BIOLOGY OF CHORDATES, GENETICS (DSZ0021)

(BSC ZOOGOLY-II)

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Lesson-1

GENERAL CHARACTERS OF CHORDATES AND OUTLINE CLASSIFICATION UPTO THE LEVEL OF ORDER

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1.1. OBJECTIVES:

The aim of this lesson is to

- Understand the characters of chordates
- Know the outline classification
- Explain the origin of chordates
- Differentiate chordates from non chordates

1.2 INTRODUCTION:

- The phylum Chordata takes its name by having the Notochord along the back of the animal.
- Chordates are highly developed triploblastic organisms in the process of evolution.
- The phylum includes diversified organisms from simple protochordates to man.
- Chordates possess the following three fundamental structures along with other general features viz.
  a) The Notochord b) Dorsal tubular nerve cord and c) Pharyngeal gill-slits
- Most of the present day chordates are tunicates, lancelets, Lampreys, fishes, Amphibians, Reptiles, Birds and Mammals.

Besides the three main chordate features, Vertebrates also possess following characters in common:

1. Bilateral Symmetry
2. Metamerism
3. Locomotory organs
4. Post anal tail
5. Coelom
6. Skeleton
7. Cephalization
8. Heart
9. Blood and Blood Vascular system
10. Excretory system
11. Reproductive system
12. Endocrine System
13. Energy Compound
14. Cleavage
15. Blastopore
16. Triploblasticity

1.3. IMPORTANT CHORDATE CHARACTERS:

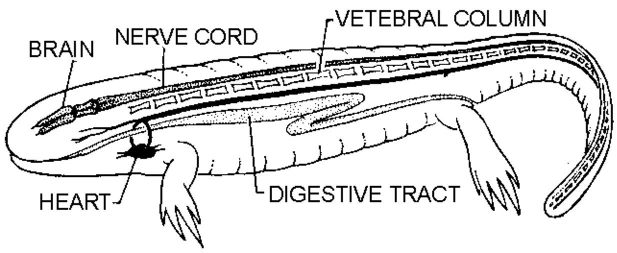

Fig.1-1. Typical chordate with important characters

1.3.1. Notochord: (Gr., Noton : back, Chorda : cord)

- The name chordata is derived from the possession of the notochord as a supporting rod on the mid-dorsal side of the body.
- It lies between the dorsal tubular nerve cord and digestive system.
- It is formed from chorda mesoderm.
- Notochord is covered by a sheat of connective tissue.
- The notochord is composed of specialized vacuolated cells. These cells are filled with a fluid and become turgid so as to form a stiff support.
- It occurs in the embryo of most chordates and persist throughout life in lower chordates.
- It is replaced by vertebral column in vertebrates.

1.3.2. Dosal Tubular Nerve cord:

- It is dorsal, hollow and single
- It is formed from ectoderm
- It's cavity is filled with cerebrospinal fluid
- It enlarges into brain at the anterior end.
- It constitutes the central nervous system.

1.3.3. Pharyngeal Gill Slits:

- These are paired lateral apertures in the Pharyngeal region.
- These are the aquatic respiratory structures.
- They are formed by the fusion of pharyngeal evaginations and ectodermal invaginations.
- The gill slits are supported by gill arches.
- They may be retained in adults as in prochordata, fishes and amphibian larvae. In Land vetebrates they are seen only in embryonic stages.

1.3.4. Other important features of chordates:

1.3.4.a. Bilateral symmetry:

- The organism can be cut into equal halves a right and a left through the sagittal plane passing from anterior to posterior end of the body.
- Each half is the mirror image of the other.

1.3.4.b. Metamerism:

- External segmentation is not recognizable.
- Segmentation is internal as evident from the musculature and arrangement of vertebrae.

1.3.4.c. Locomotory organs:

- Locomotory organs are fins (fishes) or limbs (tetrapods)
- Fins are supported by fin rays.
- Limbs are paired and pentadactyl.
- Limbs are modified according to their mode of life.

1.3.4.d. Post anal tail:

- Tail is post anal extension of the body.
- It helps in locomotion and equilibrium.
- Tail has no viscera but it has muscles, nerve cord and notochord.

1.3.4.e. Coelom:

- Chordates are true coelomate animals.
- It is enterocoel as in Echinodermata.

1.3.4.f. Skeleton:
- Living endoskeleton is present.
- It does not interfere with the animal growth, for it can increase in size with the rest of the body.
- It is made up of bone or cartilage.

1.3.4.g. Cephalization:
- Concentration of nervous tissue and sense organs in the head known as cephalization.
- Anterior part of the neural tube enlarges into brain.
- Brain is protected by Cranium or brain box in craniata.
- Complexity of cephalic region progress from cyclostomes to man.

1.3.4.h. Heart:
- Circulation of blood is maintained by muscular heart.
- It is ventral in position.
- Heart may possess one (prochordates) or two (fishes) or three (amphibians & reptiles) or four (birds & mammals) chambers.

1.3.4.i. Blood and Blood Vascular System:
- Haemoglobin, the respiratory pigment is always in Red Blood Cells.
- Presence of portal system in the body is a special feature. Blood from the alimentary canal returns to the liver through hepatic portal system.
- Blood flows backward in the dorsal blood vessel and forward in the ventral vessel.

1.3.4.j. Excretory system:
- This system consists of paired kidneys formed from mesoderm.
- Kidneys may be of Pronephric, Mesonephric or Metanephric.

1.3.4.k. Reproductive System:
- All chordates are Unisexual.
- Gonads are formed from mesoderm.
- Gonads and Gonoducts are well developed.

1.3.4.l. Endocrine Glands:
- They secrete and release hormones into the blood.
- They are the bio-chemical messengers to regulate various metabolic activities.
- Pituitary, Thyroid, Parathyroid, Pancreas, Adrenal and Gonads are the main endocrine glands in vertebrates.

1.3.4.m. Energy Compound:
- Phosphogens are biochemical energy susbstances released during muscle contraction.
- Muscle phosphogen in the chordates is creatine phosphate.

1.3.4.n. Cleavage:
- It is radial and indeterminate.

1.3.4.o. Blastopore:
- It is formed during gastrulation.

- Blastopore develops into an anus. Hence Chordates are called deuterostomes.

1.3.4.p. Triploblasticity:

- The three germinal layers formed during the development are the ectoderm, endoderm and mesoderm.
- The germinal layers contribute for the formation of various organs & organ systems.

1.4. MAIN DIFFERENCES WITH INVERTEBRATES:

Table:1-1. Differences between chordates and non-chordates

Chordates	Non-Chordates
1.Notochord is present	Absent
2.The nerve cord is hollow, dorsal and single	Nerve cord is ventral, solid and double
3.Pharyngeal gill slits are present	Absent
4.Gut position is ventral to nerve cord	Dorsal to nerve cord.
5.Heart is ventrally located	If present it is dorsally located.
6.Circulatory system is closed type	Open type
7.Haemoglobin is always in RBC	Usually in the plasma.
8.Hepatic portal system is present.	Absent
9.The direction of blood flow in the dorsal blood vessel is from anterior to posterior.	It is from posterior to anterior.
10.A true tail (post anal) is present	Tail when present is not a true one as the anus open at the end of tail.

1.5. ORIGIN AND EVOLUTION OF CHORDATES:

- There is no acceptable evidence in favour of the origin of chordates.
- The following are some of the evidences explaining the origin of chordates. Annelidan, Cnidarian, Echinoderm theories proposed by different scientists explain the invertebrate origin of chordates.
- Garstang (1894) explained that the chordates have evolved from some free swimming auricularia larva of echinoderms by Paedogenesis.
- It is also said that other chordates took their origin from hemi-chordates.

- The first Vertebrates appeared during ordovician period of Palaeozoic era were the Jawless fishes.
- First gnathostomes originated during silurian period of palaeozoic era are the true fishes.
- Amphibians took origin from osteolepid fishes during Devonian period of Palaeozoic era.
- Reptiles evolved from Labyrinthodont Amphibia during Carboniferous period.
- Birds arose in the Jurassic period from Ornithischian dinosaurs.
- Mammals evolved during mesozoic era from synapsids (mammal like reptiles) between upper carboniferous and triassic periods.

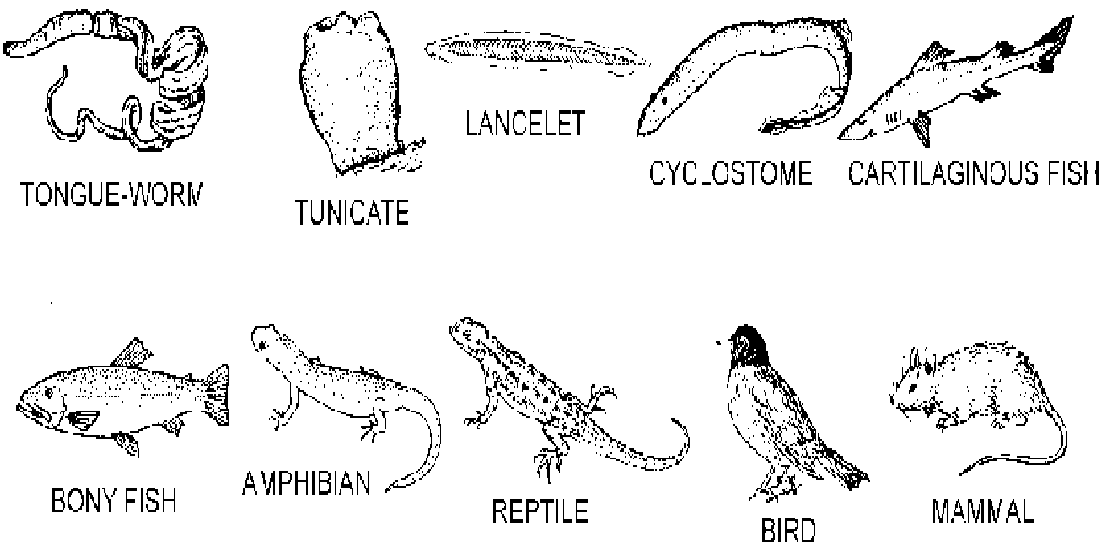

Fig.1-2. Representatives of Chordata

1.6. OUTLINE CLASSIFICATION OF PHYLUM CHORDATA:

Phylum Chordata

1.6A. Group I

Acrania or Protochordata
(Lower chordata)
(Lack head & cranium or skull)

.Subphylum I
Urochordata or Tunicata

Class I
Ascidiacea
Ex: Herdmania
Ciona

Class II
Thaliacea
Ex:Salpa
Doliolum
Pyrosoma

Class III
Larvacea
Ex:Oikopleura

Subphylum II
Cephalochordata

1.6B. Group II

Craniata (or) Euchordata
(Higher Chordata)
(distinct head & cranium are present)

Subphylum III Vertebrata
(Organisms with vertebral column)

Super Class I
Agnatha
(Jawless Vertebrates)

Class I
Ostracodermi
(Extinct)

Class II
Cyclostomata
(Round, Suctorial mouth)

Order I
Petromyzontia
Ex: *Petromyzon*
(Lamprey)

Order II
Myxionoidea
Ex: *Myxine*
(Hagfish)

Super Class II
Gnathostomata
(Jawed Vertebrates)

Group I
Pisces (fishes)

Class I
Placodermi
(Extinct)

Class II
Chondrichthycs
(Cartilaginous fishes)
Ex: sharks and rays

Class III
Osteichthyes
(Bony fishes)
Ex:Lung fishes, sea horse

Group II
Tetrapoda

Class I
Amphibia
Ex:Frogs
Toads
Salamanders

Class II
Reptilia
Ex:Turtles
Tortoises
Sphenodon , Crocodiles
Snakes, Lizards

Class III
Aves
Ex:Birds

Class IV
Mammalia
Ex:Kangaroo
Dog
Monkey
Man

1.6.A. Group I Acrania or Protochordata:

1.6.1. Subphylum I Urochordata:

- Sedentary or pelagic, marine animals.
- The body is covered by test or tunic.
- The test is formed by a substance called tunicin. Hence these animals are also referred to as tunicates.
- Notochord is present only in larval tail, hence the name Urochordata.
- Flow of blood is periodically reversal.
- Larva under goes retrogressive metamorphosis.

Subphylum Urochordata

- Class I Ascidiacea
  - Order I Enterogona Ex: *Ascidia*, *Ciona*
  - Order II Pleurogona Ex: *Herdmania*, *Botryllus*
- Class II Thaliacea
  - Order I Doliolida (Cyclomyaria) Ex: *Doliolum*
  - Order II
    - Pyrosomida Ex: *Pyrosoma*
    - Salpida (Hemimyaria) Ex: *Salpa*
- Class III Larvacea (Appendicularia)
  - Order Copelata Ex: *Oikopleura*

1.6.1a. Class 1 Ascidiacea:

- Bottom dwelling, Sedentary tunicates
- Branchial aperture is anterior and atrial aperture dorsal in position
- Pharynx is large in size with numerous gill slits
- Adult is with out Notochord, nerve cord and tail
- The more chordate like larva changes into a degenerate adult by retrogressive metamorphosis.
- Asexual reproduction by budding.

This class is divided into two orders.

Order I Enterogona:

- Gonad is unpaired and lodged below the intestinal loop.

- Neural gland is ventral to nerve ganglion.
- Larva has two sense organs cerebral eye and statocyst.

Ex: *Ciona* and *Ascidia*.

Order II Pleurogona:

- Gonads are paired and lie in the atrial wall.
- Neural gland is dorsal or lateral to nerve ganglion.
- Larva has a statocyst, but no separate eye.

Ex: *Herdmania* and *Botryllus*.

1.6.1b. Class 2 Thaliacea:

- Free swimming and pelagic tunicates
- Body is barrel-shaped
- Branchial and atrial apertures are at opposite ends i.e. anterior and posterior respectively.
- Pharynx is relatively small and has less number of gill slits.
- Life history may or may not have a tailed larva.

Order I Doliolida (Cyclomyaria):

- Muscle bands are complete
- Tailed larval stage is present
- There are two phases in life history a) Gonozooid b) Oozooid

Ex: *Doliolum*.

Order II Pyrosomida:

- Occur in compact cylindrical colonies.
- Muscle bands are feeble and occur only towards the ends of zooids.
- Gill slits are more in number.
- No tailed larval stage in life cycle.

Ex: *Pyrosoma*

Order III Salpida (Hemimyaria):

- Body in cylindrical
- Muscle bands are incomplete ventrally.
- A single pair of large gill slits is present.
- There is no larval stage.

Ex: *Salpa*

1.6.1c. Class 3 Larvacea:-(Appendicularia)

- Free swimming, pelagic and solitary
- The body is enclosed in loose gelatinous house.
- Body is small and comma shaped.

- Mouth is terminal and anus opens to outside directly.
- There is no atrium and atrial aperture.
- Only two gill slits are present in the pharynx.
- Notochord, nerve cord and tail are persistent.
- Larva develops gonads and starts reproduction like an adult (Neoteny)

  Ex: *Oikopleura*. *Appendicularia*.

1.6.2 Subphylum II Cephalochordata:

- Marine, Sedentary and Burrowing.
- Body is fish like.
- It lacks head, but possess a tail.
- Body is segmented.
- Median fins are present (dorsal, caudal and ventral). The fins are supported by fin ray boxes.
- Noto chord is rod like, extends from tail to rostrum.
- It lacks special respiratory organs.
- Exchange of gases takes place by diffusion through body surface.
- Heart is absent.
- No respiratory pigment in the blood.
- Excretory organs are paired protonephridia.
- Sexes are separate, Gonads are metamerically repeated.
- Development includes a ciliated free swimming larval stage.

  Ex: *Branchiostoma (=Amphioxus*)

1.6.B. GROUP II CRANIATA OR EUCHORDATA:

1.6.3. Subphylum III Vertebrata (L. vertebratus=Backbone):

- Notochord replaced by a veterbral column or backbone composed of vertebrae.
- Body is divisible into head, neck, trunk, and tail.
- This subphylum is divided into two super classes.

1.6.3.A. Super Class I Agnatha: (Gr.a : not, gnathos : jaw)

- Jaw less, primitive fish like vertebrates.
- Paired limbs are absent.
- This division is divided into two classes.

Class I Ostracodermi:

- First vertebrates
- Extinct group
- Heavily armoured.

  Ex: *Cephalaspis*

Class II Cyclostomata: (Gr.cyklos=circular, stoma=mouth)

- Mouth rounded and suctorial.
- Gills 5-16 pairs.
- Body is eel shaped, with out scals, Jaws and lateral fins.
- This class is divided into two orders.

Order I Petromyzontia:

- Lampreys are included in this group.
- Fresh water or Marine
- Free living or ectoparasites on fishes.
- Mouth ventral within suctorial buccal funnel beset with many horny teeth
- Dorsal fin is well developed
- Branchial basket is well developed.
- Seven pairs of gill pouches and 7 pairs of gill slits are present.

Ex: *Petromyzon* and *Lampetra*

Order II Myxinoidea:

- Hag fishes are included in this group.
- Exclusively marine.
- Primarily scavengers, burrowing into dead fishes for flesh consumption.
- Mouth terminal with 4 pairs of tentacles and few teeth. No buccal funnel.
- Dorsal fin is poorly developed.
- Poorly developed branchial basket is present.
- Gill pouches 6 to 15 pairs. Gill slits 1 to 15 pairs.

Ex: *Myxine, Bdellostoma*

1.6.3 B. Super class II:- Gnathostomata (Gr.gnathos=Jaw; Stoma=mouth)

- Jawed vertebrates having true Jaws and paired limbs.

This is divided into two Groups.

Group I Pisces

Class I Class II Class III

Placodermi Chondrichthyes Osteichthyes
(Extinct) (Cartilaginous fishes) (Bony fishes)
Ex:climatius Sub Class I Sub Class II

Selachii Holocephali
Order I Order II Ex:Rat fishes or
Chimaeras

Squaliformes Rajiformes
Ex: Sharks Ex: Rays and Skates

Sub Class I Sub Class II
Sarcopterygii Actinopterygii

Order I Order II Super Order I Super Order II Super Order III

Crossopterygii Dipnoi Chondrostei Holostei Teleostei
Ex: *Latimeria* Ex:Lung fishes

Order I Order II Order I Order II

Polypteriformes Acipenseriformes Amiiformes Semionotiformes
Ex: *Polypterus* Ex: *Acipenser* Ex: *Amia* Ex:*Lepidosteus*
Polyodon

15 orders

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Order I	Clupeiformes	Order II	Scopeliformes
Order III	Cypriniformes	Order IV	Anguililformes
Order V	Beloniforms	Order VI	Syngnathiformes

Order VII Ophiocephaliformes or Channiformes
Order VIII Symbranchiformes
Order IX Mastacembeliformes
Order X Perciformes
Order XI Scorpaeniformes
Order XII Pleuronectiformes
Order XIII Echeneiformes
Order XIV Tetradontiformes
Order XV Lophiiformes

1.6. 3. B1. GROUP I PISCES: (L.Pisces = fish)

- Exclusively aquatic
- Locomotory organs are paired fins.
- Skin usually moist and scaly.
- Respiratory organs are gills.
- Fishes are included in this group.

This group is divided into three classes.

Class I Placodermi: (Extinct)

- Earliest primitive Jawed fishes of Palaeozoic era.
- These fishes with bony head shield.

  Ex: *Climatius* and *Dinichthys*

Class II Chondrichthyes: (Gr.Chondros=Cartilage; Ichthys=fish)

- Mostly Marine.
- Endoskeleton is made of cartilage.
- Skin with placoid scales.
- Respiration by 5-7 pairs of gills. They are not covered by operculum.
- Mouth is ventral in position.
- Tail is heterocercal.
- Sharks, rays and skates are included in this group.

Sub Class I:- Selachi

- Gill slits are more in number protected by flaps.
- They have two spiracles one behind each eye.
- Cloaca present

This subclass is divided into two orders.

Order I Squaliformes or Pleurotremata: (Gr. Pleuro=side; trema=opening)

- Gill slits are present on lateral sides 5-7 pairs
- Body spindle shaped
- Spiracles small.

Ex:Dogfish (*Scoliodon*)
Zebra shark (*Stegostoma*)
Hammer-headed shark (*Sphyrna / Zygaena*)

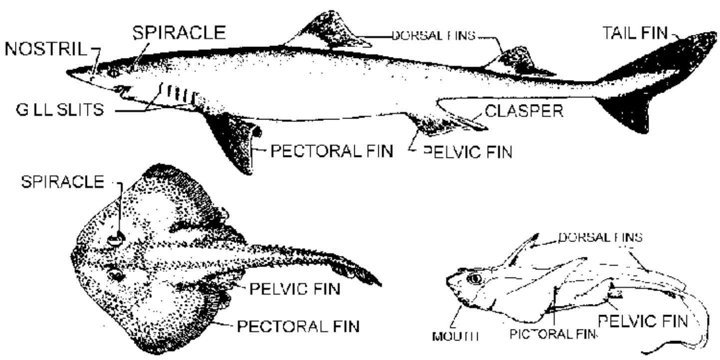

Fig.1-3. Representatives of elasmobranch fishes
a. Shark b.Ray fish c. Chimaera

Order II Rajii formes or Hypotremata: (Gr. hypo=below, trema=opening)

- Gill slits ventral, 5 pairs.
- Body depressed, flattened dorso-ventrally.
- Spiracles large.

Ex: Skate (*Raja*), Sting ray(*Trygon*), Electric ray (*Torpedo*), Sawfish (*Pristis*)

Sub Class II Holocephali:

- Single gill opening on either side covered by operculum.
- No spiracles.
- No cloaca

Ex: Rat fish (*Chimaera*)

Class III Osteichthyes: (Gr.Osteon=bone, Ichthyes=fish)

- Marine or fresh water.
- Endoskeleton is made of bone.
- Skin with embedded dermal scales of 3 types; ganoid, cycloid or ctenoid.
- Four pairs of gills protected by operculum help in respiration.
- Mouth is terminal or sub-terminal position.
- Tail fin is of homocercal or diphycercal type.

This class is divided into two subclasses.

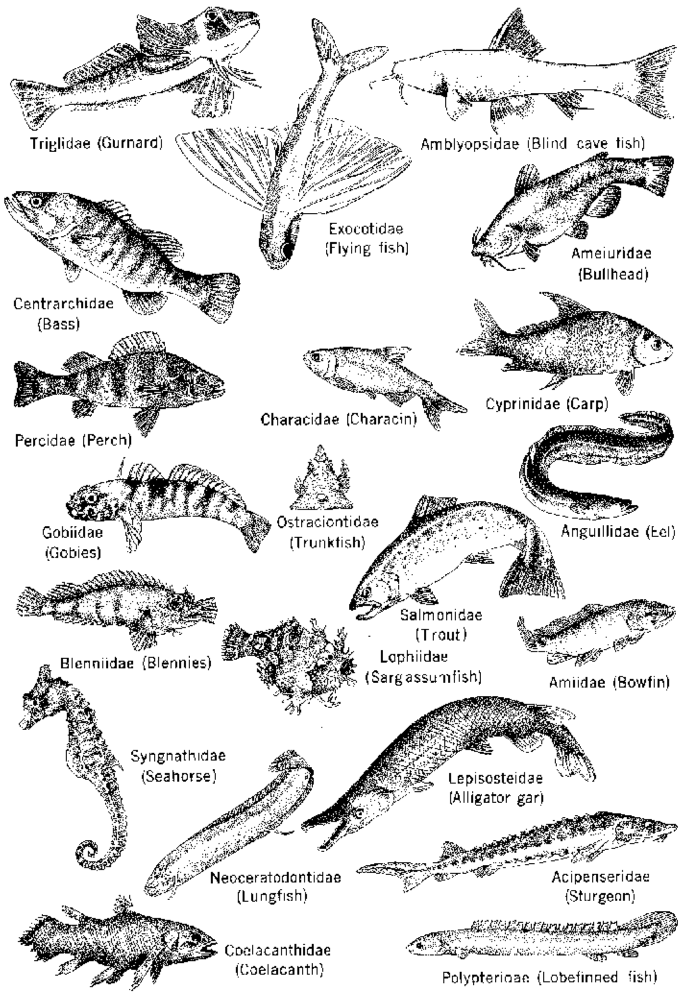

Fig.1-4. Representatives of the group Osteichthyes

Sub Class I Sarcopterygii: (Gr. Sarcos=fleshy; pterygium=fin)

- Paired fins are lobe like, fleshy with bony central axis.
- Two dorsal fins are present on body.
- Olfactory sacs usually connected to mouth cavity by internal nostrils.

This subclass is divided into two orders.

Order I Crossopterygii:

- Caudal fin 3 lobed.
- Spiracles present.
- Air bladder vestigial.

Ex: *Latimeria.*

Order II Dipnoi: (Gr., di = double, Pnoe = breathing)

- Candal fin is diphycercal.
- Spiracles absent.
- Lung (or) Air bladder single or paired.

Ex: *Epiceratodus* (Australian Lungfish)
Protopterus (African Lung fish)
Lepidosiren (American Lung fish)

Sub Class II Actinopterygii:

- Paired fins thin, with out fleshy lobes.
- One dorsal fin, may be divided.
- Olfactory sacs not connected to mouth cavity.

This subclass is divided into 3 super orders.

Super Order I Chondrostei:

- Mouth is large.
- Body is covered by ganoid scales.

This super order is divided into two orders.

Order I Polypteriformes:

- Skin covered with rhombic ganoid scales.
- Dorsal fin with many finlets.
- Lobed pectoral fins.

Ex: *Polypterus*.

Order II Acipenseriformes:

- Body covered with five rows of bony scutes.
- Skeleton Cartilaginous.

Ex: *Acipenser* (Sturgeon), *Polyodon* (Paddle fish)

Super order II Holostei:

- Mouth opening small.
- Body is covered by Ganoid or cycloid scales.

This super order is divided into two orders.

Order I Amiiformes:

- Skin is covered with thin, over lapping cycloid scales.
- Snout is rounded.

Ex: *Amia*

Order II Semionotiformes:

- Skin is covered with rhomboidal ganoid scales in oblique rows.

- Snout is elongated.
  Ex: *Lepidosteus*.

Super order III Teleostei: (Gr. Teleos=complete; osteon=bone)

- Mouth is small and terminal.
- Body is covered by cycloid or ctenoid scales.
- A hydrostatic swim bladder usually present.

This super order is divided into15 orders.

Order I Clupeiformes:

- Head and operculum not scaled.
- Pelvic fins abdominal.
  Ex: *Clupea* (Herring), *Salmo* (Salmon)

Order II Scopeliformes:

- Deep sea fishes with phosphorescent organs.
- Dorsal and anal fins without spines.
- Swim bladder absent.
  Ex: *Harpodon* (Bombay duck)

Order III Cypriniformes:

- A peculiar weberian apparatus connecting the ear with the air bladder is present.
  Ex: *Labeo rohita* (Rohu), *Catla catla* and *Saccobranchus*

Order IV Anguililformes:

- Body long, slender and snake like
- Dorsal and anal fins long and narrow
  Ex: *Anguilla* (Fresh water eel)

Order V Beloniforms:

- Pectoral fins large and high on body.
  Ex: *Exocoetus* (Flying fish), *Hemirhamphus* (half beak)

Order VI Syngnathiformes:

- Protective scales or bony rings are present on body.
- Fishes with a small mouth at the end of an elongated snout.
  Ex: *Hippocampus* (Sea horse), *Syngnathus* (Pipefish)

Order VII Ophiocephaliformes or Channiformes:

- Head depressed covered with large scales.
- Commonly called snake headed fishes.
- Accessory respiratory organs present.

  Ex: *Ophiocephalus* or *Channa* (snake head)

Order VIII Symbranchiformes:

- Body elongated, eel or snake like.
- Paired fins, fin rays and air bladder lacking

  Ex: *Symbranchus* and *Amphipnous*.

Order IX Mastacembeliformes:

- Fresh water eel shaped fishes.
- No ventral fin.
- Free spines are present infront of dorsal fin.

  Ex: *Mastacembelus.*

Order X Perciformes:

- Fins with spines.
- Two dorsal fins are present.

  Ex: *Anabas* (Climbing Perch)

Order XI Scorpaeniformes:

- Enlarged heads and pectoral fins.
- Dorsal fin is strong and spinous having poison glands.

  Ex: *Pterois* (Scropion fish)

Order XII Pleuronectiformes:

- Body flat, adapted for bottom living.
- Both the eyes are present on the upper side.

  Ex: *Pleuronectes*.

Order XIII Echeneiformes:

- First dorsal fin is modified into an adhessive disc or sucker on head for attachment.

  Ex: *Echeneis* (Sucker fish)

Order XIV Tetradontiformes:

- Scales are modified into spines.
- Scutes or bony plates cover the body.

  Ex: *Diodon* (Porcupine fish), *Tetradon* (Globe fish)

Order XV Lophiiformes:

- Luminescent organs present.
  Ex: *Antennarius* (Angler fish), *Lophius*

1.6.3.B2. GROUP II TETRAPODA: (Gr., Tetra=Four; Podos=foot)

- Aquatic or terrestrial.
- Paired pentadactyle limbs present.
- Respiration by lungs.
  This group is divided into four classes. They are 1.Amphibia 2.Reptilia 3.Aves 4.Mammalia

CLASS I AMPHIBIA: (Gr. Amphi=both; bios=life)

- Amphibians are the first terrestrial vertebrates.
- Amphibia includes the salamanders, toads, frogs and caecilians.
- Cold blooded or poikilothermous animals.
- Skin is moist and slimy due to mucous glands.
- Two pairs of limbs for locomotion. Fins are present in larvae.
- Heart three chambered; with 2 auricles and 1 ventricle.
- Respiration by gills, lungs, skin or mouth lining, separately or in combination.
- Brain with 10 pairs of cranial nerves.
- Eyes can function in both the environments to see the objects. A transparent third eyelid namely the nictitating membrane covers the eyeball and gives protection while in water.
- External ears are absent.
- Sticky tongue helps in food collection.
- Kidneys are mesonephric and excrete urea. Hence amphibians are Ureotelic.
- Unisexual.
- No embryonic membranes.
- Cloaca is common opening for digestive, excretory and reproductive systems.
- Mostly external fertilization.
- Larval stage called ‘Tadpole’ is seen in life history.

Class Amphibia is divided into two sub classes.

Class Amphibia

Subclass I | Sub Class II

Stegocephalia (Extinct)
Ex: *Eryops*, *Branchiosaurus* *Diplocaulus*

Lissamphibia

Order I | Order II | Order III

Apoda (Gymnophiona)
Ex: *Ichthyophis* *Uraeotypholus*

Urodela (Caudata
Ex: *Necturus* *Siren* *Proteus*

Anura (Salientia)
Ex: *Rana* *Alytes* *Hyla*, *Rhacophorus*

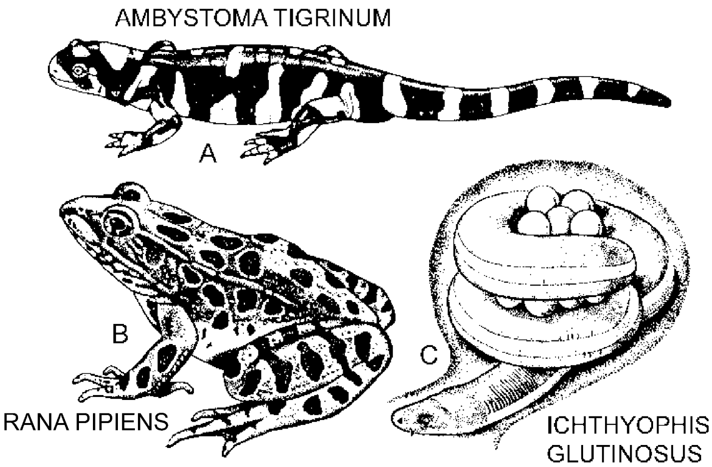

Fig.1-5. Representatives of Class Amphibia

Subclass I Stegocephalia: (Extinct)

- Extinct and primitive amphibians
- Skin with scales and bony plates.
- Skull with solid bony roof.

Ex: *Eryops, Branchiosaurus, Diplocaulus*

Subclass II Lissamphibia: (Living)

- Lacking dermal bony skeleton.

This subclass is divided into three ordens.

Order I Gymnophiona or Apoda:

- Popularly called caecilians or blind worms.
- Limbles, Burrowing forms.
- Body elongated and eel like.
- Tail short or absent.
- Dermal scales embedded in skin.
- Parental care is observed whose female coils round the eggs.

Ex: *Ichthyophis, Uraeotyphlus, Gegenophis*

Order II Urodela or Caudata:

- Newts and salamanders are included in this group.
- Body with distinct head, trunk and tail.
- Limbs are weak, short and equal in size, but in some cases hind limbs are missing.
- Skin devoid of scales, Tympanum absent.
- Larvae are aquatic.
- Axolotl larva of salamanders shows neoteny or paedogensis where the larval forms reproduce by sexual method.
- Most of the Urodeles are found in North America, which has been aptly said to be the Head quarters of Urodela'.

Ex: *Amblystoma* (Tiger Salamander), *Triton* (Newt), *Salamandra* (Salamander), *Proteus* (Blind Salamander), *Necturus* (Mud Puppy or water dog)

Order III Anura or Salientia:

- Tailless amphibians commonly called as frogs and toads.
- Body short and broad, without neck.
- Fore limbs are shorter than hind limbs for leaping.
- Eyes are large with well developed eye lids.
- Tympanum and Tympanic cavity are developed.
- A larva (Tadpole) with a finned tail and gills.

Ex: *Rana* (Common frog), *Bufo* (Common toad) *Hyla* (Tree frog), *Rhacophorus* (flying frog)

CLASS II REPTILIA:

- This class includes the lizards, snakes, turtles, tortoises, crocodiles, alligators and tuatara lizards.
- Mesozoic era is the 'Golden age' of reptiles.
- The study of reptiles is called 'Herpetology'.

General Characters:

- Terrestrial, tetrapodal vertebrates.
- The body is dry with cornified skin, with epidermal scales or shields or scutes.
- Limbs are pentadactyl ending in claws and suited to running, crawling or climbing. Limbs are absent in snakes and a few lizards.
- Body is divided into a head, neck, trunk and tail.
- Mouth is a wide gape with toothed Jaws.
- Unisexual
- Males have a pair of copulatory organs called the hemipenes.
- Internal fertilization, but development external.
- Teeth are homodont.
- Tongue is Movable and bifid in snakes.
- Skull is monocondylar with temporal fossa (cavity)
- Heart usually 3-chambered with a partly divided ventricle. Ventricle is completely divided in crocodiles (4-chambered)
- Respiration by lungs, throughout life.
- 12 pairs of cranial nerves.
- Cold blooded.
- Metanephric kidneys excrete uric acid and hence are uricotelic.
- Embryonic membranes appear during development.
- Young resembles adults. No metamorphosis.

Classification of Reptilia:

On the basis of presence or absence of temporal fossae, class Reptilia is divided into 5 subclasses.

Class Reptilia

Sub Class I Sub Class II Sub Class III Sub Class IV Sub Class V

Anapsida Euryapsida (Extinct) Parapsida (Extinct) Synapsida (Extinct) Diapsida

Order I Order II Order I Order II Order III

Cotylosauria (Extinct) Ex:Seymouria

Chelonia Ex:Turtles Tortoises and terrapins

Rhynchocephalia Ex: *Sphenodon*

Squamata Ex:Lizards Snakes

Crocodilia Ex:Crocodile Alligator

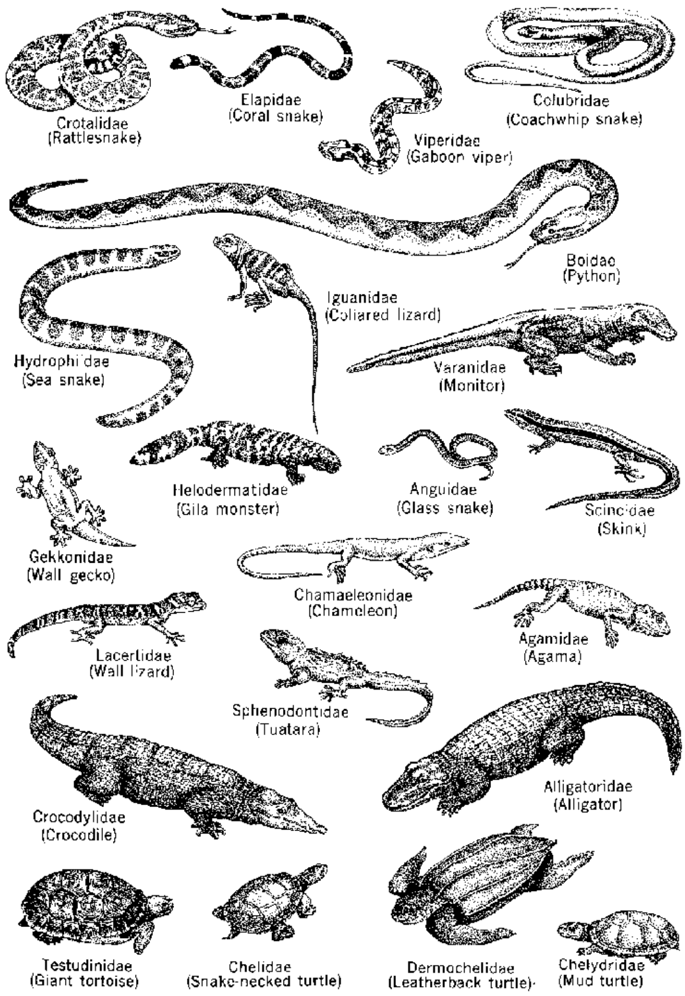

Fig.1-6. Representatives of the class Reptilia

Sub Class I Anapsida:

- Primitive reptile.
- No Temporal fossae or openings in the skull.

This subclass is divided into two orders.

Order I Cotylosauria: (Extinct)

- Resemble Labyrinthodont amphibians.
  Ex: *Seymouria.*

Order II Chelonia:

Terrestrial or aquatic.

- Body short, broad and oval.
- Trunk is enclosed in a bony shell composed of dorsal carapace and ventral plastron.

- When the animal is threatened with danger the head, neck, limbs and tail are with drawn into the shell.
- Skull has no temporal fossae. Hence it is anapsid type.
- Teeth are absent
- Jaws are provided with horny sheaths.
- Thoracic Vertebrae and ribs are fused with shell.
- The lungs are large and spongy attached to the dorsal portion of shell.
- Many aquatic turtles carry on respiration by cloaca also.
- Single copulatory organ is present in male.
- This group includes marine turtles, fresh water terrapins and terrestrial tortoises.

  Ex: *Chelone* (Green turtle), *Testudo* (Giant Land tortoise), *Trionyx* (Soft river terrapin)

Sub Class II Euryapsida
Sub Class III Parapsida Extinct (found in mesozoic period)
Sub Class IV Synapsida

SubClass V Diapsida:

- Skull with two temporal openings namely supra and infra temporal fossae on each side.

  This subclass is divided into three orders.

Order I Rhynchocephalia:

- This group is represented by single living species Sphenodon punctatum. Commonly called as 'tuatara lizard'.
- It took its origin 200 million years ago along with dinosaurs and is still seen in Newzealand. Hence it is called as living fossil.
- Body is elongated, lizard like and is divisible into head, neck, trunk and tail.
- Skin covered by scales.
- No Copulatory organs in male.

  Ex: *Sphenodon punctatum.*

Order II Squamata:

- This group includes lizards and snakes.
- Body is elongated and covered by horny epidermal scales.
- Pentadactyle limbs with claws. Limbs absent in snakes.
- Vertebrae procoelous.
- Male with eversible double copulatory organs. (hemipenes)

This order is divided into two sub-orders.

Sub Order 1 Lacertilia (Lizards)
Sub Order 2 Ophidia (Snakes)

Ex:*Hemidactylus* (wall lizard), *Calotes* (Garden lizard), *Varanus* (Monitor lizard), *Draco* (flying lizard), *Chameleon* (Mimicking lizard), Python, *Eryx johnii* (Sand boa or double headed snake), *Naja* (Cobra), *Bungarus* (Krait), *Russels viper* (Viper), *Hydrophis* (Sea snake).

Order III Crocodilia:

- Carnivorous, large-sized, aquatic reptiles.
- Exoskeleton with horny epidermal plates and scutes.
- Tail long, strong and laterally compressed.
- Limbs are powerful provided with claws.
- Teeth numerous and the codout (Lodged in sockets)
- Heart completely four chambered.
- Male has a copulatory organ.

Ex: *Crocodylus, Gavialis, Alligator.*

CLASS III AVES:

This class includes the birds. Study of birds is defined as 'feathered bipeds or 'Masters of air'. Almost every part of their body is modified to aid in aerial life. T.Huxley described them as 'glorified reptiles'.

General characters:

- Feathered, air breathing, warmblooded, bipedal, flying vertebrates.
- Body is spindle shaped with head, neck, trunk and tail.
- Skin is dry and devoid of glands except the preen gland at the root of tail.
- Jaws are teeth less, pointed and prolonged into a beak or bill.
- Fore limbs are modified into wings.
- Hind limbs help in perching, running and swimming.
- Pectoral muscles of flight are well developed.
- Tail is short provided with feathers and help in flight.
- Digestive system has a long oesophagus with a crop to store the food material.
- Endoskeleton fully ossified, light and pneumatic.
- Skull smooth and monocondylic.
- A few thoracic, lumbar, sacral and few caudal vertebrae fuse to form synsacrum.
- Heart is completely four chambered
- Only right aortic arch present.
- Warmblooded or homoiothermous.
- Lungs are spongy and not distensible, continuous with thin walled Nine(9) air sacs.
- Larynx without vocal cords. Voice box is syrinx.
- Kidneys are metanephric, urinary bladder absent
- Brain large with well developed optic lobes.
- 12 pairs of cranial nerves are present.
- Sexes separate. Sexual dimorphism is present.
- Fertilization internal.
- Eggs large with large amount of yolk and hard shell.
- Foetal membranes are present.

- Parental care is well marked.

Class Aves

Sub Class I — Sub Class II

Archaeornithes
(Extinct)

Order
Archaeopterygiformes
Ex:Archaeopteryx lithographica

Neornithes
(Modern birds)

Super Order I — Super Order II — Super Order — Super Order IV

Odontognathae
(Extinct)
(Teeth birds)
Ex: *Hesperornis*
Ichthyornis

Palaeognathae or
Ratitae
(flight less birds)

Impennae
Ex: *Penguin*

Neognathae or Carinata

Order I — Order II — Order III — Order IV — Order V — Order VI — Order VII

Struthioniformes
(African Ostrich)

Rheiformes
Ex: *Rhea*
(American Ostrich)

Casuariformes
Ex: *Casuarius*
Dromaius (Emu)

Apterygiformes
Ex: *Apteryx*
(Kiwi)

Dinornithiformes
Ex: *Dinornis*
(Moas)

Aepyornithiformes
Ex: *Aepyornis*

Tinamiformes
Ex: *Tinamus*

Super order Neognathae is divided into 19 orders

Order:1 Passeriformes Ex: Sparrow, Crow, Myna
Order:2 Piciformes Ex: Wood pecker
Order:3 Columbiformes Ex: Pigeon
Order:4 Psittaciformes Ex: Parrot
Order:5 Galliformes Ex: Peacock
Order:6 Cuculiformes Ex: Koel
Order:7 Anseriformes Ex: Duck Goose
Order:8 Coraciiformes Ex: King fisher
Order:9 Gaviiformes Ex: Loons, Gavia
Order:10 Colymbiformes Ex: Grebes
Order:11 Procellariformes Ex: Procellaria
Order:12 Pelicaniformes Ex: Pelicans
Order:13 Charadriiformes Ex: Gull, Sand piper
Order:14 Ciconiformes Ex: Heron, Flamingo
Order:15 Gruiformes Ex:Coot, Crane
Order:17 Strigiformes Ex: Owl
Order:16 Falconiformes Ex: Kite, Hawak, Vulture
Order:18 Apodiformes Ex: Swift
Order:19 Caprimulgiformes Ex: Goat Suckers

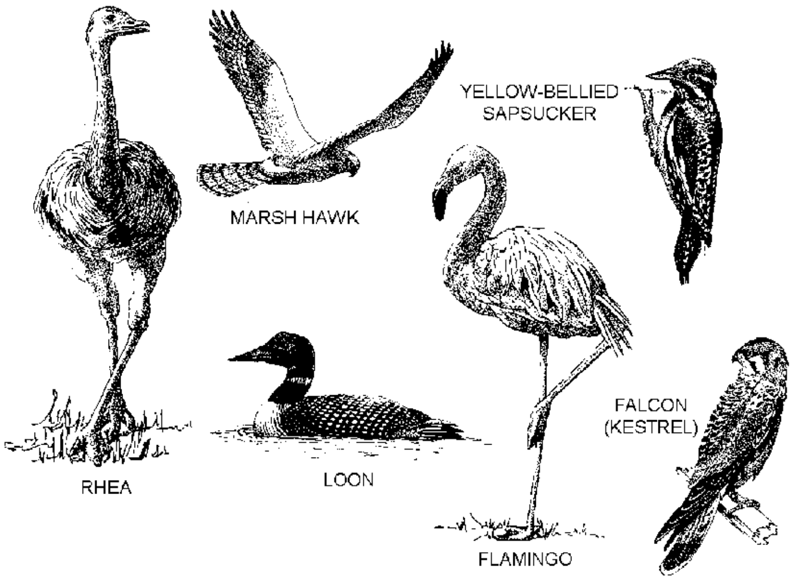

Fig.1-7. Representative birds

Sub Class I Archaeornithes: (Extinct)

- It includes a single order Archaeopterygiformes.
- Jurassic birds of Mesozoic age.
- Exhibits reptilian and Avian characters. Hence considered as a ‘connecting link’.
- Reptilian characters are a) Scales on the body and limbs b) Bones are not pneumatic c) Long lizard like tail. d) Poorly developed sternum e) Jaws provided with teeth.
- Avian characters are a) Feathers cover the body b) Forelimbs modified as wings for flight c) Jaws form an elongated beak. d) Feet are bird like e) Long tail having feathers. Ex: *Archaeopteryx lithographica.*

Sub Class II Neornithes:

- Modern birds are included in this group
- Teeth are absent except in some fossil birds.
- Tail short.
- Wings usually well developed.

This subclass is divided into four super orders.

Super Order I Odontognathae: (Extinct)

- Jaws bear teeth.
- Large flightless marine birds.

Ex: *Hesperornis, Ichthyornis*

Super Order II Palaeognathae or Ratitae:

- Large, flightless, running birds.
- Feathers devoid of interlocking mechanism.
- Wings are reduced or absent.
- Keel is absent in the sternum.
- Teeth are absent.
- Pectoral muscles poorly developed.
- Syrinx is absent.
- Oil gland is absent except in Tinamus and kiwi.
- Copulatory organ is present in Males.

This super order includes 7 orders.

Order I Struthioniformes:

- Largest of the living birds.
- Legs strongly developed, each with two toes.

Ex: *Struthio* (African ostrich)

Order II Rheiformes:

- Each leg bears three clawed toes.
- Ischia form a ventral symphysis.

Ex:*Rhea* (American Ostrich)

Order III Casuariformes:

- Each leg bears three clawed toes.
- Head bears a comb like structure.

Ex: *Casuarius, Dromaius* (Emu)

Order IV Apterygiformes:

- The smallest birds of the Ratitae.
- Feathers simple and hair like.
- Long slender beak slightly curved down wards.
- Leg bears 4 toes.

Ex: *Apteryx* (Kiwi)

Order V Dinornithiformes : (Extinct)

- wings are rudimentary
- Giant birds.

Ex: *Dinornis* (Moas)

Order VI Aepyornithiformes: (Extinct)

- Wings rudimentary.
- Legs strong with four toes.

Ex: *Aepyornis* (Giant elephant bird of Africa)

Order VII Tinamiformes:

- Small terrestrial birds.
- They have a keel on the sternum.

Ex: *Tinamus*.

Super Order III Impennae or Sphenisciformes:

- Marine flightless birds.
- Wings are paddle like used for swimming.
- Legs are included in the skin of the body.
- Toes are webbed.
- Wings are covered with scale - like feathers.

Ex: *Aptenodytes* (Penguin) (bottle birds)

Super Order IV Neognathae or Carinata:

- This group includes birds of flight with well developed wings.
- Teeth are absent.
- Feathers with inter-locking mechanism.
- Syrinx is present.
- Oil gland is present.
- Sternum with well developed keel.
- Pectoral muscles large.
- Copulatory organ is absent.

This super order is divided into 19 orders.

Order 1 Passeriformes: (Perching birds)

- Largest order of all the bird orders
- Beaks are adapted for cutting.

Ex: *Passer* (Sparrow), *Corvus* (Crow)

Order 2 Piciformes:

- Insectivorous and wood boring birds.
- Beak strong and stout.

- Tongue long and protrusible.
  Ex: *Dinopium* (Wood pecker)

Order 3 Columbiformes:

- Grain or fruit eating birds.
- Slender weak beak.
  Ex: *Columba* (Pigeon), *Streptopelia* (Dove)

Order 4 Psittaciformes:

- Beak is short, stout, strongly, hooked.
- The upper Jaw is movably articulated with the skull.
  Ex: *Psittacula* (Parrot)

Order 5 Galliformes:

- These birds scratch the ground for grain and insects.
  Ex: Peacock (*Pavo cristatus*)

Order 6 Cuculiformes:

- Birds with long and pointed wings.
- Beak greatly curved.
  Ex: *Eudynamis* (Koel)

Order 7 Anseriformes:

- Aquatic birds with broad and depressed beak.
  Ex: *Anas* (Duck), *Anser* (Goose)

Order 8 Coraciiformes:

- Beak is long, sharply pointed.
- Ex: *Halcyon* (King fisher)

Order 9 Gaviiformes:

- Legs are short.
- Toes are webbed.
  Ex: *Gavia* (loon)

Order 10 Colymbiformes:

- Ancient Marine birds
- Beak is short.
- Legs are provided with web.
  Ex: *Colymbus*.

Order 11 Procellariformes:

- Large Oceanic with great power of flight.
- Nostrils are tubular
- Wings are oily

  Ex: *Procellaria* (Petrels)

Order 12 Pelecani formes:

- Large aquatic birds modified for diving and fishing.
- Legs are short and toes are webbed.

  Ex:*Pelecanus* (Pelican)

Order 13 Charadriiformes:

- Shore birds with long legs.
- Webbed toes and mud probing beak.

  Ex:*Tringa* (Sand piper), *Larus* (gull)

Order 14 Ciconiformes:

- Long legged, marshy wading birds.
- Neck is long snake like.
- Beak is pincer like for piercing their aquatic prey

  Ex: *Ardea* (Heron), *Phonicopterus* (Flamingo)

Order 15 Gruiformes:

- Most of them are shore birds or live at edges of rivers & lakes
- Body is laterally compressed enabling the birds to move with ease in dense vegetation.

  Ex: *Fulica* (coot), *Antegone* (crane)

Order 16 Falconiformes:

- Birds of prey with short, sharp, strong curved beaks hooked at the extremity.
- Toes are with powerful claws.

  Ex: *Falco* (Falcon), *Milvus* (Kite), *Pseudogyps bengalensis* (Vulture), *Astur* (Hawk)

Order 17 Strigiformes:

- Nocturnal birds.
- Large head with huge yellow eyes.

  Ex: *Bubo* (Owl)

Order 18 Apodiformes or Micropodiformes:

- Adapted for rapid flight.
- Beak short and hooked.

  Ex: *Micropodus* (Swift)

Order 19 Caprimulgiformes:

- Nocturnal and Insectivorous.
- Mouth with wide gape ringed with long stiff hairs.

  Ex: *Camprimulgus* (Goat sucker)

CLASS IV MAMMALIA: (Gr., Mammae = mammary glands)

- Mammals are highly evolved animals occupied the top position in the animal kingdom. They derived from the reptilian group, mammal like reptiles, the Therapsida
- Unique characters of this group are presence of hair, mammary glands, muscular diaphragm and development of placenta in the Uterus of the mother.

General characters:

- Mammals are warm blooded, viviparous, Tetrapod animals.
  - Body distinctly divisible into head, neck, trunk and tail
  - Skin is covered with hair except in cetacea.
  - Skin has sweat and sebaceous glands, Mammary glands are functional in female.
  - Two pairs of pentadactyl limbs are adapted to various types of life.
  - Skull dicondylic.
  - Teeth are heterodont, thecodont and diphyodont.
  - External ears or pinnae are present.
  - Cervical vertebrae are seven in number with few exceptions.
  - A muscular partition, called diaphragm present between thoracic cavity and abdominal cavity.
  - Heart is four chambered with only left aorticarch.
  - RBC non-nucleated.
  - Respiration is pulmonary.
  - Larynx is the sound producing organ.
  - Optic lobes are four in number (Carpora quadrigemina)
  - Placenta is formed between the mother and foetus.

Classification:

Class Mammalia is divided into 3 subclasses.

Class Mammalia

Subclass I Subclass II Subclass III

Prototheria

Order I
Monotremata
Ex:Ornithorhynchus (duck billed platypus)
Echidna (spiny anteater)

Metatheria
This subclass includes a single order I Marsupialia
Ex:Macropus (Kangaroo)

Eutheria

Divided into 16 orders

Order I	Insectivora	Ex: Mole
Order II	Chiroptera	Ex: Bat
Order III	Dermoptera	Ex: Flying lemur
Order IV	Primates	Ex: Loris, Monkey, Man
Order V	Edentata	Ex: Sloths
Order VI	Pholidota	Ex: Manis
Order VII	Logomorpha	Ex: Rabbit
Order IX	Rodentia	Ex: Rat, Squirrel
Order X	Cetacea	Ex: Whales, Dolphins
Order XI	Carnivora	Ex: Tiger, Dog, Cat
Order XII	Sirenia	Ex: Sea-cow
Order XIII	Proboscidea	Ex: Elephant
Order XIV	Hyracoidea	Ex: *Hyrax*
Order XV	Perissodactyla	Ex: Horse, Zebra
Order XVI	Artiodactyla	Ex: Pig, Camel, Cow

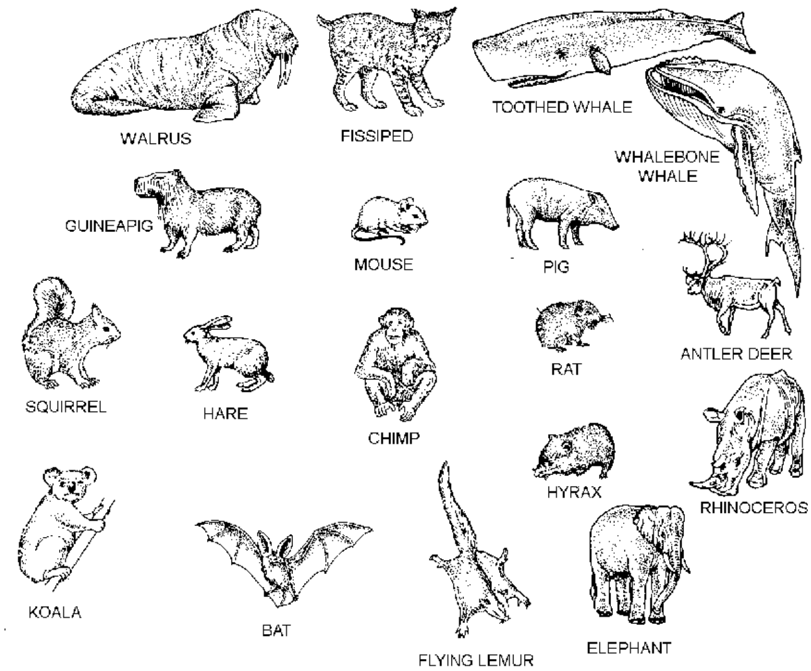

Fig.1-8. Representative Mammals

Sub Class I Prototheria:

- Egg laying mammals (oviparous)
- Prototherians exhibit many reptilian characters and form a link between reptiles and Mammals.
- Teeth are present in young ones. Adults have horny beak.External ear absent.
- Cloaca is present.
- Mammary glands lack teats or nipples.
- Corpus callosum is absent in the brain.
- Testes abdominal.

This subclass includes **a single order, Monotremata**.

Ex: *Ornithorhynchus* (Duck-billed platypus), *Tachyglossus* or *Echidna* (Spiny ant eater)

Subclass II Metatheria:

- Females have a marsupium or brood pouch to feed the immature young ones. This pouch is supported by epipubic bones.
- Viviparous.
- Corpus Callosum is poorly developed or absent.
- A common sphincter surrounds the anus and the urinogenital aperture.
- Vagina and Uterus are double (didelphic condition)

This sub class includes **a single order, Marsupialia**
Ex: *Macropus* (Kangaroo), *Didelphis* (Opossum)

Subclass III Eutheria:

- Higher Viviparous placental mammals.
- Mammary glands are well developed with nipples.
- There is no Cloaca.
- The Brain has large cerebral hemispheres and corpus callosum is well developed.
- Testes are enclosed in the scrotal sacs.
- Vagina is single.
- Embryos are retained in the Uterus till an advanced stage of development and provided with placenta.

This subclass is divided into 16 orders.

Order I Insectivora:

- Small and furry animals.
- Snout long and pointed and used to feed on insects.
  Ex: *Talpa* (Mole), *Paraechinus* (Hedgehog), *Sorex* (Shrew)

Order II Chiroptera: (Flying mammals or bats)

- Fore limbs are modified into wings for flight.
- Hind limbs are weak.
  Ex: *Pteropus* (Flying fox), *Megaderma* (Indian Vampire)

Order III Dermoptera: (Flying lemurs)

- Skin fold or patagium stretched between limbs and tail.
- Limbs are equal sized.
  Ex: *Galaeopithecus.*

Order IV Primates:

- First digit usually opposable, an adaptation for grasping.
- Corebellum is large and convoluted.
  Ex: Lemur, Monkey, Man

Order V Edentata:

- Teeth present (sloth) or absent (Ant-eater)
- Testes are abdominal.
- Toes with large, strong, curved claws.
  Ex: *Bradypus* (Sloth), *Dasypus* (Armadillo), *Myrmecophaga* (Ant eater)

Order VI Pholidota:

- Body is covered by large over lapping scales.
- Teeth are absent.

- Tongue long used to capture insects.
  Ex: *Manis* (Scaly ant eater or pangolin)

Order VII Logomorpha:

- Two pairs of incisors are present in the upper Jaw
- Out of which first pair are large chisel like and second pair are small in size.
  Ex: *Oryctolagus* (Rabbit), *Lepus* (Hare)

Order VIII Tubulidentata:

- Snout is long and tubular with round nostrils at the tip.
- Ears are long, erect and pointed.
  Ex: *Orycteropus* (The Earth Pig or pig like Aard vark)

Order IX Rodentia:

- Each Jaw with one pair of long, rootless, chisel like incisors growing throughout life.
- Dentition is adapted for gnawing and chewing.
  Ex: *Funambulus* (Squirrel), *Rattus rattus* (House Rat), *Hystrix* (Porcupine), *Mus* (Mouse)

Order X Cetacea:

- Large, marine, well adapted to aquatic life.
- No distinct neck.
- The tail is horizontally flattened into flukes.
- Fore limbs are modified into flippers for swimming.
- Hind limbs are absent.
- A thick layer of fat called blubber present below the skin.
- External Ears are absent.
  Ex: *Delphinus* (Dolphin), *Balaena* (Whale)

Order XI Carnivora: (Carnivores)

- Dentition adapted for tearing and cutting of flesh of the prey.
- Incisors are small.
- Canines are large and pointed.
- Claws well developoed.
  Ex: *Canis* (Dog), *Panthera tigris* (Tiger), *Urasus* (Bear), *Trichecus* (Walrus),P*hoca* (Seal)

Order XII Sirenia: (Seacows)

- Aquatic mammals with paddle like forelimbs.
- No hind limbs and external ears.
- Stream lined body with short neck.
  Ex: *Rhytina* (Sea cow)

Order XIII Proboscidea:

- Largest terrestrial mammals.
- Long mobile proboscis is the elongation of nose and upper lip bearing the nostrils at the tip.
- Upper incisors elongated as ivory tusks.
  Ex: *Elephas* (Elephant)

Orde XIV Hyracoidea:

- Small Rabbit like with a split snout.
- Upper incisors are rootless and pointed.

Ex: *Hyrax*

Order XV Perissodactyla:

- Large sized hoofed mammals.
- Toes are odd in number (1 or 3)
- Axis of the limbs passes through the third digit which is always larger than the rest.

Ex: *Equus* (Horse), *Rhinoceros* (Rhino)

Order XVI Artiodactyla:

- The even-toed (2 or 4) hoofed mammals.
- Axis of support passes between third and fourth toes.

Ex: *Hippopotamus* (Horse of river), *Sus* (Pig), *Camelus* (Camel), Deer, Giraffe

1.7. SUMMARY:

- Phylum chordata is the largest, highest and the most important phylum comprising a vast variety of living and extinct animals including man.
- Chordates are triploblastic animals with a dorsal tubular nerve cord, notochord and gill slits as their prime characters.
- Chordates are classified as prochordates and vertebrates basing upon the retention of the notochord in adult condition.
- Vertebrata is further classified into agnatha and gnathostomata.
- Most of the present day chordates are familiar vertebrates like fishes, amphibians, reptiles, birds, and mammals.

1.8. MODEL QUESTIONS:

1. Give the main characteristics of phylum chordata.
2. Classify phylum chordata upto classes only giving important characters and examples of each group.
3. Enumerate the prime characters of the subphylum vertebrates and classify the same with examples.
4. Give the important characters and classification of pisces with suitable examples.
5. Classify Amphibia upto orders.
6. Explain the important characters and classification of Reptilia.
7. Give the important characters and classification of Aves.
8. Write an account of characters and classification of Mammalia with suitable examples.
9. Write short notes on:-
   a) Differences between non chordates and chordates.
   b) Origin of chordates
   c) Urochordates

d) Dipnoi
e) Apoda
f) Rhynchocephalia
g) Crocodilia
h) Ratitae
i) Prototheria
j) Metatheria

1.9. REFERENCE BOOKS:

1. A text book of Zoology, Vol II by Parker & Haswell.
2. A student text book of Zoology Vol II Adam Sedgwick.
3. Vertebrate Zoology by Nigam.
4. The life of vertebrates by J.Z. Young.

…..Dr. G. Vijayalakshmi

Lesson – 2

PROTOCHORDATA

CONTENTS:

2.1. OBJECTIVES
2.2. INTRODUCTION
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2.1. OBJECTIVES:

The aim of this lesson is to understand the
a) Structure and affinities of *Amphioxus*, and
b) Structure and Metamorphosis of Ascidians.

2.2. INTRODUCTION:

- Protochordates are the first formed chordate organisms formed in the process of evolution.
- They are triploblastic.
- All the protochordates are marine.
- They possess persistent notochord, dorsal tubular nerve cord and pharyngeal gill slits except in adult ascidian.
- Heart is undivided.
- They are Unisexual (Cephalochordata) or bisexual (Ascidians)
- Protochordata includes two subphyla A) Cephalochordata B) Urochordata

A. CEPHALOCHORDATA

2.3. STRUCTURE OF *AMPHIOXUS*:

Amphioxus or *Branchiostoma* is a small fish like animal. Costa (1834) named it as *Branchiostoma lanceolatum* and Yarrel (1836) named it as *Amphioxus lanceolatum*.

2.3.1. Systematic position:

Phylum ------------ Chordata
Group ----------- Acrania
Sub-phylum ----------- Cephalochordata
Class ----------- Leptocardii
Family ------------Branchiostomidae
Type ---------- *Amphioxus (Branchiostoma lanceolatum*)

Amphioxus life cycle and anatomical details were studied by Muller(1844) Huxley (1874), Hatschek(1892), Kawalevsky (1877) and Wilson (1893).

2.3.2. Habit and Habitat:

Amphioxus is a marine animal inhabiting shallow waters on the sandy costs. It is a burrowing form burried in sand. *Branchiostoma* exhibit ciliary mode of feeding. The food consists of planktonic microorganisms.

2.3.3. External features:

2.3.3a. Shape:

Amphioxus is a slender, elongated, transparent and laterally compressed fish like animal. It is called *Amphioxus* because both the ends (anterior and posterior) are pointed. The streamlined body is well suited for burrowing as well as swimming.

2.3.3b. Size:

It measures about 3.5 to 6 cm in length.

2.3.3c. Colour:

The body exhibits flesh colour.

2.3.3d. Division of the body:

A true head is absent. The body is divisible into two regions i.e., the anterior greater part constitutes the trunk and a much shorter posterior post anal part is the tail.

(1) Rostrum:

The anterior end of the trunk projects forward as a pointed snout or rostrum.

(2) Fins:

Paired fins are absent. Three median fins are present. They are dorsal, caudal and ventral fins. Dorsal fin is running all along the length of the trunk. It is continuous with caudal fin around the tail. The ventral fin is slightly wider than the dorsal fin. The dorsal and ventral fins are supported by fin ray boxes. These boxes are formed by stiff connective tissue. These fin rays are absent in caudal fin.

(3) Oral hood:

On the ventral side of rostrum a median aperture is present surrounded by a transparent frill like membrane is present called as oral hood. The margin of it, is beset with 10 to 12 pairs of stiff cirri or tentacles. The wide cavity enclosed by the oral hood is called as vestibule or buccal cavity.

(4) Velum:

At the base of the vestibule there is a circular partition called velum. It is having a small circular aperture the enterostome. It is guarded by 12 velar tentacles.

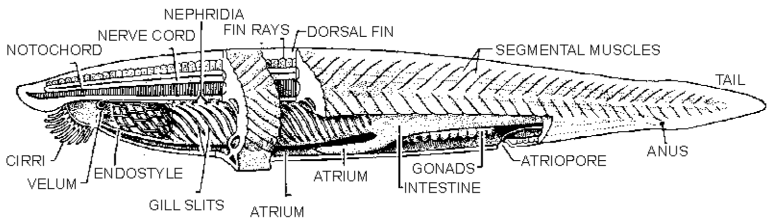

Fig.2-1. *Amphioxus*- Sagittal section

(**5) Wheel organ**:

Around the velum the wall of the vestibule bears 6 or 8 broad finger like ciliated grooves and ridges are present. This is called wheel organ or Muller's organ. It is so named because its cilia beat in such a manner and create circular water currents to sweep food organisms into mouth.

(6) Hatschek's groove:

A glandular groove called Hatschek's groove or pit is present on the roof of the vestibule between the grooves of the wheel organ. By secreting large amounts of mucous, it helps in the collection of micro organisms.

(7) Kolliker's pit:

It is present at the anterior end of the body and just behind the rostrum on left dorsal side. It is also called olfactory pit.

(8) Metapleural folds:

They are present in between the oral hood and the atriopore. The two metapleural folds are hollow membranous and meet symmetrically in the mid-ventral line just in front of the ventral fin. They help in rapid burrowing.

(9) Atriopore:

Immediately in front of the posterior union of the metapleural folds, there is a median atriopore is present.

(10) Anus:

Just behind the atriopore and on the left side of the posterior end of ventral fin, anus is present which is asymmetrical in position.

2.3.4. Internal Morphology:

2.3.4a. Body Wall:

It consists of skin, musculature and peritoneum. Skin consists of epidermis and dermis. Greater part of the body lying below the skin is made up of musculature. The musculature is formed by myotomes.

2.3.4b. Notochord:

As the notochord is extended into the head, *Amphioxus* is included in the subphylum Cephalochordata. Notochord is long cylindrical supporting axis extending along the whole length of the body. Anteriorly it extends beyond the level of brain and gives support to rostrum that helps for burrowing.

2.3.4c. Atrium:

It is a cavity present around the pharynx formed by a pair of metapleural folds and open outside by atriopore. It protects the pharynx.

2.3.4d. Digestive system:

It is very simple and consists of an alimentary canal and digestive glands. The alimentary canal consists of mouth, oral hood, buccal cavity, velum, pharynx, oesophagus, intestine and Anus. The midgut diverticulum or liver diverticulum is the only distinct gland in *Amphioxus*. The animal does not move insearch of food material but by the action of cilia in the pharynx, water currents are produced and the food material enters the mouth, hence Amphioxus is said to be a ciliary feeder or filter feeder.

2.3.4e. Endostyle:

The groove present on the ventral side of pharynx is the Endostyle. The endostyle is lined by endodermal epithelium with four longitudinal tracts of mucus secreting gland cells alternating with five tracts of ciliated cells. The cilia present on the median tract of endostyle are large in size. The endostyle is supported on its ventral side by a pair of skeletal plate.

2.3.4f. Respiration:

Special respiratory organs are absent in *Amphioxus*. The pharynx is mainly concern with the respiration since its wall is perforated with about 200 pairs of gill slits.

2.3.4g. Blood vascular system:

It shows a number of primitive features in *Amphioxus*. This system is closed type as in other vertebrates. Heart is absent. Blood is colourless and does not contain respiratory pigment. Sinus venosus is present just below the posterior end of the pharynx and opens into ventral aorta. Ventral aorta is a large median longitudinal artery which runs midventrally in the wall of pharynx below the endostyle. Numerous

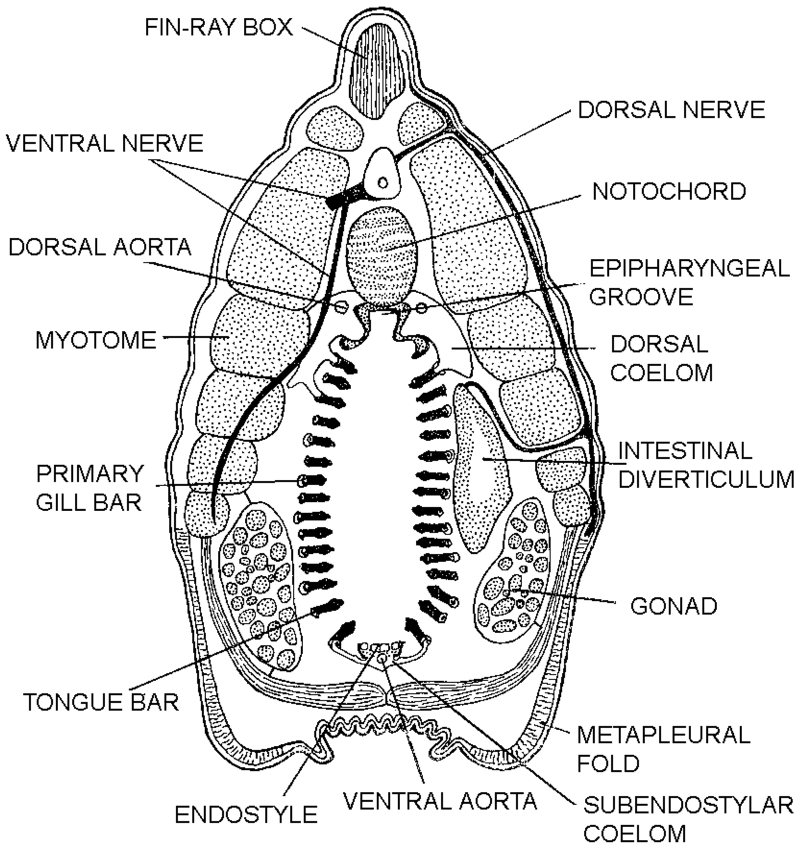

Fig.2 -2. *Amphioxus* - T.S. through Pharynx

paired branches, the afferent branchial arteries arise from the lateral sides which pass on to the pharyngeal wall on both the sides. Each afferent branchial artery at the base of gill bar dilates into a small contractile bulb called bulbillus or bulbule. Each efferent branchial vessel splits into a small capillary network called the nephric glomerular sinus before they open into lateral dorsal aorta.

The left and right dorsal aortae continuous anteriorly as carotid artery. The two lateral dorsal aortae unite at the level of the hind end of the pharynx to form a common median dorsal aorta and ends with caudal artery in the tail region.

The subintestinal veins present on the ventral wall of the hind gut. It continues anteriorly to form hepatic portal vein. Hepatic portal system occuring for the first time in *Branchiostoma.*

The two cardinal veins unite to form a common cardinal vein or ductus cuvieri.

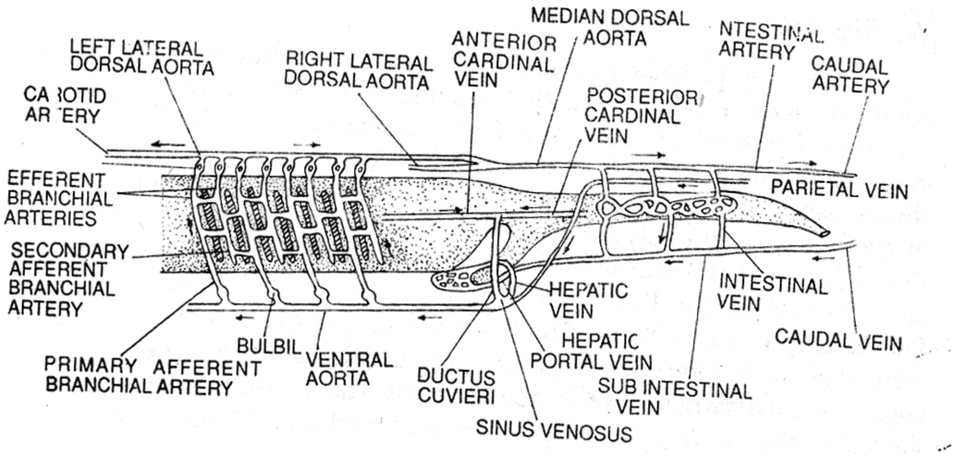

Fig.2-3. *Amphioxus*- Blood Vascular System

2.3.4h. Exretory system:

Excretory organs are a series of paired protonephridia. There are 90-100 pairs of segmentally arranged nephridia are present in pharyngeal region. Each nephridium is a minute, bent and closed tube. The body of nephridium is divisible into a long vertical limb and a small horizontal limb. On the ventral side a small nephridiopore is present. A large number of fine tubules are opened into each to be called solenocytes. Good rich reported that there are nearly 500 solenocytes in each nephridium. Each solenocyte consists of a small rounded nucleated cell at its free end and a long hollow stalk opens into lumen of side branch of protonephridium. A long vibratile flagellum arises from the basal body present in the nucleated cell. The tufts of solenocytes project into the dorsal coelomic canal and directly immersed in coelomic fluid.

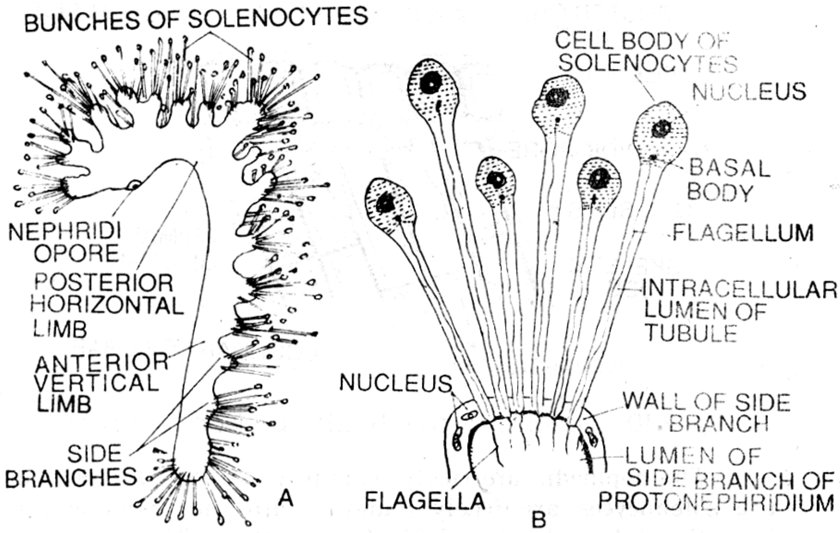

Fig.2-4. *Amphioxus*- a. Pronephridium b. Enlarged solenocyte

2.3.4i. Nervous system:

It is simple and primitive in *Amphioxus.* It is divided into central nervous system, peripheral nervous system and Autonomic or sympathetic nervous system.

A hollow, middorsal neural tube or nerve cord is situated above the notochord. Nerve ganglia are absent. The blind anterior end of nerve cord enlarges into brain or cerebral vehicle. The posterior tubular part forms the spiral cord. The neural tube is having a central hollow canal called Neurocoel filled with cerebro-spinal fluid. Giant cells and giant fibres are present all along the length of neural tube. Two pairs of cranial nerves arise from anterior end of the neural tube. The cerebral vesicle contains a pigment spot and infundibular organ.

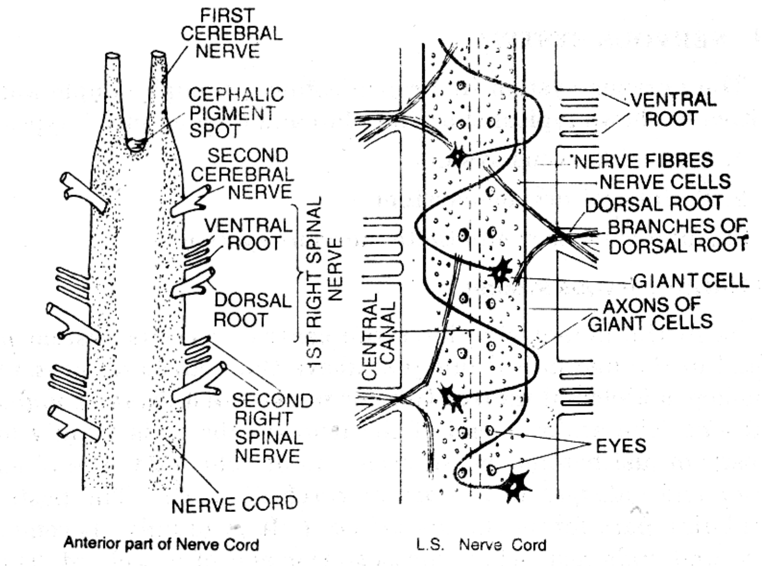

Fig.2-5. *Amphioxus* – Nervous system

The peripheral nervous system consists of paired nerves arising from the nerve cord. Autonomic nervous system is present in the form of two nerve plexus in the gut wall.

Sense organs are simple and few in number. They are olfactory pit, ocelli, infundibulum, Tactile receptors and Hatschek's groove.

2.3.4j. Reproductive system:

Amphioxus is unisexual but sexual dimorphism is not significant. About 26 pairs of gonads are present us as pouches in between 25-51 segments. The genital ducts are absent.

2.4. AFFINITIES AND SYSTEMATIC POSITION OF *AMPHIOXUS*:

The little fish like Amphioxus belongs to subphylum Cephalochordata. It was first collected and identified by Pallas (1778) who considered as a slug. Costa (1834) identified it correctly as a lower vertebrate Yarrel (1836) gave the name *Amphioxus lanceolatum. Amphioxus* shows affinities with non-chordates, tunicates and higher chordates.

2.4.1. Affinities with non-chordates or Invertebrates:

Though amphioxus exhibit large number of typical Chordata characters. Yet it shows affinities with non-chordates such as Annelida, Mollusca and Echinodermata.

2.4.1. a) Affinities with Annelida:

Similarities:

i) Metamerically symmetrical body.
ii) Metamerically arranged protonephridia with solenocytes (as in some polychaetes)
iii) Well developed coelom.
iv) Closed type of blood vascular system.
v) Filter feeding method (as in some polychaetes)

Differences:

i) Metamerism is both external and internal throughout the body in Annelids whereas in Cephalochordates metamerism is restricted only to myotomes and gonads.
ii) Coelom is schizocoelic in annelids, but in cephalochordates it is enterocoelic.
iii) The flow of blood in main blood vessels is in opposite directions in the two groups.
iv) The three basic Chordate characters (notochord, dorsal nerve cord and gill slits) are present in cephalochordates. These characters are absent in annelids.

2.4.1. b) Affinities with Mollusca:

Pallas (1778) described *Amphioxus* as a slug.

Similarities:

i) Ciliary mode of feeding.
ii) Respiratory mechanism through water current.
These similarities may be due to similar mode of life.

Differences:

i) Anatomy is completely different.
ii) Molluscs have unsegmented body. Cephalopods have segmented body with out food or podium.
iii)The three chordates characters which are present in cephalochordates are absent in molluscs.

2.4.1. c) Affinities with Echinodermata:

Similarities:

i) Enterocoelic coelom.
ii) Mesoderm formation.
iii) Creative phosphate is the energy substance (ophiuroids)
These similarties are due to common ancestry of two groups.

Differences:

i) Anatomy and Symmetry is completely different.
ii) Water vascular system of echinoderms is absent in Cephalochordata.

iii) The three chordata characters are absent in Echinodermata.

2.4.2. Affinities with Chordata:

Cephalochordata shows the three basic chordata characters.
It shows relationship with Hemichordata, Urochordata, Cyclostomes and Vertebrates.

2.4.2a. Affinities with Hemichordata:

Similarities:

i) Pharyngeal apparatus with numerous gill slits and gill bars.
ii) Enterocoelic coelom.
iii) Filter feeding Mechanism.
iv) Respiratory Mechanism
v) Numerous gonads, without gonoducts.

Differences:

i) Muscles in Hemichordata are Unsegmented, where as in cephalochordates segmented.
ii) Nervous system is of nonchordata type in Hemichordata and chordate type in Cephalochordata.
iii) Gill slits dorsal in position in Hemichordata, lateral in *Amphioxus*.
iv) Post anal tail is absent in hemichordates but present in *Amphioxus*.
v) Hemichordates are primitive than *Amphioxus*.

2.4.2b. Affinities with Urochordata:

Amphioxus shows close resemblances with urochordates.

Similarities:

i) Pharynx with lateral gill slits.
ii) Gill slits open into the atrial cavity, which open to outside through atriopore.
iii) In the pharynx, dorsal epipharyngeal groove and ventral endostyle are present.
iv) Presence of peripharyngeal bands in the pharynx.
v) Pharynx open into Intestine.
vi) Ascidian tadpole is similar to amphioxus in having Notochord surrounded by notochord sheath.
vii) Mode of development of nervous system is also similar in Ascidian tadpole and larva of *Amphioxus*.
viii) Ciliary mode of feeding.
ix) Respiratory mechanism same.
x) Identical early stages (holoblastic cleavage) of development.

Differences:

Adult ascidians are degenerate and sedentary.
Urochordates differ from cephalochordates in having the following characters.
i) Body covered by test.
ii) Unsegmented body.
iii) Without notochord and hollow nerve cord in adults.
iv) Presence of ‘U’ shaped alimentary canal.
v) With a liver.

vi) With a well developed heart.
vii) Absence of nephridia.
viii)With Hermaphrodite gonads and gonoducts.
ix) Development includes retrogressive metamorphosis.

These differences indicate that *Amphioxus* is a better evolved chordate than the Urochordate. Both might have originated from a common ancestor.

2.4.2c. Affinities with cyclostomes:

In many characters Amphioxus shows similarities with Ammocoete larva of lamprey, such as

Similarities:

i) Elongated, slender fish like body.
ii) Mouth surrounded by an oral hood and guarded by a velum.
iii) Continuous dorsal median fin.
iv) Pharynx having endostyle and gill slits.
v) Kidneys are protonephric type.

Differences:

The adult cyclostome shows differences also with *Amphioxus*.

i) Gills are sac like in adult cyclostome.
ii) Presence of buccal funnel and branchial basket in adult cyclostomes.

These differences keep away the *Amphioxus* from cyclostomes.

2.4.2d. Affinities with vertebrates:

Amphioxus or *Branchiostoma* shows affinities with ancestor of vertebrates.

Similarities:

i) Segmentally arranged myotomes.
ii) True coelom lined by mesodermal epithelium.
iii) Similar arrangement of main blood vessels.
iv) Hepatic portal system.
v) Mid gut diverticulum that can be compared with the liver.
vi) Much thicker dorsal portion of the muscle layer.
vii) Tail behind the anus.

Differences:

Cephalochordates differ from vertebrates in having the following characters.

i) True head is absent.
ii) Skull and vertebral column are absent.
iii) Very large number of gill slits open into the atrium.
iv) The myotomes are segmented and their segmentation is extended to the far anterior.
v) Paired fins are absent.
vi) Heart is absent and the blood is colourless.
vii) Unpaired sense organs are present.
viii) Gonads with out gonoducts.
ix) Epidermis is single layered.
x) Excretory organs are nephridia.

In view of its similarities and dissimilarities with the vertebrates, *Amphioxus* has been placed close to the vertebrates, but in a separate sub-phylum the Cephalochordata.

2.4.3. Systematic position:

Besides the chordate characters there are certain other characters in Amphioxus which may be divided into three groups.

a) Primitive characters.
b) Specialized characters.
c) Degenerate characters.

2.4.3a. Primitive characters:

Amphioxus retains many primitive characters. They are

i) Ciliary mode of feeding.
ii) Lack of head and appendages.
iii) Asymmetry.
iv) Single cell thick epidermis.
v) Complete metamerism.
vi) Absence of endoskeleton.
vii) Endostyle in pharynx.
viii) Stright gut.
ix) Simple circulatory system (Absence of heart and respiratory pigment)
x) Protonephridia as excretory organs.
xi) Simple nervous system (Poorly developed brain)
xii) Lack of paired sense organs (Eyes, ears)
xiii) Persistent notochord.
xiv) Segmental gonads.
xv) Single gut diverticulum.

2.4.3b. Specialized characters:

The features developed in the progress of its own line in evolution. The specialized characters of cephalochordates are

i) Large pharynx.
ii) Numerous gill slits in the pharynx.
iii)Atrium (Protects pharynx).
iv)Over developed notochord (extends beyond head to make it stiff for burrowing).
v) Oral hood with cirri for filtering the water.

The specialized characters of *Amphioxus* indicates that it is not on the direct line of chordate evolution.

2.4.3c. Degenerate characters:

These are due to sedentary life of Adult.

i) Poorly developed brain and sense organs.
ii) Notochord extends forward beyond the limit of cerebral vesicle.

iii) Head is not distinct.
iv) Absence of Heart.

These degenerate characters indicate that *Amphioxus* was better developed but later on degeneration took place during evolution. Gregory (1936) described *Amphioxus* as a degenerate Agnathan (Jawless vertebrate).

Wiley (1894) stated that *Amphioxus* can be placed along the main line of chordate evolution. According to Garstang (1928) and Berrill (1958), Cephalo chordates and vertebrates both evolved from a neotenic ascidian larva which failed to metamorphose. The specialized characters of *Amphioxus* indicate that it is not on the direct line of evolution of chordates. Costa (1834), Yarrel (1836) and Gregory (1936) consider *Amphioxus* to be modified and degenerate form.

In conclusion it may be said that *Amphioxus* is generalized, but primitive chordate very close to the vertebrates. It is also believed that *Amphioxus* resembles and originated from the fish like ancestor, Jamoytius. Which lived in the Silurian seas and it is also believed that the modern fishes also evolved from similar ancestors. Though the *Amphioxus* comes very near to vertebrates than the other prochordates, but due to many differences with vertebrates, *Amphioxus* is placed in an independent subphylum Cephalochordata.

B. UROCHORDATA

2.5. STRUCTURE OF AN ASCIDIAN:

The members of Urochordata are all marine, solitary or colonial, sedentary or planktonic. *Herdmania* is the common Ascidian.

2.5.1. Systematic position:

Phylum : Chordata.
Subphylum : Urochordata (Uro-tail, Chord-Notochord)
Class : Ascidiacea.
Order : Pleurogonia.

2.5.2. Habit and Habitat:

Herdmania is found in the Indian seas. It is carnivorous and ciliary feeder. It is sedentary and inactive.

2.5.3. Size:

Adults measure about 10 cm. in length and 7 cm in width.

2.5.4. Shape:

The body is laterally compressed, rectangular in shape with a narrow bottom for attachment. Definite anterior and posterior ends are absent.

2.5.5. Colour:

The body is pink in colour with a reddish tint which is due to the presence of vascular ampullae in the test.

2.5.6. External characters:

The adult appears as sac attached to the substratum. The body is covered by the test or tunic composed of tunicin. Body is divided into Body proper and foot.

Water enters the body through mouth or branchial opening and leaves through atrial opening. The atrial opening is small and always located at a slightly higher level than branchial opening. These openings are present on branchial siphon and atrial siphon respectively. When ascidian disturbed or stimulated it squirts out jets of water through the atrial aperture which has given it the name ‘Sea squirt’.

Test or Tunic:

The test or tunic forms a protective covering around the body. The test costs off periodically and new test will be secreted from inner side by the epidermis. Histologically the test is a sort of connective tissue consisting of matrix, corpuscles, interlacing fibrils, blood vessels and spicules, matrix is gelatinous in nature made up of polysaccharides called tunicin is homologous to cellulose. Different types of corpuscles or cells are mesodermal in origin. They are eosinophilous cells, amoeboid cells, granular cells, vacuolated cells, nerve cells and epithelial cells. Spicules are of two types a) large mega scleres b) small micro scleres.

Mantle is situated below the test. The mantle is thick and highly muscular. Histologically mantle consists of three layers. A) Outer epidermis b) Middle mesenchyme c) Inner epidermis.

2.5.7. Body Cavity or Coelom:

It is formed from mesoderm. It is greatly reduced due to the extensive development of atrium.

2.5.8. Digestive system:

Ascidians feed on microorganisms and planktonic organisms present in sea water. Ascidian is a

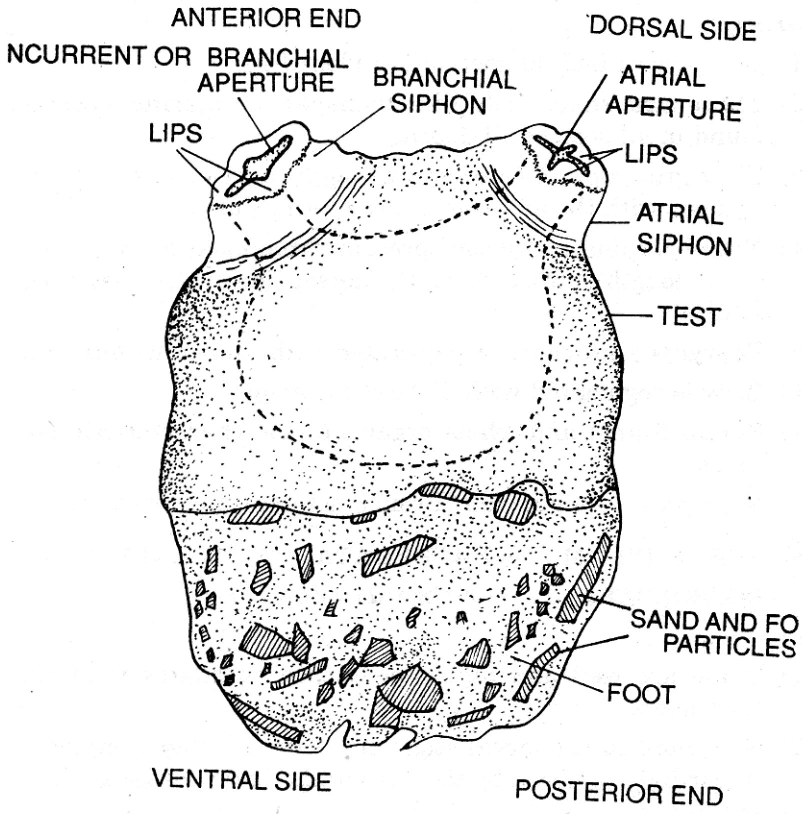

Fig.2-6. Ascidian

filter feeder or ciliary feeder because of its sedentary habit, hence it is described as ciliary mode of feeding. Digestive system consists of alimentary canal and the digestive glands. Alimentary canal consists of Mouth, buccal cavity, pharynx, Oesophagus, Stomach, intestine and Rectum. Digestive glands are liver and pyloric gland. In the roof of pharynx or branchial sac mid dorsally a thin flap like fold called dorsal lamina is present. It bears 20-30 short conical projections called languets, hang down from dorsal lamina into the cavity of branchial sac. This structure helps to pass the food into the oesophagus.

On the mid-ventral side of the pharynx a groove is present called endostyle. It consists of glandular cells and ciliated cells. Glandular cells secrete mucus. According to Muller the endostyle of Urochordates is homologous with the thyroid gland of vertebrates.

2.5.9. Respiratory system:

Special respiratory organs are absent in Ascidians. The folded inner wall of pharynx is the respiratory organ. The pharyngeal wall is supplied with blood vessels. Exchange of gases takes place between the blood and the dissolved oxygen present in the incurrent of sea water. The test with its rich supply of blood acts as accessory respiratory organ.

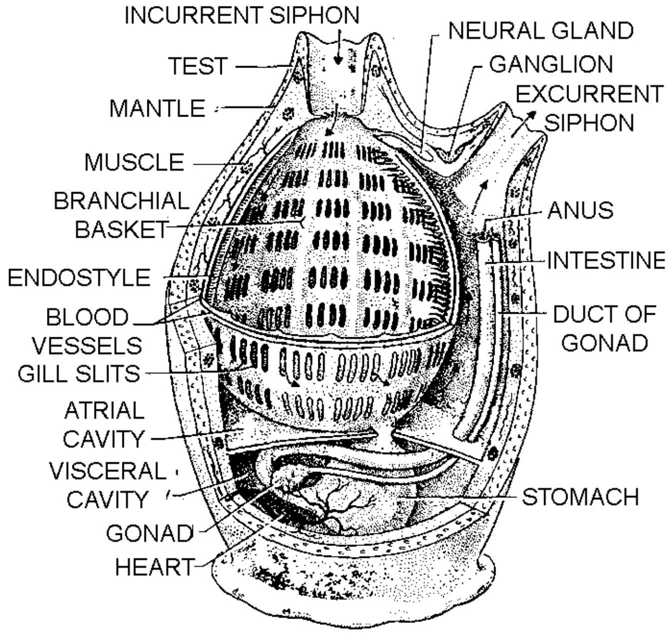

Fig.2-7. Internal organization of an ascidian

2.5.10. Blood vascular system:

It consists of heart, pericardium, blood vessels and blood. Heart is a simple sac like on showing

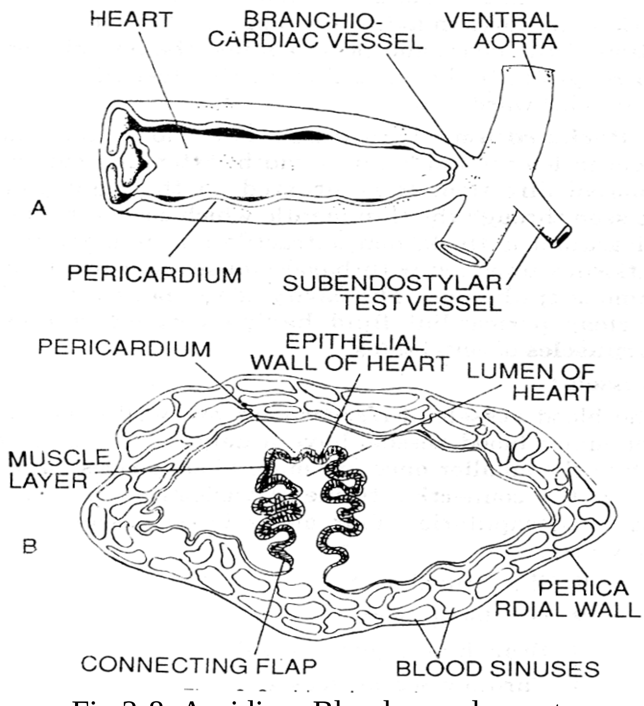

Fig.2-8. Ascidian- Blood vascular system

alternate reverse contractions. Hence the same blood vessels carrying blood to body parts also collect blood from them in a next movement. Hence they act both as arteries and veins.
The heart is tubular and centractile. It is situated in pericardium. In between the pericardial wall and the heart there is pericardial body which regulated the flow of blood in the heart. Pericardial cavity is filled by pericardial fluid. The four major blood vessels are ventral aorta, dorsal aorta, branchial & vesceral vessel and cardio visceral vessel.

The blood is hypertonic to sea water. Vanadium is the green pigment present in the plasma. Different types of cells are present in the blood. They are orange corpuscles, signet cells, Green cells, compartment cells, Eosinophilous cells, Lymphocytes, Leucocytes and Nephrocytes.

2.5.11. Nervous system:

In Ascidians the nervous system is well developed in free swimming tadpole larval stage but in the adult it is simple and degenerate. Tadpole larva shows a well developed dorsal tubular nerve cord resembling that of vertebrates. In adults it is degenerated to a solid, ganglionic mass the Brain or nerve ganglion represents the central nervous system of the adult. It is present in between mouth and atrial openings. Above this ganglion there is a neural gland (Excretory in function).

2.5.12. Neural complex:

The neural gland, nerve ganglion and the dorsal tubercle collectively called as neural complex.

2.5.13. Sense organs:

Special sense organs are lacking in *Herdmania*. A few receptor organs act as sense organs.

a) Tangoreceptors:-

They are distributed through out the non-vascular areas of test. They are sensitive to touch.

b) Photoreceptors:-

They are present at the margins of siphons. They are sensitive to light.

c) Rheoreceptors:-

These are present at the apical margins of siphons. They are sensitive to water currents.

d) Thermo receptors:-

They are present at the margins of siphons. They are sensitive to temperature.

e) Chaemoreceptos:-

They are present on branchial tetacles and dorsal tubercle and serve to taste and smell.

2.5.14. Excretory system:

There are no specific excretory organs, but the neural gland performs the function of excretion. Nephrocytes which are present in blood collect the excretory materials and send them out through neural gland.

2.5.15. Reproductive system:

Ascidians are hermaphrodite or bisexual, oviparous and protogynous animals. The reproductive system consists of two large gonads embeded in the mantle. Each gonad is an elongated, lobulated gland and has about 20 lobes. Each lobe has a large outer testicular zone and an inner ovarian zone. Thus each lobe of gland is called as Hermaphrodite gland. Each gonad has two ducts viz. Oviduct and spermatic duct running parallel to each other towards the atriopore. The testicular lobe of a gonad produce spermatozoa or sperms and the ovarian zone of gonad lobe produce ova or eggs.

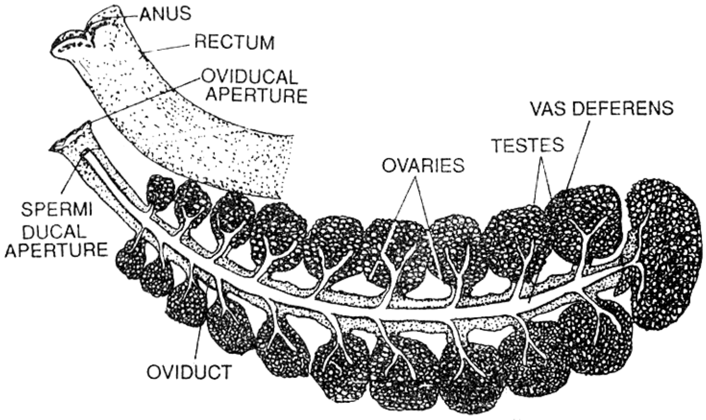

Fig.2-9. Gonads in ascidian

2.6 LIFE HISTORY OF AN ASCIDIAN – RETROGRESSIVE METAMORPHOSIS:

The life history of *Herdmania* has been described by Das and Sebestain. Ascidinas are sedentary organisms. The adults are inactive and saclike but its life cycle includes an active, highly developed free living larval stage called Ascidian tadpole. This larva undergoes retrogressive metamorphosis loosing many characters and changes to an inactive, sedentary adult. This type of metamorphosis in ascidians is the unique character among all the chordate organisms.

The three steps in the life cycle of an ascidian are

a) Development of the egg into a larval stage.

b) Organization of tadpole larva.

c) Retrogressive metamorphosis.

2.6.1. Development of the egg into larval stage:

Ascidians are hermaphrodite (bisexual) and protogynous i.e. ovary matures earlier than testes which prevents self fertilization. A mature sperm is microscopic and measures about 4 microns in length. Each sperm is having acrosome, head, neck and long tail region. A fully formed ovum (egg) is transparent and measures about 0.3 mm in diameter. It contains a small quantity of yellowish granulated yolk in the cytoplasm (microlecithal egg). The mature ovum is surrounded by three membranes a) Vitelline membrane b) Inner chorion c) Outer chorion. Mature ova and sperms of different species are liberated into the atrium from where they pass out into the surrounding sea water through the atrial aperture. Thus fertilization is external.

Sperm cell enters the egg through vegetal pole and fertilization takes place. Zygote measures 1mm. After fertilization three distinct presumptive areas are formed in the egg. They are

a) Clear cytoplasmic region which forms the embryonic ectoplasm ad presumptive ectoderm.
b) An equatorial yellow crescent of lipoid inclusions which is the presumptive tail of larva.
c) A grey, yolky region which represents the presumptive endoderm.

2.6.1a. Cleavage:

Cleavage starts half an hour after fertilization cleavage is complete, holoblastic and regular. The first two divisions are vertical, the third division is horizontal. After third division cleavage becomes irregular. In the eight celled stage four micromeres and four macromeres are present. This stage is called Morula. After further divisions the Morula changes to Blastula. It has a central blastocoel surrounded by single layer of cells.

2.6.1b. Gastrulation:

It starts after the sixth division by the process of Invagination (invagination of macromeres). The cavity enclosed is known as Archenteron. The wide opening of the archenteron is Blastopore. As the embryo elongates the blastopore becomes narrow and finally closed.

2.6.1c. Neurulation and Notogenesis:-

Formation of dorsal nerve cord (neural tube) on the mid-dorsal side of the embryo from ectodermal cells is known as neurulation. Formation of Notochord from endoderm cells of the mid-dorsal wall of archenteron of embryo is called notogeneris. Subsequent formation of mesoderm converts the bi-layered gastrula into a tri-layered neurula stage. After undergoing certain embryonic changes a larva is formed called as Ascidian tadpole.

2.6.2. Organization of Tadpole larva:

The embryo develop into a larva in about 8-24 hours after fertilization. It resembles the tadpole larva of frog. The larva is independent and free swimming. All the important characters of chordate are found in this larva.

The entire body of the larva is covered by a tunic or test. The body is divisible into two regions i.e., trunk and tail. The body is transparent, measures about 1.2 mm long.

2.6.2a. Trunk:

The trunk is 0.3 mm is length. At the anterior end of this, there are three adhesive papillae by means of which the larva attaches to a substratum during metamorphosis. Out of the three adhesive Papillae two are dorso-lateral and one is ventro-median in position. An oval, hollow sensory vesicle or brain is present on the dorsal side of the trunk. In this vesicle two ocelli and one otocyst are present. One ocellus is large in size situated postero-dorsally and the other ocellus is small and situated antero-ventrally. These ocelli act as photoreceptors. Otocyst or otolith serves as an organ of equilibrium. It is situated obliquely

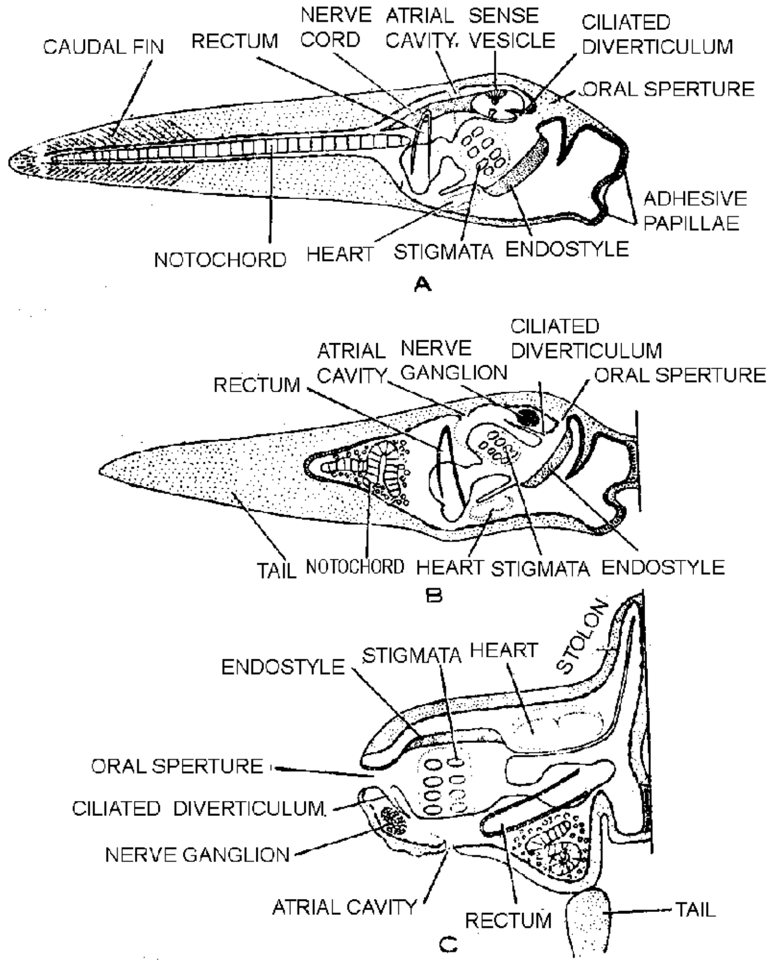

Fig.2-10. Retrogressive metamorphosis of ascidian tadpole larva

from the ventral wall of sensory vesicle.

A conical mass of nerve cells are present in front of the sensory vesicle called the corebral cone. A visceral ganglion is present behind the cerebral vesicle as a thickened mass of nerve cells. This ganglion continues as tubular nerve cord up to the tip of the tail. Mouth is antero-dorsal in position open into a rudimentary alimentary canal consisting of a narrow branchial siphon, a large sac like pharynx, a short narrow oesophagus, a swollen stomach, a slender intestine and a small rectum. The pharynx has a well developed endostyle and a pair of large gill slits. Mouth is not functional because it is closed by a covering.

A heart is present ventral to the pharynx. It is enclosed in a small tubular pericardium. The atrium present both on the lateral and dorsal sides of the pharynx open to outside by a posterior mid dorsal a trial aperture. Mesenchyme cells are distributed all over the body beneath the ectoderm.

2.6.2b. Tail:

Tail is elongated measures about 0.9 mm long. It is about 3 or 4 times the length of trunk. It is laterally compressed consisting of a broad median tail fin and a central part. The central part is made up of nerve cord, notochord and tail muscles. The nerve cord is equivalent to the spinal cord of higher chordates. Metamerically arranged ganglionic swellings are present on the nerve cord which gives out paired lateral nerves to the various parts of the tail. Notochord is restricted to tail region, hence the name uro(= tail) chordata. The tail muscles include three strong muscular bands on each side of the notochord. Ascidian Tadpole larva reveals a typical chordate plan in the following anatomical characters:1) A long post anal tail supported by fin rays 2) Extension of rod like notochord throughout the length of the tail 3) Muscle bands of tail shows metameric segmentation 4) Pharynx with true gills and endostyle. 5) Ventral heart 6) Hollow tubular nerve cord with anterior brain.

2.6.3. Retrogressive metamorphosis:

The free swimming, negatively geotrophic, positively phototrophic larva changes to sedentary, positively geotrophic, negatively phototrophic adult. The larval life is very short (about 3 hours). After complete free swimming life the larva undergoes metamorphosis.

The active, free swimming, well developed larval form changes to inactive, sedentary, poorly organised adult. This type of metamorphosis is called retrogressive metamorphosis.

The larva settles down to the bottom and attaches itself to a substratum with the help of the adhesive papillae. At this stage the larva exhibit upside-down posture. Metamorphosis takes place after an hour of its attachment to a substratum by under going the following changes.

2.6.3a. Loss of Tail:

The tail along with the caudal fin, muscles, notochord and nerve cord begins to reduce and finally disappears largely due to phagocytosis.

2.6.3b. Formation of ectodermal Ampullae:

Four ectodermal ampullae arise from the trunk which firmly anchor the larva to the substratum. They also help in respiration.

2.6.3c. Perfection of Alimentary canal:

The pharynx increases in size and stigmata increase in number by division converting the pharyngeal wall into a basket work. Stomach enlarges, intestine elongates and becomes curved and liver appears.

2.6.3d. Shifting of mouth and Atrial aperture:

The region between the adhesive papillae and the mouth undergoes rapid growth. This causes rotation of the body dorsoposteriorly through an angle of nearly 180^{o}. As a result of this, mouth and atrial aperture are carried to the opposite free end and the intestine becomes looped.

2.6.3e. Opening of mouth:

The test covering the mouth is now absorbed so that feeding by ciliary current starts. This converts free embryo into true larva.

2.6.3f. Changes in the brain:

The central nervous system begins to decrease and it forms a small solid brain or nerve ganglion and a neural gland which come to lie upwards between the mouth and the atrial aperture. Ocelli and statocyst disappear completely.

2.6.3g. Completion of heart:

The heart completes its development and get connection with the blood vessels.

2.6.3h. Development of test:

The test gradually becomes thick, tough and translucent.

2.6.3i. Development of Gonads:

Gonads and their ducts develop from the mesenchyme.

2.6.3j. Loss of adhesive papillae:

At the end of metamorphosis the adhesive papillae disappear. The rapidly growing test helps for firm attachment over the substratum.

As a result of the above changes the important chordate characters of the larval stage are lost during the retrogressive metamorphosis. The important chordate characters that are lost are a)Notochord b) Nerve cord c) Bilateral symmetry d) Metameric Segmentation. Hence the type of metamorphosis in which the adult, instead of acquiring advanced characters, loses important structures and appears as a degenerated form is known as Retrogressive Metamorphosis.

2.7. SUMMARY:

- *Amphioxus lanceolatum* belongs to phylum Chordata and subphylum Cephalochordata.
- *Amphioxus* or *Branchiostoma* is a small fish like marine burrowing animal commonly called as lancelet.
- Notochord is extended into the anterior most part of rostrum hence the name Cephalochordata.
- It is a ciliary or filter feeder.
- Excretory organs are protonephridia.
- Heart is absent.
- *Amphioxus* is unisexual.
- It shows affinities with non-chordates and chordates. It shows primitive, degenerate and specialized characters.
- *Ascidia* or *Herdmania* belongs to phylum Chordata and subphylum Urochordata.
- *Ascidia* is marine, Sedentary and ciliary feeder.
- The body is covered by test or tunic.
- Ascidians are hermaphrodite animals.

- Larva is free swimming and active, It undergoes retrogressive metamorphosis and change to saclike inactive, sedentary adult.

2.8. SELF ASSESSMENT QUESTIONS:

1. Give an account of structure of *Amphioxus.*
2. Describe the affinities and systematic position of *Amphioxus*.
3. Explain the structure of an Ascidian.
4. Define retrogressive metamorphosis?
   Explain in detail about retrogressive metamorphosis in ascidians.
5. Write short notes on:
   a. Wheel organ.
   b. Structure of solenocyte.
   c. Endostyle.
   d. Atrium.
   e. Ascidian tadpole larva.

2.9. REFERENCE BOOKS:

1. A text book of Zoology vol II by parker & Haswell.
2. Vertebrate Zoology by Nigam.
3. The life of Vertebrates by J.Z.young.
3. A student text book of Zoology vo III by Adam Sedgwick.

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Lesson – 3
GENERAL CHARACTERS OF CYCLOSTOMES AND DIFFERENCES BETWEEN *MYXINE* AND *PETROMYZON*

CONTENTS:

3.1. OBJECTIVES
3.2. INTRODUCTION
3.3. GENERAL CHARACTERS OF CYCLOSTOMATA
3.4. DIFFERENCES BETWEEN LAMPREYS AND HAGFISHES
3.5. SUMMARY
3.6. MODEL QUESTIONS
3.7. REFERENCE BOOKS

3.1. OBJECTIVES:

The aim of this lesson is to understand the
- General characters of Cyclostomata, and
- Differences between Lampreys and Hagfishes.

3.2. INTRODUCTION:

The most primitive of all vertebrates belong to the group Agnatha (=Jawless). The cyclostomata (=circular mouth) are the living agnathans with poorly developed cranium. Hence they are also called as primitive craniates. Cyclostomes are more advanced than the cephalochordates possessing almost all vertebrate characters. They include lampreys and Hagfishes in two orders petromyzontia and Myxinoidea respectively.

3.3. GENERAL CHARACTERS OF CYCLOSTOMATA:

1. Body is elongated, round, cylindrical and eel-like with laterally compressed tail.
2. Skin is soft, smooth having unicellular mucus glands.
3. Jaws, scales and paired fins are absent. Median fins with cartilaginous fin rays.
4. Mouth ventral in position, suctorial and circular, hence the name Cyclostomata.

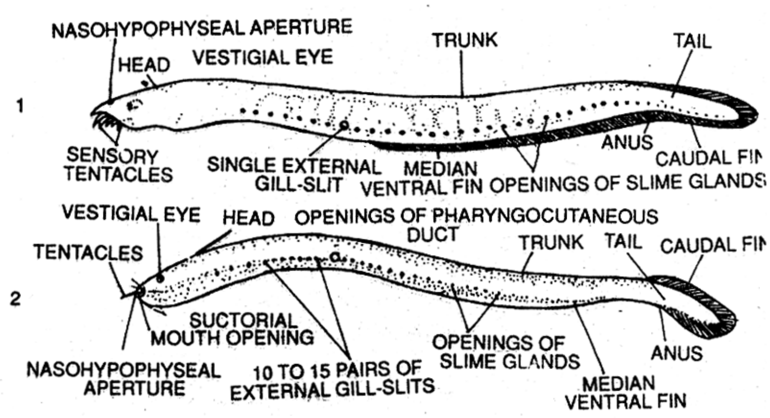

Fig 3-1. Cyclostomes – a. *Myxine* b. *Petromyzon*

5. Body is divided into trunk (including head) and tail.
6. Muscles are segmented into myotomes.
7. Endoskeleton is cartilaginous. Notochord persists throughout life.
8. Digestive system lacks a stomach, pancreas and spleen. Intestine with a fold called Typhlosole.
9. Tongue has teeth and muscles (Rasping tongue).
10. Respiration by means of 6-14 pairs of internal gills are present in pouch like gill chambers (hence marsipobranchii), Gill slits are 1-16 pairs.
11. Heart 2-chambered with 1 auricle and 1 ventricle.
12. Conus arteriosus and Renal portal system are absent.
13. Body temperature variable (poikilothermous).
14. Excretion is carried by two mesonephric kidneys.
15. Single mid-dorsal nostril and single median olfactory sac are present.
16. Internal ear consists of 1 or 2 semi circular canals.
17. Dorsal nerve cord with distinct brain.
18. 8-10 pairs of cranial nerves are present.
19. Pineal body sensitive to light.
20. Sexes separate or united. Gonad single, large, without gonoduct.
21. Fertilization is external. Development either direct or indirect (with larval stage).
22. The adults are either parasites or scavangers but the larvae are microphagous.
23. Found in fresh water and salt water.

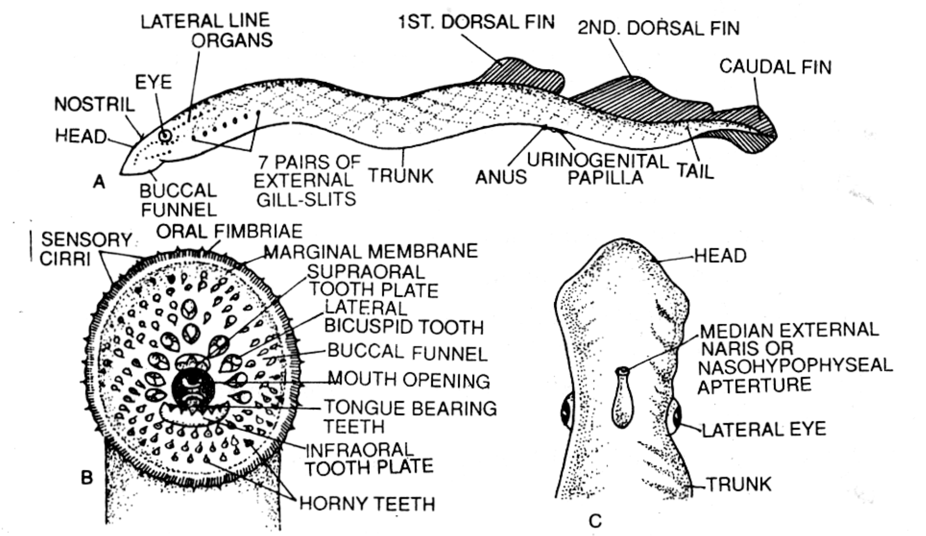

Fig.3-2. *Petromyzon* - A. Entire organism B. Buccal funnel C. Head

3.4. DIFFERENCES BETWEEN LAMPREYS AND HAGFISHES:

Table 3-1. The differences between *Myxine* and *Petromyzon*

	Character	Lampreys (*Petromyzon*)	Hagfishes (*Myxine*)
1	Habitat	Usually found in the sea (marine) and migrate to the rivers (fresh water) for spawning (anadromous Migration).	Exclusively marine.
2	Habit	Adults are ectoparasitic on larger fishes. Simply attaches to the host or prey and rasps the flesh with the tongue but does not bore. Larvae are free living	Usually attack the dying or dead fishes or worms. It bores into the muscles of prey.
3	Shape of the body	Body is cylindrical and stout. Dorsal fin is divided into two portions. Caudal fin is normally developed.	Body is slender and eel like. Dorsal fin is reduced caudal fin is slightly developed.
4	Size of the body	Reach upto 1 metre	Remain under 1 metre
5	Mouth	Mouth subterminal due to over development of upper lip to form funnel like structure called buccal funnel. Mouth lies at the	Mouth terminal and is surrounded by sensory tentacles.

		base of this funnel	
6	Buccal funnel	Present	Absent
7	Sensory oral tentacles.	Absent	3 or 4 pairs of tentacles around the mouth.
8	Tongue	Less developed large teeth are present on lips.	Well developed with small teeth.
9	Lips and teeth.	Present	Lips are absent but teeth are present on tongue.
10	Nostril	Mid dorsal in position.	Nostril is terminal
11	Nasal sac	Ends blindly	Open into the mouth cavity.
12	Eyes	Well developed.	Degenerate and covered by skin.
13	Ear	Complex with two semicircular canals	Simple with single semicircular canal
14	Skin	Slime is produced in small quantities. Thread cells are absent in skin.	Many, large mucous glands are present and secrete large quantity of mucous. Present.
15	Anti-coagulant	An oral or salivary glands secretes an anticoagulant to keep the wound bleeding	No anticoagulant is secreted.
16	Fins	Dorsal and a tail fins are well developed. Dorsal fin is divided into two by a notch.	Tail fin is developed. No dorsal fin.
17	External gill slits	Seven pairs of External gill slits	One pair
18	Gill pouches	Seven pairs open into respiratory tube.	6 pairs open directly into the pharynx.
19	Internal gill tubes.	United.	Separate.
20	Pharynx	Ends blindly as respiratory tube.	Continued into oesophagus.
21	Intestine	With spiral fold and Typhlosole.	With Longitudinal folds.
22	Bile duct and gall bladder	Absent in adults.	Present
23	Cartilaginous oral ring	Present	Absent
24	Lingual Cartilage	Poorly developed	Well Developed.
25	Branchial basket	Large and well developed	Small and poorly developed
26	Skull	Imperfectly roofed	With out roof.
27	Vertebrae	Rudimentary vertebrae are present	Absent

28	Neural arches	Present	Absent
29	Pericardial sac	Thick walled, supported by a cartilage.	Thin walled, cartilage is absent.
30	Ductus cuvieri	Single, present on right side.	Present on both sides.
31	Aortic arches	Each supplies to hemi-branch of adjacent gill pouches.	Each supplies hemi-branchs of same gill pouch.
32	Brain	Well developed.	Poorly developed.
33	Cranial nerves	10 pairs	8 pairs.
34	Spinal nerve roots	Dorsal and ventral roots are separate	United.
35	Pineal eye	Present	Absent
36	Lateral line system	Better developed	Poorly developed.
37	Kidneys	Advanced mesonephros	Primitive pronephros and mesonephros.
38	Sexes	Separate	United
39	Urino-genital sinus	Present	Absent
40	Egg	Small, round, less yolk	Large, oval, much yolk is present.
41	Egg shell	Absent	Present.
42	Cleavage	Holoblastic	Meroblastic
43	Spawning	Takes place in the gravel in streams (Anadromous)	Takes place on the ocean bed.
44	Development	Indirect with Ammocoete larval stage.	Direct, without larval stage.
45	Osmotic balance	The blood salt level is much lower than that of sea water	Blood is isotonic with sea water.

3.5. SUMMARY:

Class Cyclostomata is included in Division Agnatha and Subphylum vertebrata. Cyclostomes are Jawless vertebrates. Mouth is rounded and suctorial. Gills are pouch or sac like

- Class Cyclostomata is divided into two orders, Petromyzontia and Myxinoidea.
- Petromyzontia includes Lampreys and Myxinoidea includes Hag fishes. There are many differences between these two groups.

3.6. MODEL QUESTIONS:

1. Describe the general characters of Cyclostomata.
2. Explain the differences between lampreys and hag fishes.
3. Write short notes on:

a) Lamprey.
b) Hagfish.

3.7. REFERENCE BOOKS:

1. A text book of Zoology Vol. II by Parker and Haswell.
2. The life of Vertebrates by J.Z.Young.
3. Vertebrates Zoology by Nigam.

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4. SKELETAL SYSTEM

GENERAL INTRODUCTION:

Vertebrate organisms are the highly evolved organisms having backbone as supporting skeleton of the body. Skeletal system in vertebrates includes supporting and protective tissues besides the connective tissue and its derivatives such as cartilages and bones. All these structures are mostly derived from the mesoderm.

Skeleton is mainly of two types namely the **exoskeleton** and **endoskeleton.** Generally, the exoskeleton such as scales, scutes, plate, feathers, hair etc., is formed from the integument. This may be epidermal, dermal, or both but never it is cuticular as seen in some invertebrates like arthropodans and some molluscans. Cornification of epidermal cells into horny substance results in the formation of claws, scales, nails, horns, hair, and hoofs. Dermal exoskeleton is occurs in the form scales and fin rays (fishes) or the bony armour as in sturgeon, crocodile or armadillo.

Calcium made endoskeleton is internal and contributes to the mass of the body besides giving support and protection. It also extends support to borne the weight of the body in case of larger and heavier animal. It provides surface for the attachment of the muscles and provides free mobility **to the body and appendages. Ossification** of the cartilage during the formation of bone occurs in two ways viz., gradual invasion of the cartilage by the deposition of lime salts (ectochondrostosis) and by the transformation of the cells of cartilage into osteoblasts followed by ossification (endochondrostosis).

Endoskeleton can be divided into two types: axial skeleton consisting of skull, vertebral column and sternum. Appendicular skeleton consists of girdles (pectoral and pelvic) and limb (fore limb and hind limb) skeleton.

Lesson 4.1

SKULL

CONTENTS :

4.1.1. OBJECTIVES

4.1.2. INTRODUCTION

4.1.3. SKULL OF SHARK

4.1.3. a. Comparision with that of the frog

4.1.3. b. Comparision with that of the lizard

4.1.3 c. Comparision with that of the bird

4.1.3 d. Comparision with that of the mammal

4.1..4. SUMMARY

4.1.5. KEY WORDS

4.1.6. MODEL QUESTIONS

4.1.7. REFERENCES

4.1.1. OBJECTIVES :

The aim of this lesson is to know

- the meaning of skeleton
- the bones contributing for the formation of internal skeleton
- to compare and contrast the skulls of shark, frog, garden lizard, bird and a mammal, and
- to familarize with different bones contributing for the formation of skulls in vertebrate

4.1.2. INTRODUCTION:

Skull is the main skeletal component of the vertebrate head. Further, it consists of cranium surrounding the brain, sense capsules (olfactory, auditory and optic) and the jaws (upper and lower). Such a primitive skull is the **chondrocranium** as seen in cyclostomes, elasmobranchs and the embryonic stages of all craniates.

Associated with the formation of skull, formation of visceral arches supporting gill slits and mouth also occur. In gnathostomes the first pair of visceral arches are the mandibular arches, which bend over the corner of the mouth, and splits into two bars to support the upper and lower jaws for food capture. The upper jaw is the **palato-pterygo quadrate** or **palato-quadrate** and the lower is the mandibular or **Meckel's cartilage.** The second visceral arch viz., the **hyoid arch** in close association with mandibular connects to the chondrocranium. Rest of the visceral arches constituting the branchial skeleton are free from the skull and become modified in different ways in different organism.

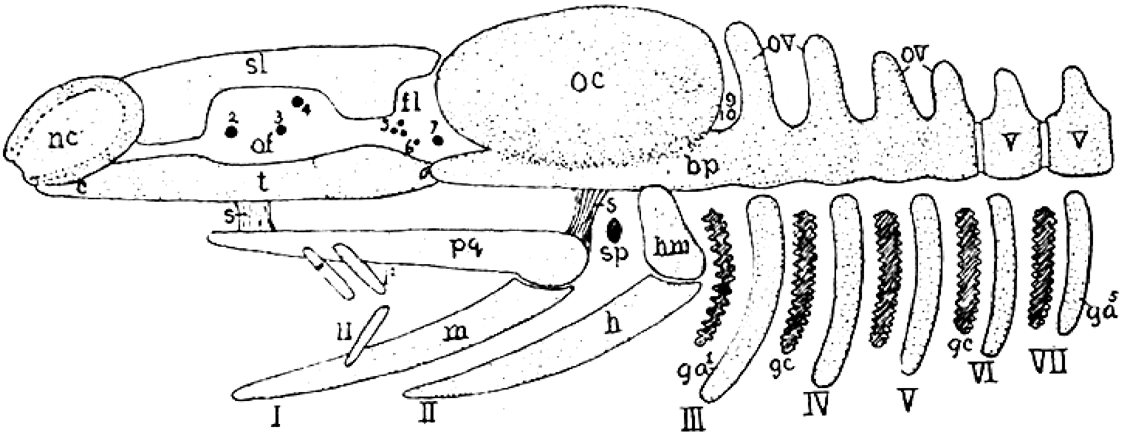

Fig.4.1-1. Fish-Skull and Gill arches:

nc-nasal cavity*;* *of*-orbital foramen; *sl*-sphenolateral; *fl*-foramen lacetum*;* *oc*-otic capsule*;* *bp*-basal plate*;* *ov*-occipetal vertebrae; *v*-vertebrae*;* *sp*-spiracle*;* *s*-suspensor ligament; *ll*-lower labial*;* *h*-hyoid arch*;* *hm*-hyomandibular*;* *ga*-gill arch; *gc*-gill cleft*;* *m*-mandibular arch*;* *pq*-pterygoquadrate

In higher vertebrates, the primitive cartilaginous elements slowly gets ossified and in association with the dermal bony plates added from outside, transforms into a complex structure. Thus the skull of higher vertebrate is composed of two sets of bones viz., the inner set of cartilage bones and the outer set of dermal bones to form the complex skull. Basing on the external composition, the skull consists of a neurocranium surrounding the brain and splanchnocranium encircling the anterior end of the alimentary canal. Thus the embryological, morphological and physiological nature of the skull reveals its double nature.

Jawbones: In general, **upper jaw** of vertebrates is mainly composed of premaxilla, maxilla, quadratojugal and quadrate. This is suspended to the cranium with pterygoid, squamosal and palatines.

Similarly, the **lower jaw** is composed of mentomeckelian cartilage, dentary, angulosplenial and Meckel’s cartilage. Hyoid apparatus supports the tongue. The lower jaw articulates with the upper jaw at their hind ends where the Meckel’s cartilage comes in contact with the quadrate of the upper jaw.

Skull in turn is formed of cranium encircling the brain, sensory capsules encircling the sensory lobes and jaws.

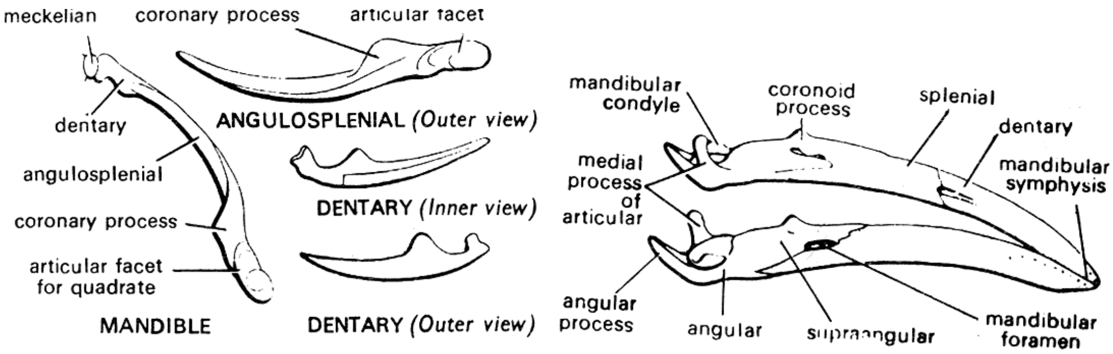

Fig.4.1-2. Lower jaw in Frog and Fowl

4.1.3. SKULL OF SHARK :

The skull includes the *cranium,* covering the brain, *olfactory capsules* (Ethmoid region), an *auditory capsule* (auditory region) and also the *visceral skeleton* including *the* jaws and the *skeletal supports* of the *gills.*

Cranium : It is simple and box like one opening both in front and behind. It has a convex roof and a flattened floor. From the anterior end of the cranium, extend forward three cartilaginous bars. They unite together to form a *Rostrum.* The sides of the cranium are hollow to accommodate the *eyes*

The olfactory capsules fuse with the antero-lateral ends of the cranium, while the auditory capsules fuse with the postero-lateral ends of the cranium. The cranium is divided into four regions. (a) occipital region, (b) auditory region (c) orbital region (d) ethmoid region.

a) *Occipital region* : It forms the posterior most region of the cranium. It has a large median opening at its posterior end called the *foramen magnum.* On either side of *it is* present a prominent bulb like elevation called *occipital condyle* which articulates with the first vertebra. The roof of the occipital condyle above the magnum possesses a prominent median ridge called the occipital crest. A large foramen lies by the side of the occipital condyle for the exit of the 10^{th} cranial nerve, the vagus.

b) *Auditory region* : The auditory region lies in front of the occipital region. It comprises, of the auditory capsules and a part of the cranium with which they are fused. In between the two laterally projected huge auditory capsules, and in the roof of the cranium is present an oval depression called *parietal fossa.* It bears two pairs of apertures. Through the anterior pair of smaller apertures, the *endolymphatic* duct (aqueductus vestibule) leads *into* the internal ear, The posterior large pair of fenestrae form the opening of the *perilymphatic* spaces of the capsules.

Each auditory capsule is provided with *3* ridges which mark the positions of the semicircular canals of the internal ear. Behind the ridge of the horizontal semicircular canal lies a foramen for the passage of the ninth cranial nerve.

c) *Orbital region*: It lies anterior to the auditory region and forms the middle of the cranium. It is hollow and lodges the eye balls, muscles, the orbital blood sinus and a number of nerves. A prominent curved *supra-orbital ridge* forms the dorsal boundary of each orbit. The anterior boundary is formed by a posteriorly directed slender process which arises from the posterior part of the olfactory capsule. It is called the *pre-orbital cartilage.* A similar process arising from the anterior part of the auditory capsule, is directed forwards forming the posterior boundary. It is called the *post-orbital cartilage.* A sub-orbital ridge is a lateral out growth of the floor of the orbit extending anteriorly into an anterior orbital process. This provides place for the insertion of the ligaments of the upper jaw. The orbit is perforated by numerous *apertures* through which nerves like oculomotor, trochlear, trigeminal, abduscens and facial along with blood vessels emerge out. The anterior-border is provided with the opening of orbitonasal canal through which the olfactory sinus communicates with the orbital sinus. The floor of the cranium is broad, flat and bears obliquely placed transverse grooves at its posterior end. These are called *carotid canals.* Each one possesses two apertures for internal carotid artery and stapedial artery. Just beneath the olfactory capsules lie two prominent articular surfaces for the ethmopalatine ligament of the upper jaw. In front of these surfaces are situated the openings of the orbito-nasal canals.

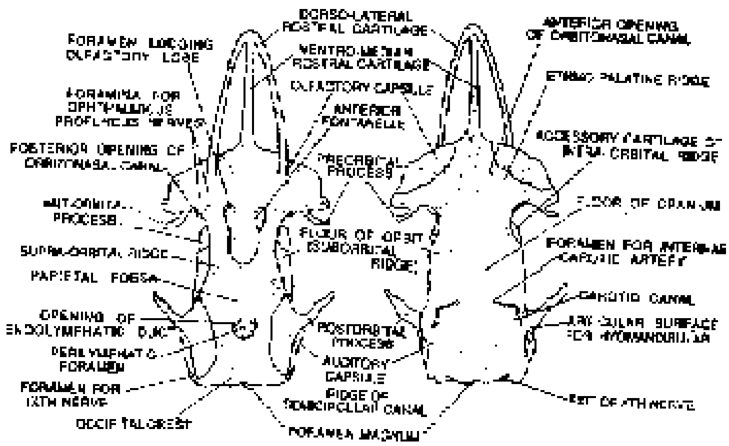

Fig . 4.1-3. Skull of *Scoliodon* (a) dorsal view (b) ventral view

d) *Ethmoid region* : The anterior region of the cranium becomes narrower and this along with the olfactory capsules and rostrum form the ethmoid region. The olfactory capsules are separated by thin median cartilage called *internal septum.* In this region the cranial roof is incomplete, as it is perforated by a large anterior fontanelle, which is covered by a sheet of connective tissue. The sides of the fontanelle bear apertures for the emergence of the ophthalmic branches of 5^{th} and 7^{th} cranial nerves. Within each olfactory capsule lies a large opening leading into the cranial cavity and it forms the entry of the large olfactory nerve into the olfactory sac. Cranium gives off three cartilaginous rods in front of the anterior fontanellae. They extend forward and unite at the end forming the *rostrum* or *snout.* Out of the three rods, two are dorsolateral arising from the roof of each olfactory capsule. The other one is ventro lateral projection from the base of the cranium.

Visceral skeleton supporting the gill slits is composed of seven pairs of visceral arches of which the first one is the mandibular and the second is the hyoid. Upper and lower jaws are formed from these arches.

e) *Jaws*: The upper jaw is formed from the mandibular arch, a highly specialized bone forming into a complete ring. This arch borders the mouth forming the upper and lower jaws. Jaws are toothed in elasmobranchs. Each half of it has an upper palato-pterygo-quadrate and a lower Meckel's cartilage. The upper cartilage of both the sides elongate along the margin of the mouth to form the upper jaw. Similarly the Meckle's cartilage of both the sides elongate in the same fashion to form the lower jaw. Both the jaws are strong and toothed. Teeth are homodont and polyphyodont. The upper jaw is directly connected to the chondrocranium. Posterior part of the Meckel's cartilage forms a movable joint with the upper jaw. Anterior processes of the palato-pterygo-quadrate and the posterior ethmopalatine ligament also help in fixing the upper jaw with the cranium. The second hyoid arch has three elements viz., the hyomandibular, ceratohyal and basihyal. Lower end of the hyomandibular is attached to the palatoquadrate and Meckel's cartilage thus strengthening the fixation of the jaws with the cranium. Since hyoid element helps in the articulation of the jaws, jaw suspensorium is called hyostylic one.

4.1.3.a. Comparision with the skull of the Frog :

The skull of the tadpole consists entirely of cartilage, but in the adult frog bones are formed in the place of cartilage. Other bones are called the membrane bones formed directly from the mesoderm. Much of the cartilage, however, remains. To understand the skull, observation of the bones from behind forwards followed by the sensory capsules.

***Cranium*:** It is the brick shaped brain-box made mostly from the cartilage. Posteriorly it has a large opening called the foramen magnum, through which the medulla comes out and extends as spinal cord to the posterior end of the organism. Either side of this opening is margined by an arch like exoccipital bone having a backwardly directed knob called the occipital condyle. The upper and lower borders of the foramen are not ossified. The only other bone in the cranium is a large flame like sphenethmoid at the anterior end. **The sphenethmoid corresponds to the mesethmoid, orbitosphenoids and presphenoid of the dog, together with part of the nasal capsule.** The roof of the cartilaginous cranium is incomplete, having a large anterior and a pair of small posterior gaps or fontanellae. These are covered by a pair of long membrane bones viz., the frontoparietals. The floor is made of a dagger-shaped membranous bone called theparasphenoid. The wall of the cranium has a number of openings or foramina for the passage of the cranial nerves and arteries.

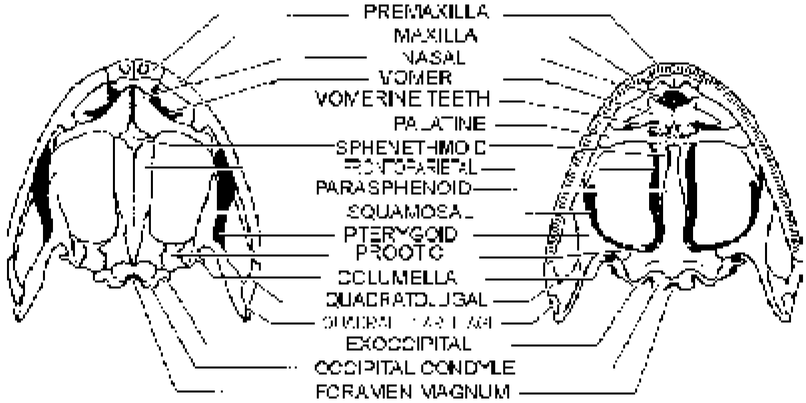

Fig.4.1-4. Skull of frog

Sensory capsules: Auditory capsules are the blocks of cartilage continuous with that of the cranium, and applied to its posterior corners of the parasphenoid. Each capsule is bordered by prootic cartilage to form the membranous labyrinth. Upper side of this capsule is covered by one large limb of the squamosal. The capsule has an opening called fenestra ovalis giving space for the thin, delicate columella auris of the middle ear to fit in.

The nasal capsules are a pair of irregular, mainly cartilaginous, enclosures continuous with the front end of the cranium. They are bordered on the dorsal side by flat, tabular and pear like nasal and by vomer or the pre-vomer on the lower side. They bear a pair of vomerine teeth just in front of the palatines. These teeth project out into the buccal cavity. The wall between the two capsules is known as the mesethmoid. The front part of the upper jaw is closely applied to the nasal capsule, but behind it diverges widely, to make a large space, the orbit, between the jaw and the cranium lodging the eye ball.

Jaws:

Upper Jaw: Upper jaw is formed of two halves and each half has a cartilage viz., the pre maxilla at the tip of the snout followed by maxilla, quadratojugal and quadrate. Maxilla bears a number of homodont maxillary teeth helping in holding the food during ingestion.

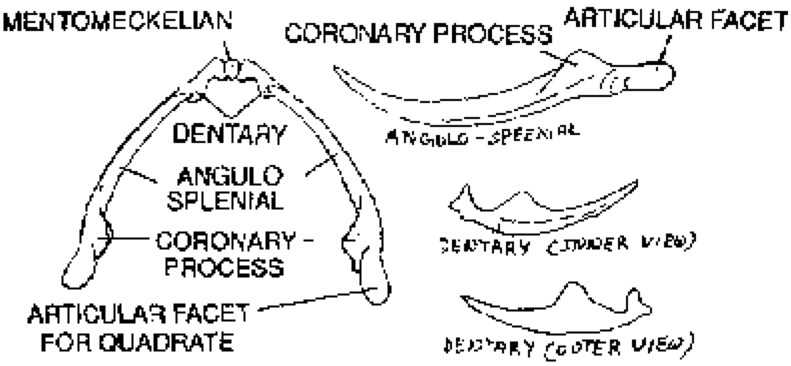

Fig.4.1-5. Frog: Lower jaw

Lower jaw : The lower jaw or mandible consists of two halves united in front by a ligament. Each half is a curved rod of cartilage, known as Meckel's cartilage, ossified at the anterior end to form the small mentomeckelian bone. It is almost en-sheathed by a couple of membrane bones, the angulo-splenial and the dentary. Lower jaw is un-toothed. At the near end or angle of the jaw, the dentary bears a small knob or condyle, which fits into a hollow on the end of the quadrate known as the mandibular fossa. Meckel's cartilage appears also to be in contact with the quadrate. The hyoid is a flat structure in the floor of the mouth

Suspensorium: The primary cartilaginous upper jaw remains un-ossified at its posterior end as a small quadrate, which articulates with the lower jaw and is held firm above by the squamosal. In front the cartilage partially ossifies to form a pterygoid and a palatine, but in the group of animals to which the frog belongs these cartilage bones are lost and replaced by membrane bones to which the same names are given. The pterygoid is Y-shaped, with the fork directed backwards, the inner arm abutting on the auditory capsule and the outer on the quadrate, which it helps to hold against the squamosal. The palatine runs transversely from the anterior end of the pterygoid to the sphenethmoid. The cartilage of the jaw runs forward from the quadrate as a continuous bar on the outside of the pterygoid bone and in front of the palatine. A second series of membrane bones is situated outside the primitive jaw, and borders the opening of the mouth. In contact with the quadrate and squamosal is a small quadratojugal, and from this runs forwards a long maxilla, which bears teeth, and is in contact in front with the nasal capsule and pterygoid. In front of the maxilla is a small premaxilla, also with teeth, which rests on the front of the nasal capsule. The two premaxillae touch in front.

4.1.3.b. Comparision with that of the Lizard :

The skull is well ossified with numerous bones. Presence of the temporal fossae or the *vacuities* in the temporal region behind the orbit is the important characteristic feature of the reptilian skull. These vucuities lodge the muscles associated with the movement of the lower jaw. The skull is differentiated into three regions for a convenient study. They are *1) cranium 2) sense capsules 3) visceral skeleton.*

Cranium: This forms the posterior part of the skull, enclosing the brain. It constitutes a posterior *occipital region,* a middle *parietal region* and an anterior *frontal region.*

The *occipital region* encircles the *foramen magnum* and consists of four bones, the *supra-occipital*, the *basioccipital* and two *exoccipitals.* The rectangular supraoccipital forms the roof of this region and articulates with the *parietals* and *pro-otics* forming the *post-temporal fossa.* The basioccipetal forming the floor, bears an *occipital condyle.* It articulates with the exoccipitals and prootics. Each exoccipital is produced into a *paraoccipital* process articulating with the supra temporal, squamosal, parietal and quadrate.

The *parietal region* comprises of only two bones, the *parietal* and the *basisphenoid.* The large flat parietal forms the roof of the cranium. It is formed by the fusion of two bones and is broad infront and narrow behind with a central *parietal foramen.* The parietal articulates with frontals anteriorly, with supra-occipital posteriorly, with post orbitals on the sides and with epipterygoid below. The *basisphenoid* along with the *basioccipital* form the floor of the cranium. It is broad, flat and rectangular. From its anterior end are given off two prominent processes called *basipterygoid processes* which unite with the pterygoids at their free ends.

The *frontal region* is formed by three bones. A pair of large, triangular *frontals* lying on the dorsal side with their apex forwards. They meet along their median line by a frontal suture and the parietals behind by a coronal suture. Frontals articulate in front with nasals; prefrontals on the sides; palatines, post orbitals and parietals behind. The *parasphenoid* is a long narrow, rod like bone lying on the mid ventral line.

Sense capsules : There are three pairs of sense capsules namely the *auditory,* the *optic* and the *olfactory.* The *auditory capsules* enclose the *internal ears* and are situated on the sides of the posterior end of the cranium. Each is made up of a vertical bone, *the prootic,* lying outside the supra-occipital. The *epiotic* and *opisthotic* are indistinguishable since the former fuses with the supra-occipital, and the later fuses with the exoccipital forming a *paraoccipital process.* The large *optic capsules* or *orbits* enclosing the eyes are located on the sides of the middle region of the skull. The two orbits are separated by a thin *interorbital septum.* Each orbit is bounded by five bones, the *pre frontal,* the *supra-orbital,* the *lacrymal, the post-orbital and the jugal.* The *pre frontal* is small and triangular, with a deep cup like concavity on its ventral side, It forms the *anterior* *boundary* of the orbit and lies obliquely between the frontal and maxilla. The *Supraorbital* is also triangalar and it *over hangs* the posterior portion of the orbit. The square shaped *lacrymal* forms the *anterior boundary.* The irregular *post frontal* or *postorbital* produces four processes and forms the *posterior boundary* of the orbit. Behind the post orbital lies a V-shaped *squamosal with its diverging arms* articulating with the post-orbital and parietal and the apex with the quadrate. A rod like curved *jugal* forms the *ventral border* of the orbit,

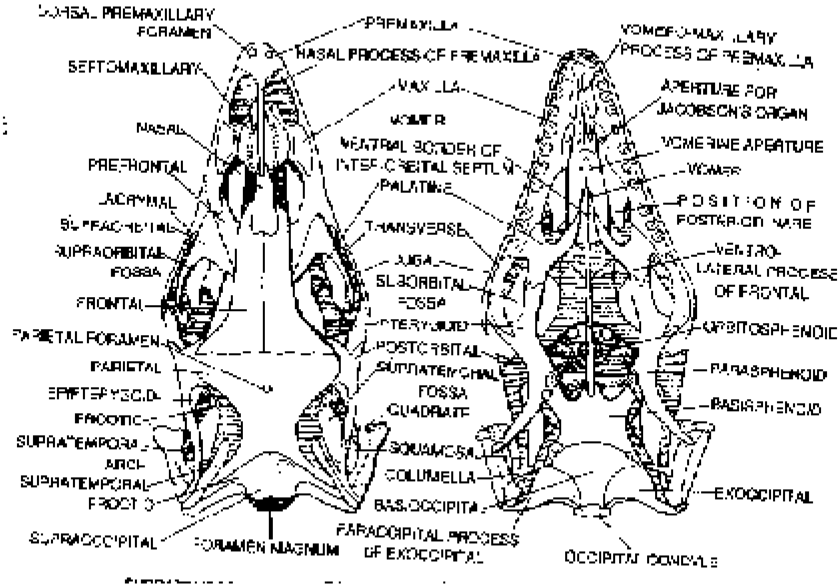

Fig.4.1-6. Skull of *Varanus* (lizard)

The *paired olfacfory capsules* lie together in front of the cranium and enclose the olfactory lobes. Each one is made up of a *nasal,* a *septo maxillary,* and a *vomer.* The nasals of the two capsules fuse in the mid line into a single bone occupying the dorsal position. Jt is narrow anteriorly and broad behind. It articulates with the nasal processes of pre-maxilla in front. An irregular, flat *septomaxillaries* lies on the dorsal side. The *vomer* is an elongated rod shaped bone forming the floor of the olfactory capsule.

Vacuities in the skull : Varanus skull is characterised by the presence of two pairs of vacuities or fossae. They are the paired *supra temporal* and *infratemporal* fossae. Supra temporal fossae are located in the roof near the posterior end of the skull. The rod of the bone formed by the *postorbital* and the *squamosal* is called the *supra temporal arcade* and the space enclosed between the supra-temporal arcade and the parietal is called the *supra temporal fossa.* The *quadrato jugal* and *jugal* forms into an arch or arcade known as the *infra-temporal-arcade.* The space between the infratemporal arcade and the surpa temporal arcade behind the orbit is called the *infratemporal fossa.* Such a type of skull is called a *diapsid skull*

Jaws :

upper jaw is an union of two, similar halves meeting anteriorly but diverge posteriorly. Each half consists of *two sets* of bones, an outer and an inner set. The *outer set* comprises of four bones, the *premaxilla,* the *maxilla,* the *jugal* and the *quadrate.* The inner set comprises of five bones, the *pterygoid, the palatine,* the *transpalatine* or *ectopterygoid,* the *epipterygoid,* and *squamosal.* The premaxilla of either side fuse in the middle line to produce a *nasal process* posteriorly. This bears 6 to 8 small teeth on its ventral margin. A pair of wing like *Vomero-maxillary* procesess arise from the ventral surface articulating with the vomers behind. The long irregular *maxilla* lying behind the pre-maxilla forms the major portion of the upper jaw and it bears 1 to 10 teeth along its outer margin (pleurodont). The rod-like *jugal* lying behind the maxilla also bounds the orbit ventrally. *Palatine* forms the roof of the buccal cavity and it is produced into 3 processes. The anterior one articulates with vomer, the posterior with pterygoid and the outer process with the maxilla. *Pterygoid* has an anterior *palatine process* and a posterior *quadrate process.* Epipterygoid is a slender bone extending from the pterygoid to the auditory region. The *squamosal* is attached to the outer surface of the supratemporal bone and one of its processes joins with the post frontal to form supratemporal arch. The *quadrate* movably articulates with the auditory region and its distal end forms the articular surface for the lower jaw.

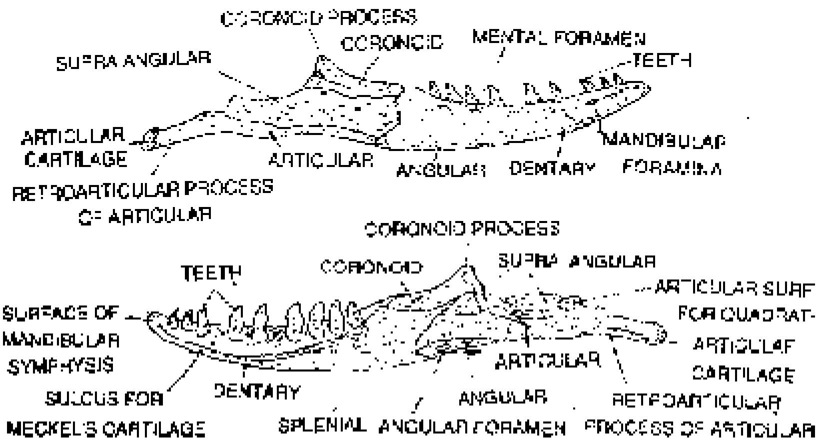

Fig.4.1-7. Lower jaw of a lizard

Lower jaw : The *lower jaw* consists of two rami each of which is composed of six bones, the *articular,* the *angular,* the *supraangular,* the *coronoid,* the *splenial* and the *dentary.* The dentary bears the *teeth.* The *Meckel's cartilage* persists to a small extent in the adult, around which the investing bones are formed.

4.1.3.c. Comparision with that of the Bird :

The skull has very large orbits, which are situated almost entirely in front of the cranium, so that the eyes are separated not by the whole width of the brain, but merely by an interorbital septum. In the adult, separate bones can hardly be distinguished in the skull, and the following account is based on what can be seen in the embryo and young bird, particularly in the domestic fowl.

Cranium: The foramen magnum is surrounded by basioccipital, supra-occipital, and two exoccipitals, and there is a single condyle formed mainly by the basioccipital. In front of the basioccipital is the basisphenoid, and above this on each side the wall of the cranium is partially formed of an alisphenoid. The front of the cranium, and the interorbital septum, consist of a single bone representing mesethmoid,

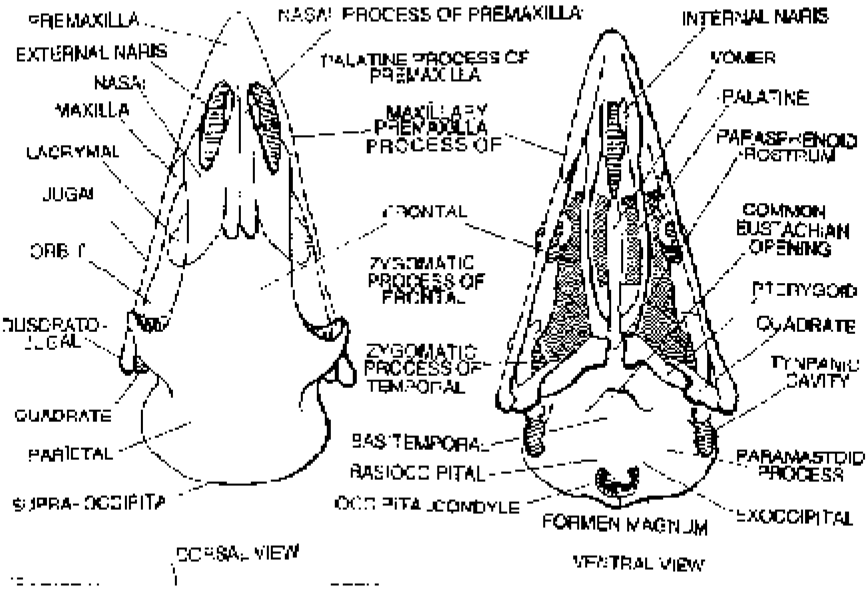

Fig.4.1-8. Skull of a bird

pre-sphenoid, and orbitosphenoids. The remainder of the cranium is formed of membrane bones viz., the parietals and frontals in the roof and small lacrimals in front of and above the orbits. Below the basiphenoid is a pair of bones sometimes called basitemporals, which represent the posterior part of the parasphenoid of the frog, and a piece of membrane bone representing the front end of this is fused on to the inter-orbital septum to form the rostrum. The basitemporals and the rostrum all become fused to the basisphenoid. The auditory completes the covering of the brain.

Sensory capsules: The nasal/ olfactory capsules are fused with the interorbital septum. Above them is a pair of nasals, deeply notched in front for the nostrils. The vomers are vestigial in the pigeon, but in the fowl are represented by a slender median rod in front of the rostrum.

The auditory capsules are almost lateral and are encircled by auditory bones.

Jaws:

Upper jaw: It is completely ossified. The quadrate is a conspicuous three branched bone articulating with the squarnosal, the pterygoid, the quadratojugal, and the lower jaw. From this, the pterygoid runs forwards and slightly inwards to meet the rostrum. From the pterygoid the palatine continues forwards to the nasal capsule. The quadratojugal is a slender splint running forward to the maxilla, which is also small and lies inside the premaxilla. On its inner surface it has a plate like projection, the rnaxillopalatine process. The premaxilla completes the upper jaw. It has two backwardly directed processes which, with the nasal, enclose the external nostril. The outer process runs back outside the front part of the maxilla. In front the premaxilla bears the beak. The connections of the palatines with the pterygoids and of the pterygoids with the quadrates are the articulations. Hence there is some movement of the upper jaw on the cranium. In parrots the nasals are also articulated to the frontals, so that when the mouth opens the whole upper jaw is raised.

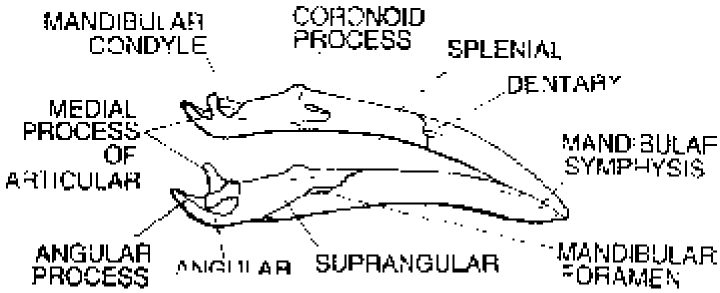

Fig.4.1-9. Lower jaw of fowl

Lower jaw of pigeon: Each half of the slender lower jaw consists of articular, angular, suprangular, dentary, splenial, prearticular elements.

4.1.3.d. Comparision with that of the Rabbit :

The following are the peculiarities of mammalian skull.

The skull is completely bony, made up of seperate bones, which are immovably joined along the sutures. The number of bones is much reduced.

The skull is marked into a well developed posterior *cranial part* edging the increased brain and an anterior f*acial part* comprising mainly the jaws. In higher mammals the facial part lies below the cranial part.

A *palate* separates the food passage from the nasal passage.

A zygomatic arch is formed on either side of the skull by squamosal, Jugal and maxillary bones.

Only *dentary* bone forms the lower jaw.

Skull is dicondylic having two occipital condyles.

Quadrate transforms into the incus of the middle ear.

Cranium: The cranial region of the skull of rabbit shows three segments, a posterior *occipital segment* a middle *parietal segment*, and an anterior *frontal segment.*

The *occipital segment* constitutes of an unpaired *basioccipital*, two paired lateral *exoccipityls* and an unpaired dorsal *supra occipital* posteriorly, thus enclose a great opening called the *foramen magnum.* Each exoccipital bears a single *occipital condyle.* Futher it is produced *into a parotic process* lying close to the tympanic bulla. The *parietal ring* is made up of a ventral *basisphenoid,* the paired lateral *alisphenoids* and two paired dorsal *parietals.* The *basisphenoid* is a rhomboidal bone and lies in front of the basioccipital. A depression called *sella turcica* lodging the pitutary body lies in its middle upper surface. The *alisphenoids* are flat wing shaped bones. They bear the *alisphenoid canal* on their surface. The paired parietals meet middorsally and meet the corresponding alishenoid on the sides. A small unpaired dorsal *interparietal* lies in between the parietals and supraoccipitals. The *frontal ring* consists of a median ventral compressed *presphenoid* lying in front of the alisphenoid, the paired *orbitosphenoids* with large cavities laterally, and paired *frontals* dorsally and laterally. The *presphenoid* forms the lower and anterior boundary of the *optic foramen.* The lateral extensions of frontals are pressed in wards to make two cavities called the *orbits* lodging the eye balls. A small bone, the malleus in between the frontal and maxilla, in the anterior wall of the orbit. It has an opening called lacrimal foramen. Dorsally the lateral margin of each frontal forms a prominent ridge over the orbit called the *supra orbital ridge of the frontal.*

The *Ethmoid* is present in front of the cranial cavity and it is perforated by small holes for the passage of olfactory nerves into the cranial cavity. As it is perforated it is commonly called *cribriform plate.*

All the above bones are joined by sutures and form the ventral, lateral and dorsal walls of the parietals and in front of the exoccipitals. In this region the wall of the cranium is formed by a large bone called-the *squamosal* which forms a part of the upper jaw.

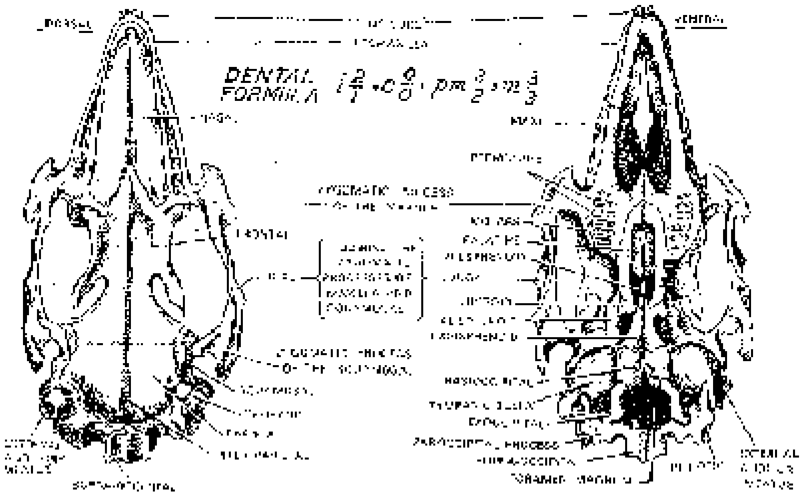

Fig.4.1-10. Skull of a rabbit

Sensory capsules: The olfactoty capsules form the *facial region* of the skull. Internally the paired nasal passages are separated by a vertical plate of bone called the *mesethmoid.* Each olfactory capsule is roofed by an elongated *nasal,* laterally by *premaxillary* and *maxillary* and ventrally by *vomer again* formed by the fusion of two bones. The *nasals, maxillaries* and *ethmoids* extend into nasal cavities in the form of thin scroll like extensions called the nasoturbinals, maxilloturbinals, ethmoidoturbinals. The turbinals are covered with mucous membrane and serve to increase the surface area of the nasal passage.

Auditory capsules : The auditory capsules are closely fused with the latereal walls of the cranium in between the parietal and occipital rings. Each capsule is formed by the fusion of three separate bones the *prootic,* the *epiotic* and *opisthotic* in the embryo and fuse to form a single *periotic* in the adult. It is irregular, perforated and is distinguished into two parts, (a) an internal hard bony part, the *petrous* surrounding the membranous labyrinth and (b) a posterior light *mastoid* part, visible externally. A flask shaped *tympanic* is attached to the outer surface of the *periotic.* The body of the flask is known as *tympanic bulla* and the tabular part of it is the *external auditory meatus.* The *tympanic membrane* lies in between these two. The tympanic bulla encloses a space called *tympanic cavity* which is traversed by a chain of three bones called the *ear ossicles,* i.e., *malleus, incus* and *stapes.* At the junction of the tympanic and the periotic is an opening leading into the *eustachian* *tube.* The outer wall of periotic has two openings called *the fenestra ovalis* and *the fenestra rotunda.*

Orbits : They are situated on the sides of the frontal segment. A median bony *interorbital septum* separates the two orbits. The sides of the orbit are protected by the *zygomatic arch* and the lower side is unossified.

Jaws:

Upper jaw : The bones of the upper jaw along with the bones of the olfactory capsule form the facial region of the skull. The *premaxillae* and *maxillae* form the nasal part of the upper jaw. Each *premaxilla* bears incisors and gives of two processes, a long *nasal process* extending backwards between the nasal and maxilla to the frontal, a *palatine process* passing backwards along with the palate to meet its fellow along the middle line below the olfactory cavity. The *maxillae* are large irregular bones situated behind the premaxillae. They bear the *premolars* and *molars.* They give off horizontal *palatine processes* internally, uniting to form the anterior part of the palate. A strong curved *zygomatic process* is given off from the outer surface of each maxilla joining with the zygomatic process of squamosal to form the *zygomatic arch.* Paired palatines and pterygoids also participate in the formation of the upper jaw. The palatines are thin vertical plates lying internal to maxillae to which they are attached anteriorly and fuse posteriorly with pterygoids. The *pterygoids* are small, irregular bony plates situated behind the palatines and joined with alisphenoids unlike in other vertebrates. The squamosal of rabbit contributes in the formation of the cranial wall and are fixed over the periotic and tympanic bones. The zygomatic process of the squamosal bears a depression on the under side called *glenoid fossa* meant for the articulation of the dentary. The zygomatic process of the maxillae and squamosal are attached by an intermediate bone called *jugal.* A *quadrate* is absent in the upper jaw as it is modified as one of the ear ossicles called the *incus.*

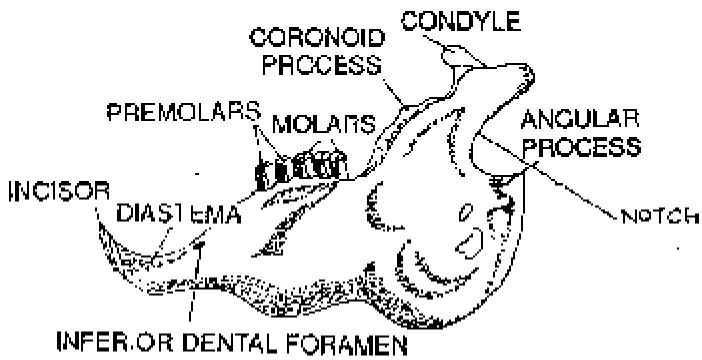

Fig.4.1-11. Lower jaw of the rabbit

Lower jaw : Each half of the lower jaw is made up of a single bone, the *dentary* or *mandible* which unites with its fellow in front by *mandibular symphysis.* The anterior portion of the dentary is horizontal and bears the teeth. The hinder part is flat and laterally compressed for the attachment of jaw muscles. At the hinder end is a *condyle* for articulation with the glenoid fossa of the squamosal. In front of the condyle is present a blunt *coronoid process.* The posterior, lower border of the dentary is rounded and inflected forming an *angular process.* An articular of the lower vertebrates is absent in rabbit as it is modified into *malleus.*

4.1.4. SUMMARY:

Skeleton gives support to the vertebrate organisms. Exoskeleton is seen on the external surface of the body while the endoskeleton protects the main internal organs of the body. Endo skeleton is mainly formed from mesoderm and is composed of several bones. Endoskeleton is further divided into axial and appendicular skeletons located on the axis and in association with the axial skeleton respectively.

Skull is the axial skeleton giving support and protection to the cephalic region. It is further composed of cranium protecting the brain, sensory capsules protecting the sence capsules and jaws encircling the buccal cavity. Different bones contributig to the formation of the skull in the five typical vertebrate organisms are discussed in detail and the skull of the fish is compared with those of the frog, lizard, bird and mammal.

4.1.5. KEY WORDS:

Skull : Capsular part in the head and protecting all the important organs
Cranium : Bony capule encircling the brain.
Jaws : the two skeletal structures lining the buccal cavity
Suspensorium : Bones contributing for the fusion of the upperjaw with cranuium
Sensory capsules : Bony capsules enclosing the sense organs.
Axial skeleton : Skeleton on the axis of the organism comprising of skull, sternum and vertebral column.
Fossae : Large and conspicuous cavities seen in the skulls of lizard.

4.1.6. MODEL QUESTIONS :

1. Describe the bones associated with the skull taking frog skull as a typical model. Compare the same with the skulls of the typical vertebrate organisms you have studied. (or)

Write a comparative account on the skulls of various vertebrate organisms you have studied. (or) With the help of diagrams, describe the skulls of the shark, frog, lizard, pigeon and rabbit. (or) Write a comparative essay on the skulls of any two vertebrate organisms you have studied.

2. Write an essay on the skull of shark. Compare the same with amphibian you have studied. Give a detailed account on the bones contributing for the formation of the skull in Shark. (or)

What are the various components of the skull? Explain the same with the help of neat and labeled diagrams in case of an elasmobranch fish.

3. Frog forms the typical vertebrate organism for detailed study of the skeleton. Give a detailed account on the bones contributing for the formation of the skull in Frog. (or)

What are the various components of the skull? Explain the same with the help of neat and labeled diagrams taking frog as an example..

4. Write an evolutionary significance of the skull of the lizard through the bones contributing for its formation. (or)

What are the various components of the skull in Uromatrix? Explain the same with the help of neat and labeled diagrams. Add a note on how it is different from other vertebrates.

5. Give a detailed account on the adaptability of the skull bones in Pigeon. (or)

What are the various components of the skull? Explain the same with the help of neat and labeled diagrams in Pigeon.

6. Give a detailed account on the bones contributing for the formation of the skull in Rabbit. (or) What are the various components of the skull? Explain the same with the help of neat and labeled diagrams.

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4.2. Lesson
GIRDLES IN VERTEBRATES

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4.2.6. MODEL QUESTIONS
4.2.7. REFERENCES

4.2.1. OBJECTIVES :

The aim of this lesson is to know

- the structure of pectoral and pelvic girdles in shark and
- to compare and contrast the girdles of shark, frog, garden lizard, bird and a mammal, and
- to familarize with different bones contributing for the formation of girdles in vertebrates.

4.2.2. INTRODUCTION:

Skeletal elements having no articular bones with the axial skeleton generally attach with the bones of the thoracic basket or sacral area by ligaments and muscles. These girdles along with limb bones help in the mobility of the organism besides supporting the trunk in all respects. They constitute the appendicualr skeleton. As mentioned above, the appendicular skeleton consists of girdles (both pectoral and pelvic) and limbs (fore and hind).

4.2.3. GIRDLES IN SHARK:

Pectoral girdle and Pectoral fin in shark: The *pectoral girdle* lies behind the last branchial arch. It is formed by the fusion of two equal halves of loop shaped bones. They fuse midveutrally but lie apart dorsally. Each half is made up of a curved rod-like *scapula* placed dorsally and a thin, flattened *coracoid lying* ventrally. Along the outer border of the junction of these bones, lies a glenoid depression with 3 foramina for the passage of branchial artery and nerve. The glenoid region is provided with three facets for the articulation with the basal cartilages of the pectoral fin. Thus the girdle is not connected to the axial skeleton. It also provides a fulcrum for the attachment to the muscle helping in the movement of the fin, The muscles attached to the coracoid control the movement of the visceral arches and hence they help in breathing.

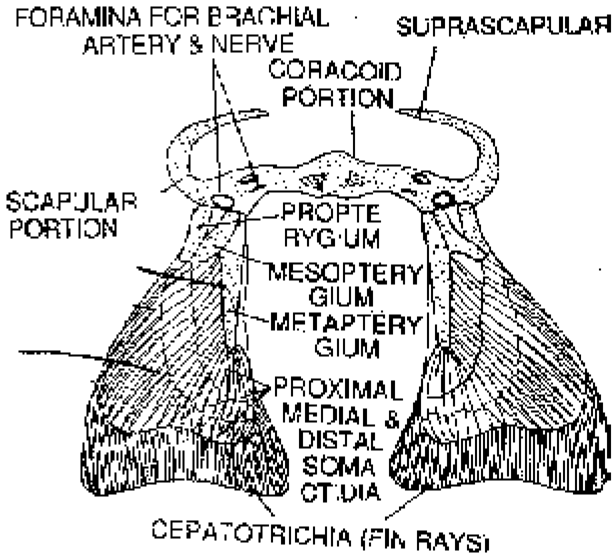

Fig 4.2-1. Pectoral girdle in Shark

The skeleton of each pectoral fin comprises of three basi- cartilages called *propterygium, mesopterygium and metapterygium.* Numerous radial cartilages arranged in three rows are attached to them distally. These three rows are called proximal, medial and distal *somactidia*. In their turn, they bear *ceratotrichia* at their distal ends supporting the web of the fin. The basals and radials together form the *prerygiophores.*

Pelvic girdle and Peivic fin: The pelvic girdle is in the form of a flat rod called *ischiopubic bar* which lies transversely in front of the cloaca. The proximal end of each side is curved. An acetabular region lies on either side of the girdle to which the pelvic fins are attached.

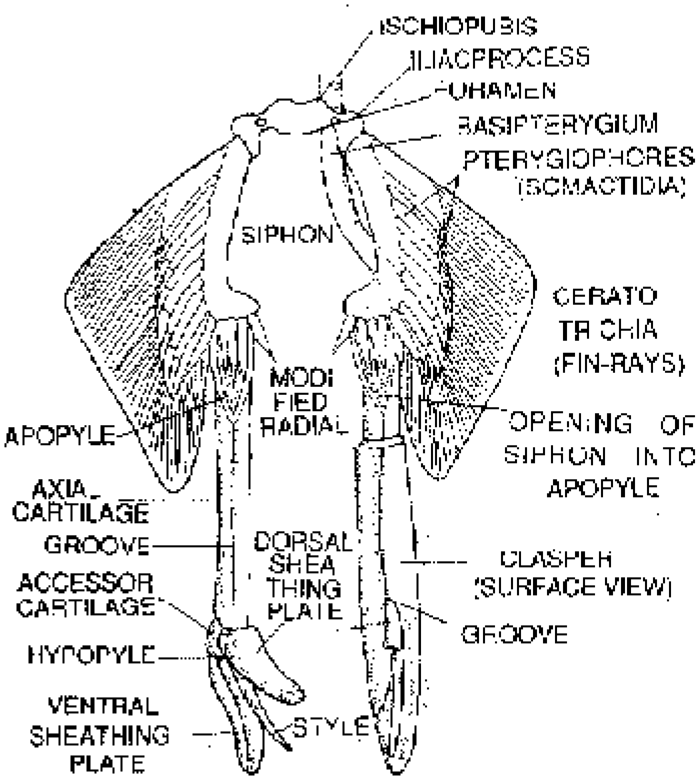

Fig.4.2-2. Pelvic girdle in shark

The pelvic fin possesses a single backwardly directed basal cartilage called *basipterygium.* It articulates with the pelvic girdle. A number of slender radials are attached to its outer border and they are celled *pterygiophores.* They in turn possess numerous *ceratotrichia* which support the expanded free margin of the fin. In male, the posterior radials of either side are enlarged and groved forming the claspers or *myxopterygium.* At its distal end is present a sharp pointed *style* enclosed in two flat tender plates viz., the dorsal and the ventral plates. Each clasper has an anterior aperture called *apopyle* and a posterior *hypopyle.* The claspers are also covered with skin and are erectile. It is used for the transport of sperms during copulation.

4.2.3. a. Comparison with the girdles in Frog:

The pectoral or shoulder girdle is a flattened structure of cartilage and bone embedded in the body-wall of the anterior part of the trunk. It is almost a girdle encircling the body. It consists of two similar halves, one on each side of the body united below and separate above. Each half is composed of an upper scapular portion or shoulder blade and a lower coracoid portion. The uppermost part bears a broad, flat plate like calcified cartilage called suprascapula embedded into the shoulder muscles. A patch of true bone lies at the point where it joins the scapula. A forward projection from this bone is known as the acromion process. To the lower end of the scapula is attached the coracoid portion of the girdle. This is a plate of cartilage and bone lying on the under side of the body in the breast region. It is pierced by a wide oval space called the coracoid fontanelle. Behind the fontanelle lies the stout coracoid bone. In front of this is a narrow strip of calcified cartilage viz., the precoracoid. Towards the inner border, coracoid has another piece of cartilage known as the epicoracoid. The two halves of the girdle come together at this precoracoid region forming into a single procoracoid through a symphysis. Scapula and coracoid are cartilage bones. A pair of slender membrane bones called the clavicles lie in association with precoracoid cartilages. Each sends forward a prolongation inside the acromion process. At the junction of the scapula and coracoid bones is a cup like depression called the glenoid cavity lined by cartilage. The head of the humerus or bone of the upper arm fits into this cavity forming a ball and socket joint.

Similar to the sternum or the breast bone, four elements are present in frog. In front of the girdle and attached to the epicoracoid is a small piece of bone viz., omosternum bearing another piece of cartilage, the episternum. Posteriorly, the mesosternum bearing a wide plate like xiphisternum is attached to the procoracoid.

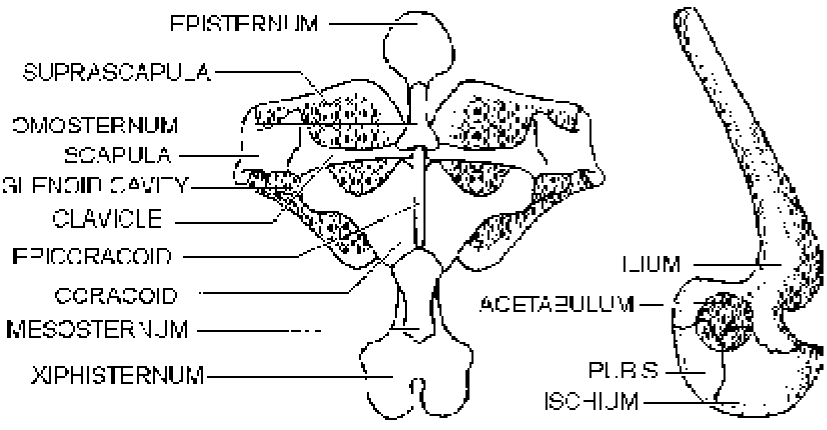

Fig.4.2-3. Pectoral and Pelvic girdles in Frog

The pelvic or hip girdle lies at the posterior end of the trunk. This is also composed of two equal halves called osinnominata. Each half is composed of three pieces, joined below through a symphysis. This girdle articulates with the sacral vertebra besides giving surface for the attachment of the muscles. The greater part of each half consists of a long slender bone, the hip-bone or ilium, running downwards and backwards from the sacral vertebra, curving inwards on the under side of the body to join its fellow. The junction is enlarged into a flattened mass by the addition of several elements which are more distinct. Behind the ilium, a ridge like bone known as the ischium is present. A slight groove marks the limits this bone. Lying ventrally in between the ilium and the ischium, lies a triangular piece of calcified cartilage called the pubis. In each of the flat sides of disc formed by the union of the three elements is a round and hollow cup like acetabulum, into which fits the head of the thigh-bone, the femur.

4.2.3. b. Comparison with the girdles in Lizard:

Pectoral girdle: It is a fused structure of two similar halves lying on either side of the interclavicle and sternum. Each half has the *coracoid,* the *clavicle,* the *scapula* and the *supra scapula.* The two halves are connected by a median slender, anchor-shaped bone, the *interclavicle.* The *coracoid* is a large flat bone which is divided into a narrow anterior *precoracoid* and a posterior broad coracoid proper by a large fenestra. It articulates with the antero-lateral border of the sternum. The bony, oblong and plate like *scapula* articulates with the outer end of the coracoid, both participating in the formation of a *glenoid cavity.* The scapula articulates dorsally with a partly calcified rectangular thin plate of cartilage, the *surpa-scapula.* Its distal border is free. *Epicoracoid is* a cartilagious irregular bone lying along the inner border of the *coracoid.* The clavicle is a selender curved rod which articulates with the *interclavicle* by its inner end and the *scapcla* by its outer end. The stem of the interclavicle is attached to the anterior part of the sternum while the cross piece lies behind the clavicle to which it is articulated. Into the glenoid cavity fits the head of *humerus.*

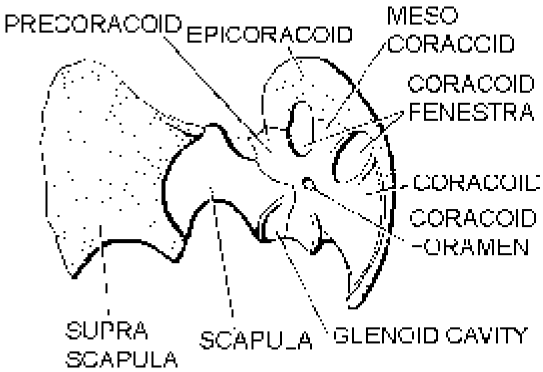

Fig. 4.2-4. Pectoral girdle in *Varanus*

Pelvic girdle : The pelvic girdle consists of two *ossinnominata.* Eech one is *triradiate* and is formed by the fusion of *ilium, ischium* and *pubis.* The acetabulum lies on the outer side of the *osinnominatum* into which fits the head of *the femur.* The ilia are directed backwards and articulate with the *sacral vertebrae.*

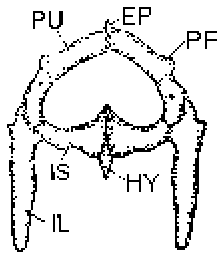

Fig.4.2-5. Pelvic girdle in *Varanus*

Pu- Pubis EP. Epiphysis PF. Pubic foramen HY. HypophysisIS. Ischium IL. Ilium

The *pubic bones* are directed downwards and fuse forming the *pubic symphysis.* The *ischia* are directed downwards and backwards. They unite to form *ischiatic symphysis.* The space between the ventral ends of *pubis* and *ischia* is called *obturator foramen*. It is divided into two by a median ligament. A nodule of calcified cartilage, the *epipubis* lies anteriory in between the two pubes. A small *hypo-ischium* extends backwards form the *ischiatic symphysis* supporting the wall of the cloaca.

4.2.3.c. Comparison with the girdles in Bird:

Pectoral girdle: The shoulder girdle contains narrow, sabre-like scapulae, stout coracoids which slope down to join the sternum, and slender clavicles joined to each other by a disc-shaped interclavicle. These three bones together make the merry thought bone or furcula.

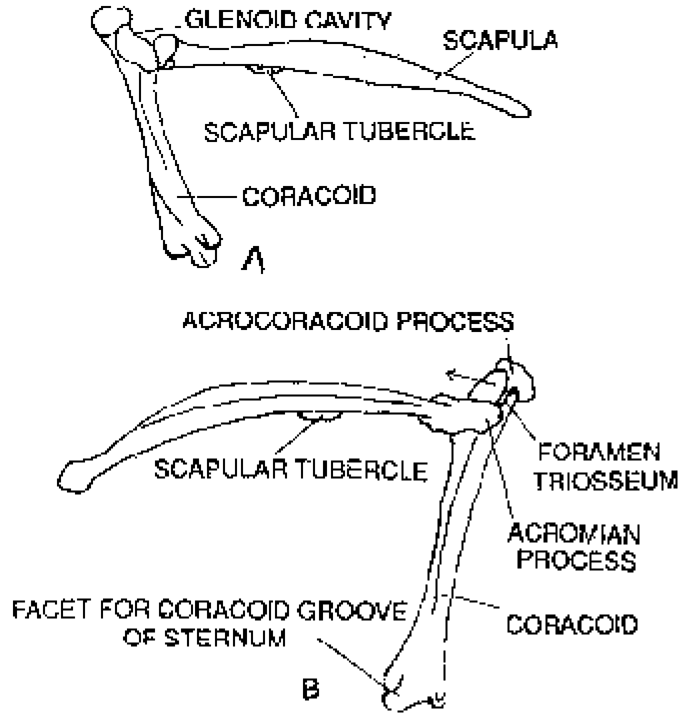

Fig.4.2-6. Pectoral girdle in Pigeon A. Upper view B. Lateral view

Foramen triosseum is a small opening lies at the junction of the above three bones. The sternum is a broad plate, bearing below a conspicuous median keel or carina for the attachment of the great wing muscles. It lies just behind two xiphoid processes. It bears facets for the ribs on either side besides flat surfaces in front for the articulation of the coracoid bones.

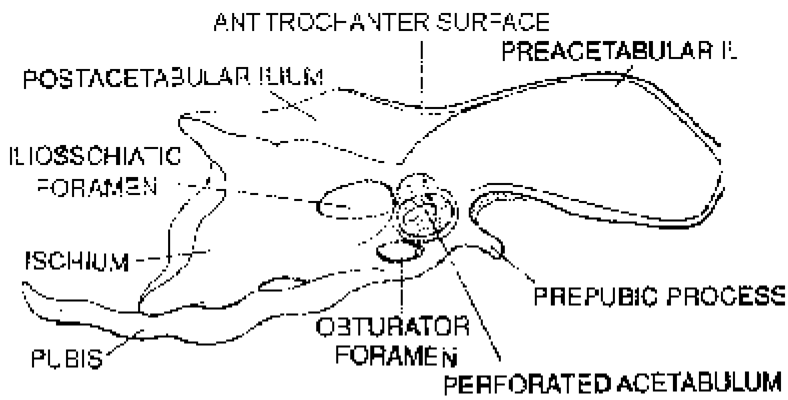

Fig.4.2-7. Pelvic girdle in Pigeon

Pelvic girdle: This has along ilium, extending up to the acetabulum. It is connected to the sacrum all along its inner side to form a single complex bone called the synsacrum. This long bone enables the trunk to be supported by the single pair of legs. The acetabulum is placed near the middle of the ilium. The ischium is a flat, backwardly directed bone. Its hinder part is fused with the ilium, but just behind the acetabulum an oval opening (the iliosciatic foramen) lies between the two. The pubis is slender and also directed backwards. In many birds it has a small prepubic or pectineal process in front. The obturator foramen is slit-like. There is no symphysis or ventral junction in the girdle.

4.2.3.d. Comparison with the girdles in Mammal:

Pectoral girdle : The development of the ribs and sternum has resulted in the separation of the two halves of the pectoral girdle. Each half is known as *innominate.* Each half is made up of a broad triangular bone the s*capula* with its apex directed forwards and downwards. It bears along its outer surface a prominent ridge the *spine.* The lower end of the spine is free and is distinguished as *acromion process.* It bears a backwardly directed *metacromian process* at its free end. A cartilaginous plate like *suprascapula* is attached to the broad dorsal edge of the scapula.

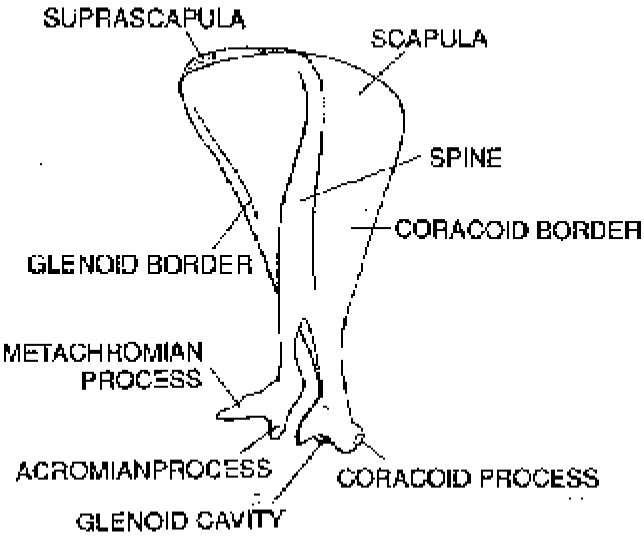

Fig.4.2-8. Pectoral girdle in Rabbit

The lower end of the scapula bears the *glenoid cavity* which is meant for the articulation of the humerus. A small inwardly curved *coracoid process* arises from the anterior border of the glenoid cavity. A slender bony rod like *clavicle* extends between presternum and the acromion process in a ligament. It consists of five elongated bony pieces known as *sternabre* and they constitute the main body of the sternum called *mesosternum.* The mesosternum bears a single long bony piece called *manubrium.* The last sternabre is the *xiphisternum* bearing a flat *xiphoid cartilage.* The first pair of ribs articulate with the sides of the manubrium and the succeeding 6 pairs at the junctions between the sternabre. Thus the ribs articulate with the vertebral column above and the sternum below to form the *thoracic basket.* This supports the thoracic wall and protects the vital organs.

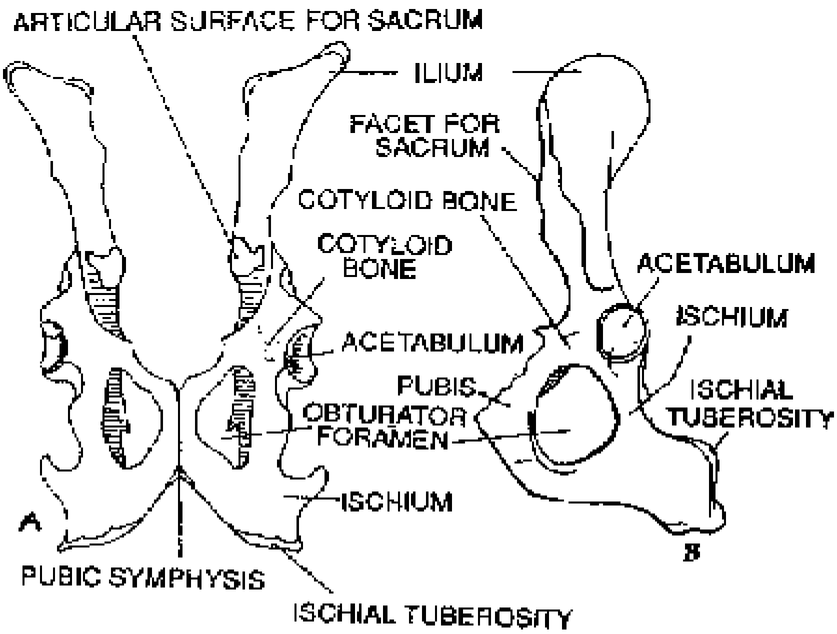

Fig.4.2-9. Pelvic girdle in Rabbit

Pelvic girdle : Each half of the pelvic girdle is made up of the same bones as in other tetrapods and is called the *os innominatum* as usual. The *ilium* is well developed, broad, flat and extends forwards and upwards. It is attached to the *sacrum* at it's expanded upper end. The *ischia* are postero-dorsal in position and meet mid-ventrally forming *ischiatic symphysis.* The pubes are anterior and ventral. They meet mid ventrally in a *pubic symphysis.* It is continuous with the *ischiatic spmphysis.* The pubis and ischium of one side are separated by a large opening called *obturator fenestra.* The *acetabulum* is formed at the junction of the ilium, ischium and a new *cotyloid bon.* This receives the head of the femur. In rabbit the *pubis* does not take part in the formation of the acetabulum.

4.1.4. SUMMARY:

Appendicular skeleton consisting of the pectoral and pelvic girdles give support to the fore and hind limbs respectively. Each half of the pectoral girdle is composed of coracoid, scapula, suprascapula and sternum while the pelvic girdle is composed of ilium, ischium and pubis. These girdles protect the internal important organ systems like urinogenital system, reproductive sytems besides the posterior part of the digestive system.

4.1.5. KEY WORDS:

Coracoid: The prime bone in the pectoral girdle forming the major part of the girdle

Scapula: Side bone of the pectoral girdle providing attachment to the shoulder muscles.

Symphysis: bone formed by the fusion of two bones

4.1.6. MODEL QUESTIONS:

1. Write a comparative account on the elements of the appendicular skeleton supporting the limbs in typical vertebrate organisms you have studied.

2. Explain the structure of the pectoral and pelvic girdle in shark. Add a note on how it is adopted for aquatic mode of life. (or)

With the help of diagrams, describe the structure of the girdles of a representative fish you have studied (or)

Write an essay on the girdles supporting the fins in an elasmobranch.

3. With the help of diagrams, describe the structure of the girdles of an amphibian you have studied (or)

Write an essay on the girdles supporting the limbs in Frog.

4. With the help of diagrams, describe the structure of the girdles of a reptile you have studied (or) Write an essay on the girdles supporting the limbs in uromastrix.

5. Give an account of the girdles of Pigeon (or)

Write an essay on the girdles supporting the limbs in Pigeon.

6. Give an account of the girdles of rabbit (or)

Write an essay on the girdles supporting the limbs in rabbit.

4.1.7. REFERENCES

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Lesson - 5
RESPIRATORY SYSTEM

CONTENTS:

5.1 OBJECTIVES
5.2. INTRODUCTION
5.3. CONDITIONS FOR RESPIRATION TO OCCUR
5.4. TYPES OF RESPIRATION
5.5 MECHANISM OF RESPIRATION
5.6. RESPIRATORY ORGANS
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5.8.4 Comparision with respiration of mammal
5.9. SUMMARY
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5.1. OBJECTIVES:

The aim of this lesson is to understand

- the concept of respiration
- the types of respiration met within the chordate organisms
- Respiratory organs and their functional significance
- Role of atmospheric pressure in the process of respiration
- Mechanism of respiration
- Basic mode of respiration
- Comparing different types of respiratory systems and the mechanisms met with typical vertebrate organsisms.

5.2. INTRODUCTION:

Various metabolic activities / physiological processes carried out by the body like movement, growth and reproduction etc., require lot of energy. Animals, obtain this energy from the food they eat. Before the energy can be used by the cells of the body it must be set free from the chemicals of the food. This process of liberating energy is called *respiration.* It involves the use of oxygen and the release of carbon dioxide. *Robert Boyle* and *Robert Hooke* (1600) were the first to give the real understanding of respiration. But it was *Lavoisier* (1743-1794) who showed the importance of oxygen in respiration.

5.3. CONDITIONS FOR RESPIRATION TO OCCUR:

Oxygen enters the animal's body from the medium like air or water surrounding it simply by diffusion and making use of partial pressure of the gases involved. In the less complex animals, oxygen is absorbed by the entire exposed general surface of the body, but in the higher animals, special respiratory organs like lungs or gills are seen. Excess carbon dioxide is usually eliminated from the same area. *Decarboxylation* is the process of the removal of carbon dioxide from a larger molecule and this can proceed independently of oxygen utilization.

Since there is considerably more oxygen in free air than is dissolved in water, free air breathers, in general, exhibit more energy than aquatic forms living in a more favourable respiratory environment. As a matter of comparison, sea water contains 5-7cc of oxygen per liter; flowing fresh water at 6-8cc; and free air above 200cc per liter.

In order to utilize the oxygen of the air, any living mechanism that has evolved should meet the following conditions:

(1) The blood that is to receive oxygen must be separated from the air by a cellular wall that is capable of retaining oxygen.

(2) The wall must be sufficiently permeable for easy osmosis of gases.

(3) The wall must be kept moist in order to permit easy and quick exchange of gases upon exposure;

(4) The total respiratory surfaces must be extensive enough in area to ensure an adequate absorption of oxygen for the organism concerned; and

(5) A current of fresh medium must be made to pass repeatedly or continuously across the respiratory surface.

These conditions are met in a variety of ways by different animals.

The life process which involves the gaseous exchange between the organism and its surrounding medium is called *respiration.* In higher organisms the process takes place in following stages:

5.4. TYPES OF RESPIRATION:

Depending upon the source of oxygen, respiration may be of two types *viz*.,

Terrestrial respiration: Most of the land living vertebrates receive oxygen from the atmospheric air. Lung are the chief organs of respiration in these organisms and hence the process may also be called as pulmonary respiration.

Aquatic respiration: Organisms living in water absorb oxygen either through their general body surface or through specially developed organs like gills.

5.5. MECHANISM OF RESPIRATION:

In either case the mechanism of respiration includes the following three steps.

a. External respiration:

It refers to such mechanisms through which the exchange of gases occur between respiratory surface such as skin, gills, lungs etc. and environment. External respiration is closely associated with breathing and involves following steps.

Inspiration is the process of taking in air to the respiratory organs or lungs.

Expiration is the process of expelling out from the respiratory organs or lungs.

b. Internal respiration or Tissue respiration: Oxygen, which is taken up by blood during external respiration, is transported to the tissue in the form of oxyhaemoglobin. In tissue, the exchange of gases occur between blood and interstitial fluid found in the tissue.

c. Cellular respiration:

It has two phases. In the first phase, cells take in oxygen from interstitial fluid and give off CO_2 to the same. The second phase refers to the sum of both oxidative and non-oxidative enzymatic reactions by which energy is made available to maintain the other vital activities.

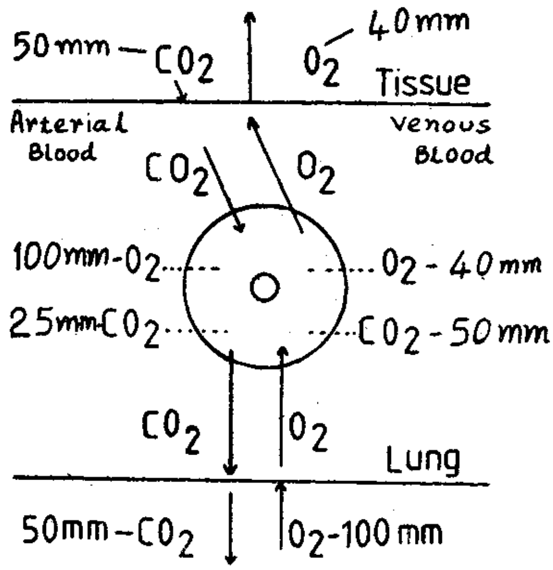

Fig.5-1. Cellular respiration

5.6. RESPIRATORY ORGANS:

In the most simplest aquatic forms like protozoans, general body surface acts as the respiratory surface and gaseous exchange can occur at any point of the body. However, during evolution, as the body organization became more and more complex, respiratory system also underwent structural and functional specializations. Thus, various structural variations occurred in different groups of both terrestrial and aquatic animals reflect nature of the respiratory medium, habit and habitat. But the basic physiological process is always the same.

The most common respiratory organs found in animals are the general body surface, gills, tracheal tubes and lungs.

General body surface:

This is the simplest arrangement of respiration found in aquatic animals, usually small ones such as protozoans, planarians, rotifers and minute worms. welcome oxygen. In all of them respiration is direct. Gases diffuse directly from water into the cell and vice versa..

Eel fishes and most of the amphibians show integumentary respiration. Exchange of gases takes place through the skin as the skin is always kept moist and is richly supplied with blood vessels.

Gills: Fishes are the true aquatic vertebrate organisms having gills as the chief respiratory structures. These are formed from the dorsal side of the gill pouches developed from the ventrolateral walls of the pharynx. Their surface is provided with gill filaments having rich blood supply. Water enters the pharynx through mouth and leaves through gill slits. Exchange of gases occur between water and deoxygenated blood. In dipnoi and such other fishes, accessory respiratory structures like air bladder, arborescent organs, etc., also aid in the process of respiration.

Lungs: Terrestrial animals possess lungs as the chief respiratory structures. They are endodermal and are formed from the ventral surface of the pharynx**.** They possess alveoli supplied with capillary network. Air flow is by inspiration and expiration caused by the specially developed muscles. Exchange of gases is by diffusion between the blood and air.

Origin of the lungs: The lungs, like the swim bladder, probably arise initially as a ventral groove from the floor of the rudimentary gill pouches. Slowly this grows as a bud which gets divided in to a bilobed sac representing the future lungs. A common stem or duct forming as an outgrowth of the lung sacs transforms into *trachea* which also divided into two bronchii. Ultimately the bronchii ramify into fine net work of branches ending in bulb like alveoli enclosed with in the *lung sacs*. Thus the lungs are endodermal in origin. The alveoli are surrounded by mesodermal blood capillaries carrying blood for purification.

Kinds of Lungs : (a) *Water Lung* is the one filled with water as seen in Pulmonate snails *(Limnaea* and *Planorbis).* (b)*Book lungs* have no ventilating mechanism as seen in e.g., spiders, scorpion etc. (c) *Diffuse lungs* are seen in vertebrates. They are of positive pressure type when the air is forced into the lungs as seen in frogs and lizards. They may be of *Negative pressure type as seen in human beings when the* air is drawn into the lungs by increasing the space through enlargement.

5.7. RESPIRATION:

Respiration is an important catabolic activity occurring in all the organisms. Here the food materials are broken down to release energy required for other body activities. This physiological activity is conducted by gills in aquatic animals, lungs in terrestrial organisms besides some accessory structures associated with this function.

5.8. RESPIRATION IN FISHES:

Gills in Elasmobranch and holocephalan fishes: Gills of elasmobranch fishes (sharks, rays and skates) are lateral in position. They open independently to the outside and are separated from each other not only by skeletal gill arches of cartilage but also by primitive partitions attached to these arches, called *branchial septa*. On either side of the septae, a set of gill filaments or *demibranch* is present. A septum and its two demibranchs together makeup a gill or *holobranch.* Finger like projections along the inner margins of the gill arches are the *gill rakers.* They not only keep food from entering the slits but also aid in directing it along the straight and narrow oesophageal path.

In elasmobranchs, the most anterior pair of the pharyngeal slits located in between the mandibular and the hyoid arches, develop into spiracles. The walls of the spiracles are not provided with true gills. In some cases they may support, on one side at least a *false gill* or *pseudobranch.*

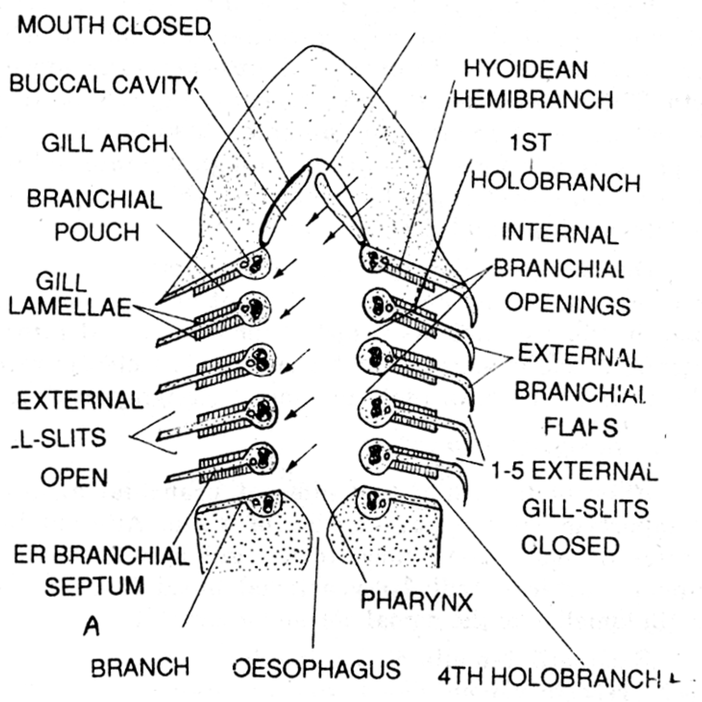

Fig.5-2. Gills in shark

In bottom feeding skates and rays the spiracles open dorsally instead of ventrally as the other pharyngeal gill slits do. They are useful in taking the water for respiration into the branchial cavity when the mouth is occupied in grabbing food in the mud. No doubt sharks and dog fishes swimming freely and gracefully in water, use the spiracles occasionally as accessory structures.

The primitive shark, Heptanchus, has seven pairs of gill slits and the frilled shark Hexanchus has six pairs. Other elasmobranchs have only five pairs besides the spiracles. Except the posterior pair, other gill slits possess a demibranch on each side thus making a total of nine pairs of demibranchs in fish with five pairs of slits.

Certain larval elasmobranchs undergoing considerable development within the egg shell before hatching have long gill filaments hanging out of the gill slits as temporary *external gills.* These unusual structures may serve not only for respiration but also in absorbing yolk.

Mechanism of Respiration: The respiratory water current enter into the gill with the help of hypo-branchial *muscles.* At the same time the visceral arches expand causing the expansion of the wall of the pharynx. The water is prevented from entering the external branchial apertures by the anterior fold of the skin on each gill pouch. In the first step, mouth is closed and the buccal floor is raised and the gill clefts, there by bathing internal branchial lamellae which is finally expelled out through the external branchial apertures. The blood flow in the gill lamellae is opposite to the water flow, there by facilitating efficient gaseous exchange through diffusion. O_2 in the water passes into the blood present in the capillaries through their thin, membranous permeable wall. Similarly CO_2 in the blood enter the water. Thus the respiratory movements are caused by the *pharyngeal muscles* innervated by 5^{th}, 7^{th}, 9^{th} and 10^{th} cranial nerves.

Structural variations: *Fishes.* Some dipnoans show a transitionary stage between the swim bladder and true lung fishes. During the aestivation, the gills in such forms are not used for respiratory purposes. The swim bladder receives venous blood through pulmonary arteries. Then it functions as a lung. In *Neoceratodus,* the lung or swim bladder is a single wide sac, resembling the swim bladder of physostomous fishes, but in *Protopterus* and *Lepidosiren,* the sac is bi-lobed, its inner surface being increased somewhat by its coarse spongy alveolar structure.

5.8.1. Comparison with the respiration in amphibians:

Adult amphibians typically breathe by means of a pair of sac like lungs lacking bronchial trees. Lungs develop as posterior diverticula from the pharynx during metamorphosis. They open into the pharynx through glottis or laryngeal opening supported by larynx with paired arytenoid cartilages. These close the laryngeal opening *(glottis)* during swallowing, since the glottis develops ventral to the esophageal opening. In anurans (frogs), the larynx is in continuation of the trachea and hence the common chamber is called *laryngotracheal* chamber. This possesses two elastic muscular *vocal cords* in males producing croaking sound to attract their mates(females). Usually the left lung is larger than the right.

Mechanism of respiration: Air inflow is by inspiration. When a frog breathes, it first inhales the air through the nostrils. With mouth and glottis closed, frog inflates its buccopharyngeal cavity by lowering the hyoid apparatus supporting the buccal floor. Then the glottis is opened followed by rising the buccal floor facilitating the air to enter the lungs. Oxygen with high pressure is absorbed by the blood. Simultaneously CO_2 muscit opens the glottis and contracts muscles of the body wall, while the elastic lungs recoil, expelling a stream of air that passes out through the open glottis and nis sent into the lungs by simple process of diffusion. Nostrils open followed by the recoiling of the lungs forcing the air to expel out and the process is the expiration.

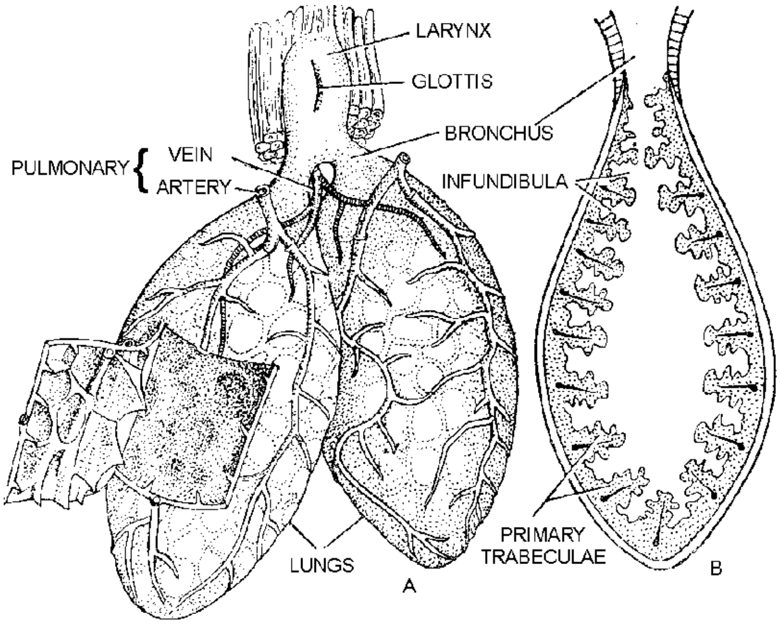

Fig. 5-3. Lungs in frog

Alternative modes of respiration in frog: Since frog is amphibious, besides pulmonary respiration, buccal and cutaneous respirations also occur. Throat pulsations during air flow accomplish buccal respiration while the mucous glands keep the skin moist for cutaneous respiration to occur.

Variations: In caudates such as N*ecturus,* besides the retained larval gills, lungs are also present as two long simple sacs having rich vascular network. *Amphiuma* goes a step further in having much enlarged inner lining of the lungs. in that the proximal half of each lung has the inside surface considerably increased by the elaboration of folds. In apodes, left lung is rudimentary. *Salamandrina,* is a lung less amphibian where respiration is conducted by the integument and the bucco-pharyngeal epithelium. Some salamanders retain internal or external gills throughout life, with or without lungs.

5.8.2. Comparison with the respiration in Reptiles:

These are the true terrestrial tetrapods totally adopted for pulmonary respiration. Lungs are Lobate and have increased alveolation besides a lengthy trachea correlating to the presence of a long neck. Internally, a well branched *bronchial tree* improves pulmonary efficiency. Mode of inhaling air is by suction as against the pushing type seen in frog. In crocodiles, *diaphragmaticus* is a muscle to pull the liver and attached transverse septum backward, expanding the thoracic cavity, while in turtles, *obliquus* muscle conduct the same function. Structural variations are minimum except for the shape and size of the lungs compared to birds and mammals.

Variations: Compared to amphibians, the lungs of reptiles are more complex structures. Snakes and lizards are characterized by a lack of symmetry between the two sides. In some lizards the right lung is the larger, whereas in others the condition is exactly the opposite. In snakes, the left lobe is smaller than the right or is altogether absent. In *Boa* and *python,* both the lungs are present. of which *left lobe is* shorter

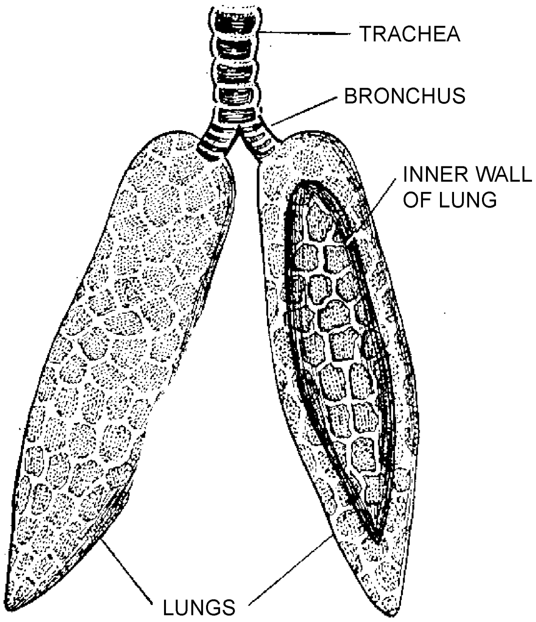

Fig.5-4.Respiratory system in a Lizard

than the right. Lungs are simple sacs lined uniformly with infundibula in S*phenodon. Chameleon* has peculiar lungs with sac like diverticula. The inflated lungs of sea turtles serve as floats in water. Throughout the reptilian class, there is a tendency towards an increase in the alveolar respiratory surface.

5.8.3. Comparison with the respiration in Birds:

The respiratory system of birds is quite unique and advanced. A long trachea leads from the larynx to the base of the neck, where it divides into two bronchii. At this junction, birds have a special sound-producing *syrinx.* The bronchii lead into the lungs. They change very little in size during breathing as they are attached to the body wall. Instead of saccular with alveolar clusters at the microscopic ends of the bronchial tree, lungs are penetrated lengthwise by air passages *(parabronchii)* opening into thin walled, distensible *air sacs.*

These sacs also facilitate the circulation of air through the lungs. They are devoid of vascular supply and hence exchange of gases does not occur. Air sacs are due to the flying adaptation in birds. Embryologically air sacs sprout out from the lungs at various points and extend into the body cavity. The pneumatic diverticula of the lungs *of Chamaeleon,* and some other lizards are considered precursors of the airsacs in birds. The system of tubes formed by the repeated branching of the primary bronchus into each lungs is called the *bronchial intercom.* The primary bronchus upon entering the lung of its medial and ventral sides loses its cartilagenous rings and is called the *mesobronchus.* In some cases mesobronchus enlarges into the *vestibule.* From the mesobronchus, arise a number of thinner tubes, the *dorsal ectobronchi,* and the *ventral endobranchi,* both of which re-branch into still thinner tubes of less than half a millimeter in diameter, the *parabronchi.* The parabronchi form interconnecting loops on the median dorsal side of the lung with the parabranchi of other secondary bronchi. The parabronchi are divided into still thinner tubes, the air *capillaries* or *bronchioles.* Each parabronchus is surrounded, by a zone of capillary loops, where actual exchange of gases takes place. In addition, there are several *saccobranchi* or *recurrent bronchi* connecting the air sacs with the adjacent part of the lungs. In birds the lungs are devoid of alveoli.

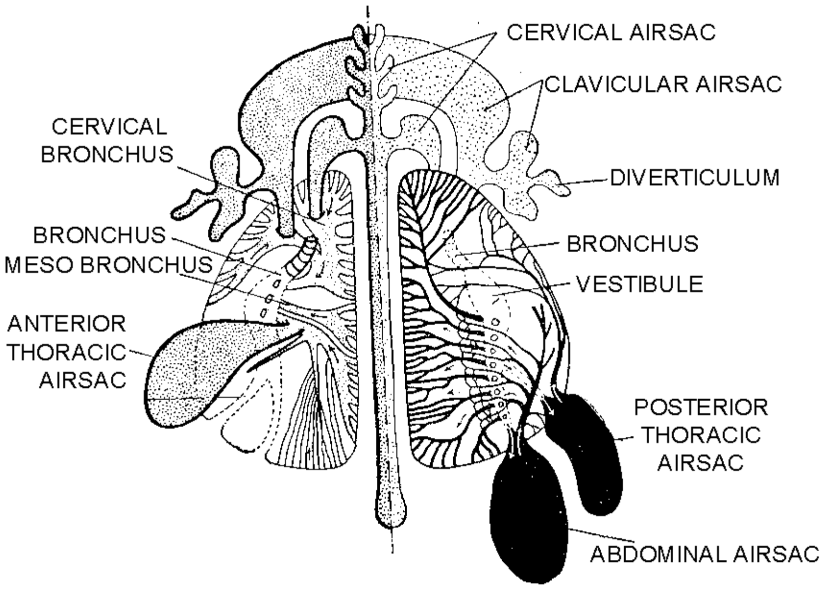

Fig.5-5.Respiratory system in a Bird

The manner of respiration is highly efficient: *(a)* no residual air remains in the lungs after exhalation (as is the case with all other pulmonate vertebrates); *(b)* fresh air passes *forward* through the lungs microscopic *air capillaries* during each inspiration *and* expiration; and *(c) crosscurrent exchange* allows an especially thorough transfer of gases between air and blood capillaries. During inhalation the anterior and posterior air sacs become inflated, while the lungs are being compressed; compression of the lungs coupled with dilation of the anterior air sac pulls air forward through the lungs into those sacs, while about 75 percent of the air being inhaled passes straight into the posterior air sacs through parabronchi. During exhalation, the air sacs are compressed while the lungs expand slightly. Air in the anterior sacs is expelled from the body, and the air in the posterior sacs is forced forward through the lungs. Thus air flows unidirectionally and nearly continuously through the air capillaries of the lung. Gas exchange through the walls of the air capillaries is efficient because the counter current of blood flow to the air flow, maintaining a steep concentration gradient.

5.8.4. Comparison with the respiration in Mammals:

In spite of varied modes of life, lungs show structural and functional similarity. The system is complex and helps in supplying total quantity oxygen required for the life to continue.

Introduction: The fully alveolated lungs of mammals enclose a *bronchial tree* branching progressively to end in microscopic *bronchioles* ultimately ending into clusters of alveolar sacs. As a result, the lungs of a mammal provide much more internal surface for gaseous exchange than the partially alveolated lungs of a reptile of equivalent size. Human lungs provide some 90-150 square meters of alveolar surface area. A section of mammalian lung tissue looks quite dense to the unaided eye against the more spongy nature of the lungs in reptiles where the bronchi terminate in macroscopic air spaces lined with alveoli.

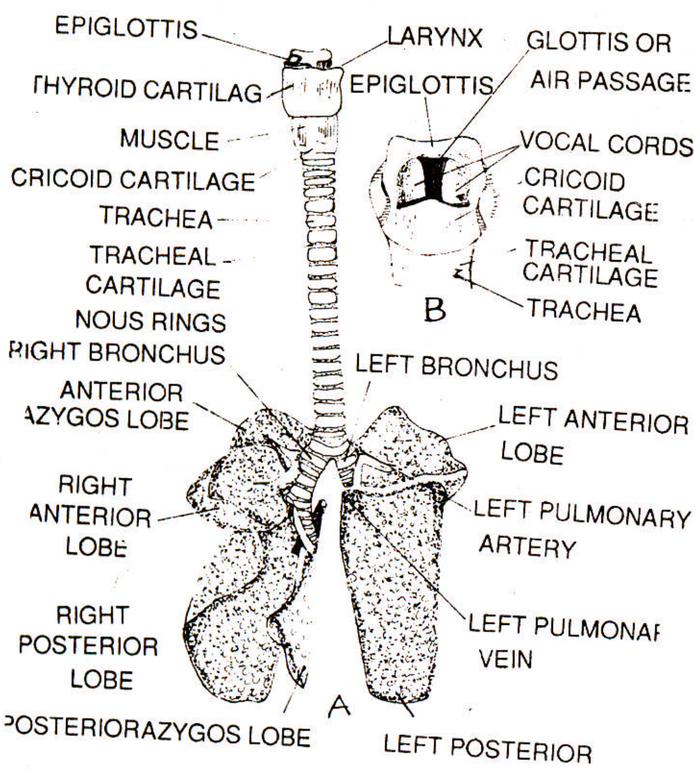

Fig.5-6. Respiratory system in rabbit

Structure of the lung in mammals: Lungs are the internal cavities with high supply of blood capillaries. Lungs are lobulate, highly alveolar and flexible, i.e. can be expanded and collapsed depending on air tensions. They occupy the greater part of thoracic cavity of mammals. In man the right lung is divided into three lobes and the left into two. Each lung is surrounded by a double walled sac of *pleural membranes.* The outer layer is the *parietal pleura* attached to the walls of the chest and diaphragm. The inner layer is the *visceral pleura,* covering the lungs themselves. The *pleural cavity,* in between the above two membranes contains a lubricating fluid and blood capillaries. Medially the pleura press against each other to form the *diastinal septa.* In the region of the heart, the septae separate forming a cavity, the *mediastinum.* This provides space for heart, blood vessels and other visceral structures. The lungs extend from the diaphragm to a point just above the clavicles and lie against the ribs in front and back. The base of the lung is broad and concave fitting over the convex diaphragm. The narrow superior portion of the lung is termed the *apex.* The surface of the lung lying against the ribs is the rounded *costal surface.* Medially, the left lung also possesses a concave *cardiac notch* for the heart to lodge. The right lung is thicker and broader than the left. It is also somewhat shorter than the left because the diaphragm is higher on the right side to accommodate the liver that lies below it. The left lung is thinner, narrower, and longer than the right. The right lung is divided into three lobes, the superior lobe, the middle lobe and the inferior lobe by means *of horizontal fissure* and *oblique fissure.* The left lung has only *oblique fissure* dividing it into a superior and inferior lobes. In mammals, the floor of the thoracic cavity is closed by a thin muscular dome shaped septum called the *diaphragm.* It is attached anteriorly to the lumbar vertebrae and posterior ribs. It fits tightly around the gut blood vessels and nerves. It's movement is governed the *internal intercostal* and *external intercostal muscle* present between the ribs. Mechanism of respiration: As in any other terrestrial vertebrate, respiration involves both inhalation and exhalation.

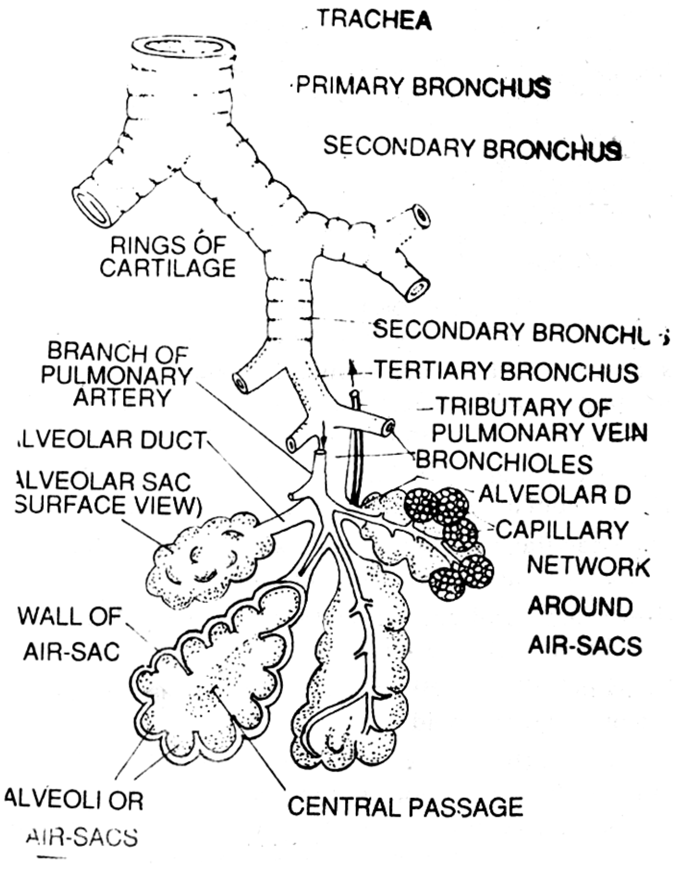

Fig.5-7. Internal structure of the lung in rabbit

Exhalation: In mammals, the muscular *diaphragm* allows ordinary exhalation without utilizing any energy. Relaxation of the muscle makes the *diaphragm* to bow forward, forcing air out of the lungs by reducing the depth of the thoracic cavity. When the diaphragm relaxes, its passive forward movement causes the lungs to deflate. At the same time, relaxation of the external intercostals allows the ribs to fall inward, reducing circumference.

Inhalation: When the dome-shaped diaphragm contracts, it flattens and pushes the abdominal organs posteriorly, increasing the depth of the thoracic cavity. This results in the sucking in of air into lungs by the lowered intra-thoracic air pressure. This action is further increased by the contraction of the external intercostal muscles increasing the circumference of the rib cage.

In contrast to this, in reptiles both inspiration and expiration are aided by muscular contraction and therefore require energy. Inhalation involves contraction of muscles that pull the oblique septum backward and expand the rib cage, while exhalation involves contraction of muscles that tense and flatten the oblique septum and compress the rib cage.

5.9. SUMMARY:

Respiration is an energy releasing process occurring internally at the cellular level. Oxygen required for this process is made availble either directly from the atmospheric air or from the surrounding medium (mostly water in aquatic organisms). For this action to occur, respiratory systems are formed incourse of evlution. Respiratory system is variously modified to suit to the mode of respiration and it gains much importance in understanding the important metablic activity.

5.10. KEY WORDS:

Lungs : Spongy sacs capable of high distension holding atmospheric air in their alveoli for exchange of gases during terrestrial respiration.

Gills : Respiratory organs in aquatic organisms.

Respiration : It is a catabolic process where food materials are oxydized releasing energy needed for the organisms.

Alveoli : The functional units of the lung having thin membrane facilitating easy gaseous exchange.

Costal muscles : muscles in association with the ribs aiding in the respiratory process.

5.11. MODEL QUESTIONS:

1. Write a comparative account on the respiratory system in the representative vertebrate organisms you have studied. (or)

Briefly explain the structural variations found in the respiratory organs of fishes, amphibians, reptiles, birds and mammals.

2. Give an account on the respiratory system of a lizard. How it is adapted for terrestrial mode of life.

3. What is the speciality with the respiratory system in a bird. How it is well suited for the arboreal mode of life as seen in birds.

4. Write an account on the Respiratory system in a Mammal you have studied. (or)
How the respiratory system in rabbit helps in conducting effectively, the function of respiration.

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Lesson - 6

CIRCULATORY SYSTEM

6.1. HEART

CONTENTS:

6.1.1 INTRODUCTION
6.1.2. OBJECTIVES
6.1.3. STRUCTURE OF THE HEART IN FISHES
6.1.4. HEART IN FROG
6.1.5 HEART IN UROMASTIX
6.1.6 HEART IN PIGEON
6.1.7 HEART IN RABBIT
6.1.8. SUMMARY
6.1.9. KEY WORDS
6.1.10. MODEL QUESTIONS

6.1.1. OBJECTIVES::

The main purpose of this unit is to make the student to understand the

- Need for the presence of circulatory system in the body.
- Components of the circularoty sytem - Significance of the heart and its general structure
- Structure of heart in different typical vertebrate organisms
- Mechanism of the working of the heart

6.1.2. INTRODUCTION:

The heart is really a modified blood vessel formed form mesoderm. It is the chief muscular pumping organ of the blood vascular system. Its wall is composed of an outer epicardium, a middle myocardium and an internal endocardium of which the outer and middle combinedly form in to epimyocardium. The myocardium is composed of cardiac muscles. The endocardium is thinnest where the myocardium is thickest, and vice versa. The tissues of heart are supplied with blood vessels formed of coronary arteries and veins to establish the coronary circulation. This facilitates the supply of more quantity of O_2 to the needy tissues of the heart as the tissues show continuous rhythmic beating. Taking the heart of fishes as a basic one, structure of heart in frog, Uromastix, pigeon and rabbit are discussed hereunder.

6.1.3. STRUCTURE OF THE HEART IN FISHES:

The ‘S' shaped heart in fishes is differentiated into four chambers viz., sinus venosus, atrium or auricle, ventricle and conus arteriosus. Of these, conus and sinus are not considered as chambers but are connected to the atrium and ventricle respectively. Thus the heart in fishes is a two chambered one having one atrium and one ventricle separated by auriculo ventricular septum.

Pericardial membranes: This heart is enclosed in a transparent membranous pericardial sac. Its inner layer is the visceral pericardium and the outer is parietal pericardium between which lies the pericardial cavity filled with pericardial fluid. This fluid protects the heart from external shocks and injuries besides acting as a lubricant during contractions.

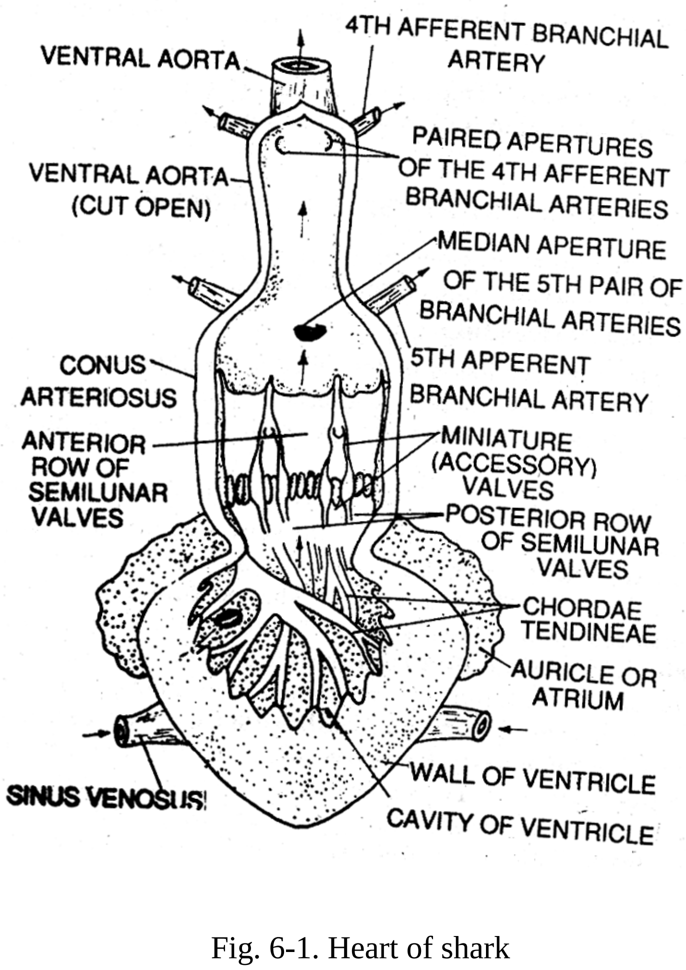

Fig. 6-1. Heart of shark

Sinus venosus: It is somewhat triangular, elastic, thin, walled chamber lying on the dorsal side of the ventricle. Laterally it receives two large veins, the ducts Cuvieri, one on each side. A pair of hepatic sinuses open into it at the postero-median line. Anteriorly it opens into the atrium through a sinu atrial aperture guarded by a pair of membranous sinuatrial valves preventing the back flow of blood.

Atrium: It is a large triangular spongy and thin walled sac situated in front of the sinus venosus. Its two lateral sides projecting beyond the ventricle appear like ears(auricular appendages). Ventrally it opens into the ventricle through an auriculo-ventricular aperture guarded by two lip like auriculo-ventricular valves. Chordae tendinae hold the lips in their position by attaching them with the inner surface of ventricle.

Ventricle: The ventricle is a prominent conical chamber with thick muscular walls. Numerous strands are present in its inner surface by which it appears spongy. It tapers anteriorly to join the conus arteriosus.

Conus arteriosus: It is a stout muscular tube extending from the ventricle up to the anterior apex of the pericardial cavity. Cavity of conus arteriosus contains two transverse rows of semi lunar valves each row having three valves (one dorsal and two ventro lateral) An accessory valve is present on either side of dorsal valve. The free ends of all the valves are attached to the wall of the ventricle by means of tender threads holding them in position. These valves prevent backward flow of blood. Conus arteriosus continues anteriorly into ventral aorta.

6.1.4. HEART IN FROG:

Atrium: Since atrium and ventricles are considered as the real chambers of the heart, and that the atrium is divided into two chambers by inter auricular septum, heart is a **tri-chambered** one comprising of two auricles and one ventricle.

The **ventricle** is an undivided part. The sinus venosus is large, triangular, thin walled sac situated on the dorsal side of heart and opens into right auricle. Three large veins, two precavals and a post caval open into sinus venosus. The truncus arteriosus is a small, thick walled cylindrical tube lying on the ventral side of right auricle. Anteriorly it splits into right and left aortic arches.

Conspicuous differences with primitive heart are :

(a) Two auricles are separated from one another by interauricular septum.

(b) The right auricle is bigger than the left and possesses a large oval opening known as sinu auricular opening guarded by a pair of lip-like sinu-atrial valves checking the back flow of blood into sinus venosus.

(c) The left auricle also possesses a single non valvular opening of the pulmonary veins bringing blood from the lungs.

(d) Auriculo-ventricular aperture between the two auricles and the ventricle is located just beneath the inter-auricular septum.

(e) This aperture is guarded by four flap like auriculo-ventricular valves arising from dorsal and ventral borders of the aperture.

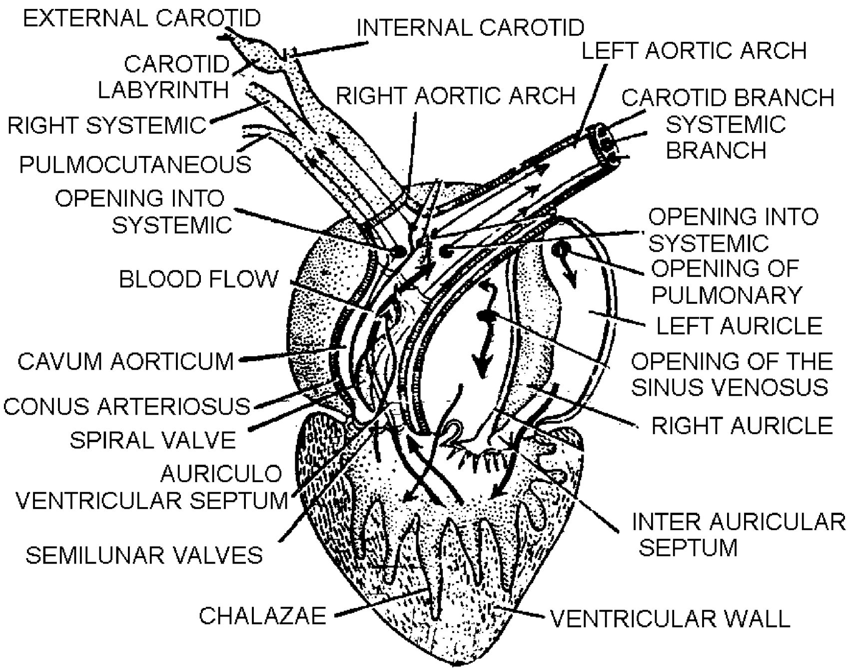

Fig.6-2. Internal structure of the Heart of Frog

(f) Several slender, but strong and elastic cords of fibres called chordae tendineae connect the larger valves with the muscular wall of ventricle. The smaller valves arising from the lateral walls of the auriculo-ventricular aperture lack chordae tendineae and open towards the ventricle only and prevents back flow of blood from ventricle to the auricles.

(g) The chordae tendineae check the valves from being pushed into the auricle by too much pressure in the ventricle.

(h) The ventricle is triangular in form.

(i) Externally the ventricle is separated from auricles by a faint transverse auriculo-ventricular groove.

(j) Inner surface of the ventricle is produced into a number of finger like projections called the columnae carneae.

(k) Truncus arteriosus runs obliquely across the right auricle. The ventricle opens into the truncus and the opening is guarded by three semilunar valves.

(l) The small cavity of the truncus is divided into two unequal regions-a large proximal region known as conus arteriosus or pylangium and a short distal bulbus arteriosus or synangium.

(m) The junction of the conus arteriosus and the bulbus arteriosus is also guarded by two pairs of semilunar valves (one pair guards the systemo-carotid and other pair to pulmo-cutaneous)

(n) The pylangium has a spirally-twisted longitudinal fold forming into a spiral valve. It remains attached to the pylangium wall dorsally but its ventral edge is free. Thus the spiral valve divides the cavity of pylangium incompletely into two halves, a right cavum aorticum and left pulmocutaneum. Cavum aorticum curves round to the left to become dorsal and pulmocutaneum curves round to the right to become ventral. The synangium is also divided by a horizontal septum into a dorsal and a ventral chamber. Cavum aorticum opens into the ventral chamber communicating anteriorly with the systemic and carotid arteries. The pulmocutaneum opens into the dorsal chamber and communicate anteriorly with pulmocutaneous arteries. The latter is guarded by pulmocutaneous valve.

6.1.5. HEART OF UROMASTIX:

The reptiles are the first true terrestrial vertebrates adapted for terrestrial respiration by lungs. Their heart is again a **tri-chambered** one with two auricles and a partially divided ventricle thus establishing **incomplete double circulation.** Still the oxygenated blood passes through the left side and the deoxygenated blood through the right side of the heart.

Conspicuous differences with primitive heart are:

(a) The heart is a reddish, conical, muscular structure, situated in mid-dorsal position in the anterior part of pleuroperitoneal cavity. It is enclosed in a tough pericardium.

(b) Sinus venosus is externally divided into two parts by a constriction, larger right and smaller left. The larger part extends backwards far beyond the boundary of the right auricle. It receives the right precaval at its antero-lateral and postcaval at its postero-lateral angle respectively. The smaller left portion of sinus-venosus does not extend beyond the posterior boundary of the left auricle. It receives the left precaval at its antero-lateral angle.

(c) The auricles are thin walled with their inner surface raised up into a network of low muscular ridges called musculipectinati. Inter-auricular septum separating the auricles is thin muscular, vertical and slightly curved in position. Anteriorly it is attached to the wall of the auricle and posteriorly free in the ventricle. The right auricle is larger than the left. It gives off a small sac like diverticulum, from its antero-posterior part on dorsal side.

(d) The anterior sinuauricular valve is larger and broader than the posterior one. A small posterior median part of right auricle extends into the lumen of ventricle as atrium dextrum interventriculare. Similarly, the median portion of left auricle also extends into the lumen of ventricle as atrium sinistrum interventriculare. Both the auricles open into ventricle by auriculo-ventricular apertures. The posterior end of the inter-auricular septum divides the auriculo-ventricular aperture into right and left halves. The inter-auricular septum bears on either side flap like auriculo-ventricular valves.

(e) Ventricle forms the posterior half of the heart with its apex directed slightly towards the right side. It has a concave dorsal surface and a convex ventral surface. The ventricle is attached to the parietal pericardium by gubernaculum cordis. The ventricle has thick and spongy walls. An inter ventricular septum extends forwards from the apex towards the center in the form of a muscular ridge, dividing the

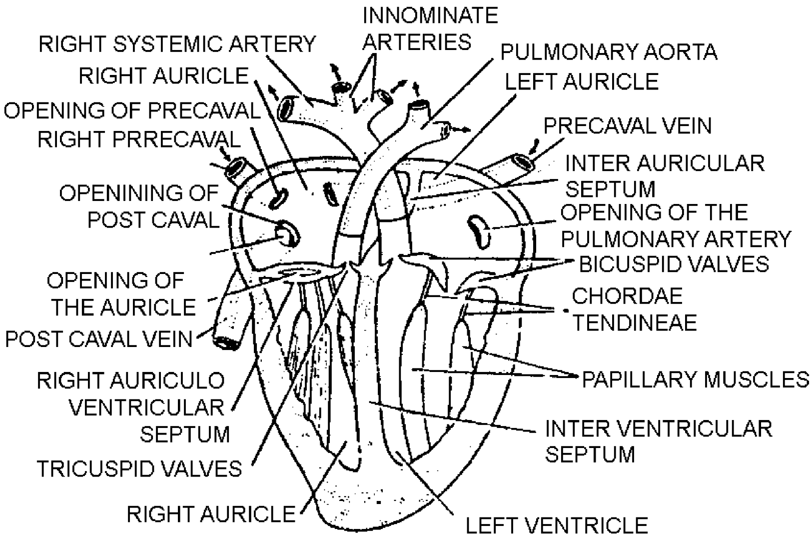

Fig. 6-3. Internal structure of the Heart of a lizard

cavity into two divisions viz., a small dorsal cavum dorsale and a ventral cavum pulmonale. Both these chambers communicate with each other over the free margin of muscular ridge through foramen penizza.

(f) The conus or ventral aorta splits up into three aortic channels *viz.*, the pulmonary, left systemic and right systemic. The pulmonary arch takes its origin from cavum pulmonale, while the systemic arches arise from cavum dorsale. Each of the three arches has a pair of semilunar valves at its apex to prevent back flow of blood.
(g) In crocodile the ventricle is completely divided into left and right ventricles by inter-ventricular septum. Thus the crocodiles are the only reptiles having four chambered heart.

6.1.6. HEART OF PIGEON:

The heart of birds and mammals show advancement over the ancestral reptilian heart in having completely **four chambered** heart with **two auricles or atria** and **two ventricles**.

Conspicuous differences with primitive heart are:

(a) Sinus venosus and conus arteriosus are absent in adult avian heart. Embryonic sinus venosus merges with right atrium. Hence the vena cavae directly open into the right auricle.

(b) The embryonic conus arteriosus is divided into a pulmonary trunk joining the right ventricle, and a systemic trunk joining the left ventricle. Therefore, these arise directly from the ventricles.

(c) Avian heart lies in the thoracic cavity partly surrounded by the liver lobes. The size is comparatively larger than other vertebrates. It weighs about 0.8% of the body weight. Its broad base is directed upward and the narrow apex directed backward.

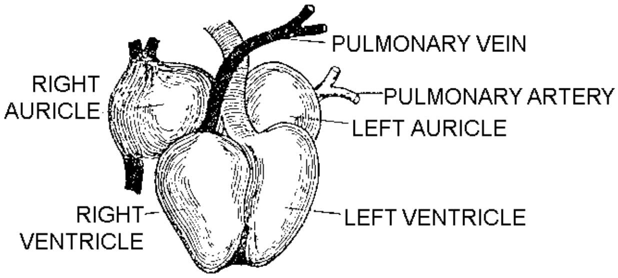

Fig. 6-4. External structure of the Heart of a Pigeon

(d) The two anterior, darker, smaller and thin-walled auricles are separated from the posterior, lighter, bigger and thick walled ventricles by an external hollow transverse groove called auriculo-ventricular groove or coronary sulcus.

e) A faint interauricular groove separates two auricles. Internally the interauricular septum. bears a small oval area in the middle called the fossa ovalis, representing the position of foramen ovale in the embryo.

(f) The right auricle is comparatively larger than the left and receives the right and left precavals and the post-caval in its dorsal wall.

(g) The opening of postcaval is guarded by a muscular Eustachian valve and checks the back flow of blood from auricle.

(h) The right auricle opens into the right ventricle by an auriculo-ventricular aperture guarded by a pair of strong muscular flaps viz., the right auriculo-ventricular valves. In function, these represents the tricuspid valve of mammals.

(i) Chorda tendineae are absent in the right ventricle.

(j) The left auricle receives four pulmonary veins from lungs. The left auricle opens into the left ventricle by a circular left auriculo-ventricular aperture guarded by two membranous flaps forming the left auriculo-ventricular valves. In function they represent the bicuspid valves or 'mitral valves' of mammals. The posterior free margins of these valves are connected by firm, elastic cord, the chorda tendineae to thick muscular processes, the musculi papillares, of the ventricular wall.

(k) The ventricles form posterior 2/3 of the heart. They are paler and stronger than auricles because of thick wall and pump the blood to body organs. The two ventricles are completely separated from each other by a thick, curved muscular inter-ventricular septum. The lumen of left ventricle is large and circular whereas the lumen of right ventricle is crescentic. This is because the right ventricle partly encircles the left ventricle. Bars of muscles, called column carneae or trabeculae traverse the cavities of the ventricles. Pulmonary aorta arising from the left ventricle soon divides into two pulmonary arteries and supplies blood to the lungs. The opening of pulmonary trunk is guarded by three semilunar valves. The left ventricle gives rise to the single aortic arch or right systemic arch which is continued into the dorsal aorta. The opening is guarded by three semilunar valves.

6.1.7. HEART IN RABBIT:

The heart is a pear-shaped or conical, muscular structure situated in the thoracic cavity a little above the left of middle line and lies in a space the mediastinum between the two pleural sacs enclosing the lungs. Its anterior broad end is called base which is turned forward to the right side. The posterior pointed end is the apex and is directed backward, downwards and slightly to the left side. The heart is enclosed in a thin walled. transparent, two-layered sac, called pericardium. The pericardium is attached to the ventral thoracic wall and diaphragm to keep the heart in position

Conspicuous differences with primitive heart are :

(a) The heart of rabbit is four chambered with two auricles and two ventricles. The truncus arteriosus is absent. An auriculo-ventricular groove separates the heart into four chambers. The posterior part of each auricle is some what swollen and flap-like called auricular appendage covering the top of corresponding ventricle.

(b) The auricles are thin walled structure their inner wall is smooth, except a network of low ridges, the musculi pectinate. Both the auricles i.e. right and left are separated by a thin partition called inter auricular septum possessing small oval area called fossa ovalis which has an opening the foramen ovalis in the embryo connecting the two auricles. In adult foramen ovalis is fully closed when lungs become functional.

(c) The right auricle receives a postcaval vein or inferior venacava and two precaval veins or superior venacavae. Opening of postcaval into the right auricle is guarded by the membranous fold, the Eustachian valve. Near this valve remnant of sinus-venosus called sinu-auricular node is situated. The right auricle also receives the coronary sinus. The opening of coronary sinus lies within the precaval. It is guarded by the valve of Thebesius. The left auricle receives two blood vessels, the right and left pulmonary veins. These open through a common aperture.

(d) The right auriculo-ventricular aperture is guarded by a tricuspid valve consisting of three membranous flaps. These are attached anteriorly along the margin of right auriculo-ventricular aperture anteriorly but posteriorly project into the ventricle. The free posterior edges are attached to the papillary muscles of right ventricle by a number of tough white cords called chordae tendineae. It checks the pushing of flaps into auricle during ventricular contraction.

(e) The left auriculo ventricular aperture is also guarded by a one-way valve, the bicuspid or mitral valve consisting of only two flaps. The free edges of these flaps are attached to the papillary muscles of the left ventricle by chordae tendineae

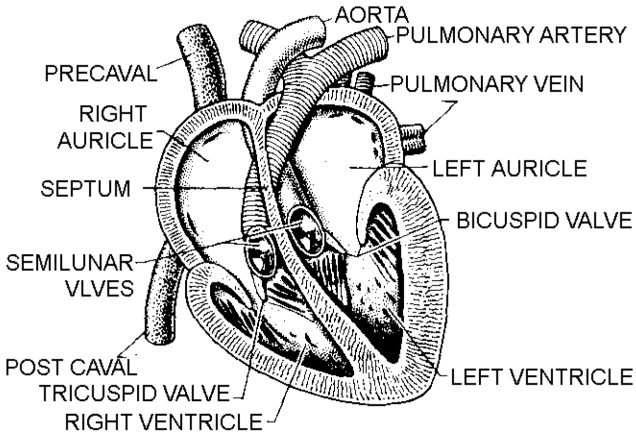

Fig. 6-5. Internal structure of the Heart of Rabbit

(f) The ventricle is a thick walled two chambered one. The left ventricle is thicker than the right ventricle because left ventricle is required to pump the blood to the farthest end of the body. The inner surface of the ventricles is raised into a network of low ridges called columnae carneae and few large and conical elevations, musculi papillares or papillary muscles. A special type of muscles are grouped together at the top of interventricular septum to from the structure bundle of His.

The opening of pulmonary aorta into the ventricle is guarded by three semilunar valves checking the return of blood into the ventricle. Similarly a carotico-systemic aorta or aortic arch arises from the left ventricle. Its opening is also guarded by three semilunar valves allowing the passage of blood only in one direction. At the place where both the aortae cross each other is present a muscular strand ligamentum arteriosum in adult. In embryonic condition both the aortae are connected with each other by ductus arteriosus.

6.1.8. SUMMARY:

Heart is the chief conical pumping organ of the vertebrate circulatory system. It is originated from mesoderm and is mainly composed of cardiac muscles. Number of chambers in the heart varies from two in fishes to four in mammals. Thus heart is a limited chambered one receiving blood from different tissues through veins and distributes blood through arteries. Mean while the impure blood received is sent to lungs for purification through pulmonary aorta. Pure blood from lungs is received by left auricle through pulmonary vein. Fundamentally the strucure of the heart remains same in all vertebrates except for few differences in the number of chambers, presence of valves and the aortae.

6.1.8. KEY WORDS:

Heart : A muscular pumping organ of the circulatory system formed from the mesoderm
Pericardium : Protective thin membrane around the heart
Sinus venosus : A pulsatile chamber receiving blood from the body through vena cava
Atria or Auricles : Thin walled muscular anterior chambers of heart.

Ventricle : A powerful muscular chamber pumping blood to different organs of the body through aortae.

Valves : Flaps located at the internal openings of the heart to prevent back flow of blood.

Pace makers : Nodes of muscle cells present over the heart to regulate the rhythmic contraction.

6.1.9. MODEL QUESTIONS:

1. Write a comparative account on the heart of the four representative vertebrate organisms studied.
2. Describe the structure of heart in shark. How it differs from the heart of amphibians.
3. Compare the hearts of the three amniote organisms you have studied.
4. Write in detail the structure of the heart in rabbit.

6.1.10. REFERENCES:

1. T.J. Parker & W.A. Haswell, 1972. *Text Book of Zoology*, Vol.2. Vertebrates(Ed.) A.J. Marshal, ELBS & Macmillan.

2. J.W. Young, 1978. *The life of Vertebrates*. Oxford University Press.

3. P.S. Dhami, J.K. Dhami, *Chordate Zoology*. R. Chand & Co.

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6.2. AORTIC ARCHES

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6.2.1 OBJECTIVES
6.2.2. INTRODUCTION
6.2.3. FORMATION OF AORTIC ARCHES
6.2.4. AORTIC ARCHES IN FISHES
6.2.5. AORTIC ARCHES IN AMPHIBIANS
6.2.6. AORTIC ARCHES IN REPTILES
6.2.7. AORTIC ARCHES IN BIRDS
6.2.8. AORTIC ARCHES IN MAMMALS
6.2.9. SUMMARY :
6.2.10. KEY WORDS
6.2.11. MODEL QUESTIONS
6.2.12. REFERENCES

6.2.1. OBJECTIVES:

The aim of this lesson is to know the

- Arterial trunks and their formation from the heart
- Formation of dorsal aorta and its branches
- Evolution of aortic arches in different vertebrate organsisms.
- Significance of aortic arches in the circulatory sytem

6.2.2. INTRODUCTION:

Although the arterial systems of different vertebrates appear to be different in arrangement, embryonic development reveals the fact that all are built upon the same fondamental plan. The increasing complexity of the heart, from the simple to two chambered structure of lower forms and to the four chambered organ of crocodilians, birds and mammals, is closely associated with the variations to be seen in the blood vascular System.

6.2.3. FORMATION OF AORTIC ARCHES :

During the formation of heart in a vertebrate embryo, ventral aorta appears in the midline of the heart and ventral to the pharynx. It soon establishes a connection with the conus arteriosus. Anteriorly the ventral aorta divides into two aortic arches. They run anteriorly on the dorsal side in the mandibular region. Anterior to the pharynx, they take a loop and continues posteriorly as paired dorsal aortae. Connecting the dorsal and ventral aortae, six pairs of aortic arches arise running through the tissue between adjacent pharynageal pouches. although there are certain discrepancies among lower froms.

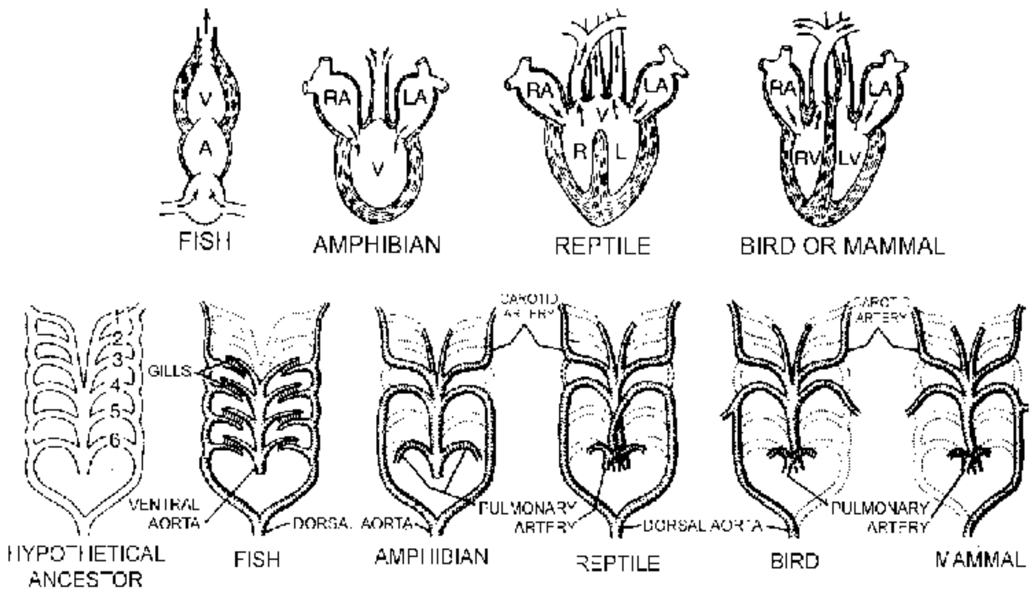

Fig. 6-6. Evolution of heart and aortic arches

Six pairs of arches : The first aortic arch is known as the mandibular aortic arch. The second is the hyoid aortic arch. The third, fourth, fifth and sixth aortic arches are numbered as they are. Each one lies anterior to the visceral cleft bearing the corresponding number.

Dorsal aorta : The paired dorsal aortae fuse posterior to the pharyngeal region toform a single dorsal aorta. It continues into the tail region as the caudal artery. Various paired and unpaired vessels arise along the length of the dorsal aorta to supply all the structures of the body posterior to the pharyngeal region. Anterior continuations of the unpaired ventral aorta and the paired branches of the dorsal aorta supply the head and anterior branchial regions. The method of branching of the dorsal aorta is uniform in all the vertebrate organisms, the aortic arches undergo conspicuous modifications in different forms. These changes are similar in the members of a given class.

Blood circulation : Blood, pumped by the heart, passes through the ventral aorta to the aortic arches. These vessels then carry the blood to the paired dorsal aortae. Then it either goes anteriorly to the head or posteriroly to the single dorsal aorta which distributes it to the rest of the body. Veins return blood to the sinus venosus or right atrium, as the case may be.

6.2.4. AORTIC ARCHES IN FISHES:

Many variations have been observed in the aortic arches of fishes. First is the reduction in the number of aortic arches within the group. Aortic arches are greatest in number in primitive sharks in which the number of the aortic archs are directly equal to the number of gill pouches.

Heptanchus has seven pairs of gill clefts in addition to the spiracle and hence it has seven pairs of aortic arches in the adult.

Hexanchus has six pairs of aortic arches.

Irrespective of the number of aortic arches in the adult stages of other fishes, six pairs are only seen connecting the vental and dorsal aortae during embryonic development. This is the primitive number of aortic arches for vertebrates.

Dorsal aorta continues as internal carotids in front of the first pair of aortic arches. Those of the ventral aorta form the carotid arteries supplying blood to the jaws and face. In most fishes each aortic arch except the first or mandibular, consists of afferent and efferent branchial branches with an interposed inter arterial capillary network. Exchange of gases occur in the capillary network of the gill lamellae.

In sharks only five aortic arches persist, the first having been lost or modified. The most anterior afferent branchial artery on each side runs through the hyoid septum, supplying the hyoid hemibranch. It will be recalled that in elasmobranchs the spiracle represented the external opening of the modified first or hyomandibular cleft. Although five afferent branchial arteries are present on each side but there are four pairs of efferent vessels.

6.2.5. AORTIC ARCHES IN AMPHIBIANS:

In amphibians and in the remaining vertebrate classes, further reduction in the number of aortic arches occur together with a greater modification of the entire complex of blood vessels in the pharyngeal region. The aortic arches never break up into afferent and efferent portions since in these higher forms internal gill lamellae are not formed.

To be sure, amphibians possess external gill filaments, at least during early development but these are not homologous with internal gill lamellae of fishes

In anurans 1, 2 and 5 aortic arches disappear. The branches between 3 and 4 arches on each side gradualry dwindles. The anterior continuations of the ventral aorta become the external carotid arteries. The third arch, together with the anterior portion of the radix of the aorta on that side, becomes the internal carotid artery. A stapedial branch represents a remnant of the second aortic arch. The portion of the ventral aorta from which the internal and external carotid arteries arise becomes the common carotid. The fourth aortic arches persist to become the systemic arches, which unite posterior to he heart to form the dorsal aorta proper. Sixth aortic arch on each side sends a branch to the developing lung and to the skin, thus becoming the pulmocutaneous artery.

6.2.6. AORTIC ARCHES IN REPTILES:

Just as in amphibians, reptiles also retain third, fourth and sixth aortic arches. The fifth aortic arch is retained in reduced form in certain lizards. A remnant of the radix between third and fourth arches 4 may persist on each side in certain snakes. The fourth aortic arch on the left side establishes a separate connection with the right side of the partially divided ventricle. This along with a portion of the radix on the left side, becomes the left arch of the aorta. The sixth arch on each side gives off a pulmonary artery to the lung and in most cases loses its conection with the radix. The two pulmonary arteries arise form a common trunk, the pulmonary aorta arising from the right side of the ventricle. The remaining vessel derived from trunchus arteriosis connects to the left side of the ventricle and as it runs forward, gives off the fourth aortic arch on the right side and finally divides into two common carotid arteries with their external and internal branches. The right fourth aortic arch, together with a portion of the radix on that side, becomes a right arch of the aorta which joins the posterior continuation of the left arch to form the dorsal aorta proper. Right and left subclavian arteries arise from the right and left aortae, respectively, in the reptiles having pectoral limbs.

Since the right aorta bears mostly oxygenated blood and the left cheifly deoxygeneated blood, mixing occurs in the dorsal aorta propes. Since these two vessels come together, some mixing may also occur through the foramen of panizzae which forms the right and left aortae as they emerge from the heart.

6.2.7. AORTIC ARCHES IN BIRDS:

The chief changes taking place in the aortic arches are similar to those of reptiles. The conspicuous change is that in birds the fourth arch and radix on the left side lose their connection with the dorsal aorta and splits into two portions, a systemic aorta and a pulmonary aorta. The systemic aorta is connected to the left ventricle, and the pulmonary aorta to the right.

The fourth aortic arch on the right side leaves the systemic aorta and by means of the radix, leads lo the main arterial channel, or dorsal aorta proper. The latter supplies the entire body with oxygenated blood, At its anterior end, the systemic aorta gives rise to external and internal carotid arteries. The fourth aortic arch on the left may possibly contribute to the left subclavian arter. But this vessel is usually a branch of the third aortic arch. The right subclavian artery either comes off from the right radix or off the third aortic arch on the right side.

The pulmonary aorta leading from the right ventricle gives off the pulmonary arteries that are actually the out growths of the sixth aortic arches. Until the time of hatching, there is a ductus artereosus on the right side, representing the portion of sixth aortic arch between pulmonary artery and radix. This serves as a shunt from the right ventricle to the dorsal aorta at a time when the lungs are not functioning.

6.2.8. AORTIC ARCHES IN MAMMALS:

The changes in the aortic arches of mammals are rather similare to those of birds except that the radix on the right side rather than the left loses its connection with the aorta. The fourth aortic arch in thé left side together with its radix, therefore, bacomes the arch of the definitive aorta. The fourth arch on thé right and a portion of the right radix becomes the right subclavian artery.The left subclavian develops as an enlargement of one of the intersegmental arteries coming off from the aorta in this région. There is much variation among mammals in the manner in which the subclavian arteries arise. In mammalian embryos there is at first a ductus artereosus on each side, but the one on the right side persists only until birth when it finally becomes closed. A ligamentum arterosum of connective tissue finally remains.

6.2.9. SUMMARY:

Heart is the chief conical pumping organ of the vertebrate circulatory system. It is originated from mesoderm and is mainly composed of cardiac muscles. Number of chambers in the heart varies from two in fishes to four in mammals. Thus heart is a limited chambered one receiving blood from different tissues through veins and distributes blood through arteries. Mean while the impure blood received is sent to lungs for purification through pulmonary aorta. Pure blood from lungs is received by left auricle through pulmonary vein. Fundamentally the strucure of the heart remains same in all vertebrates except for few differences in the number of chambers, presence of valves and the aortae.

6.2.10. KEY WORDS:

Heart: A muscular pumping organ of the circulatory system formed from the mesoderm
Pericardium: Protective thin membrane around the heart
Sinus venosus: A pulsatile chamber receiving blood from the body through vena cava
Atria or Auricles: Thin walled muscular anterior chambers of heart.
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Valves: Flaps located at the internal openings of the heart to prevent back flow of blood.
Pace makers: Nodes of muscle cells present over the heart to regulate the rhythmic contraction.

6.2.11 . MODEL QUESTIONS:

1. Write a comparative account on the heart of the four representative vertebrate organisms studied.
2. Describe the structure of heart in shark. How it differs from the heart of amphibians.
3. Compare the hearts of the three amniote organisms you have studied.
4. Write in detail the structure of the heart in rabbit.

6.2.12. REFERENCES:

1. T.J. Parker & W.A. Haswell, 1972. *Text Book of Zoology*, Vol.2. Vertebrates(Ed.) A.J. Marshal, ELBS & Macmillan.
2. J.W. Young, 1978. *The life of Vertebrates*. Oxford University Press.
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Lesson - 7
BRAIN

CONTENTS:

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7.3. FORMATION AND COMPOSITION OF THE BRAIN
7.4. CENTRAL NERVOUS SYSTEM AND THE COMPONENTS
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7.1. OBJECTIVES:

The aim of this lesson is to know about

- The brain as the significant part of nervous system
- Formation and main components of the brain
- Central nervous system and its constituents
- Detailed structure and functions of the brain
- Compative features of the brain in different chordate organisms.

7.2. INTRODUCTION:

Brain is the main component of the central nervous system. It is the anterior enlarged part of the nerve tube. It has important regulating action in the body of the vertebrate organisms. The following aspects of the brain are common in all the vertebrate organisms.

7.3. FORMATION AND COMPOSITION OF THE BRAIN:

During the development, brain is formed from the ectodermal cells. Its formation is initiated by the appearance of neural plate above the notochord. Subsequently, the plate becomes more conspicuous, and changes into neural tube by formation and fusion of the neural folds. Anterior end of the neural tube divides into neuromeres which reunite to form the three main components of the brain viz., the forebrain or procencephalon, mid brain or mesencephalon and hind brain or rhombencephalon. The brain is composed of an outer *gray matter* and an inner *white matter*. The gray matter is greyish and composed of cytons or cell bodies of nerve cells, supporting neuroglial cells and *non-medullated* basal and terminal parts of their axons. The white matter is composed of whitish and glistening medullated nerve fibres.

Divisions of the Brain: These three are further divided into telen or thalamencephalon, diencephalon, mesencephalon, metencephalon and myelencephalon. During the course of development, the neural tube undergoes flexion and torsion besides reduction in size to develop in to the short and well differentiated brain.

7.4. CENTRAL NERVOUS SYSTEM AND THE COMPONENTS:

Brain continues to the posterior end as spinal cord. Brain is enclosed in the cavity of the bony cranium while the spinal cord is protected by the vertebral column. These two constitute the central nervous system mainly concerned with the regulation of body activities.

Components of the Brain and its thickenings:

7.4.1. Procencephalon or fore brain consists of two regions *viz*., telen or thalamencephalon and diencephalon.

Telencephalon is represented by olfactory lobes and cerebrum composed of cerebral hemispheres. The dorsal or roof of the cerebrum is generally the thin pallium. The thick ventrolateral walls of the cerebrum form the corpora striata.

Diencephalon is a rhomboidal area just posterior to the cerebrum. Its dorsal walls are the epithalami. Lateral walls of the diencephalon are the thick thalami. The roof is extremely thin and membranous containing numerous blood vessels forming a folded structure known as *anterior choroid plexus* Ventrally, the walls develop into a thick walled hypothalamus or Rathke's pocket elongating posteriorly into infundibulum. To this is attached the important endocrine gland viz., the pituitary gland. The anterior wall of diacoel is thin and called *lamina terminalis.* The roof of diacoel just behind anterior choroid plexus gives rise a long slender process, the *pineal stalk.* Three *commissures*, which are formed of transverse fibres connect the right and left sides of the brain. These are an *anterior commissure* in the lamina terminalis, a Habenular commissure in front of pineal stalk and a *posterior commissure* on the dorsal side at the junction of diencephalon with mid-brain.

7.4.2. Mesencephalon or mid brain:

Largely represented as optic lobes on the dorsal side. and *Crura cerebri.* A pair of thick bands of nerve fibres running antero-posteriorly on the ventral side of the mid brain joining the fore and hind brains are the Crura cerebri.

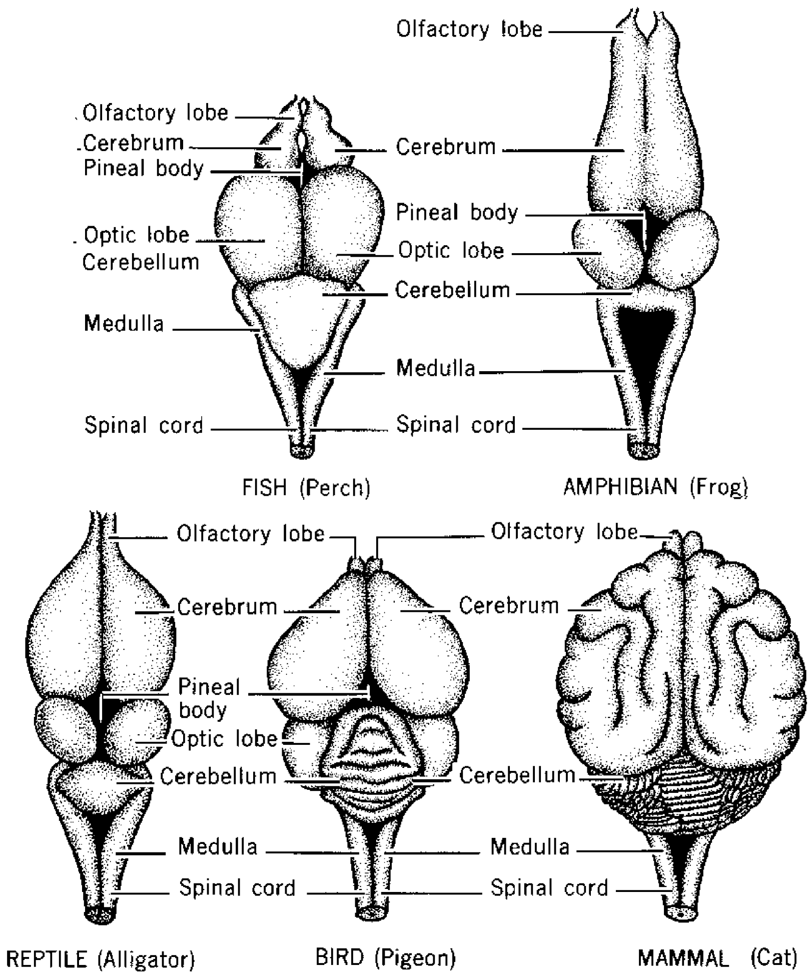

Fig.7-1. Brain in typical vertebrate organisms

7.4.3. Rhombencephalon:

Hind brain comprises of *cerebellum* and *medulla oblongata.*

(i) *Metencepahlon or Cerebellum*: It is the thick walled dorsal, rhomboidal part of the hindbrain. It is observed that a very small cavity exists as metacoel in cerebellum though it is apparently acoelous.

(ii) Myelencephalon or Medulla oblongata: Medulla oblongata forms the last part of the brain. It is somewhat triangular in shape, broader in front but tapers posteriorly and passes into the spinal cord.

7.4.4. Sensory capsules:

(i) Olfactory lobes: Two in number in front of the cerebral hemispheres connected by peduncles. They extend as olfactory nerves to the nasal chambers.

(ii) Optic lobes: These are the two bulb like enlargements present on the dorsal side of the mesencephalon. Optic nerves arising from these lobes form a cross like optic chiasma in front of the infundibulum and then innervate the sensory epithelium of the eye balls.

Protective membranes: Externally brain is enveloped by connective tissue membranes viz., the meninges. Pia-arachnoid membrane forms folded *tela choroidea* projecting into the third and fourth ventricles of brain to form *anterior* and *posterior choroid plexuses.*

7.4.5. Ventricles and their communication:

The internal cavity of the brain is differentiated into four cavities or ventricles. The first and second ventricles are the paracoels located in the cerebral hemispheres. Third ventricle is present in the diencephalon as diacoel. Fourth ventricle is seen as metacoel of cerebellum and myelocoel of medulla oblongata. The paracoels open into the third ventricle through foramen Munro. Third ventricle is communicated to the fourth ventricle through a narrow duct called sylveous aqueduct or iter. Paracoels are in communication with the rhinocoels or olfactory ventricles of the olfactory lobes through olfactory peduncles. Similarly the iter is connected to the two optocoels or diacoels of the optic lobes.

7.4.6. Vascularized regions:

Blood capillaries in association with the thin dorsal wall of the diencephalon form in to a highly vascularized anterior choroid plexus. Similarly posterior choroid plexus is located on the thin dorsal wall of the medulla oblongata. These secrete a clear watery lymph-like *cerebrospinal fluid to fill in* all the inner cavities or the ventricles and the spaces outside the brain. It protects the brain from mechanical shocks and in exchange of the metabolites from the tissues.

7.4.7. Functions:

- Olfactory lobes are concerned with the perception of smell.
- Cerebrum is for intelligence, memory, thinking and consciously conducted voluntary activities
- Optic lobes are concerned with sight and hearing.
- Cerebellum is meant for establishing muscular coordination and equilibrium.
- Medulla oblongata regulates the functions of the visceral organ systems and involuntary activities.

7. 5. CONTRASTING FEATURES OF THE BRAINS IN SCOLIODON, FROG, LIZARD, PIGEON AND RABBIT.

Part	Shark	Frog	Lizard	Pigeon	Rabbit
Olfactory Lobes	From the cerebrum; the *olfactory stalks* arise in anterio-lateral angle. They terminate into large *olfactory lobes* which are closely applied to the *olfactory sac* of their side. The bulb and tract or stalk containing a cavity or ventricle known as *rhinocoel.*	Short and stumpy attached with cerebral hemispheres through a narrow notch.	Olfactary lobes are drawn forward to form the narrow and delicate olfactory peduncles or stalks. They terminate into swollen olfactory bulbs.	Small and rounded balls immediately in front of the cerebral hemispheres.	A pair of club-shaped separate lobes in front of the hemispheres.. Each lobe consists of an *olfactory bulb* and an *olfactory tract.* The olfactory tract can be observed from ventral side as they are concealed beneath cerebral hemisphere on the dorsal side. A groove on the outer side of this tract separates it from frontal lobes called *rhinal fissure.* At the anterior end of rhinal fissure are *olfactory lobes* while at the posterior end are *hippocampal* lobes. These two lobes together constitute *rhinencephalon*
Cerebrum as cerebral hemispheres	The cerebrum is large, some what rectangular and undivided mass with smooth surface. The dorsal surface is	Long with tubular anterior and broad posterior ends. Dorsally cerebrum is divided by a furrow and hence two cerebral hemispheres are seen.	Cerebral hemispheres are smooth and comparatively large but short, being roughly oval in out line and separated from each other by a deep dorsal median longitudinal fissure. Just above the	In birds brain is short, broad and, conical in form with clear and deep sagital fissure	*(ii) Cerebral hemispheres* Well developed large triangular bodies with pointed anterior ends occupy about 2/3 of the whole brain. They partly cover the olfactory lobes in front and extend backward to cover the *diencephalon,* mid brain and even touching the *cerebellum.*

	smooth. Mid-ventrally, it has a small opening called *neuropore* through which emerges a pair *of terminal* or *pre-olfactory nerves.*	More cells from the grey matter have moved to the peripheral positions in the pallial region. The two corpora striata are interconnected by a tract of transverse fibres known as *anterior commissure*	anterior commissure is *hippocampal commissure,* connecting the hippocampal areas of cerebral hemisphere. These lobes are really the olfactory centres receiving afferent fibres from the olfactory organs. The corpora striata receives many efferent fibres from the side walls of diencephalon called *thalami*, indicating a tendency of transferring more and more functions to the cerebrum	demarcating the cerebral hemispheres. It bears neither folds nor cerebral cortex as seen in mammals.	Dorsally, between the two cerebral hemispheres there is a *median fissure.* Laterally *Sylvian fissure* dividing each hemisphere into an anterior *frontal lobe*, median posterior *median lobe* and posterior lateral *temporal lobe.* On the ventral surface of each cerebral hemisphere there is a shallow groove called *hippocampal sulcus* which divides hemisphere longitudinally into an outer consists of frontal and parietal lobes and an inner *hippocampal lobe.*
Diencephalon	It is completely covered over by cerebellum on the dorsal side. The infundibulum consists of a median large pear shaped lobe and two oval lateral lobes called *inferior lobes*. To the median lobe is attached hypophysis forming the *pituitary*	Infundibu-um is bilobed. The infundibulum and hypophysis together form the *pituitary gland* and functions as an endocrine gland. Pineal body is ridge like in the adult. It is present in tadpole larva. During metamorphos it separates from the pineal stalk	The epithalamus has a well-developed *epiphyseal* or *pineal apparatus* consisting of an anterior eye-like *parietal body*, and a posterior *pineal body.* The parietal body is used to function as an eye opening to the outside through the Optic lobes are prominent, oval bodies on the dorsal side of brain, in contact with cerebral hemispheres anteriorly. *parietal foramen* in the skull. During embryonic development, the thin dorsal wall of the	*Diencephalon.* is covered over by cerebral hemispheres on the dorsal side but visible on the ventral side.	It is comparatively small and is completely shadowed dorsally by the backward growth of cerebrum. The *pituitary body* is provided with a swelling on the posterior side called *corpus albicans* or *corpus mammillare.* *Epithalamus* is covered by vasculer piamater. The thick lateral walls of diocoel are called optic thalami forming middle commissure or massa commissure

	body. Large, thin walled vascular sacs, called *sacci vasiculosi* lie on the sides of hypophysis acting as pressure receptors.	and shifts o lie outside the skull beneath the dorsal skin of head as *brow spot.* It is apparently a vestige of the *third eye*	third ventricle possess third evagination called the *paraphysis.* It is anterior in position and gets degenerated in adults.		
Mesencephalon	Optic lobes are also known as *corpora bigemina* since each lobe is undivided. . They are almost completely covered over dorsally by cerebellum and ventrally by the infundibular growths. Their lateral sides are enlarged by the presence of longitudinal nerve tracts	Two transverse fibrous bands connect the two optic thalami together. These are a *dorsal commissure* infront and a *posterior commissure* behind. *optic lobes are the corpora bigemina.* They are partly visible from the ventral side also.	Optic lobes are prominent, oval bodies on the dorsal side of brain, in contact with cerebral hemispheres anteriorly	It is represented by two large, al *optic lobes,* shifted laterally due to backward extension of cerebral hemispheres. The two optic lobes are connected together by a transverse *optic commissure.*	Four optic lobes are situated on the dorsal surface of mid-brain although most of the part of mid-point remains covered by cerebral hemispheres. Out of 4 lobes anterior two are larger called *superior coliculi* than the posterior ones called *inferior coliculi.* The anterior and posterior lobes are connected by means posterior commissure.
Metencephalon	It extends forwards up to the cerebrum and covers the medulla	It is thin, short and triangular without enclosing any cavity.	The cerebellum is poorly developed	*Cerebllum* well developed and relatively	*Cerebellum or Metacephlon is* well developed in rabbit. It consists of a large median central lobe called *vermis, lateral lobes* situated on the sides of vermis and *two*

	oblongata backwardly. Its dorsal surface is grown into many irregular folds. Two deep transverse furrows divide it into three lobes. Sometimes a median longitudinal furrow may also divide cerebellum into right and left halves.			larger tha mammals It divided into a larg median lobe calle *vermis* an two sma conical lateral lobes called *flocculi.*	*floccular lobes* situated on the outer sides of lateral lobes. The *vermis* is further divided into anterior, middle and posterior parts. Cerebellum is connected to other parts of brain by three pairs of fibrous tracts the anterior or *superior peduncle or cerebellar peduncle* connects it with the posterior optic lobes. *Middle peduncle* joins it with the *pons varolii* and *posterior peduncle* connect it with the medulla and indirectly to the spinal cord.
Myl ence phal on	A pair of prominent, irregular, thin walled sacs, the *corpora restiformia* or *auricular lobes*, lie on the sides of the anterior part of the medulla oblongata.	It is somewhat conical, broad infront and tapering posteriorly and passes into the spinal cord without any external line of demarcation	It is the posterior most part of brain. It is broad in front and narrow behind. It has a prominent ventral flexure, where it passes into the spinal cord.	*Medulla oblonga ta* is covered over by cerebell um on dorsal side. It's broader in front and tapers behind to merge into spinal cord. The point where medulla and spinal cord	It is the posterior most part of the brain and is located underneath the cerebellum. It is the broader in front but tapers posteriorly so as to form the spinal cord. The junction of medulla and spinal cord, forming a pointed depression called *calamus scriptorius. The fold of the* posterior choroid plexus is perforated by a small median aperture, *foramen of Magendie* and two lateral *formina of Luschka*

				meet is the well marked ventral flexure	
Meninges	Only one connective tissue membrane called meninx primitiva surrounds the brain	Two meninges viz., the inner highly vascular and very thin *pia-arachnoid membrane or piamatre and an* outer very thick, tough, lowly vascularized *duramatre* forming the lining of the cranial cavity surround the brain. The narrow space between pia-arachnoid and duramatre is the *sub-dural space. Similarly, epidural space lies between the cranial cavity and the outer duramatre*	Besides the two meninges, the cranial cavity is lined internally by fibrous tissue, the *endorachis (periosteum)*	Same as in reptiles.	Besides the piamatre and duramatre, a middle meninx is also seen as arachnoid membrane. It is thin and vascular. Hence, a new space called the *sub-arachnoid space between the* piameter and arachnoid membrane; *subdural space* between *arachnoid* membrane and duramatre are seen

Fig. 2. Comparative statement on the brain in typical vertebrates

7.6. SUMMARY:

Brain is the central part of the central nervous system, well protected by the cranial box and menniges. It receives the signals and gives appropriate orders to various organs and systems in the body through radiating nerve net work. It regulates metabolic activities and coordinates the functions through neurosecretory substances. During the course of development, it takes origin from the ectoderm. It is the cerebral part which becoms complicated in different vertebrate organisms though there are changes caused in other parts of the brain. It extends to the posterior end of the body as spinal cord.

7.7. KEY WORDS:

Brain : Main part of the central nervous system controlling all the metabolic activities of the organism.

Ventricles : Cavities of the brain.

Cerebrospinal fluid : Clear nutrient fluid of the brain providing nutrients and preventing friction

Meninges : Protective membranes around the brain.

7.8. MODEL QUESTIONS:

1. Giving the description of a typical brain, list out the differences encountered in the brains of shark, frog, lizard, pigeon and a mammal.
2. Compare and contrast the structure of brain in different typical examples of different vertebrate animals.
3. List out the differences between the brains of typical vertebrate organisms you have studied.

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…..Dr. K. Kondaiah

Lesson – 8
PARENTAL CARE IN AMPHIBIA AND DENTITION IN MAMMALS

CONTENTS:

8.1. OBJECTIVES.
8.2. INTRODUCTION.
8.3. PARENTAL CARE IN AMPHIBIA.
8.4. DENTITION IN MAMMALS.
8.5. SUMMARY.
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8.7. REFERENCE BOOKS.

8.1. OBJECTIVES:

The aim of this lesson is to understand

- The different types of parental care in Amphibia and
- Dentition in Mammals.

8.2. INTRODUCTION:

Protecting the eggs and the larval forms by the parents from the predators is called the parental care. Various methods are adopted by the amphibians to take care of their eggs or larvae.

Mammals are the only vertebrates having heterodont dentition. The structure, arrangement, types, number and arrangement of teeth over the Jaws collectively called dentition. In mammals teeth are arranged in sockets (thecodont).

8.3. PARENTAL CARE IN AMPHIBIA:

Parental care is a very important factor for survival. Animals exhibit a great diversity in carrying for their eggs and young during their development. Looking after the eggs or the young until they are independent, to protect from enemies is known as parental care. Though parental care is seen among chordates right from fishes to mammals, it is generally observed to a greater extent in oviparous organisms laying less number of eggs.

Most of the Amphibians deposit their eggs in water and they are exposed to various dangers. Due to this reason they exhibit parental care in different ways to protect the eggs and young ones. This parental care is exhibited by both male and female parents. Anurans are much advanced than urodeles and apodes. Parental care in Amphibia can be studied in three heads.

1.Protection by means of nests or nurseries.
2.Direct nursing by parents.
3.Viviparity.

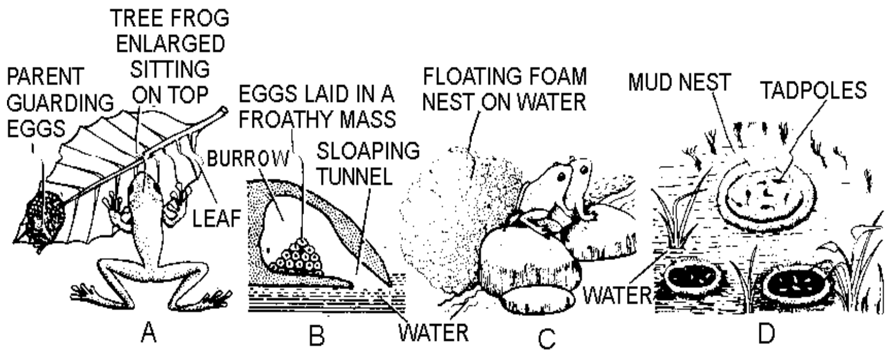
8.3.1. Anura:

8.3.1 A. Protection by means of nests or nurseries:

Many amphibians build nests or nurseries to protect their progeny.

a) In enclosures in the water:

Hylafaber (Brazilian tree frog): Protects its progeny by constructing a basin shaped nursery on the edge of the pond. In the first instance the female frog makes a small pit or depression of 3 to 4 inches depth by digging. A muddy circular wall is constructed around this pit which extends out of the surface water. The bottom of the pit is leveled by its belly and hands. The inner surface of the wall is smoothened by the webbed feet, thus it make into an aquarium. Into this male and females release the germ cells and the parents protect them from enemies. Species of the same genus lay the eggs beneath the dry leaves.



Fig, 8-1.Various types of parental care observed in different amphibians

b) In holes near water:

Rhacophorus schlegelii (Japanese tree frog): The male and female frogs embrace and burry themselves and make a hole or chamber in the damp earth few inches above water level. The walls of the chamber are polished. The female first produces a secretion from cloaca which is beaten into a froth. The eggs are deposited into the froth by female and male releases the sperms. After hatching the larvae come out of the pit and complete life cycle.

c) In nests on trees or rocks over hanging the water:

Some tree frogs like *Phyllomedusa* of South America, *Rhacophorus malabaricus* of India lay their eggs on trees, in nests made of froth which is attached to one or many leaves of branch over hanging the water. The larvae move in froth. After losing the external gills the larvae fall into the water and complete the life cycle. Eg: *Hyla resinfictrix* (tree frog) selects cavities present on trees.

d) In transparent gelatinous bags in the water:

The large eggs are enclosed in sausage shaped gelatinous transparent membrane bags, secreted by female frog and is left in the mountain streams. After the completion of development the tiny frogs come out of the bag. As gills are absent large tail serves as respiratory organ of young ones.

Ex: *Phrynixalus biroi*.

e) On trees away from water:

In American genus *Hylodes,* the large sized eggs are deposited in damp places under stones or leaves of the plants. As plenty of yolk is present in the eggs, entire development takes place there and young frogs come out with vestigial tail. As gills are absent the tail acts as a respiratory organ.

8.3.1.B. Direct nursing by parents:

a) Transferring tadpoles to water:

Small south American frogs P*hyllobates* and *Dendrobates* deposit their eggs on ground. After hatching Tadpoles adhere by their sucker like lips to the back of the parents. Thus the parents carry the tadpoles to water.

b) Protection of eggs by male:

The eggs of *Mantophryne robusta* are strung together by an elastic gelatinous envelope. The male sits on the eggs and hold them with both hands and development takes place. The larvae do not have the gills and hence the tail acts as respiratory organ.

c) Eggs glued to body:

In the European midwife toad, *Alytes obstetricans*, the female lays eggs, the male entangles them around its hind legs. It carries them till they are ready to hatch. At this time the male releases the tadpoles into nearest water.

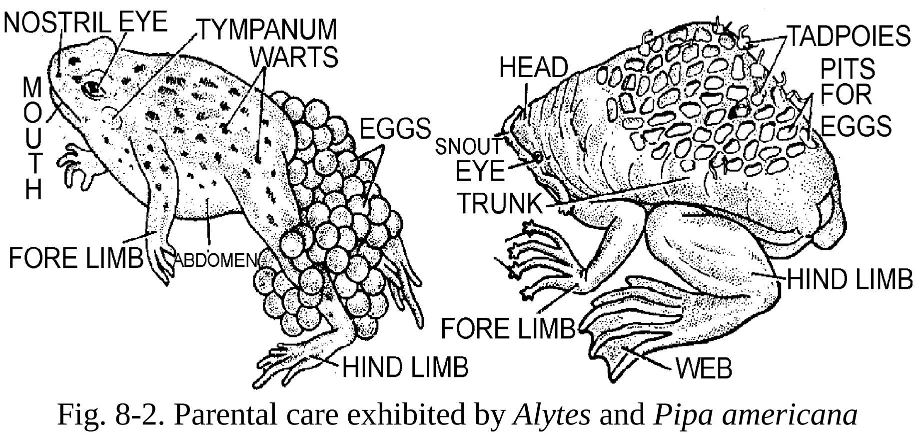


Fig. 8-2. Parental care exhibited by *Alytes* and *Pipa americana*

d) Eggs in cell-like pouches on the back of female:

In *pipa americana* the skin of female's back becomes thick, vascular, soft and gelatinous in the breeding season. The male presses fertilized eggs against female's back, where the skin grow round the eggs in the form of a pouch which is finally covered by a lid. Complete metamorphosis occurs in this pouch and the young leap out in the perfect condition.

e) Eggs in Common Pouch:

In *Nototrema*, the eggs are covered by skin forming a single large brood pouch which opens posteriorly in front of the cloacal aperture.

f) Eggs exposed on the back:

In the Brazilian tree toad, *Hyla goeldii*, the posterior part of the back of female forms a sort of brood pouch in which the eggs remain exposed.

g) Eggs carried on the belly:

The female *Rhacophorus reticulata* carries its eggs on the belly, which bears shallow impressions of the eggs when they are removed.

h) Eggs carried in the mouth:

In *Hylambates breviceps* (west African Tree frog), the female carries the eggs in her mouth. These eggs are large and few in number. The males of *Arthroleptis* carry the larvae in the mouth. Gastric incubation is found in the Australian frog *Rheobatrachus silus*. In this the female keeps the eggs in her stomach. The tadpoles are sent out through mouth.

i) In Gular pouch:

The male of south American Darwins frog, *Rhinoderma darwinii* pushes fertilized eggs into the vocal sacs where they undergo development.

8.3.1.C. Viviparity:

Pseudophryne vivipara and *Nectophryne tornieri*, are the two small East African toads. They retain eggs in oviducts and after development give birth to young ones. Thus they exhibit viviparity.

8.3.2. Urodela:

As Anurans, Urodeles also show protection of progeny by means of different methods.

8.3.2. A. Protection by means of nests or nurseries:

a) In holes on land or in trees:

In *Autodax* lay about 10-20 eggs in a dry hole in ground or in a hole on a tree, up to 30 feet above the ground. Both the parents protect their brood until the completion of development.

b) In transparent bags:

Salamandrella Keyserlingii deposits its small eggs in a gelatinous bag contains 50-60 eggs which is attached at one end by an aquatic plant just below the water level and protect them until an advanced stage of larvae.

8.3.2.B. Direct nursing by the parent:

a) By the Female:

The female of *Plethodon*, lays the eggs in small packages of about five beneath stones and the mother coils round them until the larvae come out. In *Desmognathus fusca*, The female lays eggs in the form of strings and carries on the back or round the legs.

b) By the male:

In *Megalobarachus*, the male coils round the eggs and protects them.

c) Viviparity:

Salamandra maculosa pairs on land for several months, then the female goes to the water and give birth to small young ones (10-50). In S*alamandra atra* the young ones are retained in the uterus till the completion of metamorphosis.

8.3.3. Apoda:

The female *Ichthyophis* lays large yellow eggs in burrows in damp soil and carefully coils round them and protects the eggs from enemies. *Dermophis* is Viviparous.

8.4. DENTITION IN MAMMALS:

Teeth are present in nearly all mammals but in some they do not occur in the adult condition (whale bone whale and *Ornithorhynchus*) In *Tachyglossus* (spiny ant eater) teeth are absent throughout life (edentata).

Teeth are the hard structures connected to Jaw bones in the buccal cavity. The arrangement of teeth on the Jaws is called dentition. Thecodont type dentition is the characteristic of mammals. In this type the teeth are placed in the sockets on the Jaw.

8.4.1. Origin of teeth:

Teeth are originated from stomodaeal region of the alimentary canal.

8.4.2. Structure of Tooth:

The Tooth consists of three main parts namely crown, neck and root.

8.4.2a. Crown:

It is the outer or exposed part of the tooth which is glistening white in colour.

8.4.2b. Root:

This basal part is present in socket of the Jaw. Its terminal part is the root canal remaining either open or closed. Tooth may have a single or two roots. Open rooted tooth grow continuously. Ex : Incisors of rodents and elephants.

8.4.2c. Neck:

The Junction place of crown and root and embeded in the gum is the neck.

Each tooth is formed of a hard substance called dentine enclosing the pulp cavity and filled with pulp composed of connective tissue, blood vessels, nerves and mesenchyme cells or odontoblasts. The crown part of dentine is covered by enamel which is the hardest part of the body of any vertebrate. Root part of dentine is covered by hard cementing substance fixes the root in the socket of the Jaw bone. A strong connective tissue called periodontal membrane covers this cementing layer.

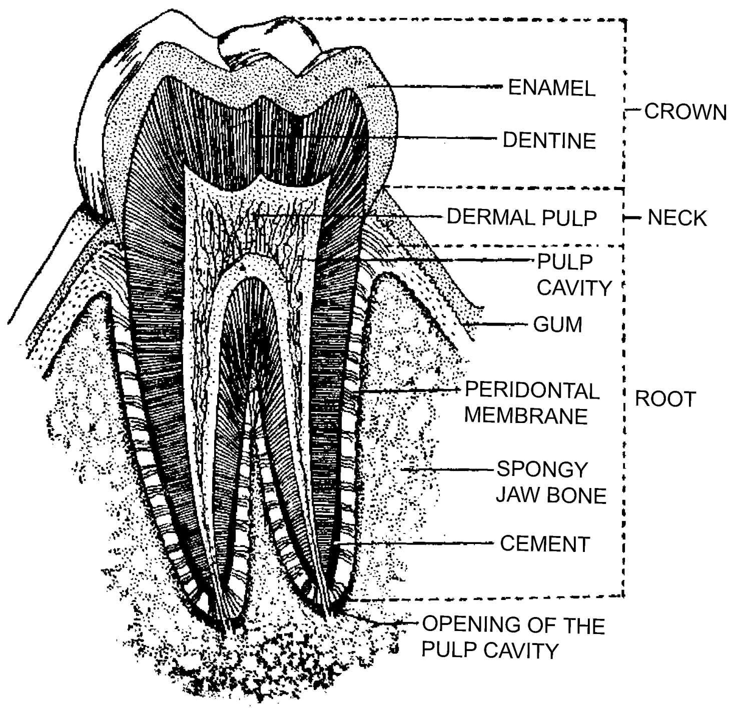


Fig.8-3. Development of Tooth

Teeth are formed partly from epidermis and partly from endodermis. Among mammals teeth are formed from the soft tissue covering the premixillae, maxillae and dentaries. Enamel of the tooth is formed from the epidermis and the remaining part from dermis. A ridge like inpushing of the ectoderm is formed along the margin of the Jaw. Then the mesodermal cells form tooth germs or buds. Then they remain in continuation with dental lamina by narrow isthmus. Cap like enamel organ is formed on dental papilla which is highly supplied with blood. Then odontoblasts form dentine layer. The cells of enamel organ form ameloblasts which give rise to enamel epithelium on dentine. Enamel is absent on the root of the tooth. Cement which is the modification of bone is deposited around the root. Through the opening in the root at the base nerves and blood vessels enter the pulp.

8.4.3. Types of Dentition:

8.4.3.a. Dentition on the basis of replacement:

There are three types on the basis of permanency.

Monophyodont :-

Only one set of teeth are present throughout the life. Ex : platypus, Marsupials, Moles.

Diphyodont :-

In most mammals diphyodont condition is present where two successive sets of teeth are formed in the life time. The first set is called deciduous or milk teeth which are formed after birth and are replaced by the second set of permanent teeth. In guinea pigs and bats milk teeth are formed and shed before birth.

Polyphyodont:-

Teeth are replaced several times during the life time of the organism. This is not seen in mammals.

8.4.3.b. Dentition on the basis of shape of teeth:

Basing on the shape dentition is of two types.

Homodont:-

All the teeth are similar in shape. Ex: Toothed whales.

Heterodont:-

In most of the mammals teeth differ in shape and function. Ex: cat, lion, man

8.4.3c. Dentition on the basis of attachment:

Depending on the attachment of tooth on the Jaw three types can be observed.

Acrodont:-

Teeth are rootless and fixed by their bases to the ridge of the Jaw.

Pleurodont:-

Teeth are rootless and fixed by their sides to the lateral surface of the ridge.

Thecodont:-

Teeth are rooted in the sockets on the Jaw.

8.4.4. Types of teeth:

Four types of teeth are present. They are incisors, canines, premolars and molars.

8.4.4a. Incisors:

They occupy the front portion of the mouth. They have a horizontal sharp cutting edge for biting and cutting the food material and a single root. These incisors are also used for holding, cropping or grazing.

Incisors are lodged in sockets in pre-maxilla in the upper Jaw and lower incisors are placed in the lower Jaw at the tip of the dentary. They may be totally absent in sloths. In some groups like rodents they are open rooted and grow continuously throughout life (carnassial). In elephants the upper incisors are modified into tusks. In lemurs they are like comb which help in cleaning the fur.

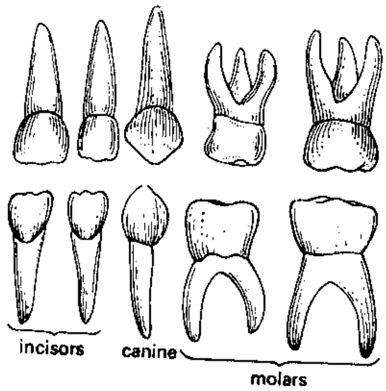


Fig. 8-4. Teeth in mammals

8.4.4b. Canines:

They lie immediately behind the incisors and are present one in each half of the Jaw. They are elongated, single rooted and with a conical sharp monocuspid crown. They are meant for offence and defence. In the group carnivora (dog, lion), the large and pointed canines are used in piercing and tearing the food. In male musk deer canines are present only in upper Jaw. Upper canines form tusks in walrus. These tusks help for locomotion on ice and digging for molluscs. Canines are absent in some herbivores (rabbit, ox) leaving a wide tooth less space called diastema.

8.4.4c. Premolars:

The premolars follow the canines. They have a double root and a compressed crown with 1 or 2 cusps. They are used for shearing and slicing.

8.4.4d. Molars:

The molars occupy the posterior part of the Jaw, lying next to the premolars. They have more than two roots and cusps. They always develop in the permanent set, having no milk predecessors. They are used for crushing and mastication.

Premolars and molars are together called as cheek teeth or grinders. The masticated food is made into paste for easy swallowing and digestion. In carnivora last premolars in upper Jaw and first molars in lower Jaw are modified into carnassial teeth which are used for breaking the bones. In man last pair of molar teeth are called wisdom teeth. In seals molars are modified to filter the plankton.

On the basis of the presence of cusps, the terms used are:

Cuspidate: having cusps
Unicuspid: tooth bearing only a single cusp
Bicuspid : tooth having two cusps
Tricuspid : tooth having three cusps

Premolars and molars are provided with number of cusps having different shapes. Different terms are used to denote the varieties of grinders.

Bunodont:

The cusps remain separate and rounded. They are used for crushing food.

Ex: Man, Monkey, pig.

Selenodont:

The crowns are broad with enamel deposited in vertical, crescent shaped columns separated by dentine used to macerate the food during mastication.

Ex: Ox, Buffalo.

Lophodont:

The ridges which the formed by the joining of cusps are called Lophos, hence the name lophodont type tooth. In this type tooth surface has intricate folding of the enamel and dentine forming transverse ridges. These teeth are large in size measuring about one foot in length and four inches in width and are used to grind the food. Ex: Elephants and Manatees.

Secodont:

Premolars and molars with sharp and knife like cusps used to shear or cut the flesh.

Ex: Carnivores.

Branchyodont:

The teeth are low crowned with long roots.

Ex: Squirrels, cheek teeth of Man.

Hypsodont:

The teeth are high crowned with short roots.

Ex: Wood rats, elephant tusks, cheek teeth of Horses.

Triconodont:

Cheek teeth having three cones are arranged in a straight line.

Ex: Fossil Mesozoic mammals.

Trituberculate Teeth:

Three cones are arranged in a triangular shape. Ex:fossil mammals.

Euthemorphic:

Cheek teeth are characterized by a square crown (4 cusps are present).

Selenolophodont:

Cheek teeth have characteristics of lophodont and Selenodont.

Dilambdodont:

Cheek teeth are characterized by w-shaped ectoloph (additional pillars of teeth).
Ex: Opossums, moles, tree shrews.

Zalambdodont:

Cheek teeth are characterized by v-shaped ectoloph. Ex: Golden moles.

8.4.5. Dental formula:

The number of teeth for each species is constant. The number and kinds of teeth in each half of the Jaw in a species of mammals can be represented by a sort of equation, which is called dental formula. Different kinds of teeth like incisors, canines, premolars and molars are indicated by the first letter i,c,pm and m. Always numerates indicates the upper Jaw and the denominator indicates the lower Jaw. The number of teeth shown by a dental formula is multiplied by 2 to get the total number of teeth.

Examples:

Man-------------	i 2/2,	c 1/1,	pm 2/2,	m 3/3	= 32
Kangaroo -------	i 3/1,	c 1/0,	pm 2/2,	m 4/4	= 34
Dog -------------	i3/3,	c 1/1,	pm 4/4,	m 2/3	= 42
Cat --------------	i 3/3,	c 1/1,	pm 3/2,	m 1/1	= 30
Cow -------------	i 0/3,	c 0/1,	pm 3/3,	m 3/3	= 32
Rabbit -----------	i 2/1,	c 0/0,	pm 3/2,	m 3/3	= 28
Rat --------------	i 1/1,	c 0/0,	pm 0/0,	m3/3	= 16
Elephant ---------	i 1/0,	c 0/0,	pm 0/0,	m 3/3	= 14
Squirrel ----------	i 1/1,	c 0/0,	pm 2/1,	m 3/3	= 22

8.4.6. Unusual Teeth:

The tusks of elephant are the upper incisor teeth with open root canals. They grow continuously throughout their life. In wild boar, the tusks are formed from lower canines, male dugong develops tusks from upper incisor. In dog the last upper premolar and the first lower molar are large and form like scissors for cutting flesh known as shearing teeth.

8.4.7. Evolution of cusps of molar teeth:

The morphogenesis responsible for the formation of molars is not clear and controversial. Different theories tried to explain the origin and evolution of molars.

8.4.7a. Concrecence theory:-

Rose proposed that the modern molars are the derivatives of the number of primitive cone shaped reptilian (S*phenodon*) teeth. Some compound molars of elephant are formed in this way.

8.4.7b. Dimer theory:-

Bolk suggested that each mammalian molar was formed by the fusion of two triconodont (row of 3 cusps) teeth. The fundamental pattern of the tooth would thus show six cusps. Since the remains of the molars of many of the earliest mammals show only three cusps and hence do not support Bolk's theory.

8.4.7c. Cope and osborn theory:-

This theory is also called as differential theory or theory of Trituberculy and is mostly accepted theory. The theory of its origin, due originally to cope, and subsequently added to and amended by osborn, is universally as the cope-osborn theory of trituberculy. Accordingly to this theory, the simple reptilian cone assumed to have elongated in an antero-posterior direction. Later two cones are formed, one at the front and the other at the hind border. Thus a triconodont tooth is formed. The cusps thus formed later rotated in opposite directions in the upper and lower jaws resulting in a tritubercular tooth. The apex of the triangular is pointed in wards in the upper jaw and outwards in the lower jaw. The cusps at the apex of the triangle represent the original repetition cone. This is named as protocone in the upper jaw and protoconoid in the lower jaw. According to some researchers the original upper molar cusp is paracone but others think that is is an amphicone which later splits into paracone and meta cone.

This theory faced criticism because it was not agreed that the protocone of the tritubercular tooth was the original reptilian cone and also there was no evidence of the rotation of cusps to form triangles.

8.5. SUMMARY:

- Amphibians are oviparous or viviparous.
- Eggs of Amphibians are small, having less amount of yolk.
- Some amphibians construct nests and protect the eggs and larvae.
- Anurans are much advanced than urodeles and Apodes in exhibiting parental care.
- Arrangement of teeth on Jaws is called Dentition.
- The teeth in mammals are limited in number.
- The detention in mammals is thecodent, diphyodont and heterodont.
- Teeth are modified in mammals according to their mode of life.

8.6. MODEL QUESTIONS:

1. Give an account of parental care in Amphibia.
2. Define dentition. Write an account of Dentition in mammals.
3. Write short notes on:-
   a. Parental care in Urodela.

b. Parental care in Anura.
c. Different types of dentition in mammals.
4. Write briefly different types of teeth in mammals.
5. What are the special teeth in mammals.
6. Write an account of dental formula.

8.7. REFERENCE BOOKS:

1. The life of Vertebrates by J.Z.Young.
2. A student text book of Zoology vol. II by Adam Sedgwick.
3. A text book of Zoology, vol. II by Parker & Haswell.
4. Vertebrate Zoology by Nigam.

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Lesson 9.1

GASTRULATION IN *AMPHIOXUS*

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9.1.1 OBJECTIVES:

The purpose of this lesson is to describe:

- the gametes, fertilization and cleave patterns and
- different processes involved in blastulation and gastrulation of *Amphioxus*.

9.1.2. INTRODUCTION:

The study of Embryology of *Amphioxus* has taxonomic significance. The early stages of development exhibit close resemblance with such non-chordates as echinoderms. At the same time, it represents vertebrate development in its simplest form. Therefore, it is regarded to exhibit possible link between non-chordates and chordates.

9.1.3. GAMETES:

In *Amphioxus* sexes are separate but without sexual dimorphism. The gonads are about 27 pairs. They occur in two rows one on either side of the body. They show a metameric arrangement from 25 to 51 segments. Gonoducts are absent. The mature sperms and ova are shed into the atrium by bursting of the walls of gonads at certain places called *Cicatrices*. Gametes escape through the atriopore into the sea water where fertilization and development takes place.

i. Sperm

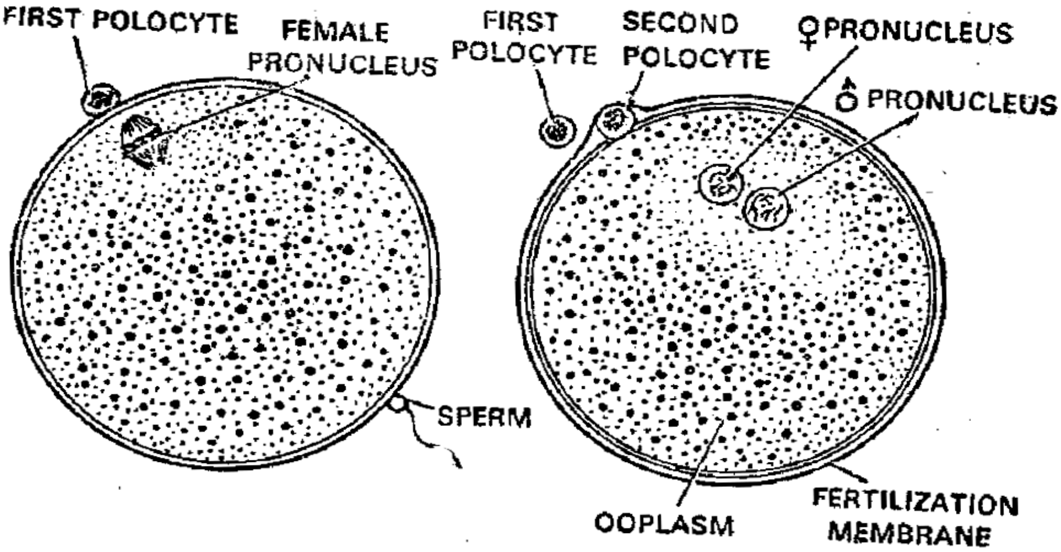
The sperm is the smallest recorded one in chordates. It is only about 18 μ long. It is differentiated into head, middle piece and tail.

ii. Egg

The egg is spherical and about 0.12 mm in diameter. It is enclosed in a thin vitelline membrane. The egg contains a small quantity of yolk and hence it is called microlecithal egg. The yolk is scattered uniformly through out the cytoplasm except for a peripheral layer with granular mitochondria. The nucleus lies on the side just beneath the peripheral layer of mitochondria. The egg is shed at the secondary oocyte stage and the first polar body lies out side the vitelline membrane.

9.1.4. FERTILIZATION:

Fertilization is external. It takes place in the sea, where eggs and sperms are shed Sperm enters the egg, which is at the secondary oocyte stage, near the vegetative pole. When sperm enters the egg its vitelline and perivitelline membranes fuse to form the fertilization membrane. The egg undergoes second maturation division forming second polar body which lies near the animal pole. The two pro-nuclei fuge slightly above the equator of the ovum and zygote nucleus is formed. A zygote nucleus with 24 diploid number of chromosomes is formed just above the equator by mixing up of the chromosomes of the egg and sperm nuclei.



Fig, 9-1. Fertilization of the ovum

9.1.5. PRESUMPTIVE AREAS:

The cytoplasm of the egg undergoes rearrangement to establish presumptive areas, to produce definite structure of the embryo. These are known as the organ forming substances. The egg showing a definite pattern of presumptive areas is called the mosaic egg. The fertilization stimulates the egg to start cleavage.

9.1.6. CLEAVAGE:

The cleavage in *Amphioxus* is total or holoblastic. It begins about an hour after fertilization. It follows a definite pattern.

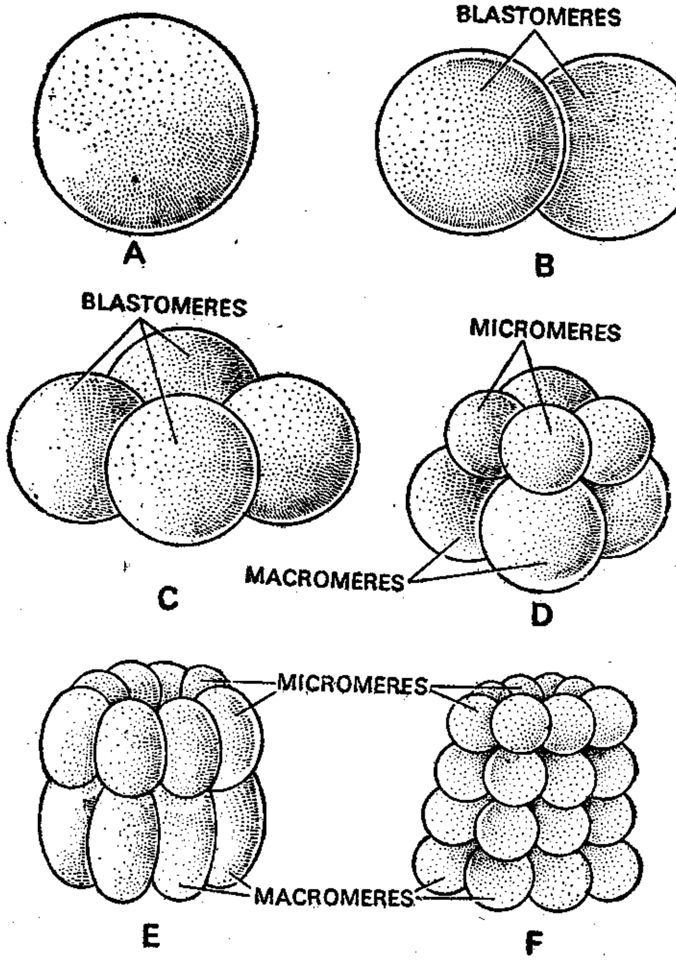
(i) **First cleavage:** The first cleavage is vertical. It passes through both the poles of the zygote. The first two blastomeres are exactly equal and shows bilateral symmetry of the adult (Fig. 9.2B).

(ii) **Second cleavage:** It is also vertical but at right angle to the first. It produce four equal blastomeres, two anterior and two posterior (Fig. 9.2C).

(iii) **Third cleavage:** It is horizontal and passes slightly above the equator. It forms eight blastomeres, of which the upper four are a little smaller than the lower four the smaller ones are called micromeres and the larger ones, the macromeres (Fig. 9.2D).

(iv) **Fourth cleavage:** It is again vertical. It occurs in two planes at right angles to each other producing sixteen cells with upper eight micromeres and lower eight macromeres (Fig. 9.2E).

Fig.9-2.Cleavage in *Amphioxus* zygote



(v) **Fifth cleavage:** It is horizontal and takes place in two planes one in the micromeres and one in the macromeres. It gives 32 cells which are arranged in four tiers of eight cells each (Fig. 9.2F).

(vi) **Sixth cleavage:** It is vertical, dividing every cell into two meridionally. It results in a total of 64 cells, which lie in four tiers of 16 cells each. After this, the cleavage becomes somewhat irregular the micromeres dividing a bit faster than the macromeres.

9.1.7. BLASTULATION:

From early cleavage, the blastomeres become rounded off and secrete a jelly. Later the jelly absorbs water and swells up. The fluid pushes the cells outwards around it. The fluid filled space is called the blastocoel or segmentation cavity, and the embryo is now called Blastula. The blastula is fully formed about 5 hours after fertilization. It has one cell thick wall consisting of partly of micromeres and partly of macromeres. It is not perfectly spherical, but is slightly pear shaped, its pointed end being posterior.

9.1.8. ORGAN FORMING SUBSTANCES DURING BLASTULATION:

The small and clear micromeres present in the antero-ventral part of the animal half represent the future ectodermal area, the large yolky macromeres at the mid-dorsal part represent the future endoderm plate. The group of smaller granular cells at posterior and lateral sides of the endoderm represents future mesodermal area. Just anterior to the endodermal area is a group of small chorda cells, which gives rise to notochord. Between chorda cells and ectoderm found a small specialised ectodermal cells called future neural plate.

9.1.9. GASTRULATION:

Gastrulation starts about six hours after fertilization and is completed in about four hours. It involves movement of the germ layers i.e., ectoderm, mesoderm and endoderm from the surface of the blastula to their proper position. It occurs by three processes.

1. Invagination
2. Involution
3. Epiboly and Growth of the lips

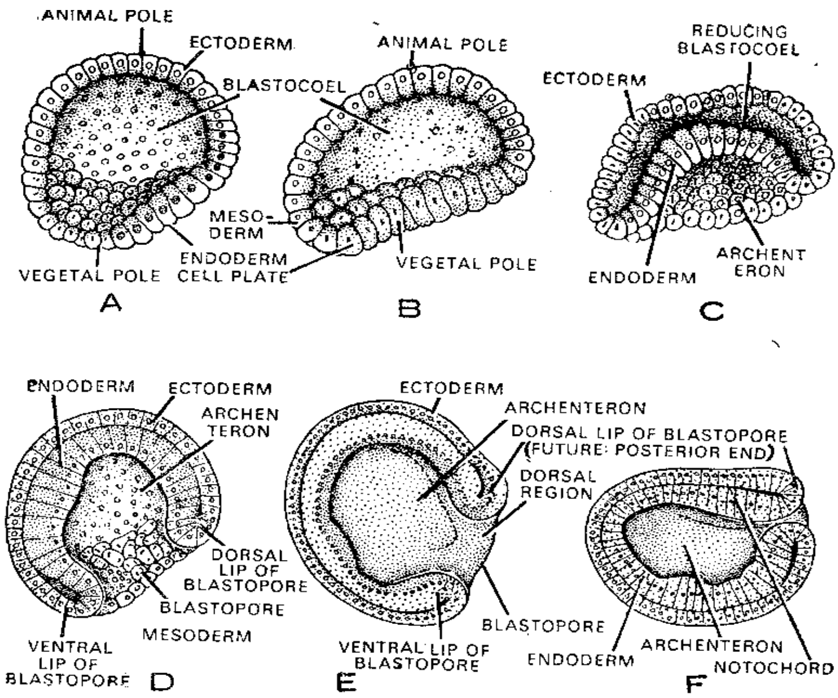


Fig.9-3. Process of gastrulation

10. (i) Invagination: The first indication of gastrulation is the flattening of the dorsal surface of the blastula to form an endodermal plate. It sinks gradually into the blastocoel which thus reduced progressively. The endodermal plate almost meets the presumptive ectoderm on the opposite side, producing a two layered cup like embryo, the early Gastrula. The sinking process is called invagination. The shallow cavity of the early gastrula is known as the Archenteron or Gastrocoel, its wide opening, the blastopore, and its circular rim, the lips of the blastopore. The dorsal lip is formed by the presumptive notochord, and lateral lip and ventral lip are formed by the presumptive mesoderm.

ii) Involution: While invagination of ectodermal plates is progressing, the presumptive notochord cells of the dorsal lip roll from exterior over its edge into the interior. This process is called involution.

iii) Growth of the lips: The form of the gastrula changes by growth of its lips. First the dorsal lip rapidly grows backwards. This is followed by a similar growth of the lateral lips. Then the ventral lip grows upwards reducing the blastopore considerably. Due to faster growth of the dorsal lip, the blastopore shifts to a posterior position.

The Gastrula is now complete. It has slightly elongated two layered body with a deep archenteron and a very small blastopore. Its outer layer consists of the presumptive ectoderm all over except presumptive neural plate on the dorsal side, the inner layer presumptive notochord in the mid dorsal line, a tract of presumptive mesoderm on either side of the presumptive notochord and endoderm in the lateral and ventral position. The blastocoel has completely disappeared due to closeness of the two layers of the embryo.

9.1.10. SUMMARY:

1. In *Amphioxus* sexes are separate without sexual dimorphism.
2. Fertilization is external and takes place in sea water.
3. Cleavage is holoblastic.
4. Blastulation and Gastrulation are by invagination, involution and growth of the lips.

9.1.11. KEY WORDS:

Mosaic egg: The egg showing a definite pattern of presumptive areas is called mosaic egg.
Blastocoel: The fluid filled cavity in the blastula
Archenteron: The principle cavity within the early gastrula.
Cicatrices: Bursting of gonads at certain points called cicatrices.

9.1.12. MODEL QUESTIONS:

1. Describe the development of *Amphioxus* upto the formulation of 3 germinal layers.

9.1.13. REFERENCE BOOKS:

1. P.S. Dhami, J.K. Dhami, R. Chand & Co.
2. P.S. Verma, V.K. Agarwal, S. Chand & Co.
3. V.B. Rastogi & M.S. Jayaraj, Schem & Co.
4. Vertebrate Embryology by McEWEN.
5. Embryology of Chordates by Huetner

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Lesson 9.2

GASTRULATION IN FROG

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9.2.12 REFERENCE BOOKS

9.2.1. OBJECTIVES:

The purpose of this lesson is to describe:

- the gonads, gametes, fertilization, cleavage patterns and blastulation and the different processes involved in gastrulation of Frog.

9.2.2. INTRODUCTION:

An understanding of frog and other amphibian development is fundamental to the interpretation of chick and mammal development. In frogs, the sexes are separate, the sexual dimorphism is well marked. The male frog has copulatory pads on the palms of the fore limbs and also possesses vocal cards.

9.2.3. GONADS AND GAMETES:

i) The Testes: Testes are a pair of whitish oval bodies attached to the upper end of kidneys. They are attached by mesorchium. Spermatogonia undergo spermatogenesis and form spermatozoa.

ii) The Sperm: A mature sperm averages about 0.03 mm in length. The head is elongated and it consists of nucleus and pointed acrosome. The middle piece is short, the tail is filamentous and longer than the head.

iii) Ovary: The ovaries are paired multi lobular organs attached to the dorsal body wall by meso-ovarium. The growing ovary has several hundreds of ovarian follicles. After the process of oogenesis, multiplication, growth and maturation phase, the egg is released in the secondary oocyte stage.

iv) Egg: The mature oocyte of frog measures about 400 to 500 μ in diametre. It is spherical in form and is covered by a vitelline membrane and a thick jelly coat. The ripe amphibian egg is differentiated into:

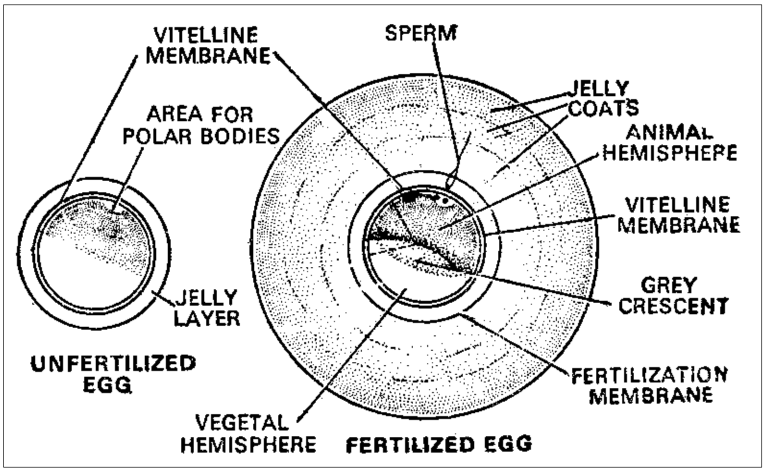


Fig. 9-4. Unfertilized and fertilized egg of frog

a) Vegetal half: It is white in colour. It contains densely packed mass of yolk.

b) Animal half: It is dark brown in colour. Its cytoplasm is rich in pigment granules. The nucleus lies in this region.

c) Marginal zone: It is found between animal and vegetal half. The ooplasm of the egg is differentiated into cortex and endoplasm.

9.2.4. FERTILIZATION:

Fertilization is external. The sperms are deposited on the eggs before these come in contact with water. The sperm enters the ovum in animal hemisphere region. The entire sperm enters the ovum but only sperm head proceeds towards the female pronucleus. Finally, the male and female pronuclei fuse together to form zygote nucleus.

9.2.5. CLEAVAGE:

The Amphibian egg is telolecithal. The cleavage is holoblastic.

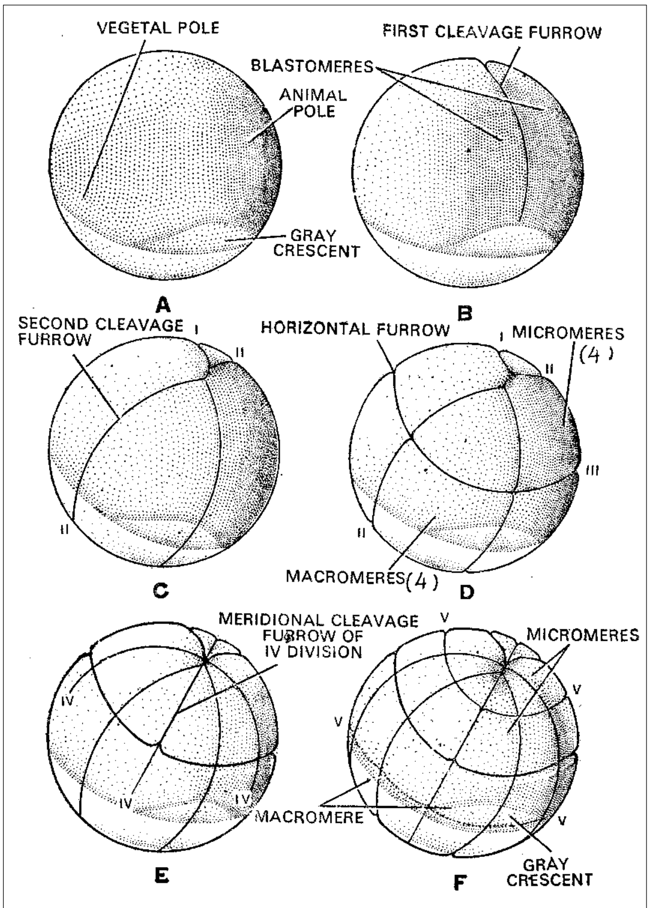


Fig. 9-5 Cleavage in Frog's egg

i) First cleavage: The first cleavage is meridional and bisects the egg into two identical blastomeres. The first cleavage takes place after 3 hours of fertilization.

ii) Second cleavage: It is also meridional but at right angles to the first one.

iii) Third cleavage: It is horizontal but at right angles to the first two cleavage furrows. Its cleavage furrow is slightly above the equator towards the animal pore. The upper four blastomeres are smaller and are known as micromeres, the lower four blastomeres are large and are known as macromeres.

iv) Fourth cleavage: It is again vertical and comprises of two cleavage furrows laid down simultaneously. The egg attains 16 celled stage.

v) Fifth cleavage: It also comprises of two cleavage furrows, laid down horizontally one in the animal pole and other in the vegetal pole. Therefore 32 blastomeres are formed and are arranged in four tiers. The upper two tiers (16 cells) are formed of micromeres and lower two tiers are of macromeres.

From now onward the regularity in cleavages is lost and micromeres divide faster than macromeres. The micromeres are present in the animal pole and the macromeres are found in vegetal pole.

9.2.6. BLASTULA:

When embryo at 8 celled stage, a cavity appears. This cavity is known as blastocoel. The blastocoel increases in size and at 32 celled stage it becomes very distinct.

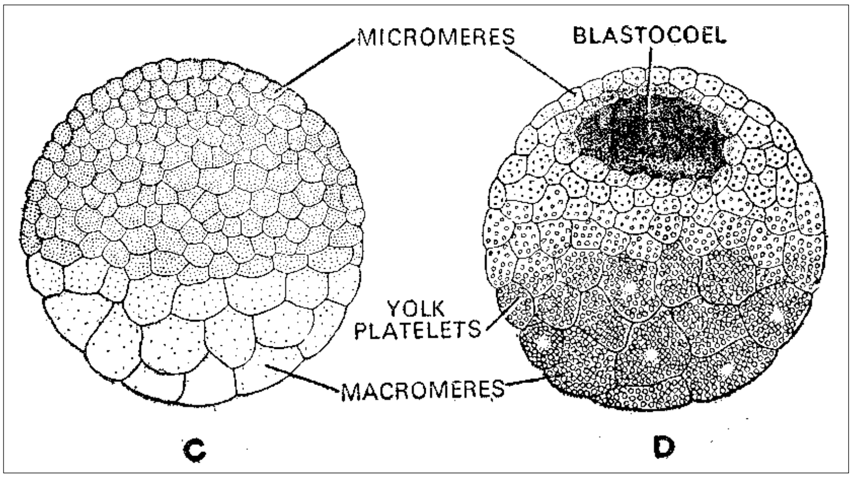


Fig. 9-6. V.S. blastula of frog. A--Early blastula, B—Late blastula

Blastula appears as a hollow sphere enclosing blastocoel. The roof of blastocoel is formed of two or more layers of micromeres and its floor is formed of large sized macromeres.

After 32 celled stage a gradient of cleavage is established. The most active region being animal pole and least active region is vegetative pole. Due to active division of micromeres in the animal pole, the cells start growing over the macromeres in the equatorial region and form a pigmented girdle. This girdle is known as germ ring.

9.2.7. FATE MAP OF BLASTULA:

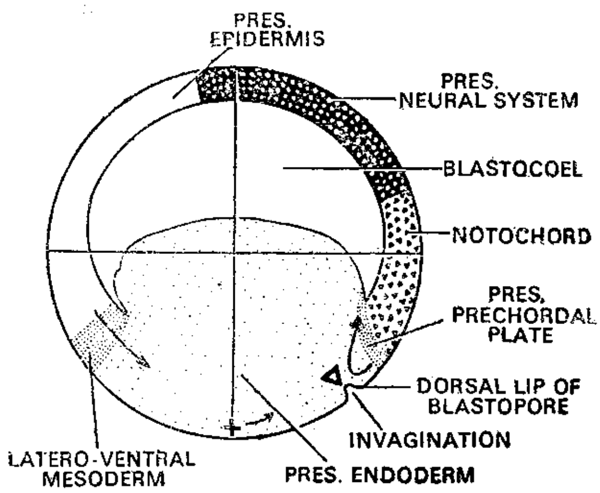
A fate map of blastula of frog shows presumptive areas of future organs. The surface of blastula has been divided into 3 areas. The pigmented area on and around the animal pole represents the presumptive ectoderm. The grey crescent and marginal zone represents notochord and mesoderm of embryo. Vegetative pole constitute the future endoderm.

9.2.8 GASTRULATION:

During Gastrulation, the differentiation of three germ layers and the movement of organ forming areas from the surface of blastula to their respective positions in the embryo takes place. The mass migration of cells during gastrulation is described as formative movements. They are:

i) Epiboly

The micromeres of the animal pole of blastula continue to divide rapidly and grow downward from all directions towards vegetal pole. This spreading of micromeres over macromeres is described as epiboly. The cells of presumptive ectoderm cover the entire surface of the embryo except in the region of blastopore.



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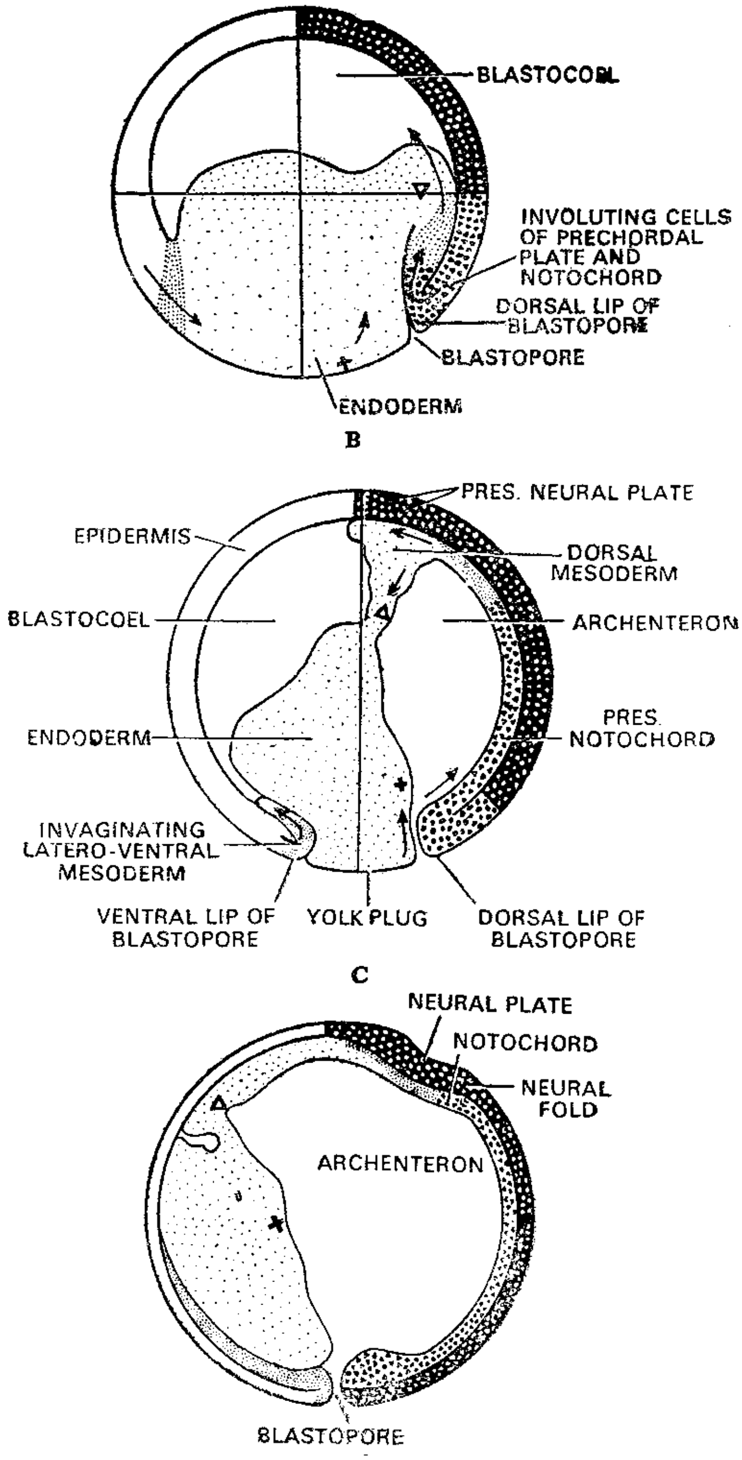

Fig.9-7. Diagrammatic section of amphibian embryo showing the migration and
Fig.9-7. Diagrammatic section of amphibian embryo showing the migration and final position of different cell regions during gastrulation

ii) Invagination

The macromeres are therefore pushed inside into the blastocoel. The process is known as pseudo-invagination. As a result, crescent shaped groove appears at the marginal zone where grey crescent meets the vegetal macromeres. This groove marks the beginning of archenteron. Its opening is known as blastopore and upper margin of the groove is dorsal lip of blastopore. The cells of the outer most layer of sinking endoderm assume bottle shaped appearance.

iii) Involution of pharyngeal endoderm and chorda-mesoderm

The endoderm cells around the dorsal lip of blastopore are the first to migrate inward. These represent the future pharyngeal endoderm. The cells of chorda-mesoderm move towards the blastoporal lip, pass curved the rim of blastopore and finally involute into the blastocoel forming an internal layer.

iv) Convergence

The pharyngeal endoderm and chorda-mesoderm have flown inward around the rim of blastopore. The cells move away from the blastopore and converge in the middle line, forming a layer of future chorda-mesoderm between the ectoderm and endoderm. These form the roof of Archenteron.

v) Formation and contraction of blastoporal lips

The dorsal lip is formed by the involution of micromeres of the grey crescent. The invagination increases and spreads laterally, so crescent shaped blastopore appears as half moon, then horse shoe shaped and finally as a full circle. Its lateral lips are formed by invagination of micromeres of marginal zone on the lateral side. These entered boundary between marginal zone and the vegetal region ultimately meet mid ventrally forming ventral lip of blastopore. The cells of vegetal pole visible through the completed blastopore are known as yolk plug. At the end of gastrulation the blastopore is recognizable only as a slit and protruding yolk plug is drawn inside into Archenteron.

9.2.9. SUMMARY:

1. The sexes are separate. Sexual dimorphism is evident.
2. Fertilization is external
3. Cleavages are holoblastic
4. Eggs are telolecithal or mesolecithal
5. Gastrulation takes place by Epiboly, Invagination, Involution, Convergence and Contraction of blastoporal lips.

9.2.10. KEY TERMINOLOGY:

Spawn: A group of eggs enclosed in jelly.

Telolecithal: Unequal distribution of yolk in the egg is called telolecithal.
Cortex: The superficial layer of ooplasm which underlies the plasma membrane of the egg.
Amphimixis: The male and female pronuclei fuse together to form the zygote is called Amphimixis.
Yolk plug: The cells of vegetal hemisphere visible through the completed blastopore are known as yolk plug.

9.2.11. MODEL QUESTIONS:

1. Describe the process of Gastrulation in Frog.
2. Write short notes on:
   a) Fertilization in Frog
   b) Fate map of Blastula

9.2.12. REFERENCE BOOKS:

1. P.S. Dhami, J.K. Dhami, R. Chand & Co.
2. P.S. Verma, V.K. Agarwal, S. Chand & Co.
3. V.B. Rastogi & M.S. Jayaraj, Schem & Co.
4. Vertebrate Embryology by McEWEN.
5. Embryology of Chordates by Huettner

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Lesson 9.3

GASTRULATION IN CHICK

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c) Formation of Axial structures
d) Extension of Embryonic axis
9.3.10 SUMMARY
9.3.11 KEY TERMINOLOGY
9.3.12 MODEL QUESTIONS
9.3.13 REFERENCE BOOKS

9.3.1. OBJECTIVES:

The purpose of this lesson is to describe:

- the gonads, gametes, fertilization, cleavage patterns and blastula, and the process of gastrulation in chick.

9.2.2. INTRODUCTION:

The evolution of land laid eggs marked a great advance in the history of life on earth. The chick embryology bears many resemblances with that of reptiles and mammals.

9.3.3. GONADS:

i) Testes

The testes are white coloured ovoid bodies which remain attached by peritoneum to the anterior end of kidneys. Sperm maturation occurs inside the seminiferous tubules. Sperm of fowl is about 50 μ in length, head is short with pointed acrosome and tail is long.

ii) Ovary

The female has only one functional ovary and a single oviduct. It is present on the left side. The ovary consists of ovarian follicles with central oocyte. The fully developed oocyte breaks through ovarian wall, ruptures the follicle and comes out into coelom near infundibulum of the oviduct (Fig. 9.8).

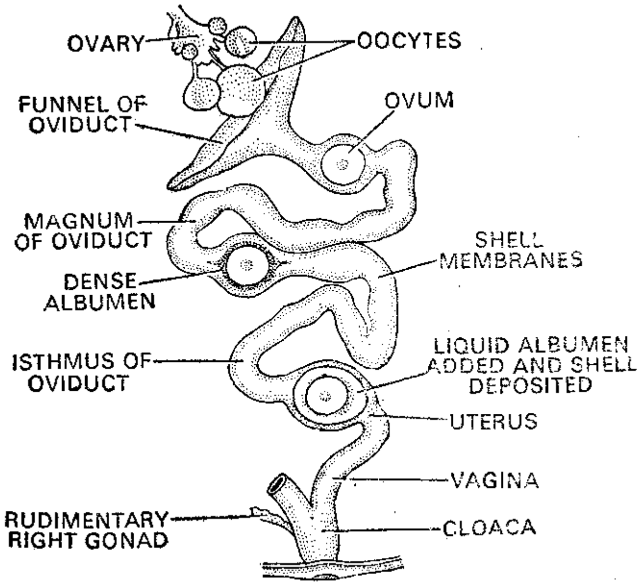

Fig. 9-8. The passage of egg in the oviduct of hen and the deposition of egg membranes (After Gilchrist, 1968)

9.3.4. FERTILIZATION:

Fertilization occurs in the anterior part of the oviduct. A number of spermatozoa enter the ovum. Only one sperm nucleus fuses with the egg nucleus. Fertilized egg moves down the oviduct.

9.3.5. STRUCTURE OF HEN'S EGG AT THE TIME OF LAYING:

The egg is released from the ovary in the form of primary oocyte. The oocytes remain covered by egg membrane. The oocyte is received by the oviduct through oviducal funnel. Fertilization occurs in this upper part of the oviduct. After fertilization when the egg passes downwards through oviduct, it receives thick albumen and form a chalaziferous layer. Oocyte again receives dense albumen above the chalaziferous layer and form a shell membrane. The egg further received a calcareous porous shell in the uterus. Now the fertilized egg laid on the land.

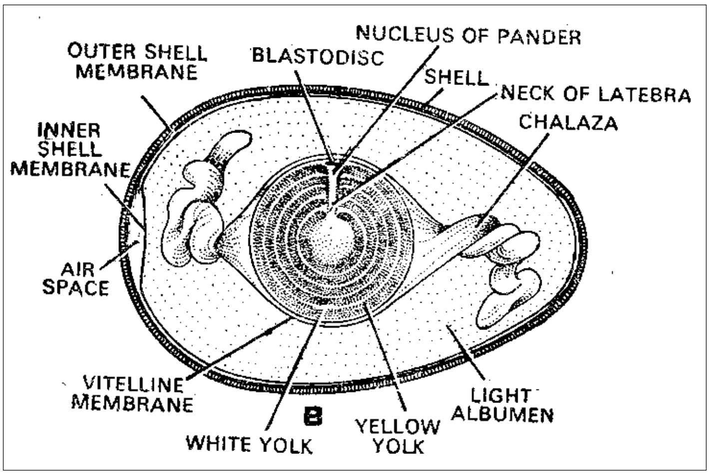

Fig. 9-9. Hen's egg.

The eggs of hen are polylecithal and macrotelolecithal. The fertilized egg covered by various other parts .

a) Egg Shell

The outer most calcareous hard part of the egg is the egg shell which is meant for protection of egg. The shell bears numerous pores to allow the embryo to carry on exchange of gases.

b) Shell membrane

Below the calcareous shell white coloured shell membranes are present. The shell membranes are double layered. The two shell membranes remain close in contact except at the broader end of egg where air space is present.

c) Albumen

Shell membrane encloses three layers of albumen. Outermost layer is thin, the middle layer is dense, and the inner most layer is forming chalazae.

d) The Egg Cell

It is also called ovum. The ovum consists of large amount of yolk surrounded by the albumen. Yolk and albumen are separated by a thin vitelline membrane. There are two kinds of yolk called yellow

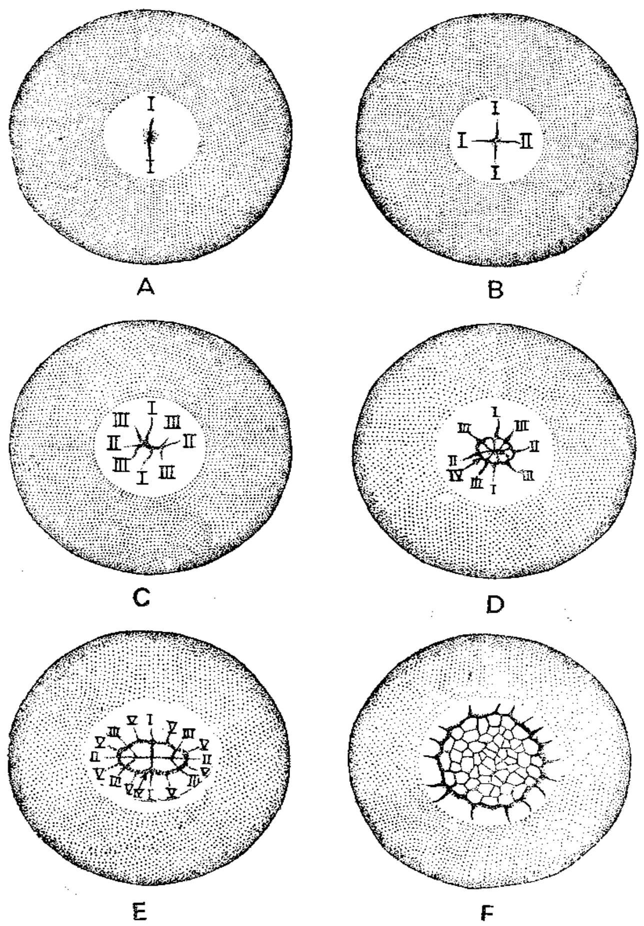

Fig. 9-10. Early cleavage in Hen's egg in surface view.
A-First cleavages; ***B***-Second cleavage; ***C***-third cleavage; ***D***-fourth cleavage;
E-fifth cleavage; ***F***-early morula.

yolk and white yolk. They are arranged in alternate concentric layers. White yolk is accumulated heavily in the central region forming a flask shaped area called latebra. The neck of latebra below the blastodisc is called nucleus of pander.

e) Blastodisc

The blastodisc is just above the nucleus of Pander. The egg nucleus lies in the blastodisc.

9.3.6. CLEAVAGE:

Shortly after fertilization while descending through oviduct the egg undergoes a series of divisions called cleavage of the egg. The process of cleavage occurs in the blasto disc only. The mass of yolk inside the egg does not divide. This type cleavage limited to small area, i.e., blastodisc is called discoidal cleavage or meroblastic cleavage (Fig. 9.10).

i) First cleavage

It is vertical, parallel with the axis of egg. The first cleavage divides only the central part of the blastodisc. It occurs in the upper part of the oviduct.

ii) Second cleavage

The second cleavage is also meridional at right angles to the first one resulting into four cells called blastomeres. It occurs in the middle part of the oviduct.

iii) Third cleavage

The four blastomeres are divided by third cleavage furrow resulting into 8 blastomeres. The third cleavage passes parallel with first one.

iv) The Fourth cleavage

The fourth cleavage now begins to cut the apical ends of the eight cells. As a result, the peripheral portions of eight cells are separated from their central portions. Thus fourth cleavage furrow forms a complete circle. It occurs in the uterus.

After the fourth cleavage there is no definite sequence of divisions. However, there are two types of divisions. The central division which cut more apical ends of the cells form central cells, radial furrows and divide the peripheral cells. The entire mass of cells produced is called blastoderm. At the same time, the horizontal cleavages also occur. These cleavages resulting into several cell layered thick central blastoderm. In the mean time, fluid starts accumulating between the multilayered blastoderm and the underlying yolk. The fluid filled space formed is called sub germinal cavity. The peripheral portion remain unsegmented, this is called periblast. Now cleavage also occurs in the region of periblast. The cells of the periblast lie over the yolk. These cells digest the yolk and form extra embryonic endoderm. The germinal disc or blastodisc is divisible into a central transluscent area – area pellucida, and the peripheral darker area, -area opaca lying above the solid yolk.

9.3.7. DISCO BLASTULA:

The sub germinal cavity of the chick is commonly compared with the blastocoel of other vertebrates and this stage of development is called blastula.

9.3.8. FATE MAPS OF DISCO BLASTULA:

The blastoderm in disco blastula of chick consists of two parts. The area pellucida and area opaca. The anterior area pellucida is future ectoderm, a crescentic area is neural plate, next to neural plate is notochord which is followed by mesoderm.

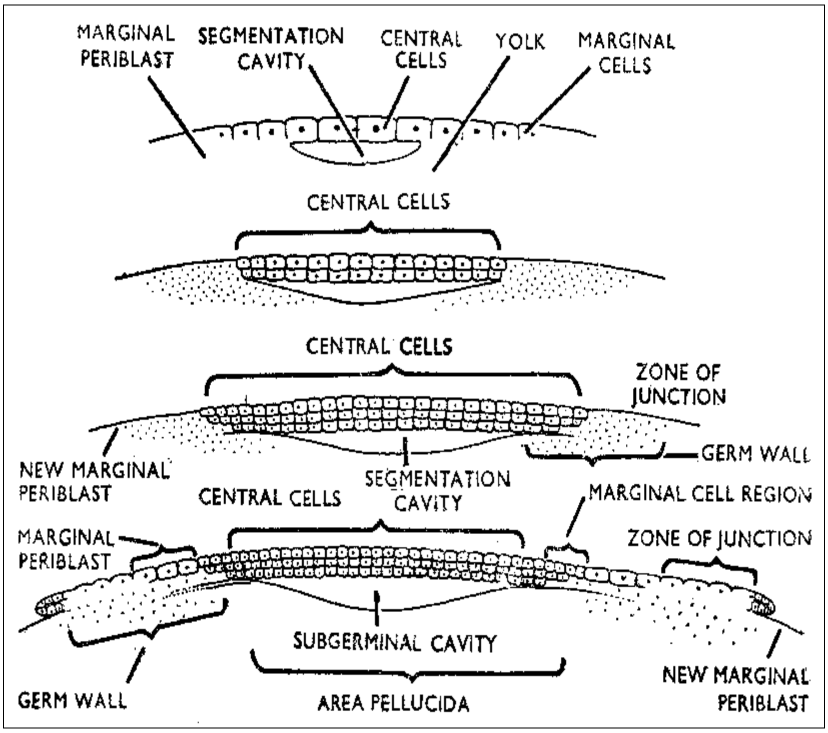

Fig. 9-11. V.S. blastoderm of Hen's egg showing different cleavage stages and formation of central and marginal cells

9.3.9. GASTRULATION:

In chick, the process of gastrulation can be studied in following four phases.

a) Formation of Embryonic Endoderm

Most of cells split away or delaminate from the lower layer of 3 to 4 cells thick blastoderm into the sub germinal cavity. Finally these cells become continuous in the floor of sub-germinal cavity and thus the hypoblast or the embryonic endoderm is established. In this gastrula stage, there is an outer layer called epiblast and an inner layer known as hypoblast or embryonic endoderm. Sub-germinal cavity now becomes the archenteron. The epiblast contains future notochord, mesoderm and ectoderm. About this stage of development, the egg is usually laid. Further development of the egg is resumed if incubated by the parents.

On incubation marginal cells of area opaca start spreading over the yolk by engulfing and digesting it. In this way extra embryonic endoderm is formed.

b) Formation of Embryonic Mesoderm and primitive streak

Some cells from the posterior part of the epiblast begins to migrate inward from each side. In the beginning, this migration of cells is very slow but soon there is a rapid mass movement of the cells, so that at the end, the epiblast consists of ectoderm alone. The migrating cells collect on the surface of the blastoderm along the middle line forming an opaque, dark, longitudinal band called primitive streak. The primitive streak bears a swelling at its anterior end which is called Hensen's node. This node consists of cells of future notochord. The primitive streak gradually elongates by adding more cells and the area pellucida becomes pear shaped with broader end on the anterior side.

A large number of cells split off and leave the primitive streak. These cells migrate on both the lateral sides into the sub-germinal cavity forming a layer of mesoderm cells. Due to migration of mesoderm cells from the primitive streak a groove appears along the whole length of the primitive streak and is called primitive groove. Primitive groove is continued in the Hensen's node in the form of a pit known as primitive pit. Primitive streak is fully formed by 19^{th} hour of incubation.

c) Formation of Axial structures

The cells from Hensen's node migrate forward into the sub-germinal cavity forming a rod of cells called notochord.

Some ectodermal cells of area pellucida situated above the notochord become thick to form the neural plate.

d) Extension of Embryonic Axis

At this stage, i.e. 20 hours of incubation, the lengthwise extension of embryo begins. Hensen's node regresses and its remnant is called the end bud. The primitive streak gradually decreases in length.

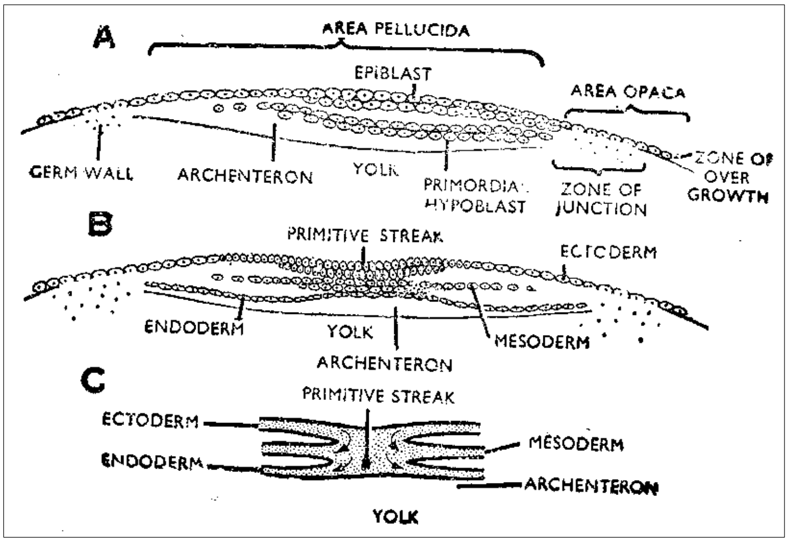

Fig. 9-12. Diagram showing gastrular movement

The embryo is formed from the cells of and around the primitive streak in the area pellucida. Area opaca which is also called extra embryonic area because it does not form any part of the embryo. The extra embryonic area also consists of ectoderm, mesoderm and endoderm layers.

Gastrulation in chick is very much different from amphibians and mammals due to telolecithal nature of egg.

9.3.10. SUMMARY:

Gastrulation is complete by the end of the first day of incubation. Endoderm reaches its proper place, the primitive streak, with its primitive knot, primitive pit and primitive groove is formed. Area pellucida becomes pear shaped. Formation of notochord and mesoderm begins. Neural folds appear and begin closing.

9.3.11. KEY TERMINOLOGY:

Epiblast: The outer or upper layer of a double layered embryo.
Meroblastic: The involvement of cleavage at restricted area of the animal pole of the egg.
Hypoblast: The inner or lower layer of double layered embryo.

9.3.12. MODEL QUESTIONS:

1. Describe the hen's egg at the time of laying.
2. Discuss the Gastrulation in chick.
3. Short notes:
   a) Primitive streak.
   b) Cleavage in Hen's egg

9.3.13. REFERENCE BOOKS:

1. P.S. Dhami, J.K. Dhami, R. Chand & Co.
2. P.S. Verma, V.K. Agarwal, S. Chand & Co.
3. V.B. Rastogi & M.S. Jayaraj, Schem & Co.
4. Vertebrate Embryology by McEWEN.
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Lesson 10.1

DEVELOPMENT OF CHICK UPTO 24 HOURS

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10.1.1. OBJECTIVES:

The purpose of this lesson is to:

- describe the development of chick embryo upto 24 hours.

10.1.2. INTRODUCTION:

The chick embryology is usually studied according to the hours of incubation of eggs. Actually the age of chick embryo is designated in terms of hours of incubation and in terms of number of somites.

10.1.3. DEVELOPMENT OF CHICK EMBRYO:

By the end of the first day of incubation, an embryonic and extra-embryonic regions of the blastoderm become sharply defined. The rapidly growing head rises above the blastoderm and projects forward as a cylindrical part of the embryo and over hangs the proamnion region.

After 20 hours of incubation, the mesodermal cells in the area opaca collect to form small groups. The inner cells of these groups develop into blood corpuscles. The blood corpuscles become surrounded by an epithelium which develops from the peripheral cells of the group. Now these groups of cells having blood corpuscles are called blood islands. These numerous blood islands differentiate the area opaca into two regions. A central area, vasculosa having blood islands and a peripheral area, vitellina devoid of blood islands. Area vitellina surrounds the area vasculosa.

Alimentary canal starts developing in the form of a fold, the head fold. It is a curved fold which extends from one side of the area pellucida upto other side. This fold constitutes ectoderm and endoderm. With further development head fold rises above the blastoderm and projects forward as a cylindrical part of the embryo. The head fold is now lifted up from the surface of underlying yolk. A cavity appears in the head fold. It is lined by endoderm. It is the beginning of foregut. The wide opening of foregut is called anterior intestinal portal.

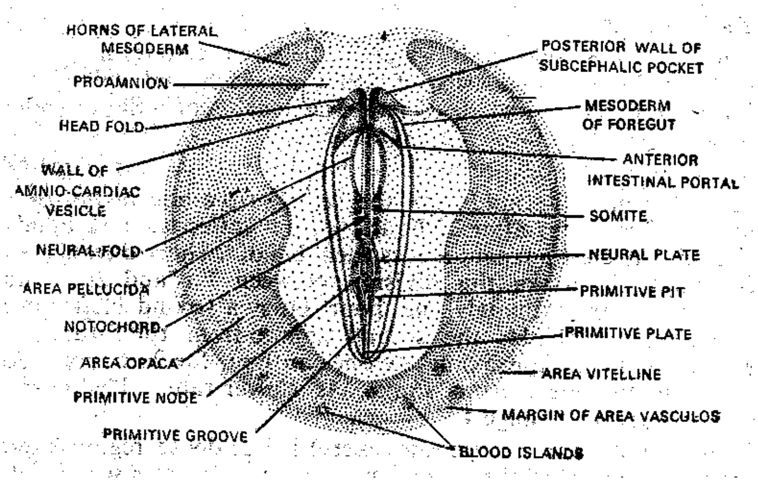

Fig.10-1. Whole mount of a 24 hour chick [viewed by transmitted light (x17)]

Development of nervous system begin during gastrulation. The dorsal ectoderm above the notochord becomes thick to form the neural plate. The median portion of neural plate sinks and its edges are raised up as neural folds. Thus the neural groove is formed. Neural folds fuse with one another to form the neural tube.

The notochord develops as a rod of cells in the gastrula. A sheath of mesenchymal cells develop around the rod.

The mesoderm developed in the gastrula stage spreads laterally on both the sides of primitive streak. The lateral wings of mesoderm grow upward to occupy in the cephalic region of the embryo. The middle of mesoderm is thickest. This portion is termed as dorsal mesoderm. Laterally the mesoderm becomes thinner and is called lateral mesoderm. A small portion of mesoderm in between the dorsal and lateral mesoderm is called intermediate mesoderm. The dorsal mesoderm is also called segmental zone because in the twenty first hour of incubation and later on, it becomes segmented by transverse grooves resulting in the formation of somites. First somite appears in the twenty first hour of incubation.

Regular addition of somites as the embryo grows in age makes the number of somites most reliable indicator of the stage of development.

10.1.4. SUMMARY:

1. The primitive streak is formed.
2. Area vasculosa and area vitellina observed.
3. Embryo at 24 hours shows 4 pairs of somites.

10.1.5. KEY TERMINOLOGY:

Area vasculosa: Area opaca having blood islands is called Area vasculosa.
Area vitellina: Area opaca devoid of blood islands is called Area vitellina.
Somites: Dorsal mesoderm segmented by transverse grooves resulting into formation of somites.

10.1.6. MODEL QUESTIONS:

1. Describe in detail the development of 24 hours chick Embryo.

10.1.7. REFERENCE BOOKS:

1. P.S. Dhami, J.K. Dhami, R. Chand & Co.
2. P.S. Verma, V.K. Agarwal, S. Chand & Co.
3. V.B. Rastogi & M.S. Jayaraj, Schem & Co.
4. Vertebrate Embryology by McEWEN.
5. Embryology of Chordates by Huettner

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Lesson 10.2
EXTRA EMBRYONIC MEMBRANES IN CHICK
or
FOETAL MEMBRANES IN CHICK

CONTENTS

10.2.1 OBJECTIVES
10.2.2 INTRODUCTION
10.2.3 YOLK SAC
10.2.4 AMNION AND CHORION
10.2.5 ALLANTOIS
10.2.6 SUMMARY
10.2.7 KEY TERMINOLOGY
10.2.8 MODEL QUESTIONS
10.2.9 REFERENCE BOOKS

10.2.1. OBJECTIVES:

The purpose of this lesson is to:

- describe the formation and structure of extra embryonic membranes and their functions in chick embryo.

10.2.2. INTRODUCTION:

In addition to the embryo proper, the blastoderm also forms certain other structures outside the embryo. These are extra embryonic structures. All of these extra embryonic membranes are composite structures. They involve two germ layers. The extra embryonic structures are yolk sac, amnion, chorion and allantois.

The amnion and chorion are composed of extra embryonic ectoderm. Somatic layer of mesoderm is called somatopleure, while yolk sac and allantois are composed of extra embryonic endoderm. While splanchnic mesoderm called splanchnopleure.

10.2.3. YOLK SAC:

This is the first membrane to develop in the embryo. The blastoderm expands, the extra embryonic splanchnopleure to spread over the yolk mass and eventually enclose the yolk in large measures and becomes yolk sac. Foregut and hindgut develops in the embryo. Between foregut and hindgut lies still undifferentiated mid gut. With the growth of foregut and hindgut, midgut narrows gradually and finally leaving a small portion connected with the yolk sac. This is yolk stalk. The yolk sac is connected to the digestive tract by the yolk stalk. The endodermal surface of the yolk sac is thrown into folds that penetrate the yolk mass. The digestive enzymes produced by the endodermal cells digest, the yolk and is ultimately absorbed by the endodermal lining of yolk and transported to the embryo by vitelline vein. The yolk however is completely absorbed during embryonic life.

Functions:

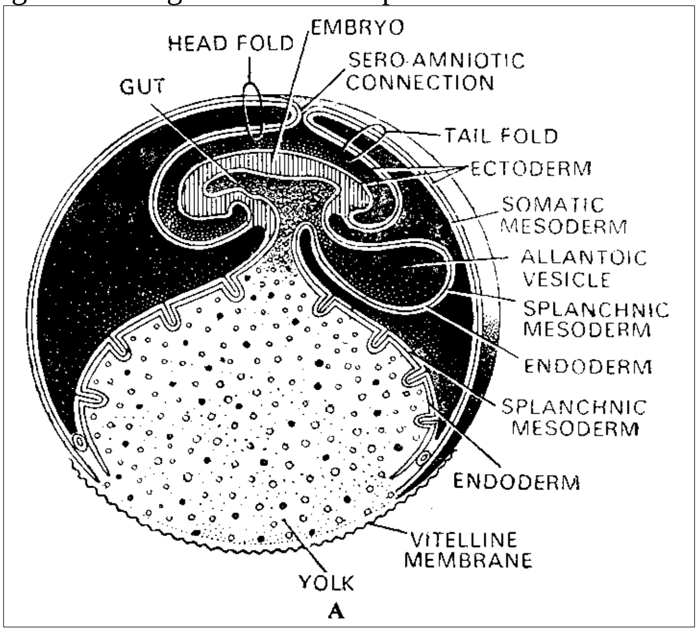
Yolk is real food of developing embryo. Thus yolk sac provides nutrition to the developing embryo.

10.2.4. AMNION AND CHORION:

Being closely associated in origin and development, amnion and chorion are always described together. Both are derivatives of extra embryonic Somatopleure.

Amnion begins to develop in the 30th hour of incubation. Head of the embryo sinks in the yolk and at the same time the somatopleure, just anterior to the head forms a fold called the head fold. Head fold points towards the tail end of embryo. A tail fold appears just posterior to the tail of embryo. Head fold grows towards the tail end and tail fold towards the head end of embryo. Two folds meet and fuse with each other. Point of fusion is called Seroamniotic connection.

Fig. 10-2. Stages in the development of foetal membranes



The head and tail folds of amnion are formed due to duplication of somatopleure on the fusion of folds. There are two layers - an outer chorion having outer ectoderm and inner somatic mesoderm, and an inner amnion which consists of outer somatic mesoderm and inner ectoderm. The space between amnion and chorion is termed as chorio-amniotic cavity. It represents extra embryonic coelom. The remarkable feature of amnion and chorion is reverse arrangement of ectoderm and mesoderm.

The chorion grows to surround yolk sac. Chorion adheres with the entire inner surface of calcareous shell. The chorion surrounds all the other foetal membranes.

Amnion forms a sac like covering of the embryo. Amniotic epithelium secretes watery fluid which fills the space between amnion and embryo. The fluid is called amniotic fluid.

Functions:

1. Amnion protects the embryo from external jerks.
2. Amniotic fluid provides free movement to the embryo.
3. Chorion also protects the embryo

10.2.5. ALLANTOIS:

Allantois begins to develop by the end of third day of incubation. It develops as a ventral out growth from the hindgut or cloaca of the embryo. Allantois is formed of splanchnopleure. Allantoic bud grows rapidly and fills extra embryonic coelom, the space between amnion and chorion. Allantois connected to the alimentary canal by allantoic stalk.

The mesodermal layer of allantois fuses with the mesoderm of chorion forming allantochorion. As a result of fusion, allantois comes very close to the porous shell. This facilitates respiratory exchange. The allantoic stalk and yolk sac stalk becomes enclosed by umbilical cord.

Functions:

1. It is mainly respiratory in function.
2. It stores excretory substances like embryonic uric acid.
3. Albumen is absorbed through allantois.
4. Allantois absorbs calcium from egg shell which is used for the formation of bones for embryo.
5. It makes egg shell thin and weak by absorbing its calcium.

10.2.6. SUMMARY:

In addition to the development of Embryo, the blastoderm also forms some extra embryonic membranous called yolk sac, Amnion or chorion, serosa, and Allantois are formed. They protect the embryo, transport nourishment from the mother, help in the process of respiration, and absorption of calcium.

10.2.7. KEY TERMINOLOGY:

1. **Somatopleure:** The extra embryonic ectoderm and somatic layer of mesoderm together called somatopleure.

2. **Splanchnopleure:** The extra embryonic endoderm and splanchnic mesoderm together called splanchnopleure.

3. **Yolk stalk:** Yolk sac continuous with the walls of the gut is called yolk stalk.
4. **Allantoic stalk:** The allantois connected to the hindgut of the embryo is called allantoic stalk.

10.2.8. MODEL QUESTIONS:

1. Describe the arrangement and mode of development of the foetal membranes in chick and explain their functions.

10.2.9. REFERENCE BOOKS:

1. P.S. Dhami, J.K. Dhami, R. Chand & Co.
2. P.S. Verma, V.K. Agarwal, S. Chand & Co.
3. V.B. Rastogi & M.S. Jayaraj, Schem & Co.
4. Vertebrate Embryology by McEWEN.
5. Embryology of Chordates by Huettner

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G.D.V. Prasada Rao

Lesson - 11

FORMATION AND TYPES OF PLACENTA IN MAMMALS

CONTENTS

11.1 OBJECTIVES
11.2 INTRODUCTION
11.3 FORMATION
11.4 CLASSIFICATION OF PLACENTA
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2) Eccentric implantation
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1) Non-deciduate placenta
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3) Contradeciduate placenta
C) Based on the nature of foetal membranes taking part in the placenta
1) Yolk sac placenta
2) Allontoic placenta
3) Chorionic placenta
D) Based on the distribution of villi on the chorion
1) Diffuse placenta
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3) Zonary placenta
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E) Based on histology of placenta
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4) Haemochorial placenta
5) Haemo endothelial placenta
11.5 FUNCTIONS
11.6 SUMMARY
11.7 KEY TERMINOLOGY
11.8 MODEL QUESTIONS
11.9 REFERENCE BOOKS

11.1. OBJECTIVES:

The purpose of this lesson is to describe:

- the formation of placenta, and
- various kinds of placenta found in mammals and their functions

11.2. INTRODUCTION:

Placenta is defined as any type of organ built up of maternal and foetal tissues jointly. It serves for the transport of nutrient substances from the tissues of the mother into those of the embryo. The placentae are not found exclusively in mammals but also appear in animals belonging to various groups of the animal kingdom, e.g. *Peripatus*, *Salpa* etc. The nature of the tissues entering into the formation of the placenta is not the same in all cases.

11.3. FORMATION:

The allanto-chorion comes in contact with the uterine wall opposite the mesometrium, a fold of peritoneum suspending the uterus. It develops a large number of branching projections, the villi. A villus consists of a layer of trophoblast and a thick core of vascular mesoderm. The villi penetrates the corresponding depressions, the crypts formed in the uterine wall. The latter gets thickened and very vascular for receiving villi. An intimate connection thus established between foetal membranes and the uterine wall is known as the placenta.

The part of the placenta contributed by the foetus is called foetal placenta, and that shared by the mother is termed the maternal placenta.

On the maternal side a single component, the endometrium is involved. On the foetal side, among four foetal membranes, the amnion may be ruled out immediately because there is no direct contribution to the placenta. There are two possible sources of chorionic vascularization – the vitelline circulation provided by yolk sac and allantoic circulation provided by the allantois. There are two essentially different main types of placenta – the chorio vitelline placenta and the chorio-allantoic placenta.

11.4. CLASSIFICATION OF PLACENTA:

A. Based on mode of Implantation (Fig. 11-1):

1. **Superficial implantation:** The chorionic sac lies in contact with the lining of main uterine cavity. e.g. ungulates, carnivores.

2. **Eccentric implantation:** The chorionic sac lies in a fold which losses off from the main uterine cavity. e.g. rat.

3. **Interstitial implantation:** The chorionic sac penetrates into the substance of the uterine lining. e.g. hedgehog.

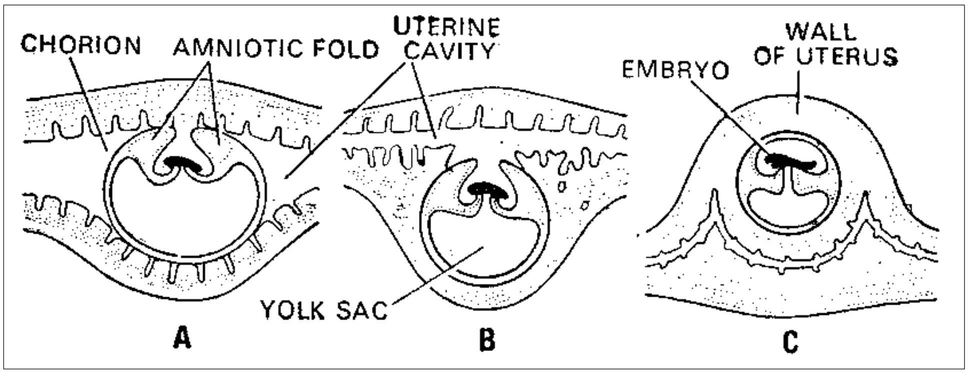

Fig.11-1. Classification of placenta based on mode of implantation
A – Superficial in monkey, ***B*** – Eccentric in rat, ***C*** – Interstitial in guinea pig and man.

B. Based on the Degree of Association:

1. **Non-deciduate placenta:** In this placenta, the implantation of embryo in the uterus is superficial. The foetal chorionic villi lie in the crypts of uterine wall but do not penetrate deeper. At the time of birth, when parturition occurs the chorianic villi are simply drawn out from the wall of the uterus, and maternal and foetal tissue are separated with out damage and no bleeding occurs. e.g. pigs, cattle.

2. **Deciduous placenta:** In some mammals, the degree of intimacy between maternal and foetal tissues becomes further increased. Chorianic villi fuse with the eroded uterine mucosa. Such placenta is called true placenta. At the time of parturition foetal part of placenta separates from the uterine part of placenta and there is extensive haemorrhage and tearing of tissues from the uterine wall. e.g. Man, rabbit.

3. **Contra-deciduate placenta:** The loss of maternal tissue and the foetal portion of the placenta, both of which absorbed *in situ* by maternal leucocytes. e.g. Talpa.

C. Based on the nature of foetal membranes taking part in the placenta:

1. **Yolk sac placenta:** Yolk sac placenta consists of yolk sac and chorion. The yolk sac grows very large and almost surrounds the embryo. The allantois is lacking or very small. e.g. Metatheria.

2. **Allantoic placenta:** The allantoic placenta consists of allantois and chorion. The two together forming allantochorion, e.g. bandicoot, Eutheria.

3. **Chorionic placenta:** The clorionic placenta consists of chorion alone. The allantois remain small and does not reach the chorion. The chorion develops villi that penetrate the uterine crypts forming chorionic placenta. e.g. Man.

D. Based on the distribution of villi on chorion (Fig. 11-2)

1. **Diffuse placenta:** The chorionic villi remain scattered all over the surface of the chorion and their placentae are correspondingly extensive. e.g. pig, horse.

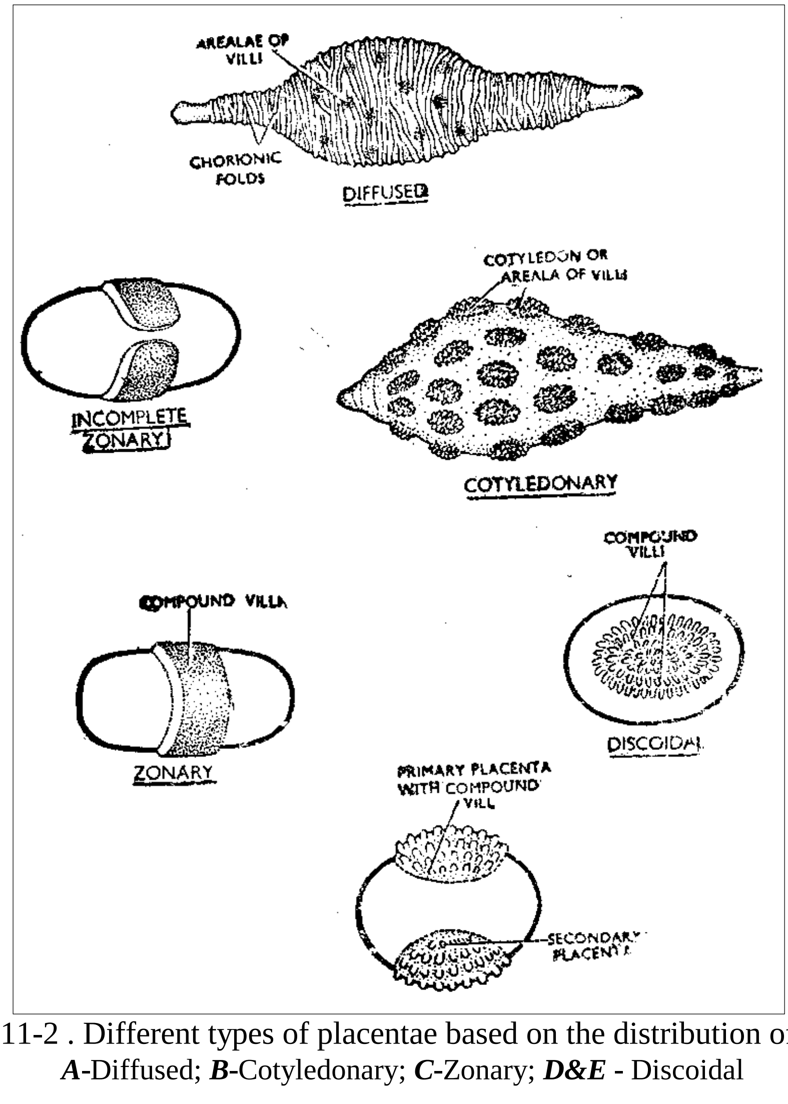

Fig. 11-2 . Different types of placentae based on the distribution of villi.
A-Diffused; ***B***-Cotyledonary; ***C***-Zonary; ***D&E*** - Discoidal

2. **Cotyledonany placenta:** The chorionic villi are found in groups, while the rest of the chorion surface remains smooth. The patches of villi are called cotyledons. e.g. cattle, sheep.

3. **Zonary placenta:** The chorionic villi are developed in the form of a belt like band around the middle of their chorionic sac. e.g. cat, dogs.

4. **Discoidal placenta:** The chorionic villi developing only on one side, while on the other parts of the chorion the villi are reduced. The functional placenta has the shape of a disc. If the placenta has a single disc, it is called mono-discoidal placenta. e.g. Man.

In monkeys, placenta consists of two disc shaped villous areas and such a placenta is called bidiscoidal placenta. e.g. Monkey.

E. Based on Histology of placenta (Fig. 11-3)

1. Epithelio chorial placenta:

This type of placenta is most primitive type. In this case, six tissues or membranes lie between the foetal and maternal blood streams.

1. the endothelium of maternal blood vessel.
2. endometrial connective tissue
3. uterine epithelium,
4. chorionic epithelium
5. chorionic connective tissue
6. endothelium foetal blood vessel

The contact of the two halves of the placenta involves chorionic epithelium and uterine epithelium. This type of placenta is called epithelio chorial placenta. e.g. pig, horse.

2. Syndesmochorial placenta:

The foetal and maternal components are fused so intimately that result, in a destruction of the uterine epithelium. The chorion comes in contact with the connective tissue of the uterine mucosa. Thus only five barriers are present. e.g. cattle, sheep.

3. Endotheliochorial placenta:

The uterine mucosa reduced and chorionic epithelium comes in contact with the endothelial wall of the maternal blood vessel. Thus four barriers are present. e.g. dog, cat.

4. Haemochorial placenta:

The endothelial walls of maternal blood vessel also disappear and the chorionic epithelium is bathed directly in maternal blood. Thus only three barriers occur. e.g. moles, shrews.

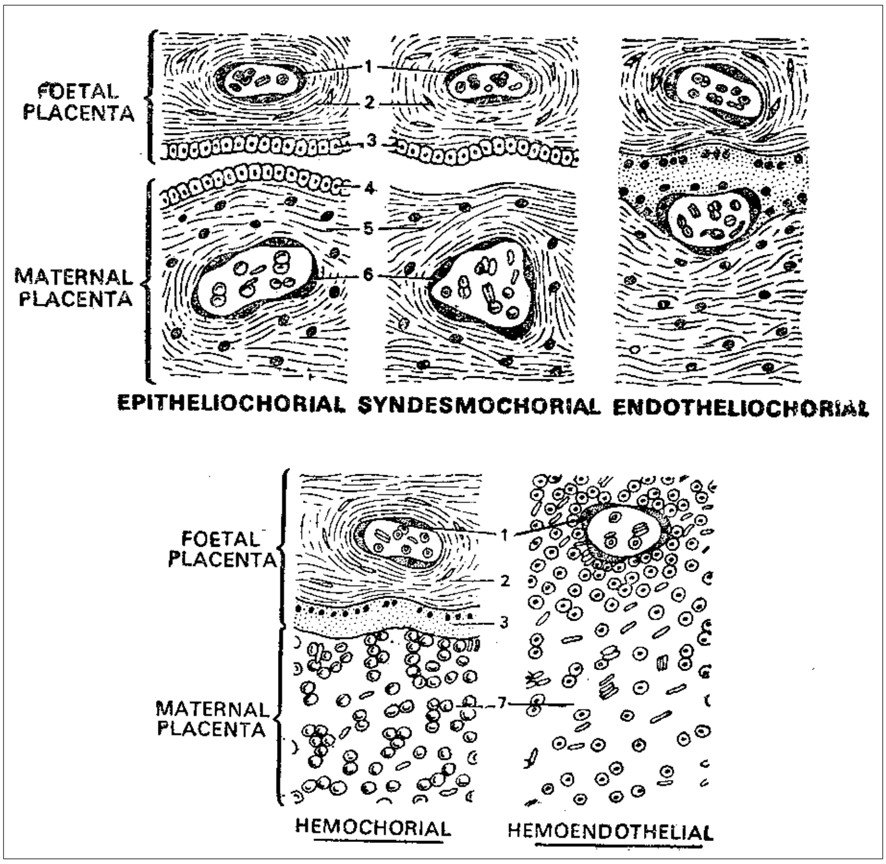

Fig. 11-3. Different types of placentae found in mammals based on the intimacy of embryonic and maternal tissue

5. Haemoendothelial placenta:

In this type, the uterine epithelium, uterine connective tissue, endothelium of maternal blood capillaries and trophoblastic epithelium are eroded with the result foetal capillaries lie freely in maternal blood. Thus only two barriers occur. e.g. Rabbit.

11.5. FUNCTIONS:

1. In mammals, an embryo in uterus is dependent upon the nutritional supplies from maternal body via placenta only.
2. Molecules of oxygen and water pass through this barrier by simple diffusion.
3. CO_2, Urea, Sodium, Potassium, Magnesium also pass through the placenta by simple diffusion.
4. Some vitamins and hormones also pass through placenta.
5. Antibodies which have developed in maternal blood also pass through placenta.

11.6. SUMMARY:

1. Placenta is built up of villi on the chorion and histology of placenta
2. Classification of placenta is based on implantation, degree of association, foetal membranes involved in the placenta, distribution of villi on the chorion and histology of placenta.
3. Placenta serves transport of nutrients to the embryo and exchange of gases between the mother and the embryo

11.7. KEY TERMINOLOGY:

Embryo: The early developmental stage of an organism produced from fertilized egg.
Endometrium: The glandular lining of the uterus in mammals.
Trophoblast: The outer wall of the mammalian blastocyst.

11.8. MODEL QUESTIONS:

1. Describe the formation of placenta?
2. What is placenta? Describe various kinds of placenta found in mammals and mention their functions?

11.9. REFERENCE BOOKS:

1. P.S. Dhami, J.K. Dhami, R. Chand & Co.
2. P.S. Verma, V.K. Agarwal, S. Chand & Co.
3. V.B. Rastogi & M.S. Jayaraj, Schem & Co.
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Lesson - 12.1
GENE INTERACTION

CONTENTS:

12.1.1 OBJECTIVES
12.1.2. INTRODUCTION
12.1.3. GENE INTERACTION
12.1.3.1. CODOMINANCE
12.1.3.2. GENE COMPLEX
12.1.3.3. EPISTASIS
12.1..4. SUMMARY
12.1.5. KEY WORDS
12.1.6. MODEL QUESTIONS
12.1.7. REFERENCES

12.1.1. OBJECTIVES :

The aim of this lesson is to make the student to acquire knowledge about

- the basis for the inheritance of parental characters to the off-spring
- the Medelian genetics and the deviations from Mendelian ratios
- gene interaction an dits consequences
- the behaviour of genes in various aspects like codominance, gene complex and epistasis with suitable examples

12.1.2. INTRODUCTION:

Most of the organisms increase their numbers by reproduction. Except few lower invertebrates, all most all the orgnisms reproduce by sexual mode. Such organisms may exhibit hermophroditic or bisexual nature or sexual dimorphism. Inspite of this, they release gametes (sperm cells and ova) produced from the gonads (testis in case of male and ovary in case of female) during sex play. Male and female gametes unite to form zygote during fertilization. G J Mendel, after conducting a number of experiments over the transmission of the characters from one generation to the other, proposed the **Laws of inheritance** to explain the behaviour of genes and their role in the inheritance of characters.

Accordingly, Law of Dominance, Law of Seggregation and Law of Independent assortment mostly govern the role of genes in the transmission of characters from parental generation to the felial generations. These were explained by Mendel through Monohybrid Cross, Dihybrid Cross, Linkage and Crossing over. Thus the study of Genetics deals with the inheritance of parental characters to the offspring through the genes present over the chromosomes in the nucleus of the gametes. Oflate, it is proved beyond doubt that there are certain aspects which never obey the principles proposed by

Mendel. In many situations, genes interact with other genes located in the sex chromosomes producing new combinations and result in the changed monohybrid and dihybrid ratios. Out of many such interactions, three imporatant ones are discussed below.

12.1.3 GENE INTERACTION :

The following concepts are independent of Mendelian Principles of inheritance and hence are grouped under interaction of genes.

12.1.3.1. Codominance : This situation arises when either of the two alleles never show complete dominance or recessiveness in heterozygous condition. This aspect is an exception to the normal Mendelian principles.

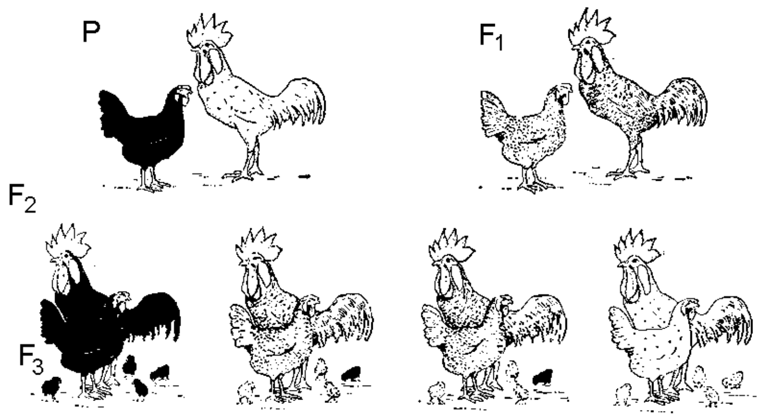

Fig.12.1-1. Codominance

P			F_1			F_2	
phenotypes	genotypes	gametes	phenotype	genotype	gametes	phenotypes	genotypes
Black	*BB*	*B*			♂ *B* and *b*	1 Black	*BB*
			Blue	*Bb*	↓╳↓	2 Blue	*Bb*
splashed white	*bb*	*b*			♀ *B* and *b*	1 splashed white	*bb*

Table. 12.1-1. Cross in fowls

Codominance is found in both plants and animals. In most cases the heterozygote is a phenotype intermediate between the homozygous dominant and recessive conditions. An example is the production of blue Andalusian fowls by crossing pure-breeding black and splashed white parental stocks. The presence of black plumage is the result of the possession of an allele for the production of the black pigment melanin. The splashed white stock lack this allele. The heterozygotes show a partial development of melanin which produces a blue sheen in the plumage.

As there are no accepted genotypic symbols for alleles showing codominance, the importance of specifying symbols in genetic explanations is apparent. For example, in the case of the Andalusian fowl, the following genotypic symhols may be used to illustrate the alleles: black - B; splashed white - b,

If the F_1 generation are allowed to interbreed, the $\mathbf{F_2}$ generation shows a modification of the normal Mendelian phenotypic monohybrid ratio of 3:1. **In** this case a phenotypic ratio of 1:2:1 is produced where half the F_2 generation have the F_1 genotype. This ratio of 2:1 is characteristic of examples of codominance.

12.1.3.2. Gene-complex

The presence of a pair of alleles occupying a given gene locus and controlling the production of a single phenotypic characteristic is true in some cases only and exceptional in most organisms. Most characteristics are determined by the interaction of several genes which form a **'gene-complex'.**

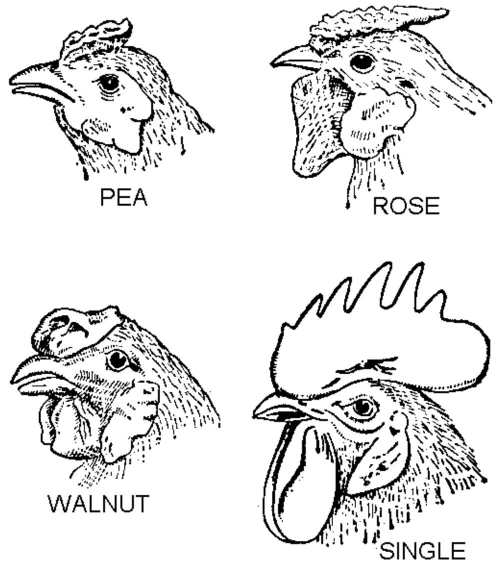

Fig.12.1-2. Combs in fowls.

For example, a single characteristic may be controlled by the interaction of two or more genes situated at different loci. In the case of the inheritance of the shape of the comb in domestic fowl there are genes at two loci situated on different chromosomes which interact and give rise to four distinct phenotypes, known as pea, rose, walnut and single combs. The appearance of pea comb and rose comb are determined by the presence of their respective dominant allele (P or R) and the absence of the other dominant allele. Walnut comb results from a modified form of codominance in which at least one dominant allele for pea comb and rose comb is present (that is PR). Single comb appears only in the homozygous double recessive condition (that is **pprr).** The genotypes and phenotypic ratios are one and the same i.e., 9(walnut) : 3(pea) : 3(rose) : 1(single). Details of the corss from a a pure-breeding pea-comb hen with a pure-breeding rose-comb cock are shown in the following checker board.

In poultry, the allele for white feather (W) is dominant over tht allele for black feather (w). The alleles for pea comb, P, and rose comb, R, produce the phenotypes stated. If these alleles are present together they produce a phenotype called walnut comb. If their recessive alleles are present in the homozygous condition they produce a phenotype called single comb.

A cross between a black rose-comb cock and a white watnut-comb hen produced the following phenotypes:

3 white walnut-comb, 3 black walnut-comb, 3 white rose-comb, 3 black rose-comb, 1 white pea-comb, 1 black pea-comb, 1 white single comb and 1 black single-comb.

Let ‘ **P’** represent presence of pea comb (dominant) ;

‘p’ represent absence of pea comb (recessive) ; **‘R’** represent presence of rose comb (dominant) ; **‘r’** represent absence of rose comb (recessive)

Parental phenotypes	*Rose Comb*	*X*	*Pea Comb*
Parental genotypes (2n)	*RRpp*		*PPrr*
***Meiosis** results in Gametes (n)*	*Rp*		*Pr*
Random fertilization rsults in			
F_1 genotypes (2n)		*RrPp (all walnut)*	
F_1 phenotypes	*Walnut*	*X*	*Walnut*
F_1 genotypes (2n)	*RrPp*	*X*	*RrPp*

Meiosis results in

Gametes (n) (as shown bymale and female) RP Rp rP pr

Random fertilisation

F_1 genotypes (2n) (shown in Punnett square)

P: genotypes and phenotypes	P: gametes	F_1: genotype and phenotype	F_1: gametes	F_2: *RP*	*Rp*	*rP*	*rp*
RRpp rose	*Rp*		*RP*	*RRPP* walnut	*RRPp* walnut	*RrPP* walnut	*RrPp* walnut
		RrPp Walnut	*Rp*	*RRPp* walnut	*RRpp* rose	*RrPp* walnut	*Rrpp* rose
rrPP pea	*rP*		*rP*	*RrPP* walnut	*RrPp* walnut	*rrPP* pea	*rrPp* pea
			rp	*RrPp* walnut	*Rrpp* rose	*rrPp* pea	*rrpp* single

Table.12.1.2. F_1 phenotypes result in the same phenotypic and genotypic ratio
9 walnut comb : 3 pea comb : 3 rosé comb : 1 single comb

12.1.3.3. Epistasis : A gene is said to be **epistatic** *(epi-* over) when its presence suppresses the effect of a gene at another locus. Epistatic genes are sometimes called **'inhibiting genes'** because of their effect on the other genes which are described as **hypostatic** *(hypo-* under). Fur colour in mice is controlled by a pair of genes occupying different loci. The epistatic gene determines the colour. presence of colour and has two alleles, coloured (dominant) and albino (white) (recessive). The hypostatic gene determines the nature of the colour and its alleles are agouti (grey) (dominant) and black (recessive). The mice may have agouti or black fur depending upon their genotypes, but this will only appear if accompanied by the allele for coloured fur. The albino condition appears in mice that are homozygous recessive for colour even if the alleles for agouti and black fur are present. Three possible phenotypes can occur and they are agouti, black and albino. A variety of phenotypic ratios can be obtained depending on the genotypes of the mating pair.

agouti × albino

AaCc × Aacc

♀ \ ♂	AC	Ac	aC	ac
Ac	AC Ac ○	Ac Ac □	aC Ac ○	ac Ac □
ac	AC ac ○	Ac ac □	aC ac △	ac ac □

3 agouti : 4 albino : 1 black

○ □ △

Table .12.1-3. Cross showing epistasis

Epistasis :

'**A**' represent agouti fur (dominant) ; '**a'** represent black fur (recessive) ;
'**C**' represent coloured fur (dominant) ; '**c**' represent albino fur (recessive)

Parental phenotypes *Agouti X Albino*
Parental genotypes (2n) *AaCc* *Aacc*
Meiosis
Gametes (n) (as shown by male(♂) and female (♀)

Random fertilization results in phenotypic ratio of

3(agounti) : 4 (albino) : 1(black)

Offspring genotypes (2n) (as shown in Punnett square)

Offspring phenotypes Offspring symbols
3 agouti : 4 albino : 1 black
A genetic explanation of how unusual phenotypic ratios can be produced in the case of epistatic genes

12.1.4. SUMMARY

Generally the characters from parent inherit following the Mendalian principles. In recent pas tit has been proved that there are some traits which are expressed under the influence of more than one pair of genes or one pair of genes may control more than one character. Inheritance of such traits constitute the basis for the concept of interaction of genes.
Epistasis, Codominance and Gene complex form suitable examples for the concept of gene interaction

12.1.5. KEY WORDS

Epistasis : Masking of the phenotype effect of either or both members of one pair of alleles by a gene of a different pair. The masked gene is said to be hypostatic.
Codominance : A conditon in heterozygotes where both members of an allelic pair contribute for the expresssion of the character in homozygous condition of the phenotype.
Gene : The particulate determiner of a hereditory trait, a particular segment of DNA molecule located on the chromosome.
Genome : A complete set of chromosomes or of chromosomal genes inherited as a unit from one parent.

12.1.6. SELF ASSESSMENT QUESTIONS

Q.1. What is gene interaction ? How it differs from the normal Mendelian inheritance ?
Q.2.Explain gene interaction taking three examples from different aspects.
Q.3. Explain the concept of interaction of genes in different angles taking suitable examples.
Q.4. Write Short notes on Epistasis, Codominance and gene complex.

12.1.7. REFERENCES

1. Genetics by Sinnot, Dunn and Dobzansky
2. A Text book of Zoology by Prof. V. Luther Das
3. The Science of Genetics by G W Burns
4. College Zoology by Richard A. Boolotian an Karl A. Stiles

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Lesson - 12.2.
FINE STRUCTURE OF GENE

CONTENTS :

12.2.1 OBJECTIVES
12.2.2. INTRODUCTION
12.2.3. FINE STRUCTURE OF DNA AS SEEN FROM ELECTRON MICROGRAPHS
12.2.4. THE NATURE OF GENES
12.2.5. STRUCTURE OF DNA AND NUCLEOTIDES
12.2.6. DNA REPLICATION
12.2.7. SUMMARY
12.2.8. KEY WORDS
12.2.9. SELF ASSESSMENT QUESTIONS
12.2.10. REFERENCES

12.2.1. OBJECTIVES :

The student will be able to understand the definition, its fine structure, its role in the expression of character, replication and functional significance after studying through this lesson.

12.2.2. INTRODUCTION :

Cells are the structural and functional units of the body. All the cells in eukaryotes possess a cell centre, the nucleus which in turn possesses a definite number of thread like structures called the chromosomes. Histochemical and cytological analyses of chromosomes of eukaryotic cells have shown them to be composed of deoxyribonucleic acid (DNA) and protein, with small amounts of chromosomal RNA. Prokaryotes possess only the DNA material and hence no chromosomes are seen. DNA has negative charges distributed along its length, and positively charged (basic) protein molecules called histones are bonded to it. This DNA protein complex is called chromatin.

12.2.3. FINE STRUCTURE OF DNA AS SEEN FROM ELECTRON MICROGRAPHS :

Lampbrush chromosomes of amphibian oocytes during metaphase show that each chromatid appears to be composed of a tightly coiled axis with several lateral loops made up of a single DNA double helix. These loops may represent DNA which has been exposed for the purpose of transcription

The large amount of DNA in cells means that there is a packaging problem. A human cell, for example, contains about 2.2m of DNA distributed among 46 chromosomes. Each chromosome therefore contains about 4.8cm (48 000 µm) of DNA. And each chromosome on average measures about 6µm long with a

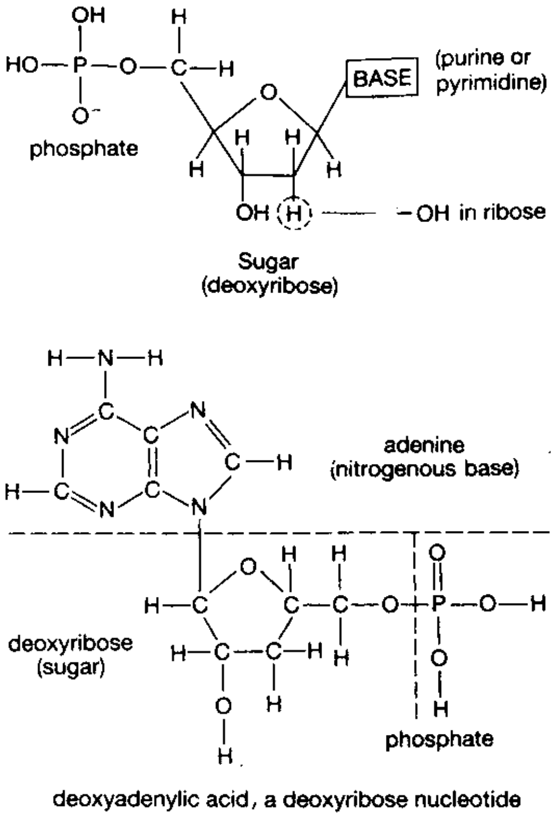

Fig.12.2-1. Chemistry of the Gene

packing ratio of 8000 **:**1. In order to maintain a high degree of organization during the folding of DNA, the histone proteins form a precise architectural skeleton for the DNA.
Recent investigations suggest that the DNA helix combines with groups of eight histone molecules to form structures known as **nucleosomes** having the appearance of beads on a string.

12.2.4. THE NATURE OF GENES :

The **particulate** nature of heredity has always been a feature of the study of inheritance. Mendel proposed in 1866 that the characteristics of organisms were determined by hereditary units called factors. These were later termed **genes** and shown to be located at the loci on the chromosomes and are transmitted from generation to generation along with chromosomes.
Despite our current knowledge of chromosomes and the structure and function of DNA, it is still extremely difficult to give a precise definition of a gene. Investigations into the nature of the gene have so far produced three possible definitions of a gene have been deduced.
(i) ***A unit of recombination*** *:* From his studies of chromosome mapping in *Drosophila,* Morgan postulated the gene as **the shortest segment of a chromosome which could be separated from**

adjacent segments by crossingover. This definition regards the gene as a large unit, a specifie region of the chromosome determining a distinct character in the organism.

(ii) ***A unit of mutation :*** Changes appearing in the characters of organisms are the result of random and spontaneous alterations in the structure of a chromosome having a sequence of bases or even a single base. It seemed therefore that a gene might be as small as a single pair of complementary bases in the nucleotide sequence of DNA, that is the shortest **segment of a chromosome which can undergo mutation.**

(iii) ***A unit of function***. Since genes were known to determine structural, physiological and biochemical characteristics of organisms, a gene was defined as **the shortest segment of a chromosome responsible for the production of a specific product.**

The third definition is the most acceptable but it lacks clearity about the nature of the specifie product. In some cases one gene is known to affect several characteristics while in other cases several genes (polygenes) may determine one specific character. Beadle and Tatum proposed this widely accepted definition of the gene known as the **one gene, one enzyme hypothesis.** This was largely substantiated by the development of a new field of biology called **molecular genetics.** Subsequently this functional concept of gene hs been attributed to one cistron, one polypeptide hypothesis

(iv) ***A unit of Plasmon*** **:** The extrachromosomal ring found in microorganisms and having the capacity to inherit is called plasmon. These are seen as chondriogenes in mitochondria and plastagenes in plastids.Plasmagene is the smallest unit of plasmon.

Basing on the functional significance, genes are of the following types :

(a) **Structural genes** synthesize enzymes and other substances required for the conduct of metabolic activities.

(b) **Modifier genes** can change the functional activity of other genes.

(c) **Supressor genes** can supress the action of other active genes

(d**) Regulatory genes** concerned with the regulation of the function of the structural genes.

DNA determines all the characteristics of an organism, and contains all the genetic material that makes us to be identified. This information is passed on from generation to generation in a species manner through the DNA.

12.2.5. STRUCTURE OF DNA AND NUCLEOTIDES

According to Watson & Crick, DNA is arranged in a *double helical* structure. The spirals of DNA are intertwined with one another continuously bending in on itself but never getting closer or wider. These strands are formed of billions of units called nucleotides each made of a Pentose sugar(Deoxyribose) and phosphate molecules bound to four different types of nitrogenous bases in a specific sequence viz., adenine, cytosine, guanine and thymine (symbolically represented as A, C, G and T). Nucleotides are situated in adjacent pairs in the double helical frame work. There are billions of these nucleotides in the

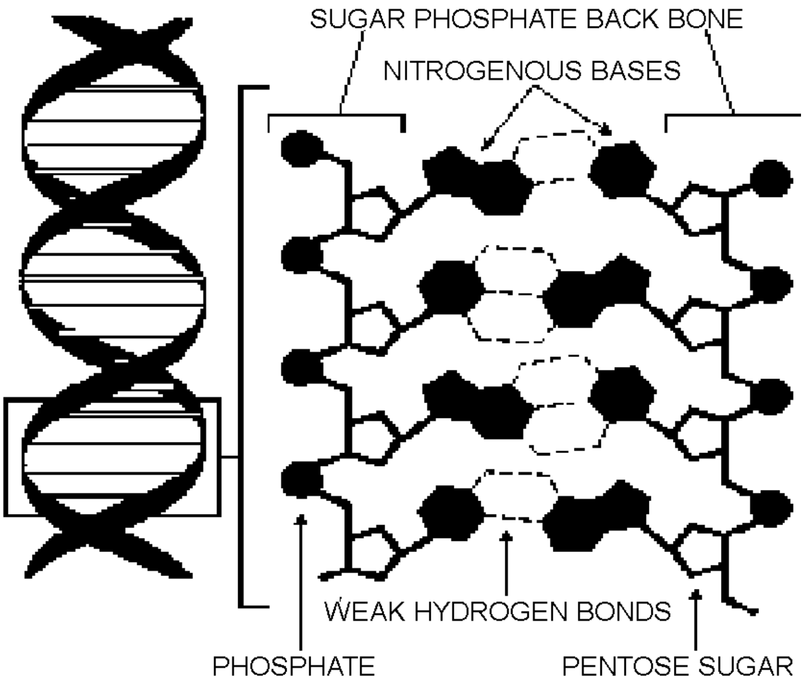

Fig.12.2-2. Watson and Crick Model of DNA

genome, and with all the possible permutations, DNA is the unique substance that makes the organisms unique. A minimum of three nucleotides are seen in any gene. Though each gene is having its own specific structure and function, it is influenced by the adjascent genes.

- Thymine and adenine can only make up a base pair
- Guanine and cytosine can only make up a base pair
- Therefore, thymine and cytosine would NOT make up a base pair, as is the case with adenine and guanine.
- There exists a double hydrogen bond between A & T and a triple bond between G & C.
- The angles between the bonds are maintained at a constant angle in each species of the organisms.

12.2.6. DNA REPLICATION : Cells do not live forever, and in view of this, they must pass their genetic information on to new cells, and be able to replicate the DNA to be passed on to offspring. It is also required that fragments of DNA (genes) have to be copied to code for particular bodily function.

It is essential that the replication of DNA is EXACT. In order for replication to occur, the following preconditions are necessary to be fulfilled viz.,

- The actual DNA to act as an exact template
- A pool of relevant and freely available nucleotides
- A supply of the relevant enzymes to stimulate reaction
- ATP to provide energy for these reactions

When replicating, the double helix structure uncoils so that each strand of DNA can be exposed. When they uncoil, the nucleotides are exposed so that the freely available nucleotides can pair up with them.

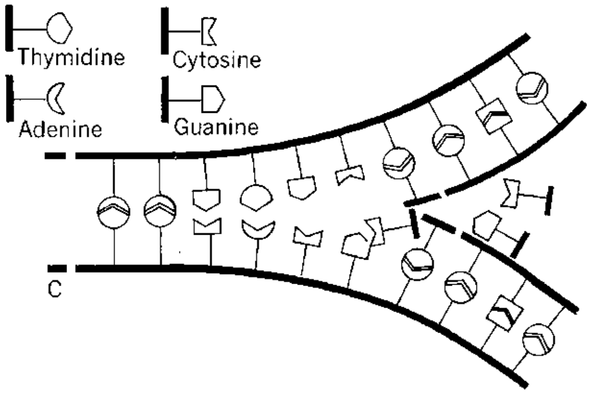

Fig.12.2-3. Self Replicating DNA molecule

When all nucleotides are paired up with their new partners, they re-coil into the double helix. As there are two strands of DNA involved in replication, the first double helix produces 2 copies of itself via each strand.

It is said that the replicated DNA is semi-conservative, because it possesses 50% of the original genetic material from its parent. These 2 new copies have the exact DNA that was in the previous one. This template technique allows genetic information to be passed from cell to cell and from parents to offspring.

Functional activity of the gene: Genes are mainly concerned with the synthesis of substances required for the construction and functioning of the living organisms. Any change occurring in the structure of the gene cause change in its functional activity also. The function of the gene is mainly based upon the characteristic triple natured genetic codes developed by the gene as complements from the nucleotides. About 64 triplet codes are required to regulate the synthesis of 20 aminoacids required for the sustenance. The gene action was proposed as Operon Concept by Jacob and Monad which is controlled by three types of genes namely the structural genes, operator genes and regulator genes.

12.2.6. SUMMARY

Gene is the particulate molecule located over the loci of the chromosomes. Its main constitutent is the Deoxy ribose nucleic acid (DNA) and is responsible for the transmisson of the parental characters to the offspring through gametes. It can replicate itself producing the daughter molecule. DNA is responsible for the regulation of protein synthesis. The messages for the synthesis and regulaton are sent in the form of codes to the place of synthesis.

12.2.7. KEY WORDS

Self replication : Formation of the similar part at its own
Recon : Recombinable part of the gene.
Muton : Mutatable part of the gene
Operon : Functionable part of the gene regulating protein sysnthesis

12.2.8. SELF ASSESSMENT QUESTIONS

Q. Give an account on the fine structure of gene and its role in the organsisms.

12.2.9. REFERENCES

1. Genetics by Sinnot, Dunn and Dobzansky
2. A Text book of Zoology by Prof. V. Luther Das
3. The Science of Genetics by G W Burns
4. College Zoology by Richard A. Boolotian an Karl A. Stiles

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Lesson. 12.3.
OPERON CONCEPT

CONTENTS :

12.3.1 OBJECTIVES
12.3.2. INTRODUCTION
12.3.3. OPERON CONCEPT
12.3.4. LAC – OPERON SYSTEM AND ITS ACTION
12.3.5. SUMMARY
12.3.6 KEY WORDS
12.3.7. ELF ASSESSMENT QUESTIONS
12.3.8. REFERENCES

12.3.1. OBJECTIVES .

The main aim of this lesson is to make the student aware of

- different types of proteins present in the body and their importance for the growth of the body and its life activities
- the knowledge of genes responsible for the synthesis of proteins,
- the knowledge about the lac operon and the genes involved in the process of protein sysnthesis.

12.3.2. INTRODUCTION: It is now an established fact that every aspect of our life depends on proteins, which are encoded by DNA. Pproteins act as the intermediaries between our DNA and our heritable traits. By now, we are beginning to understand how particular genes determine the amino acid sequences of particular proteins.

- Our genes (formed of DNA) specify the structure of our proteins.
- Our proteins, interacting with one another and various environmental factors, determine the chemical and physical properties of each of our cells.
- The combined chemical and physical properties of all of our cells determine the shape, appearance, and behavior of our body as a whole.
- For proteins to be synthesized, RNA is necessary and the regulation of the synthesis of RNA by DNA, histones from nucleolus play a great role.
- There exists two systems actively working at the cells for the synthesis of proteins. One is the end product inhibition system and the other is the Operon system regulating the synthesis of proteins.

12.3.3. OPERON CONCEPT: This was proposed by Jacob and Monad in 1961, to explain the importance of gene regulation of protein synthesis. . Accordingly, three genes are necessary for the regulation of protein synthesis.

Operon is the group of sequentially arranged **cistrons** in the functional gene. The activity of cistrons is regulated by operator and promotor positions of the gene. Operator works like a switch in the functioning of the cistron.

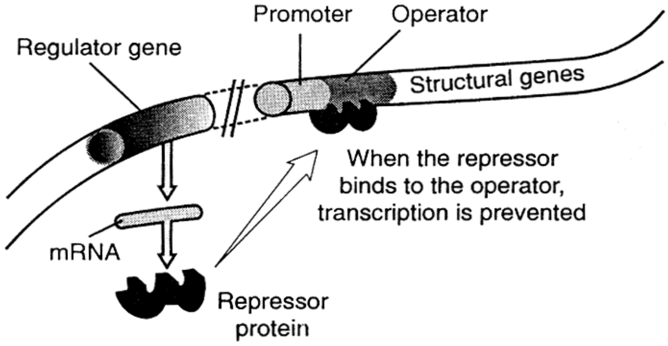

Fig.12.3-1. DNA showing operon genes

12.3.4. **LAC- OPERON SYSTEM.**

Escherechia coli can be taken as an ideal example to explain the Lac-operon concept. In the said microorganism, β- galactocide permease and β- galactocidase are the enzymes required for Lactose metaboism. In the wild stain of E.coli, the above two enzymes are synthesized in presence of Lactose itself. Hence it can be concluded that lactose acts as a stimulant for the process. The mutant stain can secrete the above enzymes either in the presence or absence of lactose. The operon segment formed by the three active cistrons viz., the z, y and a and its functional activity was presented by Bequeth, Zipser and Reznikoff .

The entire **operon concept** can be summarized in the following steps:

- Bacteria adapt to changes in their surroundings by using regulatory proteins to turn groups of genes on and off in response to various environmental signals. The DNA of *Escherichia coli* is sufficient to encode about 4000 proteins, but only a fraction of these are made at any one time. *E. coli* regulates the expression of many of its genes according to the food sources that are available to it.
- The Lactose Operon commonly called as **Lac Operon** is a **cluster of bacterial genes along with an adjacent promoter that controls the transcription of those genes.** When the genes in an operon are transcribed, a single mRNA is produced for all the genes in that

operon. This mRNA is said to be polycistronic because it carries the information for more than one type of protein.

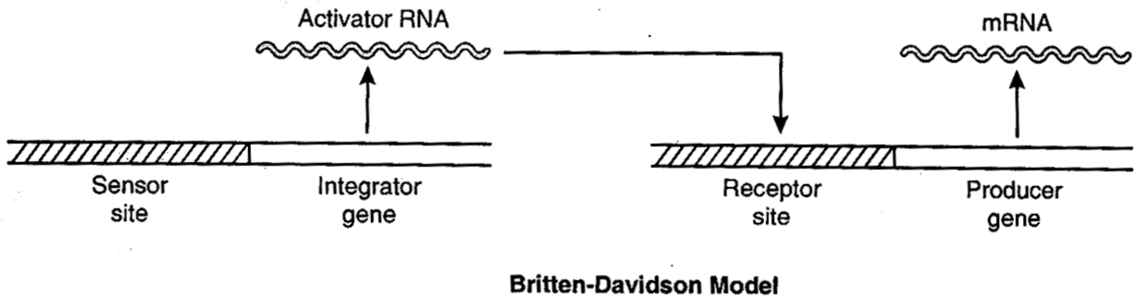

Fig. 12.3-2. Operon

- operator is a short region of DNA that lies partially within the promoter and that interacting with a regulatory protein controlling the transcription of the operon. A promoter is like a doorknob, in that the promoters of many operons are similar. An operator is like the keyhole in a doorknob, in that each door is locked by only a specific key, and is comparable to the specific regulatory protein.

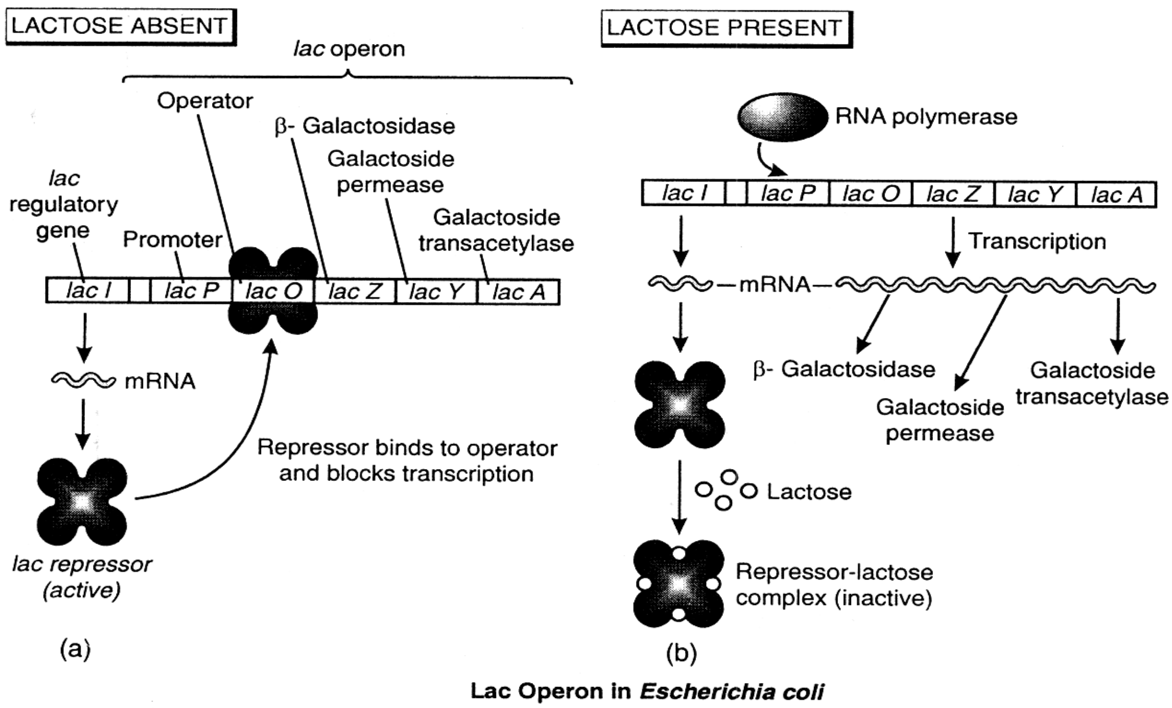

Fig.12.3-3. Lac Operon

- The *lac* Regulatory Gene or *lacI* produces an mRNA that produces a Lac repressor protein, which can bind to the operator of the *lac* operon. Regulatory genes are not necessarily close to the operons they affect and the product of a regulatory gene is a regulatory protein. The

Lac regulatory protein is called a repressor because it keeps RNA polymerase from transcribing the structural genes. Thus the Lac repressor inhibits transcription of the *lac* operon.

- In the absence of lactose, the Lac repressor binds to the operator and keeps RNA polymerase from transcribing the *lac* genes. It would be energetically wasteful for *E. coli* if the *lac* genes were expressed when lactose was not present. The effect of the Lac repressor on the *lac* genes is referred to as negative regulation.

- When lactose is present, the *lac* genes are expressed because allolactose binds to the Lac repressor protein and keeps it from binding to the *lac* operator. Allolactose is an isomer of lactose. Small amounts of allolactose are formed when lactose enters *E. coli.* Allolactose binds to an allosteric site on the repressor protein causing a conformational change. As a result of this change, the repressor can no longer bind to the operator region and falls off. RNA polymerase can then bind to the promoter and transcribe the *lac* genes

- Allolactose is called a Lac inducer because it turns on, or induces the expression of, the *lac* genes(acts like a switch)The presence of lactose

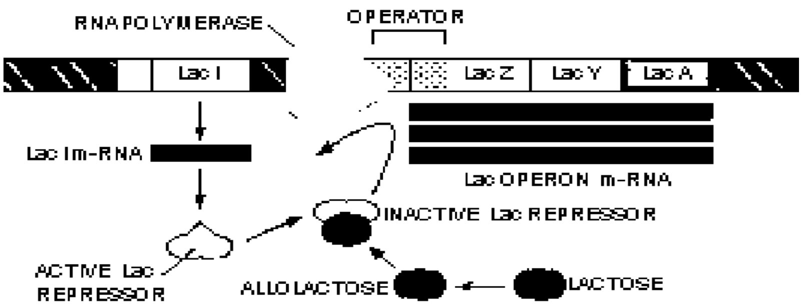

Fig.12.3.-4. Lac operon- expression of Lac gene

(and thus allolactose) determines whether or not the Lac repressor is bound to the operator.

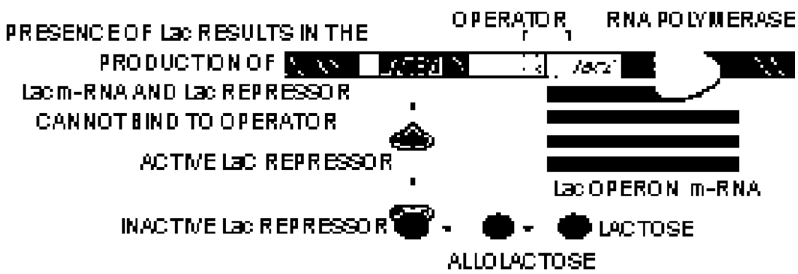

Fig.12.3-5. Lac operon-switch mechanism by allolactose

- When the enzymes encoded by the *lac* operon are produced, they break down lactose and allolactose, eventually releasing the repressor to stop additional synthesis of *lac* mRNA. Messenger RNA breaks down after a relatively short amount of time.
- Whenever glucose is present, *E. coli* metabolizes it before using alternative energy sources such as lactose, arabinose, galactose, and maltose. Glucose is the preferred and most frequently available energy source for *E. coli.* The enzymes to metabolize glucose are made constantly by *E. coli.* When both glucose and lactose are available, the genes for lactose metabolism are transcribed at low levels. Only when the supply of glucose has been exhausted, RNA polymerase starts to transcribe the *lac* genes efficiently, allowing *E. coli* to metabolize lactose.

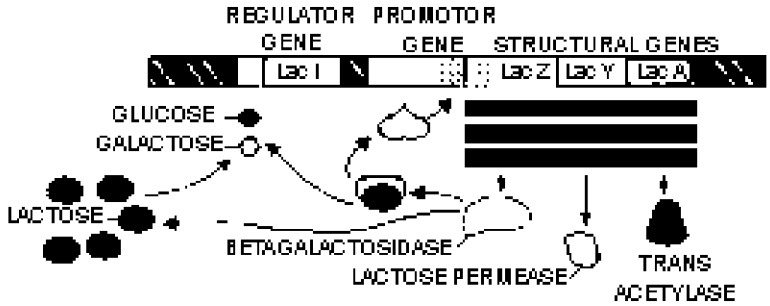

Fig.12.3-6. Lac operon-break down of allolactose

- In presence of both glucose and lactose, the genes for lactose metabolism are transcribed to a small extent. Maximal transcription of the *lac* operon occurs only when glucose is absent and lactose is present. The action of cyclic AMP and a catabolite activator protein produce this effect.
- The presence or absence of glucose affects the *lac* operon by affecting the concentration of cyclic AMP. The concentration of cyclic AMP in *E. coli* is inversely proportional to the concentration of glucose: as the concentration of glucose decreases, the concentration of cyclic AMP increases. Cyclic AMP is derived from ATP.

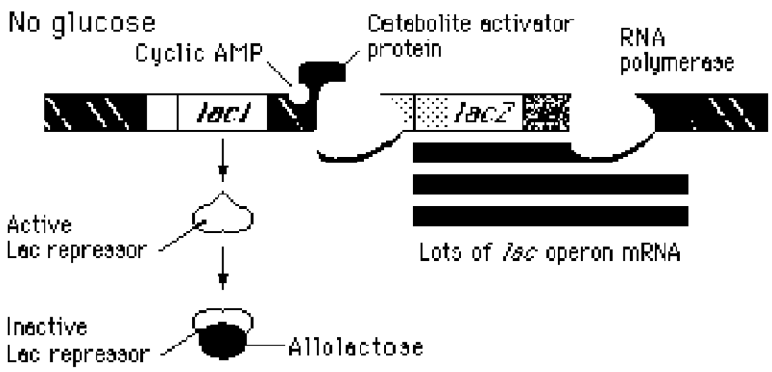

Fig.12.3-7. Lac operon- Maximum production of m-RNA in the absence of glucose and presence of Lactose

- In the presence of lactose and absence of glucose, cyclic AMP (cAMP) joins with a catabolite activator protein that binds to the *lac* promoter and facilitates the transcription of the *lac* operon. The catabolite activator protein (CAP) is also called the cAMP-receptor protein. When the concentration of glucose is low, cAMP accumulates in the cell. The binding of cAMP and the catabolite activator protein to the *lac* promoter increases transcription by enhancing the binding of RNA polymerase to the *lac* promoter.

Thus the operon concept explains the importance of promoter, regulator, operator and repressor genes in the synthesis of proteins or in regulating the gene action

12.3.5. SUMMARY

DNA sends the information relating to the formation of proteins, by producing a complementary unit of m-RNA at the beginning of protein synthesis. This contains the genetic information in the form a code formed by the contribution from the nucleotides. During the synthesis of m-RNA, the DNA becomes uncoiled, allowing the mRNA to move in and transcribe (copy) the genetic information. If the code of DNA looks like this : G-G-C-A-T-T, then the mRNA would look like this C-C-G-U-A-A.

With the genetic information now available on the mRNA strand, the mRNA moves out of the nucleus and away from the DNA towards the ribosomes. mRNA leaves the nucleus and enters the cytoplasm where ribosomes can be found, the site of protein synthesis.

12.3.6. KEY WORDS

Structural proteins : Proteins contributing for the growth of the body
Functional proteins : Proteins responsible for the formation of enzymes, hormones and other biochemical substances participating in several of the metabolic activities
Operon : It is the group of sequentially arranged **cistrons** in the functional gene. The activity of cistrons is regulated by operator and promotor positions of the gene. Operator works like a switch in the functioning of the cistron.

12.3.7. SELF ASSESSMENT QUESTIONS

1. Write the steps involved in Protein synthesis
2. Explain Operon concept in relation to the synthesis of proteins in the body.
3. Write briefly the Operon concept with an illustration

12.3.8. References

1. Genetics by Sinnot, Dunn and Dobzansky
2. A Text book of Zoology by Prof. V. Luther Das
3. The Science of Genetics by G W Burns
4. College Zoology by Richard A. Boolotian an Karl A. Stiles

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Lesson.12.4.
CLONING

CONTENTS :

12.4.1 OBJECTIVES
12.4.2. INTRODUCTION
12.4.3. CLONING
12.4.4. CLONING BY NUCLEAR TRANSPLANTATION
12.4.5 MERITS OF CLONING
12.4.6. ABUSES TO CLONING
12.4.7. EMBRYO SPLITTING
12.4.8. DOLLY'S ARRIVAL
12.4.9. FUTURE.
12.4.10 SUMMARY
12.4.11. KEY WORDS
12.4.12. SELF ASSESSMENT QUESTIONS
12.4.13. REFERENCES

12.4.1. OBJECTIVES:

The aim of this lesson is to acquire

- a comprehensive view about cloning,
- technology involved,
- merits and abuses,
- experimental evidence on animal cloning.

12.4.2. INTRODUCTION

Lord Krishna duplicated himself at times or even multiplied himself into several Krishnas to engage gopicas. Today's science is on the verge of enabling you to duplicate your exact physical identity. Krishna's duplicate had the same age but yours will be younger to you and can even be produced long after you are no more. The trick lies in transferring the genetic material from any cell of your body into a zygote (fertilized cell) whose genetic material is removed earlier. The zygote with the transplanted genetic material is to be grown in the womb of a foster mother, like in the case of a test tube baby. The test tube baby differs by fertilization of an egg by a sperm in a test tube to form the zygote. Duplication (cloning) of Dolly, the sheep and two monkeys has already been achieved successfully by Dr. Huntington Willard and scientists are now confident of extending it to humans. The technique of duplicating an adult individual is termed as cloning. Like every scientific break through, cloning technique is suspected to be abused foolishly by man.

12.4.3. CLONING:

The cloning of adult sheep (Dolly and her sisters reported in 1997) stimulated a great deal of interest in nuclear transfer (cloning) technology by the livestock industry. One method of constructing cloned embryos is to take a cell from an embryo or a developing fetus and transfer it to an unfertilized oocyte from which the female genomic DNA has been mechanically removed. The oocyte is then "activated," as though it had been naturally fertilized, and the nucleus "reprogrammed" for subsequent normal embryo development to occur. Once the donor cell population has been prepared, hundreds of cloned embryos can be produced each week in the laboratory by using oocytes extracted from the ovaries of animals destined for slaughter.

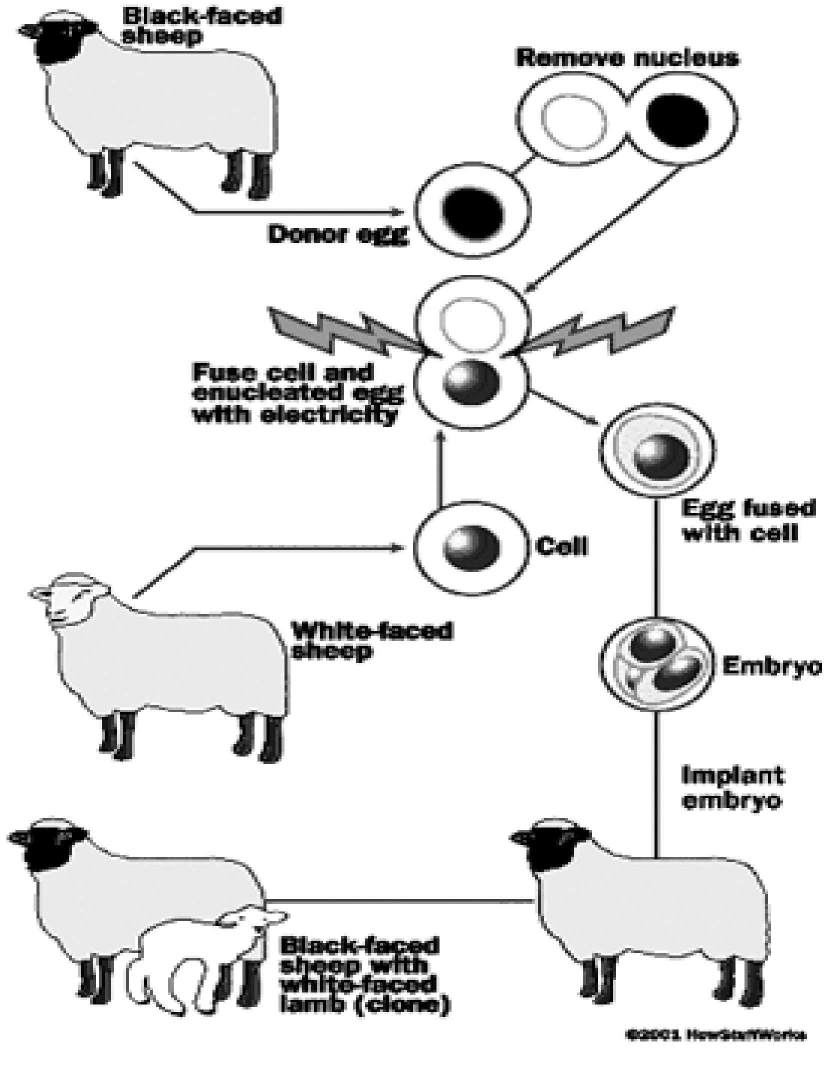

Fig.12.4-1. Steps in cloning

12.4.4. CLONING BY NUCLEAR TRANSPLANTATION

According to Siedel, Cloning by nuclear transplantation is an extremely expensive process. Only 1000 calves have been produced by this procedure - almost all of them by private companies.

The process involves taking an *in vitro* matured oocyte, or unfertilized egg followed by removing all its chromosomes through microsurgery. The individual cells of separate embryos are then fused to the oocytes by electrical pulses. The process results in 20 to 30 genetically identical, one-cell embryos that are then cultured *in vitro* for one week and transferred to recipients.

The main shortcoming of the procedure remains the huge resources in personnel, equipment and animals needed for producing large numbers of cloned, full-term pregnancies. Many a times, the procedure results in abnormal calves with high mortality rates . "Many of the calves are larger than normal, some up to 50% larger than breed averages. "Additionally, many of the calves had metabolic abnormalities like hypoglycemia and hypothermia.

12.4.5. MERITS OF CLONING:

1. The greatness of great people need not be terminated with their death. The merits can be kept alive.
2. When extra terrestrial town ships come up cloning enables easy multiplication of animals instead of a costly transport in space ships, especially when people want to migrate to other planets like Mars in future.
3. It will be possible for you to wear a new young body.
4. The test quality animal can be proliferated. Some cloned animals can give the safest blood for human blood transfusion.
5. Gene therapy can treat disease and even lead to preventive measures against dreaded disease like TB or even AIDS.
6. Dogs are believed to be derived from wolves and jackals. Similarly, mulled that are good in carrying loads are produced when donkeys mate with horses. On similar lines, new species of probably any nature can be generated.
7. New species from dog and goat or tiger and elephant or even man and cow or man and donkey can be generated. These man made species, however, may push the God-made man into extinction in the next century itself if the genetic manipulations continue at the expected rate.

12.4.6. ABUSES : The possible abuses of cloning area as follows:

1. Egoistic crooked leaders and dictators can perpetuate themselves.
2. Moral, cultural and aesthetic values face severe confusions. How far we are justified in defying nature, time will decide.
3. Man may foolishly interfere with natural ecological balances. Technical mistakes may create unwanted monsters. Afraid of the above, some governments have imposed a ban on human cloning and some fundamentalists even warned that the scientists involved in human cloning be made to suffer from the loss of penis. But fortunately or unfortunately scientific progress cannot be monopolized or controlled entirely by governments. Banned activities are always alive through clandestine operations.

12.4.7. EMBRYO SPLITTING :

Cloned sheep, goats and cattle were first produced from embryos more than 15 years ago by another type of cloning, termed embryo splitting. Using a fine glass needle or a razor blade chip to bisect the embryo, scientists can produce genetically identical offspring. The pregnancy rates using this embryo microsurgical technique are similar to those of intact embryos from the same donor female. Unfortunately, the best success rate came from bisecting the embryo into two halves, giving the opportunity for only two offspring to be produced from a single embryo.

12.4.8. DOLLY'S ARRIVAL:

More recently, there has been a major breakthrough in animal cloning. With Dolly, the famous sheep, cells for cloning were harvested from the mammary gland of an adult cow. These mammary cells were incubated in a laboratory to produce a much larger population of these dividing cells for the nuclear transfer procedure.

Fig.12.4-2. Dolly, the cloned sheep

The production of Dolly in Scotland was important because it was the first mammal produced from an adult somatic cell (a cell other than an egg or a sperm). The potential for the use of this new technology amazed the world. Today, adult cell clones have been produced in mice, sheep, cattle and recently goats. cloning will provide cattle producers an opportunity to reproduce genetically valuable founder animals (seed stock). Cloning technology will provide cattle producers with ready access to production-tested breeding seed stock, thus increasing the accuracy of selection in their breeding herds. Cloning F1 terminal-breed males to produce males for market steers might be the ultimate beef production management system. With this scenario, fewer cows would be needed to produce annual replacement heifers, so more F1 recipient females could be available to produce the cloned F1 males for use as the market steers. This assumes that the new cloning methodology becomes more efficient and is economically feasible.

12.4.9. THE FUTURE:

In future, the market-assisted selection for both single and multiple gene traits will become a potent assisted reproductive technology for embryos and newborn offspring. The challenge is identifying those traits important enough to merit the application of these new assisted reproductive technologies. Assisted reproductive technologies will likely play a larger role in embryo production and in the production of herd replacements. Our research approach is to develop those new assisted reproductive technologies that have economic, agricultural and medical applications.

12.4.10. SUMMARY

In summary, advances in assisted reproductive technologies have occurred rapidly in the last decade. Even scientists themselves are often amazed at the rate of progress made in the development and application of these technologies. The availability and the cost of some of these new technologies still remain in question. There is little doubt about their potential effectiveness to commercial cattle production, at least in the short run. It is obvious that including new technologies will require more intensive management by cattle producers. These new technologies appear to have, if economically practical, an opportunity for changing the genetic potential of farm animals at a faster rate than by conventional methods.

12.4.11. KEY WORDS

Cloning : rearing the sheep to the maximum
Surrogative mother : One who donates the womb for the development of the embryo.

12.4. 12. SELF ASSESSMENT QUESTIONS

1. What do you understand by cloning? Illustrate your answer with a suitable example.
2. What is cloning? How it helps in the progress of science?
3. Write an essay on Cloning and the technology involved in cloning.

12.4.13. REFERENCES

1. Genetics by Sinnot, Dunn and Dobzansky
2. A Text book of Zoology by Prof. V. Luther Das
3. The Science of Genetics by G W Burns
4. College Zoology by Richard A. Boolotian an Karl A. Stiles

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Lesson. 12.5.
LETHAL GENES

CONTENTS :

12.5.1 OBJECTIVES
12.5.2. INTRODUCTION
12.5.3. LETHAL GENES
12.5.4. LETHAL AFFECT OF DOMINENT GENES .
12.5.5. LETHAL AFFECT OF RECESSIVE GENES
12.5.6. SUMMARY
12.5.7. KEY WORDS
12.5.8. SELF ASSESSMENT QUESTIONS
12.5.9. REFERENCES

12.5.1. OBJECTIVES :

At the end of this lesson, the student would be able to define lethal genes, their origin and effect besides their behaviour during inheritance.

12.5.1 **INTRODUCTION** : In general and in any organism, each character is controlled by a pair of genes located at the same locus on the chromosome. The pair may be homozygous or heterozygous. Because of mutations, the genes might have transformed into several alleles. There are several conditions where a single gene may affect several characteristics, including mortality. In the case of humans and other mammals a certain recessive gene may lead to internal adhesions of the lungs resulting in death at birth. Another example involving a single gene affecting the formation of cartilage and produces congenital deformities leading to foetal and neonatal death.

12.5.3 LETHAL GENES :

Generally the genes are responsible for the inheritance of parental characters to the offspring. The genes are composedof DNA which undergoes mutations under the influence of excentric and intrinsic environmental factors. Such mutated genes are recessive and yet times cause death when present in homozygous state and hence they are called lethal genes. These may cause death either in dominant condition or in recessive condition. But in heterozygous state, they are not harmful.

12.5.4 LETHAL AFFECT OF DOMINENT GENES :

The effects of a lethal gene are clearly illustrated by the inheritance of fur colour in mice. Wild mice have grey-coloured fur, a condition known as agouti. Some mice have yellow fur. Cross-breeding yellow mice produces offspring in the ratio 2 yellow fur : 1 agouti fur. Upon close examination, it is understood that the gene for yellow colour is dominant to agouti and that all the yellow coat mice are heterozygous. The change in the Mendelian ratio is explained by the foetal *death of homozygous* yellow coat mice.

Gene 'Y' represent yellow fur (dominant) and
'y' represent agouti fur (recessive)
Parental phenotypes : yellow fur yellow fur
Parental genotypes : Yy x Yy *(2n)*
Meiosis results in

Gametes (n) Y y Y y

Random fertilization results in

Gametes	Y	y
Y	YY(dies)	Yy
y	Yy	yy

Table.12.5-1. Cross for lethal genes in mice

Offspring genotypes (2n) : Y Y Yy Yy yy
Offspring phenotypes : Yellow fur : 2 Yellow fur : 1 agouti
Genotypic ratio : 2 : 1

Genetic explanation of fur colour inheritance in mice shows that the one with yellow fur (YY) dies even before the birth. Hence homozygous dominent never exists and all the yellow rats are only heterozygous dominent.

Similar examination of the uteri of crosses between yellow fur and agouti fur mice revealed no dead yellow fetuses. The explanation is that this cross would not produce homozygous yellow (YY) mice.

12.5.5 LETHAL AFFECT OF RECESSIVE GENES

This concept can be illustrated by **sickle cell anemia.** It is a condition having sickle like RBC and are benificial to the organism as they prevent the infection by malarial parasite. Cross between persons with sickle cell anemia resulted in the youg at 1 : 2 ratio where one is having normal RBC and two with sickle celled condition. Double recessive character could not be expressed as it cannot survive and results in death during embryonic development itself.

The gene 'R' represent gene for Human with normal RBC(dominant).
The gene'r' represent the gene for sickle cell RBC (recessive)
Parental phenotypes : Human being with heterogzygous genes for sickle cells(Rr)
Parental genotypes : *(2n)* Rr x Rr

Gametes (n) R r R y

Random fertilization results in

Gametes	R	r
R	RR	Rr
r	Rr	rr(dies)

Table.12.5-2. Cross for sickle cell anaemia

Genotypic ratio in F2 generation is expressed as 1: 2 showing that the double recessive could not exist.

12.5.6. SUMMARY

Generally genes are responsible for theinheritance of ancestral characters. By mutations, such genes may arise which cause death to the organisms when present in homozygous state. The behaviour of such genes are discussed.

12.5.7. KEY WORDS

Lethal genes : Genes responsible for the death of the organisms when present in homozygous condition.

12.5.8. SELF ASSESSMENT QUESTIONS

Q. Give a detailed account on the concept of Lethal genes with suitable examples.

12.1.9. REFERENCES

1. Genetics by Sinnot, Dunn and Dobzansky
2. A Text book of Zoology by Prof. V. Luther Das
3. The Science of Genetics by G W Burns
4. College Zoology by Richard A. Boolotian an Karl A. Stiles

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Lesson-13.
SEX DETERMINATION

CONTENTS :

13.1 OBJECTIVES
13.2. INTRODUCTION
13.3. CHROMOSOMAL BASIS OF SEXDETERMINATION
13.3.1. XX-XO SEX DETERMINATION
13.3.2. XX-XY SEX DETERMINATION
13.4. BRIDGES RATIO THEORY
13.4. SUMMARY
13.5. KEY WORDS
13.6. SELF ASSESSMENT QUESTIONS
13.7. REFERENCES

13.1. OBJECTIVES :

After going through this lesson, the student acquire the knowledge about the determination of sex, chromosomal basis for sex determination, different types of sex determination and Bridges ratio theory.

13.2. INTRODUCTION :

Chromosomes are the threads present in the nucleus bearing the hereditory particles called genes composed of DNA. Their number differs according to species. In a given individual or species, the chromosomal number remains constant and are in *diploid* state in all somatic cells and haploid in gametes. Length of the chromosome and the position of the centromere in each chromosome differ. Cells of the vertebrate organisms possess definite number of chromosomes and their number is specific in differen species of the orgnisms. Every cell possesses autosomes or somatic chromosomes and one pair of allosomes or sex chromosomes. The sex chromosomes or heterosoms may be homozygous such as XX in females or heterozygous like XY in males of certain organisms.

13.3. CHROMOSOMAL BASIS OF SEXDETERMINATION :

Diploid or double set of chromosomes in animals provide with a double set of genetic instructions. Members of the homologous chromosomes ***(autosomes)*** look alike. The two chromosomes of the heterologous pair of chromosomes or sex chromosomes (**as** they determine the sex of the individual) or allosomes, differ greatly in size and genetic content. XX in female and XY in male . These two sets of allosomes play an important role in deciding the sex of the individual in following methods :

13.3.1. *XX-XO SEX DETERMINATION*:

Females possess two sex chromosomes (XX), and males have only one (XO). In other words, males have one less chromosome per cellas seen in bugs (hemipterans). Here male produces two types of sperm cells namely X type and O type. Sex of the embryo is based upon the type of sperm cell fusing with the ovum. Fertilization is a must for the egg to be developed.

13.3.2. *XX-XY SEX DETERMINATION*:

The X chromosome is a full-sized one while the other **(Y)** is a dwarf containing few genes. **XX-XY** sex determination has the following versions:

(i) The male has two full-sized chromosomes **(XX)**, and the female is **XY** (e.g., birds, moths, and butter flies). This is popularly known as ZZ male and ZW female type or female heterogametic type;

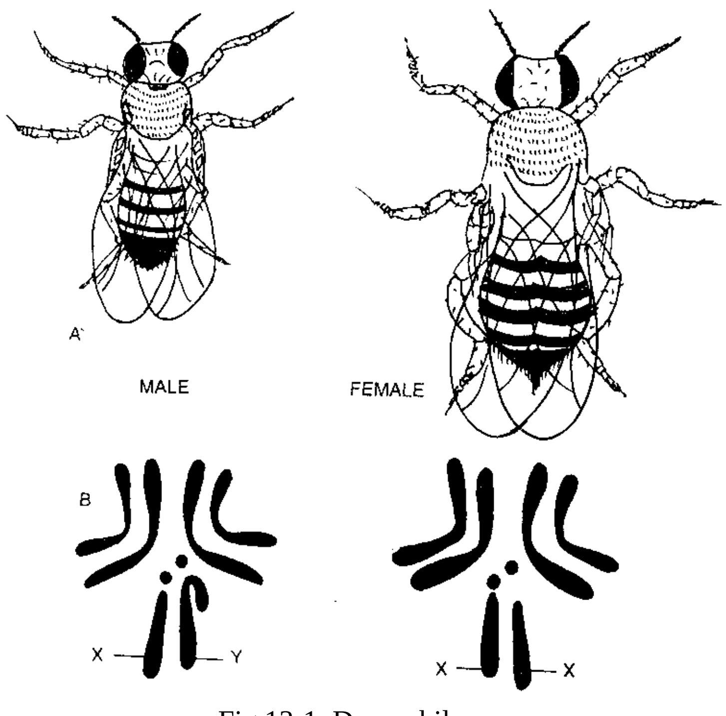


Fig.13-1. Drosophila
A. Male B. Female with their chromosomes

(ii) Females are **XX** and males **XY** (e.g., *Drosophila)* male heterogametic type : Here male insects are heterozygous in relation to the sex chromosome while female is a homozygous in nature. Thus all the eggs posess haploid X chromosome while male gametes are of two types possessing either X or Y. Sex of teh embryo is decided on the basis of type of sperm cell fusing with the egg. If the sperm cell with X chromosome fuses with the egg, the embryo develops into female. On the otherside, if the sperm cell having Y chromosome combines with the egg, the embryo develops into female. In experimentally produced **XO** individuals possessing one **X** but lack a Y still develop into male, but are sterile);

(iii) **XX** individuals are female and **XY** individuals are male as seen in most of the mammals including man. Here also, male is heterozygous one producing two types of sperm cells as seen above. But the Y chromosome in males bear a male-determining gene (e.g., mammals including man). By chance if XO individuals are formed, then it would develop into a sterile female as there is no male determining factor unlike those in drosophila).

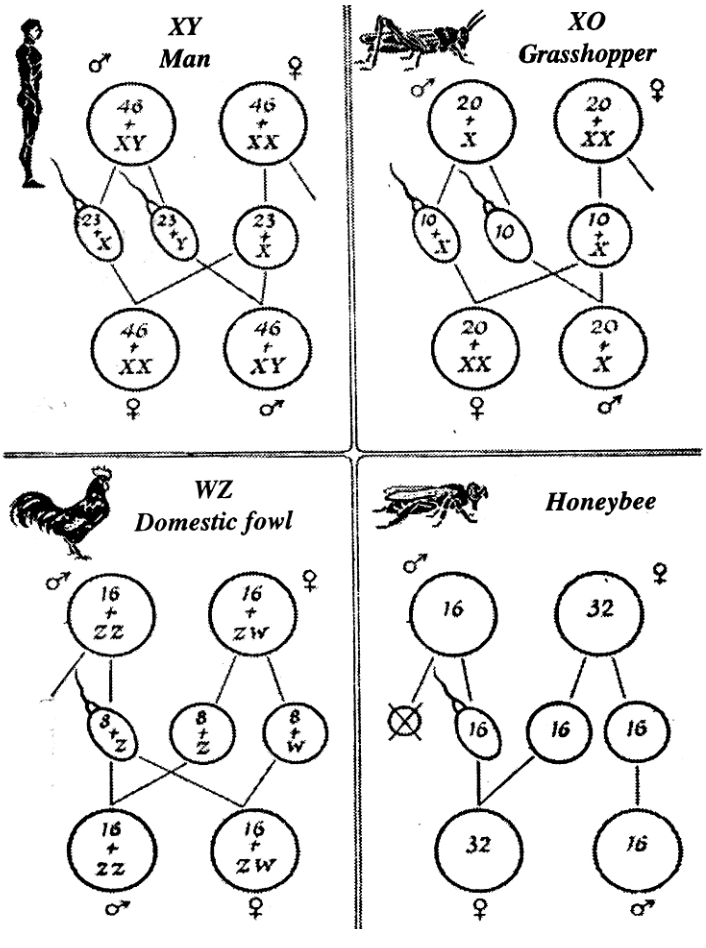


Fig.13-2. Different types of sex determination

(iv) XX female and X male type or male haploid type of sex determination as seen in honey bees. Here males are always haploid by possessing only one X chromosome while females are diploid by having a set of XX chromosomes. During reproduction, if the egg is fertilised by the sperm cells having x chromosome, they normally develop into females. Unfertilised eggs develop parthenogenetically into males.

13.4. BRIDGES RATIO THEORY :

This theory was advocated by Bridges, Sutton and Wilson. Accordingly, the genes on sex chromosomes also influence the expression of the sex.

Normal organisms are produced only when there is equilibrium between the genes on the autosomes to the genes on the sex chromosomes. Thus the theory is dependent upon the ratio of genetic forces between the autosomes and allosomes. Since Y chromosome bears no genes, it has no role in the determination of sex.

The value assigned to X chromosome is 1 and to the pair of autosomes(diplid) in each cell is 2. If the cells are triploid, the value is 3 and if they are haploid, then it is 1. The value of Y is zero because it has no genes.

Sl	Autosomal pairs	No. of sex cromosomes	X/A Ratio	Phenotype
1	2 (AA)	3 (XX)	3/2 = 1.5	Super female
2	3 (AAA)	4 (XXXX)	4/3 = 1.33	Triploid female
3	4 (AAAA)	4 (XXXX)	4/4 = 1	Tetraploid female
4	2 (AA)	2 (XX)	2/2 = 1	Diploid female
5	2 (AA)	1 (XY)	½ = 0.5	Male
6	3 (AAA)	1 (XY)	1/3 = 0.33	Triploid super male
7	4 (AAAA)	3 (XXX)	¾ = 0.75	Tetraploid intersex
8	3 (AAA0	2 (XX)	2/3 = 0.67	Triploid intersex

Table.13-1. Table in support of Bridge's ratio theory

If the ratio between the autosomes and sex chromosomes is one, it develops into female and if teh ratio is 0.5, it develops into male. It should be noted that the male characters are expressed only in presence of Y and in the absence of it, the organism still develops into male when the ratio is 0.5 but are sterile.

Effect of Temperature : Intersex organisms show both male and female features. At higher temeperatures, female characters become conspicuous while at lower temperatures, male characters are expressed.

'Tra' gene : The 'Tra' gene in homozygous condition, on the third chromosome of Drosophila changes the normal females to sterile males.

GYNANDROMORPHS: Gynandromorphs are the insects showing both male and female characters. This is formed by the divison of a normal zygote under special circumstances when one x chromosome is lost resulting in the blastomeres with AAXO condidtion. When these blastomeres are present on the other side of blastomeres withAAXX , the part with XO combination develop male characters while the other half develop female characters. If these characters are on either side of the insect, it is called bilateral gynandromorphs. When they are present in arterior and posterior parts, it is called anteroposterior gynandromorphs. If the charactes are irregular, they are called sex piebalds.

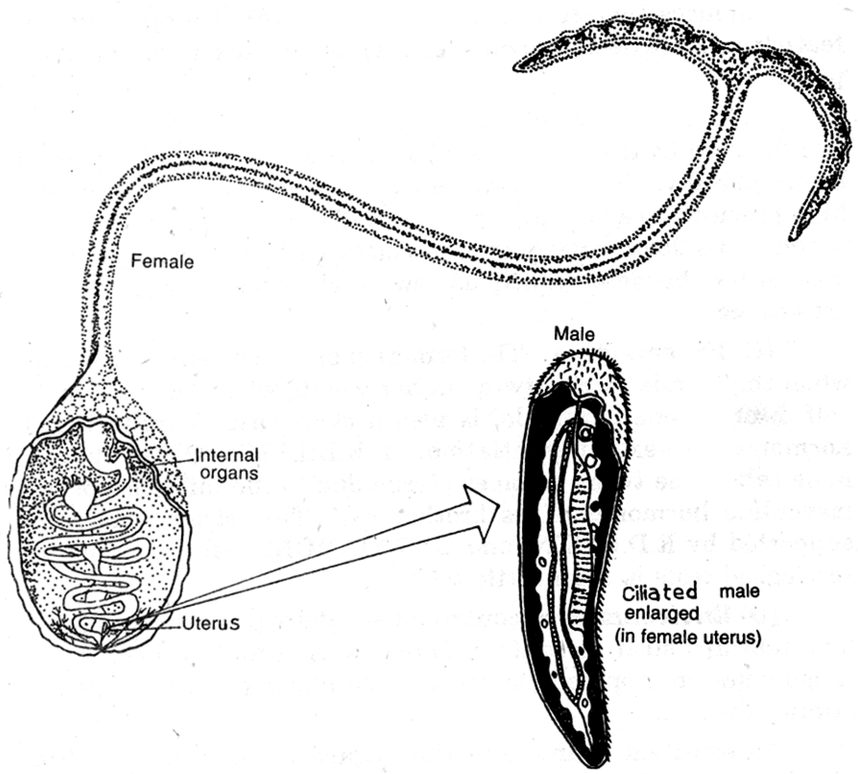


Fig.13-3. Bonellia

Besides the above, sex is also determined by hormones from Pituitary, adrenal and gonads in some organsisms ; by genes in some sp. of honey bees ; by environment as in Bonellia or by metabolic activities as in pigeons.

13.5. SUMMARY :

Sexual dimorphism is seen right from phylum nematyhelminthes to chordates. Differentiation of male and female sexes in all these sexually reproducing organisms occur at the time of fertilization. Chromosomes play an important role in the determination of sex in most of the individuals. C.P. Bridges proposed ratio
theory of sex determination by assigning values to the autosomes and sex chromosomes. Hormones and other environmental factors also play role in the determination of sex in some lower organisms.

13.6. KEY WORDS

Autosomes : Somatic chromosomes in the nucleus
Allosomes : Sex chromosomes in the nucleus

13.7. ELF ASSESSMENT QUESTIONS

1. Write an essay on different types of sex determination encountered in different groups of organisms.
2. How chromosomes are responsible for sex determination ?
3. write an essay on the role of chromosomes in the determination of sex in organisms.
4. Write an account on Bridge's ratio theory.

13.8. REFERENCES

1. Genetics by Sinnot, Dunn and Dobzansky
2. A Text book of Zoology by Prof. V. Luther Das
3. The Science of Genetics by G W Burns
4. College Zoology by Richard A. Boolotian an Karl A. Stiles

….K. Kondaiah

Lesson. 14.
SEX LINKED INHERITANCE

CONTENTS :

14.1 INTRODUCTION
14.2. OBJECTIVES
14.3. SEX LINKAGE
14.3.1. DIANDRIC TYPE
14.3.2. DIAGENIC TYPE
14.3.3. HOLANDRIC TYPE
14.3.4. HOLOGENIC TYPE
14.3.5. SEX INFLUENCED GENES
14.4. BLOOD GROUP INHERITANCE
14.4.1 MULTIPLE ALLELES
14.4.2. BLOOD GROUPS
14.4.3. INHERITANCE OF BLOOD GROUPS
14.4.4. CHROMOSOMAL BASIS OF INHERITANCE
14.5 SUMMARY
14.6. KEY WORDS
14.7. SELF ASSESSMENT QUESTIONS
14.8. REFERENCES

14.1. OBJECTIVES :

The main objective of this lesson is to make the student understand

- Linked characters and sex linked characters
- Patterns of inheritance of sex linked characters
- Different types of sex linked characters
- Multiple alleles and their behaviour in inheritance
- Blood groups and their importance
- Chromosomal basis of blood group inheritance
- ABO system of blood grouping and their significance in blood transfusion.

14.2. INTRODUCTION :

Genes carried on the sex chromosomes are said to be sex-linked. In the case of the heterogametic sex, there is a portion of the X chromosome having homologous region of the Y chromosome. Characters determined by the genes on the non-homologous portion of the X chromosome therefore appear in males even if they are recessive. This special form of linkage explains the inheritance of genes along the sex crhomosomes. Hence the characters are the **sex-linked traits** and the inheritance is the **sex linked inheritance.**

14.3. SEX LINKAGE AND TYPES :

General characters of the organisms are controled by the genes on autosomes. But there are certain characters controled by the genes located on sex chromosomes or allosomes. Such characters are transmitted from generation to the other along with the sex chromosome and hence they are called sex linked characters. Inheritance of sex linked characters is of four types :

14.3.1. DIANDRIC TYPE(CRISCROSS TYPE):

Here the genes are present on the non homologous part of the X chromosome of males and are carried all along the lne. Genes present over this part of chromosome carry the characters from parent generation to the grand son through the carrier female.

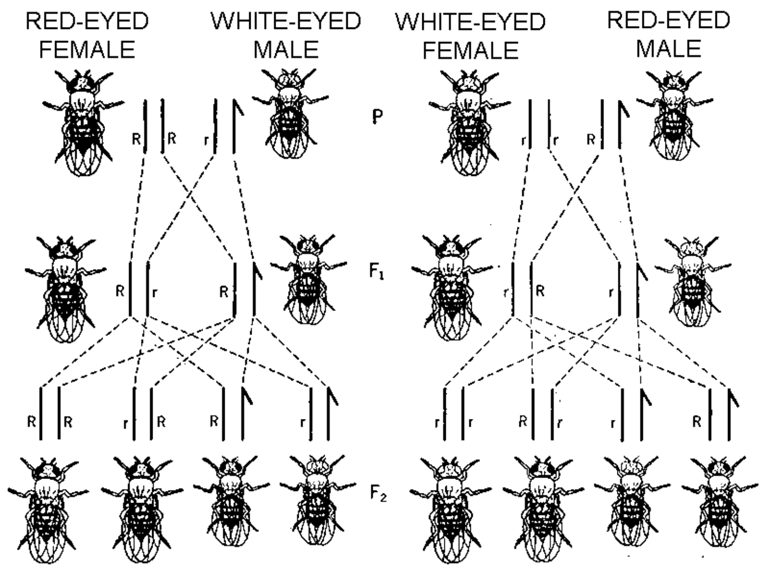


Fig.14-1. Criss cross type of inheritance od eye colour in Drosophila.

A)Eye clour in Drosophila : Morgan and his co-workers noticed that inheritance of eye colour in *Drosophila* was related to the sex of the parent flies. Red eye is dominant over white eye. A red-eyed male crossed with a white-eyed female produced equal numbers of F_1 red-eyed females and white-eyed males. A white-eyed male, however when crossed with a red-eyed female, produced equal numbers of F_1 red-eyed males and females. Inbreeding these F_1 flies produced red-eyed females, red-eyed males and white-eyed males but *no* white-eyed females. The fact that male flies showed the recessive characteristic more frequently than female flies suggests that the white eye recessive allele is present on the X chromosome and that the Y chromosome lacked the eye colour gene.

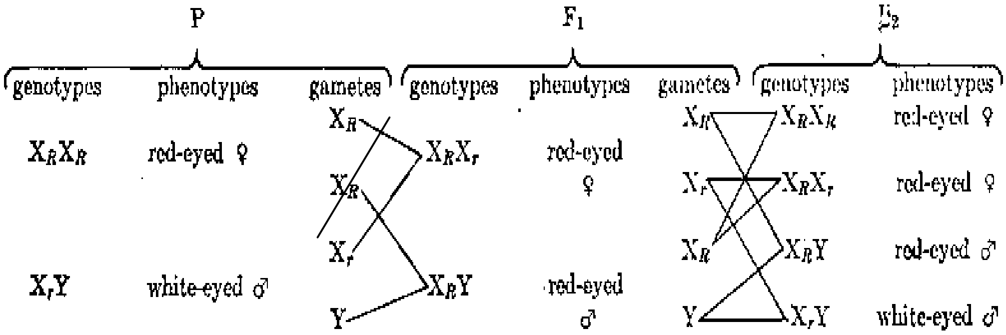


Table.14-1. showing eye colour inheritance in drosophila

To test this hypothesis Morgan crossed the original white-eyed male with an F_1 red-eyed female. The offspring included red-eyed and white-eyed males and females. From this Morgan rightly concluded that only the X chromosome carries the gene for eye colour. There is no gene locus for eye colour on the Y chromosome. This phenomenon is known as sex linkage.

B) Haemophilia in man : In human beings, traits like red-green colour blindness, premature balding and haemophilia are of sex linked nature. Haemophilia or 'bleeder's disease' is a sex-linked recessive condition which prevents the formation of an important coagulation factor (VIII). The gene for substance VIII is carried on the non-homologous portion of the X chromosome and can appear in two allelomorphic forms: normal (dominant) and mutant (recessive). The following possible genotypes and phenotypes can occur.

In all sex-linked traits, females who are heterozygous are described as **carriers** of the trait. They are phenotypically normal but half their gametes carry the recessive gene. Despite the father having a normal gene, there is a 50% probability that sons of carrier females will show the trait. In the situation where a carrier haemophiliac female marries a normal male, they may have children with phenotypes as shown in the following **table**.

'**H**' represent normal allele for blood **clotting** (dominant) ; and 'h' represent allele for haemophilia (recessive) ;

XX represent female chromosomes

XY represent male chromosomes

Genotype	Phenotype		
X^HX^H	Normal female	X^HX^h	Carrier female
X^HY	Normal male	X^hY	Haemophilic male
Parental phenotypes	Normal carrier female	X	Normal male

Parental genotypes (2n) X^HX^h X^HY

Meiosis

Gametes (n) X^H X^h X^H Y

Random fertilization

Offspring genotypes (2n) $X^H X^H$ X^HY $X^h X^H$ X^hY

Offspring phenotypes

Normal	Normal	Carrier	Haemophilic
Female	*male*	*Female*	male

Similarly the inheritance of colour blindness can be drawn taking 'C' as normal gene and its mutant allele 'c' as the gene for colour blindness.

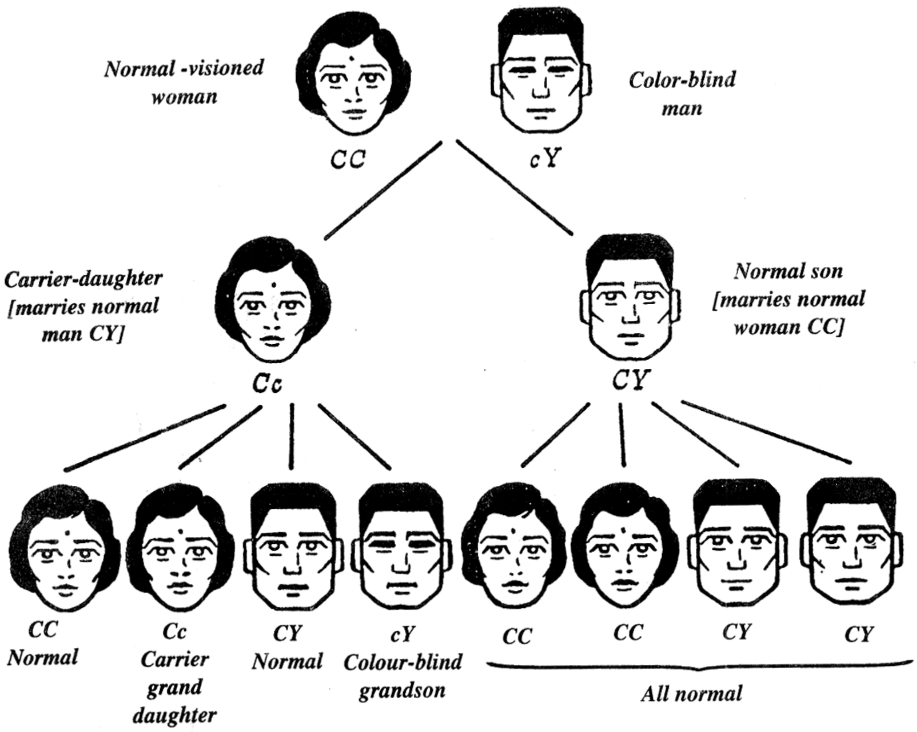


Fig.14-2. Criss-cross inheritance in humans

Parents → ↓	gametes ↓ →	Normal ♂ *X*Y		Color-blind ♂ **X**Y	
		X	Y	**X**	Y
		Children			
Normal ♀ *XX*	*X*	*XX* ♀ normal	*X*Y ♂ normal	**X***X* ♀ *carrier*	*X*Y ♂ normal
Carrier ♀ **X***X*	*X*	*XX* ♀ normal	*X*Y ♂ normal	**X***X* ♀ *carrier*	*X*Y ♂ normal
	X	**X***X* ♀ *carrier*	**XY** ♂ **color-blind**	**XX** ♀ **color-blind**	**XY** ♂ **color-blind**
Color-blind ♀ **XX**	**X**	**X***X* ♀ *carrier*	**XY** ♂ **color-blind**	**XX** ♀ **color-blind**	**XY** ♂ **color-blind**

Table14-2. Inheritance of colour blind ness in man

14.3.2. DIAGENIC CRIS-CROSS TYPE : Here the characters of a female are passed on to the grand daughters through carrier males. This is exactly opposite one to the diandric type and occurs in birds where females are heterozygous producing heterogametes. Male birds (ZZ) ; female birds (ZW). Sex linked trait is the Barred plumage in fowls.

Phenotypes Barred cock Black hen

Genotypes $\mathbf{Z^BZ^B}$ $\mathbf{Z^bW}$

Gametes Z^B Z^b W

Off spring upon random mating Z^BZ^b Z^BW

F_1 Generation Barred male Barred hen

Gamets Z^B Z^b Z^B W

F_2 Generation Z^BZ^B Z^BW Z^BZ^b Z^bW

Barred male Barred hen Barred Male Black hen

All males are barred white 50% of females are barred and 50% are black

14.3.3. HOLANDRIC TYPE : The paternal characters are directly tranmitted to the son through the genes present on the non homologous part of the Y chromosome. Hence this is an example for sex limited inheritance. Ex : Hair on ears(Hyper trichosis), Porcupine man.

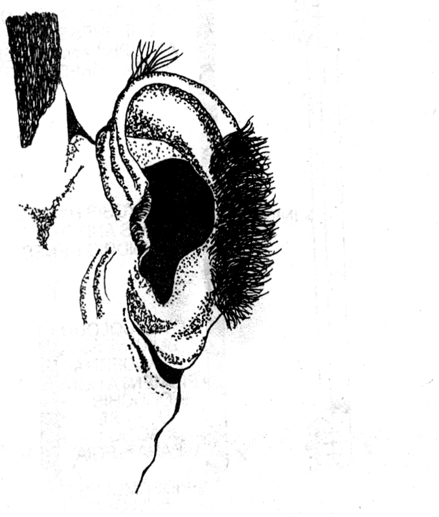


Fig.14-3. Hypertrichosis relating to hair on the ear libe of males

14.3.4. Hologenic type: Here the maternal characters are directly transmitted to the daughter through the genes present on the X chromosome and not separated during crossing over. This is also an example for sex limited inheritance. Ex : The angular bend in the fore arms of females.

Sex influenced genes: (Ex- Pattern Bald head in human beings.) Genes relating to bald ness are seen both in males and females. But they are expressed only in males and is rarely found in females when the genes are in homozygous condition. Similarly, horns in malesheep, coloured patches in cattle(Black and white patches in males, brown or red and white patches in females are expressive and dominant) are the other examples for sex infulenced genes.

Genotype	Males	Females
BB	bald	bald
Bb	bald	non-bald
bb	non-bald	non-bald

1.

	non-bald		bald
P	**bb**	X	**BB**
G	**b**		**B**
offspring	**Bb**		**Bb**
	(non-bald)		(bald)

2.

P	Non-bald		Bald
	Bb	X	**Bb**
offspring	**BB**	**Bb**	**bb**
	(bald)	(bald)	(non-bald)
	BB	**Bb**	**bb**
	(bald)	(non-bald)	(non-bald)

3.

	BB	X	**bb**
	(bald)		(non-bald)
offspring		**Bb** (bald)	
		Bb (non-bald)	

Inheritance of baldness in human beings.

Table 14-3. *cross for Sex influenced genes*

Genes for Duchenee (muscular distrophy leading to the death)are recessive, sex linked and become lethal. When they are present in homozygous state, the person would be normal up to the age of 12-15 years and die in between 12-15 years of age.

14.4. BLOOD GROUP INHERITANCE

Experiments with blood transfusions, the transfer of blood or blood components into a person's blood stream, have been carried out for hundreds of years. Many patients have died and it was not until 1901, when the Austrian Karl Landsteiner discovered human blood groups, that blood transfusions became safer.

Mixing blood from two individuals can lead to blood clumping or agglutination. The clumped red cells can crack and cause toxic reactions. This can have fatal consequences. Karl Landsteiner discovered that blood clumping was an immunological reaction which occurs when the receiver of a blood transfusion has antibodies against the donor blood cells.

Karl Landsteiner's work made it possible to determine blood types and thus paved the way for blood transfusions to be carried out safely. For this discovery he was awarded the Nobel Prize in Physiology or Medicine in 1930.

In general and in any organism, each character is controlled by a pair of genes located at the same locus on the chromosome. The pair may be homozygous or heterozygous. Because of mutations, the genes might have transformed into several alleles. There are several conditions where a single characteristic may appear in several different forms controlled by three or more alleles, of which any two may occupy the same gene loci on homologous chromosomes. This is known as the **multiple allele** (or **multiple allelomorph)** condition and it controls such characteristics such as coat colour in mice, eye colour in mice and blood group in humans.

14.4.1. Multiple alleles or polygenes :

Two or more different pairs of alleles, with a presumed cumulative effect. Such pairs govern the characters like blood groups, size, pigmentation, intelligence, etc

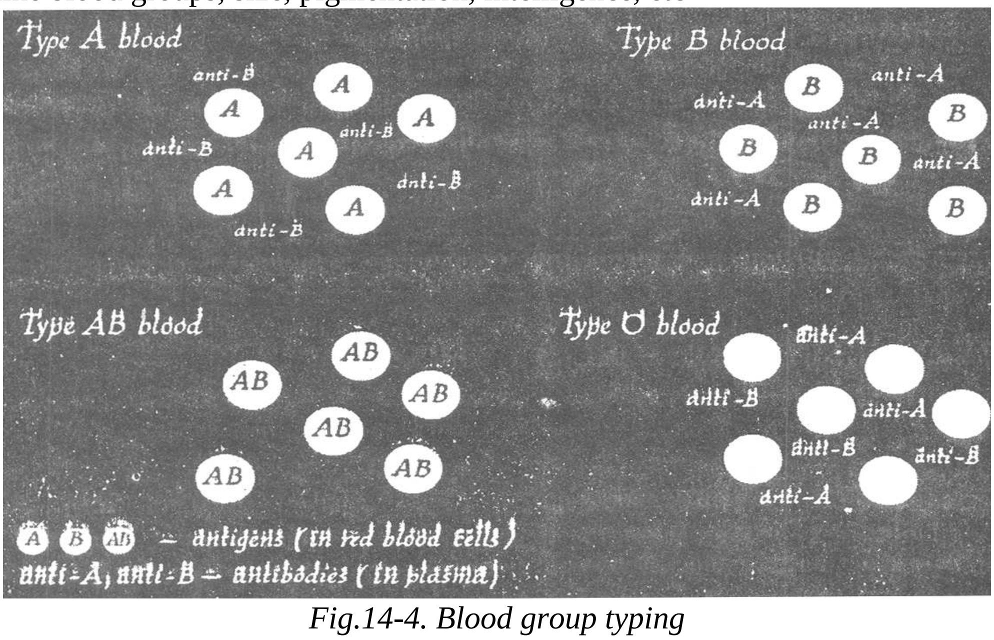


Fig.14-4. Blood group typing

14.4.2. Blood groups: The differences in human blood are due to the presence or absence of certain protein molecules called antigens and antibodies. The antigens are located on the surface of the red blood cells and the antibodies are in the blood plasma. Individuals have different types and combinations of these molecules. The blood group you belong to depends on what you have inherited from your parents.

Basing on immunological (antigenic) properties and in accordance with the specific type of substances present over the surface of RBC(Red Blood Corpuscles), four types of blood groups are differentiated in human beings. Blood groups are genetically determined and each is characterized by the presence of a specific complex **carbohydrate** . About 200 different blood group substances have been identified and placed within 20 known blood group systems. The most commonly used blood group system is the ABO, or **Landsteiner** system. Not all blood groups are compatible with each other. Mixing incompatible blood groups leads to blood clumping or agglutination, which is dangerous for individuals.

Individuals may contain the A, B, or both A and B antigenic substances, or else lack these substances (type O). In the ABO system an individual who lacks one or more of these antigens will spontaneously develop the corresponding **antibodies** (agglutinins) shortly after birth.

ABO Blood Group System

Since these agglutinins are always present in the blood, during **blood transfusion** the donor blood must be compatible with the recipient's blood, i.e., the donor's blood must not contain antigen corresponding to the recipient's antibody.

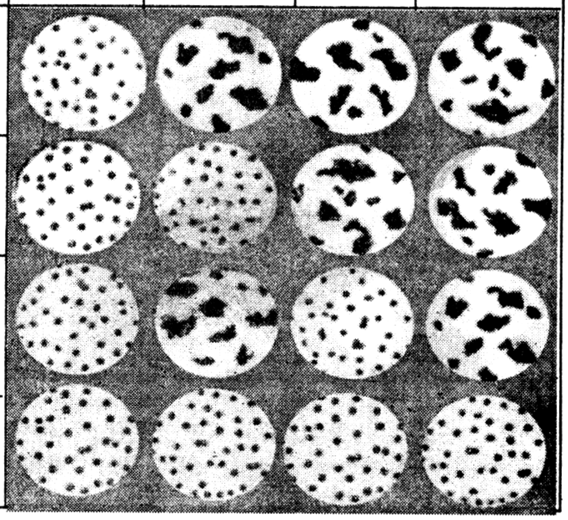
Blood Type	**Genotypes**	**ABO Enzymes Present**	**RBC Antigens Present**	**Serum Antibodies**
"A"	AA, Ai	"A"	A,	anti-B
"B"	BB, Bi	"B"	B,	anti-A
"AB"	AB	"A", "B"	A, B,	none
"O"	ii	nil	o	anti-A, anti-B

Table 14-3. showing ABO Grouping

14.4.3. Inheritance of blood groups

Blood group is controlled by an autosomal gene. The gene locus is represented by the symbol '**I'** (which stands for isohaemagglutinogen) and there are three alleles represented by the symbols A, B and o. The alleles A and B are equally dominant and o is recessive to both. The presence of a single dominant allele results in the blood producing a substance called agglutinin which acts as an antibody. For example, the genotype I^A1° would give rise to the agglutinogen A on the red blood cell membrane, and the plasma would contain the agglutinin **anti-B** (the blood group would be A).

Group	Antigens in red blood cells	Antibody present in serum	Reaction to serum (listed to left) of red blood cells from group			
			O	A	B	AB
O	O	Anti-A Anti-B				
A	A	Anti-B				
B	B	Anti-A				
AB	AB	—				



Reactions of red blood cells of O,A, B and AB individuals to antibodies anti-A and anti-B.

Fig.14-5. Identification of blood groups

The A and B genes are found on autosome 9. We inherit one gene (allele) from our father and one from our mother. The two co-dominant alleles are A or B. Anytime an individual inherits an A or B gene it will be expressed.

The O gene signifies lack of A or B antigens. It is not expressed unless this gene is inherited from both parents (OO). Therefore the O gene is recessive.

Below is the example of two individuals who are A. One inherited only one A gene along with an O gene and is therefore heterozygous. The other inherited 2 A genes and is homozygous for A.

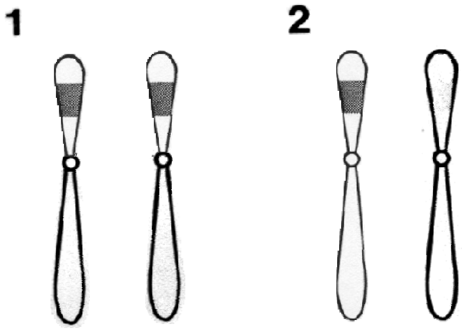


Fig. 14-6. Chromosomes for blood groups

1	2
1 = A/A	2 = A/O
1 = Homozygous A	2 = Heterozygous A
Phenotype A	Phenotype A
Genotype A/A	Genotype A/0
Can Contribute Only an A Gene to Offspring	Can Contribute A or O Gene to Offspring

a) Inheritance Patterns

We can't determine genotypes of A or B people unless family studies are done. Some basic rules of ABO inheritance are as follows:

- A/A parent can only pass along A gene
- A/O parent can pass along either A or O gene
- B/B parent can only pass along B gene
- B/O parent can pass along either B or O gene
- O/O parent can only pass along O gene
- AB parent can pass along either A or B gene

b) ABO phenotypes and genotypes

1. Group A phenotype = A/A or A/O genotype
2. Group B phenotype = B/B or B/O genotype
3. Group O phenotype = O/O genotype
4. Group AB phenotype = A/B genotype

Offspring possibilities *Table: 14-4. Chromosomal basis for blood groups*

c. Possibilities of an A/O mating with a B/O: (Children's genotypes in purple)

Mother's Genes	Father's Genes	
	B	O
A	AB	AO
O	BO	OO

d. Possibilities of AA mating with BB: (Children's genotypes in purple)

Mother's Genes	Father's Genes	
	B	B
A	AB	AB
A	AB	AB

e. Possibilities of an A/A mating with a B/O: (Children's genotypes in purple)

Mother's Genes	Father's Genes	
	B	O
A	AB	AO
A	AB	AO

f. Possibilities of an A/A mating with an O/O:

Mother's Genes	Father's Genes

	O	**O**
A	**AO**	**AO**
A	**AO**	**AO**

g. Possibilities of an A/O mating with an O/O:

Mother's Genes	**Father's Genes**	
	O	**O**
A	**AO**	**AO**
O	**OO**	**OO**

h. Possibilities of an A/B mating with a O/O:

Mother's Genes	**Father's Genes**	
	O	**O**
A	**AO**	**AO**
B	**BO**	**BO**

14.5. SUMMARY

Linkage is related to the inheritance of the normal somatic characters inherited along with the somatic chromosomes as the genes for such characters are located on autosomes. But certain genes for some special characters are located over the X chromosome. Inheritance of such characters and the behaviour of such chromosomes comes under the study of sex linked inheritance. Some characters are limited to a particular sex and such characters constitute thesex limited characters. Genes for Baldness though present in both the sexes, they are influenced by sex and hence they are called sex influenced features.

14.6. KEY WORDS

Agglutin : An antibody that roduces clumping of the antigenic substances.
Barr body : The inactive, densely staining condensed X chromosome found near to the nuclear membrane in the nuclei of the somatic cells of Xx femals.
gene: determines specific inherited trait (ex. blood type)
chromosome: unit of inheritance. Carries genes. 23 pairs of chromosomes per person, carrying many genes. One chromosome inherited from mother, one from father
locus: site on chromosome where specific gene is located
allele: alternate choice of genes at a locus (ex. A or B; C or c, Lewis a or Lewis b)
homozygous: alleles are the same for any given trait on both chromosome (ex. A/A)
heterozygous: alleles for a given trait are different on each chromosome (ex. A/B or A/O)
phenotype: observed inherited trait (ex. group A or Rh positive)
genotype: actual genetic information for a trait carried on each chromosome (ex. O/O or A/O)

dominant: the expressed characteristic on one chromosome takes precedence over the characteristic determined on the other chromosome (ex. A/O types as A)
co-dominant: the characteristics determined by the genes on both chromosomes are both expressed - neither is dominant over the other (ex. A/B types as AB)
recessive: the characteristic determined by the allele will only be expressed if the same allele is on the other chromosome also (ex. can type as O only when genotype is O/O)

14.7. ELF ASSESSMENT QUESTIONS

1. What do you understand by the term sex linkage ? Explain the same taking examples from drosophila and human beings.
2. Explain the following genetic concepts with suitable examples (a) Sex linkage (b) Sexlimited inheritance (c) Sex influenced genes
3. Write an essay on the inheritance of blood groups in human beings.
4. Define multiple alleles. Explain the same with an example.
5. Write briefly about ABO system of blood groups.

14.8. REFERENCES

1. Genetics by Sinnot, Dunn and Dobzansky
2. A Text book of Zoology by Prof. V. Luther Das
3. The Science of Genetics by G W Burns
4. College Zoology by Richard A. Boolotian an Karl A. Stiles

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Lesson-15.

CHROMOSOMAL ABBERRATIONS AND HUMAN DISEASES

CONTENTS :

15.1. OBJECTIVES
15.2. INTRODUCTION
15.3. CHROMOSOMAL ABNORMALITIES AND HUMAN SYNDROMES
15.3.1. Structural Abnormalities
15.3.2. Numerical Abnormalities
15.3.3. Autosomal aneuploidy
15.3.4. Sex chromosome aneuploidy
15.4. SUMMARY
15.5. KEY WORDS
15.6. MODEL QUESTIONS
15.7. REFERENCES

15.1. INTRODUCTION:

Generally the number of chromosomes for a given species of organisms is always constant and is maintained though the generations because of meiosis taking place during the formation of gametes. Sometimes, abnormal gametes are formed due to chromosomal nondisjunction during gametogenesis. Some gametes may possess total set of chromosomes while some may not have the set at all. Fusion of such gametes with normal or abnormal gametes result in the formation of syndromes which express some special characters. The following abnormalities are explained for the benefit of study.

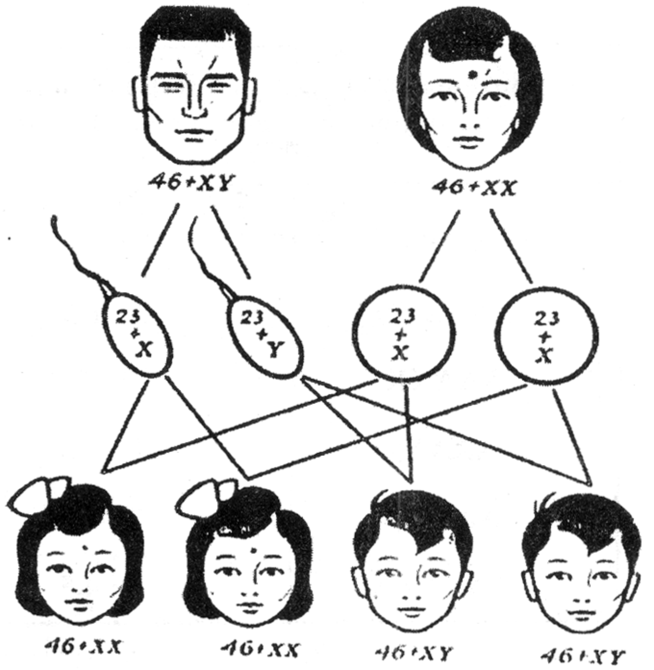
15.2. OBJECTIVES:

This lesson make the student to acquire the knowledge

- Chromosomal aberrations and the reasons for such aberrations
- about diseases inherited due to abnormality in the structure and number of chromosomes
- human syndromes.
- Special features about human syndromes

15.3. CHROMOSOMAL ABNORMALITIES AND HUMAN SYNDROMES:

Normal diploid number of chromosomes in human cells is 46 + XX and 46 + XY in females and males respectively. The structure and number given to each set of chromosomes is specific and any deviation to this leads to the formation of abnormalities and expression of diseases.



Sex determination in *man*

Fig. 15-1. Normal inheritance in man

15.3.1. Structural Abnormalities :

Structural abnormalities in chromosomes like translocations, inversions, duplications, and deletions result because of breakage and subsequent rejoining or loss of chromosome fragments. Such events can occur either spontaneously during replication or by inducing agents such as chemicals, radiation, and ultraviolet light. The effects of such structural abnormalities depend on how large they are and their place of occurrence on the chromosome.

15.3.2. Numerical Abnormalities:

Normal human cells contain 46 chromosomes, 22 pairs of autosomes and 1 pair of sex chromosomes. In humans, the euploid number is 23.

a) Polyploidy: This_ refers to the multiplication of the euploid number. In humans diploidy is 23 pairs; triploidy is 69 so on and soforth. Any such increase in chromosomal number invariably results in early death of the embryo in the uterus. Polyploidy can arise due to errors during gamete formation, problems during fertilization, or errors in mitosis during early stages of embryo formation.

b) Aneuploidy : It is not an exact multiple of the euploid number. In humans, this is most often occurring due to loss or gain of a single chromosome. Two conditions arise due to aneuploidy such as

c) Monosomy: This condition arises due to the loss of one member of a chromosome pair. Hence a person with a single monosomy would have 45 chromosomes. This is very rare.
d) Trisomy : Trisomy is the result of the addition of a of a single chromosome resulting in 47 chromosomes. This condition is more common. Either monosomies or trisomies (except for trisomy in 13, 18, and 21 chromosome) result in early spontaneous abortion.
An abnormal phenotype is the result of an excess or deficiency of the genes carried on the affected chromosomes.

15.3.3. Autosomal aneuploidy_: Trisomy in 13, 18, or 21 chromosomes is called autosomal aneuploidy. Persons with trisomy in 13 and 18 chromosome survive for 2-6 months on an average. Mostly they die during neonatal period. Signs and symptoms of these disorders include cleft lip and palate, limb deformities, severe malformations of the nervous system, heart malformations, and mental retardation. Trisomy in 21 is the only autosomal aneuploidy in which the affected can survive into adulthood.

Advanced maternal age is a main reason for these aneuploidius Most often, trisomy is due to non-disjunction of maternal chromosome. Non-disjunction occurs when chromosomes during cell division and mostly during gamete formation. Here the chromosomes fail to separate and hence they remain in the same cell.

15.3.4. Sex chromosome aneuploidy: This is different from autosomal aneuploidies and is more common in human beings. Sex chromosome aneuploidy is present in 1/400 male and 1/650 female live births.
Monosomy for the X chromosome is viable, while monosomy for the Y chromosome is invariably lethal. At least one copy of the X chromosome is essential for the survival and development. These aneuploidies also often result from non-disjunction of the chromosomes during cell division.

a) Monosomy X (Turner's syndrome): These females have only one X chromosome. Thus they possess 45 chromosomes. Typical symptoms include short stature, large skin folds on the neck, nipples close together and lack of sexual development. They develop X-linked recessive diseases that are usual and frequent in males. This occurs because of the absence of the second copy of the X chromosome to hide the effects of recessive alleles. Their frequency is about 0.03%.

b) XXY (Klinefelter syndrome): These males have two copies of the X chromosome in addition to a Y chromosome thus possessing 47 chromosomes altogether. Hence show more female secondary sexual characters. Their frequency is about 0.02% in western populations. Generally sterile, very small testes, little facial hair, moderately developed breasts, low intelligence, poor sexual development. These males may be slightly aggressive, prone for alcoholism and skin diseases, speech disorders exhibiting antisocial behaviour. Other forms of this disease involve various combinations of di- or trisomy for X or Y (XXYY, XXXY, and XXXXY). Increasing numbers of the X chromosome result in more severe manifestations of the disease.

Condition/ Genotype	*Symptoms*	*Frequency in Western populations*
Klinefelter's syndrome (XXY)	♂, possessing some ♀ secondary sexual characteristics, sterile, testes very small, little facial hair, breasts may develop, usually low intelligence	0.02%
Turner's syndrome (XO)	♀, lacking normal secondary sexual characteristics and very short, nipples close together	0.03%
XXX	♀, normal appearance, fertile, but mentally retarded	0.12%
XYY	♂, tall, variable intelligence, may possess psychopathic traits or tendency for petty criminal acts	0.1%

Table.15-1. Chromosomal aberrations

c) XYY syndrome: This karyotype was discovered during a study of male prisoners. The incidence of XYY males is about 1% in general population. This disorder has been linked to the symptoms like increased violence, above average height, and subnormal intelligence. However it is not a general conclusion that the XYY genotype is directly responsible for increased violence and aggression.

d) Down Syndrome or XXX syndrome (**Trisomy 21)::** Often these females are clinically normal in appearence, with slight increase in mental retardation and sterility(rarely fertile). Just as XXY, increasing numbers of the X chromosome are associated with more severe clinical manifestations. Frequency is about 0.12% . Other features include short stature, mental retardation, characteristic facial features, congenital heart defects (in 40% of affected individuals), increased risk of leukemia (cancer of white blood cells), increased risk of cataracts (clouding of lens of eye), and premature aging..

e) Cri-du-chat syndrome (cry of the cat**)**: This syndrome appear due to the deletion on the short arm of 5^{th} chromosome . The name comes from the distinctive crying sound from the affected infants.

15.4. SUMMARY

Chromosomal number in any species of the organisms is always constant besides the genome features. Deviations in the structure and number result due to mutations, chromosomal non disjunction during cell division and the influence of various environmental factors. Result of such abnormalities is the appearence of syndromes with special health problems.

15.5. KEY WORDS

Syndrome : abnormal organism resulting due to several reasons of which irregularity in the structure and number of chromosomes also contribute

Chromsomal non disjunction : non sepearation of chromosomes during anaphase of cell division.

15.6. Self assessment questions

1. How chromosomal aberrations occur in the organisms. Explain the nature of the syndromes formed due to chromosomal aberrations in human beings.
2. Describe the structural and numerical abnormalities of the chromosomes in human beings.
3. Explain various human syndromes and their resultant factors.

15.7. References

1. Genetics by Sinnot, Dunn and Dobzansky
2. A Text book of Zoology by Prof. V. Luther Das
3. The Science of Genetics by G W Burns
4. College Zoology by Richard A. Boolotian an Karl A. Stiles

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Lesson - 16
MODERN SYNTHETIC THEORY OF EVOLUTION
OR
NEO-DARWINISM
OR
GENETICAL THEORY OF NATURAL SELECTION
OR
MODIFIED THEORY OF DARWINISM

CONTENTS:

16.1. OBJECTIVES
16.2. INTRODUCTION
16.3. EVIDENCES FOR EVOLUTION
16.4. THEORIES OF EVOLUTION
16.5. NATURAL SELECTION
16.6. NEO-DARWINISM
16.7. MACRO AND MICRO FORCES
16.8. SUMMARY
16.9. KEYWORDS
16.10. MODEL QUESTIONS
16.11. REFERENCE BOOKS

16.1. OBJECTIVES:

The aim of this lesson is to

- Understand Evolution, Darwinism, Neo-Darwinism.
- Understand the Evidences for theories of Evolution
- Know the major and minor forces occur during evolution.

The effect of various forces and theories responsible for evolution is clearly understand from modern synthetic theory of evolution.

16.2. INTRODUCTION: In the field of biology, the term Evolution refer to the development of more complex forms from simpler ones. Organic evolution occupies unique place in biology because it is the most unifying branch of all life sciences.

"NOTHING IN BIOLOGY MAKES SENSE
EXCEPT IN THE LIGHT OF EVOLUTION" - DOBZHANSKY.

Modern synthetic theory represents a compromise between Darwinism and Mutation theory. Ignorance about the process of heredity of variation, which was the drawback of Darwin's theory, has now been removed by applying principles of Mendelism to population dynamics. As a result of this, Neo-Darwinism has emerged out as a modern Synthetic theory of Evolution or Genetic theory of Natural selection.

Genetics and the origin of species by Dobzhansky (1937) provided the initial basis of this theory. Huxley, Muller, Fisher, Sewall Wright, Haldane, Mayr, Stebbins, etc. were formulating this theory.

According to this theory, the genetic variability of the gene pool of a population, natural selection and reproductive isolation are responsible for the mechanism of evolution and formation of a new species.

The mechanism of modern synthetic theory has been explained on the basis of "Population Dynamics". There are three basic factors responsible for providing genic variability to the gene pool (total number of genes) of a population.

They are

1)Gene and chromosomal mutations
2)Gene recombination
3)Natural Selection
a)Migration
b)Hybridization
c)Genetic drift

Heredity
Variability — Adaptive Radiation — New Species
Population

New species cannot evolve merely by presence of variable genotypes alone, but evolved through Natural selection & Reproductive Isolation. Evolution is a never ending process as long as mutations are occurring and organisms possess heritable variations.

16.3. EVIDENCES OF ORGANIC EVOLUTION:

The comparative anatomy, Embryology, Palaeontology, Physiology, Zoogeography subjects provide us good evidences for evolution. Evidences from genetics is the best line to understand evolution. Mutations form the raw materials for evolution.

Charles Darwin (1809-1882) who was the father of evolution was appointed as Naturalist in 1831, upon a world survey in - ship of British Government, HMS Beagle. In his voyage, he explored the fauna and flora of a number of continents and Islands and collected numerous specimens. He believed in the "Theory of special creation and also evolution of new species by Natural selection". Darwin and Wallace were greatly influenced by the essays on "Principles of Populations written by T.R. Malthus (1798) and had developed a clear idea that organisms have to struggle for existence and so better individuals survive to continue the race and to lead to the evolution of better race.

16.4. THEORIES OF EVOLUTION:

A. Darwin's theory of Natural selection:

Darwin's theory is based on several factors, various experiences, observations, results, failures and demerits.

Main postulates of Darwin's theory:

a) Over production (Fertility power):-

"Every animal has tendency to increase its own race i.e., population, is called prodigality of production which leads to thick populations (or) over crowding.

For example:- *Paramecium* – It undergoes binary fission every 16 hours; oyster – A single oyster lays 50 million eggs in a season. If all the young ones produced undergo reproduction, they will form a volumes and volumes of their own populations.

b) Struggle for existence:-

Over production results in competition Darwin called it as "Struggle for existence". Struggle may be of 3-types, Intra-specific (Individuals of same species). Inter-specific (Different species) and struggle with environmental conditions like floods, cold waves, heat waves, earth quakes, cyclones, volcanoes etc.

c) Variations:-

Changes exist in all organisms universally. i.e., difference in character between individuals. Species of the same kind may differ in structure and behaviour. Darwin did not explain the origin of variations, but variations are favourable or beneficial, sometimes they help to evolve new individuals and are also harmful. He believed variations are heritable.

- Morphological & Anatomical Evidences
  - Homologous organ – Divergent Evolution
  - Analogous organ – Convergent Evolution
  - Vestigial organ
  - Connecting links
  - Atavistic organs
- Embryological Evidences
  - Principles
  - Biogenetic Law
- Palaeontological Evidences
  - Types of Fossils
  - Geological time scale
- Physiological Evidences
  - Biochemical Similarities
  - Comparative Serology
  - Biochemical reactions
- Zoogeographical Evidence
  - Geographical Distribution

Idea of Darwinism:

Origin of new species

Heredity — Accumulation of favourable charcters

Natural selection

Lethal

Unfavourable — Favourable

Variations

Struggle

Over production

16.5. NATURAL SELECTION:

It is an evolutionary theory proposed by Darwin. The individuals which have useful or beneficial or adaptive variation can withstand in the struggle. Such individuals are selected by the nature to survive. Herbert Spencer called this natural selection as “Survival of the fittest” i.e., fit individuals only will survive and others will perish.

Natural selection explains the mechanism of evolution and the origin of species. At each generation there is a betterment of the favourable characters. The cumulative effect of their process leads to the formation of a new species.

Stablizing selection is seen when the population in the environment is constant or normal. When the environment is constant, stabilizing selection prevails and thus evolutionary change is arrested. So there is no change in gene pool of those populations so it is stabilizing selection and also called normalizing selection. Stabilizing selection promotes a genetically constant population and it does not favour.

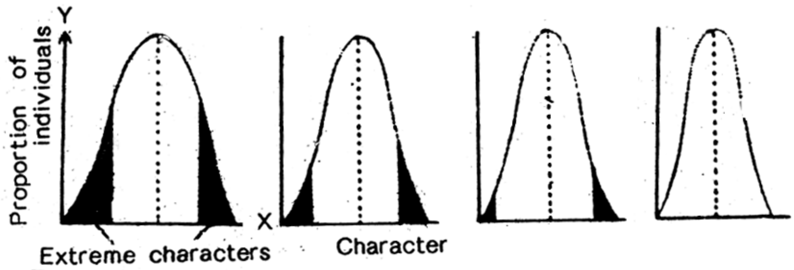


Fig 16-1. Stabilizing selection eliminating extremes

(A) Directional selection (progressive selection):

Directional selection operates when the environment is changing in one direction and it produces a genetically changed population. It favours the accumulation of mutation, and favours the specialized individuals, i.e., it brings progressive evolutionary changes.
Ex: Industrial melanism – *Biston betularia* (peppered moth)

(B) Disruptive Selection:-

When environment is heterogeneous with different micro habitats, this increases genetic divergence. So it favours two or more phenotypic modes which initiates the process of adaptive radiations.
Ex: Mimicry in Butterflies.

Though the Darwin's natural selection theory is generally accepted it has some limitations and had a number of defects which we re unable to explain in the process of evolution. Darwin theory explains only the existence of useful variations.

a) It Fails to differentiate acquired characters and inheritable variations i.e., heritable and non heritable variations.
b) Natural selection is a limiting but not an initializing force.
c) He did not explain the origin of new characterization i.e., inheritance or heredity.

16.6. NEO-DARWINISM THEORY:

Neo-Darwinism tried to give convincing evidences and explanation against the objectives and criticisms raised against Darwinism. The Neo-Darwinists who proposed modern synthetic theory of evolution are Sewall Wright, H.J.Muller, Dobzhansky, Godschr, J.J.Huxley, R.A.Fisher, J.B.S.Haldene, Ernst Mayr and G.L.Stebbins.

A. Definition:

The rearrangement of Natural selection or modified version of Natural selection is called Modern synthetic theory.

B. Explanation:

With the knowledge of genetics and cytology by taking evidences for evolution and theories which supports evolution, the Neo Darwinists formulated a correct concept for evolution, So it is a revised version as Modern synthetic theory. Modern synthetic theory is simple, reconstructed and modified Darwinism in the light of recent researches and having several experimental evidences and facts. Neo-Darwinists gave importance to mutation and variations. So, Natural Selection, Mutation, and heredity all together changed the theme of Darwinism.

C. Associate Scientists/Co-workers:

The main architects of the synthetic theory are Dobzhansky, Mayr, Huxley, Simpson, Stebbins, Fisher, Haldane, Sewall Wright, etc.

Mayr (1978) states that the modern synthetic theory of evolution amplifies Darwin's theory of Natural selection in the light of Mendelism population genetics, concept of species and Paleontology.

Huxley (1942) states that "Modern Synthesis" owes much more Darwin than to any other evolutionists and is built around Darwin's principles.

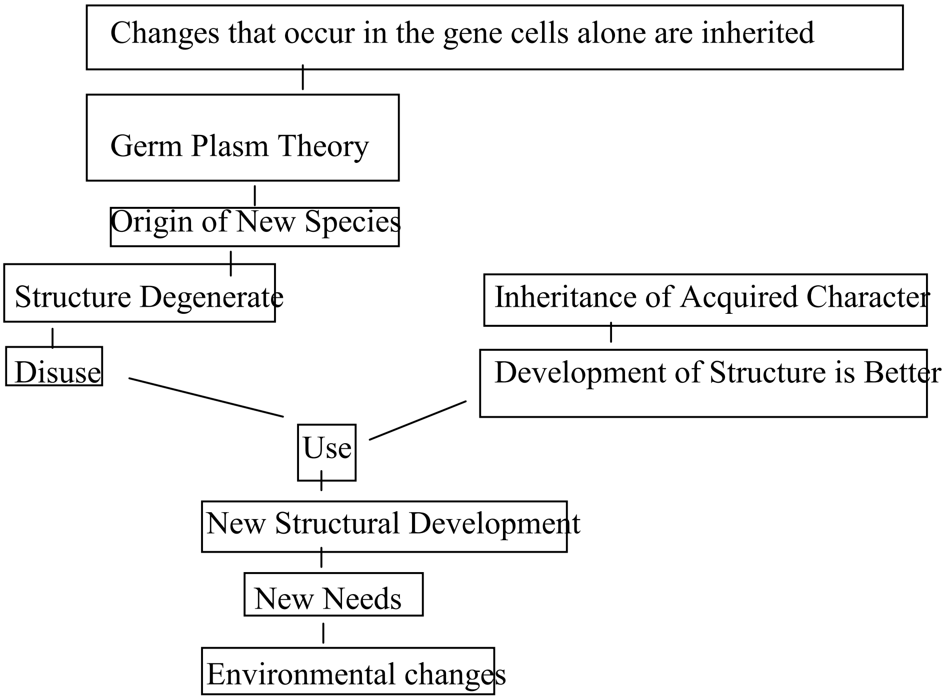
D. Need for Modern Synthetic theory:

The concept of evolution explain the origin of life and animals and plants existing on the earth. The famous theories which supports organic evolution are Lamarckism, Darwinism & De Vries.

i) Lamarckism: It consists of 4 principles,

a) Internal urge of the organism.
b) Environmental influence.
c) Use and Disuse theory.
d) Inheritance of acquired character.

MECHANISM OF LAMARKISM



ii) Darwinism: It consists of 5 principles.

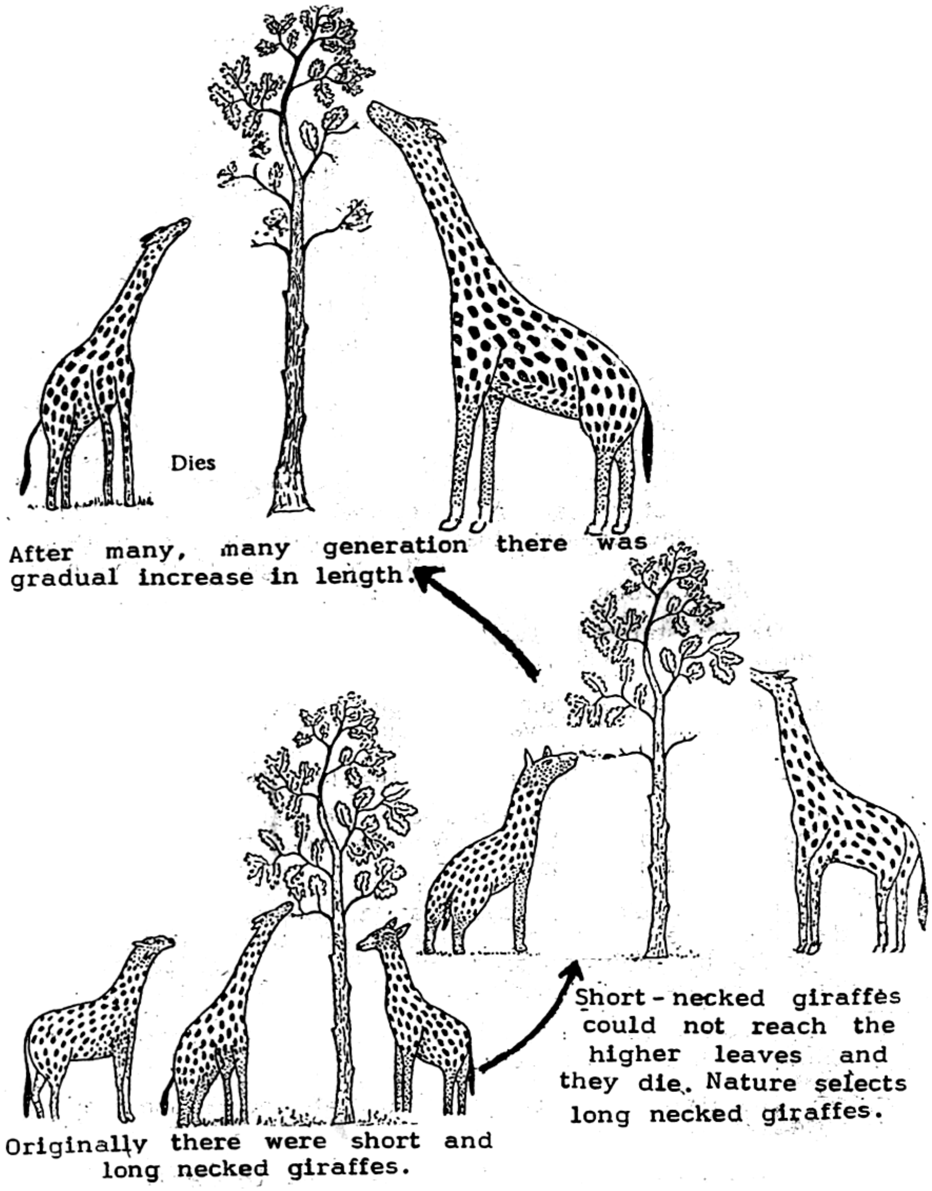
a) Prodigality of production-potentiality to increase its number.
b) Struggle for existence – competition.
c) Variations – Differences in characters.
d) Survival of the fittest – Fit would survive, unfit would eliminate.
e) Origin of species – Adaptations with respect to environment variations will lead to origin of new species.

Evidences in favour of Darwinism:

Many evidences favour Darwinism. They are pedigree of Horse and other animals, and Production of various domestic varieties by artificial selection.

Main Objections:

(1) Darwin stated that all variations are inherited but he did not distinguish between heritable and non-heritable variations.
(2) He did not explain the origin of new characters.
(3) He fails to explain inheritance.



Evolution of long neck in giraffee as per darwinism

Fig.16-2. Evolution of neck

iii) De Vries:-

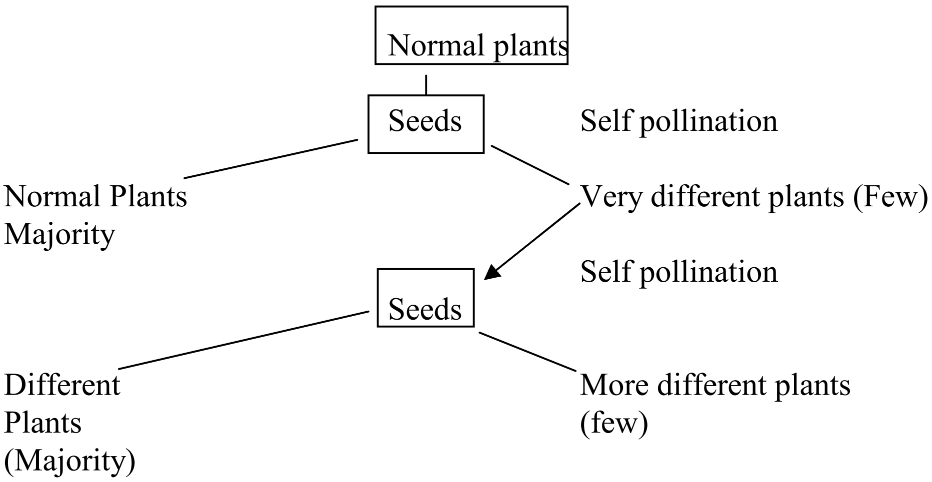
Mutations are sudden changes which occur in a gene or chromosome. Dobzhansky stated that mutation is a "mistake" or "misprint" in cell division. Mutations produce variations.

Hugo De Vries postulated the mutations theory based on his observations on an ornamental biennial plant of about 5-6 feet height called *Oenothera lamarkiana,* an evening primrose.

During his work in the gardens, DeVries observed not only original mother plant but also three other varieties which he named as

Oenothera brivistylis (short styled flower)
Oenothera leavifolia (smooth leaves)
Oenothera nannelia (broad and stouter leaves)

He cultivated three different plants in his garden for a period of 8 years and collected 54,343 plant samples out of which 837 were different from the original wild parental variety. They gave rise to a few different plants in each generation. From this, he found that marked differences as mutations and the plants bearing them as "mutants" i.e., mutations appeared suddenly and were inherited by the offspring.



The formation of variations into the population by mutations is only the first step in the process of evolution.

The second step is the influence of natural selection.

The third step of evolution involves isolation.

Nature prevents populations to interbreed which leads to reproductive isolating mechanisms.

Fourth step is chromosomal aberrations. Polyploidy plays an important role in the origin of new species (plants).

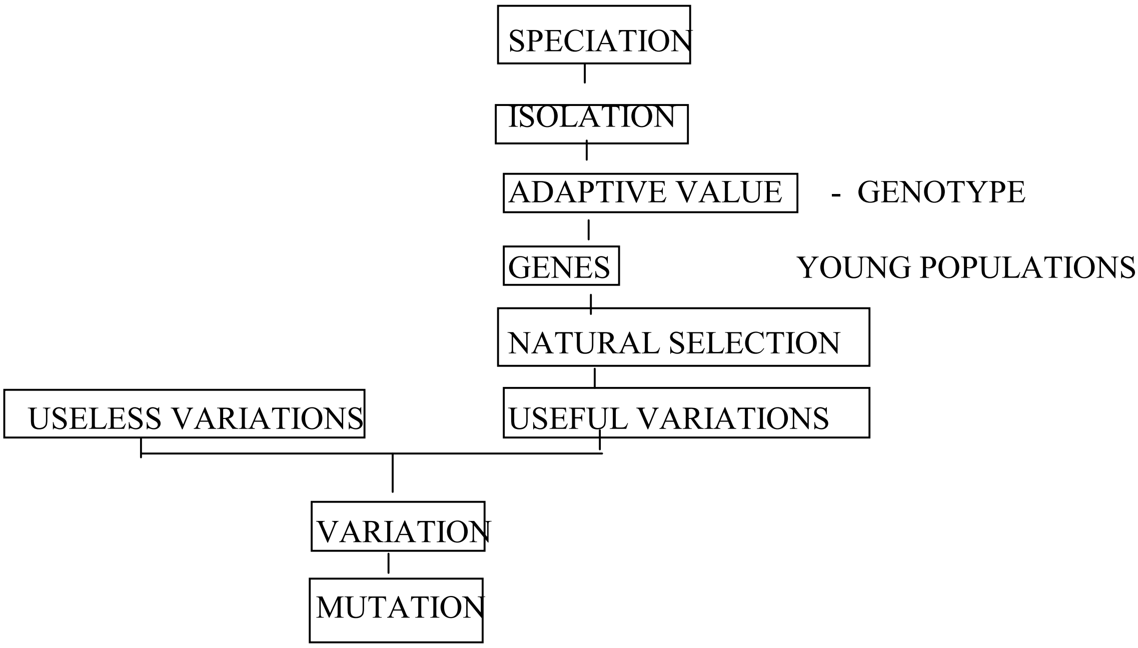
Classification of Mutant Species: (Hugo De Vries)

a) Progressive – More new character than origin plants Ex:*Oenothera gigas*.
b) Retrogressive – Loss of one or more characters of the parental nature Ex:*Oenothera Leavifolia*
c) Degressive – Loss of vital characters, so survival is difficult. Ex:*Oenothera albida*.
d) Inconstant – Mutant plants often give rise to mutants. Ex:*Oenothera Lata*.

Salient features of mutation theory:

-De Vries believes that new species originate as a result of large discontinuous variations.
-Sudden changes at a single stroke.

-No intermediate stages.
-Takes place at any direction.
-Recurring in nature.
-Mutations are subjected to natural selection.



Evidences supporting mutation theory:

Besides Objections, certain evidences are go in favour of mutation theory. Examples are

a) Ancon sheep (1981):Male lamb with short, bowed legs was appeared.

Seth Wright, a farmer reared this lamb and bred from it, the Ancon breed of sheep. It was so short that it could not jump even small fence, it became extinct about 80 years ago.

b) Hornless cattle was born for a normal cattle in 1889.
c) Albinism in rats, cats, dogs, rabbits, guinea pigs, man s another mutation.
d) Multinippled condition in sheep is due to mutations.
e) Hare lip in man.
f) White eyed condition in *Drosophila*.

Mutation theory, a deviation from Lamarckism and Darwinism:

According to Lamarckism, organisms develop variations because of influence of environment. These variations are inherited from one generation to another generation leading to the evolution of new species.

According to Darwinism, organisms develop new structures to overcome the struggle for existence, they are useful for organisms to survive in the nature. These structures are inherited from one generation to another generation, then accumulate which leads to the evolution of new species.

According to mutation theory of De Vries, sudden changes occur in populations due to changes in genetic material contribute to the evolution of new species. Most of the mutations are harmful leading to the extinction of species. Thus evolution of new species occurs as a result of large, conspicuous, discontinuous mutations.

16.7. MACRO AND MICRO FORCES OF EVOLUTION:

A. Macro forces of evolution:

Modern synthetic theory of evolution of new species depends on five fundamental aspects. They are
a) Mutations
b) Variation (Recombination)
c) Heredity
d) Natural Selection
e) Isolation

a) Mutations: (Hugo De Vries)

In nature mutations occur in rare and in slow rates and are the important sources of variations and raw materials for organic evolution. Mutations may occur at any time and at any stage from egg to adult.

Sewall Wright (1949) stated that "variations come first the organisms do the best they can with them and natural selection is the arbiter". Haldane (1937), Shapiro (1938) and Dobzhansky (1937) stated that the preservation of living species demands a store of concealed variability.

Some mutations are beneficial or useful but most of them are lethal. Mutations changes the genotype of individual in a population and consequently individuals having new phenotype are produced.

Mutations are the basis of discontinuous variation in population. They are of 2 types.

i) Chromosomal mutations:

The sudden changes occurring in the number of genes, in the arrangement of genes and in the number of chromosomes is called chromosomal mutation or chromosomal aberrations.

ii) Gene mutations:

The sudden change of a gene from one form into another is gene mutations. It is also called point mutations as it affects only a particular locus in the chromosomes. The change in the chemical composition of a gene is called gene mutations.

b) Variations:

Reshuffling of already existing genetic material in an individual is called recombination. They are possible only in sexually reproducing organisms.

Moody (1970) stated that recombination involves the re-assorting and recombining of genes already present in a chromosome.

It is produced by the following agents.

1. Independent assortment of genes takes place at the time of gametogenesis.
2. Possible union of gametes at the time of fertilization.
3. Crossing over at the time of meiosis-I.
4. Changes in chromosomal structures and number such as polyploidy, deletion, duplication, inversion, translocation.
5. Speciations (Interbreeding)

All possible new beneficial combinations are favoured, (Moody, 1970) in the evolution of new species.

c) Heredity or Inheritance:

According to Stebbins (1979) "Hybridization is crossing between populations having different adaptive gene complexes which leads to the formation of different races or subspecies or species.

Transmission of characters from parents to offspring is called inheritance, *cross involving two species resulting in the formation of hybrids*. New varieties and species are formed by hybridization. Most of the hybrids are sterile but some are fertile.

According to germplasm theory, proposed by Weismann, any change occurs in somatoplasm will not inherit, but any change occur in germplasm will inherit to the progeny. [Example- Decanalization experiments on mice) It also leads to the evolution of new species.

d) Natural Selection: (Herbert Spencer)

The fitting individuals with beneficial variations survive, the others perish, is called the survival of the fittest or natural selection. For example Industrial melanism – *Biston betularia*- Peppered moth was a good example of natural selection. In England, during mid 19^{th} century, at first moths were pale in colour when there was no industries. As England experienced industrial revolution, the surrounding turned black because of the soot liberated from factories. So black moths alone survived and pale coloured moths were eaten away by the birds.

e) Isolation:

Mayr (1963) stated that “Geographic isolation is usually a necessary step in the development of diversity between populations and the subsequent origin of species.

“Isolation means separation or Barrier, That means because of barriers, individuals will not interbreed with each other freely and they may not emerge out as new species It is of 2 types. i)Geographical isolation. ii)Reproductive isolation.

i) Geographic isolation:

It is caused by agents like land, water, deserts, mountains, rivers, etc.

ii) Reproductive Isolation:

It is caused by genetically determined factors.

B. Micro forces of evolution:

The micro forces responsible for evolution to modern synthetic theory are a) Migration b) Hybridization c) Genetic drift.

a) Migration:

Animals are not static and have tendency to move from one habitat to another. It is called migration or are the shifting of an entire population into a new habitat is described as migration. When an animal migrates from one area to other, it mates with the inmates of that population. Thus the gene of one population are transferred into another population. This is known as gene flow. Gene flow brings about an addition of or loss of genes in the gene pool and keeps adjacent population similar to each other by mixing of genes. Thus the gene frequency is altered and Hardy Weinberg law is upset. They are 2 types of migrations.

i) Immigration:

Inward movement of organisms from outside population is called Immigration. So that changing in gene pool takes place.

ii) Emigration:

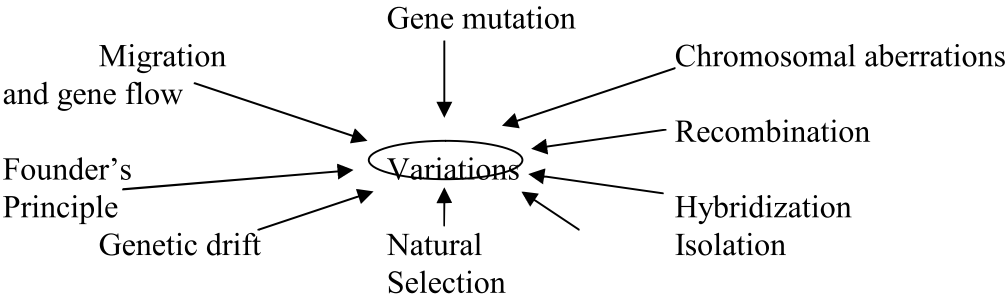
Outward movement of organisms from the population is called Emigration. So that decreasing in gene pool takes place.

b) Hybridization:

Interbreeding between two genetically distinct individuals of a species for the production of individuals having two genetic traits is called hybridization.

Hybridization promotes the origin of new characters and variability. New character can be established and fixed by placing mutations derived from one species in a new genetic background.
a) Fertility should be restored in the progeny of hybrids.
b) A variety of environmental niches should be established so that a hybrid can fit into any of the suitable environmental niches.

New combinations of genes should be stabilized under natural conditions.



c) Genetic drift or Sewall Wright (1931) effect:

The smaller the population, the greater the chance for change. So change in small population occurs due to chance or random but not due to natural selection. Hence the random change in gene frequency by chance in a small population is called genetic drift. It is an evolutionary force in which chance plays an important role in genetic drift.

Example:- Suppose for a gene, there are two alleles and the allelic frequency of a particular type is 1% ($q=0.01$). In one million alleles of a population ten thousand alleles are of that type. In 100, only one allele of that type. It means, that only one individual in a small population is having such allele. So the probability of losing that allele from a small population by chance is more. So genetic drift leads to the change in gene pool of the populations.

Genetic drift increases the homozygosity in small populations its effect is insignificant in large populations. In course of time these homozygous small populations merge out to form new populations. Founders effect or Bottle neck effect is one form of genetic drift.

C) Integration among the forces of Evolution:

Of the three processes such as mutations, genetic recombination and Natural selection, out of which mutations are raw materials for the evolutionary vehicle. Without mutations evolution does not occur. Natural selection directs the genetic variability. Genetic variations undergo genetic recombination through the shuffling of genes and chromosomes.

Reproductive isolation breaks all the barriers between populations to exchange their genetic material and has a canalizing effect. In this way various forces are integrated for the evolution of new species. The aspects, values and facts of modern synthetic theory are positive in the evolution of new species. Mutations, genetics of population and selection are basic elements of modern synthetic theory.

16.8. SUMMARY:

Modern synthetic theory of evolution is quite widely accepted theory and it revolves around the Darwin's natural selection and DeVries mutations.

It explains all macro and micro forces acting on organisms to evolve them in to a new species.

This theory explains how integration is brought between various evolutionary forces.

W.F.Blair concluded that wide distribution of species is favourably to speciation because of increased opportunities of isolation by extrinsic or environmental factors.

a) Population develop genetic variations through mutations, hybridization, recombination etc.

b) Natural selection allows the favourable genetic variations to spread in the population through differential reproduction in successive generations.

c) The populations are isolated geographically and reproductively and this leads to the failure of interbreeding.

d) When interbreeding does not occur, the populations are grouped into new species.

16.9. KEY WORDS:

Origin of species – Book written by Darwin
Prodigality - Extensive rate of multiplication.
Struggle for existence - competition for the survival.
Variations - Changes would occur in evolution.
Heredity - Likeness which one off spring bears to its parents.
Genepool - Sum total of all the allelomorphic genes occur in a population.
Mutations - Sudden hereditary changes occur in a population.
Genetic drift - Random genetic changes in small populations by chance.
Internal Urge - A strong sexual desire unable to control.

16.10. MODEL QUESTIONS:

1. Write an essay on the Modern synthetic theory of Evolution.
2. Explain the role of natural selection in the formulations of Neo-Darwinism.
3. How integration is brought about by various forces of evolution.
4. Describe Neo-Darwinism principles about Evolution.

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Lesson – 17
MUTATIONS – GENETIC BASIS OF EVOLUTION

CONTENTS:

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17.2. INTRODUCTION
17.3. MUTATION THEORY
17.3A.MUTATIONS – DEFINITION
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17.1. OBJECTIVES:

- Mutation theory explains the origin of new species or how new species are formed.
- New species are formed from pre-existing ones suddenly due to changes in the genetic material. The resultant individuals are called mutants.
- The main idea of this theory is that 'Evolution is a discontinuous and jerky process, rather than a continuous and gradual one'.

17.2. INTRODUCTION:

The mutation theory was formulated by Dutch botanist Hugo DeVries in 1902. The cause mechanism of mutation and experiments have been clearly analyzed by DeVries and other biologists on *Oenothera lamarckiana* (evening primrose) and contribute much to the modern version of mutation theory. Dobzhansky stated that mutation is a mistake or misprint in cell division.

17.3. MUTATION THEORY:

17.3a. Definition:

"Mutation is a sudden, large, heritable changes occur in a population". There is a sudden change of a gene from one form to another. So mutations are the basis of discontinuous variations in population.

17.3b. DeVries Experiment:

Hugo DeVries carried his experiment on a wild biennial plant (native of America) called *Oenothera lamarkiana* and observed not only the original plant but also three other varieties of plants in his garden after cultivation. The three different plants are

a) *Oenothera brivistylis*-short styled flowers.
b) *Oenothera leavifolia*-smooth leaves.
c) *Oenothera nannella*-broader and stouter leaves.

New type of plants were appeared in evening primrose, he called these marked differences as "mutations" and the plants bearing them as "mutants". He found that the mutations appeared suddenly and were inherited to the offspring.

Normal plants
↓ Self pollination
Seeds
↙ ↘
Normal Plants (Majority) | Very different plants (Fewer)
↓
Seeds
↙ ↘
Very different plants (Majority) | still more different plants (Fewer)

17.3c. Salient features of mutation theory:

1. New species are formed by sudden changes at a single stroke. The animals exhibiting mutations are called mutants.
2. Mutations can take place in any direction.
3. Mutations are recurring in nature.
4. Large number of the mutations appear at the same time.
5. Mutations are subjected to natural selection.
6. New species originate as a result of large discontinuous variations.

According to mutation theory, new species evolve, not by natural selection and gradual accumulation of small, continuous variations through generations, but by sudden and distinct heritable changes occur in population. So they are called mutations.

The first individual showing a "mutation" is called mutant. It is pure breeding. Obviously it transmits its mutations to its progeny and, thus, starts a new species.

All organisms have an inherent tendency to mutate, but the rate of mutation varies from time to time according to the environmental and physiological condition.

Mutations are indeterminate, one or more parts may suddenly undergo abnormally better or poorer growth or may completely disappear or new parts may appear. Thus mutation may be useful or harmful to the population.

Being indeterminate, different mutations may occur in different members of the same species, giving rise to several related new species simultaneously from the same ancestral species.

Criticism:

Occurrence of mutations was studied and confirmed by a large number of biologists (Morgan 1909, Muller 1912, Beadle and Tatum, 1945). However, the idea of De Vries that new species arose only by mutation was widely criticized and rejected.

Jeffreys, David, Gates discovered and confirmed that *Oenothera lamarckiana*, is a highly inconsistent hybrid species.

Without ascertaining the basic, biochemical cause of the sudden, random and discrete changes in characteristics; De Vries used the term "mutations" for such changes. With the advent of "Gene theory", this term is now correctly used by chemical changes in genes or chromosomes.

Mutation may render the mutants so much different from other members of the species that they generally fail to compete with the other and perish. Being random, mutations are hardly useful in adaptability. Hence they are more likely to bring about extinction of the off spring of mutants rather than evolution of new species from them.

Gradation in the characteristics of related forms, visible in connecting links were not explained by De Vries. It is now universally accepted that all mutants, irrespective of their mutation being small or large, belong to the same species to which their parents or ancestors belong.

Variations:

"All dissimilarities of characteristics between members of the same species are called variations".

If there were no variations, species would have continued unchanged from their origin, and no new species would have originated from earlier ones, i.e., evolution would not have occurred. Obviously, only heritable variations form the "raw material" for evolution.

Sources of variation: The factors are

a) Gene mutations.
b) Chromosomal aberrations.
c) Recombinations.
d) Hybridization.
e) Isolation.
f) Natural selection.
g) Founder's principle.
h) Migration and gene flow.

So the detrimental force of evolution is mutations and mutation theory.

17.4. CLASSIFICATION OF MUTATIONS:

Mutations are classified as follows.

a) Somatic mutations:

They occur in the somatic cells of organisms. Not inherited and disappear with the death of the animals.

b) Germinal mutations:

Mutations occurring in the germ cells is called germinal mutations. They are heritable.

c) Gametic mutations: They occur in gametes.

d) Zygotic mutations: They occur in the zygote.

e) Lethal mutations: Mutation affects the vital functions of an animal, as a result the mutant dies.

f) Spontaneous mutations: They occur without any cause. Eg: Nature.

g) Induced mutation: They caused by external factors Eg: X-rays, alpha rays, β,γ-rays, Infra red rays, , UV rays, Chemicals.

h) Gene mutations:
The sudden change of a gene from one form to other is called point or gene mutations.

i) Chromosomal mutations:

The sudden changes occurring in the number of genes in the arrangement of genes, and in the number of chromosome is called chromosomal mutations.

j) Biochemical mutations:

Mutations causing changes in the metabolites or their end products is called biochemical mutations. Eg: Enzymes.

So Mutations are broadly classified into two
1) Chromosomal mutations or Gross mutation.
2) Gene or point mutations.

1) Chromosomal mutations:

These are the changes occur in the number or structure of chromosomes.

a) Changes in the chromosomal Number:

Normally individuals have diploid number of chromosomes. So variation in the diploid number is further divided into 3 kinds.

i) Monoploidy or Haploidy:

Some times the eggs may develop into individuals without fertilization (By parthenogenesis). Such individuals have half number of chromosomes received from the female parent i.e., single set (n).

ii) Polyploids:

Some times the chromosonal number of individual may be more than two sets (2n) that is, the chromosonal no. may be 3n Triploidy, 4n Tetraploidy, (or) 5n Pentaploidy, etc. Such individuals are called polyploids.

iii) Aneuploidy (or) Heteroploidy:

Addition (2n+1) or deletion (2n-1) of one or more chromosomes of a diploid (2n) individual is called aneuploidy. It is divided into the following types.
a) Monosomic - 2n-1
b) Nullisomic - 2n-2
c) Trisonic - 2n+1
d) Tetrasonic - 2n-2

b) Changes in chromosomal structure:

Structural changes in the chromosome is called chromosomal aberrations. They are 4 types
i) Deficiency
ii) Duplication
iii) Inversion
iv) Translocation

i) Deletion or Deficiency:

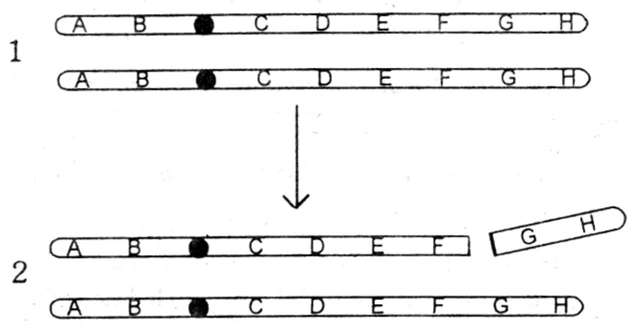

Fig.17-1. Chromosomal mutations

Deletion is the loss of one or more genes from a chromosome and it is due to the loss of a chromosome segment. During deletion, some genes are lost. *So the organisms having some segments, it depends upon the quality and the quantity of the genic material lost.* If the heterozygous genes are deleted, the organisms will be abnormal. On the other hand, if the homozygous genes are deleted, there will be lethal effects.

ii) Duplication or Repeat:

In duplication, a particular set of genes is present in double doses. Duplication plays a role in evolution. Owing to the repetition of gene compliments, additional characters are produced.

iii) Inversion:

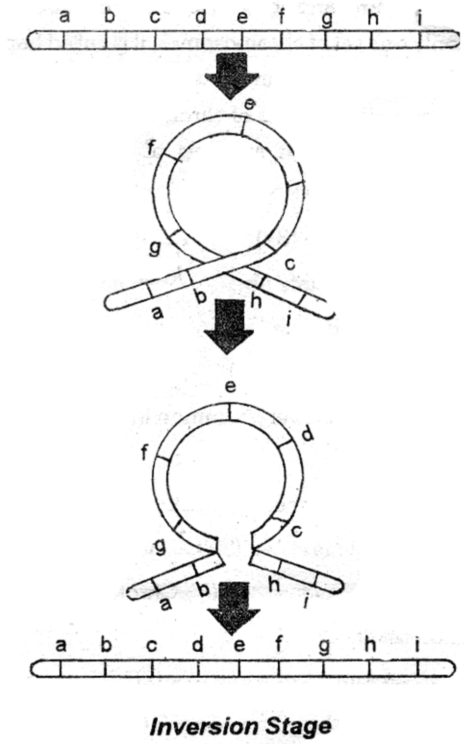

Fig.17-2.Inversion in chromosomes

In Inversion, there is no loss (or) gain of genes. But a particular segment of the chromosome is broken and is attached to the same chromosome in an inverted position. So there is a rearrangement of the original genes. In inversion, since the number of genes in the inverted chromosome remains the same, there will not be any serious effect. Sometimes phenotypic effects may change owing to change in the linear arrangement of genes (position effect). Inversion suppresses crossing over.

iv) Translocation:

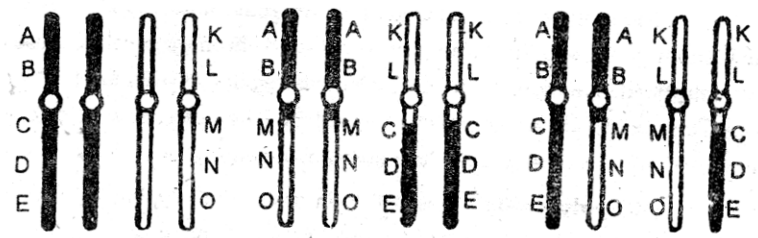

Fig.3. Stages in Translocation

In translocation, a chromosomal segment is exchanged between two chromosomes. The two chromosomes may be either homologous or non-homologous. Translocation plays a significant role in evolution. The exchange of parts between non-homologous chromosomes will produce new combinations of genes hence new varieties are produced.

2) Gene Mutations: (Point mutations)

"Gene mutation refers to changes occurring in the chemical and structural composition of a gene". That means any change in the sequence of nitrogen bases or in the structure of gene brings mutations. The gene which has undergone mutation is known as mutant gene.

Gene mutations are of 2 types

a) Spontaneous mutations – They occur in the natural course of life.

b) Induced mutations – They occur when organisms are subjected to the action of mutagenic agents like x-rays, γ rays,NH_3, Cobalt, Alcohol, UV rays, mustard gas, etc.

Mutations cause new variations in the body of organisms. Organisms with harmful variations do not survive. With beneficial mutations organisms can overcome the problem like struggle for existence and natural selection. Such organisms continue to survive and provide a quick and short cut method for evolution.

Molecular Basis of gene mutations:

The molecular mutation is classified into the following 4 types

a) Deletion: Deletion is a gene mutation caused by the loss of one or more nucleotides from a gene.

b) Insertion: It is a gene mutation caused by the addition of one or more nucleotides to a gene.

c) Inversion: It is a gene mutation brought about by the reversion of base sequence. In this case, a segment of DNA molecule is removed and reinserted in a reverse direction.

d) Substitution: Substitution is a gene mutation where the nucleotide is replaced by another nucleotide. Substitution mutation is of two types namely i) Transversion. ii)Transition

i) Transversion:It is a substitution mutation where a purine is replaced by pyrimidine or vice-versa.

ii) Transition: It is a substitution mutation where a purine is replaced by another purine or a pyrimidine is replaced by another pyrimidine. Transition is caused by the following factors.

(1) Tautomerization:-Chemicals

(2) Base analogs:- Chemicals with DNA bases.

(3) Deamination:- Removal of amino group from.

Induced Mutations (H.J.Muller):

Mutations can be artificially induced and are caused by external agents, so they are called induced mutations. The mutagenic agents are radiations like x-rays, gamma rays, alpha rays, beta rays, UV rays, infra red rays, etc. Chemical agents are mustard gas, nitrous acid, nitrogen mustard, colchicines, formaldehyde, peroxides, caffeine, phenol, etc.

17.5. EVIDENCES SUPPORTING MUTATION THEORY:

Besides objections, there are certain points which go in favour of mutation theory. Examples are as follows.

a) Ancon sheep:

In 1891, in the flock of Seth Wright, a farmer in England, found a male lamb with short, bowed legs Wright reared this lamb and bred from it, the Ancon breed of sheep. It was so short that it could not jump over an ordinary stone fence. It became extinct about 800 years ago.

b) Hornless cattle was born for a normal cattle in 1889.

c) Albinism in rats, cats, dogs, rabbits, guinea pigs, man, etc. is another mutation.

d) Multinippled condition in sheep is due to mutation.

e) Hare-lip in man is an instance of mutation.

f) White eyed condition in *Drosophila.*

17.6. MUTATION THEORY - A DEVIATION FROM LAMARCKISM AND DARWINISM:

According to Lamarckism, organisms and their organs have a tendency to continuously increase in size generation after generation. Continuous changes in environmental condition directly influence the way of living, habits and nature of organisms and tend to affect their structural organizations accordingly. Use of certain parts increases, while that of certain other parts decrease. So, the characters acquired during its life time by an organism, are hereditary. Hence they are transmitted to the offspring. Accumulating through numerous generations, these changes render the future progenies have to be regarded as members of a new species. Thus evolution is a slow process.

According to Darwinism, the evolution of new species is by natural selection. Darwin pointed out that the populations of each species tends to increase in a geometric ratio. If all descendents survive, each species is potentially capable of inhabiting the whole world with its own progenies in a short period, leaving space for no other type of organisms. However, such an increase in the population of any one species never occur in nature. In fact, the population of each species remains fairly constant, because a large number of offspring perish before they themselves becoming capable of reproducing. Each organism has to strive or struggle with others to fulfill its needs from nature. This is called “struggle for existence”. This struggle continues throughout life from zygote stage till death. Since a large number of individuals are destroyed in this struggle, each species produces offspring in a large number, so that some may survive after the “struggle for existence”. Darwin also made mention of the variations and survival of fittest. He considered mutations as rare and as having no evolutionary significance.

According to mutation theory of De Vries, new species were developed from wild ones suddenly. These changes are due to changes in the genetic material. Mutations contribute less to the evolution of new species. Most of the mutations are harmful leading to the extinction of species, only few mutations are beneficial which helps to the adaptability of newly evolved species in the changing environment. Thus evolution of new species occurs as a result of large, conspicuous, discontinuous mutations.

17.7. SUMMARY:

Members of the same species vary due to variations in their genotypes and effects of environmental conditions. Lamarck regarded all variations as characteristics acquired by organisms during their life time and held these heritable.

Darwin regarded all variations heritable and forming the “raw material” for evolution without explaining their origin. Mutation theory of De Vries provide one definite source of heritable variations upon which natural selection can operate to provide evolutionary lime.

Due to adaptability, organisms undergo variable modifications according to environmental conditions. Somatic variations are useless for evolution, but heritable variations which help organisms in adaptations. They are selected by nature for the evolution of new species. As per recent knowledge, we cannot predict new species are evolved through mutations.

17.8. KEY WORDS:

Mutations:-The sudden changes in the genetic material.
Mutants:-The organism which evolved through mutations.
Progressive species:-The newly evolved species by the addition of one or more characters through mutations.
Retrogressive species:-The newly formed species by the lost of one or more characters through mutations.
Variations:-Changes.
Recombination:-Reassorting and recombining of genes in a population.

17.9. MODEL QUESTIONS:

1. Describe mutation theory?
2. Write notes on classification of mutations?
3. Explain in detail the salient features of mutation theory?

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Lesson-18

GENETIC DRIFT, HARDY-WEINBERG LAW, ISOLATION AND SPECIFICATION

18.1. OBJECTIVES
18.2. GENETIC DRIFT – INTRODUCTION
A. DEFINITION
B. SALIENT FEATURES OF GENETIC DRIFT.
C. GENETIC DRIFT AND FREQUENCY CHANGE.
18.3. HARDY-WEINBERG LAW.
A. SALIENT FEATURES OF HARDY–WEINBERG LAW.
B. PRACTICAL APPLICATION
C. FACTORS UPSETTING HARDY-WEINBERG EQUILIBRIUM.
18.4. ISOLATION
A. TYPES OF ISOLATING MECHANISMS.
B. ROLE OF ISOLATION.
18.5. SPECIATION.
A. DEFINITION, SALIENT FEATURES OF SPECIES AND TYPES.
B. MECHANISM OF SPECIATION.
C. FACTORS INFLUENCING SPECIATION.
D. MAIN PATTERNS OF SPECIATION.
18.6. SUMMARY.
18.7 .KEY WORDS.
18.8. MODEL QUESTIONS.
18.9. REFERENCES.

18.1. OBJECTIVES:

The aim of this lesson is to

- understand the Genetic drift, Hardy-Weinberg law, Isolation and Speciation in the process of evolution.

18.2. GENETIC DRIFT - INTRODUCTION:

Genetic drift helps to explain the gene pool of population as changed by chance leading to evolution. Hardy-Weinberg law helps to study population genetics especially mendelian populations. Isolation prevents the exchange or mixing of genes between populations. But in due course of time, isolated organisms develop into new species by the effect of external and internal forces, as species are the basic unit of classification, speciation helps to understand how new species are evolved from pre-existing species.

A. Definition:

The random changes in gene frequency by chance in a small population is called genetic drift. This view was proposed by Sewall Wright (1931). So it is also called Sewall Wright effect. As a result of genetic drift, a new mutation arising in a small population is either fixed or lost.

For example, in a small population, the gene frequencies change or fluctuate purely by chances i.e., the smaller the population, the greater the chance for change. The variations that occur by chance in a small population cause deviations from Hardy-Weinberg equilibrium. Any deviation due to chance variations is called random genetic drift or Sewall Wright effect.

Chance plays an important role in genetic drift. Suppose, for a gene there are two alleles and the allelic frequency of a particular type is 1% (q=0.01). In one million alleles of a population ten thousand alleles are of that type. In 100, only one allele is of that type. It means only one individual in a small population is having such allele. So the probability of losing that allele from a small population by chance is more. The end result is either fixation (p or q=1) or loss (p or q=0) of any given allele. The probability of reading the end point (fixation or loss) depends on the size of the population.

a) Founders effect is one form of genetic drift. It is the derivation of a new population from a small isolated group of individuals [founders] that is genetically different from the parent population. The allelic frequencies of the new populations are similar to the founders rather than to the ancestral parent population. For example, Human population founded on Pitcairn's island is a good example of founder effect. Pitcairn island population is resulted from the small numbers of founders of Carcasian and Polynesian individuals. The gene frequencies in the population of Pitcairn island is neither similar to the Carsasian parent population nor the Polynesian parent population, but similar to the founders of Pitcairn islands.

b) Bottle neck effect is another form of genetic drift. Bottle necks are the natural calamities like earthquakes, volcanic eruptions, floods etc. After bottlenecks the parents of the next generation are reduced to a small number and may be genetically different from the original population. A genetically different population, from the parent population, may arise from these individuals that are left after bottle necks.

Genetic drift tends to "reduce" the amount of genetic variations with in the population mainly by removing the alleles, which have low frequency.

B. Salient features of genetic drift:

1. Genetic drift is an evolutionary force operating in small population.
2. The gene frequency change by chance.

3. Some genes may be reduced or even lost by chance. Others may be increased in frequency because of small population.
4. It upsets Hardy-Weinberg equilibrium and produces variations or destroys.
5. Certain genes eliminate completely or preserves in small population due to genetic drift.
6. Development of new mutations and work the opposition to selection.
7. Genetic drift helps in the origin of new species.
8. Heterozygous gene pair tend to become homozygous by chance. It results in non-adaptive traits in some populations.

C. Genetic drift and frequency change:

Genetic drift changes the gene frequency in small populations purely by chance. Where as Hardy-Weinberg's law is effective in large populations. For example in smaller breeding populations, when only a few offspring are formed, great fluctuations in expected ratios may takes place by chance. Thus in a very small population made of two mating pairs, if one individual has a new mutation "a", its genotype would be "Aa" and that of the other would be "AA". On the basis of chance if this individual with new mutation and its mate give rise to 6 offspring which lives to maturity and the other pair produces four that live to maturity, 5 of the offspring of the first pair will have the mutant gene "a". Thus, out of the ten individuals to form the next generation, half of them would have mutant genes. Suppose there is no selection against this gene, it would have very fair possibility of spreading further in the following generation. On the other hand, reverse may takes place in the same situation. None of the offspring of the first pair, mainly by chance, might receive the gene "a" and it would be lost immediately. Thus in small populations, genetic drift may occur by the action of selection pressure. It plays an important role in origin of new species.

Stebbins recognized both the necks in large populations. He with assumes great importance because only the reproductively active survivors can pass on genetic material. Drift during the time of a bottle neck may result in the wide distribution in a large population of one or two non adaptive phenotypes. It is a supplement of the Sewall Wright effect. Hence in small populations genetic drift promotes evolutionary process.

18.3. HARDY-WEINBERG'S LAW OR GENETIC EQUILIBRIUM:

G.H. Hardy, an English mathematician and Weinberg, a German physicist in 1908, independently answered the question "what happens with a population when random mating takes place in successive generation?". It is known as Hardy Weinberg's Law. The law is the foundation for population genetics and for modern evolutionary theory.

This law states that, "If alternate forms of genes (alleles) are present in a population in a given proportion and if random mating and equal survival of offspring exist, then the original proportion will be retained in all subsequent generation unless it is upset by some other factor, such as mutation or selection pressures".

This law states that in a large population, the gene frequencies of various kinds of genes remain constant generation after generation, if mating is at random and in the absence of mutation, selection and migration.

The genetic equilibrium has been expressed as P+Q=100%
Where P=frequency of one dominant allele in a population (T).
Q=frequency of second recessive allele in a population (t).

Substituting F. Generation of Mendel in terms of p & q the phenotype is

$$P^2+2pq+q^2=100\% \text{ or } 1$$

For eg: (P^2) TT x tt (q^2)

Tt (2Pq) --- F_1 generation

If frequency of (P & q) are equal then

$$(0.5 \times 0.5) + 2(0.5 + 0.5) + (0.5 \times 0 .5) = 1$$
$$0.25 + 0.50 + 0.25 = 1$$
$$1 = 1$$

Eg: If frequencies of “p” is 60% and that of “q” is 40% then

$$(0.6 \times 0.6) + 2(0.6 \times 0.4 + (0.4 \times 0.4) =$$
$$0.36 + 0.48 + 0.16 =1$$
$$1 = 1$$

18.3. A. Salient features of Hardy-Weinberg’s law:

1.The gene and genotype frequencies of each allele in a population remain at an equilibrium generation after generation.
2.The mating is completely a random phenomenon in a population.
3.The equilibrium in gene and genotype frequencies occur in a large population.
4.All the genotypes in a population reproduce equally and successfully.

This Hardy-Weinberg law can be explained by taking a Hamster population as an example.

Pure black (MM) Hamster population cross and with grey (mm) individuals, when mate at random, 3 types of mating are possible. They are

Dominant x Dominant (MM x MM)
Recessive x Recessive (mm x mm)
Dominant x Recessive (MM x mm)

As the black and grey individuals are in equal numbers,

M M x m m- Parents genotype

M M m m – Gametes

Mm-F1 generation -Hybrid

Among the black hamster populations there will be 50% (1/2) males and the other 50% (1/2) will be females. Among grey animals 50% (1/2) will be males and the other half will be females. The frequencies of these mating and the resultant offspring (F1) are represented in the punnet squares. In F_1 generation, 3 types are produced, they are MM, mm, Mm

For Example, .5 MMx .5 mm – p1

.25 M .25 M .25 m .25 m – Gametes

$\boxed{.25 \text{ MM}}$ $\boxed{.5 \text{ Mm}}$ $\boxed{.25 \text{ mm}}$ – F1 generation

Frequency of individual in F1 generation is

MM=1/4=0.25

Mm=1/2=0.5

Mm=1/4=0.5

Frequency of genes in F1 generation is

M=50%, m=50%

When f1 individuals mate, 9 types of mating are possible. The mating, their frequency and the frequency of offspring in the F2 generation remains constant that the frequency of offspring in the f1 generation is 1/4 MM, 1/2 Mm, 1/4 mm (or) 1:2:1. The same constancy is expected in the succeeding generations also provided the population is large, mating is at random and it is free from mutations and selection.

The above experiment can be more simplified by substituting the letter “p” for “M” and “q” for “m”.

So, Homozygous dominant (MM) individual is represented by “PP” or p^2.

-Homozygous recessive (mm) individual is represented by qq or q^2.

-Mating between MM & mm individuals can be represented by p^2q^2 or $(p+q)^2$

-The offspring of this mating can be obtained by multiplying this $(p+q)^2 = p^2+2pq+q^2$.

This formula is referred to as Hardy Weinberg formula $p^2 = M$

$q^2 = m$

$2pq = 2Mn$

18.3. B. Practical application:

Example:-Hamster population

The frequency of M gene in the population is 50%(1/2), So p=1/2(0.5%)

The frequency of m gene in the population is 50% (1/2), So q=1/2(0.5%)

$(p+q)^2=P^2+2pq+q^2$

$(0.5)^2+2x0.5x0.5+(0.5)^2$

$0.25+0.5+0.25$

So, 25% MM

50% Mm

25% mm

♀ ♂ --->	0.5 MM	0.5 mm
.5MM	0.25 MM	0.25 Mm
.5 mm	0.25 Mm	0.25 mm

When Hamster populations containing 90% of “M” genes and 10% “m” genes when mating is at random and the population is free from mutations and selection.

The frequency of “M” gene p is =90%=0.9

The frequency of m gene q is = 10% = 0.1

So $(p+q)^2=p^2+2pq+q^2$

$(0.9)^2+2x0.9x0.1+(0.1)^2$

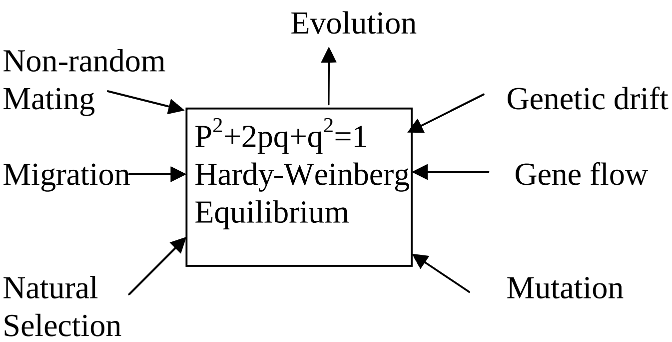
$0.81+0.18+0.01=1\%$

Significance of Hardy Weinberg law:

1. This law states that the gene frequencies is a large populations, remain constant from generation and generation when mating is at random and there is no selection and mutation.
2. Equilibrium cannot be maintained in small populations.
3. When there is no change in population, the rate of evolution is zero i.e., when equilibrium is constant.
4. The equilibrium tends to conserve characters that have been made in the past and to prevent too rapid changes.
5. Equilibrium maintains heterozygotes and stores recessive genes continuously and also it prevents evolutionary progress.
6. Evolution occurs only when Hardy Weinberg equilibrium is upset or altered.

18.3. C. Factors upsetting Hardy-Weinberg equilibrium:

Suppose, when the rate of evolution is zero i.e., evolution does not occur. Equilibrium upsets due to mutations, natural selection, genetic drift, migrations and gene flow & non-random matings.



They are,

a) Mutations:

Sudden changes which allows the genetic materials is called mutations. When occurring in a gene is called gene mutations or point mutations. When occur in a chromosome are called chromosomal mutations.

Mutations produce recessive genes normally but also produces dominant genes. When the mutation is dominant the character is controlled by the dominant gene is expressed immediately, but when the mutation is recessive one, the character will be expressed only when the recessive genes occur in the homozygous condition.

The continuous occurrence of mutation in a population is called mutation pressure, it has capacity to alter the gene frequencies in the gene pool and hence the equilibrium is upset.

For example, Hamster population of 50 individuals with 50% M genes and 50% of m genes, one “M” gene mutates to one ‘m’ gene. Thus there is a loss of one “M” gene and a gain of one ‘m’ gene in the gene pool. After mutation, the gene pool contains 49% M genes and 51% m genes. If it continues generation after generation naturally there is a change in gene frequency.

b) Natural Selection:

Natural selection operates in all populations it tends to keep the deleterious genes at a low frequency. Selection allows the efficient genes to increase by reproduction of gene combination which is more efficient under the existing environmental conditions. This differential reproduction of genes upsets equilibrium and helps evolution to progress.

c) Genetic drift: or (Sewall Wright effect)

Genetic drift operating in small populations. Thus small population is subjected to the operation of genetic drift. It helps to accumulate the certain advantageous characters and brings changes in gene frequencies. In large populations gene frequencies kept constant where as in small population the gene frequency changes purely by chance.

d) Migration and geneflow:

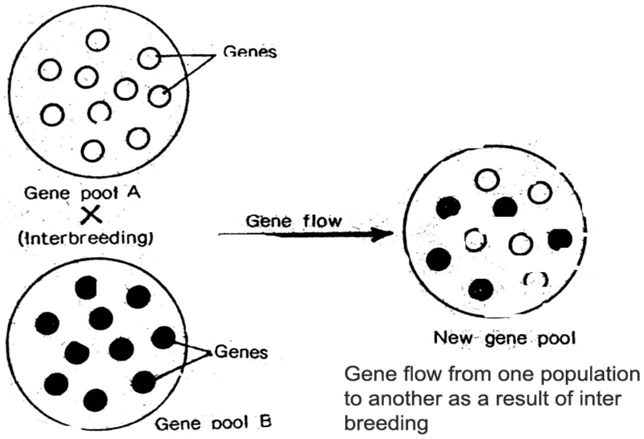


Fig.18-1. Migration and gene flow

Because of migration, mixing up of population is possible, when mating would be random. So the genes of one population are transferred into another populations. Gene flow brings about an addition of or deletion of genes in the gene pool. Thus equilibrium is upset.

e) Non-Random mating: (Assortative mating)

In natural populations, mating does not occur at random, because mating is a selective process.

For example, In a hamster populations, MM dominant individual mate with only MM individuals, mm recessive individual with recessive individuals only.

MM x MM------>MM only
Mm x mm------->mm
Mm x Mm------->1:2:1 ratio

♂		M	m
♀	M	Mm	Mm
	m	Mm	Mm

As a result of this selective, non-random mating the frequency of heterozygotes (Mm) in the population will decrease generation after generation. Hence non-random mating result in an abundance of certain genotypes at the expense of other genotypes.

Assortative mating is the preferential mating between males and females of a species. Deviation from random mating alters genotype frequencies, but not the allelic frequencies.

18.4. ISOLATION: (segregate members)

The importance of isolation was first strongly insisted by M.Wagner (1868). It can be defined as,

"Any factor or external barrier which divides in species into groups, which do not interbreed freely, is said to segregate or isolate the members of the species. That means separation of population by some barriers which prevent interbreeding, so that gene flow between populations is also prevented. Isolation also prevents the exchange of mixing of genes between population. Each population in isolation develops genetic divergence independently leading to the formation of new species. The occurrence of new mutations, natural selection, re-combination and genetic drift in one population has no effect on other population.

18.4.A. Types of isolating mechanism:

The agency which brings about isolation is called isolating mechanism. They are

a) Geographical isolation
b) Ecological isolation
c) Seasonal isolation
d) Mechanical isolation
e) Physiological isolation
f) Gametic mortality isolation
g) Zygotic isolation
h) Hybrid in viability isolation
i) Sterility hybrid breakdown isolation

Isolating Mechanism

A. Geographic Isolation

B. Reproductive Isolation

1.Pro-zygotic (pre-mating)
a) Ecological Isolation
b) Seasonal Isolation
c) Ethological Isolation
d) Mechanical Isolation
e) Physiological
f) Gametic mortality Isolation

2.Post-zygotic (Post mating)
a) Cytological
b) Zygotic mortality
c) Hybrid in viability
d) Hybrid Sterility Isolation
e) Hybrid break down Isolation

The classification of the different isolating mechanism which form the barriers between species is given by Dobzhansky (1941). Basically Iso-mechanism are of two types a) Geographical or Spatial Isolation b) Reproductive Isolation.

For spatial isolation and physiological isolation, two types of barriers are acting, they are external and internal barriers.

1) External barriers or Barriers between the parental species: They are

a) Eco-geographical
b) Ecological separation of sympatric types
c) Temporal & seasonal isolation.
d) Mechanical isolation.
e) Prevention of fertilization.

2) Internal Barriers or Barriers in the hybrids: They are

a) Hybrid in viability or weakness
b) Failure of flowering in the hybrids
c) Hybrid sterility (genic and chromosomal)
d) In viability and weakness of F2 and later segregation.

Darlington (1940) Muller (1942) and Stebbins (1942) also have recognized two major subdivisions, one is external and other is internal isolating mechanism.

Isolating mechanism are broadly classified into two types:

A) Geographical Isolation:

Geographic factors like water, mountains, landmass and deserts etc prevents interbreeding between populations. So separation of two populations of a species by a geographic barriers is called geographic isolation (Wagner 1863).

Related groups or allopatric species occupying different geographical areas have no chance to interbreed in their life time because of barriers and environmental conditions. It means that a single common gene pool is split into 2 gene pools by the barriers. Hence each is affected by separate type of environmental factors. This leads to the development of genetic divergences. i.e., evolutionary forces. The two populations will not interbreed even after the original barrier disappear then will designated as 2 separate species.

For example: a) New zealand lizard, *Lygosoma moco*
b) The Indian gaint squirrel, *Ratufa indica*
c) The southern elephant seal, *Miroungoleo mina*.

B) Reproductive Isolation:

The term Reproductive Isolation was coined by Mayr and are responsible for the formation of sympatric species (unrelated species).

It is defined as “any genetically determined factor or agent that prevents interbreeding of Mendelian population.

Reproduction isolation is classified into

1) Pre-zygotic or pre-mating – means (Restrict the union of gametes after mating).
2) Post-zygotic or post mating-(Prevent wastage of gametes).

1) Pre-zygotic Isolation:

a) Ecological Isolation:

Habitat acts as a barrier which prevents the interbreeding of population. This is called Ecological or Habitat isolation. Because of the difference between habitats, there is no opportunity to meet and mate in the animals.

Eg: 1) The pig frog, *Rana grytio*(deep waters) and *Rana areolate* (burrowing)
2) The toads, *Bufo fowleri* (stream) and *Bufo woodhousii* ; (fresh water, pond)
3) The water snake, *Natrix sipedon* (florida – fresh water and salt water)

b) Seasonal Isolation:

Interbreeding is prevented in animals because of differences in the breeding season.

Eg: *Rana clamitans*
Rana pipiens – They live in same pond in America, but breed in different seasons.
Rana sylvatica

c) Ethological Isolation:

"Sexual behaviour prevent interbreeding". The individuals of a species recognize their mates by sexual behaviour like dance, songs, lights, scents etc.

For example, 1) The grey tree frog *Hyla versicolor* and *Hyla feniralis*;
In case of *H. versicolor* the mating call is a short trill, loud and resonant, it exists less than three seconds. The mating call of *H. femoralis* is more prolonged.
2) In the case of *Drosophila* males of related species of *D.melanogaster* and *D.simulans* have specific patterns of courtship movements.

d) Mechanical isolation:

It is also known as morphological isolation. i.e., difference in the external genital organs prevents interbreeding Eg: In *Drosophila* interspecific mating causes injury to the genital organs and in severe cases death occurs.

Federal (1932) has stated that when the male moths, *Chaerocampa elpenor* copulate with the females of *Metopsilus porecellus*, they are sometimes unable to withdraw the penis, making egg deposition impossible.

e) Physiological isolation:

The physiological differences between the species prevents fertilization when two different species living in the same area, but by chance they are getting to mate.
Eg: Patterson (1945, 1947) proposed insemination reaction in *Drosophila*. A rapid secretion of a fluid into the cavity of the vagina after copulation occurs causing a great swelling of the organs, when they belong to same species. If mating occurs between member of different species the swelling remains for a few days, the fluid inside the vagina solidifies and obstructs the passage of eggs and hence the females cannot lay eggs.

f) Gametic Mortality Isolation:

Suppose when there is inter-specific mating, the gametes are killed in some species because of an antigenic reaction in the genital tracts.
Eg: Volpe (1960) shows that when mating occurs between *Bufo fowler* and *B.valliceps*, the gametes will die.

2) Post – zygotic Isolation:

It means that which prevents the growth of hybrid individual after fertilization and do not prevent wastage of gametes.

a) Cytological isolation:

The inter-specific mating mechanisms operates at the level of fertilization. Fertilization cannot occur successfully between the gametes because of differences in the chromosome number.
Example: The bronze Frog, *Rana clamitans* and bull frog, *R. catesbiana* do not produce hybrids because of cytological differences in the gametes.

b) Zygotic mortality isolation:

Even after fertilization, the zygote may not survive, it may die at any stage during its development.
Example:-When the sea-urchin, *Paracentrous lividus* and *P.microtuberculatus* are crossed, most of the embryos die before the gastrula stage.

c) Hybrid invariability isolation:

When there is inter-specific interbreeding, the resulting hybrids do not survive.
Example:-Warwick and Berry (1949) cross between goat and sheep produces normal embryo, but they die before birth.

d) Hybrid Sterility Isolation:

Some times inter-specific interbreeding produces sterile hybrids, they cannot produce young ones.
For example:- Male donkey x Female horse = Mule (Sterile)

e) Hybrid Breakdown isolation: (Adaptive inferiority of F2 hybrids)

Individuals are highly (or) partly fertile, but which give rise to weak, abnormal (or) sterile progeny in the second F2 generation. This phenomenon is called hybrid break down.
Example:-Hutchinson etal, (1947) found that *Gossypium hirsutum*, *G. barbadense* and *G. tomentosum* intercross freely to give fertile and vigorous F1 hybrids. But the F2 hybrids appears to be as vigorous as the parental species, although the hybrid males are sterile.

18.4.B. Role of Isolation:

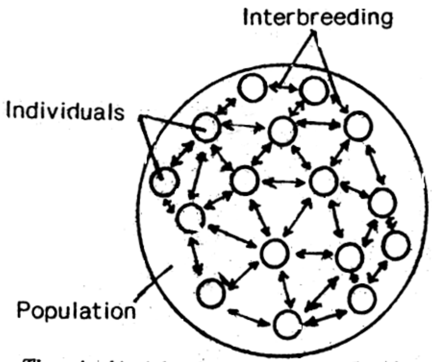
The function of isolating mechanism is to increase the efficiency of mating when other closely related species do not occur, courtship signals can afford to be general, non-specific and variable. There will be a selective premium on precision and distinctiveness of signals.

Each species likely to fit into a definite niche in its environment. Hybridization usually leads to a break down of this system. Any attribute of a species that would favour the production of inferior hybrids, is selected, it results in wastage of gametes. Such selection maintains the efficiency of a isolating mechanisms and in deed help to perfect them.

18.5. SPECIATION:

18.5 A. Definition, salient features of species and types:

The phenomenon speciation refers to the formation of new species. Species is the basic unit of classification. John ray was the first man to coined the term species mean which animals interbreed among themselves freely. Speciation helps to understand the process of evolution which was influenced and controlled by number of factors.



The individuals of a population inter-breed.

Fig. 18-2. Inter-breeding in a population

Mayr (1959) described species as biological experiment or the key stone for evolution. Speciation is the method by which evolution progresses. When there is no speciation, there would be no diversification of the populations, no adaptive radiation and no evolutionary process.

New species are formed in two ways. They are classified as 1) Phyletic speciation
2) True speciation

Species

1.Phyletic speciation — 2.True speciation

1.Phyletic speciation: a. Autogenous, b. Allogenes

2.True speciation: a. Instantaneous, b. Gradual

b. Gradual: Sympatric, Allopatric

1) Phyletic speciation:

When one species is transformed into another in time, is called phyletic speciation. Suppose for example, species A is transformed into species B in 1991, Species B is transformed into species C in 2001 and so on. Its operation is of 2 types a) Autogenous b) Allogenous

a) Autogenous speciation: (self transformation)

When one species is transformed into another by itself under the influence of evolutionary forces like mutations, natural selection and genetic drift and migration then it is called autogenous speciation.

Time Natural Selection
Species 'A' ---------------> Species 'B' --------------------> Species 'C'
Mutation Genetic drift

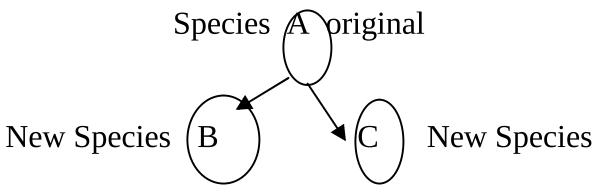
b) Allogenous: (Different transformation)

When one species is transformed into a new species by mating with another species i.e., because of hybridization then it is known as Allogenous Speciation.

Hybridization
Species A ---------------> New species

2) True Speciation:

One species is transformed into 2 or more new species by a process of splitting (or) fragmentation. That means new species are formed by the multiplication of the original species. Hence 2 or more species co-exist with the parental species.



True speciation is divided into 2 types.

a) Instantaneous: (means spontaneous development) It is caused by chromosomal aberrations and mutations (De Vries).

b) Gradual speciation: through Gradual development. It is of 2 types 1) Sympatric 2) Allopatric.

By the accumulation of genetic divergence and Reproductive isolation and also by evolutionary forces like mutation, recombination, natural selection and genetic drift gradual changes will occur in populations.

18.5. B. Mechanism of Speciation:

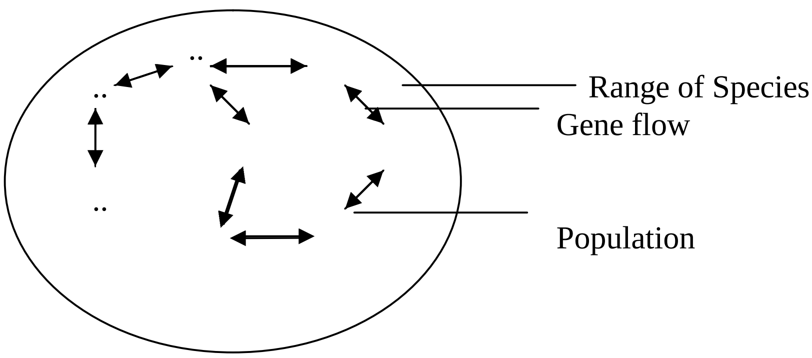


Fig. 18-3. Interbreeding and gene flow in a species.

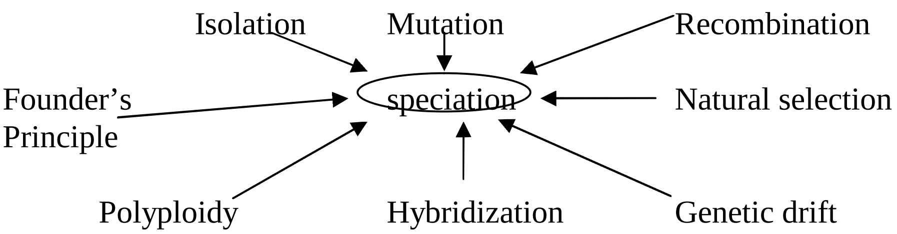
“A species is a group of potentially interbreeding natural population that is reproductively isolated from other such groups is called a species.

Naturally, the individuals of a same species interbreed among themselves not between 2 different species. Hence interbreeding bring about the transfer of genes from one individual to another. This is known as gene flow. There is no gene flow between individuals of 2 different species. So gene pool is same in each species but the quality of the gene pool differs from one species to another species. Thus species are evolved owing to the development of genetic divergences and isolating mechanisms.

For example:-Suppose a population is isolated from its parental species, when it is prevented from inter breeding with its parental species, there is failure of gene flow between the isolated population and the parental species. The gametic constitution of the isolated population gradually changes from the parental population.

18.5.C. Factors influencing speciation:

Speciation is the production of new gene complexes capable of ecological shifts. These changes are nothing but variation (or) genetic differences (or) gametic divergences. They are



i) Mutations:

Mutation is a sudden change occurs in cell duplication i.e., change in chromosomal structure. The change occurs in chemical composition of a gene so they are called point mutations. Any change in the genetic material alters, the gene pool and the characters of the animals. Mutations are important sources of variations and supply variations continuously. Variations may be beneficial or harmful or Neutral to the population.

ii) Recombination:

The formation of new gene combination in the offspring is called recombination. Recombination are produced by crossing over at the time of meiosis. Free assortment of genes at the time of gametogenesis, random union of gametes at the time of fertilization, chromosomal aberrations and interbreeding.

Recombination does not produce new genes, but assists the spreading of mutant genes in the population. Hence the original character of the animal is changed and new characters appear by recombination are tools for the production of recombinations.

iii) Natural Selection:

Natural selection does not produce genetic change, but it favours the spreading of one type of gene more, rapidly than the other. Natural selection operates over million of years to facilitate the development of new adaptive characters. Thus the interaction of mutation, recombination and natural selection results in new adaptive characters.

iv) Genetic drift:

It is defined as a random genetic change in small populations taking place purely by chance. It is also called "Wewalt Wright effect". It operates in small populations by chance. It is an operative force responsible for fixing non-adaptive (or) Neutral characters in populations and also leads to homozygosity in a few generation. Genetic drift has a considerable role in micro evolution.

v) Hybridization:

Interbreeding between the members of different species is called hybridization. The resulting offspring are called hybrids. The hybrids share the genetic materials from two different species. Hybridization leads to sympatric speciation.

vi) Polyploidy:

Increase in number of chromocomal sets more than two sets is called polyploidy. It is of 2 types. a) Autopolyploidy b) Allopolyploidy. Polyploidy brings about instantaneous speciation.

Founder's principle:- (Mayr & Shepparel 1940)

It states that when a new population is established in Isolation, its gene pool is not identical with that of the parent population because of sampling error, this difference is further improved by the different types of evolutionary pressures independently in the two populations this leads to genetic divergence.

vii) Isolation:

Isolation is the segregation or separation of populations by some barriers which prevent interbreeding. When interbreeding is prevented, gene flow between population is also prevented. Isolation prevents the exchange or mixing or genes between population. Each populations in isolation develops genetic divergence independently, leading to the formation of new species. The agency which brings about isolation is called isolating mechanism.

18.5.D. Main patterns of speciation:

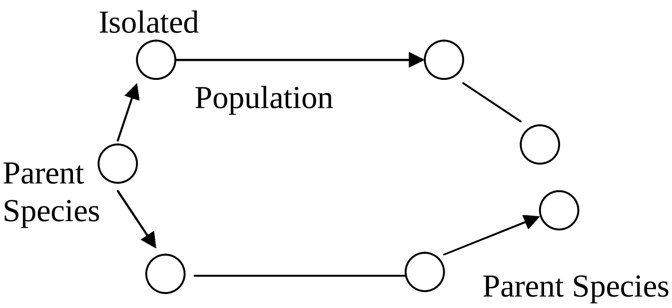
There are 4 pattern of speciation.

a) Allopatric: (Different habitats)

When two related population occupy geographically or spatially separated areas, they are called allopatric population. The evolution of allopatric populations into separate species is called allopatric speciation.

A species is formed of many interbreeding populations, they share a common gene pool. When there is geographic barrier, they split into two (or) more groups are called allopatric populations. For example, the animals moving at a faster speed (birds, mammals etc) the degree of isolation should be greater . For small sedentary animals the degree of geographical isolation is much less.

Tack (1947,1949) explained the Finches inhabiting Galapagos island, they are unlike those of Darwin finches.



The idea is when there is no opportunity for the geographic isolation of populations and hence no evolution of new sub species or an adaptive radiation. So effective means of geographic isolation is also a part for the evolution of new species.

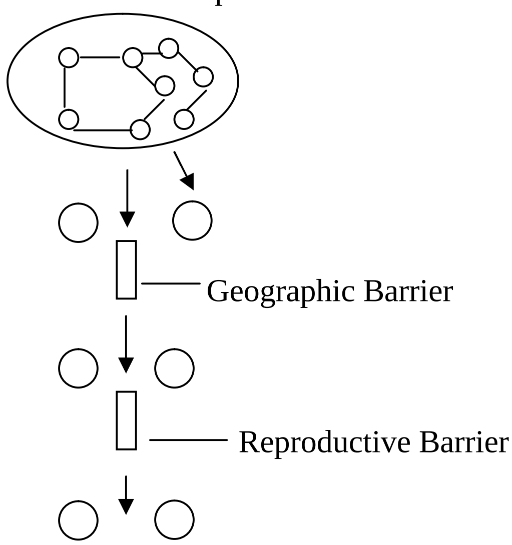


Fig. 18-4. Allopatric speciation.

b) Sympatric speciation : (same habitat)

Related populations occupying side by side of geographic area are called sympatric populations. The evolution of sympatric populations into separate species is called sympatric speciation. Usually, sympatric populations are living in the same habitat. i.e., same place, they have same basic needs, they are food, space and other requirements etc. So competition will begin (Gavse's law 1934) (or) competition exclusion principle (Hardin 1960) slates that 2 populations (or) 2 species cannot continue to occupy the same habitat indefinitely.

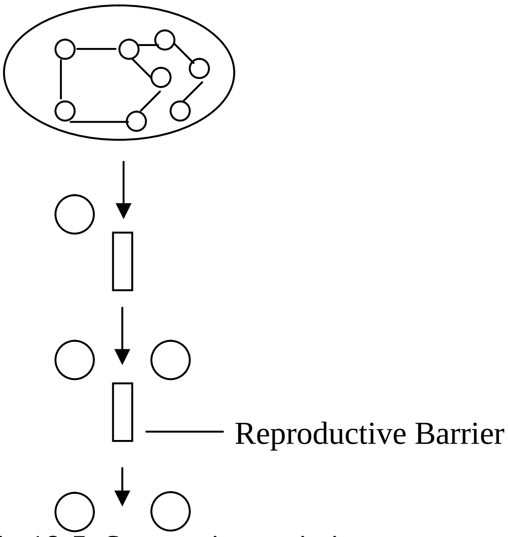


Fig.18-5. Sympatric speciation

To avoid unfavourable conditions like competition animals may became extinct may migrate to other regions, may undergo evolutionary changes. In addition to competition for food, space etc there are other factors like mutations, genetic drift, polyploidy, hybridization, Natural selection, genetic drift, Isolation, Founder's principle etc operating in the population. These factors will establish genetic divergences and variations, reproductive isolation. Hence the population fail to interbreed. So gene flow will prevent there is no possibility of mixing up of the genes. Consequently each population maintains a separate and distinct gene pool and evolved like two separate species.

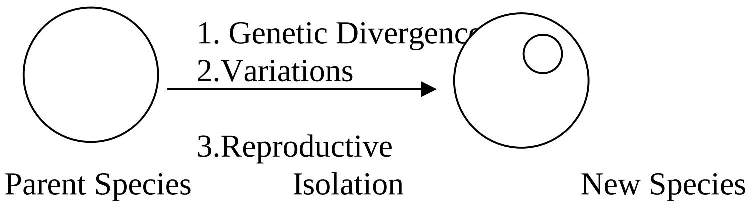


Fig.18-6. Sympatric speciation

c) Quantum speciation:

Quantum speciation refers to a more rapid and more abrupt mode of species formation.

Eg: *Drosophila* inhabiting Hawaii islands.

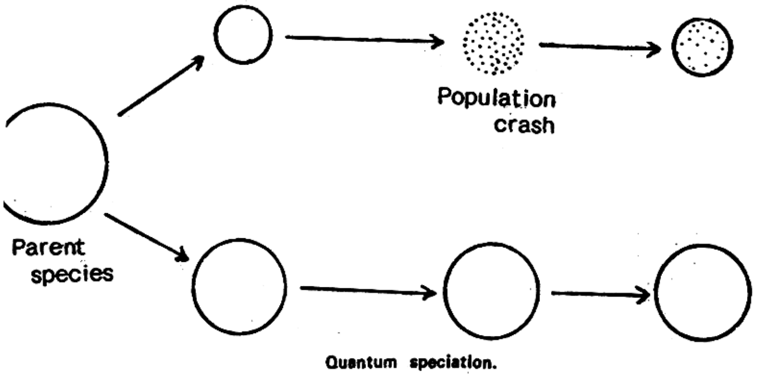


Fig.18-7. Quantum Speciation

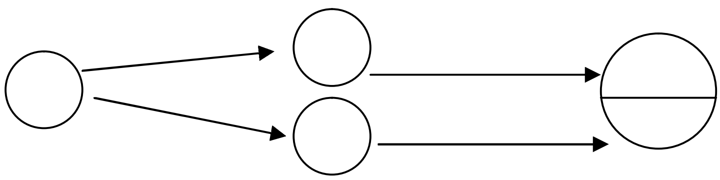
Grant (1971) defines quantum speciation as “the budding off a new and very different daughter species from a semi-isolated peripheral population of the ancestral species.

Over 7 million years older ago Hawaii islands contained about 700 species of Drosophila, still there are no sub-species in any species. Volcanic eruptions are common in Hawaii islands, kill the vegetation and pre-existing animals. Since this area is free from natural enemies (or) isolated areas, natural selection is temporarily relaxed, this leads to the development of new genetic variations. As the environment becomes saturated, population crash takes place which will eliminate almost all the individuals.

1) Quantum speciation is a sudden and rapid.
2) It does not produce sub-species.
3) Genetic drift or chance plays a major role.
4) It resembles geographic isolation.

d) Parapatric speciation:

Divergence takes place between continuous or over lapping or separated populations.



Parent Species | New population | New species

Fig.18-8. Parapatric speciation

Bush (1975) stated that parapatric speciation may occur whenever species evolve as continuous population in a continuous cline”, It involves only relatively few individual of the parent population. No geographic isolation is involved here. Reproductive isolation is the operative force and are produced by natural selection.

18.6. SUMMARY:

Genetic drift upsets Hardy-Weinberg equilibrium in small populations and promotes evolutionary process in small populations.

The gene pool of the island population will become very different from the gene pool of the parent population.

18.7. KEY WORDS:

Alleles: One of a pair of a gene that occur at a given locus (or) the chromosomes.

Locus: Position of particular gene on chromosome.

Gene pool: The sum total of genes presents in a Mendelian populations.

Gene flow: The transfer of genes from one gene pool to another.

Gene frequency: The ratio of a gene in a gene pool (or) a population is called gene frequency.

Genetic drift: It is defined as a random genetic change in small population taking place purely by chance.

Isolation: Isolation means segregation (or) separation of population by geographical barrier which prevent interbreeding.

Mutations: It is a sudden change which alter one gene or one chromosome into another form.

Recombination: The formation of new gene combinations not present in the parental type is called recombination.

Sibling species: Sympatric species that are morphologically similar but reproductively isolated.

Speciation: The formation of new species is called speciation.

Species: Organism which interbreed among themselves and producing fertile hybrids.

Allopatric: Closely related populations separated by geographical barrier.

Sympatric: Closely related populations which are separated by reproductive barrier.

Hybridization: Crossing of individuals of different species. It leads to gene flow between populations resulting in genetic divergence.

18.8. MODEL QUESTIONS:

1. Explain Hardy-Weinberg law of equilibrium with examples
2. Describe applications of Hardy-Weinberg law along with its significance.

3. Write an essay on speciation.
4. Describe species concept and add an account on mechanism of speciation.
5. Write a note on post mating or pre-mating isolation mechanisms.
6. Describe Reproductive isolation mechanisms.
7. Give an account on genetic drift.

18.9. REFERENCES:

1. Strickberger M.W.Z. 1994. Evolution CBS publishers, & Distributors, ISBN shahdra, Delhi, India.
2. Stebbins G.L.1970 Process of Organic Evolution prentice Hall.
3. Arora M.P. (1991) Organic Evolution, Himalaya publishing House.
4. N.Arumugam 2003 – Organic Evolution, Saras publications.

P. Nitya Jeeva Prada

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Lesson - 19
ORIENTAL REGION AND ITS FAUNA

CONTENTS :

19.1 OBJECTIVES
19.2. INTRODUCTION
19.3. ORIENTAL REGION - EXTENT
19.3.1 Oriental Region – Physical featues
19.3.2. Faunal wealth
19.4. SUMMARY
19.5 KEY WORDS
19.6 MODEL QUESTIONS
19.7. REFERENCES

19.1. OBJECTIVES:

The main objective of this lesson is to

- know about zoo geographical classification of the globe
- know about the location of various regions and their biotic content
- understand the extent of each region and the biodiversity of that particular land
- familiarize with the physicochemical factors and the distribution of different living organisms, and
- importance of the classification of the globe into geological realms and their significance.

19.2. INTRODUCTION:

Entire globe is distributed with different types of organisms but all the organisms are not universal in their distribution. This distribution depends upon the physical features of the environmental conditions, adaptability, availability of the food materials, density of distribution and prevalence of the predatory organisms. Since the environment is ever changing, the organisms living in a particular environment, any change caused in the environment exerts influence on the organisms of that particular region. Adaptability to the changing conditions makes the organisms to survive and succeed in their life period. Adaptability is an important aspect in the evolution of the new species. Hence zoogeography contributes for the process of evolution to progress. Hence this branch has got significant place in the study of evolution.

Six zoogeographical regions realms have been distinguished viz.:

a) Palaearctic Region : It includes Europe, temperate Asia and North Africa and Arabia.
b) Nearctic Region : It includes whole of North America and Greenland.
c) Ethiopian Region: It includes whole of Africa, Arabia, south of the tropic of Cancer and Madagascar.
d) Oriental Region : It includes India, Ceylon, Indochina, Pakisthan, Bangladesh and Malaya.

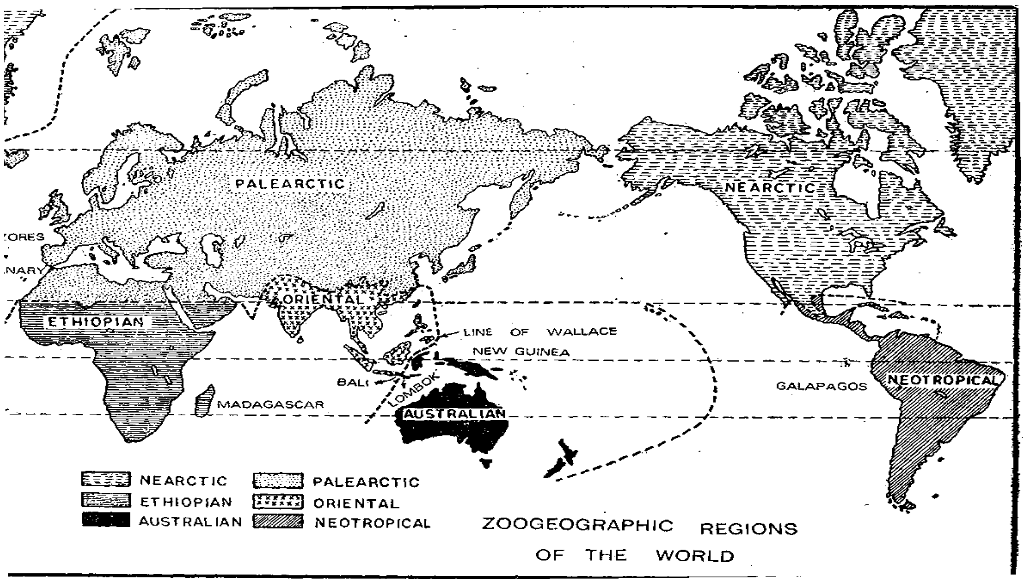

Fig.19-1. Zoogeographical regions of the world

e) Australian Region: It includes the whole of Australia, Newzealand, New Guinea and the neighbouring islands.

(f) Neotropical Region: It includes whole of South and Central America and West Indies.

19.3. EXTENT OF ORIENTAL REGION:

This region includes the portions of continental Asia, not comprised in the Palaearctic and Ethiopian Region including the Malaya Archipelago comprising Bali, Borneo, the Philippine islands and Formosa extending to far east.

19.3.1 Physical features: Towards north, Indian sub region is chiefly composed of plains and desert, more particularly in the watersheds of great rivers viz., the Indus and Ganges. Its fauna as a whole shows similarity with those of Ethiopian region possessing most of the desert adaptations. The desert in the north west is of debatable issue and may be regarded as a transitional tract between the Oriental and Palaearctic Regions. The southern portion of India is more luxurient than the northern one. This area is mostly covered with tropical forest and with a series of elevated paths culminating in Western and Eastern Ghats. Ceylon, the Indo-chinese sub region and most of the Malayan islands are almost entirely covered with luxurient tropical forests of the most and possess varied and extremely rich fauna.

19.3.2 Zoological characteristics: In this region the terrestrial vertebrates are represented by 153 families of which 10 are peculiar. These comprise 4 of Mammals, 1 of Birds and 5 of Reptiles as given below :

Mammals: (1) Hylobatidae (Gibbons) (2) Tarsiidae (Tarsiers) (3) Galeopithecidae (Flying Lemurs)- (4) Tupaiidae (Tree-Shrews).

Birds : (1) Eurylaemidae (Broad Bills)

Reptiles : (1) Elachistodontidae (2) Uropeltidae (Shield Tails) (3) Lanthanotidae (4) Gavialidae (Gavials) (5) Platysternide (Big **Head** Tortoise)

In addition to the above, several well known species and genera are quite characteristic here. Among Mammals the Orangutan (Simla satyrus}, the Macaque monkeys (Macacus), the Tiger (Pathera tigris) and Indian elephant (Elephas maximus), the Malayan Tapir (Tapirus indicus), and three out of the five known species of Rhinoceros are nearly or quite confined to the Region, while families Tragulidae (Chevrotains) and Manidae (Pangolin) are very characteristic.

Although only one family of Birds is given above as peculiar, yet many other have their monopolistic existence in the Oriental Region. They are Starlings drongos, Orioles, Honey Peckers, Bulbuls, Pittas and many others. Peacock (Indian National Bird) among birds are highly peculiar in this region.

Reptiles and Amphibians are very well represented in this region. Besides the five peculiar families mentioned above, the following families viz., Illysiidae (Cylinder Snakes), Xenopeltidae, Acrochordidae (Wart Snakes) and pit vipers, etc., Peacocks, Python among snakes,

19.4. SUMMARY:

Oriental region includes the Indian subcontinent along with Pakistan, Bangladesh, Ceylone and other neighbouring islands. This region is mostly temperate and hence dry atmosphere exists. Faunal diversity is tremendous but needs conservation.

19.5. KEY WORDS:

Zoogeography: Study of the distribution of organisms in different areas of the world.

Zoogeographical regions: Division of the universe into different regions depending upon the floral and faunal distribution

19.6. MODEL QUESTIONS:

1. Write an elaborative account on the characteristic features of Oriental region and its fauna.
2. Give an account on the classification of the universe into various Zoogeographical regions.

19.7. REFERENCES:

1. P.S. Dhami, J.K. Dhami, *Chordate Zoology*. R. Chand & Co.
2. Chordate anatomy. ……Mohan P Arora
3. College Zoology by Richard A. Boolotian an Karl A. Stiles

…..Dr. P. Padmavathi

Lesson - 20

ETHIOPIAN REGION AND ITS FAUNA

CONTENTS :

20.1. OBJECTIVES
20.2. INTRODUCTION
20.3. EHIOPIAN REGION - EXTENT
20.3.1 Ehiopian region-physical features
20.3.2 Faunal wealth
20.4. AUSTRALIAN REGION - EXTENT
20.4.1 Australian region-physical features
20.4.2 Faunal wealth
20.5. SUMMARY
20.6. KEY WORDS
20.7. MODEL QUESTIONS
20.8. REFERENCES

20.1. OBJECTIVES:

The main objective of this lesson is to make the student to know

- the reasons for variation in the distribution of animals in different continents, and
- the evolutionary significance of zoogeography.

20.2. INTRODUCTION:

Entire globe is distributed with different types of organisms but all the organisms are not universal in their distribution. This distribution depends upon the physical features of the environmental conditions, adaptability, availability of the food materials, density of distribution and prevalence of the predatory organisms. Since the environment is ever changing, the organisms living in a particular environment, any change caused in the environment exerts influence on the organisms of that particular region. Adaptability to the changing conditions makes the organisms to survive and succeed in their life period. Adaptability is an important aspect in the evolution of the new species. Hence zoogeography contributes for the process of evolution to progress. Hence this branch has got significant place in the study of evolution

Six zoogeographical regions realms have been distinguished viz.:

Palaearctic Region : It includes Europe, temperate Asia and North Africa and Arabia.
Nearctic Region : It includes whole of North America and Greenland.
Ethiopian Region: It includes whole of Africa, Arabia, south of the tropic of Cancer and Madagascar.
Oriental Region : It includes India, Ceylon, Indochina, Pakisthan, Bangladesh and Malaya.
Australian Region : It includes the whole of Australia

Newzealand, New Guinea and the neighbouring islands.
(6) **Neotropical Region** : It includes whole of South and Central America and West Indies.

20.3. EXTENT OF ETHIOPIAN REGION:

The Ethiopian region is easily defined. It consists of the whole of Africa and Arabia south of the tropic of Cancer, together with Madagascar and the small adjacent islands.

20.3.1. Physical features:

Entire area of the Ethiopian Region lies between the tropics. Hence the conditions of life are more uniform than is the case of Palaearctic and other regions. The whole coastline of Africa is remarkably free from deep indentations and extensive mountain ranges as seen in other continents. The southern and eastern portions of the region are characterized by extensive plateaus extending near to the coast. The southern half has an average elevation of nearly 4000 ft. Most important mountain range of the Ethiopian Region runs up the eastern half which includes most of the great African lake. North of Ethiopian region is having the great Sahara, the most extensive continuous desert in the world. This forms a most effective barrier between the Palaearctic and Ethiopian. Hence the fauna of north and south of the desert are remarkably distinct. South of this we have a great region of luxuriant tropical forest with an abundant and very distinct fauna serving as a basis for the separation of a 'West African' sub region. South of this again are the Kalahari and Damara Land desert-regions. Beyond the southern to tropic is the South Africa sub-region having fairly temperate climate and a wonderfully rich flora. The eastern portion of the continent is largely a region of savannas and grass land of a uniform nature. Lastly, the island of Madagascar is sufficiently distinct both geographically and zoologically requiring separate description. It is cut off from the mainland by a very deep channel. It is characterized by peculiar fauna. This interesting island had been the subject of much investigation and speculation on the part of biologists. It is presumed that at one time it formed part of a direct land connection between India and South Africa. This area was submerged and the remains left as islands during early tertiary periods. Lydekker regards Madagascar and the neighbouring islands as a distinct region which gained much justification and support from all the sides.

20.3.2. Zoological Characteristics:

The Ethiopian fauna is rich, varied and well marked. It has not less than 161 families of terrestrial vertebrates which exceeds the fauna of any other zoogeographical region in the world. Of these, 30 are peculiar.

a) Animals belonging to the class Mammalia, 12 families *viz.*,
(1) Chiromyidae (Aye Aye) (2) Chrysochloridae (Golden moles)
(3) Centetidae (Tenrecs) (4) Potamogalidae (Potamogale)
(5) Protelidae (Earth wolf) (6) Battryergidae (Aftican mole rats)

(7) Lophimyidae (Crested rats) (8) Pedetidae (African Jumping Hares)

(9) Anomaluridae (African Flying Squirrels) (10) Giraffidae (giraffees)
(11) Hippopotamidae (Hippopotamus) (12) Orycteropodidae (Aardvarks) are peculiar to this region.

b) 13 families of birds are peculiar to this region *viz*.,
(1) Promeropidae (Promerops) (2) Acerocharidae (Helmet Birds)
(3) Vangidae. (4) Philepittidae.
(5) Musophagidae (Plankton Eaters) (6) Leptosomatidae (Kiroumbos)
(7) Irrisoridae (Wood-Hoopoes) (8) Collidae (Colfes)
(9) Serpentaridae (Secretary Birds) (10) Scopidae (Hammer Head Bird)
(11) Mesoenatidae. (12) Numididae (Guinea fowl)
(13) Balaenicipitidae (Whale Head).

c) Among the Reptiles following families are peculiar :
(1) Rhachiodontidae (Egg-eating Snake) (2) Gerhosauridae
(3) Zonuridae (Girdled lizard) (4) Uropeltidae.

d) One family of Amphibians i.e. dactylethridae especially represented by clawed toads is very much peculiar here.

Besides the above, following important genera confined to this region are Chimpanzee, Gorilla, Lemurs, monkeys of genera Colobus, Cercopithecus, Lycaon, Potamochoerus and a large number of Antelopes are also peculiar and important. Animals of the following families not only range beyond the limits of the Ethiopian region but also quite characteristic and peculiar include mammals of Macroscelidae (Elephant shrews), Hyaenidae (Hyaena), Elephantidae (Elephants), Rhinocerotidae (Rhinoceros), Procavidae (Hyracoes) Equidae (Horsees), Manidae (Pangolins)and Birds of Ploceidae, Nectariniidae (Sunbirds) Zosteropidae (White Eyes), Indicatoridae (Honey Guides), Capitonidae (Barbets), Bucerotidae (Hornbills) and Struthionidae (Osriches-flightless birds).

There are no peculiarly Ethiopian families of butterflies, but one, namely, the Acraeidae, is highly characteristic.

Lastly the total absence of certain animals like moles, bears, deer, goats and sheep is worth mentioning. These animals are very much well distributed in other regions of the old world.

20.4. EXTENT OF AUSTRALIAN REGION:

The Australian Region includes the whole of Australia, Newzealand, Newguinea, the Molluca and other neighbouring islands besides all the islands in the Pacific ocean. Wallace line drawn between the islands of Bali and Lombok constitutes the western boundary of this region. This boundary line then extends to the east of Celebes or the Philippine Islands. The line further extends eastwards along the tropic of Cancer to include the Sandwick Islands also. Then it curves round to the south of Newzealand, Auckland Islands, Tasmania and Australia.

20.4.1. Physical features:

North Australia and New Guinea forming the northern part of the region lies with in the tropics and has high summer temperature. Much of the area is covered by rain forest. The interior of the Australia continent is also hot, but dry, while further south the climate becomes mainly temperate.

20.4.2. Faunal characteristics:

This very distinct Region possesses representatives of 134 families of terrestrial vertebrates of which not less than 30 families are peculiar composing of eight families of Mammals, 16 of Birds, 3 of reptiles and rest being Amphibians. The peculiar families of Mammals comprise the whole order Monotremata and most of the Marsupials. Opossums (Diadelphidae) of marsupials are confined to the Neotropical and the southern portion of the Nearctic Region. The complete list of peculiar families in the Australian Region is as follows :

a) Mammals: (I) Phascolomydae (Wombats) (2) Phalangeridae (Phalangers) (3) Macropodidae (Kangaroos) (4) Ornithorhynchidae (Ornithorhynchus (5) Notoryctidae (Marsupial) (6) Dasyuridae (Dasyures (7) Echidnidae (Echidna} (8) Peramelidae (Bandicoots),

b) Birds: (1)Paradiscidae (Paradise Birds) (2) Ptilonorhynchidae (Bower Birds) (3) Meliphagidae (Honey Eaters) (4) (Drepanididae (Drepanis) (5) Artichornithidae (Scrub Birds) (6) Xenicidae (7) Menuridae (Nestor Parrots) (8) Loriidae (Lories) (9) Cyclopsittacidae (10) Stringopidae (Owl-Parrots) (11) Phinochaetidae (Kagu) (12) Gonuidae (crowned Pigeons) (13) Didunculidae (Tooth-billed Pigeon) (14) Apterygidae (Kiwis) (15) Dromaeidae (Emus) (16) Casuariidae (Cassowaries),

c) Reptiles ; (1) Pygopodidae (Scale footed lizards) (2) Hatteriidae (Tuatra-sphenodon) (3) Carettochelydidae (Fly-River Turtle)

d) Amphibians: (1) Ceratobatrachidae (2) Genyophrynidae.

The Region is also characterized by the absence of certain important groups besides the presence of some peculiar groups. Thus there are few Mammals except Marsupials and Monotremes. The other orders being represented by some **bats** and small Rodents and a few species which have entered the Region from the Oriental boundary. Apes, Monkeys, Insectivores, Carnivores, Ungulates and edentates are practically absent. Among, Birds the Fringillidae (Finches), Emberizidae (Buntings) and Picidae (wood peckers) are absent. Among the Reptilian families Viperidae (Vipers) and Lacertidae (Tropical Lizards) are also absent.

20.5. SUMMARY:

All the regions of the world never possess the same environmental conditions and hence there is a lot of faunal diversity. Even if similar environmental conditions occur, faunal dissimilarity may be seen because of migration and recruitment. Different continents of the world also show slow movements which can not be observed easily. This movement may cause either separation of existing lands or new regions may be connected by land bridges. These are the reasons for the variation in the occurrence of flora and fauna. Ehiopian region includes south of Sahara, Medagaskar, South Arabia, Sahara in South Africa. This region is a temperate region with high temperature variations.

Australian region is special as it is an isolated area with favourable environmental conditions for the primitive mammals to lead successful life. Hence it is called the marsupial island.

20.6 KEY WORDS:

Zoogeography: Study of the distribution of organisms in different areas of the world.
Zoogeographical regions: Division of the universe into different regions depending upon the floral and faunal distribution

20.7. MODEL QUESTIONS:

1. Write an essay on the extent, physical features and faunal distribution of Ethiopian region.
2. Australian region is considered as the land of Marsupials- explain
3. Write the importance of Australian region in the world of Zoogeography.

20.8. REFERENCES:

1. P.S. Dhami, J.K. Dhami, *Chordate Zoology*. R. Chand & Co.
2. Chordate anatomy. ……Mohan P Arora.
3. College Zoology by Richard A. Boolotian an Karl A. Stiles.

…..Dr. P. Padmavathi

LAB MANUAL IN ZOOLOGY

B.Sc., ZOOLOGY: PAPER II

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II B.Sc., ZOOLOGY - PRACTICAL-II
(Chordata, Osteology, Histology and Embryology)

CHORDATA (Museum specimen)

1. **Protochordata** : Balanoglossus, Herdmania, Coina, Amphioxus, Amphioxus T.S. through Pharynx, intestine and caudal region.

2. **Cyclostomata** : Petromyzon, Myxine and Ammocoetus larva.

3. **Pisces** : Pristis, Torpedo, Chimaera, Channa, Acipenser, Amia, Arius, Pleuronectus, Hippocampus, Exocoetus, Echeneis, Notopterus, Labeo, Protopterus, Catla, Clarius, Anguilla, Anabas, Saccobranchus, Protopterus, Lepidosiren, Neoceratodus, Heteropneustes. Preparation of placoid scales

4.. Amphibia : Icthyophis, Proteus, Amblystoma, Siren, Axolotl larva, Rana, Bufo, Hyla, Rhacophorus.

5. Reptilia : Draco, Gecko, Chameleon, Uromastix, Varanus, Vipera Russets, Naja, Krait, Echis, Enhydrina, Bungarus, Crotalus, Ptyas, Eryx, Trionyx, Testudo, Crocodile, Gavialis.

6. **Aves** : Picus, Heron, Eudynamus Bubo, Alcedo, Psittacula.

7. Mammalia : Ornithorhynchus.Tachygiossus, Hedgeho Macropus, Oppossum, Loris, Herpestes, Pteropus, Funambulus, Armadillo, Manis and Macaca.

8. **Histology:** (Slides from Mammalia) Stomach, intestine, liver, pancreas, kidney, testis, ovary, lung, spinal cord, bone, cartilage, artery, vein and v.s. of skin, blood film.

9. **Embryology** : 18 hrs chick embryo, 24 hrs chick embryo, 33 hrs chick embryo and 48 hrs chick embryo (whole mounts), Slides of Chick up to 96 hours.

10. **Osteology**: Girdles of Frog, Varanus, Pigeon and Rabbit. Appendicular skeletons of Varanus, Pigeon and Rabbit.

DISSECTIONS

1. V & VII, {or) IX & X cranial **nerves of scoliodon**
2. **Arierial** system, Brain and **ear canals of Scoliodon or any locally available fish**
3. Bird (Smal! size chick): Arterial system / venous system

TWELVE PRINCIPLES OF GOOD LABORATORY PRACTICE (GLP) TO BE FOLLOWED

- PRACTICAL EXAMINATION IS CONDUCTED FOR 50 MARKS
- TIME FOR PRACTICAL EXAMINATION IS 3 HOURS
- EVERY STUDENT IS SUPPOSED TO

  *DO ONE DISSECTION WITH DISPLAY FOR 20 MARKS

  *IDENTIFY AND WRITE NOTES ON TEN SPOTTERS/SLIDES FOR 20 MARKS

  EACH SPOTTER/SLIDE CARRIES 1/2 MARK FOR IDENTIFICATION 1/2 MARK FOR CLASSIFICATION AND ONE MARK FOR WRITING AT LEAST 5-6 IMPORTANT POINTS FOR IDENTIFICATION AND DRAWING ROUGH DIAGRAM WITH PARTS

  *SUBMIT RECORD CARRYING 10 MARKS FOR EVALUATION

STUDENTS ARE ADVISED TO

- MAINTAIN AND KEEP UP THEIR RECORDS NEATLY
- DRAW ONLY COLOURED AND LABELLED ROUGH DIAGRAMS FOR EACH AND EVERY SPOTTER/SLIDE
- WRITE ONLY IMPORTANT IDENTIFICATION POINTS WITHOUT WASTING MUCH OF THEIR TIME
- DO THE DISSECTION AND DISPLAY THE SAME WITH BLACK PAPER
- DRAW LABELLED DIAGRAM ALSO FOR THE DISSECTION

<u>SYLLABUS FOR PRACTICAL EXAMINATION</u>:

DISSECTION:

MOUNTING:

SPOTTERS/SLIDES AS SHOWN IN THE LABORATORY AS PER PRESCRIBED CURRICULUM

STUDENTS ARE ADVISED TO

1. SEAT IN THE ALLOTTED SEATS
2. POSSESS NAPKIN WITHOUT FAIL FOR WIPING
3. KEEP WAX TRAYS AND WOODEN BOARDS NEAT AND CLEAN WITH OUT PINNING OR NAILING UNLESS INSTRUCTED.
4. NOTE DOWN DATE AND DETAILS RELATING TO THE EXPERIMENT IN THE OBSERVATION NOTE BOOK ON THE DAY OF PRACTICAL
5. DRAW AND LABEL THE DIAGRAM RELATING TO THE SPOTTER, SLIDE OR DISSECTION AS OBSERVED OR SEEN BY THEM FOR FURTHER REFERENCE
6. DRAW NEAT AND LABELLED DIAGRAMS AT THE CENTRE OF THE RECORD SHEET ALONG WITH CLASSIFICATION WHEREEVER NEEDED
7. GET THE DRAWN SHEETS SIGNED BY THE CONCERNED LECTURER IMMEDIATELY
8. USE WATER TO THE MINIMUM EXTENT POSSIBLE AND TO CLOSE THE TAPS AFTER USE
9. REMOVE PINS AFTER THE COMPLETION OF THE DISSECTION
10. PUT OFF LIGHTS AND FANS WHILE LEAVING THE LABORATORY
11. LEAVE THE LAB **AFTER** WASHING THEIR HANDS PROPERLY WITH SOAP
12. MAINTAIN SILENCE TO THE EXTENT POSSIBLE

MATERIALS TO BE POSSESSED BY THE STUDENT WHILE GOING TO THE ZOOLOGY LAB:

- ***OBSERVATION NOTEBOOK***
- ***HB & 4B PENCILS***
- ***ERASER***
- ***RECORD BOOK***
- ***DISSECTION BOX***
- ***NAPKIN***

YEAR END PRACTICAL EXAMINATION:

(1) *BALANOGLOSSUS*

GENERAL NAME: ACORN WORM

Phylum : CHORDATA
Sub.Phy :PROCHORDATA
Class :HEMICHORDATA
Order :ENTERONEUSTA

- Modern representative of the ancient link between the echinodermates and chordates
- Worm like organism living in the burrows along the sea shores
- Cylindrical body measures about 10-50cm in length and the body is covered by ciliated epidermis.
- Body is divided into three parts viz., a proboscis, a collar and the trunk
- Proboscis is muscular enclosing a single proboscis coelome/cavity opening out through a small proboscis pore located at the base of the proboscis.
- Collar is also muscular enclosing a pair of coelomic cavities opening out through a pair of small pores present at the posterior margin of the collar.
- Collar encloses a stomochord comparable to the notochord of higher prochordates.
- Surface of the trunk is wrinckled and hence appears as segmented.
- The part of the trunk just behind the collar is the branchiogenital region succeeded by hepatic region. Posterior to this is the abdomen ending with anus.
- Branchiogenital region has a pair of genital ridges enclosing gonads and a respiratory groove having paired respiratory openings.
- Hepatic region has hepatic caecae arranged in two rows.
- Organisms are unisexual and fertilization is external.
- Development is indirect enclosing a free swimming ciliated larval form called Tornaria
- Universal in distribution and in India, it is seen mainly in the Crusade Islands near Rameswaram.

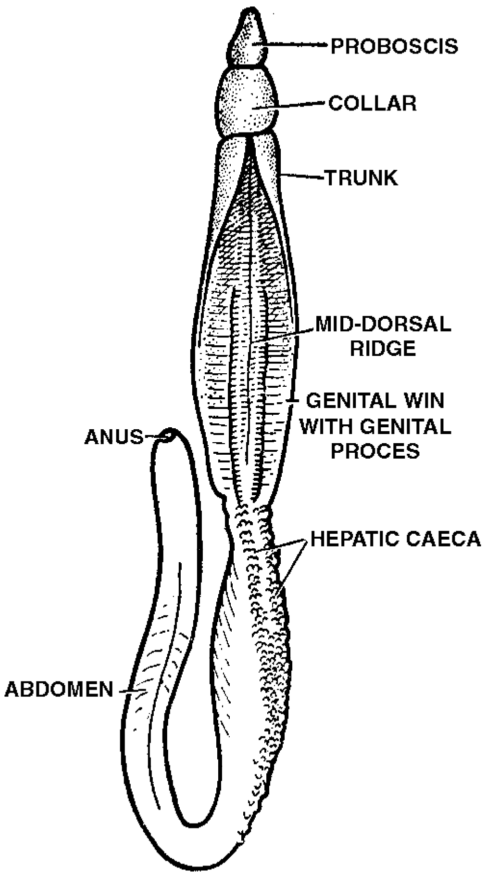


Fig 1. *Balanoglossus*

(2) *CIONA*

Phylum : CHORDATA
Sub.Phy : UROCHORDATA
Class :ASCIDIACEA

- Marine solitary organism leading sedentary life by attaching it self to the substratum.
- Cylindrical body is transparent and measures about 4-5 inches in size.
- Body is covered by a mantle.
- Free end bears a branchial and an atrial siphons into which open mouth and anus respectively.
- Both these siphons are possessed with sphincter muscles.
- Internally, the anteroposteriorly extended mantle has longitudinal muscle bands.
- Alimentary canal has an elongated basket like pharynx, tubular pharynx, sac like stomach and an intestine forming a “U” shaped loop and opening into the atrial cavity.
- Pharyngeal gill slits are rectangular.
- Cardiac pouch and gonads are entangled in the loop of the intestine.
- Gonadial ducts also open into the atrial cavity.
- Bisexual organisms and protogynous as the ovaries mature earlier than testes.
- Life cycle includes a well organized, free swimming tadpole larval stage with all the chordate features.
- Larva undergoes retrogressive metamorphosis and transforms into a poorly organized adult

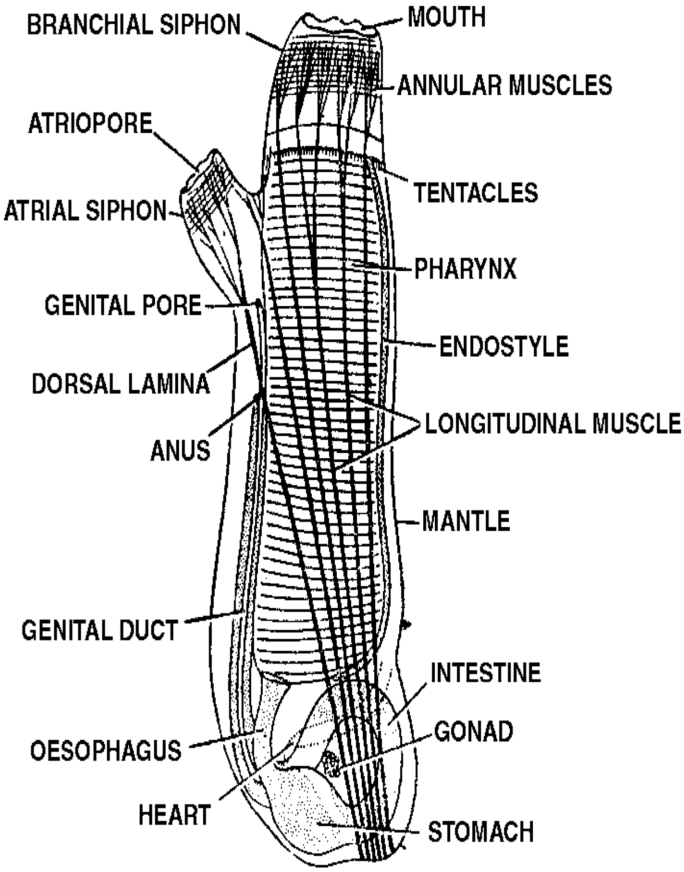


Fig 2. *Ciona*

(3) *HERDMANIA*

GENERAL NAME: ASCIDIAN

Phylum : CHORDATA
Sub. Phy :UROCHORDATA / TUNICATA
Class :ASCIDIACEA

- Solitary marine sedentary organism found attached to a solid substratum.
- Body is encircled by a tunicin made test.
- Free end bears a branchiogenital and an atrial openings.
- Alimentary canal has anteriorly located wide pharyngeal basket with a number of gill slits.
- Intestine forms a loop and opens into the atrial chamber through anus
- Neural gland acts as an organ of excretion and is located just above the ganglion.
- Adult is poorly organized and like a lump of meat.
- Bisexual or hermaphrodites enclosing male and female gonads near to the stomach.
- Gametes are released into the atrial cavity and are sent out though out going water.
- Food is composed of micro organisms and are collected by using cilia through filter feeding mechanism.
- Life cycle includes a free swimming and well organized Tadpole larva having all the important chordate features.
- Larva undergoes retrogressive metamorphosis and transforms into a lowly organized adult.

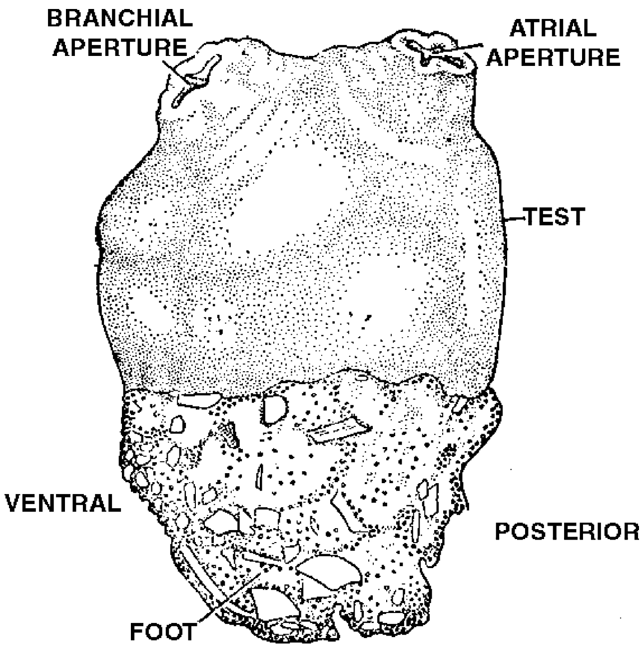


Fig 3. *Herdmania*

(4) *BRANCHIOSTOMA LANCEOLATUM*

GENERAL NAME: AMPHIOXUS

Phylum : CHORDATA
Sub. Phy :CEPHALOCHORDATA

- Transparent and burrowing fish like organism commonly seen in marine waters.
- Anteroposteriorly elongated body has lancet (pointed) ends.
- Body is laterally compressed with organs arranged on bilateral symmetry.
- Anterior pointed end is the rostrum. Just below to it and towards ventral side is the special tentacular structure called wheel organ.
- On either side of the body, the epidermis droops down into metaplural folds.
- Internally, an anteroposteriorly elongated flexible rod like notochord lies on the mid dorsal side.
- In between the notochord and the dorsal epidermis, lies a dorsal tubular nerve cord.
- Pharynx in the alimentary canal is basket like with a number of gill slits and helps in conducting both nutritive and respiratory functions.
- A number of '< ' shaped muscles are present on either side of the trunk helping in locomotion.
- Body has a dorsal, a caudal and a ventral fins in continuation of one another. They also help in locomotion.
- Ventrally, atrial opening lies in between the metaplural folds through which water and other products of excretion goes out.
- 21 pairs of Gonads are present near to the myotomes.
- Unisexual organisms without sexual dimorphism. Development is external and Life cycle is indirect involving a free swimming larval form undergoing progressive metamorphosis.

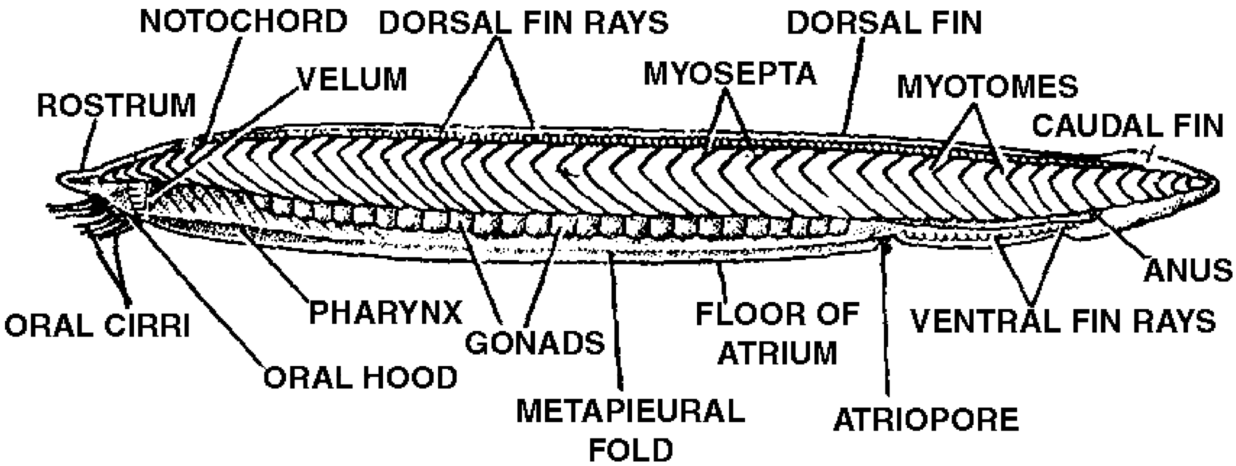


Fig 4. ***Amphioxus***

(5) *AMPHIOXUS - T.S. THROUGH PHARYNX*

- In transverse section, amphioxus appears triangular in outline with a pointed dorsal side and a wide ventral side.
- Ventrolaterally, epidermis droops as metaplural folds with lose fold of skin in between.
- Epidermis is composed of a simple columnar epithelium.
- On the mid dorsal side, a dorsal fin with fin rays is seen.
- Muscles are arranged in the form of myotomes extending between dorso- lateral to ventral side of the body
- Just below the dorsal fin, the sections of the tubular nerve cord, notochord and dorsal blood vessel are seen lying one below the other.
- Notochord is composed of vacuolar tissue surrounded by notochordal sheath.
- Pharynx lying in the space between the myotomes is laterally compressed and possess a number of gill slits.
- On the mid dorsal side of the pharynx lies a supra pharyngeal groove and mid-ventrally, a ciliated endostyle. These ciliated structures identify the food particles and entangles them in to the mucous secretions through ciliary mode of feeding (filter feeding mechanism).
- Gonads are present on the ventrolateral sides of the pharynx.
- Atrial cavity encircles the pharynx and gonads on all sides.
- Coelom extends as dorsal coelomic canals on either side of the supra-pharyngeal groove.
- Hepatic diverticulum extends below the pharynx on its right side.

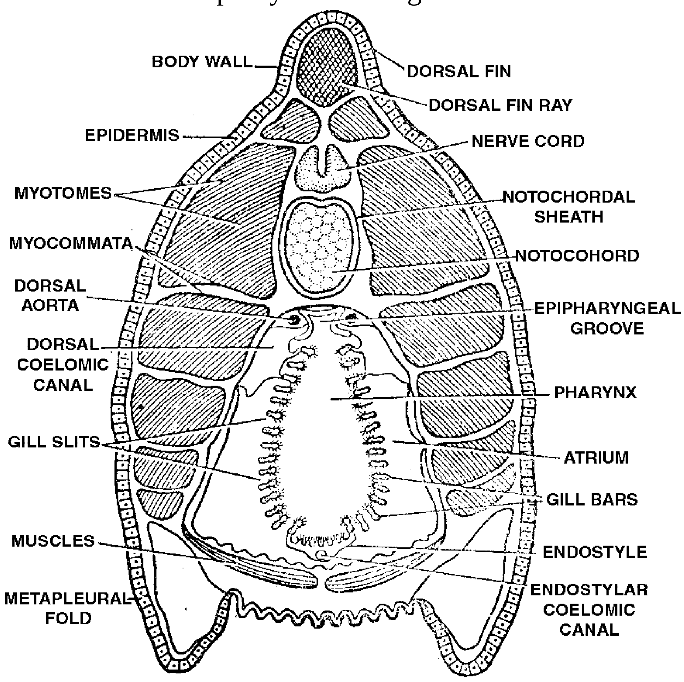


Fig 5. ***T.S.Amphioxus through pharynx***

(6) *AMPHIOXUS - T.S.. THROUGH INTESTINE*

- In transverse section, amphioxus appears triangular in outline with a pointed dorsal side and a wide ventral side.
- Ventrolaterally, epidermis droops as metaplural folds with lose fold of skin in between.
- Epidermis is composed of simple columnar epithelium.
- On the mid dorsal side, a dorsal fin with fin rays is seen.
- Muscles are arranged in the form of myotomes extending between dorso lateral to ventral side of the body
- Just below the dorsal fin, the sections of the tubular nerve cord, notochord and dorsal blood vessel are seen lying one below the other.
- Notochord is composed of vacuolar tissue surrounded by notochordal sheath.
- Dorsal aorta lies just below the notochord.
- Intestine occupies most of the cavity present in the body.
- Intestine is surrounded by a uni-laminar ciliated simple epithelium.
- Cavity present around the intestinal tube is the atrial cavity.
- Ectoderm grows as metaplural folds on the ventral side of the animal

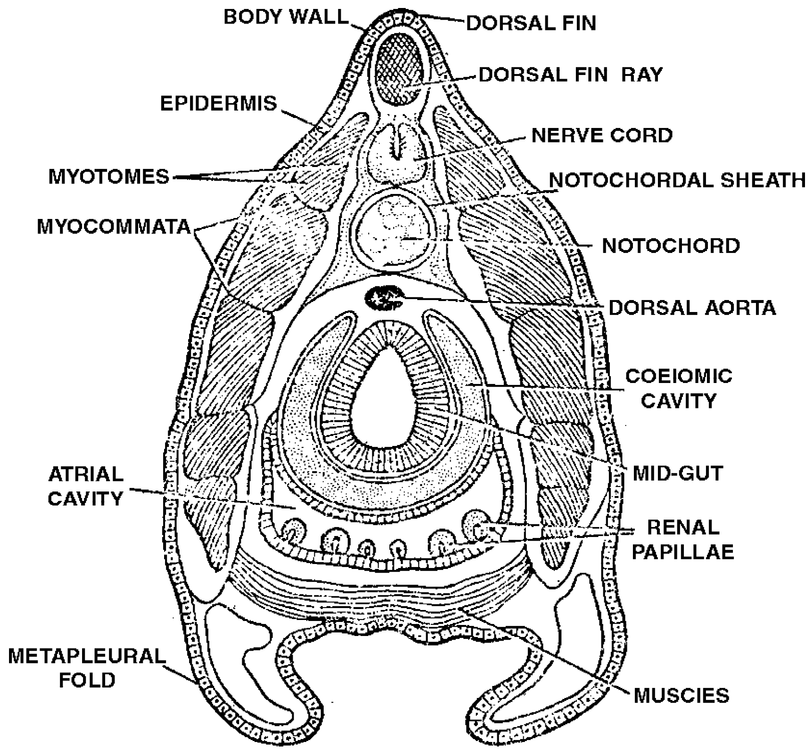


Fig 6. ***T.S. Amphioxus through Intestine***

(7) AMPHIOXUS - T.S THROUGH TAIL

- In transverse section, amphioxus appears as a swollen bulb with elongated epidermis on both dorsal and ventral side.
- Ventrolaterally, epidermis droops as metaplural folds with lose fold of skin in between.
- Epidermis is composed of a simple columnar epithelium.
- On the mid dorsal side, a dorsal fin with fin rays is seen.
- Muscles are arranged in the form of myotomes extending between dorso- lateral to ventral side of the body
- Just below the dorsal fin, the sections of the tubular nerve cord, notochord and dorsal blood vessel are seen lying one below the other.
- Notochord is composed of vacuolar tissue surrounded by notochordal sheath.
- Ectoderm grows into thin fins supported by fin rays.
- Dorsal and ventral fins help in locomotion.
- Additional blood vessel present beneath the dorsal blood vessel is the infra-intestinal vein.
- Cuttings of intestine, body cavity, atrium and metaplural folds are absent in the section.

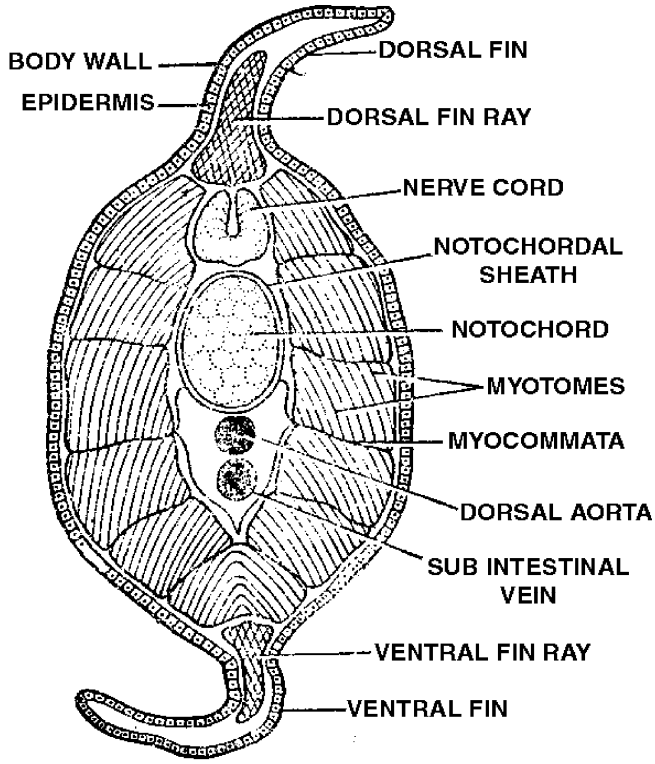


Fig 7. *T.S. Amphioxus through Tail region.*

FISHES:

(8) *PETROMYZON MARINUS*

General name: Lamprey

Phylum :Chordata
Sub.Phy :Vertebrata.
Class :Agnatha.
Sub Class: Cyclostomata.
Order :Petromyzontia

- It is a long, cylindrical, free swimming marine organism resembling a fish.
- It measures about one meter in length with laterally compressed Posterior half of the body.
- Body is divided into a head, trunk and tail.
- External surface of the body is smooth and is surrounded by rich amounts of mucous.
- Body is dark in colour due to high pigmentation and is devoid of scales.
- Antero-ventral side of the head has a buccal funnel.Its rim bears a powerful sphinctor muscle.
- The muscle acts as a sucker and helps in holding to the host firmly.
- Head grows over the funnel as a lid or cap.
- A number of horny teeth are present in the buccal funnel. Teeth are arranged in circles.
- A pair of small lateral eyes present over the head are functional.
- A single nasal opening is present at the mid dorsal side of the body.
- Seven pairs of gill slits are present on either side of the pharynx. Pharynx with gill slits appears as a pharyngeal basket.
- The dorsal, ventral and caudal fins are unpaired, undivided and are supported by cartilaginous fin rays.
- These fishes are devoid of jaws and paired fins.
- Unisexual organisms with a single gonad. Fertilization is external
- These fishes lead ectoparasitic life over other large sized fishes.
- Life history includes a free swimming Ammocoetus larva.

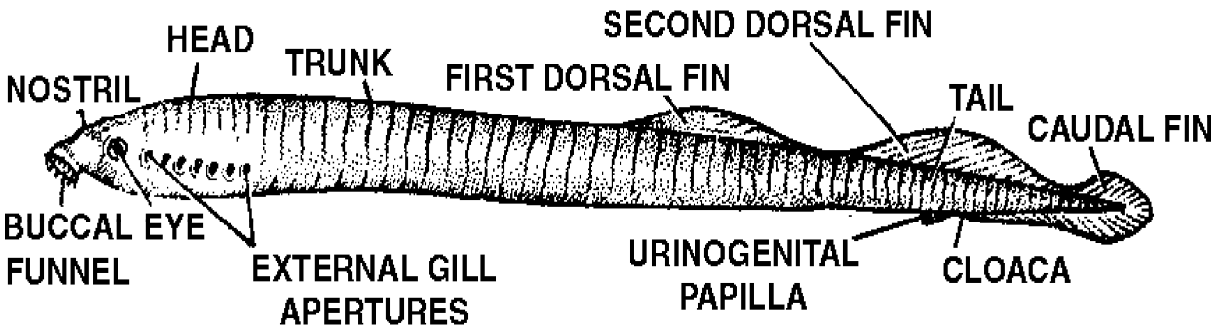


Fig 8. *Petromyzon marinus* (Hagfish)

(9) *MYXIENE GLUTINOSA*

General Name: Hag fish

Phylum :Chordata
Sub.Phy :Vertebrata.
Class :Agnatha.
Sub Class: Cyclostomata.
Order :Myxinoidea.

- It is a universally distributed nocturnal organism living at the sea bottoms.
- Body is ribbon like because of laterally compressed body.
- It makes burrows in to the muscles of larger fishes and leads parasitic life. Though the host is entire to the out side, host becomes hollow because of its presence.
- External surface is smooth and scaleless. It is surrounded by heavy quantities of mucous.
- Mouth at the anteroposterior end bears a pair of soft lips.
- Neither buccal funnel nor the horny teeth are present in the adult organism.
- Mouth is surrounded by four pairs of smooth tentacles supported by gill bars.
- A single dorsal nasal opening near to the mouth, a pair of vestigial lateral eyes, undivided dorsal, caudal and ventral unpaired fins, mucous openings along the ventrolateral sides of the body, and postero ventrally located anal opening are the salient external features.
- Internally, six pairs of gill slits on the sides of the pharynx, bisexual nature of the gonad having anterior ovary and posterior testis are the special features.

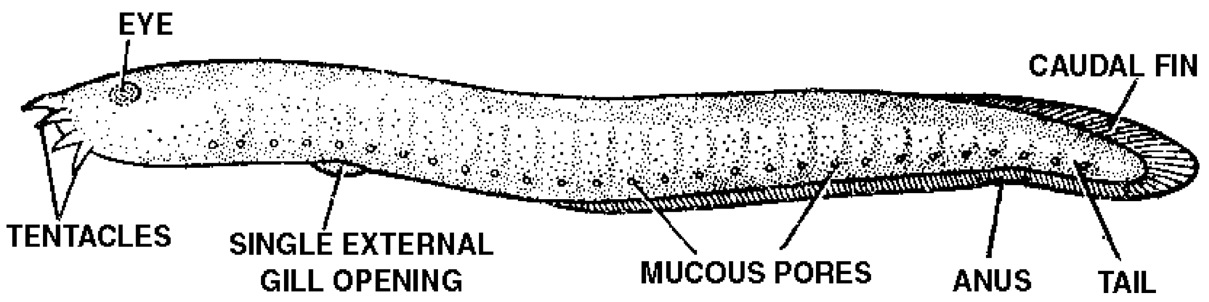


Fig 9. *Myxiene glutinosa* (Slime eel)

(10) AMMOCOETUS LARVA

GENERAL NAME:

Phylum :Chordata
Sub.Phy :Vertebrata.
Class :Agnatha.

- Free swimming larval form in the life history of Petromyzon marinus
- Body measuring about 10mm resemble amphioxus in its appearance
- Mouth is surrounded by lips and a number of sensory tentacles. Teeth and tongue are absent.
- Velum present at the posterior end of buccal cavity opens into the pharynx.
- Pharynx has seven pairs of gill slits for respiration.
- Ventral side of the pharynx has an endostyle.
- Presence of dorsal tubular nerve cord, antero-median eye, dorsal nasal opening, auditory primordium, and brain are the important features of the larva.
- Heart vesicle, liver lobe and gall bladder are formed at the postero-ventral side of the pharynx.
- Digestive system is a simple tube with pharynx, oesophagus, intestine and associated glands.
- Food is composed of microorganisms strained rough the cilia of the gill-slits.
- Larval life extends to 3-4 years and undergo metamorphosis to transform into the adult.

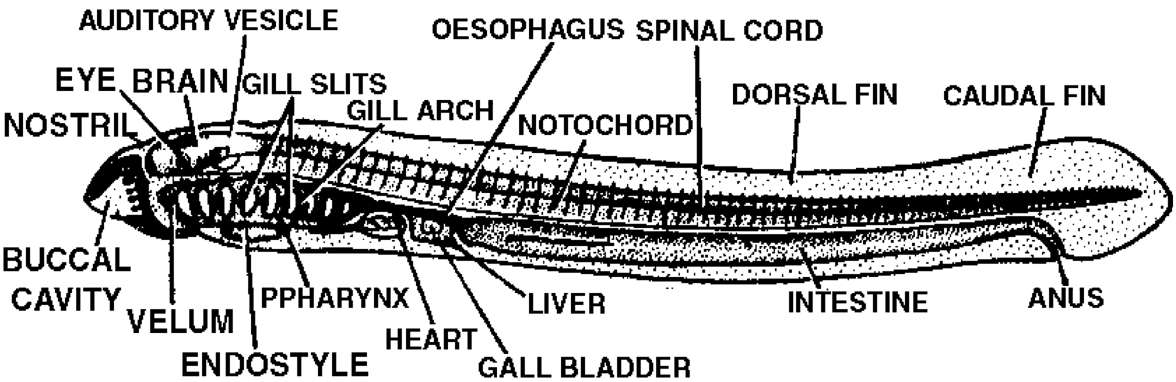


Fig 10. ***Ammocoetus larva***

(11) *PRISTIS*

GENERAL NAME: SAW FISH

Phylum: Chordata.
Sub phylum:Vertebrata/Craniata.
Super-class: Gnathostomata.
Series/Group : Pisces.
Class: Elasmobranchii/Chondrichthyes.
Sub-class: Selachii.
Super order: Hypotremata.
Order: Euselachii.

- Freeliving marine form commonly occurring in temperate and tropical seas.
- Extensively found along the coasts of Mediterranean sea, America, India and China.
- Grows to a size of 3 to 6 m and possess laterally compressed body.
- Head is flattened dorsoventrally with an elongated rostrum with pointed and sharp teeth.
- Toothed knife like rostrum is used for protection against predators.
- Head bears a pair of lateral eyes at the base of rostrum.
- A pair of branchial openings are present on either side of the pharyngeal region.
- Water entering through mouth goes out through the branchial openings.
- Mouth is ventral on the head. Jaws are toothed besides having a pair of barbels are present
- Tail is provided with heterocercal tail fin.
- Body has paired pectoral, pelvic fins besides a dorsal, a ventral and an adipose fin.
- This fish is a predator leading viviparous life.
- Oil extracted from the liver of this fish has medicinal value and hence is economically important.

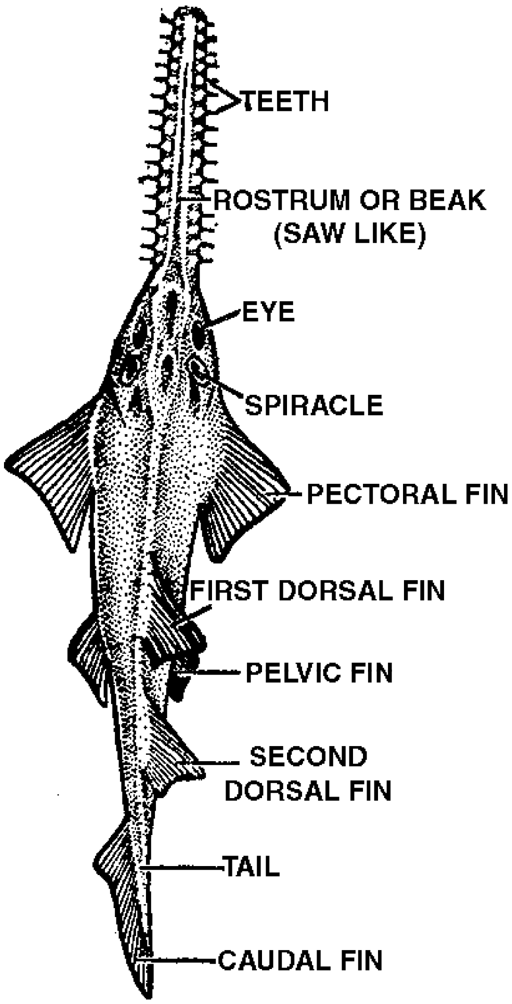


Fig 11. ***Pristis***

(12) *TORPEDO*

GENERAL NAME: ELECTRIC FISH

Phylum:Chordata.
Sub phylum:Vertebrata/Craniata.
Superclass: Gnathostomata.
Series/Group :Pisces.
Class: Elasmobranchii/Chondrichthyes.
Sub-class: Selachii.
Super order: Hypotremata.
Order: Euselachii.

- A common deep water living carnivorous fish seen on the sea bottoms of Mediterranean sea, Red sea, Indian ocean, Pacific and Atlantic oceans.
- Body is compressed dorso ventrally with an anterior half moon shaped disc like head.
- The anterior disc is supported internally by a cartilaginous endoskeleton.
- Body is covered by smooth and unscaled skin.
- Paired eyes and respiratory openings are present on the dorsal side.
- Mouth is a wide transverse opening on the anteroventral side of the head.
- A pair of electric organs are present at the base of the eyes on either side of the body. These electric organs are formed by the modification of abductor, mandibular and retractor muscles.
- They are innervated by the branches of seventh, ninth and tenth cranial nerves. The hexagonal units of these electric organs are loaded with mucous and release current to protect themselves from the predators. Their dorsal surface acts as a positive pole and ventral side as a negative pole.
- At the lower margin of the disc lies a pair of pectoral fins.
- A pair of pelvic fins are present just behind the pectoral fins. Tail is short and has a tail fin.
- A pair of dorsal fins are present on the dorsal side of the trunk.

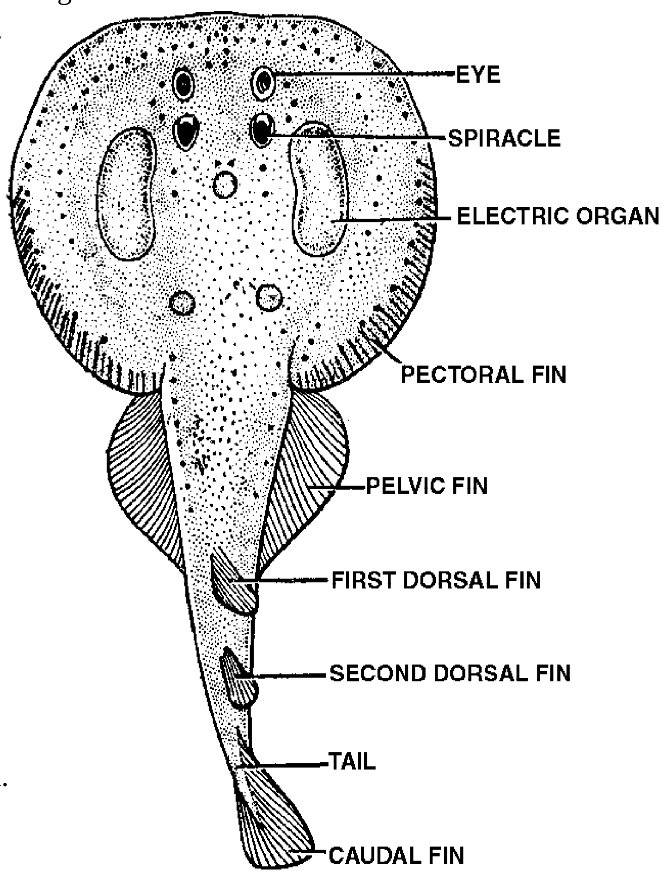


Fig 12. ***Torpedo***

(13) *CHIMERA*

GENERAL NAME: KING OF HERRINGS OR RAT FISH

Phylum:Chordata.
Sub phylum:Vertebrata/Craniata.
Super-class:Gnathostomata.
Series/Group :Pisces.
Class:Osteichthyes.
Sub class:Actinopterygii.
Super order: Holocephalii.
Order:Chimeriformes.

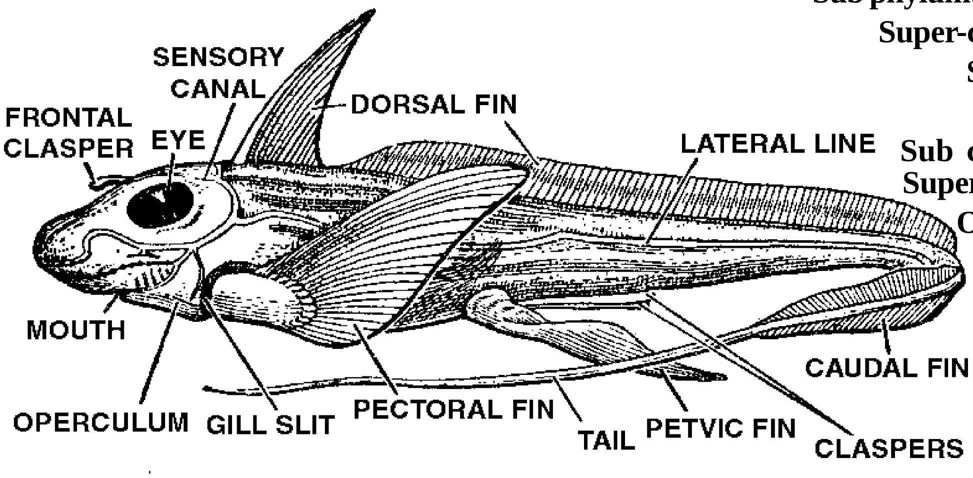


Fig 13. ***Chimera***

- Laterally compressed body grows to a length of 1m.
- This fish resembles the shark but has a half moon shaped snout.
- Mouth and nostrils are present on the ventral side of the head.
- Mouth is surrounded by folds of skin looking like lips and possess sharp and pointed teeth..
- All the gills are covered by operculum opening outside by an opercular aperture.
- Body has a dorsal fin extending from the middle of the body to the posterior end besides a pair of ventral fins near the tail besides a triangular dorsal fin near the head.
- Smooth surface of the body is devoid of scales.
- A warty projection present in front of the eyes on the dorsal side of the head is the clasper which can elongate to form into a tubular structure.
- Males have another pair of short and slender claspers are present in association with pelvic fins. Third pair of anterior claspers are present in front of the pelvic fins.
- Pectoral and pelvic fins are expanded like wings.
- Tail is long and whip like one surrounded by a diphycercal tail fin.
- The lateral line on the body encloses the lateral line sense organs.
- Along with the characters of selachian fishes, the following characters are also observed.
  Presence of autostylic jaw suspensorium in the skull,
  absence of cloaca, reduced gill slits, presence of operculum covering the gill slits.
  These characters help in concluding that these fishes are the connecting links between the cartilaginous elasmobranchs and bony fishes belonging to the group osteichthyes

(14) *ACIPENSER*

GENERAL NAME: STURGEON FISH.

PHYLUM :Chordata.
SUB.PHY :Vertebrata/Craniata.
SUPER-CLASS :Gnathostomata.
Series/Group:Pisces.
Class:Osteichthyes.
Sub class:Actinopterygii.
Superorder:Chondrostei.

- It is widely distributed along the coasts of Black sea, Caspian sea and Atlantic ocean.
- A free living organism commonly seen on the deep water zones and sea bottoms.
- Body measures about 2-3 m and is having an elongated snout at the head end with which it gets its food material.
- Body is covered by 5 rows of bony plates which bear a backwardly directed spiny free end.
- Dermal spines are present in between these surface plates.
- A pair of lateral eyes are located at the base of the snout.
- Respiratory spiracles are also present just below the eyes at the base of the snout.
- Snout and four pairs of long barbels help in searching food.
- Mouth is anteroventral but is devoid of teeth.
- Operculum, supported by bony plates, is the lid like structure covering the gill slits
- Air bladder present inside the body acts like a lung and is involved in pulmonary respiration.
- Endoskeleton is cartilaginous and fins are spine less. Body is covered by ganoid scales.
- Oviparous organisms laying around 2-3 million eggs during breeding season.
- Tail is heterocercal and bony scutes on the middorsal surface.

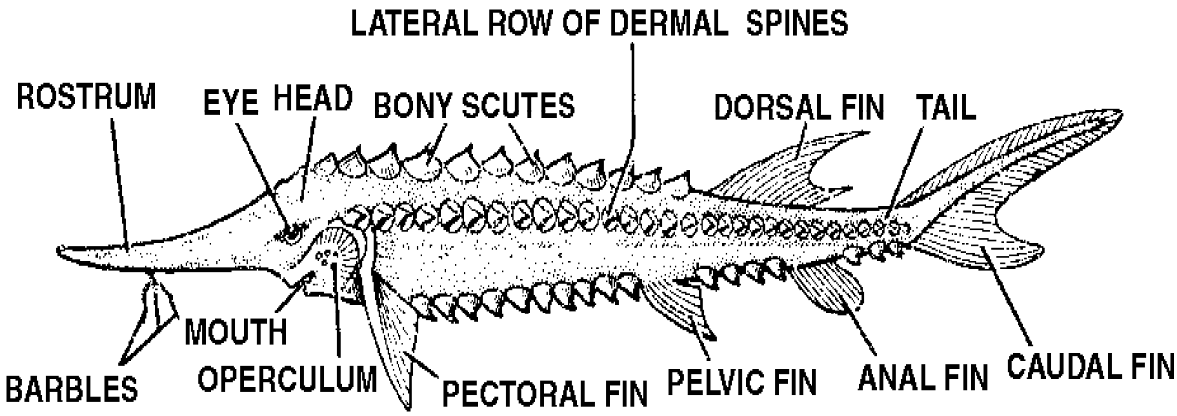


Fig 14. ***Acipenser***

(15) *AMIA CALVA*

GENERAL NAME: Bowfin.

Phylum:Chordata.
Sub phylum:Vertebrata/Craniata.
Super-class:Gnathostomata.
Series/Group :Pisces.
Class:Osteichthyes.
Sub class:Actinopterygii.
Order: Holostei.

- A freshwater carnivorous fish feeding on crustaceans, insects and small fishes.
- Spindle shaped body is laterally compressed and covered by placoid scales.
- Mouth is anteroventral and the fleshy lips bear spine like slender barbels.
- Teeth are present on all the jaw bones. They are conical and pointed. .
- Gular plate is present behind the mouth. This plate is formed of 14 branchiostegite spines.
- Dorsal fin is large and supported by a number of fin rays while the ventral fin is small.
- Tail fin is homocercal and lobular bearing a black spot.
- Air bladder works as lungs to conduct aerial respiration.
- Sexual dimorphism is very clear as males are very small compared to females.
- Males also bear a pair of comb like structures on their head.
- Vertebrae are amphicoelous.

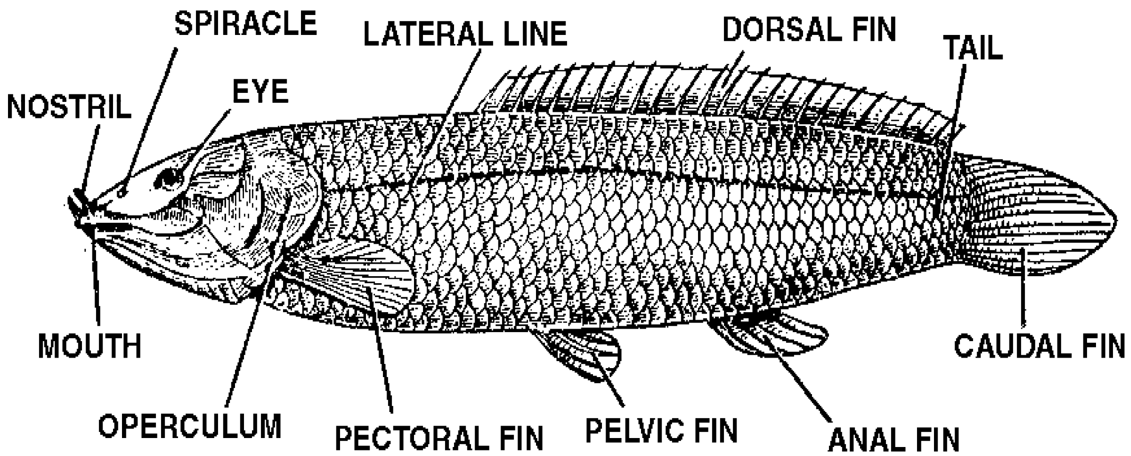


Fig 15. ***Amia calva***

(16) *ARIUS*

Phylum:Chordata.
Sub phylum:Vertebrata/Craniata.
Super-class:Gnathostomata.
Series/Group :Pisces.
Class:Osteichthyes.
Sub class:Actinopterygii. Super order: Teleostei.
Order: Cypriniformes.

- Universally distributed large sized marine catfish looking like a frog.
- Body is laterally compressed.
- Anterior end of the body is pointed with a slightly projecting snout bearing slender and long barbells.
- Body is covered by cycloid scales.
- Tail fin is homocercal type. Unpaired dorsal and ventral fins are small.
- Air bladder can work for aerial or terrestrial respiration as it works as lung.
- The special feature of this fish is that the males carry the fertilized eggs in thier mouth till they hatch in to young ones thus exhibiting parental care.

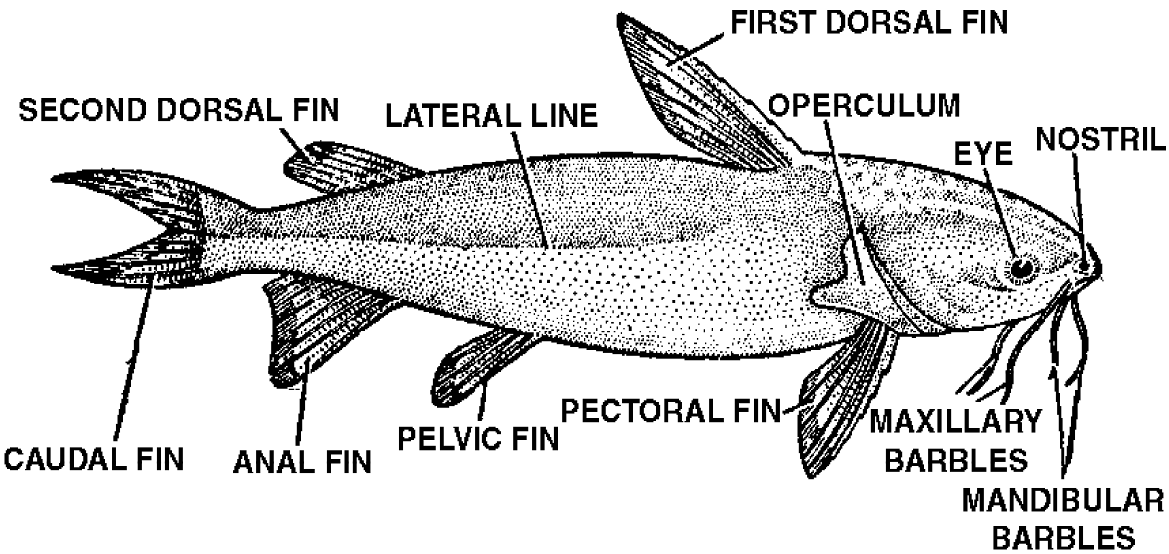


Fig 16. ***Arius batrachus***

(17) *PLEURONECTIS*

GENERAL NAME: Flat fish

Phylum:Chordata.
Sub phylum:Vertebrata/Craniata.
Super-class:Gnathostomata.
Series/Group :Pisces.
Class:Osteichthyes.
Sub class:Actinopterygii. Super order: Teleostei.
ORDER: Pluronectiformes.

- An attractive flatfish with dark bands on the body.
- Commonly seen in deep water zones
- Body is assymmetrically compressed.
- Anterior end of the cranium is also assymmetrical, hence the lateral eyes come to lie on the left side of the head. Left side of the body is the upper visible surfacr.
- Body is covered by either cycloid or ctenoid scales arranged in imbricate fashion.
- Anterior end of the head is projected as snout. Mouth is also seen from the upper surface is a small slit. Jaws are toothed and bear chistle shaped teeth.
- Organisms move by the undulations of the body.
- Unpaired dorsal, ventral and caudal fins are continuous with each other.
- Pectoral and pelvic fins are arranged almost at the anterior end.
- Air bladder is hydrostatic and helps in regulating the internal pressure with the external water force.
- Operculum is large and leaf like covering the gills near the head and behind the eyes.
- These fishes are used as food fishes.

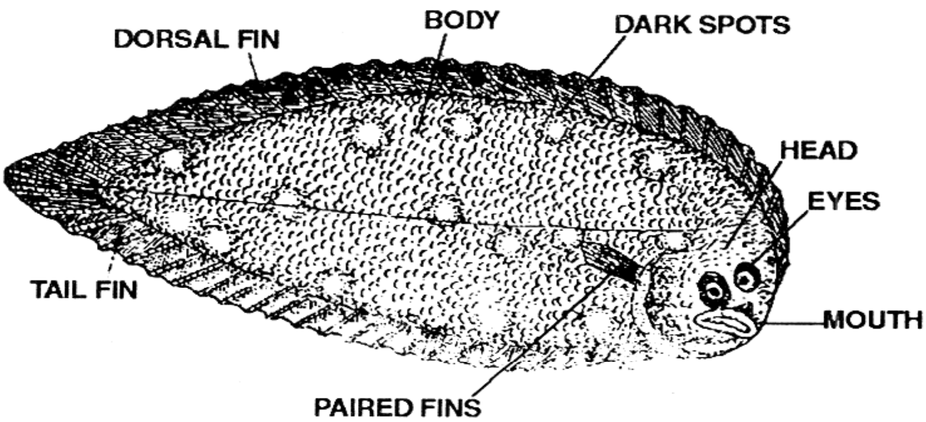


Fig 17. ***Pleuronectis***

(18) *HIPPOCAMPUS*

GENERAL NAME: SEAHORSE

Phylum:Chordata.
Sub phylum:Vertebrata/Craniata.
Super-class:Gnathostomata.
Series/Group :Pisces.
Class:Osteichthyes.
Sub class:Actinopterygii. Super order: Teleostei.
Order:Solenechthyes.

- This fish having no similarity with the fish, has a special shape and it moves slowly, elegantly and in vertical lines with the help of its tail in temperate sea waters.
- Head at the anterior end resembles the head of the horse.
- Head has an elongated snout or rostrum with a terminal mouth opening.
- Anterior margin of the head is like a crown giving it the shape of the horse head and its neck.
- Special appearance is imparted to the head because of the presence of two supra orbital spines just above the eyes located just behind the snout.
- Pectoral fins are located at the junction of the head and the neck.
- Gills are covered by the operculum
- Body armature is composed of bony oscicles formed by the transformation of the scales over the body.
- Dorsal fin is enlarged on one side while the caudal and ventral fins are absent.
- Pelvic fins are transparent.
- Males have a brood pouch just opposite to the dorsal fin at the junction of the trunk and tail.
- Brood pouch is useful for protecting the eggs till they hatch and develop into young ones.
- Tail is prehensile and helps in the slow and vertical locomotion of the organisms.

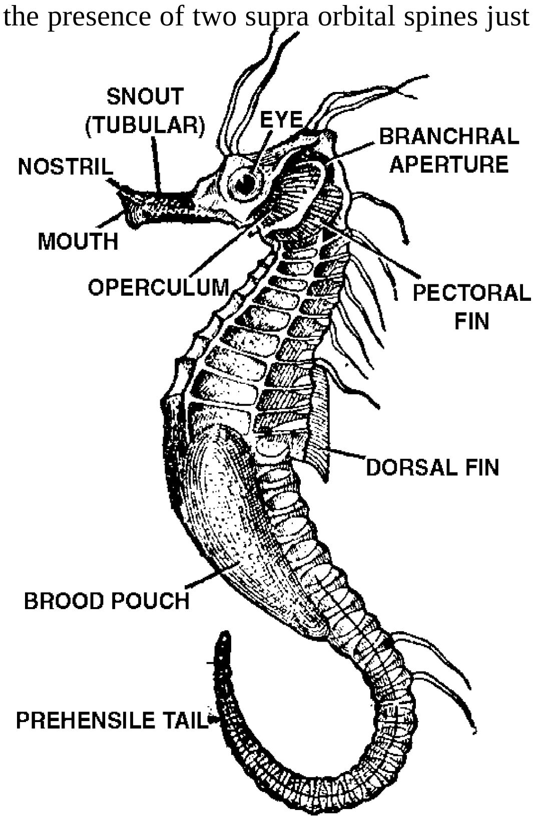


Fig 18. ***Hippocampus***

(19) *EXOCOETUS*

GENERAL NAME: FLYING FISH

Phylum:Chordata.
Sub phylum:Vertebrata/Craniata.
Super-class:Gnathostomata.
Series/Group :Pisces.
Class:Osteichthyes.
Sub class:Actinopterygii. Super order: Teleostei.
Order:Senentognathii.

- It is a flying fish moving speedily over water surface to a short distances. This fish is very common in the salt waters of Indian ocean, Pacific ocean and Atlantic.
- Body is long and laterally compressed with a homocercal tail fin.
- Head at its anteroventral side possess a small mouth supported by toothed jaws.
- Eyes are conspicuous on either side of the head.
- Body is covered by cycloid scales. Dorsal and ventral fins are supported by fin rays.
- Gills are covered by a bony operculum.
- Among the paired fins, the anterior pectoral fins are enlarged into wing like structures for jumping over the surface of water for shorter distances.
- In some species, the ventral lobe of the caudal fin is strong and create much pressure needed for locomotion.
- Pelvic fins are also enlarged into wings for flying over water surface.
- These fishes have nutritious value.

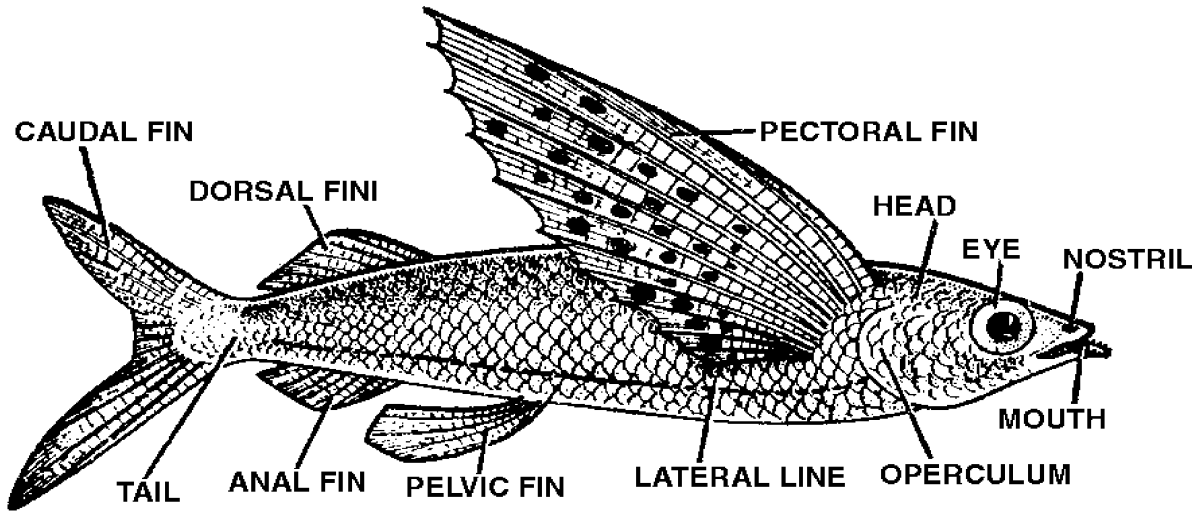


Fig 19. Exocoetus

(20) *ECHENEIS*

GENERAL NAME: SUCKER FISH

Phylum:Chordata.
Sub phylum:Vertebrata/Craniata.
Super-class:Gnathostomata.
Series/Group :Pisces.
Class:Osteichthyes.
Sub class:Actinopterygii. Super order: Teleostei.
Order: Discocephalii.

- This fish inhabits the tropical sea water areas and moves by attaching to the surface of larger fishes, logs of wood, surface of whales, boats and ships .
- Lengthy body is laterally compressed and is covered by small microscopic scales.
- Eyes small and are lateral on the head and it has a pair of terminal nostrils.
- Mouth is a wide opening at the antero-dorsal side of the head.
- Operculum is located at the junction of the head and trunk. A pair of pectoral fins are near the operculum. Pelvic fins are also located at the same region on the ventral side.
- Among unpaired dorsal and ventral fins, the anterior dorsal fin is modified into a dorsal sucker supported by powerful muscles. posterior dorsal, caudal and ventral fins are continuous.
- Tail fin is homocercal type.
- Air bladder is absent but the epi clavicle is reduced.
- These fishes move from place to place by attaching with the surface of the larger fishes, logs but they are not parasites.

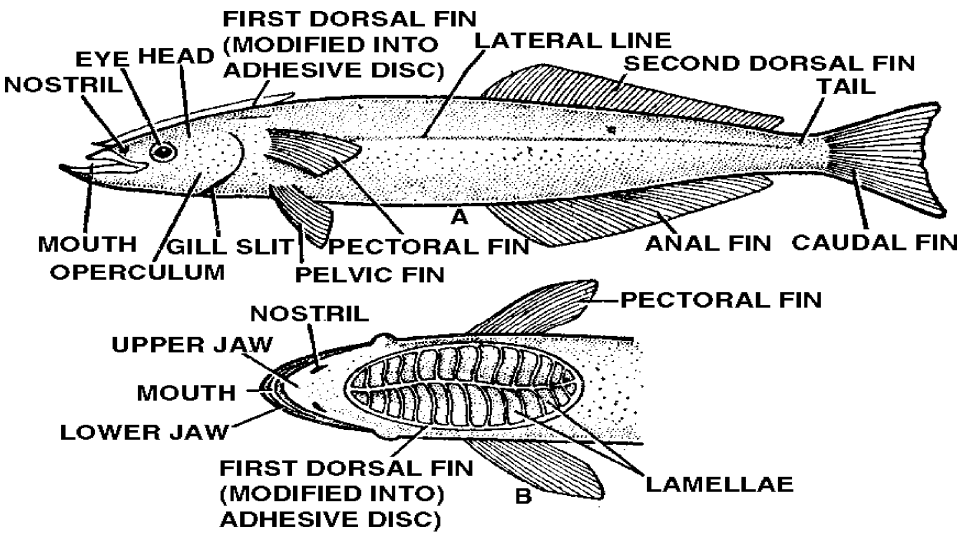


Fig 20. ***Echeneis***

(21) *NOTOPTERUS*

General name: Chital, a cat fish

Phylum:Chordata.
Sub phylum:Vertebrata/Craniata.
Super-class:Gnathostomata.
Series/Group :Pisces.
Class:Osteichthyes.
Sub class:Actinopterygii. Super order: Teleostei.
Order: Ostariophysi.

- It is an extensively distributed fresh water fish living in lakes, brackish water ponds and swamps.
- Carnivorous organisms living on water bottoms.
- Fish measures about 1-1.5m and is covered by cycloid scales arranged in imbricate fashion.
- Laterally located eyes on the head are conspicuous.
- Mouth is anteroventral and jaws are toothed.
- Gills are covered by operculum.
- Pectoral fins are present just behind the operculum. Pelvic fins are present ventrally at the same position.
- Dorsal fin is small while the ventral fin is reduced.
- Anal and caudal fins are continuous. Anal fin is seen along the ventral margin.
- Internally, the air bladder is divided into a number of chambers.

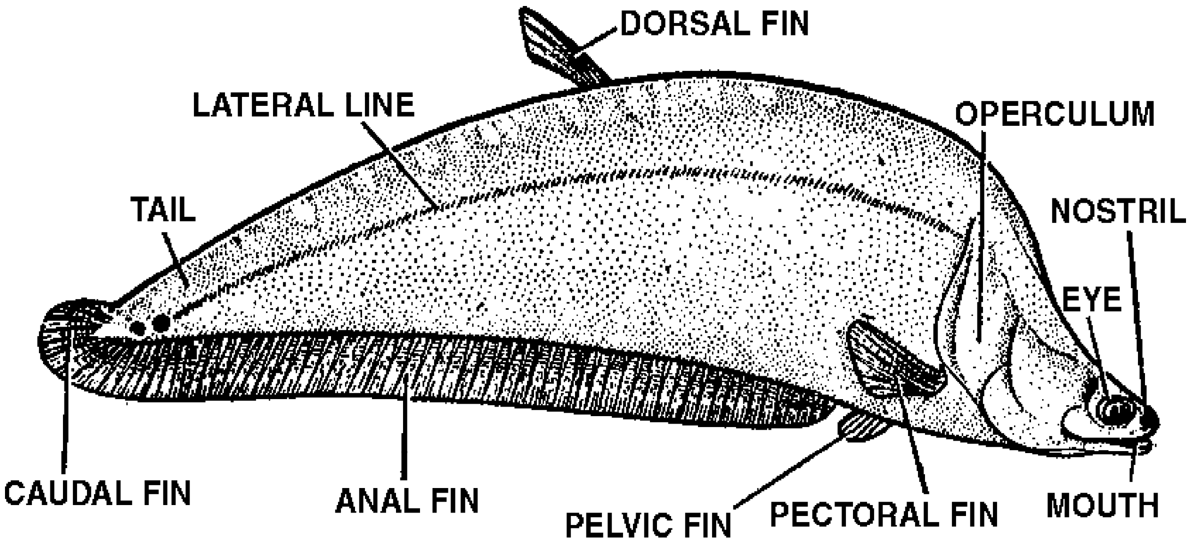


Fig 21. ***Notopterus***

(22) *LABEO ROHITA*

GENERAL NAME: ROHU

Phylum:Chordata.
Sub phylum:Vertebrata/Craniata.
Super-class:Gnathostomata.
Series/Group :Pisces.
Class:Osteichthyes.
Sub class:Actinopterygii. Super order: Teleostei.
Order:Ostariophysi

- Universally distributed fresh water fish inhabiting the waters of temperate and tropical regions.
- Commonly lives at the water bottoms and leads herbivorous life. Rarely leads carnivorous life.
- It's meat is having nutritious value and hence the fish is having high economic value.
- Fish grows to about one meter and weighs about 4-5 kg.
- Body is spindle shaped and laterally compressed.
- Gray coloured body is covered by cycloid scales.
- Body is divided into a head, trunk and tail. Neck is absent.
- Both paired (pectoral and pelvic) and unpaired (dorsal, caudal and ventral) fins are supported by cartilagineous fin rays and they help in locomotion. Tail fin is of homocercal type.
- Head has a dorsoventrally flattened snout. Mouth is surrounded by slender and fleshy lips
- Eyes are lateral and prominent and nostrils are antero-terminal.
- A pair of long cirri arise from the upper lip.
- Gills and gill chamber are covered by operculum.
- Lateral line sense organs are prominent and are seen on the lateral sides of the body.
- Ampullae of Lorenzini, located in the lateral line open out through small openings.

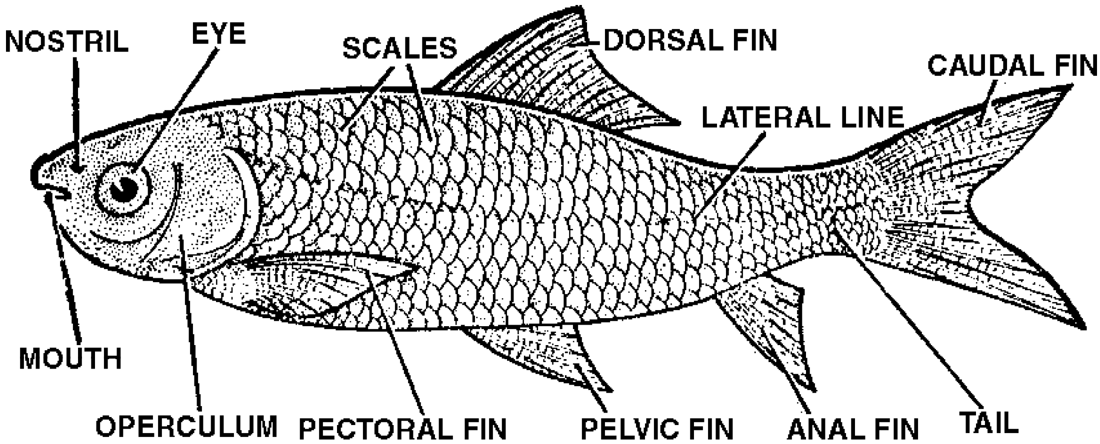


Fig 22. ***Labeo rohita***

(23) *PROTOPTERUS*

General name: AFRICAN LUNG FISH

Phylum:Chordata.
Sub phylum:Vertebrata/Craniata.
Super-class:Gnathostomata.
Series/Group :Pisces.
Class:Osteichthyes.
Sub class:Actinopterygii. Super order: Teleostei.
Order:Lepidosireniformes.

- It is an eel fish leading burrowing life in the marshy soils and river bottoms.
- It is very common in Africa, Congo, and Nile rivers.
- They aestivate during summers and their burrows are lined by mucous layer.
- These air breathing dipnoi fishes frequently come out for aerial respiration.
- Head and trunk are almost continuous without a clear demarcation.
- Head bears a pair of lateral eyes, a pair of nostrils and an antroventral mouth.
- Dorsal and caudal fins are continuous and tail fin is undivided.
- Pectoral and Pelvic fins are slender, long and thread like structures.
- Pharyngeal region bears five pairs of gill slits supported by six pairs of gill arches and covered by operculum.

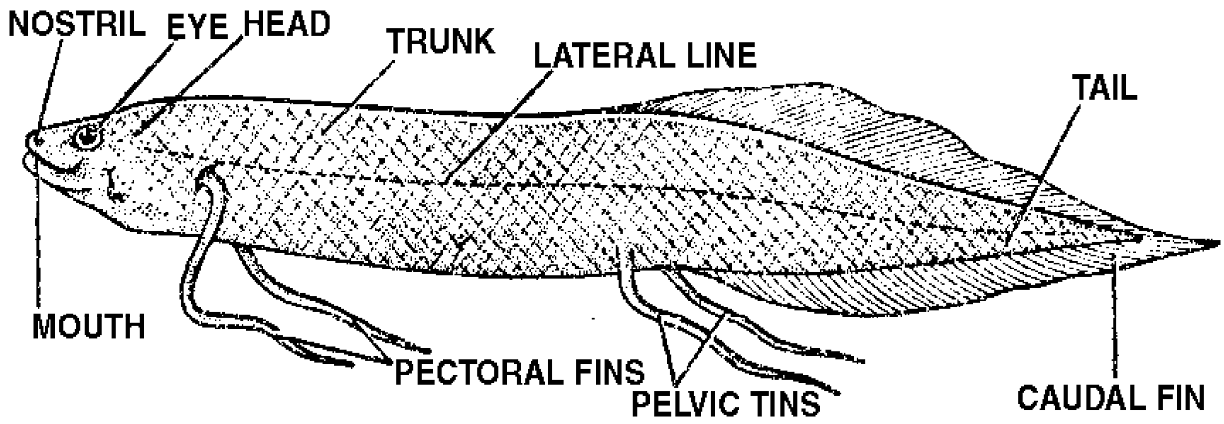


Fig 23. ***Protopterus***

(24) *CATLA CATLA*

General Name: CATLA

Phylum:Chordata.
Sub phylum:Vertebrata/Craniata.
Super-class:Gnathostomata.
Series/Group :Pisces.
Class:Osteichthyes.
Sub class:Actinopterygii. Super order: Teleostei.
Order:Ostariophysi.

- It is the major fresh water carp cultured in the natural and artificial ponds in India, Burma.Pakistan and Bangladesh.
- These fishes feed on zooplankton, algal cells, water plants, rotifers and small crustaceans.
- Head is prominent and large with antero-dorsal mouth surrounded by unfolded lips.
- Trunk is wide and stout. It grows to the maximum size and attains sexual maturity in two years. Body is covered by cycloid scales. Eyes are prominent and nostrils are small.
- Dorsal fin is supported by 14-16 fin rays.
- Tail fin is of homocercal type.
- It can even reproduce by induced breeding.
- Oviparous organisms with external fertilization and direct development.
- Economically important fish having high nutritious value and market demand.

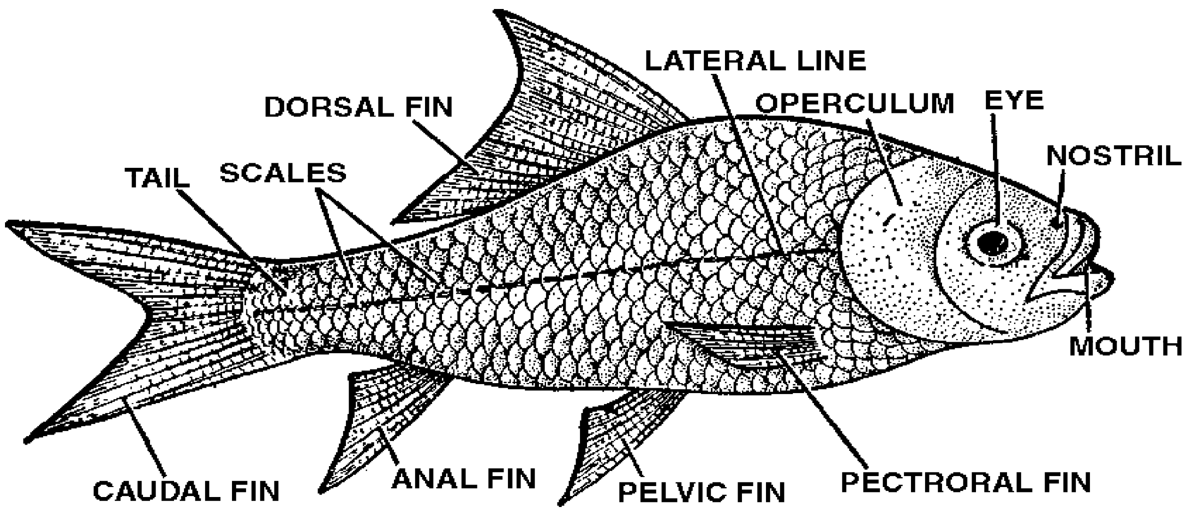


Fig 24. ***Catla catla***

(25) *CLARIUS BATRACUS*

General Name: CLIMBING PERCH

Phylum:Chordata.
Sub phylum:Vertebrata/Craniata.
Super-class:Gnathostomata.
Series/Group :Pisces.
Class:Osteichthyes.
Sub class:Actinopterygii. Super order: Teleostei.
Order:Ostariophysi.

- ❑ It is a long fish seen living in the fresh water and brackish water ponds of India, Africa, Western and South Asian countries.
- ❑ Body is laterally compressed with a pair of lateral eyes, a pair of terminal nostrils, four pairs of long cirri, accessory respiratory structures in the gill chambers, spiny pectoral fins, dorsal and caudal fins along the free margins of the body circular lobe likd diphycercal tail fin, gray couloured body, lateral lines supported by bony plates
- ❑ This predacious fish grows to a size of about 45cm.
- ❑ Its meat ishaving food value and hence the fish is exonomically important.
- ❑ Scale less Skin is soft and smooth in texture.
- ❑ Air bladder is of physostomous type having connection with the lungs.
- ❑ Internal ear consists of Webarian oscicles.

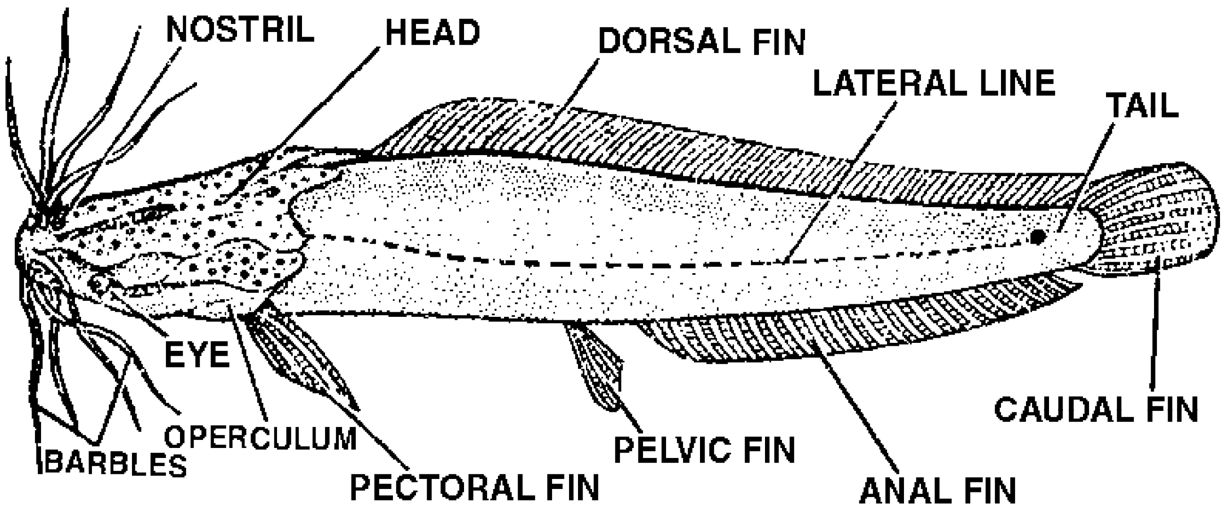


Fig 25. ***Clarius batracus***

(26) *ANGUILLA ANGUILLA*

GENERAL NAME: EEL FISH

Phylum:Chordata.
Sub phylum:Vertebrata/Craniata.
Super-class:Gnathostomata.
Series/Group :Pisces.
Class:Osteichthyes.
Sub class:Actinopterygii. Super order: Teleostei.
Order: Anguilliformes.

- ❑ Snake like fish having world wide distribution and inhabits marine water.
- ❑ It grows to a length of 1-2 meters. Slender and long body is laterally compressed. Anteriorly the body is pointed while the rest of the body is ribbon like.
- ❑ Mouth is antero dorsal.
- ❑ Gills in the pharyngeal region are covered by an operculum.
- ❑ Dorsal, caudal an ventral fins are thin and continuous along the margins of the body.
- ❑ Microscopic scales are present over the body and are arranged in special fashion.
- ❑ Air bladder is physostomous and opens into the pharynx through glottis but has no special role in aerial respiration.
- ❑ Paired pectoral fins are near the operculum but the pelvic fins are absent.
- ❑ This fish migrates into the sea for breeding and hence migration is of catadromous type.
- ❑ Life history includes leptocephalus larva commonly known as eel elver. These larvae after leading life for some time in sea water and move to Indian rivers.

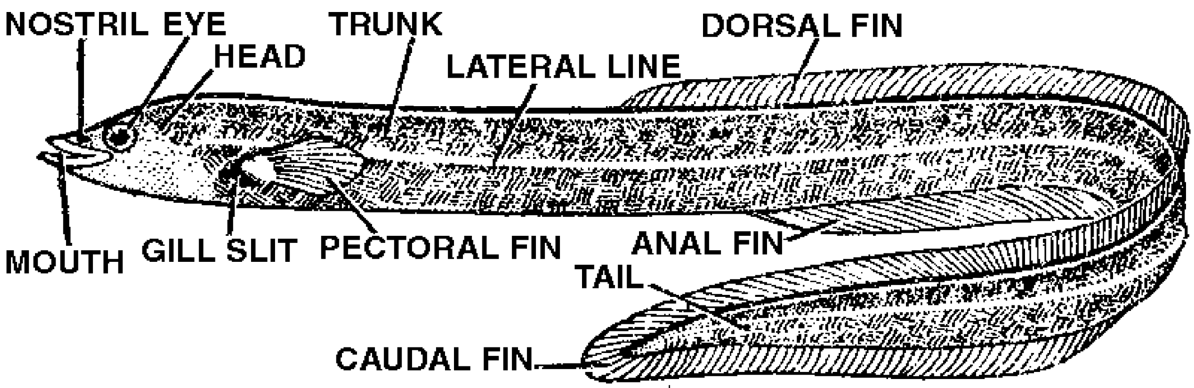


Fig 26. ***Anguilla anguilla(Eel fish)***

(27) *ANANBAS TESTUDENIUS*

General name: Arboreal fish or Climbing perch

Phylum:Chordata.
Sub phylum:Vertebrata/Craniata.
Super-class:Gnathostomata.
Series/Group :Pisces.
Class:Osteichthyes.
Sub class:Actinopterygii. Super order: Teleostei.
ORDER :Anabantidae.

- ❑ Fresh water fish having world wide distribution. It can live for longer time even out side the water.
- ❑ Body is laterally flattened. Dorsal and ventral fins are not continuous with the caudal fin.
- ❑ These fins are separated by deep notches. Caudal fin is seen as a single lobe. Both dorsal and ventral fins are divided into a anterior and a posterior lobes. They are supported by strong fin rays. Lateral lines are clear and conspicuous on the lateral sides of the body.
- ❑ Both pectoral and pelvic fins are closely arranged in the anterior half of the body.
- ❑ Mouth is terminal at the anterior end while the nostrils and conspicuous eyes are dorsal.
- ❑ Jaws are toothed and the Entire body surface is covered by cycloid scales.
- ❑ Opercular opening is large. Margin of the operculum and the anterior margin of the eye bear a number of small spines.
- ❑ Gills are extensively developed in the gill chamber and they aid in the aerial respiratory activity as accessory respiratory organs. Air bladder is of physoclystus type as it is closed and has no opening in to the pharynx. It is mainly concerned with the regulation of the internal pressure and in establishing buoyancy in water.

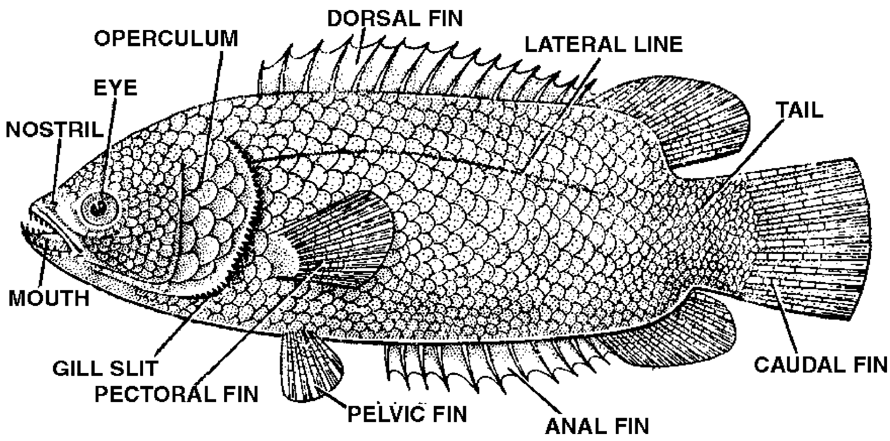


Fig 27. ***Anabas***

(28) *LEPIDOSIREN*

General name: AMERICAN LUNG FISH

Phylum:Chordata.
Sub phylum:Vertebrata/Craniata.
Super-class:Gnathostomata.
Series/Group :Pisces.
Class:Osteichthyes.
Sub class:Actinopterygii. Super order: Teleostei.
ORDER :Lepidosireniformes.

- ❑ It is a common fresh water fish seen in the marshy areas of Amazon and Peruguay of South America. It is rarely seen in the rivers of Africa.
- ❑ It also exhibits both hibernation and aestivation in relation to the environment.
- ❑ Body is elongated, flattened and is covered by cycloid scales.
- ❑ Eyes are reduced. Four pairs of gills are present on either side of the pharynx and are involved in aquatic respiration.
- ❑ Paired fins are filamentous while the dorsal, ventral and caudal fins are continuous with each other.
- ❑ Lungs are physostomous and help in conducting pulmonary respiration.
- ❑ Eyes and nostrils are located on either side of the head.
- ❑ Cranium is cartilaginous and jaws are without maxillae. Lower jaw is with mandibular plates.
- ❑ Jaw suspensorium is of autostylic type.

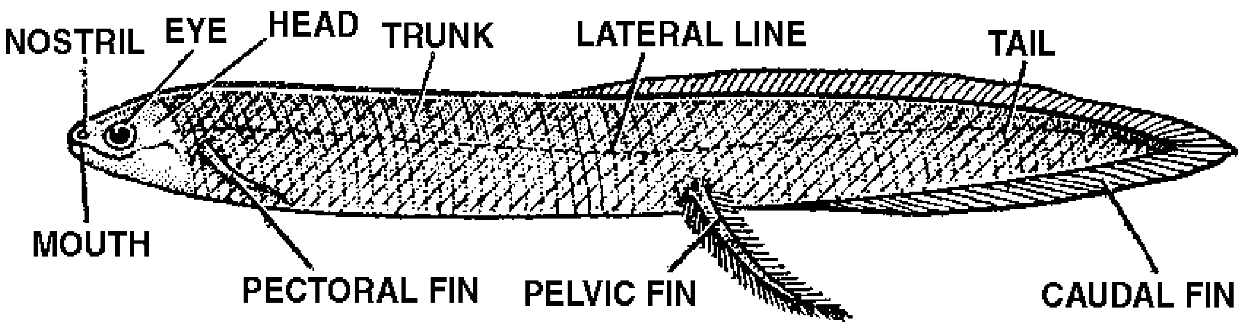


Fig 28. ***Lepidosiren***

(29) *NEOCERATODUS*

General name: AUSTRALIAN LUNG FISH (Baramunda)

Phylum: Chordata.
Sub phylum: Vertebrata/Craniata.
Superclass: Gnathostomata.
Series/Group :Pisces.
Class: Osteichthyes.
Sub class: Actinopterygii. Super order: Teleostei.

- It is a common carnivorous lung fish burrowing fish living in the marshy soils of Australia and Queen land.
- This laterally flattened fish grows to a size of 1-2m and is covered by cycloid scales.
- Lateral eyes, nostrils and a small mouth are present at the tip of the snout.
- Paired fins are lobular and are supported by fin rays. Dorsal, caudal and ventral fins are continuous and form into a diphycercal tail fin.
- Five pairs of gills aiding in respiration near the pharynx are covered by an operculum.
- Physostomous type of air bladder is present in the body to help in aerial respiration
- Lateral line sense organs are clear and kidneys are laterally elongated.
- Larval forms have no external gills for respiration.
- Presence of fin-rays on either side of the central axis of the fins is a special character.

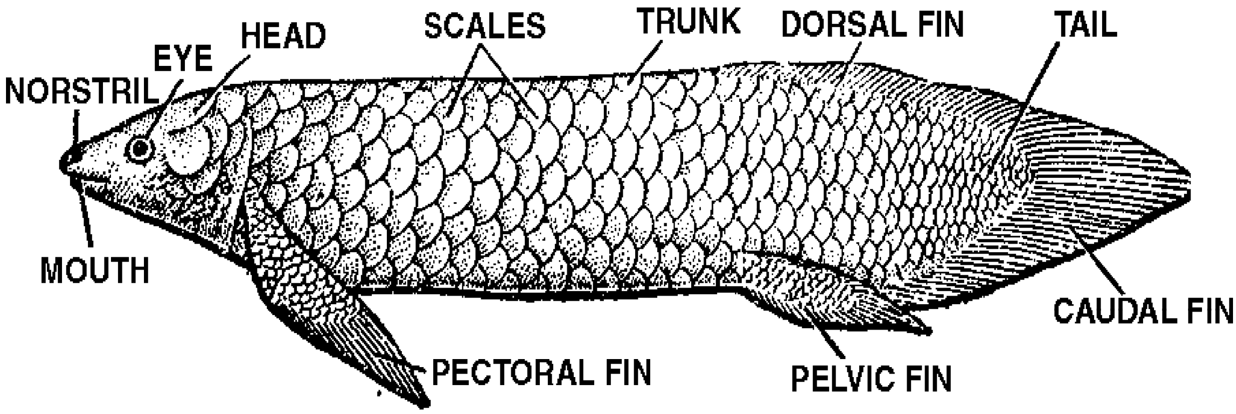


Fig 29. ***Neoceratodus***

(30) *HETEROPNEUSTES FOSSILIS*

General Name: Saccobranchus

Phylum:Chordata.
Sub phylum:Vertebrata/Craniata.
Super-class:Gnathostomata.
Series/Group :Pisces.
Class:Osteichthyes.
Sub class:Actinopterygii. Super order: Teleostei.
Order :Ostariophysi.

- These are the catfishes of the marine environment.
- Body is elongated and is covered by small and microscopic placoid scales.
- Pectoral and pelvic fins are small, paired and are located both at the anterior and posterior end.
- Mouth is antero ventral while the eyes and nostrils are antero dorsal over the hear.
- Snout bears three pairs of slender and filamentous cirri/tentacles.
- Air bladder in the body is of physostomous type and hence helps in aerial respiration.
- Two long air tubes lying on either side of the spinal cord arise from the aquatic chamber and extend up to the middle of the tail. At the tail end, these tubes end as sacs with divided chambers or alveoli. Hence the fish is also called saccobranchus.
- The air sacs are in communication with the external environment and hence they work as accessory respiratory structures.
- lateral line sense organs are well developed. Oviparous organisms.
- Presence of the undivided notochord, spiral valve in the intestine, and bulbus arteriosus in the adult are the primitive features of this organism.
- Presence of cartilaginous skull, upper jaw with out premaxilla and maxilla, lower jaw formed of mandibular plates, lungs aiding in pulmonary respiration are the special features of this organism.
- This fish has evolutionary significance as it shows discontinuous distribution.

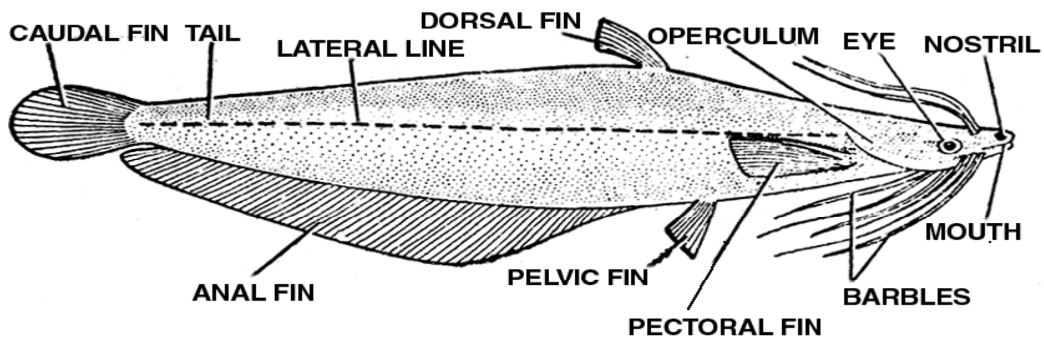


Fig 30. ***Heteropneustes***

(31) *CHANNA PUNCTATUS*

General name: Snake head fish.

Phylum:Chordata.
Sub phylum:Vertebrata/Craniata.
Super-class:Gnathostomata.
Series/Group : Pisces.
Class: Osteichthyes.
Sub class: Actinopterygii. Super order: Teleostei.
Order : Mugiliformes

- Fresh water organisms having food value.
- These are extensively used in research work.
- They are commonly seen in between the rocks of stagnant water pools.
- Body is long and serpentine. The entire body is covered by mucous secretions and hence slimy to touch.
- Head is dorsoventrally flattened and bears a terminal wide mouth
- Skin is embedded with cycloid scales.
- Dorsal and ventral fins extend all along the body from anterior to the posterior end.
- The organisms possess accessory respiratory organs. Hence they can live even outside the water. They are considered as live fishes.
- Oviparous organisms producing large number of eggs during breeding seasons.
- These can be grown along with other fishes in artificial ponds.

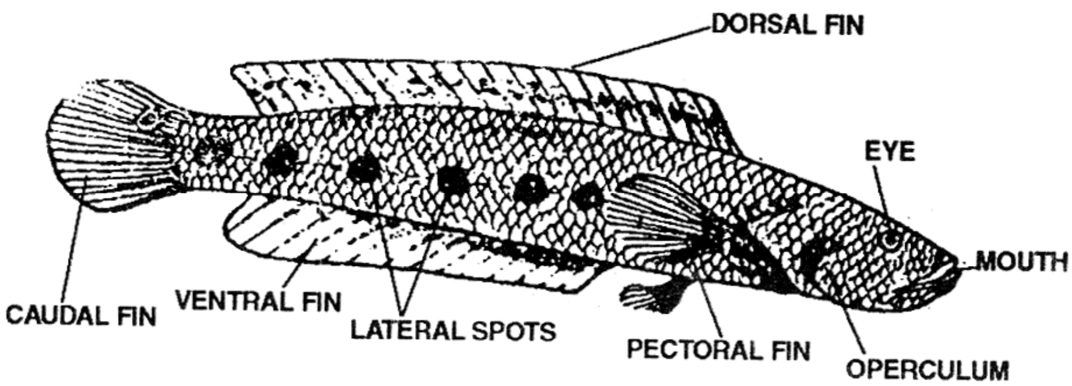


Fig 31. ***Channa punctatus***

AMPHIBIANS

(32) *ICHTHYOPHIS GLUTINOSA*

General name: Limbless amphibian or cicilian.

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
Class :AMPHIBIA.
Order :APODA/GYMNOPHIANA.

- These are the dark coloured burrowing organisms commonly seen in moist soils.
- Elongated, serpentine and worm like body is divided into a head and , trunk.
- Skin is provided with small placoid scales and allergy producing squirt glands.
- Body surface shows annulations.
- Eyes are small and covered by a fold of skin.
- A short tentacle is present in between the eye and nostril.
- Both limbs and girdles are absent.
- Vertebrae are of amphicoelous type.
- Respiratory system consists of a long trachea and lungs for terrestrial respiration. Left lung is reduced.
- Anus is at the junction of the trunk and tail on the ventral side of the body.
- Cloaca comes out as male genital organ during breeding seasons.
- Fertilization is internal but development is external.
- Females curl around the yolky eggs and take care of them till they hatch out into larval forms.
- Presence of a tri-chambered heart, urinogenital system and eversible cloaca are the advanced features of these organisms.
- Scaly skin, reduced eyes, absence of limbs and girdles are the primitive features of these amphibians.

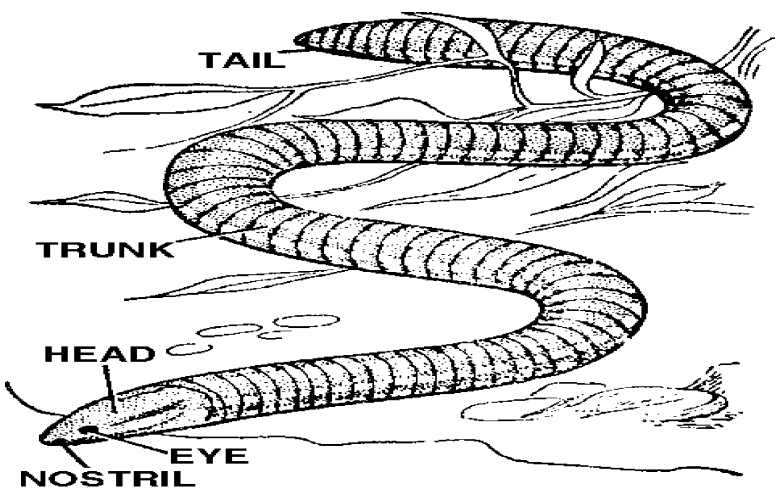


Fig 32. ***Ichthyophis glutinosa***

(33) *PROTEUS*

GENERAL NAME:

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
Class :AMPHIBIA.
Order :URODELA OR CAUDATA.

- ❑ It is a cave dwelling blind urodele seen in the caves of European countries.
- ❑ Body is divisible in to a head, neck, trunk and tail.
- ❑ Eyes are reduced while the fore and hind limbs are weak.
- ❑ Forelimbs are with three fingers while the hind limbs are with two fingers.
- ❑ Along with internal lungs, three pairs of external gills and two pairs of gillslits are seen near the pharynx.
- ❑ Skull is cartilaginous.
- ❑ Jaws are toothed and the upper jaw has no maxillae.
- ❑ Vertebrae are amphicoelous.
- ❑ Finned tail is laterally flattened and helps in locomotion.

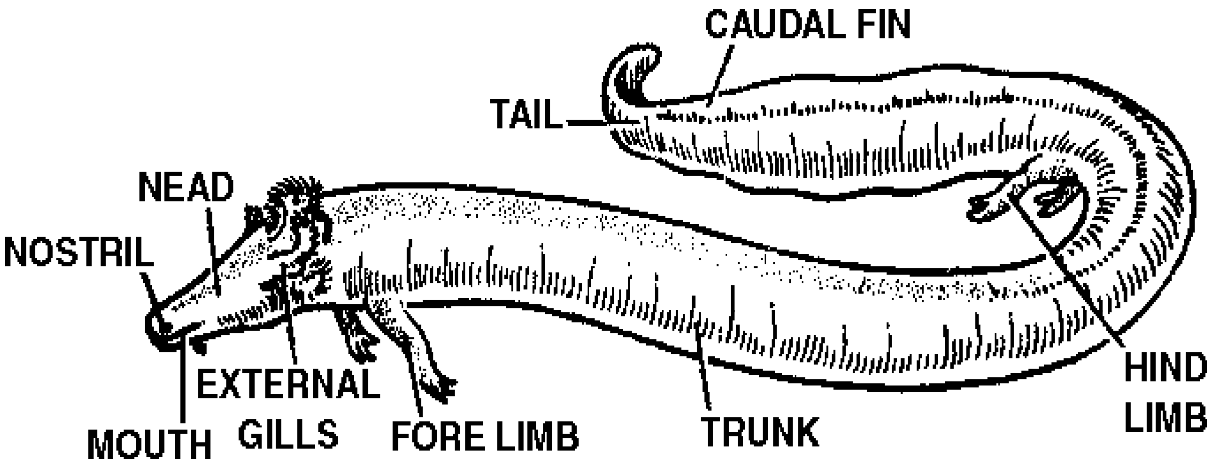


Fig 33. *Proteus*

(34) *AMBLYSTOMA TIGRINUM*

GENERAL NAME: TIGER SALAMANDER.

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
Class :AMPHIBIA.
Order :URODELA OR CAUDATA.

- It is a tailed amphibian with lizard like appearance and deep coloured patches over the body.
- Body is divisible into a head, a neck, a trunk and a tail.
- Skin is not provided with scales. Tympanic cavity and auditory ossicles are also absent.
- Forelimbs and hind limbs are weak. Both gills and fins are absent on the body.
- Eyes are small on the head.
- Skin is wrinckled and is provided with poisonous paratoid glands,
- Vertebrae are of amphicoelous type. Fertilization is internal.
- Development includes a free swimming neotenic larval form called Axolotl lara
- Larvae are capable of reproducing by sexual means even before they undergo metamorphosis. Such a condition is called neoteny or paedogenesis.

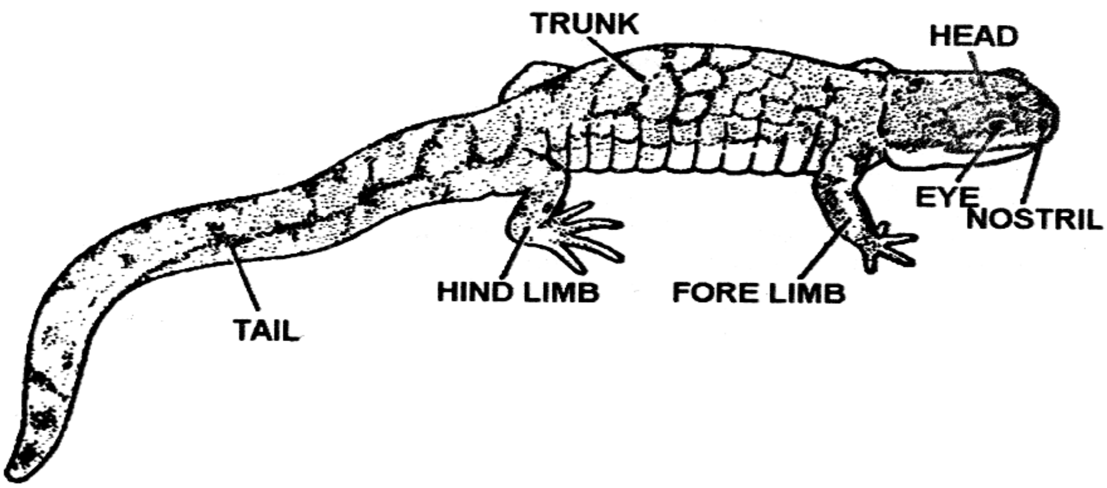


Fig. 34. Amblystoma tigrinum

(35) *SIREN*

General name: Mud eel.

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
Class :AMPHIBIA.
Order :URODELA OR CAUDATA.

- It is a common tailed amphibian in different places of America.
- It lives in marshy soils and water leading burrowing life.
- Body resembles a snake and possesses three pairs of external gills and a pair of gillslits besides a pair of fore limbs.
- Fore limbs are weak and hind limbs are absent.
- Tail is provided with a fin and helps in locomotion.
- Eyes are degenerative and function less.
- Head is made of horny material.
- Oviparous organisms having external fertilization and development.
- Larvae have prolonged larval life. Yet times, adult characters appear in the larval form itself.

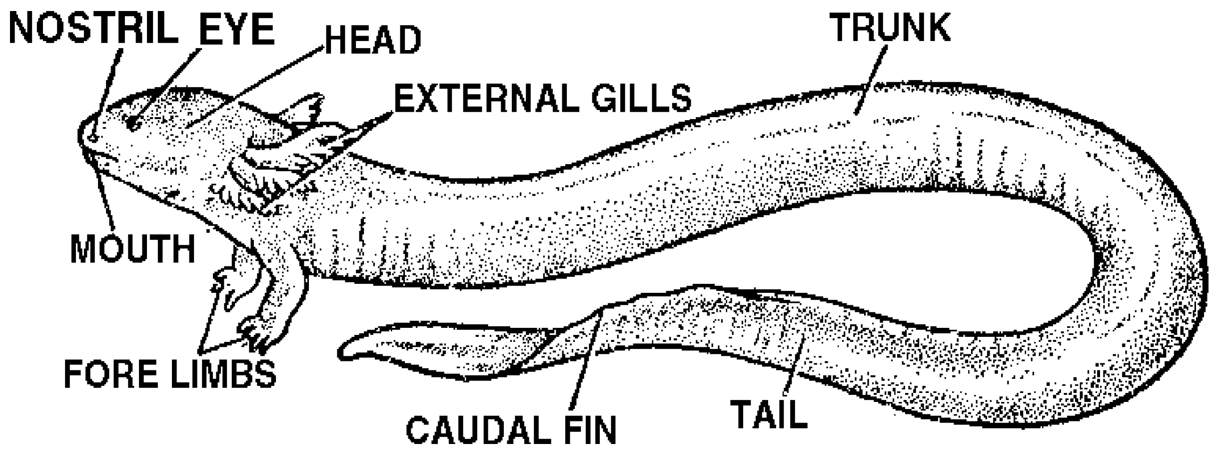


Fig 35. ***Siren***

(36) *AXOLOTL LARVA*

GENERAL NAME: NEOTENOUS LARVA

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
Class :AMPHIBIA.
Order :URODELA OR CAUDATA

- This is the larval form in the life history of salamander.
- Body is long and dorsoventrally flattened.
- The wide head is provided with small a pair of lateral eyes and a terminal mouth,
- Forelimbs and hind limbs are weak and are not useful in locomotion.
- Tail is finned and helps in locomotion.
- Three pairs of external-gills and four pairs of gill slits are present near the neck.
- Larva can reproduce sexually even with out undergoing metamorphosis. Such a phenomenon is called neoteny or paedogenesis.

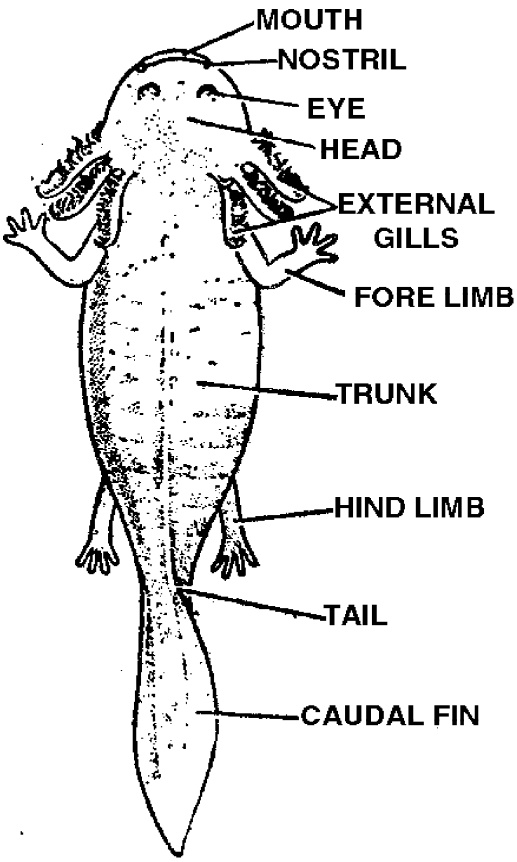


Fig 36. ***Ammocoetus larva***

(37) *RANA TIGRINA*

GENERAL NAME: COMMON FROG

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
Class :AMPHIBIA.
Order : Anura/ Salientia.

- It is the common water frog living mostly in water and comes to land for feeding during nights.
- It stays along the banks of the ponds during day and comes out during night to feed on insects.
- Body is divided into a head and trunk. Neck and tail are absent.
- Mouth is a wide opening at the antero-ventral side of the head. A pair of conspicuous eyes, a pair of nostrils and a pair of tympanums are present on the dorsal side of the head.
- Entire body surface is loaded with mucous glands and hence the body is slimy to touch.
- Limbs are pentadactyl. Forelimbs are short while the hind limbs are long thus bringing about leaping type of movement.
- Sexually dimorphic. Males possess a pair of amplexury pads in the fore limbs and a pair of vocal sacs for producing croaking sound.
- Jaws are toothed. Tongue is bifid to help in feeding and aerial respiration.
- Oviparous organisms laying eggs in water.
- Life history is indirect and includes a free swimming tadpole larva.

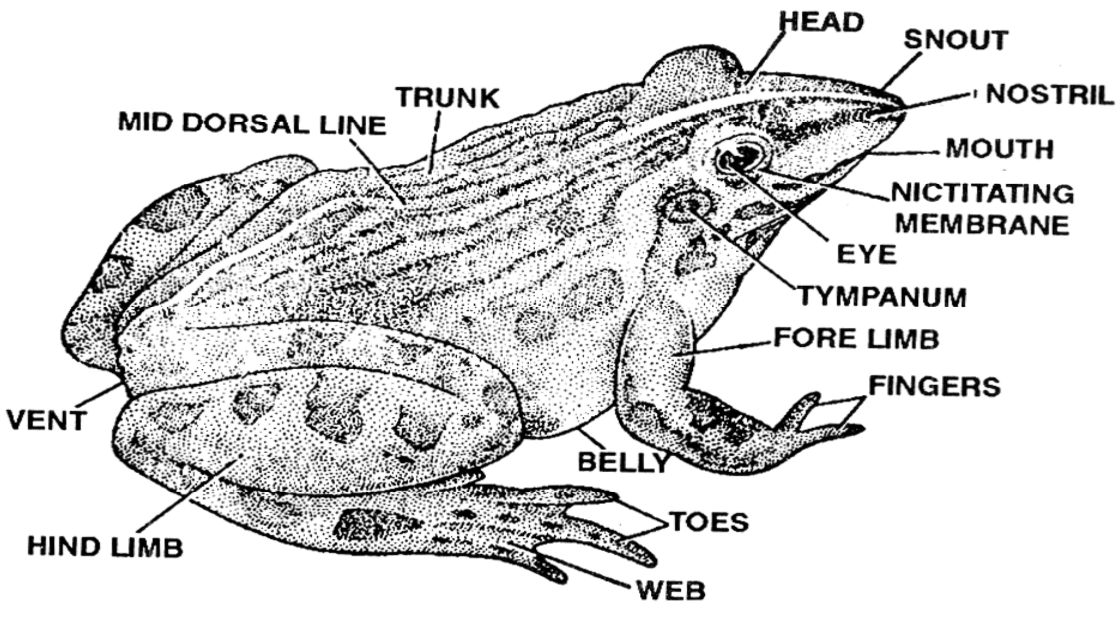


Fig 37. *Frog*

(38) *BUFO MELANOSTICUS*

GENERAL NAME: TOAD

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
Class :AMPHIBIA.
Order : Anura or Salientia.

- It resembles the normal frog except that it spends most of the time on land.
- It is a nocturnal and carnivorous organism seen near the lights.
- Skin is dry, rough and warty in nature.
- A pair of poison secreting paratoid glands are present just behind the eyes.
- Poison produced from the glands help in protecting the organism from predators.
- Absence of teeth on Jaws (edentate jaws), vocal sacs in males and sternum in the pectoral girdle are the main features of the toad.
- Vertebrae are procoelous and liver is bilobed.
- Forelimbs have four fingers while the hind limbs possess five toes.
- Males are larger than the females. Eggs are with out yolk and are released in chains.
- The important components of the poison like digitalin and Bufonin are used to cure chronic cordiac diseases. Hence these frogs are economically important.

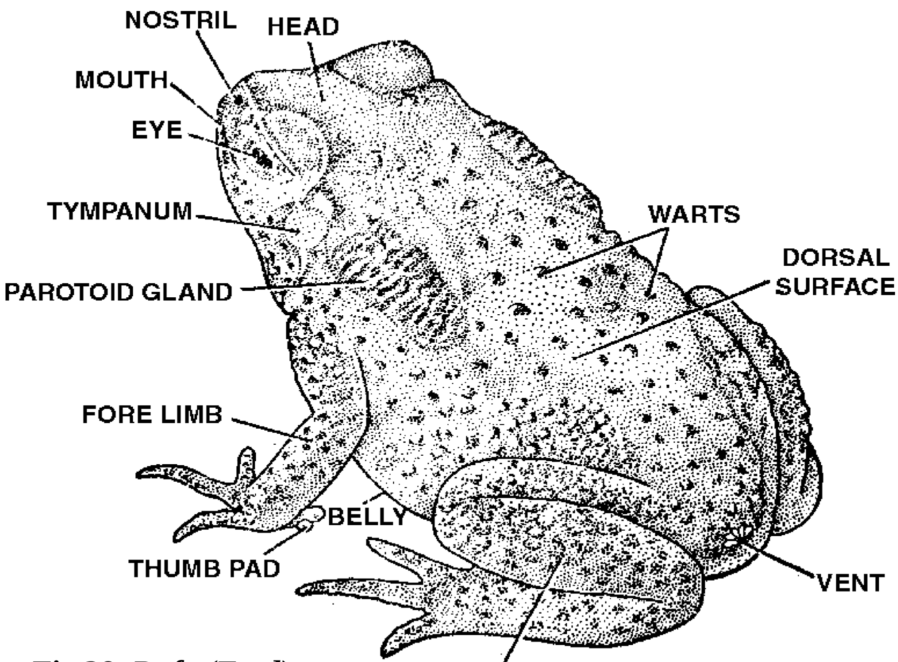


Fig 38. ***Bufo (Toad)***

(39) *HYLA ARBOREA*

GENERAL NAME: TREE TOAD

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
Class :AMPHIBIA.
Order : Anura or Salientia

- ❑ Light green coloured, smooth gelatinous skinned lean and light bodied frog living on the trunks and logs of wood.
- ❑ Limbs are considerably long compared to that of frog.
- ❑ Fingers end in adhesive pads to help in getting firm grip on the substratum.
- ❑ Ventral surface of the body is granular with hydroscopic glands producing mucous.
- ❑ Upper jaw is toothed but lower jaw is edentate (without teeth).
- ❑ Nocturnal organisms moving quickly over the trunks by leaping.
- ❑ Thin web between the fingers help in leaping in air.
- ❑ Eyes are conspicuous with transverse pupil.
- ❑ Fertilization is external.
- ❑ Males posses vocal sacs producing a peculiar sound.

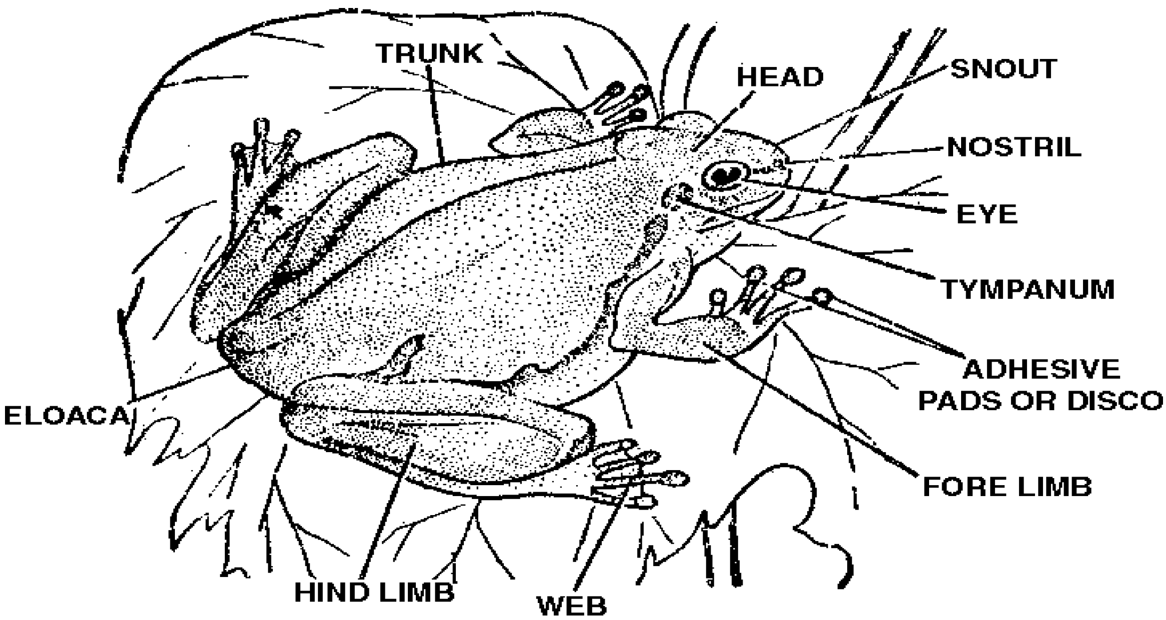


Fig 39. ***Hyla arborea***

(40) *RHACOPHORUS*

General name: FLYING FROG

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
Class :AMPHIBIA.
Order : Anura or Salientia

- ❑ It is a small frog living on tree tops.
- ❑ It can mimic the environment and hence mix up with the surroundings.
- ❑ Body is divided into a head and trunk. Neck and tail are absent.
- ❑ Eyes are conspicuous on the dorsal side of the head.
- ❑ Snout is half moon shaped.
- ❑ Limbs are weak with adnessive pads at the end of the fingers for grip over the substratum.
- ❑ Web is extensively formed between the fingers and hence forms into patagium during leaping over the tree tops. It hops over the trees from branch to branch.
- ❑ The limbs appear to be wing like during hopping.

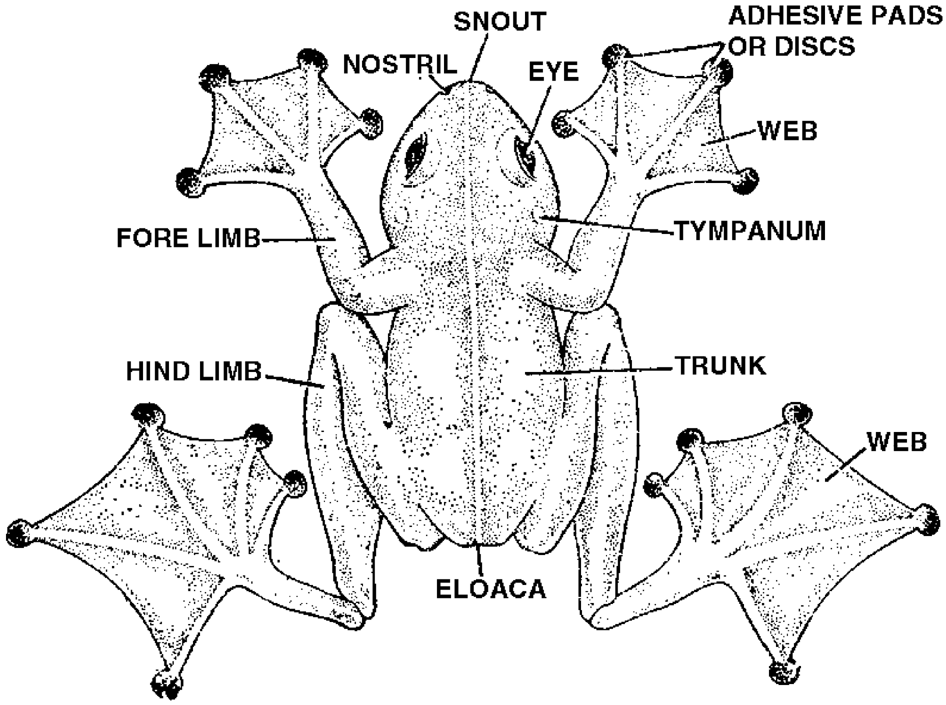


Fig 40. ***Rhacophorus***

REPTILES

(41) *DRACO DUSSUMERI*

General name: FLYING LIZARD

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
CLASS :REPTILIA
Order :SQUAMATA
Sub order: LECERTELIA

- ❑ It is a tree lizard seen in the forest regions.
- ❑ Body is dorsoventrally flattened, thin and light.
- ❑ Limbs are pentadactyl and fingers end in powerful claws.
- ❑ Skin is dry and scaly. Scales are ectodermal in origin. Skin is devoid of glands.
- ❑ Skin extends as an extensive patagium in between fore and hind limbs.
- ❑ Patagia are supported by five soft rib like bones. These lizards can fly in air using the patagia as wings. During rest, the patagia are much folded. Patagia are attractively coloured.
- ❑ Sexually dimorphic forms.
- ❑ Gular pouch is present just beneath the neck. This pouch is larger in males. Spines in these pouches help in holding the leaves.
- ❑ Eyes are small but conspicuous. Head is triangular while the dentition is heterodont.
- ❑ Tongue is short and thick.
- ❑ Vertebrae are procoelous.
- ❑ Tail is long , soft and whip like.

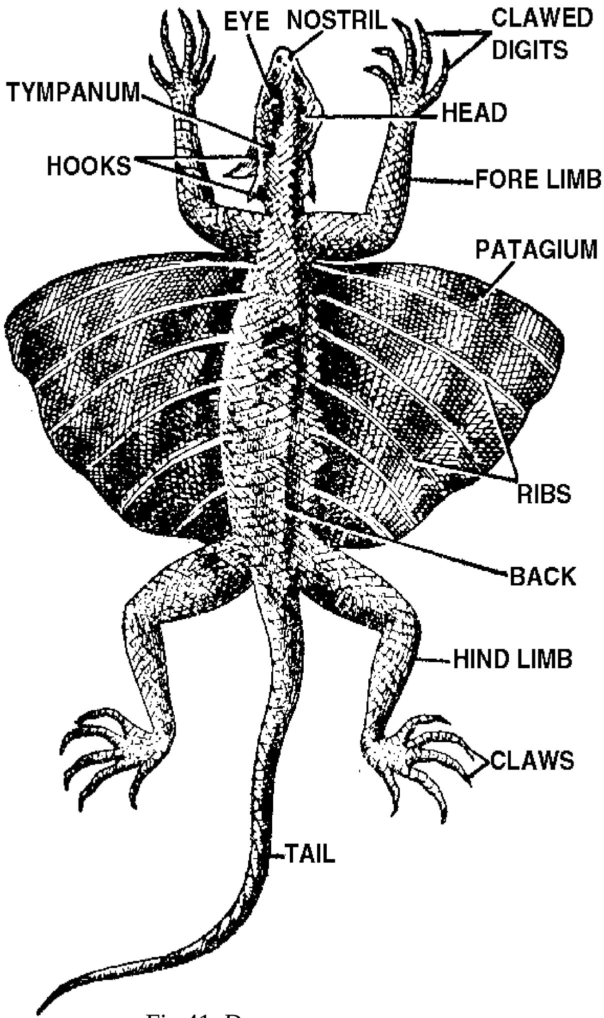


Fig 41. *Draco*

(42) *GECKO*

General name : Common wall lizard.

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
CLASS :REPTILIA
Order :SQUAMATA
Sub order: LECERTELIA

- It inhabits the human habitations and is very common in all most all the houses and godowns.
- It is seen actively moving on the walls and rarely falling from tops producing sound.
- Body is divided into a head, neck, trunk and tail. Tail can regenerate when lost.
- Body is dry and skin is scaly but non-glandular.
- Head is small and elongated into an ellipse.
- Eyes are conspicuous, black and granular.
- Trunk and tail are elongated.
- Limbs are pentadactyl and fingers are clawed.
- Adhesive pads present beneath the fingers help in getting firm gri over the substratum.
- They are insectivouous.
- Oviparous amniotes with cold blooded nature.
- Males possess a pair of copulatory organs near the cloaca, a transverse opening at the origin of tail.

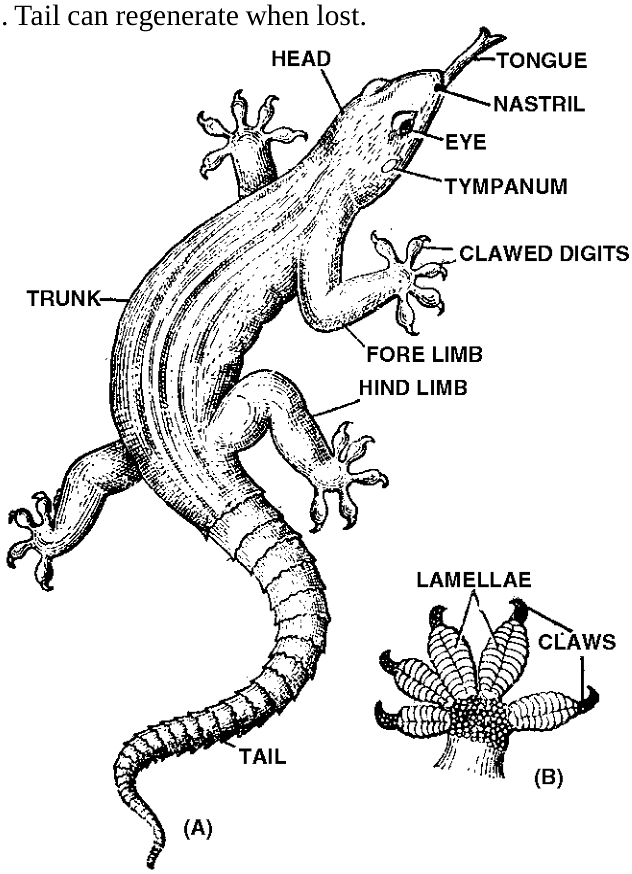


Fig 42. *Wall lizard*

(43) *CHAMELEON*

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
CLASS :REPTILIA
Order :SQUAMATA
Sub order: LECERTELIA

- ❑ An arboreal lizard having the capacity to change its colour in relation to the surroundings.
- ❑ Mimicry is its prime feature.
- ❑ Insectivorous organism moving very slowly in between the leaves on the tree branches.
- ❑ Skin is rough, dry and is embedded with granular scales.
- ❑ Body is laterally compressed with a dorsal crest.
- ❑ Body is divided into a head, a neck, a trunk and a tail.
- ❑ Eyes are conspicuous and independent of the movement. Vision is monocular.
- ❑ Tongue is long, sticky and helps in feeding.
- ❑ Dentition is acrodont.
- ❑ Vertebrae are procoelous. Skull is fused to the first vertebra.
- ❑ A number of air sacs are formed from the lungs internally.
- ❑ Fingers in the limbs fuse to form in to two bundles. In forelimbs, the inner three and outer two fuse to form two bundles. In hind limbs, the inner two and outer three unite in the same fashion. These are used to grasp the tree branches.
- ❑ Presence of a crown or a hood is the characteristic feature of this organism.
- ❑ Tail is prehensile and helps in twisting around the branches.

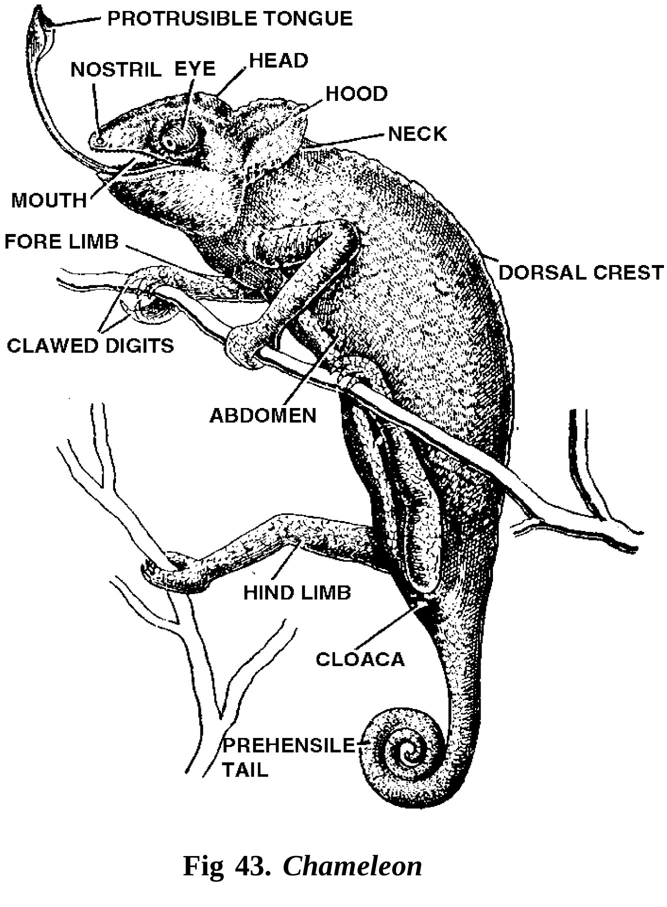


Fig 43. ***Chameleon***

(44) *UROMASTIX*

General name: Desert lizard.

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
CLASS :REPTILIA
Order :SQUAMATA
Sub order: LECERTELIA

- It is a common lizard seen in sandy areas and deserts.
- It resembles the wall lizard except for the presence of spinous tuft over the tail.
- Body is divided into a head, neck, trunk and tail. Cloaca is a transverse slit at the junction of the trunk and tail.
- Tail can regenerate when lost.
- Skin is dry, rough and covered by ectodermal scales.
- It can withstand higher temperatures of the environment and is poikilothermous in nature.
- Skull is of diapsid type and jaws are toothed.
- It generally feeds on insects and frogs.
- Oviparous organisms.

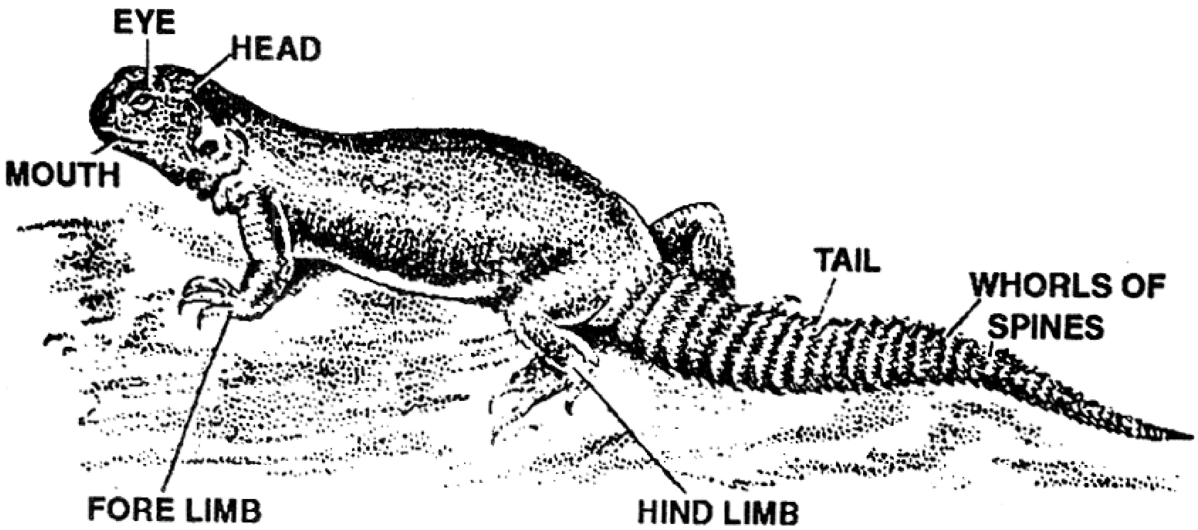


Fig 44. *Uromatix*

(45) *VARANUS*

General name: MONITOR LIZARD

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
CLASS :REPTILIA
Order :SQUAMATA
Sub order: LECERTELIA

- It is a lizard commonly seen in forests, bushes and open areas.
- It grows to a length of 1m. Body is robust, strong and weighty.
- Skin is dry, non glandular and covered by granular scales. It is brownish in colour with spots.
- Limbs are pentadactyl and fingers are clawed.
- These organisms are used to climb the trees, mountains as they have powerful grip over the substratum.
- Tongue is long, protrusible and bifid.
- Dentition is of pleurodont type.
- It feeds on small frogs, insects, birds and other lizards and hence is a carnivore.
- Eyes are conspicuous and are on the dorso-lateral sides of the triangular head.
- Nostrils are small and terminal.
- Tail is powerful and helps in storing the fat.

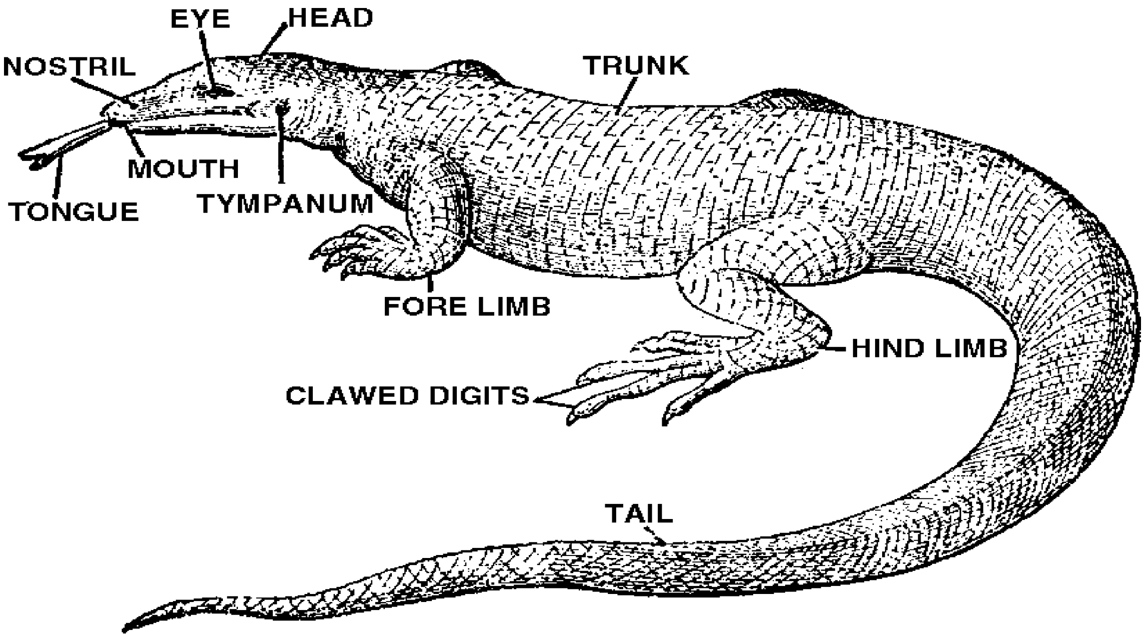


Fig 45. *Varanus*

(46) *VIPERA RUSSELI*

General name name: RUSSEL'S VIPER

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
CLASS :REPTILIA
Order :SQUAMATA
Sub order: OPHIDIA.

- It is commonly called as a chain viper growing to a length of 3- 5.5 ft. Body is long and stout.
- Head is triangular and is covered by ovoid scales.
- Eyes are conspicuous with a vertical pupil inside.
- Ventral scales are wide and cover the entire ventral surface.
- Head has a dorsal spot in between the two eyes.
- Nostrils are large and hence produce hissing sound.
- Three rows of coloured rings are present over the body arranged in the form of chains.
- Sub caudals are divided.
- Nocturnal organism feeding mostly on rats.
- Fangs are pointed and inject cardiotoxins in to the body during the bite.
- Poison is highly dangerous and affects blood vascular system.
- Oviparous organisms.

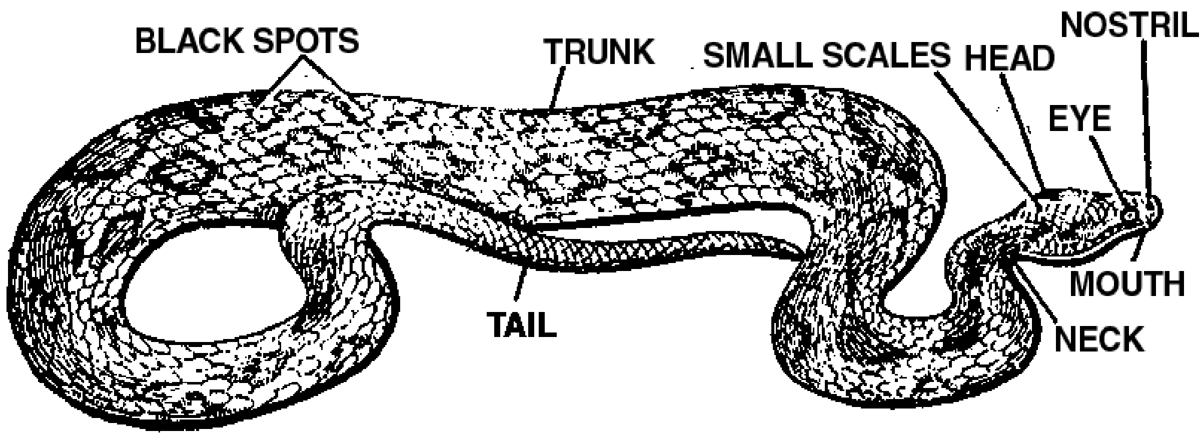


Fig 46. *Russels viper*

(47) *NAJA NAJA*

GENERAL NAME: COBRA

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
CLASS :REPTILIA
Order :SQUAMATA
Sub order: OPHIDIA.

- ❑ A South Indian active and common poisonous snake living in forests, bushes, shrubs and crevices.
- ❑ Body measures about 5-6 ‘ and is coloured light brown or yellowish green with coloured spots.
- ❑ Anteriorly, the head is covered by plates.
- ❑ Ribs in the neck region can expand to form the Hood with spectacle on the dorsal side and two black scars on the ventral side.
- ❑ Tongue is protrusive and bifid.
- ❑ Jaws are toothed of which maxillary teeth modify to form poisonous fangs to inject poison in to the prey.
- ❑ Third supra labial touches the nostril and eye.
- ❑ A small triangular wedge or keel scale is present in between the fourth and fifth sub-labial scales.
- ❑ Ventrals are wide and sub caudals are divided.
- ❑ Oviparous organisms feeding on rats and frogs.
- ❑ Very active snake raising its anterior body tounfold the hood and produce hissing sound.
- ❑ Poison is powerful and acts on nervous system. Hence it is a neuropoison.

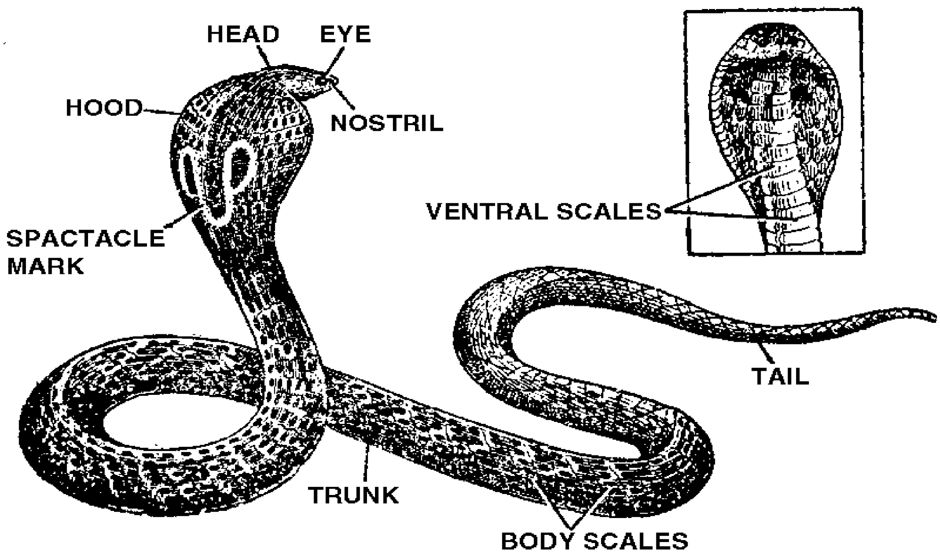


Fig 47. *Naja naja*

(48) *ECHIS CARINATA*

General name: PHOORSA

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
CLASS :REPTILIA
Order :SQUAMATA
Sub order: OPHIDIA.

- Body is an elongated cylinder like one with tapering posterior end forming the tail.
- Light coloured body is interspersed with a chain like markings or spots over the body.
- Actively moving snake producing hissing sound and measures about 3 m. in length.
- Head is an elongated triangular one while the tail is short and tapering.
- Sub caudals are entire and the ventrals are also entire extending from side to side.
- An arrow shaped scar is present over the head.
- Eyes are conspicuous.
- Dorsally, the every scale possess toothed crests which upon friction develop a peculiar type of sound called "Phoos" and hence the name Phoorsa.
- Poison is highly powerful and acts upon the cardiovascular system.

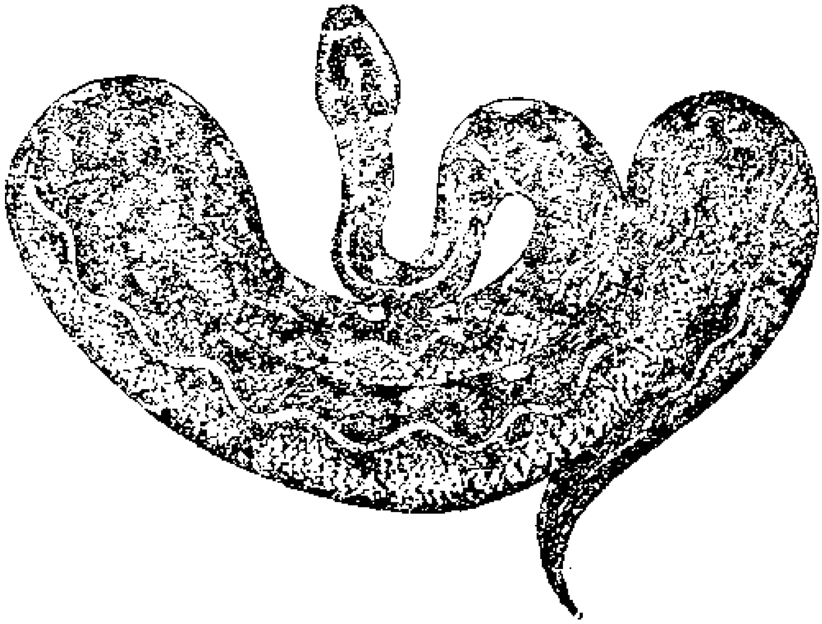


Fig 48. *Echis carinata*

(49) *ENHYDRINA*

General name: SEA SNAKE

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
CLASS :REPTILIA
Order :SQUAMATA
Sub order: OPHIDIA.

- **A small snake moving actively along the sea shores and in sea water**
- Body is a rope like one with an oar shaped, laterally flattened leaf like tail for swimming.
- Dark coloured body covered by granular ectodermal scales on all sides.
- Measures about 3 -5 feet. in length.
- Head is an elongated triangular one covered by wide plates.
- Nostrils are small and does not produce any hissing sound.
- Mainly feed on small fishes.
- Eyes are small and granular.
- viviparous organisms.
- Poison is eight times powerful than that of the cobra. These snakes never bite unless they are disturbed.

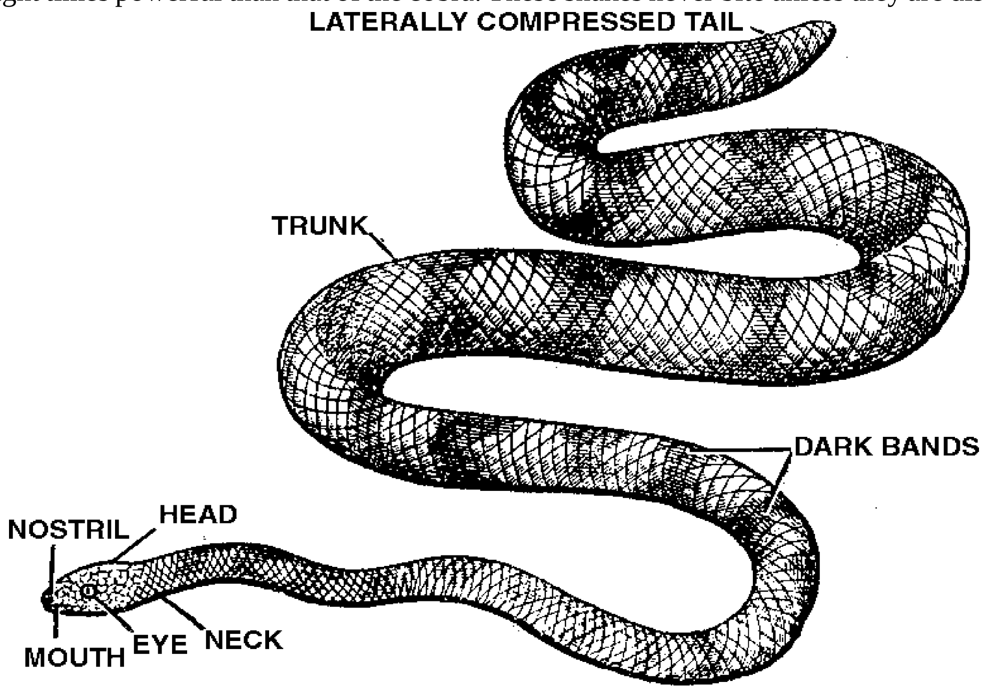


Fig 49. *Enhydrina*

(50) *BUNGARUS COERULENS*

GENERAL NAME: KRAIT

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
CLASS :REPTILIA
Order :SQUAMATA
Sub order: OPHIDIA.

- It is a poisonous snake whose poison is four times powerful than that of cobra.
- Body measures about 4-6 feet and is coloured shiny black or gray with white cross bands on the dorsal side. These bands are light in colour towards anterior half and thick towards posterior half.
- Mid dorsal scales are hexagonal and ventrals are wide extending the entire ventral side.
- Sub caudals are entire and tail is tapering.
- Head is covered by plates. Fourth sub labial is large. Ventral side is light white in colour.
- Nocturnal in habit and always move in pairs.
- They bite when disturbed.

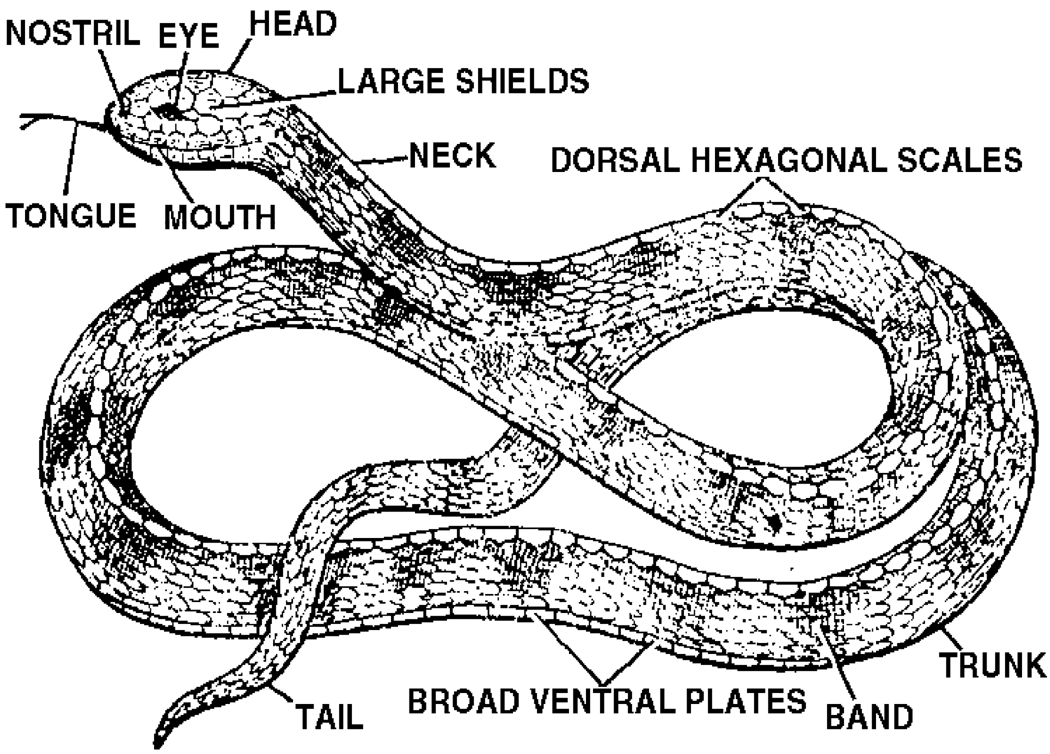


Fig 50. *Bungarus*

(51) *CROTALUS*

GENERAL NAME: **RATTLE SNAKE**

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
CLASS :REPTILIA
Order :SQUAMATA
Sub order: OPHIDIA.

- It is a poisonous snake living in bushes, forests and thick plantations.
- Snake measures about 2-3 meters in length.
- Body is coloured dark with attractive spots.
- Triangular head bears a pair of small eyes and antero- ventral mouth. Eyelids are absent.
- A sensory pit is present in between the eye and nostril.
- A pair of fangs are present in the mouth.
- Nocturnal in habit and goes for aestivation.
- Tapering tail ending in saucer shaped rattles producing dry leaf sound.

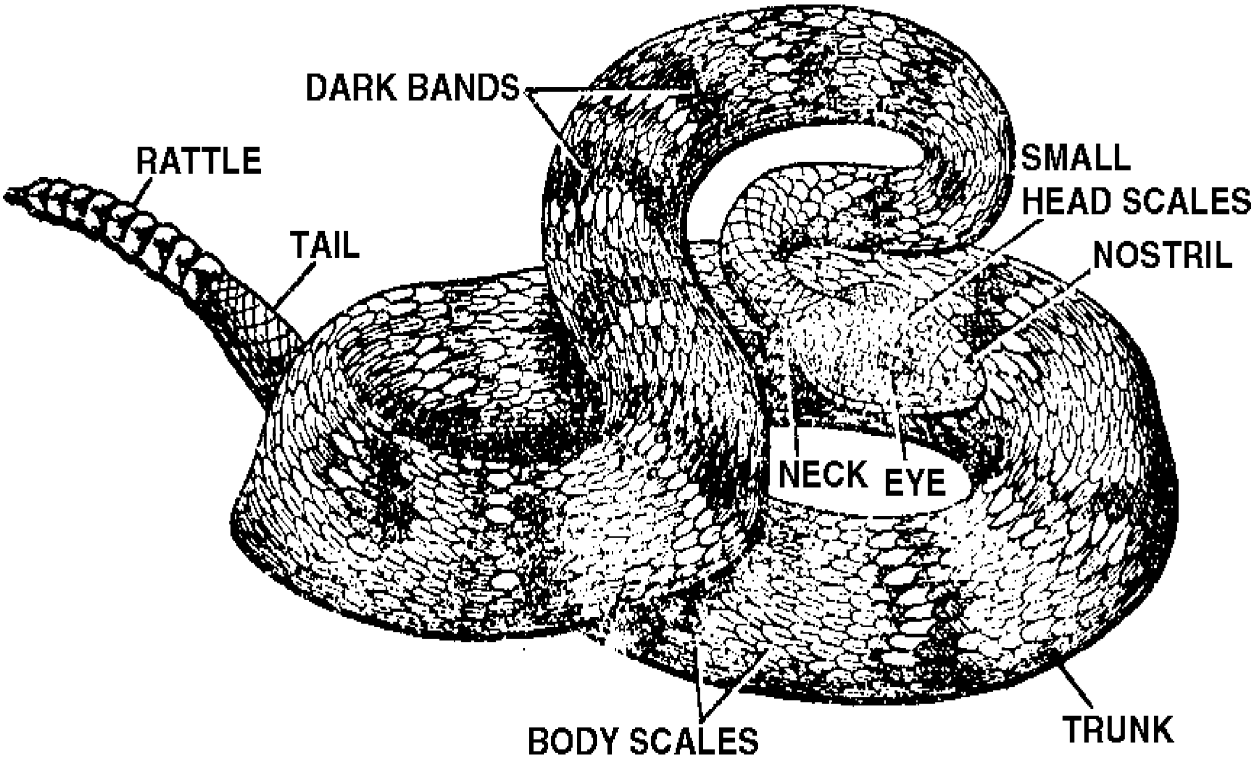


Fig 51. *Crotalus*

(52) *PTYAS*

GENERAL NAME:

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
CLASS :REPTILIA
Order :SQUAMATA
Sub order: OPHIDIA.

- A long actively creeping nonpoisonous snake measuring about 5- 7 feet in length.
- It is commonly seen in the fields, bushes, burrows, grass lands and crevices.
- Body is covered by small scales on the dorsal side and wide ventrals limited to the mid ventral part of the body.
- Body is coloured thick green or yellow.
- Whip like tail helping in attacking the prey and it is prehensile.
- Supralabials, sub labials and caudals possess black margins.
- It can swim in water and climb the trees.
- It feeds on small frogs, lizards, ratas etc.,
- It can jump and rise to attack the prey when disturbed.

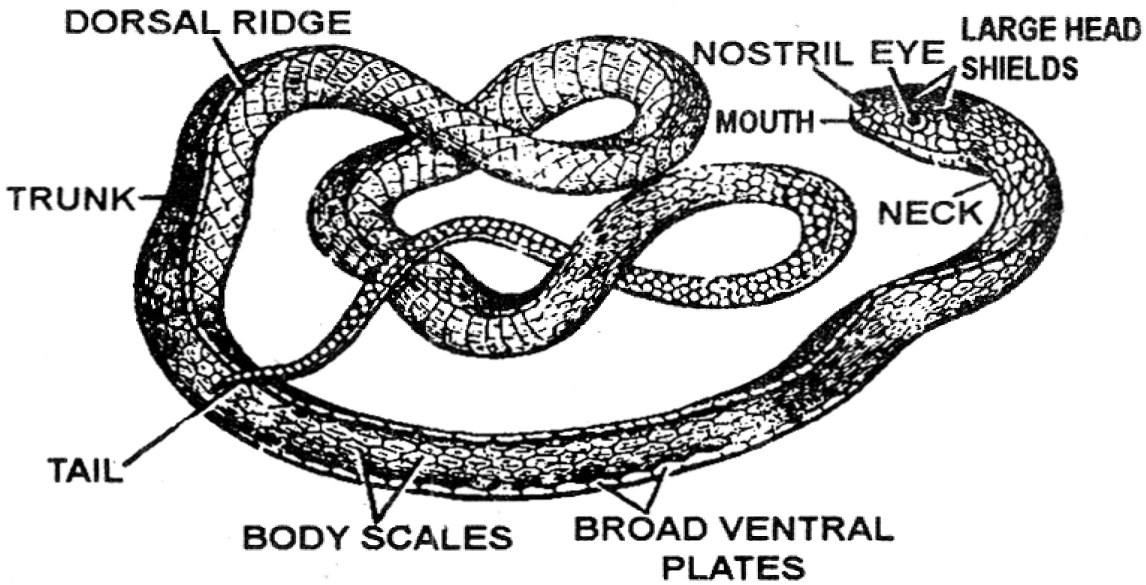


Fig 52. *Ptyas*

(53) *ERYX JOHNI*

General name: **DOUBLE HEADED SNAKE**

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
CLASS :REPTILIA
Order :SQUAMATA
Sub order: OPHIDIA.

- Terrestrial snake commonly inhabiting the sandy soils and desert regions.
- Body is short and stumpy with blunt ends. Head and tail end are almost equal in shape.
- It can move either way and hence it is called a double headed snake.
- Body is pale violet in colour and measures about 1-2 feet.
- Sluggish snake showing slow movements and covered by granular scales.
- Ventrals are wide but limited to mid ventral side of the body.
- Skin is very thick and is used for making bags, purses etc.,
- Eyes are small with vertical pupil.
- Nostrils are like slits and tympanums are absent.
- A non poisonous snake moving very slowly even if it isdisturbed.

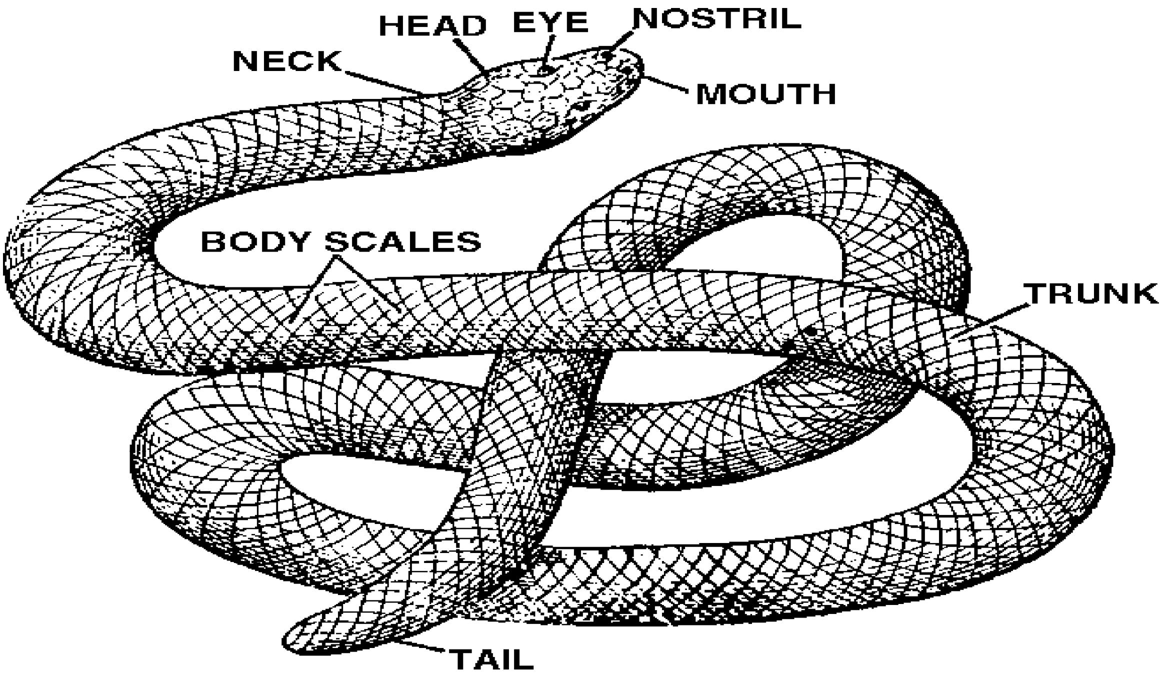


Fig 53. ***Eryx johni***

(54) *TRIONYX*

GENERAL NAME: FRESH WATER TERRAPIN

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
Class :REPTILIA
Order : CHELONIA.

- It is a common fresh water terrapin inhabiting Indian rivers.
- Body is dorsoventrally flattened and hence is flat in appearance.
- Body is protected by a shell which is covered by a thick and soft skin fold.
- Head is an elongated one with a pointed anterior end bearing a pair of nostrils at its terminus.
- Mouth is antero-ventral and is surrounded by fleshy lips.
- Nine dorsal vertebrae of the carapace are fused with each other.
- The dorsal shell plates unite to form the carapace which is fused with the ribs.
- Laterally, the carapace has eight lateral costal plate surrounded by a circle of marginal plates.
- A pair of epiplastrons, a central entoplastron, paired hyo and hypo plastrons, a single posterior plastron contribute for the formation of the plastron on the ventral side.
- The fusion lines or sutures are clearly visible on the ventral side of the plastron.
- Vertebrae of the tail and neck are freely movable.
- Feet are like oars and help in swimming. The inner three fingers of the feet are clawed.

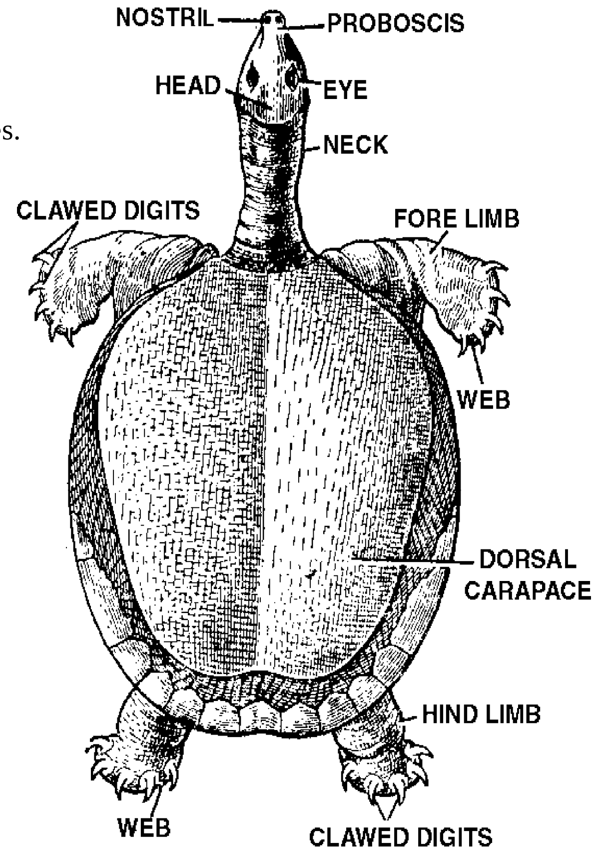


Fig 54. ***Trionyx***

(55) *TESTUDO ELEGANS*

General name : **GIANT OR TERRESTRIAL TORTOISE**

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
CLASS :REPTILIA
Order :CHELONIA.

- It is a large sized organism inhabiting fresh water, marine and terrestrial environments.
- It feeds on worms and insects.
- Jaws are edentate and skull is of anapsid type.
- It hibernates during winters.
- The body is protected by a hard shell made of dorsal carapace and ventral plastron.
- Carapace is composed of a number of coloured hexagonal plates.
- The shell is also covered by a thin fold of skin.
- Dorsal side is convex and the ventral side is almost flat.
- Head, limbs and tail are movable and can retreat into the shell when disturbed.
- Oviparous organisms laying eggs in pits made in the sand.
- Limbs are modified for walking on land.
- Uricotelic organisms excreting uric acid.

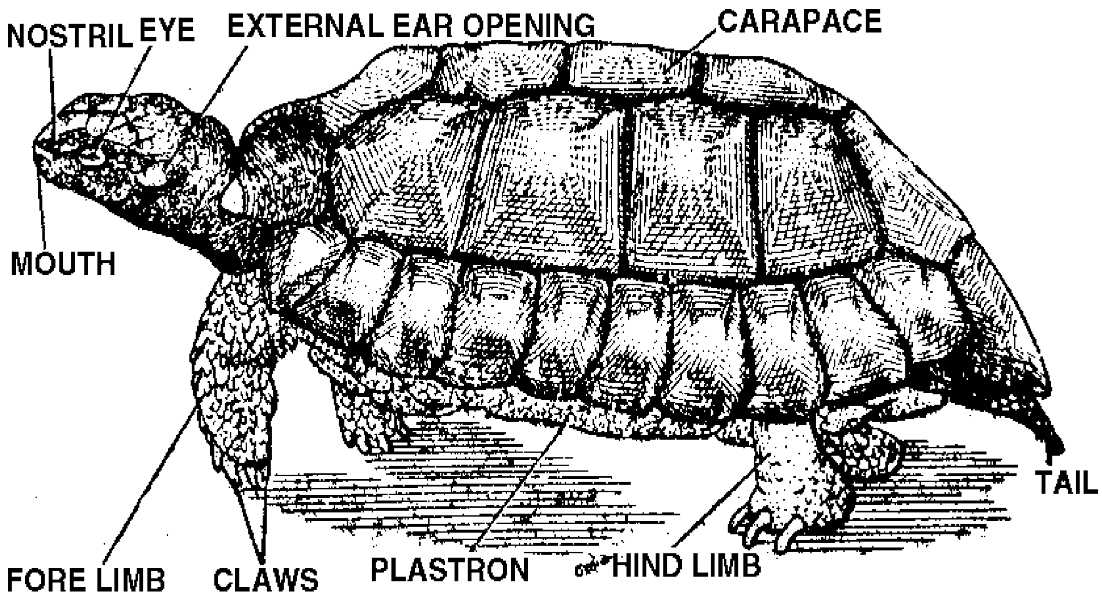


Fig 55. ***Testudo elegans***

(56) *GAVIALIS GANGETICUS*

GENERAL NAME:

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
CLASS :REPTILIA
Order CROCODELIA

- A common crocodile inhabiting Indian rivers and mainly the waters of river Ganges.
- Body measures about 10-11 feet.
- Body is divided into an elongated head, a neck, a trunk and a tail.
- Limbs are webbed, pentadactyl and digits are clawed.
- Head is drawn into an elongated tubular snout having similar, pointed and sharp teeth.
- Dentition is thecodont and homodont.
- Skin is leathery and warty giving protection to the organism.
- Tail is laterally flattened to participate in locomotion.
- Internally, the skull is diapsid, heart is four chambered and cavity is divided by the presence of a diaphragm.
- Eyes are small but conspicuous on the lateral sides of the head.
- Nostrils are terminal and ear openings are covered by skin folds.
- Feeds on aquatic organisms of fairly larger size.

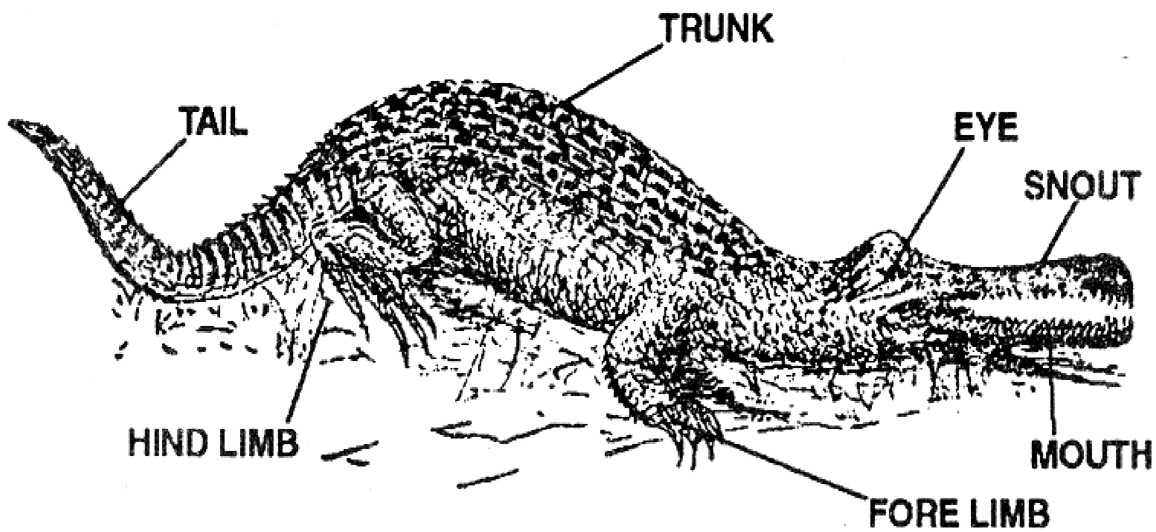


Fig 56. *Gavialis*

(57) *CROCODILUS POROSIS*

GENERAL NAME:

Phylum :CHORDATA.
Sub. Phy. :VERTEBRATA.
Super-class:GNATHOSTOMATA.
CLASS :REPTILIA
Order :CROCODILIA.

- It is a common crocodile inhabiting the lakes, rivers and fresh water areas of African and Asian countries.
- Strong and heavy/robust body measuring about 12-13 feet in length is divided into a head, a neck, a trunk and a tail.
- Fore and hind limbs are pentadactyl and clawed. Webbed feet are used in swimming.
- Leathery skin forming the external covering is warty on dorsal side and highly protective.
- Head is an elongated half moon shaped one with terminally placed nostrils and a wide mouth.
- Jaws possess thecodont and pointed, sharp homodont teeth.
- First tooth fits into a pit and fifth one into a notch.
- Ear openings are covered by skin.
- Tongue is used in food collection.
- Four chambered heart leading to a complete double circulation.
- Cold blooded organisms having diaphragm in between the thoracic and abdominal cavities.
- Urinary bladder is absent and hence release the excretory products as and when they are formed.
- It can feed on larger organisms.
- Oviparous organisms showing parental care during embryonic development.

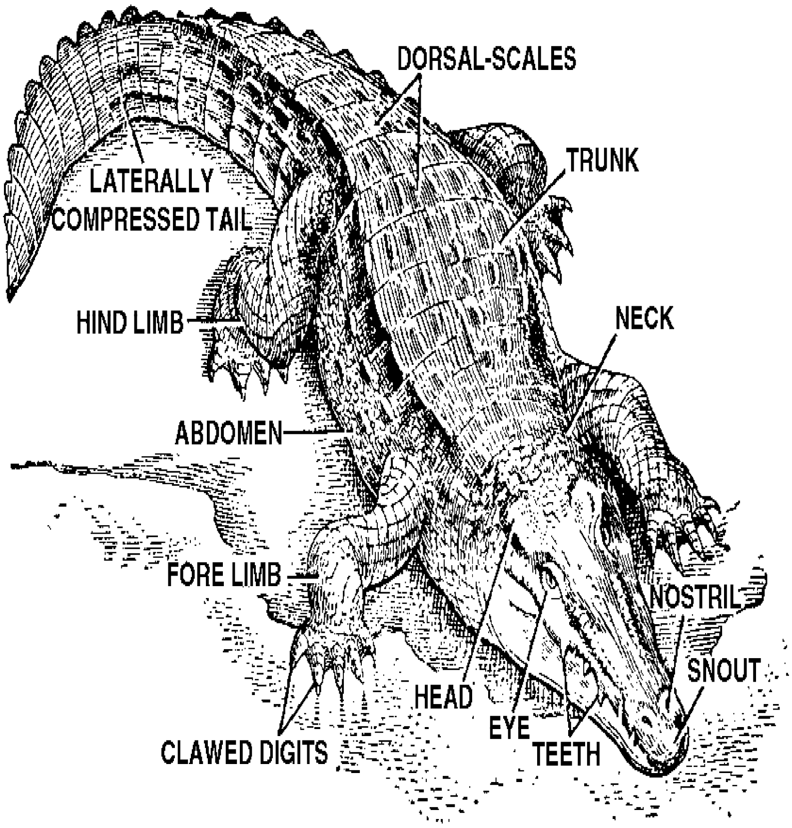


Fig 57. Crocodilus

BIRDS:

(58) *PICUS BENGALENSIS*

GENERAL NAME: **WOOD PECKER**

PHYLUM : CHORDATA
SUB.PHY : VERTEBRATA / CRANIATA
SUPER-CLASS: GNATHOSTOMATA.
CLASS : AVES
SUPER-CLASS: NEORNITHES ORDER :
PISCIFORMES

It lives in the pits made into the stems or branches of the tree.
It inhabits forest areas and feeds mostly on termites and ants. Hence it controls pests to certain extent.
Beak is long, strong and printed to help in making holes.
Tongue is long and sticky to extract food from the trees.
Hind limbs have two forward and on backward by directed toes.
They make shrewd voice and make migration to long distances.
Feathers are coloured black with white spots.
Tail is in the form of shoal. Tail feathers are long and pointed.
These birds live in pairs.
Incubation period is about 11 to 14 days.
Both male and female birds participate in the construction of nests and incubating the eggs.

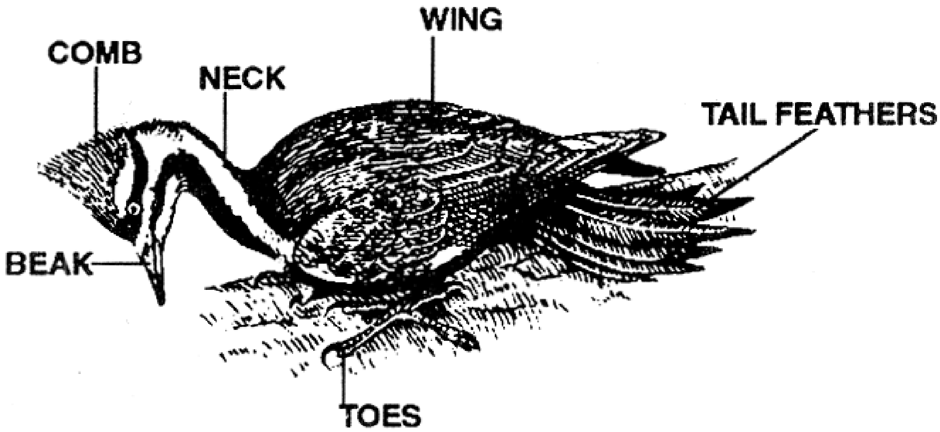


Fig 58. Woodpecker

(59) *ARDEA HERODIAS*

GENERAL NAME: POND HERON

PHYLUM : CHORDATA
SUB.PHY : VERTEBRATA / CRANIATA
SUPER-CLASS: GNATHOSTOMATA.
CLASS:AVES
SUPER-CLASS: NEORNITHES ORDER : CICONIFORMES

Migratory birds having universal distribution.
Body is divided into a head, a neck and the trunk.
Neck is naked and long with unequal Vertebrae.
Long beak with a slightly curved tip.
Legs are also long and naked.
These birds are seen along the crop fields, water areas feeding on small fishes and other aquatic organisms.
They can stand floating on the surface of water.
Body is covered by shining feathers.

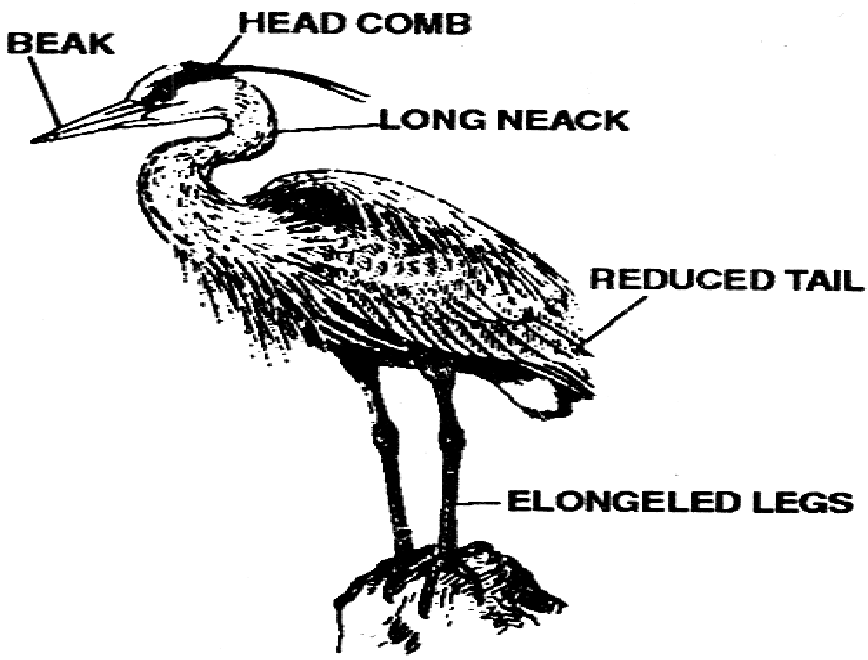


Fig 59. Pond Heron

(60) *EUDYNAMUS SCOLOPACEA*

GENERAL NAME: **KOEL**

PHYLUM : CHORDATA
SUB.PHY : VERTEBRATA / CRANIATA
SUPER-CLASS: GNATHOSTOMATA.
CLASS : AVES
SUPER-CLASS: NEORNITHES
ORDER : CUCULIFORMES

Birds of common occurance in gardens, Forests and dense plantation areas.
Sexually dimorphic and are rarely seen in human habitations.
Beak is long and strong with a slight curved tip.
They measure about the size of the crow.
Males are coloured black while females are brown with white spots.
Eyes are small with circular pupils. Tail feathers are long.
Feet and toes are strong and help in holding the branches with a firm grip.
Hind limbs possess four fingers of which two are anterior and two are posteriorly directed.
Males can sing with sweet tone.
They migrate into burrows during summers.
Females lay eggs in the nests of other birds for incubation as they themselves cannot incubate the eggs.

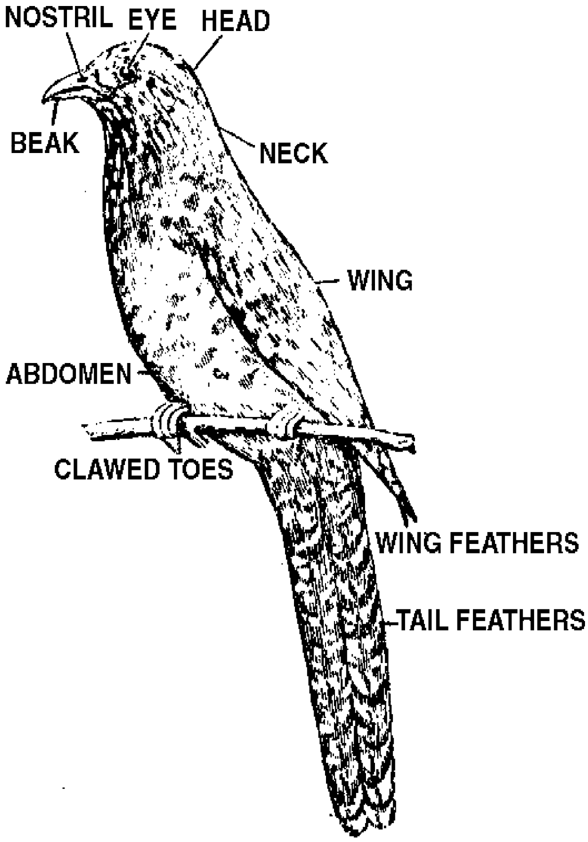


Fig 60. ***KOEL***

(61) *BUBO BUBO*

GENERAL NAME: **HORN OWL**

PHYLUM : CHORDATA
SUB.PHY : VERTEBRATA / CRANIATA
SUPER-CLASS: GNATHOSTOMATA.
CLASS: AVES
SUPER-CLASS: NEORNITHES
ORDER: STRIGIFORMES

Universally distributed noctural bird inhabiting forests, gardens and dense vegetations.
It feeds on smal! birds, rats, Lizards and other organisms.
It can stand erect on its hind legs.
Head bears a pair of conspicuous golden eyes, hook like beak, apair of long horn like feathers.
Head and body are covered by smooth and tender feathers.
Heavy body is guarded by thick brown coloured spotted feathers.
External auditory meatus is a large opening behind the eyes on the head.
These birds protect the crops from the attack of rodents by feeding on them.
Hence they have economic significance.
In day time, they live in bushes and amongst the tree branches.

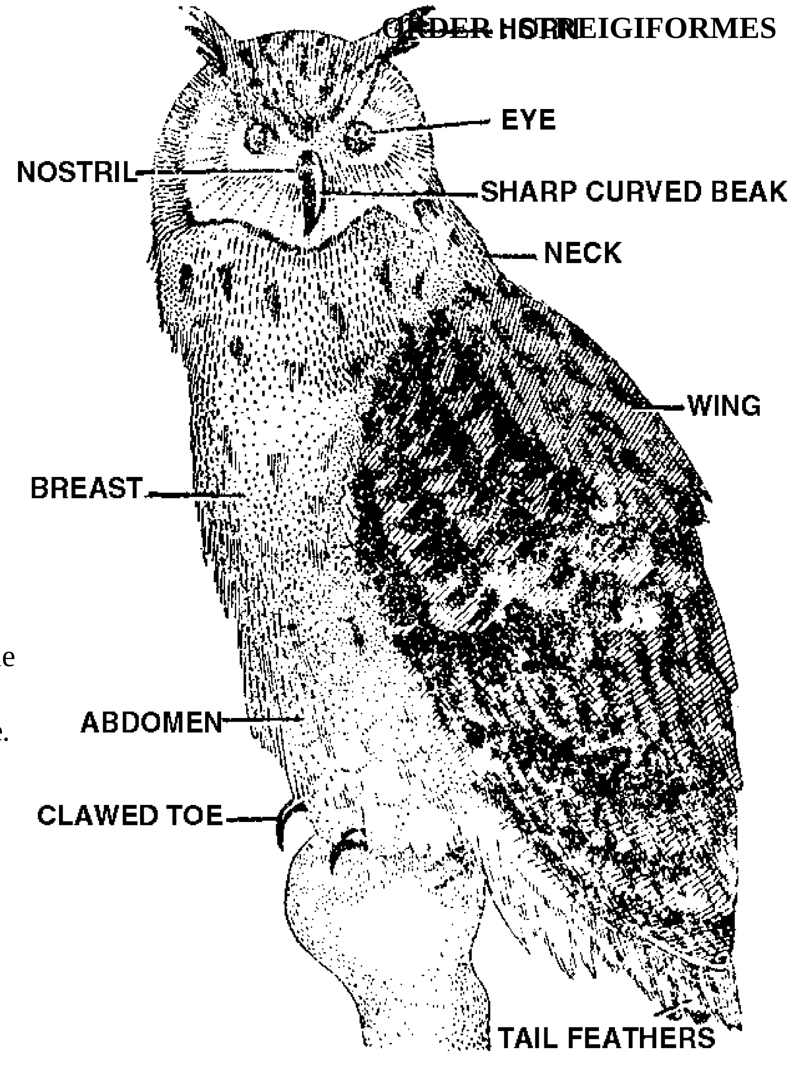


Fig 61. Bubo (Owl)

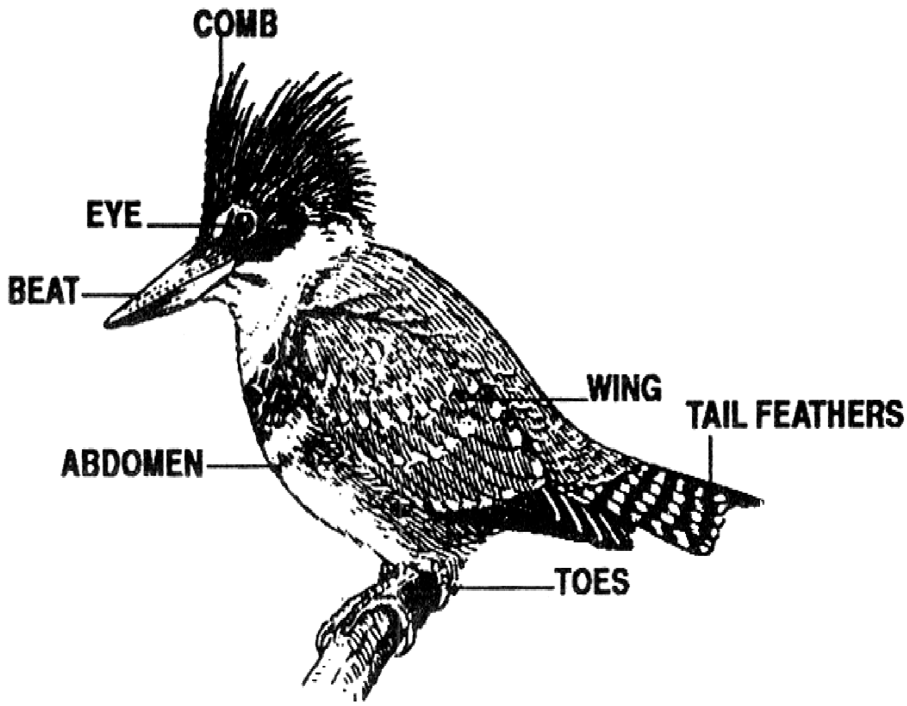
(62) *ALCEDO ATHES*

GENERAL NAME: **KING FISHER**

PHYLUM : CHORDATA
SUB.PHY : VERTEBRATA / CRANIATA
SUPER-CLASS: GNATHOSTOMATA.
CLASS : AVES
SUPER-CLASS: NEORNTTHES ORDER :
CORACIFORMES

A small bird living along the banks of water areas.
Hind limbs have three or four fmgers fused at their base.
Beak is formed of strongjaws.
Light body covered by deep coloured feathers.
Feet have three forwardly directed and one backwardy directed fmgers. Such feet help in holding the branches with a firm grip.
They live on the surface of water and feed in fishes, frogs etc.

Fig 62. Kingfisher



(63) *PSITTACULA CRAMERI*

GENERAL NAME: **PARROT**

PHYLUM : CHORDATA
SUB.PHY : VERTEBRATA / CRANIATA
SUPER-CLASS: GNATHOSTOMATA.
CLASS : AVES
ORDER : PSITTACIFORMES

It is a pet bird having universal distribution and living in stem pits and crevices of the walls.
It is abundantly seen in India, ceylone, America and Africa.
Body is covered by attractive green feathers.
Short, hooked, beak is bright reddish in colour.
Jaws are teeth less. Upper jaw is bigger than the lower one and is longer with a pointed curved tip. This can move on the frontal bone.
Tail feathers are longer than the Contours and wing feathers.
It is a pure herbivore feeding on fruits, seeds and vegetables.
In the hind limb second and third fmgers are forwardly directed while the first and fourth are backwardly directed to facilitate grip over the substratum.
Syrynx is well adapted for producing sweet sound and even it can speak upon training.
Males have a pink girdleat the neck region and **a black spot** near the throat.

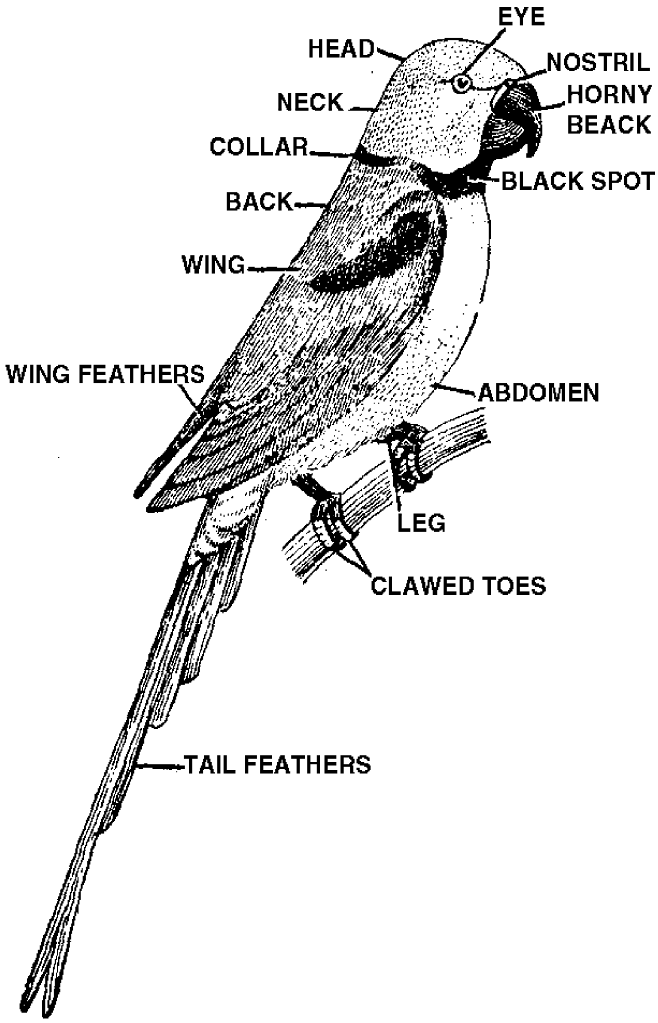


Fig 63. Parrot

MAMMALS:

(64) *ORNITHORHYNCHUS*

GENERAL NAME: **DUCK BILLED PLATYPUS**

PHYLUM : CHORDATA
SUB.PHY : VERTEBRATA OR CRANIATA.
SUPER CLASS: GNATHOSTOMATA.
CLASS : MAMMALU.
ORDER : PROTOTHERIA.

It is a small burrowing mammal seen along the banks of water ponds and rivers in Australia and Tasmania.
Body is covered by fine hair.
Head is well differentiated with a long, and smooth fur forming a covering over the body.
Flattened beak covered by thin skin fold.
Nostrils are located at the tip of the beak.
Eyes are small and protected by eye lids.Eye balls are covered by nictitating membrane.
Adults are edentate and have no extrnal ear pinnae.
Corpus callosum is absent in the brain.
Pentadactyl limbs with curved fingers.
Web is present in between the fingers of the limbs.
Tail is flat and oar like helping in swimming.
Pectroral girdle has a ‘T’ shaped inter clavicle.
Sweat glands are modified to form the mammary glands.
Teats are absent and hence milk oozes out through small pores.
Females have neither uterus nor oviduct as they are oviparous.
Eggs are laid in the nests built at their own.
Males have testes in association with kidneys in the abdominal cavity.

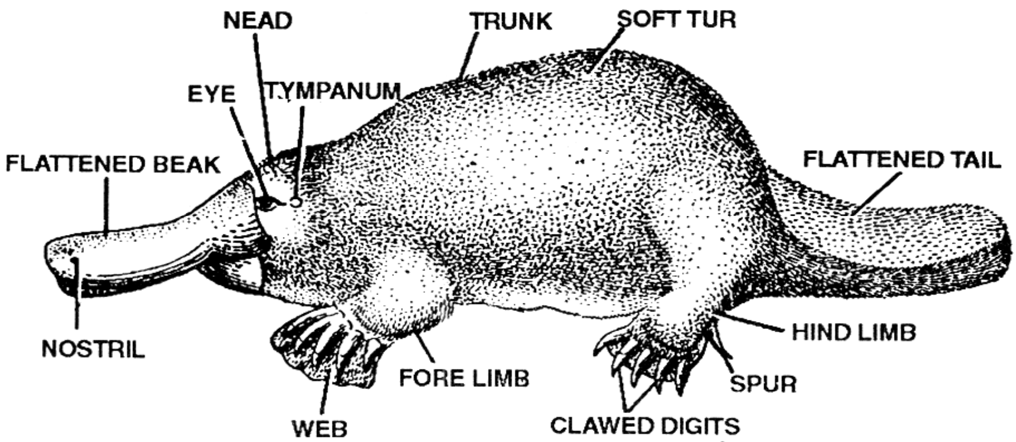


Fig 64. ORNITHORHYNCHUS

(65) *TACHYGLOSSUS OR ECHIDNA*

GENERAL NAME: **SPINY ANT EATER**

PHYLUM : CHORDATA
SUB.PHY : VERTEBRATA OR CRANIATA.
SUPER CLASS: GNATHOSTOMATA.
CLASS : MAMMALIA.
ORDER : PROTOTHERIA.

A terrestrial small burrowing, nocturnal mammal inhabiting Australia, Tasmania and Newguinea.
It feeds mainly on ants.
Head bears a long snout with nostrils at its tip.
Head and neck are almost continuous without showing any demarcation.
Eyes are small without nititating membrane.
External ear pinnae are absent. Jaws are edentate.
Tongue is sticky and helps in feeding on ants.
Pectoral and pelvic girdles resemble those of reptiles.
Web is absent in between the toes and fingers of limbs.
Claws are curved and help in digging the ground to make burrows.
Second finger of the hind limb is curved to clean the spires over the body.
Ankle bones posses a poisonous claw.
Male exhibit gynecomastism where they possess well developed mammary glands producing milk.
Mammary glands open into the brood pouch in females. Hence eggs are held in the brood pouch for incubation.

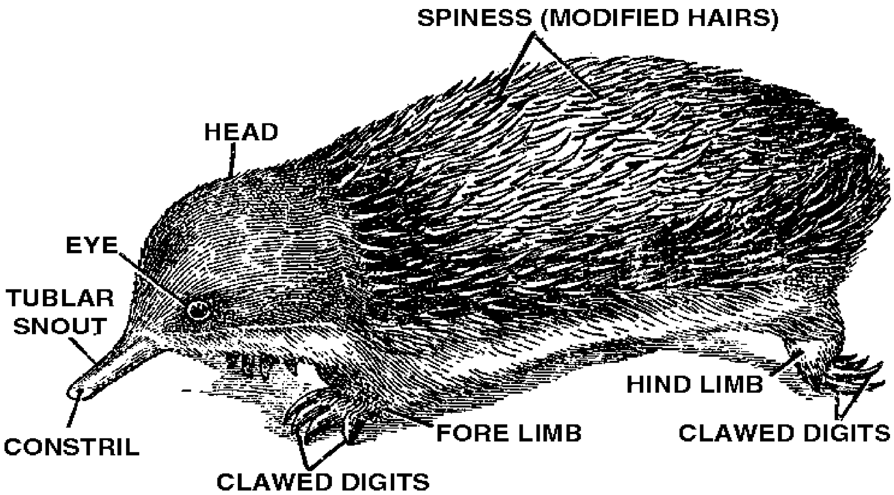


Fig 65. Echidna(Spiny ant eater)

(66) *ERINACEOUS*

GENERAL NAME: **HEDGEHOG**

PHYLUM :CHORDATA

SUB.PHY : VERTEBRATA OR CRANIATA.

SUPER CLASS: GNATHOSTOMATA.

CLASS : MAMMALIA.

ORDER rINSECTIVORA

It inhabits the bushes and burrows of the nothern hemisphere of the globe.
Dorsa! surface of the body is covered by hard, pointed and backwardly directed hard spines.
They help in protecting the organism and are formed by the modification of hair.
In between the spirnes, hair is smooth and soft.
Head is prolonged into a long, pointed snout at its free end.
Nostrils are located at the tip of the snout.
Jaws are provided with thecodont and heterodont teeth.
Dental formula is 3,1,4,3 / 3,1,4,3.
Eyes, ear pinnae and limbs are short.
Anterior part of the trunk is supported by 14-15 ribs.
Limbs are pentadactyl and fingers end in claws.
Special muscles are present for the movement of the spines.
Fertilization is interna! follwed by interna! development. Hence viviparous organism.
Spines become erect and the organism coils into a spiny ball when ever it is disturbed.
It feeds on fruits, inseets and small mammals.

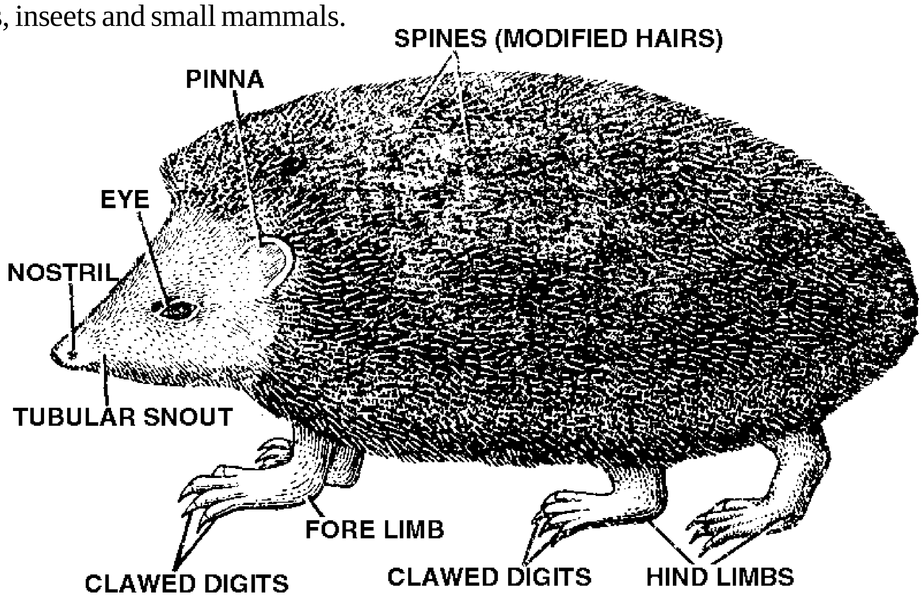


Fig 66. Hedgehog

(67) *MACROPUS*

General name: **KANGAROO**

PHYLUM :CHORDATA
SUB.PHY : VERTEBRATA OR CRANIATA.
SUPER CLASS: GNATHOSTOMATA.
CLASS : MAMMALIA.
ORDER : METATHERIA.

- It is a herbivorous mammal limited to Australia, Tasmania and Newzealand.
- It can grow to a size of about 6 feet.
- Head is small but ear pinnae are large.
- Fore limbs are short while the hind limbs are long and hence perform leaping movement.
- No hallux in the hind limb. Second and third fingers are united while fourth one is elongated and clawed.
- Hterodont and thecodont dentition showing the dental arrangement of 3, 0-1,2,4/1,0,2,4.
- The organism sits on its tail.
- Abdomen has a wide brood pouch in females only into which mammary glands open.
- Fertilization and development are internal.
- Underdeveloped eggs are released into the brood pouches where they stay till they are totally develope
- The brood pouch is supported by epiphyseal bones.

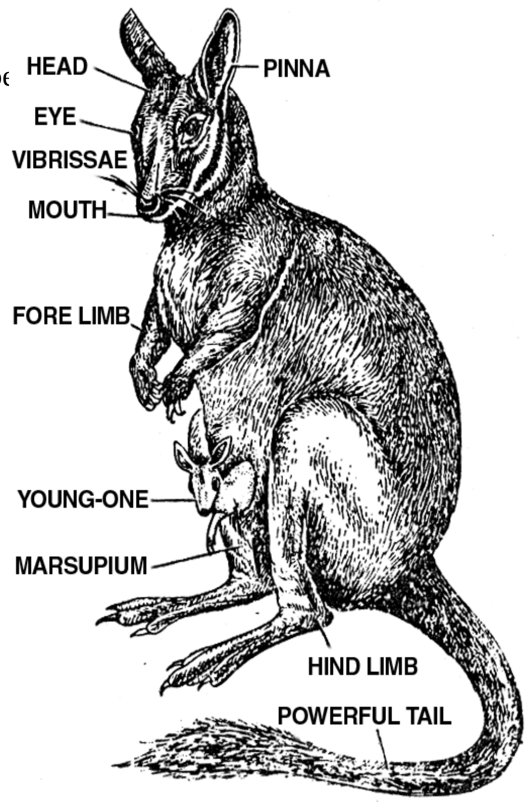


Fig 67. Kangaroo

(68) *DIDELPHIS VIRGINIANA*

GENERAL NAME: **AMERICAN OPPOSUM**

PHYLUM : CHORDATA
SUB.PHY : VERTEBRATA OR CRANIATA.
SUPER CLASS: GNATHOSTOMATA.
CLASS : MAMMALIA.
ORDER : M ARSUPALIA.

- It is a small mammal resembling rats but sized as that of a cat .It lives extensively in South America,. Nocturnal carnivore feeding mostly on insects.
- It is a good example for divergent evolution. Its ancestors were the natives of North America but migrated in different directions to develop in to new sub species.
- Snout is flat, elongated and nacked. Similarly tail is also hair less and prehensile.
- During day time, these organisms hide in the plant pits grown along the bank of the.
- These are used as food by some tribal people.
- Dentition is heterodont and dental formula is 5, 1,3,4/ 4.1.3.4.
- Canines are large and molars bear sharp cusps.
- Brood pouch is ventral and opens posteriorly.
- Mammary glands open into the brood pouch.
- Fertilization is internal and development is partial in the uterus. Partially developed embryos are laid into the brood pouch where they are suckled and develop into adult.

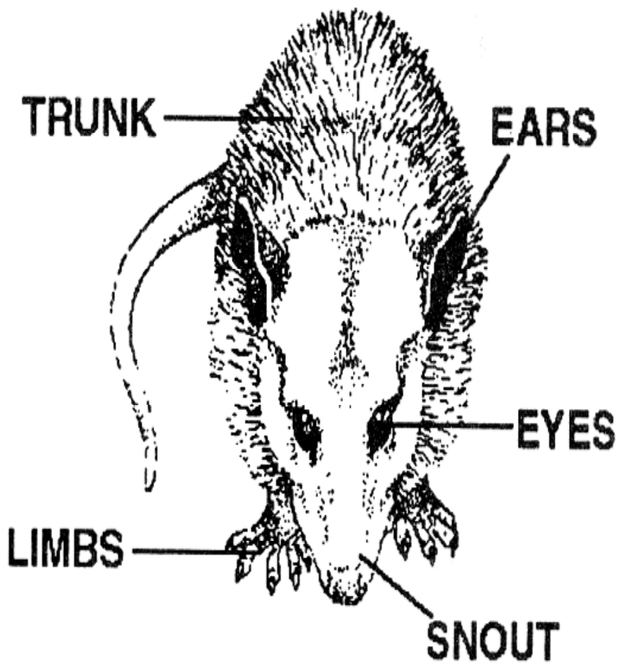


Fig.68. ***Didelphys virginiana***

(69) *LORIS TARDIGRADUS*

GENERAL NAME: **KAOLA**

PHYLUM : CHORDATA
SUB.PHY : VERTEBRATA OR CRANIATA.
SUPER CLASS: GNATHOSTOMATA.
CLASS : MAMMALIA.
ORDER :PRIMATA.

- A small nocturnal and solitary arboreal mammal inhabiting India, Ceylon and Madagascar.
- Body is covered by shiny, brown coloured dense covering of hair.
- Head is small having nostrils on the elongated and pointed snout at its free end.
- Eyes are large and ball like showing slow movements. Vision is binocular.
- External ear pinnae are small and triangular.
- Thecodont and Heterodont dentition.
- Tail is long and prehensile.
- Fore and hind limbs are long., thin and weak.
- Slow moving organisms seen hanging upside down on the tree branches.

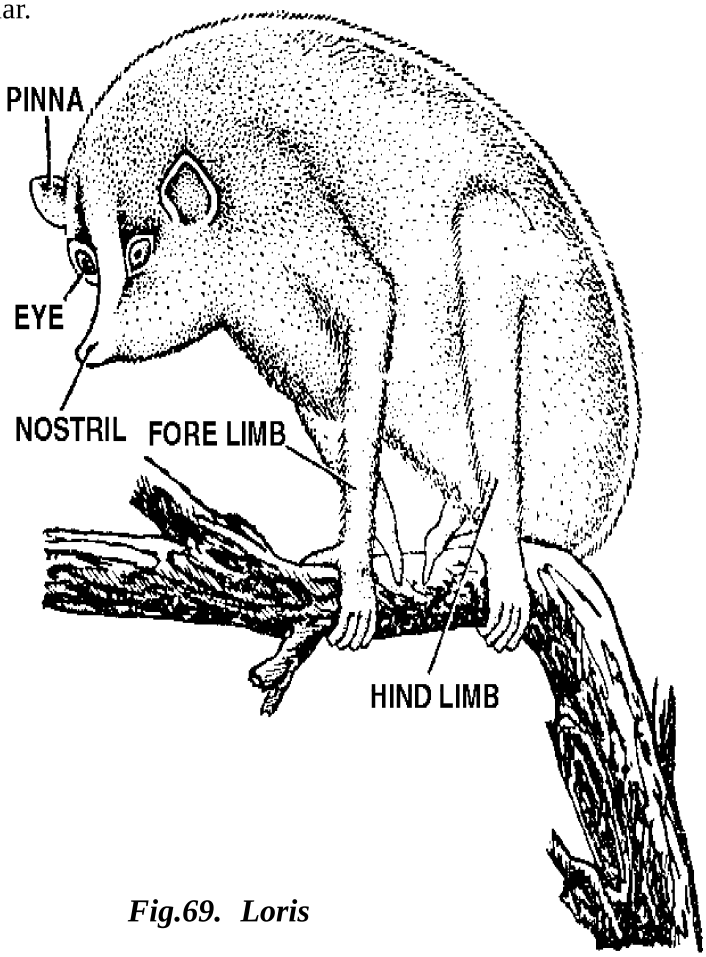


Fig.69. Loris

(70) *HERPESTES EDWARDSII*

General name: **MUNGOOSE**

PHYLUM : CHORDATA
SUB.PHY : VERTEBRATA OR CRANIATA.
SUPER CLASS: GNATHOSTOMATA.
CLASS : MAMMALIA.
ORDER : CARNIVORA.

- It is a common mammal frequently seen in the forests, bushes and grass lands of Asia and Africa.
- Elongated body is covered by brown or gray hair.
- Body is clearly divisible into an elongated head with pointed snout, a short neck, a barrel like trunk and a long bushy tail.
- skull is elongated and hence elongated snout. Eyes and ears are small.
- Limbs are pentadactyl and digits are clawed.
- It is pet organism.
- Dentition is homodont and thecodont.
- It is a powerful enemy to the snakes and hence is used to kill snakes.

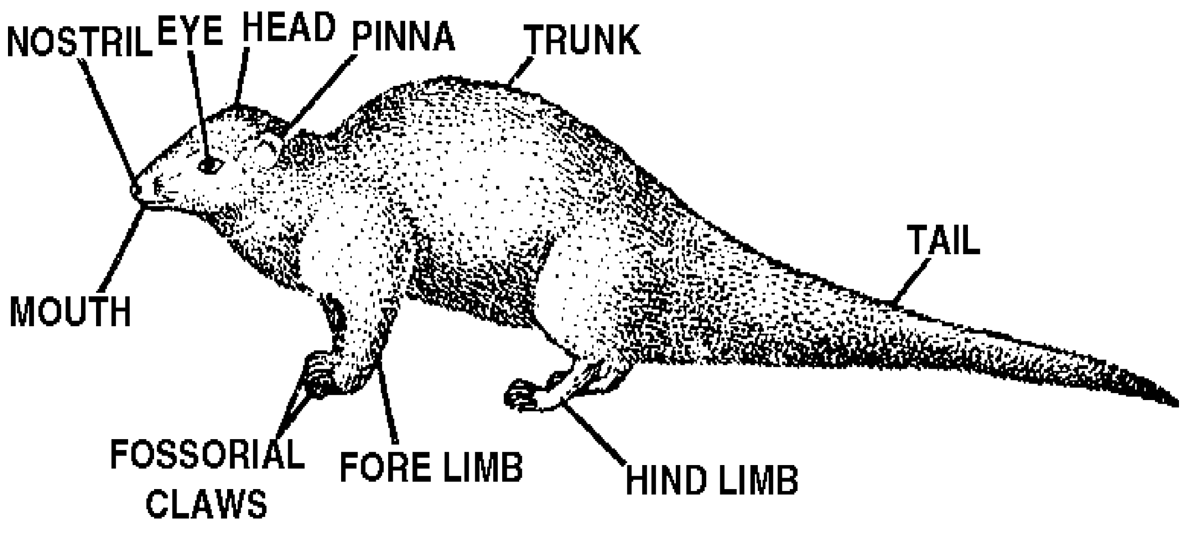


Fig.70. Mungoose

(71) *PTEROPUS*

General name: **FLYING FOX**

PHYLUM :CHORDATA
SUB.PHY : VERTEBRATA OR CRANIATA.
SUPER CLASS: GNATHOSTOMATA.
CLASS : MAMMALIA.
ORDER : CHIROTERA.

- It is generally seen in India and Asian continent.
- It is a flying mammal and hence the forelimbs are modified into wings.
- Body is divided into a head, neck and trunk. Tail is absent.
- Body is covered by black or dark coloured hair. Ventral hair is soft.
- Head is elongated with a pair of conspicuous eyes having sharp sight.
- External ear pinnae are large and very sensitive to sound waves.
- They are seen hanging from the tree branches during resting times.
- Limbs are pentadactyl and toes are clawed.
- Body is light in weight
- Lateral skin is extended in to patagium.
- Patagium is supported by fore limb bones and the first two fingers are clawed.
- Premolars are grooved and digestive system has an enlarged pyloric stomach
- Bats can receive ultrasonic waves released from their body to identify the obstacles in their way. This echo mechanism make them to escape from hitting the surfaces even during high speed movement.

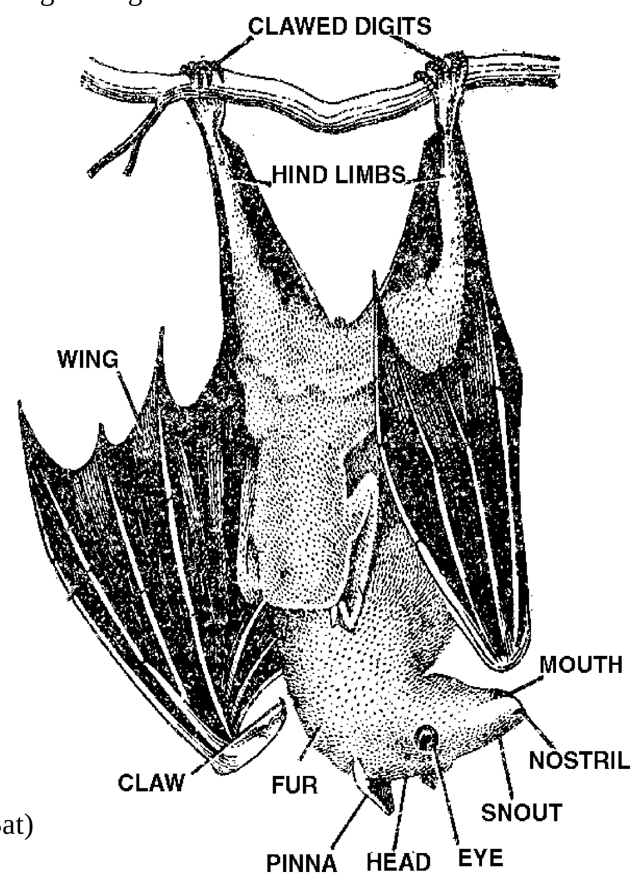


Fig. 71. ***Pteropus***(Bat)

(72) *FUNAMBULUS PALMARUM*

GENERAL NAME: **SQUIRREL**

PHYLUM : CHORDATA
SUB.PHY : VERTEBRATA OR CRANIATA.
SUPER CLASS: GNATHOSTOMATA.
CLASS : MAMMALIA.
ORDER : RODENTIA.

- ❑ Actively running arboreal organism having universal distribution.
- ❑ It is even seen moving in the human habitations.
- ❑ Body is divided into a head, a neck, a trunk and a tail.
- ❑ Head is small with an elongated snout having a pair of nostrils, a pair of conspicuous black eyes, a pair of large ear pinnae and long vibrissae near the tip of the snout.
- ❑ The organism can sit on its hind limbs when the fore limbs are used for holding the food.
- ❑ Body is dorsally having four to five coloured longitudinal stripes.
- ❑ Tail is covered with dense tuft of hair.
- ❑ Fore limbs are shorter than the hind limbs. Digits are clawed.
- ❑ Incisors work as chiscle for cutting the vegetable food material.
- ❑ Teeth show continuous growth. Hence they are put in constant use in food collection.

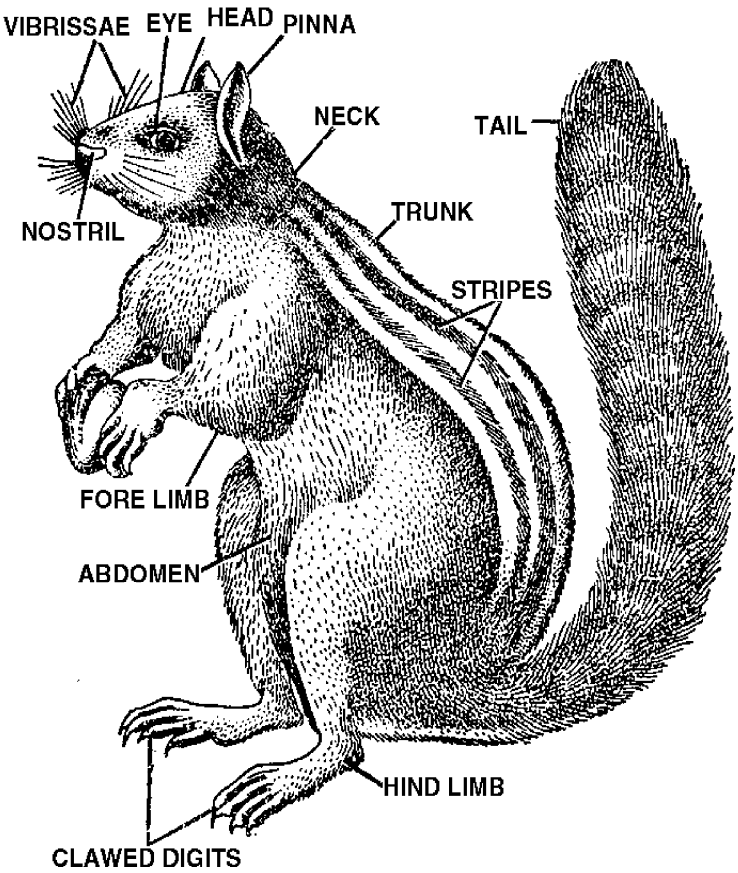


Fig. 72. Squirrel

(73) *DASYPUS*

GENERAL NAME: **ARMADILLO**

PHYLUM : CHORDATA
SUB.PHY : VERTEBRATA OR CRANIATA.
SUPER CLASS: GNATHOSTOMATA.
CLASS : MAMMALIA.
ORDER : EDENTATA.

- It is a small terrestrial burrowing mammal inhabiting Central and south America.
- Nocturnal organisms having bony armor.
- Body is divided into a head, a neck, a trunk and a tail.
- Head is small with an elongated snout having terminal nostrils.
- Body is covered by a hard and protective armor made of nine bands formed of bony plates and scales.
- The skin and hair present in between the plates is soft and smooth.
- Jaws are edentate (No teeth).
- Gestation period extends up to 18 weeks.

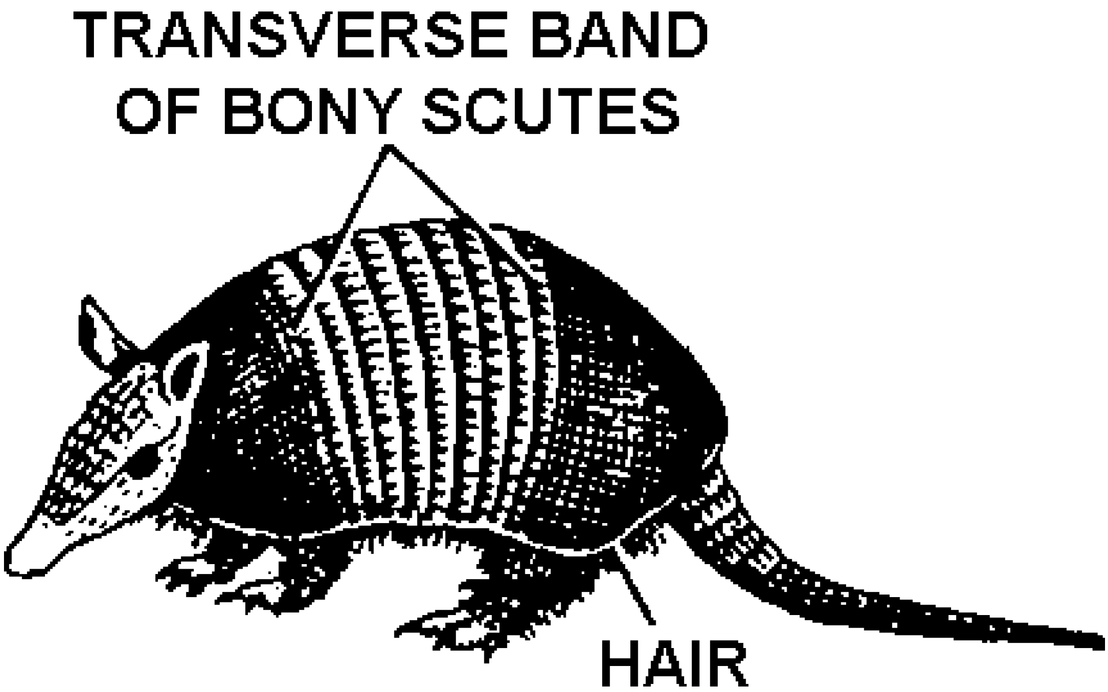


Fig. 73. Armadillo

(74) *MANIS*

General name: **PANGOLIN**

PHYLUM : CHORDATA
SUB.PHY : VERTEBRATA OR CRANIATA.
SUPER CLASS: GNATHOSTOMATA.
CLASS : MAMMALIA.
ORDER : PHOLIDATA.

- It is rarely seen in human habitations but is of common occurrence in forest areas, dense vegetations, grass lands and hilly areas of Africa, Australia, Sikkim, Nepal and India.
- It mainly feeds on ants and white ants.
- Body is divisible into an elongated head with snout, a short neck, a columnar trunk and a long tail.
- Head bears a pair of black eyes, a pair of nostrils at the tip of the snout and vibrissae.
- Elongated snout is used to collect the food material with the help of the sticky tongue.
- External ears are small and limbs are strong and pentadactyl with curved claw bearing digits.
- Entire body is covered by thick, flat and rhomboidal plates formed by the fusion of hair.
- Scales are arranged in a systematic fashion interspersed with hardened hair. Ventral surface is also covered by smooth and soft hair.
- They move very slowly on the substratum as if they are creeping.
- Internally, gizzard is seen in association with alimentary canal.
- When disturbed, the organism coils around itself in to a ball like structure to escape from the predators.

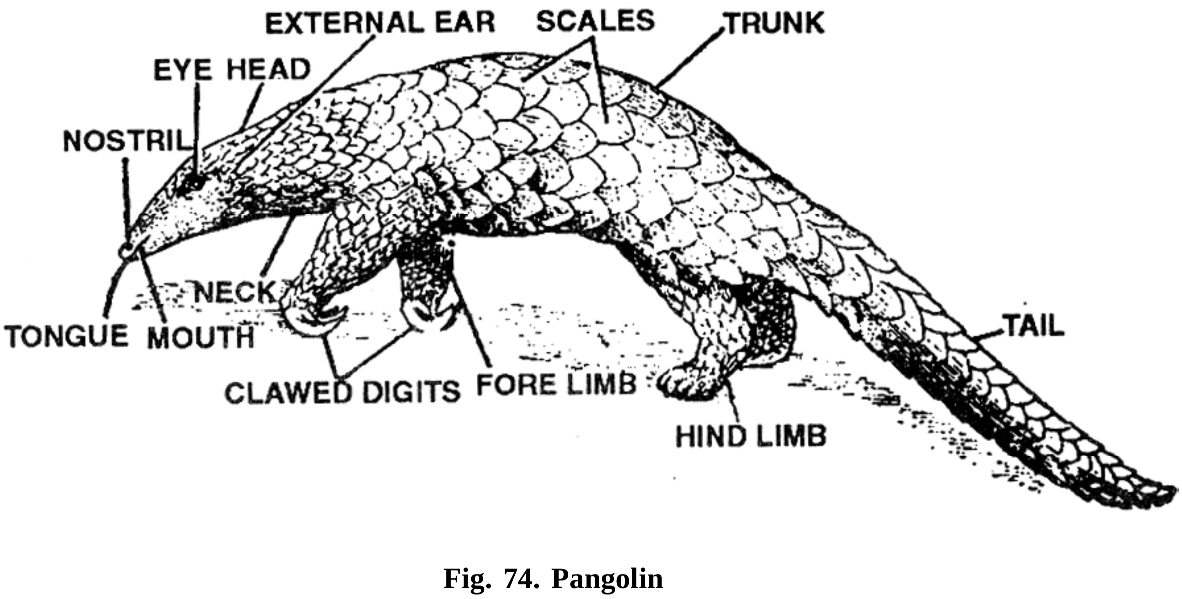


Fig. 74. Pangolin

(75) *MACACA MULLETTA*

General name: **RHESUS MONKEY**

PHYLUM : CHORDATA
SUB.PHY : VERTEBRATA OR CRANIATA.
SUPER CLASS: GNATHOSTOMATA.
CLASS : MAMMALIA.
ORDER : PRIMATA

- ❑ It is a old world monkey inhabiting the forests, dense plantations and human habitations in India, china and Vietnam.
- ❑ It is commonly called as Bander monkey.
- ❑ Head is large with a skull having larger volume.
- ❑ Nasal openings are surrounded by naked skin circles.
- ❑ Entire body is covered by light brownish soft hair.
- ❑ A pair of pouches are present at the base of the cheeks to store food material.
- ❑ External ear lobes are large and tail is long.
- ❑ It is seen frequently in human habitations and jumping from branch to branch over trees in gardens and forest areas.
- ❑ It is also grown as pet animals and trained for conducting some of the human activities.

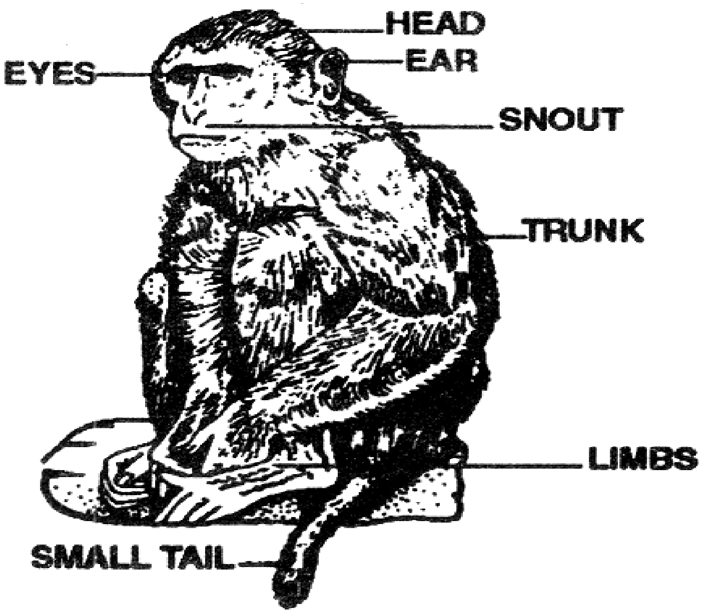


Fig. 75. Monkey

HISTOLOGY-SLIDES FROM MAMMALIA:

(76) T. S.KIDNEY

- The section through the kidney is almost bean shaped showing all the details.
- Outer most capsular covering of the kidney is made of connective tissue.
- The cavity of the kidney is occupied by cortex at the periphery and medulla at the centre.
- In the cortical protion ,lies the urinifeours tubules, glomeruli, Bowman cups and other related structures while in medulla lies the renal pyramids, medullary rays, Bertini tubules etc.,
- Hilus is the central deep notch on the surface of the kidney at whcih the blood vessels and ureters are arranged.
- Sections of the uriniferous tubules are seen in different shapes in the cortical region of the section. Those with ciliated cells are considered as proximal tubules, and with glandular cells are considered as distal tubules.Malpighian capsules are seen in between the cavities of these tubules. The glomeruli of these capsules are formed by the arterioles.
- Medullary region has the segments of the loops of Henle.
- In between these loops, sections of the collecting tubules, blood capillaries are seen.
- The main function of the medulla is to filter the excretory products from the blood reaching the kidney.

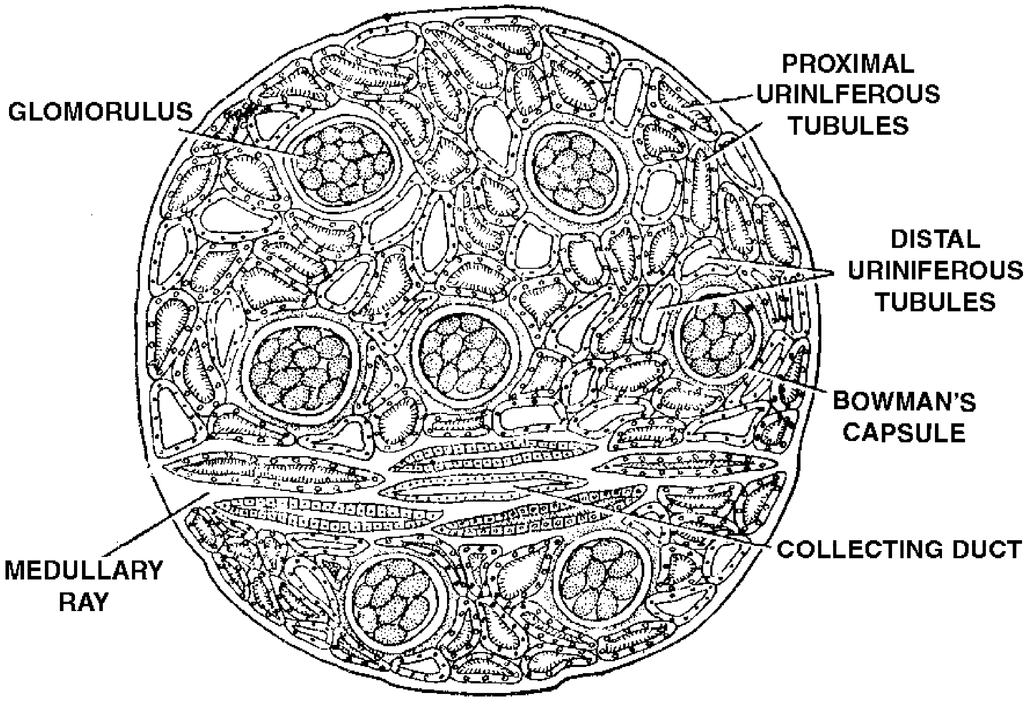


Fig . 76. T.S.Kidney

(77) T.S. TESTIS:

Capsular membrane surrounding the testis is the tunica albugemina.

Entire cavity of the testis is divided into a number of chambers by the seprate formed of intersticial cells.

Testosterone is the male hormone secreted by intersticial tissue.

Each chamber possesess a number of seminiferous tubules,

Germinal epthelium surrounds the seminiferouns tubule.

The cells divide by mitosis to produce spermatogonia.

Sperm mother cells then produced are released into the iumen of the tubule.

Large cells located in the septae are the sertoli cells of nutritive function.

The cavity of the tubule is loaded with primary spermatogonia, secondary spermatïgonia, spermatids and sperm cells.

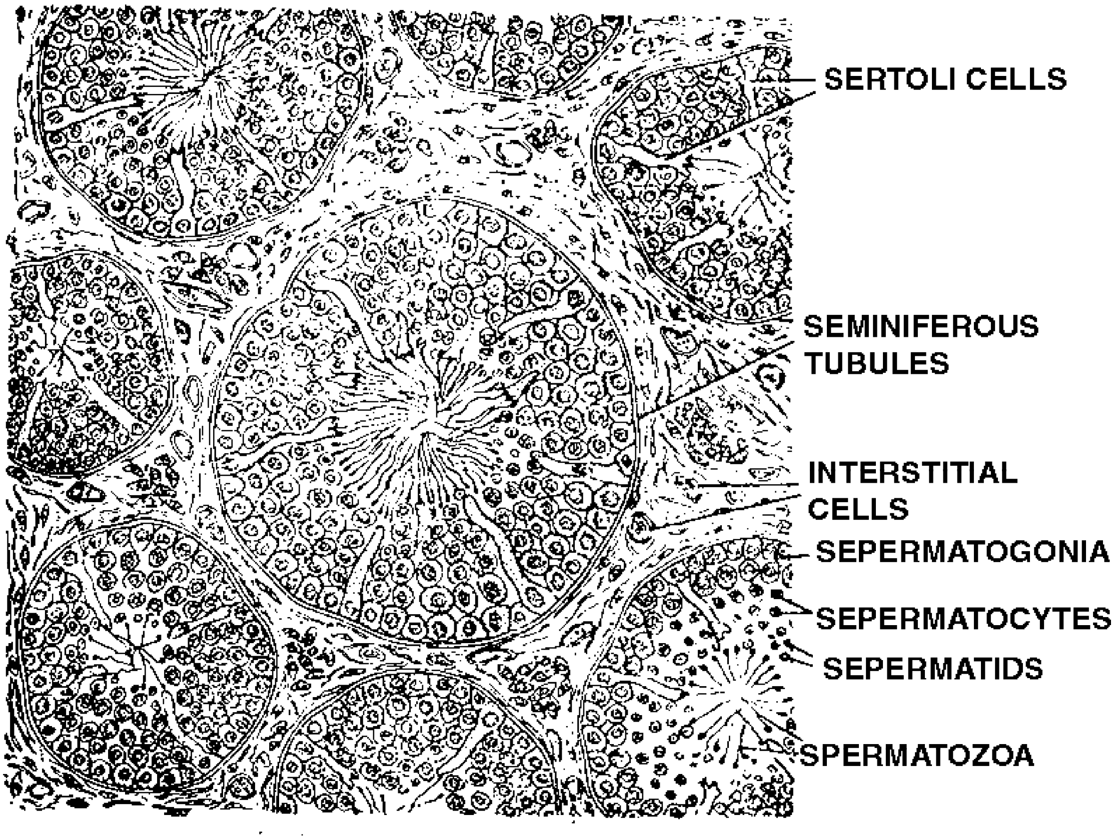


Fig . 77. T.S.Testis

78) T.S. OVARY:

Ovary is surrounded by a connective tissue membrane calïed tunica albugenia.

The cavfty of the ovary is fiïled with stroma composed of connective tissue and spindle cells.

Group of celIs entangled in the stroma tissue constitute follicles.

Each follicle is surrounded by nutritive eprithelium.

In the stroma primary oogonia, secondary oogonia, mature ova and blood capillaries canbe observed.

Follicular cells capable of developing into ova are formed from germinal epithelium.

In mammals, the mature follicie is called Graffian follicie. It is surrounded peripherally by cellular mass calïed cumulus oophorus.

Attached to cumulus oophorus is the ovum surrounded by a cavity called antrum.

Carpus leuteum is the yellow.mass of glandular tissue formed at the place of the release of ovum, secrating progesterone.

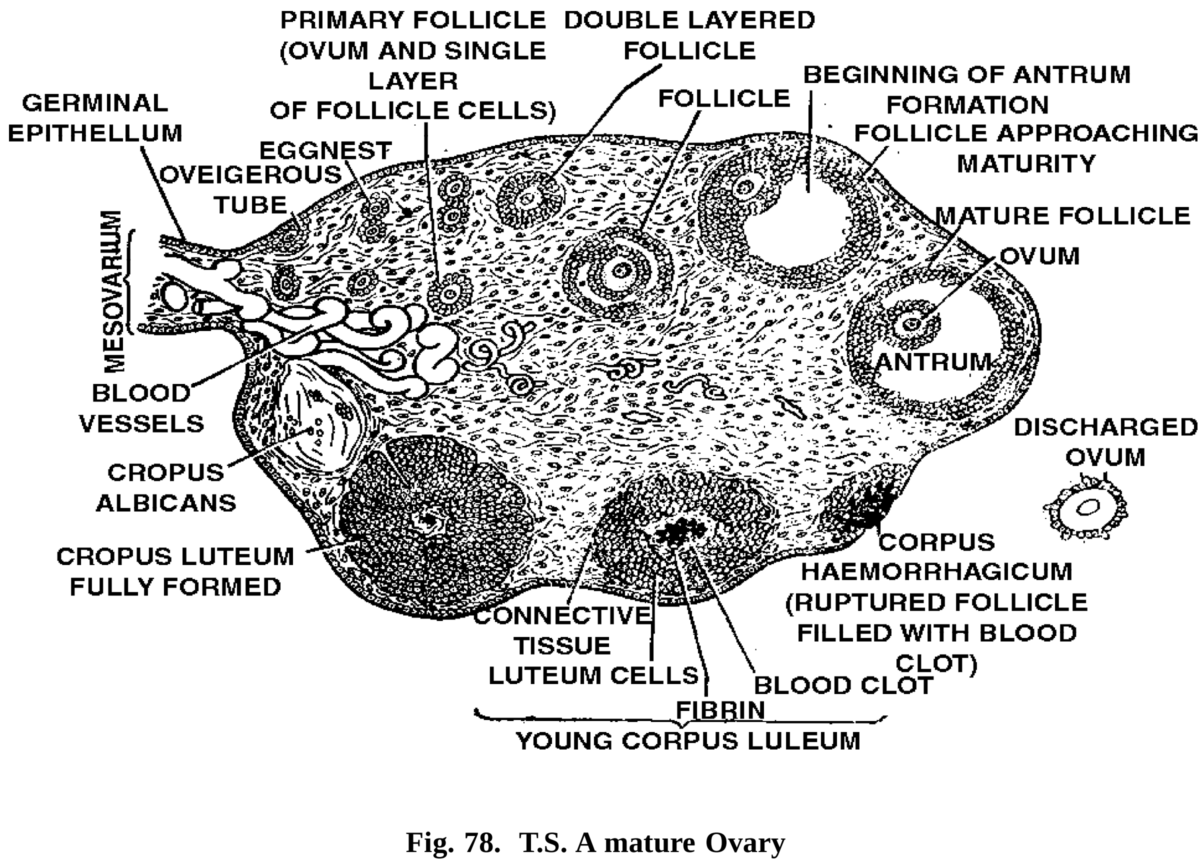


Fig. 78. T.S. A mature Ovary

79) T.S.LUNG :

Lungs are the spongy and soft lobes present in the ventral thoracic cavity.

Lungs are meant for respiration and orginated from endoderm.

The right lung is of three lobes while the left has only two.

The thin membrane surrounding the lung is the pleural peritoneum.

Section shows the wel! knit alveoli surrounded by simple epithelium.

Sections of tracheoles, pulmonary arterioles, pulmonary venules are also seen.

The wall of the alveloli is bathed in a thin layer of blood oozing from the blood capillaries.

Sections of trachea surrounded by citiated epithelium are also seen.

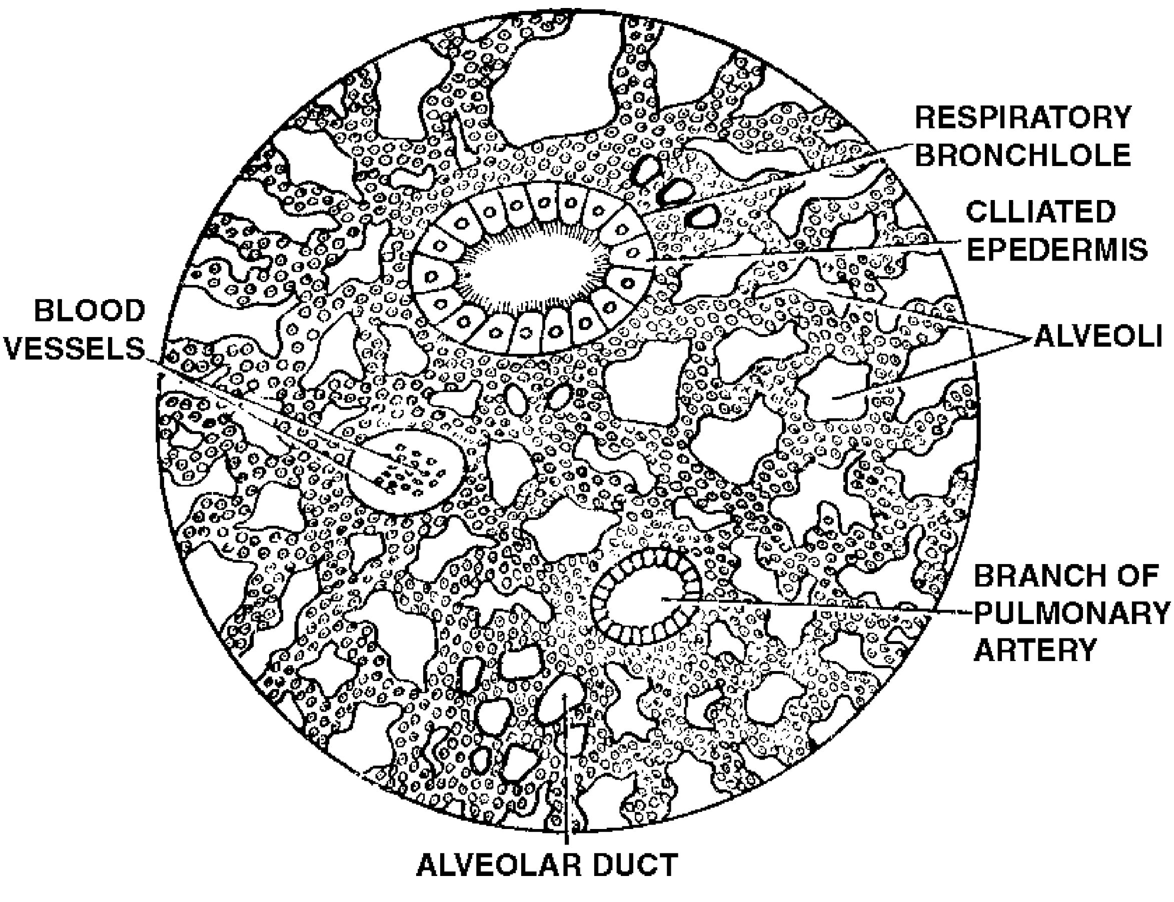


Fig 79. T.S.Lung

(80) T.S. SPINAL CORD:

SPINAL CORD IS A TUBULAR ONE PRESENT ON THE MID DORSAL SIDE OF THE BODY EXTENDING FROM ANTERIOR TO THE POSTERIOR END.

It is a component of the central nervous system.

It is the posterior extension of the medulla oblongata.

Spinal cord is formed from ectoderm.

It has a central spinal canal surrounded by gray matter and white matter.

White matter is composed of medullated nerve fibres while the gray matter is composed of neurons.

The nerve cells of the Gray matter are drawn out as dorsal and ventral horns. They contribute for the formation of spinal nerves.

Spinal cord is surrounded by three connective tissue membranes viz,, inner most piamater, outer dura mater and in between an arachnoid membrane.

Spinal cord regulates all the unvoluntary activites of the body.

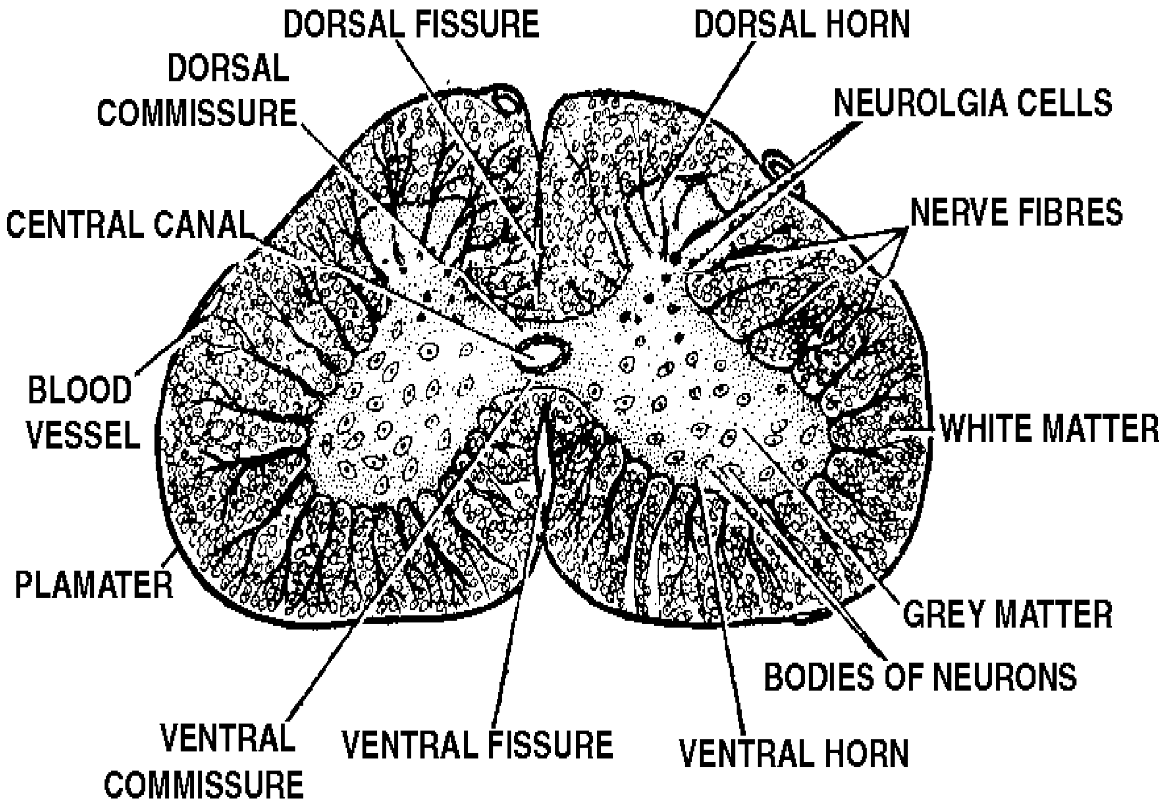


Fig. 80. T.S. Spinal cord

81) T.S.BONE:

Bones are the solid strong supporting structures of the body giving protection to the internal organs.

Bone is surrounded by a hard connective tissue membrane called periosteum.

Internally the bone cavity is lined by endosteum. The bone cavity is filled with bone marrow.

Bone proper in its section contains hard matrix composed of osseon, a hard protein.

Matrix is interspersed by a number of structural units called osteons.

Each osteon has a central haversian canal surrounded by osteocytes arranged in concentric whorls.

The branched canaliculi around the osteocytes connect the cells with each other.

The whorl around the canaliculi are formed of the lamellae of the matrix. These are called intermediate lamellae.

The vertical haversian canals are interconnected by transverse volkman canals. Bones are of two types viz. the rod like compact bones and plate like dermal bones.

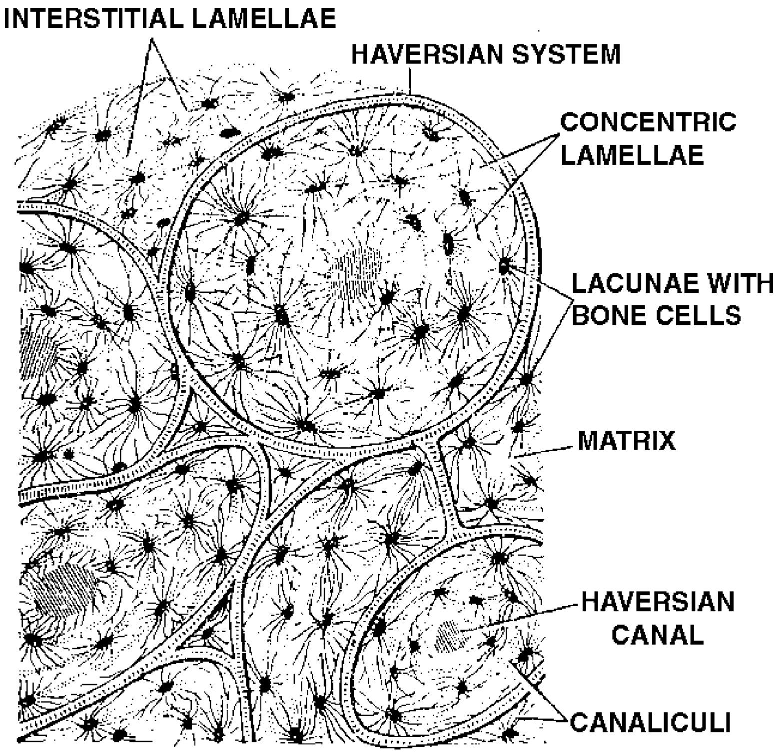


Fig. 81. T.S. Bone

(82) T.S.CARTILAGE:

Cartilage is the soft bone having flexibility.

These supporting elements are seen in external ear pinnae and nose.

In transverse section, cartilage is encircled at its peniphey by connective tissue membrane cal led perichondrium.

Central part is filled with gelatinous matrix containing chondrin as its principal protein component.

A number of vacules are present in the matrix.

Just beneath the perichondrium, chondroblast celïs are arranged in annular layers.

Hondroblasts divide mitotically to produce free condrocyte cells into the matrix.

Chondrocytes are arranged in pairs inside the vacuoles.

As the Chondrocytes are growing, the flmid filled vacutes are formed around them.

Cartilage is of three types:

(a) Hyaline cartilage or **Gristle:** Transparant one having light bluish colour. Matrix possess a number of fine filaments.

Ex: Tracheal tubes & Ends of the bones.

(b) Elastic cartilage: Matrix contain a number of yeollw fibres. It is flexible and elastic in nature. Ex. tip of the nose and epiglttis

(c) Fibrous cartilage: Matrix possesses parauelly arranged white fibrils, slightly flexible ex:: Inter vertebral discs.

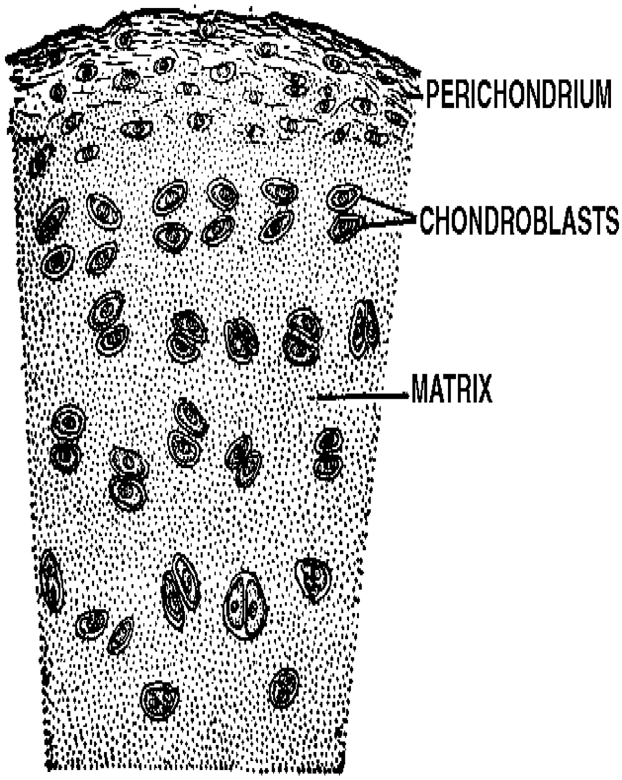


Fig. 82 : T.S. Cartilage

(83) T.S.ARTERY:

Circulatory system is responsible for the transport of materials in the body.
Arteries are meant for distribution of blood to different parts of the body.
They are the Thick walled, muscular tubes innervating all the body systems through their capillary net work.
Lumen of the artery is less considered to that of vein.
Arteries are non-valvular having theca externa (tumica adventitia) , theca intermedia (tumica media) and theca interna as (tumica intima) the components of the wall.
Theca externa is composed of connective tissue layer with elastic nature.
Theca media has muscle cells and elastic tissue as its components.
Theca interna is a unilaminar endothelium.
Blood pressure in the arteries is regulated by sympathelic nerves.

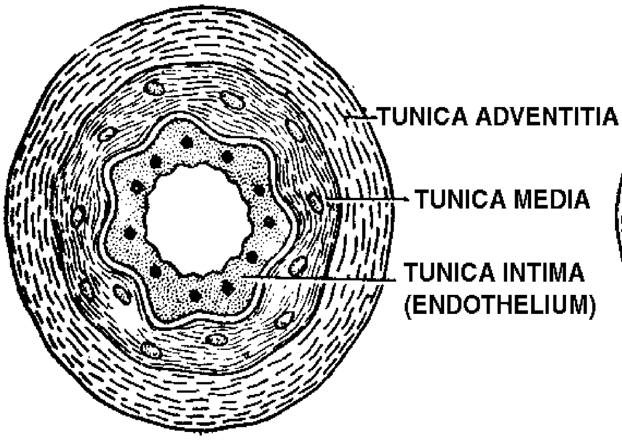


Fig. 83 T.S. Artery

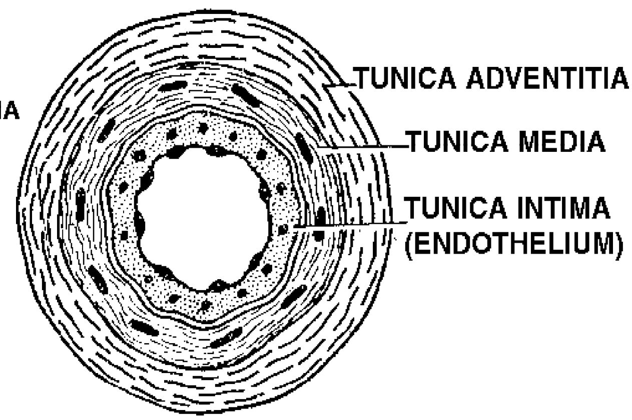


Fig. 84. T.S. Vein

(84) T.S. VEIN:

Veins are the thin walled blood vessel collecting blood from various organs

They are non muscular, non pulsatile.

Blood flows at low pressure in veins.

The outer *wall is* the theca externa composed of connective tissue with white fibres.

Theca media has elastic fibres but the muscle components are poor.

Theca interna is formed of endothelium. Lumen of the vein is wide compared to that of the artery.
Sympathetic nerve fibres are distributed in the middle layer.

(85) V.S.SKIN:

It is the limiting membrane of the body protecting the inner organs.

It is highly sensitive as it has tactile sensory cells.

Skin is composed of hvo layers viz. the epidermis and dermis.

Sweat glands, sebum glands of the skin keep it smooth and soft besides regulating body temperature.

Epidermis is further composed of an outer most corneal layer having horney substance. lts cells peal, off frequently.

lts inner layer is the stratum lucidum involved in renewing the corneal layer.

Lucidum is followed by stratum granulosum composed of granular cells and stratum germinativum having live cells to regenerate the upper layers.

Dermis is composed of stratum spongiosum habouring vacuolar cells, blood capillaries, muscle components, glands, nerve endings cetr.

Inner most layer of the skin is the stratum compactum formed of closely arranged cells.

Skin of mammals is specially provided with hair and giands.

Root of the hair is located in the root follicle present in stratum spongiosum.

Erector muscles of the spongiosum are responsible for the movement of the hair.

Pseudorific glands are the alveolar glands responsible for keeping the skin smooth and soft. :

Sweat glands are the long and coiled tubular gïands keeping the skin moist besides regulating : the body temperature and sending out some excretory substances.

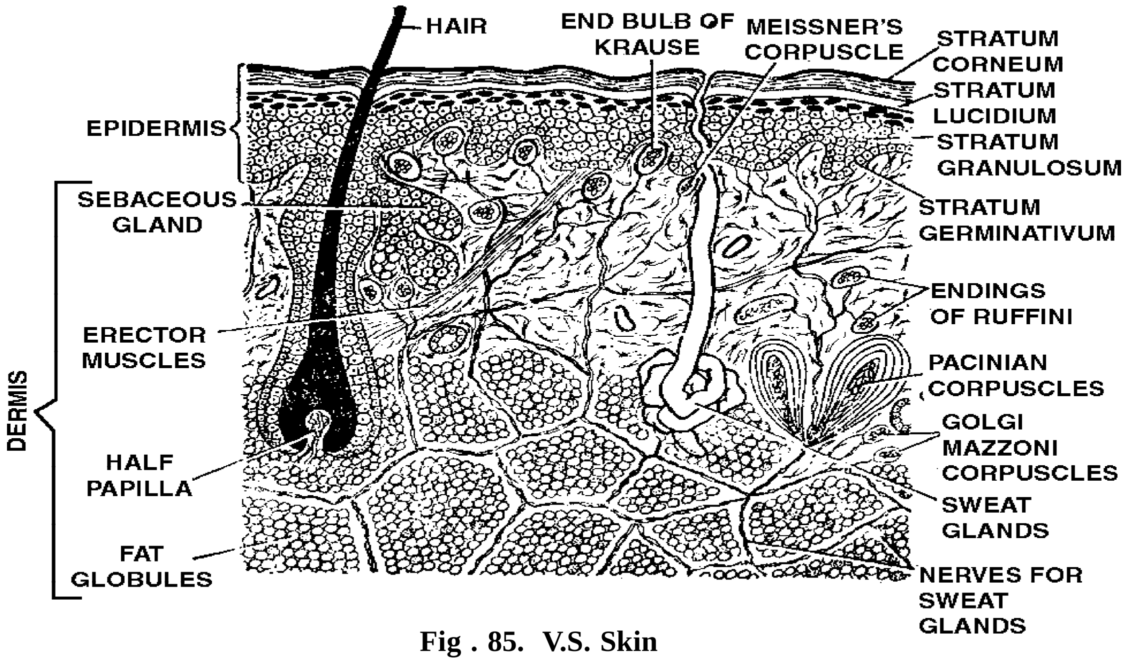


Fig . 85. V.S. Skin

(86) MAMMAL BLOOD FILM:

Intestine is the longest component of the alimentary canal.

It is a tubular one with narrow lumen and plenty of digestive glands releasing enzymes for digestion.

Intestinal wall is composed of an outer serosa, followed by muscular layer, submucosa, mucosa muscularis and inner most mucosa.

Serosa is formed of squamous epithelium whilethe mucosa is composed of columnar epithelium.

Muscle layer is composed of an outer longitudinal and inner circular muscle components. Their contractions help in moving the food in intestinal cavity.

Submucosa has connective tissue, biood capilaries and nerve endings. Mucosa muscularis is composed of thin muscle units arranged in two layers.

Mucosa is composed of Columnar cells. This layer form a number of folds called villi containing blood capillaries, lymph vessels and lymphocytes.

Leiberkuhn crypts are the glandular follicles present at the base of the villi. They form into Brunner's glands and secrete intestinal juices collectively forming into, succus entericus.

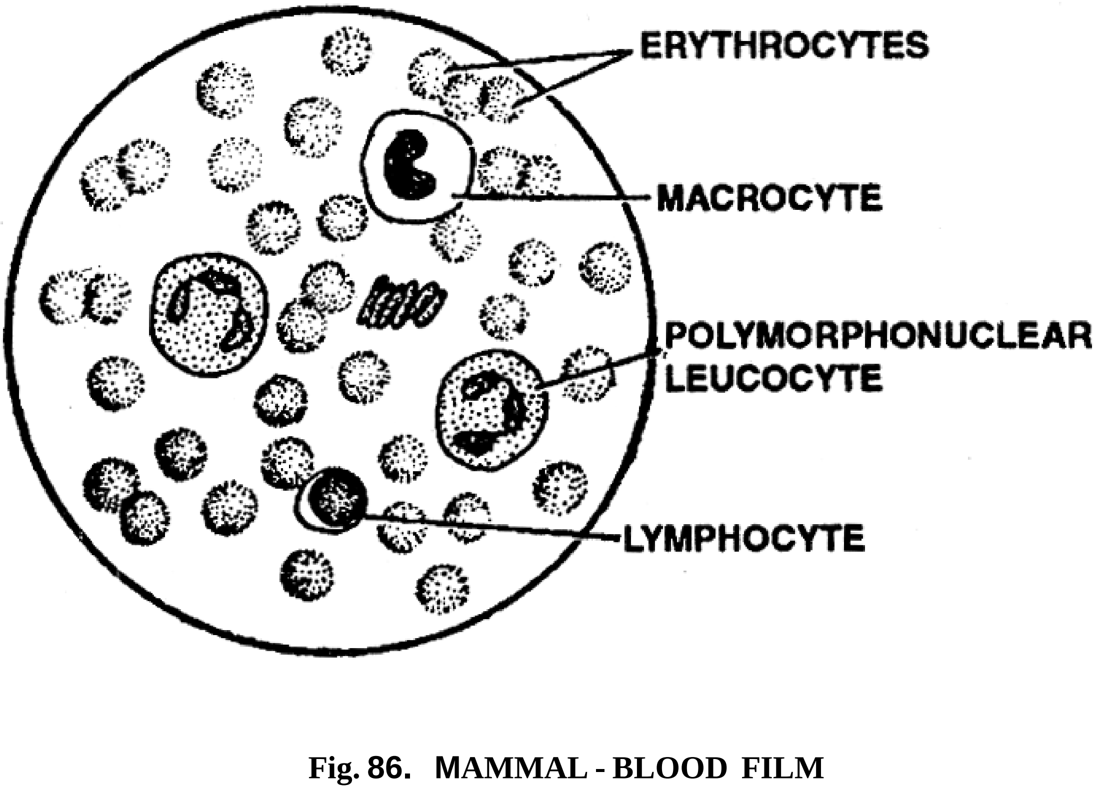


Fig. 86. MAMMAL - BLOOD FILM

(87) T.S.STOMACH:

It is the component of the alimentary canal helping to store and digest the food materials.

Wall of the stomach is composed of an outer serosa and inner mucosa. In between thetwo, mus'cular layer, submucosa and mucosa muscularis are present.

Serosa is composed of squamous epithelium while the inner most mucosa is composed of columnar epithelium.

Muscle layer is composed of an outer longitudinal and inner circular muscles. Their contractions are responsible for the peristalytïc movements to increase or decrease the lumen.

These muscles are held by connective tissue layers. Submucosa has connective tissue, blood capillaries and nerve endings. Mucosa muscularis also possess muscle cells arranged in two layers. Mucosa is thick and cells are columnar possessing tubular and gastric glands.

Oxyntic cells of the gastric glands secrate dil. Hydrochloric acid. Pepticcells secrete digestive enzymes.

Tubular glands secrete mucous material necesary for the supply of water for digestion.

Inner wall of the stomach is highly folded and the folds are called ruge . They increase the area of the stomach.

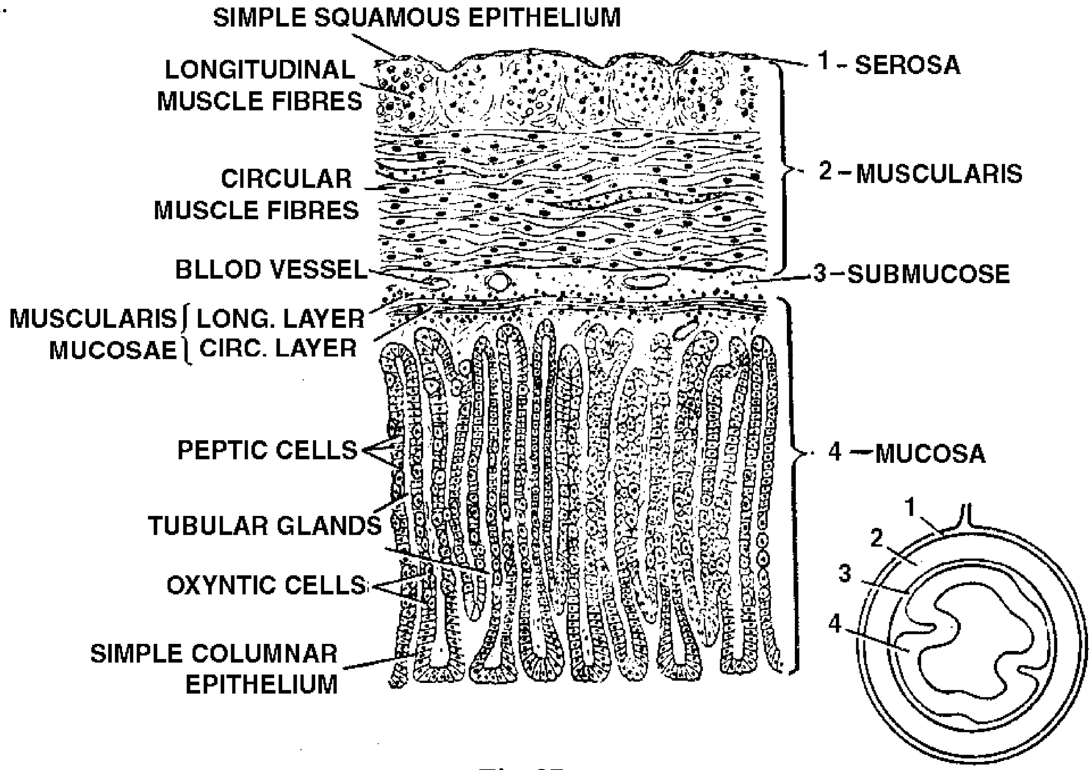


Fig. 87: T.S. Stomach

88) T.S.INTESTINE:

Intestine is the longest component of the alimentary canal.

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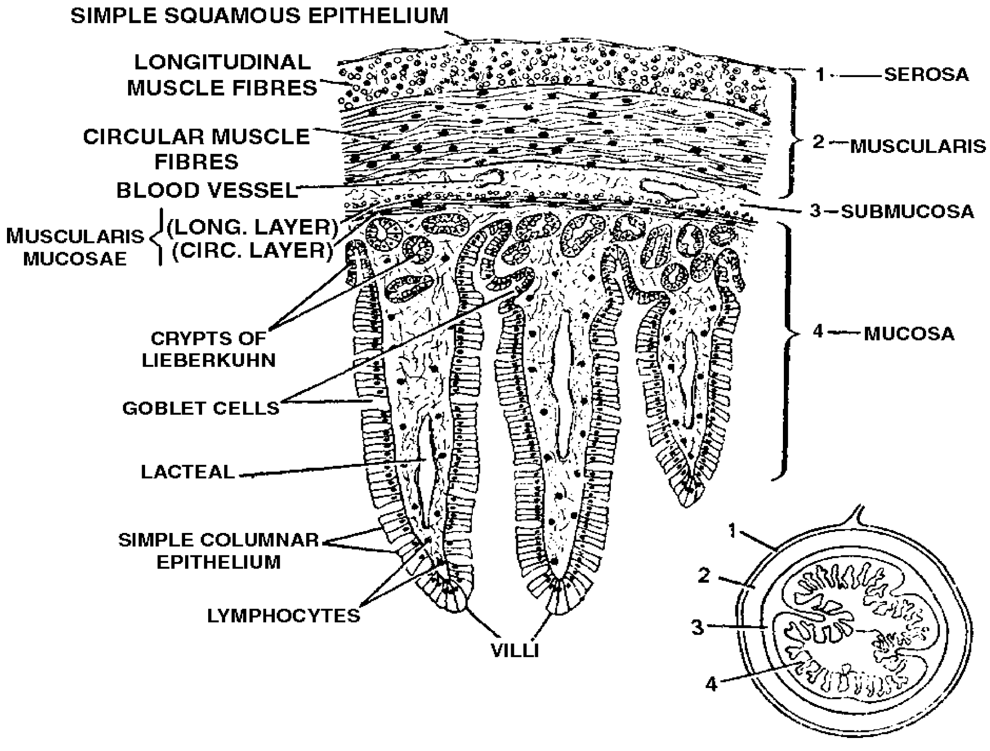


Fig . 88. T.s. Intestine

(89) T.S. T.S.PANCREAS:

One of the important digestive gland associated with intestine is the pancreas. It is of both exocrine (enzymatic) and endocrine (hormonaJ) in nature.

The gland is alveorar, spongy and is composed of a number of lobules called acini, Hence it is called acinar gland or alveolar gïand.

Each acini is composed of acinar cells responsible for secreting digestive enzymes such as steapsin, amylopsing and trypsin.

Group of cells present inbetween the acinar lobes are the islets of langer hans.

Each isJand is composed of two types of cells viz. The a cells secretiry glucogon and p -cells jecretiy insulin.

Phe hormones are reïeased directly into blood.

They help in regulating blood-glucose level in the body. Hence the gland is called a sweet read.

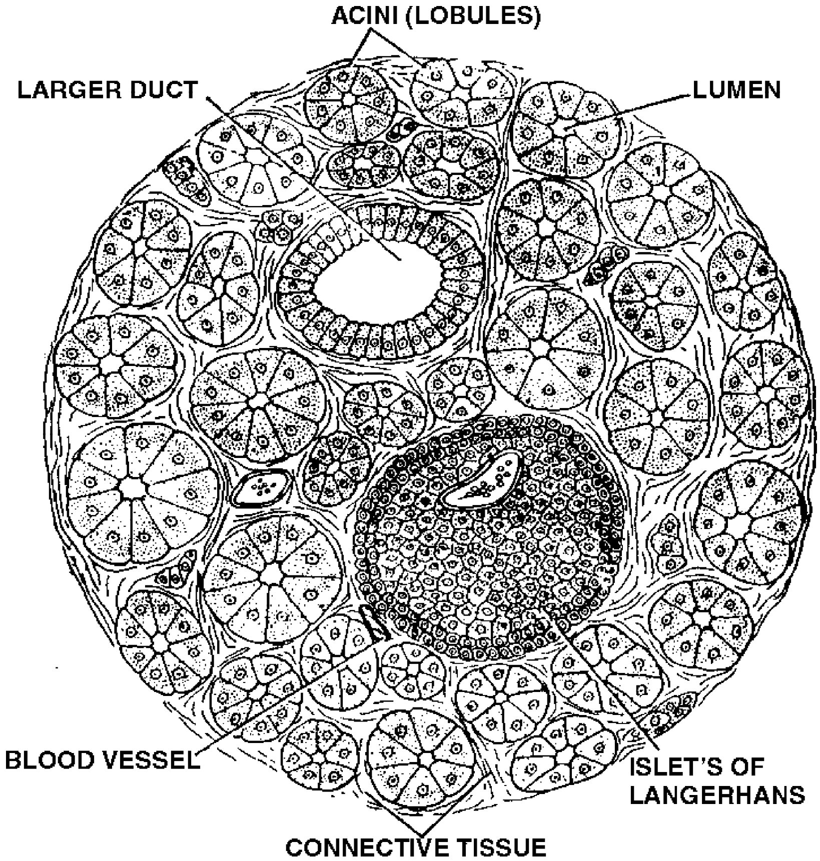


Fig . 89. T.S. Pancreas

(90) T.S. LIVER:

Liver is the largest gland of the body, associated with alimentary canal.

It is a brownish lobular gland composed of a number of hexagonal glisson capsules.

Centrally arrangeed vacuoles enclosing interlobular veins are present in between the capsules.

Each capsule encloses a number of radially arranged fine filaments called hepatic cords. Each filament is composed of a number of serially arranged poiygonal hepatic cells.

Hepatic cords are concerned with the production of bilejuice. Bile is alkaline in

nature and helps in the emulsification of the fats.

Liver is concerned with the production of excretory products, detoxification of toxic substances and in distribution of digested food materials.

It also helps in storing reserve food materials in the form of glycogen.

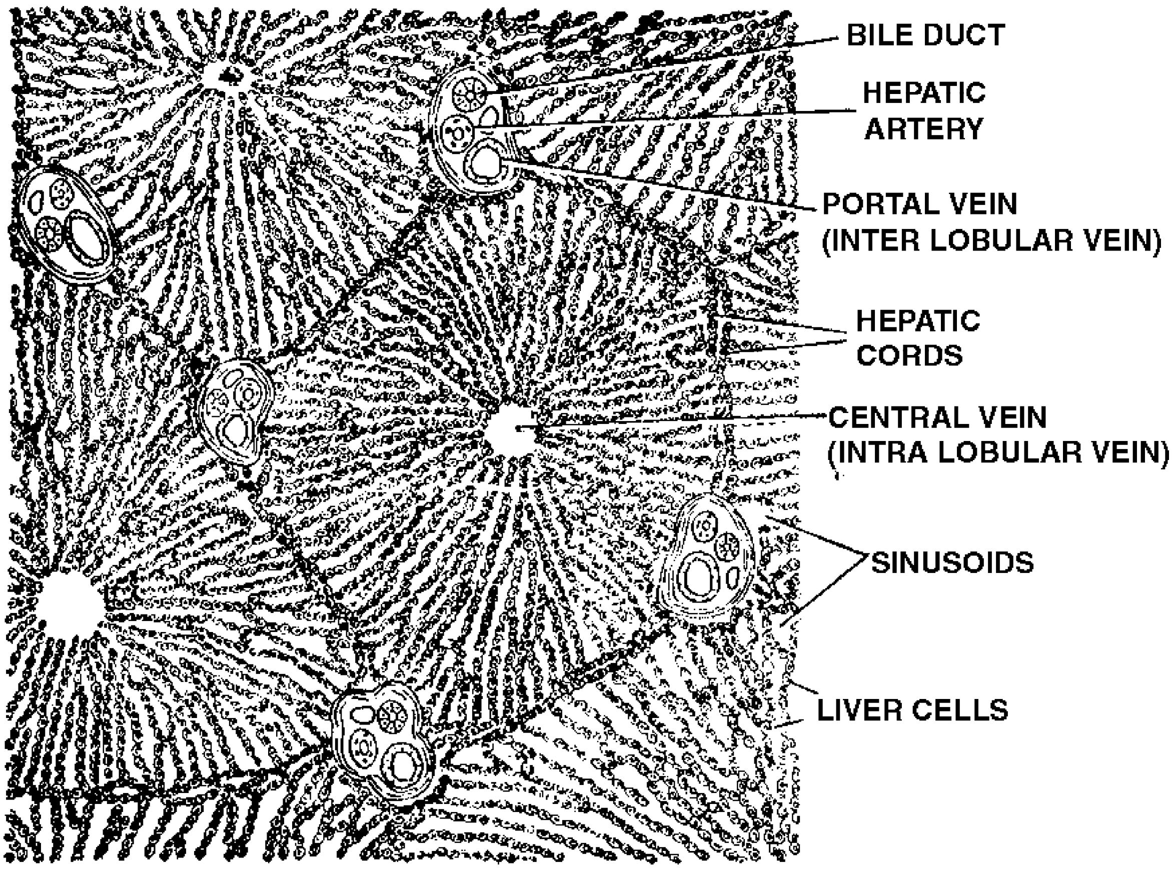


Fig . 90. T.S. Liver

EMBRYOLOGY:

(91) 18H. CHICK EMBRYO:

- Fertilization is internal and development is external as the organisms are oviparous in nature.
- Heat required for the development of the egg is provided by the mother bird during incubation.
- Development up to 24h.occurs in the oviduct itself.
- By 18h. entire surface of the embryo is composed of epiblast.
- Embryo is seen as a blastoderm in the form of a disc over the yolk material.
- The central part of the blastodisc has separated from the yolk forming into a central, transparent, multilaminar area called area pellucida
- Peripheral portion of the embryo is the area opaca, a non-transparent cellular layer in close association with the underlying yolk material.
- The central fold of epiblast having a deep groove is the primitive groove.
- The two lips on either side of the groove are the primitive folds.
- A shallow depression at the anterior end of the primitive groove is the primitive pit.
- Dense mass of cells in front of the primitive pit constitute the Hensen's node or primitive node.
- Cells involuting through the primitive pit trans forms into notochord and through the primitive groove forms into mesoderm in between .
- Epiblast cells covering the mesoderm form the ectoderm.
- Epiblast lying over the notochord develop into a neural plate.

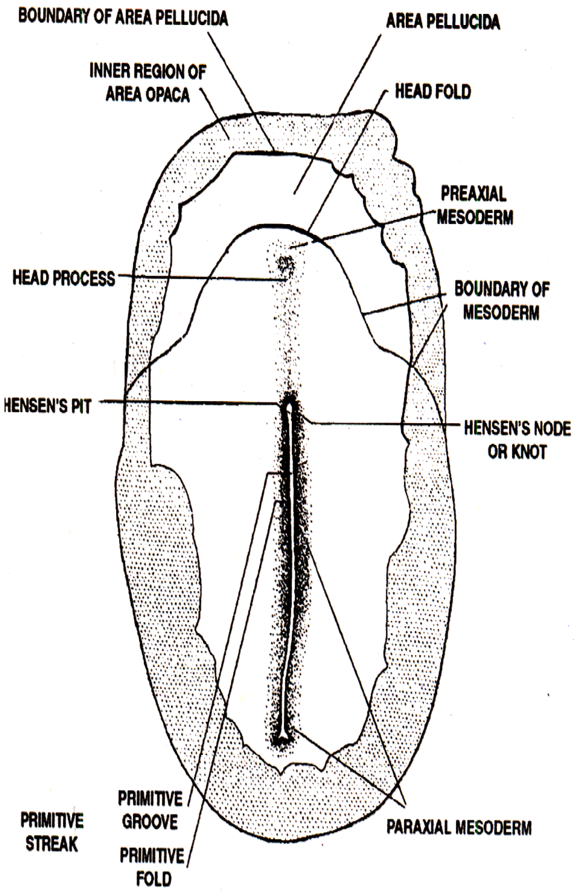


Fig. 91. 18 h. Chick Embryo

(92) 24H CHICK EMBRYO:

- ❑ Fertilization is internal and development is external as the organisms are oviparous in nature.
- ❑ Heat required for the development of the egg is provided by the mother bird during incubation.
- ❑ Development up to 24h. occurs in the oviduct itself.
- ❑ Primitive pit slowly regresses and hence is seen at the centre of the embryonic disc.
- ❑ Primitive groove extends to the tip of the embryo at the posterior end.
- ❑ Neural folds appear and grow over the neural plate enclosing the neural groove.
- ❑ Notochord is exactly situated just below the Neural plate and in front of the primitive pit.
- ❑ Mesoderm formed from the involuted cells of the epiblast is differentiated into somitic, intermediate and lateral mesoderms..
- ❑ Formation of the mesodermal somites is initiated at 20h. of incubation. from the somitic component of the mesoderm.
- ❑ By 24h. four to five pairs of mesodermal somites are formed in the embryo.
- ❑ Up grown neural folds fuse middorsally to form the neural tube opening out through anterior neuropore. The epiblast along with the anterior neural tube lifts up to form the head lobe.
- ❑ Deep notch between the head lobe and the underlying yolk material is the subcephalic pocket.
- ❑ Because of the separation of the neural tube from the epiblast, the upper most layer is called the ectoderm.
- ❑ Along with the neural plate, the endoderm also lifts up to contribute to the formation of the foregut. The opening between the fore gut and the yolk is the anterior intestinal portal.
- ❑ Primary heart is formed as a horse shoe shaped tube from the fusion of the amniocardiac vesicles.
- ❑ Groups of cells forming into blood islands can be seen in the opaca region.

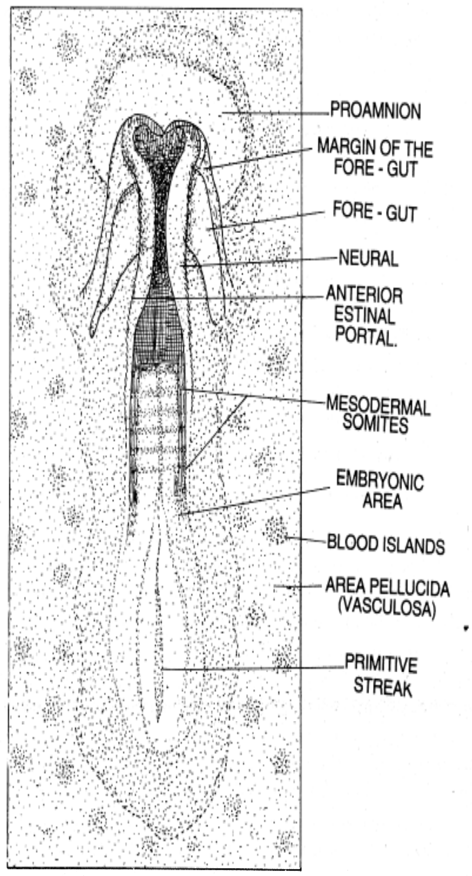


Fig. 92. 24h. Chick Embryo

(93) 33H CHICK EMBRYO:

- Fertilization is internal and development is external as the organisms are oviparous in nature.
- Heat required for the development of the egg is provided by the mother bird during incubation.
- Development up to 24h.occurs in the oviduct itself.
- 33h. embryo is identified by the presence of a ‘T’ shaped anterior brain region.
- The neural tube undergoes segmentation forming into eleven neuromeres.First thre unite to form the forebrain, next two to form the midbrain, and last six to form the hind brain.
- Fore brain extends laterally to form two bulb like sacs called optic vesicles.
- Hensen’s node and pit regresses back to remain as a mass of cells at the posteior end.
- Neural folds expand around the pit forming sinus rhomboidalis.
- Anterior end of the primitive heart is forked into the ventral aortae.They extend along the foregut, takea loop and grows back as dorsal aortae to the posterior end and spreads over the yolk as omphalomesenteric arteries.
- Posteriorly, the sinus venosus of the hear divides and expands over the yolk as omphalomesenteric veins.
- 13 to 14 pairs of somites are formed fro the mesoderm on either side of the body.
- Auditory placode appears as a thickened cell plate at the 11 neuromere region.

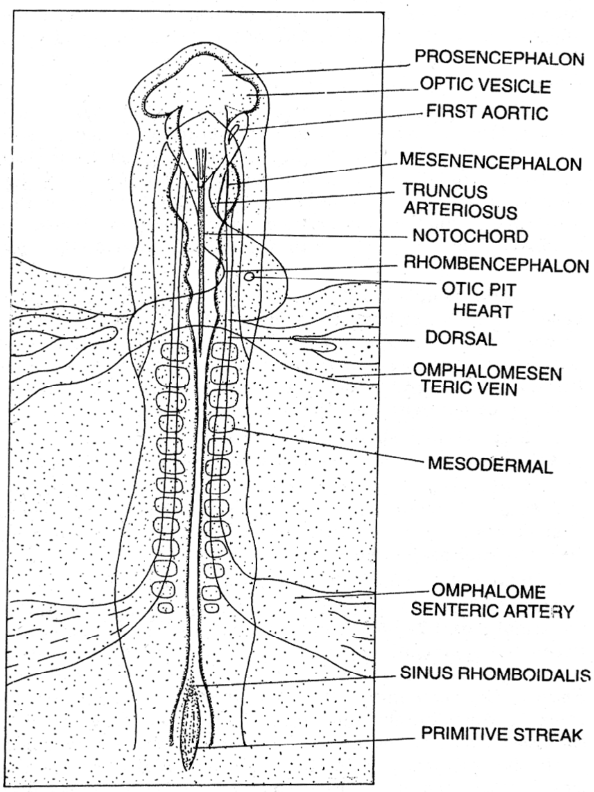


Fig. 93. 33h. Chick Embryo.

(94) 48H. CHICK EMBRYO:

- Anterior end of the embryo undergoes torsion and hence has lost its symmetry while the posterior end shows bilateral symmetry.
- Cranial and cervical flexures in the embryo makes prosencephalon to bend and lie at 90^0 to the mesencephalon and the nerve cord takes a deep curvature at the neck region.
- Twenty eight pairs of somites are formed.
- Endoderm extends into the head fold as foregut and into the tail fold as hindgut. Endoderm of the fore and hind guts comes near to the ectoderm to form oral and anal palates.
- Horse shoe shaped heart also undergoes flexion resulting in the shift of posterior atrium over to the ventricle.
- Three pairs of aortic arches are formed between the dorsal and ventral aortae.
- Omphalomesenteric veins forming from the blood c sac open into the sinus venosus. The dorsal aortae unite behind the last pair of gill slits and passes back as a single aorta and finally divide to spread over the yolk sac as omphalo mesenteric veins.
- Simultaneously anterior and posterior cardinals are formed and open into the sinus venosus.
- Outer layer of the optic vesicles invaginate into the opticoel to form the optic cup. Ectoderm present over the optic cup transforms into a lens placode. This invaginates and fits into the optic cup as lens vesicle.
- Pronephros is formed as a solid rod from the intermediate mesoderm.
- Intermediate mesoderm of the last somite region form into tubular mesonephric ducts.
- Head amniotic fold is formed from the somatopleure at the anterior end covering the head and growing towards posterior end.
- Yolk sac and Allantois are formed from the hindgut region at the posterior end of the embryo.
- Three pairs of gill pouches are formed from the pharyngeal region. First gill pouch fuses with ectodermal invagination to form the first gill slit i.e. the spiracle.

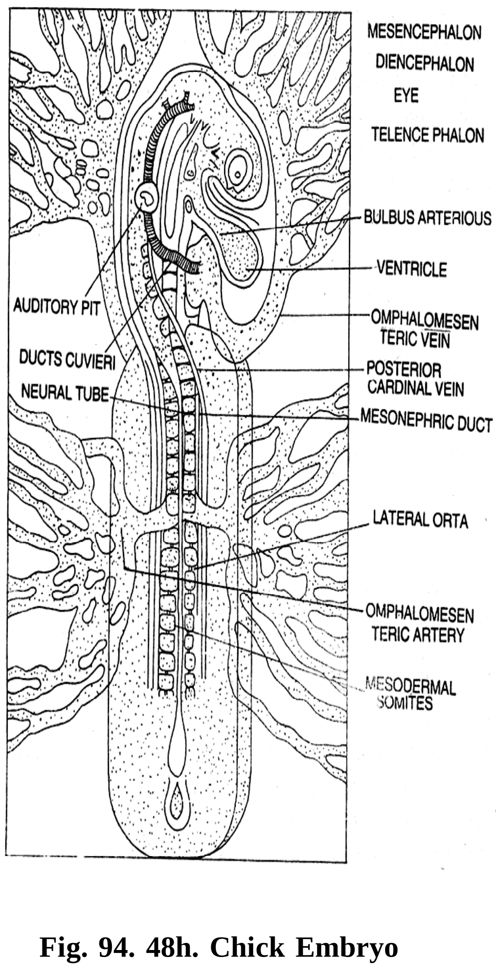


Fig. 94. 48h. Chick Embryo

95) T.S. CHICK EMBRYO THROUGH EYE:

- The section is ovoid in shape
- In section, dorsal margin is lined by somatopleure and the ventral margin towards yolk by splanchnopleure.
- Ectoderm an endoderm layers are unilaminar in nature.
- Sections of the amnion and serosa are visible because of their appearance in 48h. of incubation.
- The lateral sides of the prosencephalon grow into large optic vesicles.
- Outer margin of the vesicles invaginate into the cavity of the optic vesicles resulting in the formation of optic cups.
- Ectoderm near to the optic cup becomes thickened to form the lens primordium.
- Lens primordium also invaginates and fits into the opening of the optic cup resulting in the formation of lens vesicle.
- Section of the myelencephalon is also visible beneath the section of the prosencephalon.
- In between the sections of the prosen and myelen cephalic sections, foregut and Ratke's pocket also make their appearance.
- All the cavities of the brain are filled with Cerebrospinal fluid.

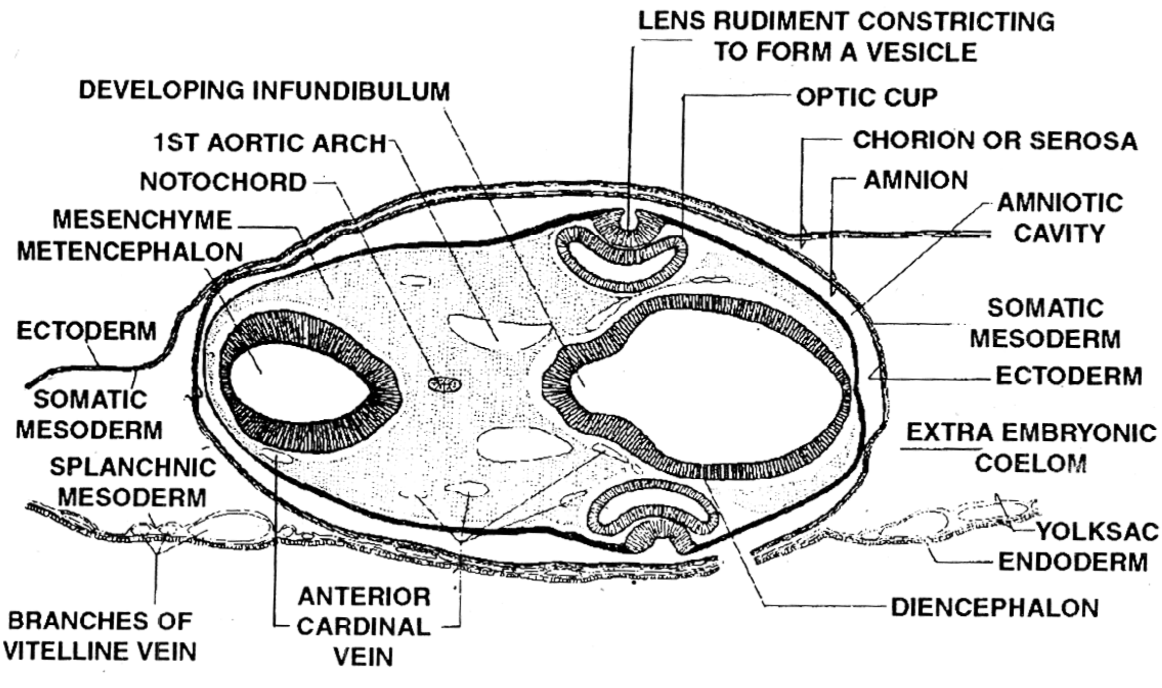


Fig. 95. T.S. Chick Embryo through Eye

(96) T.S. CHICK EMBRYO THROUGH EAR:

- Ear primordia appear in 33h. of incubation and their formation is completed by 96h.
- These are visible on either side of the myelencephalon
- In section, dorsal margin is lined by somatopleure and the ventral margin towards yolk by splanchnopleure.
- Ectoderm and endoderm layers are unilaminar in nature.
- Head fold is covered by anterior amniotic fold.
- Auditory primordia are seen as two vesicles in the myelencephalic region.
- Auditory or otic capsules take their origin from ectoderm and becomes internal subsequently.
- Besides otic capsules, secions of myelen cephalon, prosencephalon, blood vessels, spinal cord also are visible in the slide.

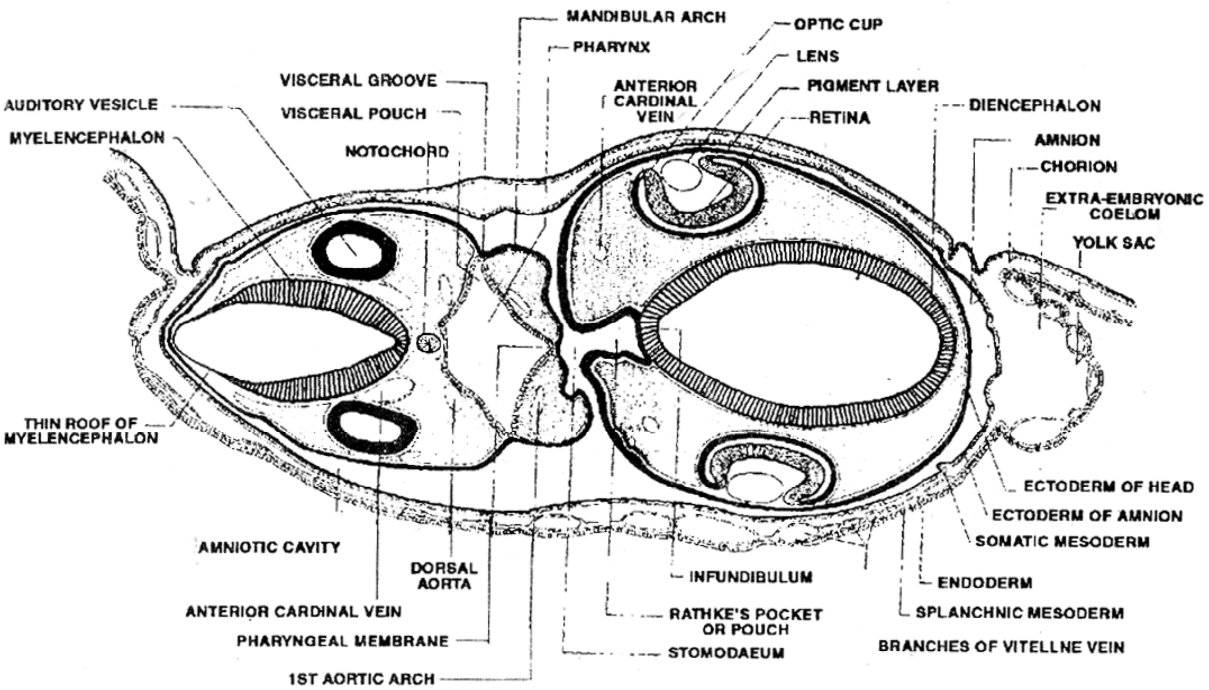


Fig. 96. T.S. Chick Embryo through Ear

(97) T.S. CHICK EMBRYO THROUGH HEART:

- In section, dorsal margin is lined by somatopleure and the ventral margin towards yolk by splanchnopleure.
- Ectoderm an endoderm layers are unilaminar in nature.
- Heart primordia appear at the region of the anterior intestinal portal and unite into a single heart vesicle only after the completion of the formation of foregut.
- Hence in the section, heart vesicle is visible as an attachment on the ventral side of the foregut by a mesodermal mesentery.
- The wall of the heart vesicle is composed of epimyocardium and endocardium
- The cavity of the heart is filled with red blood cells.
- Formation of the heart is completed by 72 or 96h. of incubation. Hence it fits into the space between the prosen and myelencephalic regions.
- The transverse section also includes the sections of the brain, blood vessels, notochord, pharynx etc.,

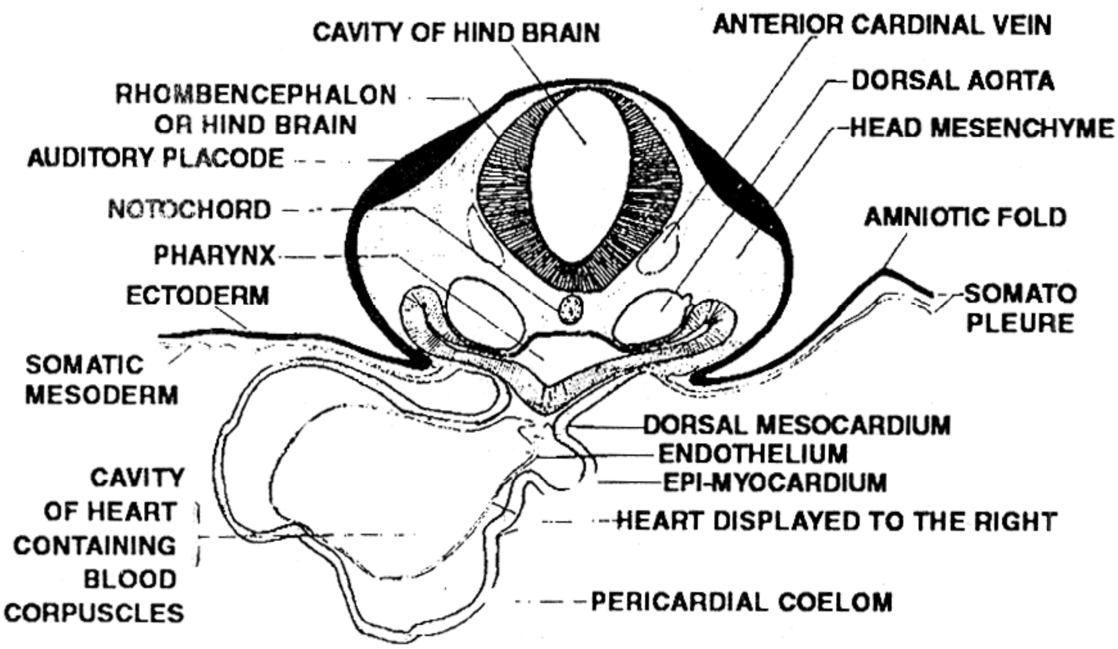


Fig. 97. T.S. Chick Embryo through Heart

(98) T.S. CHICK EMBRYO THROUGH BRAIN:

- Brain starts its appearance as a primordium in 28h. embryo. Formation of all the components of the brain is completed by 72h. of incubation.
- In section, dorsal margin is lined by somatopleure and the ventral margin towards yolk by splanchnopleure.
- Ectoderm an endoderm layers are unilaminar in nature.
- Sections of the prosencephalon and myelencephalon are clearly visible.
- The cavity of the prosencephalon is the paracoel or the first ventricle while that of the myelencephalon is the fourth ventricle.
- Optic vesicles are visible forming from the lateral sides of the embryo.
- brain components take their origin from the ectoderm.
- Depending upon the region of the section, optic and otic vesicles may also become visible in the embryo.

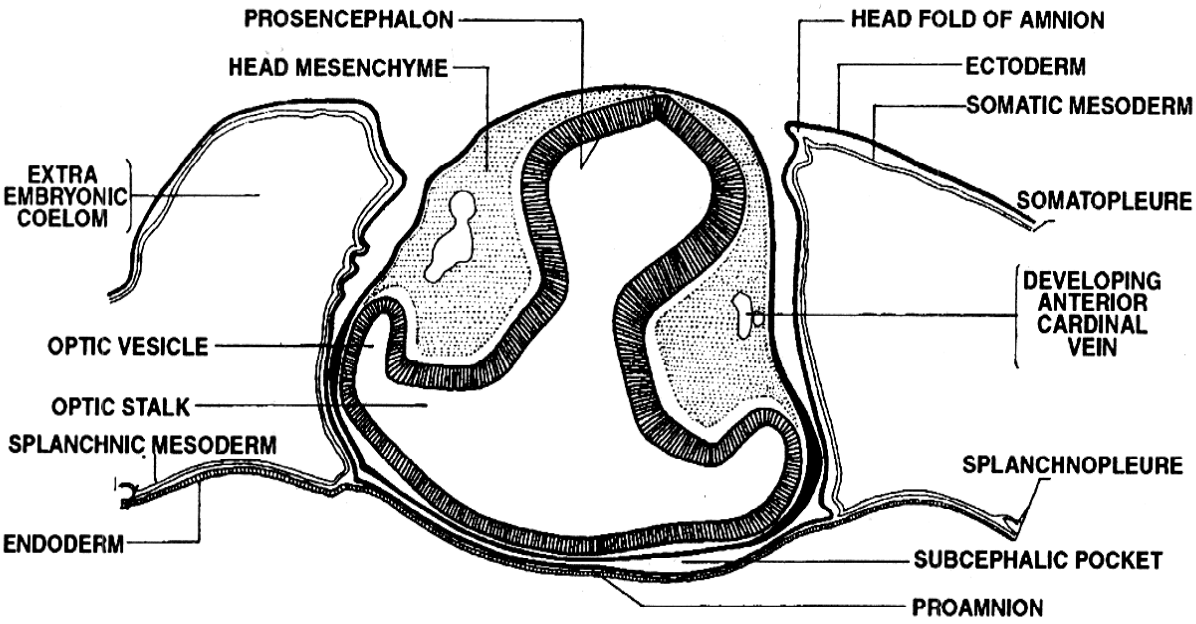


Fig. 98. T.S. Chick Embryo through Brain

(99) T.S. CHICK EMBRYO THROUGH PRIMITIVE STREAK:

- During the development of the chick, formation of primitive streak is initiated in 13h. and is completed by 18h.
- Primitive streak is an embossed part of the embryo with a deep groove at the center of the blastoderm.
- Primitive streak is composed of primitive groove, primitive folds, Primitive pit and Hensen's node.
- Section through primitive streak in 18h. chick embryo shows a middorsal groove namely the primitive groove.
- In section, dorsal margin is lined by epiblast and the ventral margin towards yolk by hypoblast.
- Ectoderm and endoderm layers are unilaminar in nature.
- Cells belonging to epiblast converge towards primitive groove and involute through the primitive groove form into mesoderm in between epiblast and hypoblast layers.
- The involuting cells diverge as mesodermal segment laterally and in anterior direction.
- Intercellular spaces between the cells of the mesoderm fuse to form a large coelom thus separating the mesoderm into somatic and splanchnic layers.
- Somatic mesoderm in combination with outer ectoderm form the somatopleure and the splanchnic mesoderm with endoderm to form splanchnopleure.
- Primitive folds grow on either side of the groove.

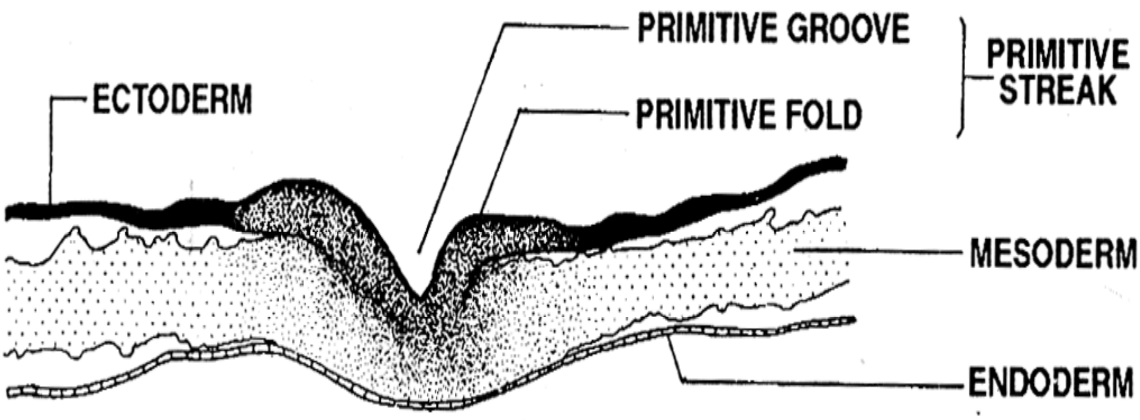


Fig. 99. T.S. Chick Embryo through Prmitive Streak

OSTEOLOGY:

100) PECTORAL GIRDLE OF VARANUS:

It belongs to the appendicular skeleton giving support to the fore limbs and protection to the heart, lungs and other important organs.

It shows bilateral symmetry and can be divided into two equal halves. Each half has a coracoid, scapula, clavicle, epicoracoid and supra scapula.

Sternum and interclavicles are present in between the two halves of the girdle. Clavicles and inter clavicles unite to form a T' shaped episternum.

Of all the bones, coracoid is larger, flat possessing coracoid fenestrae. Presence of two fenestrae divides the coracoid into an outer precoracoid, mesocoracoid and an inner epicoracoid.

Epicoracoid is cartilaginous and is formed irregularly towards the anterior margin of the coracoid.

Glenoid cavity is a cup like depression between the coracoid and scapula. Head of the humerus fits into this cavity forming ball and socket joint.

Scapula is an elongated flat bone. Coracoid is present attached to the outer margin of scapula and inner margin of suprascapula.

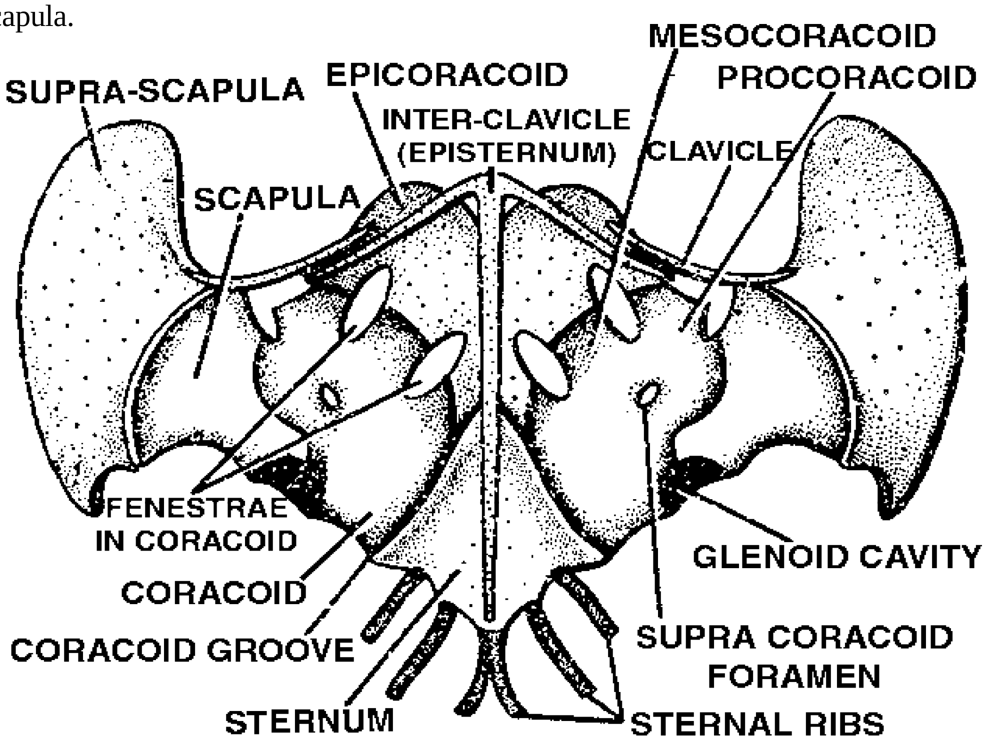


Fig . 100. Varanus- pectoral girdle

(101) PECTORAL GIRDLEOF PIGEON:

It is the anterior girdle of the appendicular skeleton giving support to the fore limbs and protection to the heart, lungs etc.

It occurs in two similar units an either side of the body.

Each unit has a clavicle, coracoid and scapula as its components. Of these coracoid and scapula are strong.

Pectoral girdle is attached to the sternum and gives the action of fulcrum during the movement of the wings.

Coracoid is a rod like bone directed towards the ventral side.

Towards inner ventral side, it is articulated to scapula. At the outer junctional point, a cup like glenoid cavity, is present into which the head of the humerus fits in.

Anterior to the glenoid cavity, coracoid grows as acrocoracoid process. Scapula is a flat showel like one with a number of tubercles over its surface.

Clavicle is present towards the anteroventral side of the fusion point of coracoid and scapula. It meats with its counter part to form a 'U' shaped furcula. This acts as a spring during flight. It is also called as a merry - thought bone.

The opening located at the junction of these three bones is the foramen triosseum. It acts as pulleys for the contraction of pectoralis minor.

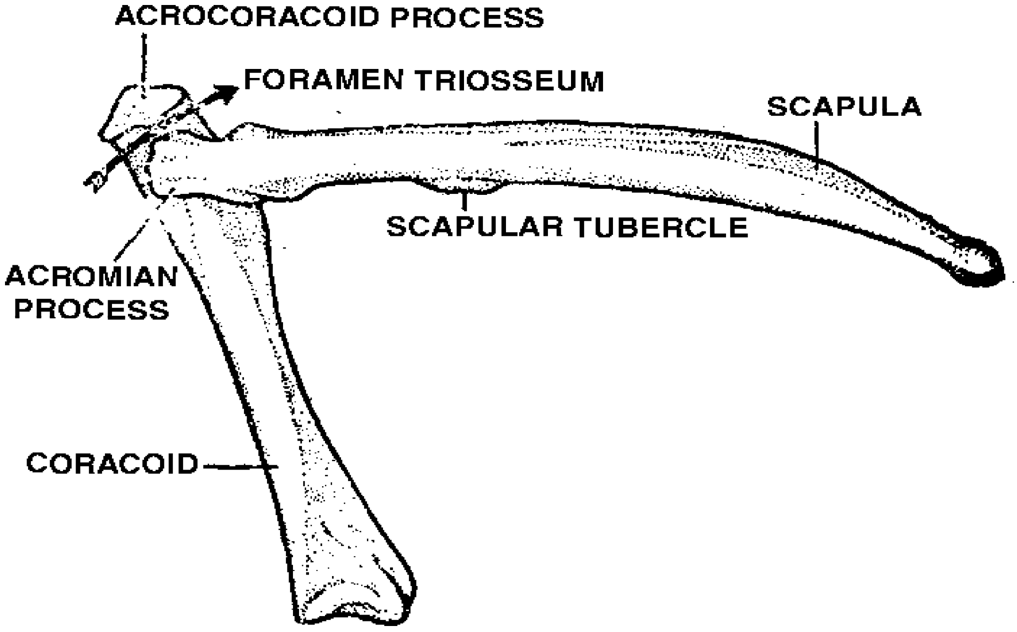


Fig. 101. Bird- Pectoral girdle

(102) PECTORAL GIRDLEOF RABBIT:

It is the anterior girdle of the appendicular skeleton giving support to the fore limbs and protection to the heart, lungs and other important organs.

In mammals also, the girdle is seen as two separate similar units on either side of the body in association with the thoracic basket.

Each unit has three bones viz, the coracoid, scapula and clavicle. Scapula is

almost a triangular expanded flat plate.

Coracoid is degenerated and in association with the narrow end of the scapula forms into a coracoid process.

Glenoid cavity is present at this junction of the compound bone. Humerus fits into

the glenoid cavity forming the ball & soket joint.

Outer margin of the Scapula is drawn into a long spiny acromion process, parallel to the coracoid process

The posterior margin of thin acromian process is backwardly directed as metacromian process or the apex of the scapula.

Supra scapula is a thin cartilaginous component in association with the dorsal margin of the scapula.

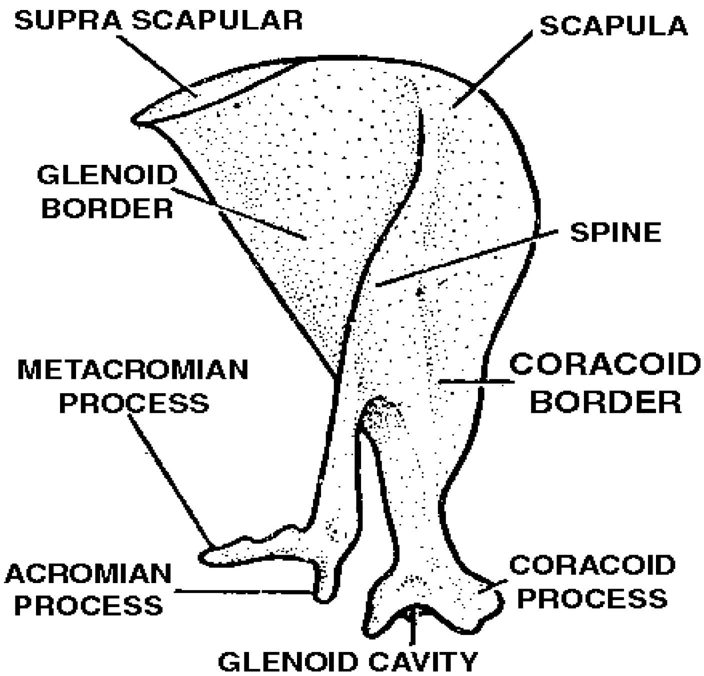


Fig 102. Pectoral girdle of a rabbit

(103) PELVIC GIRDLE OF VARANUS:

Among two girdles present in the body of the vertebrate organism, pelvic girdle is the posterior one giving support to the hind limbs and protection to the reproductive organs, gonads, kidneys etc.

Pelvic girdle has two equal halves viz, the os-innominata,

Each half is composed of three bones viz., the ilium, the ischium and pubis.

Ilium is a rod shaped bone directed dorsoposteriorly in articulation with sacral vertebrae.

Anteriorly, it is grown as an anterior process and contributes for the formation of acetabulum.

Pubis is a slightly curved bone.

It forms into a circular bone in association with its counter part through a symphysis.

Pubis has a cartilaginous epipubic tuberculum at is anterior end.

Obturator foramen is located at the junction of the ilium, ischium and pubis. Outer to this is a small rod like prepubis bone, Pubis also contributes for the formation of acetabulum.

Ischium is again a flat, curved posterior bone of the girdle. It unites with its counterpart through an ischiatic symphysis.

It is associated with the ilium and pubis at its outer edge and at the junction of these three bones, a cup like acetabulum is present. Head of the femur fits into this cavity.

Hypo - Ischium is seen as a calcified cartilage located at the anterior margin of the ischiatic symphysis

The cavity present in between the ischium and pubis is the ischiopubic foramen.

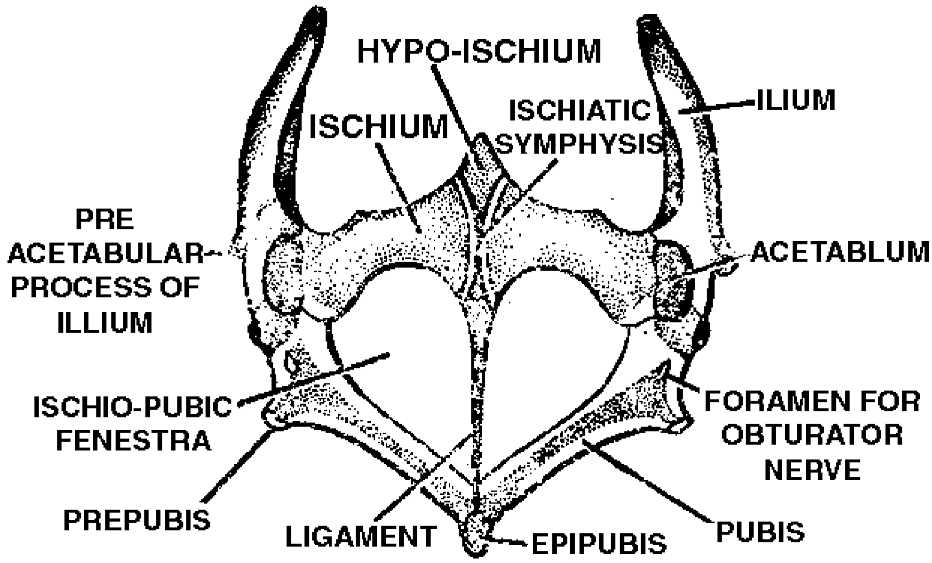


Fig. 103. Pelvic girdle of Varanus

(104) PELVIC GIRDLE OF PIGEON:

Among two girdles present in the body of the vertebrate organism, the pelvic girdle is the posterior one giving support to the hind limbs and protection to the reproductive organs, gonads, kidneys etc.

Pelvic girdle is represented in two units.

Each unit is composed of three bones viz., the ilium, the ischium and pubis.

The joint between the femur and pelvic girdle is the ball and socket joint.

Ilium is an elongated and wide flattened bone. It is grown, in both anterior and posterior directions to the acetabulum.

Its inner margin is fused with synsacrum while the outer anterior margin is concave. Ischium is attached to the postero - outer edge of the ilium.

Anterior ridge like projection infront of the acetabulum is the antetrochanter. This articulate with the trochanter of the femur.

Ischium is also a flat and wide bone extending as a rod behind the acetabulum and parellel to the ischium. It finally fuses with ilium.

The ilio ischiatic foramen separates the above bone from the ilium.

Pubis is a thin, long rod shaped bone. Posteriorly, it runs parellel to the ischium.

At acetabular cup, pubis is associated with ischium to form into a pubic process.

Foramen in between the ischium and pubis is considered as obturator foramen for the passage of obturator nerve.

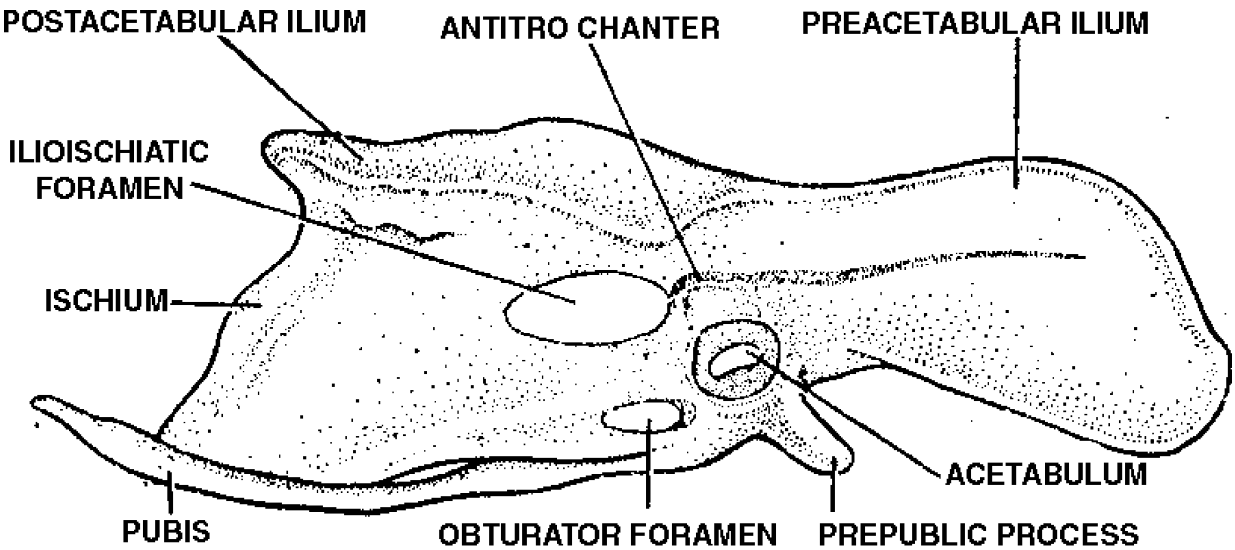


Fig . 104. Pelvic girdle of a Bird

(105) PELVIC GIRDLE OF RABBIT:

Among two girdles present in the body of the vertebrate organism, the pelvic girdle is Jie posterior one giving support to the hind limbs and protection to the reproductive organs, gonads, kidneys etc.

Pelvic girdle has two equal halves viz, the os-innominata.

Each half is composed of three bones viz., the ilium, the ischium and pubis.

Both the halves are united posteriorly by a symphysis.

Ilium is a long bone with a wide anterior rod like posterior end.

This articulates with sacral vertebrae of the vertebra! column. Towards its inner margin, acetabulum is present.

Ischium is a strong and flat bone forming the posterior part of the os-innominatum. It also contributes to the formation of acetabulum. Posteriorly, it has a conspricuous ischiatic tubercle.

Pubis is a small bone connected anteriorly with ilium and posteriorly with pubis.

In between these three bones, a wide obturator foramen is present. It is not a part of the acetabulum.

Femur fits into the acetabulum and forms a ball and socket joint with the pelvic girdle.

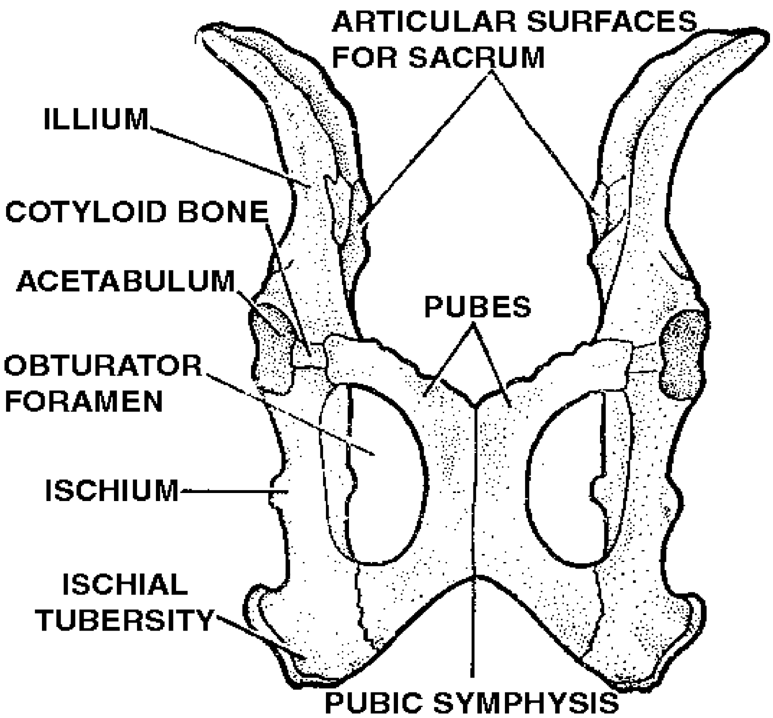


Fig. 105. Pelvic girdle of a rabbit

(106) VARANUS: FORELIMB SKELETON:

Fore limbs form ball and socket joint with pectoral girdle. They are pentadactyl and digits end in claws.

Humerus, radio ulna, carpals, metacarpals and phalanges are the chief components of the forelimbs.

Humerus: It is the bone supporting the brachium of the fore limb. It is short and strong. Its shaft is a thin rod at the centre and ends are broad. Proximally, the bone is round and forms into a head fitting into the glenoid cavity of the pectoral girdle. Distally, the bone has a pulley like trochlea. On either side of this, a radial and ulnal condyles are present in continuation of Radio ulna. Deltoid ridge is grown as a bone over to the head of the humerus. It bears a basipetal pit at its tip.

Radio Ulna: It is the bone of the antebrachium. Radio and ulna are separate at the centra and fused at their ends. Radio is a soft rod like bone. Shaft is having epiphysis in either side. Distally, it has a concave pit into which the radial fits in. Ulna is a stout and long bone arranged out side the radio.

Proximally it has an inwardly grown spine like olecranon process. Distally it is in articulation with ulnare.

Hand/Manis: It is composed of carpals, meta carpals and phalanges supporting the wrist, hand and digits and fingers. Towards radio ulna, radial, an intermedium and an ulnare are present forming the first row.

Second row is composed of one carpal and the Third row is composed of five small carpal bones.

Hand is supported by five meta carpals. Fingers are supported by phalanges. Digital formula of the fore limb is 2,3,4,4,3.

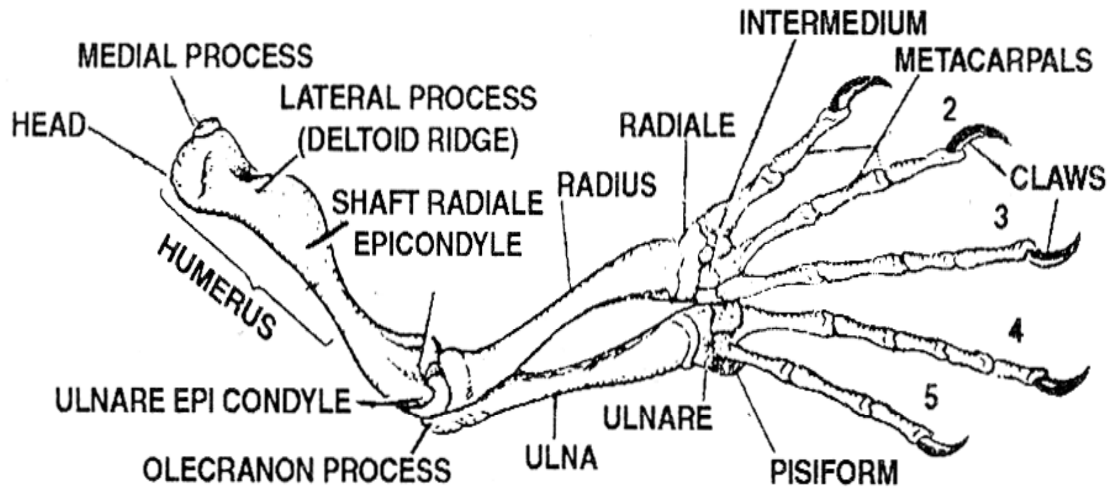


Fig : 106. Fore limb skeleonof Varanus.

(106) PIGEON: FORELIMB SKELETON:

Fore limbs are modified into wings in birds. Each wing is supported by humerus, radio ulna and a carpometacarpal.

Humerus: It is the bone of the brachium or upper hand. Shaft of the bone is elongated while both the ends are broad.

Proximal ly it is convex forming into a head fitting in the glenoid cavity. Ball and socket joint is formed in between these two bones.

At the head of the humerus, an anterior and a posterior axial tubercules are visible. Deltoid ridge is formed from the anterior axial tubercle.

Post axial tubercle is large. The shaft bears a pneumatic pore through which air tubules enter the bone.

Distally, humerus has a trochlear surface having inter condylar groove, caronoid pit and olecranon pit articulating with radio ulna.

Radio ulna : It gives support to the antebrachium. It is a compound bone having a long and tender radio proximally. Radio has a pit into which the trochlear surface of the humerus fits in. Distally it articulates with carpals.

Ulna is again a long curved, strong bone having a nutritional pore, proximally it is drawn as an olecranon process and articular surface articulating with the condyle of the humerus. Distally it is bound to carpal and radio.

Carpometacarpus: It is the bone of the wrist. Three distal carpals and three meta carpals fuse to form this compound bone. First metacarpal is stout and short. Second metacarpa! is a strong, straight bone while the third is a thin curved rod. It fuses with the second metacarpal at its postero axial end.

Hand is formed of three fingers. Digital formula of fore limbs is 1,2,1,0,0-Hence fourth and fifth fingers are absent.

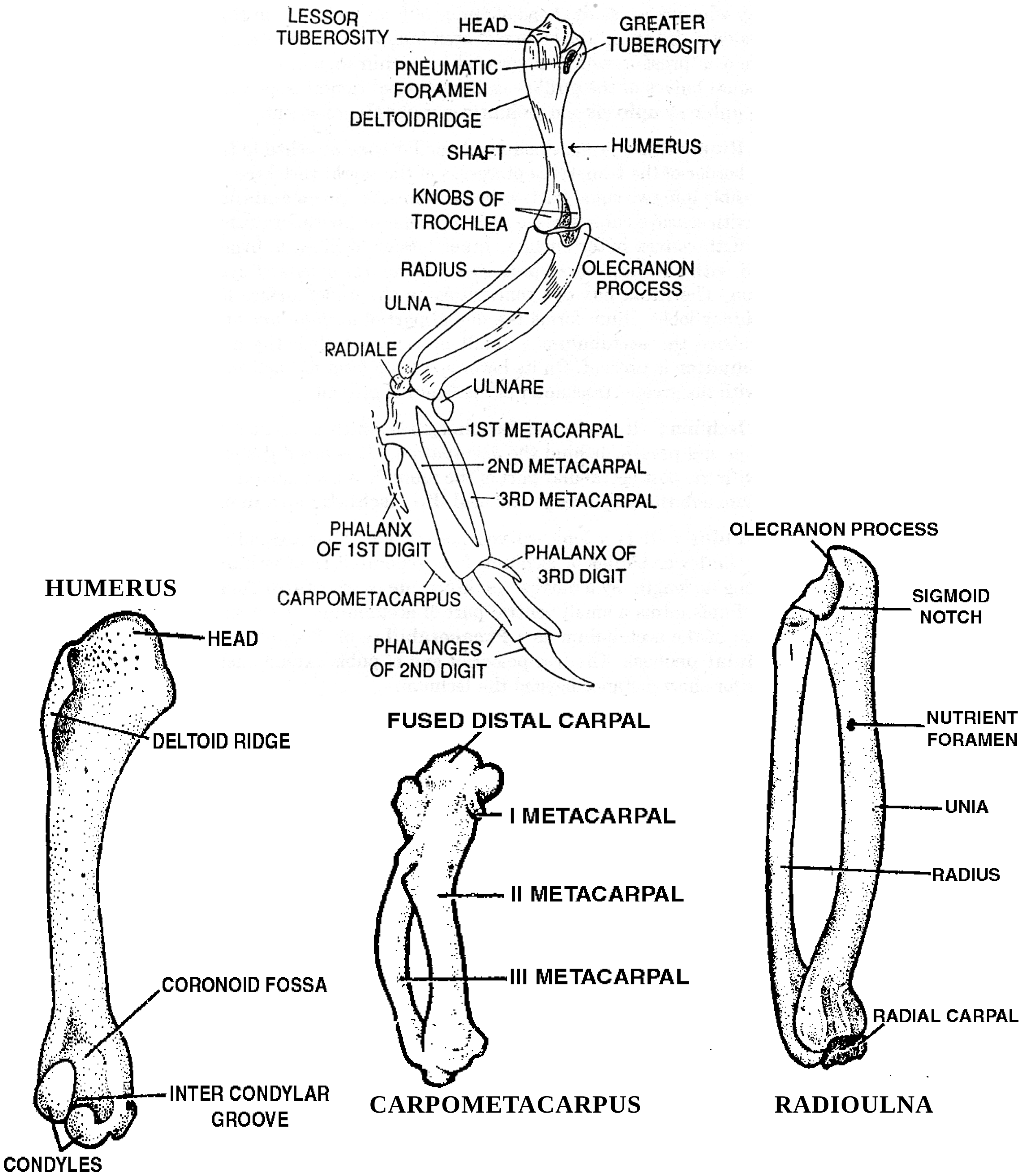


Fig. 106. Fore limb skeleton of a Bird

(107) RABBIT: FORELIMB SKELETON:

Fore limb consists of upper arm, fore arm, wrist, hand or manis and fingers supported internally by humerus, radioulna, carpals, meta carpals and phalanges respectively. Limbs are pentadactyl, and end in claws/nails.

Humerus: Long supporting bone of the upper arm. Its shaft is strong and rod like. Proximal end is broad and covex forming into the head of humerus. This fits into the glenoid cavity of the pectoral girdle and form a ball and socket joint for free and easy movement.

The two projections on either side of the head help in providing steady ness to the limbs. Head is followed by a deltoid ridge on its antero axial side. Distally the bone bears a pulley like trochlea for free articulation with radioulna. Olecranon pit and supra trochlear foramina are visible near the olecranon ridge.

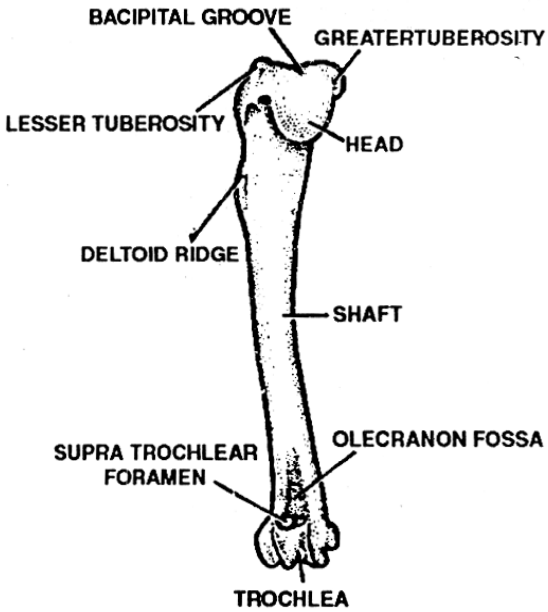
Radio ulna: This is a compound bone giving support to the fore arm and is formed by the close association of both radio and ulna. Both these bones are almost equal in length and closely arranged to give support to the fore arm.

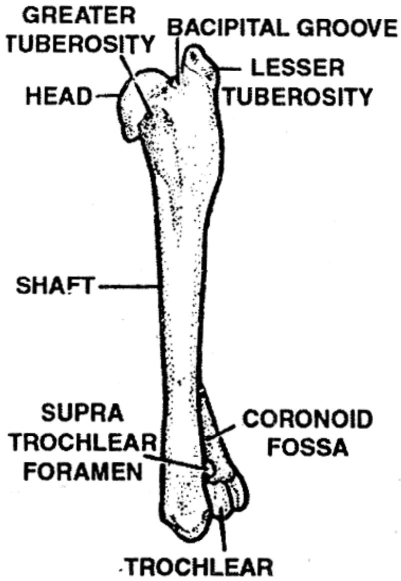
Radio is a long outer bone with a curved end towards dorsal side helping in articulating with trochlea at its proximal end and carpal at its distal end.

Ulna is the inner bone slightly longer than the radio having proximally the olecranon process.

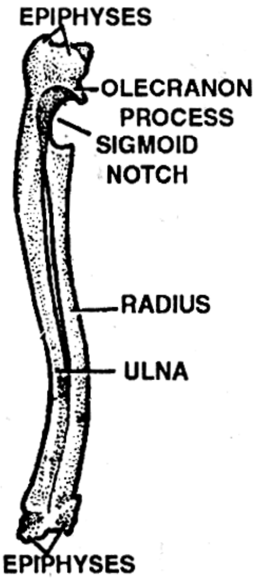
It bears a deep sigmoid notch just beneath the olecranon process into which the trochlea of the humerus fits in. Distally it becomes thin and articulates with a carpal. About eight carpals are arranged in three rows supporting the wrist. First row has three carpals viz, the radiale, intermedium and ulnare. Second row comprises of only one carpal while the third row has four pieces viz: the trapizium, osmagnum and the uncinate bones. Elongated metacarpals are attached to these bones.

Phalanges are the small bead like bones ending in claws. Their number varies from species to species.





HUMERUS LATERAL VIEW



RADIOULNA

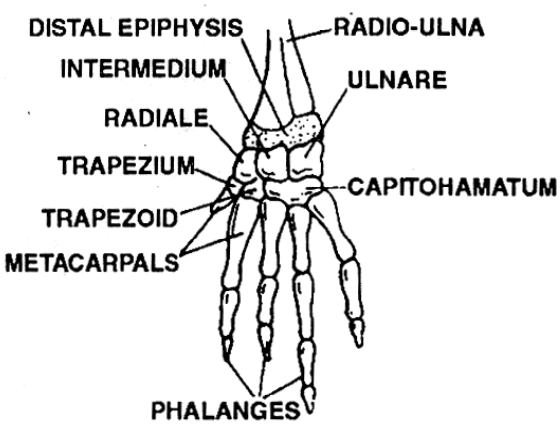


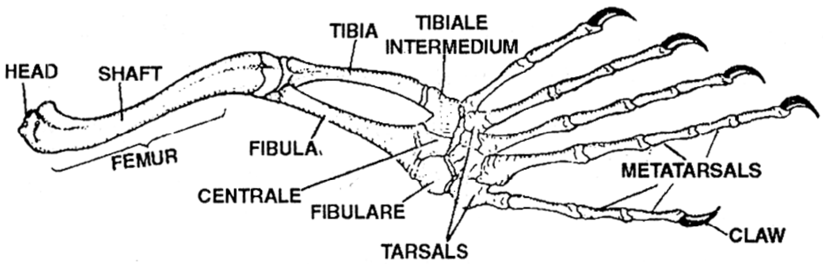
FIG. 107. FORE LIMB SKELETON OF RABBIT

(108) VARANUS: HINDLIMB SKELETON:

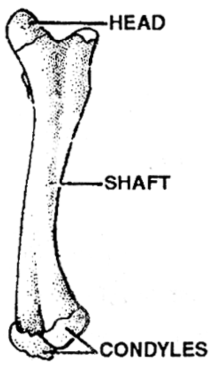
Thigh, foreleg, ankle, pes and toes are the components of the hind limb supported internally by femur and tibiofibula. Ankle bones or tarsals, metatarsals and phalanges.

Femur: It is a long and strong rod like bone supporting the thigh . It possesses two epiphyses. Proximal epiphysis is formed into a round head fitting into the acetabulum. Lesser trochanter is the second tuberculum located just beneath the first one towards the anterior axis.Grater troichanter to be seen towards the post axis is reduced and like a pulley. Distal trochanter is formed into two condyles and articulates with tibiofibula.

Tibiflobula: A compound bone formed by the union of outer tibio and inner fibula. It gives support to the foreleg.Tibio is slightly curved strong bone having knomial process at its proximal end and concavities into which the condyles of the femur fits in. Fibula is a long, thin bone articulating with femur at its proximal end. Distally it is associated with tarsal bones. Ankle is supported by five tarsals. Proximal row has two pieces and distal row has three pieces. Proximal row articulates with tibiofibula while the distal row with metatarsals. Phalanges are arranged in the formula of 2, 3,4, 5,3. All the digits end in claws.



VARANUS – HIND LIMB SKELETON



FEMUR

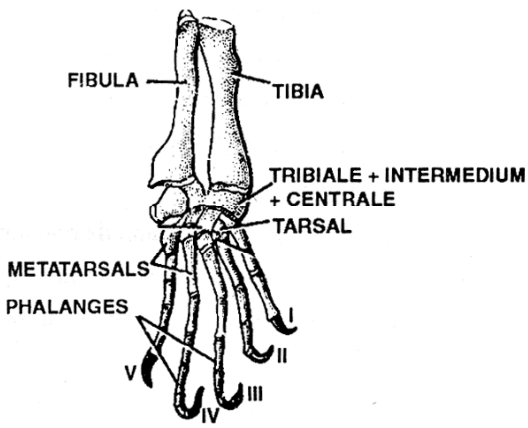


Fig. 108. Hind limb skeleton of Varanus

(109) PIGEON: HINDLIMB SKELETON:

Hind limbs are the posterior pair of limbs supported by pelvic girdle. They form ball and socket joint with the acetabulum of the pelvic girdle.Thigh, foreleg, ankle, pes and toes are the components of the limb / leg supported internally by femur, Tibiofibula. Ankle bones or tarsals, metatarsals and phalanges.Hind limbs are stronger and shorter to borne the entire weight of the body. The muscles are powerful and are used in perching/holding the substratum with firm grip.

Femur: It is a short strong bone supporting the thigh. Both proximal and distal ends are broad and flat.

Proximally, the bone becomes round and fits into the acetabulum of the pelvic girdle. Irregular outer surface is produced into greater trochanter. Into the concavity between the head and greater trochanter, the anti-trochanter of the ilium fits in. Distally, it has a patellar groove towards anterior side into which patella, the sesmoid bone fits in and forms the knee joint. On either side of the patellar groove, a pair of condyles are present forming articulation with the proximal portion of the tibiofibula.

Tibio Fibula: It is gain a compound bone formed by the association of tibio and fibula. It Supports the fore leg. Tibio fuses with tarsus to form tibiotarsus which is long, strong and a straight bone. Proximally it is drawn into a sharp knomial ridge. The pits an either side of the ridges receive the condyles of the femur. Distally, it is associated with the pulley like tarsometatarsal. Fibula is thin, slender bone associated with Tibio on its outer surface. Proximally, it articulates with femur. Distal tarsals, second, third and fourth metatarsals fuse

to form the compound tarsometatarsus. It is a strong rod like bone articulating proximally with tibiotarsus and distally with three free metatarsals. Phalanges are the small pieces attached to the metatarsals of the foot. First metatarsal is represented as a projection over the tibiotarsus. Proximally it has two cup like depressions with which tibio fibula articulates. In males, the tibiotarsus bears a conspicuous projection called spur. Phalanges of the hind limb are arranged in 2,3,4,4 formula and are clawed.

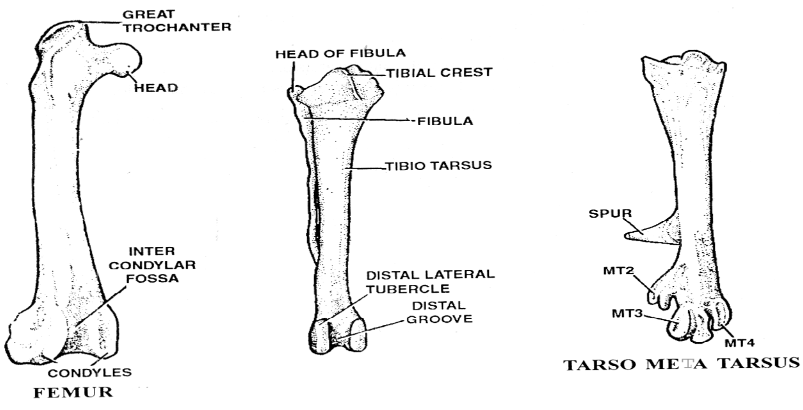


Fig. 109. Hind limb skeleton of a bird

(110) RABBIT: HINDLIMB SKELETON:

Hind limbs are the posterior pair of limbs supported by pelvic girdle. They form ball and socket joint with the acetabulumn of the pelvic girdle.

Thigh, foreleg, ankle, pes and toes are the components of the hind limb leg supported internally by femur and, tibiofibula.

Ankle bones or tarsals, metatarsals and phalanges.

Femur : It is a long and strong bone supporting the thigh region. Its proximal and distal ends ire broad.

Proximally two tubercles are visible on either side of the head of femur. These are the greater and lesser trochanter. Distally two large condyles are present in association with fibiofibula. The groove between these condyles is the patellar groove. Outer to the distal condyle, a small rejecting knob called balbella visible. Proximallly, the head of the femur fits into the acetabulum of the pelvic girdle and form ball and socket joint for free movement.

Tibiofibula: It is again a compound bone formed by the association of two bones. Of these two, Tibia is strong, Straight and rod like one with broadened proximal and distal ends. Proximally, tibia is drawn into a long knomial process.

Fibula is a thin a slender bone having a disc like patella at its proximity. Tibia articulates proximally with the condyles of the femur and distally with astragalus bone of the ankle.

Fibula articulates proximally with femur and distally with calcaneum of ankle bones or tarsals.

Foot: Ankle, pes and fingers are the components of the foot.

Ankle is supported by three rows of tarsals.

First row has astragalus and calcaneum.

Second row has a navicular bone

Third row has cuboidal, external and internal tarsals.

Calcanium is projected out at its distal end. Phalanges support the digits of the toes.

Phalangial formula of the hind limb is 2,2,2,2. All the phalanges are provided with nails.

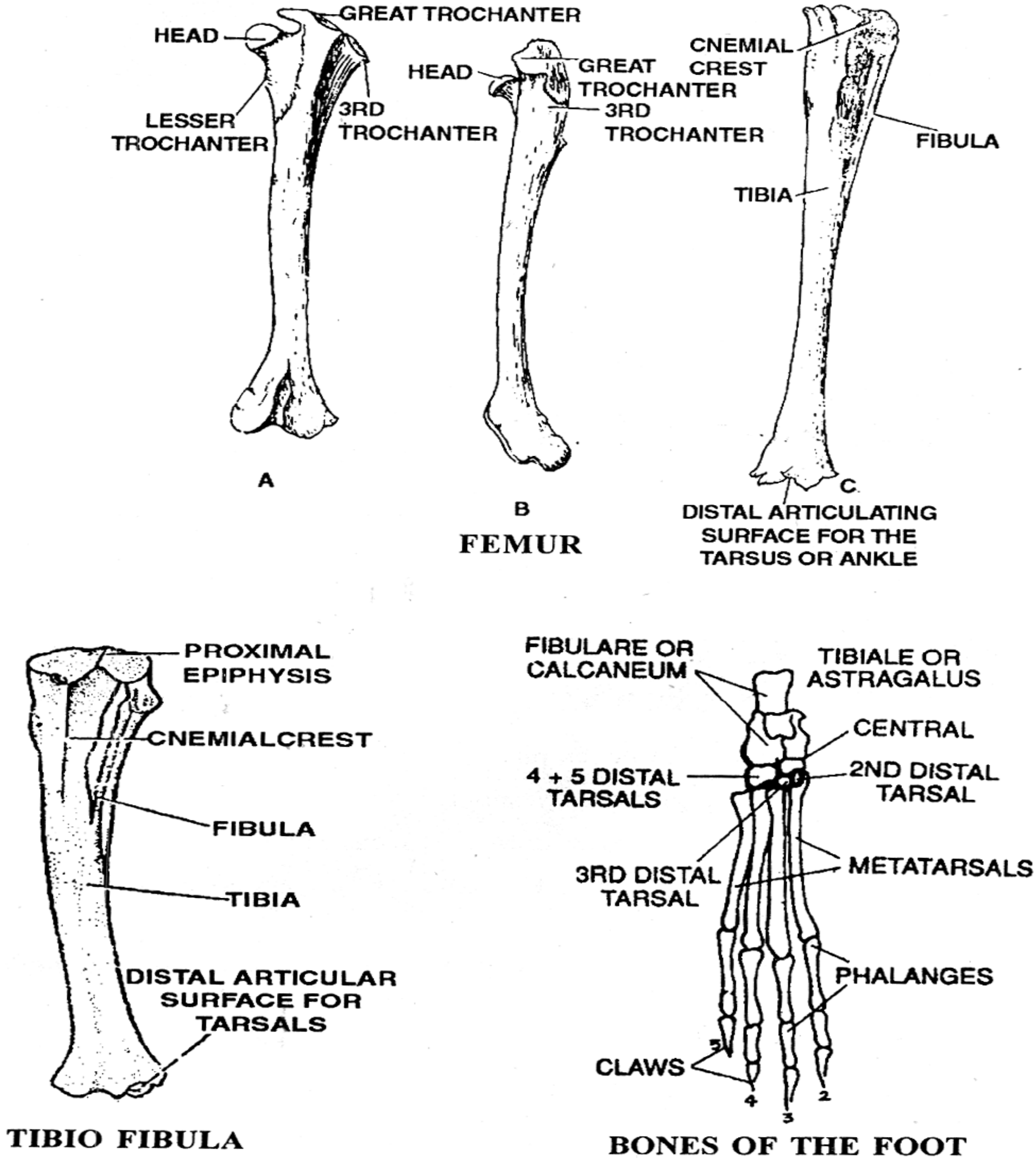


Fig. 110. Hind limb skeleton of Rabbit

DISSECTIONS:

111) SHARK -EXTERNAL FEATURES:

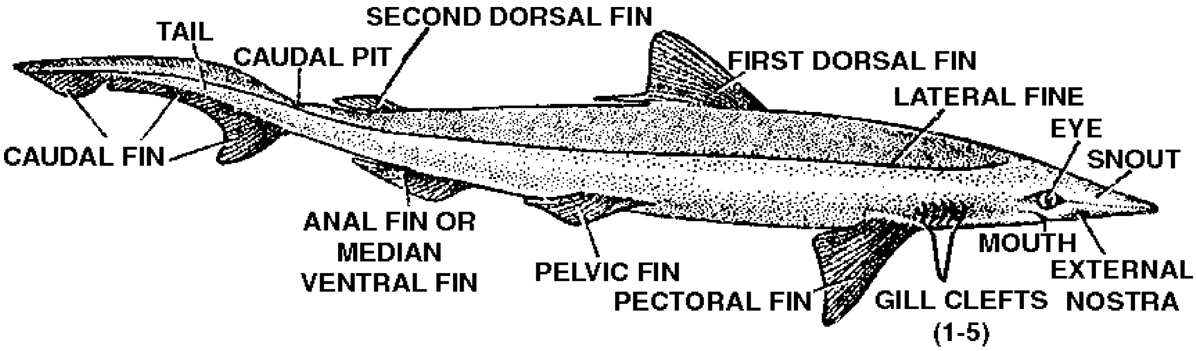


Fig. 111. Shark- External features

(112) SHARK - V AND VII CRANIAL NERVES:

Fix the shark on its dorsal side over the wooden plank.

Remove the upper skin from pectoral girdle to the snout.

Conspicuous lines are visible behind the eye indicating the location of the nerves.

Remove the surface connective tissue layer and observe for the nerves behind the eye by manipulating the muscles. Trace the nerves and clear them as shown in the diagram till their final innervations into the tissue. Place the pieces of black paper to expose the nerves. Break the cartilaginous skull and locate the ganglia.

Nerves to be exposed in 5th cranial nerve

Gassarian ganglion

Opthalmicus branch.

Superior and inferior maxillary branches.

Profundus of the Ophthalmicus.

Mandibular branch.

VII Cranial nerve -Branches to be exposed are:

Ophthalmicus superficialis, Buccalis and palatine branches.

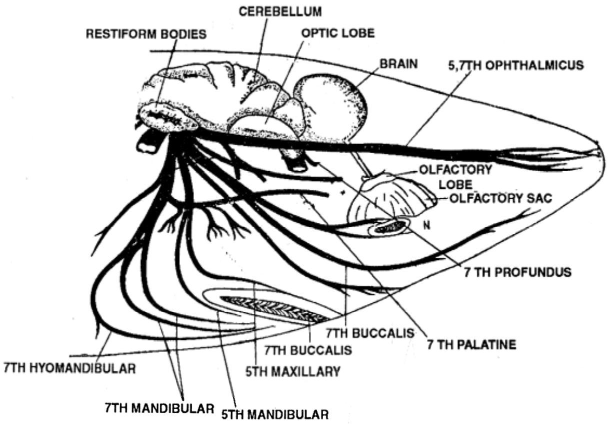


Fig.112. Shark- V & VII cranial nerves

Hyomandibular and its further branches such as hyoid, inner and outer mandibular nerves.

(113) SHARK - IX AND X CRANIAL NEVES:

Fix the shark on the plank on its dorsal side.

Remove the skin from the eye to the pectoral girdle. Remove the roof of the cranium to expose the brain. IX&X cranial nerves are visible near the gill slights.

Another lateralis nerve can be located extending on the lateral side of the body by cutting through a faint line separating white and gray areas.

Branches of the IX nerve viz., the anterior trematic and post trematic nerve are cleaned from the tissues and separated to keep the black paper.

Branches of the X cranial nerve viz., the bronchial nerves are also cleaned from the surrounding tissues and separated as shown in the diagram.

Keep small pieces of black paper to expose the nerves.

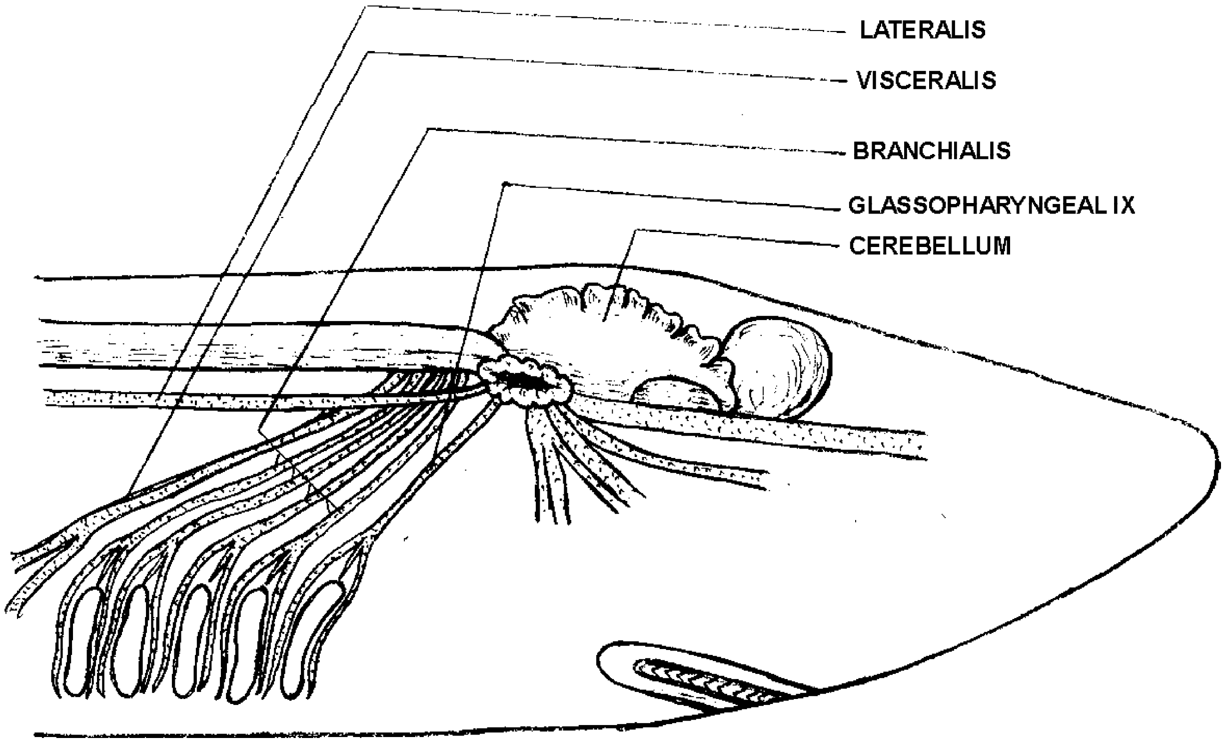


Fig. 113. Shark- IX and X cranial nerves

(114) SHARK - BRIAN:

Fix the shark specimen on its dorsal side.

Remove the skin from pectoral girdle to the tip of the snout.

Remove muscles and associated tissue till the cartilaginous skull is visible.

Remove slowly the roof of the skull and its sides when the entire Brain with sensory capsules become visible.

Tilt the specimen in such a way that the brain can be separated into a Petri dish.

Wash the Brain, and again keep it in Petri dish.

Keep the Petri dish over a piece of Black paper, so that the brain can be easily observed.

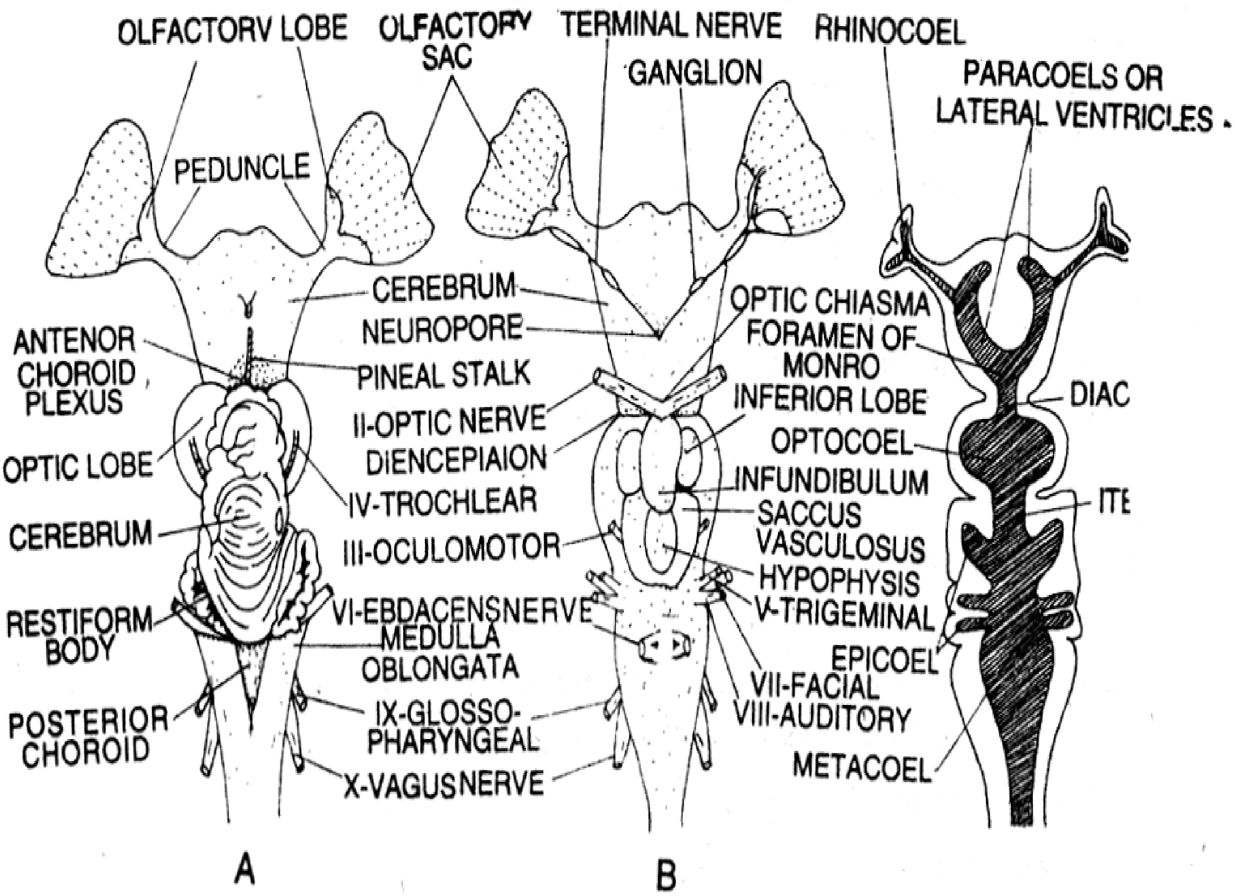


Fig . 114. Brain of shark
A. Dorsal view B. Ventral view

115) SHARK-ARTERIALSYSTEM:

Fix the shark on the plank such that its ventral side is visible.

Cut the lower jaw on one side, stretch it and fix it to another side.

Cut the inner skin on the lower jaw when the heart and aorta are visible.

Similarly remove the skin on the opposite side where the arterial branches innervating the Gill slits are visible.

Separate the branches as shown in the diagram and expose them by inserting small pieces of black paper.

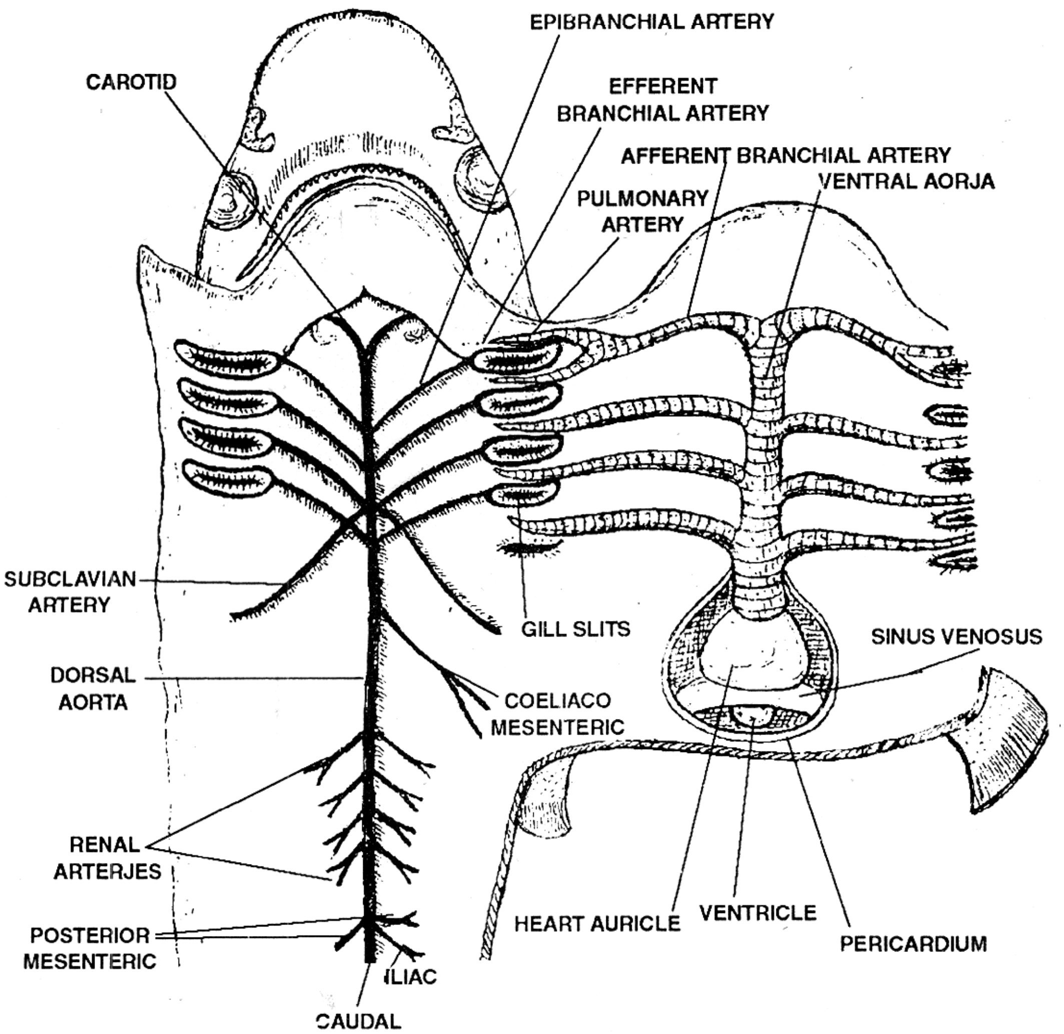


Fig. 115. Arterial system in Shark

116) SHARK - INTERNAL EAR:

Fix the shark fish with its dorsal side facing upwards.

Remove the skin and muscles from the girdle to the snout.

Just behind the eyes and towards latero ventral sides of the shark, three ridges become visible.

Puncture the ridge slowly and then remove the cartilage slowly.

Trace the three semicircular canals, their ampullae, the utriculus and the sacculus etc.,

After removing the cartilage, entire ear is separated into a pretty dish care fully.

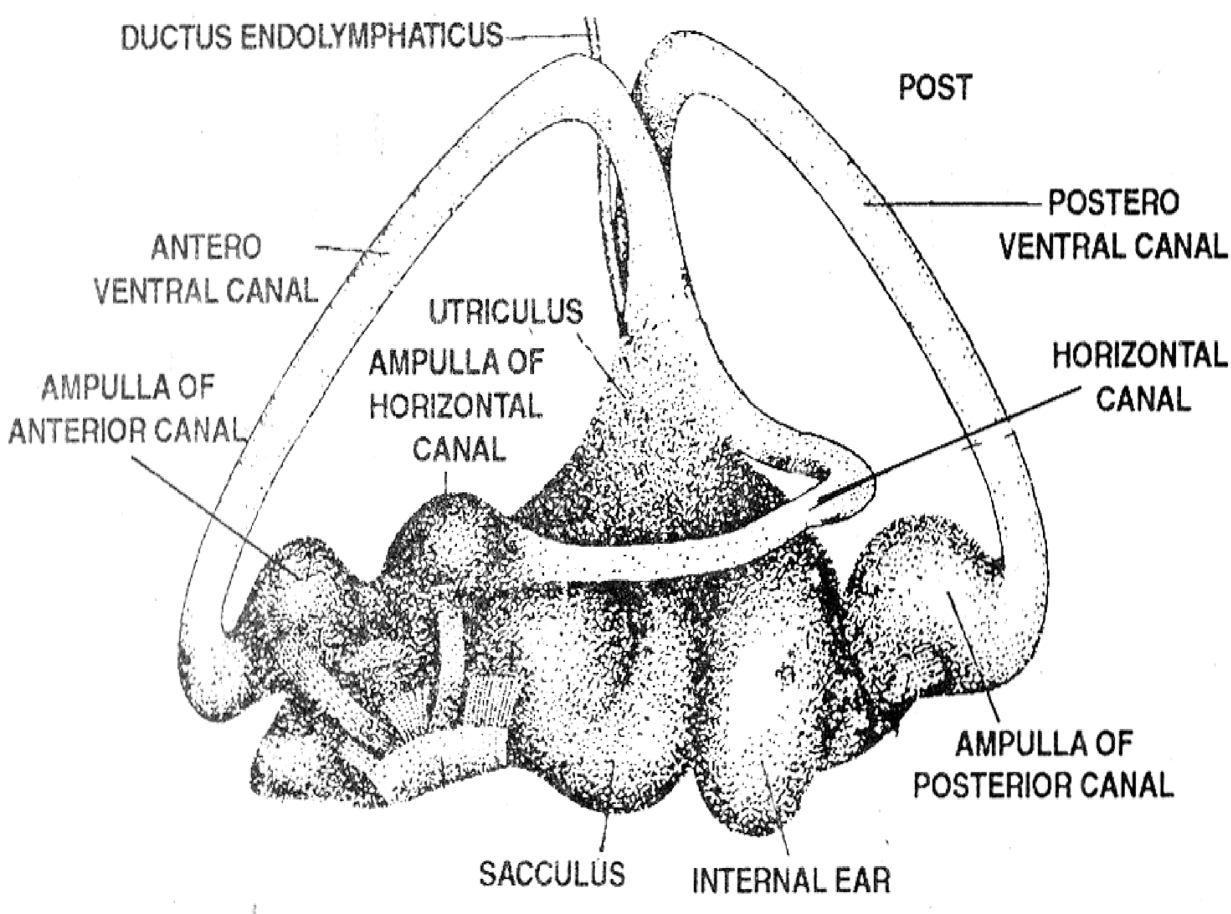


Fig. 116. Shark - Internal ear

117) SHARK - PLACOID SCALES:

Take a piece of the skin of the shark.

Make the skin into fine pieces and collect the pieces in to a test tube.

Add few drops of KOH (Potassium hydroxide). Heat the test tube over the burner till the pieces dissolve and disappear.

Keep the test tube aside till it cools. Remove the supernatant fluid. Add few drops of water. Shake , settle and then remove again the supernatant water is removed again.

The last few drops of water in the test tube are placed over the glass slide.

The slide is observed under microscope for placoid scales.

Small tridentate, granular microscopic scales can be seen as shown in the diagram.

Keep a drop of glycerin over the scales and place a cover slip to prepare a temporary slide.

Care is taken to avoid air bubbles while placing the cover slip.

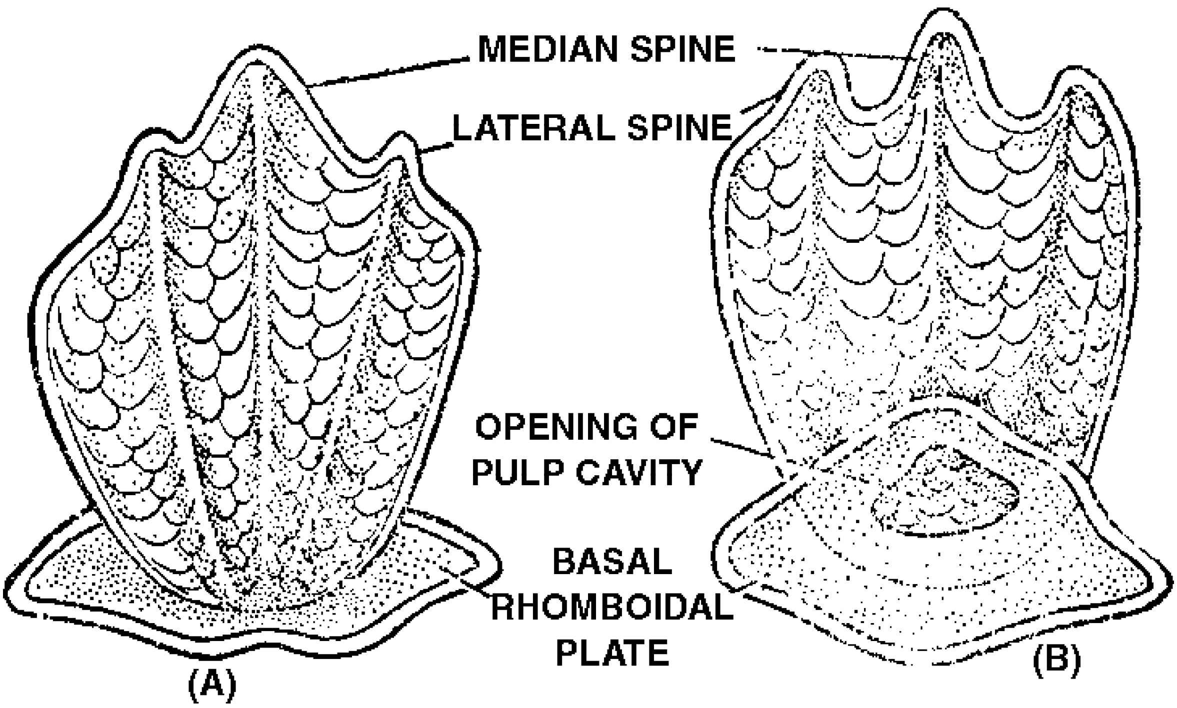


Fig. 117. Placoid scales in shark

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(118) CALOTES - ARTERIAL SYSTEM:

❑ Fix the Lizard over the plank such that the ventral side becomes visible.

cut the organism midventrally and see for the heart arteries.

Trace the arterial system starting from the aorta to the tail as shown in the figure.

Separate the arteries from the surrounding tissue and then keep small pieces of black paper to expose the branches clearly.

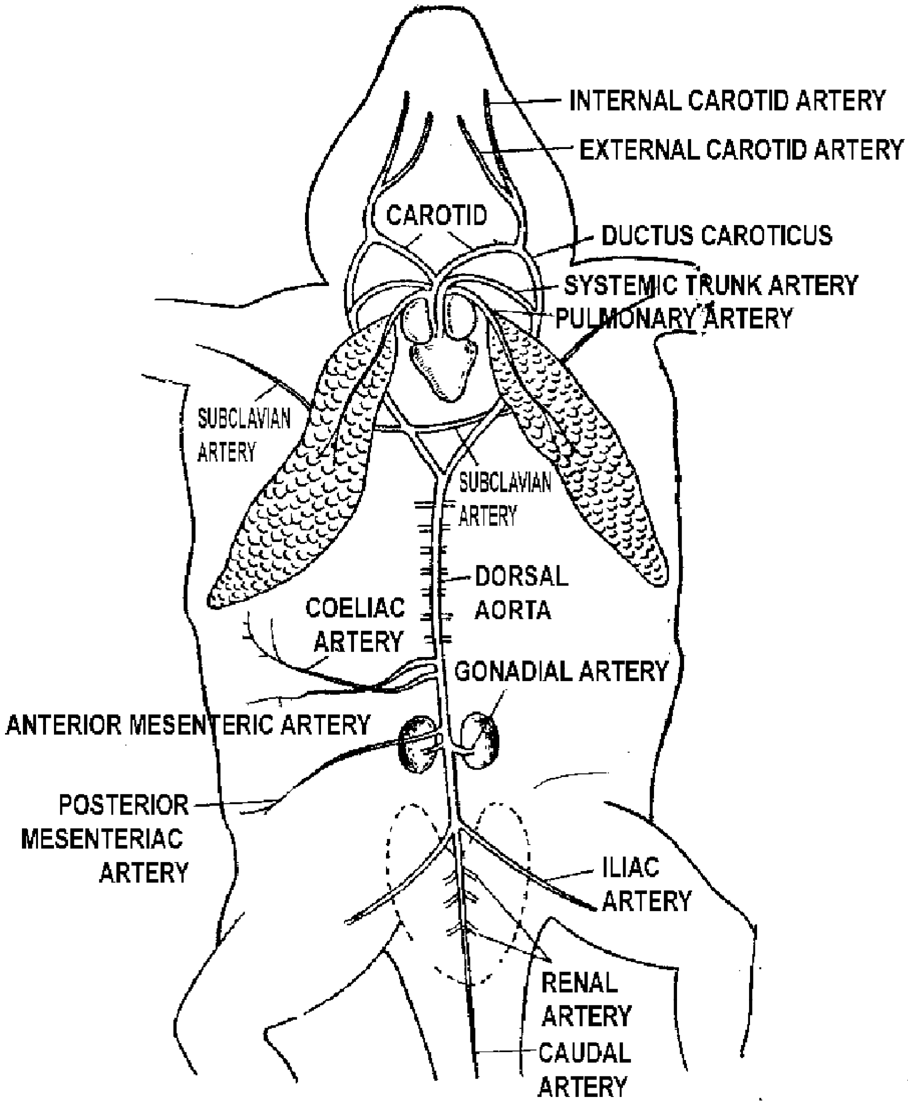

Fig. 118. Calotes-Arterial system

(119) BIRD - ARTERIAL SYSTEM:

Take a small chick and remove all the feathers.

Fix the animal over the wooden plank such that the ventral side is visible.

Cut the organism midventrally from the beak to the cloaca.

Open the organism, stretch and pin to avoid inconvenience.

Remove all the tissues and trace for arterial system starting from aorta near the heart.

Separate all the branches of the arteries and keep black paper to expose the branches clearly as shown in the diagram.

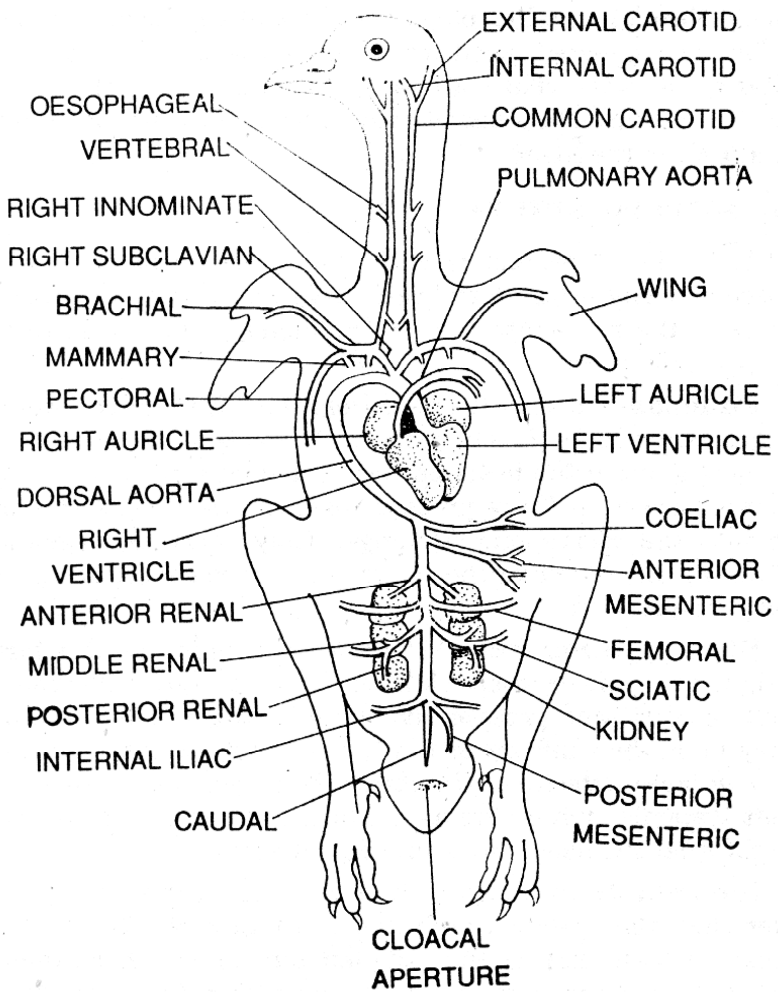

Fig. 119. Chick-Arterial system

(120) BIRD - VENOUS SYSTEM:

Take a small chick and remove all the feathers.

Fix the animal over the wooden plank such that the ventral side is visible.

Cut the organism midventrally from the beak to the cloaca.

Open the organism, stretch and pin to avoid inconvenience.

Remove all the tissues and trace for system starting from the heart.

Separate all the veins and their branches in the venous system and keep black paper to expose the branches clearly as shown in the diagram.

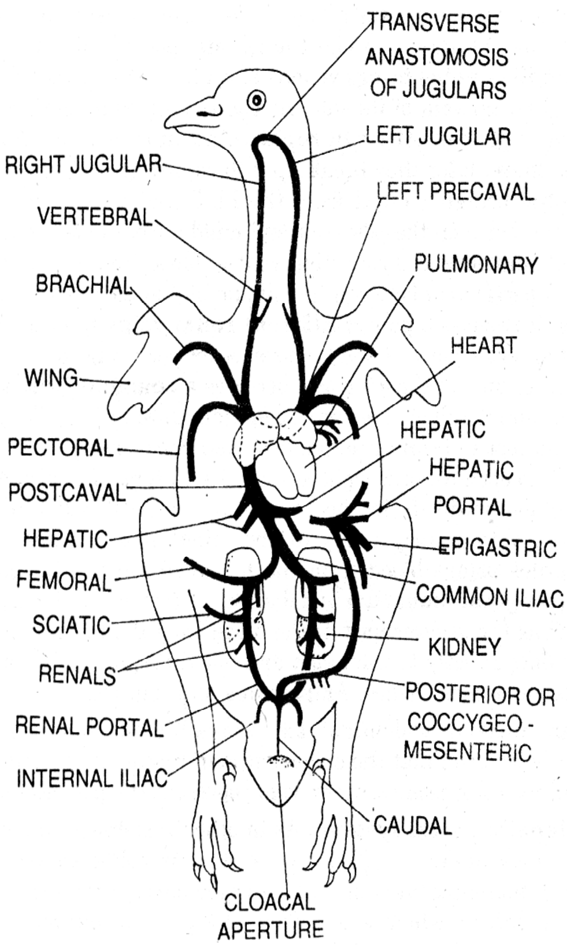

Fig. 120. Chick- Venous system