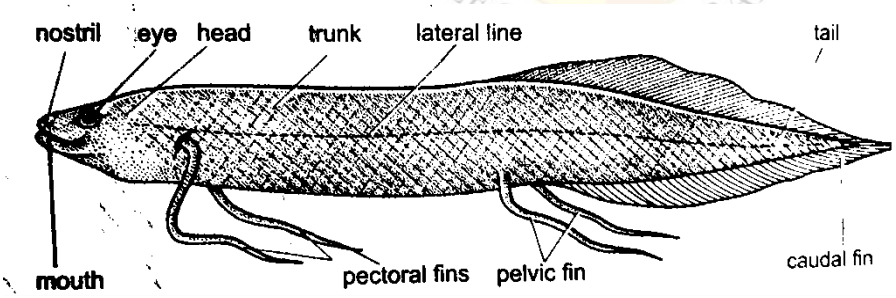
Protopterus

Super class : Pisces

Class : Osteichthyes

Sub class : Sarcopterygii

Order : Dipnoi



- They are *African lung fish*.
- Inhabitants of marshes & swamps.
- Body is eel-like, with slender & tapering paired fins.
- Caudal fin is gephyrocercal.
- Scales are small & deeply buried in the skin
- Four paired of gill slits, covered by opercula
- Gills may be present in vestigial form.

- Lungs are paired.
- During extreme dry season they may undergo aestivation.
- It burries deep into the mud, as flask like tube. It will remain in the soil keeping its tail over the head.
- During breeding season, female deposits eggs in a water filled hole on the margin of a pool. Male discharges sperms over them & fertilization takes place.
- Egg hatches in a week & the larvae remain clinged to the nest with the help of their cementing organs. Then they come out & transforms to adult.

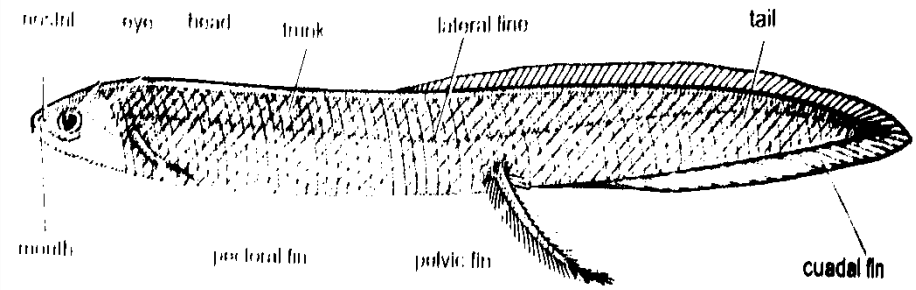
Lepidosiren

Super class : Pisces

Class : Osteichthyes

Sub class : Sarcopterygii

Order : Dipnoi



- It is the *South American lung fish.*
- Inhabitants of marshes, stagnant fresh water bodies.
- Body is eel like. Scales are small & deeply burried in the skin.
- Fins are reduced to short styles.
- Tail is gephyrocercal.
- During dry season they dig a deep tubular burrow in the mud & undergoes aestivation. The entrance of the burrow would be plugged with a holed mud stopper.
- During rainy season female deposits eggs in L-shaped excavations. Males discharges sperms over them for fertilization.
- Males remains inside the burrow until the egg hatch out in to the larvae. He lashes his pelvic fins to aerate the larvae.
- The larval life lasts for two weeks.

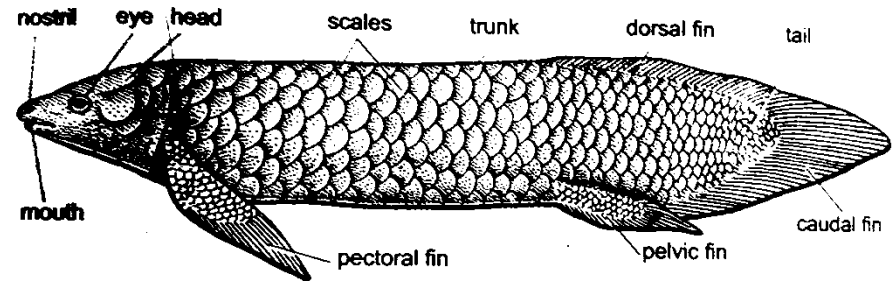
Neoceratodus

Super class : Pisces

Class : Osteichthyes

Sub class : Sarcopterygii

Order : Dipnoi



- It is the *Australian lung fish*.
- It lives in shallow pools or water-holes & comes to the surface only for breathing air.
- Since, it is a sluggish food it is an easy victim of man.
- Body is fusiform & covered with small scales.
- Median fins are represented by the continuous fin fold, formed fusion of dorsal, caudal & anal fins.
- Caudal fin is gephyrocercal.
- Gills are covered by opercula.
- During dry season, they comes to the surface & gulps air.
- It digs deep into mud & undergoes aestivation during extreme conditions of drought.
- Development is direct without any larval stage.

Sub class Actinopterygii

- Commonly called *ray finned fishes*.
- Includes fresh water & marine fishes.
- Fins are devoid of basal pieces & fin web is supported by bony fin rays.
- Scales are cycloid & ganoid.
- Tail is homocercal, heterocercal or rarely diphycercal.
- Gills are filiform & covered by bony operculum.
- No trace of internal nostrils.
- Spiracles & internal spiral valves are absent in advanced forms.

Super order Chondrostei

- Popularly known as *sturgeons.*
- Heterocercal tail.
- Five pairs of gill slits.
- Partly cartilaginous endoskeleton.
- Presence of spiracles.
- Reduced number of bones.
- Two orders :- *Acipenseroidea & Polypterini*.
- Eg:- *Acipenser*

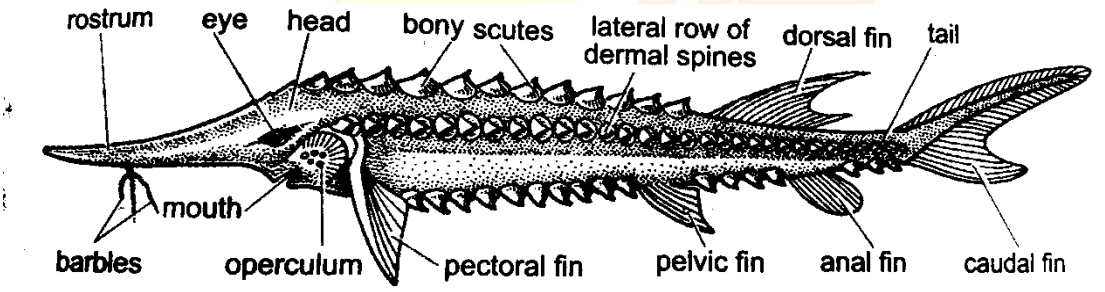
Acipenser

Super class : Pisces

Class : Osteichthyes

Sub class : Actinopterygii

Order : Acipenseroidea



- Commonly called *sturgeons*.
- Long & flat snout or rostrum, with four chin barbels.
- Suctorial ventral mouth.
- Week & toothless jaws.
- Heterocercal tail.
- Posteriorly placed dorsal fin.
- Open spiracles.
- Five rows of bony scutes or bucklers on the body.
- Dermal denticles in between the scutes.
- Rhomboid scales over tail & dorsal fin
- They are important edible & commercial fishes.
- Caviarre – renowned delicacy, is the cured & processed eggs of European sturgeons.
- The gas bladder of sturgeons yields high quality isinglass, used for the production of gelly, glue,.. & also for the clarification of wine & beer.

Super order Holostei

- It includes two orders – Seminotoidea & Amioidea.
- Eg:- Lepidosteus & Amioidea

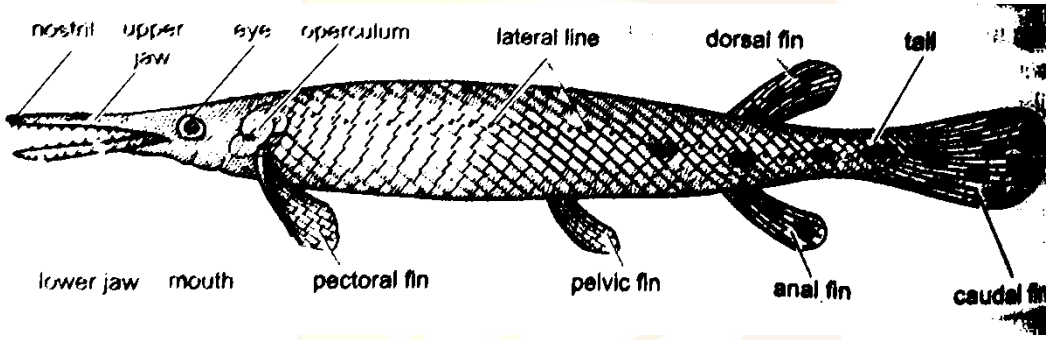
Lepidosteus

Super class : Pisces

Class : Osteichthyes

Sub class : Actinopterygii

Order : Seminotoidea



- Commonly called *gar pike*.
- It is a fresh water form.
- Body is long with an armour of thick rhomboid & ganoid scales, coated with ganoine.
- Tail is semi heterocercal.
- Spiracles are closed.
- Jaws are elongated, toothed & produced into sword like beak.
- Single air bladder
- Vertebrae are opisthcoelous.

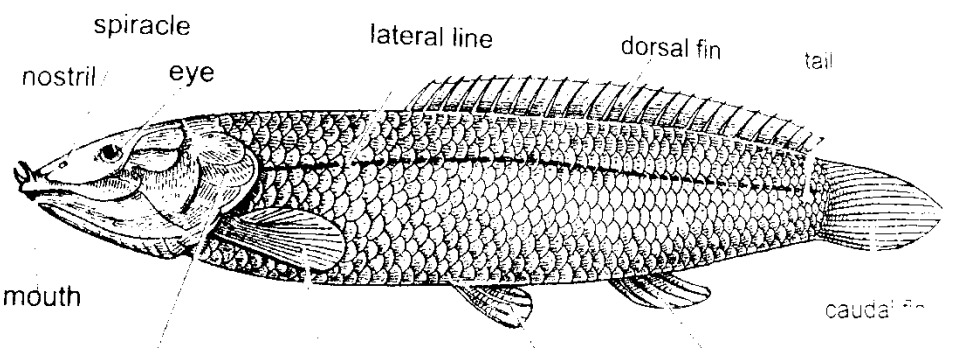
Amia

Super class : Pisces

Class : Osteichthyes

Sub class : Actinopterygii

Order : Amioidea



- Commonly called *bow-fin*.
- Fresh water fish.
- Cycloid scales are present, which do not have a coating of ganoine.
- Tail is homocercal.
- Single dorsal fin which extends over the greater part of the trunk & tail.
- Mouth is terminal.
- Snout bears a pair of barbels.
- Vertebrae are amphicoelous.
- Air bladder is present.
- Male is characterized by a dark spot on the tail.
- Females lay eggs in the nest & males take care of them.

Super order Teleostei

- Comprises vast majority of modern bony fishes.
- Homocercal or gephyrocercal tail.
- Cycloid or ctenoid scales.
- Four pairs of gill slits covered by operculum.
- Filiform gills.
- Ossified endoskeleton.
- Amphicoelous vertebrae.
- Presence of swim bladder.
- Includes the orders, Isopondyli, Ostariophysi, Apodes, Heteromi, Mesichthyes & Acanthopterygii.

Isopondyli

Primitive, spineless & soft rayed fishes, with abdominal pelvic fins, pre-maxilla & maxilla in the upper jaw & physostomous gas bladder with open duct.

Eg:- *Salmons*

Ostariophysi

Includes the fresh water fishes in which some anterior vertebrae form a chain of bones called *Webberian ossicles*, which connect the air bladder to the internal ear.

Eg:- *Carps, Catfishes*

Apodes

Comprises fresh water & marine eels. Carnivorous fishes. Body elongate, cylindrical & naked or scaly. Pelvic fin is reduced or absent. Pre maxilla replaced by vomer.

Eg;- *Electrophorous*

Heteromi

Comprises deep sea fishes. Head, trunk & tail long. True caudal fin has become lost & replaced by a long anal & a dorsal.

Eg:- *Holosaurus*

Mesichthyes

Includes bony fishes with soft fin rays. Pelvic fins are abdominal. There is a tendency for the elongation of pre-maxilla & also to exclude maxilla from the upper jaw.

Eg:- *Hippocampus, Exocoetes*

Order Acanthopterygii

Includes the fishes with spiny dorsal & ventral fins. Ventral fins are far infront of the trunk. Maxillae are toothless. Scales are usually cycloid.

Eg:- *Mullet, Sardine, Rastrelliger, Etroplus*

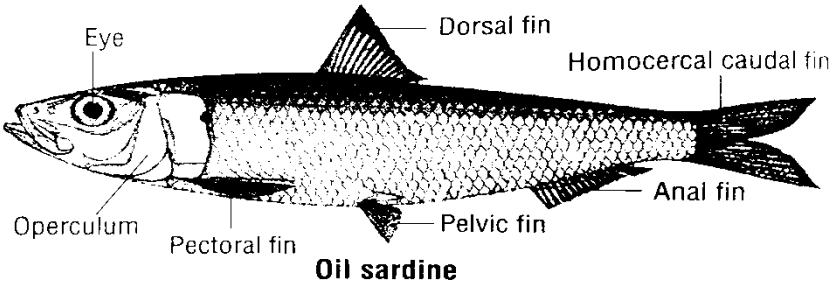
Sardinella

Super class : Pisces

Class : Osteichthyes

Sub class : Atinopterygii

Order : Malacopterygii



Oil sardine

- Commonly called *sardine*.
- Edible marine bony fish, living in large shoals in almost all seas.
- There are several varieties of sardines.
- Of these *Sardinella longiceps*, or the oil sardine, is of supreme importance in economic production and consumer preference.
- Oil sardine is common along the coasts of India, Pakistan, Sri Lanka,…
- The body of sardines is soft & sleak, & covered by cycloid scales.
- Trunk is laterally compressed & ventrally keeled, with a series of ventral scutes.
- Fins are spineless & soft rayed.
- Oil sardine is distinct from other species in having elongated body, long head, & equally convex dorsal & ventral profile.
- Its dorsal fin is located more towards the tail.
- Caudal fin is *homocercal* & deeply forked with black & pointed tips.
- It has two alar plates at its base.
- Pelvic fin is abdominal.
- Gill slits are wide & covered completely by operculum.
- Large pseudobranchiae are present.
- Body is bluish green above with golden reflections, & it is silvery white below.
- Sardines are the most important part of Indian pelagic fisheries.
- They are economically very important.
- They form a major source of food for the common man.
- Their flesh is a rich source of water, proteins, fats, phosphorous, calcium & iron.
- Sardine oil is used in jute industry, leather industry, soap industry,…

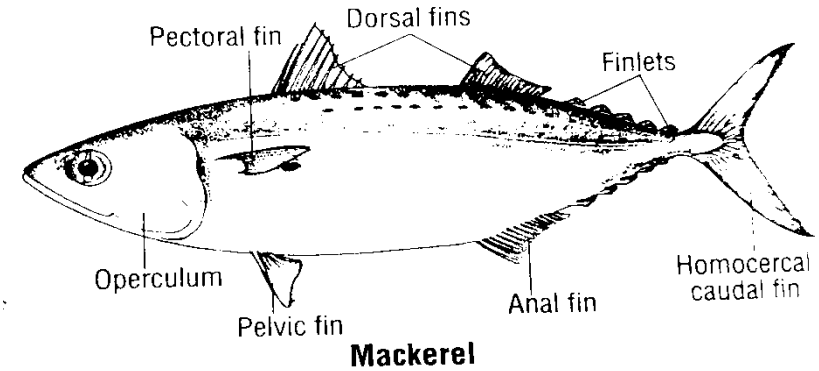
Rastrelliger

Super class : Pisces

Class : Osteichthyes

Sub class : Actinopterygii

Order : Acanthopterygii



Mackerel

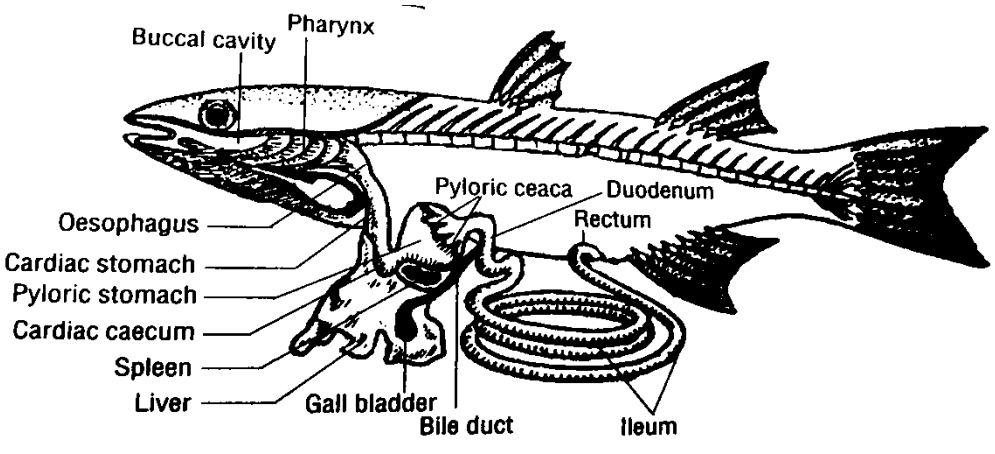
- Commonly called *mackerel*.
- It is an important food fish.
- It is widely distributed in the Indian & Pacific ocean.
- Body is soft & laterally compressed.
- It is bluish green to grey above & yellowish on sides & belly.
- The upper half may have three longitudinal grey stripes.
- Rows of irregular greyish blotches may also be present on the back.
- Head is longer than broad with a pointed snout.
- Mouth is large & oblique, with toothed jaws.
- Tail is narrow & equipped with a deeply forked *homocercal* caudal fin.
- Behind the dorsal fin & anal fin there is a series of small finlets.
- Mackerels are surface feeders.
- They feed on planktons.
- They move in large shoals.
- They have enormous fecundity.
- They also form the major part of pelagic fisheries.
- They are widely used as food & for the preparation of fish products.

Type : *Mugil cephalus* (Grey Mullet)

- Mullet is an edible marine bony fish.
- Inhabiting the coastal seas, estuaries & brackish waters.

- *Mugil cephalus* enjoys world wide distribution.
- It is olive green on back, silvery grey on flanks & has 6-8 light brown bands across the body.
- Mullet is a herbivore which feeds on the vegetation of the muddy bottom.
- They are *euryhaline*.
- The body is scale covered, moderately elongated & almost oblong, with slightly depressed head & short and blunt snout.
- Body is divisible into *head, trunk & tail*.
- Mouth is terminal & is devoid of teeth.
- A pair of external nostrils are present laterally at the anterior end of the head.
- Behind the nostrils, are the eyes.
- Eyes are devoid of eyelids.
- Behind the head there are four pairs of gills.
- On each side they are covered by a bony shield called *operculum*.
- Operculum encloses opercular chamber.
- Gill slits open to the opercular chamber.
- The locomotor organs of *Mugil* are the fins.
- There are two sets of fins, namely unpaired median fins & paired lateral fins, supported by bony fin rays.
- Median fins include two dorsal fins, an anal & the caudal fin.
- Paired fins include two pectoral fins & two pelvic fins.
- The caudal fin is homocercal & bilobed.
- *Hypural arches* : In the tail, vertebral column gets shortened & upturned. The neural arches of the upturned vertebrae are reduced, whereas their haemal arches are considerably enlarged & flattened & are called hypural arches.
- *Abdominal pelvic fins* : The pelvic fins of *Mugil* are located a little behind the pectoral fins.

Digestive system



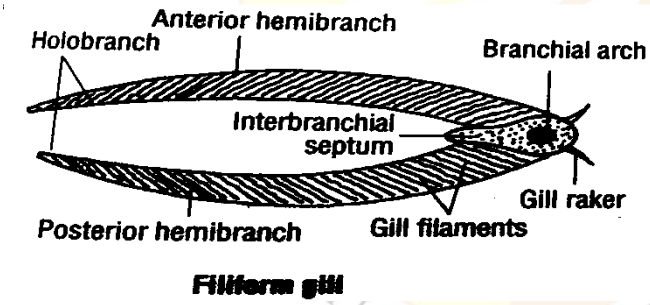
Mullet - Digestive system

- Consist of alimentary canal & associated digestive glands.
- As an adaptation for herbivory, the alimentary canal is long, tubular & highly coiled.
- Alimentary canal is differentiated into mouth, buccal cavity, pharynx, oesophagus, stomach & intestine.
- Intestine opens out by anus.
- Mouth is terminal & almost transverse.
- It is bordered by upper & lower toothless jaws.
- Buccal cavity is a spacious chamber, with a muscular tongue on its floor.
- Buccal digestion is absent.
- Pharynx is perforated by four pairs of gill slits.
- *Pharyngeal teeth* : teeth seen at the junction between pharynx & oesophagus. It serve as a filtering apparatus to filter out the mud contained in the food.
- Oesophagus is a narrow tube extending between pharynx & stomach.
- *Oesophageal valve* : The opening of oesophagus to stomach is guarded by a valve which prevents the regurtitation of food rom stomach.
- Stomach is well developed with two divisions, namely anterior cardiac stomach & posterior pyloric stomach or gizzard.
- Cardiac stomach is tubular & relatively thin walled, whereas pyloric stomach is globular & thick walled.
- *Cardiac caecum* : Junction between cardiac & pyloric stomach.
- Internal lining of the cardiac stomach contains numerous longitudinal folds.
- Intestine is long & narrow. It has three divisions duodenum, ileum & rectum.
- Duodenum is the short & uncoiled first part of the intestine that immediately follows pyloric stomach.
- *Pyloric caecum* : Junction between duodenum & pyloric stomach, glandular & tubular outgrowths produced by the pyloric stomach.
- *Pylorus* : Construction in between duodenum & pyloric stomach.
- Pyloric sphincter : Pylorus is guarded internally by a muscular sphincter.
- Ileum is long & highly coiled middle part of the intestine, devoid of spiral valve.
- It is the major centre of digestion & absorption.
- It terminates in the rectum which opens out by anus.
- Digestive glands include liver & pancrease.
- Liver is a lobular gland, consisting of upper, middle & lower lobes.
- Lying embedded in the lower lobe is the gall bladder.
- Leading from the gall bladder is the cystic duct.
- Cystic duct joins three hepatic ducts (from three lobes) & forms a common bile duct that opens to the ileum.
- The glandular cells of the liver secrete bile.
- Bile is drained by numerous bile channels which merge together to form bile capillaries.
- Bile capillaries join together to form hepatic ductules which joins to form large hepatic duct.

- Pancrease lie in between stomach & duodenum.
- Leading from pancrease is the pancreatic duct which opens to the duodenum.
- *Spleen* : Solid & dark-red lymphoid body outside the stomach.
- It is concerned with the chemical modification, functional maturation & storage of lymphocytes.

Respiratory system

- Gills are the respiratory organs of mullet.
- They are four in paires in number.
- Gills are lodged in an extra-branchial chamber or gill chamber on each side of the pharynx.
- Pharynx communicates with each extra-branchial chamber by four gill-slits.
- Extra branchial chamber opens outside by the *branchial aperture*.
- Gill chamber is covered by the bony operculum.
- *Branchiostegal fold* : The free edge of operculum is modified into a thin fold.
- *Interbranchial septum* : The branchial wall between adjacent gill-slits.
- Gills are attached to it.
- Gills are *filiform or pectinate*.



Filiform gill

- *Holobranch* : Gill filaments are born on both sides of the gill arch.
- *Hemibranch* : The gill filaments on each side constitute a half gill.
- The inter branchial septa are very much reduced, so the gill filaments freely hang into the extra branchial chamber.
- *Spiracular pseudobranch* : On the inner surface of the operculum of mullet, is a red patch.

Mechanism of respiration

- During respiration, the gill filaments are bathed by an incoming water current.
- *Oral valves* : The flow of this water from buccal cavity to pharynx is controlled by a pair of oral folds. These will prevent the back flow of water.
- Respiratory movements are carried out by the pharynx.
- Bucco-pharyngeal cavity & gill chambers function as suction pumps.
- Water is drawn in through mouth & passed out through branchial apertures.

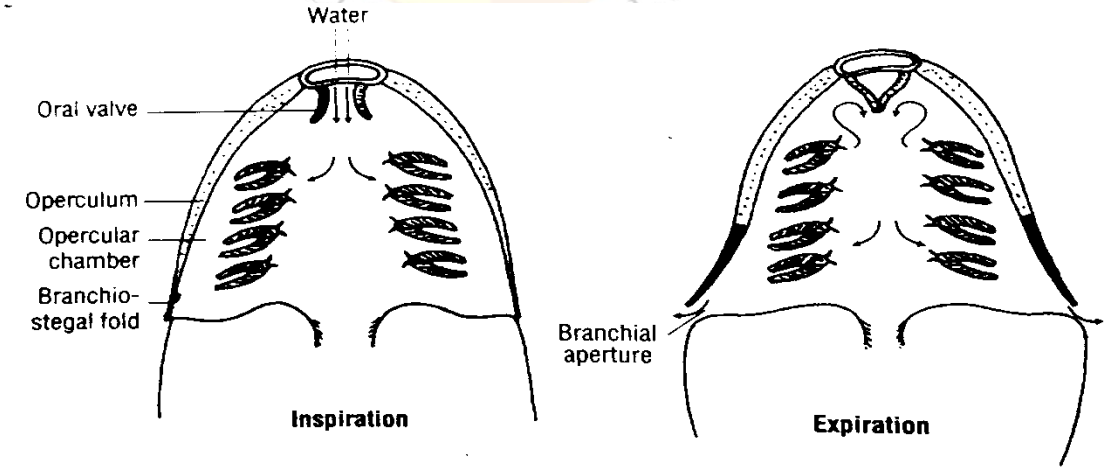
- Richly vascular gill filaments are bathed by this water, respiratory exchange takes place through the thin & permeable capillary walls.
- Respiration completes in two steps : Inspiration & expiration.

Inspiration

- Inflow of water from outside to the extra branchial chamber.
- During inspiration, the branchio-stegal folds of opercula are kept tightly pressed against the body wall. This completely closes the branchial apertures.
- Opercula are raised & the gill arches are relaxed laterally by muscular activity. This increases the volume of extra branchial chamber & expands the bucco pharyngeal cavity.
- Water rushes into the buccal cavity from outside, forcibly pushes apart the oral valves, fills the pharynx, enters the extra branchial chamber through the gill slits & bathes the gills.
- Gas exchange takes place between the O_2 in the water & the CO_2 in the capillary blood.

Expiration

- After the gas exchange, the oral folds come close to each other & prevent the free flow of water into & out of the buccal cavity through mouth.
- The branchio-stegal folds are released from the body wall, branchial apertures open widely.
- This permits the free escape of water from the extra branchial chambers to the outside
- Opercula & branchial arches return to their original position by muscular activity.
- This exerts pressure on the water contained in the chamber & drives it out through the branchial apertures.



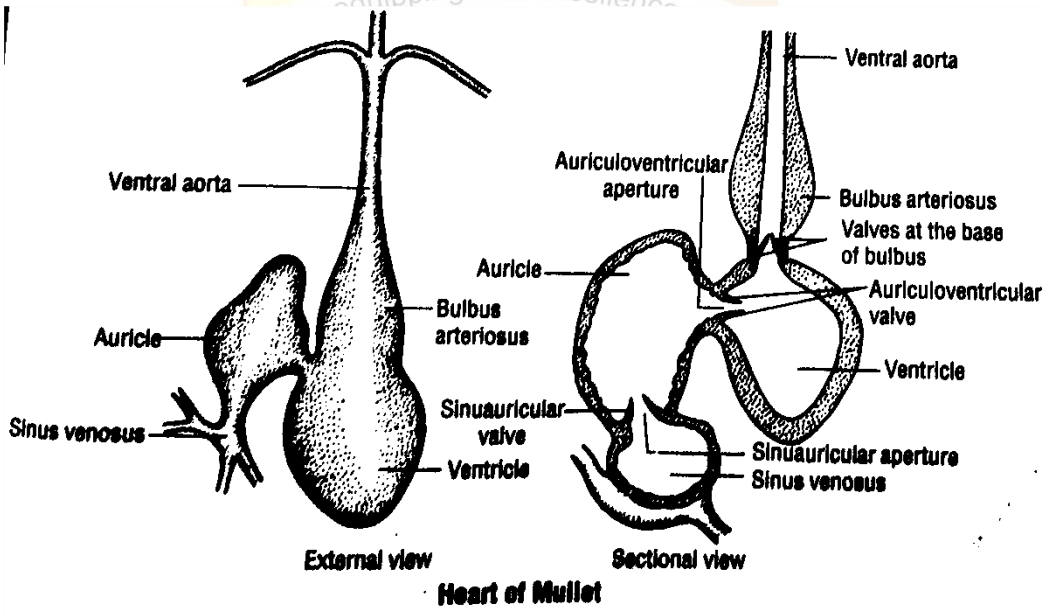
Mullet - Course of water current during respiration

Circulatory system

- Closed type blood vascular system.
- Blood is the circulating fluid.
- Blood supplies the body cells nutrients, vitamins, enzymes, hormones & oxygen.
- Blood removes CO_2, nitrogenous wastes & toxic substances from the cell.
- Heart is the muscular pumping organ, concerned with the collection & pumping of blood.
- Arteries are the blood vessels which carry blood from the heart.
- Veins are the blood vessels which carry blood to the heart.

Heart

- Heart is a dorso-ventrally bent tube, lying in the anterior portion of the body cavity.
- It is enveloped by a double layered *pericardium*.



Heart of Mullet

- Pericardium encloses the *pericardial cavity* which is filled with *pericardial fluid*.
- Heart is differentiated into three parts,
  Sinus venosus
  Atrium
  Ventricle
- Sinus venosus & auricle are the receiving chambers.
- Ventricle is the forwarding chamber.
- Sinus venosus opens to the atrium through the *sinu-atrial aperture*, which is guarded by *sinu-atrial valve*.
- Atrium opens to the ventricle through *atrio-ventricular aperture*, guarded by the *atrio-ventricular valve.*
- The heart is always filled with deoxygenated blood, hence it is called *venous heart.*

Arterial system

Arterial system has two divisions, namely *afferent branchial system & efferent branchial system.*

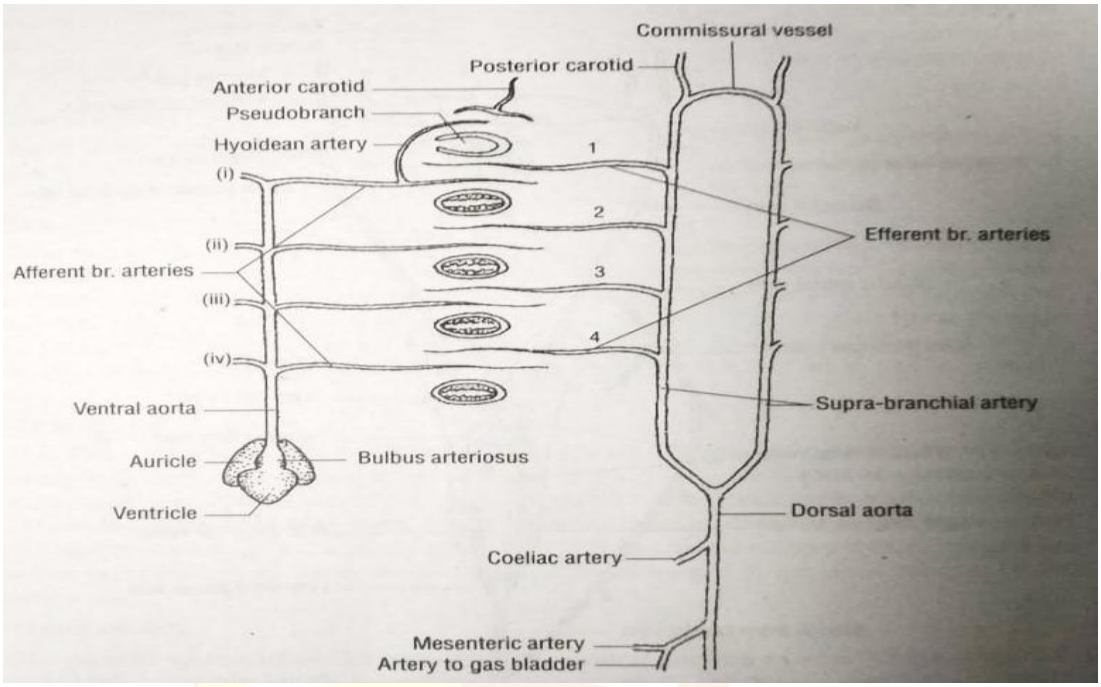
a) Afferent branchial system

- The arteries which carries venous blood from heart to gills for oxygenation.
- It begins with a median *ventral aorta,* from the ventricle.
- At its beginning there is an elastic , non contractile expansion – *Bulbus arteriosus*.
- *Bulbus arteriosus* – helps to maintain the normal blood pressure.
- Ventral aorta gives out four pairs of *afferent branchial arteries* to the gills.
- Blood from pseudobranch region is carried to the head by an *anterior carotid artery* on each side.

b) **Efferent branchial system**

- Arteries which carry oxygenated blood from gills to different body parts.
- Oxygenated blood from gills is collected by four pairs of *efferent branchial arteries*.
- On each side, the four efferent branchials join together & form an *epibranchial or supra branchial artery.*
- Anteriorly, the right & left epibranchials are connected together by a *transverse commissural vessel.*
- From the commissural vessel, a pair of *posterior carotid arteries* are given to the head.
- Posteriorly, the two epibranchials join together to form a dorso-median vessel called, *dorsal aorta*.
- *Circulus cephalicus or cephalic circle* - the two epibranchials form a circular vessel.
- The major arteries from dorsal aorta

i) *Coelic artery – to stomach & liver*
ii) *Mesenteric artery – to intestine & pancrease*
iii) *Gas bladder artery – to gas bladder*
iv) *A pair of pectoral arteries – to petoral fins*
v) *A pair of renal arteies – to kidney*
vi) *A pair of gonadial arteries to gonads*
vii) *A pair of pelvic arteries – to pelvic fins*
viii) *A pair of segmental arteries – to body wall*
ix) *Caudal artery – to tail region.*

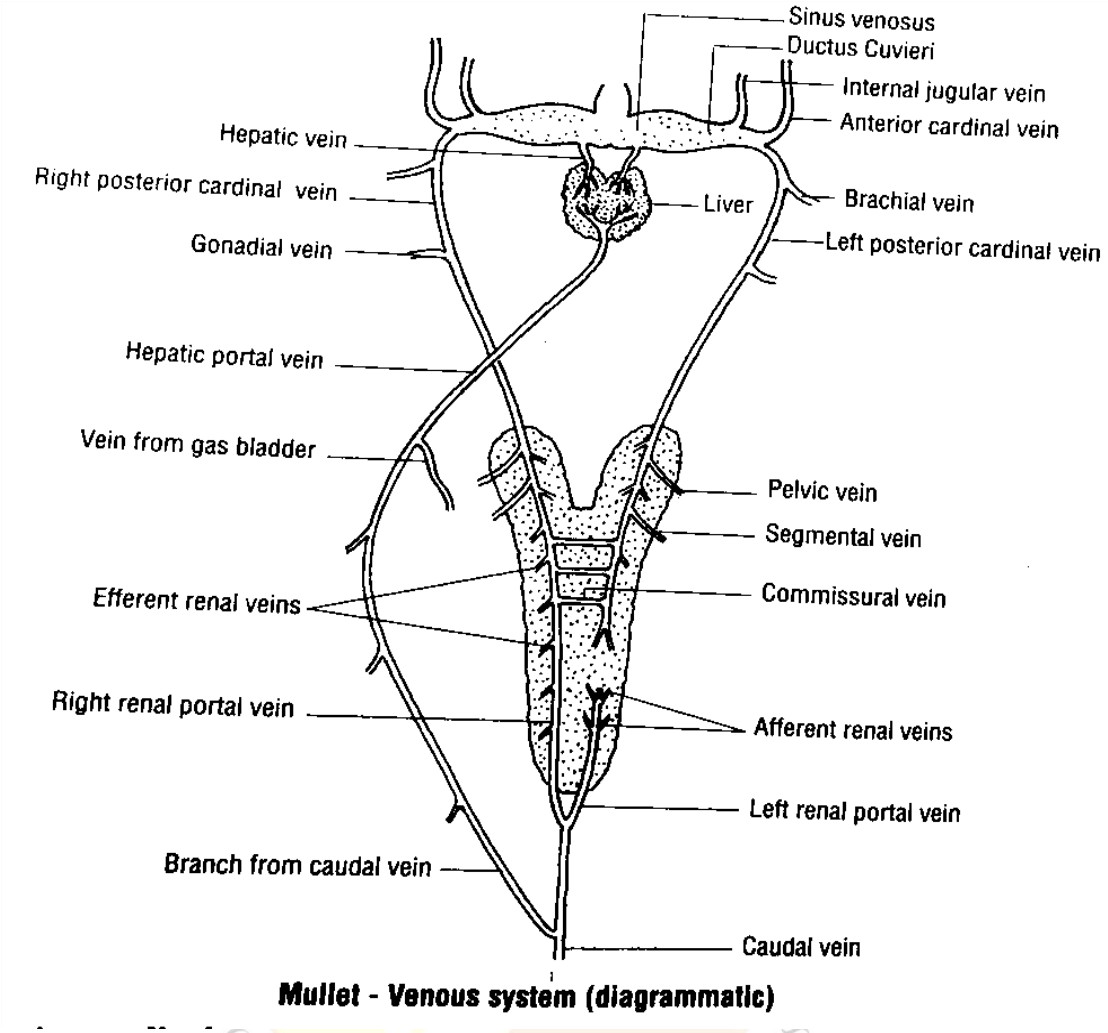


Venous system

- The deoxygenated blood, collected from the different parts of the body, is ultimately emptied to the sinus venosus through a pair of pre-caval veins & a pair of hepatic veins.
- Each pre-caval vein is formed by the union of three major veins,
  Anterior cardinal veins
  Inferior jugular vein
  Posterior cardinal vein
- The venous system can be sub divided into five
  i) Anterior cardinal system – from head
  ii) Posterior cardinal system – from kidneys & dorsal body wall
  iii) Hepatic portal system – from alimentary anal to liver
  iv) Renal portal system – from tail to kidneys
  v) Cutaneous system – from skin & body wall

Anterior cardinal system

- Anterior cardinal system collects blood from the head region.
- It consists of a pair of veins on each side, namely an *anterior cardinal vein* and *inferior jugular vein.*
- Anterior cardinal collects blood from the dorsal part of the head, & inferior jugular from the buccal floor & branchial region.
- Both these veins terminally join the pre-caval vein of their side.



Mullet - Venous system (diagrammatic)

Posterior cardinal system

- Posterior cardinal system carries blood from the kidneys & trunk region.
- It consists of the *right & left posterior cardinal veins.*
- Each of them is formed by the union of several *efferent renal veins* from the kidney.
- Joining it posteriorly, are two major veins, namely a *pelvic vein* from the pelvic fin & a *segmental vein* from the body wall.
- Anteriorly the *brachial vein* from the pectoral fin & the *gonadial vein* from the gonad.
- In the region of kidney the right & left posterior cardinals may be joined by *transverse commissural veins.*

Portal system

- It is formed by *portal veins.*
- Portal veins are the veins which begins & ends in branches.
- The two sub divisions are *renal portal system* & *hepatic portal system.*

Renal portal system

- It drains blood from tail to kidneys.
- It begins with a *median caudal vein* in the tail, formed by the union of smaller veins.
- On entering the body cavity, caudal veins divides into *right & left renal portal veins*.
- *Afferent renal veins* : Left renal portal vein enters left kidney & breaks up into branches.
- Right renal portal vein directly joins the right posterior cardinal vein.
- From kidneys, blood is drained by the *efferent renal veins*, which join the right renal portal & right and left posterior cardinal veins.

Hepatic portal system

- It carries blood from alimentary canal to liver.
- It consists of large *hepatic portal vein*, formed by the union of small veins from the alimentary canal, liver, pancrease, gas bladder, caudal region,…
- Hepatic portal vein enters the liver, breaks up into branches & empties the blood collected from the tail & posterior part of the body.
- From liver, blood is discharged to the sinus venosus by the *hepatic veins.*

Neuromast organ

Lateral line system

- Also called *lateralis system*.
- A system of tactile sense organs, unique to aquatic vertebrates from cyclostomes to amphibians.
- It serves to detect movements & pressure changes in the surrounding water.
- It is made up of a series of mechanoreceptors called *neuromasts* (lateral line organs).
- Neuromasts are arranged in an interconnected network along head & body.
- It may be arranged on the surface of the skin.
- In most fishes they are embedded in the floor of mucous filled structures called lateral line canals.
- These canals are placed just underneath the skin & only the receptor portion of each neuromast extends into the canal.
- Neuromasts are made up of a cluster of sensory & support cells encapsulated within a jelly like sheath called the *cupula*.
- Each sensory cell bears several small cilia & each cilium may be stimulated by water movement or pressure.
- Lateral line system allows the fish to determine the direction & rate of water movement.
- The fish can then gain a sense of its own movement, that of nearby predators or prey & even the water displacement of stationary objects.

Urino-genital system

- Urinary & genital systems share some common ducts.
- The two systems are collectively termed *urino-genital system*.

Urinary organs

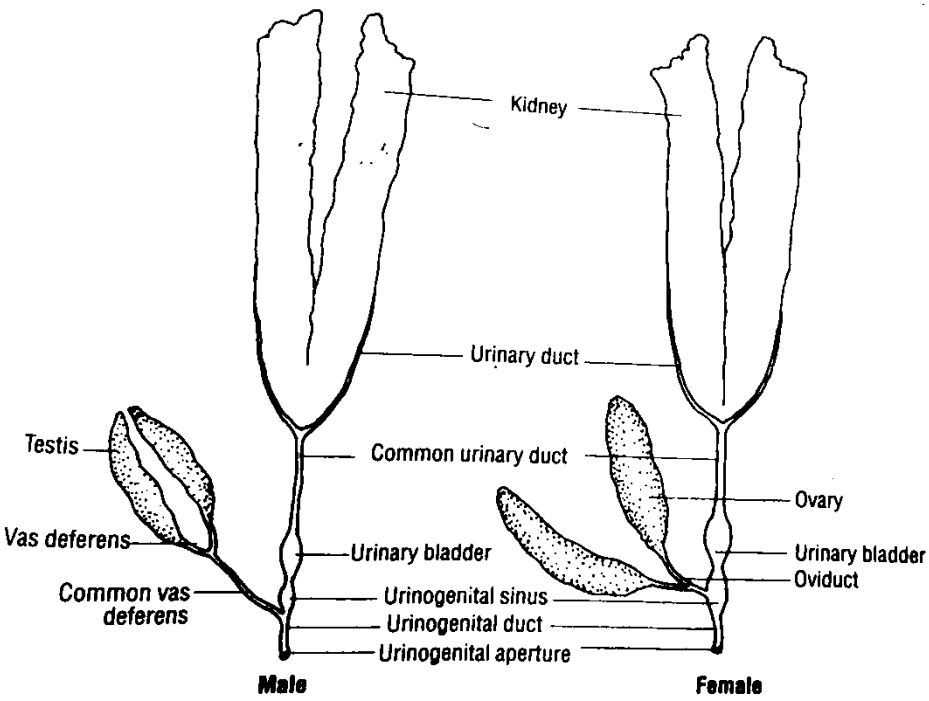
- The urinary system of mullet consists of a pair of *opisthonephric kidneys*, lying in between the vertebral column & gas bladder.
- They fuse together posteriorly, but are free anteriorly.
- Kidneys are compound tubular glands, formed of coiled renal tubules, called *uriniferous tubules.*
- Each kidney has anterior non-renal part & posterior renal part, & hence the name opisthonephrous or opisthonephric kidney.
- In male, the non-renal part has a genital role.
- But in female, the non-renal part is functionless.
- Leading backward from each kidney, is a urinary duct.
- Terminally, the right & left urinary ducts join together & form a *common urinary duct* which expands to a thin-walled *urinary bladder*.
- The bladder leads to the *urino genital sinus*, which in turn opens out by the *urino genital opening.*

Male genital system

- The male organs of mullet consist of a pair of testes.
- *Mesorchium* – testes is suspended from the body wall by a fold of peritoneum.
- *Vasa efferentia* – numerous minute sperm ductules from each testes.
- *Vas deferens* – vasa efferentia joins together & form a large sperm duct.
- Right & left vasa deferentia join together & form a common duct which opens to the uringenital sinus.
- Copulatory organs are absent.

Female genital system

- Female organ consist of a pair of compact, massive & saccular ovaries, which occupy the posterior part of the body cavity.
- *Mesovarium* – ovary is suspended from the body wall by a peritoneal fold.
- Leading from each ovary, is an *oviduct*.
- The two oviducts, join together & form a short common oviduct which opens to the urinogenital sinus.



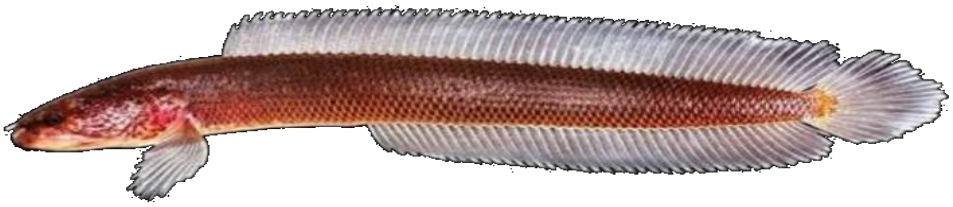
Mullet - Urinogenital system (diagrammatic)

Fertilization & development

- Mullet is oviparous.
- Female discharges large number of eggs & male discharges sperms to water.
- Fertilization is external.
- Eggs are *megalecithal*, cleavage is *meroblastic* & development is direct.
- Fry – 2-3 mm long hatched young ones.
- Fingerlings – 5-15mm long young ones.

Sub terranean fishes of kerala

Aenigmachanna Gollum



- Commonly called "Gollum snakehead".
- It is discovered in the 2018 flood, from the paddy field in Oorakam
- It is a troglophilic subterranean fish.
- Endemic to kerala.

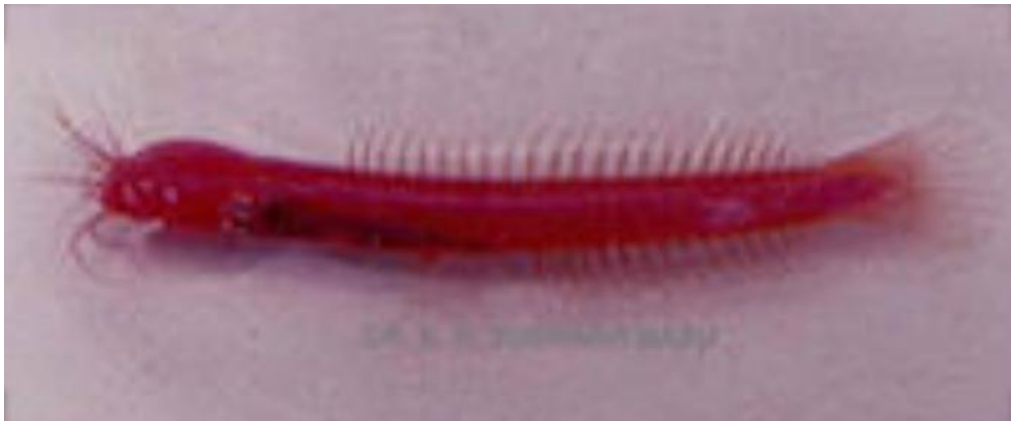
- They lack visual sense & sense mainly on olfaction, gustation & mechanoreception.
- Body is longer & slender with numerous scales.
- Very long anal fin.
- Lack of ability to maintain byoyancy.

Kryptoglanis shajii

- Subterranean catfish.
- Discovered in September 2011 from Chalakkudy.
- Inhabiting underground springs.
- Upturned mouth.
- Sub- cutaneous eyes.
- Projecting lower jaw.
- Four pairs of barbels.
- Fan shaped & spineless pectoral fins.
- Confluence of anal fin with caudal fin.
- No spines in any of the fins.
- Absence of dorsal fin.
- Fish is deep reddish brown in colour for perfect camouflage.
- It is highly photophobic – avoids light

Horaglanis krishnai

- Also called blind *cat fish.*
- Small sized, blind & cave dwelling subterranean cat fish.
- Endemic to western ghats.
- First discovered in 1950.
- Airbreathing cat fish.



- It lives underground water channels.
- They lack pigmentation & eyes.

Monopterus digressus

- Also called blind cave eel.
- Dicovered in 2002.
- Eyeless & cord-like eel.
- Olfactory as well as tactile stimuli are used for sensing.

Sahyadria denisonii

- Miss kerala.
- Also called Denison barb, red line torpedo barb or roseline shark.
- It is an endangered species.
- Endemic to Western Ghats.
- Used as a ornamental fish.
- Body is torpedo shaped, with silvery scales.
- A red line is running from snout to the middle of the body through eyes & a black line that runs from snout to tail below the red line.

- On attaining sexual maturity, a conspicuous blue or green marking appears on the top of the head.
- Female is larger, heavier & less colourful than male.
- Denisons barb is a bentho-pelagic & gregarious fish.
- The fish is crepuscular – active during twilight hours.

MODULE 6

CLASS AMPHIBIA

Amphibians were the first vertebrates to shift their homes from freshwater to land.However,they could not complete their conquest of the land.The group gets its name from the double mode of life(land and water).



SALIENT FEATURES

• Cold-blooded

• Amphibious vertebrates

• Naked and glandular skin

• 2 pairs of pentadactyl limbs

• Trilocular heart

• *3 major groups-tailless amphibians(frogs and toads),tailed amphibians(salamander) ;and tailless and limbless amphibians(caecilians) .*

A.SHARED DERIVED CHARACTERS

1. Moist,glandular and respiratory skin
2. Pedicellate teeth
3. Papilla amphibiorum
4. Operculum-plectrum(columella) complex
5. Green rods in retina
6. Levatorbulbi muscle

B.OTHER DISTINCTIVE FEATURES

1. Two pairs of pentadactyl limbs

2. Autostylic jaw suspension

3. Diplocondylian skull

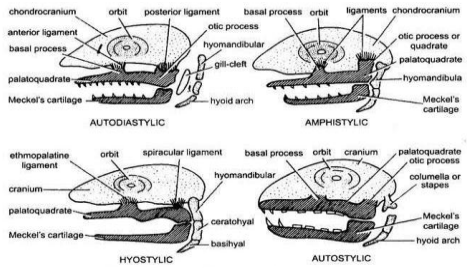


Fig. 42.7. Types of jaw suspensoria in vertebrates.

4. Trilocular heart

5. External ear absent

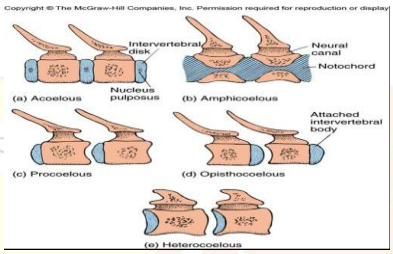
6. Fish-like aquatic larva

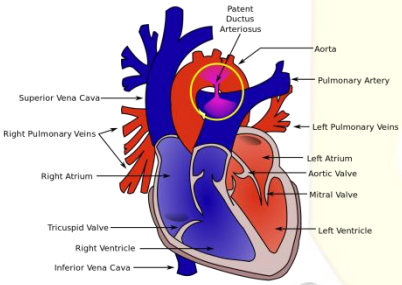
1.Sub-class-Stegocephali(extinct)
Order: *i. Labyrinthodontia* *ii. Phyllospondyli* *iii. Lepsospondyli*

2.Sub-class-Lissamphibia (living)
Order: *i. Gymnophiona(apoda/caecilia)* *ii. Caudata(urodela)* *iii. Anura(Salientia)*

<u>Order GYMNOPHIONA(caecilians)</u>

1. Circular dermal folds or annular grooves.
2. Dermal scales embedded in the grooves
3. Eyes are functionless
4. Absence of limbs,limb bones and limb girdles
5. Tail is absent or rudimentary
6. A protrusible*sensory tentacular apparatus in between eye and nostrils on each side.*
7. Solid and compact skull (correlated with the burrowing habit)
8. Persistent notochord.
9. *Amphicoelous and pseudocentrous vertebrae.*
10. *Presence of ductusbotalli connecting systemic arch to pulmonary arch*





11. *Asymmetrical lungs,* right one being larger than the left one.
12. Very long liver.
13. Male has an *eversible copulatory organ.*
14. Fertilization is internal and development may be internal or external
15. In internal development ,epithelium of the oviduct secretes a creamy white substance called “uterine milk”.

EXAMPLE:ICHTHYOPHIS and UREOTYPHLUS

1.ICHTHYOPHIS(BLIND WORM)

Super class	*Tetrapoda*
Class	*Amphibian*
Sub-class	*Lissamphibia*
Order	*Gymnophiona(apoda)*
Family	*Caecilidae*

It is a *worm-like,limbless,tailless,blind and burrowing* amphibian.

1. **Leads a burrowing life in moist soil feeding upon worms and other small soil organisms.**
2. **Body is slender,15-25 cm long an dcovered by slimy skin.**
3. **Skin has annular grooves with*calcified dermal scales* embedded in the grooves.**
4. **Body division-head and trunk**
5. **Head is dorso-ventrally flattened and skull is compact.**
6. **Cylindrical trunk**
7. **Tail,limb,limbgirdles,tympanum,tympanic cavity and columella are absent**
8. **Eyes are functionless,covered by opaque skin**
9. ***Sensory apparatus* in between eyes and nostrils.**
10. **Lower jaw bears two series of teeth**
11. **Right lung is longer.**
12. **Male has an *eversible copulatory organ.***
13. **Internal fertilization.**
14. **Exhibits *parental care***
15. **Egg hatches into *tadpoles.***

16. **Tadpole has a pairs of branched and filamentary *external gills,*a pair of *gill slits* and *laterally compressed tail with caudal fin***

2.URAEOTYPHLUS*(BLIND WORM)*

Super class	*Tetrapoda*
Class	*Amphibian*
Sub-class	*Lissamphibia*
Order	*Gymnophiona(apoda)*
Family	*Caecilidae*

It is *long,cylindrical,limbless,tailless,blind and burrowing amphibian.*

1. **Worm like with small,dorso ventrally compressed head and cylindrical trunk.**
2. **Scales are present.**
3. **Body is covered by smooth and slimy skin with dermal grooves**
4. **Limb,limb girdles and tail absent**
5. **Head is depressed and jaws are toothed**
6. **Eyes are functionless and microscopic**
7. **Sensory tentacles lodged in sensory pits**
8. **Right lung is sac like and larger**
9. **Male has an*eversible copulatory organ***
10. **Internal fertilization**
11. **Indirect development.**

Order URODELA (CAUDATA)

1. *Tailed amphibian*
2. Includes newts and salamanders
3. Scaleless and naked body
4. Two pairs of *weak limbs*
5. Vertebrae are opisthocoelous or amphicoelous
6. Presence of *DuctusBotalli*
7. Diplocondylian skull with 2 occipital condyles
8. Presence of teeth on both jaws
9. Absence of tympanic membrane and tympanic cavity.
10. Larval and adults differ very little
11. Some adults are *neotenous forms*
12. *Perennebranchiata* –adult urodele with persistent gills
13. *Caudibranchiata*-gillless adult
14. internal fertilization(*spermatophores)*
15. Most urodeles are oviparous

Newts:

- Tailed and mostly aquatic
- Body is covered by soft,glandular and moist skin
- Minute eyes
- Short and weak limbs
- Tail is laterally compressed with dorsal and ventral finfolds
- Internal fertilization
- External and indirect development
- Includes gilled larva

Salamander:

- Lizard like tailed amphibian
- Some are aquatic with gills and others terrestrial
- Body is coloured black with yellow patches or spots. This gives them *warning coloration.*

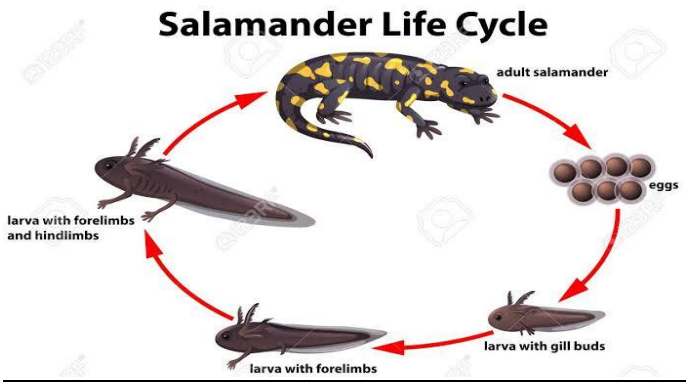
1.NECTURUS(*MUD-PUPPY/WATER DOG/WATER NEWT)*

Super-class	***Tetrapoda***
Class	***Amphibia***
Sub-class	***Lissamphibia***
Order	***Urodela***
Sub-order	***Proteida***

It is a tailed,limbed, and gill breathing aquatic *neotenousurodele.*

1. **30-40 cm long body**
2. **Rust colored body with black spots**
3. **Head ,trunk and tail-body differentiation**
4. **Depressed head with truncated snout,wide mouth, and thick lips**
5. **Small and lidless eyes**
6. **Skull is mostly *cartilaginous***
7. **Behind head,there are *3 pairs of bushy red external gills*and two pairs of gill slits**
8. **Functional lungs are also present**
9. **So,gill breathing as well as lung breathing**
10. **Tympanum absent**
11. **Trunk bears lateral line sensory organs and two pairs of weak limbs(for crawling) with 4 digits**
12. **Laterally compressed tail with *caudal fin*(for swimming)**
13. **Internal fertilization**
14. **External and indirect development**
15. **Presence of cartilaginous skull,externalgills,gillslits,lateral line sense organs and larval circulatory system reveals that necturus is permanent *neotenic larva*.**

2.AMBLYSTOMA TIGRINUM (*TIGER SALAMANDER)*



Super-class	***Tetrapoda***
Class	***Amphibia***
Sub-class	***Lissamphibia***
Order	***Urodela***
Sub-order	***Amblystomoidea***

1. **Lizard like body,nearly 20 cm long,withtransverse grooves and yellow patches or stripes on black skin**
2. **Depressed head and trunk**
3. **Flat and blunt snout with wide mouth**
4. **Head bears eyes and a pair of poison secreting *parotid glands***
5. **External gills and gill slits are absent in adult**
6. **Trunk bears well developed fore limbs and hindlimbs with 4 and 5 digits respectively**
7. **Tail is laterally compressed and flat without a caudal fin.**
8. **Fertilization is internal**

Embryo hatches out as a gill breathingaquatic larva –*axolotl*

Larvais 25cm long,with a body differentiated into head,trunk,and tail

Larval body has vertical *intercostal grooves*,4 pairs of wide gill slits.3 pairs of crimson colored *external gills*,well developed eyes,forelimbs and hindlimbs and a laterally compressed tail with caudal fin.

Axolotl provides a classical case of *neoteny(retention of juvenile characters in adult) or paedogenesis(reproduction by young or larval animal or sexually matured larvae).*

Order:ANURA

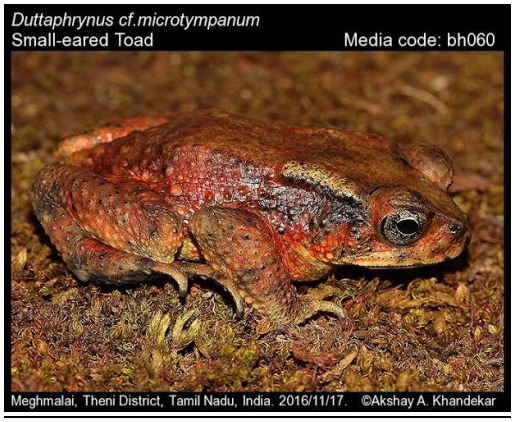
It includes frogs and toads

1. Tailless and limbed amphibian.
2. Naked,scaleless and glandular skin
3. Absence of tail,gills and gill slits in the adult
4. 2 pairs of well developedpentadactyl limbs.
5. Short vertebral column with nine vertebrae and a terminal bone called urostyle
6. Most are procoelous,someamphicoelous, and a few are opisthocoelous
7. Diplocondylian skull with two occipital condyles
8. Ribs are very rare or absent
9. Tympanum and tympanic cavity is present

10. Fertilization and development external.
11. Development indirect with afish like,tailed,gill breathing aquatic larva called *tadpole*
12. *Tadpole* metamorphoses into tailless,gill- less and lung breathing adult.

EXAMPLE:DUTTAPHRYNUS AND RHACOPHORUS

1.DUTTAPHRYNUS MELANOSTICTIS (COMMON ASIAN TOAD)



Super-class	***Tetrapoda***
Class	***Amphibia***
Sub-class	***Lissamphibia***
Order	***Anura***
Sub-order	***Procoela***

1. **Nocturnal**
2. **Stout and medium sized**
3. **Body coloration is highly variable (dorsal side :grey /brown / black with dark or reddish brown dots or streaks .vengtral side :usually dirty white with light brown specks on chin and throat)**
4. **Broad and depressed head**
5. **Short and squat trunk**
6. **Short and stout pentadactyl limbs : 4 fingers and 5 toes**
7. **Third finger bears double sub articular tubercle on its lower side**
8. **Toes have single sub-articular tubercle**
9. **Tubercles are cornified structures. During breeding season,cornified swellings develop on the inner side of the first and second fingers in male - *nuptial pad***
10. **Whole body is covered by thick,dry ,rough ,warty and glandular skin**
11. **Skin bears several scattered spiny and cornified *warts or tubercles* with *venom glands***
12. **Head region bears cornified projecting ridges called *cranial crests***
13. **Juveniles normally have smooth and soft skin**
14. **Head bears wide nostrils , prominent eyes , a pair of thick and oval or circular tympanum and a pair of swollen and projecting *parotid glands***

15. **Male have vocal sac**

16. **Juveniles have black band around throat that runs between chin and chest**

17. **Breeding takesplace in water**

18. **Fertilization is external and development is indirect (with tadpole larva)**

2.RHACOPHORUS(*TREE FROG/FLYING FROG)*

Super-class	***Tetrapoda***
Class	***Amphibia***
Sub-class	***Lissamphibia***
Order	***Anura***
Sub-order	***Diplasiocoela***

1. ***Arboreal*****anuran,specialized for climbing and gliding**
2. **Long and slender body**
3. **Broad and conical head**
4. **Trunk is narrow posteriorly with slim waist**
5. **Large eye with vertical pupil**
6. **Limbs are long and lean with broad feet and hands**
7. **All limbs are webbed for gliding**
8. **Limbs are terminally expanded to form *adhesive pads or discs*for attachment and climbing**
9. **Has power for rapid *adaptive color change*to merge with background**

10. **Crepuscular**

11. **External fertilization**

12. **Tympanum present**

3.NASIKABATRACHUS SAHYADRENSIS*(PURPLE FROG)-130 million years old*

1. **Discovered by Dr.S.D Biju and Dr.Franky Bossuyt (2003) from Western Ghat, Kerala.**
2. **Discovered in Oct. 2003 in the Idukki district**
3. **Endemic to Western Ghats in India**
4. **Remains underground most of the year except for 2-3 weeks during monsoon when it comes out for mating**
5. **Only 135 individuals of this species are known**
6. **Belongs to family nasikabatrachidae**
7. **Living fossil**
8. **Body is 7cm long**
9. **Skin is smooth and bluish black with a brown tinge above and dark grey below**

10. **Tips of digits and base of hands are white**

11. **Eyes have light blue border,iris is orange colored, pupil is black and horizontal**

12. **Head is broad,snout is protruding and pointed**

13. **Nostrils are oval**

14. **Inconspicuous tympanum**

15. **Tongue is free terminally and attached basally, and limbs are short with poorly webbed fingers**

16. **Sub-terraneous form**

17. **Leg burrower**

HOPLOBATRACHUS TIGERINUS (INDIAN BULL FROG *)*

Systematic position

Phylum : Chordate

Group : Vertebrata

Sub phylum : Gnathostomata

Class : Amphibia

Order : Anura

Genus : Rana

Species : tigrina

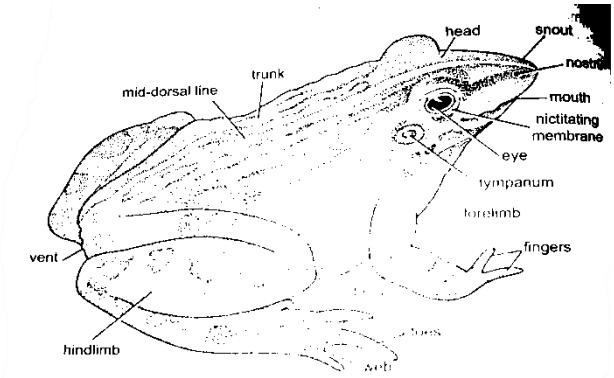


Fig. 18.3. An Indian frog, *Rana tigrina*, in sitting posture.

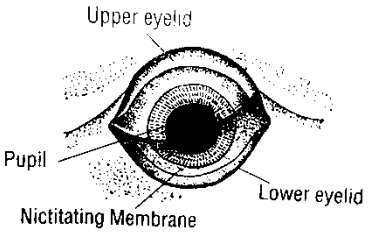
- Amphibious vertebrae
- Inhabits moist places , fresh- water ponds , streams etc

EXTERNAL FEATURES

- Body division : head and trunk ; tail and neck absent

HEAD :

- Head is flat and triangular with a blunt snout
- Near dorsal tip of the snout , is a pair of valvular external nostrils
- Head bears lateral eyes on the top
- Eye lid : immovable upper lid , movable lower lid
- Upper edge of the lower eyelid produces thin and transparent *nictitating membrane*



Eye as seen externally

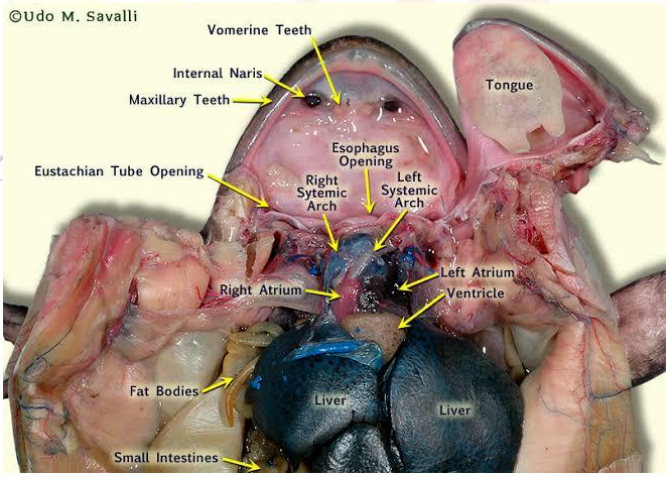
- Behind and below each eye , is a circular area of tough skin , known as tympanic membrane
- Male frog bears 2 vocal sacs on the ventral side of the head , during the breeding season

TRUNK :

- Bears paired fore-limbs and hind limbs
- Hind end of trunk bears cloacal aperture (common passage for digestive , excretory and reproductive systems

- Fore limbs has 5 divisions :
    - *Brachium (* upper arm*)*
    - *Antebrachium (* fore arm)
    - *Carpus (* wrist)
    - *Metacarpus* (palm)
    - *4 digits (*fingers)
- Male frog has a paddle-like swelling known as nuptial pad , on the index finger (1) during breeding season

- Hind limb has 5 divisions :
    - Femur (thigh)
    - Crus (shank)
    - Tarsus (ankle)
    - Metatarsus (sole)
    - 5 digits (toes)
- Toes are joined together by a fold of skin called web
- Toes and web together forms a swimming pad



SKIN

- Tough , smooth , slimy , moist and glandular
- Devoid of exoskeleton
- 2 main parts ,
    - **Epidermis**
    - **Dermis**
- **Epidermis:**
    - 2 distinct layers : outer stratum corneum (corneous layer) and inner stratum Malpighii (Malpighian layer)

- Corneous layer is formed of keratinized and dead squamous epithelium
- Malpighian layer is made of actively dividing columnar epithelium

- **Dermis :**
  - Mainly connective tissue layer , traversed by connective tissue fibres , nerve fibres, muscle fibres and blood vessels
  - 2 distinct parts : stratum spongiosum (outer and loose layer) and stratum compactum (inner and compact)
  - Contains cutaneous glands(mucous glands and poison glands) and chromatophores (melanophores , guanophores ., lipophores).

Functions of skin :

- Protection
- Secretions make skin slimy and slippery
- Forms chief respiratory surface for gas exchange
- Sense organ
- Displays protective coloration
- Skin of larva produces hatching enzymes

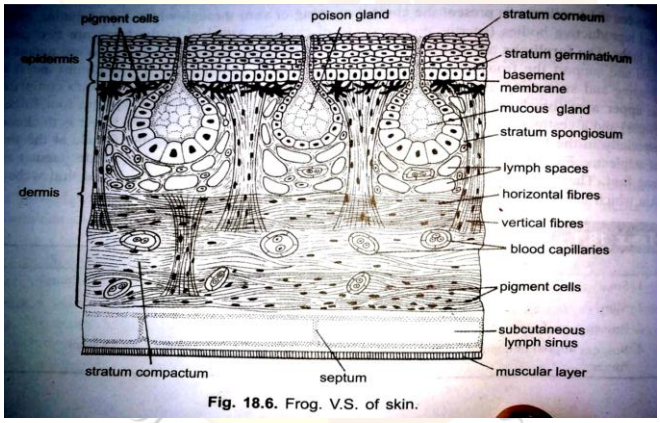


Fig. 18.6. Frog. V.S. of skin.

DIGESTIVE SYSTEM

Alimentary canal

ALIMENTARY CANAL	DIGESTIVE GLANDS
→ Buccal cavity	→ gastric glands
→ Pharynx	→ liver
→ Oesophagus	→ pancreas
→ Stomach	→ intestinal glands
→ Intestine	

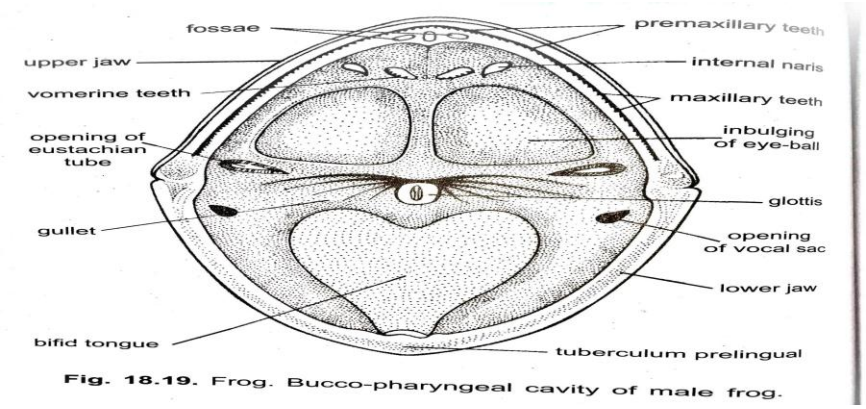


Fig. 18.19. Frog. Bucco-pharyngeal cavity of male frog.

- **Mouth :** wide opening bounded by immovable upper and movable lower jaws ; immovable lips
- **Buccal cavity :** wide space into which mouth opens
- Upper jaw bears a row of backwardly directed maxillary teeth
- Anteriorly , on the buccal roof , is a pair of internal nostrils
- Internal nostrils communicates with the external nostrils through a pair of nasal canals
- Between two internals nostrils are two prominences which bears groups of *vomerine teeth* (for holding the prey)
- Near posterior end of the buccal roof , 2 openings known as Eustachian recesses leading to Eustachian tubes which opens to tympanic cavity
- Anterior buccal floor lies the tongue (sticky , muscular terminally bifid)
- Posterior buccal floor , vertical opening called *glottis*
- Male frog bear 2 openings on the buccal floors (opening s for vocal sacs)
- **Pharynx :** buccal cavity leads to muscular pharynx which in turn leads to short and distensible **oesophagus**
- **Stomach :** 2 divisions : wide cardiac stomach and narrow pyloric stomach
- **Small intestine :** 2 divisions : duodenum (short , anteriorly curved initial part) and ileum (long and coiled terminal part)
- **Large intestine :** consists of rectum which passes to **cloaca** that opens out by cloacal aperture and guarded by cloacal sphincter
- **Cloaca :**common passage for digestive , excretory and genital system

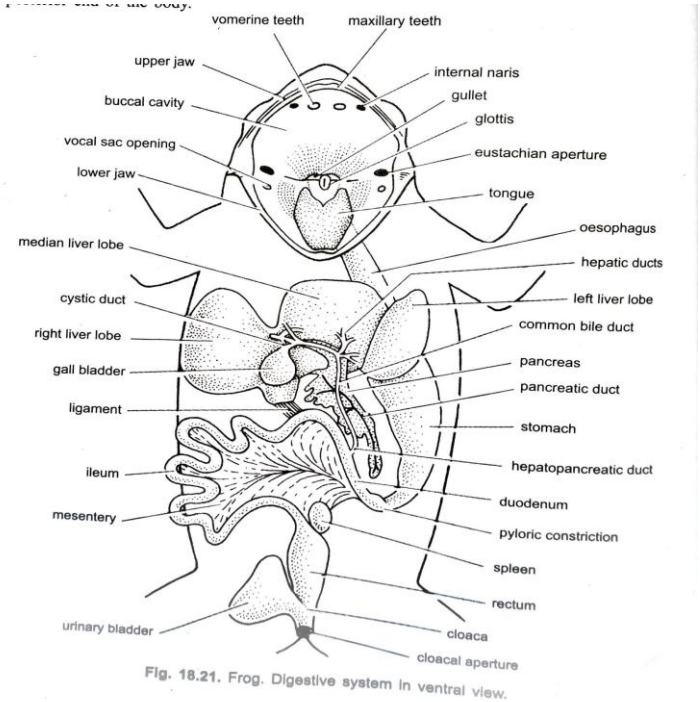


Fig. 18.21. Frog. Digestive system in ventral view.

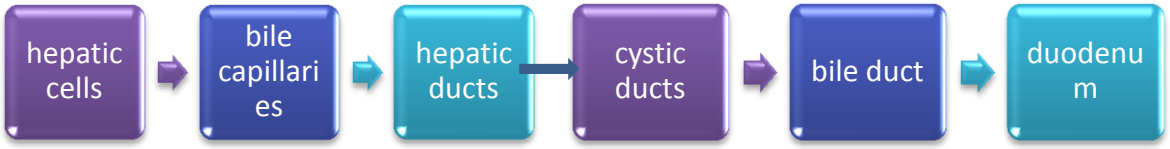
Histology

5 distinct layers :

1) ***Serosa* :**outermost connective tissue covering . absent in buccal cavity , pharynx and oesophagus
2) ***Muscular layer* :** consists of outer longitudinal and inner circular muscles
3) ***Sub-mucosa* :** thick layer of connective tissue
4) ***Muscularis* :** thin patch of 1 or 2 muscle layers
5) ***Mucosa* :** internal lining . contains mucous or goblet cells

Digestive glands

1) **Gastric glands :**
   - seen in stomach wall.
   - Secretes gastric juice which contains HCl and pepsin
2) **Liver :**
   - trilobed
   - in between right and left lobes is the gall bladder.
   - Hepatic cells secretes bile which is collected by bile capillaries.



3) **Pancreas :**
   - Heterocrine in action – endocrine as well as exocrine.
   - Exocrine part secretes alkaline pancreatic juice which contains amylopsin , trypsin and lipase.
   - Acinar cells contains zymogen granules which is later converted into enzymes and released into the duodenum through hepato -pancreatic duct.
   - Endocrine part secretes hormone insulin by Islets of Langerhans

4) **Intestinal glands :**
   - seen in epithelial lining of small intestine .
   - Secretes intestinal juice which contains carbohydrate – splitting , protein – splitting and fat- splitting enzymes

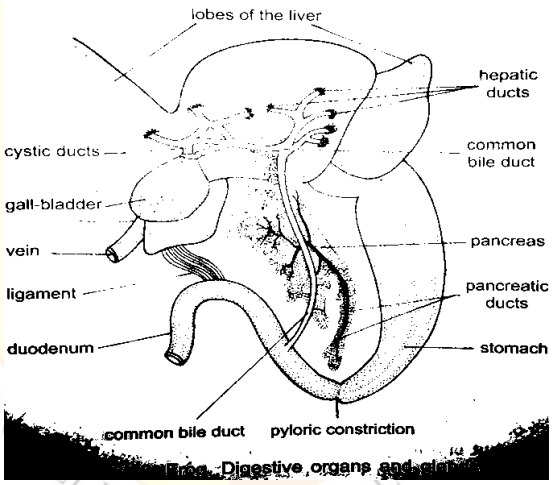


Fig. Digestive organs and glands

Mechanism of digestion:

- Starts in the stomach
- HCl kills the prey
- Acted upon by pepsin (protein to peptones)
- Partly digested food in stomach : *chime*
- Passes to intestine ; acted upon by bile ; pancreatic juice and intestinal juice
- Bile emulsifies at, neutralizes chime and renders action of pancreatic and intestinal enzymes
- Pancreatic enzymes : *trypsin* , *amylopsin* and *lipase* converts proteins , carbohydrates and lipids into amino acid , sugar and fatty acids and glycerol respectively
- Further breakdown by intestinal juice
- Food is absorbed by absorptive cells of the intestinal wall
- Undigested food is thrown out through cloaca

RESPIRATORY SYSTEM

2 stages

EXTERNAL RESPIRATION

- exchange of O_2 of the external medium and CO_2 of the tissue fluid

INTERNAL RESPIRATION

- involves several energy yielding biochemical reactions within the cell

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SKIN

INTEGUMENTARY /CUTANEOUS

BUCCO-PHARYNGEAL EPITHELIUM

BUCCO-PHARYNGEAL

LUNGS

PULMONARY

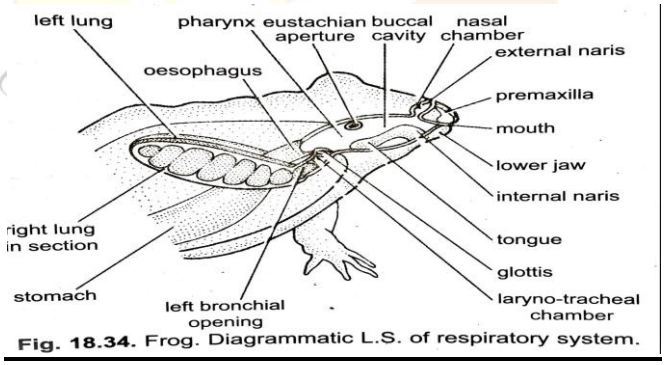


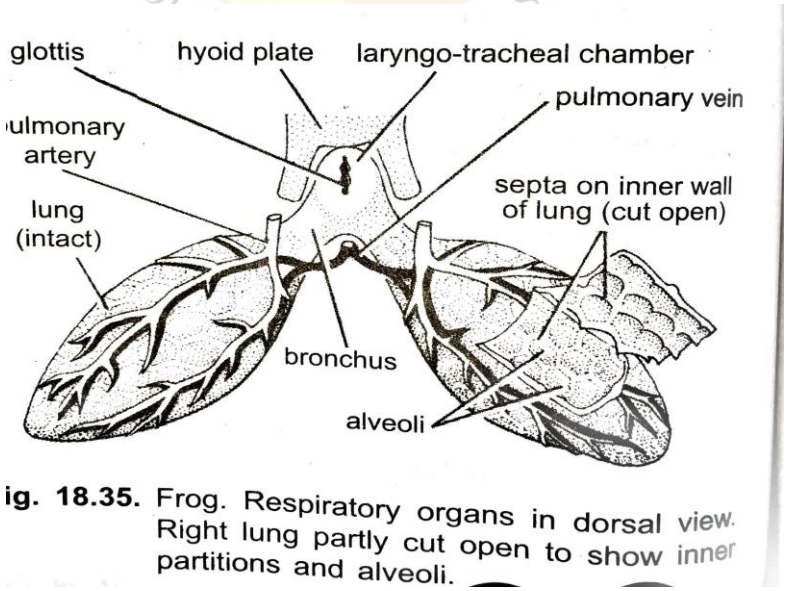
Fig. 18.34. Frog. Diagrammatic L.S. of respiratory system.

1) **Cutaneous / integumentary respiration**
   - Skin of frog is thin , vascular and moist
   - Takes place both in water and land
   - Mechanism ; simple diffusion
   - " always occurring respiration "
   - Most effective ; satisfies most of the need for oxygen
2) **Bucco-pharyngeal respiration**
   - Mechanism : simple diffusion
   - Bucco-pharyngeal epithelium is thin , moist and highly vascular
   - Takes place when frog is on land and floats on water surface
   - During this , frog keeps its external nostrils open , mouth and glottis closed

- Buccal floor moves up and down by muscular activity
- When buccal floor is moved down , volume increases , pressure decreases in buccal cavity ; soon fresh air enters the buccal cavity through nostrils
- Gas exchange takes place through the bucco-pharyngeal epithelium between O_2 and CO_2 in the blood
- Buccal cavity gets filled with CO_2.
- Buccal floor moved up and CO_2 forced out through nostrils

3) <u>Pulmonary respiration</u>

- Less significant because it can supply only a small quantity of oxygen. : Reason : air taken to lungs is of mixed type, with very low oxygen content
- Possible when on land
- **Organs**:
    - Lungs
    - air passage (external nostrils , nasal canal , internal nostril , bucco-pharyngeal cavity , glottis , laryngo – tracheal chamber and a pair of bronchi
- Wall of laryngo-tracheal chamber is supported by 5 cartilages : 2 *arytaenoid*,2 pre-*arytaenoid* and cricoid cartilage
- Lungs : pink colored, thin walled , ovoid , elastic
- Lungs have external peritoneal epithelium called pleural membrane and an internal ciliated epithelium
- Ciliated epithelium bears mucous glands.
- Cilia and mucus trap the particulate matters
- Cavity of lung is partitioned to several air chambers called *alveoli* by means of septa
- Lung wall and septa are richly vascularised



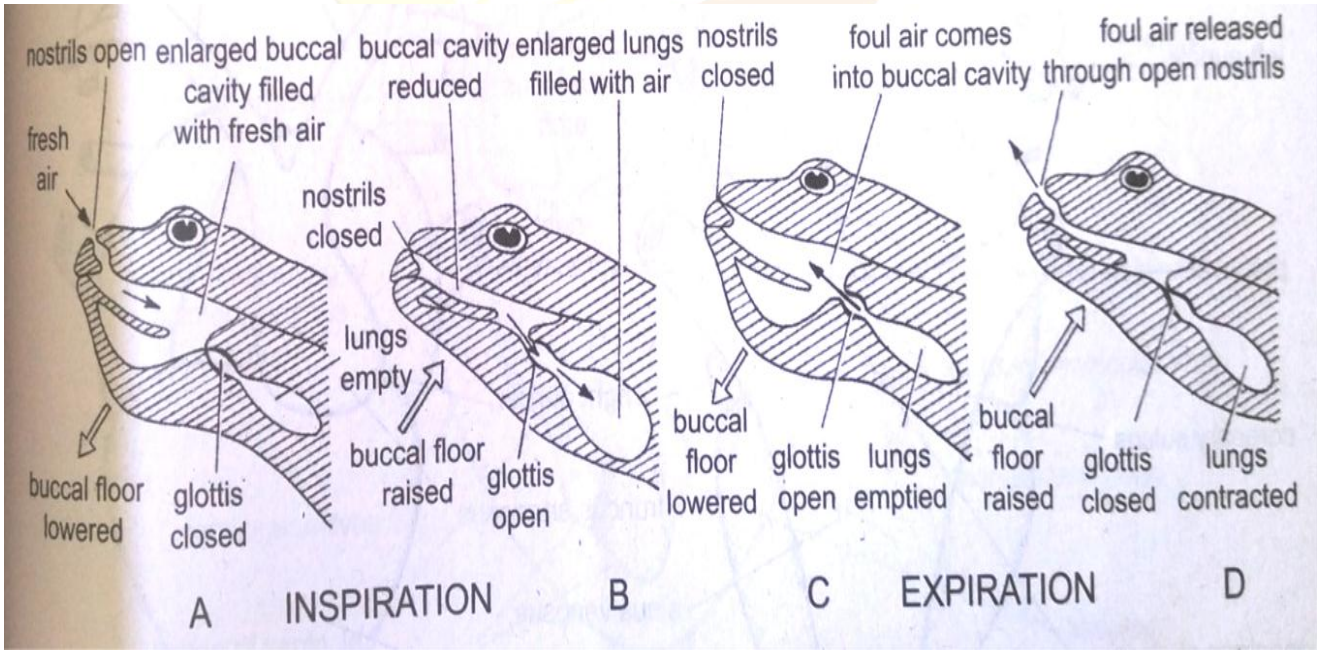
ig. 18.35. Frog. Respiratory organs in dorsal view. Right lung partly cut open to show inner partitions and alveoli.

- **Mechanism :** 2 process,

- Inspiration
- Expiration

- By up and down movement of buccal floor
- Supported by *sterno-hyal muscles* and *petro -hyal muscles*
    - Sternohyal muscles extend between coracoid of pectoral girdle and lower surface of hyoid.
    - Petro-hyal muscles extend between auditory capsules and surface of hyoid

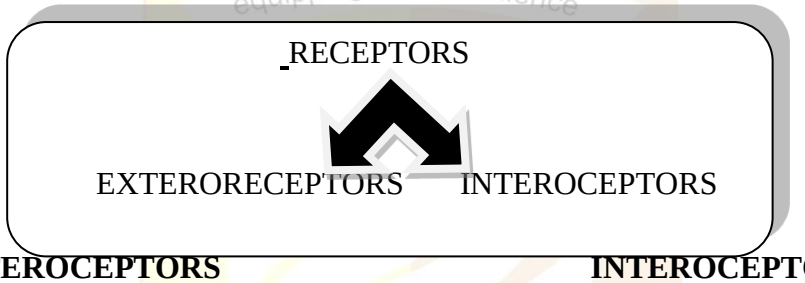
- Steps,
    1. Nostrils and glottis open ; mouth closed.
    2. *Sterno-hyal* contracts ,buccal floor moves down.
    3. Petro-hyal muscle relaxes .
    4. Volume increses , pressure decreases .
    5. Air from outside and lungs rush to buccal cavity
    6. Mixing up of air
    7. *Petrohyal muscle* contracts ,buccal floor moves to normal level.
    8. Pressure increases , volume decreases.
    9. Mixed air moves in two directions.
    10. Part of it is driven outside through nostrils : expiration. Rest is forced to lungs through glottis : inspiration
    11. Gas exchange takes place between O_2 of the mixed air in the alveoli and CO_2 in the blood.
    12. As a result, alveoli gets filled with CO_2 .Part of it flows to buccal cavity



Pulmonary respiration is unique in following features ,

a. Respiratory movements are brought about by buccal floor
b. Respiration and inspiration takes place more or less simultaneously
c. There is free mixing of impure and pure air in the buccal cavity

RECEPTORS (SENSE ORGANS)



EXTEROCEPTORS

- Perceive external stimuli
- Photoreceptors,stato-acoustic receptors, olfactoreceptors, gustatoreceptors, cutaneous receptors

INTEROCEPTORS

- Perceive stimuli from within the body
- Includes propioceptors (in muscles and joints) and interoceptors (in viscera and alimentary canal)
- Includes sensory nerve endings concerned with perception of pain , hunger etc

1.PHOTORECEPTORS (EYES)

- Fluid filled eye ball
- Lodged in eye socket in the orbit
- Guarded by immovable upper eyelid and movable lower eye lid
- Upper edge of lower eyelid is modified into – nictitating membrane controlled by retractor bulbi muscle and levator bulbi muscle
- Eye ball movement is controlled by 6 eye muscles : 4 recti muscles and 2 oblique muscles

- Eye ball is innervated by 2nd cranial nerve and eye muscle by branches of 3rd , 4th and 6th cranial nerves
- *Harderian gland* : moistens eye ball and lubricates nictitating membrane
- Excess secretions are drained to the nasal canal by a naso-lachrymal duct
- Eye ball is formed of 3 concentric layers

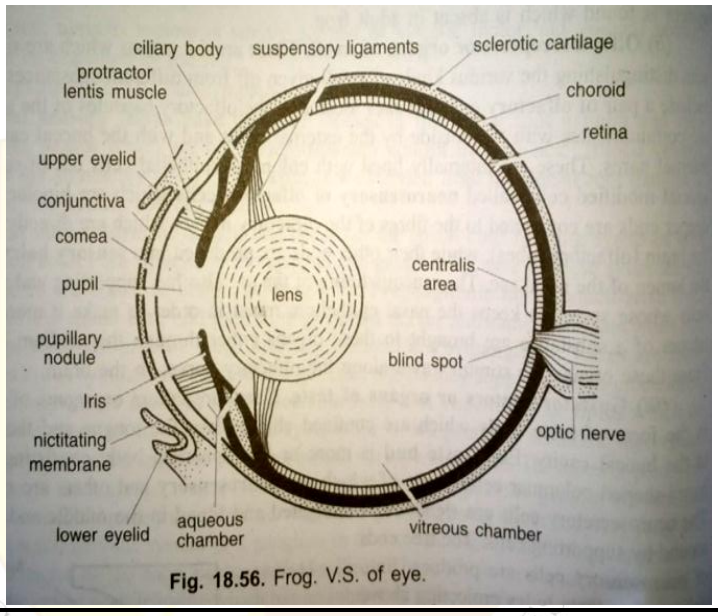


Fig. 18.56. Frog. V.S. of eye.

a) Sclerotic

- Outer most thick protective layer
- Made of fibrous connective tissue and cartilage
- Exposed portion : *cornea* (transparent)
- Cornea is externally covered by thin transparent layer : *conjunctiva* (vascular)
- Function : protection , maintain shape and provides surface area for attachment of eye muscles

b) Choroid

- Middle vascular and pigmented layer
- Nutritive layer
- Made of loose connective tissue fibres
- Towards anterior end , it thickens to *ciliary body* having ciliary processes
- Exposed portion *: iris*
- Center of iris have an adjustable opening *: pupil*
- Between ciliary body and cornea : have protractor lentis muscles
- Iris are attached with two sets of smooth muscles known as sphincters and dilators

- Sphincter muscle : arranged in the form of concentric layers ;when sphincter muscle contracts ,pupil constricts
- Dilator muscles are arranged radially ; on contraction ,pupil dilates
- Behind iris : *crystalline lens* , enclosed within a thin and transparent lens capsule
- Lens is suspended by dorsal and ventral suspensory ligaments
- Iris divides eyeball into:
    i. ***Vitreous chamber*** **(**fluid :vitreous humour**)**
    ii. ***Aqeous chamber*** (fluid : aqeous humour **)**

c) <u>Retina</u>

- Innermost sensitive layer in the posterior part
- Made of ,
    i. Outer pigmented (having outer light sensitive :rods and cones ; middle: bipolar neurons and ; inner :ganglion cells layer)
    ii. Inner sensory layer (transparent)
- Distinct type of rods : *green rods*
- Frog cannot perceive any color vision other than grey
- Innervated by optic nerves
- Yellow spot : behind retina, contains only cones and an yellow pigment ;where images are formed
- **Blind spot** : point where optic nerve enters the retina ; contains no rods and cones and is insensitive to light

Accommodation : during vision , lens is focused for far and near objectsin such a way that the imageis registered exactly on the retina ; accomplished by forward and backward movement of the lens by the activity of the protractor lentis muscle.Frog has monocular vision : both the eyes cannot focus simultaneously for the same object , and the images of the two eyes never overlap

2. <u>STATO-ACOUSTIC ORGANS (EARS)</u>

- Organs of equilibration and hearing
- Include ears
- 2 portions : middle and inner ear ;external ear absent
- Middle ear cavity is externally closed by the tympanic membrane

<u>Middle ear :</u>

- Cavity : tympanic cavity
- Connects with pharynx through *eustachian tube* or pharyngo-tympanic canals
- Tympanic cavity – bridged by a slender bone : *plectrum* or columella auris
- Inner end of columella is attached to a cartilaginous plate called *stapedial plate*
- Tympanic cavity communicates with inner ear through *fenestra ovalis*
- Fenestra ovalis is bordered by a bony ring called called operculum

- Operculum and plectrum fuse together to form *operculum-columella* complex

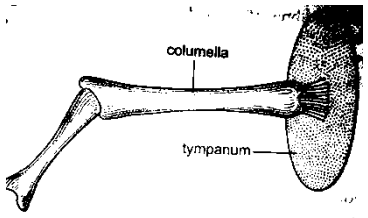


Fig. 18.59. Frog. Columella auris.

Inner ear :

- Consists of a fluid filled membranous bag : *membranous labyrinth* ;filled with *endolymph*
- Membranous labyrinth is enclosed within a bony capsule of the pro-otic bone : bony labyrinth which is filled with *perilymph*
- *Membranous labyrinth* contains receptors for hearing and balancing
- Membranous labyrinth has 2 portions ,
  - Vestibule
  - 3 semicircular canals with a swollen terminal part called ampula (anterior vertical , posterior vertical and horizontal canals)
  - Vestibule consists of : *utriculus* and *sacculus*
  - Sacculus bears 2 terminal dilations : pars lagena and pars basilaris

> ❖ Semi-circular canals , utriculus and sacculus : BALANCING
> ❖ Pars lagena : HEARING

- Wall of the membranous labyrinth bears 6 sensory patches having sensory hair cells and supporting cells ;sensory patches on ampullae : *cristae* and others are called *maculae*
- Cristae is covered by cupula and macula *by otolith membrane* ; each innervated by auditory nerves
- Wall of sacculus bears 2 sensory areas : *papilla amphibiorum* (sensitive to sound frequencies below 1000Hz) and *papilla basilaris* (above 1000 Hz)

Mechanism of hearing :

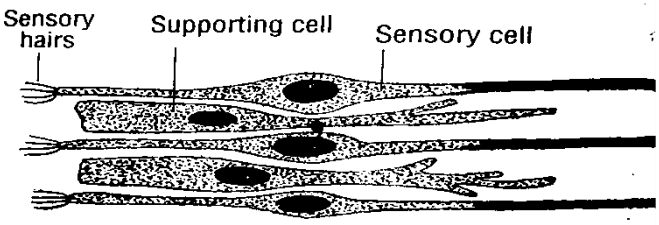
1) Sound waves strike on tympanic membrane
2) Membrane vibrates , sound waves transformed into vibrations
3) Vibrations are transmitted to membranopus labyrinth by columella and stapedial plate
4) Perilymph and endolymph vibrates
5) Vibrations are perceived by sensory hair cells of lagena
6) Hair cells get stimulated ;elicit nerve impulses
7) Auditory nerve transmit the impulse to auditory centre in the brain
8) Brain analyses and interprets as audible sound

Mechanism of balancing:

1) Change in position
2) Endolymph and otolith starts moving;exerts pressure
3) 3 cristae and 1 maculae gets stimulated
4) Impulses transmitted by nerve fibres to brain
5) Impulses to muscles
6) Position correction

3. OLFACTORECEPTORS

- Receptors for perceiving sense of smell
- Lodged in pair of olfactory sacs or nasal sacs ;located in the olfactory capsules of the skull
- Sac communicate with outside through external nostrils ;and with buccal cavity through internal nostrils
- Sac is lined internally by a sensory epithelium : *Schneiderian membrane* or *olfactory epithelium* ; innervated by the fibres of the olfactory nerve
- Olfactory epithelium is formed of 2 kinds of cells : supporting cells and neuro sensory cells
- Supporting cells are non-nervous columnar cells
- Olfactory cells are sensory hair cells ,provided with sensory hairs which gets stimulated when they come in contact with the odorous chemicals that are dissolved in the secretions of the nasal mucosa
- Stimulus is transmitted to olfactory centre in the brain along the olfactory nerve

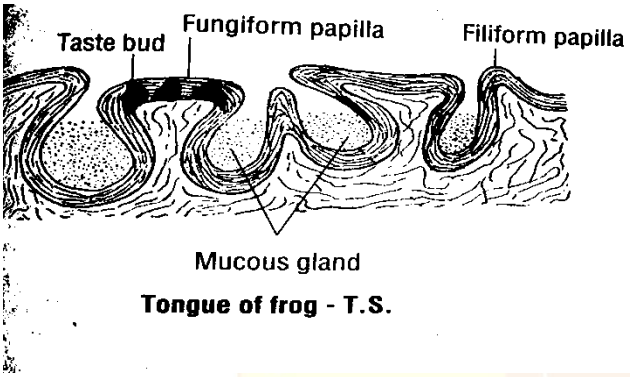


Frog-Cells of olfactory epithelium

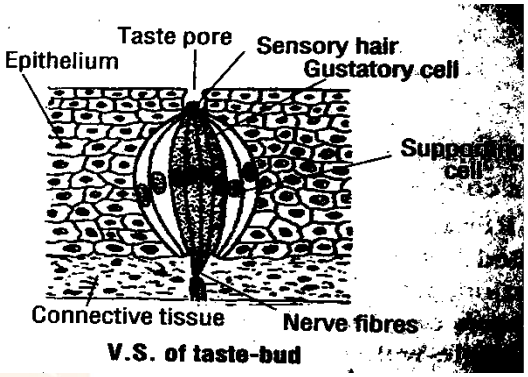
4. GUSTATORECEPTORS

- Taste receptors
- Developed on the tongue as taste buds
- Taste buds : group of barrel-shaped columnar epithelial cells
- 2 kinds : non nervous supporting cells and sensory hair cells
- Supporting cells are arranged around the sensory hair cells
- Innervated by 7^{th} and 9^{th} cranial nerves

- Taste buds are arranged on the papillae of the mucous membrane of the tongue called lingual papillae / taste papillae
- 2 types of papillae: *filiform and fungiform*
- Taste buds are seen on fungiform papillae
- Taste buds get stimulated when the sensory hair cells of the taste cells come in contact with the substances in solution



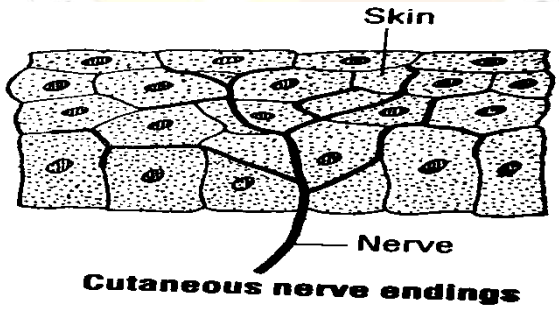
Tongue of frog - T.S.



V.S. of taste-bud

5. CUTANEOUS RECEPTORS :

- Includes sensory nerve endings in the epidermis
- *Tactile patches* : area where several epidermal cells form groups which are profusely supplied with sensory nerve endings
- Tactile patches are sensitive to touch , heat , cold ,pain and action of chemicals



Cutaneous nerve endings

EXCRETORY ORGANS

- Includes,
  - a pair of opisthonephric kidneys (located on the sides of urostyle)
  - Pair of ureter
  - Urinary bladder
  - cloaca

- From the outer margin of each kidney leads down an excretory duct : urinary duct ; which opens to cloaca
- Lying attached to the ventral surface of each kidney is an endocrine gland : adrenal gland

Kidney:

- *Opisthonephric*
- Tadpole : pronephros; adult: mesonephros
- Located on each sides of urostyle
- Compact, elongated,dark red
- Covered by peritoneum
- Formed of numerous coiled tubules : *uriniferous tubules (nephrons*)
- All the uriniferous tubules opens into set of transverse tubules : collecting tubules
- Collecting tubules joins and form urinary duct
- Lying near inner margin of the kidney , is a longitudinal canal : *bidder's canal*; connected to the urinary duct by the transverse collecting tubules
- Renal tubules are long and coiled with proximal capsular part called malpighian capsule (Glomerulus and Bowman's capsule) and distal tubular urinary tubule
- Afferent arteriole brings blood into *malpighian capsule* and efferent arteriole take away blood from capsule after ultra filtration

Ureter:

- Also known as *Wolffian duct*
- Opens to cloaca
- Contains an inflated portion towards the kidney in male frog : *vesicular seminalis* (sperm storage)
- Urinogenital ducts : because it is the common passage for sperm and urine

Urinary bladder:

- Large , thin-walled and bilobed
- Opens to cloaca

Cloaca:

- Common opening for the elimination of undigested waste , excretory waste and also for the sperm
- Small sac bearing : anus , urinogenital aperture and opening of urinary bladder
- Opens between hindlimbs

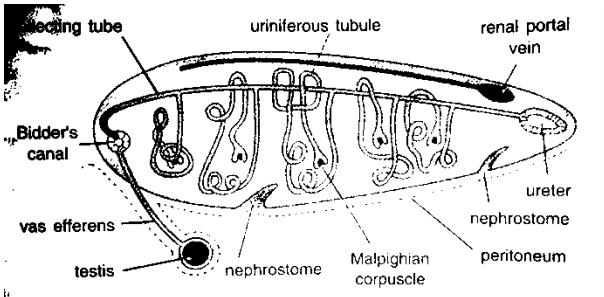


Fig. 18.62. Frog. Diagrammatic representation of kidney.

MALE REPRODUCTIVE SYSTEM

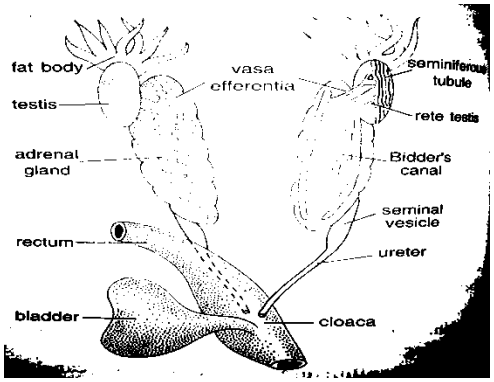
- Includes ,
  - Pair of testes
  - Vasa efferentia (2)
  - Urinogenital ducts(2)
  - No copulatory organs

Testis:

- Attached to kidney by *mesorchium*
- Round , ovoid ,light yellow in color
- Surrounded by peritoneum
- Contains fat body at the anterior edge
- Formed of numerous glandular tubules : *seminiferous tubules*
- Wall of tubules – germinal cells – sperms
- Interstitial cells – hormone testosterone

Seminiferous tubules → vasa efferentia → kidney → bidder's canal → collecting tubules → ureter

In male frog,urinary duct serves as a renal duct and also as a genital duct .So,it is called a urino-genital ducts or ureter



FEMALE REPRODUCTIVE ORGAN

- No direct connection with the excretory organs
- Includes,
  - 2 ovaries
  - 2 oviduct

Ovaries :

- Attached to kidney by *mesovarium*
- Large ,lobulated hollow sac-like
- Germinal cells- oogonia-ovarian follicle-ovum
- Attached to each is a fat body

Oviduct:

- Coiled , glandular , and ciliated
- Also known as *Mullerian duct*
- Starts near base of lung by oviducal funnel
- not continous with the ovary
- Begins with a wide funnel : *oviducal funnel or infundibulum*
- Terminally , oviduct slightly dilates to form ovisac (uterus) and opens to *cloaca*

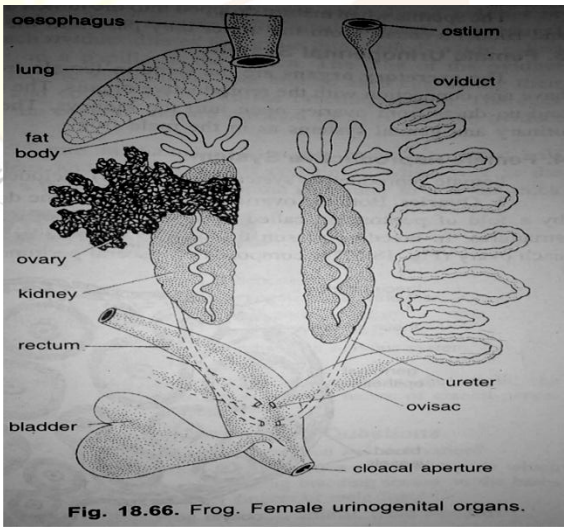


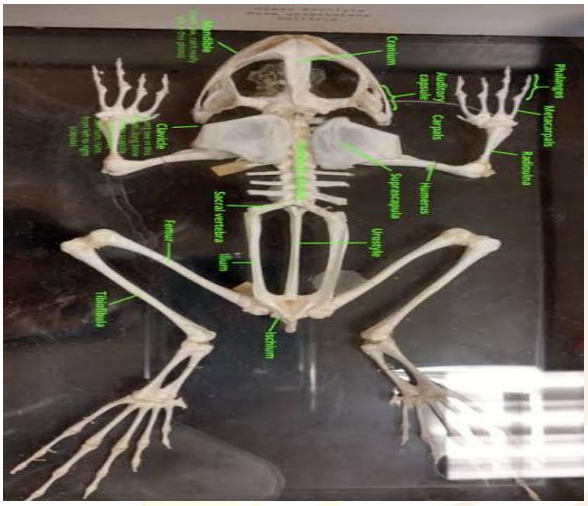
Fig. 18.66. Frog. Female urinogenital organs.

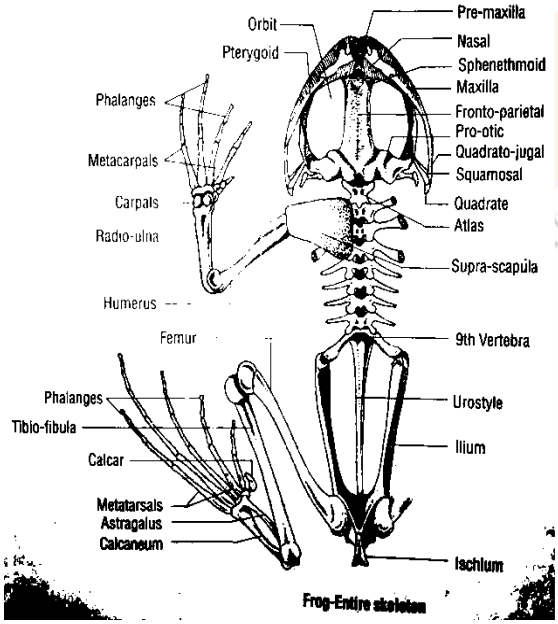
SKELETAL SYSTEM

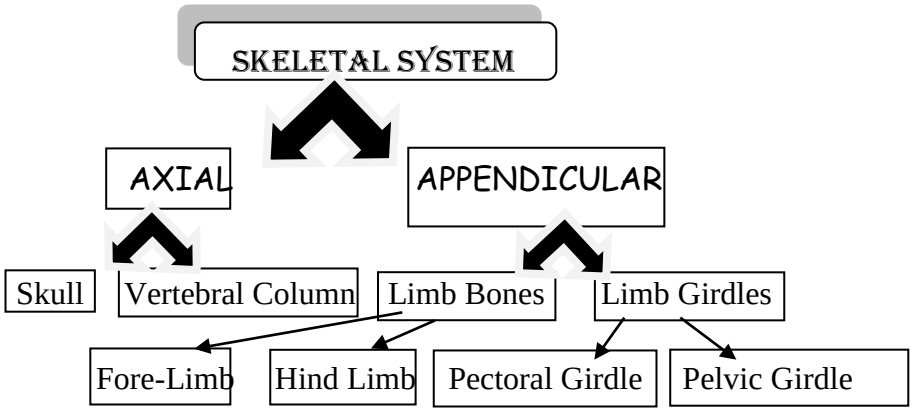
- Includes,
  - Bone
  - Cartilage

Function:

- Give body definite shape and form
- Provide support
- Protects internal organs
- Forms levers for movement and locomotion
- Provides surfaces for attachment of muscles
- Store house of minerals
- Red marrow serves as the seed bed of RBC

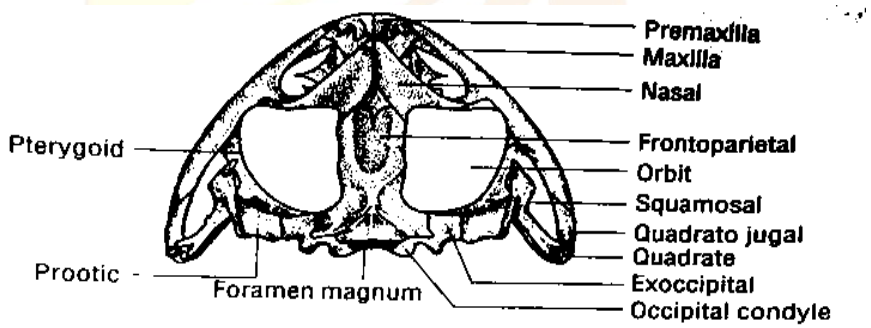




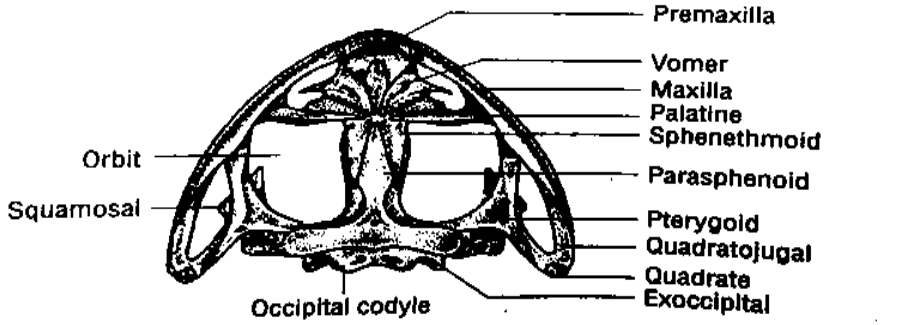


SKULL

- Skeleton of the head region
- 6 regions ,
  - Cranium
  - Auditory capsules
  - Olfactory capsules
  - Upper jaw
  - Lower jaw
  - Hyoid apparatus



Skull of frog - Dorsal view



Skull of frog-Ventral view

Cranium:

- Brain case ; bony casket that encloses the brain

- Posterior end ; an opening :foramen magnum through which spinal cord leads out from the brain
- Sides of foramen magnum , 2 bones : *exoccipitals*
- Diplocondylian : exoccipitals bears 2 rounded prominences called *occipital condyles* , for articulation with the 1st vertebra
- Floor : parasphenoid ; roof : fronto-parietals

Auditory and olfactory capsules :

- AC encloses internal ears ; formed of pro-otic bones
- OC: encloses organ of smell ; roofed by nasal bone and floored by *vomer* with minute vomerine teeth

Upper jaw:

- Arch : maxillary arch
- Each half is united with cranium except in the middle ;separated by a wide space : orbit
- Each half is formed of 3 bones : pre –maxilla , maxilla and quadrate-jugal
- Pre-maxilla bears: pre-maxillary teeth ; maxilla bears : maxillary teeth
- Extending between the margin of the upper jaw and the cranium : 3 bones on each sides*: palatine , pterygoid and squamosal*

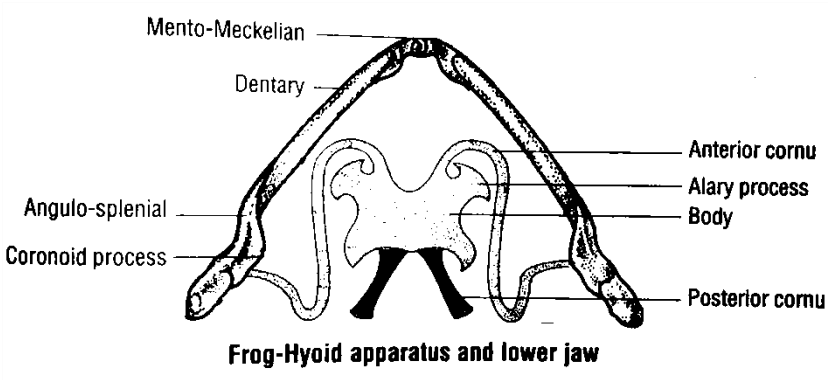
Lower jaw :

- Arch : mandibular arch
- Each half is having a central core of cartilage : *Meckel's cartilage* ; covered by 3 bones : Mento-Meckelian , dentary and angulo-splenial
- Teeth are absent

Jaw suspension: Autostylic : jaws do not directly articulate with the cranium , but are connected to the cranium by quadrate

Hyoid apparatus :

- Vestigial structure : represents the remnant of the branchial skeleton of the larva
- Supports buccal floor and provides a surface for the attachment of tongue
- Consists of,
    - Central cartilaginous plate : body
    - Body bears 3 pairs of processes :
        - alary processes (small , flat and cartilaginous)
        - anterior cornua (long ,slender and cartilaginous)
        - posterior cornua (short , stout and only bony part)



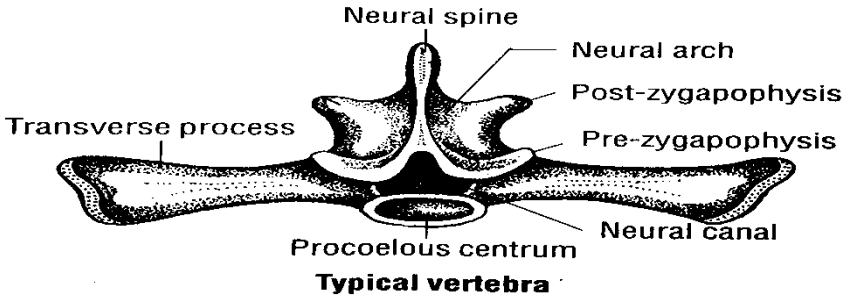
Frog-Hyoid apparatus and lower jaw

VERTEBRAL COLUMN

- axial skeleton of the trunk
- encloses and protects spinal cord
- consists of 9 vertebrae and a terminal bone : *urostyle*
- intervertebral foramina : paired openings in between successive vertebrae for the exit of spinal nerves
- 1st, 8th and 9th vertebra differ from all others

Typical vertebra :

- *Centrum* : disc-like body : procoelous : concave anteriorly and convex posteriorly
- Dorsally ,Centrum bears *neural arch* ,which encloses a space or canal : *neural canal or spinal canal* through which spinal cord passes backwards
- Neural arch has a median *neural spine* and a pair of *transverse processes*
- Neural arch bears 2 pairs of articular processes : anterior and posterior *zygapophyses* to prevent the vertebrae from displacement
- Anterior / pre-zygapophyses : for articulation with the vertebra in front
- Posterior / post-zygapophyses are for articulation with the vertebra behind

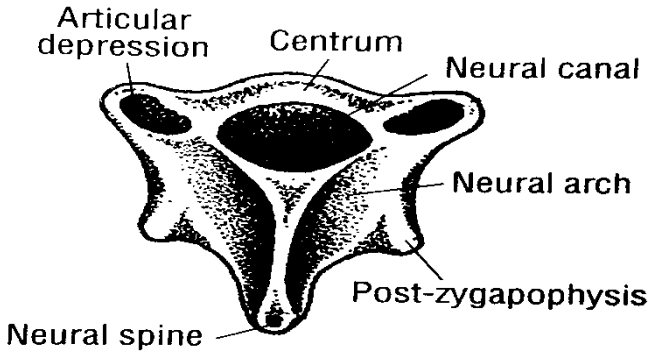


Typical vertebra

Atlas vertebra :

- 1st vertebra
- Almost ring-like , with a thin and reduced centrum
- 2 articular / anterior depressions for the articulation of the occipital condyles of the skull

- Centrum bears neural arch, neural canal and post-zygapophyses and a much reduced neural spine
- Transverse processes and pre-zygapophyses being absent



Atlas

8th vertebra :

- Amphicoelous / bi-concave centrum (concave anteriorly and posteriorly)
- Dorsally ,Centrum bears *neural arch* ,which encloses a space or canal : *neural canal or spinal canal* through which spinal cord passes backwards
- Neural arch has a median *neural spine* and a pair of *transverse processes*
- Neural arch bears 2 pairs of articular processes : anterior and posterior *zygapophyses* to prevent the vertebrae from displacement
- Anterior / pre-zygapophyses : for articulation with the vertebra in front
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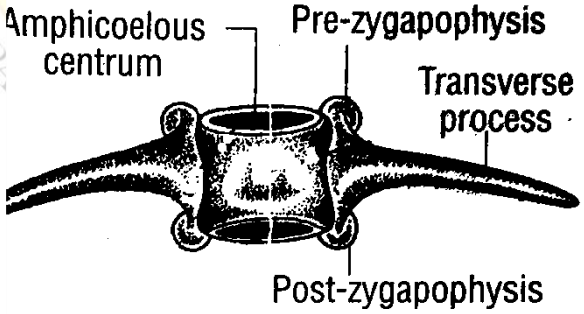
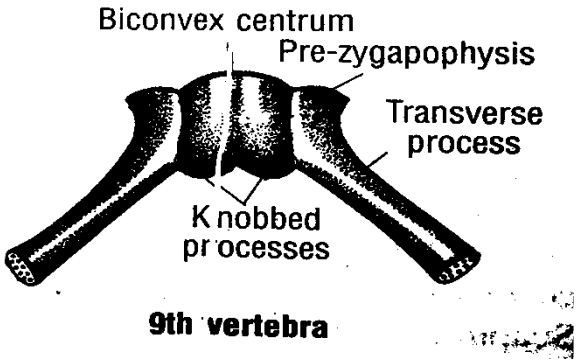


8th vertebra

9th vertebra :

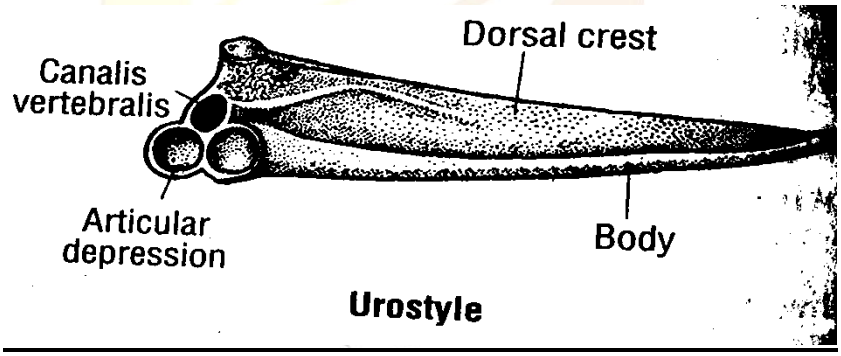
- Biconvex centrum
- Posteriorly , it has two knobbed processes , which fit into corresponding depressions of the urostyle
- Centrum bears neural arch ,that encloses the neural canal , a pair of transverse processes and a pair of pre-zygapophyses
- Post-zygapophyses are absent
- Neural spine is much reduced

- Transverse processes are broad and backwardly directed; for the articulation with the pelvic girdle



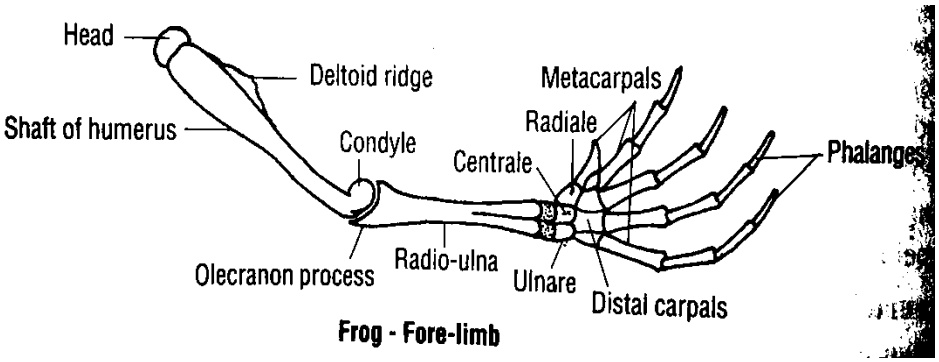
Urostyle :

- Terminal portion of the vertebral column
- Represents fused tail vertebra of tadpole
- Long, flat and terminally tapering
- Dorsally , it bears longitudinal ridge or crest , formed by the fusion of the neural spine of the larval tail vertebrae
- Crest contains a canal called : *canalis vertebralis* which lodges the tip of the spinal cord (filum terminale)
- Anteriorly , urostyle has two articular drpressions for accommodating the posterior knobs of the 9^{th} vertebra



FORE –LIMB

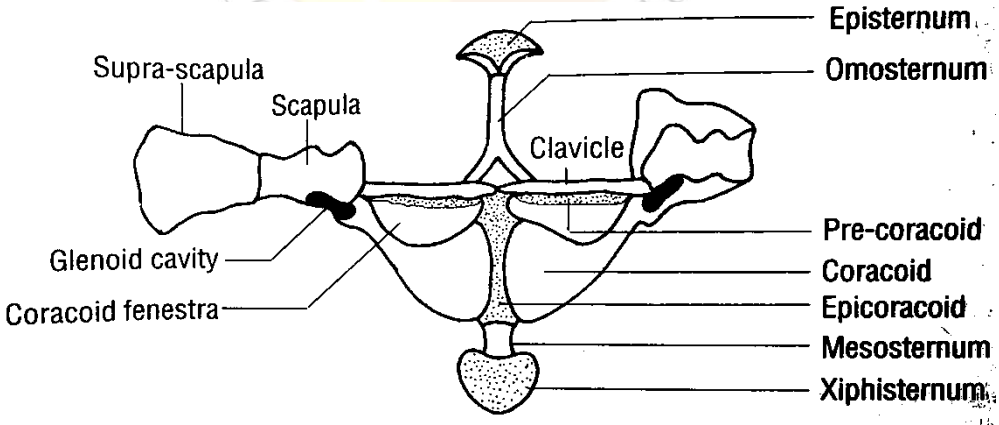
- Upper –arm : humerus .Humerus has a central cylindrical shaft ; and basal head and terminal condyle
- Fore-arm : radio-ulna
- Elbow joint : basally , radio-ulna has a backward process called olecranon process which encloses a cup into which condyle of humerus is fixed to form elbow joint
- Wrist : carpus : supported by b6 carpals arranged in 2 rows of 3 each : radiale , central and ulnare
- Palm : metacarpus : supported by 5 metacarpals
- Fingers : phalanges : 4 fingers ; thumb being absent : phalanges formula : 0,2,2,3,3



Frog - Fore-limb

PECTORAL GIRDLE AND STERNUM

- Shoulder girdle consists of 2 similar halves ,united together ventrally and separated dorsally
- Each half has : upper scapular and inner coracoids
- Scapular has bony scapula and calcified cartilage supra-scapula
- Coracoid has 2 bones : clavicle and coracoid which is separated by a space called *coracoid fenestra*
- Lying below the clavicle is a thin cartilage : pre-coracoid
- Clavicle and coracoid extend to the mid –ventral line and meet a median cartilage : *epicoracoid*
- Shoulder joint : clavicle and coracoids meet scapula at their outer end having a cup-like cavity called glenoid cavity into which the head of humerus fits to form shoulder joint
- Sternum or breast bone : is actually a part of the axial skeleton , but in frog ,it is closely associated with pectoral girdle
- Sternum has 4 segments : *episternum, omosternum , mesosternum* and *metasternum*

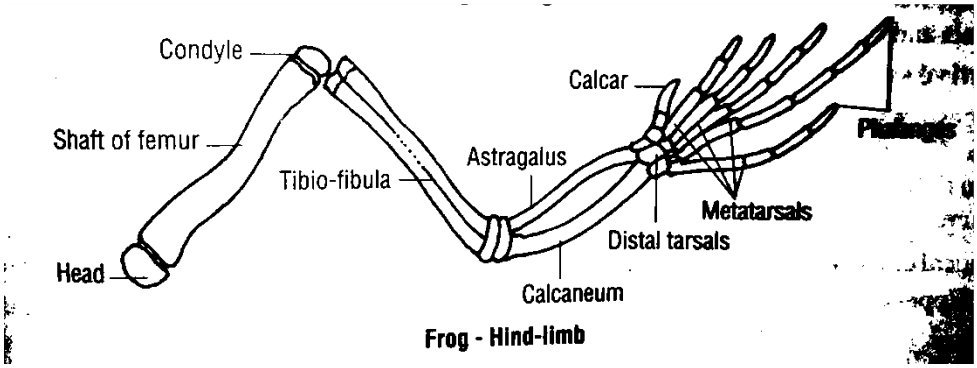


Frog-Pectoral girdle and sternum

HIND-LIMB

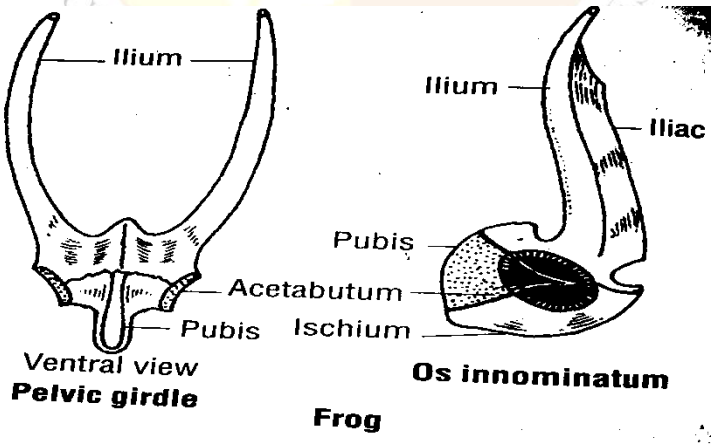
- Thigh : femur .Thigh has a central shaft and basal head and terminal condyle
- Shank : tibio-fibula
- Tarsus: supported by 4 tarsals , arranged in 2 rows of 2 each : tibiale and fibulare

- Metatarsus : 5 metatarsals
- Toes : supported by phalanges ;phalangal formula : 2,2,3,4,3
- There are5 completre toes and 1 supplemental toe
- 6^{th} toe is inner to the hallux ;so it is called pre –hallux or calcar



PELVIC GIRDLE

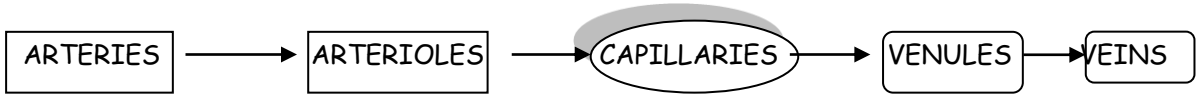
- V-shaped structure
- 2 similar halves
- Each half consists of a compound bone ;innominatum
- Innominatum is formed of : ilium , ischium and pubis
- Laterally , at the junction of innominatum is a cup-like cavity : acetabulum
- Hip joint : head of femur is joined to the cup-like cavity of acetabulum to form the hip-joint
- Terminally , each ilium articulates with the transverse process of the 9^{th} vertebra
- Pubis and ischium of each side join their fellows of the opposite side , with a median strip of cartilage in between to form pubis-ischiatic symphysis



CIRCULATORY SYSTEM

- Closed type
- System transports O_2 , CO_2 ,digested food , hormones , metabolic wastes etc
- Composed of ,
    - Blood : fluid part which circulated all over the body

- Heart : collecting and pumping station of blood
- Arteries : carries blood from heart to tissues
- Veins : return blood from tissues back to heart



BLOOD

- Red-colored fluid
- Consists of ,
  - Plasma : fluid part ; formed of water ,organic and non-organic components; it is the transporting medium
  - RBC : red colored ;nucleated oval cells ;contains haemoglobibn ;involved in the transport of respiratory gases
  - WBC : colorless amoeboid cells ;provides immunity
  - Thrombocytes : spindle cells ;helps in blood-clotting

HEART

- Muscular pulsating organ , located in the anterior part of the body cavity
- Concerned with the collection , storage and pumping of blood
- Pericardium : heart is enclosed within a double-layered membranous bag
- Pericardium : consists of inner visceral layer and outer parietal layer;in between it encloses pericardial fluid in the pericardial cavity
- 4 main parts ,
  - Sinus venosus : dorsal
  - Truncus arteriosus : ventral part
  - Right and left auricles: upper part
  - Ventricle : lower part

Sinus venosus collects blood from all parts of the body.It opens to auricle .Truncus arteriosus arises from the ventricle .Its branches supply blood to various parts of the body

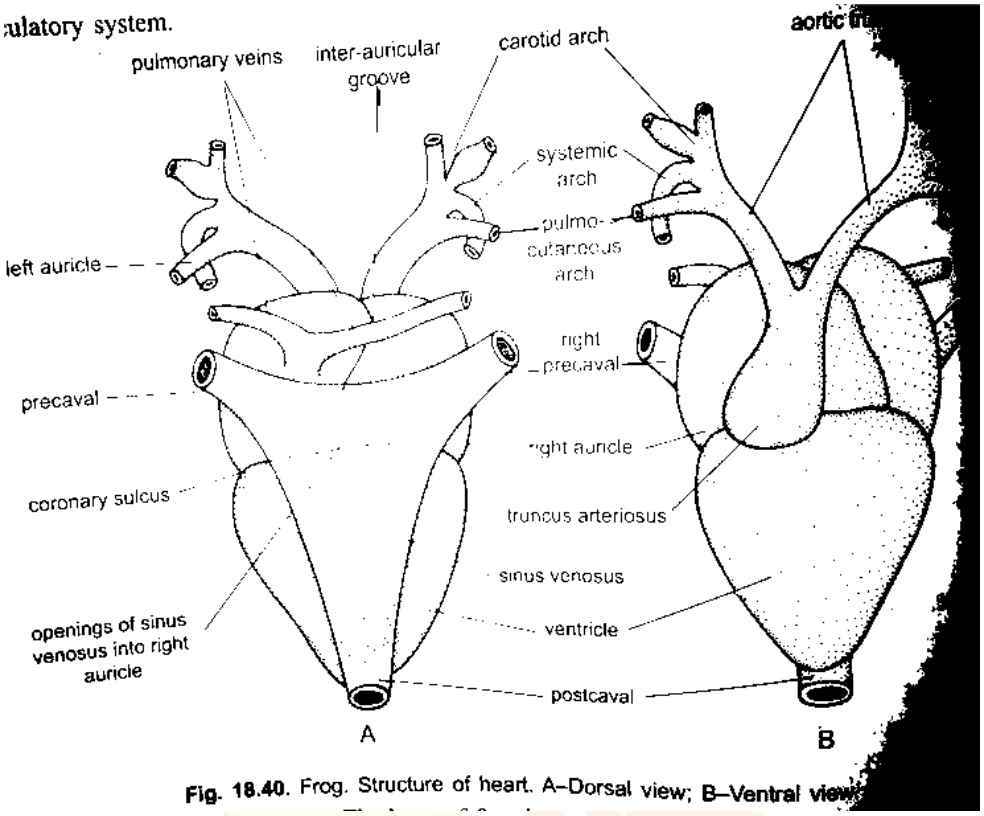


Fig. 18.40. Frog. Structure of heart. A–Dorsal view; B–Ventral view

Internal structure of heart

- Trilocular
- Atria :
  - 2 upper chambers
  - Thin walled
  - R and L chambers are separated by inert atrial ceptum
  - R is larger than L
  - Sinus venosus opens to right chamber by the sinu-atrial aperture guarded by sinu-atrial valve
  - Common pulmonary vein opens to left atrium ;non-valvular
- Ventricle :
  - single lower chamber
  - Thick walled
  - Separated from atrium by atrio-ventricular septum ;upper atrium opens to ventricle by atrio-ventricular septum ,guarded by bi-cuspid atrio-ventricular valve
  - Ventricular wall has numerous muscular ridges : trabeculae and several papillary muscles
  - *Chordate tendinae* : holds the valves in position and prevent them folding during ventricular contraction

- *Truncus arteriosus* arises from the right side of the ventricle guarded by 3 semilunar valves
- Truncus arteriosus is internally divided into : pylangium and synangium
- Pylangium is further divided into 2 halves : aortic chamber an pulmo-cutaneous chamber

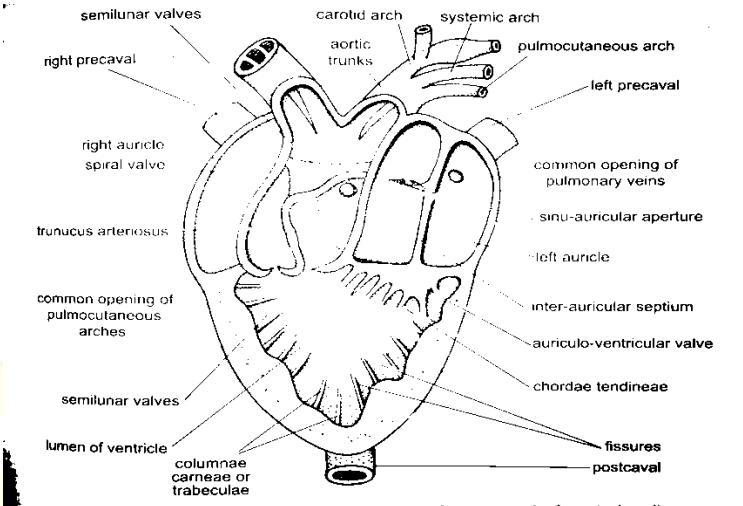


Fig. 18.41. Frog. Internal structure of heart after removal of ventral wall.

Working of heart :

1. Involves regular rhythmic heart beats with : alternate systole (contraction) and diastole (dilation)
2. Sinus venosus contracts , blood forced to right auricle
3. Left auricle gets filled with blood brought by pulmonary vein
4. Auricular systole
5. Blood reaches ventricle
6. Ventricular systole
7. Blood forced into *truncus arteriosus*
8. Truncus arteriosus contracts ; blood reaches the lungs and all body parts
9. Systole is followed by combined diastole of the chambers for re-filling

Double circulation consists of two major routes :

- Pulmonary: back and forth movement of blood between heart and lungs
- Systemic : to and fro circulation of blood between heart and various body parts ,other than lungs

In frog , there is only 1 ventricle , so both routes mix together in the ventricle :incomplete double circulation

Arterial system :

- Consists of the branches of truncus arteriosus
- Truncus at first divides into 2 ;each splits into 3 aortic arches ,
    - Carotid trunks : oxygenated blood
    - Systemic trunk : mixed type of blood
    - Pulmo-cutaneous trunk : lesser oxygenated blood

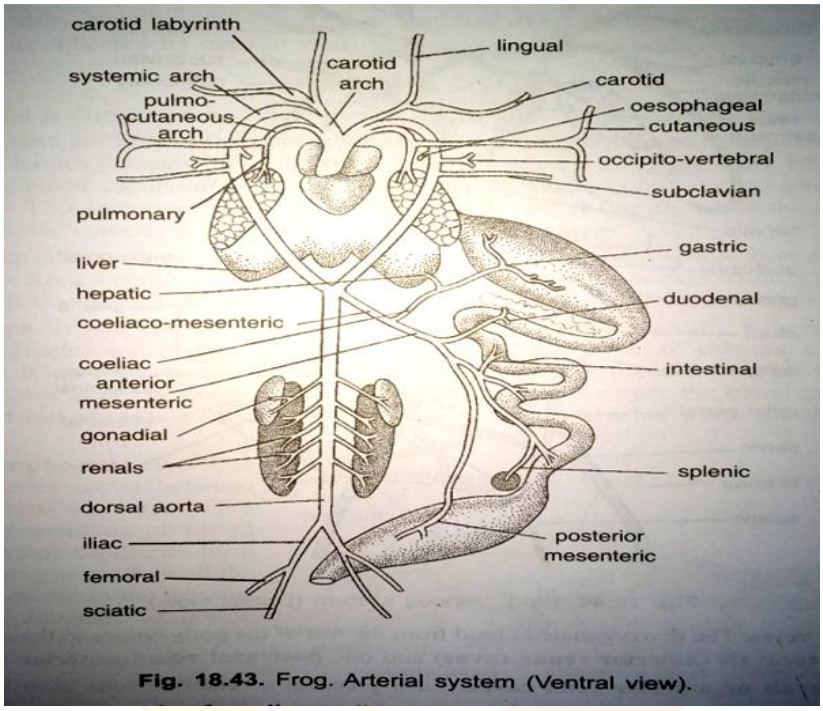


Fig. 18.43. Frog. Arterial system (Ventral view).

Venous system :

- Consists of,
    - Pulmonary system : consists of left and right pulmonary veins from lungs ;which form common pulmonary vein that opens to left auricle
    - Systemic system : 3 large veins :2 pre-caval or anterior venae cavae (drains blood from head and fore-limb) and posterior vena cava or post-caval vein (drains blood from hindlimbs and other posterior parts)
    - Portal system : veins which begin with branches and also ends in branches which carry blood to kidney or liver: renal portal system (from hind-limbs to kidney and liver) and hepatic portal system(from alimentary canal to liver)

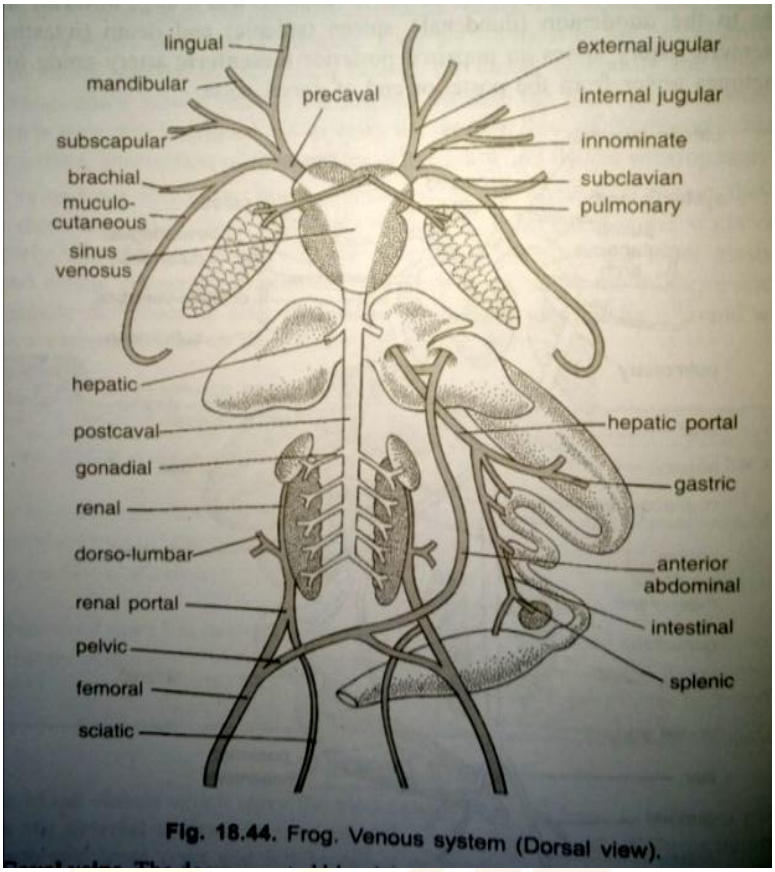
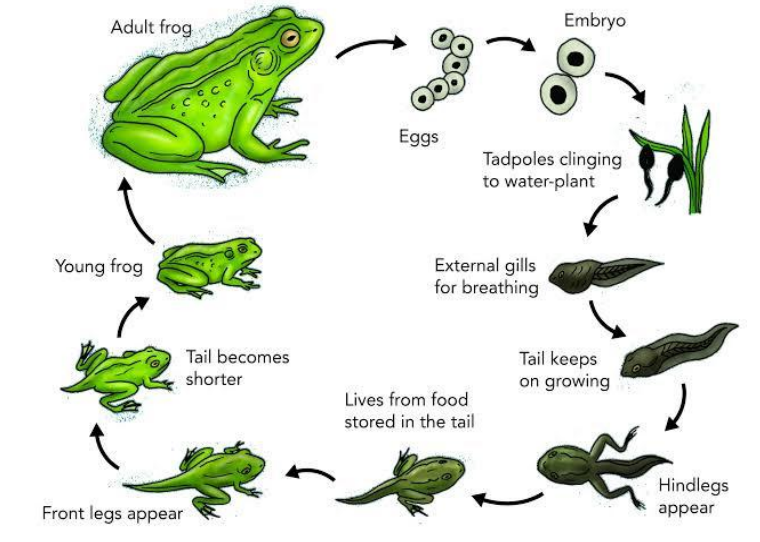


Fig. 18.44. Frog. Venous system (Dorsal view).

METAMORPHOSIS



- It involves the transformation of the fish-like, aquatic, gill breathing,herbivorous, tailed tadpole to an amphibious, air-breathing, carnivorous,tailless adult frog.
- The larval life lasts for about 2 & half to 3 months.
- 3 weeks after the establishment of pulmonary respiration, the larva undergoes certain dramatic changes & eventually transforms to the adult.

- It involves a number of morphological, anatomical & physiological changes.

The most significant ones among them are the following:

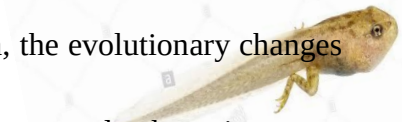
- Tadpole stops feeding, being nourished by the food reserved in its tail.
- Consequently, the tail gradually degenerates & ultimately disappears.
- The larval epidermis is cast off, & horny jaws are discarded.
- Cutaneous glands appear, & they keep the skin moist.
- Mouth becomes wider, and its large & frilled lips shrink.
- Tongue enlarges and becomes glandular & sticky.
- Stomach & liver enlarge, but intestine shortens.
- Gill-slits close up, & the gills completely disappear.
- Branchial skeleton becomes functionless & it transforms to a *hyoid apparatus* for the attachment of the tongue.
- Vascular system gets modified in relation to pulmonary respiration.
- Ammonotelic excretion becomes ureotelic.
- Eyes fully develop and becomes & become functional.
- Hind-limb becomes long & stout for jumping.

When all these changes are completed, a young frog emerges.

- It leaves water & comes to the damp land.
- It feeds & grows and eventually becomes a full-fledged adult.

Significance of tadpole larva:

- Amphibian tadpoles represent a piscine stage.
- The changes undergone by it agree with the *Biogenetic Law* or *Recapitulation Theory*, which states that *ontogeny is a short recapitulation of phylogeny*
- *phylogeny is the mechanical cause of ontogeny.*
- During the developmental stages of an individual organism, the evolutionary changes & stages, undergone by its race, will be briefly repeated.
- So, the piscine stage ,represented by the tadpole larva , reveals that pisces are ancestral to amphibia



DISCOVERY OF BUSH FROG , DANCING FROG AND NIGHT FROG

PSUDOPHILATUS AMBOLI (Philatus amboli)

Class:Amphibia

Order:Anura

Family:Rhacophoridae

Genus:Pseudophilautus

- Commonly called **amboli bush frog**
- Endemic to the western ghats of india
- It was discovered by Dr. Biju and Dr.Bossuyt in 2009.
- Pseudophilautus is a small frog.
- Its body length snout to vent is 34 mm in male and 37.5 mm in female.
- Male will have a large and transparent vocal sac during breeding season.
- It amplifies the crocking sound which serve as a sexual call to attract the female.
- Tympanum is dark brown , the dorsal surface of the body is uniformly blackish brown ,and the throat is lemon yellowish and marbled with minute black spots.
- Development is direct without larval stage.
- Pseudophilautus is now a critically endagered amphibian.
- It lives in extremely disturbed areas
- The major threat to it is the fragmentation and loss of habitat due to expanding urbanization and increasing tourism development

MICRIXALUS

Class : Amphibia

Order : Anura

Family : Micrixalidae

Genus : Micrixalus

- Commonly called **dancing frog.**
- Is a genus of frog from the endemic to the Western Ghats in India .
- Peculiar habit of waving their feet to attract females during breeding season.
- They are monotypic within the family
- Found in the vicinity of fast and slow moving perennial streams in the Western Ghat forest
- During the breeding season Male dancing frogs call from spots close to running water and display their prominent white vocal sac.
    - Male tap their hind feet and extent it subsequently stretching the foot out ward and shaking it.
    - This type of hind leg movement has been termed as *foot flagging*.
    - The mating pair enter the water where the eggs are fertilized.
    - The pair detach, the female lay her eggs in the chamber in the streambed and buries the spawn with sand and gravel using the hind limbs.
    - They are extremely vulnerable as their habitat is severely threatened .
- Their population are declining moving to habitat destruction ,chemical pollution, climate change ,disease and invasive species
- In 2014 ,researchers uncovered 14 new species in genus Micrixalus

NYCTIBATRACHUS

Class:Amphibia

Order:Anura

Family:Nyctibatrachidae

Subfamily:Nyctibatrachinae

Genus:Nyctibatrachus

- Commonly called **night frog.**
- Endemic to the western ghats of India.
- They are the only extant members of the monotypic sub family *Nyctibatrachinae.*
- They are robust bodied frog .
- Range in size from small (snout to vent length 13 mm up to 84 mm).
- They have a concealed tympanum, dorsum with longitudinal skin folds, femoral glands, and expanded finger and toes disks.
- In this species the male moves over the eggs after the female has deposited them.
- Based on integrated molecular morphology and bio acoustic evidence seven new species are formally described.
- Nyctibatrachus species and the new arrivals: (*N. athirappillyensis, N. manalari, N. pulivijayani, N. radcliffei, N. robinmoorei, N. sabarimalai and N. webilla).*
- Four of the new species are extremely tiny in size they can comfortably sit on a coin or thumbnail

MODULE 7

CLASS REPTILIA

Reptiles are cold-blooded, lung-breathing, oviparous tetrapods, with dry skin covered by an exoskeleton of epidermal scales, called *corneoscutes.*

The group is a heterogeneous assemblage, represented by lizards, snakes, crocodiles, turtles, tortoises and lizard-like Sphenodon.

SALIENT FEATURES

- Skin is dry due to the development of hard and cornified epidermis or due to keratinisation.
- Exoskeleton consists of epidermal scales, plates, scutes and spines.
- Among vertebrates,epidermal scales appear first in reptiles as a terrestrial adaptation to prevent the evaporational loss of water.
- Cutaneous glands are extremely reduced or absent, except in some forms where they are modified for the production of scent to attract mates.
- Two pairs of pentadactyl limbs whose digits are tipped with claws
- Vertebrae are gastrocentrous (centrum formed by interventrals, basiventrals being reduced) and procoelous.
- Skull is monocondylian (single occipital condyle)
- jaw suspension is autostylic.
- Temporal fossae are present in the skull (with the exception of cotylosauria and chelonia).
- Pectoral girdle is characterised by an interclavicle.
- Heart is incompletely four-chambered, with two auricles and a partially divided ventricle (crocodiles :4 chambered)
- Respiration is purely pulmonary, gills being absent at any stage.
- Truncus arteriosus is practically absent, and the aortic arches take their origin directly and independently from the ventricle
- Adult functional kidney is metanephros
- Middle ear contains columella auris
- Fertilization is internal.
- Eggs are macrolecithal (heavily yolked), cleidoic (shelled),and amniote (embryo is enclosed within a fluid-filled bag, called amnion).

CLASSIFICATION OF REPTILIA

Based on the number and presence or absence of temporal fossae reptiles were for grouped under four sub-classes as follows:

(i) **Anapsida** - No temporal fossae. e.g., Cotylosauria, Chelonia.

(ii) **Synapsida** - Only lateral temporal fossae present. This group is believed to have g rise to mammals.

(iii) **Parapsida** - Only supra-temporal fossae present.

(iv) **Diapsida** - Supratemporal and infratemporal fossae present.

Later studies on fossil reptiles made it clear that the above classification does not re the evolutionary or phylogenetic relation of the main groups. For example, Ichthyopterygi and Sauropterygians, included under Parapsida, are only very distantly related. So a Lepidosauria and Archosauria, though diapsidans, have evolved separately from the pri tive reptilian stocks. The terms 'Parapsida' and 'Diapsida' are now seldom used, though names 'Anapsida' and Synapsida are still retained. The more widely accepted classificati is to divide Reptilia into six sub-classes, namely *Anapsida, Ichthyopterygia, Synaptosaur Lepidosauria, Archosauria* and *Synapsida.*

Class Reptilia

1. Sub-class Anapsida

Orders :

(i) Cotylosauria (stem reptiles) - Extinct - e.g., *Limnoscelis, Captorhinus.*

(ii) Chelonia (Testudinata) - Living - e.g., turtles, tortoises and terrapins.

2. Sub-class Ichthyopterygia

Orders :

(i) Mesosauria - Ext - Freshwater forms - e.g., *Mesosaurus.*

(ii) Ichthyosuria - Ext - Marine forms - e.g., *Ichthyosaurus.*

3. Sub-class Synaptosauria

Orders :

(i) Protosauria - Ext - Terrestrial - e.g., *Araeoscelis.*

(ii) Sauropterygia - Ext - Aquatic - e.g., *Elasmosaurus, Pleosaurus.*

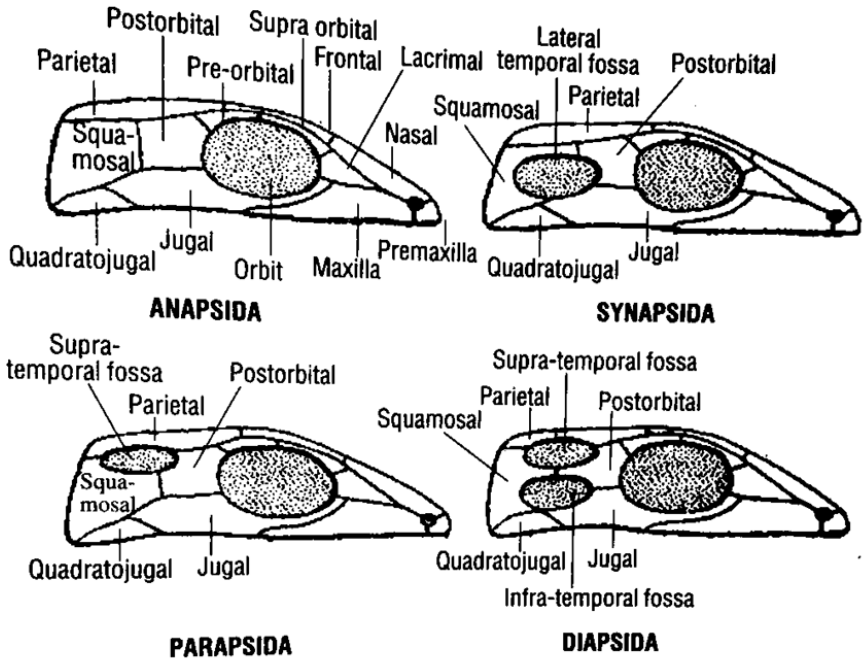
Sub-class Lepidosauria

Orders :

(i) Eosuchia - Ext - e.g., *Youngia*

(ii) Rhynchocephalia - Living - e.g., *Sphenodon.*

(iii) Squamata - Living - e.g., *lizards, snakes.*



Types of reptilian skulls showing the arrangement of fossae

Skull and temporal fossae of reptiles		
Subclasses of reptiles	***No. of fossae on each side and their arrangement***	***Groups***
1. Anapsida	None; roof of skull solid	Cotylosaurs, chelonians.
2. Synapsida	One (lateral temporal fossa); low behind the eye, with postorbital and squamosal meeting above.	Pelycosaurians, mammal-like reptiles.
3. Parapsida	One (supra-temporal fossa); high behind eye, usually with post-frontal and squamosal meeting below.	Mesosaurs and Icthyosaurs.
4. Diapsida	Two (supra and infra-temporal fossae); postorbital and squamosal usually meet between them.	Eosuchians, Rhynchocephalia, dinosaurs, pterosaurs, Crocodilia, Squamata.

5. **Sub-class Archosauria (Ruling reptiles)**

   Orders :

   (i) Thecodontia - Ext - e.g., *Euparkeria.*

   (ii) Pterosauria (Pterodactyla) - Ext - Flying reptiles - e.g., *Pteranodon.*

   (iii) Saurischia (dinosaurs) - Ext - e.g., *Tyrannosaurus, Brontosaurus.*

   (iv) Ornithischia (dinosaurs) - Ext - e.g., *Stegosaurus, Triceratops.*

   (v) Crocodilia - Living - e.g., *crocodiles, alligators, gavials.*

6. **Sub-class Synapsida (Mammal - like reptiles)**

   Orders :

   (i) Pelycosauria - Ext - e.g., *Varanosaurus.*

   (ii) Therapsida - Ext - e.g., *Cynognathus.*

   (iii) Ictidosauria - Ext - e.g., *Tritylodon.*

ORDER:COTYLOSAURIA

1. Cotylosauria is a group of earliest, primitive and extinct reptile.
2. It forms the basic stem *'stem reptiles'*-which the reptiles group have evolved
3. Cotylosaurians lived from upper Carboniferous to middle *Triassic.*
4. They were contemporaries of Carboniferous primitive amphibians and early Permian times.
5. Many of them have a advancement over their labyrinthodont ancestors.
6. Cotylosaurians skeletal features closely resemble to *Labyrinthodontia.*
7. Cotylosaurians probably has a mixed origin and it's members are grouped together based on two features :
   - Anapsid skull
   - Flattened and plate like pelvis.
8. Cotylosaurians remains have been found in North America and South Africa.

EXAMPLE *: HYLONOMUS*

CLASS:REPTILIA
SUBCLASS:ANAPSIDA
ORDER:COTYLOSAURIA

1. Extinct genus of reptile lived in 312 million years ago during late carboniferous period
2. Earliest reptile
3. Only species : *Hylonomus lyelli*
4. Small lizard like animal that apparently lived in forested habitats
5. 20-25 cm long (including tail)
6. Small sharp teeth and it ate small invertebrates ,such as millipedes or early insects, land snails

7. Small head like lizard , sprawled legs , long tapering tail , slender fingers and toes were seen
8. Skulls are simple
9. Females probably deposited eggs on land in moist areas.
10. Animal was discovered by John William Dawson and species name was given by Dawson's teacher ,the geologist Charles Lyell
11. Fossils of hylonomus have been found in the remains of fossilised club moss stumps in the joggins formation, Joggins, Nova Scotia in Canada
12. It is supposed that after harsh weather the club mosses would crash down with the stumps eventually rotting and hollowing out
13. Small animals like hylonomus seeking shelter , would enter and become trapped in hollow trunks , then starving to death.

ORDER CHELONIA

1. Chelonia includes the *turtles,tortoises* and *Terrapins*
2. They are aquatic or terrestrial reptiles with pentadectyl walking legs or flipper like swimming paddles
3. Short and broad body,encased by Bony shell.
4. They differ from all other reptiles in having the *Bony shell*.
5. shell consist of dorsal portion called c*arapace* and a ventral portion called *plastron*
6. Pentadectyl limbs modified into walking or large oar like swimming paddles
7. Toothless jaws covered by a had horny Add produce it in front into a beak
8. *Anapsid skull* without a temporal fossae
9. Single headed ribs with c*apitulum* only;*tuberculum* is absent
10. Only two *sacral vertebrae*
11. Humerus has *entepicondylar foramen*
12. *Pubes a*nd *ischia* form symphyses
13. Quadrate is fixed and immovable(*monimostylic)*
14. Cloacal opening is more longitudinal

EXAMPLE : MELANOCHELYS

CLASS:REPTILIA
ORDER: TURTLES
FAMILY: GEOEMYDIDAE

1. Melanochelys is a genus of turtles in the family Geoemydidae.
2. Members are found in India, Myanmar, Bangladesh, Sri Lanka and Nepal.
3. Melanochelys contains only 2 species.
4. *Melanochelys trijuga :*

- Indian black turtle or Indian pond terrapin inhabits a variety of water bodies including ponds, marshes streams, rivers and artificial water bodies like rice paddies,
- It is a species of medium-sized freshwater turtle found in South Africa.
- The turtle has been introduced to some of the islands of the western Indian Ocean by seafarers
- Omnivorous in dietary habits, the species takes aquatic plants in addition to Invertebrates
- 2 to 16, elongated, brittle-shelled eggs are laid with eggs and hatchlings showing considerable size variation.

5. *Melanochelys tricarinata*:

- Tricarinate hill turtle or three keeled land turtle is a species of turtle found in Northeastern India, Bangladesh and Nepal.

EXAMPLE : CHELONE

CLASS:REPTILIA
SUBCLASS:ANAPSIDA
ORDER:CHELONIA

1. *Chelone mydas* commonly called *sea turtle or soup turtle*.
2. It is one of the largest sea turtle.
3. It is edible ,seen in Indian, Pacific and Atlantic oceans.
4. In India, green turtle basks on beaches near sea around Andaman Islands.
5. Name "green turtle" is due to the presence of green fat in the body.
6. Green turtle come ashore only for egg laying and basking .
7. Green turtle often migrate to long distances.
8. It is long living, their average life expectancy is 150 years .green turtle is now a seriously threatened species on account of mass killing by man.
9. Large body enclosed within a rigid shell.
10. Carapace of shell is brownish ,heart shaped and formed of horny scutes or plates.
11. It joins to plastron by ligaments only, no bony bridges.
12. Adult body colour ranges from green to brown, with spots, blotches or streaks. Those markings are brown or black on dorsal side and pale yellow on ventral.
13. Head is small , neck is short
14. limbs are paddled or flipper like and tail is short and stumpy.
15. Head and neck is partially retractile into shell .
16. Jaws have denticulate edges .
17. Shell and skull are light and porous to reduce body weight .
18. Respiration is pulmonary and lungs have numerous compartments for air storage .
19. Eyes covered by transparent nictitating membrane.
20. Visual power is very high and hearing power is very poor.

ORDER RHYNCHOCEPHALIA :Sub-class:Lepidosauria

1. The sister group to the order squamata,and rhynchocephalids
2. Rhynchocephalids is an ancient reptilian order
3. *Living fossil*
4. They were common and wide-spread in mesozoic times
5. The group is at present by a single surviving genus namely -*sphenodon*
6. Lizard-like reptiles

EXAMPLE : SPHENODON

1. Sphenodon popularly known as, *tuatara*
2. It is restricted exclusively in New Zealand
3. Timid , lizard like ; nocturnal
4. Scaly skin ; flattened tail and pentadactyl limbs
5. Tail is autotomous
6. Vertical pupil
7. No copulatory organs
8. Tranverse slit :cloaca
9. *Diapsidan skull*
10. *Monimostylic*
11. *Acrodont*
12. *Amphicoelous*
13. *Pro-atlas*
14. *Chevron bones*
15. Double headed ribs : *tuberculum and capitulum*
16. Humerus has *entepicondylar and extepicondylar foramina*
17. Radius and ulna separate ; tibia and fibula separate
18. 10 /11 carpals

19. Pectoral girdle has interclavicles ; coracoids lack *fenestra*

20. 3 complete arterial arches

21. Well developed pineal organ

Affinities

only survivor of a very ancient reptilian stock. S0, naturally it shows affinities with lizards and with chelonians, crocodilians and dinosaurs

It is more closely related to Lacertilia

Lacertilian features :

1. General form and shape of the body, with long and laterally compressed tail and clawed limbs.
2. Similar general internal anatomy.
3. Cloaca is a transverse slit.
4. Centrum of caudal vertebrae is divided by cartilaginous septum as in some lizards.
5. Ability for *autotomy* and regeneration of tail.
6. Pelvis is somewhat lacertilian.
7. Chevron bones in caudal vertebrae.
8. Respiratory organs are similar to those of lizards.
9. Presence of *pineal eye.*
10. Lacertilian plan of vascular system.

Primitive features

1. Presence of *infra-temporal fossa* and exclusion of *supra-temporal bone* from supra - temporal arcade.
2. Presence of hard palate.
3. Immovably articulated (*monimostylic)* quadrate.
4. Pro-atlas and *amphicoelous v*ertebrae with vestiges of notochord.
5. Presence of an unbroken series of chevron bones.
6. Presence of double-headed ribs.
7. Elaborate abdominal ribs.
8. Presence of *uncinate process.*

9. Ilium is more erect than in lizards.
10. Humerus with *entepicondylar* and *ectepicondylar foramina.*
11. Presence of primitive number of carpals (numerous carpals).
12. Head is longer and neck is shorter than in lizards.
13. Presence of reduced sinus venosus and persistent conus.
14. Primitive type of aortic arches and presence of ductus
15. Very poorly developed ventricular septum.
16. Absence of copulatory organs.
17. Presence of median pineal eye.

Affinities with Crocodilia

1. Presence of *pro-atlas.*
2. Development of a hard palate.
3. Presence of infra-temporal arcade.
4. Presence of abdominal ribs.
5. Presence of *uncinate process.*
6. *Monimostylic quadrate.*
7. Presence of *pre-maxillary* and *maxillary teeth.*
8. Presence of *chevron bones.*
9. Ten separate carpals as in crocodiles.
10. Erect *ilium.*

Sphenodon differs from Crocodilia in the presence of amphicoelous vertebrae (procoelous in crocodilia), acrodont dentition (dentition is thecodont in crocodiles), clavicle and three-chambered heart (four-chambered heart in crocodilia), and in the absence of pecten and copulatory organ. At the same, in some of its features, it resembles chelonians and dinosaurs also.

ORDER SQUAMATA : Sub-class:Lepidosauria

1. Comprises lizards and Snakes.
2. Lizards first appeared in the Jurassic and underwent extensive radiations in the cretaceous.
3. Snakes obviously derived from lizard like ancestors.
4. Skull is modified diapsid type.
5. In many lizards,the supra-temporl fossa alone present; in other lizards and all snakes,both the supra temporal and infra temporal fossae are absent.
6. The skull of lizards and snakes shows an interesting phenomenon,called kinesis : In this,the upper jaw is able to move in the relation to the rest of the cranium.This mechanism to increase the absolute gape of the mouth.
7. In lizards ,and snakes quadrate is streptostylic and jaw suspension is autostylic.
8. squmates vertebrae are *procoelous.(*except geckos *: amphicoelous)*
9. Body of squamates is covered by horny epidermal scales.
10. In squamata,there is a tendency for the reduction of limbs,and in snakes and in some worm lizards limbs are altogether absent.
11. Specialisation of tongue and *jacobson's organ* for sensory perception.
12. In sphenodon,cloacal opening is a transverse slit.
13. Male is provided with a pair of erectile copulatory organs , called hemipenis.
14. Order Squamanta is divided into three sub-orders : *Amphisbaenia ,Lacertilia and Ophidia.*

SUB-ORDER LACERTILIA : order : squamata

1. Lizards
2. 4 limbed squamates
3. *Infra-temporal fossa* absent
4. *Procoelous* (geckos : amphicoelous)
5. T*uberculum* absent
6. Autotomous tail
7. Tympanum and nictitating membrane present
8. Oviparous

EXAMPLE : CHAMELEON

CLASS : REPTILIA
SUB-CLASS : DIAPSIDA
ORDER: SQUAMATA
SUB- ORDER: LACERTILIA

1. Chameleon is an arboreal lizard found in India, Africa and Madagascar.
2. Its body is covered over by scales that are modified into granular tubercles.
3. The scales on mid -dorsal surface of neck and trunk are modified into a *serrated dorsal crest.*
4. Head bears a prominent *helmet or hood.*
5. Male has characteristic *tarsal spur.*
6. Hands and feet are modified as grasping organs for an arboreal life.
7. Digits are partially fused and are arranged in opposable bundles: *zygodactyly.*This
8. Tail is long strongly prehensile and it can be rolled downwards. It is used as fifth limb to hold on to tree branches.
9. Tongue serves as a remarkably specialized organ of food capture ; tip is club-shaped and sticky, and the base is narrow.
10. Eyes of Chamaeleon are large and independently movable.
11. Pupil is a transverse slit.
12. The whole eye, excepting the pupil, is covered with a thick glandular lid.
13. Each eye has its own range of vision : eye focus on same object :*Binocular vision* is essential for the estimation of the distance of the object.
14. Males of almost all species of chameleons are territorial.
15. The power of Chamaeleon to change colour : Under excitement, the body may become mottled with yellow, blue or black transverse patches or bands.
16. The mechanism of colour change depends on activity *chromatophores* located in the deeper part of the skin.
17. Most species of Chamaeleon lay egg.

Arboreal adaptations ;

- Zygodactyly
- Long and prehensile tail
- Long and extensile tongue
- Large ,independently revolving eyes
- Binocular vision
- Adaptive color changes

EXAMPLE : HEMIDACTYLUS

CLASS :REPTILIA
SUB-CLASS:DIAPSIDA
ORDER :SQUAMATA
SUB-ORDER:LACERTILIA

1. It is the common *House lizard or Wall lizard*
2. It enjoys world – wide distribution, and is quite common in India, Sri Lanka, China, Africa, Europe and the USA
3. *Hemidactylus* is a nocturnal carnivore, feeding upon insects and other small invertebrates.
4. During winter, it may hibernate under wood and logs, and also in crevices of the wall

1. Body is nearly 25cm long, slender and covered dorsally by minute granular or keeled scales.
2. Head is broad, flat and triangular.
3. Snout is obtusely pointed and tongue is protrusible, sticky
4. Eyes are covered with a transparent glassy membrane.
5. Ear opening are vertical.
6. Limbs are weak, and digits are free, clawed and dilated.
7. Tail is fragile and depressed.
8. Digits are furnished below with adhesive pads or vacuum-cups, formed by a complex system of velvetty *lamellae.*

9. Lamellae work on the vacuum-cup principle of adhesion.
10. They enable the lizard to adhere to soft surface, and also to run along ceiling and vertical walls.
11. House lizard has an ingenious method of self defence by caudal autotomy or self mutilation.
12. When alarmed or threatened by enemy, it serves a portion of its tail to divert the attention of the enemy. The severed part of the tail attracts the attention of the enemy. This enables the lizard to escape. The last portion of the tail will be regenerated later

SUB-ORDER OPHIDIA : Order:Squamata

1. Also known as “serpentes".
2. Ophidia includes snakes.
3. Body is elongated.
4. Absence of limbs (except in pythons and boas having rudimentary hind limbs).
5. Absence of external ear openings.
6. Lidless eyes covered with a transparent watch glass like *brille.*
7. Elongated deeply forked and retractile tongue enclosed in a basal sheath.
8. Absence of urinary bladder ; because the urine is semi solid.
9. Teeth ankylosed to inner edge of jaw bone ; they are numerous, small, sharp and recurved.
10. *Aglyphous teeth*
11. *Poison fangs* in poisonous snakes
12. *Jacobson’s organ*
13. Body covered by horny epidermal scales.
14. *Moulting or ecdysis* : periodic casing off and renewal of scaly epidermis.
15. Skull bones are movably articulated.
16. Fore limb bones absent.
17. Greater development of right lung in the expense of the left one.
18. Majority of the snakes are oviparous.
19. Ovoviviparity is found in some snakes.

EXAMPLE : PYTHON MOLURUS : family : boidae

1. Python molurus is a large, non -venomous
2. Python species native in tropical and subtropical region of the Indian subcontinent.
3. It is known by the common names Indian python, Black tailed Python, Asian rock Python.
4. It is generally lighter colored than the Burmese python and reaches usually 3m.
5. Carnivorous ; can devour animals by stretching mouth
6. The rock pythons color pattern is whitish or yellowish with the blotched patterns varying from dark brown shades.
7. They consist of entirely egg laying species .
8. Specimen from the hill forest of Western Ghats and Assam are darker, while those the Deccan and eastern Ghats are usually lighter.
9. The nominate subspecies occurring in India typically grows to 3m.
10. The longest scientifically recorded specimen, collected in Pakistan was 4-6m long and weight 52kg

EXAMPLE : PTYAS MUCOSUS

1. Name *: Ptyas mucosus*(oriental rat snake).
2. previously known as *Ptyas mucosa.*
3. Length : up to 370cm but usually under 3 meters.
4. Habitat : The oriental rat snake prefers open forests, and at times comes into residential
5. Areas.it is terrestrial, and arboreal ,but spending most time on the ground.
6. Active time : these snakes are active during the day and the dawn.at night the snakes can be
7. found sleeping in loose rolls on bushes and in the branches of trees.
8. Description : long, thick snake somewhat resembling possibly mistaken for a king cobra.
9. these are distinctive black lines on lower jaw which are distinctive.
10. the snake is brown bodied, with light bands on the base of the neck and mid-body,turning to black bands towards the tail.
11. Food : ptyas mucosus eats rodents, lizards, frogs, birds and other small animals
12. Defensive behaviour : This snake is not a big biter, despite its size and significant strength
13. Danger : danger of a strong bite which may get infected

EXAMPLE : **GONGYLOPHIS (ERYX) CONICUS *Family : Boidae***

1. Commonly known as the " *earth snake*" , " common *sand boa* " , or "*Russell's sand boa".*
2. Inhabits sandy soil, burrows, piles of bricks and stones, rocky areas, etc.
3. Body is short and thick, 50-100 cm long, and grey, yellow, white, or dark-green in colour.
4. There are uneven chains of irregular, reddish-brown, or blackish blotches on the back.
5. Head bears small scales, instead of shields.
6. Scales are rough and keeled.
7. Snout is projecting, with the mouth placed under it . This is an adaptation for burrowing into the sand.
8. Tail is short, sharply tapering and conical .
9. Sand boa looks like a baby python.
10. Also resembles Russell's viper in having dorsal patches.
11. The patches of viper are rounded or oval and uniform, while those of sand boa are irregular.
12. Sand boa is a burrowing nocturnal snake .
13. It is extremely sluggish . it feeds on small lizards, snakes ,etc.
14. It may go for hunting the prey often in darkness , or may lie in wait for a passing prey , with it's head and neck out of the burrow .
15. It kills the prey by constriction.
16. Sand boa is ovoviviparous. A female gives birth to 6-8 living young ones .

EXAMPLE : INDOTYPHLOPS BRAMINUS :Family – Typhlopidae

1. It is commonly called worm snake or blind snake .
2. It is small earthworm like degenerate snake growing up to 15 to 30cm length .
3. They are found in tropical America , S.Europe , S.Asia , Australia.
4. The body of the common worm snake is slender and cylindrical with blunt head and tail.
5. The back of the body is reddish-brown in color and the under is lighter.

6. The whorl body is covered by extremely minute, smooth, overlapping and shinning scales which have an iridescent sheen.
7. Head is not very clearly distinct from the neck.
8. Eyes are vestigial, very minute and covered by scales and hence they are barely visible dots.
9. Supra labials are four on each side in all species.
10. Lower jaws is without teeth .
11. Tail is provided with tiny spine.
12. Worm snakes live under ground in ant nests and termitaria ,under logs and moist leaves.
13. In soft grounds they can burrow easily. Though worm snakes are regarded as primitive .
14. They are highly specialised for under ground survival and their sensory behaviour and mechanics of movement are highly interesting.
15. When irritated worm snake exudes an unpleasant musk ; it acts like *pheromone* to let other worm snake to sense its presence. Also it act as a *repellent* to ants and predators.
16. Worm snakes prey on worms and the eggs and soft bodied larvae of ants and termites.
17. They lay 5- 8 eggs at a time
18. The time of egg laying is not definitely under stand.
19. It is also claimed that all members of Typhlina are parthenogenic females , males altogether absent

EXAMPLE : COMMON INDIAN KRAIT (BUNGARUS CAERULEUS) : Family : Elapidae

1. Popularly known as "*wolf snake*"
2. Medium sized, highly venomous nocturnal snake
3. Usually inhabiting human dwellings or near around them
4. Smooth and glossy body, which is glistening bluish-black or steel-black above and white below
5. Head is slightly wider than neck and head shields are large
6. A series of white arches or bands across the back. They may be very slightly distinct or entirely absent on head
7. Young ones and some adults may have white spots near the end of head
8. Tail is blunt and cylindrical

9. Vertebral (mid-dorsal) scales are typically hexagonal
10. Belly plates are broad and *sub caudals* are entire(undivided)
11. Infra-labials are four on each side
12. Fangs are *proteroglyphous*
13. Krait feeds mainly on small snakes, lizards and rodents
14. A true cannibal, feeding upon smaller kraits
15. Usually timid and inoffensive
16. It has powerful venom
17. Rarely bites humans. Attacks only when annoyed, trodden or injured
18. Bite is mostly fatal
19. Venom is *neurotoxic i*n action
20. Local symptoms are not much conspicuous and general symptoms appear within 15-30 minutes
21. Krait bite symptoms are similar to those of cobra bite
22. Other symptoms are severe abdominal pain due to intestinal bleeding, drop in BP and confusion followed by death.

***EXAMPLE : NAJA NAJA*:[common Indian cobra or Naja Naja] :Family: Elapidae**

1. Naja naja is a black, buff or wheat-coloured and occasionally brown diurnal snake.
2. It is common in agricultural fields where it has plenty of rats for food and holes to live in.
3. Granaries, termitaria, earthen dams and rock piles also are its favourite haunts.
4. It can also swim in water and climb on trees.
5. Its body is medium-sized (male grows up to 2m), and covered by smooth, shiny scales.
6. There are mostly found north-eastern India, parts of U. P, Bihar, Orissa and Andamans, and all over Bengal and Assam
7. There are 2 sub-species:
   - Naja naja naja(spectacled cobra)
   - 2.Naja naja kaouthia(monocled cobra)
8. Small and indistinct head, rounded pupil.
9. Presence of prominent hood, supported by ribs and marked by *binocellate* (spectacled)or m*onocellate*(monocled) mark.
10. Two black spots or patches on the ventral side of the neck.
11. Third *supralabial* shield is large and it extends between the nasal and ocular shields.
12. A tiny cuneate shield is present, wedged between the 4th and 5th **infralabials**;only in rare cases this is absent.
13. Tail is cylindrical and sub-caudals are doubled or divided.
14. Large head shields, small vertebrals and broad ventrals.
15. *Proteroglyphous fangs*.
16. Hood is the most prominent feature.It is a lateral expansion of the neck,supported by cervical ribs. It has a characteristics spectacle- shaped or oval mark.

17. They are not normally aggressive, but fairly placid and inoffensive and prefer to flee rather than to fight.
18. However, when distributed, threatened, or frightened, they may react ferociously; they may raise the front part of the body, spread out the hood.
19. It produce violent hissings and sway the head back and forth and side to side, ready to strike.
20. All these are threat displays or warning signals to scare away the enemy.
21. The bite of cobra is usually a quick snap, but may be tenacious.
22. Cobra venom is n*eurotoxic* in action.
23. It is very potent, and may kill a human being in about 2 to 6 hours after bite,if a lethal dose is injected.
24. Death is usually due to respiratory paralysis.
25. The symptoms are local as well as constitutional.
26. Studies have shown that cobra venom can destroy certain cancer cells in mice.
27. Painkillers, such as ' Cobroxin' and ' Nyloxin 'have been prepared from cobra venom.

EXAMPLE : RUSSELL'S VIPER : Family : Viperidae

1. Russell's viper also called the *chain viper* and *daboia.*
2. Heavy bodied and brown or yellow coloured.
3. They are ovoviviparous.
4. May grown up to 1.5 to 2m.
5. Thick and rough scaled body, narrow neck and blunt tail.
6. Flat, broad and triangular head, covered by small keeled head scales.
7. V-shaped mark and some spots on the head.
8. 3 longitudinal rows of reddish- brown patches on the back, each encircled by black and white lines
9. *Solenoglyphous fangs.*
10. Habits of viper is hills, forests and plain areas. All over the India.
11. During day time it is very lazy and usually remains coiled in grasses or in safe place.
12. It performs fast movement in short spurts.
13. Female retains 20-40 eggs in her oviduct and give birth to living young ones during May-July.
14. Young ones will eat other snakes, lizards and some arthropods.
15. Adults are rodent eaters.
16. The venom of viper is *haemotoxic*..
17. The local symptoms of viper bite include swelling, stinging pain and bruising of the bitten part.
18. Constitutional symptoms include rapid collapse and failure of the heart, victim may feel sick, vomit blood, followed by unconsciousness and ultimate death from cardiorespiratory failure.

EXAMPLE : OPHIOPHAGUS HANNAH : Family :Elapidae

1. The king cobra also known as the *hamadryad*, is a venomous snake species in the family Elapidae endemic to forest from India through southeast Asia.
2. It is threatened by habitat destruction and has been listed as vulnerable on the IUCN red list since 2010.
3. It is the world's longest venomous snake.
4. Adult king cobras are 3.18 to 4 m(10.4 to 13.1 ft) long on average.
5. The longest known individual measured 5.85 m(19.2 ft)
6. It is the sole member of genus Ophiophagus.
7. It preys chiefly on other snakes and occasionally on some other vertebrates such as lizard and rodents.
8. It is a highly venomous and dangerous snake when agitated or provoked that has a fearsome reputation in itsrange., although it is typically shy and avoids confrontation with humans when possible.
9. The king cobra is a prominent symbol In the mythology and folk traditions of India, Sri Lanka and Myanmar.
10. It is the national reptile of India.

IDENTIFICATION KEY FOR POISONOUS AND NONPOISONOUS SNAKES

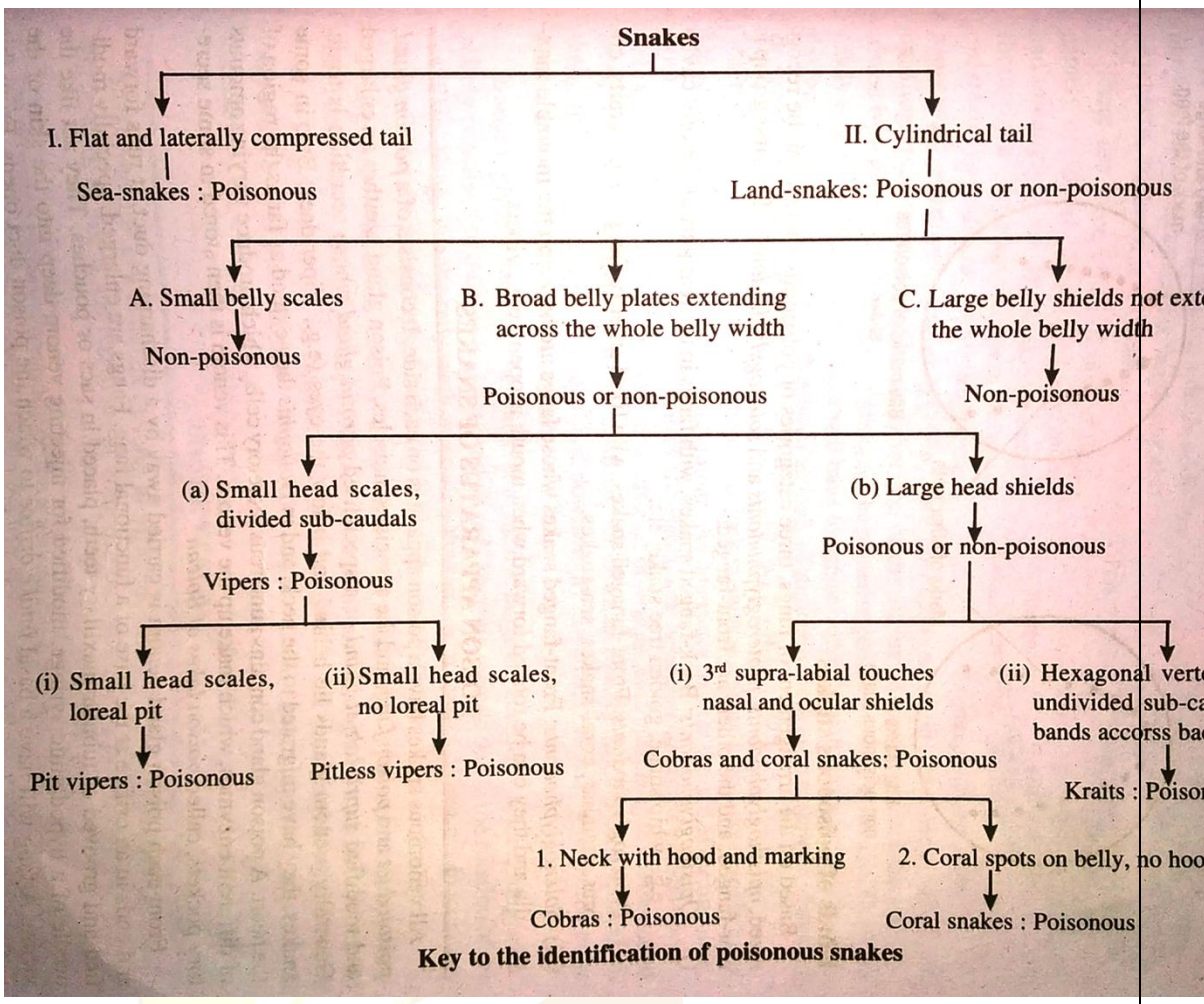
All snakes have well developed labial and salivary glands whose secretion is powerfully toxic.

NON- POISONOUS SNAKES

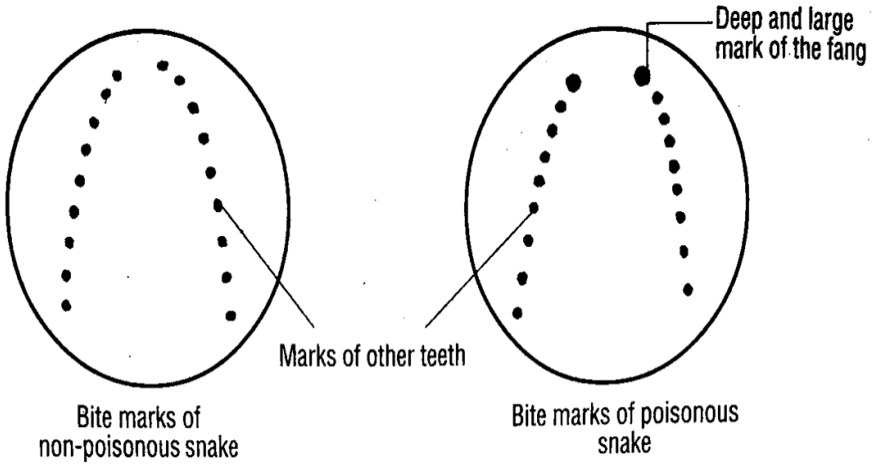
- In the case of non- poisonous snakes , the bites of these snakes produce no signs or symptoms of venom action.
- This is because of the absence of venom injecting fangs in them.
- Thus, the non- poisonous snakes are not the snakes which do not produce venom, but are the snakes whose bites never evoke signs or symptoms of envenomation, despite the presence of toxins in their saliva.
- More over their teeth are all solid, and never grooved or tubular.

POISONOUS SNAKES

- Poisonous snakes are the snakes which possess one to four pairs of grooved or tubular fangs Which act as hypodermic needles specialised for injecting venom , So the bites of these snakes will produce serious symptoms of envenomation
- Poisonous snakes are found in tropical and subtropical countries.
- They are altogether absent in New Zealand and Ireland.
- In India, there are about seventy species of poisonous snakes of which 40 are land- snakes and the others are sea- snakes.
- The commonest ones among them *are cobras , kraits , vipers ,coral snakes and sea snakes*



Key to the identification of poisonous snakes



Kinds of poisonous snakes

Based on the arrangement of fangs, three categories of poisonous snakes can be recognized, *opisthoglyphodonts, proteroglyphodonts* and *solenogylyphodonts*. The first group is rear-fanged, and the others are front-fanged.

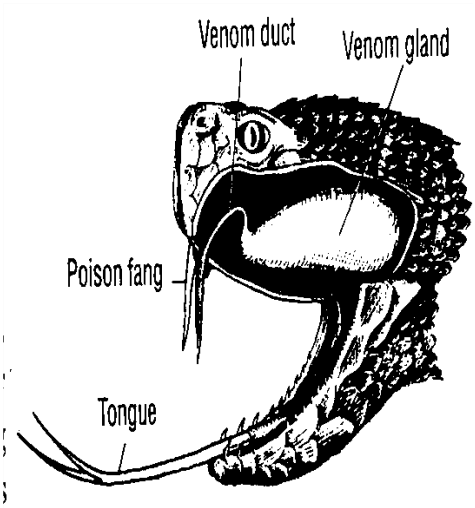
(i) *Opisthoglyphodonts*: Back-fanged snakes, with fangs in the rear part of the oral cavity - e.g., whip snake, golden tree snake, etc.

(ii) *Proteroglyphodonts*: Front-fanaged snakes, with fixed anterior fangs - e.g., kraits, cobras, mambas, coral-snakes, sea-snakes.

(iii) *Solenoglyphodonts*: Front-fanged snakes whose fangs are borne on the movable maxilla and they can be rotated forward when mouth is open - e.g., vipers.

Poisonous snakes can be distinguished from Non- poisonous snakes based on the following external features :

- Tail flat and laterally compressed - sea -snakes ; poisonous
- Tail cylindrical and not compressed - land - snakes ; poisonous
- Small scales on belly as on back - Non- poisonous
- Large belly plates, which do not extend all across the belly plates - Non poisonous
- Broad belly plates, extending over the entire width of the belly - poisonous or Non- poisonous
- Small scales on head , divided sub- caudals - viper; poisonous
- Small head scales , loreal pit in between eye and nostril - pit viper ;poisonous
- Small and keeled head scales , no loreal pit - pitless viper ; poisonous
- Large shields on head - poisonous or Non- poisonous
- Third upper lip shield (supra - labial) touches the nasal and ocular shields - cobras and coral snakes
- Neck with hood and marking- cobras; poisonous
- Coral spots on belly - coral snakes ; poisonous
- Single row of hexagonal vertebrals, undivided sub- caudals , bands or half rings across back.



Poison apparatus of snake

ORDER CROCODILIA

1. Lizard -like and depressed body, covered by a thick osteodermal armour of modified epidermal scales and bony scutes.
2. Prolonged jaws and wide oral gape.
3. Nostrils are valvular and situated dorsally near the tip of the snout.
4. Eyes are guarded by upper and lower eye -lids and transparent nictitating membrane.
5. External ear opening is covered by a flap of skin, which can close the ear opening by muscular action.
6. Tongue is non-protrusible and fixed to the buccal floor. In marine crocodilians, tongue contains salt glands for the elimination of excess salts from the body fluid. Salt glands are absent in freshwater forms.
7. Short *pentadactyl limbs* with webbed and clawed digits.
8. Massive and laterally compressed tail which is used as a swimming organ and also as an offensive and defensive weapon.
9. *Supralabial* and *infralabial glands* which produce a tear -like secretion.
10. Pre -maxillary and nasal glands in the upper jaw, which are similar to salivary glands.
11. Peg -like teeth and *thecodont dentition*.
12. A bony secondary palate, which cuts off the oral cavity from the nasal canals.
13. A muscular septum seperating the heart and lungs from the abdominal cavity. It is analogous to the diaphragm of mammals and it presumably increases the efficiency of the ventilation of lungs.
14. Four -chambered heart, with an opening between the right and left systemic arches, called foramen of panizza.

15. Autostylic jaw suspension and monimostylic (immovable)quadrate.
16. The presence of pro -atlas, in front of atlas, chevron bones in caudal vertebrae, and uncinate processes on ribs.
17. Diapsidan skull, with supratemporal and infratemporal fossae and arcades.

Crocodilians differ from other living reptiles and resemble mammals in possessing some advanced features, such as bony secondary palate, thecodont dentition, diaphragm -like muscular partition, four -chambered heart, pleural membranes convering the lungs etc.

EXAMPLE : CROCODYLUS

CLASS:REPTILIA
ORDER:CROCODILIA
FAMILY:CROCODYLIDAE

- ***CROCODYLUS POROSUS***

1. Estuarine crocodile
2. Semi-aquatic
3. Body is thick and dark olive brown above , with thick spots or patches
4. Shielded with *osteoscutes* arranged transversely
5. Tail is powerful , long and laterally compressed
6. Short and broad snout
7. *Thecodont* teeth hind feet : webbed for swimming
8. Feeds on fishes , reptiles , water birds and small mammals
9. Endangered

- ***CROCODYLUS PALUSTRIS***

1. Marsh crocodile
2. Commonly called mugger
3. Smaller than others ; grows upto 3 to 5 m
4. Dark olive body ; shielded with *osteoscutes*
5. Tail: laterally compressed and powerful
6. Head : large ,snout is short and broad
7. *Thecodont* teeth hind feet : webbed for swimming
8. Feeds on fishes , reptiles , water birds and small mammals
9. Endangered

EXAMPLE : GLAVIALIS GANGTICUS

1. Commonly called the *gavial or gharial*.
2. Is a fresh water crocodilian,found in India and Malaysia.
3. It inhibts the indus,Ganges,Brahmapura and Mahanadi rivers.
4. Habitually it banks on river banks for long periods in summer.
5. Body is thick,coverd with osteoscutes or bonyplates .

6. Body is olive coloured with dark brown spots or bars
7. Grows to 6m or more
8. Head is small,and snout is long,narrow and beak like.
9. Male has a hump at the end of the snout
10. Jaws are armed with sharp teeth.
11. Tale is laterally compressed and powerful.
12. Hind feet are webbed.
13. Gravial feeds on fishes,birds and small mammals.
14. Gravial is now *critically endagered* due to massive killing for its hide.

EURYAPSIDA

1. Euryapsida is a polyphyletic group of reptiles (polyphyletic – unnatural, as the various members are not closely related)
2. The Euryapsida were typically aquatic types. Especially from the mid-Triassic on wards
3. Euryapsida first appeared in the Permian and became extinct at the end of the Mesozoic
4. The Euryapsids are distinguished by a single *temporal fenestra,* an opening behind the orbit, under which the postorbital and squamosal bones articulate
5. They are different from synapsid, which also have a single opening behind the orbit by the placement of the fenestra
6. In synapsid this opening is below the articulation of the *postorbita*l and *squamosal bones*
7. It is now commonly believed that Euryapsids are in fact diapsids(which also have two fenestra behind the orbit)
8. The subclass includes the Plesiosauroidea, Nothosauria, placodontidae
9. The Ichthyosauria had a similarly placed opening but there were key different in the arrangement of the bones forming its margins. For this and other reasons the ichthyosaurs are placed in the subclass *Ichthyopterygia*

PARAPSIDA

1. Extinct
2. Skull-parapsid
3. Skull with a single *dorso -lateral temporal* opening on either side
4. Protosaurs, Nothosaurus, placodonts showed this type of skull
5. These opening are bounded below by the supra temporal and post frontal bones
6. They lived during mesozoic to cretaceous period

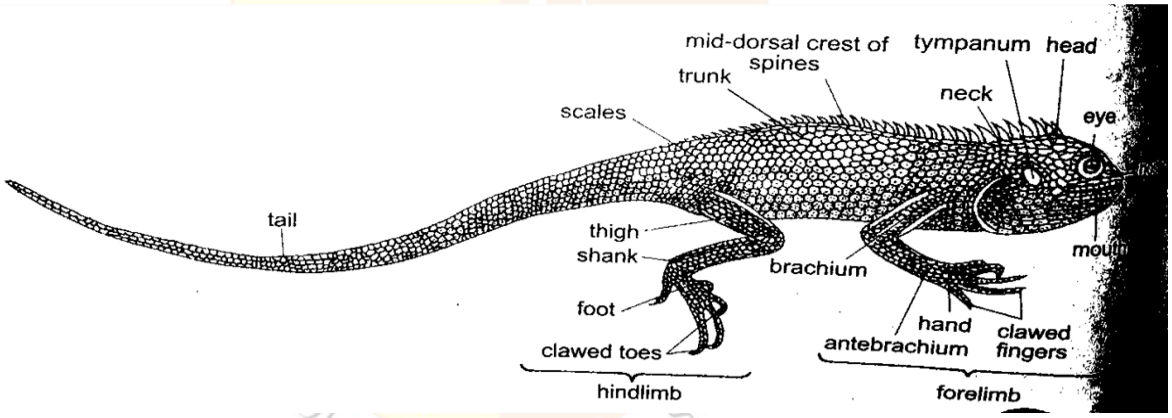
- Mesosauria- extinct, Eg:- mesosaurus
- Icthyosauria-extinct, Eg:- Icthyosaurus
- Proterosauria-extinct, Eg:- Araoscelis
- Sauropterygia-extinct, Eg:- Cyamodus,Kronosaurus

SYNAPSIDA

1. Extinct mammal - like reptiles, supposed to be ancestral to mammals.
2. Only the lateral temporal fossa present.
3. Is an interesting group of reptiles which shows various stages of mammalian evolution from earliest reptiles.
4. Divided into 3 orders :

- Pelycosauria:
    - Eg. Varanosaurus.
- Therapsida :
    - Or true mammal-like reptiles
    - Eg. Cynognathus.
- Ictidosauria:
    - Eg. Tritylodon.

TYPE : CALOTES VERSICOLOR (GARDEN LIZARD)



- Commonly called : garden lizard
- Body divisible into : head , neck , trunk and tail
- Body is covered by exoskeleton of *horny epidermal scales*
- Mid-dorsally, neck and trunk bears *: spiny crest*
- Neck becomes crimson-red color during breeding and also when excited
- Head bears mouth and paired nostrils, ear openings and eyes.
- Each eye is provided with upper and lower eyelids and a nictitating membrane.
- Behind the eyes, are auditory apertures, covered by the tympanic membrane.
- Trunk bears paired pentadactyl fore-limbs and hind-limbs.
- Fore-limb has three divisions: *brachium* (upper arm), *antebrachium* (fore-arm) and *manus* (hand)
- Manus is divisible into three regions, namely c*arpus* (wrist), *metacarpus* (palm) and 5 terminally clawed *digits or fingers.*

- Hind-limb also has three divisions : *femur* (thigh) ,*crus* (shank) and *pes* (foot).
- Pes is divisible into tarsus (ankle), metatarsus (sole) and 5 terminally *clawed toes*.
- Situated ventrally at the root of the tail is the *cloacal aperture*

SKIN OR INTEGUMENT

rough, dry and scaly and has almost no glands to prevent the loss of water(this is an adaptation to prevent evaporation of water)

The histological structure of skin Shows 2 layers

- *an outer epidermis*
- *an inner dermis.*

1. Epidermis.

- The epidermis is stratified and derived from ectoderm.
- Comprises a well developed *stratum corneum* or horny layer which serves admirably protect the lizard trom desiccation.
- The *stratum corneum* is composed of thin, flattened and dead cells due to the deposition of horny scleroprotein or keratin.
- Epidermis produces horny scales covering the body.
- This layer undergoes ecdysis ,periodically.
- Below this is a layer of chromatophores.
- At the base of epidermis lies a Single-layered germinal epithelium with prominent nuclei
- *Germinal epithehum* proliferates cells which move outward and form the stratum corneum.
- Horny layers covering the terminal ends of digits form the claws.

2. Dermis

- The dermis lies beneath the epidermis.
- It is a well developed thick layer of dense fibrous connective tissue
- Contains muscle-fibres, blood vessels, nerves and *chromatophores.*
- The scales , covering the entire surface of the animal, are formed from special folds of dermis.
- No glands in the skin except a few femoral glands which are found on the ventral surface of thigh
- These glands secrete a substance in males that hardens into temporary spines which help in clasping the female at the time of copulation.

3. Muscles

- Below the body wall or skin is present a layer of muscles which help in locomotion

- Beneath the muscle layer is the peritoneum which is formed of closely fitting mesodermal cells.
- It encloses the body cavity

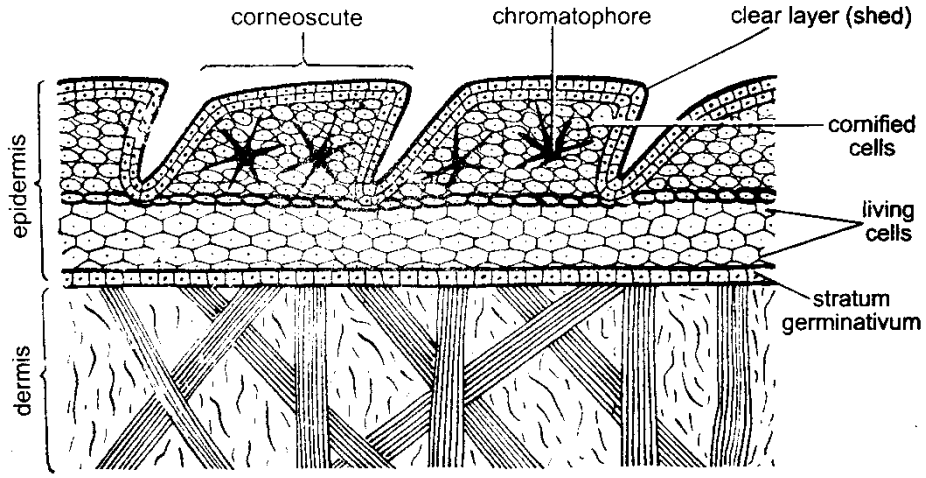
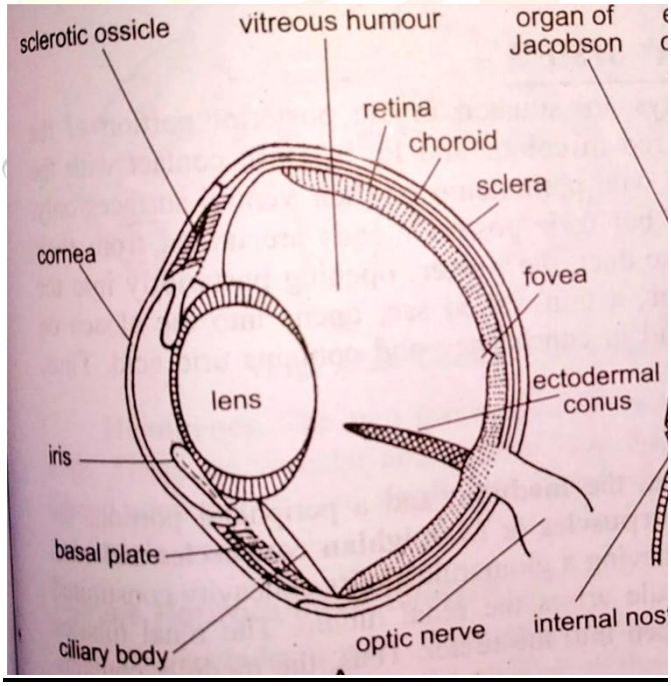


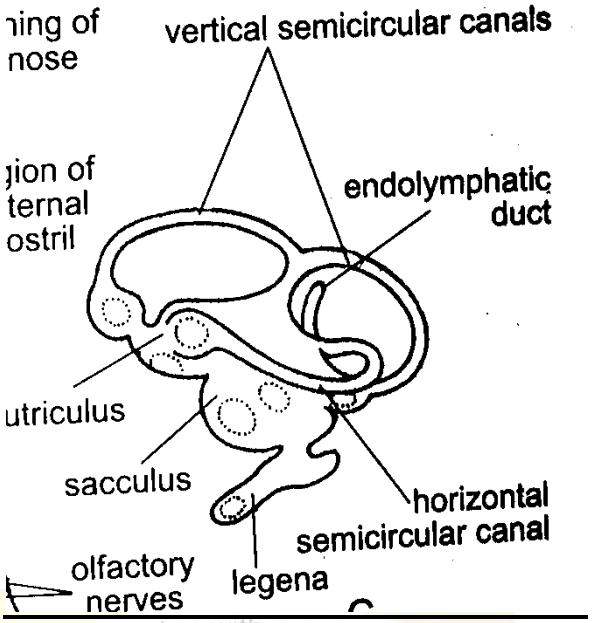
Fig. 21.3. *Uromastix*. V.S. of integument. (Diagrammatic).

SENSE ORGANS

1. **EYE**



2. **EAR**



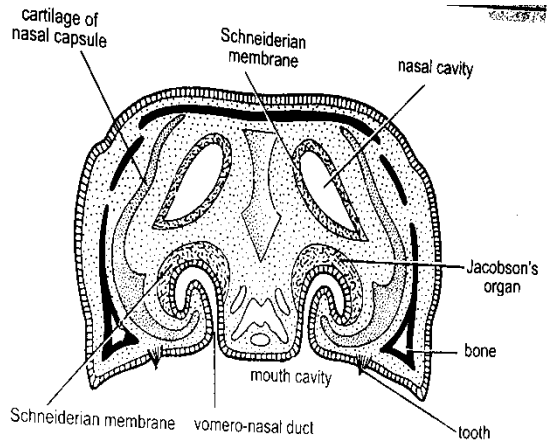
3. PINEAL EYE

- In most reptiles (Lacerta, Calotes, Varanus, Anguis, ete.) And particularly in Sphenedon ,the roof of diencephalon is produced into a hollow median outgrowth, in front of epiphysis or pineal organ
- The parietal organ or pineal eye is situated in the parietal foramen of the cranial roof just under the integument and covered in the young by a transparent scale. The distal end of this becomes constricted off as a hollow sphere, while the remainder is converted into a nerve.
- The wall of the hollow sphere becomes divergently modified on opposite sides.
- The distal side gives rise to a lens-like thickening.
- The proximal side forms a membrane several layers in thickness the retina.
- The whole is enclosed in a capsule of connective tissue.
- The nerve usually degenerates before the animal reaches maturity.

4. JACOBSON'S ORGAN

- There are a pair of vomero-nasal organs or Jacobson's organ
- The organs of Jacobson are well developed sac-like chambers lying below the nasal cavity but above the buccal Cavity.
- Each organ consists of a blind sac lined with olfactory epithelium
- It develops as a ventral hollow outgrowth of the nasal cavity
- They are lined with olfactory epithelium
- Each sac opens to buccal cavity by a narrow duct
- The organ of Jacobson is innervated by branches of the olfactory and trigeminal nerves
- This sense organ is important in most lizards and snakes and appreciates scent particles introduced into it by the tongue tips.
- These organs serve to smell the food

- In some reptiles. They play a part in activities such as trailing prey and locating members of the opposite sex.
- Chemoreceptor



ENDOSKELETON

2 divisions :

- Axial : skull , vertebral column ,ribs , sternum and hyoid apparatus
- Appendicular : limbs and girdles

1. VERTEBRAL COLUMN

4 regions :

- *Cervical / neck region* :8 vertebrae
- *Thoraco-lumbar / dorsal region* : 22 vertebrae
- *Sacral region* : 2 vertebrae
- *Caudal / coccygeal* : varrying number

a) Typical vertebra

- A vertebra from the anterior thoracic region can be taken as a typical vertebra.
- Its centrum is elongated and *procoelous*
- Centrum bears the *neural arch*, that encloses the *neural canal* or spinal canal for the passage of the spinal cord.
- *Neural arch* bears a short *neural spine* and a pair of transverse processes.
- *Transverse processes* are extremely reduced.
- Articular processes, called *pre* and *post zygapophyses*, are present for articulation with the vertebra in front and behind.
- On each side, at the junction between centrum and neural arch, is an articular facet, : *capitular facet*, for the articulation of rib.

b) Cervical vertebrae

- Cervical vertebrae, in general, are similar to the trunk vertebrae, though they are a little shorter.
- the first (atlas) and second vertebrae (axis)differ greatly
- All cervical vertebrae, behind the third one, have paired articular surfaces for *cervical ribs*.

➢ **Atlas**

- Atlas is almost ring-like, without a definite centrum.
- On its anterior face, is an articular facet for the occipital condyle of the skull.
- Atlas is composed of three pieces :1 ventral and the others dorso-lateral.
- The dorso-lateral pieces are connected together by :*ligamentum transversum*.
- Ligament divides the space inside the atlas into two portions: *spinal canal* and *odontoid canal*.

➢ **Axis**

- Axis has a short conical process, called *odontoid process*.
- On the ventral surface of the axis and all the remaining cervical vertebrae, is a bony nodule: *intercentrum or hypapophysis*.

c) Thoraco-lumbar and sacral vertebrae

- Similar structure of the typical vertebra.
- Have attached ribs.
- Sacral vertebrae have short centra and expanded transverse processes.
- Their transverse processes meet the ilia of the pelvic girdle and thus serve as *sacral ribs.*

d) Caudal vertebrae

- Anterior caudal vertebrae are similar to the sacral vertebrae, but have longer centrum and neural spine, and slender transverse processes.
- Posteriorly, caudal vertebrae become progressively smaller and their various processes get reduced to mere prominences.
- At the end of the tail, the whole vertebra is represented by *a rod-like centrum*.
- Attached to the centrum of several anterior caudal vertebrae are Y-shaped bones, called *chevron bones*,

e) Ribs and sternum

- Curved slender rods.
- They are single-headed, with only *capitulum (tuberculum* being absent)
- All pre-caudal vertebrae, with the exception of the first three cervicals, bear ribs.
- Cervical ribs are very short, and are not connected with the *sternum.*
- Thoracic ribs are large and articulate with the sternum

- Each of them has two portions: a dorsal bony part: *vertebral rib / bony rib*, and a ventral cartilaginous part, called *sternal rib or cartilaginous rib*.
- The sternal ribs of the first three thoracic vertebrae articulate with the sternum, while those of the remaining thoracic vertebrae are very short and so they do not reach the sternum.
- Sternum is a rhomboidal cartilage.
- The sternal ribs of the first three thoracic vertebrae articulate with it.
- Fixed to its apex anteriorly is a T-shaped bone, called *interclavicle.*
- Connected to the two limbs of the interclavicle are 2 *clavicles.*
- Pectoral girdles articulate with the antero-lateral border of the sternum.

2. FORE-LIMB

- In the fore-limb, the upper arm is supported by a short and stout bone: *humerus* which has an ossified *shaft* and unossified cartilages : *epiphyses*, at its proximal and distal extremities.
- Shaft has a prominent ridge, called *deltoid ridge*.
- The rounded proximal extremity of humerus is called *head*, and its expanded and pulley-like distal extremity is called *trochlea*.
- Trochlea has two articular surfaces for radius and ulna and two protuberances : epicondyles : the *radiale epicondyle* and the *ulnare epicondyle*
- Fore-arm is supported by two slender bones, radius and ulna.
- The proximal end of ulna is produced into an upwardly directed process : *olecranon process*.
- At the lower end of radius, is a small *styloid process.*
- *Carpus* or wrist region is supported by ten small bones, called *carpals*.
- Supporting the *metacarpus* or palm region are five *metacarpals*.
- Digits are supported by *phalanges.*
- Phalangal formula of the fore-limb is 2, 3, 4, 5, 3.

3. PECTORAL GIRDLE

- Pectoral girdle of lizards is characteristic in having a median T-shaped bone, called *interclavicle*.
- Articulating with the two limbs of the interclavicle are two *clavicles.*
- each half of the pectoral girdle consists of the *Coracoid, Scapula* and *Suprascapula*.
- Laterally, at the junction between coracoid and scapula, is the *glenoid cavity* into which the head of humerus is fixed to form the *shoulder joint*

- In the coracoid, there is a pair of wide openings : *Coracoid Fenestra* , which divide the coracoid into two portions :pre-coracoid, and posterior coracoid. Coracoid and interclavicle articulate with the sternum ventrally.

4. HIND LIMB

- The thigh is supported by a stout bone, called *femur* ;which has a cylindrical *shaft* and two *epiphyses.*
- The rounded proximal extremity of the femur forms the head.
- The distal extremity is pulley-shaped with outer and inner pronminences, called c*ondyles,* for articulation with tibia and fibula.
- Shank or crus region is supported by *tibia* and *fibula*.
- Along its dorsal edge, tibia has a longitudinal ridge, called *cnemial crest*.
- *Tarsus* region is supported by the *tarsals*
- *Distal tarsals* (iv and v) articulate with the *metatarsals*.
- The metatarsus region is supported by five metatarsals, and the *digits (toes)* are supported by *phalanges.*
- Phalangeal formula : 2,3,4,5,3

5. PELVIC GIRDLE

- Consists of two compound bones: os innominata one on each side.
- Each os innominatum is a triradiate bone, formed by the fusion of three bones
    - Ilium
    - Ischium
    - Pubis.
- Laterally,at the junction of these, is a cup-like cavity, called *acetabulum* into which the head of femur is fixed to form the *hip joint*.
- Ilium extends forwards and backwards and articulates with the sacral vertebrae.
- The pubes of the two sides meet together to form the *pubic symphysis*.
- The right and left Ischia form the ischiatic symphysis.
- Extending upward from the pubic symphysis is a calcified cartilage : *epipubis*.
- Extending downward from the ischiatic symphysis : *hypoischium.*
- In between the ischium and pubis on each side is a wide space: *obturator foramen / ischio-pubic foramen*.

URINOGENITAL SYSTEM

1. Excretory organs :

- Includes a pair of *metanephric kidneys* ,lying in the posterior part of the body cavity

- Kidney : dark colored and lobulated
    - 2 parts : broad anterior part (remain separated) and narrow posterior part (remain in close apposition with each other)
- Leading from each kidney : urinary duct or *metanephric duct*
- Terminally, urinary duct opens directly to urodaeum of the cloaca in female. But in male, it joins the vas deferens forming urinogenital duct or ureter and then opens to urodaeum
- Thin walled urinary bladder also opens to urodaeum
- Kidneys are tubular glands formed of numerous tubules called *nephrons*

Adaptations to reduce water loss

- Glomeruli and malpighian body is reduced in size : adaptation to reduce water loss
- Excretion : uricotelic : nitrogenous waste are excreted as uric acid with very little loss of water
- Water is reabsorbed from the urine in urodaeum and urinary bladder

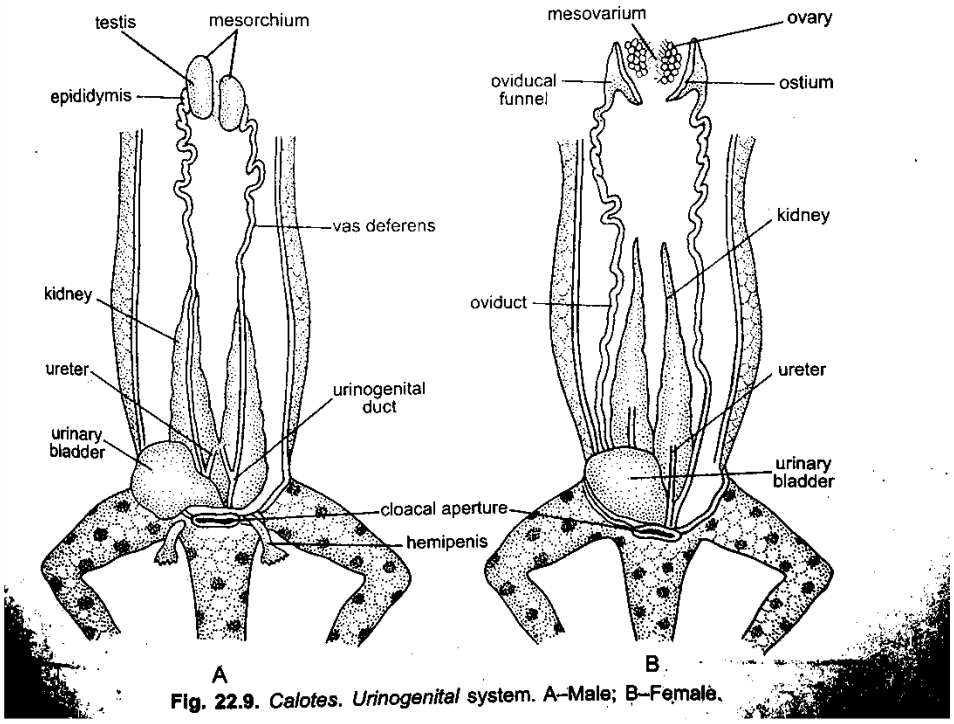


Fig. 22.9. *Calotes. Urinogenital* system. A–Male; B–Female.

2. **Male reproductive system :**
    - Pair of whitish and oval testes : attached to dorsal body wall by a double fold peritoneum : *mesorchium*
    - testis : compound tubular gland , formed of a large number of coiled tubules : *seminiferous tubules*

- seminiferous tubules terminally form a network in each testis
- leading from this : *vasa efferentia*
- vas a efferentia joins a median sperm duct : vas deferens (*Wolffian Duct)*
- highly convoluted aprt of vas deferens : *epididymis*
- vas deferens terminally jpoins the urinary duct and forms the urino-genital duct , which opens to urodeaum

Arising from proctodeaum of cloaca are two grooved , vascular and eversible copulatory organs : *hemipenis* : copulatory organ : helps in transferring sperms to female genital tract

3. <u>Female reproductive organs :</u>

- Includes a pair of irregular ovaries : suspended from the dorsal body wall by : *mesovarium*
- Ovary is formed of numerous lobule s: ovarian follicles
- Mature ova are released by the rupture of the follicles
- There are 2 oviducts (*Mullerian Duct*) ;not continuous with the ovaries
- Oviducts are held in position by : *mesotubularium*
- Basal part of oviduct : oviduccal funnel which opens to the body cavity by a ciliated opening *: ostium*
- Oviduct enlarges at the posterior end :*ovisac (*uterus)
- Oviduct opens to urodaeum
- Oviduccal wall is glandular :2 glands *: shell glands* and *albumen glands*
- Fertilization : internal
- Oviparity
- Fertilizatrion occurs in the initial part of the oviduct
- Eggs are *cleidoic (shelled) , amniote* and *macrolecithal*
- Developing embryo within the egg is enveloped and enclosed by the embryonic membrane s: amnion and allantois

<u>DIGESTIVE SYSTEM</u>

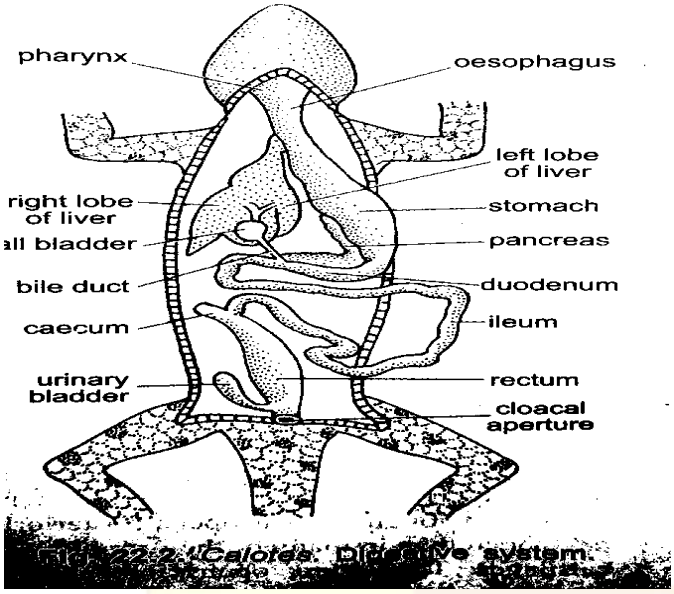
1. <u>Alimentary canal :</u>

- Long , coiled and tubular
- Difrentiated into ,
    - Mouth
    - Buccal cavity
    - Pharynx
    - Oesophagus
    - Stomach
    - Intestine
    - Cloaca

- **Mouth :** wide gap , bordered by scaled upper and lower lips bounded by jaws
- Jaws are provided with single row of teeth
- Dentition : *homodont*
- Dentition is *pleurodont* (teeth are fused with the inner edge of the jaw bone)
- **Buccal cavity :** anterior end of roof : internal nostrils ;posterior end : Eustachian openings . lying on the buccal floor : muscular and protrusible tongue
- Pharynx : buccal cavity is folloed by pharynx whose lining may be thrown into longitudinal folds
- **Stomach :** 2 portions : cardiac and pyloric portion
- Pyloric stomach leads to duodenum **:** junction : is marked ny a constriction called *pylorus ;*guarded by pyloric sphincter
- Duodenum and ileum constitutes the **small intestine**
- Colon is less distinct
- Rectum constitutes the **large intestine**
- At the junction between ileum and colon is a blind pouch on the left side : *caecum*
- Rectum opens to cloaca
- Cloaca has 3 distinct portions ,
    - Anterior *coprodaeum* : opens rectum
    - Middle *urodaeum* : opens urinogenital ducts
    - Posterior *proctodeaum* : common chamber for all
- Alimentary canal is held in position: by peritoneum
- Stomach is suspended by : *mesogaster*
- Intestine is suspended by : *mesentery*

1. **<u>Digestive glands :</u>**

- Includes ,
    - Gastric glands
    - Intestinal glands
    - Pancreas
    - Liver



RESPIRATORY SYSTEM

- No auxilliary means of respiration
- Pulmonary respiration
- Air tract consists of ,
  - External nostrils
  - Nasal chamber
  - Internal nostrils
  - Pharynx
  - Glottis and larynx
  - Trachea
  - Bronchi
- Laryngeal walls are supported by paired *cricoids* and *arytaenoid* cartilages and laryngeal muscles
- Trachea is tubular ;walls supported by numerous *tracheal rings* (cartilaginous)
- Trachea bifurcates into 2 : bronchi supported by *bronchial rings*
- Bronchus enters each lungs of its sides and does not undergo branching
- **Lungs** : fusiform sacs
- Inner lining of lung is raised into several ridges (septa) , giving the lungs a spongy or honey-comb appearance
- Ridges are more prominent in the anterior part;posterior part serves as a space for storage of air
- Ridges divides the lung cavity into numerous small air pouches : *alveoli*
- Walls are richly vascularised
- Mechanism : brought about by the movement of the body wall and ribs
- Inspiration is active whereas expiration in passive

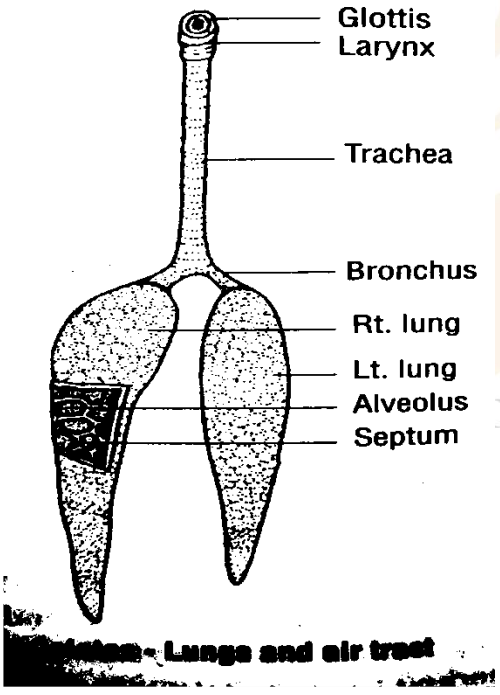
- During respiration , ribs are pulled up and down and inward and outward by the activity of the intercostals muscles.
- **Steps :**

Inspiration :

1. Body wall dilates
2. Expansion of body cavity
3. Contraction of intercostal muscles
4. Ribs get raised
5. Lungs get dilated
6. Air is drawn into lungs

Expiration:

7. Muscles of the body wall and intercostals muscles relax
8. Ribs and body
9. wall return to its original position
10. Body cavity shrinks
11. Lungs get compressed
12. Air gets expelled out



Lungs and air tract

CIRCULATORY SYSTEM

a) Heart :

- Lies mid ventrally on the anterior part of the body cavity ,below sternum : **primitive feature**

- The heart of Calotes and other lizards is more advanced than that of amphibians, even though the arterial and venous streams are not completely separate.
- Heart is almost triangular, with broad and anteriorly directed base and narrow and posteriorly directed apex
- enclosed within a transparent and double-layered *pericardium,* and its cavity is lined by *endocardium.*
- Heart is connected to the pericardium at its apex by a ligamentous cord, called *gubernaculum cordis.*
- Tetrapartite : Truncus arteriosus is absent.
- The heart of Calotes is a tetrapartite organ:

➢ ***Sinus venosus*** :

- The dorsal part, lying above the auricles.
- It is a thin-walled and bilobed chamber
- receives the venous blood brougnt from the diiferent parts.
- It has two asymmetrical portions: a large right half and a small left half.
- The right half receives two veins: namely the *post caval vein* and the *right pre-caval vein,* and the left half receives the *left pre-caval vein*.
- Sinus venosus opens to right auircle by the *sinu-auricular aperture* guarded by two *sinu-auricular valves*

➢ ***right auricle, left auricle:***

- Auricles are thin-walled chambers.
- The right auricle is larger than the left one.
- separated from each other by an *interauricular septum*.
- The inner surface of the auricles is raised into a network of muscular ridges: *musculi pectinati (pectinate muscles*).
- The right auricle receives the *sinus venosus*, and the left one receives the *common pulmonary vein*.
- auricles are separated from the ventricle below by the *auriculoventricular septum*.
- Each auricle opens to the ventricle by an *auriculo-ventricular aperture,*guarded by the *auriculo-ventricular valve.*

- ***Partially divided ventricle :***

- Ventricle is the thick-walled posterior chamber of the heart.
- By an incomplete *interventricular septum* its internal cavity is partially divided into two portions*: cavum ventrale*(also called *cavum pulmonale*, since it is associated with pulmonary artery) and *cavum dorsale*.
- *Cavum dorsale*, in turn, is partially subdivided into two portions :*cavum arteriosum* and *cavum venosum*, by a prominent ridge formed the fusion of *myocardiac trabeculae*

Ventricle consists of three partially separated chambers *: cavum ventrale, cavum arteriosum and cavum venosum.*

- Ventricular wall is thick, spongy and muscular.
- Internally, it is raised into numerous muscular idges and columns, known respectively as *columnae carneae* and *papillary muscles.*
- The flaps or Cusps of the auriculo-ventricular valves are fastened to the papillary muscles by fibrous cords, called *chordae tendineae.*
- Arising from the ventricle are three aortic arches : *the pulmonary, right systemic* and *the left systemic*

b) <u>Arterial system</u>

- embryonic truncus arteriosus splits at its base itself so that the 3 arterial arches lead directly and independently from the tripartite ventricle
- The three aortic arches are:
  - *Pulmonary* : from *cavum ventrale*
  - *left systemic :* from *cavum venosum*
  - *right systemic*: from *cavum arteriosum*
- Pulmonary arch divides into two pulmonary arteries, each passing to the lung of its side.
- Right systemic arch gives off an short artery: *innominate artery* (carotid artery) :divides into two common carotid arteries to the head region.
- Ductus caroticus almost corresponds to the *Ductus Botalli*
- Since the left systemic gives off both the carotid arteries, it is often described as the *carotico-systemic trunk.*
- The right and left systemic arteries curve round the heart, run posteriorly, and join together to form the *dorsal aorta*

c) <u>Venous system</u>

Venous system has three major divisions :

- *Pulmonary* : Pulmonary system carries oxygenated blood from lungs to left auricle
- *Systemic systems*: Systemic system carries venous blood from all other parts to the *Sinus Venosus*
- *Portal system* : includes renal portal system and hepatic portal system ;carries venous blood from tail to kidneys and liver, and from hind-limbs and digestive system to liver.

d) <u>Working of the heart and the course of blood circulation</u>

- involves regular and rhythmic heart-beats.
- Each heart beat, in turn,involves the alternate contraction (*systole)* and relaxation (*diastole*) of the heart-walls.

The independent origin of the aortic arches and the incomplete division of the ventricle are beginning of the specialisations for the attainment of the advanced condition of birds and mammals.

- During auricular systole, blood is emptied from auricles to the ventricles. .
- During ventricular systole, the venous blood from *cavum ventrale* will pass to the pulmonary artery for aeration in the lungs.
- The arterial blood from *cavum arteriosum* will pass to the right systemic.
- A portion of it will flow to the head region through carotids. The mixed type of blood from *cavum venosum* will pass to the left systemic.
- Part of it will flow to the left carotid through *ductus caroticus*
- Cavum Ventral : Venous Blood,
- Cavum Arteriosum : Arterial Blood
- Cavum Venosum : Mixed Type Of Blood

In lizards, as in amphibians, the pulmonary and systemic circulations are not completely separated from each other. Since ,the ventricular partition is incomplete, they mix together in the ventricle. Hence, circulation is described as *incomplete double circulation*. It is distinct from the complete double circulation of crocodiles, birds and mammals where inter-ventricular partition is complete and hence the two circulations are kept completely separate throughout their course.