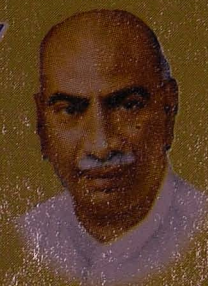




MADURAI KAMARAJ UNIVERSITY

(University with Potential for Excellence)

DIRECTORATE OF DISTANCE EDUCATION



B.Sc.

(ZOOLOGY)

First Year

PAPER - II

CHORDATA

(THEORY)

www.mkd.de.org

5026

UZ0002

MADURAI KAMARAJ UNIVERSITY

(University with Potential for Excellence)

DIRECTORATE OF DISTANCE EDUCATION

Palkalai Nagar, Madurai – 625 021, India

Ph : 0452 – 2458471 (30 Lines) Fax : 0452 – 2458265

E-mail	: mkudde@mkudde.org
General grievances	: mkudde_grievances@gmail.com
UG Courses	: mkuddeug@gmail.com
PG Courses	: mkupg@gmail.com
MBA Courses	: mkuddembag@gmail.com
MCA Courses	: mkuddemcag@gmail.com
Education Courses	: mkuddeedu@gmail.com
Website	: www.mkudde.org
IVRS	: 0452 – 2459990
	: 0452 - 2459596

Student Support Service : 0452 – 2458419

DDE – Examinations

Fax : 0452 - 2458261

E-mail : mkuace@yahoo.com

Examn. Grievance Redress Cell : 0452 – 2458471 – Extn. 515

Reading Material Disclaimer

This reading material, developed by **Mr. Ga. Bagavathiappan & Mrs. M. Vanitha**, S.B.K College, Arupukottai. and reviewed by **Dr. (Mrs) I. Isabel P.G. Professor & Head, Department of Zoology**, Lady Doak College, Madurai-20 is an aid for the students of Directorate of Distance Education, Madurai Kamaraj University, to understand the course content. It is only for the registered students of DDE, MKU and is not for private circulation.



MADURAI KAMARAJ UNIVERSITY

(University with Potential for Excellence)

Madurai – 625 021.



DIRECTORATE OF DISTANCE EDUCATION

B.Sc.

(ZOOLOGY)

FIRST YEAR

PAPER II

CHORDATA

(THEORY)

Recognized by D.E.C

UZOO02

5026



MADURAI KAMARAJ UNIVERSITY

(University with Potential for Excellence)

Madurai - 625 021.

DIRECTORATE OF DISTANCE EDUCATION



B.Sc.

(ZOOLOGY)

FIRST YEAR

PAPER II

CHORDATA

(THEORY)

Recognized by D.E.C.

Printed at Vimala Note book
Copies - 1000 First Print

U200002

5026

SYLLABUS

1. Chordate Zoology – E.L. Jordon and P.S. Verma (S Chand & co), New Delhi.

2. Chordate Zoology - P.S. Dhami and J.K. Dhami, New Delhi

3. Chordate – Ekambaranatha Ayyar and Ananthakrishnan, Chennai.

4. Vertebrate zoology – R.L.Kotpal, - Meerat.

5. Text book of Vertebrate – N Arumugam et al., Saras pub, Nagercoil

Paper II – CHORDATA (Theory)

Unit – I : General characteristics, Outline classification up to class level with example.

Type study-- Amphioxus – external morphology, digestive system, excretory system only.

Ascidian tadpole larva and retrogressive metamorphosis.
Affinities of Balanoglossus.

Unit – II : Classification of fishes, Type study – Shark, -Migration of fishes, Economic importance of fishes, Parental care in Amphibia.

Unit – III : Type study – Calotes. Poisonous and non-poisonous Snakes,- identification and biting mechanism, first aid. Decline of Mesozoic reptiles (Dinosaurs).

Unit – IV : Type study – Pigeon; external morphology, respiratory system, pectoral and pelvic girdles only. –Flight adaptation in birds, - Migration of birds, - Flightless birds, -Fossil bird Archaeopteryx and its evolutionary importance.

Unit V : Classification of Mammals with examples, Type study- Rabbit, - external morphology, nerves system and reproductive system only. Dentition in mammals, Aquatic mammals, Stomach in mammals.

REFERENCE BOOKS:

1. Chordate Zoology – E.L. Jordon and P.S. Verma (S.Chand & co). New Delhi.
2. Chordate Zoology - P.S. Dhami and J.K. Dhami. New Delhi
3. Chordate – Ekambaranatha Ayyar and Ananthakrishnan, Chennai.
4. Vertebrate zoology – R.L.Kotpal, - Meerat.
5. Text book of Vertebrate – N.Arumugam et al., Saras pub. Nagercovil.

UNIT NO.	TITLE OF LESSON	PAGE NO.
	Ascidian tadpole larva and retrogressive metamorphosis. Affinities of Balanoglossus.	1-21
2	Classification of fishes, Type study – Shark, - Migration of fishes, Economic importance of fishes, Parental care in Amphibia.	22-55
3	Type study – Calotes. Poisonous and non-poisonous Snakes, -identification and biting mechanism, first aid. Decline of Mesozoic reptiles (Dinosaurs).	56-66
4	Type study – Pigeon; external morphology, respiratory system, pectoral and pelvic girdles only. -Flight adaptation in birds, -Migration of birds, - Flightless birds, -Fossil bird Archaeopteryx and its evolutionary importance.	67-94
5	Classification of Mammals with examples, Type study- Rabbit, - external morphology, nerves system and reproductive system only. Dentition in mammals, Aquatic mammals, Stomach in mammals.	95-123

UNIT NO.	TITLE OF LESSON	PAGE NO.
1	General characteristics, Outline classification up to class level with example. Type study-- Amphioxus – external morphology, digestive system, excretory system only. Ascidian tadpole larva and retrogressive metamorphosis. Affinities of Balanoglossus.	1-21
2	Classification of fishes, Type study – Shark, - Migration of fishes, Economic importance of fishes, Parental care in Amphibia.	22-55
3	Type study – Calotes. Poisonous and non-poisonous Snakes, -identification and biting mechanism, first aid. Decline of Mesozoic reptiles (Dinosaurs).	56-66
4	Type study – Pigeon; external morphology, respiratory system, pectoral and pelvic girdles only. –Flight adaptation in birds, -Migration of birds, - Flightless birds, -Fossil bird Archaeopteryx and its evolutionary importance.	67-94
5	Classification of Mammals with examples, Type study- Rabbit, - external morphology, nerves system and reproductive system only. Dentition in mammals, Aquatic mammals, Stomach in mammals.	95-123

1.2 Objectives

After studying this unit, you will be able to:

Enumerate the distinctive characters of chordates and explain how these are characteristically different from the non-chordates.

CHORDATA

Unit – I

- 1.1 Introduction to chordates
- 1.2 Objectives
- 1.3 General characteristics of chordates
- 1.4 Outline classification up to class level with example
- 1.5 Prochordates
- 1.6 Type study- Amphioxus
 - External morphology
 - Digestive system
 - Excretory system
- 1.7 Ascidian tadpole larva
 - Retrogressive metamorphosis
- 1.8 Affinities of Balanoglossus
- 1.9 Questions

1.1 Introduction to Chordates

What is Chordata?

The name of this phylum is derived from Greek words, the chorde meaning a string or cord, and ata meaning bearing. Thus, chordates are animals having a cord, i.e., notochord. The animals belonging to all other phyla of the Animal Kingdom are often termed 'the non-chordates' or 'the invertebrates' since they have no notochord or backbone in their body structure. Most of the living chordates are the well-known familiar vertebrate animals such as the fishes, amphibians, reptiles, birds and mammals. The subphylum Vertebrata includes 46,500 species; of these, fishes are the most numerous with approximately 25,000 species. It is commonly assumed that amphibian species number about 2500, reptiles 6000, birds 9,000 and mammals 4,500. The vertebrates, in particular, are considerably large and many of them are among the largest of living animals. The gigantic blue whale (*Balanoptera musculus*), which grows to 35 meters long and 120 tons in weight, is the biggest known animal. The whale shark (*Rhineodon typus*) reaches a length of 15 meters and is the second biggest vertebrate after whales. The smallest fish is a Philippine goby (*Pandaka*) measuring only 10 mm long.

1.2 Objectives

After studying this unit, you will be able to:

Enumerate the distinctive characters of chordates and explain how these are characteristically different from the non-chordates.

Classify the chordates giving suitable examples.

Describe the natural history and basic adaptive features of hemichordates and protochordates.

Outline the affinities, ancestry and evolution of hemichordates and protochordates in relation to other groups in the animal kingdom.

Three Fundamental Chordate Characters

All the chordates possess three outstanding unique characteristics at some stage in their life history.

These three fundamental morphological features include:

1. A dorsal hollow or tubular nerve cord
2. A longitudinal supporting rod-like notochord
3. A series of pharyngeal gill slits

1.3 General characteristics of Chordates

a. Notochord:

A dorsal longitudinal skeletal rod is located beneath the nerve cord. It is made up of *vacuolated notochordal cells*. In higher chordates, it is surrounded or replaced by a *vertebral column*.

b. Nerve cord:

A single, tubular (*hollow*) nerve cord is located *dorsal* to the alimentary canal. In the invertebrate phyla, the nerve cord is often paired, solid and ventral to the alimentary canal.

c. Pharyngeal gill slits:

Paired openings are present on either side of the pharynx.

d. Post-anal tail:

The body is differentiated into head, trunk and tail in majority of the animals. Tail is present at some stage of the life cycle. May or may not persist in the adult.

e. Closed vascular system:

The blood never comes out of the blood vessels and it contains *capillaries*.

f. Haemoglobin:

Haemoglobin is present in the RBC.

g. Ventral heart:

The chordate heart is located on the ventral side of the body.

h. Direction of blood flow:

In chordates, the blood is pumped anteriorly, then dorsally and posteriorly.

i. Hepatic portal system:

The food-laden blood from the alimentary canal is carried to the liver through a *hepatic portal vein*.

j. Bilateral symmetry:

All chordates are bilaterally symmetrical at least in the embryonic stage.

k. Cephalization:

In bilaterally symmetrical animals, there is a concentration of nervous tissue and sense organs in or toward the head. This is known as *cephalization*.

l. Metamerism:

Certain structures that are repeated on after another are said to be metameric. Eg. Some nerves, blood vessels, vertebrae, ribs, muscles, etc.

m. Coelom:

All chordates have a true body cavity (between the body wall and the gut wall) lined entirely with mesoderm. The coelom is *entero coelous* developing from the gut.

n. Germ layers

Presence of three germ layers namely ectoderm, mesoderm and endoderm.

1.4 Outline classification upto class level with examples:

Phylum Chordata can be divided into two groups: Acrania (Protochordata) and Craniata (Euchordata) having contrasting characters.

Group A. Acrania (Protochordata)

(Gr. a, absent; kranion, head, or, Gr. protos, first; chorde, cord) . All marine, small, primitive or lower chordates. Lacking a head, a skull or cranium, a vertebral column, jaws and brain. About 2,000 species. The Acrania is divided into three subphyla: Hemichordata, Urochordata and Cephalochordata, chiefly on the character of notochord present.

Subphylum I. Hemichordata

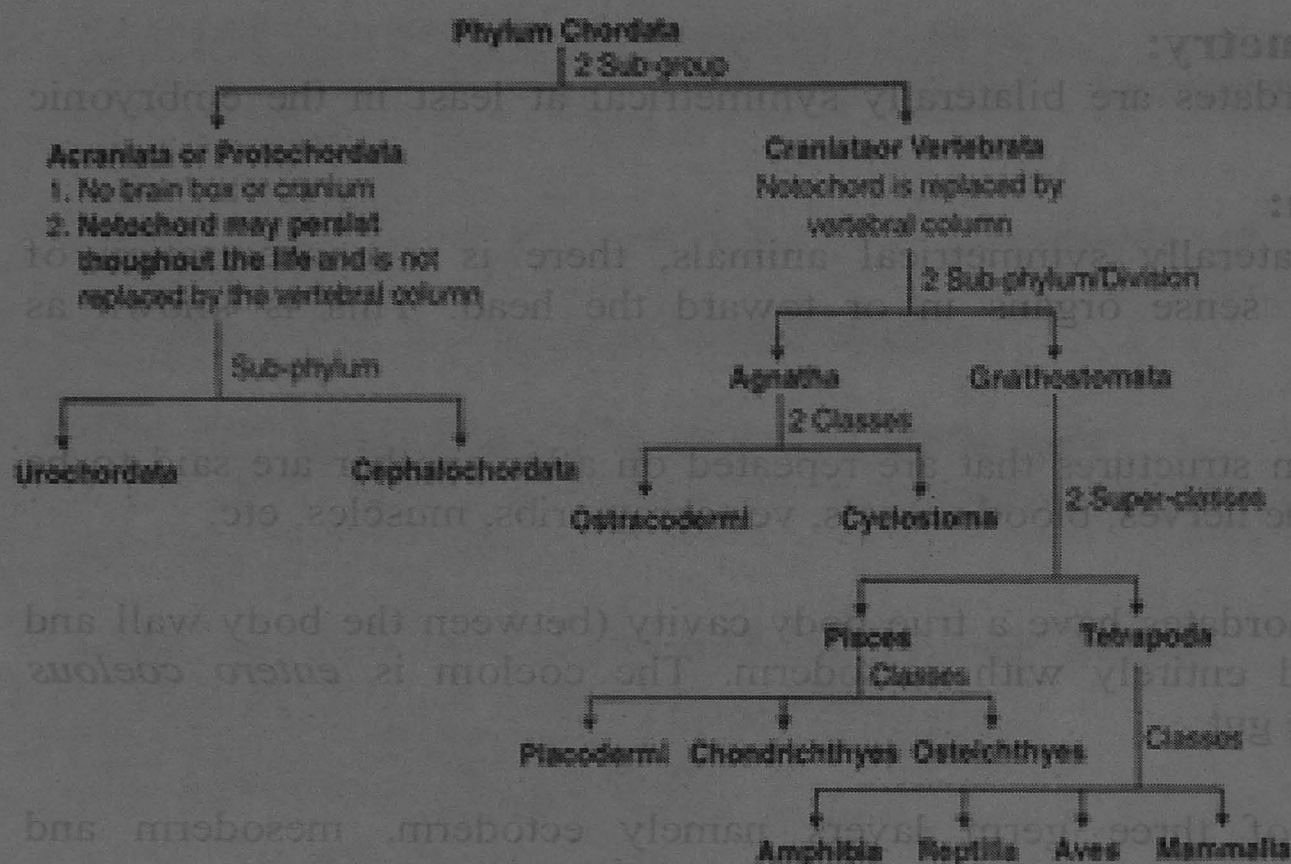
(Gr. hemi, half; chorde, cord). Hemichordate means half-cord. They were called so because they have half-notochord. Body divided into 3 regions: proboscis, collar and trunk. Notochord doubtful, short, confined to proboscis and non-homologous with that of chordates.

Class 1. Enteropneusta. (Gr. enteron, gut; pneustos, breathed) . Body large and worm-like. Gill-slits numerous. Intestine straight. Acorn or tongue worms. 70 species. Balanoglossus, Saccoglossus.

Class 2. Pterobranchia. (Gr. pteron, feather; branchion, gill). Body small and compact. Gill-slits one pair or none. Intestine U-shaped. Pterobranchs. 20 species. Cephalodiscus, Rhabdopleura.

Subphylum II. Urochordata or Tunicata

(Gr. oura, a tail; L. chorda, cord). Urochordata includes chordates containing notochord in the tail region. Notochord and nerve cord only in tadpole-like larva. Adult sac-like often sessile and encased in a protective tunic. Tunicates.



Class 1. Ascidiacea. Sessile tunicates with scattered muscles in tunic. Solitary, colonial or compound. Gill-clefts numerous. Ascidians or sea squirts. 1,200 species. *Herdmania*, *Ciona*, *Molgula*.

Class 2. Thaliacea. Free-swimming or pelagic tunicates with circular muscles in tunic. Sometimes colonial. Slaps or chain tunicates. 30 species. *Salpa*, *Doliolum*, *Pyrosoma*.

Class 3. Larvacea. Tiny, transparent, free-floating. Adults retain many larval features including tail. Only two gill-slits. 30 species. *Oikopleura*.

Subphylum III. Cephalochordata

(Gr. kephale, head; L. chorda, cord). Chordate containing a notochord extending up to the tip of the head. Notochord and nerve cord present throughout life along entire length of body.

Class Leptocardii. Body fish-like, segmented with distinct myotomes and numerous gill-slits. Free-swimming and burrowing. Lancelets. 30 species. *Branchiostoma* (= *Amphioxus*), *Asymmetron*.

Group B. *Craniata* (Euchordata)

Aquatic or terrestrial, usually large-sized, higher chordates or vertebrates with distinct head, a vertebral column, jaws and brain protected by a skull or cranium. The Craniata includes a single subphylum, the Vertebrata.

Subphylum IV. Vertebrata

(L. vertebrates, backbone). Notochord supplemented or replaced by a vertebral column or backbone composed of overlapping vertebrae. Body divisible into head, neck, trunk and tail. Usually dioecious. Vertebrates. Largest chordate subphylum including about 46,500 species.

The subphylum Vertebrata is divided into two divisions: Agnatha and Gnathostomata, with contrasting characters as follows:

Division I. Agnatha

(Gr. a, not; gnathos, jaw). Jawless primitive fish-like vertebrates without true jaws and paired limbs.

Class 1. Ostracodermi . (Gr. ostrakon, shell; derma, skin). Several extinct orders of ancient primitive heavily armoured, Palaeozoic, world's first vertebrates, collectively called the ostracoderms. Cephalaspis, Drepanaspis.

Class 2. Cyclostomata. (Gr. cyklos, circular, stoma, mouth). Body eel-shaped, without scales, jaws and lateral fins. Mouth rounded and suctorial. Gills 5-16 pairs. Parasites and scavengers. 45 species. Lampreys (Petromyzon) and hagfishes (Myxine).

Division II. Gnathostomata

(Gr. gnathos, jaw; stoma, mouth). Jawed vertebrates having true jaws and paired limbs.

For convenience, some taxonomists further divide Gnathostomata into two superclasses. All the fishes and fish-like aquatic gnathostomes are placed in the superclasses Pisces, whereas all the four-footed terrestrial gnathostomes in the superclass Tetrapoda. Their contrasting features are as follows:

Superclass 1. Pisces

(L. piscis, fish). Fish or fish-like aquatic forms with paired as well as median fins, gills and scaly skin.

Class 1. Placodermi. Several extinct orders of primitive earliest jawed fishes of Palaeozoic with bony head shield movably articulated with trunk shield. Placoderms. Climatius, Dinichthys.

Class 2. Chondrichthyes. (Gr. chondros, cartilage; ichthys, fish). Mostly marine. Cartilaginous endoskeleton. Skin with placoid scales. Gill-slits not covered by operculum. Pelvic claspers in male. Cartilaginous fishes. Approximately 600 species. Scoliodon (dogfish), Chimaera (ratfish).

Class 3. Osteichthyes. (Gr. osteon, bone; ichthys, fish). Freshwater and marine. Endoskeleton mostly bony. Skin having various types of scales (cycloid, ctenoid) other than placoid. Gill-slits covered by operculum. Males without claspers. Bony fishes. 20,000 species. Labeo (rohu), Protopterus (lungfish), Hippocampus (seahorse).

Superclass 2. Tetrapoda

(Gr. tetra, four; podos, foot). Land vertebrates with two pairs of pentadactyle limbs, cornified skin and lungs.

Class 1. Amphibia. (Gr. amphi, both; bios, life). Larval stage usually aquatic and breathes by gills. Adult typically terrestrial and respire by lungs. Skin moist, glandular and with no external scales. Heart 3-chambered. Amphibians. Approximately 2,500 species. Rana(frog), Bufo (toad), Ambystoma (salamander).

Class 2. Reptilia.(creeping). Terrestrial tetrapods, skin dry, covered by ectodermal horny scales or bony plates. Heart incompletely 4-chambered. Cold-blooded. Respiration by lungs. 7,000 species. Hemidactylus (wall lizard), Naja (cobra), Sphenodon, Crocodilus(crocodile).

Class 3. Aves. (L. avis, bird). Typically flying vertebrates covered with feathers. Forelimbs modified into wings. No teeth in beak. Heart 4-chambered. Warm blooded. Birds. About 9,000 species. Struthio(African ostrich), Columba(pigeons), Gallus(fowl).

Class 4. Mammalia. (L. mamma, breast). Body covered by hair. Skin glandular. Female with mammary glands which secrete milk for suckling the young. Heart 4-chambered. Warm blooded, air breathing vertebrates. 4,500 species. Echidna(spiny anteater), Macropus(Kangaroo), Rattus(rat), Homo(man).

1.5 Prochordate

Prochordates are the first chordates. They are the primitive chordates. They are the intermediate link between invertebrates and chordates. They are called invertebrate chordates.

This prochordates or lower chordates have no backbone or vertebrae. They have no brain and cranium (brain case). Hence, they are grouped together as Acrania.

1.6 Type study - Amphioxus

Branchiostoma (=Amphioxus): The Lancele

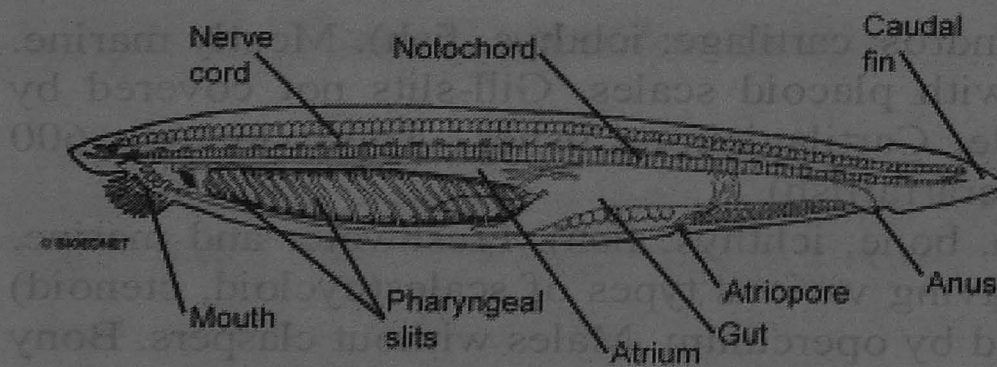


Fig. Amphioxus

The members of the subphylum Cephalochordata are small, marine and superficially fish-like chordates. They are of special significance because they possess the three distinctive or primary chordate characters such as notochord, dorsal tubular nerve cord and pharyngeal gill-slits, in simple primate chordate life.

Systematic	Position
Phylum	Chordata
Group	Acrania
Subphylum	Cephalochordata
Class	Leptocardii
Family	Branchiostomidae
	Type Branchistoma (=Amphioxus) (The Lancelet)

Derivation of Names

The old generic name Amphioxus (Gr., amphi=double + oxys=sharp) and the common name “lancelet” or “lancelet” (a little lance) refer to both ends of the body which are sharp, pointed and lance-like.

Habits and Habitat

Branchiostoma is a marine animal commonly found in shallow waters, preferably brackish or salt water, on the sandy coasts. It leads a double mode of life. Mostly it is buried in sand in an upright condition with only the anterior end protruding above the sand. However, at night or dusk, it comes out of the sand swims actively by lateral undulating movements of its body caused by muscles. It swims vertically in water. When disturbed, it jumps out of its burrow, swims a short distance, dives back into sand keeping head downwards, makes a U-turn inside so that the anterior end comes up again above the sand. Branchiostoma is a typical ciliary feeder. It feeds on planktonic microorganisms brought along with respiratory-cum-food water current, which constantly enters the mouth placed on its projecting anterior end, and leaves through the atriopore. Male and female individuals are separate. They release their gametes in water where fertilization takes place. Development is indirect involving a free-swimming larval stage, which gradually assumes the shape of the adult.

External Features

Shape, size and colour.

Branchiostoma is a small-elongated narrow and fish-like animal 5 to 8 cm in length. Body is whitish, somewhat translucent, laterally compressed, and pointed at both the ends, hence the common name “lancelet” which means “a little lance”. The streamline body is well suited for burrowing as well as swimming. The posterior end is more tapering and pointed than the anterior end.

Division of body. A true head is degenerate and absent. The body is divisible only in two regions. The greater anterior region constitutes the trunk and a much

shorter post anal posterior region is the tail. The anterior end of trunk projects in front as appointed snout or rostrum.

Apertures. The trunk bears three openings: mouth, atriopore and anus. Anteriorly, below the rostrum is a tentaculated structure, the oral hood, formed by dorsal and lateral projections of the body. It shall be described later as a part of the digestive system. Mouth is a very wide antero-ventral aperture bordered by the free margin of oral hood.

Atriopore is a small mid-ventral rounded aperture lying just in front of the ventral fin. The large atrial cavity surrounding the pharynx opens to outside through atriopore. Another small aperture, the anus, lies somewhat asymmetrical to the left of mid-ventral line at the base of caudal fin. The small posterior body region behind the anus is the tail.

Fins and folds. Branchiostoma bears three longitudinal median or unpaired fins: dorsal, caudal and ventral. The dorsal fin runs as a low, mid-dorsal fold along the entire length of trunk. It is continuous behind with a much broader caudal fin around the tail. The ventral fin runs mid-ventrally from caudal fin upto atriopore along the posterior trunk region. It is slightly wider than the dorsal fin. The dorsal and ventral fins are internally supported respectively by one and two rows of small rectangular fin-ray boxes, each formed by stiff connective tissue containing a central nodule. Fin rays are lacking in the caudal fin. The structure of fins and fin-ray boxes is different from that in fishes.

Paired fins are absent. However, running longitudinally along the ventro-lateral margins of the anterior two-third part of trunk, from oral hood to atriopore, there are two hollow membranous metapleural folds. These possibly help in burrowing in sand rapidly due to turgescence caused by flow of body lymph in their cavities. The two folds are connected by a horizontal fold of body wall, called epipleur, which forms the floor of the atrial cavity inside. Thus, the anterior two-third of the body, in the region of metapleural folds, appears roughly triangular in cross section, while the posterior one-third, in the region of ventral and caudal fins, nearly oval.

Myotomes and gonads. On each lateral side of body a series of < shaped muscle bands, called myotomes or myomeres can be seen through the transparent body wall. Between mouth and atriopore, can also be seen on either side below the myotomes, a series of gonads.

Digestive System

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

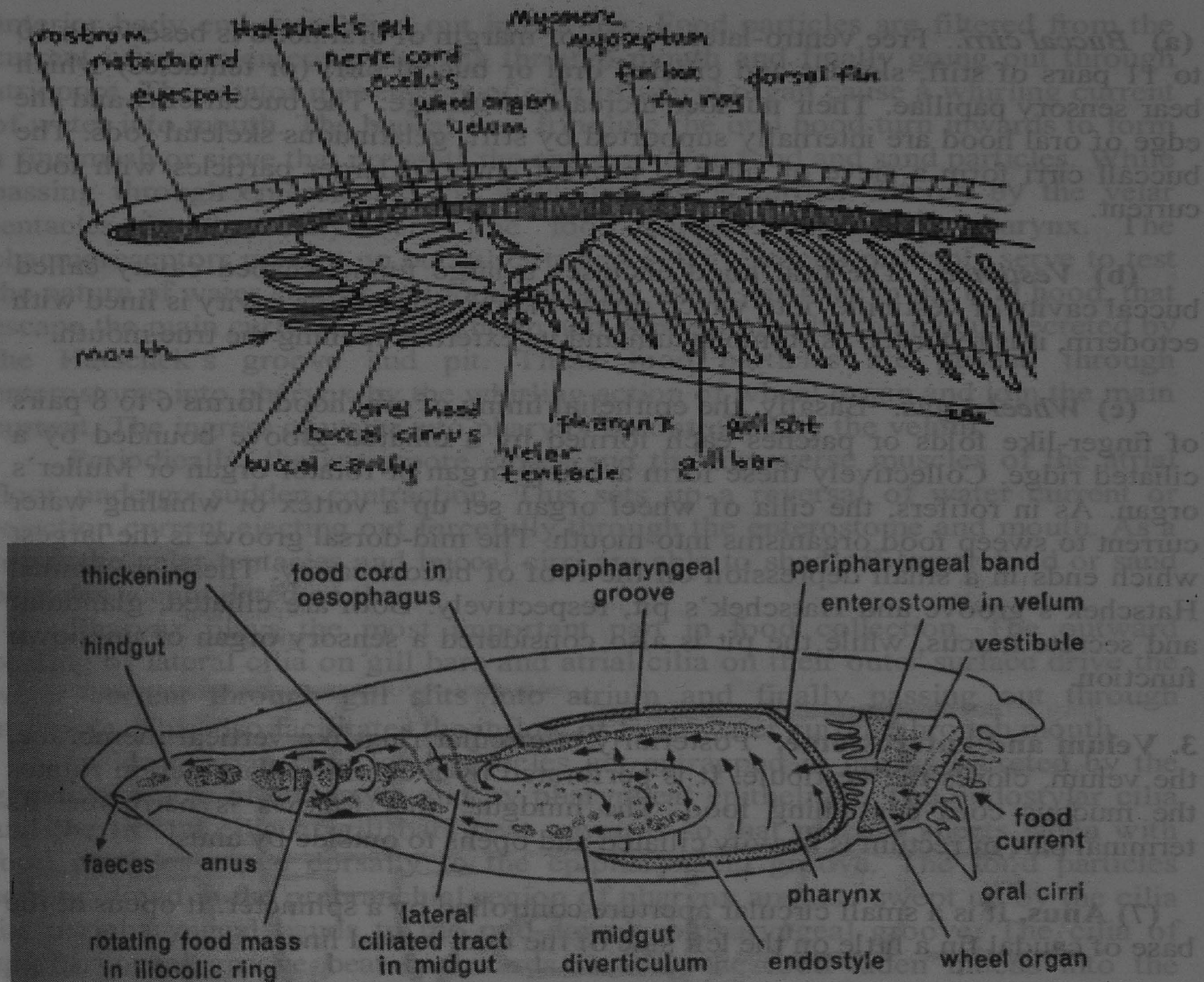


Fig. 6-26. *Branchiostoma*. Movements of ciliary currents and food in the alimentary canal.

g mechanism. *Branchiostoma* is a dorsally to the epipharyngeal

[I] Alimentary canal

The alimentary canal is a straight and complete tube from mouth to anus. It is lined throughout by ciliated epithelium and its diameter varies in different parts.

1. Mouth. Mouth is a large oval medial aperture situated antero-ventrally below the rostrum or anterior most tip of the trunk. It is bordered by a frill-like membrane, the oral hood.

2. Oral hood and buccal cavity. The oral hood is formed by the dorsal and lateral projections of the anterior end of trunk.

(a) *Buccal cirri*. Free ventro-lateral edge or margin of oral hood is beset with 10 to 11 pairs of stiff, slender and ciliated oral or buccal cirri (or tentacles) which bear sensory papillae. Their number increases with age. The buccal cirri and the edge of oral hood are internally supported by stiff, gelatinuous skeletal rods. The buccal cirri form a sieve or filter to prevent entry of larger particles with food current.

(b) *Vestibule*. The oral hood encloses a large funnel-shaped cavity called buccal cavity or vestibule into which opens the mouth. As this cavity is lined with ectoderm, it is regarded as stomodaeum and its external opening the true mouth.

(c) *Wheel organ*. Basally, the epithelial lining of oral hood forms 6 to 8 pairs of finger-like folds or patches each formed by a ciliated groove bounded by a ciliated ridge. Collectively these form a wheel organ or rotator organ or Muller's organ. As in rotifers, the cilia of wheel organ set up a vortex or whirling water current to sweep food organisms into mouth. The mid-dorsal groove is the largest which ends in a small depression on the roof of buccal cavity. These are named Hatschek's groove and Hatschek's pit, respectively. Both are ciliated, glandular and secrete mucus, while the pit is also considered a sensory organ of unknown function.

3. Velum and enterostome. Posteriorly, a circular ring-like vertical membrane, the velum, closes the vestibule. It is perforated by a central ciliary action rotates the mucous cord containing food. The hindgut that follows is narrower. Its terminal part or rectum is heavily ciliated and opens to outside by anus.

(7) **Anus.** It is a small circular aperture controlled by a sphincter. It opens at the base of caudal fin a little on the left side of the mid-ventral line.

[II] Digestive glands

The midgut diverticulum, often referred to as "liver", is the main digestive gland. It arises as a blind pouch from the ventral junction of oesophagus and midgut and extends forward into atrial cavity on the right side of pharynx up to one-third of its length. It is surrounded by a narrow coelomic cavity. Its inner lining has a strong ciliated groove for movement of food. Its zymogen cells secrete a number of digestive enzymes. Besides, the epithelial lining or intestine also contains numerous gland cells that secrete digestive enzymes.

[III] Physiology of digestive system

1. Food. Branchiostoma is a microphagous animal feeding on diatoms, desmids, protozoans and other pelagic microscopic organisms, suspended in seawater.

2. Feeding mechanism. Branchiostoma is a ciliary or filter feeder, like an ascidian. The animal leads a sedentary life buried in sand and with only the

anterior body end protruding out into water. Food particles are filtered from the current of water entering pharynx through mouth and finally going out through atriopore. The rotator movements of cilia of wheel organ cause a whirling current of water into mouth. The buccal cirri fringing the oral hood turn inwards to form a fine mesh or sieve that prevents the entry of large food and sand particles. While passing through enterostome the water current is further filtered by the velar tentacles so that only very fine food particles enter the pharynx. The chaemoreceptors present on buccal cirri and velar tentacles probably serve to test the nature of water current and food particles. Food particles in the oral hood, that escape the main current, are caught up and concentrated by the mucus secreted by the Hatschek's groove and pit. These food particles are pushed through enterostome into pharynx by the whirling action of wheel organ and join the main current. The ingress of water into pharynx is controlled by the velum.

Periodically, the antriopore closes and the transverse muscles of the atrial floor undergo sudden contraction. This sets up a reversal of water current or rejection current ejecting out forcefully through the enterostome and mouth. As a result the velar tentacles and buccal cirri are able to shed off larger food or sand particles accumulated on them.

Pharynx plays the most important part in food collection. The outward beating of lateral cilia on gill bars and atrial cilia on their outer surface drive the water current through gill slits into atrium and finally passing out through atriopore. This also facilitates the inflow of fresh water current through mouth.

Inside pharynx, the food particles get entrapped in mucus secreted by the glandular tracts of endostyle and by pharyngeal epithelium. The endostylar cilia and the frontal cilia of gill bars beat upwards so that mucous sheets laden with food particles move dorsally to the epipharyngeal groove. The food particles settling down in the prebranchial region of pharynx are also swept up by the cilia for peripharyngeal bands to the mid-dorsal epipharyngeal groove. The cilia of epipharyngeal groove beat backwards moving the food laden mucus into the oesophagus in the form of a narrow food cord or food cylinder.

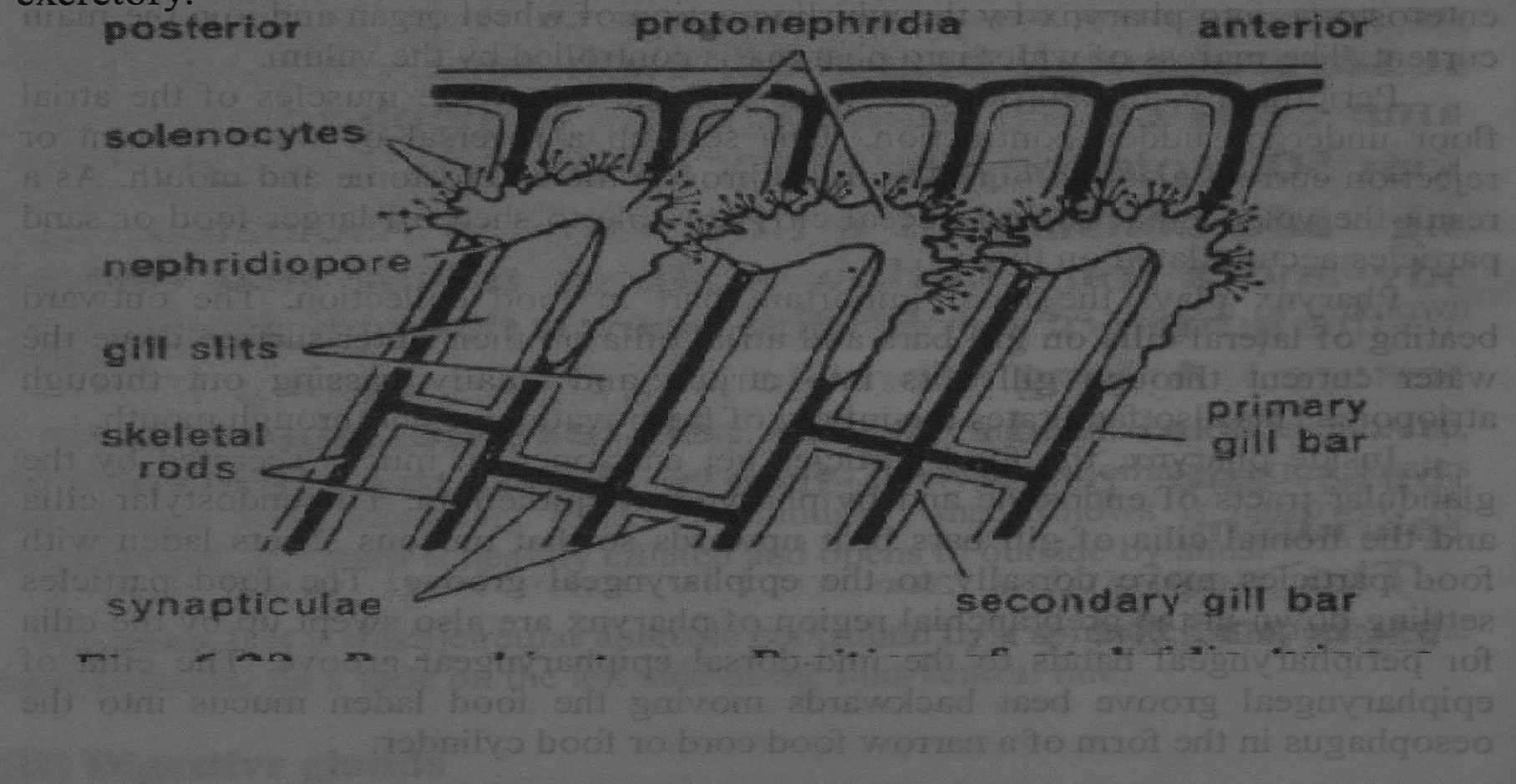
3. Digestion

Digestive enzymes are secreted from two sources, midgut diverticulum and the midgut epithelium. The food cord from pharynx passes through oesophagus into midgut. By lateral tract of cilia, it is directed into midgut diverticulum and driven again to midgut by ciliary action. Digestion starts in the midgut and continues in the remaining part of intestine. In the ilio-colic ring, the food cord undergoes rotation due to ciliary activity. This breaks up the food material into still smaller particles, thoroughly mixes up enzymes with food and delays the backward passage of food to allow more time for the action of enzymes. Digestion is mainly extracellular but intracellular digestion also takes place, which is unique as it is unknown in other vertebrates. Intracellular digestion takes place mainly in the phagocytic cells of midgut diverticulum. The digestive enzymes of branchiostoma are amylase, lipase and protease. Digested food is absorbed partly in midgut but mostly in hindgut and the undigested material is finally thrown out of anus.

Occasionally, some food particles may pass into arterial cavity and eventually engulfed by the phagocytic cells present in renal papillae on the floor of atrial cavity.

Excretory System

While excretory organs of other chordates are coelomoducts or mesodermal kidneys, those of Branchiostoma are entirely different. They closely resemble the protonephridia of flatworms or poly-chaete annelids, thus providing a good example of parallel evolution. Some other organs and cells are also regarded to be excretory.



3. Digestion

Digestive enzymes are secreted from two sources, midgut diverticulum and the midgut epithelium. The food cord from pharynx passes through oesophagus into midgut. By lateral wall of midgut, it is directed into midgut diverticulum and driven again to midgut by ciliary action. Digestion starts in the midgut and continues in the remaining part of intestine. In the (ileo-caecal) part, the food cord undergoes rupture due to ciliary activity. This breaks up the food material into still smaller particles, thoroughly mixes up enzymes with food and delays the backward passage of food to allow more time for the action of enzymes. Digestion is mainly extracellular, but intracellular digestion also takes place which is unique as it is unknown in other vertebrates. Intracellular digestion takes place mainly in the phagocytic cells of midgut diverticulum. The digestive enzymes of Branchiostoma are amylase, lipase and protease. Digested food is absorbed partly in midgut but mostly in hindgut and the undigested material is finally thrown out of anus.

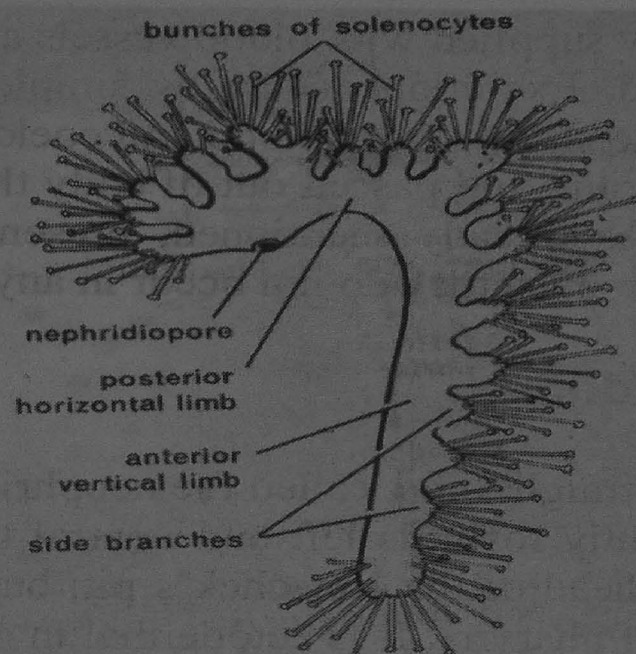


Fig. 6-30. *Branchiostoma*. Entire protonephridium.

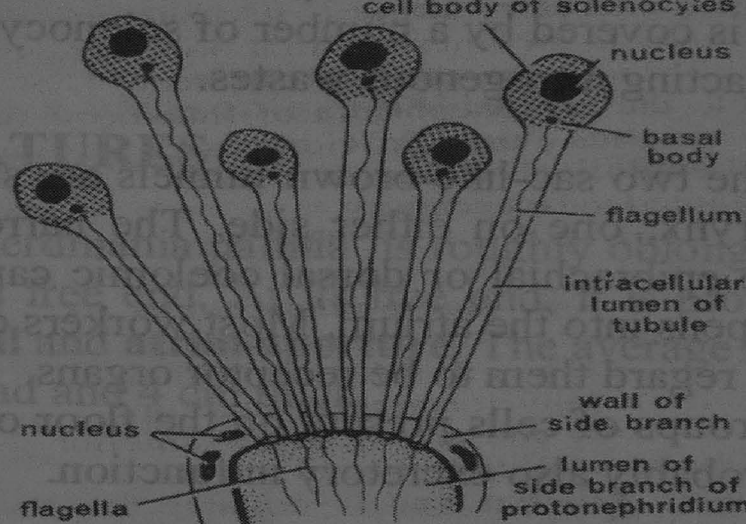


Fig. 6-31. *Branchiostoma*. An enlarged view of solenocytes.

1. Protonephridia.

The protonephridia of *Amphioxus* are simple, closed, ciliated, sac-like and thin-walled ectodermal tubules. 90 to 100 pairs are present segmental on dorso-lateral pharyngeal wall one above each gill slit on either side. Each nephridium is bent forming a small upper posterior horizontal limb and a long lower anterior vertical limb. The vertical limb lies in the coelomic canal of the primary gill bar and terminates blindly. The horizontal limb also lies in the dorsal coelomic canal but opens into the atrium opposite a secondary gill bar by a small ciliated aperture, the nephridiopore. The dorsal and anterior surface of nephridium gives out several small branches, each receiving a tuft of flame cells called solenocytes. A nephridium bears about 500 solenocytes. Each solenocyte is nearly 50μ long and consists of a tiny rounded nucleated cell body and a long hollow stalk or tubule that opens into the lumen of nephridial branch through a separate aperture. A long vibratile flagellum arising from a minute basal body in the cell extends through the tubule and projects freely into the lumen of nephridium.

The nephridia are richly supplied with blood vessels and the solenocytes freely project into coelomic fluid. Excretion occurs by simple diffusion. Nitrogenous wastes are extracted by solenocytes from blood and coelomic fluid, discharged by nephridio pores into the atrium and passed out of body through atriopore with the outgoing water current. As already mentioned, presence of protonephridia in amphioxus is quite peculiar since they do not occur in any other chordate.

2. Hatschek's nephridium.

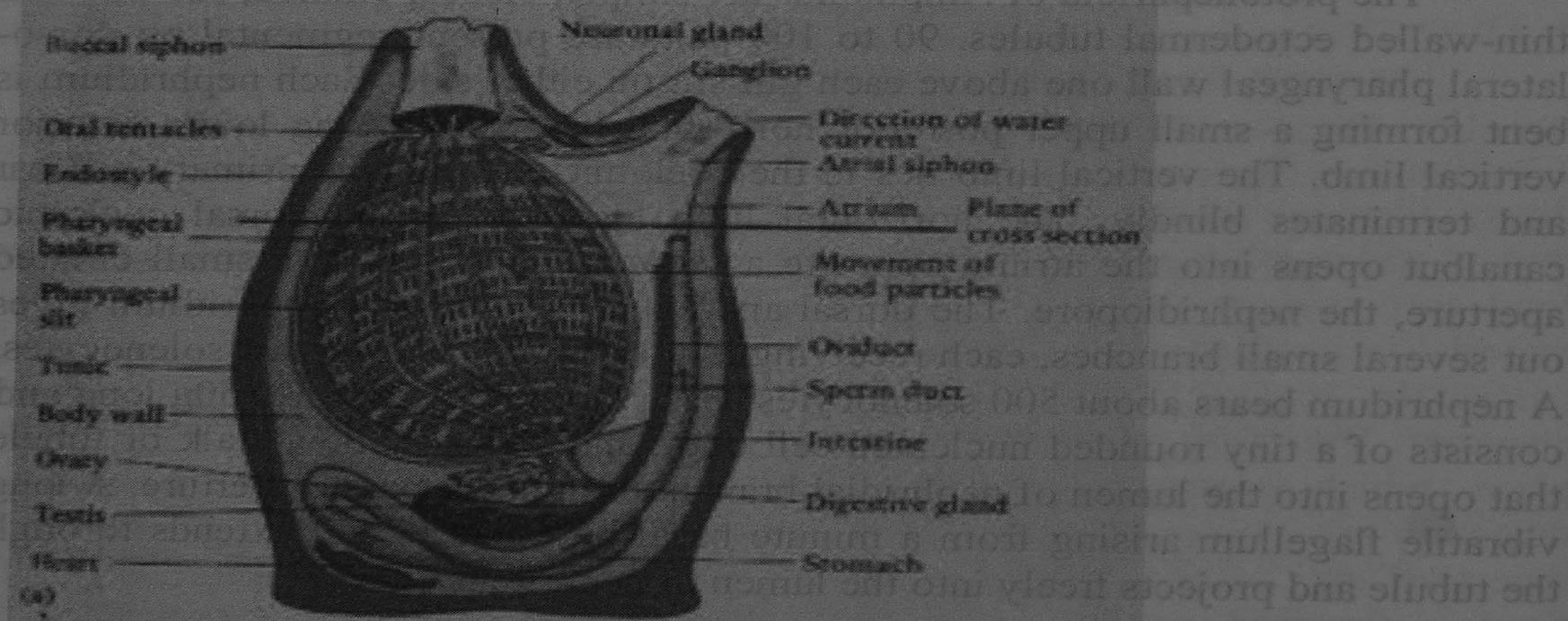
A single long and straight tube, called the neuphridium of Hatschek, lies in the roof of oral hood slightly towards left and ventral to notochord. Its anterior blind end lies somewhat ahead of the Hatschek's pit, but the posterior end opens into the prebranchial sac of pharynx. It is ectodermal in origin and supplied blood by the dorsal aorta. Its structure is basically like that of a protonephridium already described. Its surface is covered by a number of solenocytes each surrounded by a coelomic sac and extracting nitrogenous wastes.

3. Brown funnels. The two sac-like brown funnels are situated dorsally upon the posterior end of pharynx, one on either side. The narrow anterior end of each funnel opens into the epibrachial or dorsal coelomic canal of its side, while the broad posterior end opens into the atrium. Most workers consider the funnels to be excretory while some regard them to be receptor organs.

4. Renal papillae. Groups of cells present on the floor of atrial cavity form renal papillae, which are probably also excretory in function.

1.7 Ascidians tadpole larva and retrogressive metamorphosis HABIT AND HABITAT

Herdmania pallida (ascidian) is a solitary marine form. Each animal is found attached to the substratum usually separately, at its postero-ventral end by means of a foot.



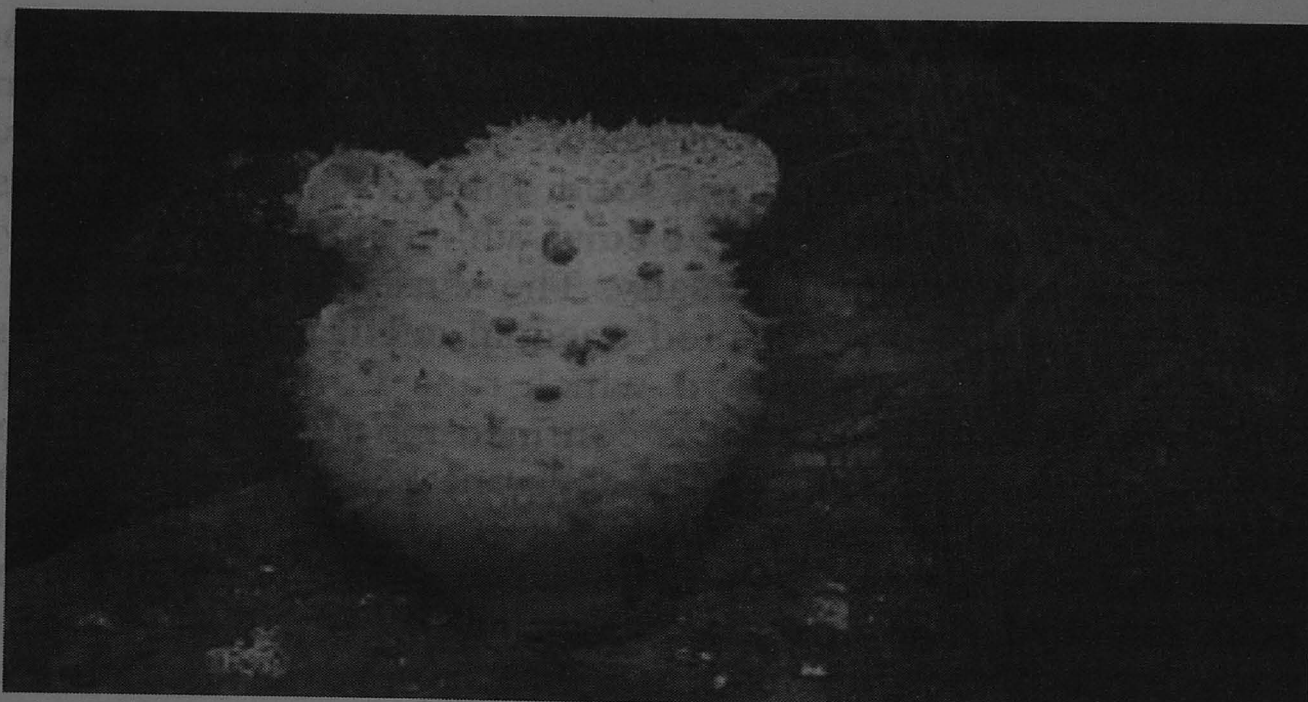


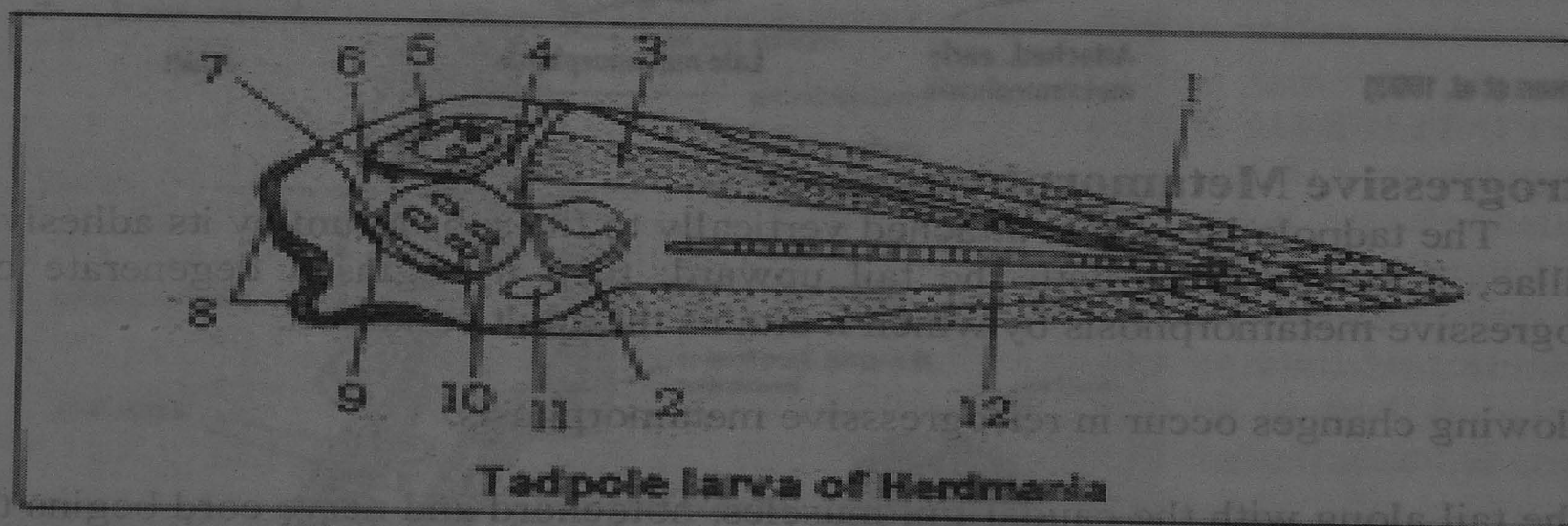
Fig. Ascidian

EXTERNAL FEATURES

The body of *Herdmania pallida* is roughly oblong in out-line, narrower at its attached than at its free end. At its free end, it is provided with two external openings the **branchial** and **atrial aperture**. The average size of the adult is about 9.5 cm long, 7 cm broad and 4 cm thick.

Tadpole Larva

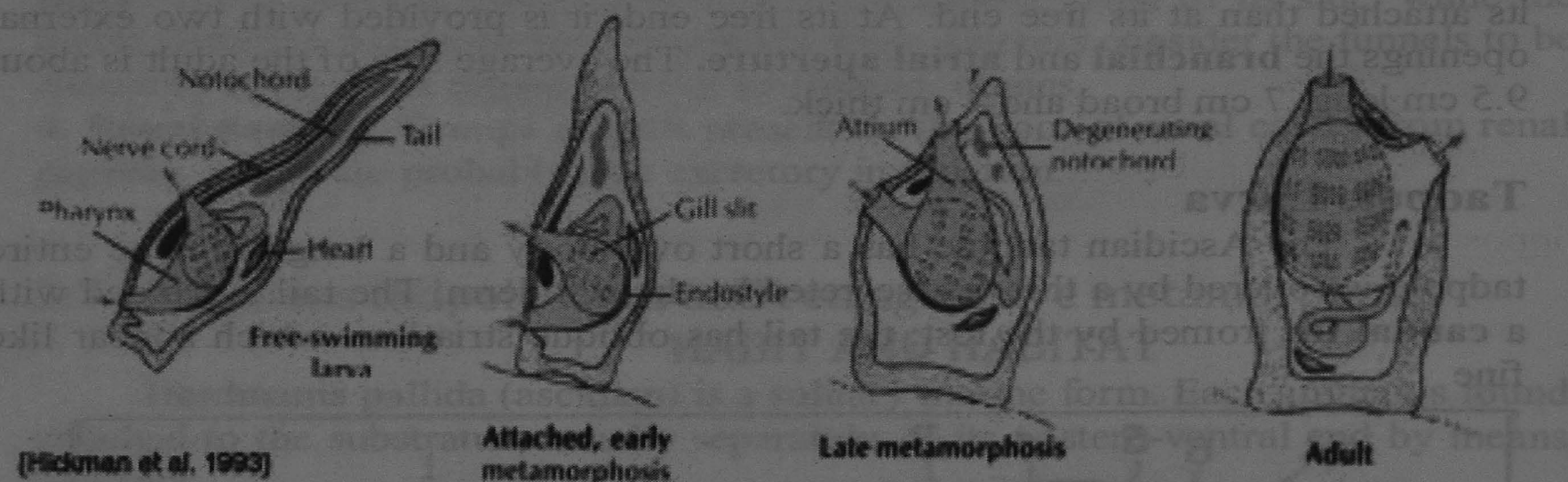
The Ascidian tadpole has a short oval body and a long tail. The entire tadpole is covered by a thin test secreted by the ectoderm. The tail is fringed with a **caudal fin** formed by the test; the tail has oblique striations which appear like fine



- | | | |
|------------------|----------------------|--------------------------|
| 1) Tail fin | 2) Intestine | 3) Nerve cord |
| 4) Atrial cavity | 5) Sensory vesicle | 6) Ciliated diverticulum |
| 7) Oral aperture | 8) Adhesive papillae | 9) Endostyle |
| 10) Stigmata | 11) Heart | 12) Notochord |

rays. At the sides of the tail are bands of muscle fibres. At the anterior end of the trunk are three **adhesive papillae** made of ectodermal cells. The nervous system consists of an enlarged anterior part called **sense vesicle** or brain which is hollow. The sense vesicle is continued posteriorly into a solid, thick mass of nerve cells, the **visceral ganglion**, it is continued into a **nerve cord** which is hollow, the nerve cord is continued into the tail and lies mid-dorsally. The sense vesicle contains a pigmented **statocyst** (otocyst) and two pigmented unequal **ocelli** as sense organs. Lying ventral to the nerve cord is a **notochord** which runs from the endoderm cells of the trunk to the end of the tail, hence it is confined mostly to the tail. The alimentary canal begins to be distinguished, it has a pharynx, oesophagus, stomach and intestine, but it is not functional since the mouth is covered by the test, and the larva does not feed. The pharynx has an **endostyle** and also some **stigmata**. An **atrial cavity** is formed around the pharynx and it opens to the exterior by an etrial aperture lying dorsally. The heart and pericardium have been formed.

The ascidian tadpole larva is unquestionably a true chordate and after about three hours of non-feeding and free-swimming existence, it sinks to the bottom.



Retrogressive Metamorphosis

The tadpole larva gets attached vertically to the substratum by its adhesive papillae, it stands erect with the tail upward; then it begins a degenerate or retrogressive metamorphosis by which it attains the adult condition.

Following changes occur in retrogressive metamorphosis:

- The tail along with the caudal fin, muscles, notochord and nerve cord begins to reduce and finally disappears largely due to phagocytosis and partly due to loss.
- Four ectodermal ampullae arise from the trunk which firmly anchor the larva to the substratum.

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

d. The atrial cavity enlarges, the pharynx also increases in size and the stigmata increase in number by division. The stomach and intestine grow. A heart and circulatory system develop.

e. The central nervous system begins to decrease and it forms a small solid brain and a neural gland, which come to lie upwards between the mouth and the atrial aperture. The sense organs (ocelli and statocyst) disappear completely.

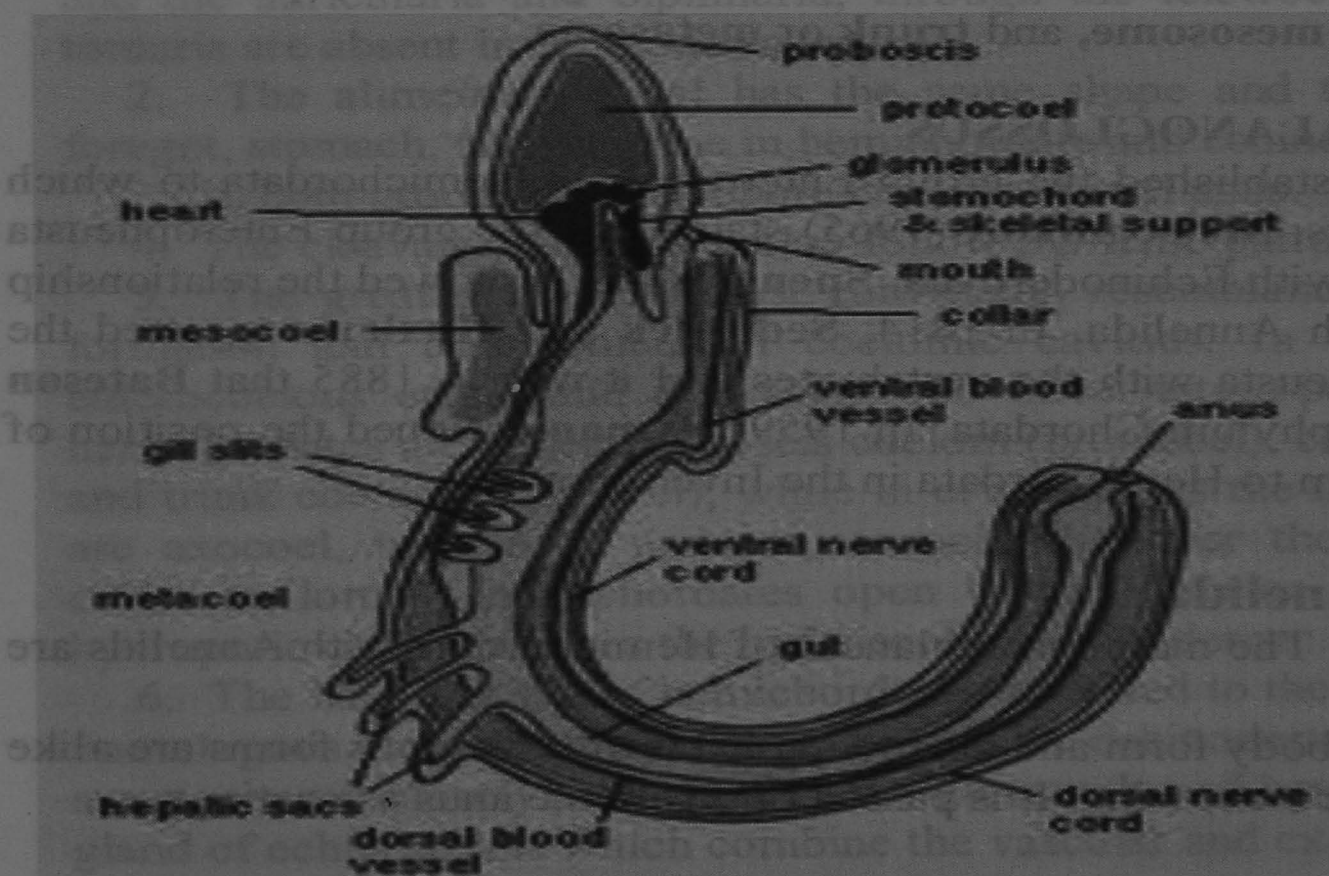
f. Gonads arise from the mesenchyme.

g. Adhesive papillae and ectodermal ampullae are lost.

h. The test encloses the entire animal, it increases in thickness and it may form a foot. These changes result in the formation of an inert, sessile and degenerate adult in which the chordate characters, except gill clefts, are lost.

1.8 Affinities of Balanoglossus

Balanoglossus (Gr., balano, acorn; glossa, tongue) belongs to class **Enteropneusta** which have a straight digestive tube with mouth and anus at opposite ends. They have numerous gill-clefts but have no anus. They are burrowing animals ranging in size from about 2 cm to 50 cm. Balanoglossus has about 20 species.



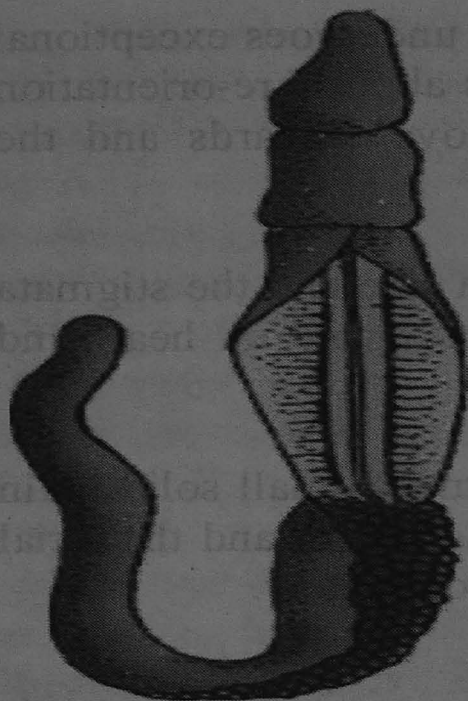


Fig. Balanoglossus

HABIT AND HABITAT

Balanoglossus is a burrowing and exclusively marine animal. It is found in shallow waters between tide marks along the coast of warm and temperate oceans. Balanoglossus is world-wide in distribution. Balanoglossus is tubicolous living in U-shaped burrows excavated in the sandy bottom.

EXTERNAL CHARACTERS

The body of balanoglossus is soft, elongated, cylindrical, being richly ciliated all over and covered with mucous. The length of animal varies from 2 cm to 2.5 metres. Most forms are drab coloured, through reddish tints are present, several species are luminescent due to mucous. They have an offensive odour. The body is bilaterally symmetrical and divided into three regions, viz., **proboscis** or **protosome**, **collar** or **mesosome**, and **trunk** or **metasome**.

AFFINITIES OF BALANOGLLOSSUS

Gegenbaur (1870) established the group Enteropneusta Hemichordata to which Balanoglossus belongs. **Metschnikoff** (1965) stated that the group Enteropneusta had certain affinities with Echinodermata. **Spengel** (1893) showed the relationship of Enteropneusta with Annelida. In 1814, **Sedgwick** and **Huxley** suggested the affinities of Enteropneusta with the vertebrates and it was in 1885 that **Bateson** included them in the phylum Chordata. In 1959, **Hyman** assigned the position of an independent phylum to Hemichordata in the Invertebrata.

Affinities with Annelida

Resemblances: The main resemblances of Hemichordata with Annelids are as follows:

1. The general body form and burrowing habit of tubicolous forms are alike and mud is ingested in burrowing. It is passed out from the anus as castings.

2. The vascular system of most hemichordates is like that of annelids with blood flowing anteriorly in the dorsal vessel and posteriorly in the ventral vessels.

3. The hemichordate **tornaria larva** appears like a modified **trochosphere** larva of polychaete worms.

Differences: The differences between two groups are so great that there can be no phylogenetic relationship between them. The differences are as follows:

1. Gill-slits are absent in annelids.
2. Paired nerve cords are present in annelids.
3. The larva of Hemichordata and Annelids also differ in the following ways:
 - (i) Nephridia are absent in tornaria larva.
 - (ii) Pre-oral coelom is absent in trochosphere larva.
 - (iii) In trochosphere blastopore becomes the mouth, while in tornaria it becomes the anus.

Affinities with Echinodermata

The adult hemichordate and adult echinoderm are so different that one cannot suspect any relationship between them, the only anatomical similarity between them is their nervous system which in both cases consists of a nerve net lying near the surface embedded in the epidermis. But there is a strong affinity between the two phyla on embryological evidence, the method of formation of the gastrula and the coelom is very similar in the two phyla and for years the tornaria larva was considered to be the larva of an echinoderm. The **tornaria larva** shows a very striking resemblance with the **auricularia larva** and specially with **bipinnaria** of **Asteroides**.

Resemblances: The resemblance extends into the following details:

1. The ciliated band is identical and follows the same course in the tornaria and the auricularia and bipinnaria, through the telotroch and eye spots of the tornaria are absent in echinoderm larvae.
2. The alimentary canal has the same shape and the same divisions into foregut, stomach, and intestine in hemichordate and echinoderm larvae.
3. In both groups the blastopore becomes larval anus.
4. The cleavage and gastrulation follow the same pattern in both.
5. The greatest and the most convincing resemblance lies in the method of formation and arrangement of coelomic cavities. In both the coelom is of enterocoelous origin and it divides into three antero-posterior parts, which in hemichordates are called proboscis coelom (protocoel), collar coelom (mesocoel), and trunk coelom (metacoel), while in echinoderms the three parts of the coelom are axocoel, hydrocoel, and somatocoel. Moreover the proboscis coelom and collar coelom of hemichordates open to the exterior by pores through short hydroporic canals, as does the hydrocoel in echinoderms.
6. The heart vesicle of hemichordates is related to the proboscis coelom and is homologous with the madreporic vesicle of echinoderm larvae, and both these structures are closely connected to the glomerulus of hemichordates and the axial gland of echinoderms which combine the vascular and excretory functions.

Differences: There are following differences between two groups:

1. Eye spot is absent in bipinnaria.
2. The apical plate and telotroch are absent in bipinnaria.
3. The protocoel is paired in echinoderms, while unpaired in tornaria larva.

The many embryonic resemblances between hemichordates and echinoderms cannot possibly be accidental or due to convergent evolution. The only infallible conclusion is that the two groups are closely related and that they arose from a common ancestor. Echinoderms have deviated greatly from the ancestral type, while hemichordates are closer to it. The common ancestor gave rise to echinoderms as a blind side branch, while the main line of evolution produced the hemichordates and chordates.

Affinities with Chordata

Bateson (1887) introduced Hemichordata in phylum Chordata, since then a close relationship has been acknowledged between hemichordates and chordates. This arrangement exists even today in most books.

Resemblances: The phylogenetic relationship of hemichordates and chordates is based on the supposed presence of three fundamental chordate characters in both groups, viz., a **notochord**, **central nervous system** and **gill-clefts**.

The buccal diverticulum or stomochord of hemichordates has been regarded as the equivalent of a notochord since the time of **Bateson**. Modern workers of hemichordates do not accept this idea and have raised many objections:

1. The buccal diverticulum is a hollow evagination of the anterior wall of the buccal cavity, and it is not definite whether it is endodermal or ectodermal in origin, whereas the notochord is a long solid rod formed from the roof of the archenteron.

2. The buccal cavity diverticulum is generally made of ordinary epithelial cells, while the notochord of vertebrates consists of large vacuolated cells.

3. The buccal diverticulum has no enclosing sheath as found around the notochord.

4. The buccal diverticulum lies ventral to the dorsal blood vessel, whereas the vertebrate notochord is always dorsal to the main dorsal blood vessels.

5. The buccal diverticulum is small and confined to the proboscis, while the notochord extends far backwards. It can be safely concluded that there is no representative of the notochord in hemichordates.

There are certain resemblances between the nervous system of hemichordates and chordates, such as its position, formation of the dorsal nerve cord from the dorsal epidermis, and the hollow collar cord, which often has a neuropore and is comparable with the neural cord of vertebrates. However, there are major differences, such as its superficial position in contact with the epidermis, possession of a main ventral nerve cord, and a circumenteric nerve ring, in these features the nervous system is distinctly invertebrate. Thus the invertebrate features of the nervous system of hemichordates outweigh its chordate characters.

The chief link between the hemichordates and chordates lies in the pharynx and its gill-clefts. The details of the branchial apparatus having tongue bars, M-shaped skeletal rods and synapicula are exactly like those of *Amphioxus*. But the endostyle and epibranchial groove are absent from the pharynx of hemichordates. Such similarity can be only due to common ancestry, and phylogenetic relationship of hemichordates and chordates cannot be denied.

Differences : But the inclusion of hemichordates in phylum Chordata cannot be justified on a few similarities which are more than outweighed by important differences. The main differences are:

1. Chordates do not have the body and coelomic regions corresponding to those of hemichordates.
2. The circulatory and nervous systems of hemichordates are like those of invertebrates.
3. There is no post-anal tail in hemichordates.
4. Chordates are metamerically segmented animals, thin segmentation is clearly shown by the muscular, nervous, circulatory, and excretory systems, whereas there is a total absence of segmentation in hemichordates.

Conclusion

Hemichordates are definitely invertebrate in their construction and morphology, they are closer to the echinoderms than to the chordates. It appears most reasonable to place them in the invertebrates as an independent phylum which has arisen from an ancestral stock that has given rise, on the one hand, to echinoderms and on the other hand to hemichordates and chordates.

Invertebrates possess phosphoarginine as the energy rich compound. But chordates possess phosphocreatine as the energy rich compound. But *Balanoglossus* contains both phosphoarginine and phosphocreatine in their muscles. Hence, it is concluded that *Balanoglossus* is intermediate between invertebrates and chordates.

1.9 Questions

1. Give the main characteristics of phylum chordata.
2. Classify phylum chordata up to class level with example.
3. Describe the habitat, habits and external characters of lancelet.
4. Describe the excretory organs of *Amphioxus*.
5. Give an account on digestive system of *Amphioxus*.
6. Describe the structure of Ascidian tadpole larva.
7. Write an account on retrogressive metamorphosis of Ascidian tadpole larva.
8. Explain the affinities of *Balanoglossus*.

Unit-II Pisces and Amphibians

- 2.1 Introduction
- 2.2 Objectives
- 2.3 Classification of fishes
- 2.4 Type study – Shark
 - 2.4.1 External Morphology
 - 2.4.2 Digestive System
 - 2.4.3 Circulatory System
- 2.5 Migration of fishes
- 2.6 Economic importance of fishes
- 2.7 Questions
- 2.8 Introduction for Amphibians
- 2.9 Objectives
- 2.10 Type Study of Frog
 - 2.10.1 External morphology
 - 2.10.2 Respiratory System
 - 2.10.3 Reproductive System
 - 2.10.4 Development
- 2.11 Parental Care in Amphibian
- 2.12 Questions

2.1 INTRODUCTION

Pisces are cold blooded vertebrates that breathe by means of gills and live in water. There are about 30,000 to 40,000 species of fishes differing widely from each other in shape, size, habits and habitat. Fishes usually have a streamlined body but some are elongated snake-like and few are dorso-ventrally flattened. They have paired and unpaired fins supported by soft or spiny fin rays. Dorsal, anal and caudal fins are unpaired, while the pectorals and pelvics are paired. Respiratory organs are chiefly gills.

2.2 OBJECTIVES

After studying this unit you may be able to

- x know the brief classification of fishes
- x understand the external morphology, digestive system and circulatory system of Shark.
- x comprehend the concept behind migration of fishes and
- x have an awareness on the economic importance of fishes

2.3 CLASSIFICATION OF FISHES

Fishes are cold blooded aquatic vertebrates having jaws, gills, fins and scales. Fishes are included in the phylum Chordata because the embryos develop a notochord. They contain a vertebral column. So they are included in Vertebrata.

The brain is enclosed in a cranium. So they are included in Craniata. They have jaws. So they are included in Gnathostomata. The fishes are included in three classes, namely

Class 1. Placodermi

Class 2. Chondrichthyes

Class 3. Osteichthyes

The three classes of fishes are also together called **Class Pisces**.

Class Placodermi includes extinct fishes. They were called plate-skinned fishes because the body was covered by bony armour. They were the first fishes.

Eg. *Coccosteus*

Class Chondrichthyes includes cartilaginous fishes. Chondrichthyes is characterized by **cartilaginous skeleton, placoid scales, heterocercal caudal fin and claspers in male**.

The Class Chondrichthyes is divided into 2 subclasses, namely

Subclass 1. Elasmobranchii

Subclass 2. Holocephali

Elasmobranchii is characterized by plated gills. Eg. *Scoliodon* (shark), *Pristis*, *Narcine*, *Torpedo* etc.

Holocephali means entire head. It includes *Chimaera*. It is intermediate between Chondrichthyes and Osteichthyes.

Class Osteichthyes includes bony fishes (Osteon, bone:ichthys, fish)

Osteichthyes is characterized by **bony skeleton, ganoid or cycloid or ctenoid scales, operculum covering the gills, homocercal or diphycercal caudal fin and air bladder**.

Class Osteichthyes is divided into subclasses namely

Subclass 1. Acanthodii

Subclass 2. Actinopterygii

Subclass 3. Sarcopterygii

a. Acanthodii means **spine like**. They have a series of lateral fins supported by spines. It includes *Climacodus*. It was the first freshwater fish. It had ganoid scales.

b. Actinopterygii includes **ray-finned fishes**. Most of the modern fishes are included in Actinopterygii. The order **Teleostei** is the largest group. Eg. *Eel*, *Sardinella*, *Hippocampus*, *Exocoet* us, etc.

c. Sarcopterygii included the fishes finned fishes. Eg. *Latimeria*, *lung fishes* etc.

2.4 TYPE- *SCOLIODON* (Dog-fish)

SYSTEMATIC POSITION

Phylum : Chordata

Group : Vertebrata

Subphylum : Gnathostomata

Series : Pisces

Class : Elasmobranchii
Sub class : Selachii
Suborder : Pleurotremata
Order : Lamniformes
Genus : *Scoliodon*

HABIT AND HABITAT

Scoliodon is marine like most sharks. It is **carnivorous**, feeding on crabs, lobsters, worms and fishes, etc. It is a fast swimmer as the body is perfectly streamlined without having rigid projections. Fertilization is internal. It is **viviparous**, i.e., producing living young ones that develop in the uteri.

2.4.1. EXTERNAL FEATURES OF *SCOLIODON*

Shape, Size and Colour *Scoliodon* has a long, laterally compressed spindle – shaped body tapering at both ends. The colour of the body is dark grey above and pale white beneath, while the portions of the caudal fin are more or less dark.

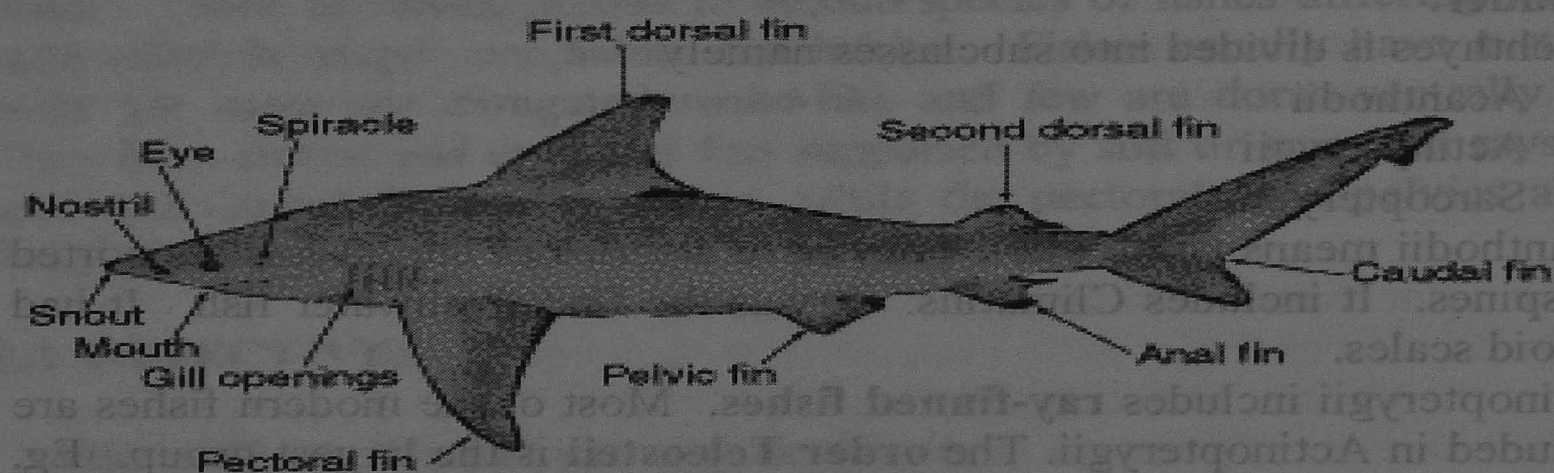
DIVISION OF THE BODY

The body is divisible into head, trunk and tail.

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

Trunk: The trunk is almost elliptical in transverse section. The trunk gradually tapers behind into the tail.

Tail : The tail is laterally compressed and its bent upwards at a small angle. Such a tail is known as **heterocercal tail**.



MOUTH

On the ventral side of the head is a wide crescentic mouth. It is bounded by upper and lower Jaws. Each jaw is armed with one or two rows of backwardly directed teeth.

NOSTRILS

On the sides of the mouth are crescentic apertures the ventral nostrils leading into the olfactory sacs. The nostrils are only olfactory and have no respiratory function.

EYES

On each side the head is a large circular eye. Each eye has two poorly-formed movable eye-lids and movable nictitating membrane. The pupil is narrow and vertical.

GILL-CLEFTS

Behind the eyes are situated a series of vertical slits, five on each side, called branchial or gill-clefts.

FINS

Scoliodon is provided with two sets of fins which are flattened expansions of the skin supported by cartilaginous rods and horny fin rays which are unpaired median fins and paired lateral fins.

MEDIAN FINS

The median fins are two dorsal fins, a ventral or anal fin and a caudal fin. The first dorsal fin is large and triangular in shape and is situated a little in front of the middle of the body. The second dorsal fin is also triangular in outline but is very small. The caudal fin extends along the dorsal and ventral surfaces of the tail in the median line and forms of a dorsal and ventral lobe. The ventral median fin is situated in the mid-ventral line about 2 inches in front of the caudal fin, more or less opposite the second dorsal. The basal edges of each of the two dorsal and of the ventral fin are produced behind into long and narrow fleshy processes called basal lobes.

The lateral fins are paired pectoral and pelvic fins. The large pectoral fins originate from the ventro-lateral margin of the body immediately behind the gill-clefts. The pelvic fins are much smaller than the pectoral fins and arise close together from the ventral surface at the junction of the trunk and tail.

All the fins are directed backwards a feature which is advantageous in forward progression.

CLOACAL APERTURE

The cloacal aperture is an elongated opening at the root of the tail between two pelvic fins. It leads into the cloaca into which the intestine and urinary and genital ducts open.

ABDOMINAL PORES

There is a pair of openings situated on the elevated papillae on either side of the cloaca; these are the abdominal pores. Through these pores the coelom communicates with exterior.

LATERAL LINE

A faint line runs on either side of the body extending from the head to the posterior end of the tail, this is called the lateral line

CAUDAL PIT

At the root of the tail, just in front of the caudal fin, is a small dorsal and a ventral caudal pit.

SEXUAL DIMORPHISM

In the male the inner margins of the pelvic fins bear a pair of rod-shaped copulatory organs called **claspers**, they are modified parts of the pelvic fins. The siphon, begins at the base of clasper.

SKIN

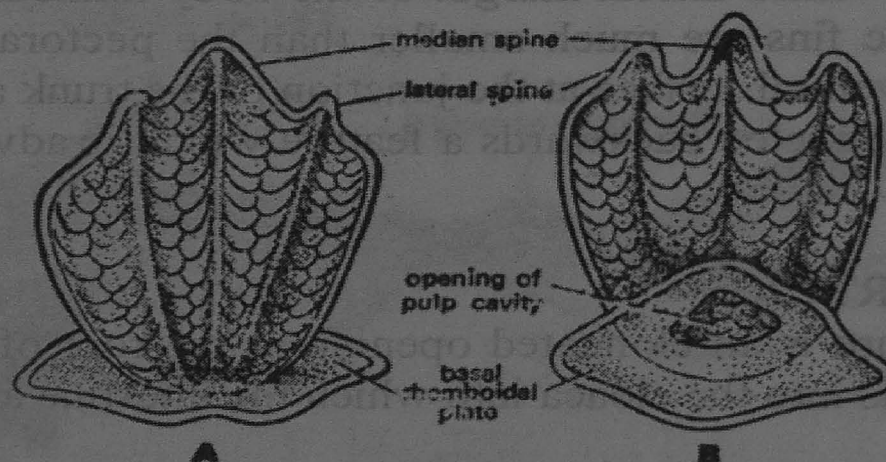
In Scoliodon, the skin consists of two layers outer epidermis and an inner dermis. The epidermis is composed of many layers of epithelial cells amongst which are interspersed numerous unicellular mucous glands. The dermis comprises dense connective tissue mixed with smooth muscle fibres, blood capillaries, pigment cells and nerves. In fresh specimen the skin is slimy, but in preserved specimens the slimy mucous is generally removed and the skin becomes rough. This roughness of the skin is due to the presence of closely lying minute dermal denticles called **placoid scales**.

EXOSKELETON

In Scoliodon, the exoskeleton comprises the **placoid scales**

PLACOID SCALES

A typical placoid scale consists of mainly two parts: the basal plate and the spine. The basal plate is diamond-shaped and lies embedded in the skin. The basal plate is formed of a trabecular calcified tissue closely allied to the cement. The inner surface of the basal plate bears an opening which leads into the pulp cavity. During life the pulp cavity is filled with vascular connective tissue called the pulp containing numerous odontoblasts, blood vessels, and nerves.



The spine is flat and trident and projecting out of the skin. The surface of the spines is not smooth but presents a stratified appearance under the microscope. The spine is composed of a hard calcareous substance, the dentine. The dentine is traversed by minute nearly parallel canaliculi with delicate branches and is coated externally with a hard dense substance, the enamel. The placoid scales are derived partly from the dermis and partly from the epidermis. The basal plate and the dentine of the spine are derived from mesoderm, while the enamel is secreted by the ectoderm.

2.4.2 DIGESTIVE SYSTEM OF *SCOLIODON*

The digestive system of *Scoliodon* can be described under the following heads:

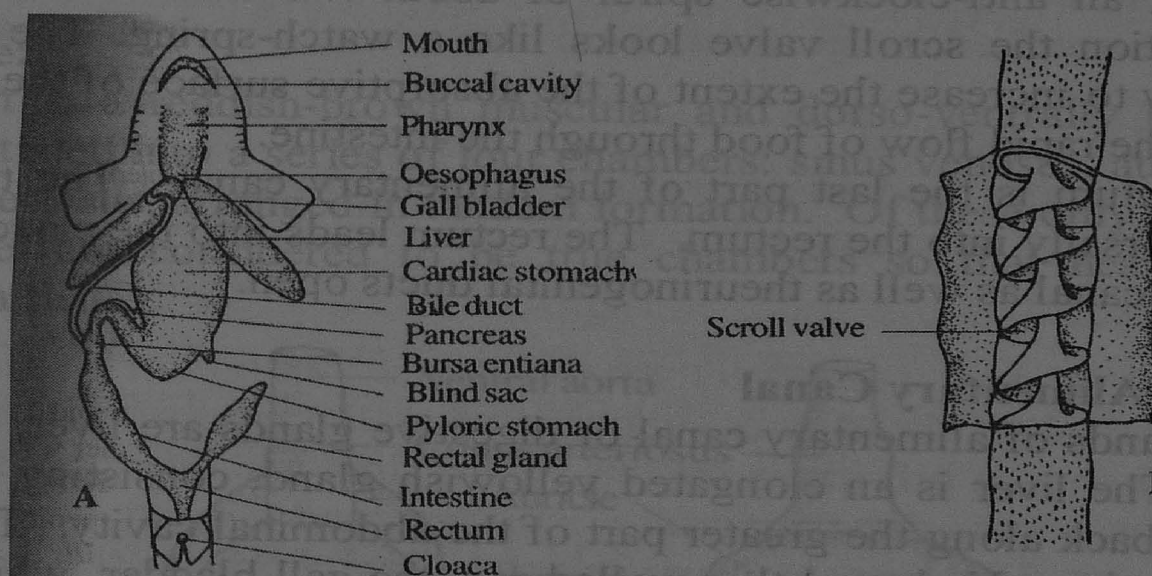
- a. Alimentary canal and
- b. Glands of alimentary canal

Alimentary canal

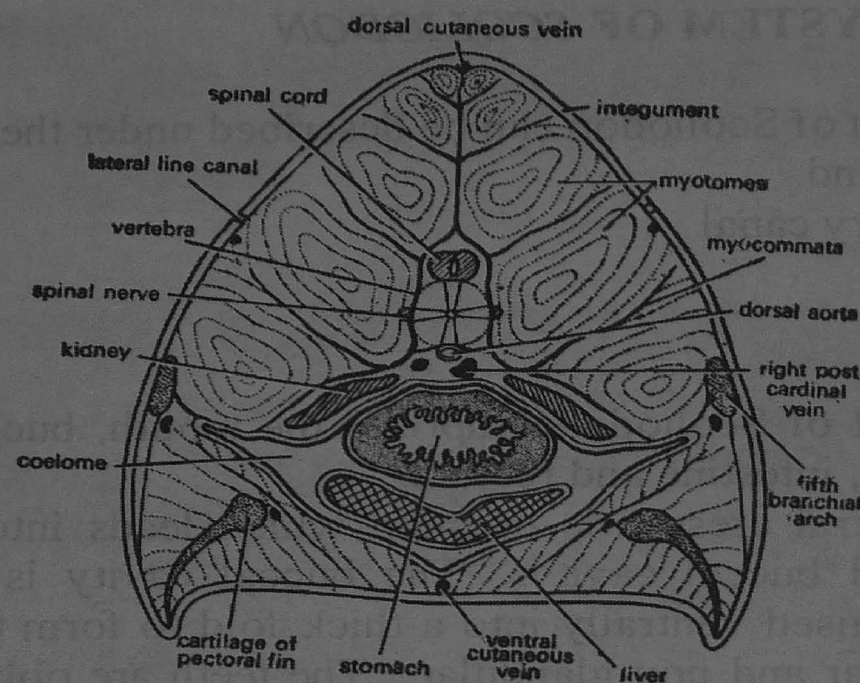
The alimentary canal of *Scoliodon* comprises the mouth, buccal cavity, pharynx, oesophagus, stomach, intestine and rectum.

The mouth is a ventral crescentic opening which leads into a spacious dorso-ventrally compressed buccal cavity. The buccal cavity is lined with a thick mucous membrane raised ventrally into a thick fold to form the so-called tongue which is non-muscular and non-glandular. The teeth are oblique and have sharp more or less compressed cusps, the edges of which are smooth and non-serrated. The teeth are all alike in shape, homodont. The teeth are used to catch the prey and prevent its escape but not to crush or masticate it.

The buccal cavity opens into the pharynx on either side of which lie the internal openings of the spiracle and give gill pouches.



The pharynx narrows posteriorly to form the short oesophagus. The oesophagus has thick muscular walls with an internal lining of mucous membrane. The oesophagus widens posteriorly to form the large muscular stomach. The stomach is bent on itself and forms a J-shaped organ, the long proximal limb of which is called the cardiac stomach, while the short distal limb is called the pyloric stomach. At the junction of cardiac and pyloric limbs there is a blind sac. The lining of the pyloric stomach is quite smooth proximally but is slightly folded distally. At the end of pyloric stomach there is a muscular **bursa entiana**. The opening of pyloric stomach into the bursa entiana is guarded by a circular band of muscle-fibres called the **pyloric valve**.



The bursa entiana continues into the intestine. The intestine is a wide tube running straight backwards into the abdominal cavity and opening posteriorly into the rectum. The internal surface of the intestine is increased by a characteristic fold of the mucous membrane, the scroll valve, having one edge attached to the inner wall of the intestine and the other rolled up longitudinally on itself into a scroll, making an anti-clockwise spiral of about two and a half turns. In a transverse section the scroll valve looks like a watch-spring. The scroll valve serves not only to increase the extent of the absorptive surface of the intestine but also prevents the rapid flow of food through the intestine.

The rectum is the last part of the alimentary canal. The tubular rectal gland opens dorsally into the rectum. The rectum leads into the cloaca into which the alimentary canal as well as the urinogenital ducts open.

Glands of the Alimentary Canal

The glands of alimentary canal or digestive glands are liver, pancreas and rectal gland. The liver is an elongated yellowish gland, consisting of two lobes which extend back along the greater part of the abdominal cavity. The right lobe of the liver carries a V-shaped thin walled sac, the gall bladder, which stores the bile secreted by the liver. The gall bladder communicates with the intestine through bile-duct. The pancreas is a compact bilobed gland situated in the angle between the cardiac and pyloric stomach. The pancreatic duct opens into the intestine just opposite to the opening of the bile-duct. The rectal gland is a short thick **diverticulum** arising from the dorsal wall of the rectum. It discharges a fluid into the intestinal lumen but the physiological effect of the fluid is unknown.

2.4.3 CIRCULATORY SYSTEM OF *SCOLIODON*

The Circulatory system comprises of heart and pericardium, arteries, veins and blood

(I) HEART AND PERICARDIUM

The heart of *Scoliodon* receives venous blood only which pumps into gills for aeration. Such heart is called a **venous or branchial heart**.

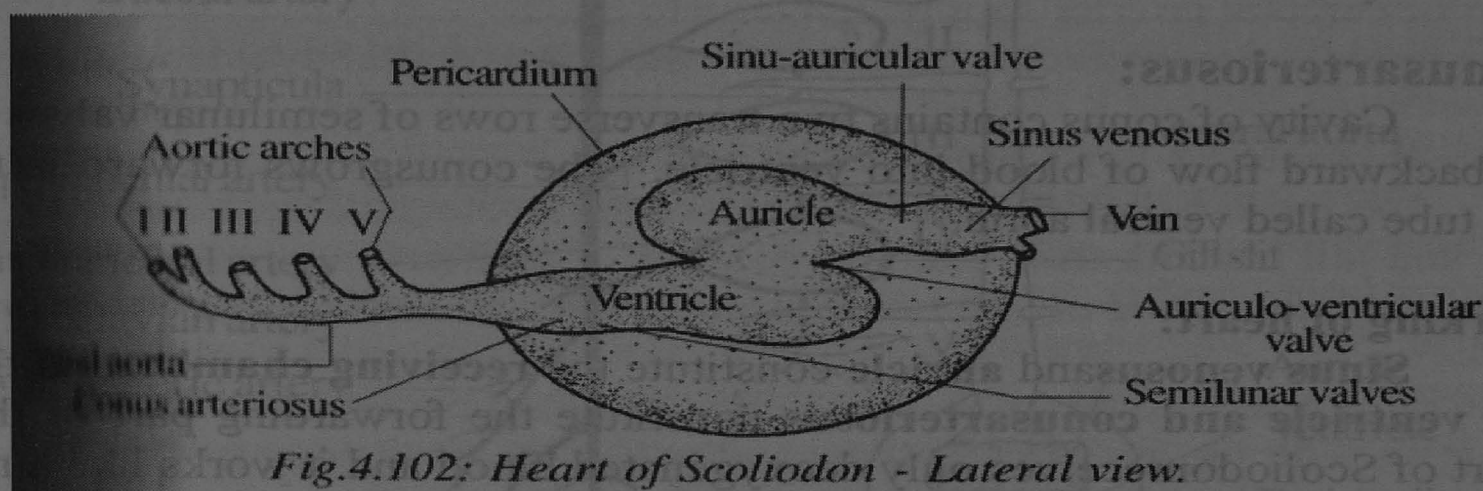


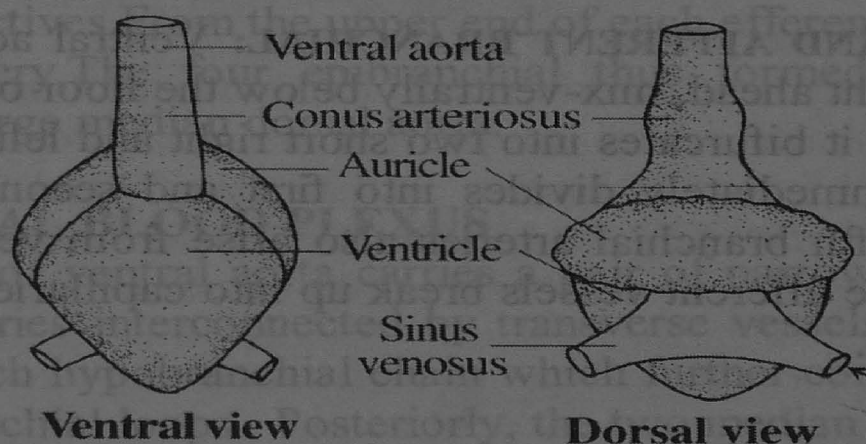
Fig.4.102: Heart of *Scoliodon* - Lateral view.

a. Position:

The heart is situated mid-ventrally in head beneath the pharynx, supported below by the coracoid cartilages of the pectoral girdle. It lies within the pericardial cavity in a two-layered membranous pericardium.

b. Structure:

Heart is a reddish-brown muscular and dorso-ventrally bent, S-shaped tube differentiated into a series of four chambers: sinus venosus, auricle, ventricle and conus arteriosus, arranged in tandem formation. Of these only two the auricle and ventricle, are considered to be true chambers so that heart is only two chambered in fishes.



Sinus venosus:

It is the most posterior chamber. It is triangular, elastic, thin-walled. It receives venous blood through two large veins, called ductus Cuvieri, and through a pair of hepatic sinuses posteriorly.

Auricle:

The atrium or auricle lies in front of sinus venosus dorsally upon the ventricle. It is a large, triangular sac. It opens into ventricle through an auricle-ventricular aperture also guarded by two pocket like valves to prevent backward flow of blood.

Ventricle:

Ventricle is the most prominent and pear-shaped chamber of heart. Chordae tendineae are attached to opposite walls to prevent ventricle from expanding beyond its capacity.

Conus arteriosus:

Cavity of conus contains two transverse rows of semilunar valves to block the backward flow of blood into ventricle. The conus grows forward in the form of a tube called ventral aorta.

Working of heart:

Sinus venosus and auricle constitute the receiving chambers of the heart. The ventricle and conus arteriosus constitute the forwarding part of the heart. Heart of Scoliodon receives only deoxygenated blood and it works like a muscular pump for pumping its venous blood to the gills for aeration. To achieve this, different parts of the heart rhythmically contract at regular intervals and in a definite succession, first sinus venosus, then auricle, then ventricle and finally the conus arteriosus. Each contraction, called **systole**, is followed by a relaxation, called **diastole**. Different valves of the heart serve to prevent the backward flow of blood into preceding chambers through the apertures that they guide. The walls of the heart are supplied oxygenated blood through special coronary arteries.

(II) ARTERIAL SYSTEM

Arteries are stronger and their walls are more muscular than veins. When venous blood from conus of heart enters the ventral aorta, it has entered the arterial system. It can be described under five categories as follows.

VENTRAL AORTA AND AFFERENT BRANCHIAL: Ventral aorta is a single stout artery running straight ahead, mid-ventrally below the floor of pharynx. Reaching upto the hyoid arch, it bifurcates into two short right and left innominate arteries. Each innominate immediately divides into first and second branchial arteries. Third, fourth and fifth branchial arteries also arise from ventral aorta almost at regular intervals. The afferent vessels break up into capillaries in the gill lamellae for aeration of blood.

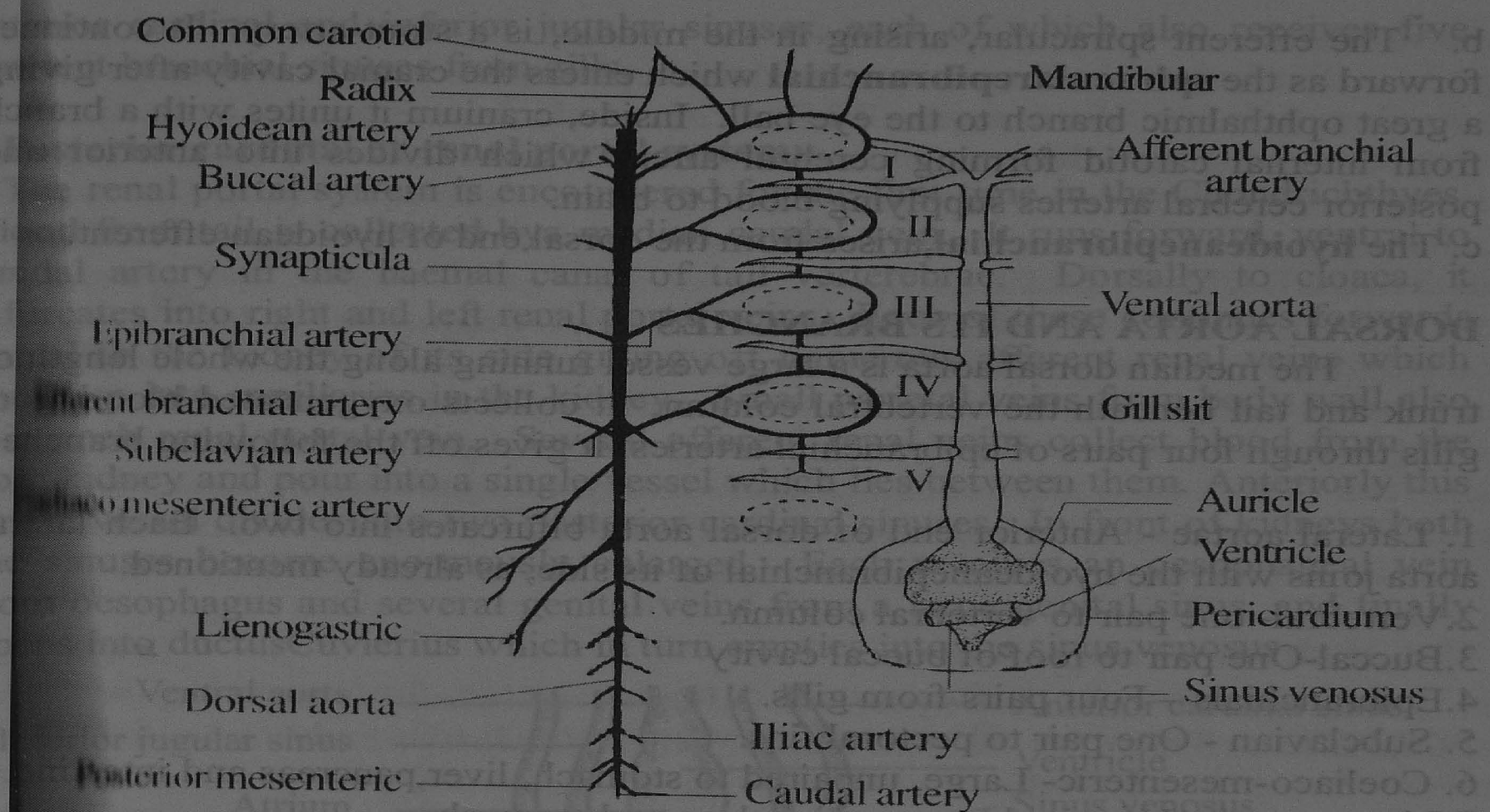


Fig.4.104: Shark - Arterial system.

EFFERENT BRANCHIAL AND EPIBRANCHIAL ARTERIES

Aerated blood from capillaries of gills is collected by a series of nine efferent branchial arteries. The first eight efferent vessels form four complete loops around the first four gill pouches. The single ninth efferent vessel runs alone along the anterior side of fifth gill pouch. Adjacent loops are interconnected by short longitudinal connectives. From the upper end of each efferent branchial loop arises an epibranchial artery. The four epibranchial thus formed run backwards and inwards to join a large median dorsal aorta.

HYPOBRANCHIAL BLOOD PLEXUS

The ventral wall of ventral aorta carries a pair of narrow, longitudinal median hypobranchial arteries interconnected by transverse vessels. Four commissural vessels connect each hypobranchial chain which further connects the ventral ends of the efferent branchial loops. Posteriorly, the two median hypobranchials unite to form a median coracoids artery which branches into a coronary artery to heart and a pericardial artery sending further branches to pericardium and coracoid region of pectoral girdle.

ARTERIES OF HEAD

The head region is supplied blood mostly by three branches originating from the hypoidean or first efferent.

a. The external carotid arises ventrolaterally. It branches into a ventral mandibular to coraco-mandibular muscles and a superficial hyoid to skin muscles and subcutaneous tissue of hyoid arch.

- b. The efferent spiracular, arising in the middle, is a stout artery. It continues forward as the **spiracularepibbranchial** which enters the cranial cavity after giving a great ophthalmic branch to the eye ball. Inside, cranium it unites with a branch from internal carotid forming cerebral artery which divides into anterior and posterior cerebral arteries supplying blood to brain.
- c. The **hyoideanepibbranchial**, arises from the dorsal end of hyoidean efferent.

DORSAL AORTA AND ITS BRANCHES

The median dorsal aorta is a large vessel running along the whole length of trunk and tail beneath the vertebral column. It collects oxygenated blood from gills through four pairs of epibranial arteries. It gives off the following branches

1. Lateral aortae - Anterior end of dorsal aorta bifurcates into two. Each lateral aorta joins with the hyoideanepibbranchial of its side, as already mentioned.
2. Vertebral- one pair to vertebral column.
3. Buccal- One pair to roof of buccal cavity
4. Epibranials - Four pairs from gills.
5. Subclavian - One pair to pectoral fins.
6. Coeliaco-mesenteric- Large, unpaired to stomach, liver, pancreas and intestine.
7. Lineo-gastric- Unpaired to gonads, spleen and stomach.
8. Posterior mesenteric- Unpaired to rectal gland.
9. Iliac - Paired to pelvic fins.
10. Parietals - Several small pairs of segmental arteries to myotomes, spinal cord, lateral line canal, kidneys and gonads.
11. Caudal - Posteriorly, the dorsal aorta continues into tail as caudal artery lying in the haemal canal of caudal vertebrae.

(III) VENOUS SYSTEM

Venous blood from body is returned to heart by veins which have thinner walls than arteries and contain valves to prevent a backward flow of blood. A characteristic feature of venous system is that many veins are in the form of simple, primitive and wide irregular spaces without definite walls, more properly called sinuses. Venous system of *Scoliodon* can be described under the following five heads.

1. Anterior cardinal system:

Blood from head region is returned on either side by two sinuses.

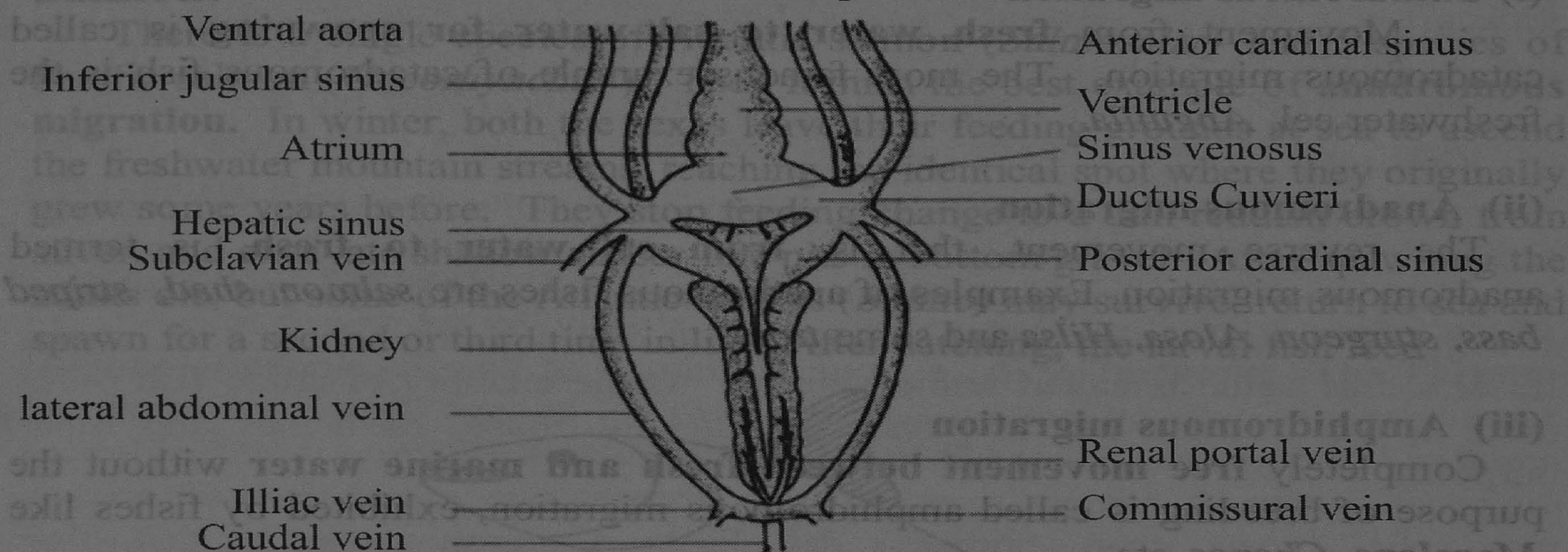
Inferior jugular sinus: It is the smaller median ventral sinus. It collects blood from the floor of bucco-pharyngeal region, gill pouches and pericardial region, before opening into the **ductusCuvierius**.

Internal jugular vein or sinus: It is the larger dorso-lateral sinus. It collects blood from the dorsal region of head and gill pouches. It starts as an anterior facial vein from rostrum joining an olfactory or nasal sinus. It is joined by a narrow neck to a large orbital sinus behind the skull. Orbital sinus leads through a narrow postorbital sinus located just in front of the first gill, connects together the

anterior cardinal and inferior jugular sinuses, each of which also receives five nutrient branchial sinuses from gills.

2. Posterior cardinal or renal portal system:

The renal portal system is encountered for the first time in the Chondrichthyes. Blood from tail is collected by a median caudal vein. It runs forward, ventral to caudal artery in the haemal canal of tail vertebrae. Dorsally to cloaca, it bifurcates into right and left renal portal veins. Each of these continues forwards dorsal to the kidney of its side giving off numerous afferent renal veins which break up into capillaries in the kidney. Small parietal veins from body wall also join each renal portal vein. Several efferent renal veins collect blood from the both kidney and pour into a single vessel which lies between them. Anteriorly this single vessel divides into two posterior cardinal sinuses. In front of kidneys both the sinuses become enormously enlarged. Each receives an oesophageal vein from oesophagus and several genital veins from a large genital sinus, and finally opens into ductus Cuvierius which in turn empties into the sinus venosus.



3. Hepatic portal system:

Hepatic portal system occurs in all vertebrates beginning with the cyclostomes. Blood from different parts of alimentary canal and associated glands is drained by several branches, which unite to form a single large hepatic portal vein. It runs to the liver lobes into which it breaks up into capillaries. From each liver lobe blood is collected by a large hepatic sinus which opens into the sinus venosus near its partner of the opposite side.

4. Lateral abdominal system:

Blood from inner lateral part of body wall, cloacal region and paired fins on either side of the body is collected by a large lateral abdominal vein.

5. Cutaneous system:

It includes a mid-dorsal, amid-ventral and two lateral **cutaneous veins**, collecting blood from their respective parts of skin and finally pouring it into the sinus venosus via **ducti Cuvieri**.

(IV) Blood

Scoliodon blood consists of colorless plasma and corpuscles suspended in it. Corpuscles are of two types- RBC are oval and nucleated bodies and contain respiratory pigment, haemoglobin and WBC are amoeboid cells resembling with lymphocytes of other vertebrates.

2.5 MIGRATION IN FISHES

Many fishes, like birds, perform seasonal migrations. The barracudas (*Sphyraena*) and swordfish (*Xiphias gladius*) of the warm tropical seas perform latitudinal migration, moving north in spring and south in autumn. Some deepwater fishes perform daily vertical migration. Migration is sometimes limited to freshwaters only, it is called **potamodromy** or **limnodromy** and sometimes limited within the sea called **oceanodromy**. However, migration between the two is called **diadromy**, which is classified into two categories:

(i) Catadromous migration

Movement from **fresh water to salt-water for spawning** is called catadromous migration. The most famous example of catadromous fish is the freshwater eel, *Anguilla*.

(ii) Anadromous migration

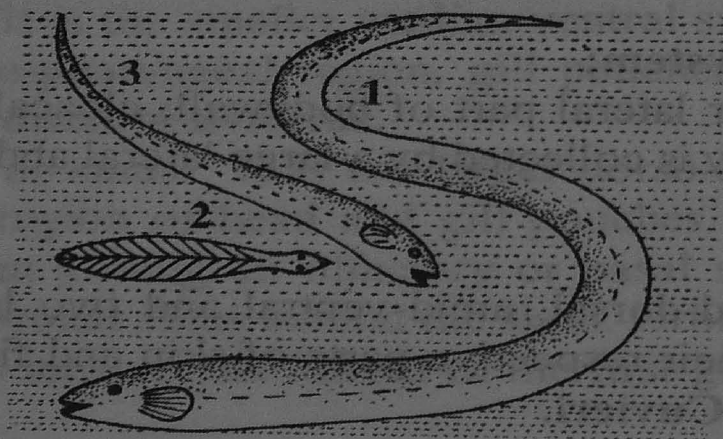
The reverse movement, that is, **from salt-water to fresh**, is termed anadromous migration. Examples of anadromous fishes are *salmon*, *shad*, *striped bass*, *sturgeon*, *Alosa*, *Hilsa* and some *trout*.

(iii) Amphidromous migration

Completely **free movement between fresh and marine water** without the purpose of breeding is called amphidromous migration, exhibited by fishes like *Megalopa*, *Chanos* etc.

EELS

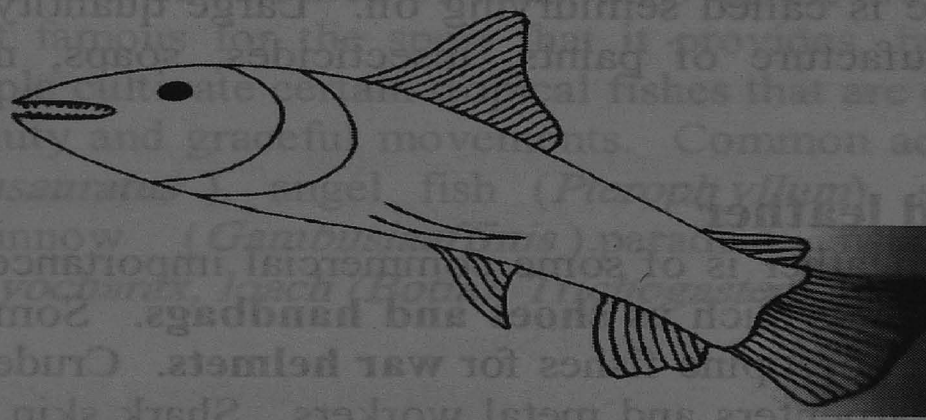
The best example of catadromous migration is furnished by two common species of eels, *Anguilla rostrata* of European freshwater rivers and *Anguilla vulgaris* of America. With the advent of autumn, their colour changes from yellow to metallic silver. Feeding stops with the shrinking of their digestive tract. Eyes become larger, snout becomes sharper with thinner lips and the gonads are fully mature.



The *silvery eels* then enter sea and migrate about 4500 kilometers westwards from Europe or eastwards from America. Reaching their breeding place in the Sargasso Sea off Bermuda, the adults die immediately after spawning in deep waters. The eggs hatch into little transparent, leaf-like flattened pelagic larvae, called *leptocephalia*, less than 6 mm long. They have sharp needle-like teeth for feeding. During their long return journey towards homes of their parents, they grow into *elvers or glass eels* about 8 cm long, with cylindrical bodies. On reaching land, the males remain behind in brackish waters near coasts, while the females ascend freshwater streams and rivers. The elvers feed and grow to become yellow eels in some years. Until their real identity was discovered, the leptocephali larvae were called glass fishes and placed in the genus *Leptocephalus*. The biggest larva of some unknown species was 184 cm long which was captured in 1930 by Dana Expedition west of the Cape of Good Hope (Africa).

Salmon:

There is a single species of Atlantic salmon (*Salmosalar*) and 5 species of Pacific salmon (*Oncorhynchus*). They furnish the best example of **anadromous migration**. In winter, both the sexes leave their feeding grounds at sea to ascend the freshwater mountain streams, reaching the identical spot where they originally grew some years before. They stop feeding change to a dull reddish brown from silver, and excavate shallow saucer-like pits in bottom gravel. After spawning the adults die, but some of the Atlantic species (*Salmo*) may survive, return to sea and spawn for a second or third time in life. After hatching, the larval fish feed



and grow for some time in the streams before going out to sea. The young salmons grow faster in the ocean because of abundant food there. Experimental evident shows that strong olfactory sense of salmon determines its homing into the original birth place, for different streams have different odours.

2.6 ECONOMIC IMPORTANCE OF FISH

Fish have considerable economic importance. They are useful as well as harmful to man.

Useful fishes

1. As food.

Nearly all fish, freshwater and marine are edible and have been an important source of protein food since time immemorial. In most fishes, the flesh is white, contains 13 to 20% of protein and has a food value of 300 to 1600 calories per pound. **Fish meat** contains **vitamin A** and **D** together with large amount of **phosphorus** present in it. Important marine food fishes include *salmon, cod, halibut, herring, eels, tuna, mackerel* and *sardines*. Important freshwater food fishes are *catfish, trout bass, perch* and *mullet*. Even eggs of certain fishes, such as Russian *sturgeon*, are eaten as cavier. The major food fishes of India include species of *Labeo, Catla, Cirrhina, Mystus, Wallago, Notopterus, Ophiocephalus*, etc. The cartilaginous **sharks, skates** and **rays** are also used as human food in several countries. They are eaten by poorer classes of people along the sea coasts of India and Sri Lanka. The canned meat of sharks is sold commercially under the name of gray fish. In south-east Asian countries, shark fins are dried and boiled to get a gelatinous material used in soups. Fresh fish meat is usually cooked for human consumption. However, large quantities are refrigerated, salted smoked, canned or pickled.

2. Fish oils

Fishes provide vast supplies of commercial oil. Oils are extracted from liver and body of several fishes like *sharks, rays, cod, salmons, sardines, herrings, mackerels*, etc. Liver oil is good source of vitamin A and D. The body oil is of two types. The oil having higher iodine value is called drying oil. And oil having lesser iodine value is called semidrying oil. Large quantity of crude fish oil is used in the manufacture of paints, insecticides, soaps, medicines and other purposes.

3. Fish skin and leather

Shark skin leather is of some commercial importance in the manufacture of many useful articles such as **shoes and handbags**. Some tribal people used skins of puffer and porcupine fishes for **war helmets**. Crude skins of sharks and rays are used by carpenters and metal workers. Shark skin tanned with placoid scale on it, is called **shagreen**. It has been used as an **abrasive for polishing wood and ivory** and also for covering jewel-boxes, fine books and sword handles.

4. Fish meal and fish manure

Suitable scraps from canneries as well as unpalatable and unmarketable fishes are ground, dried and prepared into **fish meal used to feed poultry, pigs, cattle and pet animals**. Sharks mixed with other unpalatable fishes, crushed and ground bones and refuse of no other use, make **good fertilizer** for tea, coffee and rubber plantation. It is rich in **nitrogen and calcium phosphate**.

5. Fish glue.

Liquid glues are prepared from skin, heads and other trimmings of certain fishes. It has adhesiveness of great power.

6. Isinglass

It is a gelatinous product obtained from the air bladders of certain fishes such as *sturgeons*, *carps*, *perches*, *salmons*, *catfishes*, *cods*, etc. It is variously used for making certain cements, jellies and for clarification of wines and beers. The finest quality of isinglass is obtained from Russia.

7. Medicines and disease control.

Refined oils extracted from livers of cods and sharks are rich in vitamins A and D. Pituitary glands yield important extracts for medicines. Fishes like **top minnows** (*Gambusiaaffinis*), *Trichogaster*, *Esomus*, *Barbus*, *Panchax*, etc., feed voraciously on mosquito larvae. These **larvicidal fishes** are propagated and distributed widely into ponds, lakes and tanks to destroy mosquito that transmit malaria, yellow fever and other dreadful diseases of tropical countries. Unani medicines for the treatment of duodenal ulcers, skin diseases, night blindness, general weakness, loss of appetite, colds, coughs, bronchitis, ashtma, tuberculosis, etc.

8. Sport and recreation

Sport fishing by individuals and fishing parties is a popular recreation for millions of people, as well as a source of food, all over the world. The **Tarpon**, for example is most famous for the sport that it provides, but its flesh is not palatable. Many people cultivate certain tropical fishes that are displayed in home aquaria for their beauty and graceful movements. Common aquarium fishes are gold fish (*Carassiusauratus*), angel fish (*Pterophyllum*), sword tail guppy (*Xiphophorus*), minnow (*Gambusiaaffinis*), paradise fish (*Marcropodus*), *Hemigrammus*, *Aphyocharax*, loach (*Botia*), *Trichogaster*, *Tilapia*, etc.

9. Fancy articles

Scales of garpike (*Lepidosteus*) are used for **jewellery and novelties**. From scales of some fish is secured a pigment whose water suspension is known as pearl essence. It is used in the **manufacture of artificial pearls in Europe**, especially in France.

10. Scientific study

Fishes have considerable use as **experimental animals**, especially in the fields of Genetics, Embryology, Animal Behaviour and Pharmacology. Certain fishes such as *Latimeria* and *Dipnoans* have anatomical features of great zoological interest. Fishes like dog fish (*Scoliodon*), Perch (*Perca*), and carp (*Labeo*), etc., are used extensively in scientific experiments.

Harmful fishes

1. Destructive.

All cartilaginous fishes are **predaceous** and feed chiefly on large quantities of crabs, lobsters, squids and other valuable marine animals. They cause great harm by destroying eggs, young and even adults of our food fishes. Sharks are particularly a big nuisance to fisherman because they tear nets, steal baits, devour captured fish and drive away squids and fishes to be netted. The damage done by these sharks amounts to several hundred thousand rupees.

2. Injurious.

Larger sharks and sword fish may capsize small boats and injure or even kill fisherman. All sharks, small or big, are a menace to bathers and skin divers in shallow waters. The **pirhanas** of Central and South America have very strong teeth and are dangerous even to men. Some fishes like cartilaginous electric ray (*Torpedo*) have electric organs which give powerful shocks to swimmers and fishermen. An extreme case of specialization is the bony electric eel (*Electrophorus electricus*) of the Amazon. It can generate electricity upto 60 volts in potential with a maximum output of 1000 watts.

3. Poisonous.

Poisonous glands are found in many cartilaginous fishes such as stingray (*Trygon*), and eagle ray (*Myliobatis*). They can inflict painful wounds, sometimes fatal by their poisonous stings or spines. Poison glands are also found in *Squalus* (dog fish), *Heterodontos*, *Chimaera*, *Diodon* (porcupine), *Tetrodon* (globe fish), *scorpion* fish etc. These are also capable of causing wounds by their spines or spiny opercula. Flesh of some tropical fishes (e.g. *Tetrodon*) is also poisonous.

2.7 Questions

1. Write a brief note on classification of fishes.
2. Explain the External morphology of Shark.
3. Describe the Digestive system of Shark.
4. Distinguish anadromous migration from catadromous migration with examples.
5. List down the Economic importance of fishes.

AMPHIBIANS

2.8 INTRODUCTION

Frogs live in fresh water, moist and damp places. They are **poikilothermic** (cold blooded). Frog becomes active in rainy season and they breed in rainy season. In winter and summer season, they live under soil and are inactive. The winter period is called hibernation and summer period is called aestivation. During hibernation and aestivation, they utilize food stored in their body. Amphibians are cold blooded vertebrates. In the Devonian period of **palaeozoic era** they were originated from fishes, in the **carboniferous period**, they increased their number, hence that period is called '**Age of amphibians**'

General characters of Amphibians

- 1) Amphibians are cold blooded vertebrates which can live on land and in water.
- 2) Amphibians show four limbs with which they can swim in water and jump or walk on the land (But in **Apoda** limbs are absent).
- 3) In Amphibians exoskeleton is absent. (But in apoda animals small cycloid scales are present).
- 4) Adult Amphibians **have lungs**. Gills are absent. But In some Urodelans the gills are present.
- 5) In Amphibians Skin is the respiratory organ.
- 6) The Amphibians skull is **dicondylic**.
- 7) In Amphibians **Ribs are absent**.
- 8) In Amphibians the body divisible into **head and trunk**. Tail is present in, Urodela animals.
- 9) Amphibians digestive system is well developed with **a well-developed liver**.
- 10) **External ear is absent**. Middle and inner ears are found, the middle ear columella auris is present.
- 11) Amphibians heart is **3 chambered** with 2 auricles and 1 ventricle, the blood contains R.B.C. **They are nucleated**. They contain haemoglobin.
- 12) Blood vascular system contains **hepatic and renal portal systems**.
- 13) Amphibians Kidneys are **mesonephric**. Urinary bladder is present. It stores urine.
- 14) Central nervous system is well developed. The brain occupies completely the cranial cavity. The brain is divided into fore, mid and hind brains. Brain continues as spinal cord.
- 15) There are ten pairs of cranial nerves.
- 16) Sexes are separate.
- 17) Male and female can be identified - **Sexual dimorphism**.
- 18) In Amphibian life history a larval stage may be present.
- 19) Amphibian Eggs are **telolecithal**, cleavage is **holoblastic unequal**.

2.9 OBJECTIVES

After going through this unit, you will be able to:

- x Know the general characters of amphibians,
- x Describe the external features of frog,
- x Illustrate the respiratory system of frog,
- x Explain the reproductive system of frog,
- x Know the importance of parental care in amphibians.

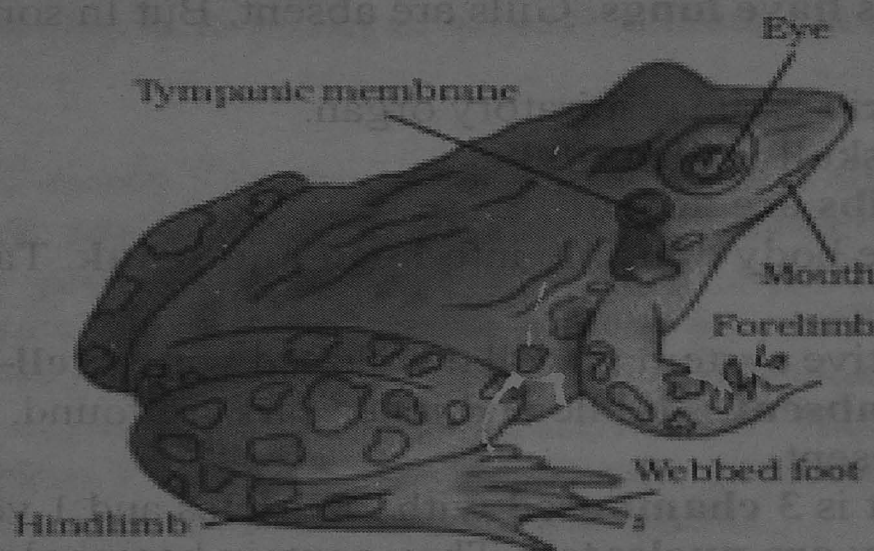
2.10 Type Study of Frog

SYSTEMATIC POSITION

Kingdom	: Animalia
Phylum	: Chordata
Group	: Vertebrata
Subphylum:	Gnathostomata
Class	: Amphibia

Order : Anura
Suborder : Diplasiocoela
Family : Ranidae
Genus : *Rana*
Species : *tigrina*

2.10.1 External Features of Frog



Shape, Size and colour

Besides aerial mode of life frog also leads aquatic mode life. Therefore, it has streamlined body which is the characteristic of the aquatic animals and assists in swimming in water. The anterior and posterior ends of the body are pointed and the triangular flattened head, with its blunt apex directed forward, is broadly united to the trunk. Thus there is no neck to connect the head and trunk together.

The size of the frog varies from species to species or even in the same species depending upon the age of the individual.

The colour of the body at the dorsal side is green with black spots and streaks but ventrally it is paler. This type of colouration harmonises with that of surrounding environment.

DIVISION OF BODY

The body is bilaterally symmetrical and dorsoventrally flattened. Skin is moist, smooth, and slippery. On the dorsal side, there is mid dorsal line running from head to tail. Ventral side is pale yellow in colour and dorsal side is dark green with dark patch. Body is divided into head and trunk. In each eye, there are two eyelids .upper eyelid is immovable and eyelid is movable. There is third eyelid arising from lower eyelid, which is thin and transparent called **nictitating membrane**. It is freely movable and protects eye from dirty water. male frog have vocal sac on either side of throat which produces croaking sound to attract female in breeding season.

Head:

The head is almost triangular and somewhat flattened. The anterior blunt apex is known as snout. On the top but on either side, the head bears two large prominent bulging eyes. In each eye, there are two eyelids .upper eye lid is

immovable and lower eye lid is movable. There is third eyelid arising from lower eyelid, which is thin and transparent called **nictitating membrane**. It is freely movable and protects eye from dirty water. male frog have **vocal sac** on either side of throat which produces croaking sound to attract female in breeding season. There are no external ears but behind and below each eye there is a nearly circular obliquely placed area covered with a tough transparent covering or the **tympanic membrane** under which is the Eustachian tube leading to the internal ear. At the tip of the snout are placed two **nostrils** or **external nares** communicating with the buccal cavity through internal nares, through which the frog takes in air for the purpose of respiration. The head also bears a wide horizontal opening the mouth, which is extended nearly from one ear to the other. In the male frog under the head on either side are placed two bluish wrinkled patches of skin – the vocal sacs which are used to produce croaking sound to attract the females for copulation.

Trunk :

The head is broadly joined with short somewhat flattened trunk of which at the dorsal side, in the resting stage there is a characteristic hump which is due to the linking of the hip girdle to the vertebral column. Attached to the trunk are two pairs of limbs. The fore-limbs are shorter while the hind-limbs are larger. The fore-limbs are meant to hold and support the front part of the body at the time of jumping but the hind-limb assist in swimming as the webs are present in between the toes. Each fore-limb comprises an upper arm, fore-arm, wrist and hand: the latter has a small palm with tubercles beneath, four fingers and a vestigial thumb. In male the inner digit is thickened especially in the breeding season. Each hind-limb comprises an upper thigh, shank or lower leg, ankle and long foot; the latter has a narrow sole and five slender toes connected by broad thin webs. At the posterior end of the body in between the hind-limbs there is a **cloacal opening** through which faeces, urine and reproductive bodies are discharged

Skin:

Skin is moist, smooth. The outer most layer is epidermis. Below epidermis, two glands are present, the **poison gland** and **mucous gland**. Mucous gland secretes a kind of watery fluid called **mucin**, which keeps skin moist.

Function – Skin is protective covering of the body. Mucous glands secrete mucin and keep the skin moist. Poison glands in the skin, protect the frogs from enemies. Frog does not drink water but water is absorbed through skin.

SEXUAL DIMORPHISM

Male – Female

1. Males are generally smaller and darker in colour. While females are larger and lighter in colour.
2. Males are slimmer and females are stouter(fat)
3. Males croak loudly due to the presence of vocal sacs. Females do not croak as

vocal sacs are absent in them.

4. Males have swollen, **copulatory or nuptial pad**. Nuptial pads are absent in females.

2.10.2 RESPIRATORY SYSTEM OF FROG

Respiration can be defined as a process by which living beings obtain oxygen to oxidize their digested food reserve in order to release energy, which is required for keeping all other metabolic activities in order. In the course of this reaction carbon-dioxide is also formed which is removed regularly from the body due to its injurious property.

Frog, due its amphibious life, respire through **skin, lining of the bucco-pharyngeal cavity and the lungs**. Ordinary respiration is met by the skin and bucco-pharyngeal cavity and lungs are used only when the need of oxygen is great. However in **tadpole larva**, respiration takes place through **gills**.

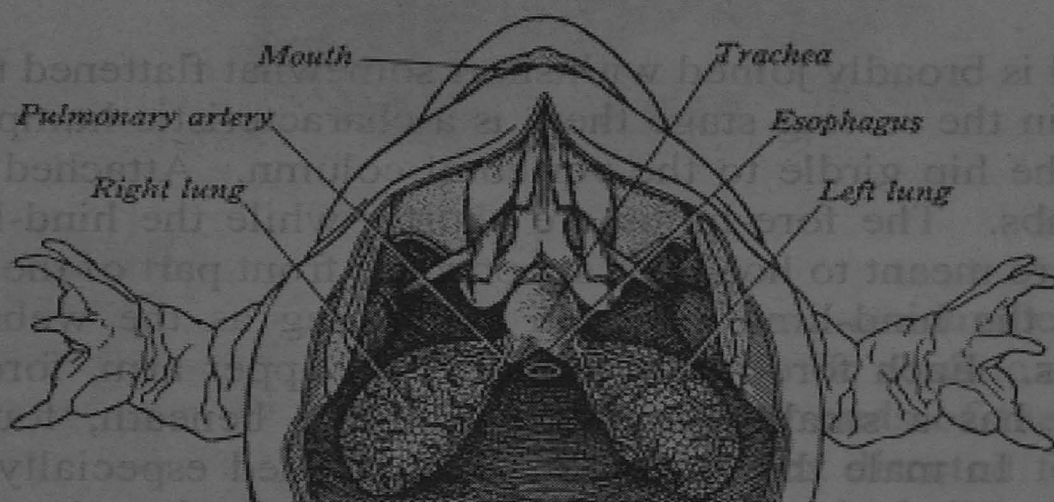


FIG. 388. Lungs of Frog

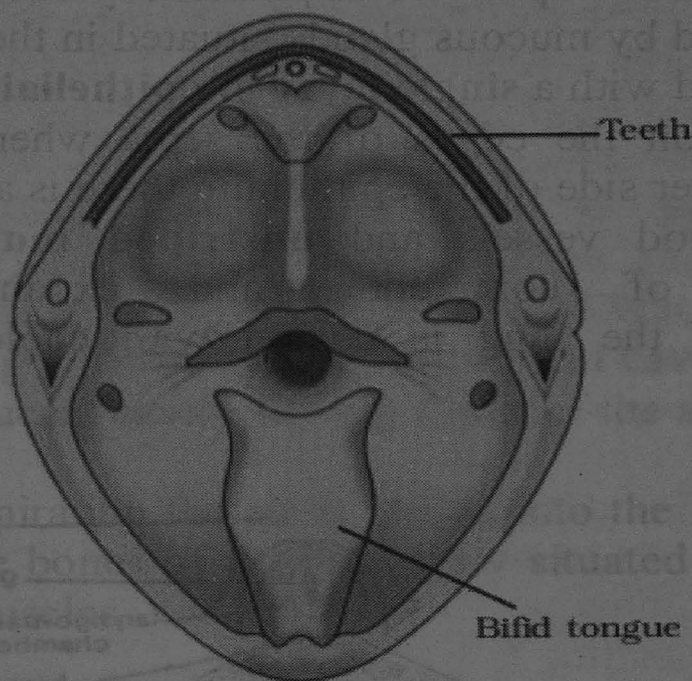
Types of respiration

1. Cutaneous respiration:

Respiration through moist skin is called as cutaneous respiration. Skin is richly supplied with blood vessels and is permeable to gases. Oxygen gets dissolved in moist surface of skin then diffuses into the blood circulating in the blood capillaries, while the resultant carbon dioxide passes out from the blood into the surrounding medium thus exchange of gases takes place by diffusion. The blood of frog contains a respiratory pigment haemoglobin which combines with oxygen and forms oxyhaemoglobin which is conveyed by blood to different tissues where it is readily broken into free oxygen and haemoglobin. Thus oxygen thus liberated is used by tissue cells to oxidise the stored digested food to obtain energy and the resultant carbon dioxide is carried by blood in the same manner to the skin from where it is diffused outside of the body into the film of water. It goes on all the time whether the frog is in water or on land. It is only mode of respiration during hibernation or aestivation or when frog is under water.

2. Buccal respiration:

The mucous lining of the buccal cavity is richly supplied with blood capillaries and remains moist by the mucus, thereby, lowering and raising of the floor of the buccal cavity bring the bucco-pharyngeal respiration, during the course of which the air is constantly sucked into the buccal cavity and is drawn out through the external and internal nostrils or the nares. When the floor of the buccal cavity is lowered, the air enters the buccal cavity through the nostrils. The oxygen of air dissolves in the layer of mucus and then goes into blood with the help of haemoglobin. At the same time carbondioxied is given out into the buccal cavity from the blood which is expelled along with residual air through the nostrils when the floor of the buccal cavity is raised. During this respiration glottis remains closed.



The floor of buccal cavity is alternately raised and lowered so that air is drawn into and expelled out of buccal cavity through, nostrils. The epithelial lining of buccal cavity is moist and highly supplied with alone capillaries and exchange of gases takes place through it.

3. Pulmonary respirations

Organs associated with respiration:

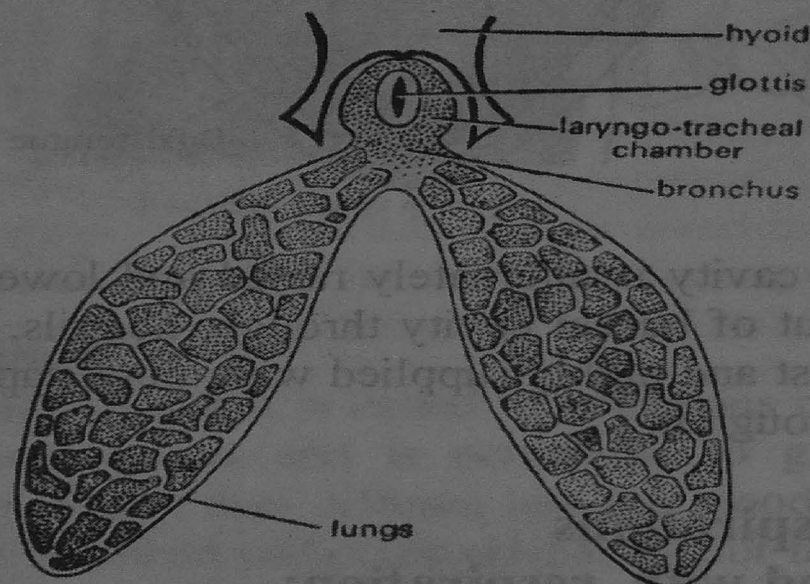
It consists of respiratory tract and lungs.

Respiratory tract: the passage through which air enters and leaves lungs is called respiratory tract and it consists of external nares, nasal chambers, internal nares, bucco-pharyngeal cavity, glottis, laryngo-tracheal chamber and two bronchi. The glottis opens into small, thin walled chamber called as laryngo-tracheal chamber. Its wall remains supported by 2 arytenoid and 1 cricoid cartilages. Internally it contains a pair of elastic horizontal bands called as vocal cords. Vibration of vocal cord produces sound. Thus larynx or laryngo-tracheal chamber is called as voice box.

When air from lungs is forced out between vocal cords, they vibrate producing croaking sound. Vocal sacs of male frog amplify the croaking sound. From larynx a very small tube, the bronchus, leads to each lung.

Lungs:

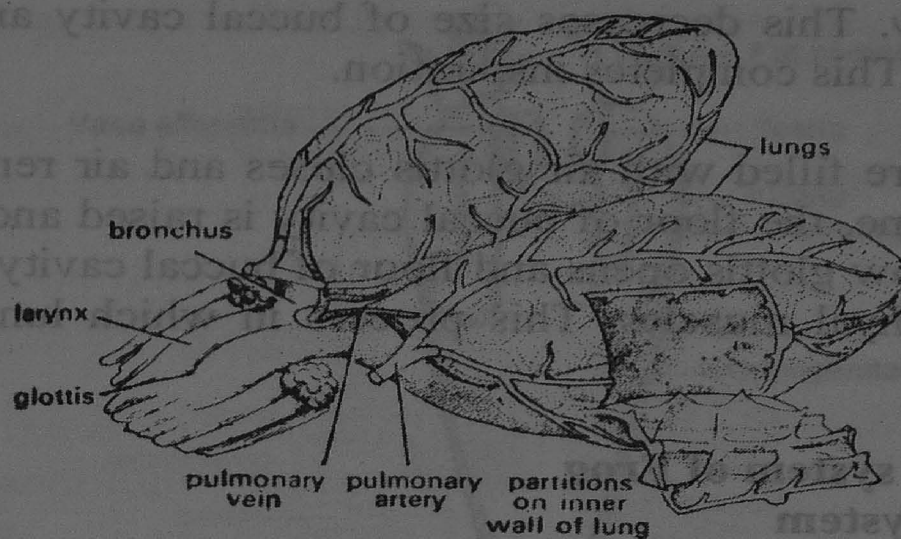
The lungs of frog are not only the organs of respiration but also hydrostatic organ as they enable frog to float in water when they are inflated. They are somewhat covered over by liver lobes and are found in the anterior part of the body cavity one on either side of the heart. They are ovoid, thinwalled, elastic sacs with shallow internal folds that increase the inner surface to form many chambers called alveoli. These are separated from each other through septa. These are lined with blood capillaries of pulmonary circulation and remain moist with the mucus secreted by mucous glands situated in the wall. The inner surface of the alveoli is covered with a **single layer of epithelial cells** which are very thin and flattened except on the edges of the septa where they are ciliated and cylindrical. On the inner side of the epithelium there is areolar type of connective tissue comprising blood vessels and **unstripped muscle fibres** which give remarkable power of contraction and expansion to the lungs. The outer surface of the lung is coated with **coelomic epithelium** called **peritoneum**.



Each lung connects by a short bronchus to the larynx, the so-called voice box behind the glottis. The larynx is supported by a ring like cricoid cartilage and two crescentic arytenoid cartilage which prevents the larynx from collapsing.

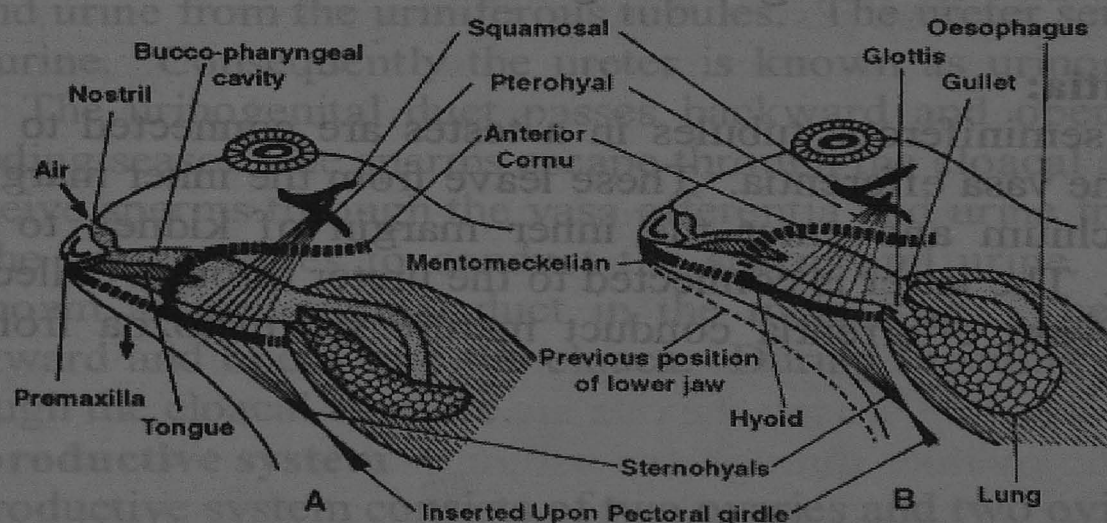
Mechanism of pulmonary respiration

The incoming and outgoing of the air from the lung is brought about by the action of the floor of the buccal cavity which actually acts as a buccal force pump. The actions of the floor of the buccal cavity are brought about by two sets of muscles; the **sternohyal and petrohial muscles**.



The sternohyal muscles arise from the coracoid and clavicle and run towards, the hyoid apparatus located in the floor of the buccal cavity. When these muscles contract the hyoid apparatus along with the floor of the buccal cavity is pulled downwards that result in the enlargement of the buccal cavity due to which the pressure of the enclosed air in the buccal cavity is reduced and consequently more of air from the surrounding environment rushes in through the nares. The petrohyal muscles arise from the outer side of the auditory capsule and run towards the upper surface of the hyoid apparatus. When these muscles contract, the hyoid apparatus along with the floor of the buccal cavity is raised, this results in the reduction of the buccal cavity forcing a part of the air to go out through the nares.

During pulmonary respiration the air is forced into the lungs. This is aided by the movable premaxillae bones of the upper jaw situated just below the external nares and the foresaid muscles.



A. Lowering of lower Jaw : B. Closing of external nares and rising of lower jaw

The Pulmonary respiration consists of two steps - Inspiration and expiration.

Inspiration

The process in which lungs are filled up with air is called inspiration. During it, glottis and mouth remains closed while nostrils remain open. The sternohyal muscles contract lowering the floor of buccal cavity. Thus, the buccalcavity get enlarged and air comes into the buccal cavity through nostrils. Now the glottis opens and nostrils are closed. Now petrohyal muscles contract which raises the

floor of buccal cavity. This decreases size of buccal cavity and air passes into lungs through glottis. This completes inspiration.

Expiration

When lungs are filled with air glottis closes and air remains in lungs for some time. At this time, the floor of buccal cavity is raised and lowered to carry buccal respiration. Now glottis opens and floor of buccal cavity is lowered by the contraction of sternohyal muscles. This process in which lungs are emptied is called expiration.

2.10.3 Reproductive system of Frog

Male reproductive system

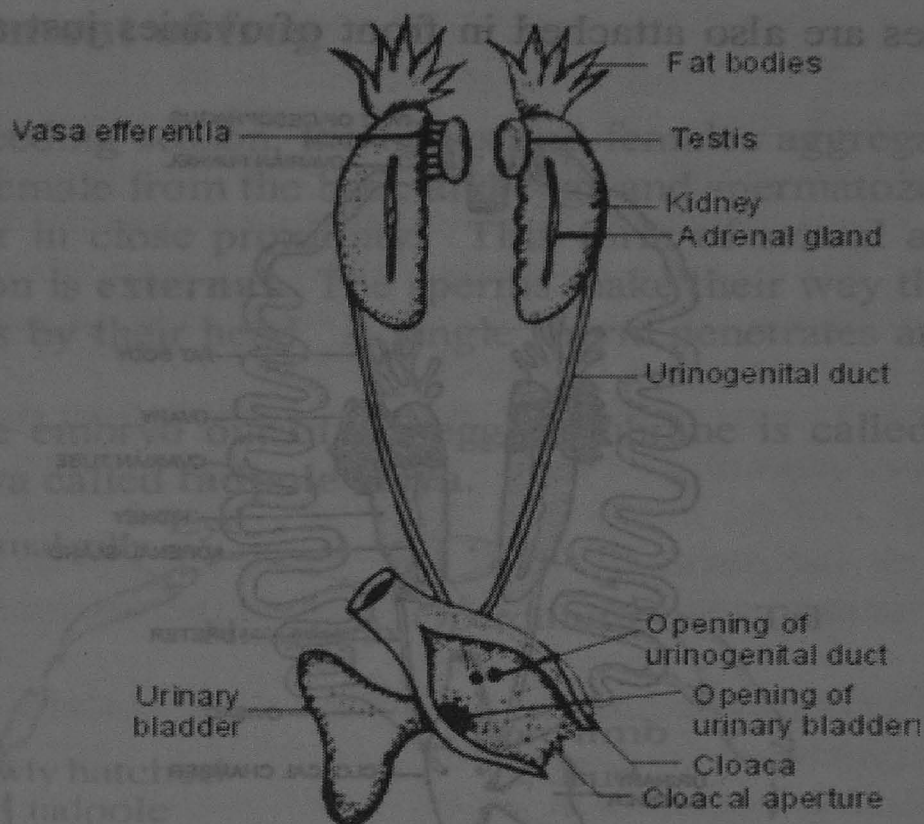
Male reproductive system consists of two testes attached to kidneys, several vasa efferentia and two urinogenital ducts. Copulatory organs are lacking

1. Testes:

A testis is an elongated or ovoid, light-yellow body attached to the antero-ventral surface of each kidney by a double fold of peritonium, called mesorchium. Near the anterior end of testis, several branched finger-like fat bodies arise which provide reserve food used to nourish developing spermatozoa and during hibernation. Histologically each testis is a compact mass of much coiled seminiferous tubules, the epithelial lining of which produces spermatozoa by spermatogenesis. A mature sperm is microscopic, elongated, about 0.03 mm long structure. It consists of a small rounded anterior acrosome, a long cylindrical head containing nucleus, a short middle piece containing centrioles and mitochondria, and a much elongated posterior motile tail terminating in a flagellum.

2. Vasa efferentia:

All the seminiferous tubules in a testes are connected to form 10 or 12 narrow tubes, the vasa efferentia. These leave from the inner margin of testis, run through mesorchium and enter the inner margin of kidney to open into the Bidder's canal. The latter is connected to the ureter through collecting tubules of kidney. Thus vasa efferentia conduct mature spermatozoa from testis to the ureter of kidney.



Urinogenital system of male frog

3. Urinogenital duct:

Ureter in male frog is both a urinary duct and a vas deferens, hence it is called a urinogenital duct. The ducts of both the sides open into roof of cloaca separately on urinogenital papillae. In some species of frog, the urinogenital ducts are enlarged near kidneys or cloaca forming seminal vesicles for temporary storage of spermatozoa until needed. Ureters receive sperms through the vasa efferentia and urine from the uriniferous tubules. The ureter serves to conduct the sperm and urine. Consequently the ureter is known as urinogenital duct in the male frog. The urinogenital duct passes backward and opens into the cloaca. During breeding season, the sperms escape through the cloacal aperture.

Ureters receive sperms through the vasa efferentia and urine from the uriniferous tubules. The ureter serves to conduct the sperm and urine. Consequently the ureter is known as urinogenital duct in the male frog. The urinogenital duct passes backward and opens into the cloaca. During breeding season, the sperms escape through the cloacal aperture.

Female reproductive system

Female reproductive system consists of two ovaries and two oviducts

1. Ovaries:

Each ovary is attached to the dorsal abdominal wall, near kidney supported by a peritoneal fold called mesovarium. It is large, irregularly folded, multiboded, hollow sac greyish or blackish in colour. In breeding season, the two ovaries become greatly enlarged. Histologically, each ovary contains innumerable dark round ova in different stages of development. Ova arise from germinal epithelial lining by oogenesis. When ripe, the ova are shed by rupture of ovarian wall into the body cavity from where they are moved by cilia of peritoneum into the ostia of

oviducts. Fat bodies are also attached in front of ovaries just as before testes in male frog.

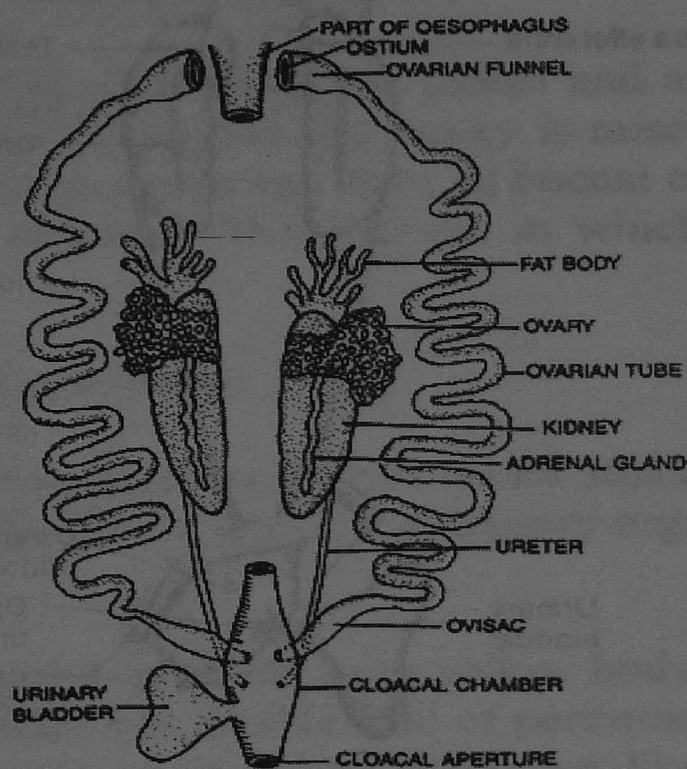


Diagram of female reproductive organs of frog

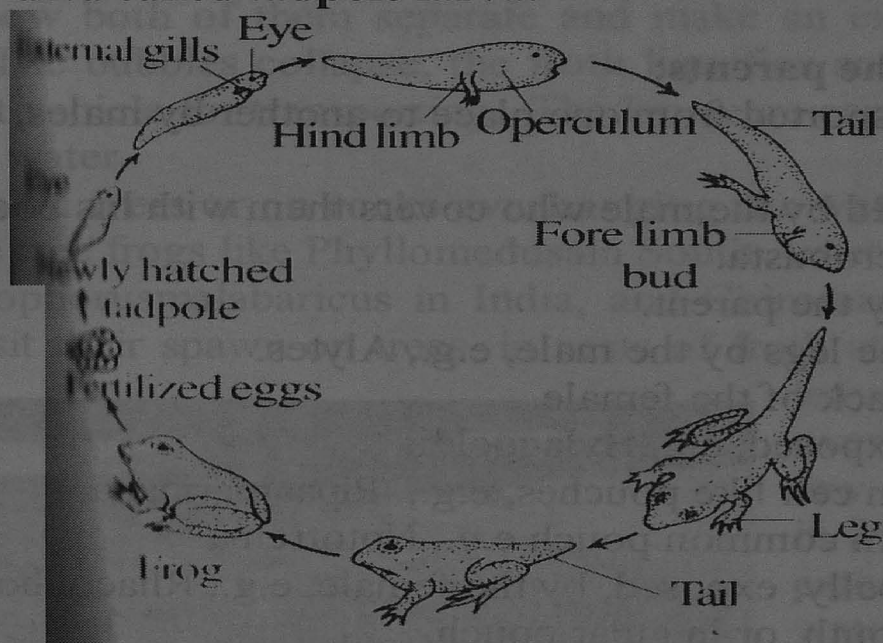
2. Oviducts :The two oviducts are long and much coiled white glandular tubes not connected directly to the ovaries. Their anterior ends form ciliated funnel-like openings, the ostia. These are placed quite anteriorly in the body cavity at the bases of lungs one on either side of oesophagus. Cilia present on the inner walls of oviducts move the eggs posteriorly while glands secrete an albuminous coat around each egg during its passage. The posterior ends of oviducts open dorsally into cloaca separately on papillae just in front of the apertures of uterus. Just before entering cloaca, each oviduct forms a thin-walled enlargement, the ovisac, sometimes called uterus. The eggs are collected inside ovisacs before being laid. During the breeding season the ova are released into the body cavity. The ova enter the oviduct through the **ostium** and get collected in the **ovisac**. Later they are released into the water through the cloacal aperture. Posteriorly each oviduct dilates to form a thin walled sac, the ovisac. The oviducts from both sides open separately into the cloaca. During the breeding season the ova are released into the body cavity. The ova enter the oviduct through the ostium and get collected in the ovisac. Later they are released into the water through the cloacal aperture. An unfertilized ripe egg of frog is spherical and nearly 1.75 mm in diameter. Its upper black pigmented half containing nucleus is called animal hemisphere or pole. The lower whiter half containing yolk is called vegetal hemisphere or pole. Quantity of yolk is much larger than in the egg of Branchistoma. Egg of frog is telolecithal and radially symmetrical. Around the egg is a two layered vitelline membrane of its own secretion. The outer albuminous coat on contact with water swells into a thick jelly like layer which probably prevents overcrowding and protects from infections and predators.

2.10.4 Development of frog

2.10.5

During the breeding season, the males and females aggregate in the pond. The male grasps the female from the back and eggs and spermatozoa are shed into the surrounding water in close proximity. This form of sexual act is known as **amplexus**. Fertilization is **external**. The sperms make their way through the jelly and penetrate the eggs by their head. A single sperm penetrates an ovum and the zygote is formed.

The emergence of the embryo out of the egg membrane is called hatching. The egg hatches into a larva called **tadpole larva**.



Metamorphosis

The radical changes which convert the tadpole larva into the adult frog constitute metamorphosis. Metamorphic changes begin after 2 to 3 months of larval life. The metamorphic changes occur for about one month. The changes include both internal and external. They include morphological, physiological and biochemical changes. The changes are as follows:

1. The gill respiration is replaced by lung respiration.
2. The intestine becomes shortened.
3. Herbivorous habit changes into carnivorous habit.
4. The larval skin is cast off.
5. The horny jaws disappear.
6. The small oval mouth is changed into a wide mouth.
7. Eyes grow more prominent.
8. Fore limbs emerge out by breaking the operculum.
9. The hind limbs increase in length.
10. Gills atrophy, gill slits are closed and the lungs develop.
11. The tail regresses.
12. Sex differentiation begins.
13. Free swimming habit is changed into a crawling habit

The whole process of metamorphosis is under the control of hormones.

2.11 PARENTAL CARE IN AMPHIBIANS

In amphibians there are many devices for the protection during the early stages of development and in this way nature has practiced economy in the number of eggs, which varies in direct proportion to the chances of destruction.

These devices fall under two heads, which may be found combined in some forms. 1. Protection by the parents, either by means of nest or nurseries, or by direct nursing 2. Shortening of metamorphosis.

The nursing of eggs and embryos by the parents is called **parental care** which is well developed in Amphibia.

Direct nursing by the parents:

i. Tadpole transported from one place to another by males, e.g., *Phyllobates*, *Dendrobates*.

ii. Eggs protected by the male who covers them with his body, e.g., *Mantophrynerobusta*.

iii. Eggs carried by the parent.

(a) Round the legs by the male, e.g., *Alytes*.

(b) On the back of the female.

(i) Exposed, e.g., *Hyla*.

(ii) In cell like pouches, e.g., *Pipa americana*,

(iii) In common pouch e.g., *Nototrema*.

(c) On the belly, exposed, by the female, e.g., *Rhacophorus reticulatus*.

(d) In the mouth, or in gular pouch.

(i) By the male, e.g., *Rhinoderma darwini*

(ii) By the female, e.g., *Hyla brevicauda*.

iv. Oviparous or viviparity, e.g., *Pseudophryne vivipara*.

Protection by means of Nest and Nurseries:

A. In enclosures in the water (mud nest)

A large tree frog (*Hyla faber*) is known in Brazil as the **Ferreiro**. It protects its progeny by building a basin-shaped nursery in shallow water on the border of the pond. The female scoops mud to a depth of 3 or 4 inches and with the material thus removed a circular wall is built which emerges above the surface of the water. The inside wall is smoothed by the webbed and flattened hands, the bottom is leveled by belly and hands. The eggs and early larvae are thus protected from attack of many insects and fishes, etc., at least for some time, heavy rains later on destroy the wall and larvae go to the water.

B. In holes near water (Foam nest)

A still better mode of protecting the offspring during the early stages of development has been adopted by a **Japanese tree frog** *Rhacophorus schlegelii*. The male and female in embrace bury themselves in the damp earth on the edge of ditch or flooded rice field, and make a hole or chamber, a few inches above water level. The walls of this chamber are polished and during this process the gallery by which they enter into that chamber gets obliterated, oviposition begins. The female first produces a secretion from cloaca which is beaten into a froth. The eggs are deposited into the froth. Now the inactive male impregnates them, now both of them separate and make an exit gallery towards the ditch. The bubbles collapse, the froth liquefies and this liquid acts as an efficient vehicle for transporting. The larvae are carried down in the tunnel into the water.

C. In nests on trees or on rocks overhanging the water (Tree nest)

Some tree frogs like *Phyllomedusa* in South America, *Rhacophorus malabaricus* in India, and *Chiromantis* in tropical Africa, deposit their spawn on trees, in nests of froth attached to one or many



leaves stuck together and overhanging a pool for a few days. The larvae move in froth and after losing the external gills, they fall in water to complete metamorphosis.

Rhacophorus malabaricus



D. In transparent gelatinous bag in the water

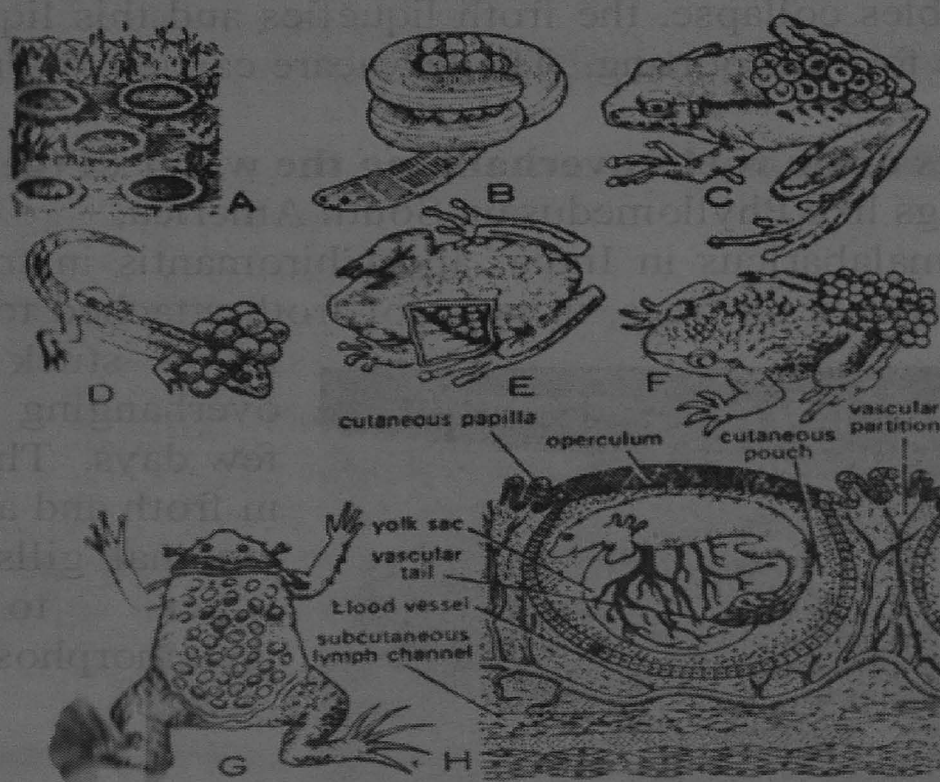
The eggs of *Phrynxalus biroii* are large which are enclosed in sausage shaped transparent common membrane secreted by the female and is left

in the mountain streams. The whole development takes places within the eggs and little frogs go out in perfect condition. No gills have been observed and the large tail serves as a breathing organ of young ones. *Salmandrellakeyserlingi* lays its eggs in a gelatinous bag which is fastened to aquatic plants.

Salmandrella keyserlingi

E. On trees or in moss away from water:

In several species of tropical American genus *Hylodes*, the eggs are deposited in damp places under stones or moss or plant leaves and are of large size.



(Parental care in amphibians, A-Mud nests of *Hyla*. B-*Ichthyophis* coiling round the eggs. C-*Cryptobranchus evansi*. D-*Desmognathus* with eggs. E-*Gastrotheca*. F-*Alytes*. G-*Pipapipa*. H-Pseudoplacentation in *Pipadorsigera*.)

The metamorphosis is hurried up within the egg, there is a plenty of yolk in the egg and hence entire development takes place there and young frog hops out as an air breather with a vestige of tail which was fully developed and highly vascularized and served as a respiratory organ. No gills have been seen.

2. Direct Nursing by the parent

A. Tadpoles transported from one place to another by males:

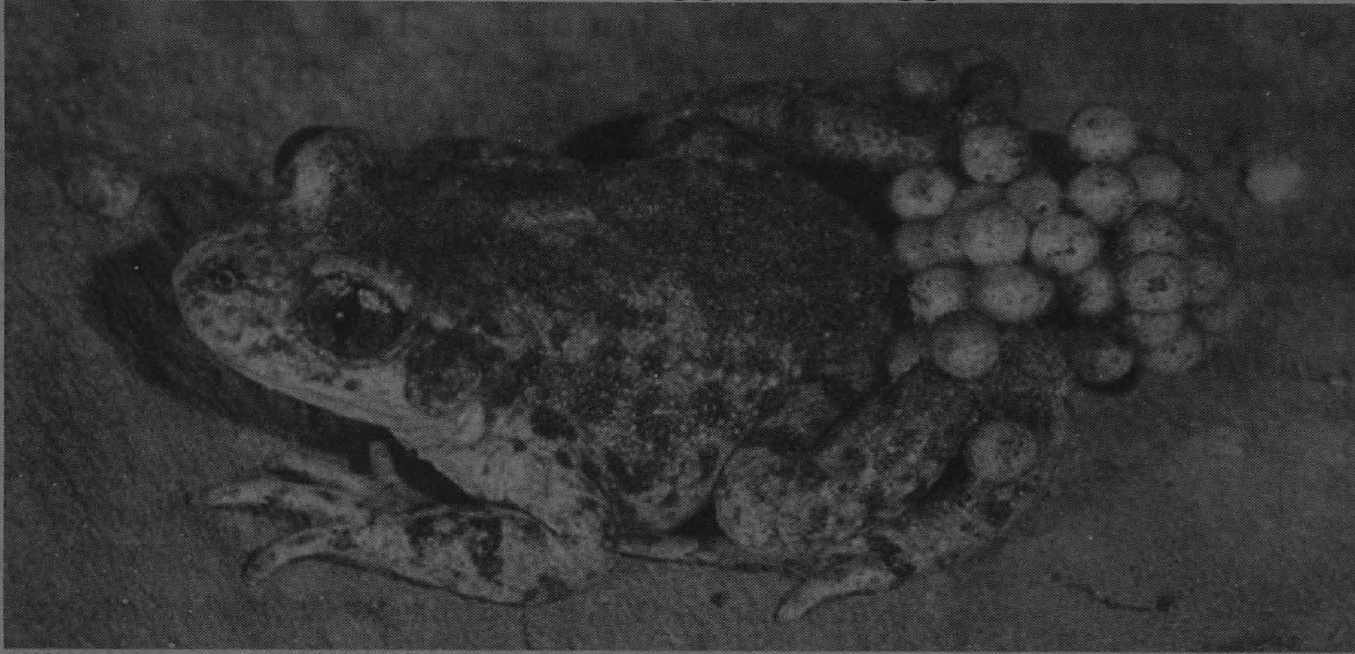
Small South American frogs *Phyllobates* and *Dendrobates* have been repeatedly observed carrying well-developed tadpoles on their back. Tadpoles adhere by their sucker-like and flattened abdomen and thus they are carried from one place to the other place and in this way they can even go from one pool to the other and this is particularly when one pond is to dry up.

B. Eggs protected by male who covers with its body:

The eggs of *Mantophrynerobusta* are stung together by an elastic gelatinous envelope. They are seventeen in number and form a clump over which the male sits, holding it with both hands and development takes place there. It may be outside water. The larvae have no gills, well developed legs, large tail which is vascular and respiratory.

C. Eggs carried by the parent

a) Round the legs by the male: *Alytes obstetrucans* was discovered in France. The pairing and oviposition takes place on land and when the eggs are deposited the male first leave the female's waist and shifts hold to the base of head. The eggs are passed out in two or three times at short intervals. The male then lubricates the cloacal region of the female where upon the female discharges the eggs. The eggs are fertilized.



Alytes obstetrucans

After fertilization the eggs are wrapped round the back of the thigh of the male and the male withdraws himself into a hole near the pond. Now and then the male carries the egg to the water to moisten them. When the eggs are nearly ready to hatch, he takes them to the water where the larvae come out and further development and metamorphosis take place.

b) On the back of female

(i) **Exposed:** In a Brazilian tree-frog, *Hylagoeldii*, it is the female which takes charge of the eggs, carrying them on the back. In *Nototrema* also this phenomenon is seen.

(ii) **In cell-like pouches:** In *Pipa americana* the eggs are carried on the back of the mother, but the skin thickens and grown round the eggs, until each is enclosed in a dermal cell, which is finally covered by a lid, believed to be formed by a secretion from the glands of the skin. The eggs are about 100 in number and they develop in these pouches and the young leaps out in the perfect condition. The Pipa is a thoroughly aquatic and

pairing of course takes place in water. The male clasps the female round the waist. During egg laying the cloaca projects as a bladder-like pouch directed forwards between the back of the female and the breast of the male and by means of this oviposition the eggs are evenly distributed over the whole back of the female. How the eggs are fertilized are not known.

(iii) **In common pouch:** In *Nototrema* the whole of the brood is sheltered in a common pouch. It is a condition foreshadowed by the lateral everted fold of *Hylagoeldii*. This dorsal pouch develops only during breeding season. How the eggs are introduced into the pouch is still unknown, the opening of this pouch is small and situated on the posterior part of the back.

c) **On the belly exposed, by the female:** The female of the Ceylonese *Rhacophorus reticulatus* carries its eggs on the belly, which bears shallow impressions when the eggs are removed.

d) **In the mouth or gular pouch:**

(i) **By the male:** *Rhinoderma darwini*, a small frog believed to be viviparous but revealed that the young about 10 to 15 in number, are sheltered and develop in the gular pouch which is a modified vocal sac.



Rhinoderma darwini

(ii) **By female:** The female of a West African tree-frog, *Hylambates breviceps*, carries the eggs in her mouth. These eggs are large and few in number.

Ichthyophis is a burrowing, limbless amphibian coils around the egg mass until they are hatched. The female takes the eggs into the water shortly before hatching.



Ichthyophis

D. Ovoviviparity: Some amphibians are ovoviviparous. The females retain their eggs in the oviduct and they give birth to young ones. Eg. **Toads** like *Nectophrynoides* and *Pseudophryne*, salamanders like *Salamandra* and *S. atra* and apodans like *Typhlonectes*, *Geotrypetes*, *Dermophis*, etc.

2.12 Questions

1. Write the General characters of Amphibians.
2. Explain the Importance of Pulmonary respiration in Frog
3. Describe the Male and Female reproductive system of fro.
4. Discuss the stages noted in metamorphosis of frog.
5. Give an account on Parental Care in Amphibians.

UNIT III

- 3.1 Type study - Calotes
- 3.2 Nervous system
- 3.3 Urinogenetal system
- 3.4 Poisonous and non-poisonous snake
- 3.5 Decline of Mesozoic reptiles

3.1 Calotes

Systematic position

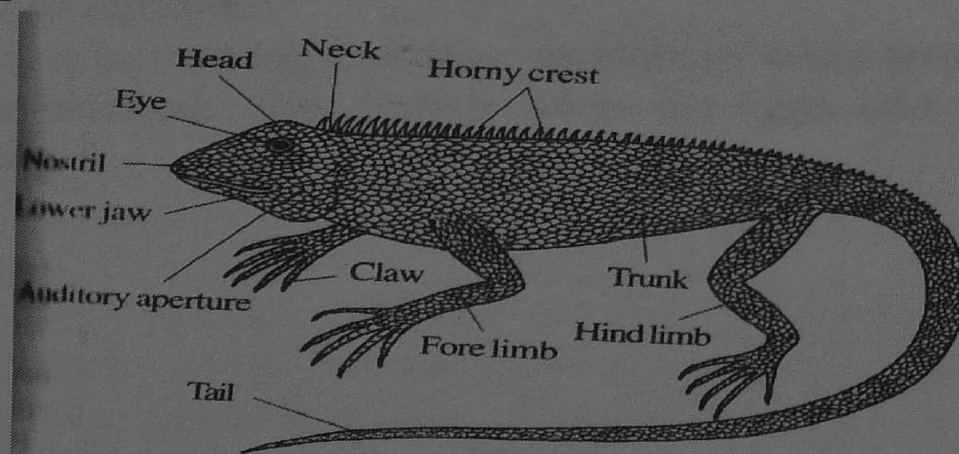
Phylum	: Chordata
Subphylum	: Vertebrata
Division	: Gnathostomata
Superclass	: Tetrapoda
Class	: Reptilia
Subclass	: Diapsida
Order	: Squamata
Suborder	: Lacertilia
Family	: Agmidae
Type	: Calotes versicolor

Shape, size and colour:

Body is elongated slender, lizard-like and clearly divisible into four parts – head, neck, trunk and tail. Male is brightly coloured, golden yellow with a greenish tinge. Throat is scarlet red, often with a black transverse bar. Female is not so brightly coloured. The male is stronger and larger than female and measures about 35 cm in length including tail.

Head

The large head is pyramidal in shape with a short conical snout, bearing a wide slit-like transverse terminal mouth and a pair of small oval apertures, the external nares. Lips are absent. The lower jaw of male shows a characteristic curve not present in female. Each eye is shielded by movable eyelids and a nictitating membrane. Behind each eye is a shallow external ear opening provided with a tympanum at its bottom.



Trunk

A short neck connects the head with an elongated trunk which is compressed laterally but flattened ventrally. Between trunk and tail mid-ventrally opens a transverse slit-like vent or cloacal aperture. A large cloacal plate is found at front of the cloacal aperture. The trunk bears 2 pairs of limbs, the hind limbs being longer than the forelimbs. Each forelimb comprises antebrachium, brachium, manus and 5 clawed fingers; while each hind limb comprises femur, crus, pes and 5 clawed toes.

Tail

Tail is cylindrical, tapering like a whip and two and a half times longer than the head and trunk. In adult male the base of tail just behind the cloacal aperture becomes markedly swollen due to hemipenes. The tail shows alternate dark and light annuli.

Skin and exoskeleton

The entire body is covered by rough epidermal horny, imbricate and backwardly directed scales of unequal size. On the head, a prominent shield covers the parietal foramen and 2 spines are present above each ear opening. On the head and trunk, along mid-dorsal line, is a characteristic frill or crest of larger spine-like movable scales pointed backwards and gradually diminishing in size posteriorly. Scales are shed periodically in ecdysis. Skin is dry and devoid of glands; femoral pores on thighs are absent in females. In males, these glands become functional during breeding seasons.

Calotes skin first develops as a simple cuboidal ectoderm. Subsequently it differentiates into outer periderm and inner basal germinativum layer. Later it becomes stratified due to addition of outer layers composed of an inner layer of columnar cells, stratum germinativum which is found on basement membrane. The outermost layer is made of dead cells called stratum corneum. Between the two a transitional layer is also present.

Scales and claws form the exoskeleton of most of the reptiles including Calotes.

Scales

Scales form a continuous cover over the body of Calotes, but become thinner in the grooves between the scales. Scales on the body of Calotes are of two types viz., large scales and small scales. Sensory devices in the form of bristles are present on both the scales called prototrichus. It is believed to evolve into hair in mammals, during the course of evolution. Scales are epidermal in origin, develop from malpighian layer. Each scale is a plate like structure supported by bony plate or ossicle.

Claws

Tips of the digits of Calotes are provided with sharp claws. Each made up of a dorsal and ventral scale like horny plate. Dorsal plate is called unguis and ventral one is called subunguis. The latter is flattened. Both these plates are derived from the malpighian layer and placed in such a way, that they converge to form a sharp claw.

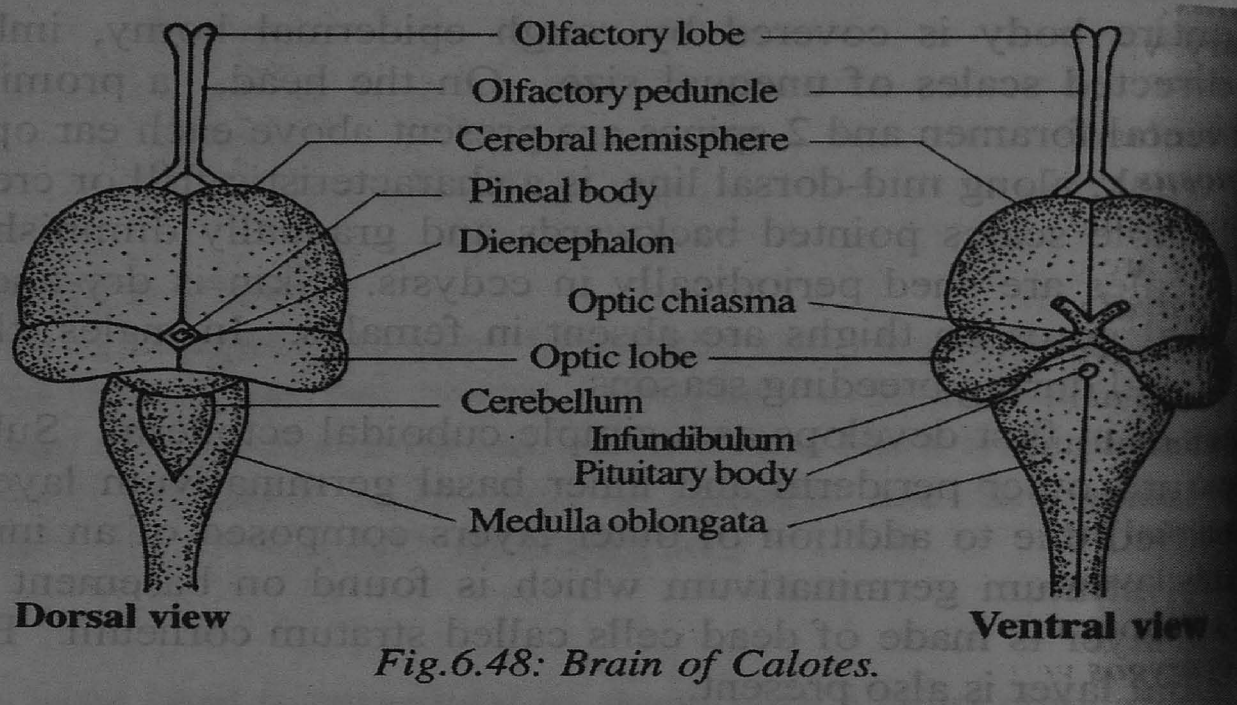
3.2 Nervous system

The nervous system of *Calotes* basically resembles that of Amphibia. However, it shows some advancement apparently because of the terrestrial mode of life. As in other vertebrates, the nervous system consists of the following three divisions:

1. Central nervous system, comprising brain and spinal cord.
2. Peripheral nervous system, comprising cranial and spinal nerves.
3. Autonomic nervous system, comprising two lateral trunks with ganglionic enlargements connected to spinal nerves.

Brain

The brain of *Calotes* is simple and similar to that of frog, but, comparatively, it is more advanced in the relatively greater size of cerebral hemispheres and smaller size of the olfactory lobes. The brain lies inside the cranial cavity covered by two membranes, the inner pia mater and the outer dura mater.



The three divisions of the brain are: forebrain, midbrain, and hindbrain.

Forebrain:

It is the anterior part of the brain including olfactory bulbs, cerebral hemispheres and diencephalon.

a. Olfactory bulbs. The anterior most part or telencephalon is in form of the two narrow and elongated stalk-like olfactory peduncles each having a distal, small, nodule-like olfactory bulb, from which originates an olfactory nerve.

b. Cerebral hemispheres. Posteriorly, the olfactory peduncles are attached to the cerebral narrow in front and broad behind. They are closely applied together but clearly demarcated by a mid-dorsal groove, the median longitudinal fissure. The thin roof of each cerebral hemisphere is termed pallium, whereas the thick floor and the sides form the corpus striatum. The two corpora striata are connected together by a transverse anterior commissure. Above it lies the hippocampal regions of both the hemispheres. The pallium of *Calotes*, however,

shows an increase in thickness and number of neurons as compared with that of amphibians.

c. Diencephalon. The diencephalon or thalamencephalon is a small rounded area covered between the cerebral hemispheres and the optic lobes, and hardly visible dorsally. Its roof is thin, non-nervous and highly vascular, forming the anterior choroid plexus. From the dorsal surface of diencephalon projects a median outgrowth, the pineal apparatus, comprising an anterior parietal organ and a posterior pineal body or epiphysis. The thick lateral walls of diencephalon form the optic thalami, and the thick floor is called the produced downwards into an infundibulum, behind which is attached the pituitary gland or hypophysis. In front of infundibulum, the two optic nerves cross each other forming the optic chiasma.

Midbrain

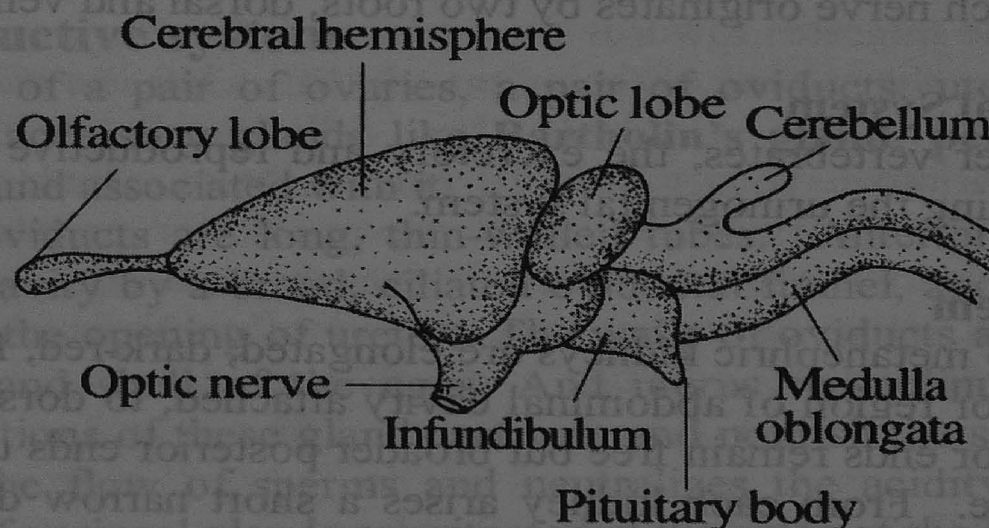
The middle part of brain, or the mesencephalon, includes two large rounded optic lobes placed dorso-laterally. The two thick longitudinal bands of nerve fibres beneath the optic lobes are termed cruracerebri.

Hindbrain

The posterior part of the brain is formed by the hindbrain or the rhombencephalon. It includes cerebellum and medulla oblongata.

a. Cerebellum: The cerebellum or metencephalon is well-developed. It is a narrow, flat, semicircular ridge covering the anterior dorsal surface of medulla.

b. Medulla oblongata: The triangular medulla oblongata or myelencephalon is broad in front by narrow and tapering behind. Its thin and highly vascular roof forms the posterior choroid plexus. Posteriorly, it shows a strong ventral flexure where it passes into the spinal cord.



Cavities of brain.

The brain is a hollow organ with internal cavities known as ventricles. The first and second **lateral ventricles** or **paracoels** are the cavities of the two cerebral hemispheres. Each of them is connected anteriorly to the cavity of the olfactory lobe of its side, called **rhinocoel**. Posteriorly, the two **paracoels** communicate through a small aperture, the **foramen of Monro**, with the cavity of diencephalon, called the third ventricle or the **diacoel**. It is connected with the cavity of medulla oblongata, called the fourth ventricle or **metacoel**, through a

narrow median passage, the **iter**. The cavities of the optic lobes or **optocoels**, are also connected with the iter.

The cavities of brain are continuous with that of the spinal cord. They are filled with a watery cerebrospinal fluid secreted by the **choroid plexus**.

Histology of brain.

The brain is composed of an external grey matter made of nerve cells, and an internal white matter made of nerve fibres. Their arrangement is reversed in the medulla oblongata.

II Spinal cord

The spinal cord is a long, whitish and somewhat dorso-ventrally flattened tube lodged in the neural canal of the vertebral column. The meninges covering the brain are continuous over it. Its grey matter is H-shaped pattern with well-developed dorsal and ventral horns. A shallow mid-dorsal fissure and a prominent mid-ventral fissure are evident. Its central canal is filled with the cerebro-spinal fluid and is continuous with the fourth ventricle of medulla oblongata. The spinal cord controls the reflex activities.

III Nerves

There are 12 pairs of cranial nerves, the first 10 pairs corresponding with those of the fishes and amphibians. The two extra pairs are the spinal accessory and hypoglossal. They arise from medulla behind the 10th pair. They innervate the muscles of the larynx, neck and tongue. 16 pairs of spinal nerves arise from the spinal cord. Each nerve originates by two roots, dorsal and ventral.

3.3 Urinogenital System

As in all other vertebrates, the excretory and reproductive organs are closely associated forming the urinogenital system.

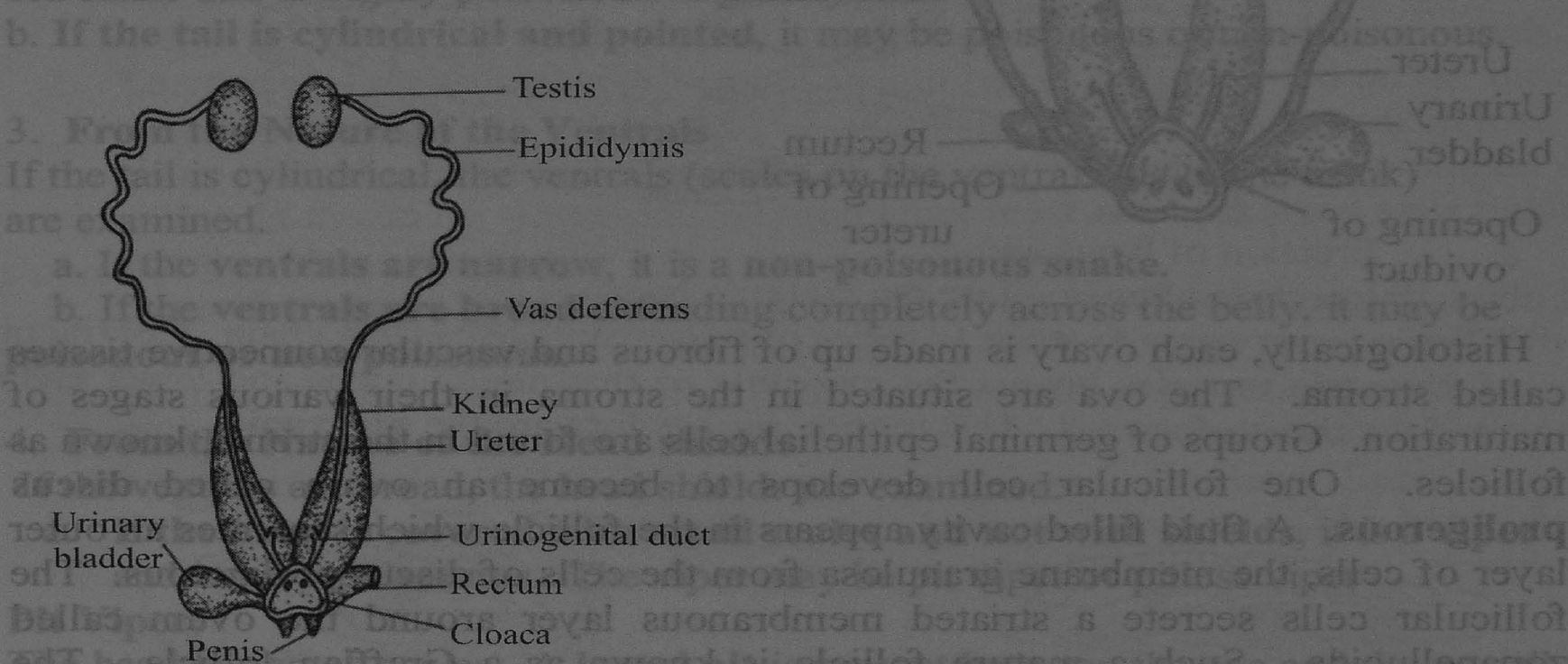
Excretory system

The two metanephric kidneys are elongated, dark-red, flattened and lobed, lying in posterior region of abdominal cavity attached, to dorsal bodywall. Their narrower anterior ends remain free but broader posterior ends united forming a V-shaped structure. From each kidney arises a short narrow duct, the ureter. In female it opens dorsally into urodaeum of cloaca independently. In male the ureter joins the vas deferens of its side to form the urinogenital duct. A thin-walled urinary bladder allantoic in origin, opens mid-ventrally into urodaeum of cloaca. Calotes is uricotelic.

Periodic shedding of scales, the ecdysis is a feature of Calotes. It is seen that some nitrogenous metabolic wastes are also removed during ecdysis thus, ecdysis is also a process of excretion.

Male reproductive system

A pair of oval white testes are situated just ahead of kidneys, each suspended from dorsal bodywall by a peritoneal fold, the **mesorchium**. Right testis is larger and anterior in position. Histological structure is similar to those of frog. On the inner side of each testis is attached a long and much coiled tube, the **epididymis**, which receives **vasa efferentia** from testis. Epididymis is continued behind as a narrow and spirally twisted duct, the **vas deferens**. It joins with the ureter of its side forming the **urinogenital duct** before opening into cloaca. At the base of tail behind cloaca are present a pair of eversible and erectile copulatory sacs. During copulation, they protrude through the cloacal aperture as **grooved hemipenes** meant to transfer sperm of male into the cloacal cavity of female.

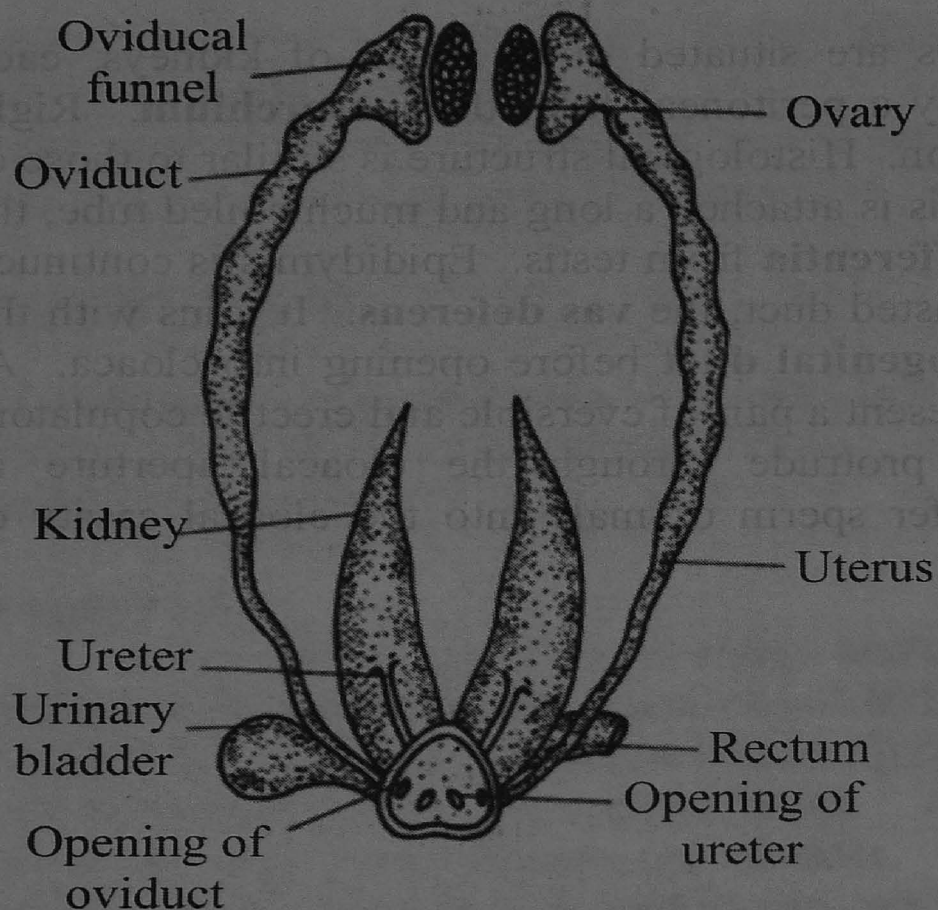


Female reproductive system

It consists of a pair of ovaries, a pair of oviducts, uterus, vagina and vestibule. Some accessory glands like **Bartholin's gland**, **perineal** and **rectal glands** are also found associated with it.

The two oviducts are long, thin-walled tubes. Anteriorly, each oviduct opens into body cavity by a broad, ciliated oviductal funnel, and posteriorly into cloaca in front of the opening of ureter. The walls of oviducts are glandular and secrete albumen and shell of the eggs. And uterus masculinus constitute the semen. The secretions of these glands activate and nourish the sperms, provide a fluid media for the flow of sperms and neutralizes the acidity of the urethral passage. A pair of perineal glands are situated at the sides of the base of the penis. These glands open to the outside by the ducts into a hairless perineal depression. The secretion of these glands provide a characteristic odour to the rabbit. A pair of large rectal glands are also situated at the sides of the rectum whose function is not well known.

The ovaries are paired, small, whitish, oval bodies found attached to the dorsal wall of the abdomen behind the kidneys. The ovaries are attached with the dorsal body wall by the mesentery called mesovarium. Each ovary shows on its surface many projections when ripe. These projections rupture releasing the ova.



Histologically, each ovary is made up of fibrous and vascular connective tissues called stroma. The ova are situated in the stroma in their various stages of maturation. Groups of germinal epithelial cells are found in the stroma, known as follicles. One follicular cell develops to become an ovum called **discus proligerous**. A fluid filled cavity appears in the follicle which separates an outer layer of cells, the membrane granulosa from the cells of discus proligerous. The follicular cells secrete a striated membranous layer around the ovum called zonapellucida. Such a mature follicle is known as a Graffian follicle. The Graffian follicle migrates towards the surface of the ovary and ruptures to release the ovum. After the release of the ovum, all that is left is a mass of follicular cells surrounding a blood clot. Gradually these follicle cells proliferate and the blood clot transforms into a yellow coloured corpus luteum which produces hormones. The hormones of the corpus luteum are responsible for preparatory changes in the uterus for fertilization and retention of the embryo during gestation. The corpus luteum remains active throughout the period of embryonic development and if somehow, no fertilization occurs it degenerates leaving a scar called corpus albicans.

3.4 Identification of Poisonous Snakes

The poisonous snakes are identified by the following features:

1. The nature of the snake bite
2. The nature of the tail
3. The nature of the ventrals
4. The nature of the head and shields
5. The nature of the sub-caudal scales
6. The nature of the vertebrals

From the Nature of the Snake Bite

- a. When a poisonous snake bites, there will be **two punctures** or **only one puncture** or just a scratch on the skin of the victim. If a non-poisonous snake bites, there will be many punctures on the skin.
- b. If a poisonous snake bites there will be a **continuous flow of blood** from the wound. The venom prevents the clotting of blood. If a non-poisonous snake bites the flow of blood is stopped after sometime owing to the clotting of blood.

2. From the Nature of the Tail

- a. If the tail of a snake is flat, laterally compressed and oar-shaped, it is a sea snake and is **highly poisonous**. Eg. *Enhydrina*
- b. If the tail is cylindrical and pointed, it may be poisonous or non-poisonous.

3. From the Nature of the Ventrals

If the tail is cylindrical, the ventrals (scales on the ventral side of the trunk) are examined.

- a. If the ventrals are narrow, it is a **non-poisonous snake**.
- b. If the ventrals are broad extending completely across the belly, it may be **poisonous or non-poisonous**.

4. From the Nature of the Head shields

If the ventrals are broad, the head shields are examined.

- a. If the head is covered with small scales and not with shields, it is a **viper** and is **very poisonous**. The viper may be pit viper or pitless viper

Pit Viper:

The head has small scales. A **loreal pit** is present between the eye and the nostril. It is highly poisonous. Eg. *Trimeresurus*.

Pitless Viper: The head has small scales, but without any loreal pit. It has a **double sub-caudal**. Eg. *Russel's viper*.

If the head is covered with shields, it may be **poisonous or non-poisonous**.

5. From the Nature of the Vertebrales

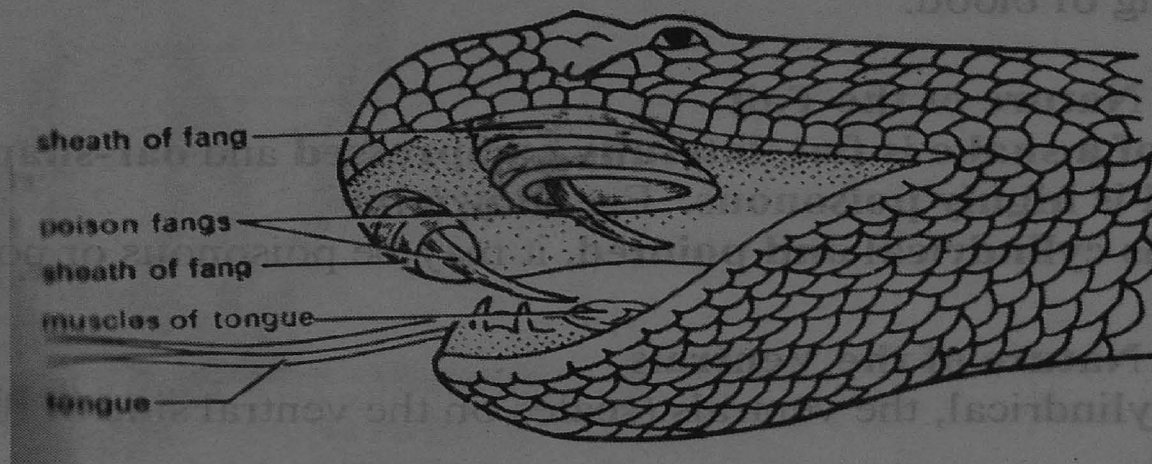
If the head is covered with shields, the vertebrales, (scales present along the mid-dorsal line on the back) are examined. They may be large or small.

- a. If the vertebrales, are large, it is **Krait** and is **highly poisonous**. In addition the krait has only four infralabials of which the fourth is the largest. The sub-caudals are single. Eg. *Bungarus*
- b. If the vertebrales are not large, examine the **supralabial shields** (shields forming the margin on the upper jaw). If the 3rd supralabial touches the nasal shield and the eye, it is a **cobra**. The cobra is identified by a **neck with a hood**.

Coral snakes have cylindrical tails and elongated broad ventrals. The head is covered with shields and not scales. The vertebrales are small and elongated. Peculiar markings are present on the belly.

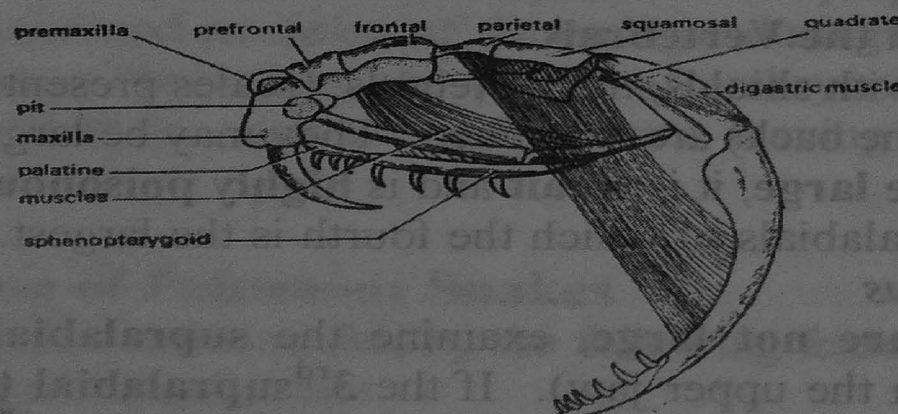
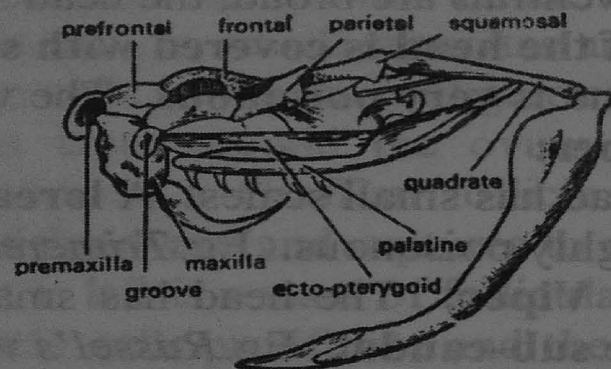
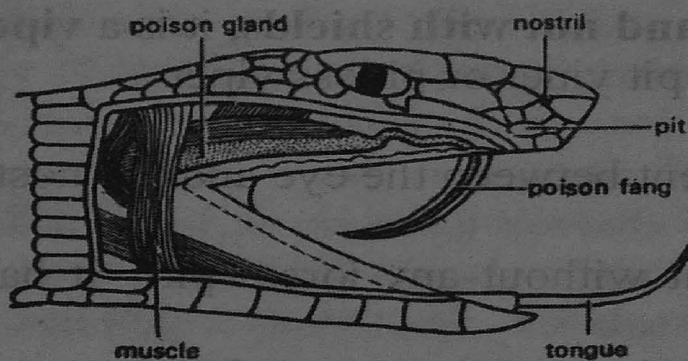
Biting mechanism

The skull and jaw bones of poisonous snakes are very flexible. They are loosely or movably articulated thus allowing a considerable degree of adjustment during the act of swallowing or striking. In cobras, the fangs are permanently erect. But in vipers, the large fangs lie against the roof of mouth when closed. Therefore, mechanism for biting serves two main purposes.



- Erection of fangs and
- Injection of poison into the victim's body

When a viper wants to strike, a series of movements occur in a chain. Contraction of **digastric muscles** lowers the mandible so that mouth opens and lower end of quadrate thrusts forward. This in turn, pushes forward the **pterygoid**.



This is also aided by the contraction of **sphenopterygoid muscles**. The forward pull of pterygoid in turn pushes the transverse or **ectopterygoid** upwards. This causes, the maxilla bearing fangs to rotate through 90 degree at the hinge-joint with lacrimal. As a result, the fangs become vertically erect and in the most effective position to strike. A simultaneous **stretching of constrictor muscles** around the poison gland, **forces its poison** through poison duct into the canal or

groove of fang to be injected into the victim. When mouth is closed by the contraction of temporal muscles, the above movements are reversed. The fangs embed in the prey which is drawn into the mouth. At the same time the vertical fangs rotate to become horizontal.

First Aid Treatment of Snake Bite

First aid treatment includes emergency care of the victim of snake bite before complete medical or surgical treatment can be secured. The following first aid methods are recommended by experts:

1. **Psychological:** The fright or fear due to snake bite may cause heart failure and death even if the snake was non-poisonous. Therefore, the victim should first of all be treated psychologically with reassuring and encouraging words.
2. **Tourniquet:** A tourniquet or ligature should be immediately tied on the bitten limb towards heart by any suitable available material such as handkerchief, a piece of cloth, rubber tube, cord, etc. This prevents or delays circulation of poison in the body. However, the tourniquet must not be applied very tightly and should be removed for a few minutes in between.
3. **Care of wound:** Wound should be washed with clean water. Application of potassium incision, about 1 cm deep, should be made near the wound with a clean sterilized blade or knife. This will let out some poison with blood. Poison may also be sucked out by a suction cup and not by mouth. X-shaped cuts should be avoided as they require longer time for healing. Some experts do not recommend incision which may lead to infection. The bitten part should be cooled with ice to slow down blood circulation and spread of poison.
4. **Care of person:** Anything causing excitement to the victim should be avoided. Alcoholic beverages should be avoided. Instead, the victim may be served with hot milk, coffee or tea. The victim should be shifted immediately to a hospital or a qualified doctor for treatment with an antivenin injection.

3.5 Decline of Mesozoic Reptiles

Dinosaurs roamed on the earth for about **160 million years**. Then all of them mysteriously vanished. About 67 million years ago Dinosaurs still flourished. But two million years later all were extinct. All rocks formed since 65 million years ago contain no Dinosaurs fossils. Not only Dinosaurs died out. The flying Pterosaurs, swimming Mosasaurs and Plesiosaurs went with them. So did ammonites and some much smaller sea invertebrates.

There are many theories about the cause of the extinction of Dinosaurs.

1. Eruption Theory

This theory was proposed by Charles B. Officer et. al.(Nature, 1987). This theory explains the mass extinction of dinosaurs. This theory claims that widespread volcanism could be the real cause for mass extinction. Volcanoes led to the large scale emission of sulphur dioxide in the atmosphere. The sulphur dioxide destroyed the ozone umbrella and allowed in

ultraviolet light to reach the surface of the Earth killing animals and plants. Smoke and dust blocked out the Sun. The climate cooled. Plant died. This led to the extinction of dinosaurs. When there was rain the sulphur dioxide dissolved in rain water and this acid rain destroyed the marine life.

2. Competition

The extinction of dinosaurs is caused by the competition with the primitive mammals. The primitive mammals ate the eggs of dinosaurs and caused their downfall.

3. Epidemic

It is believed that most of the Mesozoic reptiles became extinct by epidemic, viral, bacterial or protozoan diseases.

4. Racial Senescence

It is believed that groups of organisms become old, just as individual organisms do and extinction follows from senile degeneration.

5. Large Size

Certain dinosaurs reached enormous size. They were too clumsy to survive.

6. Poor Faculty of Reproduction

The dinosaurs became extinct because they were unable to reproduce. This was caused by the failure of production of sperms because of too much heat. Too much of heat made their eggs all hatch out into males. Without females dinosaurs could not have gone on breeding.

Unit –IV

- 4.1 Introduction to Aves
- 4.2 Type study- Pigeon –external morphology
- 4.3 Pigeon Respiratory system
- 4.4 Pigeon pectoral and pelvic girdle only
- 4.5 Flight adaptation in Birds
- 4.6 Beak and Feet modification in Birds
- 4.7 Migration in Birds
- 4.8 Flightless Birds
- 4.9 Fossil bird – Archaeopteryx and its evolutionary importance
- 4.9.1 Questions

4.1 Introduction to Aves

Birds belong to the class Aves (L., avis, bird) of the superclass Tetrapoda. The most distinguishing feature of birds is the possession of feathers which do not occur in other animals. The study of birds is termed Ornithology. The birds are defined as warm blooded, bipedal, air-breathing vertebrates with fore limbs modified into wings and non-glandular skin covered with feathers.

The feathers, the wings and the beaks are the three important identifying features, which make the birds distinct from other vertebrates.

Columba livia : The Common Rock Pigeon

Pigeons are quite familiar birds that we see every day of our lives. They are best suited for type study because of their convenient size, harmless nature and easy procurement in large numbers.

Systematic Position

Phylum	-	Chordata
Subphylum	-	Vertebrata
Superclass	-	Tetrapoda
Class	-	Aves
Subclass	-	Neornithes
Supercorder	-	Neognathae
Order	-	Columbiformes
Type	-	<i>Columba livia</i>

(The blue rock pigeon)

More than 500 species of pigeons have been described.

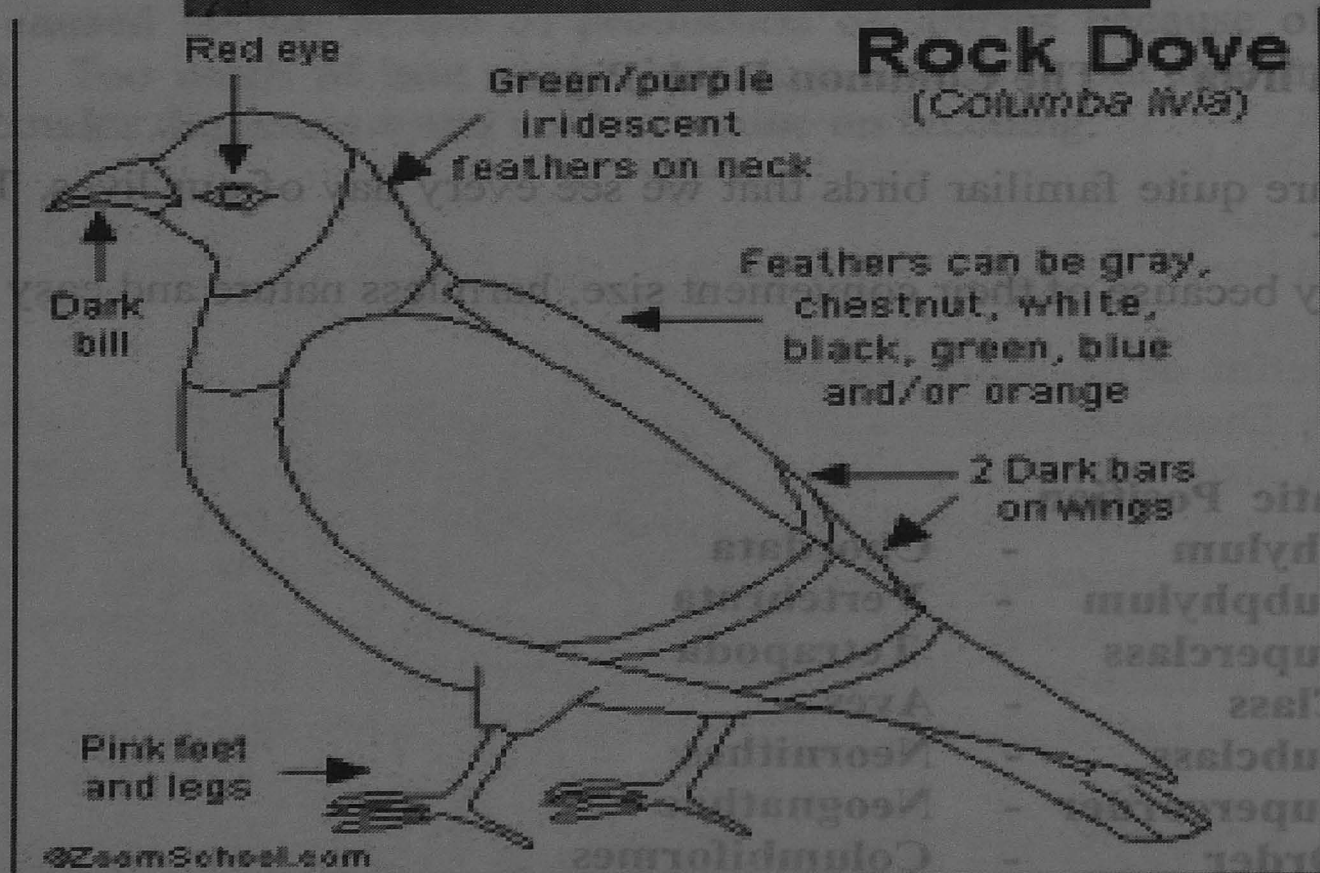
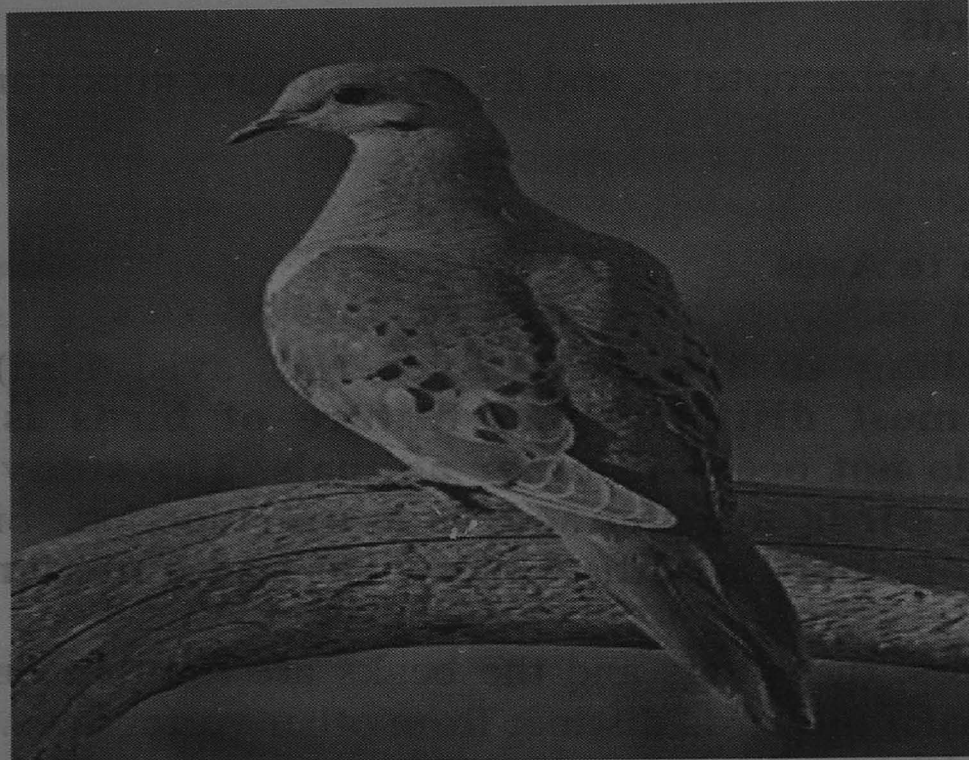
4.2 Pigeon –external morphology

Habitat. In its wild state, pigeon lives in perfect freedom in ledges, fissures and holes of rocks, forts, old crumbling buildings, and other inaccessible places, but never nests on trees. They often nest in houses tenanted by man.

Food and feeding. Pigeons are vegetarian feeding on grains, pulses, seeds of fruits and grasses, etc.

External Features

The structure of pigeon does not differ a great deal from that of other birds.



[I] Shape, size and colouration

The compact, fusiform or boat-shaped streamlined body is well adapted for rapid flight and offers minimum resistance to air. Blue rock pigeon is slightly smaller than the common house-crow and measures about 33 cm in length. Pigeon is a very beautiful bird. It is a slaty-grey bird with glistening metallic green and purple sheen on the upper breast and around the neck. Eyes and the feet are pink. Rump or posterior region of back is ash-coloured and not white as in *Columba livia* of Europe. There are two prominent black bars on the wings.

[II] Division of body

Body of a pigeon is distinctly divisible into four parts: head, neck, trunk and tail, invested in a close covering of feathers. All these parts are clearly recognised when the body is stripped of its feathers.

1. Head. Head is small in proportion to the body, somewhat rounded and mobile.

(a) Beak. Anteriorly, the head is drawn out into a short straight and pointed bill or beak, formed by the elongated upper and lower jaws. There are no teeth in the two jaws which remain covered with a horny sheath called *ramphotheca*. The terminal slit-like *mouth*, bounded by the horny beaks, forms a wide gap.

(b) Nostrils. At the base of the upper beak open the two slit-like *external nares* or nostrils. Each nostril is dorsally overhung by a small, whitish, swollen area of barren, soft and sensitive skin, the *operculum* or *cere*. The nostrils can apparently be closed by the cere.

(c) Eyes. Behind the cere are located a pair of large, lateral and rounded eyes. An upper and a lower eyelid and a transparent third eyelid, or the *nictitating membrane*, which can be drawn independently across the eyeball from the anterior upper corner of the orbit, guards each eye. The eyelids are bare, without eyelashes and eyebrows.

(d) Auditory apertures. A little below and behind each eye is an external ear opening, or the *auditory aperture*, hidden under special auricular features. It leads into a short tube, the external auditory meatus, which is closed below by the tympanic membrane.

2. Neck. The modified cervical vertebrae makes the long and cylindrical neck very flexible. It serves for handling food and compensates for the conversion of the forelimbs into wings.

3. Trunk. The trunk is compact, stout and spindle-shaped. It bears mid-ventrally a prominent bony ridge, the *keel* or *carina*. A large and transversely elongated *cloacal aperture* opens ventrally at the hind end of the trunk.

The trunk can be further differentiated into an anterior thorax to which the wings are attached and a posterior abdomen to which the legs are attached.

4. Tail. The small stumpy, conical projection of the trunk beyond the cloacal aperture forms the true tail or *uropygium*. It bears a fan-like group of elongated tail-features or rectrices, which constitute what is ordinarily termed the tail. The tail is used as a rudder in flight, to suddenly check flight, and as a balancer in perching.

[III] Appendages

The limbs are two pairs: one pair of wings and one pair of legs, borne by the trunk.

1. Wings. The two forelimbs are modified into wings which are the chief organs of flight. They are attached high on the back, to the anterior or thoracic region of the trunk, and are very powerful when compared with the size and strength of the bird. Each wing is elongated, flattened and distally pointed with its longitudinal axis at right angles to that of the trunk. While at rest, it remains folded in the form of a Z. When extended, the wing shows the three typical divisions: the upper arm or the brachium, the lower arm or the ante-brachium and the hand or manus, all closely bound together by skin.

2. Legs. Each leg is made of the usual three parts- thigh, shank and foot. The short and muscular thigh is directed downwards and forwards and closely bound to the trunk so that the knee is not visible. The long and muscular *shank* extends from the knee downwards and backwards. The foot or *pes* contains tendons but no muscles and remains covered by horny, epidermal scales. Proximal slender part of foot is called *tarsometatarsus*. Distally, it bears four long and clawed digits or *toes*, of which the first or *hallux* is directed backwards and the remaining three, forwards/ Feet are well adapted for perching with long toes and curved claws.

4.3 Respiratory System.

The intense activity of flight demands large supplies of oxygen, so that the respiratory system of birds is more complicated than that of any other vertebrate. Respiration is *pulmonary* and the respiratory organs are fairly simple. A true muscular *diaphragm* is absent in birds and the expansion of the thoracic wall is limited. The lungs are relatively small and compact organs, continued into a unique system of *air sacs*. The expiration is more active process than inspiration. The respiratory system includes the *respiratory tract*, the *respiratory organs* or the lungs and the air sacs.

[1] Respiratory tract

It includes the nares, nasal sacs, glottis, larynx, trachea and syrinx.

1. Nares. The nostrils or external nares are a pair of slit-like oblique openings lying at base of the upper beak, overlapped by a swollen sensitive pad of skin, the cere or operculum. The nostrils lead into short olfactory or nasal sacs, which open directly into the pharynx by internal nares.

2. Trachea. A median slit-like opening, the glottis, situated just behind the root of the tongue, leads into the wind pipe or trachea. At its anterior end, the trachea has an expanded voiceless chamber, the larynx. It is greatly reduced in birds. It is supported by a cricoid cartilage composed of four pieces, and by paired arytenoid cartilages. But the thyroid cartilage and the vocal cords, characteristic of mammals, are absent, so that larynx does not produce sound in birds.

3. Syrinx and sound production. At the posterior end or base of the trachea, at its junction with the bronchi, is found a special structure, the syrinx or voice box, concerned with sound production. It is characteristic of birds as it does not occur in other vertebrates.

[II] Respiratory organs or lungs

The two bright-red lungs are small, compact and inelastic bodies. They are different from the lungs of other vertebrates in that they do not store air. They do not hang freely in the thoracic cavity, but are closely applied by their dorsal surface to the thoracic vertebrae and the ribs.

The two lungs of a bird are rather solid, spongy structures, as in a mammal, and not hollow thin-walled sacs with lobulated walls, as in frog.

[III] Air sacs

Around the lungs and connected with the ends of the main bronchial branches are remarkable, large, thin-walled, membranous, non-muscular and non-vascular air sacs. They lie among the viscera and even extended into some of the larger bones.

The nine major air sacs of pigeon are as follows:

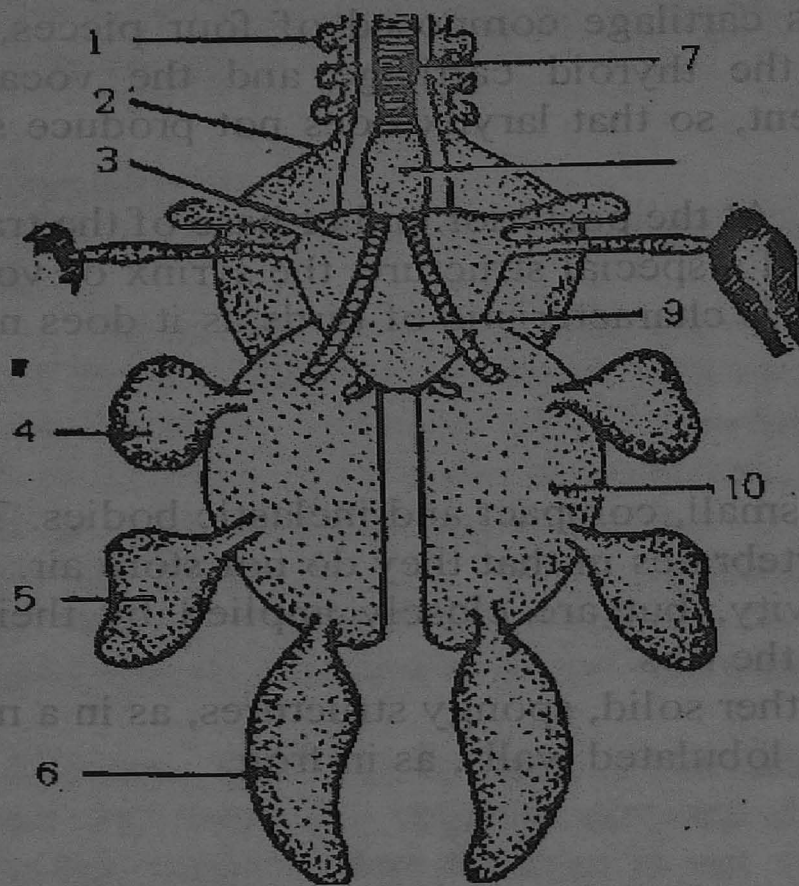
1. Interclavicular. It is a single median and somewhat triangular air sac connected with both lungs. It is situated in the angle between the two limbs of the furcula. On either side it gives off an axillary or extra-clavicular sac in the arm-pit, communicating with an air-cavity of the humerus, and a clavicular sac.

2. Cervical. A pair of small cervical sacs arises anteriorly, one from each lung. They lie at the base of the neck, dorsal to the interclavicular and alongside the vertebral column. They give off minor sacculles in the neck.

3. Anterior thoracic. A pair of anterior thoracic air sacs lies ventral to the lungs in the anterior part of the chest, in close contact with the ribs and the pericardium. They extended back so as to overlap the posterior thoracic air sacs.

4. Posterior thoracic. The pair of small posterior thoracic air sacs is found in the posterior part of the thoracic cavity, just in front of the abdominal air sacs. Each sac overlaps the posterior end of its lung and communicates with its outer posterior angle.

5. Abdominal. A large posterior or abdominal air sac arises from the outer posterior angle of each lung. They lie along the dorsal wall of the abdomen, ventral to the kidneys, amongst the coils of the small intestine.



- 1 & 2 Cervical air sac
3. Interclavicular air sac
- 4 Anterior thoracic air sac
5. Posterior thoracic air sac
6. Abdominal air sac
7. Trachea
8. Syrinx
9. Interclavicular air sac
10. Left lung.

Functions of the air sacs. The air sacs communicate with bronchi on the one hand, and with the pneumatic cavities of the bones, on the other hand. The following functions have been attributed to them.

(a) **Lightness.** They probably act as balloons to provide lightness and buoyancy to the body, probably by reducing the specific gravity of the body, although this view is no longer supported now.

(b) **Flight.** Their association with flight is also confirmed by the fact that the best fliers amongst birds possess the most highly developed air sacs.

(c) **Accessory respiratory organs.** The sacs function principally as the accessory breathing organs. Their smooth lining is devoid of capillaries and does not take part in gaseous exchange. But they serve as reservoirs and take part in the movements of air during respiration.

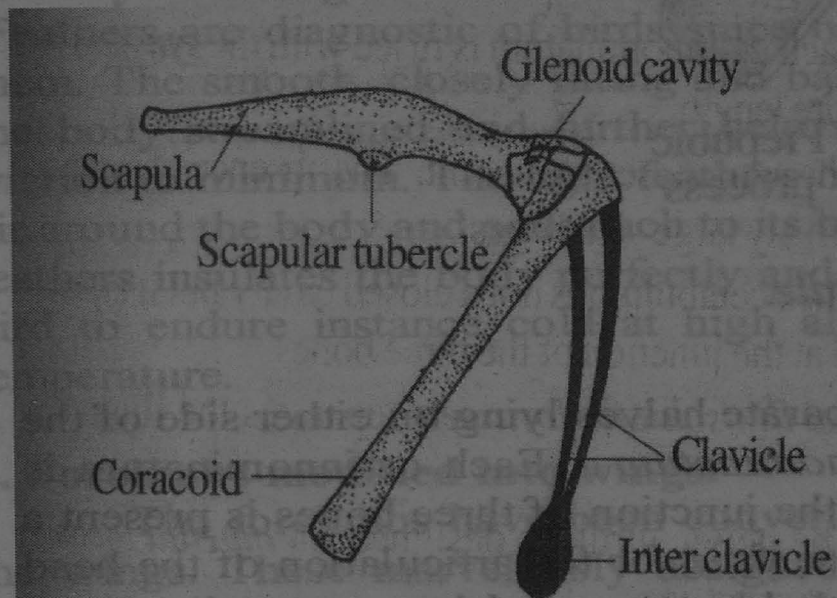
(d) **Temperature regulation.** They may also aid as cooling devices in the regulation of the temperature of the body, thereby compensation for lack of sweat glands. It occurs by internal perspiration i.e., water vapours diffuse from blood into the cavities of air sacs and pass out through the lungs, accompanied by loss of body heat.

(e) **Cardiac movements.** Another probable function of air sacs, according to Muller (1908), appears to allow for the movement of the heart in an otherwise very rigid thorax.

4.4 Pigeon - pectoral and pelvic girdle

The endoskeleton of pigeon is quite light and completely ossified. The endoskeleton comprises the usual two divisions, viz., the axial skeleton and the appendicular skeleton. The axial skeleton forms the skull, vertebral column, sternum and ribs. The appendicular skeleton includes the bones of the limbs and the girdles by means of which they are connected to the axial skeleton.

Pectoral girdle

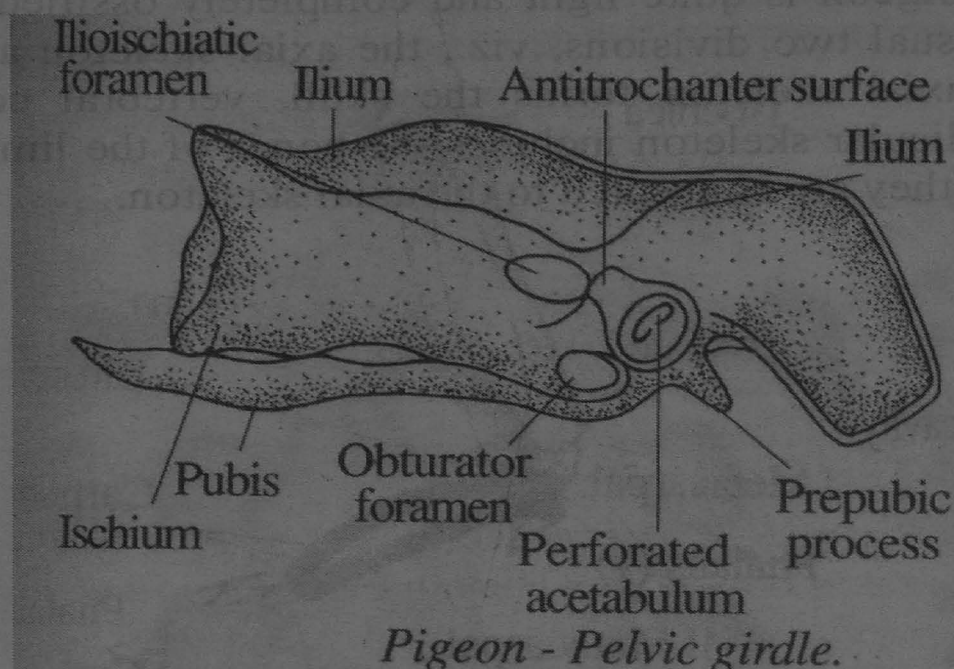


Pigeon - Pectoral girdle.

The pectoral girdle is very stout bony structure connected with the sternum on either side to support the wings. On either side it consists of a scapula, coracoids and a clavicle. Scapula is long, flattened sabre-shaped bone lying above the thoracic ribs and parallel to the vertebral column. The expanded anterior end of scapula is firmly united with the coracoids by ligament. On its either side it bears a shallow depression forming a part of glenoid cavity. The **glenoid end of scapula** is produced into an *acromian process* to provide articulate surface to the clavicle and to form a part of the *foramen triosseum*. Supra-scapula is wanting.

Coracoids is a stout straight bone directed downwards and articulates with the articular surface of the coracoids on the antero-lateral edge of the sternum at the base of manubrium. The upper end of coracoids on its inner side articulates with the scapula and on its outer side it bears a deep cup-shaped depression completing the glenoid cavity. The upper end of the coracoids is also produced into an acrocoracoid process directed upwards and inwards. Clavicles are a pair of slender curved bones connected by their expanded upper ends the coracoids and scapula. Ventrally the two clavicles are fused with the interclavicles to form a laterally compressed disc. The forked bone thus formed is known as *furcula or merry thought*.

Pelvic girdle:



The pelvic girdle consists of two separate halves lying on either side of the *syngsacrum*. Each half is known as *os-innominatum*. Each *os-innominatum* is composed of ilium, ischium and pubis. At the junction of three bones is present a concavity, the *acetabulum* which provides surface for the articulation of the head of femur. *Ilium* is an elongated and remarkably expanded bone extending both anterior and posterior to the acetabulum. The inner margin of ilium is fused with the *syngsacrum* whereas the outer surface of its anterior part is concave and posterior part is fused with the *ischium*.

On the outer surface above the acetabulum is a projection the *antitrochanter* which articulate with the great trochanter of femur. Ischium is also dorso-ventrally flattened bone projecting backwards behind the acetabulum and parallel to the posterior part of the ilium. *Ischium* is fused posterior with the ilium but separated anteriorly from it by an oval *ilio-ischiatic foramen*. Pubis is a long slender bone directed backward parallel to the outer margin of ischium with which it is usually fused. Behind the acetabulum the pubis and ischium are separated by a slit-like opening, the *obturator foramen*. Just in front and outside the acetabulum the pubis gives off a short and blunt process, the prepubic process.

4.5 Aerial or Flight Adaptations

Birds are aptly described as the masters of air. Man constructed aeroplanes after seeing birds. Birds are the good fliers. Their morphology, anatomy and physiology are highly modified for movement in the air.

The following are the flight adaptations of birds.

1. Shape.

The shape of the body represents the sum of all its several adaptations. The perfectly streamlined spindle-shaped body of a bird is designed to offer minimum resistance to the wind, and hence easily propelled through the air in the same manner as the fish swim through water quite easily without any waste or effort.

2. Compact body.

The compact body, light but strong dorsally and heavier ventrally, helps in maintaining balance in the air. The attachment of the wings high up on the thorax, the high position of such light organs as lungs and air-sacs, the low and central position of the heavy muscles, sternum and digestive organs beneath the midline of the attachment of two wings and consequently low centre of gravity, are also structural facts of importance.

3. Body-covering of feathers.

Feathers are diagnostic of birds since no other group of animals has developed them. The smooth, closely fitting and backwardly directed contour feathers make the body streamlined and further help its passage through the air by reducing friction to minimum. The light feathers hold a considerable blanket of enveloping air around the body and add much to its buoyancy. The nonconducting covering of feathers insulates the body perfectly and prevents loss of heat, which enables the bird to endure instance cold at high altitudes and also to maintain a constant temperature.

4. Forelimbs modified into wings.

The forelimbs have been converted into the unique and powerful organs, the wings. These marvelously designed structures equipped with special flight muscles have been developed as instruments of propulsion through air. The particular shape of the wing, with a thick strong leading edge, convex upper surface and concave lower surface, causes reduction in air pressure above and increase below, with minimum turbulence behind. This helps in driving the bird forwards and upwards during flight.

5. Short tail.

The short muscular tail bears a series of long, strong but light caudal feathers or *rectrices* arranged in a fan-like manner and serves as a rudder for steering during flight, to suddenly check flight and as a counterbalance in perching.

6. Beak.

The conversion of forelimbs into wings is duly compensated by the presence of a bill or beak. The mouth is drawn out into the horny beak, which is used as a pair of forceps in picking up things. Besides procurement of food, the beak is also used for nest building, which in other animals is done by the forelimbs.

7. Mobile neck and head

The neck of the bird is very long and flexible. Since the bird's bill is used for feeding, preening, nest-building, offence and defense, mobility of neck and freedom of movement of the head are very important.

8. Bipedal locomotion

The forelimbs being no longer available, the hind limbs or legs spring somewhat anteriorly from the trunk to balance and to support the entire weight of

the body and for locomotion on the ground or in water. Bipedality is a characteristic of birds, since flightless birds have all retained the habit of walking on two legs. The legs are relatively stronger.

9. Integument.

The loose skin is a modification for flight. It is responsible for extensive movement of the skeletal musculature.

10. Large muscle for flight

The wing is operated by a set of muscles called flight muscles. There are four sets of flight muscles. They are 1. *Pectoralis major*, 2. *Pectoralis minor*, 3. *Coracobrachialis* and 4. *Tensor muscles*. The pectoralis major and coracobrachialis bring about the downstroke of the wing. The pectoralis minor brings about the upstroke of the wing. The tensor muscles keep the prepatagium tensely stretched when the wing is extended in flight.

11. Perching.

The hind limbs of a bird are suited for an arboreal life. Their muscles are well developed and help in perching. Thus a bird sleeping on a perch cannot fall down.

12. Endoskeleton

Most of the bones are pneumatic and filled with air sacs instead of bone marrow. Skull bones are light and most of them firmly fused together. In the vertebral column about 14 vertebrae are fused together to form a plate-like structure called *synsacrum*. It acts as a girder to support the entire weight of the bird. It is formed by the fusion of the following vertebrae.

Thoracic vertebra -- 1(last)

Lumbar vertebra -- 6

Sacral vertebra -- 2

Caudal vertebra -- 5

The fusion of pelvis with synsacrum provides firm attachment to the legs, supports the weight of the body when the bird is walking and counteracts the effect of shock as the bird alights.

13. Digestive system

The rate of metabolism in birds is very high, food requirements are great and digestion rapid. The food that is selected has a high caloric value, largely utilized, with a minimum of indigestive waste. The rectum is short because the faecal matter is relatively small. As the flying animals cannot afford to be weighed down with any excess faecal luggage it is got rid of at once.

14. Air-sacs and respiration

The air-sacs which grow out from lungs and occupy all the available space between internal organs, even extending to the cavities of hollow bones. The air-

sacs secure more perfect aeration of lungs and help in internal perspiration, thus helping in the regulation of the body temperature.

15. Warm-bloodedness

Birds are warm-blooded animals. This helps the perfect aeration of the blood and a great output of energy. The constant body temperature helps the birds to take flight at high altitudes and in all seasons.

16. Circulatory system

Rapid metabolism and warm-bloodedness require a large oxygen supply and an efficient circulatory system. The avian heart is large and completely divided into four chambers. It functions very efficiently with a double circulation of blood.

17. Ureotelic excretion

Birds do not have a urinary bladder, which is present to store the urine temporarily in other animals. Urine is in the form of semi-solid uric acid. These features help in reducing the unnecessary weight of the body.

18. Brain and sense organs.

The eyes occupy a large portion of the head, and both eyes together are often heavier than the brain. The power of eyes is very high. It has pecten. This helps birds to see objects from very high altitudes.

19. Single ovary

Presence of a single functional ovary of the left side in the female bird also leads to reduction of weight, which is so essential for flight.

20. Furcula

The clavicles of the two pectoral girdles are fused ventrally to form a V-shaped structure called furcula or merry thought bone or wishbone. It works like a spring between the two wings.

4.6 Types of beaks in Birds

The upper and lower jaw bones become elongated to form a peculiar beak or bill covered by a horny sheath called rhamphotheca. Beaks are the horny projections of the jaws of birds.

Functions of the Beak

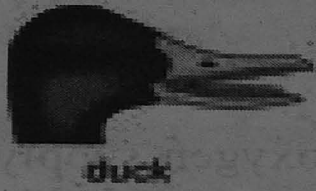
The beaks function as the hand and mouth of the birds. They do following functions.

1. to obtain food, 2. to handle food, 3. to preen the feathers, 4. to collect nest materials, 5. to build nest, 6. to feed the young ones, 7. for defence, 8. for courtship.

1. Seed-eating beaks

Seed eating beaks are short, stout and conical. They are used for crushing large and hard-shelled seeds. Eg. Sparrows and Finches.

BIRD BEAKS



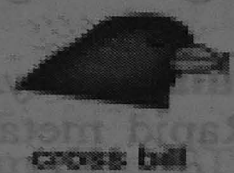
duck



gull



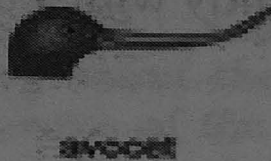
eagle



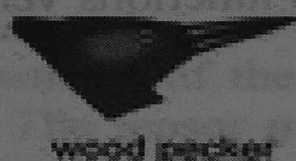
cross bill



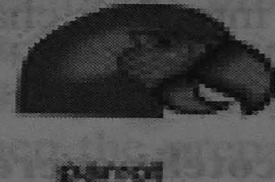
night hawk



avocet



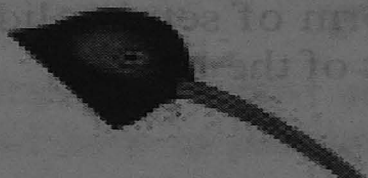
wood pecker



parrot



flamingo



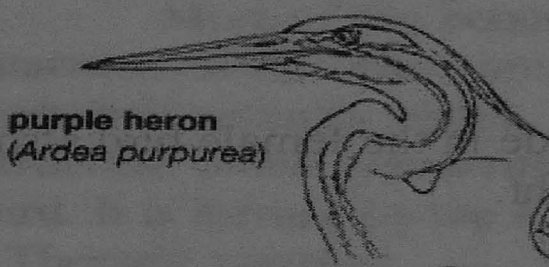
kiwi



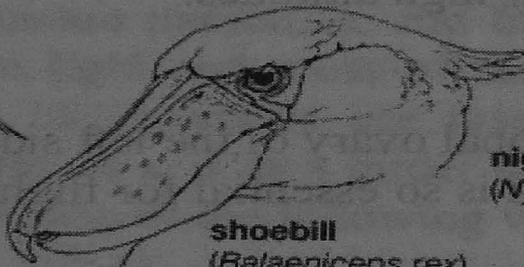
spoon bill



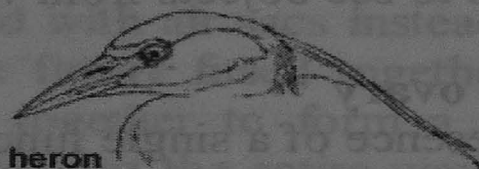
pelican



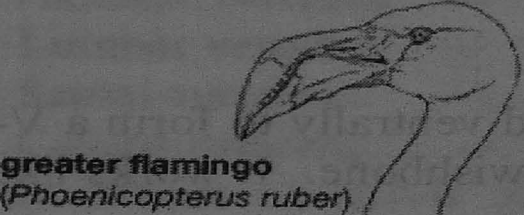
purple heron
(*Ardea purpurea*)



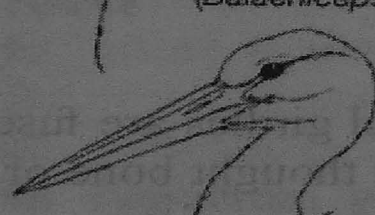
shoebill
(*Balaeniceps rex*)



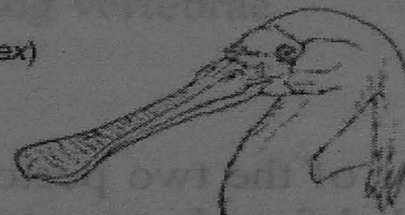
night heron
(*Nycticorax nycticorax*)



greater flamingo
(*Phoenicopterus ruber*)



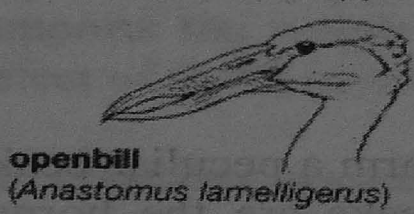
white stork
(*Ciconia ciconia*)



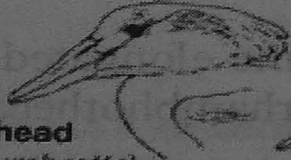
African spoonbill
(*Platalea alba*)



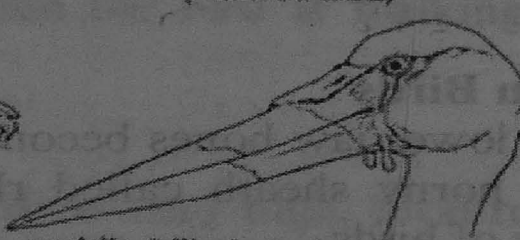
glossy ibis
(*Plegadis falcinellus*)



openbill
(*Anastomus lamelligerus*)



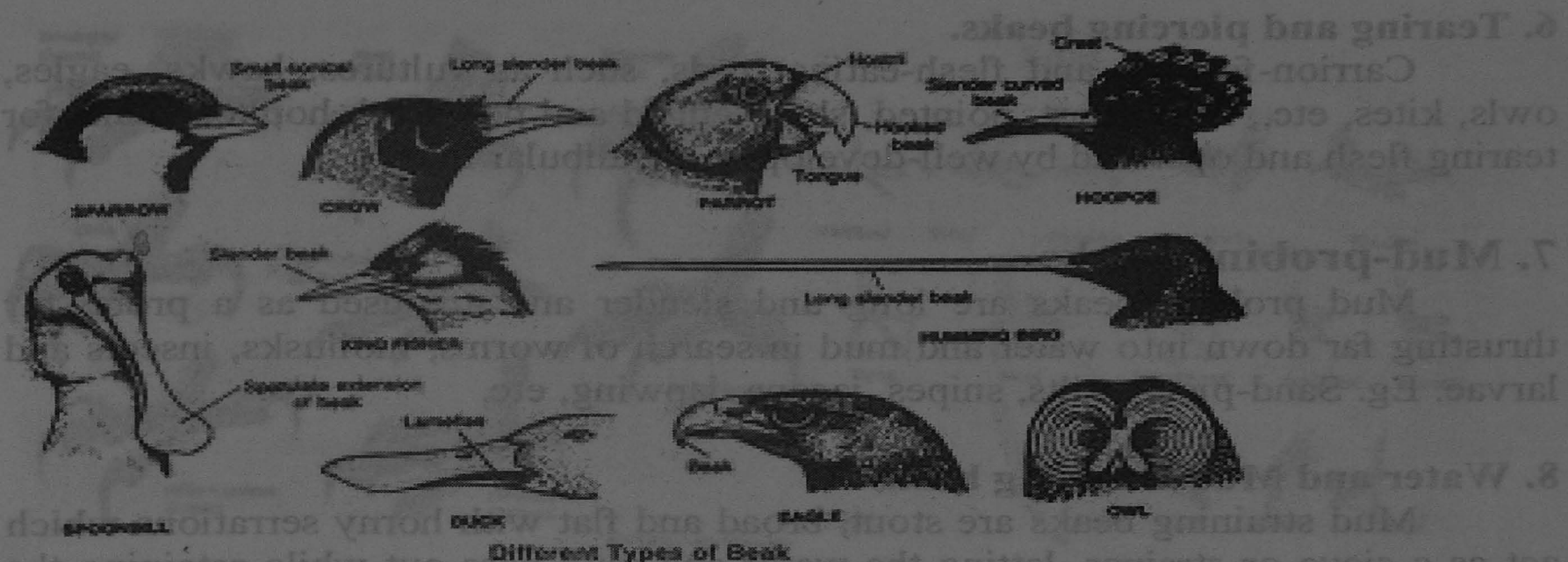
hammerhead
(*Scopus umbretta*)



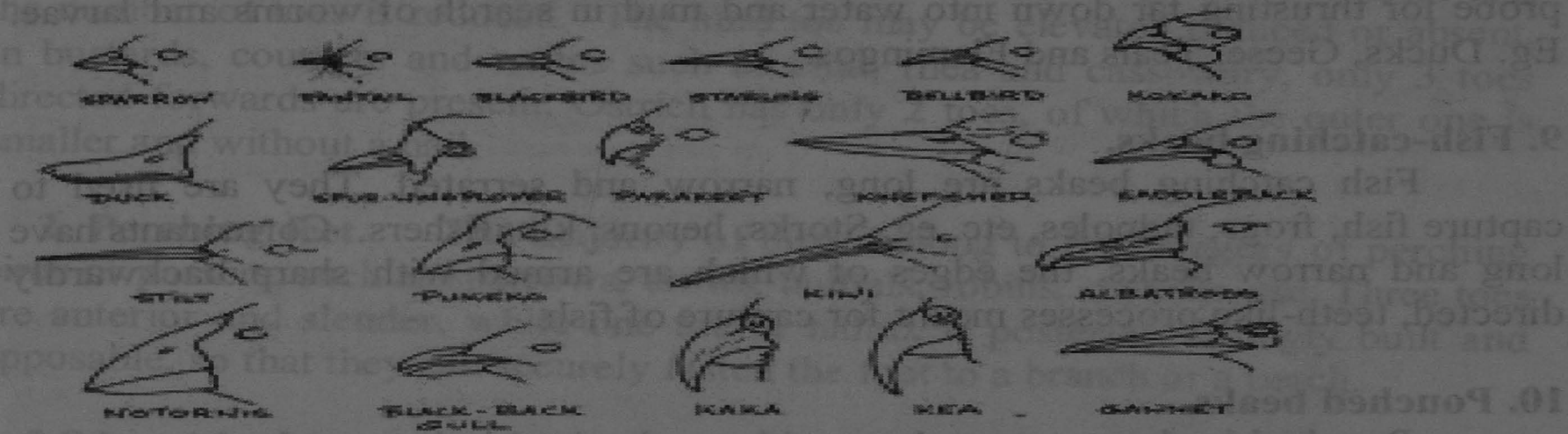
saddle-billed stork
(*Ephippiorhynchus senegalensis*)



boat-billed heron
(*Cochlearius cochlearius*)



BIRDS BEAKS



2. Cutting beaks.

Cutting beaks are stout and sharp with cutting edges. They are used for tearing prey, breaking eggs, cutting fruits, etc. eg. Crows

3. Fruit eating beaks.

Fruit eating beaks are sharp, stout, massive, deeply hooked and extremely strong. It is well adapted for gnawing or breaking open hard seeds and nuts, which form their staple diet. Eg. Parrots and Cross bills.

4. Insect eating beaks

Insect eating beaks are small, short and slender. Eg. Swallows, Swifts and Robin. In flycatchers, the beak is short but strong, with rectal bristles at the base. In hoopoe, the beak is long, slender and slightly curved and meant for turning the leaves or probing into the soil for insect grubs and pupae, etc.

5. Wood-chiseling beaks.

Woodpeckers have elongated, straight and stout chisel-like beaks for drilling into the barks or wood for insect larvae or for nest construction. They have thickened, shock-absorbent skull bones and strong neck muscles to make such pounding feasible.

6. Tearing and piercing beaks.

Carrion-feeding and flesh-eating birds, such as vultures, hawks, eagles, owls, kites, etc., have short, pointed, sharp-edged and powerful, hooked beaks for tearing flesh and operated by well-developed mandibular muscles.

7. Mud-probing beaks.

Mud probing beaks are long and slender and are used as a probe for thrusting far down into water and mud in search of worms, mollusks, insects and larvae. Eg. Sand-piper, stilts, snipes, jacana, lapwing, etc.

8. Water and Mud-straining beaks.

Mud straining beaks are stout, broad and flat with horny serrations which act as a sieve or strainer, letting the water and mud pass out while retaining the food in the mouth. Their beaks are extremely long and slender and are used as a probe for thrusting far down into water and mud in search of worms and larvae. Eg. Ducks, Geese, Teals and Flamingos.

9. Fish-catching beaks.

Fish catching beaks are long, narrow and serrated. They are used to capture fish, frogs, tadpoles, etc. eg. Storks, herons, kingfishers. Cormorants have long and narrow beaks, the edges of which are armed with sharp backwardly directed, teeth-like processes meant for capture of fish.

10. Pouched beaks.

Pouched beaks are stout, long with an elastic skin bag on the lower beak. Pelicans consume enormous quantities of fish. Their beak is large, with a capacious gular pouch of extensile skin attached to the lower mandible and serving as fishing net.

11. Flower-probing beak.

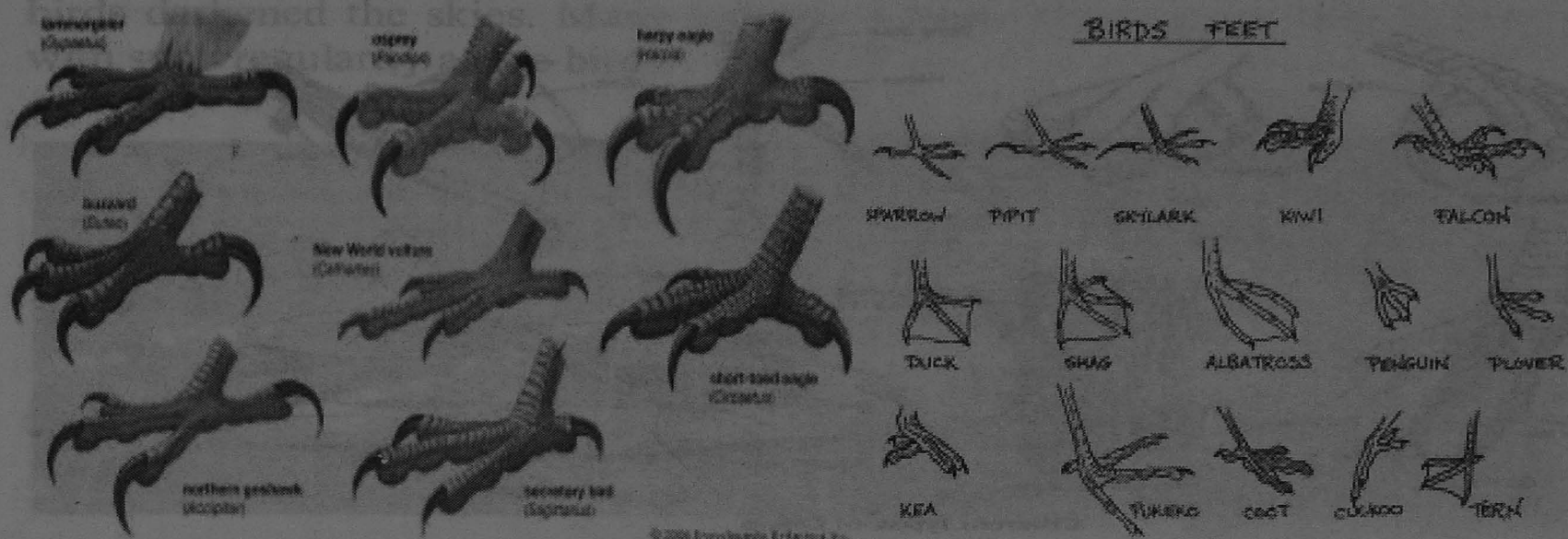
Flower probing beaks are long, narrow and pointed. They are used for drawing nectar from the flowers. They suspend themselves in mid air before the flowers, while they extract their honey and insects. Eg. Humming bird, Sunbird.

12. Spatulate beak.

The spoon-bill possesses a very specialized form of beak. It is flattened throughout its length but terminates in a broad, spatulate or spoon-like expansion meant for dabbling in water and mud in search of insects, worms, fish, mollusks and other small animals upon which the bird feeds.

Feet modification in Birds.

The feet of birds are also modified variously in accordance with the character of the environment and the manner of locomotion.



1. Cursorial or running feet. In running birds, the legs are powerful and the number of toes is reduced. The hind toe may be elevated reduced or absent. In bustards, coursers and ratites such as emu, rhea and cassowary, only 3 toes directed forwards are present. Ostrich has only 2 toes, of which the outer one is smaller and without a nail.

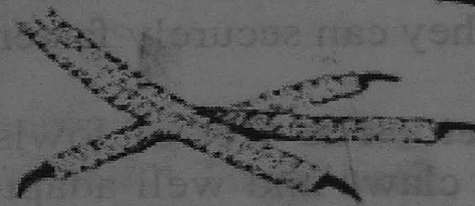
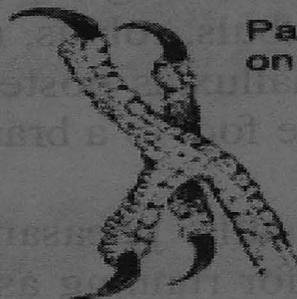
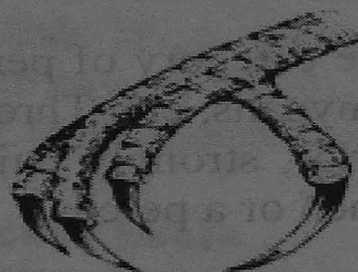
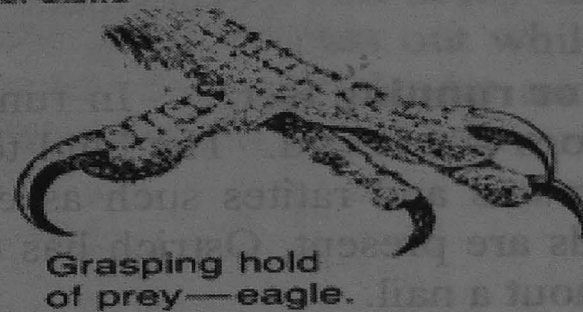
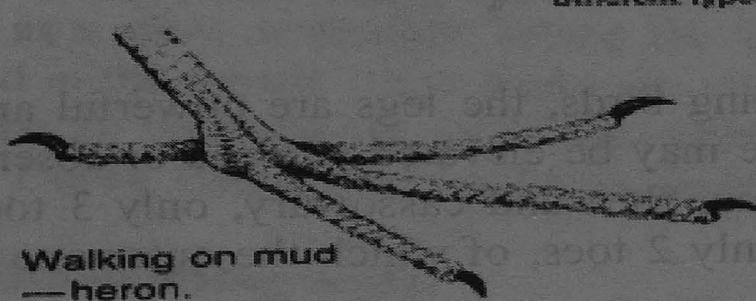
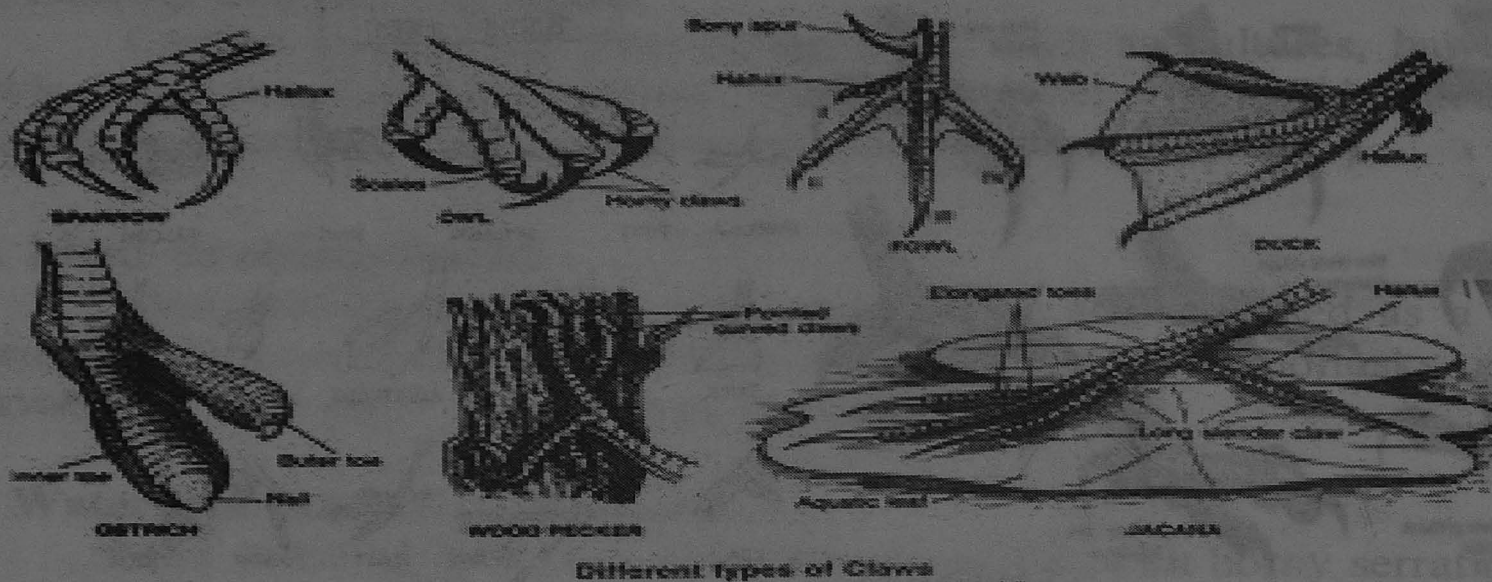
2. Perching feet. The majority of birds belong to the category of perching birds or passers, such as sparrows, crows, bulbuls, robins, mynahs, etc. Three toes are anterior and slender, while one toe or hallux is posterior, strongly built and opposable, so that they can securely fasten the foot to a branch or a perch.

3. Scratching feet. The feet of fowls, quails, pheasants, etc, are stout, with strongly developed claws and well adapted for running as well as scratching the earth. The foot of male bird is usually provided with a pointed bony spur for offence and defence.

4. Raptorial feet. Predatory or carnivores birds, such as eagles, kites, vultures, owls, etc, have strongly taloned feet for striking and grasping their prey. The toes have strongly developed, sharp and curved claws. Large and fleshy bulbs, called tylari, are found on the undersurface of toes, especially developed in the sparrowhawk. In osprey and Ketupa, tylari are absent but horny spines are present, which help in gripping slippery preys such as fish.

5. Wading feet. The legs and toes are exceptionally long and slender in wading or marshy birds such as herons, snipes, jacana, lapwing, etc. These serve to walk over aquatic vegetation or marshes. The web is absent or feebly developed.

6. Swimming feet. In swimming birds, the toes are webbed, partially or completely. In deviding birds, like coots and grebes, the web is lobate and the toes are free. In swimming and padding birds, such as ducks and teals, only the anterior three toes are united in a web. In pelican and cormorant, all the four toes are enclosed in the webs.



7. Climbing feet. In parrots and woodpeckers the feet are used as grasping organs and especially adapted for climbing vertical surfaces. The second and third toes point in front, while the first and the fourth toes point backwards.

8. Clinging feet. In swifts, martins and humming-birds, all the four toes point forwards and serve to cling to steep faces of cliffs or under caves of houses etc.

9. Other modifications of feet. The pectinate claw (comb) on the middle toe of the poorwill serves to scratch the feathers of head, to straighten the disarranged rectal bristles and probably to comb out lice. Freshly fringes of skin develop on the sides of toes of the snowshoe-like feet of the ruffed grouse, during winter only, for walking on the snow. The long hind claw of larks and certain fringillids may also bear some functional significance.

4.7 Migration of Birds

One of the most spectacular events concerned with bird life is the seasonal migration of many species and their uncanny ability to navigate. It has intrigued mankind for many centuries. Man has looked up in wonder as clouds of migrating

birds darkened the skies. Many animals migrate but none to such distances and with such regularity as the birds.



[I] Definition of migration

In a broad sense, “migration”, as defined by Cahn, “is a periodic passing of animals from one place to another, (L., migrate, to travel)”. When applied to other animals, it means their dispersal or immigration, implying no return journey. On the other hand, bird migration is a two-way journey. It means a regular, periodic, to-and-fro movement of a population of some birds between their summer and winter homes, or from a breeding and nesting place to a feeding and resting place.



[II] Migratory and resident birds.

Not all species of birds take part in the great pageant of migration. Bobwhite and the ruffed sand grouse, do not migrate at all. Birds which remain throughout the year in a country are known as residents. Every gradation may be found between resident birds which do not migrate and migratory birds which cover thousands of miles in their periodic journeys.

[III] Kinds of migration

Migration in birds takes place in a variety of manners, some of which are as follows:

1. Latitudinal migration. Because of the gift of wings, birds conveniently exploit two different parts of the earth. The most familiar migrations are latitudinal that is, north to south and vice versa. These are pronounced in the

Northern Hemisphere, having larger land masses. Birds move during summer over the temperate and sub-arctic regions of Northern Hemisphere, where there are facilities for feeding and nesting. The birds return to the south for shelter during winter, when north is covered with ice and snow. Several North American and Eurasian birds cross the equator to spend winter in deeper and warmer parts of South America and Africa. The American golden plover (*Pluvialis dominica*) passes the nine months of winter 8,000 miles south in the pampas of Argentina, thus enjoying two summers such year and knows not a hint of winter. Some birds of Siberia visit the plains of Himalayas in India.

An opposite but lesser movement occurs in the Southern Hemisphere, where the seasons are reversed.

2. Longitudinal migration. Some birds make migrations that are longitudinal rather than latitudinal, that is, east to west and vice versa. Thus, the starling moves from a breeding area in east Europe or Asia towards the Atlantic coast, to avoid the continental winter.

3. Altitudinal migration. Wherever large mountains are found in temperate regions, the birds migrate regularly up and down their slopes, as the weather changes. The birds pass the summer in the mountainous regions, but return to the lowlands in winter. It is merely a dispersal or short journey from the bleaker slopes to the more protected valleys and has been called altitudinal or vertical migration. It occurs in the grebes and coots of Andes in Argentina, violet green swallows of Great Britain, and the willow ptarmigan of Siberia.

4. Partial migration. Many species of temperate regions are only partial migrants. An addition is made in constant residents, which do not migrate at all, by an influx of new individuals of the same species for a short period. Thus, barn owls (*Tyto alba*), blue-birds and many blue jays of Canada and Northern United States travel southwards to mingle with the sedentary populations of the southern states. Songthrush, redbreast, titmouse, finch, etc., seen throughout the year, actually represent partial migrants, as the birds seen in winter are not the same as seen in summer.

5. Irregular or vagrant migration. In some birds, such as herons, after breeding, the adults and the young may stray from their home to disperse in all directions over many or a few hundred miles in search of food and safety from enemies. Sometimes, sea birds are taken by hurricanes to as far as 2,000 miles away from home seas to drop exhausted or to die on unfamiliar shores.

6. Seasonal migration. Field observes in temperate countries have grouped migrating birds according to seasons. Thus, in Britain, swifts, swallows, nightingales and cuckoos are summer visitors, for they arrive in spring from the south, remain to breed and leave for the south in autumn. Some like fieldfare, snow bunting and redwing are winter visitors, as they arrive in autumn, chiefly from the north, stay throughout the winter and fly northwards again in spring.

While some, like snipes and sandpipers are the birds of passage, seen for a short time twice a year on their way to colder or warmer countries in spring and autumn.

[IV] Modes of flight in migration

1. Nocturnal and diurnal flight. Ducks, gulls, shore birds and many others may migrate at night or in the day.

Many larger birds fly mainly by day, such as the crows, swallows, robins, blackbirds, hawks, bluebirds, jays, cranes, loons, pelicans, geese and other shore birds. They may stop to forage in suitable places, but swallows and swifts capture their insect food in the air as they travel. These diurnal migrants have a greater tendency to travel in flocks, which may be well organized (ducks, geese and swans) or loose (swallows).

But a vast majority of birds are chiefly nocturnal migrants. These include mostly small passerine birds, such as warblers, thrushes, sparrows, etc. They prefer to fly at night, under the protective cover of darkness, to escape their enemies.

2. Segregation during migration. Certain birds, such as night hawks, swifts and kingfishers, travel in separate companies, while swallows, turkeys, bluebirds, etc., travel in mixed companies of several species, due to similarity in their size, method of search of food, etc. In some species, the male and female members travel separately. Males arrive first to build the nests. The young birds generally accompany the females.

3. Range of migration. The distances travelled by migratory birds depend upon local conditions and the species concerned. The Himalayan snow partridges descend a few hundred feet only and cover hardly a mile or two, while the chickadees come down nearly 8,000 feet. The champion long-distance migrant is unquestionably the arctic tern. It spends the summer and breeds along the northernmost ice-free coasts of Labrador, far inside the Arctic circle. Then it travels a distance of 11,000 miles to reach its destination to the edges of Antarctica in winter, and returns again through the same distance in summer. European white stork winter in South Africa after a journey of about 8,000 miles.

4. Altitude of flight. Some birds fly quite close to the earth, while most routine migration probably takes place within 3,000 feet of the earth. Radar has shown that some small land birds, migrating at night, fly at 5,000 to 14,000 feet. Some species even cross the Andes and the Himalayas at altitudes of 20,000 feet or more.

5. Speed and duration of flight. Average flight velocity of most small birds seldom exceeds 30 miles per hour. The greatest speed, recorded in India, of two species of swifts by E.C. Stuart, is 171-200 miles per hour. Several hundreds of miles may be covered nonstop in a day or a night, with an average of about 500

miles. Birds usually travel 5 to 6 hours a day, resting in between for food or drink. The golden plover holds the world record with the longest nonstop bird flight, from Hudson Bay and Alaska to South America, a distance of 2,400 miles.

6. Regularity of migration. Several species of migratory birds show a striking regularity year after year, in their timings of arrival and departure. In spite of long distances travelled or vagaries of weather, they are often punctual within a day or two in their time of arrival. Another remarkable feature, besides punctuality, is that they sometimes come back to the same breeding place year after year.

7. Routes of migration. The data furnished from lighthouses and ships reveal that migratory birds usually follow definite lines of flight. Observations by telescopes and radars show that nocturnal migration of small land birds proceeds with the general airflow on a broad front. In spring, it occurs northwards along warm air currents from the south, and, in autumn, southward on the cool winds of the north. Deviation in path occurs due to configuration land, coastline, courses of great rivers or intervening mountain chains, etc.

[V] Problems of migration

The perplexing problems of migration have puzzled man ever since prehistoric times when he started watching the flights of birds and pondered their disappearance in the fall and their reappearance in the spring. It was the most intriguing mystery, resolving itself into separate problems, such as:

- (1) How do migratory birds find their way?
- (2) What was the original cause of migration?
- (3) What is the stimulus for starting migration?
- (4) What is the purpose or advantage of migration?
- (5) How are the long flights of many species sustained?

Many of these problems have been solved by the modern scientists.

1. Way-finding or navigation. The aspect of migration eliciting the greatest wonder is "how do birds navigate or find their way?" Various explanations or theories of navigation have been given for what determines the direction and course of migration.

(a) Visual landmarks. The sense of direction has been attributed to obvious topographical features or landmarks, such as great rivers, river valleys, coastal lines, chains of oceanic islands, mountain ranges, etc. But a vast majority of birds migrate at night when they cannot easily make use of landmarks. Moreover, for birds crossing great stretches of seas, there are no sea-marks for them to follow.

(b) Experience. A few naturalists have suggested that the birds learn by experience. Some older members, benefiting by a tradition following a path in past several years, become leaders to guide the younger generations. However,

birds certainly do not learn their route from elders, as some of them do not fly in flocks at all. In many cases, young birds make their first journey independently, without the guidance of the adult parents. They are evidently guided by instinct impressed on their nervous system in some way through countless generations.

(c) *Telluric currents.* Others have suggested the action of telluric currents. Certainly the air-currents, which would lead the birds straight to their destination, must be very obliging and highly ingenious.

(d) *Homing instinct.* Some have spoken of a homing instinct, enabling the birds to return to a goal, as in the case of ants, bees and carrier pigeons have proved the importance of vision in navigation.

(e) *Earth's magnetic field.* Some workers, such as Von Middendorff and Henry L. Yeaglev, advanced the idea that birds navigate through responses to the earth's magnetic field and their inner ear reacts to the mechanical Coriolis effect produced by the rotation of the earth. But there is no reliable evidence of a magnetic or any other esoteric direction sense in birds.

(f) *Celestial bodies.* The late Gustav Kramer, a German Ornithologist, claimed in 1949, that the birds which travel by day use the sun as compass for orientation. Experimenting with starlings, in closed cages, he also made the sensational discovery that birds even possess an internal time sense or time clock, with which they make necessary adjustments in their courses according to the changes in the angle or position of the sun as the day progressed. He proved this by altering the direction of flight by using mirrors to give a false apparent direction of the sun. The instinct has to be inherited because young birds, that have never migrated before, make similar navigational orientations to sun when travelling independent of their parents.

Advantages of migration. The purpose or gross advantage of migration are obvious and logical.

Migration helps birds avoid harsh climatic extremes. Migration from higher altitudes and latitudes (breeding areas in the north) during winter affords protection from cold and stormy weather, shorter days available for searching food and scarcity of food.

The migrants get more food and better conditions in their winter quarters in temperate or tropical regions than they would if they stayed at home.

Whereas a return in summer to the breeding areas in north once again provides suitable and unconquered nesting grounds, abundance of food, with minimum efforts, and long hours of day-light for searching food at a time when their population is increasing greatly.

Thus, birds migrate in order to utilize the food supply of both the hemispheres and to exploit new areas for nesting purposes, till the conditions become inclement for them.

Sustenance during migration. All long-distance migrants must fly for several hundreds of miles without food or drink. It is here that the importance of the pre-migratory deposition of fat comes in. There is a physiological advantage of fat over glycogen as a storage product, as fat produces more energy per unit weight. It also produces more water to cope with the high rates of metabolism and breathing, as there must be much evaporation from the lungs.

4.8 Flightless Birds (Ratitae)

The living wingless or flightless birds belong to the superorder *Palaeognathae* (or Ratitae) of the subclass *Neornithes*. They are characterized by having a palaeognathous plate, a keeless raftlike sternum and curly feathers. Ratites are represented by several species on earth today and have persisted over a long period of geological time. These birds are much alike and all are ground-dwelling. They are usually very large, some reaching as much as 4 meters in height. They have well-developed powerful legs, small heads and rudimentary wings with fluffy feathers which are useless for flight. In fact they depend on their fleetness for security. An interesting fact is that all modern flightless birds live in parts of the world where there are no carnivores, hat is no members of the cat or wolf tribes.

[I] Orders of flightless birds

The living flightless birds belong to the following 4 orders of the superorder Palaeognathae:

Order 1. Struthioniformes. Ostriches of Southwest Asia and Africa.

Order 2. Rheiformes. Rheas of South America.

Order 3. Casuariiformes. Cassowaries and emus of Australia and adjacent islands.

Order 4. Apterygiformes. Kiwis of New Zealand.

[IV] Examples of Ratitae

1.Ostrich.

African Ostrich (Struthio) is represented by atleast 4 species occurring naturally in arid regions of Africa and Arabia. It is the largest living bird attaining a height of more than 2.5 meters and a weight of 150 kg. Head, neck and legs are sparsely feathered. Male and female birds differ in the colour of their plumage. The tail and wing feathers are white while the rest are black in the male. Female is clad in a somber brownish livery. The thick skin can be made into leather. The long sturdy legs are admirably suited to match the speed of zebras and antelopes in whose company it feeds. It can run at a speed of 80 kilometers per hour, covering more than 8 meters in a single stride. Each foot has 2 toes only, with stunted nails. Inner toe is quite large and clawed. Both beak and feet serve as weapons of defence.



The food consists chiefly of herbage including seeds and fruits. Contrary to popular belief, an ostrich does not hide its head in sand when in danger. Ostriches travel about in groups. They are polygamous as one male attends several females. The male has a single solid retractile penis while female has a clitoris. The egg of the ostrich is very large and next in size to that of mackerel shark. Each egg weighs nearly 1.5 kg and requires 50 minutes to boil it. Ostrich meat is coarse and of little use for food. The feathers of adult bird are used by women as decorative plumes. Ostriches are easily domesticated and there are a number of Ostrich forms in Africa and United States.

2. Rhea.

Rhea is represented by 3 species inhabiting the plains or pampas of South America. They are smaller (1.5 meters) than the true or Old World ostriches (Struthio), but their habits are quite similar. In the rheas, there are 3 clawed toes on each foot. The rudimentary wings are better developed than in true ostrich. It has no distinct tail feathers nor the showy wing plumes of the African ostrich. Its head and neck are feathered, not naked as in ostrich. Rheas are very fond of bathing and are even able to swim. The male is polygamous.



Though the plumes are of an inferior quality to those of ostrich, they are used in the manufacture of feather dusters.

3. Emu

Next to ostrich, emu (*Dromaius*) is the largest living bird, standing more than 1.5 mt. high. There are 2 species confined to Australia, inhabiting sandy plains or open forests. Emu has a more slender built than an ostrich. But it has a shorter neck covered with feathers. Body is covered with a drab-coloured plumage and both sexes are similarly coloured. There are no large decorative plumes in the males' tail. The feathers have long aftershafts, nearly equal to shafts, so that each feather looks as if it were double. There is a remarkable tracheal pouch connected by a slit with the windpipe, and only fully developed in the adults. The bird feeds on fruits, roots and herbage. It loves bathing and swimming. Emu is invariably monogamous though seen in small parties after breeding. The newly hatched young are strikingly striped longitudinally, a characteristic which disappears on maturity. Emu's skin with feathers attached is often manufactured into rugs and mats.



The bird's fat is used as a lubricant. The beautiful, granulated, dark-green eggs are frequently converted into ornaments. Flesh is moderately good for eating.

4. Cassowary



The cassowaries the world's third largest flightless birds, live in the densely wooded parts of Australia, New Guinea and the adjacent islands, represented by about 20 species and subspecies. There are shy, nocturnal and rarely seen. Adults

are black in colouration which is brown in the young. Forelimbs or wings are very small and bent at the elbow. Each foot has 3 clawed toes. The barbs of the wing feathers are in the form of long black spines, suggesting the quills of a porcupine. The rectrices are unrecognizable. The aftershaft is as long as the main shaft. The bird is distinguished from its compatriot, the emu, by a horny helmet or casque on the head. It protects the bent head as the bird rushes through the scrub. The skin of the head and neck is brightly tinted. They are quarrelsome and vicious birds and old males may attack even human being if disturbed. The natives sometimes capture and rear the young birds. Such individuals become very tame and affectionate. Their flesh is considered very palatable.

5. Kiwi



Kiwi is the smallest living flightless bird about the size of a large domestic hen. They are characterized by reddish or grayish-brown coarse hair-like feathers, strong backwardly situated legs with 3 toes in front and hallux behind, and by the elongated narrow beak curving gently downwards and strong as a rapier of steel. An extraordinary peculiarity is the location of nostrils near the apex of the beak. Their wings are rudimentary and tail feathers are lacking. Head and eyes are comparatively small. They possess a keen sense of smell which is unique in birds. Kiwis are nocturnal and burrowing in habit, passing the daytime asleep in an underground hole, but emerging at night in search of food which includes worms and insects. It runs with great speed making wide strides. Female is larger than male. In proportion to the size of the body, the kiwi lays the largest eggs of any known animal. The enormous egg weighs about one fourth as much as the parent.

6. Tinamus

They are very small birds which can fly to some extent. They have a keel in the sternum. The palate is dromaeognathous. The males have a penis. The eggs are incubated by the male. The common species of Tinamus are: 1. Variegated Tinamou, 2. Crested Tinamou.

7. Moas

They are extinct ratite birds and they lived in New Zealand about 500 years back. They were very large birds with long neck and rudimentary wings. The feet has three toes. Eg. Dinornis.

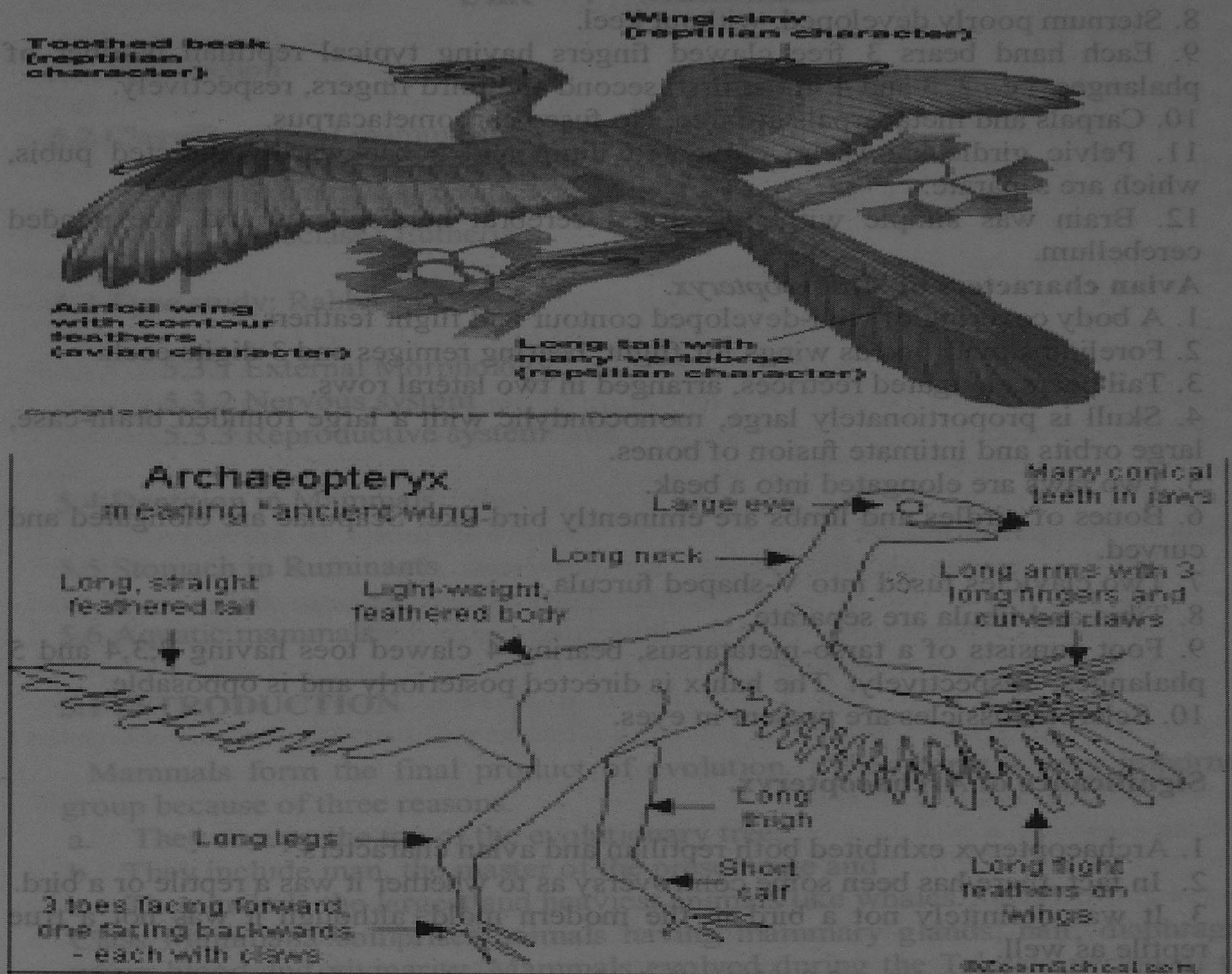
8. Elephant birds



These birds lived in Madagascar about 2,000 years back. They were huge size. The eggs were large with a capacity of two gallons. The legs were long and stout with four toes.

4.9 Fossil bird- Archaeopteryx and its evolutionary importance.

The bird originated from reptiles in the Mesozoic era. Even though the birds have many reptilian characters they are highly specialized than the reptiles. The earliest-known bird in the fossil record is *Archeopteryx lithographica*. It dates back to the late Jurassic period about 140 million years ago. It was discovered in a slate quarry at Langenaltheim, Bavaria (Germany), in 1861, by Andreas Wagner. Second skeleton was discovered in 1877 and a third in 1956 from the same locality.



Archaeopteryx seems to have been a terrestrial bird, about the size of a crow and with a long tapering tail like that of a typical dinosaur. This primitive bird is considered to a connecting link or transitional stage between reptiles and birds, as it possesses both reptilian as well as avian characters

Reptilian characters of *Archaeopteryx*.

Archaeopteryx shows striking, reptilian affinities as

1. scales are present on body and limbs.
2. bones are not pneumatic.
3. the strong jaws are provided with homodont peg-like teeth lodged in sockets.
4. a long tapering, lizard-like tail composed of about 20 free caudal vertebrae.
5. Cervical vertebrae are fewer (9 or 10) than in any other bird. There is no fusion of trunk or sacral vertebrae.
6. Centra of vertebrae are amphicoelous as in *Sphenodon*.
7. Free cervical and abdominal ribs are also present, as in *Sphenodon* and Crocodiles, in addition to single-headed thoracic ribs which are without uncinate processes.

8. Sternum poorly developed, without keel.
9. Each hand bears 3 free clawed fingers having typical reptilian number of phalanges, i.e., 2, 3 and 4 in the first, second and third fingers, respectively.
10. Carpals and metacarpals are free. No fused carpometacarpus.
11. Pelvic girdle shows an elongated ilium and a backwardly directed pubis, which are separate.
12. Brain was simple with cylindrical cerebral hemispheres and unexpanded cerebellum.

Avian characters of *Archaeopteryx*.

1. A body covering of well-developed contour and flight feathers.
2. Forelimbs modified as wings for flight, bearing remiges and 3 digits each.
3. Tail bears elongated rectrices, arranged in two lateral rows.
4. Skull is proportionately large, monocondylic with a large rounded brain-case, large orbits and intimate fusion of bones.
5. Two jaws are elongated into a beak.
6. Bones of girdles and limbs are eminently bird-like. Scapulae are elongated and curved.
7. Two clavicles fused into V-shaped furcula.
8. Tibia and fibula are separate.
9. Foot consists of a tarso-metatarsus, bearing 4 clawed toes having 2,3,4 and 5 phalanges, respectively. The halux is directed posteriorly and is opposable.
10. Sclerotic ossicles are present in eyes.

Significance of *Archaeopteryx*.

1. *Archaeopteryx* exhibited both reptilian and avian characters.
2. In fact, there has been some controversy as to whether it was a reptile or a bird.
3. It was definitely not a bird in the modern mold, although it was not a true reptile as well.
4. With the exception of feathers, it had a general resemblance to archosaurian reptiles.
5. It was probably not the direct or immediate ancestor of modern birds.

4.9.1. Questions:

1. Give an account on external morphology of pigeon.
2. Describe the respiratory organs and the mechanism of respiration in pigeon.
3. Write short notes on (i). pelvic and (ii). pectoral girdle of pigeon.
4. Write an essay on flight adaptation in birds.
5. Give an account of beak modification in birds.
6. Describe the various types of feet modification in birds.
7. Discuss migration of birds.
8. Write short notes on flightless birds.
9. Describe the evolutionary importance of fossil bird *Archaeopteryx*.

Unit – V Mammalia

5.1 Introduction

5.2 Classification of mammals

5.2.1 Subclass : Prototheria

5.2.2 Subclass : Metatheria

5.2.3 Subclass : Eutheria

5.3 Type study: Rabbit

5.3.1 External Morphology

5.3.2 Nervous system

5.3.3 Reproductive system

5.4 Dentition in Mammals

5.5 Stomach in Ruminants

5.6 Aquatic mammals

5.1 INTRODUCTION

Mammals form the final product of evolution. They form a very important group because of three reasons.

- They occupy the top of the evolutionary tree;
- They include man, the master of the present age and
- They include the largest and heaviest animals like whales.

Class Mammalia comprises animals having mammary glands, hair, diaphragm, warm blood and viviparity. Mammals evolved during the Triassic period of the Mesozoic era from mammal-like reptiles. Mammals had a polyphyletic origin. After their origin they evolved in different directions and coenozoic era is rightly called the 'age of mammals'.

5.2 Classification of Mammals with examples.

Mammals form the final product of evolution. They include approximately 5,000 living species and numerous fossils forms. Their classification differs with different authorities. They are included in the phylum Chordata because they develop a notochord and vertebral column. Mammals are warm-blooded vertebrates with mammary glands, hair and diaphragm. (Mamma=breast). They give birth to young ones and give milk to young ones. The skin has sweat glands and sebaceous glands. In females, there are mammary glands to nourish the young ones. Class mammalia is divided into three subclasses, namely:

Subclass 1. Prototheria

Subclass 2. Metatheria

Subclass 3. Eutheria

5.2.1 Subclass : Prototheria (Mono-tremata)

Prototheria are primitive, reptile-like, oviparous or egg-laying mammals. The mammary glands are unspecialized and without teats. Eggs are large, yolky and shelled. Development is external and there is no placenta. In the brain, there is no corpus callosum. Pinna is absent and the cochlea is very simple. Testes are abdominal. They are imperfectly warm blooded. There is no uterine gestation. Eg. Ornithorhynchus (Duck-billed platypus), Echidna.

5.2.2 Sub class : Metatheria (Marsupialia)

They have a marsupium or brood pouch in which the young born in an immature state are kept and fed with milk by the mother. Distinct teats are present. The brood pouch is supported by the epipubic bone. A true placenta is absent. The egg is small and develops in the lower portion of the oviduct. Pinna is present and cochlea is much coiled. The subclass marsupialia is divided into three orders on the basis of the character of the teeth.

Order 1. Polyprotodontia:

In this marsupials, the incisors are numerous about four or five in the upper jaw and one or two in the lower jaw. The canines are large and the molars are furnished with sharp cusp. They are insectivorous or carnivorous. The caecum is absent or very small. Examples.

1. Didelphys (American Opossum)
2. Thylacinus (Tasmanian wolf)
3. Mymecobius (Banded anteater)
4. Perameles.

Order 2: Diprotodontia

They are herbivorous marsupials in which the incisors are adapted for gnawing. There are three pairs of incisors in the upper jaw and one pair in the lower jaw. The canines are usually small or absent. The molars are furnished with blunt tubercles. Eg. Petaurus (flying phalanger), Macropus (kangaroo).

Order 3. Coenolestidae

This order includes three species belonging to the genus Coenolestes. They have the upper jaw resembling the polyprotodont and the lower jaw is typically diprotodont. They are nocturnal, terrestrial animals represented only in South America.

5.2.3 Subclass: Eutheria

They are warm-blooded animals. They have a true allantoic placenta and the embryos are kept in the uterus till an advanced stage of development. Mammary glands are well developed with teats. Pinna or external ear is present. The anus and urinogenital apertures are separate and cloaca is absent. The testes are extra abdominal and are usually enclosed in the scrotal sacs. Eggs are small and alecithal (yolkless). Eg. Rat, Rabbit, Cow, Elephant, Monkey, Man.

5.3 Type study -Rabbit

Systematic Position

Phylum	:	Chordata
Subphylum	:	Vertebrata
Class	:	Mammalia
Subclass	:	Eutheria
Order	:	Lagomorpha
Genus	:	Oryctolagus
Species	:	cuniculus

5.3.1 EXTERNAL FEATURE OF RABBIT

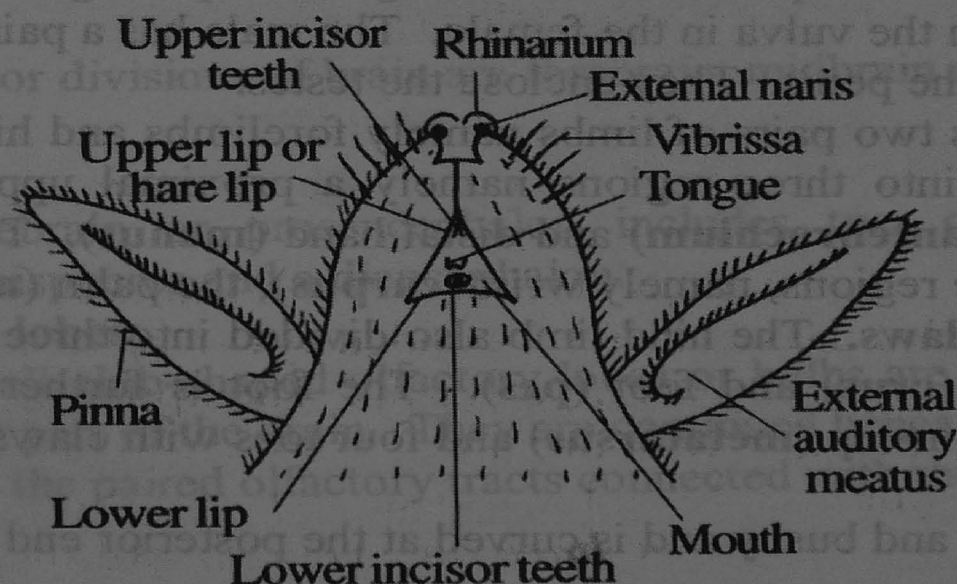
Rabbit is a typical mammal with **mammary glands**, a **thick covering of hair** and **warm blooded**. It gives birth to young ones and nourishes them with milk.

It enjoys cosmopolitan distribution. It is **gregarious** that is, it lives in groups. It is a **burrowing or fossorial animal**. It is **herbivorous**. It is domesticated for flesh. It is used extensively for biological and medical researches. Rabbit is **polygamous** and one male lives with many females.

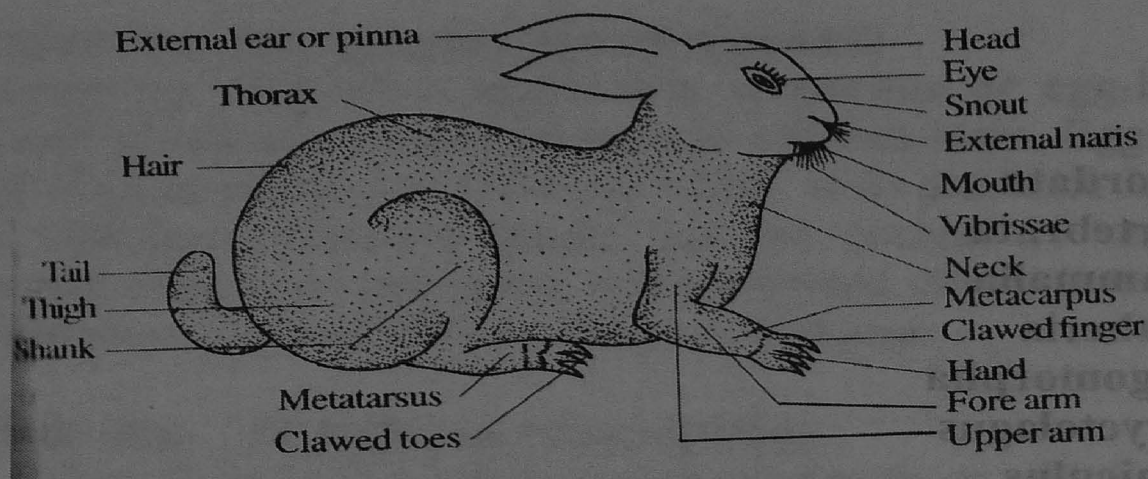
It is usually brown in colour; but its colour varies in domesticated animals. It is about 16 inches long and it weighs 2 to 4 pounds. The body is divisible into four regions, namely a **head**, a **neck**, a **trunk** and a **tail**. The trunk is further subdivided into an anterior thorax and a posterior abdomen.

Head

The head is elongated. Anteriorly the head is produced into a pointed snout. The mouth is transverse slit located at the anterior end, but on the ventral side of the snout. It is bounded by two lips, an upper lip and a lower lip. The upper lip has a **cleft** in the middle through which the incisor teeth are clearly visible. Such a lip is called **hare lip**. The sides of the upper lip produce stiff long thick hairs called **vibrissae or whiskers**. They are **tactile sensory organs**.



Just above the mouth, there are two oblique openings called external nostrils or **external nares**. Two eyes are present on the sides of the head. They are protected by an upper and a lower eyelid. A third eyelid called nictitating



membrane is also present on the inner corner of the eye. It is also movable and used to clean the cornea. The top of the head bears a pair of movable **pinnae**.

They are used to direct

the sound vibrations into the ear. At the base of the pinna, there is an opening called **external auditory meatus**.

Neck

The neck is short and it connects the head with the trunk. It helps in the free movement of the head.

Trunk

The trunk is divisible into an interior thorax and a posterior abdomen. The thorax encloses a cavity called thoracic cavity and the cavity lying inside the abdomen is called abdominal cavity. The two cavities are internally separated by a muscular partition called diaphragm. The thoracic cavity is bounded by a skeletal framework formed of ribs.

The ventral side of the abdomen is provided with 4 or 5 teats or nipples. They are present in both sexes but well developed in females. The ducts of the mammary glands open at the tip of teats. The anus is present at the posterior end of the abdomen. A pair of depressions found on either side of the anus. These are called **perineal pouches**. The **perineal glands**, lying inside, open into these pouches. The secretions of these glands give the characteristic **odour** of the rabbit.

In male ventral to the anus, a penis is present. In female, in the same place a slit-like vulva is present. The urinogenital opening is situated on the penis in the male and in the vulva in the female. The male has a pair of scrotal sacs, one on either side of the penis. They enclose the testes.

The trunk bears two pairs of limbs namely forelimbs and hindlimbs. Each fore limb is divided into three regions namely a proximal upper arm (brachium), middle forearm (**antebrachium**) and distal hand (**manus**). The hand is further divided into three regions, namely wrist (**carpus**), the palm (**metacarpus**) and the five **digits** with **claws**. The hind limb also divided into three regions, namely the thigh, the shank (**crus**) and foot (**pes**). The foot is further subdivided into an ankle (**tarsus**), an instep (**metatarsus**) and four toes with claws.

Tail

The tail is short and bushy and is curved at the posterior end of the trunk.

5.3.2 NERVOUS SYSTEM OF RABBIT

The entire nervous system of rabbit consists of three main subdivisions namely

1. Cranial nervous system including brain and spinal cord.
2. Peripheral nervous system including cranial and spinal nerves.

3. Autonomic nervous system including sympathetic and parasympathetic nerves and ganglia.

Brain

The brain of rabbit is essentially built on the same as that of frog or any other vertebrate. However, the mammalian brain is more highly evolved and the two **cerebral hemispheres are very much larger** than in the lower vertebrates. The brain lies within the cranial cavity of skull.

Meninges

The brain is covered by three membranes collectively known as **meninges**. The inner membrane, called **piamater** is thin, soft, vascular and closely supplied to the surface of brain. The outer layer, called **duramater**, is thick, very tough, and lines the inner wall of cranium. The middle layer, called **arachnoid**, is also delicate and highly vascular. The space between duramater and arachnoid is called **subdureal cavity** and the space between arachnoid and piamater is called **sub-arachnoid cavity**.

Cerebrospinal fluid and ventricles

The brain is hollow from within. The cavities of its various parts are called ventricles. These are filled with a lymph-like cerebro-spinal fluid. It is secreted by the anterior and posterior choroid plexuses. The narrow sub-arachnoid space between arachnoid and piamater is also filled with the cerebro-spinal fluid and crossed by fibres from arachnoid membrane.

Histology

Histologically, the brain is made of two types of nervous tissue. The outer part of brain, called cortex, is made of grey matter. It consists mainly of nerve cells besides nerve fibres, neuroglia and blood vessels. The inner part of brain, called medulla, is made of white matter. It includes only nerve fibres and neuroglia.

Parts of brain

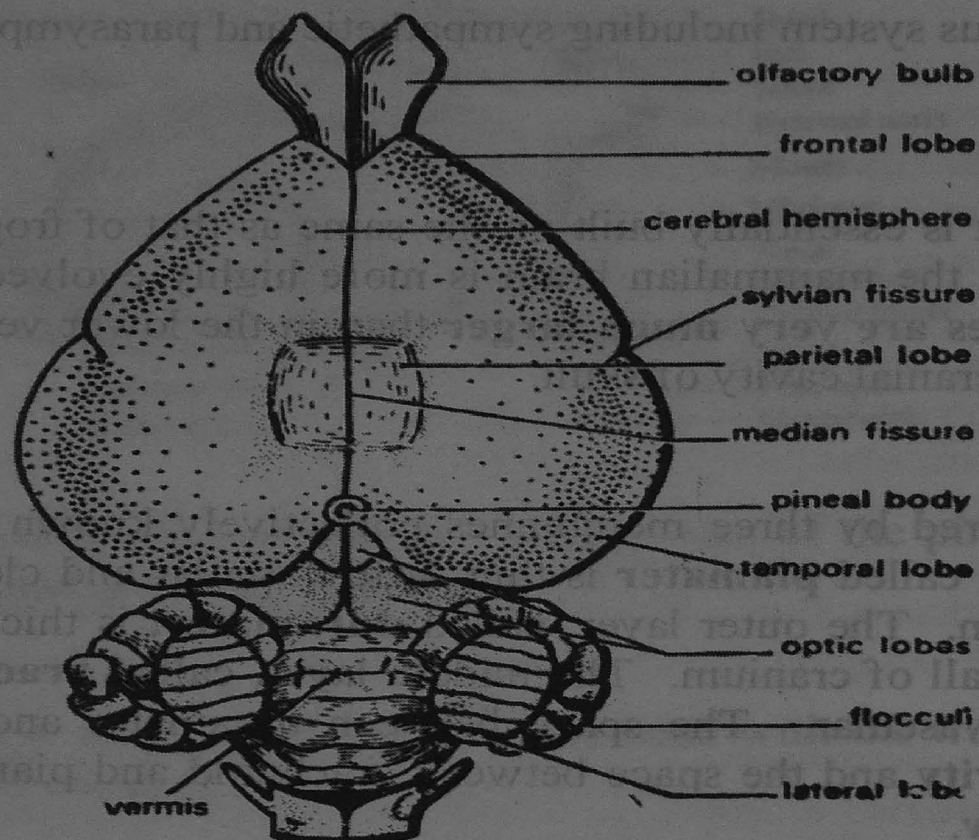
The three major divisions of brain are forebrain, midbrain and hindbrain.

1. Forebrain

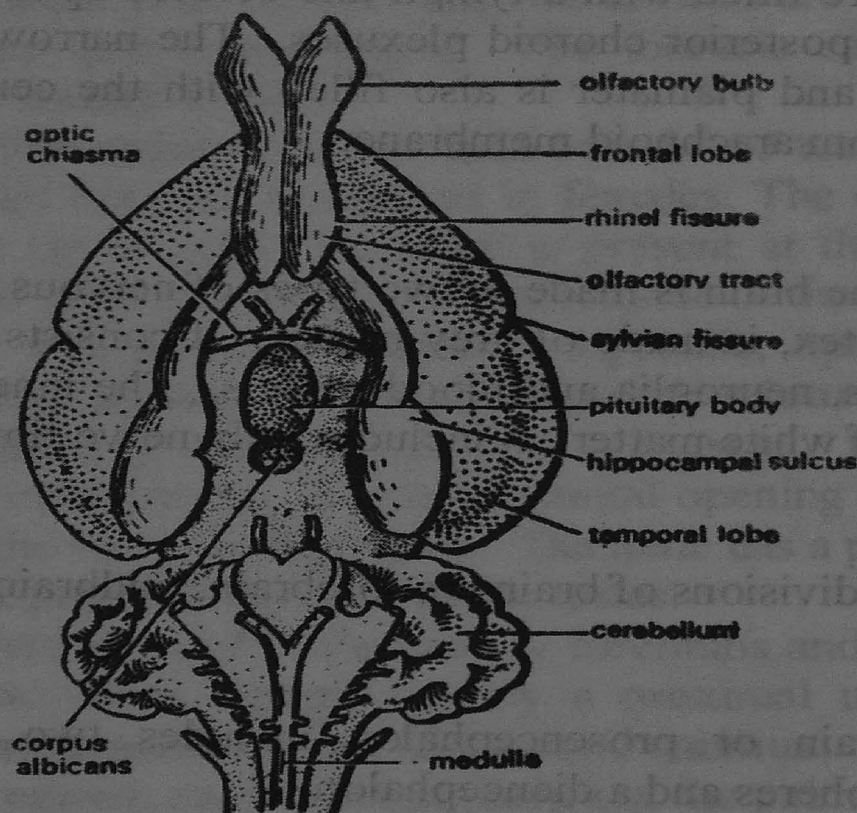
The forebrain or prosencephalon includes two olfactory lobes, two cerebral hemispheres and a diencephalon.

a. Olfactory lobes

The two small club-shaped olfactory lobes or bulbs are separate forming the anteriormost part of the brain. They are continued beneath the frontal lobes of cerebrum as the paired olfactory tracts connected with the hippocampal lobes.



The narrow cavity of each olfactory lobe is called the first ventricle or rhinocoel. The sense of smell is controlled by the olfactory lobes.



b. Cerebral hemispheres

The two cerebral hemispheres are separated by a deep longitudinal median fissure. They are narrow in front but broad behind and nearly smooth-surfaced. A shallow lateral, somewhat oblique **Sylvian fissure** divides each hemisphere into a large anteromedian **frontal lobe**, and a smaller posterolateral **temporal lobe**. Ventrally a longitudinal **rhinal fissure** demarcates the olfactory tract, with another longitudinal **hippocampal lobe**.

Connecting the two hemispheres internally is a broad transverse band of nerve tissue, the **corpus callosum**, which is characteristic of placental

mammals. Inner cavity of each hemisphere is called the **second ventricle** or lateral ventricle or **paracoel**. The two paracoels are connected with each other and with the **diacoel** through a passage called the **foramen of Manro**. The cerebral hemispheres are the seat of highly complicated activities such as **thought, reasoning, memory, intelligence**, etc.

(c) Diencephalon

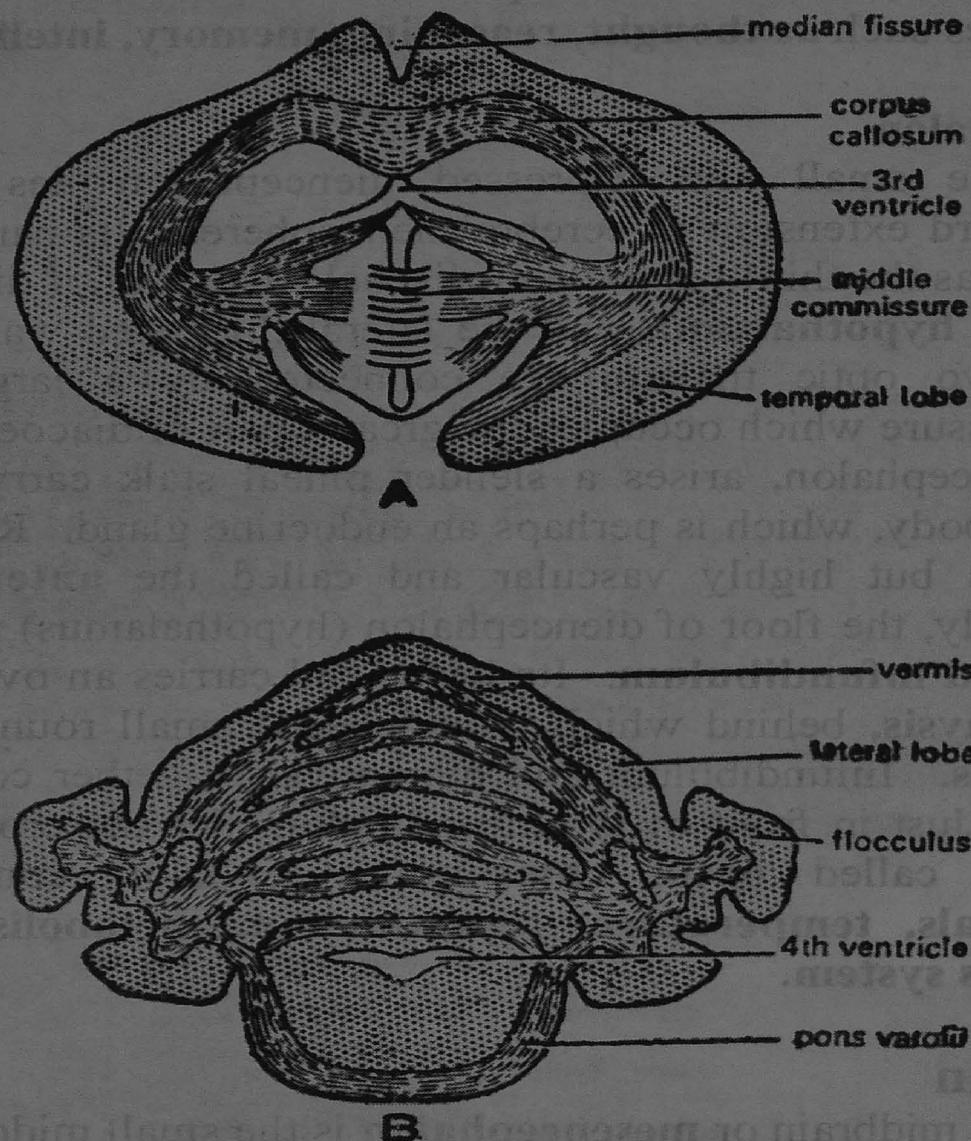
The small and depressed diencephalon lies covered below the backward extension of cerebral hemispheres. Its narrow internal cavity is known as the third ventricle or diacoel. The roof of diacoel is **epithalamus**, floor is **hypothalamus** and the lateral thickened walls are **optic thalami**. The two optic thalami are connected by a large transverse middle commissure which occupies the greater part of diacoel. Dorsally, from roof of diencephalon, arises a slender pineal stalk carrying a small rounded pineal body, which is perhaps an endocrine gland. Rest of the roof is non-nervous but highly vascular and called the **anterior choroid plexus**. Ventrally, the floor of diencephalon (hypothalamus) projects into a median **rounded infundibulum**. Its lower end carries an oval **Rathke's pouch** or **hypophysis**, behind which is attached a small rounded body, the **corpus albicans**. Infundibulum and hypophysis together constitute the **pituitary body**. Just in front of the infundibulum lies the crossing of the two optic nerves, called **optic chiasma**. Diencephalon controls **perception of chemicals, temperature, reproduction, metabolism and autonomous nervous system**.

2. Midbrain

The midbrain or **mesencephalon** is the small middle part of brain which is partly concealed below the cerebral hemispheres. It differs from that of other vertebrates in having on the dorsal surface four small rounded optic lobes collectively known as the **corpora quadrigemina**. The anterior two optic lobes are larger, called **superior colliculi**. They are homologous with those of other vertebrates and concerned with sight. The posterior two optic lobes are smaller, called **inferior colliculi**, and associated with acute hearing. The cavity of midbrain is a narrow longitudinal passage, called **iter**. Its floor is formed by thick tracts of fibres, called **cruracerebri**, which link the fore and hindbrains together.

3. Hind brain

The hindbrain or **rhombencephalon** includes **cerebellum**, **pons varolli** and **medulla oblongata**.



a. Cerebellum

The cerebellum is very well developed and transversely elongated. It consists of a large median lobe, the vermis, and two lateral lobes each with a ventro-lateral extension called flocculus. There is no cavity inside cerebellum, but its surface is much folded thus increasing its grey matter. Surface foldings of the cerebellum forms a number of elevations called gyri and groves called sulci. Cerebellum controls equilibrium and coordination of voluntary muscular movements.

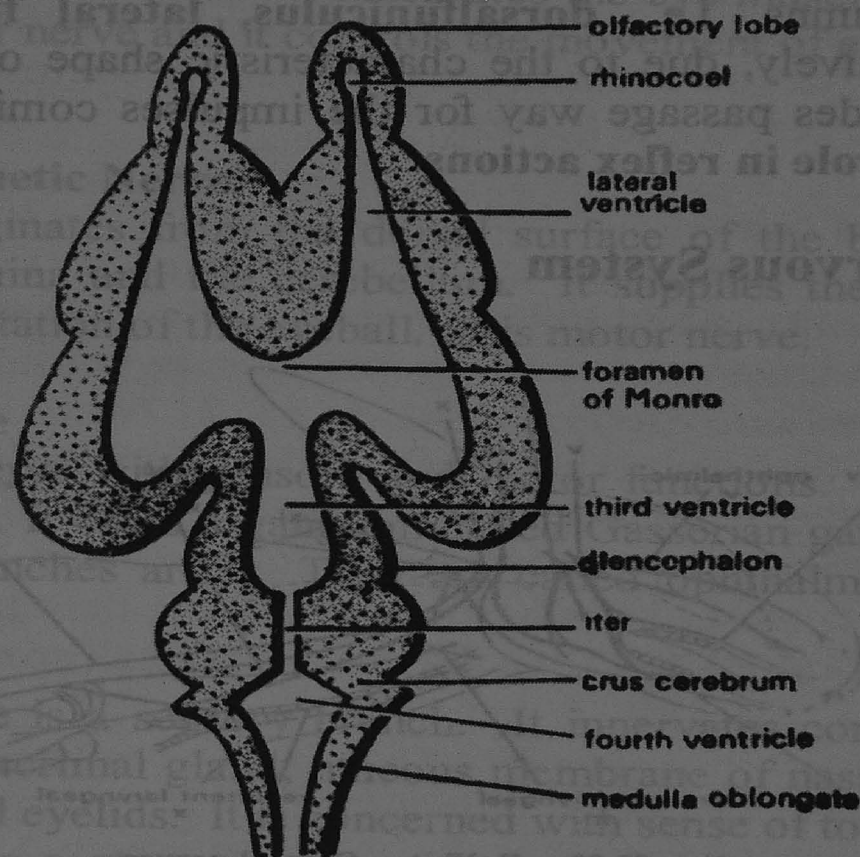
b. Pons varolli

The ventral surface of hindbrain shows a stout transverse band of fibres. It connects the right and left halves of the cerebellum. It is named pons varolli after the Italian anatomist Costanzo Varolio.

c. Medulla oblongata

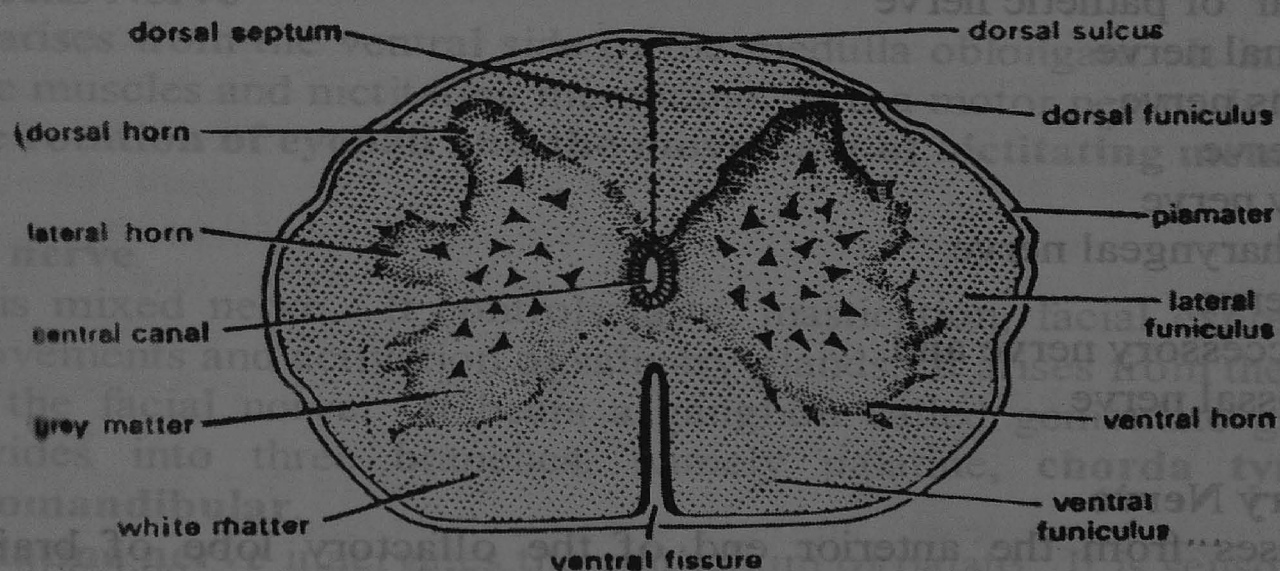
The medulla forms the last part of the brain. It is broad and triangular anteriorly but tapers back into the spinal cord. Its cavity is known as the **fourth ventricle or metacoel** which is continuous with the central canal of the spinal cord. The roof of metacoel is non-nervous and vascular, called the **posterior**

choroid plexus. Medulla oblongata and pons Varolii control the involuntary activities in the body such as digestion, respiration, excretion, circulation, etc.



4. Spinal cord

The spinal cord is the continuation of the medulla oblongata, after coming out of the cranium through foramen magnum. It starts from the cervical region, travels in the neural canal of the vertebrae and terminates in the lumbar region as **filum terminale**. The fourth ventricle of the medulla is continued in the spinal cord as central canal which is filled with the cerebro-spinal fluid.



Exactly, like brain, the spinal cord is also enclosed in the three membranes – the **duramater**, **arachnoid layer** and the **piamater**. Actually, in transverse section it appears to be a more or less spherical structure having a central canal. It is composed of a central grey matter with nerve cells which seems to be a butterfly-like structure. The grey matter is provided with the dorsal, lateral and ventral horns. This grey matter is surrounded by the white matter in which **medullated nerve fibres** are found. The white matter is distinctly divided into

two compartments by a narrow dorsal septum and a deep ventral fissure. The white matter of each compartment can be further distinguished into dorsal, lateral and ventral columns, i.e., **dorsalfuniculus**, **lateral funiculus** and **ventral funiculus** respectively, due to the characteristic shape of the grey matter. The spinal cord provides passage way for the impulses coming from the brain and **plays important role in reflex actions**.

Peripheral Nervous System

Cranial nerves

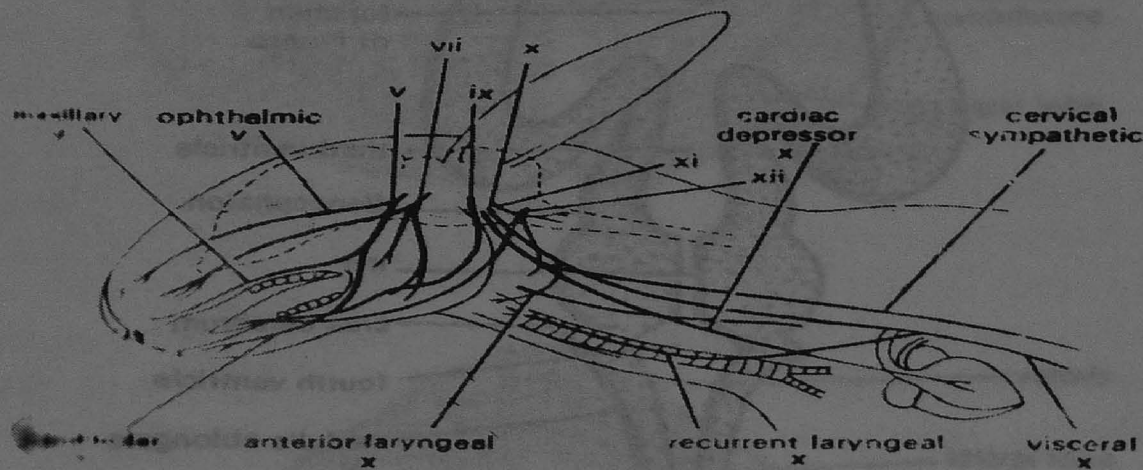


Fig. 20-65. Rabbit. Cranial nerves.

The nerves coming out from the brain constitute the cranial nerves. In rabbit **twelve pairs of cranial nerves** are found. Each cranial nerve originates from a distinct separate root. The twelve pairs of cranial nerves are the following:

1. Olfactory nerve
2. Optic nerve
3. Oculomotor nerve
4. Trochlear or pathetic nerve
5. Trigeminal nerve
6. Abducens nerve
7. Facial nerve
8. Auditory nerve
9. Glossopharyngeal nerve
10. Vagus nerve
11. Spinal accessory nerve and
12. Hypoglossal nerve

1. Olfactory Nerve

It arises from the anterior end of the olfactory lobe of brain. It is concerned with smell. It is sensory nerve.

2. Optic Nerve

They arise from the diencephalon. They cross each other to form a cross called optic chiasma. The crossing is incomplete in mammals, especially primates due to binocular vision. The optic nerve supplies the retina. It is sensory nerve and it is concerned with the sense of sight.

3. Oculomotor Nerve

It starts from the cerebrum. It innervates the eye muscles, iris and ciliary body. It is a motor nerve and it controls the movement of eyeball, iris, ciliary body and lens.

4. Trochlear or Pathetic Nerve

This nerve originates from the dorsal surface of the brain between the corpora quadrigemina and the cerebellum. It supplies the eye muscles. It brings about the rotation of the eyeball. It is motor nerve.

5. Trigeminal Nerve

It is a mixed nerve with sensory and motor functions. It starts from the medulla oblongata. It bears a ganglion called Gasserian ganglion. From the ganglion three branches arise. They are called ophthalmic, maxillary and mandibular.

Ophthalmic nerve is a sensory branch. It innervates conjunctiva, cornea, iris, ciliary body, lacrimal gland, mucous membrane of nasal sac and skin of forehead, snout and eyelids. It is concerned with sense of touch.

Maxillary nerve is a sensory nerve. It innervates lower eyelid, slides of snout, vibrissae, upper lip, teeth of upper jaw and palate. It is concerned with the **sense of touch**. **Mandibular nerve** is a mixed nerve with sensory and motor nerve fibres. Sensory fibres innervate the skin of temporal region, external ear, lower part of the face and lower lip, mucous membrane of the anterior part of the tongue and teeth of lower jaw.

6. Abducens Nerve

It arises from the ventral side of the medulla oblongata. It innervates the eye muscles and nictitating membrane. It is a motor nerve. It brings about the **rotation of eyeball and the movement of nictitating membrane**.

7. Facial nerve

It is mixed nerve. It controls taste, mastication, facial expression, neck movements and activation of salivary glands. It arises from the lateral side of the facial nerve. It bears a ganglion called geniculate ganglion. It divides into three branches, namely palatine, **chorda tympani** and **hyomandibular**.

Palatine nerve innervates the epithelium of palate. It is sensory nerve. It is concerned with the sense of touch.

Chorda tympani nerve innervates the **taste buds** of tongue. It is sensory nerve and is concerned with the sense of taste.

Hyomandibular nerve is mixed nerve with sensory and motor fibres. The motor nerves supply the muscles of lower jaw, face, hyoid, neck, pinna and salivary glands. The hyomandibular nerve is concerned with facial expression, mastication and neck movements.

8 . Auditory Nerve

Auditory nerve originates from the side of medulla oblongata. It bears a ganglion called acoustic ganglion. It divides into two branches namely vestibular nerve and cochlear nerve. Auditory nerve is a sensory nerve. It controls equilibrium and hearing.

9. Glossopharyngeal Nerve

It is a mixed nerve. It controls, taste, touch, blood pressure, pharyngeal contractions and secretion of saliva. It starts from the side of medulla oblongata. It bears a **petrosal ganglion**. It has two branches, namely **lingual and pharyngeal**.

Lingual is a sensory nerve. It innervates the taste buds of the tongue and the mucous membrane of pharynx and carotid sinus. It controls the sense of taste and blood pressure.

Pharyngeal is motor branch. It innervates the muscles of pharynx and the parotid salivary gland. It controls pharyngeal contraction and salivary secretion.

10. VagusNerve

Vagus nerve is the tenth nerve. It arises from the side of medulla oblongata. This nerve has two ganglia, one inside the cranium called jugular ganglion and the other outside the cranium called nodosal ganglion. The vagus nerve has **six branches**, namely **anterior laryngeal, cardiac depressor, recurrent laryngeal, oesophageal, pulmonary and visceral nerves**.

Anterior laryngeal nerve innervates mucous membrane of larynx and **cricothyroid muscles**. It is concerned with touch and sound.

Cardiac depressor innervates **heart**. It is concerned with **heart beat**.

Recurrent laryngeal or posterior laryngeal innervates the muscles of **larynx**. It is concerned with the movement of larynx and sound. It is a motor nerve.

Pulmonary nerve innervates the lungs. It is concerned with the movement of lungs.

The **visceral nerve** divides into a few branches and they supply **oesophagus, stomach and intestine**. The visceral nerve is concerned with the movement of alimentary canal.

11. Spinal Accessory Nerve

It is a motor nerve originating from the medulla oblongata. It consists of a cranial and a spinal part. The cranial part is composed of fibres derived from the vagus nerve. The spinal part is formed of fibres of a few anterior spinal nerves. The cranial fibres innervate the muscles of pharynx and larynx. The spinal fibres **supply the muscles of neck and shoulder**.

The **spinal accessory nerve** controls the **movements of pharynx, larynx, neck and shoulder**.

13. Hypoglossal Nerve

It originates from the ventral side of medulla oblongata. It innervates the muscles of the tongue and lower jaw. It brings about the movement of tongue. It is a motor nerve.

Spinal nerves

The dorsal and ventral nerve roots of the spinal nerves which originate from the dorsal and ventral horn of the grey matter of the spinal cord meet and divide usually into three branches-ramus dorsalis, ramus ventralis and ramus communicans. The sensory nerve fibres are found in the dorsal nerve root and motor nerve fibres are found in the ventral nerve root. The dorsal root after coming out from the spinal cord swells to form a dorsal ganglion.

The spinal nerves in rabbit are 37 pairs which can be divided into five zones, which **8 pairs cervical, 12 pairs thoracic, 7 pairs lumbar, 4 pairs sacral and 6 pairs caudal nerves.**

The spinal cord terminates in the form of **filum terminale** in the lumbar region.

Autonomic nervous System

The autonomic nervous system is mainly responsible for controlling the involuntary activities of the body. It is of two types namely the sympathetic nerves extending from the neck to the end of the abdomen situated at the lateral sides of the dorsal aorta and below the vertebral column. The ganglia of sympathetic nerves are connected with the spinal nerves of ramus communicans. The head and tail are supplied by the nerve fibres originating from the ganglia of neck and trunk. In rabbit, the sympathetic nerve bears two ganglia in the neck region, an inferior cervical and superior cervical. The nerve fibres from these ganglia supply to the eyes, salivary glands, heart and lungs. The sympathetic nerve is provided with regularly arranged ganglia in the thoracic and lumbar regions. One ganglion for each spinal nerve. Nerve fibres from the sympathetic chain in the lower thoracic and upper lumbar regions unite to open in a large coeliac ganglion and then supply to the smooth muscles and blood vessels of the stomach, pancreas, liver and small intestine. Similarly the nerve fibres from the sympathetic chain of the lumbar region unite with the hypogastric ganglion. Nerves from the hypogastric ganglion supply to the colon, rectum, gonads, bladder and kidney.

Parasympathetic nervous system

Parasympathetic nervous system is formed by the **fibres of IIIrd, VIIth, IXth and Xth cranial nerves** and some **fibres of sacral spinal nerves**. The 3rd cranial nerve runs to the ciliary ganglion in the orbit and from these, nerve fibres supply to the muscles of the iris. The parasympathetic fibres from the VII and X cranial nerves supply to the lacrimal gland, salivary gland, lungs, heart, liver and different parts of alimentary canal. The parasympathetic nerve fibres of the sacral region unite to form a pelvic ganglion on each side and the nerve fibres from this ganglion supply to the bladder, kidney, rectum and gonads.

The sympathetic and parasympathetic nervous system work independently but opposite to one another. Thus each visceral organ is supplied by a sympathetic fibre which stimulates the organ to start the function and a parasympathetic fibre which inhibits and stops the function.

5.3.3 Reproductive system

Male reproductive system

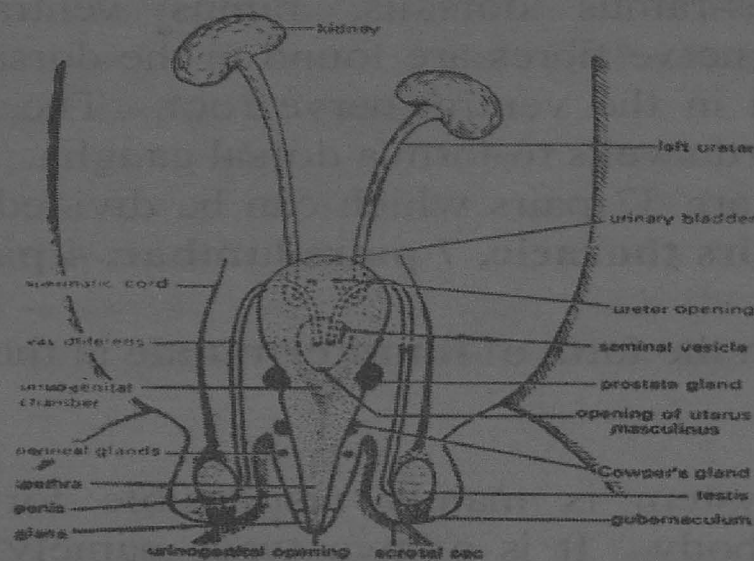


Fig. 20-78. Rabbit. Urinogenital system of male.

It consists of a pair of testes, a pair of vasa deferentia uterus masculinus, urethra, penis and a number of accessory glands like prostate, Cowpers, perineal, and rectal glands. The testes are paired ovoid bodies which lie in the young animal on the dorsal wall of the abdomen near the kidneys but descent before birth from the body cavity into a special part of the coelom, the scrotal sacs. The scrotal sacs are covered externally by a hairy skin, situated at the lateral sides of the penis. Each testis remains connected by a spermatic cord with its original position. The spermatic cord consists of connective tissue having an artery, a vein and a nerve. The cavities of the scrotal sacs are connected with the abdominal cavity by a narrow passage known as inguinal canal. Each testis is provided with a mass of twisted tubules along their sides called epididymis.



Fig. 20-79. Rabbit. T.S. of testis.

Histologically, each testis is covered by a tough coat of connective tissue called tunica albuginea which is provided into the substance of testis in form of partitions. The spaces between these partitions are occupied by long convoluted seminiferous tubules. The seminiferous tubules are lined by germinal epithelial cells which produce spermatozoa after spermatogenesis. Some large-sized sterile cells are found in between the germinal epithelial cells called Sertoli cells which nourish the spermatozoa. The connective tissue has interstitial cells, are found in between the seminiferous tubules. These cells secrete hormones which control the secondary sexual characters.

The testis is attached with the epididymis which is enlarged in front and behind the testis to form the caput epididymis or globus major and cauda epididymis or globus minor respectively. The cauda epididymis is connected with the scrotal sac by a cord known as gubernaculum. From each epididymis a vas deferens continues which pass forwards in the scrotal sacs and then enters the abdominal cavity through the inguinal canal. Then it curves over the ureter and passes backwards to open in a median bag called uterus masculinus or seminal vesicle situated above the neck of the bladder. The neck of the bladder then continues as urinogenital canal or urethra which passes into the penis to open at its tip. The urethra thus serves as a passage for urine and spermatic-fluid.

The penis is a muscular cylindrical, erectile organ with spongy vascular wall which hangs in front of the anus from the ventral wall of the abdomen. The penis is covered by a loose sheath of skin and the skin hangs over the tip of the penis as a prepuce. The tip of the penis covered by prepuce is called **glans penis**. The blood spaces of the penis gets filled with the blood at the time of sexual excitement to make the penis stiff and enlarged.

A large prostate gland is situated at the base of uterus masculinus which opens into the urethra by numerous ducts. A pair of Cowper's glands are situated just below the prostate glands on urethra. The sperms from the testes along with the secretions of prostate gland, Cowper's gland are sent out as ejaculate.

Female reproductive system

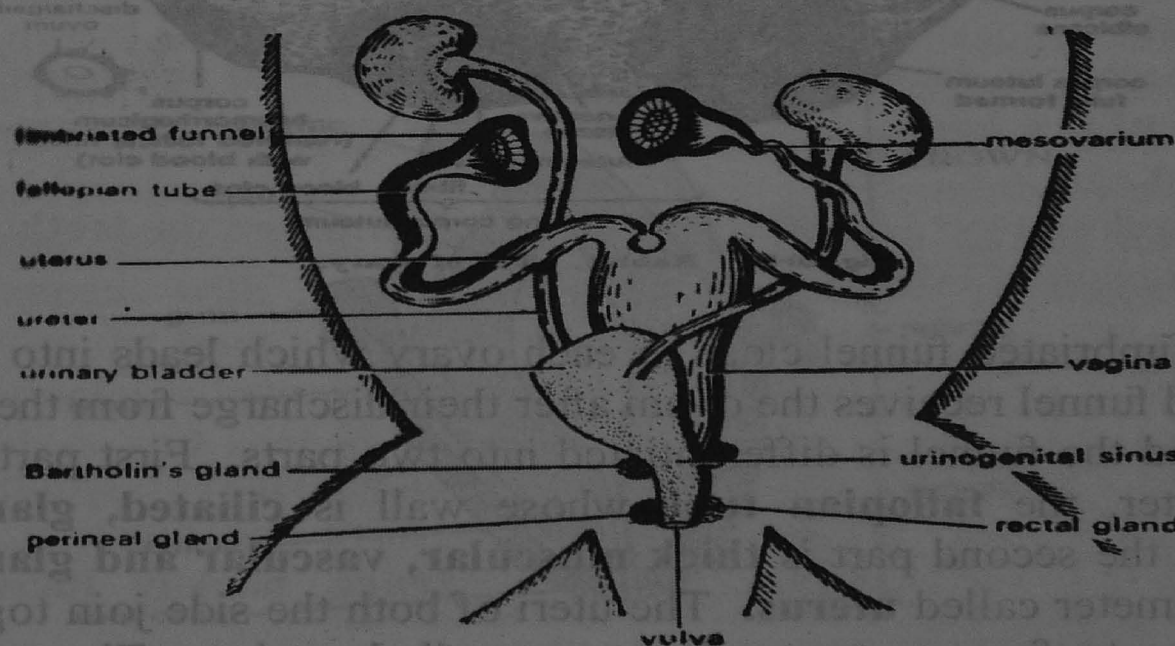


Fig. 20-83. Rabbit. Urinogenital system of female.

It consists of a pair of ovaries, a pair of oviducts, uterus, vagina and vestibule. Some accessory glands like **Bartholin's gland**, **perineal** and **rectal glands** are also found associated with it.

The ovaries are paired, small, whitish, oval bodies found attached to the dorsal wall of the abdomen behind the kidneys. The ovaries are attached with the dorsal body wall by the mesentery called **mesovarium**. Each ovary shows on its surface many projections when ripe. These projections rupture releasing the ova.

Histologically, each ovary is made up of fibrous and vascular connective tissues called **stroma**. The ova are situated in the stroma in their various stages of maturation. Groups of germinal epithelial cells are found in the stroma, known as **follicles**. One follicular cell develops to become an ovum called **discus proligerous**. A fluid filled cavity appears in the follicle which separates an outer layer of cells, the membrane **granulosa** from the cells of discus proligerous. The follicular cells secrete a striated membranous layer around the ovum called **zonapellucida**. Such a mature follicle is known as a **Graffian follicle**. The Graffian follicle migrates towards the surface of the ovary and ruptures to release the ovum. After the release of the ovum, all that is left is a mass of follicular cells surrounding a blood clot. Gradually these follicle cells proliferate and the blood clot transforms into a yellow coloured **corpus luteum** which produces hormones. The hormones of the corpus luteum are responsible for preparatory changes in the uterus for fertilization and retention of the embryo during gestation. The corpus luteum remains active throughout the period of embryonic development and if somehow, no fertilization occurs it degenerates leaving a scar called **corpus albicans**.

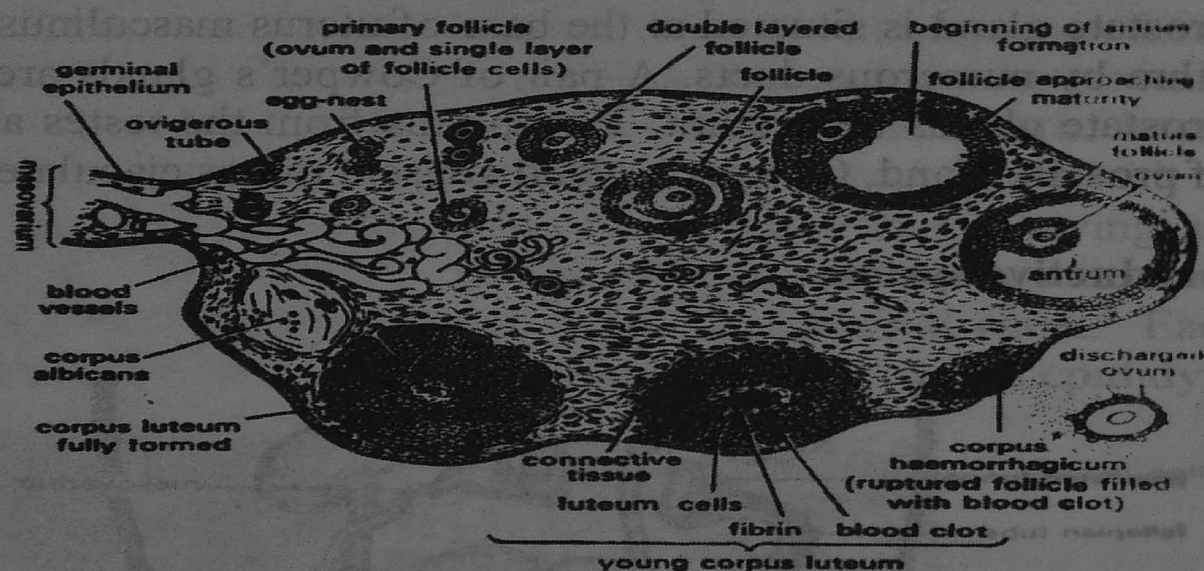


Fig. 20-84. Rabbit. T.S. of ovary.

There is a fimbriated funnel close to each ovary which leads into the oviduct. The fimbriated funnel receives the ovum after their discharge from the ovary. The oviducts behind the funnel is differentiated into two parts. First part coiled with narrow diameter, the **fallopian tube** whose wall is **ciliated**, **glandular** and **muscular** and the second part is **thick muscular**, **vascular** and **glandular** wall with wider diameter called **uterus**. The uteri of both the side join together along the median line to form a common passage called **vagina**. The vagina passes backwards with which joins the neck of the urinary bladder, thereby with which

joins the neck of the urinary bladder, thereby forming a common passage called **urinogenital canal** or **vestibule**. The vestibule opens to the outside by a self-like aperture, the vulva. At the ventral side of the vestibule is situated a small rod-like clitoris which is homologous to the penis of males. The clitoris consists of erectile tissue which is highly sensitive.

The pair of small **Bertholin's glands** are situated on the dorsal wall of vestibule. Secretions of those glands are discharged in the vestibule which lubricates the vaginal passage. They are similar to the Cowper's glands of the males. The prostate glands are not found in female rabbit. A pair of perineal glands and a rectal gland are also found like those of the male rabbit.

On the ventral side of the trunk of the female rabbit, there are four pairs of teats on which mammary glands open. The mammals become enlarged after the birth of young ones which start secreting milk for feeding the young ones.

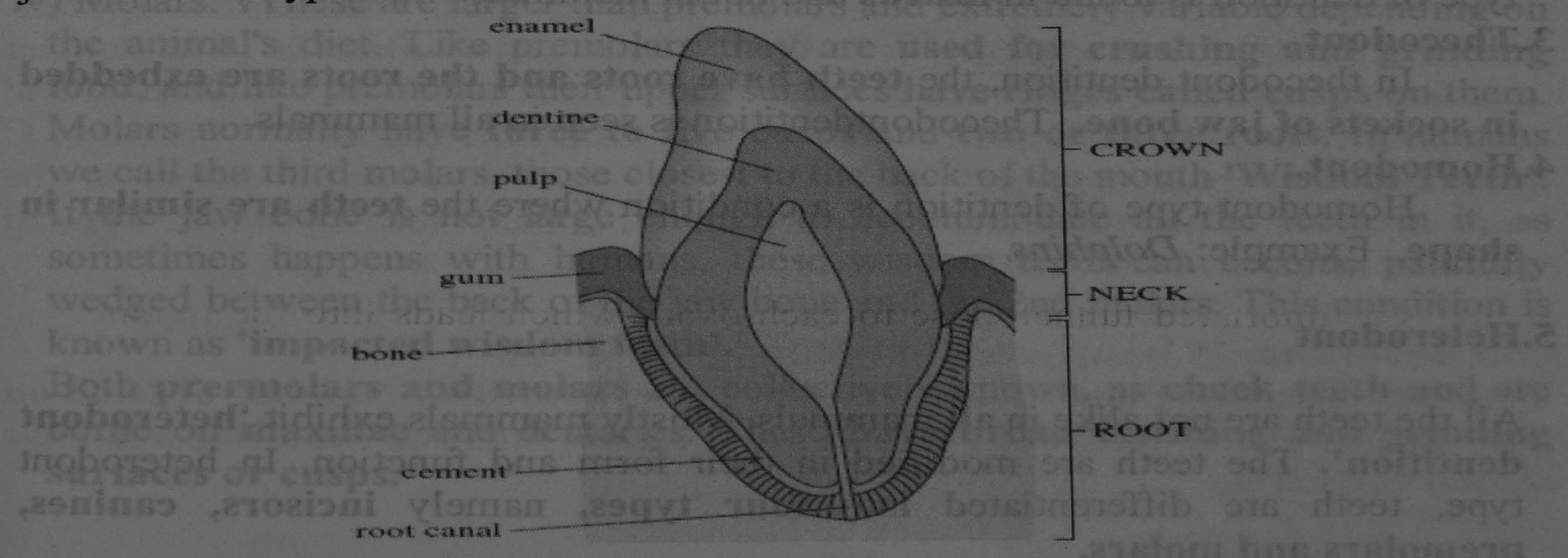
Copulation

The domestic rabbits can copulate at any time but wild rabbits copulate from January to June. Usually a female copulates only when it is in **oestrus condition** or **on heat** in most mammals of which rabbit may be an exception. At the time of copulation the penis of the male is introduced in the vagina of the female where semen is ejaculated.

5.4 DENTITION IN MAMMALS

The **arrangement of teeth** in the upper and lower jaws is called **dentition**. Teeth are borne on the **premaxillae**, **maxillae** and **mandibles**. Teeth are present in all mammals except in whale-bone whale, spiny anteater and *Ornithorhynchus*. Teeth are the dermal derivatives of integument. Along with the ridge of the two jaws, the teeth are arranged in a row. The teeth are present in almost all the mammals except in a few mammals. In **whale**, the teeth are **fused into plates** and **lost in the adult stage of Ant eaters**. But in *Echidna* (spiny ant eater) the teeth are absent even in the embryo.

Structure of tooth: Each typical mammalian tooth is placed in the socket over the jaw bone. A typical mammalian tooth has a crown, neck and root.



- 1) Root - It is the basal part embedded in the bony socket.
- 2) Neck - it is the part above the root enclosed by the gum
- 3) Crown - It is the upper part beyond the surface of the gum.

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

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

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

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

IV)Cement: It surrounds the denting of the root portion of the tooth. It is bony in nature,

Types of Dentition

Based on the **attachment of teeth in the jaw bone**, the teeth are classified into three types, namely Acrodont, Pleurodont, Thecodont

Based on the types of teeth, dentition is classified into two types, namely Homodont and Heterodont dentition.

Based on the number of **sets of teeth** that develops during the life time, the dentition is classified into three types.

Monophyodont, Diphyodont and Polyphyodont

1.Acrodont

In this type of dentition, the **teeth have no roots** and they are **fused to the edge of the jaw bone**. Acrodont dentition is seen in **lower vertebrates** like amphibians and reptiles but not in mammals.

2.Pleurodont

In pleurodont dentition, the **teeth are attached to the rim of jaw**. This type of dentition is found in **lizards** and not in mammals.

3.Thecodont

In thecodont dentition, the **teeth have roots and the roots are exbedded in sockets of jaw bone**. Thecodontdentition is seen in all mammals.

4.Homodont

Homodont type of dentition is a condition where the **teeth are similar in shape**. Example: *Dolphins*.

5.Heterodont

All the teeth are not alike in all mammals. Mostly mammals exhibit '**heterodont dentition**'. The teeth are modified in their form and function. In heterodont type, teeth are differentiated into **four types**, namely **incisors, canines, premolars and molars**.

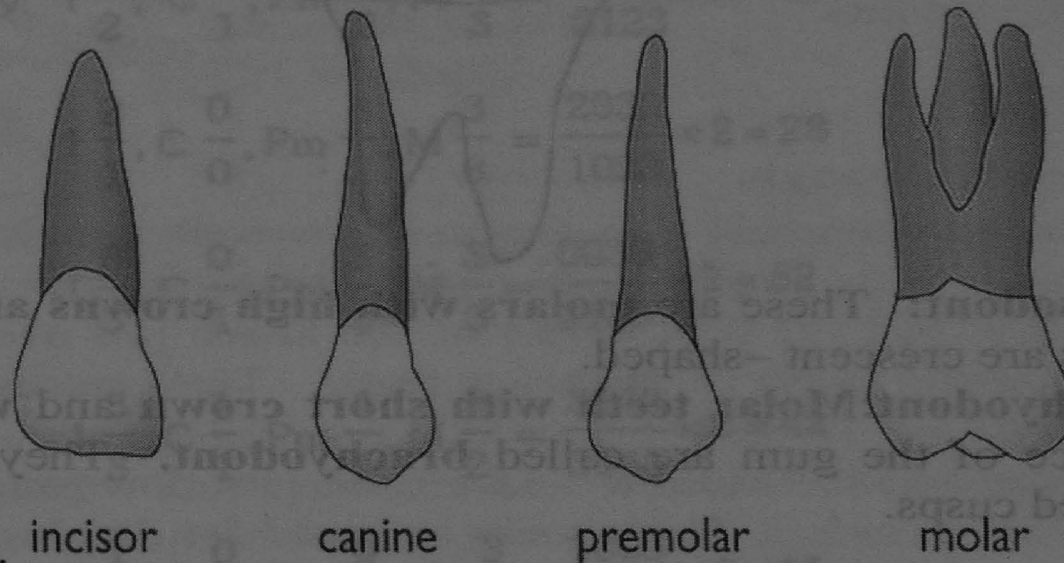
6.Monophydoont

In certain mammals, **only one set of teeth develops** during the life time and this condition is called monophyodont. Examples: *Moles* and *squirrels*.

7. Diphyodont.

Two sets of teeth develop during life time. The first set of teeth develop in the young and known as '**milk or deciduous teeth**', after certain age these are replaced by the second set of **permanent teeth**. But in **bats** and **guinea pigs**, the milk teeth are **shed before birth**. All the teeth are not alike in all mammals. Mostly mammals exhibit '**heterodont dentition**'. The teeth are modified in the form and function. But in *Dolphins* and *porpoises* it is **homodont** (all teeth are alike). There are four types of mammalian teeth.

- (i) **Incisors:** These are present on the premaxillae bones of the upper jaw and dentary bones of the lower jaw. They have only one row and sharp cutting edges. So this type of teeth is used in cutting.
- ii) **Canine :** These are present between the incisors and premolar. There is a single such tooth in each half of each Jaw. These are long, conical teeth with a single root and simple, sharp-pointed crown.
- iii) **Premolars:** These follow the canines. They have double root and compressed crown with one or two cusps. These possess grinding and crushing surfaces. Premolars are replaced once in life time.

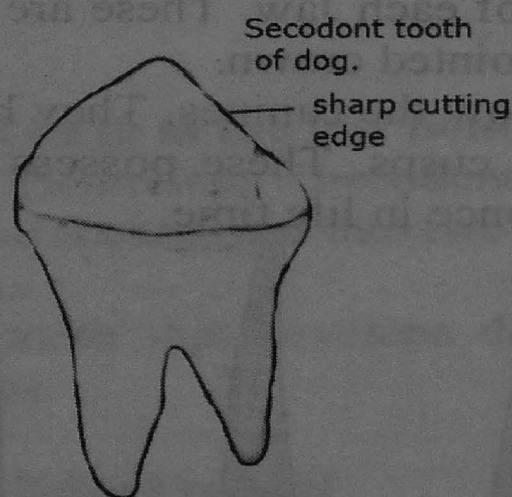


- iv) **Molars:** These are larger than premolars and extremely variable depending on the animal's diet. Like premolars they are **used for crushing and grinding food**, and like premolars their upper surfaces have **ridges called cusps** on them. Molars normally have **three to five cusps** and **two or three roots**. In humans we call the third molars, those closest to the back of the mouth '**Wisdom Teeth**'. If the jaw bone is not large enough to accommodate all the teeth in it, as sometimes happens with humans, these wisdom teeth can become painfully wedged between the back of the jaw bone and the 2nd molars. This condition is known as '**impacted wisdom teeth**'. Both premolars and molars are collectively known, as **cheek teeth** and are borne on maxillae and dentaries. These have **broad crushing and grinding surfaces or cusps**.

Cusp pattern of Molars

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

1. **Monocuspid:** This is characterized by the presence of only one cusp.
2. **Bicuspid:** When two cusps are present, the tooth is called bicuspid.
3. **Tricuspid:** These are molars having three cusps. Tricuspid teeth are also called triconodont and trituberculate.
4. **Bunodont:** In bunodont type, the crown has a number of blunt or pointed cusps. Example: Man.
5. **Lophodont:** When the cusps are arranged in the form of ridges, it is called lophodont. Example: Indian elephant.
6. **Selenodont:** These are molars with cusps in the form of crescent. Eg. Cow and sheep.
7. **Secodont:** In secodont type of molars, the crown has cusps having sharp cutting edges. Eg. Carnivorous mammals.



8. **Hypsodont:** These are molars with high crowns and short roots. The cusps are crescent-shaped.
9. **Brachyodont:** Molar teeth with short crown and with the neck at the surface of the gum are called brachyodont. They have also crescent-shaped cusps.

DENTAL FORMULA:

Mostly the number of teeth is fixed in each mammalian species. Mammalian heterodont dentition is expressed by a '*dental formula*'. The number and arrangement of teeth in each half of the upper and lower jaws is constant and identical. Hence the teeth can be expressed by using the initials – I (incisors) C (canines), Pm (premolar) and m (molar). The number of teeth differs in the various orders of mammals and is closely related to their 'feeding habits. **Typical number of teeth in the mammals is 44.**

The dental formula is expressed as follows:

Number of teeth on one half of the upper jaw divided by Number of teeth on one half of the lower jaw. This can be observed in Horse and pig and their dental formula is

Horse and Pig and their dental formula is :

$$I \frac{3}{3}, C \frac{1}{1}, Pm \frac{4}{4}, M \frac{3}{3} = \frac{3143}{3143} \times 2 = 44$$

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

The dental formulae of some common mammals are given below.

The dental formulae of some common mammals are given below:

a) Man & Monkey $I \frac{2}{2}, C \frac{1}{1}, Pm \frac{2}{2}, M \frac{3}{3} = \frac{2123}{2123} \times 2 = 32$

b) Rabbit $I \frac{2}{1}, C \frac{0}{0}, Pm \frac{3}{2}, M \frac{3}{3} = \frac{2033}{1023} \times 2 = 28$

c) Cow & Goat $I \frac{0}{3}, C \frac{0}{1}, Pm \frac{3}{3}, M \frac{3}{3} = \frac{0033}{3133} \times 2 = 32$

d) Dog $I \frac{3}{3}, C \frac{1}{1}, Pm \frac{4}{4}, M \frac{3}{2} = \frac{3142}{3143} \times 2 = 42$

e) Rat & Mouse $I \frac{1}{1}, C \frac{0}{0}, Pm \frac{0}{0}, M \frac{3}{3} = \frac{1003}{1003} \times 2 = 16$

f) Elephant $I \frac{1}{0}, C \frac{0}{0}, Pm \frac{3}{3}, M \frac{3}{3} = \frac{1033}{0033} \times 2 = 26$

g) Kangaroo $I \frac{3}{2}, C \frac{1}{0}, Pm \frac{2}{2}, M \frac{4}{4} = \frac{3124}{?4} \times 2 = 34$

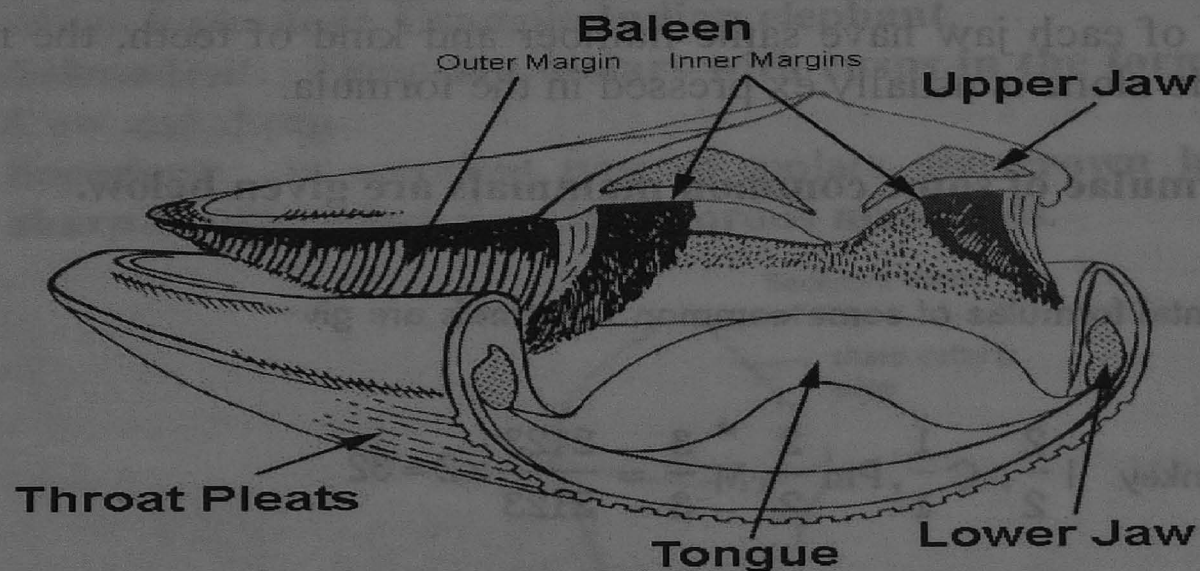
h) Sheep $I \frac{0}{3}, C \frac{0}{1}, Pm \frac{3}{3}, M \frac{3}{3} = \frac{0033}{3133} \times 2 = 32$

Modification of Teeth based on Diet. The teeth are modified based on the diet of the mammal.

1. Aquatic Mammals

In *Dolphins*, the teeth are of uniform size, recurved and prevent the escape of the struggling fish.

In **baleen whales**, the teeth are completely absent. The teeth are replaced by more than 300 plates called **baleen plates**. These baleen plates hang from the palate in rows like the leaves of book. The baleen plates are used to trap plankton. Since baleen whales feed on plankton they are called **planktonophagous animals**.

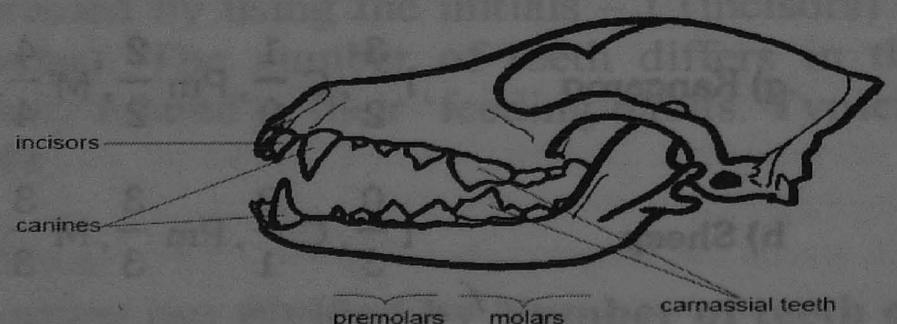


2. Carnivorous Mammals

In Carnivorous mammals, the **canines** are well developed for biting and tearing the prey. In the cheek, the **carnassial teeth** are seen. The last premolar in the upper jaw and the first molar of the lower jaw are enlarged and they are called **carnassial teeth** or **shearing teeth**. They are used for cutting the flesh.

In **Walrus**, the upper canines are developed into downward-pointing tusks as long as twenty seven inches. These teeth are used for digging for bivalves.

Canine teeth of walrus



Skull of Dog showing carnassial teeth

3. Insectivorous Mammals

In insectivorous mammals, the **upper and lower incisors meet precisely to capture small prey like insects.**

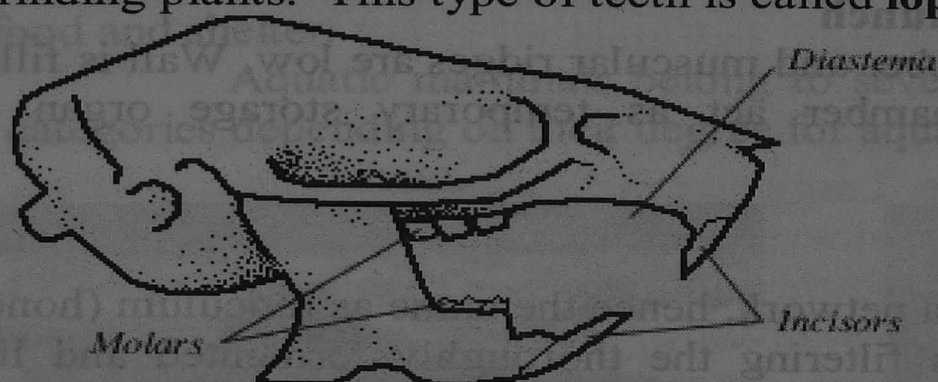
4. Herbivorous Mammals

In herbivores, the **incisors are used for cropping the plants.** The **ruminants** such as cows, sheep, etc. have lost the upper incisors. Rodents have **chisel-like upper and lower incisors for gnawing.** These incisors grow continuously.

The **canines are lost in herbivorous animals** and a gap called **diastema** is seen in its place.

The cheek teeth have shown the maximum modification in herbivores. The cheek teeth show **different cusp patterns for grinding grass.**

In **horses**, the teeth have **high crowns and short root (hypsodont)** for chewing grass. In **elephants**, the **cusp join to form sharp transverse ridges covered with enamel and between the ridges is dentine.** These teeth are used for grinding plants. This type of teeth is called **lophodont teeth.**



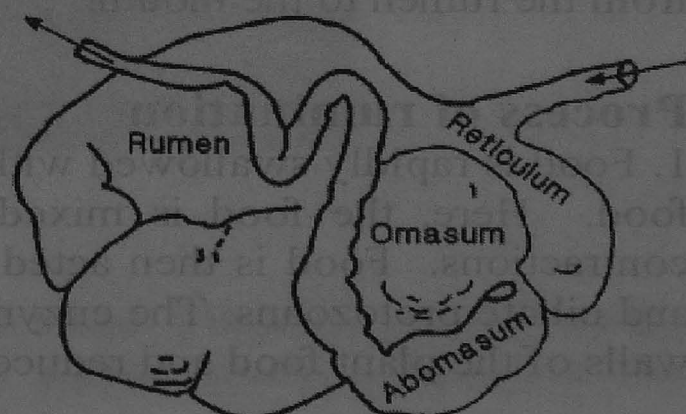
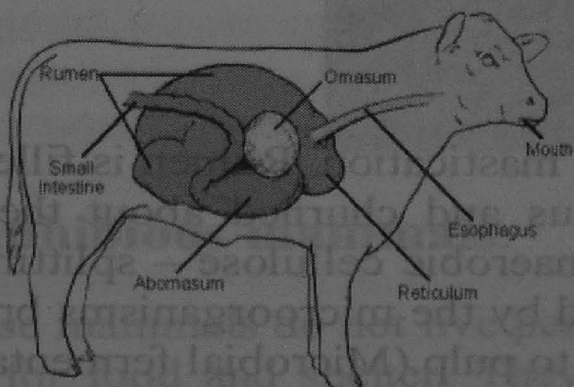
Skull of Rodent showing dentition and diastema

5. Omnivorous Mammals

In mammals, with a mixed diet (man and monkey) **the cusps on the cheek teeth are low and rounded.** This type of cheek teeth is called **bunodont type.** The incisors are used for cutting the food.

5.5 Stomach in ruminants

The stomach is an expansion of the alimentary canal between oesophagus and intestine. It is originally an organ for the temporary storage of food and maceration of solid food and for preliminary stages of digestion.



A true stomach is not present in prochordates, cyclostomes, lungfishes and some primitive teleosts. Only when its epithelial lining contains gastric glands, is it properly called a true stomach.

In most of the mammals, the stomach has assumed a transverse position. It is either U-shaped or J-shaped.

The end of the stomach following the oesophagus is nearer the heart, hence this end is called cardiac end. The main portion is called the body. The end of the stomach leading into small intestine is the pyloric end. This consists of a sphincter muscle. The pyloric end terminates at a valve called the pylorus or pyloric valve.

Ruminating or cud-chewing mammals have the most complex stomachs of all. The ruminant stomach is adapted for extracting the maximum nutrients from plant materials.

Typically, the stomach of ruminants consists of four well-defined chambers. The first three chambers are lined by a stratified epithelium folded into muscular ridges.

First chamber: Rumen or paunch

Large sacculated chamber and muscular ridges are low. Wall is filled with symbiotic bacteria. This chamber act as temporary storage organ and as fermentation chamber.

Second chamber: Reticulam

Muscular ridges form a network, hence the name as reticulum (honeycomb tripe). This chamber act as filtering the thoroughly fermented and liquefied chime.

Third chamber: Omasum or psalterium

Muscular ridges occur as overlapping leaves hence the name psalterium. Function of the chamber is retarding (slowing) the flow of its contents and in absorption of nutrients released by bacterial fermentation.

Fourth chamber: Abomasum or true stomach

Lining epithelium of stomach contains gastric glands and the gastric enzymes act upon the remaining chime.

Rumen represents the cardiac end; the reticulum the body; the omasum the lesser curvature and the abomasums, the pyloric end. There is a groove leading from oesophagus to omasum. When the lips of oesophageal groove are approximated (brought together), food does not enter the reticulum and is returned from the rumen to the mouth.

Process of rumination

1. Food is rapidly swallowed without proper mastication. Rumen is filled with the food. Here, the food is mixed with mucus and churned about the muscular contractions. Food is then acted upon by anaerobic cellulose – splitting bacteria and ciliate protozoans. The enzymes secreted by the microorganisms break up the walls of the plant food and reduce the whole to pulp (Microbial fermentation).

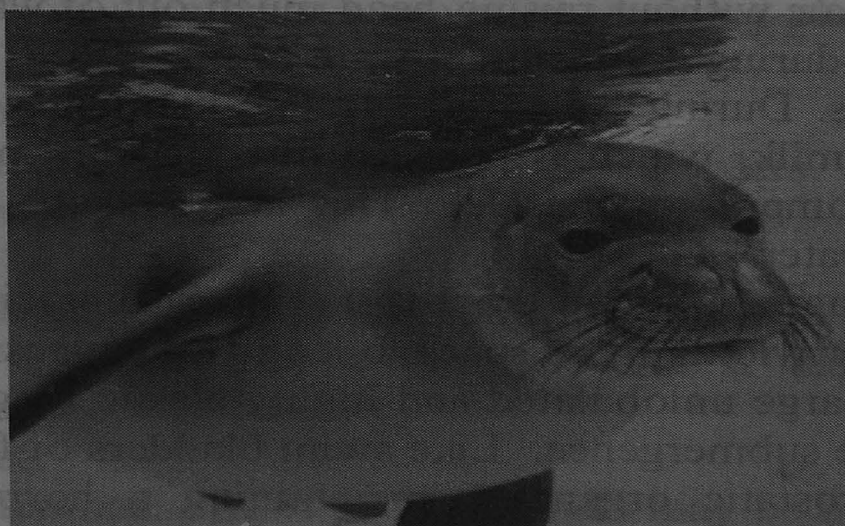
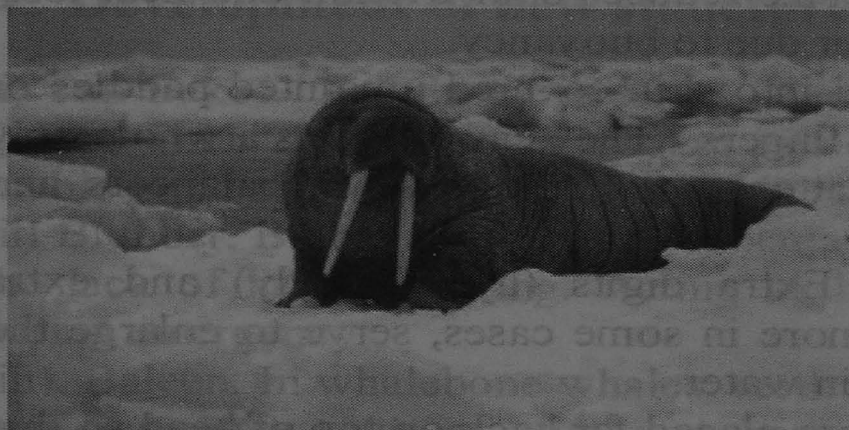
2. When the ruminant begins its cud chewing at leisure, the lips of the oesophageal groove are brought together. As a result, the poorly chewed and partly fermented food in the form of bolus (rounded mass) is returned to the mouth from the rumen (regurgitation) instead of entering the reticulum.

3. The bolus is resalivated and rechewed as cud in the mouth. After chewing, the bolus is again swallowed. Now the oesophageal groove opens. As a result, the food passes to the reticulum and omasum. Reticulum aids in filtering the thoroughly fermented and liquefied chyme. Omasum aids in slowing the flow of contents and in absorption of nutrients released by microbial fermentation. The remaining chyme enters the abomasum, the true stomach with gastric glands. Here, gastric enzymes act upon the chyme.

5.6 Aquatic Mammals.

Mammals are primarily terrestrial animals. However, some of them have secondarily adopted an aquatic mode of life. The fact that all of them are not gill-breathers but breathe air through lungs, indicates their original terrestrial mode of life. They have reverted to water probably because of extreme competition on land for food and shelter.

Aquatic mammals belong to several orders and may be put under two categories depending on their degree for aquatic adaptation.



1. Amphibious mammals.

These mammals do not live permanently in water. They live on land but go into water for food and shelter. They show only partial aquatic adaptations such as

(1)small external ears, (2)webbed feet, (3)flattened tails, (4)subcutaneous fat, etc. Examples: Seals, Otters, Walrus, Hippopotomous, Ornithorhynchus etc.

2. Completely aquatic mammals:

These mammals never come to land and are perfectly at home in water. Examples: Whales, Dolphins, Porpoises, etc.

Aquatic adaptations.

The specializations or adaptations of truly aquatic mammals fall into three major categories:

1. Modifications of original structure
2. Loss of structures and
3. Development of new structures.

1. Modifications of original structures-

- (a). Body shape- Body shape is of primary importance in aquatic mammals. The external fish-like form, elongated head, indistinct neck and tapering streamlined body offers little resistance and swims rapidly through water.
- (b). Large size and weight – Whalebone whale may grow up to 35 meters in length and weigh about 150 tons. Large size reduces skin friction and heat loss, but creates no problem for support in water due to buoyancy.
- (c). Flippers – Forelimbs are transformed into skin-covered unjointed paddles or flippers, having no separate indication of fingers. They can move as a whole only at the shoulder joint. The broad and flattened flippers serve as balancers and provide stability during swimming.
- (d). Hyperdactyly and hyperphalangy. Extra digits (hyperdactyly) and extra phalanges (hyperphalangy), upto 14 or more in some cases, serve to enlarge the surface area of flippers for greater utility in water.
- (e). High and valvular nostrils. Nostrils are placed far back on top of head so that animal can breathe air without raising head much out of water. Nostrils can also be closed by valves during diving under water.
- (f). Mammary ducts. During lactation, ducts of mammary glands dilate to form large reservoirs of milk, which is pumped directly into mouth of young by the action of special compressor muscle. This arrangement facilitates suckling of young ones under water.
- (g). Oblique diaphragm. Oblique diaphragm makes thoracic cavity larger, dorsal and barrel shaped, providing more space to lungs for expansion.
- (h). Large lungs. Large unlobulated and highly elastic lungs ensure taking down maximum air before submergence. Like swim bladders of fishes, the dorsal lungs also serve as hydrostatic organs in maintaining a horizontal posture during swimming.
- (i). Intra-narial epiglottis. Elongated, tubular and intranarial epiglottis, when embraced by the soft palate, provides a continuous and separate air passage, thus allowing breathing and feeding simultaneously.

(j). Endoskeleton. Cranium becomes small but wider to accommodate the short and wide brain. Facial part of skull projects forming elongated snout or rostrum. Ribs become arched dorsally to increase thoracic cavity. Bones are light and spongy.

(k). Teeth. In toothed whales, teeth are monophyodont, homodont and numerous, as many as 250. This helps in seizing prey, prevent its escape and swallowing it without mastication.

3. Loss of structure.

(i) Hair. Skin surface usually remains smooth and glistening due to loss of hairs except for few sensory bristles on snout or lips in some cases.

(ii). Ear. Pinnae(ear) are also absent.

(iii) Skin glands. Lacrimal glands and all kinds of skin glands such as sweat and sebaceous glands are also absent because they would have been useless under water.

Other structure. Hindlimbs are represented only by button-like knobs in the foetus but disappear in the adult. Pelvis is also rudimentary. Fingernails are absent. Scrotal sacs are also absent and testes remain inside abdomen.

4. Development of new structures.

(i) Tail flukes. Tail develops large, lateral or horizontal expansions of skin called flukes. Their up and down strokes not only propel the body through water but enable rapid return to the surface for breathing after prolonged submersion.

(ii) Blubber. Blubber is the thick subcutaneous layer of fat which compensates for the lack of hairy covering. Acting as heat insulator and act as food reservoir during emergency.

(iii). Baleen. In whalebone whales, teeth are absent. Instead, the upper jaw carries two transverse rows of numerous triangular fringed horny plates of baleen or whalebone. These serve as an effective sieve for straining plankton which forms their chief food.

Outline classification of Aquatic Mammals

Class Mammalia(aquatic) represents three orders. They are order **Cetacea, Sirenia, Carnivora.**

Order Cetacea includes the whales and dolphins.

The order –Cetacea is divided into two sub-orders, namely sub-order 1. Odontoceti and sub- order 2. Mysticeti.

Sub-order 1. Odontoceti

It includes the toothed whales. The members may be marine or freshwater forms. The cervical vertebrae are not fused. They bear a long beak with sharp homodont teeth on both jaws.

Odontoceti includes the following types:

1. Platanista(Ganges dolphin), 2. Physeter (sperm whales), 3. Delphinus(dolphin), 4. Phocaena(porpoise), 5. Monodon(narwhale), 6. Orcinus(killer whale).

Sub-order 2. Mysticeti. It includes the baleen whales or the whalebone whales or toothless whales. Eg. Blue whale.

Order-Sirenia: Sirenia is a group of aquatic sluggish mammals with heavy bones. Eg. Sea cow.

Order-Carnivora: Pinnipedia is a sub-order of carnivora. They have hairy coats. Pinnipedia includes three families, namely

Family 1. Phocidae(true or earless seals), they have no external ears, short neck and nailed digits. The palm and soles are covered with hair. The earless seals include 1. Phoca(harbor seal) and 2. Mirounga(sea elephant).

Family 2. Otariidae(eared seals), they have external ears. The palms and soles are naked and the digits have no nails. Eg. Sea lions sometimes called hair seals and fur seals sometimes called seabears.

Family 3. Odobenidae(walrus). Walruses resemble true seals in having no external ears.

The upper canines are developed into downward pointing tusks about 27 inches.

1. Dolphin

Dolphin is the aquatic mammal. It has a beak separated from the snout by a groove. Its length does not exceed eight feet and it has 100 teeth. It is a fastest aquatic mammal. It feeds on herrings and sardines. The Dolphins are highly intelligent. They have become famous for their playful exploits in aquariums.

2. Monodon(narwhale).

Monodon inhabits the Arctic waters and is very rarely seen elsewhere. It is distinguished by the black spots on its white skin and by its peculiar dentition. The foetus has all tooth buds but all of them except the incisors disappear by birth. In males, one of the incisors grows enormously like tusk as a secondary sexual character.

3. Phocaena(porpoise).

Phocaena is found in the Pacific and Atlantic oceans. It differs from dolphins in having a beakless and round head.

Whales

Whales are marine mammals. They are the largest living animals. They belong to the order cetacean. The whales are different types such as killer whale, Sperm whale, Blue whale or Baleen whale, Nar whale, etc.

Killer whale may attain a length of about 9.3 meters and the body bears white and black marks. The dorsal fin is triangular. It is a fierce killer feeding on fishes and other whales. It occurs in all seas from Greenland to Tasmania.

Sperm whale- It is a giant whale attaining a length of 18.5 meters. The head is elongated to form a swollen structure called rostrum. The rostrum contains

oil called spermaceti. Its intestinal secretion forms a stone like substance called ambergris, which is used for the manufacture of perfumes.

Blue whale- it is a largest living animal in the world. It reaches a length of about 100 feet and weighs about 150 tones. It weighs as much as 1500 men or 24 elephants. The heart weighs about about 1300 pounds and measures about 3 feet each way.

The adults have no teeth. The teeth are replaced by more than 300 triangular plates called baleen plates. These baleen plates hang from the upper jaw in rows like the leaves of a book. The baleen is arranged in two rows, one on either side of the upper jaw.

It is a plankton feeder. During feeding, the baleen plates serve to filter out the micro-organisms found in the water. Every now and then, the whale's tongue cleans the baleen and passes the food to the stomach. A blue whale may consume up to 4 tones of plankton a day.

Dugong (Halicore)

This is a sirenian. It is commonly called sea cow. This is found in the red sea and along the shores of Indian and Pacific coasts. It is a sluggish animal with heavy bones. The males have small tusks projecting downwards. The tusks are modified upper incisors the tail is fish-like with tail flukes. It is a herbivorous animal.

Phoca (Harbour seal)

Phoca is an earless seal found in all seas except Indian Ocean. The body is covered with soft fur. The digits have nails. The fore limbs are modified as paddles. The hind limbs are directed backwards. When on land it wriggles on its abdomen aided by movements of the fore limbs.

Mirounga (Sea elephant)

Mirounga is an earless seal which is the largest of the seals. Bulls may reach twenty feet and more with 3 tones weight. The males can inflate their nostrils to form a hood or crest. This is a secondary sexual character.

Eumetopias (Sea lion)

Eumetopias is an eared seal found in the Pacific coast. The palms and soles are naked and the digits have no nails. The fore limbs are long. The eared seals are capable of what may be called quadrupedal locomotion.

Walrus

This is found in Arctic seas. It feeds on fish, bivalves and crustaceans. The canines are long and used for climbing on ice and for digging for bivalves. The upper lip is thick, fleshy and is provided with sensory bristles. The fore limbs are used for swimming and the hind limbs are used for locomotion on land.

Reference Books:

1. Chordate Zoology- **E.L.Jordon and P.S.Verma** (2006) S.Chand & co. New Delhi.
2. Chordate Zoology- **P.S.Dhami and J.K.Dhami** (2006) R.Chand & co. New Delhi.
- 3.Chordate- A Manual of Zoology, **M.Ekambarnatha Iyer and T.N.Ananthakrishnan**(2003) Viswanathan Publications, Chennai.
4. Vertebrate Zoology-**R.L.Kotpal**,(2005) Rastogi Publications, Meerat.
- 5.Text book of Vertebrate-**N.Arumugam et al.**,(2008) Saras Publications, Nagerkovil.

MADURAI KAMARAJ UNIVERSITY

(University with Potential for Excellence)

DIRECTORATE OF DISTANCE EDUCATION

Palkalai Nagar, Madurai - 625 021, India

Ph : 0452-2458471 (30 Lines) Fax : 0452-2458265

E-mail	: mkudde@mkudde.org
General grievances	: mkuddegrievance@gmail.com
UG Courses	: mkuddeug@gmail.com
PG Course	: mkuddepg@gmail.com
MBA Course	: mkuddembag@gmail.com
MCA Course	: mkuddemcag@gmail.com
Education Courses	: mkuddeedu@gmail.com
Website	: www.mkudde.org
IVRS	: 0452 - 2459990
	: 0452 - 2459596

Student Support Service : 0452 - 2458419

DDE - Examinations

Fax No.	: 0452 - 2458261
E-mail	: mkuace@yahoo.com
Examn., Grievance Redress Cell:	0452-2458471-Extn.515